ISSN 0002-9920

Notices

of the American Mathematical Society

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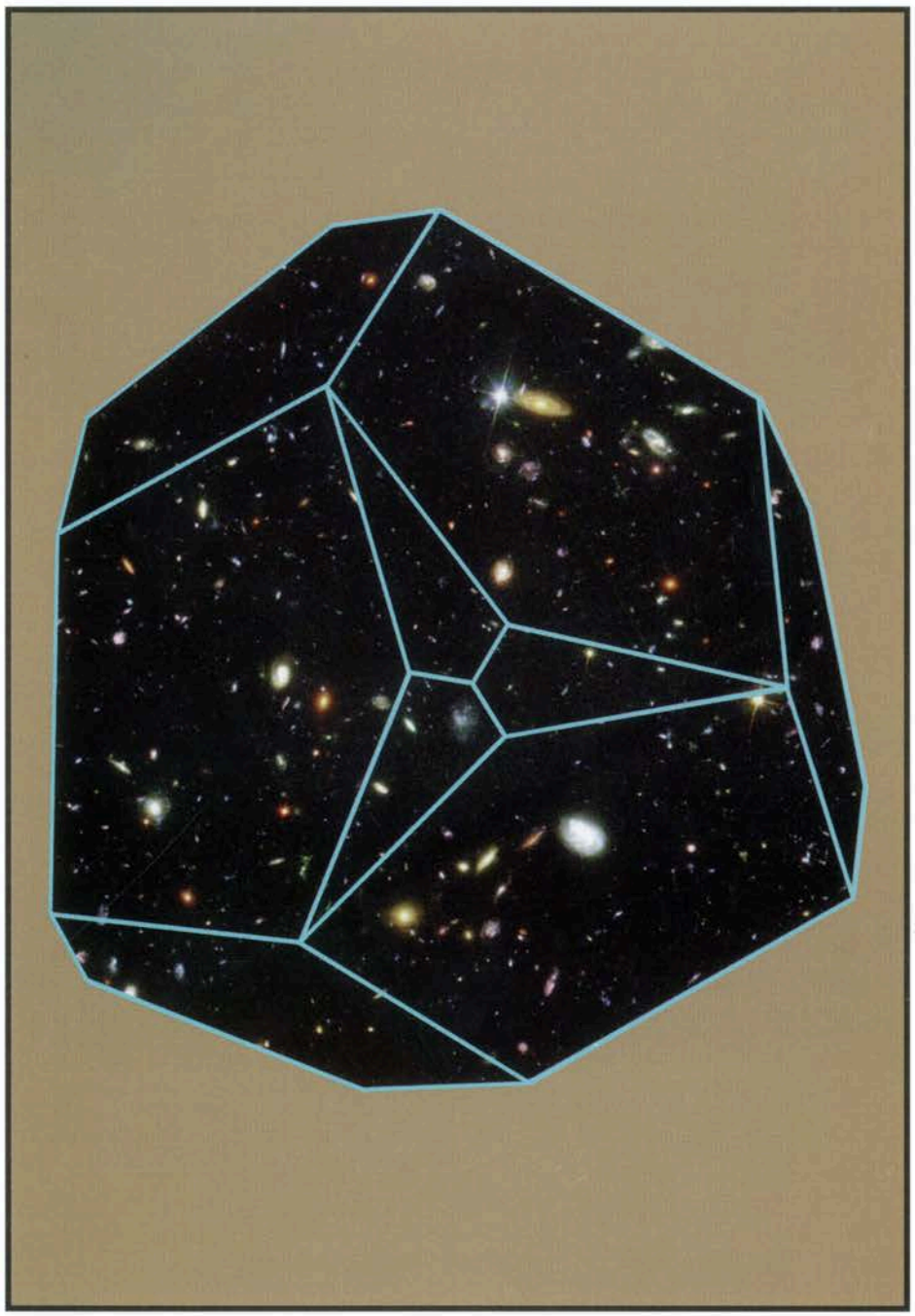

A Finite Universe? *(See page 1471)*

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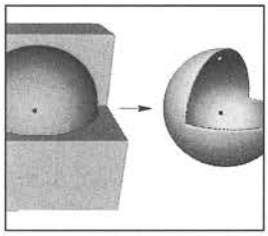

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Notices

of the American Mathematical Society

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SUBSCRIPTION INFORMATION: Subscription prices for Volume 46 (1999) are $309 list; $247 institutional member; $185 individual member. (The subscription price for members is included in the annual dues.) A late charge of 10% of the subscription price will be imposed upon orders received from nonmembers after January 1 of the subscription year. Add for postage: Surface delivery outside the United States and India—$15; in India—$36; expedited delivery to destinations in North America—$35; elsewhere—$70. Subscriptions and orders for AMS publications should be addressed to the American Mathematical Society, P.O. Box 5904, Boston, MA 02206-5904. All orders must be prepaid.

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[*Notices of the American Mathematical Society* is published monthly except bimonthly in June/July by the American Mathematical Society at 201 Charles Street, Providence, RI 02904-2213. Periodicals postage paid at Providence, RI, and additional mailing offices. POSTMASTER: Send address change notices to *Notices of the American Mathematical Society*, P.O. Box 6248, Providence, RI 02940-6248.] Publication here of the Society's street address and the other information in brackets above is a technical requirement of the U.S. Postal Service. All correspondence should be mailed to the post office box, not the street address. Tel: 401-455-4000; e-mail: `notices@ams.org`.

From the Executive Director

Some Advice for Young Mathematicians

These are tough times for young mathematicians, and you are likely asking yourself, "What are professional societies doing to help? What good are professional societies anyway?"

I can give a partial answer to the first question, but my answer may not be entirely satisfying. What is the AMS doing? Employment registers, interview facilities at meetings, job-seekers list (in late spring), statements on good hiring practices, surveys about our changing environment, Centennial Fellowships, the nonacademic employment project — the list is much longer. Each of these is a small step, however, and a longer list may not impress you. The problems young mathematicians face are deep, serious, and complex. These problems won't be solved by resolutions of outrage, but rather by many small, steady, deliberate steps over long periods of time.

I can give you a better answer to the second question. I am often asked about the value of professional societies, and I only recently realized that I was told the answer long ago. Twenty-five years ago, when I arrived at Indiana University, a senior faculty member took me aside and gave me some advice. "Ewing," he said, "here are five things you ought to do in the next few years if you want to be a mathematician."

- Publish ... and do it sensibly. Get your thesis into print, but publish some other things as well. Don't be intimidated: all research looks "easy" once it's done. Have confidence that other people want to know about your work, but don't be sloppy and publish wrong things, and don't be slovenly and publish trivial things either.
- Discover what's being done ... constantly. Read *Math Reviews* every month, and look at *Current Mathematical Publications*. Get on preprint lists; pick up the phone (today he would say send e-mail and scan preprint servers) to find out who's doing what. You need to be a scholar.
- Travel ... as much as possible. Go to meetings to learn about things outside your field; go to conferences to learn about new developments inside. This is the way you meet the people who will be your mathematical colleagues for the next fifty years, and fifty years from now you'll thank me for the advice.
- Talk mathematics ... as much as possible and as widely as possible. Go to lunch with people in the department daily or at least weekly. Talk mathematics at tea every day (and if there isn't one, organize it). Talk in the hallways; talk on the way to and from work.
- Teach your students ... with enthusiasm and passion. They learn more that way, but so do you. Answer every question, and then ask another of yourself and your students. No matter what the level, you learn new mathematics when you teach it with enthusiasm.

Publish sensibly, discover constantly, travel extensively, talk widely, teach passionately. Do those things, he said, and mathematics becomes a part of your life—not just a job, but a profession. That was good advice.

What good are professional societies? They make it easier—in fact, they make it *possible*—to take this advice. Societies publish journals so that you can publish papers. They provide services such as *Math Reviews* and *CMP* so that you can discover. They hold meetings and conferences that build community as well as research. They sustain professional development that fosters talking and teaching. They provide news and information that connects the various mathematics communities to each other and to the public. And they provide a way to share the responsibility for these activities among many mathematicians.

What good are professional societies? They provide the framework in which mathematicians, both young and old, can be professionals.

—John Ewing

Commentary

In My Opinion

Parting Shot

The end of January will see another change of secretaries for the AMS. In the 110 years of its existence, the AMS has had eight secretaries; Bob Daverman will be the ninth. That's fewer than the number of popes or chief justices of the Supreme Court in the corresponding years.

It was my philosophy as secretary to carry out the duties as prescribed in the various official and unofficial documents. I viewed the task as one of seeing that procedures as outlined in the Bylaws and as adopted by the Council were followed. I attempted to separate my personal opinions from opinions that were formed by interpretations of the Bylaws and Council directives.

It has been a wonderful ten years. The success of the meetings and publication programs has been excellent. The AMS has grown from a $10M operation to a $22M operation. Although membership has not grown at the same rate, the AMS has been able to reach out to many more mathematicians by its meetings and publications to help them teach and maintain their research interests. I have truly enjoyed working with all of you to create a better Society.

The secretary is mostly concerned with the internal operations of the governance of the AMS. I considered the position as the administrator of science policy of the AMS. This means that the secretary facilitated the creation of policy and saw that it was promulgated.

Under my watch the creation and administration of policy has become much more difficult due to the creation of two organizational stumbling blocks: the Editorial Boards Committee and the policy committees. My parting shot is to recommend the elimination of these committees.

Before the creation of the Editorial Boards Committee (EBC), all suggestions for appointments to editorial boards came from the Nominating Committee (NC), and suggestions for appointment as associate editors came from the Committee on Committees.

The EBC was created as a parallel to the Nominating Committee and was intended to be a committee of members elected by the membership and reporting to the Council that would concern itself with all aspects of the structure of the editorial boards of the Society. The tasks for the committee included, not exclusively, making recommendations to the Council for appointment to the standing journal editorial boards and making recommendations to the president for appointment of associate editors and others to other editorial committees. The original intent was that the EBC should also monitor the activities of the editorial boards, see that "standards" were being upheld in the journals, and see that the boards functioned carefully.

It sounded great, especially since some of the burden of oversight would be removed from the secretary. The recommendations by the EBC have been superb for the most part. The EBC has handled several very sensitive problems in the publication realm. Some very sensitive and difficult problems have not gone to the EBC. Due to many misunderstandings, the administration of these suggestions, the appointment process in general, and the monitoring of journal and publication problems have not gone well. Currently there is some overlap of areas of concern between the EBC and the Committee on Publications. It is very difficult to get individuals to stand for election to the EBC.

What should replace it? The nomination of editors for standing journal boards can be done by the Nominating Committee, as was done in the past. The NC works only in January and February on nominations for the fall elections. At other times of the year the task of identifying potential editors could be done by the members of the NC. Recommendations of associate editors can be handled by the Committee on Committees.

Problems regarding workings of editorial committees can be handled administratively, and problems of an ethical nature, such as disputes about reviews in the *Bulletin*, can be put onto other existing committees, such as the Committee on Professional Ethics.

There are five policy committees, four of them new during my time. The new ones are the Committees on Education, Meetings and Conferences, the Profession, and Publications. My suggestion is to "discharge with thanks" these four new committees, retaining the Committee on Science Policy.

I estimate that each of these committees costs in excess of $100,000 per year to operate, for a total cost to the AMS of $500,000 per year. (That's the dues of about 4,000 members or the data access fee of about 50 institutions.) The marginal cost of providing transportation, lodging, and meals for the members and guests of a committee is close to $25,000 per committee per year. The rest is my estimate of the cost of administration of the committees in Providence and elsewhere.

In addition to the financial cost there are enormous personal costs to the members of the Society and the administrators who take their jobs on these committees seriously. The president, the secretary, and the executive director are members of each of these committees and must travel to Washington, DC, or Chicago almost every weekend in the fall and often in the spring. What is accomplished?

Some of these committees have become involved with micromanagement of AMS affairs, especially in the area of meetings and publication, with no such charge from the Council. Some have come up with "mandates" that bear enormous hidden costs and that have not been sanctioned by the Council. Too often persons with specific agendas are appointed who then focus discussion on pet projects or ideas that completely bog down the operation of a committee.

Long lists of rules have evolved about how subcommittees should be appointed, how each committee should interact with other of these committees, and how chairs of the committees should share information. It's an administrative headache of the highest order.

What have been the results? About five action items per year have come to the Council from all of these committees. That's about $100,000 per item.

What should replace them? Let the Committee on Science Policy (CSP) continue to function as it did in the past by handling all the items of policy except those related to publications. Put the chair of CSP back on the Council, and include many Council members on the Committee. Broaden the charge to include educational policy matters and matters of the profession. Send all publication problems to the trustees. Put the Council back into the picture.

These are two relatively mild suggestions that I believe will improve the creation and administration of science policy within the AMS.

—Robert M. Fossum
Associate Editor

Letters to the Editor

Hidden Commercials

I would like to share with you the mixed feelings which I experienced while reading the article "Theory into Profit: Microsoft Invests in Mathematicians" by Allyn Jackson in the June/July issue of *Notices*.

A person who has to reboot his/her PC with Windows 95/98 a dozen times per day may admit that the *profit* obtained by Microsoft is mainly due to aggressive marketing rather than to high-quality products or an elegant *theory*. The PC-users community is starting to understand the damage of such an activity, and it was reflected in recent actions of the Justice Department. One could expect that Microsoft will try to recover its public image by new initiatives.

I have no doubt that Allyn Jackson tried to provide balanced coverage of Microsoft Research. But the theory of advertisement has its own psychological rules, which are actively used by public relations offices. Even a neutral mention of a product name works as a hidden commercial (do you remember the Windows logo written everywhere during 1995?). Considering this, I am not sure that the article could really be considered a neutral one.

I understand that the interaction of mathematics and industry is a very important and interesting topic. There is no doubt that they should be reflected in the Society's journals. For example, I will read with interest a paper which tells about and compares many other research units: AT&T, IBM (who is a long-term corporate member of the AMS, right?), etc., but not one preselected firm.

—Vladimir Kisil
Odessa State University

(Received August 13, 1998)

On Pontryagin's Autobiography

A May letter to the *Notices* by Joan Birman discussed Shafarevich in connection with a conference to honor the memory of Pontryagin. But the problem concerns not only Shafarevich. That discussion reminded me of passages in Pontryagin's short autobiography published by the main Soviet mathematical journal *Uspehi Matematicheskih Nauk* (cf. *Russian Mathematical Surveys*, 1978, issue 6). Let us consider only one (but the most vivid) example, and everything will be clear. Pontryagin wrote (p. 23): "The attempt was made by Zionists to take the international Union of Mathematicians into their hands. They tried to raise Professor N. Jacobson, a mediocre scientist but an aggressive Zionist, to the Presidency of the IMU. I managed to repel this attack." To those who don't know, it's necessary to explain that after World War II any anti-Semitic campaign in the Soviet Union was presented as fighting against at first cosmopolitans and then Zionists. Consequently, this rude attack against the famous mathematician N. Jacobson, who obtained a lot of fundamental results in algebra, explicitly demonstrates the views of Pontryagin and explains why such a person as Shafarevich is one of the leading organizers of the conference in question.

—Mark Burgin
University of California, Los Angeles

(Received July 22, 1998
Revised August 20, 1998)

Look to the Elementary Schools

David Sanchez (letter in September 1998 *Notices*) has some excellent data on American student performance in mathematics. I personally believe he did not identify the right problem. As an experienced AP teacher (both BC Calculus and Statistics) I feel that there are too few students taking AP mathematics courses, especially among minorities. Since I have taught mathematics from first grade through graduate school, I can look at the entire education spectrum and perhaps see what Sanchez cannot see.

I believe that the source of the problem lies in our elementary schools. We have elementary teachers who, in large part, seem ill prepared to teach mathematics. Based on my teaching in six different elementary schools and observing in many others, it is my belief that many (not all) elementary teachers do not like the subject. That could be overcome by meaningful staff development. But staff development is not all that is needed. The current system features a curriculum so watered down that most students enter sixth grade not knowing much beyond whole number operations, if that! Lack of ability grouping makes the teacher's job more difficult, as does a lack of understanding in many places that mathematics is a cumulative subject. We find fifth-grade classes with students who cannot add or subtract; students who can work with fractions, decimals, and integers; and everything in between. The teacher spends much of the year reviewing what the students should have learned in earlier years. The bright students are bored, while the less able students don't "get it" and believe that they will never "get it". Principals often fail to encourage staff development or to understand the elements of substantive curricular change; even if they are supportive, the resources may not be there. The parents are not worried; they proclaim, "I was never good in math and look how well I have done!"

If we had elementary schools where there were meaningful standards and opportunities for students to be challenged without being overwhelmed, we would find more students taking more mathematics in high school and college. In 1996–97 (while in a different district), I taught a fourth-grade class composed of minority children, many of whom were in single-parent, non-English speaking and/or poverty-level families. At the start of school they could barely multiply. By May they were successfully computing with mixed numbers, decimals, and integers and enjoying their work. It can be done if parents, teachers, school administrators, and mathematicians will join together to focus our efforts. Perhaps we can then worry that there will not be enough AP mathematics teachers.

—Murray H. Siegel
Greenville (SC) Public Schools

(Received August 20, 1998)

"Guide" Not a Guide

We believe that the paper of E. H. Lieb and J. Yngvason (*Notices*, May 1998, pp. 571–581), whatever its specific interest, cannot be considered "A Guide to Entropy and the Second Law of Thermodynamics", except in the narrowest of terms. More specifically, their paper does not seem appropriate to the *Notices* unless considerably more background and context for the reader were provided. Indeed, the paper strikes us basically as a further, not uninteresting, research contribution, whose publication would be entirely appropriate to a research journal.

A true guide to entropy and the Second Law would have to say much more about the broad nature of the subject, the historical background, and the extensive mathematical developments which have been published in the past thirty-five years by a large number of authors.

To obtain a flavor of these developments up through 1983, interested mathematicians might look at the textbook *A First Course in the Mathematical Foundations of Thermodynamics* by David Owen, which appeared in the Springer series Undergraduate Texts in Mathematics. Also, they may consult the extensive monograph *Mechanics and Thermodynamics of Continuous Media* recently published by Miroslav Silhavy (Springer, New York, 1996).

—Walter Noll and
William O. Williams
Carnegie Mellon University
James Serrin
University of Minnesota

(Received September 11, 1998)

Lieb and Yngvason Reply

We are pleased that our colleagues Noll, Serrin, and Williams found our contribution "not uninteresting". The works they cite offer important alternative perspectives and are among the references in our lengthy article to appear in *Physics Reports*. In our short May 1998 *Notices* article we directed the reader to the long article [7], which is easily available on two Web archives and which includes a historical account.

The word "Guide" in the title is, admittedly, slightly unusual, but a bit of color in the *Notices* is not a bad thing. What we had in mind was the famous Arabic work by Maimonides (a twelfth-century Jewish Spanish philosopher) entitled *Dalalat al-ha'irin* or *A Guide for the Perplexed*. To us and just about everyone else we know, the second law of thermodynamics is a subject that can perplex even the angels.

—Elliott Lieb
Princeton University
Jakob Yngvason
Vienna University

(Received September 13, 1998)

Perspective

At Hearing the News of Their Awarding Me the Kyoto Prize

I was overjoyed at the news of their awarding me the 1998 Kyoto Prize in basic sciences. My feeling of great happiness is beyond description. As a young man, I selected stochastic analysis as my lifework. In recognition of my long study of stochastic analysis, I will be awarded the prestigious Kyoto Prize. How happy I am! Obviously, at the news of my winning the prize, people will be aware that stochastic analysis is important. Scientists in the field will be encouraged to hear the news. It is obvious to me that mathematical sciences will make rapid progress.

In 1935 I entered the University of Tokyo. When I began studying at the Department of Mathematics, very few mathematicians were interested in probability. At first, I also had little or no interest in probability; however, I regarded the theory of probability as "a new mathematical field for researching random events" after reading papers written by foreign mathematicians: Kolmogorov of Russia (USSR in those days), Wiener of the USA, and Paul Lévy of France. In 1942 I devised stochastic differential equations. Stochastic differential equations are divided into two parts: the "average part" and the "random displacement part". On a special occasion, when the latter part is zero, they are treated as nonstochastic differential equations. In 1951 I improved the theory of stochastic differential equations and derived the conversion formula of stochastic differential equations (Itô's formula) from this theory. It consolidated the foundation of stochastic analysis. Unfortunately, very few people showed interest in the theory in those days. I was depressed, and at least ten years passed.

Since about 1960 an increasing number of mathematicians, from Japan and abroad, have become interested in stochastic analysis, whose theory has made rapid progress. As a result, Malliavan of France reached the apex of research on this theory. Nowadays stochastic analysis is widely used in new sciences, such as the theory of stochastic control, population genetics, and the theory of stochastic finance.

Such progress in theory and application of stochastic analysis is the fruit of the efforts of many researchers who worked in international cooperation. In winning the Kyoto Prize, I feel eternal gratitude to them.

Of course, nonstochastic analysis has also made rapid progress, pointing to the even further development of stochastic analysis. I will continue studying such branches in order to enrich the theory and application of stochastic analysis. I hope to continue to achieve results in my studies and thereby fulfill expectations of the Kyoto Prize councilors.

—Kiyosi Itô

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Kunihiko Kodaira: Mathematician, Friend, and Teacher

F. Hirzebruch

Kunihiko Kodaira died July 26, 1997, and a memorial article appeared in the March 1998 *Notices*, pp. 388–389.

Kunihiko Kodaira

Kunihiko Kodaira was friend and teacher for me. My wife and I remember our last visit to the Kodairas' house in Tokyo. He was working at the kitchen table on textbooks for secondary schools. Seiko Kodaira had to push the papers away when preparing the meal. In 1995 I congratulated him on his eightieth birthday. He answered in his charming way. But when we came to Tokyo in 1996, he was already in the hospital. We could not talk to him anymore.

I have read the obituaries by D. C. Spencer in the *Notices of the AMS* (March 1998) and by M. F. Atiyah for the London Mathematical Society. Both say much about our mutual friend; I do not have to repeat it.

I want to report about the influence which Kodaira had on my mathematical work. I shall emphasize the period from 1952 to 1954 when I was a member of the Institute for Advanced Study in Princeton. On Monday, August 18, 1952, I arrived in Hoboken, New Jersey, on the *Ryndam* of the Holland America Line. D. C. Spencer and Newton Hawley picked me up. On Saturday, August 23, I wrote to my parents that I had worked every day in the Institute with Kodaira, Spencer, and Hawley. When I read this letter again after forty-six years, I was surprised to see that my mathematical training in Princeton under Kodaira and Spencer started immediately after my arrival in spite of the Princeton summer.

When I arrived, I knew nothing about sheaves and very little about algebraic geometry and characteristic classes. This improved fast. Our heavy work was made easier by a fine picnic given by Kunihiko and Seiko Kodaira.

In 1975 Kodaira's *Collected Works* appeared in three volumes (Iwanami Shoten, Publishers, and Princeton University Press) with a preface by his student Walter L. Baily Jr. giving a survey and appreciation of Kodaira's work until then.

At the end of this paper I shall reproduce twenty-six entries from the table of contents of the *Collected Works* using the numbering there. These are mostly the papers quoted in my book *Topological Methods in Algebraic Geometry* (Translation and Appendix One by R. L. E. Schwarzenberger, Appendix Two by A. Borel), which was published by Springer-Verlag in 1966 as the English version of *Neue topologische Methoden in der algebraischen Geometrie* (Springer-Verlag, 1956). I added reference [28] ("Work done at Princeton University, 1952"). These are the lecture notes of his course at Princeton University which I attended, at least partially, in the winter 1952–53. I do not know how much of [28] he covered in his course, but this

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rich material certainly occurred in the many conversations and private seminars of Kodaira, Spencer, and me. In September 1952 Spencer picked me up by car quite regularly at 9 a.m. and drove me to the Institute, where we worked until 5 p.m., mostly with Kodaira, whose course began at the end of September. I also added [37], which is the announcement of his great result that the Hodge manifolds are all projective algebraic, which is fully presented in [38]. I added [63, 66, 68], which together with [60] are the four papers of the famous series "On the structure of compact complex analytic surfaces", which I quoted in my paper *Hilbert modular surfaces* (Enseign. Math. **19** (1973), 183–281) and which I used so much in teaching and research. This paper on Hilbert modular surfaces grew out of my International Mathematical Union lectures, Tokyo, February–March 1972. I remember vividly that Kodaira and Kawada picked us up at the airport. This was the first journey to Japan by my wife and me. Kodaira, having returned to Japan in 1967, was in full action as dean at the University of Tokyo. He introduced me to many of his brilliant students, who later became research visitors in Bonn. For the first time we enjoyed Kunihiko's and Seiko's hospitality in Japan. Finally, I added [64] to the list because it gave rise to my paper *The signature of ramified coverings*, published in the volume *Global Analysis* (University of Tokyo Press, Princeton University Press, 1969), dedicated to Kodaira at the time when he left the United States for Japan.

I have explained how my selection of papers from Kodaira's *Collected Works* was motivated. Among them are eight joint papers by Kodaira and Spencer. Atiyah characterized the collaboration between the two, from which I profited so much: "The Kodaira-Spencer collaboration was more than just a working relationship. The two had very different personalities which were complementary. Kodaira's shyness and reticence were balanced by Spencer's dynamism. In the world of university politics Spencer was able to exercise his talents on Kodaira's behalf, providing a protective environment in which Kodaira's mathematical talents could flourish."

I now begin to go into more detail concerning some of the selected papers. In [28] results of earlier papers are incorporated. Sheaves do not occur yet. The theory of harmonic integrals is used to study the vector space of all meromorphic differentials W of degree n on an n-dimensional Kähler manifold V_n of dimension n which satisfy $(W)+S \geq 0$, where S is a given divisor of V_n. The dimension of this space equals $\dim \mid K+S \mid +1$ if K is a canonical divisor, where $\mid K+S \mid$ is the complete linear system of divisors linearly equivalent to $K+S$ and is called the *adjoint system* of S. Several Riemann-Roch type formulas for $\dim \mid K+S \mid$ are proved. Following Severi, Kodaira introduces the numerical characteristic $a(V_n)$ by the formula

$$(1)\quad a(V_n) = g_n(V_n) - g_{n-1}(V_n) + \ldots + (-1)^{n-1} g_1(V_n),$$

where $g_i(V_n)$ is the dimension of the space of holomorphic differentials of degree i. He formulates a Riemann-Roch theorem for adjoint systems (assuming now that V_n is projective algebraic and E is a smooth hyperplane section for some embedding). He proves (Theorem 2.3.1 in [28])

$$(2)\qquad \dim \mid K+E \mid = a(V_n) + a(E) - 1.$$

Not much later we would say that it is better to consider the holomorphic Euler number

$$(3)\qquad \chi(V_n) = \sum_{i=0}^{n} (-1)^i g_i(V_n)$$

($g_0 = 1$ if V_n is connected) and for a divisor D the number

$$(4)\qquad \chi(V_n, D) = \sum_{i=0}^{n} (-1)^i \dim H^i(V_n, \Omega(D)),$$

where $\Omega(D)$ is the sheaf of local meromorphic functions f with $(f)+D \geq 0$. Then $\dim H^0(V_n, \Omega(D)) = \dim \mid D \mid +1$. By the Kodaira vanishing theorem [35] the spaces $H^i(V_n, \Omega(K+E))$ are zero for $i > 0$. Hence $\dim \mid K+E \mid +1 = \chi(V_n, K+E)$, but by Serre duality $\chi(V_n, K+E) = (-1)^n \chi(V_n, -E)$ (true for any divisor E and for the individual terms in the alternating sum). Serre duality is mentioned in [34] and [35]. Therefore (2) becomes

$$(5)\qquad \chi(V_n, -E) = \chi(V_n) - \chi(E),$$

which follows from an easy exact sequence of sheaves.

But let us go back to [28]. Kodaira proves that $\dim \mid D+hE \mid$ is a polynomial $\nu(h, D)$ in h for large h (often called a Hilbert polynomial) and that $\nu(0, D)$ depends only on D. It is called the virtual dimension of $\mid D \mid$. Now we follow [31]. There are two distinct ways in which arithmetic genera may be defined. In the first place we may define the *arithmetic genus* $P_a(V_n)$ to be the virtual dimension $\nu(0, K)$ of $\mid K \mid$ increased by $1-(-1)^n$ and alternatively the *arithmetic genus* $p_a(V_n)$ by $(-1)^n \nu(0,0)$. In [31] the authors point out that $p_a(V_n) = P_a(V_n)$ has not been established before for $n \geq 5$. They prove it using sheaves. In [28] Kodaira showed $P_a(V_n) = a(V_n)$ in general and $P_a(V_n) = p_a(V_n)$ for a special class of varieties, including complete intersections in projective spaces. A little later we would say

$$\dim \mid D+hE \mid +1 = \chi(V_n, D+hE)$$

for h large by the Kodaira vanishing theorem. But $\chi(V_n, D+hE)$ is a polynomial for all h. Therefore $\nu(0, D)+1 = \chi(V_n, D)$ and

$$\nu(0,0)+1 = (-1)^n(\nu(0, K)+1)$$

At the Institute for Advanced Study, August 1952. Left to right: F. Hirzebruch, Mrs. Kodaira, K. Kodaira.

by Serre duality. But this is the equality $p_a = P_a$. I pointed out "A little later we would say...." Here I must mention the papers [31]–[36] from which I could learn so much (of course, before the papers were written). These papers were all communicated to the *Proceedings of the National Academy of Sciences* by S. Lefschetz. Let us look briefly at [32] and [35].

In [32] Kodaira works with a compact complex analytic variety V of complex dimension n and a holomorphic line bundle F over V and studies the sheaf (faisceau, stack) $\Omega^p(F)$ over V of germs of holomorphic p forms with coefficients in F. I quote from [32]: "The faisceau $\Omega^p(F)$ introduced recently by D. C. Spencer and, independently, by J.-P. Serre turned out to be of importance to applications of faisceaux to the theory of compact analytic varieties. However, for these applications, we need a basic theorem to the effect that the cohomology groups $H^q(V;\Omega^p(F))$ of V with coefficients in $\Omega^p(F)$ have finite dimension. The purpose of the present short note is to give an outline of a proof of this basic theorem." Kodaira uses a Hermitian metric and has to generalize Hodge theory on Kähler manifolds to this more general case using the complex Laplace-Beltrami operator studied earlier by Garabedian and Spencer in the case where F is trivial. The Laplace-Beltrami operator is elliptic. Solution spaces are finite dimensional. With respect to this operator $H^q(V;\Omega^p(F))$ can be identified with the vector space $H^{p,q}(F)$ of all harmonic forms of type (p,q) on V with coefficients in F. In [35] Kodaira writes, "In the present note we shall prove by a differential-geometric method due to Bochner some sufficient conditions for the vanishing of $H^q(V;\Omega^p(F))$ in terms of the characteristic class of the bundle F." In particular he proves: If the characteristic class of F is positive in the sense of Kodaira (representable by a Kähler form), then $H^q(V,\Omega^n(F))$ and $H^{n-q}(V,\Omega^0(-F))$ (Serre duality) both vanish for $1 \le q \le n$. Bochner's papers (*Curvature and Betti numbers, I and II*) appeared in the *Annals of Mathematics* in 1948 and 1949. In [36] Kodaira and Spencer study the holomorphic Euler numbers

$$\chi_V^p(F) = \sum_q (-1)^q \dim H^q(V;\Omega^p(F)) \tag{6}$$

and prove the "form term formula"

$$\chi_V^p(F) = \chi_V^p(F-\{S\}) + \chi_S^p(F_S) + \chi_S^{p-1}(F_S - \{S\}_S) \tag{7}$$

(for a line bundle or divisor F and a smooth hypersurface S), which was very important for me when I studied the polynomial

$$\chi_y(V,F) = \sum_{p=0}^{n} \chi_V^p(F) y^p \tag{8}$$

(also for a holomorphic vector bundle F), where the χ_y-genus $\chi_y(V)$ is the polynomial obtained if F is the trivial line bundle. These polynomials occur in the proof of my Riemann-Roch theorem.

The χ_y-genus is a generalization of the holomorphic Euler number $\chi(V)$ (for $y=0$) and $\chi(V)$ equals $(-1)^n a(V)+1$ if $n = \dim V$ (see (3)).

At this point let me emphasize the Paris-Princeton relations of the early 1950s. I recommend reading the letter of Serre to Borel of April 16, 1953 (published in Serre's *Collected Papers*, Vol. 1, No. 20, Springer-Verlag, 1986), and Serre's comments (Vol. 1, p. 588).

In my recent lecture "Learning Complex Analysis in Münster-Paris, Zürich and Princeton from 1945 to 1953" (Journée en l'Honneur d'Henri Cartan, June 14, 1997; *Gazette des Mathématiciens* **74** (1997), 27–39) I talk about Paris-Princeton on pp. 35–36.

In the introduction of my book I speak of four definitions of the arithmetic genus

$$p_a(V), P_a(V), a(V) = g_n - g_{n-1} + \ldots + (-1)^{n-1} g_1$$

and the Todd genus. The basic reference is J. A. Todd, *The arithmetical invariants of algebraic loci*, Proc. London Math. Soc. **43** (1937), 190–225, where Todd uses the characteristic classes K_i of Eger and Todd, which are $(2n-2i)$-dimensional cycles $(K_1 = K)$, to express $(-1)^n P_a(V)+1$ as a polynomial in the K_i. The proof relies on an unproved lemma of Severi from which Todd concludes that such polynomials must exist. He characterizes them by requesting that they give the correct values on the complete intersection of smooth hypersurfaces of degrees $n_1, n_2, \ldots, n_d$ in the projective space of dimension $2d$. Todd's formalism of his polynomials is very difficult to read. Kodaira ([28], (6.1.1)) gave a formula for the Todd polynomial which is close to my multiplicative sequences and stems from his careful analysis of Todd's paper. However, I do not remember whether I realized this in the old days. Clearly, the power series $(e^x-1)/x$ is recognizable in his formula, as it is in Todd's formula (22),which can be interpreted as a formula for the arithmetic genus of the complete intersection V of smooth hypersurfaces of degrees $n_1, \ldots, n_d$ in $P_{2d}(\mathbb{C})$ involving the total Todd class of the normal bundle of V in $P_{2d}(\mathbb{C})$ and the total Todd class of $P_{2d}(\mathbb{C})$. Staying close to Todd's formalism, Kodaira proves that the Todd polynomial gives the arithmetic genus $P_a(V)$ for a class of varieties including complete intersections in projective spaces. At one point, relating the characteristic classes of the tangent bundle of a hypersurface to those of the ambient variety and of the normal bundle, he

needs the help of S. S. Chern, who had just proved his "duality theorem" for Chern classes. Kodaira was aware of the fact that the K_i of Eger and Todd coincide up to the factor $(-1)^i$ with the Chern classes $c_i \in H^{2i}(V, \mathbb{Z})$. With the use of multiplicative sequences, the inductive proof for Kodaira's result that the Todd polynomials give the arithmetic genus on complete intersections became very simple. At a time when I had formulated the Riemann-Roch theorem but could not yet prove it, I also conjectured as a special case of the Riemann-Roch theorem that the polynomial $\chi_y(V)$ is the genus belonging to the power series

$$\frac{x(y+1)}{1-e^{-x(y+1)}} - xy = \frac{x}{f_y(x)}\ , \tag{9}$$

and I proved it for complete intersections. This leads me to the following story. (Compare my *Collected Papers*, Vol. 1, Commentaries, Springer-Verlag, 1987, p. 785.)

A. Weil wrote to Kodaira on October 22, 1953, asking in particular for the Hodge numbers of the complete intersection of two quadrics. Kodaira answered on November 4, 1953, explaining my result on the χ_y-genus of complete intersections by which all Hodge numbers of complete intersections are known. At the end of this letter Kodaira writes:

"Recently I could prove that every Hodge variety (i.e. a Kähler variety whose fundamental form $i\Sigma g_{\alpha\bar{\beta}} dz^\alpha \wedge dz^{\bar{\beta}}$ is homologous to an integral cocycle) is an algebraic variety imbedded in a projective space. I believe that my proof is correct; however, I am afraid that my result is too good. I would appreciate very much your comment on this result."

Here Kodaira announces one of his most famous and deep results ([37], communicated by S. Bochner on February 23, 1954, and [38]). I do not know Weil's answer. He must have reacted, because Kodaira wrote him on November 18, 1953, thanking him for a letter and explaining to him in all detail my formulas, which make the calculation of the $h^{p,q}$ of complete intersections more explicit and which are published in the *Proceedings of the International Congress of Mathematicians, Amsterdam, 1954* (my *Collected Papers*, Vol. 1, No. 12, formula (1)).

In the introduction to [38] Kodaira recalls that Hodge had introduced in 1951 the Kähler manifolds of special type and A. Weil had called them Hodge manifolds (A. Weil, *On Picard varieties*, Amer. J. Math. **74** (1952), 865–894). A. Weil proves theorems on Hodge manifolds and recalls Hodge's result that the Picard variety of a Hodge manifold is projective algebraic.

For the proof of his fundamental result Kodaira has to use results of earlier papers, for example, his vanishing theorem. He proves that for a Hodge variety V there exists a real $(1,1)$-form β such that, for any complex line bundle F whose characteristic class contains a closed real $(1,1)$-form $\gamma > \beta$, the holomorphic sections of F define a biregular mapping of V into a projective space (Theorem 3 in [38]).

Kodaira's fundamental theorem generalizes classical results characterizing those complex tori which are projective algebraic. He gives several applications. One was especially important for me. Section 18 of my book *Topological Methods in Algebraic Geometry* carries the title "Some fundamental theorems of Kodaira". I quote Theorem 18.3.1 (Kodaira):

Kodaira on Princeton campus, 1952.

"A complex analytic fiber bundle L over the projective algebraic manifold V with the projective space $P_r(\mathbb{C})$ as fiber and $\mathrm{PGL}(r+1, \mathbb{C})$ as structure group is itself a projective algebraic manifold."

This is used for the proof of my Riemann-Roch theorem, which was completed on December 10, 1953, and announced in the *Proceedings of the National Academy of Sciences* (communicated by S. Lefschetz on December 21, 1953). I had to reduce everything to complex split manifolds where the structural group is the triangular group contained in the general linear group. Then the arithmetic genus can be expressed by virtual signatures which (by the signature theorem as a consequence of Thom's cobordism theory) can be expressed by characteristic classes. But for certain inductive processes I had to stay in the category of projective algebraic manifolds. For a projective algebraic manifold the total space of the flag manifold bundle associated to the tangent bundle is a split manifold. It is projective algebraic by repeated applications of Kodaira's theorem 18.3.1. In my announcement I refer to Kodaira in footnote 9 ("Kodaira, K., not yet published"). I also needed results on the behavior of genera in fiber bundles. The best result is in Appendix Two (by A. Borel) of my book :

"Let $\xi = (E, B, F, \pi)$ be a complex analytic fiber bundle with connected structure group, where E, B, F are compact connected, and F is Kählerian. Let W be a complex analytic fiber bundle over B. Then $\chi_y(E, \pi^* W) = \chi_y(B, W)\chi_y(F)$."

The cooperation with A. Borel in Princeton was of great importance for Kodaira, Spencer, and me in learning characteristic classes and in many other

ways, as can be seen, for example, by remarks of Kodaira in [38].

Of course, I am very proud to have one joint paper with Kodaira [41], which was published only in 1957, though I had announced the result already in my talk in Amsterdam in 1954 (loc. cit.). One of my main discoveries (standard joke) is the formula

$$\frac{x}{1-e^{-x}} = e^{x/2} \cdot \frac{x/2}{\sinh x/2},$$

which showed that the Todd genus is expressible by the first Chern class c_1 and the Pontryagin classes. The latter ones do not depend on the complex analytic structure. For a divisor D the number $\chi(V,D)$ depends on the cohomology class $d + c_1/2$ where d is the cohomology class of D and otherwise only on the oriented differentiable manifold V. This we used in [41]. This remark led to the introduction of the $\hat{A}$-genus which is defined for oriented differentiable manifolds. It equals $\chi(V,D)$ if $2d + c_1 = 0$. From here a new development started whose beginning for me was Atiyah's lecture at the Bonn *Arbeitstagung* in 1962, where it was conjectured that for a spin-manifold the $\hat{A}$-genus is the index of the Dirac operator. This was proved a little later by Atiyah and Singer as a special case of their general index theorem for linear elliptic operators. The index theorem also included my Riemann-Roch theorem as a special case even for complex manifolds (used by Kodaira in [60]). The paper [41] was for me a sign of the importance of the $\hat{A}$-genus.

One more word about the χ_y-genus. If S and T are smooth hypersurfaces in the projective algebraic manifold V and if the divisor $S+T$ is also represented by a smooth hypersurface such that the intersections $S \cdot T$ and $S \cdot T \cdot (S+T)$ are transversal and hence smooth, then

$$(10)\quad \chi_y(S+T) = \chi_y(S) + \chi_y(T) + (y-1)\chi_y(S \cdot T) - y\chi_y(S \cdot T \cdot (S+T)),$$

which I deduced from the four-term formula (7). The functional equation (10) is also true for the χ_y-genus in terms of characteristic classes using the power series (9). It follows from a corresponding elementary functional equation of $f_y(x)$. Kodaira often proved and used (10) for $y = 0$. (See his concept of A-functional in [28], Sections 2.7 and 6.3). It is clear that (10) is useful for the study of complete intersections (inductive proofs).

Kodaira's and Spencer's joint work on deformations of complex analytic structures ([43], [48], and several other papers) is perhaps the greatest achievement of their cooperation. It is an enlightment to read in the introduction of [43], "... we *define* a differentiable family of compact complex structures (manifolds) as a fiber space $\mathcal{V}$ over a connected differentiable manifold M whose structure is a mixture of differentiable and complex structures." Kodaira and Spencer introduce the sheaf Θ on $\mathcal{V}$, the corresponding sheaf of cohomology $\mathcal{H}^1(\Theta)$ on M, and a homomorphism (the Kodaira-Spencer map) $\rho : T_M \to \mathcal{H}^1(\Theta)$ where T_M is the sheaf of germs of differentiable vector fields of M. The complex structure V_t, $t \in M$, is independent of t if and only if ρ vanishes. By restricting Θ to V_t (fixed fiber over $t \in M$) they obtain the homomorphism $\rho_t : (T_M)_t \to H^1(V_t, \Theta_t)$ of Frölicher and Nijenhuis, where $(T_M)_t$ is the tangent space of M at t and Θ_t is the sheaf of germs of holomorphic vector fields on V_t. The vanishing of ρ_t for all t does not imply the vanishing of ρ, as "jumps" show, for example, from the smooth quadric surface to the singular quadric with a node and the node blown up (Atiyah, Brieskorn). Now I quote again from the introduction of [43]: "Next we extend Riemann's concept of number of moduli to higher dimensional complex manifolds (Section 11). The main point here is to avoid the use of the concept of the space of moduli of complex manifolds which cannot be defined in general for higher dimensional manifolds (Section 14, (γ)). Moreover, a necessary condition for the existence of a number $m(V_0)$ of moduli of a complex manifold V_0 is that $H^1(V_0, \Theta_0)$ contain only one deformation space; hence $m(V_0)$ is not defined for all compact complex manifolds...." Kodaira and Spencer find it surprising that $m(V_0) = \dim H^1(V_0, \Theta_0)$ for so many examples and consider a better understanding of this fact as the main problem in deformation theory. I do not want to say more about their deformation theory. Surveys are in Baily's preface to Kodaira's *Collected Works* and in the introduction by K. Ueno and T. Shioda to the volume *Complex Analysis and Algebraic Geometry* (Iwanami Shoten, Publishers, and Cambridge University Press, 1977), dedicated to Kodaira on the occasion of his sixtieth birthday. Anyhow, this report is personal and concerns those aspects of Kodaira's work related to my own. Hence, for lovers of Riemann-Roch, I write what this theorem gives for Θ_0 in dimension $n = 1$ (Riemann) and $n = 2$ (Max Noether).

$n = 1$:

$$\dim H^0(V_0, \Theta_0) - \dim H^1(V_0, \Theta_0) = 3 - 3g.$$

The number of moduli equals $3g - 3$+ dimension of the group of automorphisms of V_0.

$n = 2$:

$$\dim H^0(V_0, \Theta_0) - \dim H^1(V_0, \Theta_0) + \dim H^2(V_0, \Theta_0) = -10\,\chi(V_0) + 2c_1^2,$$

where χ is the holomorphic Euler number.

Let us remark that by Serre duality

$$H^i(V_0, \Theta_0) \simeq H^{n-i}(V_0, \Omega^1(K)),$$

which, for $n = 1$ and $i = 1$, is the isomorphism to the space of holomorphic quadratic differentials (see the obituary by Spencer). We have

$$\chi(V_0, \Theta_0) = (-1)^n \chi^1_{V_0}(K).$$

These numbers can be calculated by the Riemann-Roch theorem as linear combinations of Chern numbers. For a Kähler manifold with trivial canonical bundle, $\dim H^i(V_0, \Theta_0)$ equals the Hodge number $h^{1,n-i}$. For a $K3$-surface we have $h^{1,1} = 20$. Kodaira and Spencer discuss many more examples. For the complex projective space $P_n(\mathbb{C})$ we have $\dim H^1(P_n(\mathbb{C}), \Theta_0) = 0$ in agreement with the result in [41].

With the exception of three papers, the whole Volume III of Kodaira's *Collected Works* is concerned with complex analytic surfaces. His work in this area is overwhelming. He can use his earlier papers on complex manifolds and on deformations. I have used the papers in Volume III very often. Looking, for example, at my joint paper with A. Van de Ven, *Hilbert modular surfaces and the classification of algebraic surfaces* (Invent. Math. **23** (1974), 1–29), I find that we used the following:

1. *Rough classification of surfaces, Kodaira dimension* ([68], Theorem 55). Kodaira proves that the compact complex surfaces free from exceptional curves can be divided into seven classes. Class 5 comprises the minimal algebraic surfaces of general type. Class 7 surfaces are mysterious surfaces with first Betti number equal to 1. Van de Ven and I specialize Kodaira's classification to algebraic surfaces, where this classification in broad outline was known to the Italian school, but many of the proofs are due to Kodaira.
2. *Kodaira's proof of Castelnuovo's criterion for the rationality of algebraic surfaces.*
3. *Study of elliptic surfaces, their multiple fibers, and a formula for the canonical divisor.*
4. *Classification of the exceptional fibers in elliptic surfaces.*
5. *The fact that all $K3$-surfaces are homeomorphic and hence simply connected.* Kodaira proves more ([60], Theorem 13): Every $K3$-surface is a deformation of a nonsingular quartic surface in a projective 3-space.

The surfaces in Class 7 are also called VII_0-surfaces ([60], Theorem 21). Masahisa Inoue (*New surfaces with no meromorphic functions II*, in the volume dedicated to Kodaira's sixtieth birthday) has constructed such surfaces using my resolution of the cusp singularities of Hilbert modular surfaces. Such a surface has only finitely many curves on it. They are rational and arranged in two disjoint cycles.

Now a last case where a paper of Kodaira was especially close to my interest. In [64] he constructed algebraic surfaces with positive signature whose total spaces are differentiable fiber bundles with compact Riemann surfaces as base and fiber. In the early 1950s we did not know a single surface with signature greater than 1 and often talked about it at Princeton. How the situation developed over the years can be seen, for example, in the book *Geradenkonfigurationen und Algebraische Flächen* (by Gottfried Barthel, Thomas Höfer, and me, Vieweg, 1987). Also, Kodaira's surfaces give examples in which the signature of the total space of a fibration is not equal to the product of the signatures of base and fiber. The multiplicativity of the signature in fiber bundles (of oriented manifolds) was proved by S. S. Chern, J.-P. Serre, and me under the assumption that the fundamental group of the base operates trivially on the real cohomology of the fiber (*On the index of a fibered manifold*, Proc. Amer. Math. Soc. **8** (1957), 587–596).

Grauert, Hirzebruch, Remmert return to Germany after the Conference on Analytic Functions at the Institute for Advanced Study, September 1957. From left to right: F. Hirzebruch, Joan Frankel (Mrs. Theodore Frankel), D. C. Spencer, K. Kodaira, A. Borel, W.-L. Chow, H. Grauert. Foreground: R. Remmert.

Far from attempting to give a thorough appreciation of Kodaira's great mathematical work, I wanted to show how much I am indebted to him and where our mathematical lives crossed.

Selected Papers from Kodaira's Collected Works

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Measuring the Shape of the Universe

Neil J. Cornish and Jeffrey R. Weeks

Introduction

Since the dawn of civilization, humanity has grappled with the big questions of existence and creation. Modern cosmology seeks to answer some of these questions using a combination of mathematics and measurement. The questions people hope to answer include How did the universe begin?, How will the universe end?, Is space finite or infinite?. After a century of remarkable progress, cosmologists may be on the verge of answering at least one of these questions: Is space finite? Using some simple geometry and a small NASA satellite set for launch in the year 2000, the authors and their colleagues hope to measure the size and shape of space. This article explains the mathematics behind the measurement and the cosmology behind the observations.

Before setting out, let us first describe the broad picture we have in mind. Our theoretical framework is provided by Einstein's theory of general relativity and the hot big bang model of cosmology. General relativity describes the universe in terms of geometry, not just of space, but of space and time. Einstein's equation relates the curvature of this spacetime geometry to the matter contained in the universe.

A common misconception is that the curvature of space is all one needs to answer the question, Is space finite or infinite?. While it is true that spaces of positive curvature are necessarily finite, spaces of negative or zero curvature may be either finite or infinite. In order to answer questions about the global geometry of the universe, we need to know both its curvature and its topology. Einstein's equation tells us nothing about the topology of spacetime, since it is a local equation relating the spacetime curvature at a point to the matter density there. To study the topology of the universe, we need to measure how space is connected. In doing so we will not only discover whether space is finite but also gain insight into physics beyond general relativity.

The outline of our paper is as follows: We begin with an introduction to big bang cosmology, followed by a review of some basic concepts in geometry and topology. With these preliminaries out of the way, we go on to describe the plan to measure the size and shape of the universe using detailed observations of the afterglow from the big bang.

Big Bang Cosmology

The big bang model provides a spectacularly successful description of our universe. The edifice is supported by three main observational pillars: (1) the uniform expansion of the universe, (2) the abundances of the light elements, (3) the highly uniform background of microwave radiation.

The primary pillar was discovered by Edwin Hubble in the early 1920s. By comparing the spectral lines in starlight from nearby and distant galaxies, Hubble noticed that the vast majority of distant galaxies have their spectra shifted to the red, or long wavelength, part of the electromagnetic spectrum. Moreover, the redshift was seen to be larger for more distant galaxies and to occur uni-

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formly in all directions. A simple explanation for this observation is that the space between the galaxies is expanding isotropically. By the principle of mediocrity—i.e., we do not live at a special point in space—isotropic expansion about each point implies homogenous expansion. Such a homogeneous and isotropic expansion can be characterized by an overall scale factor $a(t)$ that depends only on time. As the universe expands, the wavelength λ of freely propagating light is stretched so that

$$\lambda(t_0) = \lambda(t)\frac{a(t_0)}{a(t)}, \tag{1}$$

where t_0 denotes the present day and t denotes the time when the light was emitted. Astronomers define the *redshift* z as the fractional change in the wavelength:

$$z = \frac{\lambda(t_0) - \lambda(t)}{\lambda(t)}. \tag{2}$$

Since we expect atoms to behave the same way in the past, we can use atomic spectra measured on Earth to fix $\lambda(t)$. Using equation (1), we can relate the redshift to the size of the universe:

$$a = \frac{a_0}{(1+z)}. \tag{3}$$

We have adopted the standard shorthand $a_0 = a(t_0)$ for denoting quantities measured today and $a = a(t)$ for denoting quantities measured at a generic time t. By measuring the redshift of an object, we can infer how big the universe was when the light was emitted. The relative size of the universe provides us with a natural notion of time in cosmology. Astronomers like to use redshift z as a measure of time ($z = 0$ today, $z = \infty$ at the big bang), since, unlike the time t, the redshift is a measurable quantity.

A photon's energy E varies inversely with its wavelength λ. A gas of photons at temperature T contains photons with energies in a narrow band centered at an energy E that is proportional to the temperature. Thus $T \sim E \sim \lambda^{-1}$, and the temperature of a photon gas evolves as

$$\frac{T}{T_0} = \frac{E}{E_0} = \frac{\lambda_0}{\lambda} = \frac{a_0}{a} = 1 + z. \tag{4}$$

This equation tells us that the universe should have been much hotter in the past than it is today. It should also have been much denser. If no particles are created or destroyed, the density of ordinary matter is inversely proportional to the occupied volume, so it scales as $\rho_m \sim a^{-3}$. If no photons are created or destroyed, the number of photons per unit volume also scales as a^{-3}. However, the energy of each photon is decreasing in accordance with equation (4), so that the energy density of the photon gas scales as $\rho_\gamma \sim a^{-4}$.

Starting at the present day, roughly 10 or 15 billion years after the big bang, let us go back through the history of the universe. With time reversed we see the universe contracting and the temperature increasing. Roughly $t \simeq 300,000$ years from the start, the temperature has reached several thousand degrees Kelvin. Electrons get stripped from the atoms, and the universe is filled with a hot plasma. Further back in time, at $t \simeq 1$ second, the temperature gets so high that the atomic nuclei break up into their constituent protons and neutrons. Our knowledge of nuclear physics tells us this happens at a temperature of 10^{10} °K. At this point let us stop going back and let time move forward again. The story resumes with the universe filled by a hot, dense soup of neutrons, protons, and electrons. As the universe expands, the temperature drops. Within the first minute the temperature drops to 10^9 °K, and the neutrons and protons begin to fuse together to produce the nuclei of the light elements deuterium, helium, and lithium. In order to produce the abundances seen today, the nucleon density must have been roughly 10^{18} cm^{-3}. Today we observe a nucleon density of $\sim 10^{-6}$ cm^{-3}, which tells us the universe has expanded by a factor of roughly $(10^{18}/10^{-6})^{1/3} = 10^8$. Using equation (4), we therefore expect the photon gas today to be at a temperature of roughly 10°K. George Gamow made this back-of-the-envelope prediction in 1946.

In 1965 Penzias and Wilson discovered a highly uniform background of cosmic microwave radiation at a temperature of ~ 3°K. This *cosmic microwave background* (CMB) is quite literally the afterglow of the big bang. More refined nucleosynthesis calculations predict a photon temperature of ~ 3°K, and more refined measurements of the CMB reveal it to have a black body spectrum at a temperature of $T_0 = 2.728 \pm 0.010$ °K. Typical cosmic microwave photons have wavelengths roughly equal to the size of the letters on this page.

The CMB provides strong evidence for the homogeneity and isotropy of space. If we look out in any direction of the sky, we see the same microwave temperature to 1 part in 10^4. This implies the curvature of space is also constant to 1 part in 10^4 on large scales. This observed homogeneity lets cosmologists approximate the large-scale structure of the universe, not by a general spacetime, but by one having well-defined spatial cross-sections of constant curvature. In these Friedman-Robertson-Walker (FRW) models the spacetime manifold $\mathcal{M}$ is topologically the product $\mathbb{R} \times \Sigma$, where the real line $\mathbb{R}$ represents time and Σ represents a 3-dimensional space of constant curvature.[1] The metric on the spacelike slice $\Sigma(t)$ at time t is given by the scale factor $a(t)$ times the standard metric of constant curvature

[1] *Even though elementary particle theory suggests the universe is orientable, both the present article and the research program of the authors and their colleagues permit nonorientable universes as well.*

$k = +1, 0, -1$. The sectional curvature is $k/a(t)^2$, so when $|k| = 1$, the scale factor $a(t)$ is the curvature radius; when $k = 0$, the scale factor remains arbitrary.

The function $a(t)$ describes the evolution of the universe. It is completely determined by Einstein's field equation. In general Einstein's equation is a tensor equation in spacetime, but for a homogeneous and isotropic spacetime it reduces to the ordinary differential equation

$$\left(\frac{\dot{a}}{a}\right)^2 + \frac{k}{a^2} = \frac{8\pi G}{3}\rho. \tag{5}$$

Here G is Newton's gravitational constant, ρ is the mass-energy density, $\dot{a} = da/dt$; and we have chosen units that make the speed of light $c = 1$.

The first term in equation (5) is the Hubble parameter $H = \dot{a}/a$, which tells how fast the universe is expanding or contracting. More precisely, it tells the fractional rate of change of cosmic distances. Its current value H_0, called the *Hubble constant*, is about 65 (km/sec)/Mpc.[2] Thus, for example, the distance to a galaxy 100 Mpc away would be increasing at about 6,500 km/sec, while the distance to a galaxy 200 Mpc away would be increasing at about 13,000 km/sec.

Substituting $H = \dot{a}/a$ into equation (5) shows that when $k = 0$, the mass-energy density ρ must be exactly $3H^2/8\pi G$. Similarly, when $k = +1$ (resp. $k = -1$), the mass-energy density ρ must be greater than (resp. less than) $3H^2/8\pi G$. Thus, if we can measure the current density ρ_0 and the Hubble constant H_0 with sufficient precision, we can deduce the sign k of the curvature. Indeed, if $k \neq 0$, we can solve for the curvature radius

$$a = \frac{1}{H}\sqrt{\frac{k}{8\pi G\rho/3H^2 - 1}} = \frac{1}{H}\sqrt{\frac{k}{\Omega - 1}}, \quad k \neq 0, \tag{6}$$

where the *density parameter* Ω is the dimensionless ratio of the actual density ρ to the critical density $\rho_c = 3H^2/8\pi G$.

The universe contains different forms of mass-energy, each of which contributes to the total density:

$$\Omega = \frac{\rho}{\rho_c} = \frac{\rho_\gamma + \rho_m + \rho_\Lambda}{\rho_c} = \Omega_\gamma + \Omega_m + \Omega_\Lambda, \tag{7}$$

where ρ_γ is the energy density in radiation, ρ_m is the energy density in matter, and ρ_Λ is a possible vacuum energy. Vacuum energy appears in many current theories of the very early universe, including the inflationary paradigm. Vacuum energy with density $\rho_\Lambda = 3\Lambda/8\pi G$ mimics the cosmological constant Λ, which Einstein introduced into his field equations in 1917 to avoid predicting an expanding or contracting universe and later retracted as "my greatest blunder."

In a universe containing only ordinary matter ($\Omega_\gamma = \Omega_\Lambda = 0$), the mass density scales as $\rho = \rho_0(a_0/a)^3$. Substituting this into equation (5), one may find exact solutions for $a(t)$. These solutions predict that if $\Omega < 1$, the universe will expand forever; if $\Omega > 1$, the expansion will slow to a halt and the universe will recontract; and in the borderline case $\Omega = 1$, the universe will expand forever, but at a rate $\dot{a}$ approaching zero. These predictions make good intuitive sense: under the definition of Ω as the ratio $8\pi G\rho/3H^2$, $\Omega > 1$ means the mass density ρ is large and/or the expansion rate H is small, so the gravitational attraction between galaxies will slow the expansion to a halt and bring on a recollapse; conversely, $\Omega < 1$ means the density is small and/or the expansion rate is large, so the galaxies will speed away from one another faster than their "escape velocity".

Cosmologists have suffered from a persistent misconception that a negatively curved universe must be the infinite hyperbolic 3-space $\mathbb{H}^3$. This has led to the unfortunate habit of using the term "open universe" to mean three different things: "negatively curved", "spatially infinite", and "expanding forever". Talks have even been given on the subject of "closed open models", meaning finite hyperbolic 3-manifolds (assumed to be complete, compact, and boundaryless). Fortunately, as finite manifolds are becoming more widely understood, the terminology is moving toward the following. Universes of positive, zero, or negative spatial curvature (i.e., $k = +1, 0, -1$) are called "spherical", "flat", or "hyperbolic" respectively. Universes that recollapse, expand forever with zero limiting velocity, or expand forever with positive limiting velocity are called "closed", "critical", or "open" respectively. (Warning: This conflicts with topologists' definitions of "closed" and "open".)

Messengers from the Edge of Time

In the early 1990s the COBE satellite detected small intrinsic variations in the cosmic microwave background temperature, of order 1 part in 10^5. This small departure from perfect isotropy is thought to be due mainly to small variations in the mass distribution of the early universe. Thus the CMB photons provide a fossil record of the big bang. The field of "cosmic paleontology" is set for a major boost in the next decade as NASA plans to launch the *Microwave Anisotropy Probe* (MAP) and ESA, the *Planck Surveyor*. These satellites will produce clean

[2] *The abbreviation Mpc denotes a megaparsec, or one million parsecs. A parsec is one of those strange units invented by astronomers to baffle the rest of us. One parsec defines the distance from Earth of a star whose angular position shifts by 1 second of arc over a 6-month period of observation. i.e., a parsec is defined by parallax with two Earth-Sun radii as the baseline. A parsec is about three light-years.*

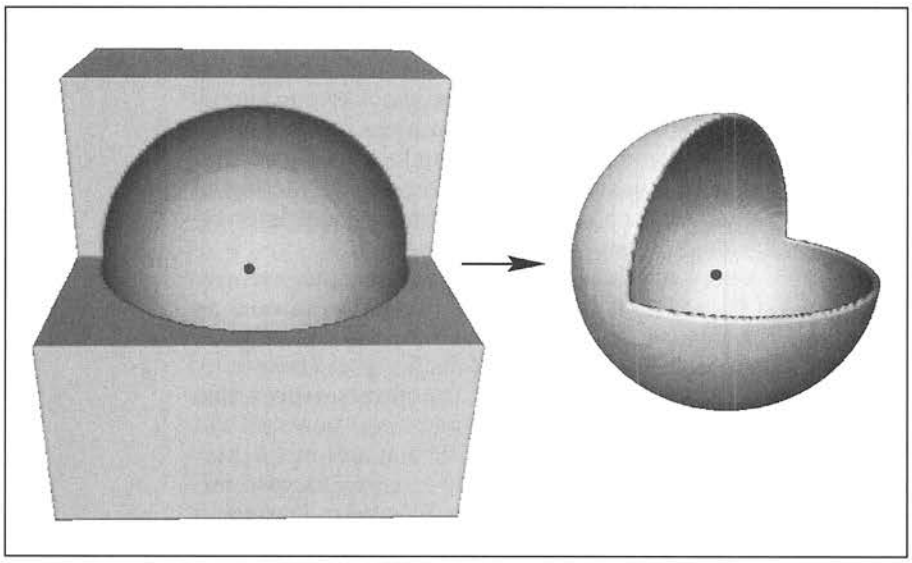

Figure 1. (Left) A block of space at the time of last scatter sliced open to show the surface of last scatter seen by us today. The dot marks the point where the Earth will eventually form. (Right) A cut-away view showing the spherical shell we refer to as the last scattering surface.

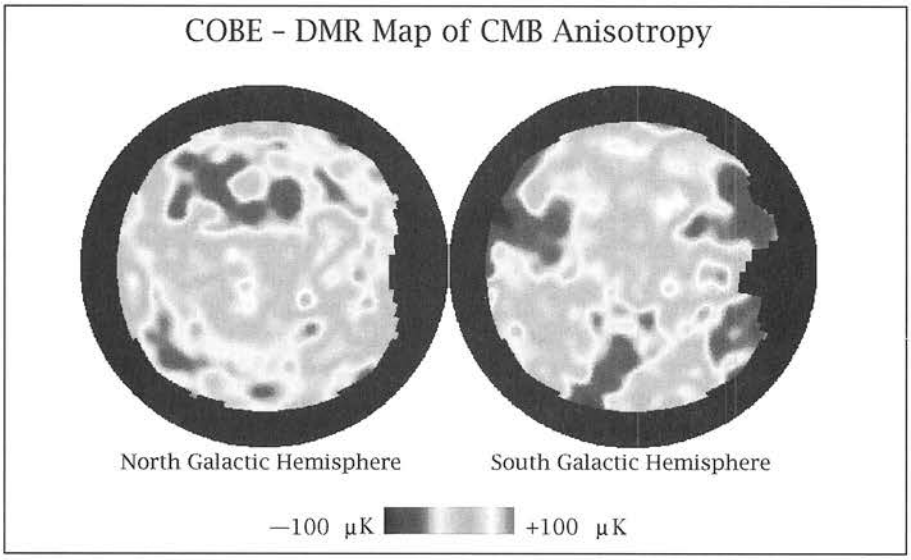

Figure 2. The temperature variations in the CMB measured by the COBE satellite. The northern and southern hemispheres of the celestial sphere have been projected onto flat circular disks. Here the equator is defined by the galactic plane of the Milky Way. The black pixels correspond to portions of the sky where the data were badly contaminated by galactic emissions.

all-sky maps of the microwave sky with one fifth of a degree resolution. In contrast, the COBE satellite produced a very noisy map at ten degree resolution [1]. But where are the CMB photons coming from, and what can they tell us about the curvature and topology of space?

The first thing to realize about any observation in cosmology is that one cannot talk about "where" without also talking about "when". By looking out into space, we are also looking back in time, as all forms of light travel at the same finite speed. Recall that about 300,000 years after the big bang, at a redshift of $z \simeq 1400$, the entire universe was filled with an electron-ion-photon plasma similar to the outer layers of a present-day star. In contrast to a gas of neutral atoms, a charged plasma is very efficient at scattering light and is therefore opaque. We can see back to, but not beyond, the surface of last scatter at $z \simeq 1200$.

Once the plasma condensed to a gas, the universe became transparent, and the photons have been travelling largely unimpeded ever since. They are distributed homogeneously throughout the universe and travel isotropically in all directions. But the photons we measure with our instruments are the ones arriving *here* and *now*. Our position defines a preferred point in space, and our age defines how long the photons have been travelling to get here. Since they have all been travelling at the same speed for the same amount of time, they have all travelled the same distance. Consequently, the CMB photons we measure today originated on a 2-sphere of fixed radius, with us at the center (see Figure 1). An alien living in a galaxy a billion light years away would see a different sphere of last scatter.

To be precise, the universe took a finite amount of time to make the transition from opaque to transparent (between a redshift of $z \simeq 1400$ and $z \simeq 1200$), so the sphere of last scatter is more properly a spherical shell with a finite thickness. However, the shell's thickness is less than 1% of its radius, so cosmologists usually talk about the sphere of last scatter rather than the shell of last scatter.

Now that we know where (and when) the CMB photons are coming from, we can ask what they have to tell us. In a perfectly homogeneous and isotropic universe, all the CMB photons would arrive here with exactly the same energy. But this scenario is ruled out by our very existence. A perfectly homogeneous and isotropic universe expands to produce a perfectly homogeneous and isotropic universe. There would be no galaxies, no stars, no planets, and no cosmologists. A more plausible scenario is to have small inhomogeneities in the early universe grow via gravitational collapse to produce the structures we see today. These small perturbations in the early universe will cause the CMB photons to have slightly different energies: photons coming from denser regions have to climb out of deeper potential wells and lose some energy while doing so.

There will also be line-of-sight effects as photons coming from different directions travel down different paths and experience different energy shifts. However, the energy shifts en route are typically much smaller than the intrinsic energy differences imprinted at last scatter. Thus, by making a map of the microwave sky, we are making a map of the density distribution on a 2-dimensional slice through the early universe. Figure 2 shows the map produced by the COBE satellite [1]. In the sections that follow we will explain how we can use such maps to measure the curvature and topology of space. But first we need to say a little more about geometry and topology.

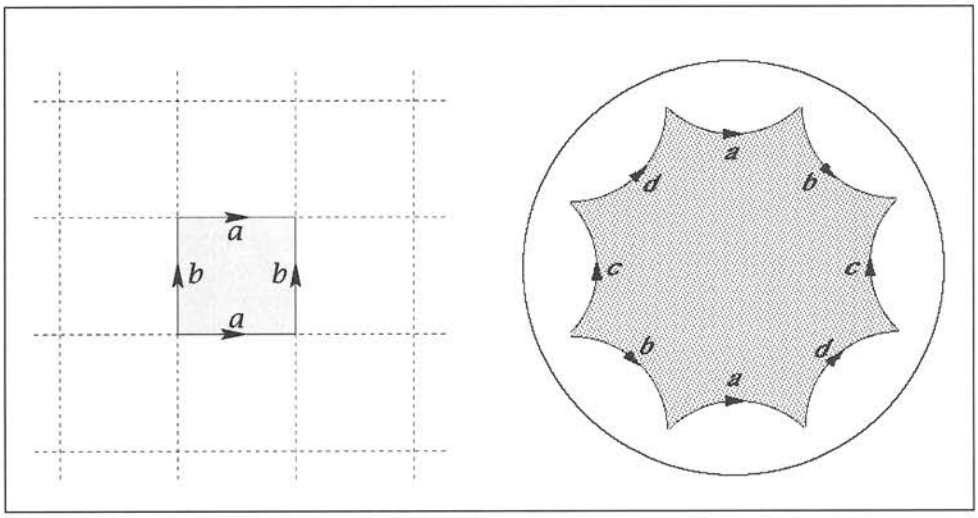

Figure 3. (a, left) Flat torus. (b, right) Closed hyperbolic manifold.

Geometry and Topology

Topology Determines Geometry

For ease of illustration, we begin with a couple of 2-dimensional examples. A flat torus (Figure 3a) may be constructed as either a square with opposite sides identified (the "fundamental domain" picture) or as the Euclidean plane modulo the group of motions generated by $x \to x+1$ and $y \to y+1$ (the "quotient picture"). Similarly, an orientable surface of genus two (Figure 3b) may be constructed as either a regular hyperbolic octagon with opposite sides identified or as the hyperbolic plane modulo a certain discrete group of motions. In this fashion, every closed surface may be given a geometry of constant curvature.

Note that in the construction of the torus the square's four corners come together at a single point in the manifold itself, so it is crucial that the square's angles be exactly $(2\pi)/4 = \pi/2$. In other words, it is crucial that we start with a Euclidean square; a hyperbolic square (with corner angles less than $\pi/2$) or a spherical square (with corner angles greater than $\pi/2$) would not do. Similarly, in the construction of the genus-two surface, the octagon's eight corners come together at a single point in the manifold itself, so it is crucial that the angles be exactly $(2\pi)/8 = \pi/4$. A Euclidean or spherical octagon would not do. In fact, even a smaller (resp. larger) hyperbolic octagon would not do, because its angles would be greater (resp. less) than $\pi/4$. More generally, in any constant curvature surface the Gauss-Bonnet theorem $\int k\,|dA| = 2\pi\chi$ forces the sign of the curvature k to match the sign of the Euler number χ.

The constructions of Figure 3 generalize to three dimensions. For example, a 3-torus may be constructed as either a cube with opposite faces identified or as the 3-dimensional Euclidean space $\mathbb{E}^3$ modulo the group generated by $x \to x+1$, $y \to y+1$, $z \to z+1$. Similar constructions yield hyperbolic and spherical manifolds. In the spherical and hyperbolic cases, the connection between the geometry and the topology is even tighter than in two dimensions. For spherical and hyperbolic 3-manifolds, the topology *completely* determines the geometry, in the sense that if two spherical or hyperbolic manifolds are topologically equivalent (homeomorphic), they must be geometrically identical (isometric) as well.[3] In other words, spherical and hyperbolic 3-manifolds are rigid. However, this rigidity does not extend to Euclidean 3-manifolds: a 3-torus made from a cube and a 3-torus made from a parallelepiped are topologically equivalent but geometrically distinct. The final section of this article will explain how the rigidity of a closed spherical or hyperbolic universe may be used to refine the measured radius of the last scattering sphere.

When we look out into the night sky, we may be seeing multiple images of the same finite set of galaxies, as Figure 3 suggests. For this reason cosmologists studying finite universes make heavy use of the "quotient picture" described above, modelling a finite universe as hyperbolic 3-space, Euclidean 3-space, or the 3-sphere, modulo a group of rigid motions. If we could somehow determine the position and orientation of all images of, say, our own galaxy, then we would know the group of rigid motions and thus the topology. Unfortunately, we cannot recognize images of our own galaxy directly. If we are seeing it at all, we are seeing it at different times in its history, viewed from different angles; and we do not even know what it looks like from the outside, in any case. Fortunately, we *can* locate the images of our own galaxy indirectly, using the cosmic microwave background. The section "Observing the Topology of the Universe" will explain how.

[3] *In the hyperbolic case this result is a special case of the Mostow Rigidity Theorem.*

Geometric Models

Elementary linear algebra provides a consistent way to model the 3-sphere, hyperbolic 3-space, and Euclidean 3-space.

Our model of the 3-sphere $\mathbb{S}^3$ is the standard one. Define Euclidean 4-space $\mathbb{E}^4$ to be the vector space $\mathbb{R}^4$ with the usual inner product $\langle u, v\rangle = u_0v_0 + u_1v_1 + u_2v_2 + u_3v_3$. The 3-sphere is the set of points one unit from the origin, i.e., $\mathbb{S}^3 = \{v \mid \langle v, v\rangle = 1\}$. The standard 4×4 rotation and reflection matrices studied in linear algebra naturally represent rigid motions of $\mathbb{S}^3$, both in theoretical discussions and in computer calculations. These matrices generate the orthogonal group $O(4)$.

Our model of the hyperbolic 3-space $\mathbb{H}^3$ is formally almost identical to our model of the 3-sphere. Define Minkowski space $\mathbb{E}^{1,3}$ to be the vector space $\mathbb{R}^4$ with the inner product $\langle u, v\rangle = -u_0v_0 + u_1v_1 + u_2v_2 + u_3v_3$ (note the minus sign!). The set of points whose squared "distance" from the origin is -1 is, to our Euclidean eyes, a hyperboloid of two sheets. Relative to the Minkowski space metric, though, each sheet is a copy of hyperbolic 3-space. Thus, our formal definition is $\mathbb{H}^3 = \{v \mid \langle v, v\rangle = -1, v_0 > 0\}$. The rigid motions of $\mathbb{H}^3$ are represented by the "orthogonal matrices" that preserve both the Minkowski space inner product and the sheets of the hyperboloid. They comprise an index-2 subgroup of the Lorentz group $O(1,3)$.

The tight correspondence between our models for $\mathbb{S}^3$ and $\mathbb{H}^3$ extends only partially to the Euclidean 3-space $\mathbb{E}^3$. Borrowing a technique from the computer graphics community, we model $\mathbb{E}^3$ as the hyperplane at height 1 in $\mathbb{E}^4$ and represent its isometries as the subgroup of $GL_4(\mathbb{R})$ that takes the hyperplane rigidly to itself.

Natural Units

Spherical geometry has a natural unit of length. Commonly called a radian, it is defined as the 3-sphere's radius in the ambient Euclidean 4-space $\mathbb{E}^4$. Similarly, hyperbolic geometry also has a natural unit of length. It too should be called a radian, because it is defined as (the absolute value of) the hyperbolic space's radius in the ambient Minkowski space $\mathbb{E}^{1,3}$. The scale factor $a(t)$ introduced in the "Big Bang Cosmology" section connects the mathematics to the physics: it tells, at each time t, how many meters correspond to one radian. In both spherical and hyperbolic geometry the radian is more often called the *curvature radius*, and quantities reported relative to it are said to be in *curvature units*. Euclidean geometry has no natural length scale, so all measurements must be reported relative to some arbitrary unit.

Measuring the Curvature of the Universe

To determine the curvature of the universe, cosmologists seek accurate values for the Hubble constant H_0 and the density parameter Ω_0. If $\Omega_0 = 1$, space is flat. Otherwise, equation (6) shows the curvature radius a_0. The parameters H_0 and Ω_0 may be deduced from observations of "standard candles" or the CMB.

Standard Candle Approach

Astonomers observe objects like Cepheid variables and type Ia supernovae whose intrinsic luminosity is known. In a static Euclidean space the apparent brightness of such standard candles would fall off as the square of their distance from us. In an expanding, curved universe the distance-brightness relationship is more complicated. Different values of H_0 and Ω_0 predict different relationships between a standard candle's apparent brightness $\mathcal{F}$ and its redshift z. Sufficiently good observations of $\mathcal{F}$ and z for sufficiently good standard candles will tell us the values of H_0 and Ω_0 and thence the curvature radius a_0.

The results of standard candle observations are still inconclusive. Some recent measurements [2] have yielded results inconsistent with the assumption of a matter-dominated universe and point instead to a vacuum energy Ω_Λ exceeding the density Ω_m of ordinary matter! More refined measurements over the next few years should settle this issue.

CMB Approach

The temperature fluctuations in the CMB (recall Figure 2) are, to a mathematician, a real-valued function on a 2-sphere. As such they may be decomposed into an infinite series of spherical harmonics, just as a real-valued function on a circle may be decomposed into an infinite series of sines and cosines. And just as the Fourier coefficients of a sound wave provide much useful information about the sound (enabling us to recognize it as, say, the note A$^\flat$ played on a flute), the Fourier coefficients of the CMB provide much useful information about the dynamics of the universe. In particular, they reflect the values of H_0, Ω_0, Ω_Λ, and other cosmological parameters.

In the year 2002, when data from the MAP satellite become available, one of two things will happen: either the spectrum of Fourier coefficients will match some choice of H_0, Ω_0, etc., and we will know the basic cosmological parameters to unprecedented accuracy, or Mother Nature will surprise us with a spectrum inconsistent with our current understanding of big bang physics. The reader may decide which possibility is more appealing.

Observing the Topology of the Universe

In a finite universe we may be seeing the same set of galaxies repeated over and over again. Like a hall of mirrors, a finite universe gives the illusion of being infinite. The illusion would be shattered if we could identify repeated images of some easily recognizable object. The difficulty is finding ob-

jects that can be recognized at different times and at different orientations. A more promising approach is to look for correlations in the cosmic microwave background radiation. The CMB photons all originate from the same epoch in the early universe, so there are no aging effects to worry about. Moreover, the shell they originate from is very thin, so the surface of last scatter looks the same from either side. The importance of this second point will soon become clear.

Consider for a moment two different views of the universe: one from here on Earth and the other from a faraway galaxy. As mentioned earlier, an alien living in that faraway galaxy would see a different surface of last scatter (see Figure 4). The alien's CMB map would have a different pattern of hot and cold spots from ours. However, so long as the alien is not too far away, our two maps will agree along the circle defined by the intersection of our last scattering spheres. Around this circle we would both see exactly the same temperature pattern, as the photons came from exactly the same place in the early universe. Unless we get to exchange notes with the alien civilization, this correlation along the matched circles plays no role in cosmology.

But what if that faraway galaxy is just another image of the Milky Way, and what if we are the aliens? (Recall the flat torus of Figure 3a, whose inhabitants would have the illusion of living in an infinite Euclidean plane containing an infinite lattice of images of each object.) Cornish, Spergel, and Starkman [3] realized that in a finite universe the matched circles can transform our view of cosmology, for then the circles become correlations on a single copy of the surface of last scatter: i.e., the matched circles must appear at two different locations on the CMB sky. For example, in a universe with 3-torus topology we would see matched circles in opposite directions on the sky. More generally, the pattern of matched circles varies according to the topology. The angular diameter of each circle pair is fixed by the distance between the two images. Images that are displaced from us by more than twice the radius of the last scattering sphere will not produce matched circles. By searching for matched circle pairs in the CMB, we may find proof that the universe is finite.

At present we do not have a good enough CMB map to perform the search, but this will soon change. The CMB map produced by COBE (reproduced here in Figure 2) has a resolution of 10 degrees, and 30 percent of what one sees is noise, not signal. However, by 2002 the MAP satellite will have furnished us with a far superior map at better than 0.5° resolution. In the interim we can test our search algorithms on computer-generated sky maps. One example of a synthetic sky map is shown in Figure 5. The model has a cubical 3-torus topology and a scale invariant spectrum of density perturbations. The nearest images are separated by a distance equal to the radius of the last scattering surface. Consequently, there are thirteen matched circle pairs and three matched points (circles with angular diameter 0). The matched circles are indicated by black lines. With good eyes and a little patience, one can follow the temperature pattern around each pair of matched circles and convince oneself that the temperatures at corresponding points are correlated.

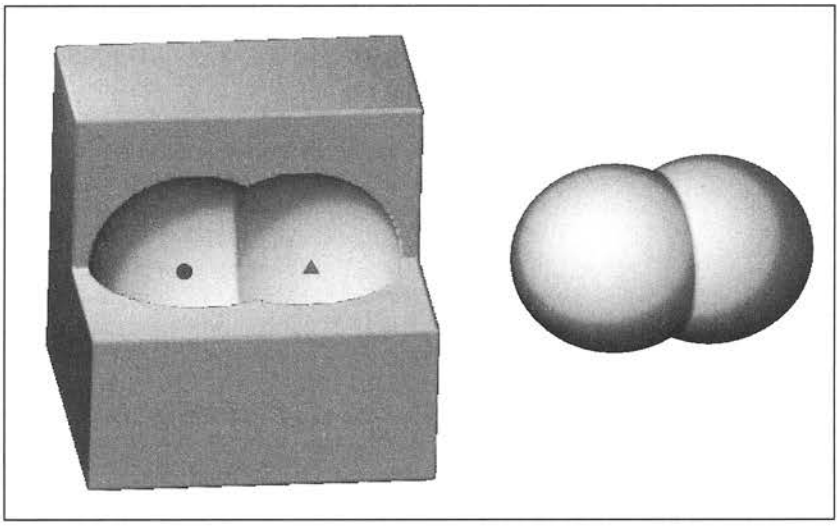

Figure 4. (Left) A block of space at the time of last scatter sliced open to show two different surfaces of last scatter. The dot marks our vantage point, and the triangle marks the alien's vantage point. (Right) An outside view showing how our shell of last scatter intersects the alien's.

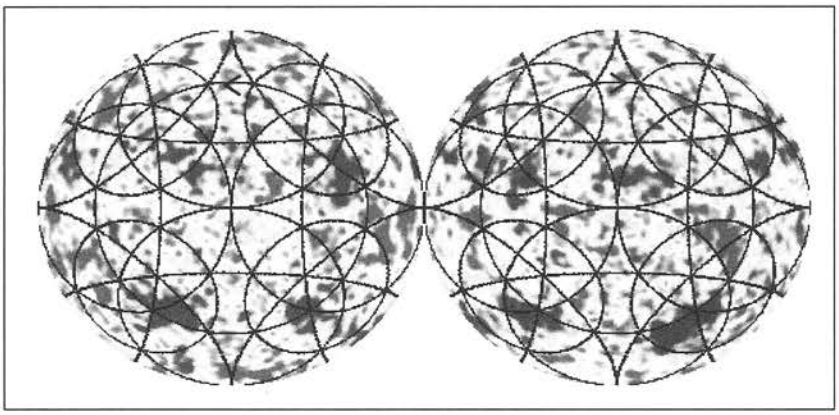

Figure 5. The northern and southern hemispheres of the CMB sky in a 3-torus universe. The thirteen matched circle pairs are marked by black lines.

An automated search algorithm has been developed [3] to search for matched circle pairs. The computer searches over all possible positions, diameters, and relative phases. On a modern supercomputer the search takes several hours at 1° resolution. Our prospects for finding matched circles are greatly enhanced if the universe is highly

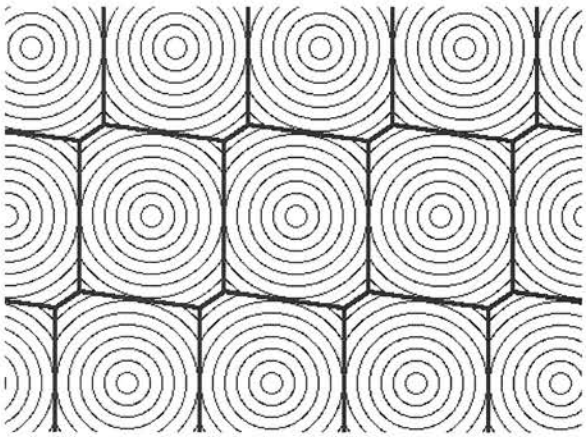

Figure 6. To construct a Dirichlet domain, inflate a balloon until it fills the universe.

curved. The rigidity described in the previous section means that the distance between images is fixed by the curvature scale and the discrete group of motions. We will be most interested in hyperbolic models, since observations suggest $\Omega_0 \approx 0.3$. In most low-volume hyperbolic models our nearest images are less than one radian away. The crucial quantity then becomes the radius of the last scattering surface expressed in curvature units:

$$\eta = \frac{R_{sls}}{a_0} \simeq \operatorname{arcsinh}\left(\frac{2\sqrt{1-\Omega_0}}{\Omega_0}\right). \tag{8}$$

In a universe with $\Omega_0 = 0.3$ we find $\eta \approx 2.42$, so all images less than $2\eta \approx 4.84$ radians away will produce matched circle pairs. However, we may have difficulty reliably detecting matched circles with angular diameters below $\theta = 10°$; we therefore restrict ourselves to images within a ball of radius 4.6 radians. In the universal cover $\mathbb{H}^3$, a sphere of radius 4.6 encloses a volume of about 15,000; so if the universe is a hyperbolic manifold of volume less than about 100, there will be an abundance of matched circles.

Reconstructing the Topology of the Universe

If at least a few pairs of matching circles are found, they will implicitly determine the global topology of the universe [4]. This section explains how to convert the list of circle pairs to an explicit description of the topology, both as a fundamental domain and as a quotient (cf. the section "Geometry and Topology"). The fundamental domain picture is more convenient for computing the manifold's invariants (such as its volume, homology, etc.) and for comparing it to known manifolds, while the quotient picture is more convenient for verifying and refining the astronomical observations. Assume for now that space is finite and that all circles have been observed with perfect accuracy.

The fundamental domain we construct is a special type known as a *Dirichlet domain.* Imagine inflating a huge spherical balloon whose center is fixed on our galaxy and whose radius steadily increases. Eventually the balloon will wrap around the universe and meet itself. When it does, let it keep inflating, pressing against itself just as a real balloon would, forming a planar boundary. When the balloon has filled the entire universe, it will have the form of a polyhedron. The polyhedron's faces will be identified in pairs to give the original manifold.

Constructing a Dirichlet domain for the universe, starting from the list of circle pairs, is quite easy. Figure 6 shows that each face of the Dirichlet domain lies exactly halfway between its center (our galaxy) and some other image of its center. The previous section showed that each circle-in-the-sky also lies exactly halfway between the center of the SLS (our galaxy) and some other image of that center. Thus, roughly speaking, the planes of the circles and the planes of the Dirichlet domain's faces coincide! We may construct the Dirichlet domain as the intersection of the corresponding half spaces.[4]

Finding the rigid motions (corresponding to the quotient picture in the "Geometry and Topology" section) is also easy. The MAP satellite data will determine the geometry of space (spherical, Euclidean, or hyperbolic) and the radius for the SLS, as well as the list of matched circles. If space is spherical or hyperbolic, the radius of the SLS will be given in radians (cf. the subsection "Natural Units"); if space is Euclidean, the radius will be normalized to 1. In each case, the map from a circle to its mate defines a rigid motion of the space, and it is straightforward to work out the corresponding matrix in $O(4)$, $O(1,3)$, or $GL_4(\mathbb{R})$ (recall the subsection "Geometric Models").

Why bother with the matrices? Most importantly, they can verify that the underlying data are valid. How do we know that the MAP satellite measured the CMB photons accurately? How do we know that our data analysis software does not contain bugs? If the matrices form a discrete group, then we may be confident that all steps in the process have been carried out correctly, because the probability that bad data would define a discrete group (with more than one generator) is zero. In practical terms, the group is discrete if the product of any two matrices in the set is either another

[4] *All but the largest circles determine planes lying wholly outside the Dirichlet domain, which are superfluous in the intersection of half spaces. Conversely, if some face of the Dirichlet domain lies wholly outside the SLS, its "corresponding circle" will not exist, and we must infer the face's location indirectly. The proof that the Dirichlet domain correctly models the topology of the universe is, of course, simplest in the case that all the Dirichlet domain's faces are obtained directly from observed circles.*

matrix in the set (to within known error bounds) or an element that is "too far away" to yield a circle. More spectacularly, the matrices corresponding to the dozen or so largest circles should predict the rest of the data set (modulo a small number of errors), giving us complete confidence in its validity.

We may take this reasoning a step further and use the matrices to correct errors. Missing matrices may be deduced as products of existing ones. Conversely, false matrices may readily be recognized as such, because they will not fit into the structure of the discrete group; that is, multiplying a false matrix by almost any other matrix in the set will yield a product not in the set. This approach is analogous to surveying an apple orchard planted as a hexagonal lattice. Even if large portions of the orchard are inaccessible (perhaps they are overgrown with vines), the locations of the hidden trees may be deduced by extending the hexagonal pattern of the observable ones. Conversely, if a few extra trees have grown between the rows of the lattice, they may be rejected for not fitting into the prevailing hexagonal pattern. Note that this approach will tolerate a large number of inaccessible trees, just so the number of extra trees is small. This corresponds to the types of errors we expect in the matrices describing the real universe: the number of missing matrices will be large because microwave sources within the Milky Way overwhelm the CMB in a neighborhood of the galactic equator, but the number of extra matrices will be small (the parameters in the circle matching algorithm are set so that the expected number of false matches is 1). In practice, the Dirichlet domain will not be computed directly from the circles, as suggested above, but from the matrices, to take advantage of the error correction.

Like all astronomical observations, the measured radius R_{sls} of the sphere of last scatter will have some error. Fortunately, if space is spherical or hyperbolic, we can use the rigidity of the geometry to remove most of it! Recall that the hyperbolic octagon in Figure 3b had to be just the right size for its angles to sum to 2π. The Dirichlet domain for the universe (determined by the circle pairs; cf. above) must also be just the right size for the solid angles at its vertices to sum to a multiple of 4π. More precisely, the face pairings bring the vertices together in groups, and the solid angles in each group must sum to exactly 4π. If the measured solid angle sums are consistently less than (resp. greater than) 4π, then we know that the true value of R_{sls} must be slightly less than (resp. greater than) the measured value, and we revise it accordingly. The refined value of R_{sls} lets us refine Ω_0 as well, because the two variables depend on one another.

Acknowledgments

Our method for detecting the topology of the universe was developed in collaboration with David Spergel and Glenn Starkman. We are indebted to Proty Wu for writing the visualization software used to produce Figure 5 and to the editor for his generous help in improving the exposition. One of us (Weeks) thanks the U.S. National Science Foundation for its support under Grant DMS-9626780.

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About the Cover

An artist's impression of a finite universe showing galaxies inside a fundamental domain of the Weeks manifold. The galaxy field is taken from the Hubble Deep Field image (http://www.stsci.edu/ftp/science/hdf/hdf.html)—our deepest and most detailed optical view of the universe. It is possible that one of the galaxies seen in this image is our own Milky Way, and the light we receive from it has made a complete trip around the universe.

—Neil J. Cornish
Jeffrey R. Weeks

Wolfgang Heinrich Johannes Fuchs (1915–1997)

J. Milne Anderson, David Drasin, and Linda R. Sons

Biographical Sketch

Wolfgang Heinrich Johannes Fuchs was born in Munich on May 19, 1915. He joined the faculty of Cornell University in 1950, where he remained through his retirement in 1985 until his death on February 24, 1997. His life and career were characterized by an unrelentingly positive and supportive attitude. He read avidly (in many languages), travelled widely, and was devoted to intellectual dignity and the international mathematical community. He wrote two important monographs and more than sixty-five papers in complex function theory and related areas. These achievements were recognized by the award of three fellowships: Guggenheim (1955), Fulbright-Hays (1973), and Humboldt (1978).

Wolfgang graduated in 1933 from Johannes Gymnasium in Breslau (Wrocław), where his teacher, Hermann Kober (remembered for his *Dictionary of Conformal Representations*), convinced him to become a mathematician. Wolfgang's obituary of Kober, published in 1975, contains warm memories of those times. Outside school hours he studied Russian and Chinese.

Graduation occurred shortly after Hitler assumed power in Germany. Wolfgang's parents were classified as Jews, and they recognized at once that a normal life would be impossible in Germany. They arranged for Wolfgang to enter St. John's College, Cambridge, in the fall term of 1933 and were able to join him before war erupted in 1939.

At this time the predominant figures in analysis at Cambridge were G. H. Hardy and J. E. Littlewood, and Wolfgang soon came under their spell. He received a Ph.D. in 1941 under the direction of A. E. Ingham [10]; we discuss this work below.

In 1938 Wolfgang received a fellowship to Aberdeen, where he was fortunate to have W. W. Rogosinski, another refugee, as a colleague. They had known each other from Cambridge days and shared an interest in summability. Their collaboration intensified in the summer of 1940, when both were interred on the Isle of Man as "enemy aliens". He would later describe this period as a "beautiful summer vacation": there was a rich mathematical environment, and, since a chef of Buckingham Palace was another detainee, the food was rather good.

In 1943, while still at Aberdeen, he met and married Dorothee Rausch von Traubenberg, another refugee from Germany, who was a student at the university. "His relationship with her was the center of his being" [W. K. Hayman]. Dorothee came from a distinguished academic family. Her father was dismissed from a professorship at Kiel in 1937 for his pacifist beliefs, but, above all, for

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David Drasin coordinated the writing of this article. The authors thank Luchezar Avramov and Paul Koosis for their assistance. All quotations were obtained in 1998 unless otherwise cited.

being married to a Jewish woman. He continued his research in atomic physics without a proper position, assisted only by his wife. However, his sudden death in 1944 left her unprotected, and Dorothee's mother was soon sent to Theresienstadt, where she was ordered to document this research. In this way her life was spared until the camp was liberated by the Red Army in 1945.

In time, Wolfgang's work (in particular, [12]) attracted the attention of R. P. Agnew, who was chairman of the Cornell mathematics department. Agnew invited Wolfgang to Cornell for 1948–49, where he accepted a permanent appointment.

At Cornell Wolfgang carried out his research on Nevanlinna theory (value-distribution theory). This was the most sustained output of his career and is discussed below. While Nevanlinna theory was already well known among complex analysts, it was usually viewed as a tool rather than as a subject of its own. It had attracted almost no research in the U.S. before the early 1950s.

Wolfgang was drawn to the subject by Albert Edrei, of Syracuse University. Edrei had been trained by G. Pólya and M. Plancherel in Zürich and thus had a strong function-theoretic background. In 1950 Edrei, then at the University of Saskatchewan, heard I. J. Schoenberg lecture about his conjecture on the characterization of generating functions of "totally positive sequences". Within a few months Edrei applied Nevanlinna theory to settle this problem completely. This convinced him that many important and beautiful results were ripe for harvest, and in 1955, at a mathematics picnic at Fall Creek Park in Ithaca, Wolfgang agreed to join him in the chase.

Nevanlinna theory remained the main focus of both Edrei and Fuchs for the remainder of their careers. They, their students and co-authors, and other groups developing in China, England, Germany, and parts of the former Soviet Union entered a long golden age of one-variable value-distribution theory. Almost all subsequent work that dealt with functions of finite order used the formalisms and computational techniques that Edrei and Fuchs introduced. When Rolf Nevanlinna died, Wolfgang was the obvious choice to deliver the address devoted to Nevanlinna's theory at the memorial conference in 1981.

Edrei and Fuchs remained close friends until Wolfgang's death, and Edrei died the following year, on April 29, 1998.

Wolfgang was also anxious to study new ideas from others, and his monographs influenced a generation of complex analysts. Extremal length? In [20] P. Koosis writes, "The most accessible introduction is in W. Fuchs' little book" [16]. This "little book" also includes Mergelyan's solution to the weighted approximation problem and an attractive selection of ideas from potential theory.

Photograph courtesy of Dorothee Fuchs.

Wolfgang Fuchs, 1949.

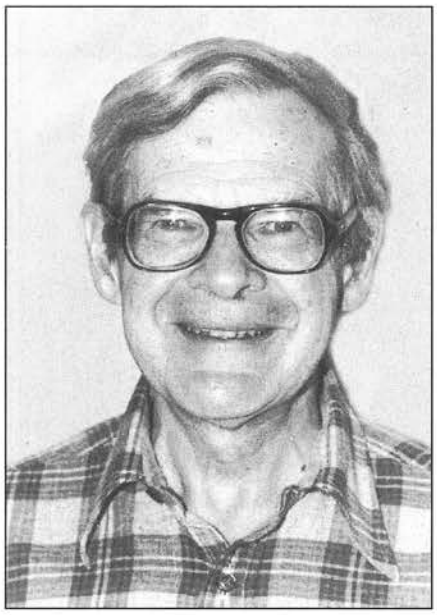
He read widely and kept detailed notebooks with his own derivations and impressions from his reading. Frequently he would contribute these expositions to the original authors, and often this became what was published. This made him a valuable editor of several mathematical journals, notably the *Proceedings of the AMS*.

"My recollection is that [Wolfgang] always felt that one-variable value-distribution theory ...was too narrow and needed infusion of the kind of geometric ideas advocated by Ahlfors. ...[The] essence of his message was just to broaden the subject. At first I thought he was merely making a philosophical statement, but twice he wrote me complimenting me on specific things I said in my geometrical work. Although I believe he was unduly impressed with something rather trivial with which he happened not to be familiar, I came to understand that this advocacy was more than an empty gesture" [H. Wu].

"What impressed me is that he was still very eager to learn what was happening ..., so he would take new papers and really work through them in all details" [W. Bergweiler, who was at Cornell in 1987–89 under Wolfgang's aegis].

Two of his many foreign contacts warrant special mention. In fall 1964 he participated in an official exchange with the USSR Academy of Sciences and attended an international conference in Erevan the following summer. There he intensified his contacts with several mathematicians in the outstanding schools of value-distribution theory and approximation theory. Soon after, he worked out Arakelyan's construction of functions of finite order with infinitely many Nevanlinna defects (available at that time only in a short *Doklady* note), and his 1967 Montreal lectures [18], with all details, became the standard reference for this work. Work by the Soviet mathematicians Keldysh, Mergelyan, and Goldberg, in addition to Arakelyan, occupy the major portion of [18]. His efforts to bring important work to the attention of Western

mathematicians continued all his life. This orientation also led him to purchase gift memberships in the American Mathematical Society for several colleagues from abroad.



Fuchs in Berlin, October 1978.

"Mathematicians of the world can admire how in the years of the cold war he was building bridges between the divided spheres of mathematicians. Today it is hard to imagine ...what was the common situation of fifteen years ago. [In those times] personal contacts were the privilege of only a very narrow circle. W. Fuchs understood that separation and mutual mistrust would only be detrimental to the science of mathematics. Many people understood this fact, but only a few took an active part in popularizing the achievements of Soviet mathematicians in the West" [A. A. Goldberg].

He was thrilled to make an official visit to China in 1980. The Cultural Revolution had ended only a few years earlier, and during that period no one in China could enter a scientific career. Wolfgang enthusiastically lectured and arranged for mathematics students to come to the U.S. to help restore mathematics in China. This was an important resource and contact for Chinese mathematicians, since function theory was one of the few active areas of mathematical research in China at that time (cf. [9]). "In simple words, the work done by Zhang [Guang-Hou] and me in the seventies was mainly based on the knowledge of French scholars [active before 1940] and the influence of Edrei and Fuchs's papers" [Yang Lo]. Wolfgang publicized the work of Yang, Zhang, and others and arranged for many mathematicians to visit the U.S. Thus he felt outrage at the massacre of June 1989 in Tiananmen Square and at once organized and arranged that the letter [1] be published in the *Notices*. "[It] was first suggested to me by [Wolfgang]. As a Chinese-American I would never have done it alone" [H. Wu]. His concern continued for the rest of his life: the letter [2] decried the reimprisonment of the dissident Wang Dan. Because of human rights considerations, he publicly declined later invitations to China and, on other occasions, to Israel.

Wolfgang was a charter member of the Ithaca chapter of Amnesty International and served as coordinator. "Our group had strong links with the international scientific community, and Wolfgang took an active role in establishing contacts with scientists in Eastern Europe, the Palestinians in the West Bank, and elsewhere, including such well-known dissidents as Andrei Sakharov and Yuri Orlov. He continued to attend meetings and support Amnesty activities long after the state of his health would have justified slowing down" [Peter Wetherbee].

He contributed a poem at the 1985 conference to celebrate de Branges's proof of the Bieberbach conjecture. It is the closing item in the published proceedings (1986), and the way he describes the history of the problem and its solution displays and preserves some of the charm his colleagues and friends long appreciated. "My first encounter with Wolfgang Fuchs changed my life. I visited Cornell in 1965 to consider an offer from the mathematics department. One evening in Wolfgang's home convinced me that it would be a privilege to live and work in the same community as this wonderfully wise, kind, and witty man" [Clifford Earle, 1997].

Some Mathematical Accomplishments

We describe some aspects of Wolfgang's research that display his breadth, insight, power, and influence in analysis. A full bibliography and discussion appear in a special issue of *Complex Variables* [3] dedicated to him and Edrei.

Thesis

Many theorems about entire and meromorphic functions are obtained by comparing growth rates of appropriate increasing real-valued functions. If f is entire, the most common such function associated to f is the *maximum modulus*

$$M(r) = M(r,f) \equiv \max_{\theta} |f(re^{i\theta})|,$$

but for given $p > 0$ we could as well consider $M_p(r,f)$, the L_p-mean of f on $\{|z| = r\}$. Wolfgang's thesis [10] confirmed a remarkable conjecture by Ingham: when $p \neq \infty$, M_p itself is almost an analytic function.

> Let f and g be analytic in $\{r_1 < |z| < r_2\}$ and suppose for a fixed $0 < p < \infty$ we have $M_p(r,f) = M_p(r,g)$ for a sequence of r with limit point in (r_1, r_2). Then $M_p(r,f) \equiv M_p(r,g)$ for $r_1 < r < r_2$.

This theorem completely fails when $p = \infty$. Hayman considers this and [8], written with Erdős, his favorites. The theorem is not hard to prove when f and g have no zeros, and "the proof of the analyticity [in r of the L_p mean] across the modulus of a zero is a brilliant and subtle piece of work" [Hayman].

Nevanlinna Theory

Wolfgang's greatest impact on American mathematics came from his work on Nevanlinna theory. Nevanlinna developed his theory in the 1920s as

a potential-theoretic analysis of Picard's theorem (1879), which asserts that a nonconstant meromorphic function in the plane cannot omit three values. The obvious example $f(z) = e^z$ shows that the theorem is sharp. For the next fifty years, Borel, Valiron, and others attempted to find more insightful proofs. Not only was Nevanlinna's approach the most successful, but his techniques became standard in potential theory and the foundation for a subject of its own. Thus, let f be meromorphic in the plane. If $0 < r < \infty$ and $n(r, a)$ is the number of solutions to the equation $f(z) = a$, with $|z| < r$, account being taken of multiplicities, we set

$$N(r, a) = \int^r n(t, a) t^{-1}\, dt$$

(this is slightly modified when $f(0) = a$). Nevanlinna's *characteristic* $T(r) = T(r, f)$ can be defined as

$$T(r) = \int_{\hat{C}} N(r, a)\, d\mu(a),$$

where μ is the uniform distribution on the Riemann sphere $\hat{C}$, and the *deficiency* $\delta(a) = \delta(a, f)$, $a \in \hat{C}$, is

$$\delta(a) = 1 - \limsup_{r\to\infty} \frac{N(r, a)}{T(r)}.$$

It is elementary that $T(r) \uparrow \infty$ and $0 \le \delta(a) \le 1$. Of course, $\delta(a) = 1$ if the equation $f(z) = a$ has no solutions. Nevanlinna's famous Second Fundamental Theorem implies that

$$\sum_a \delta(a) \le 2, \tag{1}$$

a deep generalization of the Picard theorem. Nevanlinna theory in the plane asks for refinements of (1), given other properties of f. Nevanlinna's $T(r)$ plays the role of the maximum modulus $M(r)$ in the special case that f is entire; we then simply have $\delta(\infty) = 1$. The standard references are [18] and [19].

Nevanlinna's key insight was his "lemma of the logarithmic derivative", which states that for most large r,

$$\int_0^{2\pi} \log^+ \left| \frac{f'}{f}(re^{i\theta}) \right| d\theta = o(\log(rT(r))). \tag{2}$$

Thus, the left side of (2) is negligible when compared to $T(r)$. Since in (2) we may replace f by $f - a$ for any complex number a, (2) indicates that if f is very close to a complex value a on a portion I of $\{|z| = r\}$, then f' must also be small on I.

Wolfgang's first works revisited the expression (2) in a direct manner, by estimating

$$M(I, F) \equiv \int_I \left| \frac{f'}{f}(z) \right| |dz|, \tag{3}$$

where I is any subarc of $\{|z| = r\}$. This integral is far more treacherous than (2); in fact, it diverges whenever I contains a zero or pole of f. His estimates appear in [14] and [15]; later Petrenko found the sharpest bounds.

Wolfgang obtained two striking applications from his estimates. To explain them, we need the notion of the *order* ρ of a meromorphic function f:

$$\rho = \limsup_{r\to\infty} \frac{\log T(r, f)}{\log r}. \tag{4}$$

For example, $\exp(z^k)$ has order k. In [14] Wolfgang showed that when $\rho < \infty$, (1) alone does not describe the full situation: in addition, we have that

$$\sum \delta^{1/2}(a) < \infty, \tag{5}$$

which confirmed a conjecture of Teichmüller. Wolfgang considered this and the paper [8] (with Erdős, discussed below) his two best. Some years later, Weitsman, following insights of Hayman, showed that $1/3$ is the optimal exponent in (5). That (5) reflects special properties of functions of finite order became clear when, with Hayman, Wolfgang showed (cf. [18], Chapter 5, and [19], Chapter 4) that Nevanlinna's defect relation (1) is sharp among all entire functions.

Paper [15] proved a conjecture that G. Pólya posed in his famous paper [23]. Let f be entire and of order $\rho < \infty$ with power series development

$$f(z) = \sum a_k z^{n_k}. \tag{6}$$

If $n_k/k \to \infty$ as $k \to \infty$, then

$$\limsup_{r\to\infty} \frac{L(r, f)}{M(r, f)} = 1,$$

where L and M are, respectively, the minimum and maximum modulus of f on $\{|z| = r\}$. Thus, in a very precise sense, these gap series behave as monomials for arbitrarily large values of r.

The first joint work of Edrei and Fuchs ([5] and [6]) completely characterized entire functions f of finite order for which $\sum \delta(a) = 2$; i.e., equality holds in (1). Not only is ρ a positive integer (this was shown earlier by Pfluger), but the global asymptotic behavior and Taylor expansion of f are completely described. In particular, only a finite number of nonzero terms can appear in the deficiency sum (1). These conclusions were obtained as limiting cases when the difference $2 - \sum \delta(a)$ is sufficiently small. One significant problem arising from this work remains open to this day: If ρ is "close to" an integer k and $\sum \delta(a)$ is "nearly" equal to 2, can there be only finitely many nonzero terms in (1)?

Their paper [7] introduced two major ideas that have transformed much future research. First, they made a serious study of "Pólya peaks" and showed that these peaks gave a new, elegant, and unified way to interpret the hypothesis that the order ρ in (4) be finite. This led to the common principle that a function f should be studied by comparing

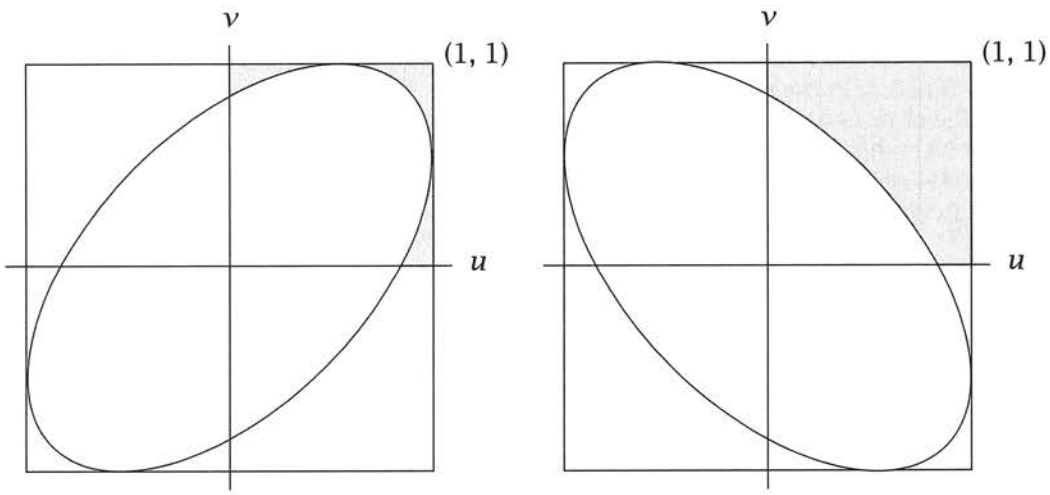


Figure 1. The possible values of (u, v) must always be inside the first quadrant. According to the "ellipse theorem", they are also limited to the portion outside the ellipse $u^2 + v^2 - 2uv\cos\pi\rho = \sin^2\pi\rho$. The shaded regions here show the set in question for $\rho = .33$ and $\rho = .7$.

its characteristic $T(r)$ to simple local comparison functions defined intrinsically in terms of $T(r)$. Before [7] authors were forced to create many ad hoc comparisons between $T(r)$ and r^ρ, but after [7] most of these notions were forgotten.

The derivation by Edrei and Fuchs in [7] of a key inequality of Goldberg provided an essential foundation on which A. Baernstein later could build his $*$-function. The $*$-function continues to have a major impact on symmetrization and geometric function theory.

While the impact of [7] on later work was enormous, its main conclusion should not be ignored. The "ellipse theorem" gives a complete relation between any two terms that appear in the deficiency sum (1) and the order ρ of a function f when $0 \le \rho \le 1$. Thus let a and b be fixed in $\hat{C}$, and set $u = 1 - \delta(a)$, $v = 1 - \delta(b)$. Any understanding of the pair (u, v) sheds light on any two terms appearing in (1). It is clear that (u, v) is always confined to the square $0 \le u, v \le 1$. Edrei and Fuchs prove that, in addition, the point (u, v) must lie on or outside the ellipse

$$u^2 + v^2 - 2uv\cos\pi\rho = \sin^2\pi\rho$$

and this condition is best possible in all cases. See Figure 1.

This result is nearly forty years old. Except in some trivial cases, when $\rho > 1$ there is no complete description of the possibilities of $\{(u, v)\}$ as f ranges over all meromorphic functions of order ρ. For entire functions, the "trivial case" occurs when ρ is an integer k, in which case (u, v) can lie anywhere in the square, with $f_k(z) = \exp(z^k)$ being extremal.

Closure Problems

Although Wolfgang wrote fifteen papers during his stay in Britain, he is probably best remembered today for his paper [11] on the closure of the functions $\{e^{-t}t^{a_\nu}\}$ in $L_2(0, \infty)$. The subject begins with Weierstrass's theorem that polynomials are dense in $C[a, b]$. H. Müntz proved in 1914 that if S is any subset of the positive integers, then the linear span of $\{t^m;\ m \in S\}$ is dense in $L_2(0, 1)$ if and only if $\sum_S m^{-1} = \infty$. This result suggested that approximation of rather general functions might be possible by using specific subclasses that have attractive structures and led to a wide development. A more refined analysis is needed in [11]; on the finite interval $(0, 1)$ it corresponds to a study of the closure of $\{(\log(1/x))^{a_\nu}\}$. In addition, the possibility that the a_ν's are positive but not necessarily integers raises many technical complications. Let

$$\psi(r) = 2\sum_{a_\nu < r} a_\nu^{-1} \tag{7}$$

for $r > a_1$. Wolfgang's theorem shows that the system $\{e^{-t}t^{a_\nu}\}$ is complete in $L_2(0, \infty)$ if and only if

$$\int_{a_1}^{\infty} [\exp\psi(r)]r^{-2}\,dr = \infty.$$

Roughly speaking, this says that if $a_\nu \sim \alpha\nu$ as $\nu \to \infty$, then the system is complete if $\alpha \le 1/2$ and incomplete if $\alpha > 1/2$.

The basic problem is that the integral may converge without the $\{a_\nu\}$ satisfying the Blaschke condition $\sum a_\nu^{-1} < \infty$. This necessitates consideration of a function of the form

$$H(z) = \prod_{\nu=1}^{\infty} \left(\frac{z - \lambda_\nu}{z + \lambda_\nu}\exp(-2z/a_\nu)\right) \tag{8}$$

to cancel out the zeros of a certain function $G(z)$, analytic in the right half-plane. The paper, written before the contribution of functional analysis to closure problems in complex analysis was fully appreciated, involves a highly sophisticated application of the Ahlfors Distortion Theorem and shows Wolfgang already at the height of his analytical powers.

Although (8) is regular only in the right half-plane, Wolfgang uses an inverse integral transform to obtain the desired function orthogonal to the family $\{e^{-t}t^{a_\nu}\}$.

The product (8) itself has many uses. It provided a key ingredient for [12], which was so admired by

Ph.D. Students of Wolfgang Fuchs:
Tseng-Yeh Chow (1953)
Alan Schumitzky (1965)
Linda R. Sons (1966)
David Drasin (1966)
Virginia W. Noonburg (1967)
M. A. Selby (1970)
I-Lok Chang (1971)
Subinoy Chakravarty (1975)

Agnew. Let f be of exponential type k (we write $f \in \mathcal{E}_k$): this means that $\log M(r) = O(kr)$ as $r \to \infty$, with $M(r)$ equal to the maximum modulus as above. Let us call a sequence $\{a_\nu\}$ of positive real numbers a *determining sequence corresponding to* $\mathcal{E}_k$ if the conditions $a_{\nu+1} - a_\nu > c > 0$ for all ν, $f \in \mathcal{E}_k$, and $f(a_\nu) = 0$ for $\nu = 1, 2, \ldots$ imply that $f \equiv 0$. The most famous theorem of this type is due to F. Carlson: If $k < \pi$, then $\{\nu;\ \nu \geq 0\}$ is a set of uniqueness for $\mathcal{E}_k$, and the example $f(z) = \sin \pi z$ shows that this bound on k is exact. The contribution of [12] is to give a condition both necessary and sufficient for any k: If ψ is constructed as in (7) from the $\{a_\nu\}$, then

$$\limsup_{r\to\infty} \psi(r) r^{-2k/\pi} = \infty.$$

Several other papers are in this vein and are extensively discussed in the monographs of Mandelbrojt [22] and Boas [4]. These problems, with more general weights than e^{-t}, were also considered in the thesis of Malliavin, who related them to "Watson's problem". In 1967 Wolfgang showed that his original approach led to an elegant solution to one result in Malliavin's thesis.

In the 1950s Malliavin carried the ideas of (8) much further and deduced the converse to Pólya's maximal density theorem concerning gap series. In [23] Pólya had proved that if a power series of the form (6) has radius of convergence one and the (Pólya) maximal density of the nonzero coefficients in (6) is D, then every arc of $\{|z| = 1\}$ of length greater than $2\pi D$ contains a singularity of f. This richly amplifies the well-known fact that the circle of convergence of any power series has at least one singularity.

While the precise definition of maximal density is too complicated to be reproduced here, any subset of integers does have such a density (this density is defined in terms of a lim sup). Thus it is natural to ask if the Pólya density is the precise notion needed to guarantee Pólya's theorem. Malliavin was influenced by [13] to develop an extensive theory, which among other things showed that Pólya's notion of density was exact. In [20], Chapter 9, Koosis uses Malliavin's arguments to establish this converse directly from [13]. This discussion also provides an exhaustive explanation of the significance of products such as (8).

Additive Number Theory

Erdős shared Wolfgang's enthusiasm for their joint paper [8]: "[It] certainly will survive the authors by a few centuries" (quoted in [24]). An excellent exposition is in [21], Chapter II.

Thus, let $A = \{a_k\}$ be a nondecreasing sequence of nonnegative integers, and for $n \in \mathbb{Z}$ let $r(n; A)$ be the number of solutions to the inequality $a_i + a_j \leq n$ with $a_i, a_j \in A$, using any consistent method of enumeration. Special techniques are available when $A = \mathcal{Q} = \{m^2,\ m \geq 0\}$; in this case $r(n; A)$ is simply the number of points of the integral lattice in $\{|z| \leq n^{1/2}\}$, and so $r(n; \mathcal{Q}) \sim \pi n$. In classical work dating back to Hardy in 1915, it was shown that this asymptotic relation cannot be attained too rapidly: when $A = \mathcal{Q}$ and $c = \pi$, then

$$\limsup_{n\to\infty} \frac{|r(n; A) - cn|}{\Phi(n)} > 0, \tag{9}$$

where $\Phi(n) = \{n \log n\}^{1/4}$.

These arguments were heavily based on the interpretation of $r(n; A)$ when $A = \mathcal{Q}$. The contribution of [8] is that such limitations are, in H. Halberstam's words from 1988, "a law of nature." In fact, if A is any such sequence, then there is a universal $\Phi(n) \uparrow \infty$ such that (9) must hold for any $c > 0$. Of course, if we allow $c = 0$, then a sufficiently sparse A allows that $r(n; a)\, n^{-1} \to 0$ as rapidly as desired. Erdős-Fuchs show that $\Phi(n) = n^{1/4} \log^{-1/2} n$ gives (9) for any A.

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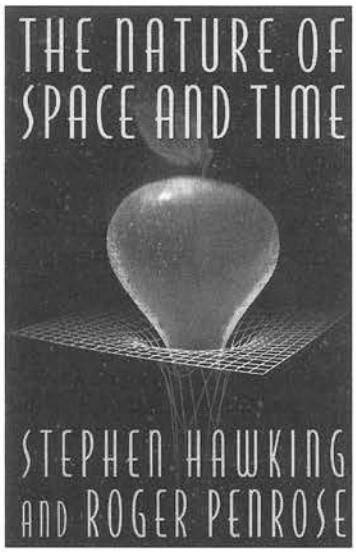
The Nature of Space and Time

Reviewed by Claude LeBrun

The Nature of Space and Time
Stephen Hawking and Roger Penrose
Princeton University Press, 1996
ISBN 0-691-03791-4
150 pages; Hardcover, $26.95

On May 9, 1994, a motley crowd packed the main lecture hall of the Newton Institute in Cambridge, England. Renowned physicists and mathematicians, often accompanied by their brightest graduate students, were sprinkled through the crowd. Around them pushed a mob of intellectual tourists—"town and gown"—spilling into the foyer and out the side doors of the Institute. Television cameramen waded through the crowd, blinding the audience with klieg lights and littering the floor with a spaghetti of cables. Somehow the culmination of a series of semitechnical lectures on the foundations of physics was beginning to look like a media circus.

The occasion was a public debate between Stephen Hawking and Roger Penrose, Fellows of the Royal Society and joint recipients of the Wolf Prize. For the tourists, of course, these credentials were as irrelevant as the identity of the moderator (Michael Atiyah). After all, both participants were bona fide celebrities: best-selling authors [5, 12, 13] and hosts of popular television documentaries. One has become a sort of pop culture icon: the wheelchair-bound genius with the synthetic voice. The other's ideas have quite literally become the intellectual wallpaper of our age.



This brief, charming book faithfully records the three lectures given by each man, as well as the debate which followed. The lectures attempted to be nominally intelligible to advanced Cambridge undergraduates and primarily sought to convey a few of the key ideas of the subject, along with some sense of the intellectual excitement inherent to the field. Intellectual tourists are by all means welcome on this journey, and indeed it is they who may find the trip most exhilarating. The style of the lectures was informal and highly personal. It is therefore high time that the lecturers be properly introduced.

Roger Penrose, an algebraic geometer by training, revolutionized general relativity in the 1960s by proving [9] the stability of black-hole singularities, using techniques of global differential geometry. Even earlier he had begun [8] to systematically develop the theory of spinors on 4-manifolds [14]. This ultimately led to a remarkable set of links, collectively known as twistor theory, between 4-dimensional geometry and complex manifold theory

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[11]. As Rouse-Ball Professor of Mathematics at Oxford, Penrose became a tireless advocate of the special nature of dimension four. Armed with results on Yang-Mills moduli spaces proved by twistor methods, he thereby helped lay the foundations for the revolutionary work of Donaldson.

Visualizable mathematics is Penrose's lifelong obsession. As the present book will attest, his geometric visions have altered the face of gravitational physics, but their influence by no means stops there. In his twenties Penrose invented the perspectival paradox exploited by M. C. Escher in *Ascending and Descending*, and in his forties he invented his eponymous nonperiodic tilings of the plane. Like those of many other great geometers, Penrose's discoveries have presented themselves as revelations rather than as syllogisms, leaving him convinced—as he argues in two engaging but controversial bestsellers [12, 13]—that human thought differs fundamentally from the algorithmic processes studied by present-day computer science.

Stephen Hawking, who is a decade younger than Penrose, first made his mark [2] by applying Penrose's differential-geometric insights to the theory of the big bang. This occurred while he was still a graduate student and not long after he had been diagnosed as suffering from amyotrophic lateral sclerosis, a rare (and typically fatal) degenerative disease of the nervous system. Walking with a cane, Hawking began a collaboration with Penrose in which the two eventually proved [7, 6, 10] that generic solutions of Einstein's equations must be geodesically incomplete. By simply surviving to see these papers published, Hawking defied all the predictions of his physicians. Astonishingly, however, his best work was still to be done—albeit in a motorized wheelchair. Intrigued by analogies between thermodynamics and the behavior of black holes, he discovered, to the shock and disbelief of his colleagues, that quantum mechanics predicts that a black hole cannot be black at all, but must emit thermal radiation at a temperature proportional to its surface gravity [3].

While this phenomenon, now known as *Hawking radiation*, was initially described in terms of conventional pseudo-Riemannian space-time, Hawking soon discovered that the temperature of a nonrotating black hole could be succinctly understood in terms of the geometry of an associated (positive-definite) Riemannian 4-manifold obtained by analytic continuation. As Lucasian Professor of Mathematics at Cambridge, Hawking has dedicated much of his time to the pursuit of this intriguing lead. By doing so, Hawking, like Penrose, has adopted Einstein's belief that ultimate explanations should be geometric in character—although this, in part, is a matter of necessity for Hawking, whose medical condition long ago deprived him of the use of pencil and paper. Whatever the physical merits of Hawking's Riemannian approach to quantum gravity [1, 4], it has, in any case, had a profound impact on pure mathematics.

The lecture series began with a pair of talks on classical general relativity, developed from the point of view of causal structures [6, 10]. Hawking's lecture was primarily aimed at the theory of black-hole event horizons, while Penrose's was primarily dedicated to the differential geometry of the big bang. The degree to which the two men's points of view have influenced each other is strikingly illustrated here; after all, it was Penrose who first used these techniques to study black holes, and Hawking who first used them to study the big bang. Already, however, their fundamental disagreements were beginning to surface. For Hawking the big bang might as well be considered a time-reversed black hole. For Penrose these two entail wildly different curvature singularities, and this is precisely what ultimately distinguishes the past from the future.

The second pair of lectures dealt with quantum theory in curved space-time. Hawking's talk began with a clear discussion of the connection between the temperature of a static black hole and the geometry of the Riemannian analog of the Schwarzschild metric and concluded with a highly speculative theory of the virtual creation and annihilation of pairs of black holes. Penrose instead chose to discuss the measurement problem in quantum mechanics and proposed that the collapse of the wave function might be an objective physical process imposed by the nonlinear nature of Einstein's equations. Both lectures make for engaging reading, but in both cases the reader is apt to have the uneasy feeling that we are no longer on solid ground.

The final pair of lectures asked how one might apply quantum theory to the universe as a whole. Hawking's proposal was that one should first build a quantum theory of Riemannian metrics on compact 4-manifolds and then analytically continue the answers to provide transition amplitudes for our approximately pseudo-Riemannian world. Penrose's point of view instead focused on the crucial role played by complex numbers in quantum mechanics and connected this with the ways in which 4-dimensional geometry may be given a complex-manifold interpretation via twistor theory.

As the lectures progressed, the level of disagreement between the participants became more pronounced, and it was all too appropriate that the series should end with a systematic airing of differences. The final debate provided a suitable forum, although what transpired was actually less a debate than an exchange of critiques, both of which were substantially on target. While the reader may thus come away with the conviction that nothing has fundamentally been settled by this exchange of views, it is nonetheless laudable that the

authors have shown the courage to openly discuss foundational difficulties of modern physics, which are usually passed over in embarrassed silence. It remains to be seen, however, whether these difficulties are susceptible to direct attack or whether their resolution must await the arrival of revolutionary new ideas from some unexpected quarter.

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Mathematics People

Wooley Awarded 1998 Salem Prize

The Salem Prize for 1998 has been awarded to TREVOR WOOLEY of the University of Michigan for his work in additive number theory, in particular on problems of Waring's type. The prize, established in 1968, is given each year by the Salem Prize Committee to a young mathematician who is judged to have done outstanding work in the area in which Raphaël Salem worked, primarily Fourier series and related topics. There was no Salem Prize in 1997. The selection committee for the 1998 prize consisted of J. Bourgain, C. Fefferman, P. Jones, N. Nikolski, T. Wolff, and J. C. Yoccoz.

—J. Bourgain, Institute for Advanced Study

Presidential Awards for Mentoring

Ten individuals and eight institutions have been chosen as recipients of the 1998 Presidential Awards for Excellence in Science, Mathematics and Engineering Mentoring. This three-year-old award is administered and funded through the National Science Foundation (NSF). The awards recognize outstanding individual efforts and organizational programs designed to increase the participation of underrepresented groups in mathematics, engineering, and science from kindergarten through twelfth grade and on through the graduate level. Up to ten individuals and ten institutions annually may qualify for the award, which includes a $10,000 grant and a commemorative presidential certificate.

Four institutions have been honored in the mathematical sciences. They are: Times2, Inc. (To Improve Mathematics, Engineering, and Science Studies), Rhode Island; the University of California, Berkeley, Coalition for Excellence and Diversity in Mathematics, Science, and Engineering; the University of Nebraska, Lincoln, Department of Mathematics and Statistics; and the University of North Carolina, Chapel Hill, Mathematics and Science Education Network Precollege Program.

—from a NSF announcement

Deaths

THOMAS B. ANDREWS, retired from NASA, died on November 28, 1997. Born on August 13, 1923, he was a member of the Society for 53 years.

ROBERT JOHN BATTIG, of Cornell University, died on December 1, 1997. Born on November 6, 1968, he was a member of the Society for 1 year.

RONALD M. FOSTER, of Belmar, New Jersey, died on February 2, 1998. Born on October 3, 1896, he was a member of the Society for 77 years.

HANSGEORG JEGGLE, of the Technical University of Berlin, Germany, died on August 22, 1998. Born on October 13, 1939, he was a member of the Society for 23 years.

GEORGE KOLETTIS, professor emeritus, University of Notre Dame, died on August 7, 1998. Born on February 12, 1928, he was a member of the Society for 44 years.

KARL KRONSTEIN, associate professor emeritus, University of Notre Dame, died on February 24, 1998. Born on February 9, 1928, he was a member of the Society for 43 years.

PAN D. PANAGIOTOPOULOS, of Aristotle University of Thessaloniki, Greece, died on August 12, 1998. Born on January 1, 1950, he was a member of the Society for 8 years.

Mathematics Opportunities

National Institute for Science Education Fellowships

The National Institute for Science Education (NISE), funded by the National Science Foundation and based at the University of Wisconsin-Madison, has openings for several one-year fellows for the 1999–2000 College Level One (CL-1) Institute.

The 1999–2000 CL-1 Institute will address issues of the use of technology in introductory undergraduate science, mathematics, engineering, and technology (SMET) courses. For example, products could include assessments of the utility of technology in the classroom and developing usage guides for instructional technology and digital libraries.

Fellows are expected to have a record of research and/or extensive classroom practice in this field. Responsibilities will include research and writing toward a synthesis of present knowledge, creation of dissemination tools for postsecondary faculty and administrators, organization of seminars and symposia, and extensive interaction with other fellows and NISE members.

The academic requirement is a doctorate in science, mathematics, engineering, or education. Possible candidates include faculty who teach SMET courses and who have experience using technology in their classrooms, education researchers with expertise in instructional technology, and members of faculty development programs. Residence at UW-Madison for the 1999–2000 academic year is preferred. For further information and application procedures, contact Paula White, National Institute for Science Education, University of Wisconsin-Madison, 1025 West Johnson Street, Madison, Wisconsin 53706; e-mail: pwhite@macc.wisc.edu; or visit the NISE Web site: www.wcer.wisc.edu/NISE/NISE_Fellows/cl1_team_fellows.html.

—from an NISE announcement

NRC-Ford Foundation Postdoctoral Fellowships for Minorities

The National Research Council (NRC) administers the Ford Foundation Postdoctoral Fellowships for Minorities. This program enables teacher-scholars to engage in postdoctoral research and scholarship in an environment free from the interference of their normal professional duties and helps them to achieve greater recognition in their respective fields and to develop the professional associations that will make them more effective and productive in academic employment.

Approximately 25 one-year postdoctoral fellowships will be awarded for 1999. The total award package for each fellowship is $40,000, which includes a $30,000 stipend and a travel and relocation allowance.

Eligible applicants must be U.S. citizens or nationals who are members of one of the following ethnic minority groups: Alaskan Natives (Eskimo or Aleut), Black/African Americans, Mexican Americans/Chicanos/Chicanas, Native American Indians, Native Pacific Islanders (Polynesian or Micronesian), or Puerto Ricans. Applicants are required to have earned the Ph.D. or Sc.D. degree from a U.S. educational institution by March 3, 1999, and may not have held the degree for more than seven years as of the deadline date.

The deadline date for applications is **January 4, 1999.** Awards will be announced in early April.

Further information is available at http://fellowships.nas.edu/, or contact the Fellowship Office, National Research Council, 2101 Constitution Avenue, NW, Washington, DC 20418; telephone 202-334-2872.

—from an NRC announcement

NRC-Ford Foundation Dissertation Fellowships for Minorities

The National Research Council (NRC) administers the Ford Foundation Dissertation Fellowships for Minorities. This program enables individuals of demonstrated ability the opportunity to complete the dissertation required for a Doctor of Philosophy (Ph.D.) or Doctor of Science (Sc.D.). Awards are made for study in research-based doctoral programs in the behavioral and social sciences, humanities, engineering, mathematics, physical sciences and life sciences, or for interdisciplinary programs composed of two or more eligible disciplines.

Approximately 29 dissertation fellowships will be awarded for 1999. The stipend is $21,500 for one year.

Eligible applicants must be U.S. citizens or nationals who are members of one of the following ethnic minority groups: Alaskan Natives (Eskimo or Aleut), Black/African Americans, Mexican Americans/Chicanos/Chicanas, Native American Indians, Native Pacific Islanders (Polynesian or Micronesian), or Puerto Ricans. Applicants must have completed all course work, examinations, language requirements, and all other departmental and institutional requirements for the Ph.D. or Sc.D. (except for writing and defense of the dissertation) by February 14, 1999.

The deadline date for applications is **November 14, 1998.** Awards will be announced in early April.

Further information is available at http://fellowships.nas.edu./, or contact the Fellowship Office, National Research Council, 2101 Constitution Avenue, NW, Washington, DC 20418; telephone 202-334-2872.

—from an NRC announcement

NRC-Ford Foundation Predoctoral Fellowships for Minorities

The National Research Council (NRC) administers the Ford Foundation Predoctoral Fellowships for Minorities. This program identifies individuals of demonstrated ability and provides them with the opportunity to engage in advanced study leading to a Doctor of Philosophy (Ph.D.) or Doctor of Science (Sc.D.) in research-based doctoral programs in the behavioral and social sciences, humanities, engineering, mathematics, physical sciences and life sciences, or for interdisciplinary programs composed of two or more eligible disciplines.

Approximately 50 predoctoral fellowships will be awarded for 1999. The annual stipend is $14,000 and an annual institutional allowance of $7,500 to the fellowship institution in lieu of tuition and fees for three years.

Eligible applicants must be U.S. citizens or nationals who are members of one of the following ethnic minority groups: Alaskan Natives (Eskimo or Aleut), Black/African Americans, Mexican Americans/Chicanos/Chicanas, Native American Indians, Native Pacific Islanders (Polynesian or Micronesian), or Puerto Ricans. Applicants must be at or near the beginning of study toward a Ph.D. or Sc.D. degree; applicants already enrolled in an eligible doctoral program must require at least three years of full-time support as of September 1999 in order to complete their degree. Scores from Graduate Record Examinations (GRE) General Test are required for all Predoctoral Fellowship applicants.

The deadline date for applications is **November 14, 1998.** Awards will be announced in early April.

Further information is available at http://fellowships.nas.edu/, or contact the Fellowship Office, National Research Council, 2101 Constitution Avenue, NW, Washington, DC 20418; telephone 202-334-2872.

—from an NRC announcement

Call for Proposals: The Mittag-Leffler Institute

The Mittag-Leffler Institute has issued a call for proposals for the scientific program of the academic year 2001–02. The Institute runs programs in specialized areas of mathematics to which leading scientists in the area are invited. In a concurrent junior visiting program, postdoctorates and advanced graduate students are invited to participate. The selection criteria for proposals are scientific strength and timeliness and the degree to which the program would benefit mathematical research in Scandinavia, including Finland and Iceland. The deadline for applications is **February 28, 1999.** Proposals should be addressed to The Board, Institut Mittag-Leffler, Auravägen 17, S-182 62 Djursholm, Sweden. More information can be found on the World Wide Web at http://www.ml.kva.se/proposals.html, or contact the director of the Institute, Kjell-Ove Widman, at widman@ml.kva.se.

—The Mittag-Leffler Institute

MAA Grants for Women and Mathematics Projects

The Mathematical Association of America (MAA) awards grants each year for projects designed to encourage col-

lege and university women or high school and middle school girls to study mathematics. The Tensor Foundation, working through the MAA, is soliciting college, university, and secondary mathematics faculty (in conjunction with college or university faculty) and their departments and institutions to submit proposals. Projects may replicate existing successful projects, adapt components of such projects, or be innovative. Some possible projects may be organizing a club for women interested in mathematics or mathematics and science, providing release time to faculty preparing courses on women and mathematics, or conducting summer mathematics programs for high school girls.

Ten grants of up to $5,000 each will be made to the institution of the project director and are to be spent within the year. An institution is expected to supply matching funds or in-kind support.

Proposals must be received by **February 5, 1999**. Applicants will be notified by the end of February 1999.

Completed proposals or requests for further information should be sent to Bernice Kastner, Mathematical Association of America, 1529 Eighteenth Street, NW, Washington, DC 20036; e-mail: bkastner@maa.org; telephone 800-741-9415. More detailed information is also available on the World Wide Web at http://www.maa.org/projects/solic_99.html.

—from an MAA announcement

Society of Women Engineers Scholarship Program

The Society of Women Engineers (SWE) is offering approximately 90 scholarships that vary in amount from $200 to more than $5,000 per year, for a total of more than $150,000. Scholarships are available for reentry, undergraduate, and graduate students. Although none of the scholarships is for mathematics students, mathematics faculty may wish to refer mathematically inclined computer science and engineering students to this program.

Deadlines for each category of scholarship, as well as further information on the program, can be found at the SWE Web site: http://www.swe.org/SWE/StudentServices/Scholarship/brochure.htm; or contact the Society of Women Engineers, 120 Wall Street, 11th Floor, New York, NY 10005-3902; telephone 212-509-9577; e-mail: hq@swe.org.

—from an SWE announcement

NASA Administrator's Fellowship Program

The NASA Administrator's Fellowship Program (NAFP) is designed to enhance the professional development of mathematics, science, and engineering faculty members at historically black colleges and universities, Hispanic-serving institutions, and tribal colleges and universities. Fellowships cover a two-year period, over which fellows conduct research at a NASA center, another government agency, a research university, or a private-sector organization. Academic fellows receive a stipend equal to their current salary, as well as full compensation for relocation and other travel expenses incurred as part of the program.

New eligibility guidelines, application materials, and deadlines for the 1999 fellowships were made available in September 1998.

Further information is available through the World Wide Web at http://www2.nas.edu/fo/2116.html or by contacting NAFP Fellowship Office - TJ2038, National Research Council, 2101 Constitution Avenue, Washington, DC 20418; telephone 202-334-2872; e-mail: nafp@nas.edu.

—from a National Academy of Sciences announcement

Reference

*The **Reference** section of the* Notices *is intended to provide the reader with frequently sought information in an easily accessible manner. New information is printed as it becomes available and is referenced after the first printing. As soon as information is updated or otherwise changed, it will be noted in this section.*

Upcoming Deadlines

November 25, 1998: Deadline for receipt of proposals for NSF Interdisciplinary Grants in the Mathematical Sciences. More information can be found at the National Science Foundation Web site, `http://www.nsf.gov/cgi-bin/getpub?nsf98145/`.

December 1, 1998: Deadline for receipt of applications for the Latin American and Caribbean competition for the Guggenheim Memorial Fellowships. For more information and application forms, contact the John Simon Guggenheim Memorial Foundation, 90 Park Avenue, New York, NY 10016; telephone 212-687-4470; fax 212-697-3248; electronic mail: `fellowships@gf.org`. Information and application forms may also be obtained through the Foundation's Web site, `www.gf.org/`.

December 1, 1998: Deadline for receipt of applications for the AMS Centennial Fellowships. For application forms, write to the Executive Director, American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248; send electronic mail to `ams@ams.org`; or call 401-455-4103. Application forms are also available over the Internet at `http://www.ams.org/employment/`.

January 4, 1999: Deadline for receipt of applications for the NRC-Ford Foundation Postdoctoral Fellowships for Minorities. For details, see "Mathematics Opportunities" in this issue.

February 5, 1999: Deadline for receipt of proposals for MAA Grants for Women and Mathematics Projects. For details, see "Mathematics Opportunities" in this issue.

February 28, 1999: Deadline for proposals for the 2001–02 scientific program of the Mittag-Leffler Institute. For details, see "Mathematics Opportunities" in this issue.

Where to Find It

A brief index to information that appears in this and previous issues of the *Notices*.

AMS e-mail addresses
November 1998, p. 1369

AMS Ethical Guidelines
June 1995, p. 694

AMS officers and committee members
October 1998, p. 1209

Board on Mathematical Sciences and Staff
May 1998, p. 632

Bylaws of the American Mathematical Society
November 1997, p. 1339

Classification of degree-granting departments of mathematics
January 1997, p. 48

Mathematical Sciences Education Board and Staff
May 1998, p. 632

Mathematics Research Institutes contact information
May 1997, p. 598

National Science Board of NSF
November 1996, p. 1380

NSF Mathematical and Physical Sciences Advisory Committee
May 1997, p. 597

Officers of the Society 1997 and 1998 (Council, Executive Committee, Publications Committees, Board of Trustees)
May 1998, p. 625

Program officers for federal funding agencies (DoD, DoE, NSF)
October 1998, p. 1181

Backlog of Mathematics Research Journals (Updated)

Journal (Electronic)	Number of Article Posted in 1997	1997 Median Time (in days) from: Submission to Final Acceptance	1997 Median Time (in days) from: Acceptance to Posting	Format(s)
Conform. Geom. Dyn. (www.ams.org/ecgd/)	7	116	58	html, pdf, ps, dvi, tex
Discrete Math. Theor. Comput. Sci. (dmtcs.thomsonscience.com)	16	176	21	pdf, ps
Doc. Math. (www.mathematik.uni-bielefeld.de/documenta/) (www.math.uiuc.edu/documenta/)	15	112	13	ps, dvi
Electron. J. Combin. (www.combinatorics.org)	53	191*	4	pdf, ps, dvi, tex
Electron. J. Differential Equations (ejde.math.unt.edu) (ejde.math.swt.edu) (www.emis.de/journals/EJDE)	25	95	5	pdf, ps, dvi, tex
Electron. J. Linear Algebra (www.math.technion.ac.il/iic/ela/)	8	205	2	ps, tex
Electron. J. Probab. (www.math.washington.edu/~ejpecp/)	8	274	7	html, ps, dvi, tex
Electron. Res. Announc. Amer. Math. Soc. (www.ams.org/era/)	22	100	12	html, pdf, ps, dvi, tex
Electron. Trans. Numer. Anal. (etna.mcs.kent.edu)	9	150	70	html, pdf, ps
(ESAIM Control Optim. Calc. Var. (www.emath.fr/cocv/)	15	243	122	ps, dvi
ESAIM Probab. Statist. (www.emath.fr/ps/)	16	365	91	ps, dvi
Geom. Topol. (www.maths.warwick.ac.uk/gt/index.html)	7	150	3	pdf, ps
J. Artificial Intelligence Res. (www.jair.org/)	19	77	91	html, pdf, ps
J. Funct. Logic Programming (cs.tu-berlin.de/journal/jflp)	5	186	292	pdf, ps, dvi, tex
Math. Phys. Electron. J. (www.ma.utexas.edu/mpej)	5	91	2	ps
New York J. Math. (nyjm.albany.edu:8000/nyjm.albany.edu)	9	91	23	pdf, ps, dvi, other
Represent. Theory (www.ams.org/ert/)	15	125	43	html, pdf, ps, dvi, tex
Sem. Lothar. Combin. (cartan.u-strasbg.fr/~slc)	4	91	1	html, ps, dvi, tex, other
Sorites (www.filosoficas.unam.mx/~sorites)	6	61	122	html, ps, other
Southwest J. Pure Appl. Math. (rattler.cameron.edu/swjpam)	12	183	183	tex, other
Stud. Nonlinear Dyn. Econom. (mitpress.mit.edu/e-journals/SNDE)	13	84	30	html, pdf, ps
Theory Appl. Categ. (www.tac.mta.ca/tac)	11	152	21	ps, dvi
Ulam Quart. (www.ulam.usm.edu)	22	239	115	ps, tex

The original survey published in the September 1998 issue of *Notices* inadvertently omitted some electronic journals. The complete survey of electronic journals is listed above.

1997 Median Time. This information is as reported by the editor of the journal.

*Based on regular volume only. A regular volume refers to the fact that over the past couple of years, *Festschrifts* have been published in honor of birthdays of distinguished mathematicians and publication times of the articles therein are coordinated so that they appear together.

From the AMS

Honorary Members of the AMS

Listed below are the Honorary Members of the American Mathematical Society, those who have been members for fifty years or more.

The American Mathematical Society offers congratulations to all its Honorary Members on their longstanding affiliation with the AMS and extends appreciation for their continued commitment to the mathematics profession.

Abbott, James C.
Ablow, Clarence M.
Adney, Joseph E. Jr.
Aissen, Michael I.
Alder, H. L.
Alt, Franz L.
Ancochea, German
Anderson, Florence R.
Anderson, R. Lucile
Anderson, Richard D.
Anderson, Theodore W.
Apostol, Tom M.
Arens, Richard F.
Arnold, Bradford H.
Artzy, Rafael
Asprey, Winifred A.
Aurora, Silvio
Ayoub, Christine W.
Bade, William G.
Baker, Edward G.
Baker, George A. Sr.
Ball, Richard W.
Ballou, Donald H.
Barber, S. F.
Barr, William J.
Bartels, Robert C. F.
Bateman, Paul T.
Bazer, Jack
Beard, Helen P.
Beaty, Marjorie Heckel
Beckman, Frank S.
Bell, Earl L.
Bell, Janie L.
Bell, Philip O.
Berger, Agnes
Bergmann, Peter G.
Berkowitz, Jerome
Bernardi, Salvatore D.
Betz, Ebon E.
Birnbaum, Z. William
Blackall, Clair J.
Blackwell, David
Blanc, Charles
Blank, Albert A.
Blum, Edward K.
Blum, Joseph
Boothby, William M.
Botts, Truman A.
Bower, Julia W.
Boyle, Evelyn Hull
Brady, Wray G.
Breves Filho, J. A.
Brigham, Nelson A.
Brown, Arthur A.
Brown, Arthur B.
Brown, Richard H.
Brown, Robert Goodell
Brunk, Hugh D.
Brunschwig, Mildred C.
Brunswick, Natascha A.
Buck, Ellen F.
Buehler, Royce E.
Burroughs, Winifred K.
Butchart, John H.
Butler, John B. Jr.
Carlitz, Leonard
Carlson, Bengt G.
Carroll, Charles L. Jr.
Caywood, Thomas E.
Chandrasekharan, K.
Charpentier, Marie R. J.
Chen, Y. W.
Chern, Shiing S.
Chernoff, Herman
Choquet, Gustave
Chowla, Sarvadaman
Chung, Kai Lai
Civin, Paul
Clark, Charles L.
Clark, F. Eugene
Clark, Robert A.
Clement, Mary Dean
Cohen, Haskell
Cohen, Herman J.
Cohn, Harvey
Cohn, Richard M.
Cole, Charles A.
Coleman, A. John
Coler, Myron A.
Colson, Henry D.
Cook, E. Allen Jr.
Cotlar, Mischa
Coxeter, H. S. MacDonald
Crandall, Stephen H.
Creese, Franklyn G.
Criscenti, Jacqueline P.
Critchlow, Florence G.
Crow, Edwin L.
Cunningham, Frederic Jr.
Curtis, Herbert J.
Cuthill, Elizabeth H.
Danskin, John M.
Dantzig, George B.
Darling, Donald A.
Davis, Chandler

Davis, Martin D.
Delange, Hubert
Derry, Douglas
Diamond, Ainsley H.
Dimsdale, Bernard
Dinneen, Gerald P.
Doob, Joseph L.
Dubisch, Roy
Duren, William L. Jr.
Durfee, William H.
Durst, Lincoln K.
Dutka, Jacques
Dwork, Julius S.
Dye, Leaman A.
Dyer-Bennet, John
Eachus, J. J.
Early, Madeline L.
Eckmann, Beno
Eddy, Robert P.
Eiardi, Anthony J.
Eisele, Carolyn
Eisenstadt, B. J.
Elliott, H. Margaret
Emerson, Marion P.
Epstein, Benjamin
Epstein, Bernard
Ericksen, Wilhelm S.
Ewy, Daniel J.
Fan, Ky
Farley, Belmont G.
Federer, Herbert
Feldman, Chester
Fialkow, Aaron D.
Fishback, William T.
Flanders, Harley
Fowler, Franklin H.
Franck, Abraham
Free, Norman S.
Freilich, Gerald
Freundlich, Marianne Smith
Frink, Aline H.
Fry, Cleota G.
Gaal, Lisl Novak
Gaalswyk, Arie
Gaffney, Matthew P.
Gale, David
Galliher, Herbert P.
Garabedian, Paul R.
Garcia, Mariano Jr.
Garding, Lars
Garfin, Louis
Geckler, Richard D.
Gelbaum, Bernard R.
Gerst, Irving
Ghent, K. S.
Gilbarg, David
Gillman, Leonard
Gleason, Andrew M.
Glusman, Sidney
Goffman, Casper
Goldberg, Samuel
Goldhaber, J. K.
Goldstine, Herman H.
Golomb, Michael
Gonzalez, Mario O.
Good, Richard A.
Goodman, A. W.
Gottschalk, Walter H.
Green, John W.
Greenspan, Bernard
Gulden, S. L.
Gunderson, Norman G.
Gurney, Margaret
Hailperin, Theodore
Haimo, Deborah Tepper
Halmos, Paul R.
Hammer, Carl
Hamstrom, Mary-Elizabeth
Handelman, George H.
Harary, Frank
Hardin, R. I.
Harrington, Walter J.
Harris, Theodore E.
Hartman, Philip
Harvey, A. Raymond
Hay, George E.
Hayes, Charles A.
Heins, Maurice H.
Heller, Alex
Hemmingsen, Erik
Henderson, Emma M.
Henkin, Leon A.
Henriques, Anna S.
Herriot, John G.
Hershner, Ivan R. Jr.
Herzog, Fritz
Hewitt, Edwin
Hildebrand, F. B.
Hillman, Abraham P.
Hirsch, W. M.
Hirschfelder, Elizabeth S.
Hochschild, Gerhard P.
Hoffman, William C.
Horn, Alfred
Howard, Bernard E.
Hsiung, Chuan C.
Huck, Raymond
Huff, Gerald B.
Humphreys, M. Gweneth
Hunter, Louise S.
Hurwitz, Solomon
Huskey, Harry D.
Isaacson, Eugene
Jaco, William H.
Jacobson, Florence D.
Jacobson, Nathan
Jaffe, William J.
James, Robert C.
Jenkins, James A.
Johanson, Ralph N.
Johnson, L. Wayne
Jones, F. Burton
Jones, Phillip S.
Jonsson, Bjarni
Kakutani, Shizuo
Kalisch, Gerhard K.
Kaplan, Edward L.
Kaplan, Samuel
Kaplan, Wilfred
Kaplansky, Irving
Kasriel, Robert H.
Kelly, John B.
Kelly, Paul J.
Kennedy, Edward S.
Kincaid, Wilfred M.
Kirk, David B.
Klamkin, Murray S.
Klee, Victor
Koehler, C. Frederick
Komm, Horace
Konijn, H. S.
Koss, Walter E.
Kossack, C. R.
Kossack, Carl F.
Krabill, David M.
Ladd, Dorothy C.
Landin, Joseph
Langebartel, Ray G.
Langenhop, Carl E.
Laning, J. Halcombe
Larguier, Everett H.
Larney, Violet H.
Lauritzen, Steffen L.
Laush, George
Lax, Anneli
Lax, Peter D.
LeVeque, William J.
Leavitt, William G.
Leger, George F.
Lehner, Joseph
Leibler, Richard A.
Leipnik, Roy B.
Lengyel, Bela A.
Lepson, Benjamin
Levene, Howard
Levi, Howard
Levine, Jack
Levit, Robert J.
Lewis, D. J.
Lewis, Sister Mary Teresine
Lichnerowicz, Andre
Light, F. W. Jr.
Lipschutz-Yevick, Miriam A.
Lipsich, H. David
Lister, William G.
Livingood, J. N. B.
Lorch, Lee
Lorell, Jack
Loud, Warren S.
Luchins, Edith H.

Mac Lane, Saunders
Mackey, G. W.
Macphail, Moray S.
Madow, William G.
Maier, Lucille
Mann, Henry B.
Mann, W. Robert
Mansfield, Ralph
Marchand, Margaret O.
Marcou, R. J.
Maria, May H.
Mark, J. C.
Martin, M. H.
Martin, William T.
Masani, Pesi R.
Massey, William S.
McBrien, Vincent O.
McCormick, Clyde T.
McCoy, Dorothy
McCoy, N. H.
McDonald, Janet
McLaughlin, Jack E.
McMillan, Audrey W.
McMillan, Brockway
Meder, Albert E. Jr.
Meier, Paul
Mendelsohn, N. S.
Merriell, David M.
Meserve, Bruce E.
Meyer, Burnett C.
Meyer, Herman
Mielke, Paul T.
Miller, D. D.
Miller, Donald S.
Miller, Kenneth S.
Miller, Rose Mary
Mills, William H.
Miloslavsky, G. C.
Miser, Hugh J.
Mitchell, Josephine M.
Moise, Edwin E.
Moore, Marvin G.
Moore, W. Keith
Moran, Charles W.
Morduchow, Morris
Morgan, Kathryn A.
Morrison, Donald R.
Mostow, George Daniel
Moyls, Benjamin N.
Murray, Francis J.
Naef, Walter
Nelson, David
Nesbitt, Cecil J.
Neumann, Bernhard H.
Newlander, August Jr.
Newman, Morris
Nirenberg, Louis
Niven, Ivan
Noble, Andrewa R.
Nordhaus, Edward A.
Novikoff, Albert B.
O'Neill, Anne F.
Olmstead, P. S.
Olshen, A. C.
Olum, Paul
Orloff, Daniel
Ostrom, T. G.
Paige, Lowell J.
Palmer, Theodore P.
Parker, Francis D.
Parrish, Herbert C.
Payne, Lawrence E.
Peixoto, Mauricio M.
Penico, Anthony J.
Pepper, Paul M.
Perlis, Sam
Petrie, George W. III
Pfluger, Albert
Phillips, Ralph S.
Pinney, Edmund
Piranian, George
Pitcher, Everett
Podmele, Theresa L.
Polachek, Harry
Pollak, H. O.
Potts, Donald H.
Prenowitz, Walter
Price, G. Baley
Prim, Robert C. III
Protter, Murray H.
Putnam, Alfred L.
Putnam, Calvin R.
Quarles, D. A. Jr.
Raney, George N.
Rankin, Robert A.
Rapoport, Anatol
Rauch, Lawrence L.
Reade, Maxwell O.
Rechard, Ottis W.
Redheffer, Raymond M.
Rees, Paul K.
Reingold, Haim
Reynolds, Robert R.
Rickart, Charles E.
Riess, Karlem
Robertson, Malcolm S.
Robinson, Robin
Rose, Gene F.
Rose, Israel H.
Rosenbaum, Robert A.
Rosenbloom, J. H.
Rosenlicht, Maxwell A.
Ross, Arnold E.
Rothberger, Fritz
Rubin, Herman
Rudin, Mary E.
Rudin, Walter
Rust, Charles H.
Salkind, William
Saltzer, Charles
Salzer, Herbert E.
Samelson, Hans
Samuel, Pierre
Sangren, Ward C.
Santalo, L. A.
Scanlon, Jane Cronin
Schaerf, Henry M.
Schafer, Alice T.
Schafer, Richard D.
Schechter, Samuel
Schiffer, Max M.
Schild, Albert
Schoenfeld, Lowell
Schubert, Jewell E.
Schurrer, Augusta L.
Schwartz, Benjamin L.
Schwartz, Jacob T.
Scott, Leland L.
Shaffer, Dorothy B.
Shepherd, J. C.
Sherman, Bernard
Shniad, Harold
Sholander, Marlow C.
Shreve, Darrell R.
Silverman, Edward
Sinclair, Annette
Slook, Thomas H.
Smithies, Frank
Snapper, Ernst
Snell, J. Laurie
Sopka, John J.
Spears, Otis S.
Specht, Edward J.
Spencer, Guilford L. II
Spitzbart, Abraham
Spragens, William H. Jr.
Springer, George
Starr, David W.
Steen, F. H.
Stegun, Irene A.
Stein, Marvin L.
Stein, Sherman K.
Steinberg, Maria W.
Steinberg, Robert
Stephens, Clarence F.
Stone, Arthur H.
Strange, William J.
Strohl, G. Ralph Jr.
Struik, Dirk J.
Sturley, Eric A.
Sullivan, Sister M. Helen
Supnick, Fred
Sutton, P. P.
Tanimoto, Taffee T.
Taub, Abraham H.
Taylor, Angus E.
Terzuoli, Andrew J.
Thomas, Clayton J.
Thomas, George B. Jr.
Thompson, Layton O.

Thomsen, D. L. Jr.
Thorne, Charles J.
Thrall, Robert M.
Thron, Wolfgang J.
Todd, John
Togliatti, E. G.
Tomber, Marvin L.
Transue, William R.
Tuckerman, Bryant
Turquette, Atwell R.
Tyler, E. F.
Utz, W. Roy Jr.
Valentine, F. A.
Van Tuyl, A. H.
Vance, Elbridge P.
Vinograde, Bernard
Walker, Arthur G.
Waltcher, Azelle B.
Walters, Eleanor B.
Waterman, Daniel
Wechsler, Martin T.
Wehausen, John V.
Welmers, Everett T.
Wend, David V. V.
Wendel, James G.
Wernick, William
Western, D. W.
Wetzel, Marion D.
Wheeler, Charles H. III
White, Myron E.
Whitehead, George W.
Whitehead, Kathleen B.
Whitman, Philip M.
Whitney, D. Ransom
Wightman, Arthur S.
Wilcox, L. R.
Wilkins, J. Ernest Jr.
Wilson, Robert L.
Wing, G. Milton
Winter, Eva P.
Wong, Yung-Chow
Wood, Rhoda M.
Woodbury, Max A.
Wouk, Arthur
Wrench, John W. Jr.
Wulf, Leo M.
Wurster, Marie A.
Yagi, Fumio
Yood, Bertram
Young, Gail S.
Young, Laurence C.
Young, Paul M.
Zarantonello, Eduardo H.
Zelinsky, Daniel
Zemmer, Joseph L. Jr.
Zilber, Joseph A.
Zilmer, Delbert E.
Zimmer, J. W.
Zimmerberg, Hyman J.

Statistics on Women Mathematicians Compiled by the AMS

At its August 1985 meeting, the Council of the AMS approved a motion to regularly assemble and report in the *Notices* information on the relative numbers of men versus women in at least the following categories: membership in the AMS, invited hour addresses at AMS meetings, speakers at special sessions at AMS meetings, percentage of women speakers in AMS Special Sessions by gender of organizers, and members of editorial boards of AMS journals.

It was subsequently decided that this information would be gathered by determining the sex of the individuals in the above categories based on name identification and that additional information on the number of Ph.D.s granted to women would also be collected using the AMS-IMS-MAA Annual Survey. Since name identification was used, the information for some categories necessitated the use of three classifications:

Male: names that were obviously male;

Female: names that were obviously female;

Unknown: names that could not be identified as clearly male or female (e.g., only initials given, non-gender-specific names, etc.)

The following is the thirteenth reporting of this information. Updated reports will appear annually in the *Notices*.

Invited Hour Address Speakers at AMS Meetings (1988–1997)

Male:	408	85%
Female:	66	14%
Unknown:	8	1%
Total checked:	482	

Speakers at Special Sessions at AMS Meetings (1993–1997)

Male:	8,037	80%
Female:	1,263	13%
Unknown:	710	7%
Total checked:	10,010	

Percentage of Women Speakers in AMS Special Sessions by Gender of Organizers (1997)

Special Sessions with at Least One Woman Organizer

Total number of speakers:	680	
Male:	519	76%
Female:	108	16%
Unknown:	53	8%

Special Sessions with No Women Organizers

Total number of speakers	1,788	
Male:	1,488	83%
Female:	179	10%
Unknown:	121	7%

Members of the AMS Residing in the U.S.

Male:	13, 182	71%
Female:	3,341	18%
Unknown:	2,152	11%
Total checked:	18,675	

Trustees and Council Members

	1997		1996		1995		1994	
Total:	49		48		48		49	
Male:	38	78%	36	75%	34	71%	35	71%
Female:	11	22%	12	25%	14	29%	14	29%

Members of Editorial Boards of AMS Journals

	1997		1996		1995		1994		1993		1992		1991		1990		1989		1988	
Total:	213		198		194		176		177		178		169		183		194		161	
Male:	189	89%	177	89%	175	90%	161	91%	159	90%	163	92%	156	92%	171	93%	182	94%	148	92%
Female:	24	11%	21	11%	19	10%	15	9%	18	10%	15	8%	13	8%	12	7%	11	6%	13	8%

Ph.D.s Granted to U.S. Citizens

	1997		1996		1995		1994		1993		1992		1991		1990		1989		1988	
Total:	516		493		567		469		526		430		461		401		411		363	
Male:	368	71%	377	76%	426	75%	345	74%	381	72%	327	76%	349	76%	312	78%	313	76%	287	79%
Female:	148	29%	116	24%	141	25%	124	26%	145	28%	103	24%	112	24%	89	22%	98	24%	76	21%

Add this Cover Sheet to all of your Academic Job Applications

How to use this form

1. Using the facing page or a photocopy, (or a TEX version which can be downloaded from the e-math "Employment Information" menu, `http://www.ams.org/employment/`), fill in the answers which apply to *all* of your academic applications. Make photocopies.

2. As you mail each application, fill in the remaining questions neatly on one cover sheet and include it *on top of* your application materials.

The Joint Committee on Employment Opportunities has adopted the cover sheet on the facing page as an aid to job applicants and prospective employers. The form is now available on e-math in a TEX format which can be downloaded and edited. The purpose of the cover form is to aid department staff in tracking and responding to each application.

Mathematics Departments in Bachelor's, Master's and Doctorate granting institutions have been contacted and are expecting to receive the form from each applicant, along with any other application materials they require. Obviously, not all departments will utilize the cover form information in the same manner. Please direct all general questions and comments about the form to:
`emp-info@ams.org`
or call the Professional Programs and Services Department, AMS, at 800-321-4267 extension 4105.

JCEO Recommendations for Professional Standards in Hiring Practices

The JCEO believes that every applicant is entitled to the courtesy of a prompt and accurate response that provides timely information about his/her status. Specifically, the JCEO urges all institutions to do the following after receiving an application:

(1) Acknowledge receipt of the application—immediately; and
(2) Provide information as to the current status of the application, as soon as possible.

The JCEO recommends a triage-based response, informing the applicant that he/she
(a) is not being considered further;
(b) is not among the top candidates; or
(c) is a strong match for the position.

Academic Employment in Mathematics

AMS Standard Cover Sheet

Last Name _____

First Name _____

Middle Names _____

Address *through June 1999* _____ **Home Phone**

_____ _____

_____ **e-mail Address**

_____ _____

Current Institutional Affiliation **Work Phone**

_____ _____

Highest Degree and Source _____

Year of Ph.D. (optional) _____

Ph.D. Advisor _____

If the Ph.D. is not presently held, date on which you expect to receive _____

Indicate *the mathematical subject area(s) in which you have done research using, if applicable, the 1991 Mathematics Subject Classification printed on the back of this form. If listing more than one number, list first the one number which best describes your current primary interest.*

Primary Interest _____

Secondary Interests *optional* _____

Give a brief synopsis *of your current research interests (e.g. finite group actions on four-manifolds). Avoid special mathematical symbols and please do not write outside of the boxed area.*

_____

_____

Most recent, if any, position held *post Ph.D.*

University or Company _____

Position Title _____

Indicate the position for which you are applying and position posting code, if applicable

_____

If unsuccessful for this position, would you like to be considered for a temporary position?

☐ Yes ☐ No If yes, please check the appropriate boxes.

☐ Postdoctoral Position ☐ 2+ Year Position ☐ 1 Year Position

List the names, affiliations, and e-mail addresses *of up to four individuals who will provide letters of recommendation if asked. Mark the box provided for each individual whom you have already asked to send a letter.*

☐ _____

☐ _____

☐ _____

☐ _____

This form is provided courtesy of the American Mathematical Society.

This cover sheet is provided as an aid to departments in processing job applications. It should be included with your application material.

Please print or type. Do not send this form to the AMS.

1991 Mathematics Subject Classification

00 General
01 History and biography
03 Logic and foundations
04 Set theory
05 Combinatorics
06 Order, lattices, ordered algebraic structures
08 General mathematical systems
11 Number theory
12 Field theory and polynomials
13 Commutative rings and algebras
14 Algebraic geometry
15 Linear and multilinear algebra, matrix theory
16 Associative rings and algebras
17 Nonassociative rings and algebras
18 Category theory, homological algebra
19 K-theory
20 Group theory and generalizations
22 Topological groups, Lie groups
26 Real functions
28 Measure and integration
30 Functions of a complex variable
31 Potential theory
32 Several complex variables and analytic spaces
33 Special functions
34 Ordinary differential equations
35 Partial differential equations
39 Finite differences and functional equations
40 Sequences, series, summability
41 Approximations and expansions
42 Fourier analysis
43 Abstract harmonic analysis
44 Integral transforms, operational calculus
45 Integral equations
46 Functional analysis
47 Operator theory
49 Calculus of variations, optimal control
51 Geometry
52 Convex and discrete geometry
53 Differential geometry
54 General topology
55 Algebraic topology
57 Manifolds and cell complexes
58 Global analysis, analysis on manifolds
60 Probability theory and stochastic processes
62 Statistics
65 Numerical analysis
68 Computer science
70 Mechanics of particles and systems
73 Mechanics of solids
76 Fluid mechanics
78 Optics, electromagnetic theory
80 Classical thermodynamics, heat transfer
81 Quantum theory
82 Statistical mechanics, structure of matter
83 Relativity and gravitational theory
85 Astronomy and astrophysics
86 Geophysics
90 Economics, operations research, programming, games
92 Biology and other natural sciences, behavioral sciences
93 Systems theory, control
94 Information and communication, circuits

Mathematics Calendar

The most comprehensive and up-to-date Mathematics Calendar information is available on e-MATH at `http://www.ams.org/mathcal/`.

December 1998

2-4 **Mathematical Economics**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan. (Sept. 1998, p. 1049)

4-5 **NIPS*98 Post Conference Workshops**, Breckenridge, Colorado. (Jun/Jul. 1998, p. 757)

7-9 **Spectral and Scattering Theory and Related Topics**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan. (Sept. 1998, p. 1049)

7-11 **III International Symposium on Hamiltonian Systems and Celestial Mechanics**, Morelia, Michoacan, Mexico. (Sept. 1998, p. 1049)

7-11 **Microlocal Analysis and Systems of PDE in the Complex Domain**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan. (Sept. 1998, p. 1049)

9-11 **Blowup, Breakdown, and Related Topics in Nonlinear PDEs**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan. (Sept. 1998, p. 1049)

13-15 **CMS Winter 1998 Meeting**, Queen's University and Royal Military College, Kingston, Ontario, Canada. (Aug. 1998, p. 898)

14-16 **Algebraic Combinatorics**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan. (Sept. 1998, p. 1049)

14-18 **First International Conference on Semigroups of Operators, Theory and Applications**, Marriot Hotel, Newport Beach, California. (Feb. 1998, p. 296)

14-18 **Hyperbolic Spaces and its Related Topics**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan. (Sept. 1998, p. 1049)

16-22 **Symmetry and Perturbation Theory II**, Rome, Italy. (Apr. 1998, p. 534)

17-19 **International Symposium on Recent Advances in Mathematics and Applications (ISRAMA 98)**, Calcutta, India. (Oct. 1998, p. 1228)

* 18-20 **DIMACS-HKUST Far-East Workshop on Algorithms and Combinatorics**, Hong Kong University of Science and Technology, Hong Kong.
Sponsors: DIMACS Center, Hong Kong University of Science and Technology.
Goal: The goal of this workshop is to foster greater communication and collaboration between DIMACS and algorithm researchers in Asia. Its focus will be on algorithms, combinatorics and the interplay between them. Two types of talks are planned; extended surveys by nine distinguished invited speakers and shorter presentations by the attendees describing their current research. In addition, there will be open problem sessions.
Invited Speakers: M. Blum (Univ. of California at Berkeley), F. Chung (Univ. of Pennsylvania), D.-Z. Du (Univ. of Minnesota), R. Graham (AT&T Labs and Rutgers), W.-L. Hsu (Academia Sinica), F. Hwang (Academia Sinica), R. Pollack (NY Univ. (Courant Inst.)), R. Sedgewick (Princeton Univ.), M. Sharir (Univ. of Tel Aviv), N. Sloane (AT&T Labs).
Contacts: M. Golin, Hong Kong University of Science and Technology, `golin@cs.ust.hk`.
Information: WWW: `http://dimacs.rutgers.edu/Workshops/index.html`.

19-21 **(ORSI Convention) International Conference on Operations Research and Industry**, Institute of Basic Science, Agra, India. (May 1998, p. 642)

* 21-24 **International Conference on p-Adic Analysis, Summability Theory, Fuzzy Analysis and Applications (INCOPASFA)**, Chennai, India.
Organizers: Forum d' Analystes, Madras. Cosponsored by Crescent Engineering College, Vandalur.

This section contains announcements of meetings and conferences of interest to some segment of the mathematical public, including ad hoc, local, or regional meetings, and meetings and symposia devoted to specialized topics, as well as announcements of regularly scheduled meetings of national or international mathematical organizations. A complete list of meetings of the Society can be found on the last page of each issue.
An announcement will be published in the *Notices* if it contains a call for papers and specifies the place, date, subject (when applicable), and the speakers; a second announcement will be published only if there are changes or necessary additional information. Once an announcement has appeared, the event will be briefly noted in every third issue until it has been held and a reference will be given in parentheses to the month, year, and page of the issue in which the complete information appeared. Asterisks (*) mark those announcements containing new or revised information.
In general, announcements of meetings and conferences held in North America carry only the date, title of meeting, place of meeting, names of speakers (or sometimes a general statement on the program), deadlines for abstracts or contributed papers, and source of further information. Meetings held outside the North American area may carry more detailed information. In any case, if there is any application deadline with respect to participation in the meeting, this fact should be noted. All communications on meetings and conferences in the mathematical sciences should be sent to the Editor of the *Notices* in care of the American Mathematical Society in Providence or electronically to `notices@ams.org` or `mathcal@ams.org`.
In order to allow participants to arrange their travel plans, organizers of meetings are urged to submit information for these listings early enough to allow them to appear in more than one issue of the *Notices* prior to the meeting in question. To achieve this, listings should be received in Providence **six months** prior to the scheduled date of the meeting.
The complete listing of the Mathematics Calendar will be published only in the September issue of the *Notices*. The March, June, and December issues will include, along with new announcements, references to any previously announced meetings and conferences occurring within the twelve-month period following the month of those issues. New information about meetings and conferences that will occur later than the twelve-month period will be announced once in full and will not be repeated until the date of the conference or meeting falls within the twelve-month period.
The Mathematics Calendar, as well as Meetings and Conferences of the AMS, is now available electronically through e-MATH on the World Wide Web. To access e-MATH, use the URL: `http://e-math.ams.org/` (or `http://www.ams.org/`). (For those with VT100-type terminals or for those without WWW browsing software, connect to e-MATH via Telnet (`telnet e-math.ams.org`; login and password `e-math`) and use the Lynx option from the main menu.)

Description: Forum d' Analystes is an autonomous international organization created (i) to promote study of mathematical analysis and particularly the fundamental branches thereof, (ii) to publish good surveys, research work, source books in analysis, (iii) to promote computational techniques in analysis, (iv) to organize meetings and workshops in analysis. In consonance of the avowed policy of the Forum d' Analystes to promote the interest of mathematical analysis and analysts, it is proposed to host an international conference in honor of Professors Dr. M. S. Rangachari and Dr. G. Rangan in recognition of their many years of service to mathematics in general and the mathematics community in India and Madras in particular.
Aim: This conference will provide an opportunity for young researchers working in these fields to come into contact with internationally reputed experts and have fruitful discussions. The conference will have invited half-hour talks by experts and paper presenting sessions by youngsters.
Information: For more information and all correspondence contact: S. A. Settu, Convener, INCOPASFA, Department of Mathematics, D. G. Vaishnav College, Arumbakkam, Chennai - 600 106, India; e-mail: saithu@hotmail.com.

23-25 **The Joint Annual Conference of the Bharat Ganita Parisad and the Jammu Mathematical Society-A symposium on functional analysis and applications**, Department of Mathematics, Lucknow University, Lucknow, India. (Jun/Jul. 1998, p. 757)

January 1999

January-June **The Fields Institute for Research in Mathematical Sciences Program in Probability and Its Applications**, The Fields Institute, Toronto, Ontario, Canada. (Sept. 1997, p. 1031)

4-8 **Cell Adhesion and Motility**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 757)

4-9 **National Academy of Sciences Colloquium on Nonlinear Partial Differential Equations**, Irvine, California. (Oct. 1998, p. 1228)

7-9 **Semidefinite Programming and its Applications to Large Scale Discrete Optimization**, Computer Science Dept., Princeton University, Princeton, New Jersey. (Oct. 1998, p. 1228)

7-11 **Singular and Oscillatory Integrals**, University of Wisconsin-Madison, Madison, Wisconsin. (Sept. 1998, p. 1049)

8-9 **Nonlinear Differential Equations: A Meeting Honoring Professor Alan Lazer on the Occasion of his 60th Birthday**, The University of Miami, Coral Gables, Florida. (Apr. 1998, p. 535)

8-12 **Twenty-third Holiday Symposium: Algebraic Structures For Logic**, New Mexico State University, Las Cruces, New Mexico. (May 1998, p. 642)

11-12 **Evolution as Computation**, Princeton University, Princeton, New Jersey. (Nov. 1998, p. 1376)

11-14 **Workshop on Coding and Cryptography**, Cercle militaire St. Augustin, Paris, France. (Aug. 1998, p. 898)

13-16 **Joint Mathematics Meeting**, San Antonio Convention Center, San Antonio, Texas. (Oct. 1998, p. 1263)

15-16 **ASL Winter Meeting (in conjunction with AMS annual meeting)**, San Antonio, Texas. (Oct. 1998, p. 1228)

15-16 **Workshop on Algorithm Engineering and Experimentation (ALENEX99)**, Omni Hotel, Baltimore, Maryland. (Nov. 1998, p. 1377)

17-19 **Tenth Annual ACM-SIAM Symposium on Discrete Algorithms (SODA'99)**, Omni Inner Harbor Hotel, Baltimore, Maryland. (Jun/Jul. 1998, p. 758)

18-20 **Coherent Vatical Structures - Their Roles in Turbulence Dynamics**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan. (Sept. 1998, p. 1050)

18-21 **DMTCS'99, Discrete Mathematics and Theoretical Computer Science and CATS'99, Computing: The Australasian Theory Symposium**, University of Auckland and CDMTCS, Auckland, New Zealand. (Oct. 1998, p. 1228)

19-23 **Introductory Workshop in Random Matrix Models and their Applications**, Mathematical Sciences Research Institute, Berkeley, California. (Jun/Jul. 1998, p. 758)

25-29 **Computational Modeling in Biological Fluid Dynamics**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 758)

25-29 **Researches on Automorphic Forms and L-functions**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan. (Sept. 1998, p. 1050)

26-30 **Fields Institute Workshop on Probability in Finance**, Fields Institute, Toronto, Canada. (Aug. 1998, p. 898)

February 1999

1-4 **Singularity Theory and Differential Equations**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan. (Sept. 1998, p. 1050)

7-11 **35th Australia-New Zealand Applied Mathematics Conference (ANZIAM 99)**, Mollymook Golf Club, Ulladulla, New South Wales. (Dec. 1997, p. 1500)

8-12 **Membrane Transport and Renal Physiology**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 758)

* 11-12 **Combustion Meeting in Honor of Professor Brian F. Gray**, Mollymook, Ulladula, New South Wales.
Information: G. Mercer, School of Maths and Stats, University College, ADFA, UNSW, Canberra 2600, e-mail: g-mercer@adfa.edu.au, Web: http://www.ma.adfa.oz.au/Events/Conferences/BFGmeeting.html.

12-13 **Fifteenth Conference on Applied Mathematics (CAM)**, University of Central Oklahoma, Edmond, Oklahoma. (Nov. 1998, p. 1377)

13 **Hormones**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 758)

15-19 **Endocrinology: Mechanism of Hormone Secretion and Control**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 758)

* 18-21 **Sunbelt XIX, International Sunbelt Social Network Conference**, Hawthorn Suites Hotel, Charleston, South Carolina.
Focus: The International Sunbelt Social Network Conference is a major forum for social scientists, mathematicians, computer scientists, and all others interested in social networks. The conference provides an opportunity for individuals interested in theory, methods, or applications of social networks to share ideas and common concerns.
Sponsors: Sponsors of Sunbelt XIX are the International Network for Social Network Analysis (INSNA) and the Department of Sociology at the University of South Carolina.
Topics: Current session topics include: Corporate and inter-organizational networks; Intra-organizational networks; Personal community networks; Networks and health; Networks and game theory; Diffusion; Networks through time; Social support; Cognitive networks; Biological networks; HIV/AIDS; Communication networks; Network exchange; Methods and statistics for network analysis. This list is preliminary. If you wish to organize a session, contact the organizers at the addresses below.
Keynote Speaker: N. Lin, Professor of Sociology and Director of the Asian Pacific Studies Institute, Duke Univ., will deliver the keynote address entitled "Building a Network Theory of Social Capital."
Workshops: Planned workshops include: B. Wellman's "A Non-Technical Introduction to Social Network Analysis"; S. Borgatti and M. Everett's "Introduction to the Analysis of Network Data"; and S. Wasserman and Company "Statistical Methods for Social Networks," and L. Freeman "Generating Images of Networks".
Paper Submission: To submit a paper, send an abstract of no more than 200 words by e-mail or in an ASCII file on diskette for DOS platforms and a hard copy to one of the organizers no later than December 15, 1998. Submission of more than one multiple-authored paper is acceptable. But, we may need to limit program participation to the equivalent of one single-authored paper per person.

Registration: Pre-registration is $50.00 for INSNA members, $75.00 for non-members, $25.00 for students, and $15.00 for registration-in-absentia for INSNA members ($30.00 for non-members). All fees will be $10.00 higher for registration at the conference. Deadline for preregistration is February 1, 1999.
Organizers: K. Faust, Department of Sociology, Univ. of South Carolina, Columbia, SC 29208; tel: 803-777-6848; e-mail: faust@garnet.cla.sc.edu; J. Skvoretz, Department of Sociology, Univ. of South Carolina, Columbia, SC 29208; tel: 803-777-4968; e-mail: skvoretz-john@sc.edu.
Information: Conference information will be updated regularly at the INSNA web site: http://www.heinz.cmu.edu/project/INSNA/.

22–26 **Random Matrices, Statistical Mechanics, and Integrable Systems**, Mathematical Sciences Research Institute, Berkeley, California. (Jun/Jul. 1998, p. 758)

March 1999

1–4 **M/SET, International Conference on Mathematics/Science Education & Technology**, San Antonio, Texas. (Sept. 1998, p. 1050)

3–5 **Theory and Applications of Realtime Computation**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan. (Sept. 1998, p. 1050)

5 **Audition**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 758)

7–13 **Dirac Operators, Index Theorems and Numerical Invariants of Manifolds**, Greifswald University, Germany, Island of Usedom. (Jun/Jul. 1998, p. 759)

7–14 **Eighth International Conference on Geometry**, Nahsholim, Israel. (Sept. 1998, p. 1050)

8–12 **Audition**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 759)

12–13 **AMS Southeastern Section Meeting**, University of Florida, Gainesville, Florida. (Jun/Jul. 1998, p. 759)

13–15 **International Conference on Scientific Computations**, Beirut Arab University, Beirut, Lebanon. (Oct. 1998, p. 1228)

13–17 **1999 Arizona Winter School: Local-to-Global Principles in Arithmetical Algebraic Geometry**, University of Arizona, Tucson, Arizona. (Oct. 1998, p. 1229)

16–20 **1999 UAB-GIT International Conference on Differential Equations and Mathematical Physics**, University of Alabama at Birmingham, Birmingham, Alabama. (Jun/Jul. 1998, p. 759)

17–19 **International Conference on Differential Equations and Nonlinear Mechanics**, University of Central Florida, Orlando, Florida. (Nov. 1998, p. 1377)

18–21 **AMS Central Sectional Meeting**, University of Illinois-Urbana, Urbana, Illinois. (Aug. 1997, p. 846)

20–23 **ASL Annual Meeting**, San Diego, California. (Oct. 1998, p. 1229)

*20–23 **Measurable and Topological Dynamics**, University of Maryland, College Park, Maryland.
Information: For information see http://www.math.umd.edu/~krb/dynsys.html.

22–24 **Ninth SIAM Conference on Parallel Processing for Scientific Computing**, Adam's Mark San Antonio-Riverwalk Hotel, San Antonio, Texas. (Jun/Jul. 1998, p. 759)

24–26 **DIMACS Workshop on Mobile Networks and Computing**, DIMACS Center, Rutgers University, Piscataway, New Jersey. (Sept. 1998, p. 1050)

24–27 **Fifth SIAM Conference on Mathematical and Computational Issues in the Geosciences**, Adam's Mark San Antonio-Riverwalk Hotel, San Antonio, Texas. (Jun/Jul. 1998, p. 759)

25–26 **Third International Multidisciplinary Congress in Quality and Reliability**, Paris, France. (Aug. 1998, p. 899)

25–28 **International Conference on Algebra and its Applications**, Ohio University, Athens, Ohio. (Oct. 1998, p. 1229)

*29–April 1 **British Mathematical Colloquium**, University of Southampton, Southampton, England.
Plenary Speakers: F. Buekenhout, E. Ghys, A. Shalev, D. Vogan.
Special Sessions: Geometric Group Theory (organiser D. B. A. Epstein), Stochastic Analysis (organiser T. J. Lyons).
Support: The British Mathematical Colloquium is supported financially by the London Mathematical Society.
Information: See http://www.maths.soton.ac.uk/bmc/or e-mail I. Leary at ijl@maths.soton.ac.uk.

April 1999

6–9 **London Mathematical Society Invited Lecture Series**, University of Bath, Bath, United Kingdom. (Oct. 1998, p. 1229)

7–9 **Fourth International Conference on Typed Lambda Calculi and Applications (TLCA'99)**, l'Aquila, Italy. (Jun/Jul. 1998, p. 759)

10–11 **AMS Western Sectional Meeting**, University of Nevada, Las Vegas, NV. (Apr. 1997, p. 481)
Information: W. Drady, wsd@ams.org.

12–15 **Nonlinear Evolution Equations and Wave Phenomena: Computation and Theory**, Athens, Georgia. (Apr. 1998, p. 535)

17–18 (NEW DATE) **Riviere-Fabes Symposium on Analysis and PDE**, University of Minnesota, Minneapolis, Minnesota. (Sept. 1998, p. 1050)

*15–17 **Complex Dynamics: The University of Arkansas Annual Lectures in the Mathematical Sciences.**, University of Arkansas, Fayetteville, Arkansas.
Principal Lecturers: M. Lyubich and J. Milnor (SUNY at Stony Brook).
Program: The meeting will consist of at least five sessions: morning and afternoon sessions on Thursday and Friday and a morning session on Saturday. Each session will begin with a lecture by Professor Milnor or Professor Lyubich, followed by two or three talks by invited speakers or contributed papers.
Call for Papers: Contributed papers should be submitted before Feb.15,1999.
Funding: A proposal has been submitted to the National Science Foundation for funds to assist graduate students and young researchers with expenses.
Information: Contact I. Monroe or V. Retakh, Department of Mathematical Sciences, SCEN 301, Univ. of Arkansas, Fayetteville, AR 72701; e-mail: imonroe@comp.uark.edu or vretakh@comp.uark.edu.

*15–17 **Thirty-second Biennial Kappa Mu Epsilon National Convention**, Florida Southern College, Lakeland, Florida.
Program: There will be approximately 15 student talks on all aspects of math, stat and computer science presented. A banquet with an invited faculty speaker will be part of the agenda. Awards for the top four undergraduate talks are given.
Call for Papers: KME students should submit five copies of their talk by February 10, 1999 to: R. Bailey, Department of Math, Niagara University, NY 14109.
Information: P. Costello, Department of Math, Eastern Kentucky University, Richmond, KY 40475-3133; tel: 606-622-1925; e-mail: matcostello@acs.eku.edu.

19–23 **Local Interaction and Global Phenomena in Vegetation and Other Systems**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 759)

24–25 **AMS Eastern Sectional Meeting**, State University of New York, Buffalo, NY. (Apr. 1997, p. 481)
Information: W. Drady, wsd@ams.org.

May 1999

7–8 **1999 ASL Spring Meeting**, New Orleans, Louisiana (in conjunction with a meeting of the Central Division of the American Philosophical Association, May 5–8, 1999). (Oct. 1998, p. 1229)

10–12 **Sixth SIAM Conference on Optimization**, Radisson Atlanta Hotel, Atlanta, Georgia. (Jun/Jul. 1998, p. 760)

12–15 **1999 SIAM Annual Meeting**, Radisson Atlanta Hotel, Atlanta, Georgia. (Jun/Jul. 1998, p. 760)

13–14 **Introduction to Epidemiology and Immunology**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 760)

14-16 **BLMS'99, Joint meeting of the London Mathematical Society and the Belgian Mathematical Society**, Université Libre de Bruxelles, Brussels, Belgium. (Sept. 1998, p. 1050)

17-21 **Mathematical Approaches for Emerging and Reemerging Infectious Diseases**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 760)

19-22 **Fourth International Joint Meeting of the AMS and the Sociedad Matematica Mexicana (SMM)**, University of North Texas, Denton, Texas. (Nov. 1998, p. 1377)

24-28 **Fifth SIAM Conference on Applications of Dynamical Systems**, Snowbird Ski and Summer Resort, Snowbird, Utah. (Jun/Jul. 1998, p. 760)

26-28 **Crystallographic Groups and their Generalizations II**, K. U. Leuven (Campus Kortrijk), Kortrijk, Belgium. (Aug. 1998, p. 899)

26-29 **Third International Conference on Dynamic Systems and Applications**, Atlanta, Georgia. (Sept. 1998, p. 1051)

26-29 **Twelfth Biennial Conference of the Association of Christians in the Mathematical Sciences**, Gordon College, Wenham, MA. (Oct. 1998, p. 1229)

27-29 **Mathematics Towards The Third Millennium**, Accademia Nazionale dei Lincei, Rome, Italy. (Oct. 1998, p. 1230)

31-June 4 **The 19th International Conference on Distributed Computing Systems (ICDCS '99)**, Austin, Texas. (Nov. 1998, p. 1377)

31-June 4 **Turku Symposium on Number Theory in Memory of Kustaa Inkeri**, University of Turku, Finland. (Sept. 1998, p. 1051)

June 1999

1-4 **Day on Diffraction'99**, St. Petersburg Branch of Steklov Mathematical Institute, St. Petersburg, Russia. (Nov. 1998, p. 1377)

7-9 **Theoretical, Experimental & Computational Mechanics**, Cincinnati, Ohio. (Oct. 1998, p. 1230)

7-11 **From Individual to Aggregration: Modeling Animal Grouping**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 760)

7-11 **Random Matrices and Their Applications: Quantum Chaos, GUE Conjecture for Zeros of Zeta Functions, Combinatorics, and All That**, Mathematical Sciences Research Institute, Berkeley, California. (Jun/Jul. 1998, p. 760)

7-11 **Second IMACS Conference on Monte Carlo Methods**, Varna, Bulgaria. (Sept. 1998, p. 1051)

10-12 **1999 International Conference on Preconditioning Techniques for Large Sparse Matrix Problems in Industrial Applications**, University of Minnesota, Hubert H. Humphrey Institute, Minneapolis, Minnesota. (Nov. 1998, p. 1378)

13-17 **Conference on The Mathematics of Public-Key Cryptography**, The Fields Institute, Toronto, Ontario, Canada. (Sept. 1998, p. 1051)

*14-19 **MATHTOOLS'99, 2nd International Conference "Tools for Mathematical Modelling"**, Saint-Petersburg State Technical University, Saint-Petersburg, Russia.

Focus: MATHTOOLS'99 is a multidisciplinary conference on latest advances in the theory of ordinary differential equations and the role of the theory for explanation of some nonlinear effects arising in real systems as well as demonstration of up-to-date efficient methods for solving of applied technical problems, providing an ideal forum for researchers to disseminate knowledge, research results and applications in many sectors of activity.

Topics: Papers may address a broad range of research fields of current interest. A list of possible topics includes (but is not limited to) the following: Mathematical modelling; Computer algebra; Design techniques; Numerical methods; Parallel and distributed algorithms; Computer modeling in dynamical systems; Mathematical models in biology, medicine, ecology, etc.; Applications to physics, electrotechniques, and electronics; Dynamic economic models; General macroeconomic models; Market models; Wavelets and their applications.

Organizing Committee: Y. Ivanov (St. Petersburg Technical Univ., secretary), G. S. Osipenko (St. Petersburg Technical Univ., chair).

Scientific Committee: L. Belous (Ukraine), D. Dytte (Denmark), J. Hugger (Denmark), A. Kasterin (Russia), V. Malozemov (Russia), M. Mrozek (Poland), A. Petukhov(Russia), M. Seppala (USA), V. Sterla (USA), G. Tardivel (UK), V. Tkachenko (Ukraine), V. Zavadskii (Belorussia), V. Zheludev (Israel), A. Zhizchenko (Russia), and S. Znamensii (Russia).

Abstracts: The papers selection for the meeting will be made on the basis of an abstract. The abstract (in 1-2 complete pages, hard copy only) should include the title of the paper, names of all authors, addresses and complete affiliations, and appropriate references.

Deadlines: Abstracts due: April 30, 1999; registration form: April 30, 1999.

Information: Y. Ivanov, MATHTOOLS'99, Dept. of Mathematics, State Technical University, Polytechnicheskaya st., 29, St. Petersburg 195251, Russia; fax: +7+812+5343314 or +7+812+5341404; e-mail: `lab@osipenko.stu.neva.ru`, `math@math.hop.stu.neva.ru`, or `petukhov@pdmi.ras.ru`.

17-20 **Six Projects in Mathematics and Physics-A Cooperation Project between Scientists from the CIS and Germany**, Technische Universitaet Berlin, Germany. (Aug. 1998, p. 899)

21-25 **International Workshop on Special Functions: Asymptotics, Harmonic Analysis, and Mathematical Physics**, City University of Hong Kong, Hong Kong, China. (Nov. 1998, p. 1378)

25-30 **Intermediate questions of Model Theory and Universal Algebra**, Novosibirsk State Technical University & Math. Institute of Siberian branch of Academy of Russia, Novosibirsk, Russia. (Sept. 1998, p. 1052)

29-July 3 **Theory and Mathematics in Biology and Medicine (TMBM99)**, Vrije Universiteit, Amsterdam, The Netherlands (Sept. 1998, p. 1052)

July 1999

*2-5 **Fourteenth Annual IEEE Symposium on Logic in Computer Science**, Trento, Italy.

Sponsors: The symposium is sponsored by the IEEE Technical Committee on Mathematical Foundations of Computing in cooperation with the Association for Symbolic Logic, the European Association for Theoretical Computer Science, and the Association for Computing Machinery. The symposium is hosted by ITC-IRST, and is a part of the Federated Logic Conference (FLoC'99). For more information about FLoC, see `http://www.cs.bell-labs.com/cm/cs/what/floc99/`.

Topics: Topics of interest include: abstract data types, automated deduction, bounded arithmetic, categorical models and logics, combination of logics, concurrency, constraint programming, constructive mathematics, database theory, denotational semantics, domain theory and applications, finite model theory, formal methods, game semantics, hybrid systems, logics of knowledge, lambda and combinatory calculi, linear logic, logical aspects of computational complexity, logics in artificial intelligence, logics of programs, logic programming, modal and temporal logics, model checking, logical aspects of protocol security, rewriting, semantics, software specification, type theory and type systems, universal algebra, and verification.

Call for Papers: Paper submission: e-mail an extended abstract (not a full paper) to the program chair, `Giuseppe.Longo@ens.fr`, and to the associate chair, `Gilles.Dowek@inria.fr`, to be received by December 10, 1998. The abstract should mention, on the first page, one or more keywords (possibly from the list above), in decreasing order of relevance. The deadline is firm; late submissions and papers without keywords will not be considered. Authors will be notified of acceptance or rejection by February 17, 1999. Accepted papers in a specified format for the proceedings will be due by April 5, 1999.

Format your abstract as a PostScript file, accompanied by a separately e-mailed textfile cover letter. One hard copy must be sent to the program chair, to arrive before December 18, 1998.

Program Chair: G. Longo, Attn: LICS, LIENS (CNRS) et DMI, École Normale Superieure, 45 Rue D'Ulm, 65005 Paris, France; e-mail:

Giuseppe.Longo@ens.fr, tel: +33-1-4432-3328; fax: +33-1-4432-2080.

2-10 **The 1999 Federated Logic Conference (FLoC '99)**, Trento, Italy. (Sept. 1998, p. 1052)

5-9 **The Fourth International Congress on Industrial and Applied Mathematics**, Edinburgh, Scotland. (Dec. 1997, p. 1500)

*9-17 **Computation in Group Theory and Geometry**, University of Warwick, Coventry, England.
Information: Please see the Web page http://www.maths.warwick.ac.uk/~dbae/symposium99.html.

12-16 **First International Joint Meeting of the American Mathematical Society and the Australian Mathematical Society**, Melbourne, Australia. (Nov. 1998, p. 1378)

12-17 **Journees Arithmetiques 1999**, Rome, Italy. (May 1998, p. 642)

7-17 **Emerging Applications of Dynamical Systems**, University of Minnesota, Minneapolis, Minnesota. (Mar. 1998, p. 427)

13-16 **International Conference on Applied Partial Differential Equations**, Tongji University, Shanghai, China. (Oct. 1998, p. 1230)

25-August 7 **The 14th International Conference on Banach Algebras**, Pomona College, Claremont, California. (Sept. 1998, p. 1052)

26-30 **ENUMATH 99 - Third European Conference on Numerical Mathematics and Advanced Applications**, University of Jyvaskyla, Jyvaskyla, Finland. (Sept. 1998, p. 1052)

August 1999

August-December **MSRI Program in Galois Groups and Fundamental Groups**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 1998, p. 1053)

August-May 2000 **MSRI Program in Noncommutative Algebra**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 1998, p. 1053)

1-6 **1999 ASL European Summer Meeting (Logic Colloquium '99)**, Utrecht, The Netherlands. (Oct. 1998, p. 1230)

1-7 **EQUADIFF 99**, Free University, Berlin, Germany. (Nov. 1998, p. 1378)

2-13 **IMA Summer Program: IMA Workshop on Codes, Systems and Graphical Models**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 760)

*8-14 **Second International Conference on Boundary Value Problems, Integral Equations and Related Problems**, Chengde, Hebei, and Beijing, China.
Topics: The conference will be about the following five subjects: 1) Various boundary value problems for partial differential equations including free and moving boundary problems; 2) The theory and methods of integral equations including singular integral equations; 3) Applications of boundary value problems and integral equations to mechanics and physics; 4) Numerical methods of integral equations and boundary value problems; 5) Some related problems with analysis and above subjects.
Organizing Committee: Z. Y. Hou (Fudan Univ.), W. Lin (Zhongshan Univ.), J. K. Lu (Wuhan Univ.), G. C. Wen (Peking Univ.), G. W. Yang (Hebei Sci. & Tech. Univ.) and Z. Zhao (Beijing Normal Univ.).
Information: More detailed information, please contact G. C. Wen, Dept. of Math., Peking Univ., Beijing 100871, China; tel: 008610-62755937; fax: 008610-62751801; e-mail: wengc@pku.edu.cn.

9-14 **Gyorgy Alexits Memorial Conference**, Budapest, Hungary. (Jun/Jul. 1998, p. 760)

*9-20 **Summer School on Empirical Processes**, University of Aarhus, Denmark.
Forum: From Monday, August 9, 1999, to Friday, August 20, 1999, MaPhySto will organize a summer school on empirical processes.
Lectures: Each of the following have agreed to give a series of lectures (7-9 lectures of 45 min. each): Uniform Central Limit Theorems by R. M. Dudley (MIT); Empirical Processes at Work in Statistics by A. W. Van der Vaart (Amsterdam) & J. A. Wellner (Seattle); Empirical and Partial-sum Processes Revisited as Random Measure Processes by P. Gänssler (Munich); Convergence in Law of Random Elements and Sets by J. Hoffmann-Jørgensen (Aarhus). Furthermore there will be 5-10 guest speakers (still leaving slots for the participants to speak).
Information: See http://www.maphysto.dk/events/EmpirProc99/.

*16-18 **Conference in Honor of Daniel J. Kleitman's 65th Birthday**, M.I.T., Cambridge, Massachusetts.
Information: See http://www.math.uiuc.edu/~west/kcc.html.

19-21 **20th Anniversary of Boundary Elements Conference (BEM 20)**, University of Central Florida, Orlando, Florida. (Mar. 1998, p. 427)

23-27 **International Conference on Topology and its Applications**, Kanagawa University, Yokohama, Japan. (Aug. 1998, p. 899)

September 1999

1-3 **First International Conference on the Integration of Dynamics, Monitoring and Control (DYMAC 99)**, Manchester, United Kingdom. (Sept. 1998, p. 1053)

14-16 **ElectrIMACS—Conference on Electrical Machines, Converters and Systems**, Lisbon, Portugal. (Apr. 1998, p. 535)

October 1999

2-3 **AMS Eastern Sectional Meeting**, Providence College, Rhode Island. (Sept. 1997, p. 1031)
Information: W. Drady, e-mail: wsd@ams.org.

8-10 **AMS Central Sectional Meeting**, University of Texas, Austin. (Sept. 1997, p. 1031)
Information: W. Drady, e-mail: wsd@ams.org.

15-17 **AMS Southeastern Section Meeting**, University of North Carolina, Charlotte, North Carolina. (Nov. 1998, p. 1378)

The following new announcements will not be repeated until the criteria in the next to the last paragraph at the bottom of the first page of this section are met.

September 2001

*1-May 31 **Institut Mittag-Leffler Call for Proposals**, Djursholm, Sweden.
Aim: The Institute runs programs in specialized areas of mathematics to which leading scientist in the area are invited. In a concurrent junior visiting program, post-docs and advanced graduate students are invited to participate. The programs can run for the whole year, or be of semester length.
Criteria: The selection criteria for proposals are scientific strength and timeliness, and the degree to which the program would benefit mathematical research in Scandinavia including Finland and Iceland. Proposals should contain: a description of the intended area of specialization; the names of the proposed committee; a list of suggested invitees, most of whom should have indicated an interest in the program and a willingness to participate; a description of the Scandinavian connection.
Steering Committee: The scientific programs are led by a steering committee of 2-4 persons which will work closely with the director and which will suggest invitees to the board. It is expected that at least one member of the committee be present at all times during the period of the program.
Information: Proposals should be addressed to The Board, Institut Mittag-Leffler and sent to: Institut Mittag-Leffler, Auravägen 17, S-182 62 Djursholm, Sweden. The deadline for applications is February 28, 1999. For further information, consult the Institute's home page: http://www.ml.kva.se, or contact the director, K.-O. Widman, e-mail: widman@ml.kva.se.

New Publications Offered by the AMS

Algebra and Algebraic Geometry

Back in Print from the AMS

Classical Galois Theory with Examples

Lisl Gaal

This book is strongly recommended to beginning graduate students who already have some background in abstract algebra ... The large number of partially or fully solved examples is its special feature.

—***Mathematical Reviews***

Contents: Prerequisites: 1.1 Group theory; 1.2 Permutations and permutation groups; 1.3 Fields; 1.4 Rings and polynomials; 1.5 Some elementary theory of equations; 1.6 Vector spaces; Fields: 2.1 Degree of an algebraic extension; 2.2 Isomorphisms of fields; 2.3 Automorphisms of fields; 2.4 Fixed fields; Fundamental theorem: 3.1 Splitting fields; 3.2 Normal extensions and groups of automorphisms; 3.3 Conjugate fields and elements; 3.4 Fundamental theorem; Applications: 4.1 Solvability of equations; 4.2 Solvable equations have solvable groups; 4.3 General equation of degree n; 4.4 Roots of unity and cyclic equations; 4.5 How to solve a solvable equation; 4.6 Ruler-and-compass constructions; 4.7 Lagrange's theorem; 4.8 Resolvent of a polynomial; 4.9 Calculation of the Galois group; 4.10 Matrix solutions of equations; 4.11 Finite fields; 4.12 More applications; Bibliography; Index.

AMS Chelsea Publishing

September 1998, 248 pages, Hardcover, ISBN 0-8218-1375-7, LC 73-649, 1991 *Mathematics Subject Classification*: 12-01, 12A55; 12F10, **All AMS members $18**, List $20, Order code CHEL/268.HN

Back in Print from the AMS

The Theory of Matrices

F. R. Gantmacher

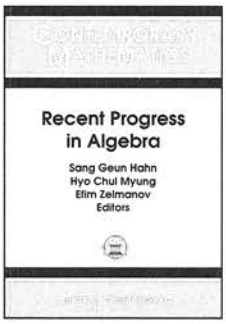
This treatise, by one of Russia's leading mathematicians, gives in easily accessible form, a coherent account of matrix theory with a view to applications in mathematics, theoretical physics, statistics, electrical engineering, etc. The individual chapters have been kept as far as possible independent of each other, so that the reader acquainted with the contents of Chapter 1 can proceed immediately to the chapters of special interest. Much of the material has been available until now only in the periodical literature.

Contents: *Volume 1:* I. Matrices and operations on matrices: 1. Matrices. Basic notation; 2. Addition and multiplication of rectangular matrices; 3. Square matrices; 4. Compound matrices. Minors of the inverse matrix; II. The algorithm of Gauss and some of its applications: 1. Gauss's elimination method; 2. Mechanical interpretation of Gauss's algorithm; 3. Sylvester's determinant identity; 4. The decomposition of a square matrix into triangular factors; 5. The partition of a matrix into blocks. The technique of operating with partitioned matrices. The generalized algorithm of Gauss; III. Linear operators in an n-dimensional vector space: 1. Vector spaces; 2. A linear operator mapping an n-dimensional space into an m-dimensional space; 3. Addition and multiplication of linear operators; 4. Transformation of coordinates; 5. Equivalent matrices. The rank of an operator. Sylvester's inequality; 6. Linear operators mapping an n-dimensional space into itself; 7. Characteristic values and characteristic vectors of a linear operator; 8. Linear operators of simple structure; IV. The characteristic polynomial and the minimal polynomial of a matrix: 1. Addition and multiplication of matrix polynomials; 2. Right and left division of matrix polynomials; 3. The generalized Bézout theorem; 4. The characteristic polynomial of a matrix. The adjoint matrix; 5. The method of Faddeev for the simultaneous computation of the coefficients of the characteristic polynomial and of the adjoint matrix; 6. The minimal polynomial of a matrix; V. Functions of matrices: 1. Definition of a function of a matrix; 2. The Lagrange-Sylvester interpolation polynomial; 3. Other forms of the definition of $f(A)$. The components of the matrix A; 4. Representation of functions of matrices by means of series; 5. Application of a function of a matrix to the integration of a system of linear differential equations with constant coefficients; 6. Stability of motion in the case of a linear system; VI. Equivalent transformations of polynomial matrices. Analytic theory of elementary divisors: 1. Elementary transformations of a polynomial matrix; 2. Canonical form of a λ-matrix; 3. Invariant polynomials and elementary divisors of a polynomial matrix; 4. Equivalence of linear binomials; 5. A criterion for similarity of matrices; 6. The normal forms of a matrix; 7. The elementary divisors of the matrix $f(A)$; 8. A general method of constructing the transforming matrix; 9. Another method of constructing a transforming matrix; VII. The structure of a linear operator in an n-dimensional space: 1. The minimal polynomial of a vector and a space (with respect to a given linear operator); 2. Decomposition into invariant subspaces with co-prime minimal polynomials; 3. Congruence. Factor space; 4. Decomposition of a space into cyclic invariant subspaces; 5. The normal form of a matrix; 6. Invariant polynomials. Elementary divisors; 7. The Jordan normal form of a matrix; 8. Krylov's method of trans-

forming the secular equation; VIII. Matrix equations: 1. The equation $AX = XB$; 2. The special case $A = B$. Commuting matrices; 3. The equation $AX - XB = C$; 4. The scalar equation $f(X) = 0$; 5. Matrix polynomial equations; 6. The extraction of m-th roots of a non-singular matrix; 7. The extraction of m-th roots of a singular matrix; 8. The logarithm of a matrix; IX. Linear operators in a unitary space: 1. General considerations; 2. Metrization of a space; 3. Gram's criterion for linear dependence of vectors; 4. Orthogonal projection; 5. The geometrical meaning of the Gramian and some inequalities; 6. Orthogonalization of a sequence of vectors; 7. Orthonormal bases; 8. The adjoint operator; 9. Normal operators in a unitary space; 10. The spectra of normal, hermitian, and unitary operators; 11. Positive-semidefinite and positive-definite hermitian operators; 12. Polar decomposition of a linear operator in a unitary space. Cayley's formulas; 13. Linear operators in a euclidean space; 14. Polar decomposition of an operator and the Cayley formulas in a euclidean space; 15. Commuting normal operators; X. Quadratic and hermitian forms: 1. Transformation of the variables in a quadratic form; 2. Reduction of a quadratic form to a sum of squares. The law of inertia; 3. The methods of Lagrange and Jacobi of reducing a quadratic form to a sum of squares; 4. Positive quadratic forms; 5. Reduction of a quadratic form to principal axes; 6. Pencils of quadratic forms; 7. Extremal properties of the characteristic values of a regular pencil of forms; 8. Small oscillations of a system with n degrees of freedom; 9. Hermitian forms; 10. Hankel forms; Bibliography; Index; *Volume 2:* XI. Complex symmetric, skew-symmetric, and orthogonal matrices: 1. Some formulas for complex orthogonal and unitary matrices; 2. Polar decomposition of a complex matrix; 3. The normal form of a complex symmetric matrix; 4. The normal form of a complex skew-symmetric matrix; 5. The normal form of a complex orthogonal matrix; XII. Singular pencils of matrices: 1. Introduction; 2. Regular pencils of matrices; 3. Singular pencils. The reduction theorem; 4. The canonical form of a singular pencil of matrices; 5. The minimal indices of a pencil. Criterion for strong equivalence of pencils; 6. Singular pencils of quadratic forms; 7. Application to differential equations; XIII. Matrices with non-negative elements: 1. General properties; 2. Spectral properties of irreducible non-negative matrices; 3. Reducible matrices; 4. The normal form of a reducible matrix; 5. Primitive and imprimitive matrices; 6. Stochastic matrices; 7. Limiting probabilities for a homogeneous Markov chain with a finite number of states; 8. Totally non-negative matrices; 9. Oscillatory matrices; XIV. Applications of the theory of matrices to the investigation of systems of linear differential equations: 1. Systems of linear differential equations with variable coefficients. General concepts; 2. Lyapunov transformations; 3. Reducible systems; 4. The canonical form of a reducible system. Erugin's theorem; 5. The matricant; 6. The multiplicative integral. The infinitesimal calculus of Volterra; 7. Differential systems in a complex domain. General properties; 8. The multiplicative integral in a complex domain; 9. Isolated singular points; 10. Regular singularities; 11. Reducible analytic systems; 12. Analytic functions of several matrices and their application to the investigation of differential systems. The papers of Lappo-Danilevskiĭ; XV. The problem of Routh-Hurwitz and related questions: 1. Introduction; 2. Cauchy indices; 3. Routh's algorithm; 4. The singular case. Examples; 5. Lyapunov's theorem; 6. The theorem of Routh-Hurwitz; 7. Orlando's formula; 8. Singular cases in the Routh-Hurwitz theorem; 9. The method of quadratic forms. Determination of the number of distinct real roots of a polynomial; 10. Infinite Hankel matrices of finite rank; 11. Determination of the index of an arbitrary rational fraction by the coefficients of numerator and denominator; 12. Another proof of the Routh-Hurwitz theorem; 13. Some supplements to the Routh-Hurwitz theorem. Stability criterion of Liénard and Chipart; 14. Some properties of Hurwitz polynomials. Stieltjes' theorem. Representation of Hurwitz polynomials by continued fractions; 15. Domain of stability. Markov parameters; 16. Connection with the problem of moments; 17. Theorems of Markov and Chebyshev; 18. The generalized Routh-Hurwitz problem; Bibliography; Index.

AMS Chelsea Publishing

Volume 1: September 1998, 384 pages, Hardcover, ISBN 0-8218-1376-5, 1991 *Mathematics Subject Classification*: 15-02, **All AMS members $35**, List $39, Order code CHEL/131.HN
Volume 2: September 1998, 276 pages, Hardcover, ISBN 0-8284-0133-0, 1991 *Mathematics Subject Classification*: 15-02, **All AMS members $23**, List $25, Order code CHEL/133N
Set: September 1998, 660 pages, Hardcover, ISBN 0-8218-1393-5, 1991 *Mathematics Subject Classification*: 15-02, **All AMS members $53**, List $59, Order code CHELGANTSETN



Recent Progress in Algebra

Sang Geun Hahn, *Korea Advanced Institute of Science & Technology, Taejon*, **Hyo Chul Myung**, *Korea Institute for Advanced Study, Seoul*, and **Efim Zelmanov**, *Yale University, New Haven, CT*, Editors

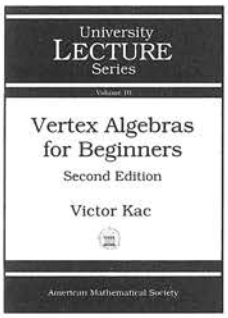
This volume presents the proceedings of the international conference on "Recent Progress in Algebra" that was held at the Korea Advanced Institute of Science and Technology (KAIST) and Korea Institute for Advanced Study (KIAS). It brought together experts in the field to discuss progress in algebra, combinatorics, algebraic geometry and number theory. This book contains selected papers contributed by conference participants. The papers cover a wide range of topics and reflect the current state of research in modern algebra.

Contents: G. W. Anderson, A double complex for computing the sign-cohomology of the universal ordinary distribution; **G. Benkart**, Down-up algebras and Witten's deformations of the universal enveloping algebra of $\mathfrak{sl}_2$; **T. Chinburg, B. Erez, G. Pappas**, and **M. Taylor**, Localizations of Grothendieck groups and Galois structure; **I. V. Dolgachev**, Invariant stable bundles over modular curves **X(p)**; **A. Elduque**, Okubo algebras and twisted polynomials; **E.-U. Gekeler**, Some new results on modular forms for $\mathbf{GL}(2, \mathbb{F}_q[T])$; **H. C. Jung**, Counting jump optimal linear extensions of some posets; **M. Kosuda**, The irreducible representations of categories; **A. R. Magid**, Prounipotent prolongation of algebraic groups; **C. Martinez**, Graded simple Jordan algebras and superalgebras; **D. Moon**, The centralizer algebra of the Lie superalgebra $\mathfrak{p}(n)$ and the decomposition of $V^{\otimes k}$ as a $\mathfrak{p}(n)$-module; **I. Yu. Potemine**, Drinfeld-Anderson motives and multicomponent **KP** hierarchy; **Yu. G. Zarhin** and **B. J. J. Moonen**, Weil classes and Rosati involutions on complex abelian varieties; **E. Zelmanov**, On some open problems related to the restricted Burnside problem.

Contemporary Mathematics, Volume 224

November 1998, 243 pages, Softcover, ISBN 0-8218-0972-5, LC 98-35282, 1991 *Mathematics Subject Classification*: 00B20, 05D05, 05E15, 05E25, 11G09, 11F11, 11F75, 11R18, 11R33, 17B10, 17B37, 17B65, 17B70, 17D05, 19A31, 20C15, 20C20, 20E18, 20F05, 20F50, **Individual member $33**, List $55, Institutional member $44, Order code CONM/224N

Recommended Text



Vertex Algebras for Beginners

Second Edition

Victor Kac, *Massachusetts Institute of Technology, Cambridge*

Very good introductional book on vertex algebras.
—Zentralblatt für Mathematik

Essential reading for anyone trying to learn about vertex algebras ... well worth buying for experts.
—Bulletin of the London Mathematical Society

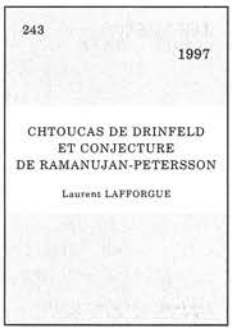
This is an improved and expanded edition of Kac's original introduction to algebraic aspects of conformal field theory, which was published by the AMS in 1996. This revised edition is based on courses given by the author at MIT and at Rome University in spring 1997. New material is added, including the foundations of a rapidly growing area of algebraic conformal theory. Also, in some places, the exposition is significantly simplified.

This text will also be of interest to those working in mathematical physics.

Contents: Preface; Preface to the second edition; Wightman axioms and vertex algebras; Calculus of formal distributions; Local fields; Structure theory of vertex algebras; Examples of vertex algebras and their applications; Bibliography; Index.

University Lecture Series, Volume 10

November 1998, 201 pages, Softcover, ISBN 0-8218-1396-X, LC 98-41276, 1991 *Mathematics Subject Classification*: 17B69; 17B65, 81T05, 81T40, **All AMS members $23**, List $29, Order code ULECT/10.RN



Chtoucas de Drinfeld et Conjecture de Ramanujan-Petersson

Laurent Lafforgue, *Université de Paris Sud, Orsay, France*

A publication of Société Mathématique de France.

This book discusses the Ramanujan-Petersson conjecture over function fields. This conjecture is proved for automorphic cuspidal representations of GL_r when r is odd, and a partial result is given when r is even.

The proof consists of studying the stacks classifying Drinfeld's shtukas. In particular, it combines the Grothendieck-Lefschetz fixed point theorem, the Deligne purity theorem and a version of the Arthur-Selberg trace formula over function fields.

This text will also be of interest to those working in number theory.

Distributed by the AMS in the United States, Canada, and Mexico. Orders from other countries should be sent to the SMF, Maison de la SMF, B.P. 67, 13274 Marseille cedex 09, France, or to Institut Henri Poincaré, 11 rue Pierre et Marie Curie, 75231 Paris cedex 05, France. Members of the SMF receive a 30% discount from list.

Contents: Introduction; $\mathcal{D}$-chtoucas: généralités; Chtoucas réductibles. Filtrations de Harder-Narasimhan; Description adélique des chtoucas. Nombres de Lefschetz; Le cas des $\mathcal{D}$-chtoucas de rang $r = 1$; Calcul des nombres de Lefschetz en rang $r \geq 2$; Formule des traces d'Arthur-Selberg et conjecture de Ramanujan-Petersson; Bibliographie.

Astérisque, Number 243

November 1997, 329 pages, Softcover, 1991 *Mathematics Subject Classification*: 11G, 14G5, 11G09, 11F70, 11F60, 14F20, 11F72, **Individual member $81**, List $90, Order code AST/243N

Fonctions Symétriques, Polynômes de Schubert et Lieux de Dégénérescence

Laurent Manivel, *Université de Grenoble I, Institut Fourier, Saint Martin d'Hères Cedex, France*

A publication of Société Mathématique de France.

This course begins with two chapters of combinatorial nature. The first is devoted to symmetric functions and to the properties of Schur polynomials, studied using Young tableaux and the Knuth insertion algorithm. It is shown that these polynomials can be identified with the characters of the irreducible representations of the symmetric group.

The second chapter is a study of Schubert polynomials, as defined by A. Lascoux and M.-P. Schützenberger in terms of divided differences. These polynomials are associated with permutations. Their combinatorics is related to the Bruhat order on symmetric groups and to certain Hecke algebras of these groups.

The third and final chapter is of geometrical nature. Its main theme is the study of Schubert varieties inside Grassmannians and flag manifolds. The fact that the homology classes of these varieties can be represented by Schur or Schubert polynomials allows geometrical translation of most of the results of the first two chapters. And since these Schubert varieties are universal models for certain degeneracy loci of morphisms between vector bundles, expressions are deduced for the homology classes of these loci in terms of characteristic classes of the bundles involved. Text is in French.

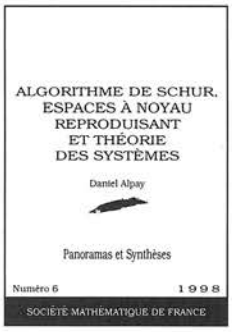
Distributed by the AMS in the United States, Canada, and Mexico. Orders from other countries should be sent to the SMF, Maison de la SMF, B.P. 67, 13274 Marseille cedex 09, France, or to Institut Henri Poincaré, 11 rue Pierre et Marie Curie, 75231 Paris cedex 05, France. Members of the SMF receive a 30% discount from list.

Contents: Introduction; L'anneau des fonctions symétriques; Les polynômes de Schubert; Les variétés de Schubert; Une brève introduction à l'homologie singulière; Bibliographie; Index.

Cours Spécialisés—Collection SMF, Number 3

July 1998, 179 pages, Softcover, ISBN 2-85629-066-3, 1991 *Mathematics Subject Classification*: 05E05, 05E10, 14M15, 14N10, 20C30, 57T15, **Individual member $40**, List $44, Order code COSP/3N

Analysis



Algorithme de Schur, Espaces à Noyau Reproduisant et Théorie des Systèmes

Daniel Alpay, *Ben Gurion University, Beer-Sheva, Israel*

A publication of Société Mathématique de France.

The same positive functions (in the sense of reproducing kernel spaces) naturally appear in two different domains, namely the modeling of time-invariant dissipative linear systems and the theory of linear operators. The author uses the associated reproducing kernel Hilbert spaces to study the relationships between these domains. The inverse scattering problem plays a key role in the exposition. The reproducing kernel approach allows for more natural solutions to general cases, such as nonstationary systems, the case of non-positive metrics and the case of pairs of commuting nonself-adjoint operators. Text is in French.

Distributed by the AMS in the United States, Canada, and Mexico. Orders from other countries should be sent to the SMF, Maison de la SMF, B.P. 67, 13274 Marseille cedex 09, France, or to Institut Henri Poincaré, 11 rue Pierre et Marie Curie, 75231 Paris cedex 05, France. Members of the SMF receive a 30% discount from list.

Contents: Introduction; Espaces à noyau reproduisant; Théorie des systèmes linéaires; Algorithme de Schur et problème de diffusion inverse; Modèles d'opérateurs; Interpolation; Le cas indéfini; Le cas non stationnaire; Surfaces de Riemann; Épilogue; Bibliographie; Index.

Panoramas et Synthèses, Number 6

July 1998, 189 pages, Softcover, ISBN 2-85629-067-1, 1991 *Mathematics Subject Classification*: 46E22, 93-02, **Individual member $40**, List $44, Order code PASY/6N

Études Spectrales d'Opérateurs de Transfert et Applications

A. Broise, *Université de Paris-Sud, Orsay, France*, and **F. Dal'bo** and **M. Peigné**, *Université de Rennes I, France*

A publication of Société Mathématique de France.

Ce livre présente deux travails, le premier de Broise, et le deuxième de Dal'bo et Peigné.

La première partie, intitulée "Transformations dilatantes de l'intervalle et théorèmes limites," présente un travail de synthèse sur les transformations dilatantes de l'intervalle ayant une partition finie ou dénombrable. L'auteur montre l'existence de mesures invariantes absolument continues par rapport à la mesure de Lebesgue pour une classe de transformations dilatantes plus large que celle étudiée habituellement.

Ensuite, Broise montre des théorèmes limites central et local et donne la vitesse de convergences et des conditions d'annulation de la variance basées sur les points périodiques de la transformation. On précise les théorèmes limites obtenus par des théorèmes de grands écarts. Enfin l'auteur montre comment s'appliquent ces théorèmes sur divers exemples de transformations.

La deuxième partie est intitulée "Comportement asymptotique du nombre de géodésiques fermées sur la surface modulaire en courbure non constante." Soit $\bar{g}_\epsilon$ une perturbation de la métrique hyperbolique sur $M = \mathbb{H}^2/PSL_2(\mathbb{Z})$, les auteurs démontrent que le nombre de géodésiques fermées sur $(M, \bar{g}_\epsilon)$ de longueur au plus a est équivalent quand a tend vers $+\infty$ à $e^{a\delta_\epsilon}/a\delta_\epsilon$ (où δ_ϵ est l'exposant critique de la série de Poincaré associée à $PSL_2(\mathbb{Z})$). La démonstration de ce résultat repose sur un codage des géodésiques fermées de $(M, \bar{g}_\epsilon)$ relié au développement en fractions continues de réels et sur l'utilisation d'un théorème du renouvellement harmonique nécessitant une étude spectrale précise de l'opérateur de transfert mis en jeu. Les auteurs retrouvent également par cette méthode probabiliste la distribution asymptotique des constantes de Lévy des nombres quadratiques.

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Contents: A. Broise, Transformations dilantantes de l'intervalle et théorèmes limites; **F. Dal'bo** and **M. Peigné**, Comportement asymptotique du nombre de géodésiques fermées sur la surface modulaire en courbure non constante.

Astérisque, Number 238

August 1998, 177 pages, Softcover, 1991 *Mathematics Subject Classification*: 60F05, 53C22; 28D05, 58F11, 60J05, 58E10, **Individual member $50**, List $55, Order code AST/238N

Back in Print from the AMS

Introduction to Approximation Theory

Second Edition

E. W. Cheney

In this book, which is intended to be an introduction to the subject, the author steers a middle course between the various viewpoints. On the one hand, he presents his material within the framework of (elementary) functional analysis ... and on the other hand he treats various algorithms which prepare the way for the numerical solution of various types of approximation problems. One of the highlights of the book is Chapter V on rational approximation which is an important case of non-linear approximation ... The book concludes with a detailed and interesting section on historical notes and a lengthy bibliography. There are approximately 430 good exercises. The author has provided a usable and very versatile text which is certainly to be recommended.

—Mathematical Reviews

E. W. Cheney's highly respected and well-known book ... covers an enormous amount of material ... [It] is written with a clarity and precision which those who are familiar with the author's many papers have come to expect. ... There is an appendix

which supplements each chapter with copious notes and serves to place the particular topic in historical perspective. ... [T]he notes are invaluable; their effect is to make a small book almost encyclopedic in character. ... In the quality of its exposition and the skill and craft manifest in its organization, the book is a classic with few competitors. Anyone involved with computer mathematics will want it nearby.

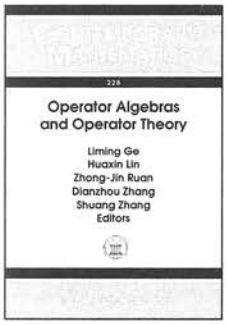
—Computing Reviews

This text will also be of interest to those working in applications.

Contents: *Introduction:* 1 Examples and prospectus; 2 Metric spaces; 3 Normed linear spaces; 4 Inner-product spaces; 5 Convexity; 6 Existence and unicity of best approximations; 7 Convex functions; *The Tchebycheff Solution of Inconsistent Linear Equations:* 1 Introduction; 2 Systems of equations with one unknown; 3 Characterization of the solution; 4 The special case; 5 Pólya's algorithm; 6 The ascent algorithm; 7 The descent algorithm; 8 Convex programming; *Tchebycheff Approximation by Polynomials and Other Linear Families:* 1 Introduction; 2 Interpolation; 3 The Weierstrass theorem; 4 General linear families; 5 the unicity problem; 6 Discretization errors: General theory; 7 Discretization: Algebraic polynomials. The inequalities of Markoff and Bernstein; 8 Algorithms; *Least-squares Approximation and Related Topics:* 1 Introduction; 2 Orthogonal systems of polynomials; 3 Convergence of orthogonal expansions; 4 Approximation by series of Tchebycheff polynomials; 5 Discrete least-squares approximation; 6 The Jackson theorems; *Rational Approximation:* 1 Introduction; 2 Existence of best rational approximations; 3 The characterization of best approximations; 4 Unicity; Continuity of best-approximation operators; 5 Algorithms; 6 Padé Approximation and its generalizations; 7 Continued fractions; *Some Additional Topics:* 1 The Stone approximation theorem; 2 The Müntz theorem; 3 The converses of the Jackson theorems; 4 Polygonal approximation and bases in $C[a,b]$; 5 The Kharshiladze-Lozinski theorems; 6 Approximation in the mean; Notes; References; Index.

AMS Chelsea Publishing

September 1998, 259 pages, Hardcover, ISBN 0-8218-1374-9, LC 81-67708, 1991 *Mathematics Subject Classification*: 41-01, **All AMS members $26**, List $29, Order code CHEL/317.HN



Operator Algebras and Operator Theory

Liming Ge, *Massachusetts Institute of Technology, Cambridge*, **Huaxin Lin**, *University of Oregon, Eugene*, **Zhong-Jin Ruan**, *University of Illinois, Urbana*, **Dianzhou Zhang**, *East China Normal University, Shanghai*, and **Shuang Zhang**, *University of Cincinnati, OH*, Editors

This volume contains the proceedings from the International Conference on Operator Algebras and Operator Theory held at the East China Normal University in Shanghai (China). Participants in the conference ranged from graduate students to postdocs to leading experts who came from around the world. Topics covered were C^*-algebras, von Neumann algebras, non-self-adjoint operator algebras, wavelets, operator spaces and other related areas. This work consists of contributions from invited speakers and some mathematicians who were unable to attend. It presents important mathematical ideas while maintaining the uniqueness and excitement of this very successful event.

Contents: E. Berkson and **T. A. Gillespie**, Operator means and spectral decomposability in ergodic theory and Hilbert space operator theory; **X. Chen** and **Q. Xu**, Some remarks on Toeplitz operators on discrete groups; **J. Cuntz**, A general construction of bivariant K-theories on the category of C*-algebras; **M. Dadarlat**, Residually finite dimensional C*-algebras; **E. G. Effros** and **Z.-J. Ruan**, $\mathcal{OL}_p$ spaces; **G. A. Elliott** and **X. Fang**, Simple inductive limits of xsd*-algebras with building blocks from spheres of odd dimension; **G. A. Elliott**, **G. Gong**, and **L. Li**, Approximate divisibility of simple inductive limit C*-algebras; **U. Haagerup** and **E. Størmer**, On maximality of entropy in finite von Neumann algebras; **D. Hadwin**, Free entropy and approximate equivalence in von Neumann algebras; **R. Ji**, Bivariant Chern character and the analog Baum-Connes map; **R. V. Kadison**, Dual cones and Tomita-Takesaki theory; **Y. Kawahigashi**, Subfactors and paragroup theory; **A. Kumjian**, Notes on C*-algebras of graphs; **D. R. Larson**, Frames and wavelets from an operator theoretic point of view; **H. Lin**, A classification theorem for infinite Toeplitz algebras; **C. Pasnicu**, AH algebras with the ideal property; **Q. Lin** and **N. C. Phillips**, Ordered K-theory for C*-algebras of minimal homeomorphisms; **M. A. Rieffel**, Questions on quantization; **M. Rørdam**, On sums of finite projections; **A. J.-L. Sheu**, Groupoid approach to quantum projective spaces; **J. Tomiyama**, Representations of topological dynamical systems and C*-algebras; **S. Zhang**, Purely infinite simple C*-algebras arising from reduced group C*-algebras.

Contemporary Mathematics, Volume 228

December 1998, 399 pages, Softcover, ISBN 0-8218-1093-6, LC 98-41143, 1991 *Mathematics Subject Classification*: 47A05, 47D15, 46L05, 46L10, 46L80, **Individual member $51**, List $85, Institutional member $68, Order code CONM/228N

Back in Print from the AMS

Introduction to Hilbert Space and the Theory of Spectral Multiplicity

Second Edition

Paul R. Halmos

The main purpose of this book is to present the so-called multiplicity theory and the theory of unitary equivalence, for arbitrary spectral measures, in separable or not separable Hilbert space ... The approach to this theory, as presented by the author, has much claim to novelty. By a skillful permutation of the fundamental ideas of Wecken and Nakano, and consistently referring to the simple situation in the finite-dimensional case, the author succeeds in presenting the theory in a clear and perspicuous form.

—Mathematical Reviews

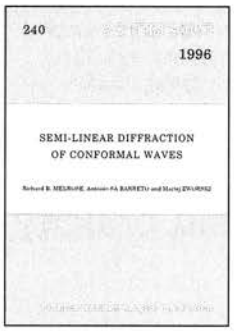
Contents: *The Geometry of Hilbert Space:* 1. Linear functionals; 2. Bilinear functionals; 3. Quadratic forms; 4. Inner product and norm; 5. The inequalities of Bessel and Schwarz; 6. Hilbert space; 7. Infinite sums; 8. Conditions for summability; 9. Examples of Hilbert space; 10. Subspaces; 11. Vectors in and out of subspaces; 12. Orthogonal complements; 13. Vector sums; 14. Bases; 15. A non-closed vector sum; 16. Dimension; 17. Boundedness; 18. Bounded bilinear functionals; *The Algebra of Operators:* 19. Operators; 20. Examples of operators; 21. Inverses; 22. Adjoints;

23. Invariance; 24. Hermitian operators; 25. Normal and unitary operators; 26. Projections; 27. Projections and subspaces; 28. Sums of projections; 29. Products and differences of projections; 30. Infima and suprema of projections; 31. The spectrum of an operator; 32. Compactness of spectra; 33. Transforms of spectra; 34. The spectrum of a Hermitian operator; 35. Spectral Heuristics; 36. Spectral measures; 37. Spectral integrals; 38. Regular spectral measures; 39. Real and complex spectral measures; 40. Complex spectral integrals; 41. Description of the spectral subspaces; 42. Characterization of the spectral subspaces; 43. The spectral theorem for Hermitian operators; 44. The spectral theorem for normal operators; *The Analysis of Spectral Measures:* 45. The Problem of unitary equivalence; 46. Multiplicity functions in finite-dimensional spaces; 47. Measures; 48. Boolean operations on measures; 49. Multiplicity functions; 50. The canonical example of a spectral measure; 51. Finite-dimensional spectral measures; 52. simple finite-dimensional spectral measures; 53. The commutator of a set of projections; 54. Pairs of commutators; 55. Columns; 56. Rows; 57. Cycles; 58. Separable projections; 59. Characterizations of rows; 60. Cycles and rows; 61. The existence of rows; 62. Orthogonal systems; 63. The power of a maximal orthogonal system; 64. Multiplicities; 65. Measures from vectors; 66. Supspaces from measures; 67. The multiplicity function of a spectral measure; 69. Conclusion; References; Bibliography.

AMS Chelsea Publishing

September 1998, 114 pages, Hardcover, ISBN 0-8218-1378-1, LC 57-12834, 1991 *Mathematics Subject Classification*: 46-01, 46CXX, **All AMS members $17**, List $19, Order code CHEL/82.HN

Semi-Linear Diffraction of Conormal Waves



Richard B. Melrose, *Massachusetts Institute of Technology, Cambridge*, **Antonio Sá Barreto**, *Purdue University, West Lafayette, IN*, and **Maciej Zworski**, *University of Toronto, ON, Canada*

A publication of Société Mathématique de France.

In this volume, the authors study the conormal regularity of bounded solutions to semi-linear hyperbolic equations on domains with diffractive boundaries: $Pu = f(x,u)$ in $X_1 u \restriction_{\partial X} = 0$, $u \in \infty L^{\infty}_{lo} c(X)$.

When $X_- \subset X$ and X is the domain of influence of X_- the authors consider solutions such that $\operatorname{singsupp}(u) \cap X_- \cap \partial X = \varnothing$ and further suppose that $u \restriction_{X_-}$ is conormal with respect to a smooth characteristic hypersurface, the incoming front.

For the linear equation, $f \equiv 0$, the singular support of u is contained in the union of the incoming front and the reflected front obtained using the rules of geometrical optics; these two characteristic surfaces are tangent at the glancing set, the locus of points at which the incoming bicharacteristics are tangent to the boundary. The authors prove that in the semi-linear case the only new singularities which may occur appear on the characteristic half-cone over the glancing set. The actual conormal regularity result presented in the paper is considerably more precise.

The authors' conclusions are best illustrated by taking for P the constant coefficient wave equation with X the product of $\mathbb{R}_t$ and the exterior of a strictly convex obstacle. Then $X_- = X \cap \{t > -T\}$ and for the initial data one can take locally an anti-derivative of the plane wave $\delta(t - \langle x, \omega \rangle)$ with T appropriately large.

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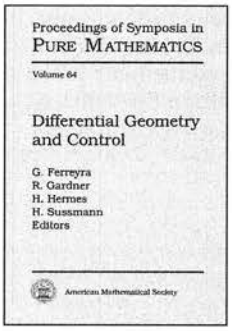
Contents: Introduction and statement of results; Diffractive geometry; Resolution of singularities and the conormal spaces; Microlocally characterized spaces of distributions; Refined estimates in the past; The extension property; Estimates for the Dirichlet problem; Proof of the main theorem; Glancing hypersurfaces and b-geometry; b-Sobolev spaces; Bibliography.

Astérisque, Number 240

August 1998, 132 pages, Softcover, 1991 *Mathematics Subject Classification*: 35Lxx; 58G17, **Individual member $39**, List $43, Order code AST/240N

Applications

Differential Geometry and Control



G. Ferreyra, *Louisiana State University, Baton Rouge*, **R. Gardner**, *University of North Carolina, Chapel Hill*, **H. Hermes**, *University of Colorado, Boulder*, and **H. Sussmann**, *Rutgers University, New Brunswick, NJ*, Editors

This volume presents selections from talks given at the AMS Summer Research Institute on Differential Geometry and Control held at the University of Colorado (Boulder). Included articles were refereed according to the highest standards. This collection provides a coherent global perspective on recent developments and important open problems in geometric control theory. Readers will find in this book an excellent source of current challenging research problems and results.

This text will also be of interest to those working in geometry and topology.

Contents: **G. R. Wilkens**, Remembering the mathematics of Robert Brown Gardner; **A. Agrachev**, **G. Stefani**, and **P. Zezza**, A Hamiltonian approach to strong minima in optimal control; **H. Airault**, The Heisenberg group H_3 in terms of the orthonormal frame bundle $O(R^2)$ and the control of variation of the Heisenberg diffusion; **V. Ayala** and **J. Tirao**, Linear control systems on Lie groups and controllability; **Z. Bartosiewicz**, Real analytic geometry and local observability; **E. Paw łuszewicz** and **Z. Bartosiewicz**, External dynamic feedback equivalence of observable discrete-time control systems; **R. M. Bianchini**, Good needle-like variations; **A. M. Bloch** and **P. E. Crouch**, Representations of Dirac structures on vector spaces and nonlinear L-C circuits; **B. Bonnard**, **M. Chyba**, and **I. Kupka**, Non integrable geodesics in SR-Martinet geometry; **V. F. Borisov**, Singular

extremals of order 3 and chattering; **J.-M. Coron**, Some open problems in control theory; **A. V. Dmitruk**, Quadratic order conditions of a local minimum for singular extremals in a general optimal control problem; **T. E. Duncan**, Some solvable infinite time horizon stochastic control problems in hyperbolic three space; **J. D. Lawson**, Geometric control and Lie semigroup theory; **U. Ledzewicz** and **H. Schättler**, Analysis of abnormal extremals in optimal control; **A. Marigo** and **A. Bicchi**, Rolling bodies with regular surface: The holonomic case; **V. Ramakrishna**, On degenerate Monge-Ampere equations; **F. Rampazzo**, Lie brackets and impulsive controls: An unavoidable connection; **Y. L. Sachkov**, Survey on controllability of invariant systems on solvable Lie groups; **G. R. Wilkens**, Centro-affine geometry in the plane and feedback invariants of two-state scalar control systems; **J. Yang**, On hypersurfaces satisfying a basic equality.

Proceedings of Symposia in Pure Mathematics, Volume 64

December 1998, 341 pages, Hardcover, ISBN 0-8218-0887-7, LC 98-38711, 1991 *Mathematics Subject Classification*: 49-XX, 53-XX, 93-XX; 22-XX, 60-XX, 35-XX, **Individual member $47**, List $79, Institutional member $63, Order code PSPUM/64N

Differential Equations

Back in Print from the AMS

Partial Differential Equations

P. R. Garabedian

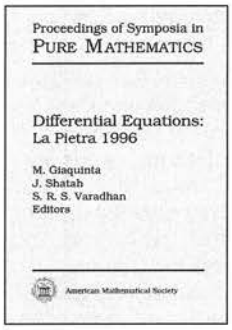
This book is a gem. It fills the gap between the standard introductory material on PDEs that an undergraduate is likely to encounter after a good ODE course (separation of variables, the basics of the second-order equations from mathematical physics) and the advanced methods (such as Sobolev spaces and fixed point theorems) that one finds in modern books. Although this is not designed as a textbook for applied mathematics, the approach is strongly informed by applications. For instance, there are many existence and uniqueness results, but they are usually approached via very concrete techniques.

The text contains the standard topics that one expects in an intermediate PDE course: the Dirichlet and Neumann problems, Cauchy's problem, characteristics, the fundamental solution, PDEs in the complex domain, plus a chapter on finite differences, on nonlinear fluid mechanics, and another on integral equations. It is an excellent text for advanced undergraduates or beginning graduate students in mathematics or neighboring fields, such as engineering and physics, where PDEs play a central role.

Contents: The method of power series; Equations of the first order; Classification of partial differential equations; Cauchy's problem for equations with two independent variables; Eigenvalue problems; Tricomi's problem; formulation of well posed problems; Finite differences; Fluid dynamics; Free boundary problems; Partial differential equations in the complex domain; The fundamental solution; Cauchy's problem in space of higher dimension; The Dirichlet and Neumann problems; Dirichlet's principle; Existence theorems of potential theory; Integral equations; Bibliography; Index.

AMS Chelsea Publishing

September 1998, 672 pages, Hardcover, ISBN 0-8218-1377-3, LC 85-73601, 1991 *Mathematics Subject Classification*: 35-01, **All AMS members $41**, List $45, Order code CHEL/325.HN



Differential Equations: La Pietra 1996

M. Giaquinta, *University of Pisa, Italy*, and **J. Shatah** and **S. R. S. Varadhan**, *New York University, Courant Institute, NY*, Editors

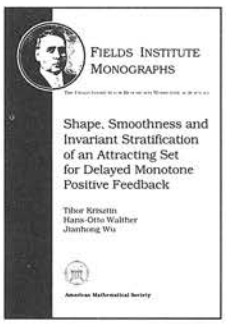
This volume contains the proceedings of a conference held in celebration of the seventieth birthdays of Peter Lax and Louis Nirenberg at Villa La Pietra in Florence (Italy). Speakers from around the world gave talks on subjects related to the mathematical areas in which Lax and Nirenberg worked: analysis, partial differential equations, applied mathematics and scientific computing. The two men played seminal roles in these areas and had significant influence on the development of many other mathematicians. This volume gives testament to the major role played by Lax and Nirenberg in the development of mathematical analysis.

This text will also be of interest to those working in analysis and geometry and topology.

Contents: H. Brezis, Symmetry in nonlinear PDE's; **L. Caffarelli** and **J. L. Vazquez**, Viscosity solutions for the porous medium equation; **D. Christodoulou**, Symplectic geometry and partial differential equations; **A. Grigor'yan** and **S.-T. Yau**, Decomposition of a metric space by capacitors; **H. Hofer** and **M. Kriener**, Holomorphic curves in contact dynamics; **H. R. Jauslin**, **H. O. Kreiss**, and **J. Moser**, On the forced Burgers equation with periodic boundary conditions; **H. P. McKean**, A novel aspect of action-angle variables; **R. Melrose**, Scattering theory for strictly pseudoconvex domains; **P. Sarnak**, A sample of Lax's contributions to classical analysis, linear partial differential equations and scattering theory; **R. Schoen** and **J. Wolfson**, Minimizing volume among Lagrangian submanifolds; **F. Treves**, Symplectic geometry and analytic hypo-ellipticity.

Proceedings of Symposia in Pure Mathematics, Volume 65

December 1998, 219 pages, Hardcover, ISBN 0-8218-0610-6, LC 98-37249, 1991 *Mathematics Subject Classification*: 35-XX, 58-XX, 49Qxx, 28A12, 58Fxx, **Individual member $23**, List $39, Institutional member $31, Order code PSPUM/65N



Shape, Smoothness and Invariant Stratification of an Attracting Set for Delayed Monotone Positive Feedback

Tibor Krisztin, *University of Szeged, Bolyai Institute, Hungary*, **Hans-Otto Walther**, *Universität Giessen, Germany*, and **Jianhong Wu**, *York University, North York, ON, Canada*

This book contains recent results about the global dynamics defined by a class of delay differential equations which model basic feedback mechanisms and arise in a variety of applications such as neural networks. The authors describe in detail

the geometric structure of a fundamental invariant set, which in special cases is the global attractor, and the asymptotic behavior of solution curves on it.

The approach makes use of advanced tools which in recent years have been developed for the investigation of infinite-dimensional dynamical systems: local invariant manifolds and inclination lemmas for noninvertible maps, Floquet theory for delay differential equations, a priori estimates controlling the growth and decay of solutions with prescribed oscillation frequency, a discrete Lyapunov functional counting zeros, methods to represent invariant sets as graphs, and Poincaré-Bendixson techniques for classes of delay differential systems.

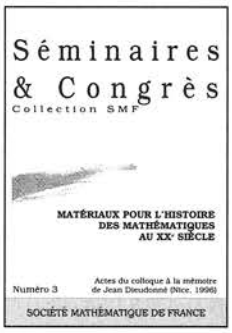
Several appendices provide the general results needed in the case study, so the presentation is self-contained. Some of the general results are not available elsewhere, specifically on smooth infinite-dimensional center-stable manifolds for maps. Results in the appendices will be useful for future studies of more complicated attractors of delay and partial differential equations.

Contents: Introduction; The delay differential equation and the hypotheses; The separatrix; The leading unstable set of the origin; Oscillation frequencies; Graph representations; Dynamics on $\overline{W}$ and disk representation of $\overline{W} \cap S$; Minimal linear instability of the periodic orbit $\mathcal{O}$; Smoothness of $W \cap S$ in case $\mathcal{O}$ is hyperbolic; Smoothenss of $W \cap S$ in case $\mathcal{O}$ is not hyperbolic; The unstable set of $\mathcal{O}$ contains the nonstationary points of $\mathrm{bd}\, W$; $\mathrm{bd}\, W$ contains the unstable set of the periodic orbit $\mathcal{O}$; $H \cap \overline{W}$ is smooth near p_0; Smoothness of $\overline{W}$, $\mathrm{bd}\, W$ and $\overline{W} \cap S$; Homeomorphisms from $\mathrm{bd}\, W$ onto the sphere and the cylinder; Homeomorphisms from $\overline{W}$ onto the closed ball and the solid cylinder; Resumé; Equivalent norms, invariant manifolds, Poincaré maps and asymptotic phases; Smooth center-stable manifolds for C^1-maps; Smooth generalized center-unstable manifolds for C^1-maps; Invariant cones close to neutrally stable fixed points with 1-dimensional center spaces; Unstable sets of periodic orbits; A discrete Lyapunov functional and a-priori estimates; Floquet multipliers for a class of linear periodic delay differential equations; Some results from topology; Bibliography; Index.

Fields Institute Monographs, Volume 11

December 1998, 245 pages, Hardcover, ISBN 0-8218-1074-X, LC 98-44070, 1991 *Mathematics Subject Classification*: 34K15; 58F12, 58F22, 34C30, **Individual member $41**, List $69, Institutional member $55, Order code FIM/11N

General and Interdisciplinary



Matériaux pour l'Histoire des Mathématiques au XX Siècle

A publication of the Société Mathématique de France

This volume presents many of the talks given at the Jean Dieudonné memorial conference held in Nice (France). These papers make a valuable contribution to the history of mathematics in the 20th century. Text is in French.

Contributors include: P. Deligne, B. Eckmann, L. Gårding, T. Hawkins, C. Houzel, J.-P. Kahane, Yu. I. Manin, G. Pisier, R. Remmert, N. Schappacher.

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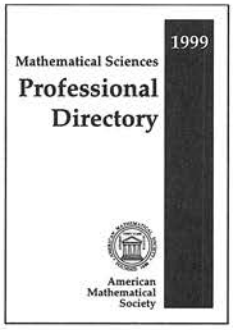
Contents: P. Deligne, Quelques idées maîtresses de l'œuvre de A. Grothendieck; **B. Eckmann**, Naissance des fibrés et homotopie; **L. Gårding**, Hyperbolic equations in the twentieth century; **T. Hawkins**, From general relativity to group representations; **C. Houzel**, Histoire de la théorie des faisceaux; Photo de famille; **J.-P. Kahane**, Le mouvement brownien; **Yu. I. Manin**, Interrelations between mathematics and physics; **G. Pisier**, Problèmes de similarité pour les opérateurs sur l'espace de Hilbert; **R. Remmert**, From Riemann surfaces to complex spaces; **N. Schappacher**, On the history of Hilbert's twelfth problem; Index des noms propres.

Séminaires et Congrès, Number 3

April 1998, 282 pages, Softcover, ISBN 2-85629-065-5, 1991 *Mathematics Subject Classification*: 01A65, 14-03, 35-03, 55-03, 46-03, 17B10, 22E46, 60J65, **Individual member $50**, List $55, Order code SECO/3N



Mathematical Sciences Professional Directory, 1999

This annual directory provides a handy reference to various organizations in the mathematical sciences community. Listed in the directory are the following: officers and committee members of over thirty professional mathematical organizations (terms of office and other pertinent information are also provided in some cases); key mathematical sciences personnel of selected government agencies; academic departments in the mathematical sciences; mathematical units in nonacademic organizations; and alphabetic listings of colleges and universities. Current addresses, telephone numbers, and

electronic addresses for individuals are listed in the directory when provided.

March 1999, approximately 225 pages, Softcover, ISBN 0-8218-1090-1, 1991 *Mathematics Subject Classification*: 00, List $50, Institutional member $40, Order code PRODIR/99N

Séminaire Bourbaki, Volume 1995/96, Exposés 805–819

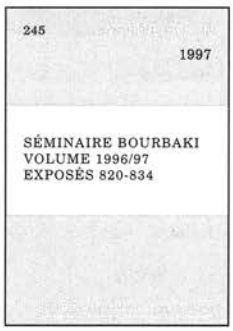
A publication of Société Mathématique de France.

This volume contains 15 survey lectures on topics of current interest: spaces of operators; classification of C^*-algebras; spectral geometry; group actions on trees; cohomology of spaces of automorphic foms; orbital integrals on certain symmetric spaces; the application of logic to algebraic geometry; resolution of singularities in algebraic geometry; quantum cohomology; subriemannian geometry; mathematical aspect of image analysis; and characteristic classes. Some articles are in French and some in English.

Distributed by the AMS in the United States, Canada, and Mexico. Orders from other countries should be sent to the SMF, Maison de la SMF, B.P. 67, 13274 Marseille cedex 09, France, or to Institut Henri Poincaré, 11 rue Pierre et Marie Curie, 75231 Paris cedex 05, France. Members of the SMF receive a 30% discount from list.

Contents: *Novembre 1995:* **C. Anantharaman-Delaroche**, Classification des C^*-algèbres purement infinies nucléaires [d'après E. Kirchberg]; **M. Audin**, Cohomologie quantique; **D. Bennequin**, Monopôles de Seiberg-Witten et conjecture de Thom [d'après Kronheimer, Mrowka et Witten]; **F. Paulin**, Actions de groupes sur les arbres; **J.-L. Waldspurger**, Cohomologie des espaces de formes automorphes [d'après J. Franke]; *Février 1996:* **P. Delorme**, Inversion des intégrales orbitales sur certains espaces symétriques réductifs [d'après A. Bouaziz et P. Harinck]; **J. B. Goode**, H. L. M. (Hrushovski-Lang-Mordell); **D. Kotschick**, The Seiberg-Witten invariants of symplectic four-manifolds [after C. H. Taubes]; **J. M. Morel**, La conjecture de Mumford-Shah en segmentation d'images; **G. Pisier**, Espaces d'opérateurs: une nouvelle dualité; *Juin 1996:* **P. Berthelot**, Altérations de variétés algébriques [d'après A. J. de Jong]; **A. Connes**, Brisure de symétrie spontanée et géométrie du point de vue spectral; **I. Kupka**, Géométrie sous-riemannienne; **C. Sabbah**, Classes caractéristiques et théorèmes d'indice: point de vue microlocal; **C. Soulé**, Classes caractéristiques secondaires des fibrés plats.

November 1997, 424 pages, 1991 *Mathematics Subject Classification*: 46L35, 46L80, 53C15, 53C23, 53C80, 58D99, 32G13, 32G15, 81T30, 81T40, 14J30, 14J45, 14C20, 35Q60, 57M25, 57M50, 57R15, 58G40, 81T13, 81T60, 20E08, 20F32, 22E40, 11F75, 11G18, 22E46, 14G05, 03C45, 57R57, 58D27, 49Q05, 68U10, 35K65, 35K55, 65C20, 49L25, 46L05, 46M05, 46M10, 46B05, 14E15, 14B07, 14N05, 14H10, 14C17, 14F30, 14F20, 46L89, 53C07, 53C20, 53C22, 58A30, 58E10, 49K15, 35H05, 35K10, 58G05, 58G10, 32C38, 32C35, 14C40, 32S60, 14C25, 57R20, **Individual member $99**, List $110, Order code AST/241N



Séminaire Bourbaki, Volume 1996/97, Exposés 820–834

A publication of the Société Mathématique de France

This volume contains fifteen survey lectures on topics of current interest. A highlight of the volume is the article by 1998 Fields Medalist M. Kontsevich on the work of R. Borcherds (also a 1998 Fields Medal recipient) on product formulas for modular forms. Other topics discussed in the book are celestial mechanics, holomorphic dynamical systems, boundary value problems, combinatorics, p-adic differential equations, algebraic geometry, hypergeometric functions, Riemannian geometry, motivic cohomology and arithmetical algebraic geometry.

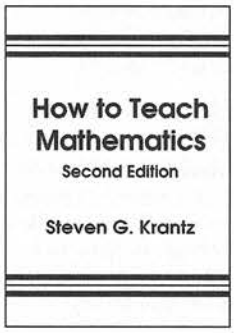
Distributed by the AMS in the United States, Canada, and Mexico. Orders from other countries should be sent to the SMF, Maison de la SMF, B.P. 67, 13274 Marseille cedex 09, France, or to Institut Henri Poincaré, 11 rue Pierre et Marie Curie, 75231 Paris cedex 05, France. Members of the SMF receive a 30% discount from list.

Contents: *Novembre 1996:* **X. Buff**, Ensembles de Julia de mesure positive; **M. Kontsevich**, Product formulas for modular forms on $O(2,n)$; **F. Loeser**, Exposants P-adiques et théorèmes d'indice pour les équations différentielles P-adiques; **P. Pansu**, Volume, courbure et entropie; **M. Waldschmidt**, Sur la nature arithmétique des valeurs de fonctions modulaires; *Mars 1997:* **A. Abbes**, Hauteurs et discrétude; **N. Burq**, Mesures semi-classiques et mesures de défaut; **O. Debarre**, Variétés de Fano; **G. J. Heckman**, Dunkl operators; **A. Valette**, Graphes de Ramanujan et applications; *Juin 1997:* **J.-P. Bourguignon**, Métriques d'Einstein-Kähler sur les variétés de Fano: obstructions et existence; **J.-F. Boutot**, Uniformisation p-adique des variétés de Shimura; **A. Chenciner**, A l'infini en temps fini; **E. M. Friedlander**, Motivic complexes of Suslin and Voevodsky; **B. Kahn**, La conjecture de Milnor.

Astérisque, Number 245

469 pages, Softcover, 1991 *Mathematics Subject Classification*: 58F23, 11F22, 11F12, 17B67, 12H25, 28D20, 58F17, 57M50, 53C35, 57E11, 11J91, 11F11, 14H52, 33B15, 33E05, 14Kxx, 11Gxx, 35L20, 35B27, 78A05, 14J45, 14C05, 14G05, 14D22, 14E20, 53C30, 53C07, 20G05, 22E46, 33C70, 05C35, 11F30, 22D10, 46L35, 53C25, 53C55, 58G30, 11G18, 14G35, 14L05, 70D05, 70F15, 70F10, 70H33, 19E15, 19F99, 14-02,ndividual member $81, List $90, Order code AST/245N

Recommended Text



How to Teach Mathematics, Second Edition

Steven G. Krantz, *Washington University, St. Louis, MO*

Praise for the First Edition ...

An original contribution to the educational literature on teaching mathematics at the post-secondary level. The book itself is an explicit proof of the author's claim "teaching can be rewarding, useful, and fun".

—Zentralblatt für Mathematik

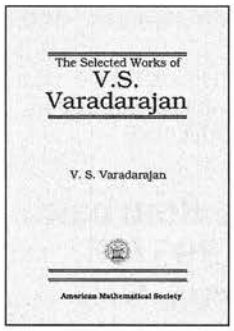
This expanded edition of the original bestseller, *How to Teach Mathematics*, offers hands-on guidance for teaching mathematics in the modern classroom setting. Twelve appendices have been added that are written by experts who have a wide range of opinions and viewpoints on the major teaching issues.

Eschewing generalities, the award-winning author and teacher, Steven Krantz, addresses issues such as preparation, presentation, discipline, and grading. He also emphasizes specifics—from how to deal with students who beg for extra points on an exam to mastering blackboard technique to how to use applications effectively. No other contemporary book addresses the principles of good teaching in such a comprehensive and cogent manner.

The broad appeal of this text makes it accessible to areas other than mathematics. The principles presented can apply to a variety of disciplines—from music to English to business. Lively and humorous, yet serious and sensible, this volume offers readers incisive information and practical applications.

Contents: Guiding principles; Practical matters; Spiritual matters; Difficult matters; A new beginning; *Appendices:* **G. E. Andrews**, The irrelevance of calculus reform: Ruminations of a sage-on-the-stage; **R. Askey**, Mathematical content; **D. M. Bressoud**, Personal thoughts on mature teaching; **W. J. Davis**, Remember the students; **E. Dubinsky**, Reflections on Krantz's*How to Teach Mathematics* A different view; **D. Hughes Hallett**, Are we encouraging our students to think mathematically?; **D. Klein**, Big business, race, and gender in mathematics reform; **W. McCallum**, Will this be on the exam?; **K. C. Millett**, Teaching or appearing to teach: What's the difference?; **J. J. Uhl**, Why (and how) I teach without long lectures; **H. Wu**, The joy of lecturing—with a critique of the romantic tradition in education writing; **S. Zucker**, Teaching freshmen to learn mathematics; Bibliography; Index.

January 1999, approximately 363 pages, Softcover, ISBN 0-8218-1398-6, 1991 *Mathematics Subject Classification*: 00A25, 00A05, 00A20, **All AMS members $19**, List $24, Order code HTM/2N



The Selected Works of V.S. Varadarajan

V. S. Varadarajan, *University of California, Los Angeles*

V.S. Varadarajan has made significant contributions to a remarkably broad range of mathematical subjects which include probability theory, various mathematical aspects of quantum mechanics, harmonic analysis on reductive groups and symmetric spaces, and the modern theory of meromorphic differential equations. The papers included in this volume have been selected to highlight these contributions.

This text will also be of interest to those working in algebra and algebraic geometry and differential equations.

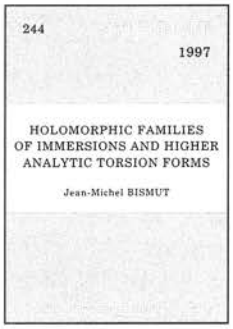
This book is jointly published by the AMS and the International Press.

Contents: Comments; Measures on topological spaces; Probability in physics on a theorem on simultaneous observability; Discrimination of Gaussian processes; Groups of automorphsism of Borel spaces; Representations of complex semisimple Lie groups and Lie algebras; On the ring of invariant polynomials on a semisimple Lie algebra; Spherical transforms on semisimple Lie groups; Asymptotic behaviour of eigen functions on a semisimple Lie group: The discrete spectrum; On an infinitesimal characterization of the discrete series; Spectra compact locally symmetric manifolds of negative curvature; Oscillatory integrals and their applications to harmonic analysis on semisimple Lie groups; Some remarks on meromorphic differential equations with simple singularities; Local moduli for meromorphic differential equations; The Eigenvalue problem on negatively curved compact locally symmetric manifolds; Hilbert space representations of the Poincaré group for the Landau gauge; The concept of a quantum semisimple group; Lorentz invariant distributions supported on the forward light cone; Universal deformations of reductive Lie algebras; Finite approximations to quantum systems; Variations on a theme of Schwinger and Weyl; Linear meromorphic differential equations: A modern point of view; Path integrals for a class of p-adic Schrödinger equaitons.

Collected Works, Volume 11

November 1998, 630 pages, Hardcover, ISBN 0-8218-1068-5, LC 98-36452, 1991 *Mathematics Subject Classification*: 01A75; 22E46, 35P20, 41A60, 34A20, 32G34, 81P10, 81Q99, 81T99, 60B05, 60G15, 28D15, 17B37, **Individual member $75**, List $125, Institutional member $100, Order code CWORKS/11N

Geometry and Topology



Holomorphic Families of Immersions and Higher Analytic Torsion Forms

Jean-Michel Bismut, *Université de Paris Sud, Orsay, France*

A publication of Société Mathématique de France.

This volume calculates the behavior of the higher analytic torsion forms of a Kähler fibration under composition of an immersion and a submersion. This extends a previous result by Lebeau and Bismut to the relative case. The result is compatible with the Riemann-Roch formula in Arakelov geometry conjectured by Gillet and Soulé.

This text will also be of interest to those working in differential equations and analysis.

Distributed by the AMS in the United States, Canada, and Mexico. Orders from other countries should be sent to the SMF, Maison de la SMF, B.P. 67, 13274 Marseille cedex 09, France, or to Institut Henri Poincaré, 11 rue Pierre et Marie Curie, 75231 Paris cedex 05, France. Members of the SMF receive a 30% discount from list.

Contents: Introduction; Families of immersions and connections on the relative tangent bundle; Kähler fibrations, higher analytic torsion forms and anomaly formulas; Kähler fibrations, resolutions, and Bott-Chern currents; An identity on two parameters differential forms; The analytic torsion forms of a short exact sequence; A proof of Theorem 0.1; A new horizontal bundle on V and the conjugate superconnection $\tilde{A}_{u,T}$; A Taylor expansion of the superconnection $\tilde{A}_{1,T}$ near W; The asymptotics of supertraces involving the operator $\exp(-B^2_{u,T})$ for large values of u, T; The asymptotics of the metric $g_T^{H(Y,\eta|_Y)}$ as $T \to +\infty$; The analysis of the two parameter semi-group $\exp(-A^2_{u,T})$ in the range $u \in]0,1], T \in [0, \frac{1}{u}]$; The analysis of the kernel of $\tilde{F}_u(A^2_{u,T/u})$ for $T > 0$ as $u \to 0$; The analysis of the two parameter operator $\exp(-A^2_{u,T})$ in the range $u \in]0,1], T \geq 1/u$; A proof of Theorem 0.2; A new derivation of the asymptotics of the generalized supertraces associated to a short exact sequence; Bibliography.

Astérisque, Number 244

July 1998, 275 pages, Softcover, 1991 *Mathematics Subject Classification*: 33L10, 57R20, 58G10, **Individual member $50**, List $55, Order code AST/244N

Classified Advertisements

Positions available, items for sale, services available, and more

ALABAMA

THE UNIVERSITY OF ALABAMA AT BIRMINGHAM

Applications are invited for two tenure-track positions to begin September 1, 1999. One position is at the level of associate professor, and one position is at the level of assistant professor. Applicants should have demonstrated strong potential in research commensurate with the level of the position and a commitment to excellent teaching. Postdoc experience is desirable for candidates applying for the position of assistant professor. All qualified candidates are encouraged to apply. We are especially interested in candidates whose research is compatible with the department's current research expertise in differential equations, differential geometry, dynamical systems, mathematical physics, and topology, including the computational aspects of these research areas. Our home page can be found at `http://www.math.uab.edu/`.

In order to apply, please send a completed AMS Standard Cover Sheet (available from the AMS, `http://www.ams.org/employment/coversheet-info.html`) and a curriculum vitae. Review of applications will begin November 15, 1998, and will continue until the positions are filled. Please arrange for at least three letters of reference to be sent. Applications and letters of reference should be sent to the following address: Search Committee, Department of Mathematics, UAB, Birmingham, AL 35294-1170. UAB is an AA/EO Employer.

ARIZONA

ARIZONA STATE UNIVERSITY Department of Mathematics

The Department of Mathematics at Arizona State University invites applications for several tenure-track and visiting positions at the assistant professor levels, pending budgetary approval, commencing fall 1999. All candidates must have a Ph.D. in mathematics, statistics, mathematics education, or a closely related area and demonstrated potential for excellence in research and teaching at the undergraduate level. All visiting candidates must have demonstrated potential for (visiting assistant level) or evidence of (visiting associate level), excellence in research and teaching at the undergraduate level.

Tenure-track candidates must have research strengths in one or more of the following areas: (i) mathematical biology, (ii) discrete/combinatorial mathematics or, (iii) analysis. Candidates in the first two areas should expect to participate fully in a cross-disciplinary environment.

Applications for visiting positions are invited from candidates with research strengths that complement existing research strengths of the Department. These include (i), (ii), and (iii) above, and (iv) algebra/number theory, (v) statistics/probability, (vi) mathematics education, (vii) dynamical systems, (viii) control theory, and (ix) applied and computational mathematics. Candidates in areas of applied mathematics should have interests in modeling, computation and expect to participate in multidisciplinary activities.

The main campus of Arizona State University has approximately 43,000 students and is located in the rapidly growing metropolitan Phoenix area, which provides a wide variety of recreational and cultural opportunities. The Department of Mathematics currently has 57 full-time faculty members, 25 lecturers and over 70 supported graduate students. Departmental computing facilities include networked clusters of high-end workstations as well as several graphics computers and access to the University's central computing facilities.

Applicants must send (i) their résumé, (ii)

Suggested uses for classified advertising are positions available, books or lecture notes for sale, books being sought, exchange or rental of houses, and typing services.

The 1998 rate is $100 per inch or fraction thereof on a single column (one-inch minimum), calculated from top of headline. Any fractional text of 1/2 inch or more will be charged at the next inch rate. No discounts for multiple ads or the same ad in consecutive issues. For an additional $10 charge, announcements can be placed anonymously. Correspondence will be forwarded.

Advertisements in the "Positions Available" classified section will be set with a minimum one-line headline, consisting of the institution name above body copy, unless additional headline copy is specified by the advertiser. Headlines will be centered in boldface at no extra charge. Ads will appear in the language in which they are submitted.

There are no member discounts for classified ads. Dictation over the telephone will not be accepted for classified advertising.

Upcoming deadlines for classified advertising are as follows: January issue–October 26, 1998; February issue–November 12, 1998; March issue–December 21, 1998; April issue–January 16, 1999; May issue–February 23, 1999; June/July issue–April 26, 1999.

U.S. laws prohibit discrimination in employment on the basis of color, age, sex, race, religion, or national origin. "Positions Available" advertisements from institutions outside the U.S. cannot be published unless they are accompanied by a statement that the institution does not discriminate on these grounds whether or not it is subject to U.S. laws. Details and specific wording may be found on page 1373 (vol. 44).

Situations wanted advertisements from involuntarily unemployed mathematicians are accepted under certain conditions for free publication. Call toll-free 800-321-4AMS (321-4267) in the U.S. and Canada, or 401-455-4084 worldwide, for further information.

Submission: Promotions Department, AMS, P.O. Box 6248, Providence, Rhode Island 02940, or via fax, 401-331-3842, or send e-mail to `classads@ams.org`. AMS location for express delivery packages is 201 Charles Street, Providence, Rhode Island 02904. Advertisers will be billed upon publication.

an AMS cover sheet, (iii) a letter stating for which position they wish to be considered and addressing their research agenda, (iv) a statement of teaching philosophy, and (v) at least three letters of recommendation by the deadline to:

R. A. Renaut, Chair
Department of Mathematics
P.O. Box 871804
Arizona State University
Tempe, AZ 85287-1804

Review of the applications will begin on November 30, 1998, and will continue weekly until the positions are filled. AA/EOE.

ARKANSAS

UNIVERSITY OF ARKANSAS AT LITTLE ROCK
Chairperson of the Department of Mathematics and Statistics

Applications are invited for the position of chairperson of the Department of Mathematics and Statistics, available on July 1, 1999. Candidates with a strong record of research in an area of specialization within any field of mathematics or statistics whose experience is commensurate with the rank of associate professor with tenure are encouraged to apply. Applicants should have an earned doctorate, a strong commitment to teaching, research, and service. Some administrative and/or professional experience in a mathematical sciences program is desirable. The ability to work effectively with people is important. The chairperson is expected to facilitate the interaction of the faculty with the University of Arkansas Medical Sciences campus, regional governmental organizations, private research and development organizations, and local high schools.

The University of Arkansas at Little Rock is a metropolitan institution located in the population center of Arkansas. The current enrollment is about 11,000 students. The position carries a 12-month appointment. Rank and salary will be commensurate with qualifications. The Department of Mathematics and Statistics consists of twenty-four full-time faculty members. In addition to B.A. and B.S. degrees, the Department offers an M.S. degree in applied mathematics.

Letters of application should include a curriculum vitae, and names, addresses, and telephone numbers of at least three references. Applications received by February 15, 1999, will receive full consideration and should be addressed to: Chairperson, Search Committee, Department of Mathematics and Statistics, University of Arkansas at Little Rock, 2801 South University Avenue, Little Rock, Arkansas 72204. The University of Arkansas at Little Rock is an Affirmative Action/Equal Opportunity Employer and actively seeks the candidacy of minorities and women. This position is subject to available funding. Under Arkansas law, all applications are subject to disclosure.

CALIFORNIA

CALIFORNIA STATE UNIVERSITY, CHICO
Mathematics Education

Applications are invited for a tenure-track position in mathematics education at the assistant or associate professor level to commence fall 1999. Responsibilities include teaching both mathematics and mathematics education courses, supervision of mathematics education master's degree thesis projects, engaging in scholarly activities in mathematics education, pursuing significant external funding, and service to K-12 teachers. Minimum requirements: a doctorate in mathematics education or a mathematical science (including at least the equivalent of a strong master's degree in mathematics); evidence of quality teaching, and capacity for excellence in research, writing, or other scholarly activities.

As a university that educates students of various ethnic and cultural backgrounds, we value a diverse faculty and seek to create as diverse a pool of candidates as possible. For further information visit our Web site: `http://www.csuchico.edu/math/`. Submit a letter of application that describes your professional goals and addresses the qualifications and experiences required for this position. Include a vita, three letters of recommendation (including at least one relating to teaching effectiveness), and graduate transcripts. Send to: Dr. Jim Jones, Mathematics Education Search Committee, Department of Mathematics and Statistics, California State University, Chico, Chico, CA 95929-0525. Closes January 29, 1999.

MILLS COLLEGE
Assistant Professor of Mathematics

Mills College invites applications for a tenure-track position as assistant professor of mathematics starting fall 1999. Required: Ph.D. in mathematics and a broad background in mathematics. Preference will be given to candidates with expertise in analysis. Applicants must submit evidence of superior teaching and research abilities. Teaching load: five courses per year. Duties: teach a variety of courses in mathematics, contribute to an environment that excites women about mathematics and prepares them for careers that use mathematics, help build a strong program in mathematics that is attractive to students with diverse backgrounds and interests.

Mills College is a small, well-known liberal arts college for women located in the San Francisco Bay Area. It offers 33 majors and 18 graduate programs, including a master's program in interdisciplinary computer science. The faculty/student ratio is 1:11.

Please send a vita, at least three letters of recommendation, and statements of teaching philosophy and research agenda to: Chair of the Mathematics Search Committee, Mills College, 5000 MacArthur Blvd., Oakland, CA 94613 (e-mail address: `mathsearch@mills.edu`). The deadline for receiving this material is January 22, 1999. Hard copies required; electronic copies optional. For more information see `http://www.mills.edu/ADMIN_INFO/PROVOST/SEARCHES/`.

Women and minorities are encouraged to apply. AA/EOE.

STANFORD UNIVERSITY
Department of Mathematics
Assistant Professorships in Honor of Gabor Szego

The department expects to make one or more appointments in 1999–2000 for these special three-year positions. Applicants are expected to show outstanding promise in research and clear evidence of achievement. They should have received the Ph.D. prior to the start of the appointment but not before 1997. Stanford is committed to excellence in teaching, and applicants should count this as one of their goals. Candidates should send a letter of application with a curriculum vitae, a list of publications and information concerning teaching experience, and three letters of recommendation to Prof. Leon Simon, Chairman, Department of Mathematics, Stanford University, Stanford, CA 94305-2125, by December 15, 1998. Stanford is an Affirmative Action/Equal Opportunity Employer and welcomes applications from women and minorities.

STANFORD UNIVERSITY

The department expects to make at least one tenure-track or tenured appointment beginning September 1999 among the following fields: (1) analysis; (2) geometry or topology; (3) algebra, number theory, or logic; (4) applied mathematics or probability. In the last case there are also possibilities for joint appointments with other departments. At the tenured level, preference would go to individuals in the earlier years of their ranks, though a more senior appointment may be possible for an extremely well-qualified individual.

Candidates should send a letter of application and a curriculum vitae, a list of publications, and a cover sheet clearly stating the following information: name, area of specialization, institution, (expected) date of Ph.D., and Ph.D. advisor. Also, the candidate should arrange to have three letters of recommendation and some evidence of commitment to excellence in teaching sent

to Prof. Leon Simon, Department of Mathematics, Stanford University, Stanford, CA 94305-2125, by January 15, 1999.

Stanford is an Equal Opportunity/Affirmative Action Employer and welcomes applications from women and minorities.

UNIVERSITY OF CALIFORNIA, LOS ANGELES
Department of Mathematics
Regular Positions in Pure and Applied Mathematics

The UCLA Department of Mathematics invites applications for three or more tenure-track positions in mathematics. Exceptional promise in research and teaching is required. Positions are generally budgeted at the assistant professor level, but sufficiently outstanding candidates will be considered at higher levels. Teaching load is an average of 4.5 quarter courses per year. Positions subject to availability of resources and administrative approval. To apply, send e-mail to `search@math.ucla.edu`, or open `http://www.math.ucla.edu/~search/` on the World Wide Web, or write to Staff Search, Department of Mathematics, University of California, Los Angeles, CA 90095-1555. UCLA is an Equal Opportunity/Affirmative Action Employer.

UNIVERSITY OF CALIFORNIA, LOS ANGELES
Department of Mathematics
Temporary Positions

Subject to availability of resources and administrative approval:

(1) Three E.R. Hedrick Assistant Professorships. Applicants must show very strong promise in research and teaching. Salary $47,100. Three-year appointment. Teaching load: four quarter courses per year, which may include one advanced course in the candidate's field. Preference will be given to applications completed by January 6, 1999.

(2) One or two Research Assistant Professorships in Computational and Applied Mathematics (CAM). Applicants must show very strong promise in research and teaching. Salary $47,100. Three-year appointment. Teaching load: normally reduced to two quarter courses per year by research funding as available; may include one advanced course in the candidate's field. Preference will be given to applications completed by January 6, 1999.

(3) One Adjunct Assistant Professorship or Lectureship in the Program in Computing (PIC). Applicants for the adjunct position must show very strong promise in teaching and research in an area related to computing. Teaching load: four quarter programming courses and one more advanced quarter course per year. One-year initial appointment, with the option of applying for renewal for a second year and possibly longer, up to a maximum service of four years. Salary $50,400. Applicants for the lectureship must show very strong promise in the teaching of programming. An M.S. in computer science or equivalent degree is preferred. Teaching load: six quarter programming courses per year. One-year appointment, probably renewable one or more times, depending on the needs of the program. Salary is $41,472 or more, depending on experience. Preference will be given to applications completed by February 6, 1999.

(4) An Adjunct Assistant Professorship. One-year appointment, probably renewable once. Strong research and teaching background required. Salary $43,600–$45,900. Teaching load: five quarter courses per year. Preference will be given to applications completed by January 6, 1999.

(5) Possibly one or more positions for visitors.

To apply, send e-mail to: `search@math.ucla.edu`, or open `http://www.math.ucla.edu/~search/` on the World Wide Web, or write to: Staff Search, Department of Mathematics, University of California, Los Angeles, CA 90095-1555. UCLA is an Equal Opportunity/Affirmative Action Employer.

UNIVERSITY OF SOUTHERN CALIFORNIA, LOS ANGELES

The Core Mathematics Section of the Department of Mathematics expects two tenure-track positions at the assistant or associate professor level.

The positions will be in any traditional area of core mathematics, but with a preference in geometry/topology or analysis. In addition, there will be several visiting and postdoctoral positions. Applicants must show exceptional promise in research and teaching.

To apply, please submit the following materials in a single package: letter of application (including your e-mail address, fax number, and position applied for), the AMS cover sheet, and a curriculum vitae. Candidates for assistant professor, visiting, and/or postdoctoral positions should also arrange for three letters of recommendation to be sent. Mail all materials to: Core Math Search Committee, Department of Mathematics, DRB 155, University of Southern California, Los Angeles, CA 90089-1113. Review of applications will begin December 1, 1998. Additional information about USC can be found on the Web at `http://www.usc.edu/`. USC is an Equal Opportunity/Affirmative Action Employer.

UNIVERSITY OF CALIFORNIA, DAVIS
Visiting Research Assistant Professorships in Mathematics

Applications are invited for anticipated Visiting Research Assistant Professorship (VRAP) positions in the Department of Mathematics at the University of California, Davis, effective July 1, 1999. These positions are contingent upon budgetary and administrative approval.

Duties include mathematical research, undergraduate, and graduate teaching. The teaching load is four quarter-courses per year. Minimal qualifications include a Ph.D. degree in mathematical sciences and great promise in research and teaching. Applicants for these positions are required to have completed their Ph.D. no earlier than 1995. Visiting positions are renewable for a total of three years contingent upon satisfactory performance in research and teaching. Salaries for 1999 will be $38,500.

The Department of Mathematics is interested in applicants in the following areas for the VRAP positions: (1) analysis/PDEs, (2) applied mathematics, (3) geometry/topology/discrete mathematics, (4) mathematical physics/representation theory, (5) numerical analysis/scientific computation.

The application deadline is December 15, 1998, or until positions are filled. To initate the application process, request an application package by sending an e-mail message to: `vforms@math.ucdavis.edu`. Those who do not have access to e-mail can obtain a package by writing to:

Chair of VRAP Search Committee
Department of Mathematics
University of California
Davis, CA 95616-8633

The University of California, Davis, is an Affirmative Action/Equal Opportunity Employer with a strong institutional commitment to the achievement of diversity among its faculty and staff.

UNIVERSITY OF CALIFORNIA, SANTA BARBARA
Department of Mathematics
Faculty Positions

The University of California, Santa Barbara, invites applications for positions in the Department of Mathematics, beginning fall 1999.

1) Ky Fan Assistant Professorship: Candidates will be considered in the following areas: algebra, differential geometry, analysis, numerical analysis/applied mathematics, and low-dimensional topology. The Ky Fan Assistant Professorship is a special two-year nonrenewable position that carries a research stipend and a course load of 4 one-quarter courses per year. Appointment begins July 1, 1999. Candidates must possess a Ph.D. by September 1999 and should have held their Ph.D. for no more than five years as of January 1, 1999. Selection will be based primarily on research achievement, but documented evidence of satisfactory teaching is necessary and departmental research priorities will be taken into account.

2) Visiting Assistant Professorships: Several one-year visiting assistant professorships in the research areas listed above, with possibility of a second year, carrying a teaching load of 6 one-quarter courses per year. Applicants for the Ky Fan position will automatically be considered for

these positions as well. Excellence in research, potential for interaction with other faculty, and documented evidence of good teaching are all required. Candidates must possess a Ph.D. by September 1999.

Applicants should send the following materials to the Search Committee at the Department of Mathematics, University of California, Santa Barbara, CA 93106-3080: a vita, a publication list, and a statement of research interests and the American Mathematical Society cover sheet (available online at `http://www.ams.org/`). Include an e-mail address if available. Applicants should also arrange to have at least four letters of recommendation sent to the appropriate committee. Applications which are complete by January 4, 1999, will be given full consideration.

UCSB is an Affirmative Action/Equal Opportunity Employer.

UNIVERSITY OF CALIFORNIA, SANTA CRUZ
Department of Mathematics

The Mathematics Department at the University of California, Santa Cruz, is recruiting for a tenure-track assistant professor Step I-III in the areas of algebra and number theory, with primary emphasis in number theory; please refer to #517. The position will be effective July 1, 1999, contingent on budgetary approval. The teaching load is four one-quarter courses per year. Minimum qualifications: Ph.D. or equivalent in mathematics or closely related field; prefer Ph.D. by June 30, 1999, must be in hand no later than June 30, 2000; demonstrated achievements or potential for excellence in research and teaching. Step commensurate with experience. Salary range: $41,200-$45,900. Application deadline: January 11, 1999. Please refer to position number indicated above in your correspondence. Applicants should send a curriculum vitae, a summary of their research and teaching experience, and four letters of recommendation with at least one letter addressing teaching experience and ability (all letters will be treated as confidential documents) to: Recruitment Committee, Mathematics Department, University of California, Santa Cruz, CA 95064. Inquiries (not applications) can be sent to `mathrcr@cats.ucsc.edu`. UCSC is an AA/EEO/IRCA Employer.

UNIVERSITY OF CALIFORNIA, SANTA CRUZ
Department of Mathematics

The Department expects to have visiting assistant professorships beginning fall 1999 (subject to availability of funding). Appointees will be expected to teach and pursue their research. These positions are available for periods of one quarter to the full academic year, with a possible extension. Min. qualifications: Ph.D. or equivalent in mathematics or a closely related field, and demonstrated achievements or potential for excellence in research and teaching. Salary: $41,200. Available: fall 1999. Application deadline: 1/11/99. Refer to #T98-3. Applicants should send a CV, a summary of their research and teaching experience, and three letters of recommendation, with at least one letter addressing teaching experience and ability (all letters are treated as confidential documents), to: Recruitment Committee, Mathematics Department, University of California, Santa Cruz, CA 95064. Inquiries (not applications) can be sent to `mathrcr@cats.ucsc.edu`. UCSC is an AA/EEO/IRCA Employer.

COLORADO

UNIVERSITY OF COLORADO AT COLORADO SPRINGS

The Department of Mathematics at the University of Colorado at Colorado Springs invites applications for a tenure-track position to start AY 1999-2000. Applicants should document strength in both teaching and research. The Department is looking for a candidate whose research interests are closely related to a departmental specialty: ring and module theory, probability, differential equations, harmonic analysis and wavelets, and applied mathematics. The normal teaching load is five semester courses per year. To apply, please submit in a single package a letter of application, the AMS Standard Cover Sheet, and a curriculum vitae. Candidates should arrange for three letters of recommendation to be sent. Mail all materials to: Search Committee, Department of Mathematics, University of Colorado, Colorado Springs, CO 80933-7150. Selection of candidates will begin on February 1, 1999. Women and minorities are especially encouraged to apply. The University of Colorado is an Equal Opportunity/Affirmative Action Employer.

CONNECTICUT

FAIRFIELD UNIVERSITY
Department of Mathematics and Computer Science
Assistant Professor

Fairfield University's Department of Mathematics and Computer Science invites applications for a tenure-track assistant professorship starting in September 1999. A doctorate in mathematics with a strong background in statistics or a doctorate in statistics with a strong background in mathematics is required. We are looking for a person who can help us develop and teach courses in statistics at both the undergraduate and master's level. Strong evidence of research potential, demonstrated success in classroom instruction, and a solid commitment to teaching are essential.

Fairfield University is a comprehensive, Jesuit university with about 3,000 undergraduates and a strong emphasis on liberal arts education. There are 14 full-time faculty members in the department. The teaching load is three courses/nine credits per semester. Fairfield offers a very competitive compensation package. The picturesque campus overlooks Long Island Sound in southwestern Connecticut, about 50 miles from New York City. Fairfield is an Affirmative Action/Equal Opportunity Employer.

Send a letter of application, a curriculum vitae, and three letters of recommendation which comment on the applicant's experience and promise as a teacher and scholar to: Chris Bernhardt, Mathematics and Computer Science Department, Fairfield University, Fairfield, CT 06430-5195; 203-254-4000, ext. 2516; `cbernhardt@fair1.fairfield.edu`. Full consideration will be given to complete applications received by January 8, 1999.

DELAWARE

UNIVERSITY OF DELAWARE

The Department of Mathematical Sciences invites applications for a tenure/tenure-track position to begin September 1, 1999. The position is in applied mathematics with level open. Strong preference will be given those individuals at the associate or entry full professor level. Evidence of a strong publication record and fundable research are required. Experience and interest in establishing or mentoring links with industry and other academic disciplines will weigh heavily in the candidate's favor. Expertise in any of the areas of wave propagation, fluid dynamics, material science, scientific computaion and inverse problems will also weigh heavily in the candidate's favor. Evidence of effective teaching at the graduate and undergraduate level is essential. Applicants should send CV (including funding history), reprints and/or preprints, and three letters of recommendation sent to: Applied Math Search Committee, Department of Mathematical Sciences, University of Delaware, Newark, DE 19716. Applications must be received by January 15, 1999, to receive full consideration. The University of Delaware is an Equal Opportunity Employer which encourages applications from qualified minority group members and women.

FLORIDA

FLORIDA INTERNATIONAL UNIVERSITY
Department of Mathematics

The Department of Mathematics invites applications for a tenure-track position, subject to administrative approval, effective August 1999. The position will probably be

at the assistant professor level. Duties will include mathematical research, teaching, and service. Candidates must have a Ph.D. in mathematics. Applications from applied mathematicians are encouraged.

Florida International University is a member of the State University System of Florida, with over 30,000 students. The Department offers bachelor's and master's degrees. Current research interests of the faculty include algebra, number theory, analysis/P.D.E., numerical analysis, logic, and differential geometry/topology.

To apply, send a letter of application, a vita, and three letters of recommendation to:

Recruitment Committee
Department of Mathematics
Florida International University
Miami, FL 33199
http://www.fiu.edu/~math/

Florida International University is an Equal Opportunity/Equal Access Employer.

GEORGIA

GEORGIA INSTITUTE OF TECHNOLOGY

The School of Mathematics expects to have visiting and tenure-track positions at various levels in pure and applied mathematics and statistics beginning in fall 1999. The School intends to expand its areas of expertise and foresees the potential for 10–15 new appointments in the next five years. Candidates with strong research and teaching records or potential should arrange for a résumé, at least three letters of reference, and a summary of future research plans to be sent to the Hiring Committee, School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332-0160. Georgia Tech, an institution of the University System of Georgia, is an Equal Opportunity/Affirmative Action Employer.

GEORGIA INSTITUTE OF TECHNOLOGY
The Southeast Applied Analysis Center

The Southeast Applied Analysis Center, in the School of Mathematics, invites applications for postdoctoral/visiting positions in applied mathematics. Fields of interest include: scientific computing, analysis, statistics, combinatorics and algorithms, stochastic analysis, differential equations and modeling. Applicants should arrange for a curriculum vitae, at least three letters of recommendation, and a summary of research plans to be sent to: Regents Professor, Leonid A. Bunimovich, and Director, SAAC, School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332-0160. Georgia Tech, a member of the University System of Georgia, is an Equal Opportunity/Affirmative Action Employer.

ILLINOIS

ILLINOIS INSTITUTE OF TECHNOLOGY
Department of Computer Science and Applied Mathematics

Applications are invited for two tenure-track positions in mathematics (one possibly at senior level) beginning in August 1999. Applicants must have a doctorate in applied mathematics or related fields. The Department is particularly interested in the areas of numerical/computational mathematics and probability/statistics.

To ensure complete consideration, applicants should submit a detailed curriculum vitae, a statement of research and teaching interests, and the names and e-mail addresses of at least three references by January 15, 1999, to:

Prof. P. Deliyannis
Department of Computer Science
and Applied Mathematics
Illinois Institute of Technology
Chicago, IL 60616

The Illinois Institute of Technology is an Equal Opportunity/Affirmative Action Employer.

ELMHURST COLLEGE
Mathematics Department

Tenure-track position beginning fall 1999 (pending approval of the Board of Trustees). Qualifications desired: Ph.D. in mathematics at time of hire, interest in continued scholarship, and a strong commitment to undergraduate teaching in a liberal arts college. Teaching load: six courses per year. Elmhurst College is a four-year private institution located in the western suburbs of Chicago. Applications should include a curriculum vitae and three letters of reference. Please send to: Prof. Jon L. Johnson, Dept. of Mathematics, Elmhurst College, 190 Prospect Ave., Elmhurst, IL 60126, by January 1, 1999. Minority and women candidates are strongly urged to apply. EOE.

ILLINOIS WESLEYAN UNIVERSITY

The Department of Mathematics and Computer Science at Illinois Wesleyan University invites applications for a full-time, tenure-track position jointly in both mathematics and computer science to begin August 1999. Candidates must have a Ph.D. in computer science or mathematics and possess considerable expertise in both areas. The position is open to all areas of specialization in mathematics and CS.

Illinois Wesleyan is a highly selective undergraduate liberal arts university of 1,900 students located in Bloomington, Illinois, a community of about 100,000. The Department of Mathematics and Computer Science is located in the new Center for Natural Science Learning and Research. This $25 million facility is equipped with over ninety Sun SPARC stations for student and faculty use. For additional information on the computer science curriculum and facilities, see http://www.iwu.edu/~cs/. Send letter of application, AMS cover sheet, and résumé, plus three letters of reference under separate cover, to: Dr. Melvyn Jeter, Chair, Department of Mathematics and Computer Science, Illinois Wesleyan University, P.O. Box 2900, Bloomington, IL 61702-2900.

Illinois Wesleyan University is an Equal Opportunity Employer. Applications will be reviewed beginning January 31, 1999. Preference may be given to those completed by this date. Preliminary interviews for this position will be held at the Joint Mathematics Meetings in San Antonio, Texas (January 1999). Review of applications will continue until the position is filled.

INDIANA

UNIVERSITY OF NOTRE DAME
Notre Dame, IN 46556
Department of Mathematics
Regular Positions in Pure Mathematics

The Department of Mathematics of the University of Notre Dame invites applications for two positions starting August 24, 1999. The fields of interest are algebraic geometry, differential geometry, and Lie representation theory, but outstanding candidates in all fields are encouraged to apply. The positions are at the tenure-track level, although a tenured appointment may be possible for an exceptional candidate. The teaching load is one course in one semester and two courses in the other semester. Salaries are competitive.

Applications, including a curriculum vitae, a letter of application, and a completed AMS Standard Cover Sheet, should be sent to Alexander J. Hahn, Chair, at the above address. Applicants should also arrange for at least three letters of recommendation to be sent to the chair. These letters should address the applicant's research accomplishments and supply evidence that the applicant has the ability to teach articulately and effectively. Notre Dame is an Equal Opportunity Employer. Women and minorities are urged to apply. The evaluation of candidates will begin December 1. Information about the Department is available at http://www.math.nd.edu/math/.

UNIVERSITY OF NOTRE DAME
Notre Dame, IN 46556
Department of Mathematics
Regular Position in Stochastic Analysis

The Department of Mathematics of the University of Notre Dame invites applications for a position in the field of stochastic analysis to start on August 24, 1999. Of special interest are candidates with expertise in stochastic control, stochastic optimization, or stochastic differential

equations. The position is at the tenure-track level, but a tenured appointment may be possible for an exceptional candidate. The teaching load is one course in one semester and two courses in the other semester. The salary is competitive.

Applications, including a curriculum vitae, a letter of application, and a completed AMS Standard Cover Sheet, should be sent to Alexander J. Hahn, Chair, at the above address. Applicants should also arrange for at least three letters of recommendation to be sent to the chair. These letters should address the applicant's research accomplishments and supply evidence that the applicant has the ability to teach articulately and effectively. Notre Dame is an Equal Opportunity Employer. Women and minorities are urged to apply. The evaluation of candidates will begin December 1. Information about the Department is available at `http://www.math.nd.edu/math/`.

IOWA

UNIVERSITY OF NORTHERN IOWA
Assistant/Associate Professor of Mathematics

Seeking candidates who possess a Ph.D. in mathematics, ability and interest in maintaining a superior teaching record, and an emerging record of scholarship for a tenure-track position. The successful candidate will be expected to teach a broad spectrum of mathematics courses at both the undergraduate and graduate levels. Recent collegiate teaching experience, experience using technology in mathematics courses, and expertise in analysis and/or research interests that are compatible with departmental offerings are preferred.

Appointment begins in August 1999. Salary is competitive, with excellent fringe benefits. Application must be received by January 22, 1999, for full consideration. For more information see position announcement at `http://www.math.uni.edu/`, or contact Gregory Dotseth, Department of Mathematics, University of Northern Iowa, Cedar Falls, IA 50614-0506; `dotseth@math.uni.edu`; 319-273-2397. AA/EOE.

KANSAS

EMPORIA STATE UNIVERSITY
Mathematics and Computer Science

The Division of Mathematics and Computer Science at Emporia State University seeks to fill two nine-month, tenure-track entry-level mathematics positions beginning August 1999. Salary is commensurate with qualifications. A Ph.D. in mathematics is required. Candidates must possess an excellent teaching background and have a strong commitment to continuing scholarly activity. Review of applications will begin December 15, 1998, and will continue until all positions are filled. To apply, send a letter of application, résumé, unofficial transcripts, three letters of recommendation, a statement of teaching philosophy, and evidence of teaching skills or innovative teaching techniques to: Dr. Joe Yanik (`yanikjoe@emporia.edu`), Search Committee Chair, Division of Mathematics and Computer Science, Emporia State University, Campus Box 4027, Emporia, KS 66801-5087. AA/EOE. We encourage applications from members of protected classes.

KANSAS STATE UNIVERSITY
Department of Mathematics

Subject to budgetary approval, applications are invited for tenure-track and visiting positions commencing August 8, 1999; rank and salary commensurate with qualifications. The Department seeks candidates whose research interests mesh well with current faculty. Preference will be given to specialists in differential equations and algebra.

Applicants must have strong research credentials and a commitment to excellence in teaching. A Ph.D. in mathematics or a Ph.D. dissertation accepted with only formalities to be completed is required. Letter of application, current vita, description of research, at least three letters of reference evaluating research, and at least one reference letter concerning the applicant's teaching should be sent to:

Louis Pigno
Department of Mathematics
Cardwell Hall 138
Kansas State University
Manhattan, KS 66506

Offers may begin by December 7, 1998, but applications for positions will be reviewed until February 1, 1999, or until positions are closed. AA/EOE.

UNIVERSITY OF KANSAS
Department of Mathematics

Applications are invited for a tenure-track position and a temporary position at the assistant professor level beginning August 18, 1999, or as negotiated. (These positions are contingent on final budgetary approval.) For the tenure-track position preference will be given to candidates in nonlinear dynamical systems and chaos and otherwise to candidates in pure or applied mathematics or statistics whose specialties mesh well with those already represented in the Department. For the temporary position, preference will be given to candidates in quantum groups and otherwise to candidates whose research interests mesh well with those of our faculty. Candidates must have a Ph.D. or its requirements completed by August 15, 1999. Postdoctoral experience for the tenure-track position is preferred.

Letter of application, detailed résumé with description of research, completed AMS standardized application form, and three letters of recommendation should be sent to C. J. Himmelberg, Chairman, Department of Mathematics, 405 Snow Hall, University of Kansas, Lawrence, KS 66045-2142.

Deadlines: Review of applications will begin on January 1, 1999, and will continue until the positions are filled.

EO/AA Employer.

KENTUCKY

UNIVERSITY OF KENTUCKY

The Department of Mathematics at the University of Kentucky invites applications for at least two tenure-track assistant professorships to begin in fall 1999 (subject to budgetary approval). We are interested in applicants in the areas of discrete mathematics/combinatorial optimization and algebra/number theory. However, applicants in other areas are also welcome. We encourage applications from women and minority groups. Using the AMS application cover sheet, applicants should submit a vita; a description of research, including future research plans; and evidence of effective teaching. In addition, they should arrange to have at least three letters of recommendation sent to: Chair of the Recruiting Committee, Department of Mathematics, 715 POT, University of Kentucky, Lexington, Kentucky 40506-0027. The deadline for submission of applications is January 31, 1999. We expect to begin evaluating applications on December 1, 1998.

LOUISIANA

LOUISIANA TECH UNIVERSITY
College of Engineering and Science
Mathematics Positions

Louisiana Tech University, Mathematics and Statistics Program, seeks applicants at all ranks for one or more tenure-track positions. The college has interest in applicants that have experience in curriculum development and research activity in a field of applied mathematics with expertise in computation, modeling, or numerical simulation. Applicants must have a Ph.D. in mathematics or a closely related discipline. The position requires a person with excellent skills in written and oral English; teaching experience in precalculus, calculus, or differential equations; the ability to build and sustain an externally funded research program; the ability to supervise graduate students; a commitment to high-quality professional service; and participation in college responsibilities.

The College of Engineering and Science offers the B.S. and M.S. degrees in mathematics, as well as a Ph.D. in applied computational analysis and modeling. Research in the college focuses on the five

centers: Center for Applied Physics Studies, Center for Numerical Simulation and Modeling, Center for Rehabilitation Science and Biomedical Engineering, Institute for Micromanufacturing, and Center for Trenchless Technology.

Applicants should send a curriculum vitae, a statement of teaching and research goals, and names with contact information for at least three references to: Dr. George M. Butler, Chairman of the Search Committee, Mathematics and Statistics Program, Louisiana Tech University, Ruston, LA 71272 (butler@coes.latech.edu). The committee will review applications beginning immediately until the positions are filled. The positions have a starting date of September 1, 1999.

Ruston is located in the beautiful piney woods of north Louisiana. Louisiana Tech University is an Equal Opportunity/Affirmative Action Employer. Women and minorities are encouraged to apply. Additional information about the university and the college can be found at our Web site: http://www.latech.edu/.

MARYLAND

TEACH IN ASIA OR EUROPE

University of Maryland, University College, continually seeks excellent teachers for openings on U.S. military bases overseas. Appointments begin January or August, 1999. Requirements include M.A. or Ph.D., recent U.S. university teaching experience, and U.S. citizenship. Competence to teach in another discipline desirable. Benefits include transportation, health insurance, military base privileges (PX, commissary, etc.), and TIAA/CREF. Frequent relocation and the cost of schooling make these positions difficult for those with children. Further information can be found at http://www.umuc.edu/ under "Military" and "Faculty/Staff". Send résumé to: Dr. Rosemary Hoffmann, University of Maryland University College, Overseas Programs, College Park, MD 20742-1642, or overseas_programs@admin.umuc.ed. AA/EOE.

MASSACHUSETTS

BOSTON UNIVERSITY

The Department of Mathematics and Statistics at Boston University invites applications for a two-year position at the visiting assistant professor level in the area of dynamical systems. The position will begin in September 1999, subject to administrative approval. Candidates should demonstrate a strong commitment to teaching and research. Please submit the AMS application cover sheet with at least three letters of recommendation to: Dynamical Systems Search Committee, Department of Mathematics, Boston University, 111 Cummington Street, Boston, MA 02215. Application deadline: January 15, 1999. Boston University is an Affirmative Action/Equal Opportunity Employer.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, MA 02139-4307
Applied Mathematics

Applications are invited for a limited number of positions in applied mathematics starting fall 1999. Available positions include instructorships, lectureships, assistant professorships, and possibly higher levels. Appointments will be made mainly on the basis of demonstrated research accomplishment and potential. Complete applications must be received by January 8. To apply, please send a vita with a description of your recent research and research plans, and arrange to have three letters of reference sent. Address: Committee on Applied Mathematics, Room 2-345, Department of Mathematics, Massachusetts Institute of Technology, Cambridge, MA 02139-4307. M.I.T. is an Equal Opportunity/Affirmative Action Employer.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, MA 02139-4307
Department of Mathematics

The Department of Mathematics may make a few appointments at the lecturer and at the assistant professor or higher levels in pure mathematics for the year 1999–2000. The teaching load will be six hours per week in one semester and three hours per week in the other, or other combinations totaling nine hours. Open to mathematicians with doctorates who show definite promise in research. Applications should be completed by January 15. Applicants please arrange to have sent (a) a vita, (b) three letters of reference, (c) a description of your most recent research, and (d) the research that you plan for the next few years to: Pure Mathematics Committee, Massachusetts Institute of Technology, Room 2-263, Cambridge, MA 02139-4307. M.I.T. is an Equal Opportunity/Affirmative Action Employer.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, MA 02139-4307
Department of Mathematics
C.L.E. Moore Instructorships In Mathematics

Open to mathematicians with doctorates who show definite promise in research. Teaching loads are six hours per week during one semester, and three hours per week during the other. Applications should be completed by January 1. Please arrange to have sent (a) a vita, (b) three letters of reference, (c) a description of the research in your thesis, and (d) the research which you plan for next year to: Pure Mathematics Committee, Massachusetts Institute of Technology, Room 2-263, Cambridge, MA 02139-4307. M.I.T. is an Equal Opportunity/Affirmative Action Employer.

NORTHEASTERN UNIVERSITY
567 Lake Hall
Boston, MA 02115
Department of Mathematics

We invite applications for a tenure-track position at the assistant professor level, pending budgetary approval, to begin in September 1999.

Outstanding candidates in the fields of algebra, geometry, analysis, and their applications are encouraged to apply. We are particularly interested in candidates who will use their strength in research to join the Department's efforts to build and support collaborations with other departments and with industry.

Applications, including a curriculum vitae, a statement of current research plans and teaching interests, and a completed AMS Standard Cover Sheet, should be sent to the Chair of the Hiring Committee at the above address. Applicants should also arrange for at least three letters of recommendation to be sent to the Chair of the Hiring Committee. These letters should address the applicant's research accomplishments and teaching effectiveness.

Candidates must possess a Ph.D. before the start date. The evaluation of candidates will begin immediately. In order to ensure full consideration, applications should be received by December 15, 1998.

Northeastern University is an Affirmative Action/Equal Opportunity Employer that strongly encourages applications from women and minority candidates.

Information about Northeastern University and its graduate and undergraduate programs in mathematics is available at http://www.math.neu.edu/.

WILLIAMS COLLEGE
Williamstown, MA 01267
Department of Mathematics

Anticipated tenure-eligible position in statistics, beginning fall 1999, probably at the rank of assistant professor. In exceptional cases, however, more advanced appointments may be considered. Excellence in teaching and statistics, including scholarship and consulting, and Ph.D. required. Applicants with emphasis in operations research will also be considered.

Please have a vita and three letters of recommendation on teaching and research sent to Hiring Committee. Evaluation of applications will begin November 15 and continue until the position is filled. As an EEO/AA employer, Williams especially welcomes applications from women and minority candidates.

MICHIGAN

CENTRAL MICHIGAN UNIVERSITY
Department of Mathematics

The Department of Mathematics invites applications for a tenure-track position in statistics at the assistant professor level or higher. Candidates should have a Ph.D. in statistics or mathematics, show evidence of having conducted research in statistics, and have effective communication skills. The successful candidate will be expected to teach graduate and undergraduate statistics and mathematics courses, to conduct research in statistics, and to apply for external funding. Of special interest are individuals with expertise in actuarial science and with research interests that overlap existing research of the faculty. The usual teaching load is nine semester hours. Salary is competitive and benefits include university-paid retirement, medical, dental, disability, and group life insurance. Pending administrative approval, a second tenure-track position in statistics may also be available.

Central Michigan University has an enrollment of 16,600, of which 2,000 are graduate students, and offers bachelor's, master's, and Ph.D. degrees. The Department of Mathematics, which includes pure and applied mathematics, statistics, and mathematics education, has 31 tenure-track faculty.

Please send a letter of application, résumé, transcript, and names of three references to: Professor Sidney Graham, Chair, Department of Mathematics, Central Michigan, Mt. Pleasant, MI 48859; phone: 517-774-3596; fax: 517-774-2414; e-mail: `math@cmich.edu`; Web site: `http://www.cst.cmich.edu/units/mth/`. Consideration of applications will begin on December 1, 1998, but applications will be accepted until the position is filled.

CMU, an AA/EO institution, is strongly and actively committed to increasing diversity within its community (see `http://www.cmich.edu/aaeo.html`).

NEW HAMPSHIRE

DARTMOUTH COLLEGE
John Wesley Young Research Instructorship in Mathematics

The John Wesley Young Research Instructorship is a two-year postdoctoral appointment for promising new or recent Ph.D.s whose research interests overlap a department member's. Current departmental interests include areas in algebra, analysis, combinatorics, differential geometry, logic and set theory, number theory, probability, and topology. Teaching duties of four 10-week courses spread over two or three quarters typically include at least one course in the instructor's specialty and include elementary, advanced, and (at instructor's option) graduate courses. Nine-month salary of $40,000 supplemented by summer research stipend of $8,889 for instructors in residence for two months in summer. Send letter of application, résumé, graduate transcript, thesis abstract, description of other research activities and interests if appropriate, and three, or preferably four, letters of recommendation (at least one should discuss teaching) to: Betty Harrington, Department of Mathematics, 6188 Bradley Hall, Hanover, NH 03755-3551. Applications received by January 15 will receive first consideration; applications will be accepted until position is filled. Dartmouth College is committed to Affirmative Action and strongly encourages applications from minorities and women.

DARTMOUTH COLLEGE

The Department of Mathematics anticipates a tenure-track opening for an assistant professor of mathematics in the field of combinatorics, with initial appointment in the 1999–2000 academic year. In exceptional cases, an appointment at a higher level is possible. A candidate for the position must be committed to outstanding teaching at all levels of the undergraduate and graduate curriculum and must give evidence of a well-regarded research program that shows real promise for the future. Candidates with several years of experience should in addition be ready to direct Ph.D. theses.

To create an atmosphere supportive of research, Dartmouth offers new faculty members grants for research-related expenses, a quarter of sabbatical leave for each three academic years in residence, and flexible scheduling of teaching responsibilities. The teaching responsibility in mathematics is four courses spread over two or three quarters. The department encourages good teaching with a combination of committed colleagues and bright, responsive students.

To apply, send a letter of application, curriculum vitae, and a brief statement of research results and interests. Also arrange for four letters of reference to be sent, at least one of which addresses teaching and, if the applicant's native language is not English, the applicant's ability to use English in a classroom. All application materials should be addressed to: Betty Harrington, Recruiting Secretary, Department of Mathematics, Dartmouth College, 6188 Bradley Hall, Hanover, NH 03755-3551. Applications completed by January 15 will receive first consideration. Dartmouth is committed to Affirmative Action and encourages applications from African Americans, Asian Americans, Hispanics, Native Americans, and women. Inquiries about the progress of the selection process can be directed to Dwight Lahr, Recruiting Chair.

NEW JERSEY

DIMACS Center
Postdoctoral Fellowships

DIMACS, the Center for Discrete Mathematics and Theoretical Computer Science, invites applications for several postdoctoral fellowships for 1999–2000. DIMACS, an NSF Science and Technology Center, is a partnership of Rutgers University, Princeton University, AT&T Labs - Research, Bell Laboratories, Bellcore, and NEC Research. Research at DIMACS focuses on such areas as analysis of algorithms, combinatorics, complexity, computational algebra, discrete and computational geometry, discrete optimization, graph theory, and outreach from discrete mathematics/theoretical computer science to such areas as molecular biology, statistical mechanics, and telecommunications. Recent Ph.D.s in all areas of theoretical computer science and discrete math are invited to apply. Most positions will be in special year and focus areas of Large Scale Discrete Optimization, Massive Data Sets, DNA Computing, Mathematical and Computational Support for Molecular Biology, and Simulations of Telecommunications Systems, and in particular in the new special year on Computational Intractability and the continuing special focus on Networks.

Most postdoctoral fellowships will be for one year and will be headquartered at Rutgers or Princeton. But several positions are planned for two years, with part of the time spent at a partner institution such as AT&T Labs or the Institute for Advanced Study. In particular, we are planning two 2-year postdoctoral fellowships jointly with AT&T Labs.

Postdoctoral Fellows conduct research and may collaborate with many visitors and permanent members at the partner sites. They are encouraged to participate in the research, outreach, and educational activities of the center.

Application Procedure: The Center's WWW site, `http://dimacs.rutgers.edu/Participation/`, contains full information about these postdoctoral positions and should be consulted for application information. Applications are due January 8, 1999, for full consideration.

DIMACS Center, Rutgers University, 96 Frelinghuysen Road, Piscataway, NJ 08854-8018; tel: 732-445-5928; e-mail: `postdoc@dimacs.rutgers.edu`.

DIMACS is an EO/AA Employer.

NEW MEXICO

NEW MEXICO STATE UNIVERSITY
Department of Mathematical Sciences

The Department invites applications for possible tenure-track and visiting positions in pure and applied mathematics

and statistics for academic year 1999–2000, with a priority for a tenure-track position in dynamical systems. Tenure-track appointments are expected to be at the assistant professor level. The Department has 31 tenure-track faculty members and offers B.S., M.S., and Ph.D. degrees. Applicants should demonstrate strong potential for success in both teaching and research.

A complete application consists of an introductory letter, the American Mathematical Society's application cover sheet (limited to one page), a curriculum vitae, and three letters of recommendation. The AMS form must clearly identify the candidate's research area and interest in tenure-track or visiting positions. The letters of recommendation should document abilities in both teaching and research.

For tenure-track positions, the applicant's letter, vita, and AMS form must be received by December 18. Letters of recommendation received by January 2 will be used in the screening process.

Application materials should be sent to: Hiring Committee, Department of Mathematical Sciences, New Mexico State University, Las Cruces, NM 88003.

NMSU is an Equal Opportunity/Affirmative Action Employer.

NEW YORK

YESHIVA UNIVERSITY

Yeshiva College, the small, selective, men's undergraduate college of Yeshiva University, seeks a full-time, tenure-track assistant professor in mathematics beginning fall 1999. Ph.D. is required; teaching experience at the postdoctoral level is preferred. All fields will be considered. A strong commitment to excellence in undergraduate education and the ability to work well with others in a small department is essential. Send vita and three letters of recommendation on teaching and research to: Mathematics Search Committee, Office of the Dean, Yeshiva College, 500 West 185th Street, New York, NY 10033. EO Employer. Women and minorities are encouraged to apply.

NORTH CAROLINA

DUKE UNIVERSITY
Lecturer

Applications are invited for one position as Lecturing Fellow in the Department of Mathematics at Duke University. Candidates should have completed a doctorate as of September 1, 1999; have excellent teaching credentials; and have a strong interest in curriculum development.

The teaching load will be six hours per week per semester. In addition, Lecturing Fellows are expected to participate in the Department's ongoing revision of laboratory calculus and to continue their own research program in mathematics. Duke University is an Affirmative Action/Equal Opportunity Employer.

The appointment is for two years and is not renewable. The 9-month salary will be $36,000, covering work in the regular two-semester year.

Applicants please send (a) a vita, (b) a teaching statement and a description of any experience in curriculum development, (c) a description of current and past research (1–3 pages), and (d) a plan for future research. The AMS Standard Cover Sheet should be completed electronically from the address below. Each applicant is requested to include in their materials the name(s) of one or more members of the faculty of the Department of Mathematics at Duke working in their general area of research.

Applications should include at least three letters of recommendation, including two which evaluate teaching, sent directly to Duke by mid-January. All correspondence, including references, but NOT AMS cover sheet, should be addressed to:

Lecturer Committee
Department of Mathematics
Box 90320
Duke University
Durham, NC 27708-0320

AMS cover sheets should be completed at `http://www.phds.org/`. E-mail inquiries: `appts@math.duke.edu`.

DUKE UNIVERSITY
Assistant Research Professorship of Mathematics

Applications are invited for two positions as assistant research professor of mathematics. Candidates should have completed a doctorate as of September 1, 1999, and should show definite promise in research and teaching. The teaching load will be two courses during one semester and one course during the other, so that the appointee will have additional time for research. Duke University is an Affirmative Action/Equal Opportunity Employer.

The appointments are for one year and will be renewable for two additional years. The salary will be $39,000 covering work in the regular two-semester year.

Applicants please send (a) a vita, (b) a description of current and past research (1–3 pages), (c) a plan for future research. The AMS Standard Cover Sheet should be completed electronically from the address below. Each applicant is requested to include in their materials the name(s) of one or more members of the faculty of the Department of Mathematics at Duke working in their general area of research.

Applications should be filed by December 20; early application is advisable. The applicant should have at least three letters of recommendation, including one which evaluates teaching, sent directly to Duke by mid-January. All correspondence, including references, but NOT AMS cover sheet, should be addressed to:

Appointments Committee
Department of Mathematics
Box 90320
Duke University
Durham, NC 27708-0320

AMS cover sheets should be completed at `http://www.phds.org/`. E-mail inquiries: `appts@math.duke.edu`.

DUKE UNIVERSITY
Assistant or Associate Professorship in Mathematics

Applications and nominations are invited for a tenure-track position as assistant professor or associate professor (possibly with tenure) in probability; there may also be a position in geometry/number theory. Salary is open; the position is to start September 1, 1999. Duke University is an Affirmative Action/Equal Opportunity Employer.

Applicants please send (a) a vita, (b) a description of current and past research (1–3 pages), (c) a plan for future research. The AMS Standard Cover Sheet should be completed electronically from the address below.

Applications should be filed by December 15; early application is advisable. The applicant should have at least three letters of recommendation, including one which evaluates teaching, sent directly to Duke by mid-January. All correspondence, including references, but NOT AMS cover sheet, should be addressed to:

Faculty Search Committee
Department of Mathematics
Box 90321
Duke University
Durham, NC 27708-0321

AMS cover sheets should be completed at `http://www.phds.org/`. E-mail inquiries: `appts@math.duke.edu`.

UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL
Department of Mathematics

We invite applications for a three-year, nonrenewable research assistant professorship effective fall 1999. Applicants must have a recent Ph.D. in an area of pure mathematics which is currently represented in the department. A strong research potential and a commitment to quality teaching is required. The teaching load is three courses per year.

Send a curriculum vitae, abstract of current research, statement of teaching goals, and four letters of recommendation to: Research Assistant Professor Search, Dept. of Mathematics, CB #3250 Phillips Hall, UNC-Chapel Hill, Chapel Hill, NC 27599-3250. A copy of this ad may be found on our Web site at `http://www.math.unc.edu/General/Job.announcements/`. Further information about the Mathematics Dept.

may be found at our Web site, http://www.math.unc.edu/. EO/AA Employer. Women and minorities are encouraged to apply and to identify themselves. Applications received by January 15 are assured of full consideration.

WAKE FOREST UNIVERSITY
Department of Mathematics and Computer Science

Applications are invited for a tenure-track position at the assistant professor level beginning August 1999. Duties include teaching statistics, operations research, and modeling at the undergraduate level, teaching in one of these areas at the graduate level, and continuing research. A Ph.D. in statistics, mathematics, or operations research is required. Leadership and participation in the departmental major in mathematical business is required; this is a joint major with the School of Business and Accountancy. Research areas of interest include optimization, mathematical statistics, regression and time series analysis, categorical data analysis, game theory, modeling, and other areas of operations research, statistics, or applicable mathematics. Women and minorities are encouraged to apply. The department has 25 members and offers a B.S. and M.A. in mathematics, a B.S. and M.S. in computer science, and a B.S. in each of mathematical business and mathematical economics. Send a letter of application and résumé to: Richard D. Carmichael, Chair, Department of Mathematics and Computer Science, Wake Forest University, Box 7388, Winston-Salem, NC 27109-7388. AA/EO Employer.

OHIO

CASE WESTERN RESERVE UNIVERSITY
Faculty Positions in Mathematics

The Department of Mathematics anticipates making appointments at the tenure-track and visiting levels beginning August 1999.

Case Western Reserve University is a private research university with, in addition to a school of arts and sciences, schools of medicine, business, engineering, and other areas that interact with the Department. Current research interests of the Department include both core and applied mathematics in areas of algebra, analysis, differential equations/dynamical systems, geometry, probability, numerical and computational mathematics, imaging reconstruction and analysis, theoretical computer science, and certain areas of modeling. The Department also seeks to expand its undergraduate majors program. Candidates in all fields of mathematics will be considered, with particular interest in those fields that fit in well with the current state of mathematics at CWRU; we are also interested in candidates who demonstrate an ability to apply mathematics to problems arising from other disciplines.

Required: Ph.D. in mathematics and exceptional promise, with accomplishments commensurate with experience in research and teaching. A complete application should contain AMS cover sheet, letter of application (including e-mail address and fax number), curriculum vitae, and relevant (p)reprints. Candidates should also have three letters of recommendation sent.

Mail all materials to: James Alexander, Chair, Department of Mathematics, Case Western Reserve University, Cleveland, OH 44106-7058. No e-mail or fax applications will be accepted. Screening and processing applications will begin December 15; however, applications will be accepted until positions are filled.

CWRU is an Affirmative Action/Equal Opportunity Employer.

THE OHIO STATE UNIVERSITY
Department of Mathematics

The Department of Mathematics of the Ohio State University expects to have available at least one tenure-track/tenured position and several visiting positions, effective autumn quarter 1999. Candidates in all areas of pure and applied mathematics are invited to apply. The Department will also have available several Hans J. Zassenhaus Assistant Professorships and Arnold Ross Assistant Professorships. These term positions are renewable annually up to a total of three years. Significant mathematical research accomplishments or exceptional promise and evidence of excellent teaching ability are required.

Please send a CV and at least three letters of recommendation to: Professor Peter March, Chair, Department of Mathematics, The Ohio State University, 231 W. 18th Avenue, Columbus, Ohio 43210.

The Ohio State University is an Equal Opportunity/Affirmative Action Employer. Women and minority candidates are encouraged to apply.

OKLAHOMA

OKLAHOMA STATE UNIVERSITY
Department of Mathematics

The Department anticipates the availability of three tenure-track assistant professor positions beginning fall 1999. Applicants should have demonstrated outstanding research potential and have made major contributions beyond their doctoral research. Duties include a blend of research and teaching, and all applicants should have a commitment to excellence in undergraduate and graduate education; the usual teaching load is 5 or 6 hours each semester. The Department has several research groups, and preference will be given to applicants whose research interests relate to one or more of these groups or to applied mathematics.

The Department also invites applications for several temporary postdoctoral positions beginning fall 1999. These positions are for new or recent recipients of the Ph.D. and are a one-year appointment with possibility of renewal. Applications are welcome from individuals who have held postdoctoral positions; an appointment to one of these positions does not exclude an individual from future consideration for a tenure-track position. The duties incorporate a blend of research and teaching; the usual teaching load is 5 or 6 hours each semester. Mathematicians with research interest close to a member of the regular faculty or in applied mathematics will receive preference.

All applicants should submit a curriculum vitae, abstracts of completed research, a statement regarding teaching experience and philosophy, and four letters of recommendation to the address below. One letter of recommendation should address the applicant's teaching experience. Applicants should use the AMS standardized form—Academic Employment in Mathematics, Application Cover Sheet—and indicate their subject area using the AMS subject classification numbers. Full consideration will be given to those applications received by December 15, 1998; however, all applications will be given consideration until the available positions are filled. Electronic applications are encouraged; information and instructions for electronic applications can be found on our Web page: http://www.math.okstate.edu/~jobs/.

Oklahoma State University is located in Stillwater, a town of approximately forty thousand in north central Oklahoma. The Department boasts a very dynamic faculty with 32 members successfully engaged in mathematics research and education. An active Ph.D. program, support for colloquium and other visitors, approximately 8–10 postdoctoral fellows, as well as involvement of undergraduates in research experiences add to the lively and scholarly atmosphere of the Department. The Department has received national recognition for the research of its faculty and for the faculty's contributions to mathematical education. More information on the Department and the University can be obtained through our Web page: http://www.math.okstate.edu/.

Oklahoma State University is an Equal Opportunity/Affirmative Action Employer. Women and minorities are encouraged to apply.

Prof. Jim Cogdell, Chair
Appointments Committee
Department of Mathematics
401 Math Science
Oklahoma State University
Stillwater, OK 74078-1058

THE UNIVERSITY OF OKLAHOMA
Department of Mathematics

Applications are invited for one full-time, tenured-track position beginning August 16, 1999. The position is initially budgeted at the assistant professor level, but an appointment at the associate professor level may be possible for an exceptional candidate with qualifications and experience appropriate to that rank. Normal duties consist of teaching two courses per semester, conducting research, and rendering service to the Department, University, and profession at a level appropriate to the faculty member's experience. The position requires an earned doctorate and research interests that are compatible with those of the existing faculty; preference will be given to applicants with potential or demonstrated excellence in research and prior successful undergraduate teaching experience. Salary and benefits are competitive. For full consideration, applicants should send a completed AMS cover sheet, curriculum vitae, a description of current and planned research, and three letters of recommendation (at least one of which must address the applicant's teaching experience and proficiency) to:

Search Committee
Department of Mathematics
University of Oklahoma
601 Elm, Phsc 423
Norman, OK 73019
Tel: 405-325-6711
Fax: 405-325-7484
e-mail: search@math.ou.edu

Screening of applications will begin on December 15, 1998, and will continue until the position is filled.

The University of Oklahoma is an Equal Opportunity/Affirmative Action Employer. Women and minorities are encouraged to apply. OU has a policy of being responsive to the needs of dual-career couples.

OREGON

UNIVERSITY OF OREGON

Applications are being accepted for a two-year postdoctoral position in mathematics or mathematical statistics beginning September 1999. This is a research position with a reduced teaching load. Qualifications are a Ph.D. in mathematics or mathematical statistics, research accomplishment, and evidence of teaching ability. Preference will be given to candidates with research interests that complement those currently represented. Competitive salary and excellent fringe benefits. Send complete résumé and three letters of recommendation to: Hiring Committee, Mathematics Department, 1222 University of Oregon, Eugene, OR 97403-1222. Closing date is January 15, 1999. Women and minorities are encouraged to apply. An EO/AA/ADA Institution committed to cultural diversity.

PENNSYLVANIA

GETTYSBURG COLLEGE
Mathematics

Gettysburg College invites applications for a tenure-track assistant professor position in mathematics beginning August 1999. A Ph.D. in mathematics, promise of excellence in teaching, and a commitment to continued scholarship are essential. Applicants are expected to have a strong interest in undergraduate teaching and a desire to involve undergraduate students in their research programs.

Gettysburg College is a highly selective liberal arts college located within 90 minutes of the Baltimore-Washington area. Established in 1832, the College has a rich history and is situated on a 220-acre campus with an enrollment of 2,200 students.

Send letter of application, curriculum vitae, and statements of teaching philosophy and scholarship goals in a liberal arts environment to: Mathematics Search Committee, Department of Mathematics and Computer Science, Gettysburg College, Gettysburg, PA 17325. Do not send additional information, including letters of recommendation, with your application.

The College also invites applications for 2 one-year sabbatical replacement positions in mathematics. Please indicate in your letter the position(s) for which you wish to be considered.

Applications received by January 15, 1999, will receive full consideration; applications received after this deadline may be considered until the positions are filled.

The College seeks to promote diversity in its community through its Affirmative Action/Equal Opportunity programs; included in an attractive benefits package is a Partner Assistance Program.

MUHLENBERG COLLEGE
Mathematical Sciences Department

Full-time tenure-track position beginning August 1999. Duties include teaching undergraduate mathematics courses at all levels, three courses per semester. Although teaching is the highest priority at Muhlenberg, professional activity and service to the College are also required. Doctorate in mathematical sciences required. Teaching excellence must be documented. Full-time teaching experience at the college level preferred. Candidates should have knowledge and experience in the calculus reform movement and be familiar with the use of technology in the classroom. The Department offers B.S. degrees in mathematics and computer science. The College is an independent, undergraduate, coeducational liberal arts institution. Located in the picturesque Lehigh Valley, just south of the Pocono Mountains, the College is within easy driving distance of both New York City and Philadelphia. To apply, submit résumé; statement detailing teaching experience, research, and educational philosophy; and three letters of recommendation to: Dr. John Meyer, Search Chair, Mathematical Sciences Department, Muhlenberg College, Allentown, PA 18104-5586. Application review begins immediately and will continue until the position is filled. EOE. Visit our Web site at http://www.muhlenberg.edu/.

TENNESSEE

THE UNIVERSITY OF TENNESSEE AT CHATTANOOGA

The University of Tennessee at Chattanooga invites applications for the head of the Department of Mathematics. A Ph.D. in a mathematical science, at least five years of college mathematics teaching experience, and qualifications commensurate with the rank of associate professor or higher are required. Applicants should provide evidence of leadership in curriculum development, teaching, public service, and research/scholarly activities. In this primarily undergraduate institution, the faculty is expected to exhibit excellence in teaching while maintaining a strong commitment to research and public service. The mathematics department has 22 full-time faculty members, including a Chair of Excellence in Applied Mathematics. Located in a very scenic metropolitan area of over 450,000, UTC has a student enrollment of 8,500.

Send applications, including vita, names of at least five references, and supporting documents to: Chair of the Head Search Committee, Department of Mathematics, University of Tennessee at Chattanooga, 615 McCallie Ave., Chattanooga, TN 36403-2598; tel: 423-755-4545; fax: 423-755-4586; e-mail: MathHead-search@utc.edu. Screening of applicants' credentials will begin on January 4, 1999, and will continue until the position is filled. Women and minorities are encouraged to apply. UTC is an Equal Opportunity/Affirmative Action/Title VI& IX/Section 504/ADA/ADEA Institution.

UNIVERSITY OF TENNESSEE - KNOXVILLE

The Mathematics Department of the University of Tennessee seeks to fill two tenure-track assistant professorships: (1) in probability and stochastic processes, with preference shown to those candidates working in such areas of applied probability as communication networks, mathematical biology and genetics, and mathematical finance, and (2) in computational mathematics, with preference shown to those candidates pursuing new and innovative research in applications of computational mathematics to material sciences, biology, or finance. A Ph.D. is

required. Some postdoctoral experience is preferred, but not required. Substantial research promise as well as dedication to teaching are paramount. Employment begins August 1, 1999.

Interested applicants should arrange to have a vita, three reference letters, a research statement (including abstracts), and evidence of quality teaching sent to Professor John B. Conway, Probability Search or Computational Math Search, (whichever applies), Mathematics Department, University of Tennessee, Knoxville, TN 37996-1300. Electronic applications are not acceptable. Use of the recent AMS application form is appreciated. Review of applications will begin December 1 and will continue until the position is filled. Information about the Department can be found at `http://www.math.utk.edu/`.

UTK is an EEO/AA/Title VI/Title IX/Section 504/ADA/ADEA Employer.

VANDERBILT UNIVERSITY
Department of Mathematics

We expect openings in geometric topology and geometric group theory beginning fall 1999. Applications are invited from outstanding candidates at all levels. Definite promise in research for a tenure-track appointment, a record of exceptional scientific achievement for a tenured appointment, and evidence of effective teaching in either case are required. To apply, send the following materials in a single mailing by January 15, 1999: letter of application (including e-mail address and fax number), curriculum vitae, and research summary. Do not send additional information (including letters of recommendation) unless requested to do so after the initial screening.

Contact Person: Bruce Hughes, 1326 Stevenson Center, Nashville, TN 37240

Vanderbilt University is an Affirmative Action/Equal Opportunity Employer.

VANDERBILT UNIVERSITY
Department of Mathematics

We expect several non-tenure-track openings at the assistant professor level beginning fall 1999. These are two-year appointments, normally renewable for a third year. They are intended for recent Ph.D. recipients with demonstrated research potential and a strong commitment to excellence in teaching who would like to spend time in a department with a vigorous research atmosphere. To apply, send the following materials in a single mailing to the contact person in your area of research by December 15, 1998: letter of application (including e-mail address and fax number), curriculum vitae, and research summary. Do not send additional information (including letters of recommendation) unless requested to do so after the initial screening.

Contact Persons: Mark Ellingham (graph theory and combinatorics), Douglas Hardin (analysis and applied analysis), Bruce Hughes (geometry and topology), Larry Schumaker (computational mathematics), Steven Tschantz (algebra and logic). Address: 1326 Stevenson Center, Nashville, TN 37240. Application Deadline: December 15, 1998.

Vanderbilt University is an Affirmative Action/Equal Opportunity Employer.

TEXAS

BAYLOR UNIVERSITY

The Department of Mathematics invites applications for a tenure-track position at the assistant professor level starting in August 1999. Excellence in teaching and research/scholarship is essential.

A current curriculum vitae, three recent letters of reference, copies of all official transcripts, and a professional statement must be included in an application. Applications will be reviewed beginning November 1, 1998, and will be accepted until the position is filled. To ensure full consideration, an application should be received by January 4, 1999.

Baylor is a Baptist university affiliated with the Baptist General Convention of Texas. As an Affirmative Action/Equal Employment Employer, Baylor encourages minorities, women, veterans, and persons with disabilities to apply. The University offers generous benefits, including tuition remission for qualified family members. Send all materials to: Mathematics Search Committee, P. O. Box 97328, Waco, TX 76798-7328; e-mail address: `Ed_Oxford@baylor.edu`.

RICE UNIVERSITY

Griffith Conrad Evans Instructorships postdoctoral appointments for two to three years for promising research mathematicians with research interests in common with the active research areas at Rice, particularly geometric topology, geometric analysis, differential geometry, wavelets, combinatorics, and ergodic theory. Duties will include research and classroom teaching. Applications received by December 31, 1998, will receive full consideration. Rice University is an Equal Opportunity/Affirmative Action Employer and strongly encourages applications from women and minority group members. Inquiries and applications should be addressed to: Chair, Evans Committee, Department of Mathematics, Rice University, P.O. Box 1892, Houston, TX 77251-1892. Submitting the AMS application cover sheet (available in *Notices*, EIMS or e-MATH) would be greatly appreciated.

SOUTHERN METHODIST UNIVERSITY
Department of Mathematics

Applications are invited for two tenure-track assistant professor positions to begin in the fall semester of 1999. Applicants must provide evidence of outstanding potential for research in applied mathematics and a strong commitment to teaching at all levels. The Department of Mathematics has an active doctoral program in applied mathematics, specializing in physical applied mathematics, numerical mathematics, and scientific computation. Research interests include fluid mechanics, nonlinear dynamics and the computational aspects of ordinary and partial differential equations. For one position, preference will be given to candidates whose research has an applied component related to industrial applications and/or to other sciences or engineering. The second position is open to any applied mathematician whose research is closely related to the current interests in the Department.

To apply, send a letter of application with a curriculum vitae, a list of publications, a research statement, and a teaching statement to: The Faculty Search Committee, Department of Mathematics, Southern Methodist University, P. O. Box 750156, Dallas, TX 75275-0156. Applicants must also arrange for three letters of recommendation to be forwarded to the Faculty Search Committee.

The committee will begin its review of the applications on or about January 5, 1999. To ensure full consideration for the position, the application must be postmarked on or before January 5, 1999.

SMU is an Equal Opportunity/Affirmative Action/Title IX Employer.

Visit the Department's WWW site at `http://www.smu.edu/~math/`, and contact the Search Committee by sending e-mail to `mathsearch@mail.smu.edu`; tel: 214-768-2506; fax: 214-768-2355.

TEXAS TECH UNIVERSITY
Department of Mathematics and Statistics

Applications are invited for one or two tenure-track assistant professor positions beginning fall 1999. Highest priority will be given to candidates in statistics/biostatistics. Subject to availability of resources, consideration will also be given to candidates in numerical analysis or biomathematics. Applicants must possess a Ph.D. Strong promise in research and teaching is required. Please send a résumé and three letters of recommendation to: Alex Wang, Hiring Chair, Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409-1042. Review of applications will begin on December 15, 1998, and will continue until the positions are filled. Additional information is available at `http://www.math.ttu.edu/`

employ.html. Texas Tech is an AA/EO Employer.

THE UNIVERSITY OF TEXAS AT AUSTIN
Austin, TX 78712
Department of Mathematics

Openings for fall 1999 include: (a) instructorships, some of which have R. H. Bing Faculty Fellowships attached to them, and (b) two or more positions at the tenure-track/tenure level.

a) Instructorships at The University of Texas at Austin are postdoctoral appointments, renewable for two additional years. It is assumed that applicants for instructorships will have completed all Ph.D. requirements by August 31, 1999. Other factors being equal, preference will be given to those whose doctorates were conferred in 1998 or 1999. Candidates should show superior research ability and have a strong commitment to teaching. Consideration will be given only to persons whose research interests have some overlap with those of the permanent faculty. Duties consist of teaching undergraduate or graduate courses and conducting independent research. The projected salary is $35,000 for the nine-month academic year.

Each R. H. Bing Fellow holds an instructorship in the Mathematics Department, with a teaching load of two courses in one semester and one course in the other. The combined instructorship-fellowship stipend for nine months is $38,500, which is supplemented by a travel allowance of $1,000. Pending satisfactory performance of teaching duties, the fellowship can be renewed for two additional years. Applicants must show outstanding promise in research. Bing Fellowship applicants will automatically be considered for other departmental openings at the postdoctoral level, so a separate application for such a position is unnecessary.

Those wishing to apply for instructorship positions are asked to send a vita and a brief research summary to the above address c/o Instructor Committee. Transmission of the preceding items via e-mail (address: instructor@math.utexas.edu) is encouraged.

b) An applicant for a tenure-track or tenured position must present a record of exceptional achievement in her or his research area and must demonstrate a proficiency at teaching. In addition to the duties indicated above for instructors, such an appointment will typically entail the supervision of M.A. or Ph.D. students. The salary will be commensurate with the level at which the position is filled and the qualifications of the person who fills it.

Those wishing to apply for tenure-track/tenure positions are asked to send a vita and a brief research summary to the above address, c/o Recruiting Committee. Transmission of the preceding items via e-mail (recruit@math.utexas.edu) is encouraged.

All applications must be supported by three or more letters of recommendation, at least one of which speaks to the applicant's teaching credentials. The screening of applications will begin on December 1, 1998.

The University of Texas at Austin is an Equal Opportunity Employer.

UTAH

UTAH STATE UNIVERSITY
Head
Department of Mathematics and Statistics

Applications are invited for the position of head of the Department of Mathematics and Statistics at Utah State University.

Applicants should have a doctorate in mathematics or statistics, should qualify for a full professorship at USU, and should enjoy an outstanding and current record of research, excellent teaching credentials at the undergraduate and graduate levels, and an established record of university and professional service. Applicants must possess demonstrated administrative skills and leadership abilities necessary to promote the development of a growing department with diverse research, teaching, and service responsibilities and goals. A strong commitment to support scholarly activity in pure and applied mathematics, statistics, and mathematics education, and to undergraduate and graduate education is required.

Utah State University is a Carnegie I, Land-Grant institution with an enrollment of 16,000 undergraduate and 4,000 graduate students. The Department of Mathematics and Statistics offers the Ph.D. degree in mathematical sciences and various degree programs at the master's and bachelor levels. The Department has approximately 35 faculty members with research interests in pure mathematics, applied mathematics, mathematical physics, computational mathematics, mathematics education, and statistics.

Utah State University is located in Cache Valley, just north of the Wasatch Range of the Rocky Mountains. More information about the University and Department can be found at http://www.usu.edu/.

The committee will begin screening applications on December 15, 1998, and will continue until the position is filled. Send a letter of application; vita; telephone number and e-mail address; and a list of names, mailing addresses, and e-mail addresses of five references to:

Chairman, Screening Committee
Mathematics and Statistics Head
Utah State University
Logan, Utah 84322-3900

Two references should be able to evaluate administrative and leadership skills, and one reference should address teaching credentials. For further information, please direct inquiries to headsrch@math.usu.edu.

Utah State University is an Equal Opportunity/Affirmative Action Employer.

VIRGINIA

GEORGE MASON UNIVERSITY
Department of Mathematical Sciences

The Department expects to fill one tenure-track position, preferably at the assistant professor level in the fall of 1999. Successful candidates must demonstrate the potential to make significant contributions to both the B.S. and M.S. programs in either computational and applied mathematics or actuarial mathematics. Faculty teach at both the undergraduate and graduate levels, maintain active research programs, and pursue external funding opportunities. Faculty may also teach and supervise Ph.D. students in the interdisciplinary Institute for Computational Sciences and Informatics. Preference will be given to candidates whose research is compatible with current George Mason research.

Arrange for a vita, statements of teaching and research interests, and at least three letters of reference to be sent to: T. Kiley, Chair of Search Committee, Department of Mathematical Sciences, George Mason University, MS 3F2, 4400 University Drive, Fairfax, VA 22030-4444 (e-mail: tkiley@gmu.edu). To ensure consideration, apply before December 31, 1998; late applications will be accepted until the position is filled. George Mason University is an AA/EEO Employer. Women and minorities are encouraged to apply.

WEST VIRGINIA

WEST VIRGINIA UNIVERSITY
Eberly College of Arts and Sciences
Chair, Department of Mathematics

Applications and nominations are invited for the position of chair, starting July 1999. The Department of Mathematics seeks an innovative individual with strong interpersonal skills and proven administrative talent. The applicant should have professional credentials qualifying for appointment at the rank of associate or full professor; the ability to manage the diverse missions of the Department of Mathematics; and a commitment to excellence in the areas of teaching, research, and service.

West Virginia University is the Land Grant, Research I institution in the State of West Virginia, enrolling 23,500 students. The Department of Mathematics has 24 full-time faculty members and approximately 30 M.S. and Ph.D. students. The Department is housed in newly refurbished facilities, which include networked offices and the University's Mathematics Library. The University is located in Morgantown,

a city with a metropolitan population of about 50,000. Morgantown has a large federal research presence, diverse cultural and recreational opportunities, excellent medical facilities, and a favorable location with ready access to such areas as Pittsburgh, PA, and Washington, DC.

Applicants should provide a letter of application, a vita, and the names of five references. Applications, nominations, and inquiries should be sent to: Dr. George Trapp, Chair of the Search Committee, West Virginia University, Eberly College of Arts and Sciences, 201 Woodburn Hall, P.O. Box 6286, Morgantown, WV 26506-6286. Screening of applicants will begin on January 12, 1999.

West Virginia University is an Equal Opportunity/Affirmative Action Employer. Minorities, disabled, and women candidates are urged to apply.

CANADA

MEMORIAL UNIVERSITY OF NEWFOUNDLAND
St. John's, Newfoundland, Canada A1C 5S7
Department of Mathematics and Statistics

Applications are invited for a tenure-track senior position in algebra effective September 1, 1999, subject to availability of funds.

We are looking for an outstanding researcher in classical associative algebra and preferably in nonassociative algebra too. The successful candidate will be expected to maintain a vigorous and well-funded research program, to attract graduate students and postdoctoral fellows, and generally to enhance the reputation of this department's active algebra group. Excellence as a teacher and the ability to work well with students at both the graduate and undergraduate levels are requirements. Rank and salary depend upon qualifications and are subject to negotiation.

Applications, marked **REF: MS/SEN-ALG/99**, should include a curriculum vitae and a statement of current and proposed research. They should also include the names and mailing/e-mail addresses of four potential references who collectively are likely to provide a wide base of information about the applicant.

MS/SEN-ALG/99
Department of
Mathematics and Statistics
Memorial University of Newfoundland
St. John's, NF, Canada A1C 5S7

The closing date for receipt of applications is **December 31, 1998**.

Memorial University is committed to the principle of equity in employment. In accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and permanent residents. If suitable Canadian citizens or permanent residents cannot be found, other individuals will be considered.

Memorial University is part of a vibrant, local scientific and engineering community which maintains an inventory of available positions for qualified partners. Partners of candidates for these positions are invited to include their résumé for possible matching with other job opportunities.

UNIVERSITY OF OTTAWA

The Department of Mathematics and Statistics of the University of Ottawa invites applications from recent Ph.D.s for one tenure-track position at the assistant professor level beginning July 1, 1999. Applications in all areas of mathematics and statistics are invited. The department's priorities are modern applied mathematics and statistics. In accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and permanent residents. Applicants should send a curriculum vitae and three letters of recommendation to: Wulf Rossmann, Chairman, Department of Mathematics and Statistics, University of Ottawa, Ottawa, ON, Canada, K1N 6N5, by January 15, 1999. Conditions of employment are set by a collective agreement. Employment equity is University policy, and the University strongly encourages applications from women.

The University of Ottawa has a student population of over 25,000. It has a full range of academic and professional programs, several research institutes, and is near the federal government with all its agencies and laboratories. The region is home to Canada's biggest concentration of high-tech companies.

The Department of Mathematics and Statistics has 28 full-time faculty members, more than 80% of whom hold national research grants. Shared computing facilities (Sun, RS/6000) with mathematical and statistical software are available for the successful applicant. New tenure-track appointees begin with reduced teaching and administrative loads and usually receive a start-up grant. Please contact `http://www.uottawa.ca/science/mathstat/` for further information.

YORK UNIVERSITY
Department of Mathematics and Statistics
Faculty Position in Mathematics
Algebra

Subject to budgetary approval, applications are invited for a tenure-track appointment at the assistant professor level in the Department of Mathematics and Statistics, to commence July 1, 1999. Applicants must have a completed Ph.D. and proven teaching abilities. The successful candidate will be expected to have an established record of research excellence with a demonstrated ability to make significant, original, and independent contributions to a contemporary area of algebra or closely related areas such as algebraic geometry or algebraic number theory. The salary will be commensurate with experience and will be in the normal range for the assistant professor rank.

Applicants should send résumés and at least three letters of recommendation, to arrive before January 15, 1999, directly to: Alan Dow, Chair, Department of Mathematics and Statistics, York University, 4700 Keele Street, Toronto, Ontario, M3J 1P3, Canada; fax: (416) 736-5757; e-mail: `chair@mathstat.yorku.ca`; WWW: `http://www.math.yorku.ca/Hiring/`.

York University is implementing a policy of employment equity, including affirmative action for women faculty. The Department encourages applications from women, underrepresented minorities, First Nations, and persons with disabilities. In accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and permanent residents.

YORK UNIVERSITY
Department of Mathematics and Statistics
Faculty Position in Mathematics
Applied Differential Equations or Numerical Analysis

Applications are invited for a tenure-track appointment at the assistant professor level in the Department of Mathematics and Statistics in applied differential equations or numerical analysis or in an applications area related to one of these. The position is subject to budgetary approval and is to commence July 1, 1999. The successful candidate must have a Ph.D. and is expected to have a proven record of research and successful experience in teaching. Preference will be given to candidates who can make solid contributions to the graduate program and to those whose expertise could strengthen areas of present and ongoing research activity. The selection process will begin on January 29, 1999. Applicants should send résumés and three letters of recommendation (one of which should address teaching) directly to: Alan Dow, Chair, Department of Mathematics and Statistics, York University, 4700 Keele Street, Toronto, Ontario, M3J 1P3, Canada; fax: (416) 736-5757 or (416) 736-5730; e-mail: `chair@mathstat.yorku.ca`; WWW: `http://www.math.yorku.ca/Hiring/`.

York University is implementing a policy of employment equity, including affirmative action for women faculty. The Department encourages applications from women, underrepresented minorities, First Nations, and persons with disabilities. In accordance with Canadian immigration requirements, this advertisement is directed

to Canadian citizens and permanent residents.

UNIVERSITY OF ALBERTA
Department of Mathematical Sciences

The Department of Mathematical Sciences at the University of Alberta invites applications for two tenure-track positions starting July 1, 1999. The positions require a Ph.D. and will be initially considered at the assistant professor level with the salary range $40,638–$57,510.

Functional Analysis (FA-99): A position is available for an outstanding candidate in functional analysis. We are particularly interested in a mathematician working in operator spaces, with an emphasis on Banach space and C*-algebra aspects of the theory. Functional analysts in areas such as abstract harmonic analysis, geometric functional analysis, probabilistic methods in Banach spaces and in harmonic analysis will also be considered.

Postdoctoral Positions: One to three postdoctoral positions may be available within the areas of stochastic processes, scientific computation, partial differential equations, mathematical modeling, and inference. One or more postdoctoral positions may be available in statistics, generalized linear models, survival analysis, missing data analysis, and random effects models. These positions will be for one to two years, commencing any time between September 1998 and April 1999, with a competitive compensation package and a travel budget.

Applicants for all positions are expected to possess a strong research record, outstanding promise for future research, excellent communication skills and leadership potential. The successful candidate for tenure-track positions must have a commitment to graduate and undergraduate education in mathematical sciences. The Department of Mathematical Sciences has 64 faculty specializing in algebra, fluid dynamics, mathematical statistics, analysis, differential equations, stochastic processes, geometry, numerical analysis, and optimal statistical designs. For further information, please see `http://www.math.ualberta.ca/`.

In accordance with Canadian immigration requirements, priority will be given to Canadian citizens and permanent residents of Canada. If suitable Canadian citizens and permanent residents cannot be found, other individuals will be considered.

Applications should include a curriculum vitae, research plan, and a teaching profile outlining experience and/or interests. Candidates should arrange for at least three confidential letters of reference to be sent to:

S.D. Riemenschneider, Chair
Department of Mathematical Sciences
University of Alberta
Edmonton, Alberta T6G 2G1
Canada

The closing date for the tenure-track position is Friday, January 8, 1999. Postdoctoral applications will be considered on an ongoing basis. Early applications are encouraged.

The University of Alberta is committed to the principle of equity in employment. As an employer we welcome diversity in the workplace and encourage applications from all qualified men and women, including aboriginal peoples, persons with disabilities, and members of visible minorities.

University of Alberta
Department of Mathematical Sciences
Mathematical Finance Position (MF-99)

The Department of Mathematical Sciences, University of Alberta, invites applications for a tenure-track assistant professorship in mathematical finance with some expertise in actuarial science starting July 1, 1999. The position requires a Ph.D. and will be initially considered at the assistant professor level with the salary range $40,638–$57,510.

The successful candidate must be able to teach graduate courses on the modelling of the term structure of interest rates and on the mathematics of derivative securities. Moreover, the successful candidate must be willing to teach undergraduate courses in actuarial mathematics. Expertise in the areas of probability theory, stochastic analysis, stochastic differential equations, point processes, or stochastic control is highly desirable.

Applicants are expected to possess a strong research record, outstanding promise for future research, excellent communication skills, and leadership potential. The successful candidate must have a commitment to graduate and undergraduate education in mathematics and statistics. The Department of Mathematical Sciences has 64 faculty specializing in algebra, fluid dynamics, mathematical statistics, analysis, differential equations, stochastic processes, geometry, numerical analysis, and optimal statistical designs. For further information, please see `http://www.math.ualberta.ca/`.

Applications should include a curriculum vitae, research plan, and a teaching profile outlining experience and/or interests. Candidates should arrange for at least three confidential letters of reference to be sent to:

S.D. Riemenschneider, Chair
Department of Mathematical Sciences
University of Alberta
Edmonton, Alberta T6G 2G1
Canada

Closing date for applications is Friday, January 8, 1999, or until a suitable candidate is found. Early applications are encouraged.

Postdoctoral Positions: One to three postdoctoral positions may be available within the areas of stochastic processes, scientific computation, partial differential equations, mathematical modeling, and inference. One or more postdoctoral positions may be available in statistics, generalized linear models, survival analysis, missing data analysis, and random effects models. These positions will be for one to two years, commencing any time between September 1998 and April 1999, with a competitive compensation package and a travel budget. Applications will be considered on an ongoing basis.

The University of Alberta is committed to the principle of equity in employment. As an employer we welcome diversity in the workplace and encourage applications from all qualified women and men, including aboriginal peoples, persons with disabilities, and members of visible minorities.

SWEDEN

THE ROYAL SWEDISH
ACADEMY OF SCIENCES
INSTITUT MITTAG-LEFFLER
Call for Proposals

The board of the Mittag-Leffler Institute invites proposals for the scientific program of the academic year Sept 1, 2001–May 31, 2002.

The Institute runs programs in specialized areas of mathematics to which leading scientists in the area are invited. In a concurrent junior visiting program, post-docs and advanced graduate students are invited to participate. The programs can run for the whole year or be of semester length. Around ten senior visitors are in residence at any given time. The minimum length of stay is one month, and it is expected that two or three leading mathematicians will stay for at least a semester each.

The selection criteria for proposals are scientific strength and timeliness and the degree to which the program would benefit mathematical research in Scandinavia, including Finland and Iceland.

Recent and future programs include: 1996/97, Enumerative Geometry and Its Interaction with Theoretical Physics; 1997/98, Computational Methods of Differential Equations; 1998/99, Topology and Geometry of Quantum Fields; 1999/00, Potential Theory and Nonlinear Partial Differential Equations; 2000/01, Mathematical Logic. A complete list can be found at `http://www.ml.kva.se/history.html`.

The scientific programs are led by a steering committee of 2–4 persons who will work closely with the director and who will suggest invitees to the board. It is expected that at least one member of the committee will be present at all times during the period of the program.

The Institute is housed in a patrician 19th-century villa in a suburb of Stockholm. Visitors are housed on the grounds.

Proposals should contain: a description of the intended area of specialization; the names of the proposed committee; a list of suggested invitees, most of whom should have indicated an interest in the program and a willingness to participate; and a description of the Scandinavian connection.

Proposals should be sent to:
The Board
Institut Mittag-Leffler
Auravägen 17
S-182 62 Djursholm, Sweden

The deadline for applications is **February 28, 1999**.

For further information, consult the Institute's home page: `http://www.ml.kva.se/`, or contact the director, Professor Kjell-Ove Widman, at `widman@ml.kva.se`.

TAIWAN

TSING HUA UNIVERSITY
Mathematics Division
National Center for Theoretical Sciences
Postdoctoral/Visiting Positions

The National Center for Theoretical Sciences (NCTS) is a new center in Taiwan inteded to promote research in major areas of mathematics and theoretical physics. It is supported by a special grant from the National Science Council of the Republic of China. Various activities—workshops, advanced schools, and topical programs—are taking place at this center, sited at Tsing Hua University. Special topics chosen for the year 1998/99 are Dynamical Systems, Geometric Analysis, Number Theory and Discrete Mathematics.

The members of the center consist of center scientists, visiting scientists, and postdocs. We are expecting to offer several postdoctoral positions starting in fall 1999. These can be either one-year or two-year appointments. Junior mathematicians who are interested in applying for our postdoctoral positions should send curriculum vitae, three letters of reference, research plans, and reprints/preprints, or their enquiries to: National Center for Theoretical Sciences, Tsing Hua University, Hsinchu, Taiwan 30043; e-mail: `cts@math.nthu.edu.tw`; home page: `http://www.math.nthu.edu.tw/~cts/`.

The deadline for applications is March 1, 1999.

SERVICES AVAILABLE

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DocuTEXing is a high-quality TEX typesetting facility for mathematical journals and monographs. Our services also include HTML coding, reference validation, and illustrations. We can see an electronic journal through from start to finish. For more information, samples, and references, please e-mail `mainoffice@DocuTeXing.com` or visit `http://www.DocuTeXing.com/`.

PUBLICATIONS WANTED

MATHEMATICS BOOKS PURCHASED

Pure & appl. adv. & research level, any age, usable cond. Reprints OK. One box to whole libraries sought. Contact: Collier Brown or Kirsten Berg @ **Powell's Technical Bks.**, Portland, OR. Call 800-225-6911, fax 503-228-0505, or e-mail: `kirsten@technical.powells.com`.

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Meetings & Conferences of the AMS

PROGRAM ALERT: In order that AMS meeting programs include the most timely information for each speaker, abstract deadlines have been moved to dates much closer to the meeting. What this means is that most meeting programs will appear in the *Notices* ***after*** the meeting takes place. However, complete meeting programs will be available on e-MATH about two to three weeks after the abstract deadline. ***Remember***, e-MATH is your most comprehensive source for up-to-date meeting information. See `http://www.ams.org/meetings/`.

Winston-Salem, North Carolina

Wake Forest University

October 9–10, 1998

Meeting #936

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: August 1998
Program issue of *Notices*: December 1998
Issue of *Abstracts*: Volume 19, Issue 3

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

State College, Pennsylvania

Pennsylvania State University

October 24–25, 1998

Meeting #937

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: August 1998
Program issue of *Notices*: January 1999
Issue of *Abstracts*: Volume 19, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Tucson, Arizona

University of Arizona, Tucson

November 13–15, 1998

Meeting #938

Western Section
Associate secretary: Robert M. Fossum
Announcement issue of *Notices*: September 1998
Program issue of *Notices*: January 1999
Issue of *Abstracts*: Volume 19, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

San Antonio, Texas

Henry B. Gonzales Convention Center

January 13–16, 1999

Meeting #939

Joint Mathematics Meetings, including the 105th Annual Meeting of the AMS, 82nd Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL).
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: October 1998
Program issue of *Notices*: January 1999
Issue of *Abstracts*: Volume 20, Issue 1

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired
For summaries of papers to MAA organizers: Expired

MAA Sessions

Legacy of R.L. Moore Project, Thursday, Friday, and Saturday, organized by **Albert C. Lewis**, Indiana University-Purdue University; **Ben G. Fitzpatrick**, North Carolina State University; and **Donald J. Albers**, MAA. This project was established at the Center of American History at the University of Texas at Austin to help advance studies of the mathematician and teacher of mathematics, Robert Lee Moore (1882–1974, and president of the AMS in 1938). The focus of this multi-day session is to promote the study of effective methods of learning and teaching at all educational levels and in all subjects.

What Math Do Teachers Need to Know?, Friday, 1:00 p.m.-2:30 p.m., moderated by **W. James Lewis**, University of Nebraska, and chair of the CBMS MET Project. The CBMS Mathematics Education of Teachers (MET) Project is a collaborative effort of the mathematics community to define the knowledge, skills, and perspectives that teachers need in order to prepare students to achieve at high levels. The panel will discuss progress to date and seek ideas about what is important.

Other Organizations

Association for Symbolic Logic
Invited Addresses will be given by **Michael Benedikt**, AT&T Bell Labs; **Chris Laskowski**; **Steffen Lempp**, University of Wisconsin, Madison; **William Mitchell**; **Anand Pillay**, University of Illinois; and **Robert Soare**, University of Chicago. In addition, talks will be given by **Geoffrey LaForte**, Victoria University; **Slawomir J. Solecki**, UCLA; and **Reed Solomon**. There will also be sessions for contributed papers.

Association for Women in Mathematics
The AWM panel discussion on Wednesday afternoon is titled *The Education of Women in Mathematics: An International Perspective.*

The AWM panel discussion to be held during the workshop on Saturday, from 12:30 p.m. to 2:00 p.m., is titled *Launching a Career in Mathematics.* The workshop is open to all participants.

Corollary Conference

American Statistical Association (ASA)
The American Statistical Association will hold two LearnSTAT courses prior to the Joint Mathematics Meetings. Both courses will take place at the University of Texas at San Antonio. For more information, including how to register, please send e-mail to Sue Kulesher (sue@amstat.org) at the ASA. The two courses are:
Teaching Introductory Statistics with Simulation/Resampling by **Peter C. Bruce**, codeveloper of the software Resampling Stats. This course will take place on Sunday, January 10, 1999, and cover simulation/resampling solutions to problems involving count and measured data with hands-on computer work.

Teaching Contemporary Statistics with Active Learning by **Allan Rossman**, Dickinson College, and **Beth Chance**, University of the Pacific. This course will take place on Monday and Tuesday, January 11 and 12, and is designed for mathematicians and others who teach courses in introductory statistics but have little recent training.

Gainesville, Florida

University of Florida

March 12–13, 1999

Meeting #940

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: January 1999
Program issue of *Notices*: To be announced
Issue of *Abstracts*: Volume 20, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: November 25, 1998
For abstracts: January 20, 1999

Invited Addresses

Alexander N. Dranishnikov, University of Florida, *Title to be announced.*

Gregory F. Lawler, Duke University, *Title to be announced.*

Michael P. Loss, Georgia Institute of Technology, *Title to be announced.*

John G. Thompson, University of Florida, *Title to be announced.*

Special Sessions

Algebraic and Geometric Combinatorics (Code: AMS SS P1), **Andrew J. Vince** and **Neil L. White**, University of Florida.

Analytical Problems in Mathematical Physics (Code: AMS SS M1), **Eric A. Carlen**, Georgia Institute of Technology, and **Laszlo Erdos**, Courant Institute, NYU.

Computability Theory (Code: AMS SS G1), **Douglas Cenzer**, University of Florida, **Geoffrey Louis LaForte**, University of West Florida, and **Rick L. Smith**, University of Florida.

Continuum Theory and Dynamical Systems (Code: AMS SS A1), **Philip Boyland** and **Beverly Brechner**, University of Florida, and **John Mayer**, University of Alabama at Birmingham.

Ergodic Theory and Dynamical Systems (Code: AMS SS R1), **Jonathan L. F. King**, University of Florida.

Finite Groups and Their Representations (Code: AMS SS D1), **Alexandre Turull**, University of Florida.

Galois Theory (Code: AMS SS E1), **J. G. Thompson** and **H. Voelklein**, University of Florida.

Geometric Topology (Code: AMS SS H1), **James E. Keesling** and **Alexander N. Dranishnikov**, University of Florida.

Geometry of Interacting Particles, Random Walks, and Brownian Motion (Code: AMS SS N1), **Irene Hueter**, University of Florida, and **Gregory F. Lawler**, Duke University.

Groups and Geometries (Code: AMS SS F1), **Chat Ho** and **Peter Sin**, University of Florida.

Linear Operator Theory (Code: AMS SS J1), **Leiba Rodman**, College of William & Mary, and **Scott A. McCullough**, University of Florida.

Markov Processes and Potential Theory (Code: AMS SS C1), **Joe Glover** and **Murali Rao**, University of Florida.

Partial Differential Equations and Applications (Code: AMS SS K1), **Gang Bao** and **Yun-mei Chen**, University of Florida.

Probability on Algebraic Structures (Code: AMS SS Q1), **Gregory M. Budzban** and **Philip Feinsilver**, Southern Illinois University at Carbondale, and **Arunava Mukherjea**, University of South Florida.

Structure and Representation Theory of Lattice-Ordered Groups and f-Rings (Code: AMS SS L1), **Jorge Martinez**, University of Florida.

The Erdős Legacy and Connections to Florida (Code: AMS SS B1), **Krishnaswami Alladi** and **Jean Larson**, University of Florida.

Urbana, Illinois

University of Illinois, Urbana-Champaign

March 18–21, 1999

Meeting #941

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: January 1999
Program issue of *Notices*: To be announced
Issue of *Abstracts*: Volume 20, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: December 2, 1998
For abstracts: January 27, 1999

Invited Addresses

Alexander Beilinson, MIT, *Title to be announced.*

Alexandra Bellow, Northwestern University, *Title to be announced.*

Igor Krichever, Columbia University, *Title to be announced.*

Steven Rallis, Ohio State University, *Title to be announced.*

Trevor Wooley, University of Michigan, *Title to be announced.*

Special Sessions

Algebraic K-Theory (and the 5th Annual Great Lakes K-Theory Conference) (Code: AMS SS H1), **Daniel Grayson**, University of Illinois-Urbana.

Combinatorial Designs (Code: AMS SS M1), **Ilene H. Morgan**, University of Missouri, Rolla, and **Walter D. Wallis**, Southern Illinois University, Carbondale.

Commutative Algebra (Code: AMS SS P1), **Joseph Brennan**, North Dakota State University, and **Sankar Dutta**, **Robert Fossum**, and **Phillip Griffith**, University of Illinois, Urbana.

Diophantine Equations, Inequalities and Related Arithmetic Problems (Code: AMS SS F1), **Michael Bennett**, University of Illinois, Urbana, and **Trevor Wooley**, University of Michigan.

Elementary and Analytic Number Theory (Code: AMS SS E1), **Harold G. Diamond** and **A. J. Hildebrand**, University of Illinois, Urbana.

Galois Representations (Code: AMS SS C1), **Nigel Boston**, University of Illinois, Urbana, and **Michael Larsen**, University of Missouri.

Graph Theory (Code: AMS SS G1), **Douglas B. West**, University of Illinois, Urbana.

Holomorphic Vector Bundles and Complex Geometry (Code: AMS SS L1), **Maarten Bergvelt**, **Steven Bradlow**, and **John P. D'Angelo**, University of Illinois, Urbana, and **Lawrence Ein**, University of Illinois, Chicago.

Integrable Equations (Code: AMS SS I1), **Igor Krichever**, Columbia University, and **Kirill Vaninsky**, Kansas State University.

Low-dimensional Topology (Code: AMS SS O1), **Mark Brittenham**, University of North Texas, **Charles Delman**, Eastern Illinois University, and **Rachel Roberts**, Washington University.

Martingales and Analysis (Code: AMS SS D1), **Joseph Max Rosenblatt**, **Renming Song**, and **Richard B. Sowers**, University of Illinois, Urbana.

Nonstandard Analysis (Code: AMS SS B1), **C. Ward Henson** and **Peter Loeb**, University of Illinois, Urbana.

Operator Spaces and Their Applications (Code: AMS SS J1), **Gilles Pisier**, Texas A&M, and **Zhong-Jin Ruan**, University of Illinois, Urbana.

Optimization Problems in Geometry (Code: AMS SS N1), **Robert Kusner**, University of Massachusetts, Amherst, and **John M. Sullivan**, University of Illinois, Urbana.

Recent Progress in Elementary Geometry (Code: AMS SS A1), **John E. Wetzel**, University of Illinois, Urbana, and **Clark Kimberling**, University of Evansville.

Symplectic Geometry and Topology (Code: AMS SS K1), **Eugene M. Lerman** and **Susan Tolman**, University of Illinois, Urbana.

Wavelet Analysis and Multiresolution Methods (Code: AMS SS Q1), **Tian-Xiao He**, Illinois Wesleyan University.

Las Vegas, Nevada

University of Nevada, Las Vegas

April 10–11, 1999

Meeting #942

Western Section
Associate secretary: Bernard Russo
Announcement issue of *Notices*: February 1999
Program issue of *Notices*: To be announced
Issue of *Abstracts*: Volume 20, Issue 3

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: December 23, 1998
For abstracts: February 17, 1999

Special Sessions

Analysis and Geometry (Code: AMS SS I1), **Peter Li** and **Song-Ying Li**, University of California, Irvine.

Combinatorial Theory (Code: AMS SS G1), **Kequan Ding**, University of Illinois, Urbana, **Peter Shiue**, University of Nevada, Las Vegas, and **Yeong-Nan Yeh**, Academia Sinica.

Control and Dynamics of Partial Differential Equations (Code: AMS SS A1), **Zhonghai Ding**, University of Nevada, Las Vegas.

Diophantine Problems (Code: AMS SS J1), **Arthur Baragar**, University of Nevada, Las Vegas, and **Michael Bennett**, University of Illinois.

Geometric Group Theory (Code: AMS SS H1), **Eric M. Freden**, Southern Utah University, and **Eric Lewis Swenson**, Brigham Young University.

Graph Theory (Code: AMS SS B1), **Hung-Lin Fu**, National Chiao-Tung University, Taiwan, **Chris A. Rodger**, Auburn University, and **Michelle Schultz**, University of Nevada, Las Vegas.

Invariants, Distributions, Differential Operators and Harmonic Analysis (Code: AMS SS K1), **Ronald L. Lipsman**, University of Maryland, College Park.

Nonlinear PDEs—Methods and Applications (Code: AMS SS C1), **David Costa**, University of Nevada, Las Vegas.

Number Theory (Code: AMS SS F1), **Gennady Bachman**, University of Nevada, Las Vegas, **Richard A. Mollin**, University of Calgary, and **Peter J. Shiue**, University of Nevada, Las Vegas.

Numerical Analysis and Computational Mathematics (Code: AMS SS E1), **Jun Zhang**, University of Minnesota and University of Kentucky, and **Jennifer Zhao**, University of Michigan, Dearborn.

Set Theory (Code: AMS SS D1), **Douglas Burke** and **Derrick DuBose**, University Nevada, Las Vegas.

Symmetries of Knots and Three-Manifolds (Code: AMS SS M1), **Swatee Naik**, University of Nevada, Reno, and **Jozef H. Przytycki**, George Washington University.

Buffalo, New York

State University of New York, Buffalo

April 24–25, 1999

Meeting #943

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: February 1999
Program issue of *Notices*: To be announced
Issue of *Abstracts*: Volume 20, Issue 3

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: January 6, 1999
For abstracts: March 3, 1999

Invited Addresses

Michèle M. Audin, Université of Louis Pasteur, *Title to be announced.*

Russel Caflisch, University of California, Los Angeles, *Title to be announced.*

Jeff Smith, Purdue University, *Title to be announced.*

Alexander Voronov, MIT, *Title to be announced.*

Gregg J. Zuckerman, Yale University, *Title to be announced.*

Special Sessions

Combinatorics and Graph Theory (Code: AMS SS C1), **Harris Kwong**, SUNY College at Fredonia.

Complex Geometry (Code: AMS SS G1), **Terrence Napier**, Lehigh University, and **Mohan Ramachandran**, State University of New York, Buffalo.

Integrable Systems (Code: AMS SS J1), **Michèle Audin**, Université Louis Pasteur et NCRS, and **Lisa Claire Jeffrey**, McGill University.

Knot and 3-Manifolds (Code: AMS SS E1), **Thang T.Q. Le**, State University of New York, Buffalo, **William W. Menasco**, SUNY, Buffalo, and **Morwen B. Thistlethwaite**, University of Tennessee.

Mathematical Physics (Code: AMS SS D1), **Jonathan Dimock**, SUNY, Buffalo.

Operads, Algebras, and Their Applications (Code: AMS SS H1), **Alexander A. Voronov**, MIT.

Representations of Lie Algebras (Code: AMS SS F1), **Duncan J. Melville**, Saint Lawrence University.

Smooth Categories in Geometry and Mechanics (Code: AMS SS A1), **F. William Lawvere**, SUNY, Buffalo.

Thin Films: Solid and Liquid (Code: AMS SS B1), **E. Bruce Pitman**, and **Brian Spencer**, SUNY, Buffalo.

Denton, Texas

University of North Texas

May 19–22, 1999

Meeting #944

Fourth International Joint Meeting of the AMS and the Sociedad Matemática Mexicana (SMM).
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: January 1999
Program issue of *Notices*: To be announced
Issue of *Abstracts*: Volume 20, Issue 3

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: March 24, 1999

Invited Addresses

Raymundo Bautista, UNAM, *Title to be announced.*

William Fulton, University of Michigan, Ann Arbor, *Title to be announced.*

Francisco Gonzalez Acuna, UNAM, *Title to be announced.*

Ronald L. Graham, AT&T Labs, *Title to be announced* (Erdos Memorial Lecture).

Jack K. Hale, Georgia Institute of Technology, *Title to be announced.*

Onesimo Hernandez-Lerma, CINVESTAV del IPN, *Title to be announced.*

Special Sessions

Algebraic Geometry and Commutative Algebra (Code: AMS SS F1), **Javier Elizondo**, UNAM, **Alberto Corso**, Michigan State University, and **David A. Jorgensen**, University of Texas, Austin.

Algebraic Topology (Code: AMS SS Q1), **Frederick R. Cohen** and **Samuel Gitler**, University of Rochester, and **Carlos Prieto**, UNAM.

Combinatorics (Code: AMS SS N1), **Jorge Urrutia**, IMATE-UNAM.

Continuum Theory (Code: AMS SS D1), **Wayne Lewis**, Texas Tech University, and **Sergio Macias** and **Alejandro Illanes**, UNAM.

Differential Equations, Nonlinear Analysis, and Numerical Solutions to PDEs. (Code: AMS SS E1), **John W. Neuberger**, University of North Texas, and **Alfredo C. Nicolas**, UAM.

Functional Analysis and Complex Analysis (Code: AMS SS C1), **S. Perez-Esteva**, UNAM, **E. Ramirez se Arellano**, CINVESTAV, **John E. Fornaess**, University of Michigan, Ann Arbor, and **Josefina Alverez**, University of New Mexico.

Geometric and Symbolic Dynamical Systems (Code: AMS SS G1), **Luca Q. Zamboni**, University of North Texas, and **Edgardo Ugalde**, University of San Luis Potosi.

Low Dimensional Topology (Code: AMS SS H1), **Mark W. Brittenham**, University of North Texas, **Luis G. Valdez**, University of Texas, El Paso, and **F. Gonzalez-Acuna**, IM-UNAM.

Noncommutative Geometry, Quantum Groups, and Applications (Code: AMS SS L1), **M. Durdevich**, UNAM, and **Hanna Ewa Makaruk** and **Robert M. Owczarek**, Los Alamos National Laboratory.

Nonlinear Models in Biology and Celestial Mechanics (Code: AMS SS M1), **Ernesto Perez-Chavela** and **Jorge X. Velasco-Hernandez**, UAM.

Representation Theory of Algebras (Code: AMS SS A1), **Jose A. de la Pena** and **Christof Geiss**, UNAM, and **Birge Zimmerman**, University of California, Berkeley.

Ring Theory (Code: AMS SS K1), **Carlos Signoret-Poillon**, UNAM-UAM, and **Sergio Lopez-Permouth**, Ohio University.

Smooth Dynamical Systems (Code: AMS SS P1), **David A. Delatte** and **Dan Mauldin**, University of North Texas, **Jose Seade**, UNAM, **Mariusz Urbanski**, University of North Texas, and **Alberto Verjofsky**, University of Lille, I.

Stochastic Processes (Code: AMS SS J1), **Frederi G. Viens**, University of North Texas, **Jorge A. Leon**, CINVESTAV, and **Juan Ruiz de Chavez**, UAM.

Stochastic Systems and Control (Code: AMS SS B1), **Daniel Hernandez-Hernandez** and **Onesimo Hernandez-Lerma**, CINVESTAV, and **Guillermo Ferrayra**, Louisiana State University.

Melbourne, Australia

Melbourne, Australia

July 12–16, 1999

Meeting #945

First International Joint Meeting of the American Mathematical Society and the Australian Mathematical Society
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Jennifer Chayes, Microsoft, *Title to be announced.*

Michael Eastwood, University of Adelaide, *Title to be announced.*

Gerhard Huisken, University of Tuebingen, *Title to be announced.*

Vaughan Jones, University of California, Berkeley, *Title to be announced.*

Hyam Rubinstein, Melbourne University, *Title to be announced.*

Richard M. Schoen, Stanford University, *Title to be announced.*

Neil Trudinger, Australian National University, *Title to be announced.*

Special Sessions

Fluid Dynamics (Code: AMS SS C1), **Susan Friedlander**, Northwestern University, and **Roger H. J. Grimshaw**, Monash University.

Geometric Group Theory (Code: AMS SS K1), **Swarup Gadde** and **Walter Neumann**, University of Melbourne.

Geometric Themes in Group Theory (Code: AMS SS A1), **Gustav I. Lehrer**, University of Sydney, **Cheryl E. Praeger**, University of Western Australia, and **Stephen D. Smith**, University of Illinoi, Chicago.

Group Actions (Code: AMS SS H1), **Marston Conder**, **Gaven Martin**, and **Eamonn O'Brien**, University of Auckland.

Low Dimensional Topology (Code: AMS SS D1), **William H. Jaco**, Oklahoma State University, and **Hyam Rubinstein**, Melbourne University.

Mathematical Physics: Many Body Systems (Code: AMS SS B1), **Alan L. Carey**, University of Adelaide, **Paul A. Pearce**, University of Melbourne, and **Mary Beth Ruskai**, University of Massachusetts, Lowell.

Mathematics Learning Centers (Code: AMS SS G1), **Judith Baxter**, University of Illinois, Chicago, **Jackie Nicholas**, University of Sydney, and **Jeanne Wald**, Michigan State University.

Moduli Spaces of Riemann Surfaces, Mapping Class Groups and Invariants of 3-Manifolds (Code: AMS SS F1), **Ezra Getzler**, Northwestern University, and **Richard Hain**, Duke University.

Nonlinear Dynamics and Optimization (Code: AMS SS L1), **A. F. Ivanov**, Penn State University and University of Ballarat, **A. Mees**, University of Western Australia, and **A. Rubinov**, University of Ballarat.

Probability Theory and Its Applications (Code: AMS SS E1), **Timothy Brown**, University of Melbourne, **Phil Pollett**, University of Queensland, and **Ruth J. Williams**, University of California, San Diego.

Recent Trends in Operator Theory and Harmonic Analysis (Code: AMS SS J1), **Michael T. Lacey**, Georgia Institute of Technology, and **Alan G. R. McIntosh**, Macquarie University.

Salt Lake City, Utah

University of Utah

September 25–26, 1999

Meeting #946

Western Section
Associate secretary: Bernard Russo
Announcement issue of *Notices*: August 1999
Program issue of *Notices*: To be announced
Issue of *Abstracts*: Volume 20, Issue 4

Deadlines

For organizers: January 21, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Providence, Rhode Island

Providence College

October 2–3, 1999

Meeting #947

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: January 6, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Dan M. Barbasch, Cornell University, *Title to be announced.*

David Mumford, Brown University, *Title to be announced.*

Special Sessions

Algebraic and Geometric Combinatorics (Code: AMS SS A1), **Vesselin N. Gasharov**, Cornell University, and **Ira M. Gessel**, Brandeis University.

Representation Theory of Reductive Groups (Code: AMS SS B1), **Dan M. Barbasch** and **Birgit Speh**, Cornell University.

Austin, Texas

University of Texas, Austin

October 8–10, 1999

Meeting #948

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: January 6, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Mikhail Kapranov, Northwestern University, *Title to be announced.*

John Roe, Oxford University and Pennsylvania State University, *Title to be announced.*

Catherine Sulem, University of Toronto, *Title to be announced.*

Tatiana Toro, University of Washington, *Title to be announced.*

Special Sessions

Aperiodic Tiling (Code: AMS SS D1), **Charles Radin** and **Lorenzo Sadun**, University of Texas, Austin.

Harmonic Analysis and PDEs (Code: AMS SS C1), **William Beckner** and **Luis A. Caffarelli**, University of Texas,Austin.

The Development of Topology in the Americas (Code: AMS SS A1), **Cameron Gordon**, University of Texas, Austin, and **Ioan Mackenzie James**, University of Oxford.

Wavelets and Approximation Theory (Code: AMS SS B1), **Don Hong**, Eastern Tennessee State University, and **Michael Prophet**, Murray State University.

Charlotte, North Carolina

University of North Carolina, Charlotte

October 15–17, 1999

Meeting #949

Southeastern Section
Associate secretary:
Announcement issue of *Notices*: August 1999
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: January 20, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions

Knot Theory and Its Applications (Code: AMS SS A1), **Yuanan Diao**, University of North Carolina, Charlotte.

Washington, District of Columbia

Marriott Wardman Park Hotel and Omni Shoreham Hotel

January 19–22, 2000

Joint Mathematics Meetings, including the 106th Annual Meeting of the AMS, 83rd Meeting of the Mathematical Association of America (MAA), with minisymposia and other special events contributed by the Society for Industrial and Applied Mathematics (SIAM), and the annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).
Associate secretary: Robert M. Fossum
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 20, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Lowell, Massachusetts

University of Massachusetts, Lowell

April 1–2, 2000

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 1, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions

Invariance in Convex Geometry (Code: AMS SS A1), **Daniel A. Klain**, Georgia Institute of Technology, and **Elisabeth Werner**, Case Western Reserve University.

Notre Dame, Indiana

University of Notre Dame

April 7–9, 2000

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 7, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Lafayette, Louisiana

University of Southwestern Louisiana

April 14–16, 2000

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 14, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Odense, Denmark

Location to be announced

June 12–15, 2000

First AMS-Scandinaivan International Mathematics Meeting. Sponsored by the AMS, Dansk Matematisk Forening, Suomen matemaattinen yhdistys, Icelandic Mathematical Society, Norsk Matematisk Forening, and Svenska matematikersamfundet.
Associate secretary: Robert M. Fossum
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Toronto, Ontario Canada

University of Toronto

September 22–24, 2000

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

New York, New York

Columbia University

November 3–5, 2000

Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: February 3, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

New Orleans, Louisiana

New Orleans Marriott and ITT Sheraton New Orleans Hotel

January 10–13, 2001

Joint Mathematics Meetings, including the 107th Annual Meeting of the AMS, 84th Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 11, 2000
For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Columbia, South Carolina

University of South Carolina

March 16–18, 2001

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: June 15, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Lawrence, Kansas

University of Kansas

March 30, 2001

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: June 28, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Hoboken, New Jersey

Stevens Institute of Technology

April 28–29, 2001

Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 28, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Williamstown, Massachusetts

Williams College

October 13–14, 2001

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: January 11, 2001
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

San Diego, California

San Diego Convention Center

January 6–9, 2002

Joint Mathematics Meetings, including the 108th Annual Meeting of the AMS and 85th Meeting of the Mathematical Association of America (MAA).
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 4, 2001
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Presenters of Papers

Winston-Salem, North Carolina; October 9–10, 1998

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Program of the Sessions

Winston-Salem, North Carolina, October 9–10, 1998

Friday, October 9

Meeting Registration and AMS Book Sale and Exhibit

7:30 AM – 4:00 PM **Lobby, Benson University Center**

Special Session on Modern Methods in Set Theory and General Topology, I

8:00 AM – 10:50 AM **Room 10, Calloway Hall**

Organizers: **Winfried Just**, Ohio University
Paul Szeptycki, Ohio University

8:00AM (1) *Metrizability of completely normal, hereditarily cwH manifolds.*
Peter J. Nyikos, University of South Carolina, Columbia, SC (936-54-216)

8:30AM (2) *Countably compact spaces with a small diagonal.* Preliminary report.
Gary Gruenhage, Auburn University (936-54-77)

9:00AM (3) *Survey of results on convergence in topologic algebraic systems.*
Alexander Y. Shibakov, Tennessee Tech (936-54-192)

9:30AM (4) *Metrizable subspaces of free topological groups on metrizable spaces.* Preliminary report.
Kohzo Yamada, Auburn University (936-54-114)

10:00AM (5) *On universal c-algebras and universal uniform Eberlein compacta, and related problems.*
Mirna Dzamonja, University of East Anglia (936-04-177)

10:30AM (6) *$C_p(X)$ and the Berner-Juhasz point-picking game.*
Marion Scheepers, Boise State University (936-54-186)

Special Session on Recent Results on the Topology of Three-Manifolds, I

8:30 AM – 10:50 AM **Room 3, Calloway Hall**

Organizer: **Hugh Nelson Howards**, Wake Forest University

8:30AM (7) *Minimizing Morse functions transverse to boundaries.*
David C. Bachman, University of Texas at Austin (936-57-102)

9:00AM (8) *Systoles of hyperbolic 3-manifolds.*
Colin C. Adams*, Williams College, and **Alan W. Reid**, University of Texas (936-57-83)

9:30AM (9) *Dehn surgery on knots.* Preliminary report.
John E. Luecke, University of Texas, Austin (936-57-185)

10:00AM (10) *Free Seifert surfaces for knots.*
Mark Brittenham, University of North Texas (936-57-64)

10:30AM (11) *Knotted graphs in balls.*
Hugh N. Howards, Wake Forest University (936-57-181)

Special Session on Commutative Ring Theory, I

8:30 AM – 10:50 AM **Room 20, Calloway Hall**

Organizers: **David F. Anderson**, University of Tennessee, Knoxville
Evan Houston, University of North Carolina, Charlotte

8:30AM (12) *Relating two "closures" of ideals primary for the maximal ideal in an RLR.* Preliminary report.
David C. Lantz, Colgate University (936-13-151)

9:00AM (13) *Extended modules.* Preliminary report.
Roger Wiegand, University of Nebraska (936-13-81)

9:30AM (14) *Noetherian domains inside a homomorphic image of a completion I.*
William J. Heinzer, Purdue University, **Christel Rotthaus**, Michigan State University, and **Sylvia M. Wiegand***, University of Nebraska, Lincoln (936-13-27)

10:00AM (15) *Noetherian domains inside a homomorphic image of a completion II.*
William J. Heinzer*, Purdue University , **Christel**, Michigan State University, and **Sylvia M. Wiegand**, University of Nebraska Lincoln (936-13-28)

The time limit for each contributed paper in the sessions is ten minutes. In the Special Sessions the time limit varies from session to session and within sessions. To maintain the schedule, time limits will be strictly enforced.
For papers with more than one author, an asterisk follows the name of the author who plans to present the paper at the meeting.
Papers flagged with a solid triangle (▸) have been designated by the author as being of possible interest to undergraduate students.
Abstracts of papers presented in the sessions at this meeting will be found in Volume 19, Issue 3 of *Abstracts of papers presented to the American Mathematical Society*, ordered according to the numbers in parentheses following the listings. The middle two digits, e.g., 897-**20**-1136, refer to the Mathematical Reviews subject classification assigned by the individual author. Groups of papers for each subject are listed chronologically in the *Abstracts*. The last one to four digits, e.g., 897-20-**1136**, refer to the receipt number of the abstract; abstracts are further sorted by the receipt number within each classification.

10:30AM ▸ (16) *Primary decomposition of ideals in polynomial rings.* Preliminary report.
Robert Gilmer* and **Guang Fu**, Florida State University (936-13-14)

Special Session on Topology in Dynamics, I

8:30 AM – 10:50 AM **Room 17, Calloway Hall**

Organizers: **Marcy Barge**, Montana State University-Bozeman
Krystyna M. Kuperberg, Auburn University

8:30AM (17) *Periods vs. rotation numbers in dimension one.* Preliminary report.
Alexander Blokh, University of Alabama in Birmingham, and **Michal Misiurewicz***, IUPUI (936-58-57)

9:00AM (18) *Trajectory of the turning point is dense for a co-σ-porous set of tent maps.*
Karen M. Brucks*, UWM-Milwaukee, and **Zoltán Buczolich**, Eötvös Loránd University (936-99-56)

9:30AM (19) *Inverse limit spaces of unimodal maps with finite critical orbits.*
Henk Bruin, KTH, Stockholm (936-53-09)

10:00AM (20) *Topology of laminations.* Preliminary report.
Luther Johnson, Montana State University (936-54-191)

10:30AM (21) *Hereditarily indecomposable inverse limits of horseshoes.*
Piotr Minc, Auburn University (936-54-141)

Special Session on Boundary Value Problems, I

8:30 AM – 10:50 AM **Room 101, Guy T. Carswell Hall**

Organizers: **John V. Baxley**, Wake Forest University
Stephen B. Robinson, Wake Forest University

8:30AM (22) *Global existence and blow-up of classical solutions for degenerate quasilinear parabolic problems with slow diffusions.*
Chiu Yeung Chan*, University of Southwestern Louisiana, and **Wai Yuen Chan**, University of Science and Arts of Oklahoma (936-35-166)

9:00AM (23) *A degenerate parabolic quenching problem.*
Lan Ke, University of Southwestern Louisiana (936-35-171)

9:30AM (24) *A partial functional differential equation.* Preliminary report.
Lawrence Turyn, Wright State University (936-34-124)

10:00AM ▸ (25) *Dynamics and bifurcations of a 3D system modeling thermal instability.*
Miaohua Jiang, Wake Forest University (936-34-53)

10:30AM ▸ (26) *The stationary power-law Stokes equation in convex domains.* Preliminary report.
Lew E. Lefton* and **Dongming Wei**, University of New Orleans (936-35-167)

Special Session on Operator Theory and Holomorphic Spaces, I

8:30 AM – 10:50 AM **Room 208, Guy T. Carswell Hall**

Organizers: **Tavan T. Trent**, University of Alabama
Zhijian Wu, University of Alabama

8:30AM (27) *Nontangential limits in $P^2(\mu)$ and the index of an invariant subspace.* Preliminary report.
Alexandru Aleman, Fernuniversitaet Hagen, and **Stefan Richter***, University of Tennessee (936-47-158)

9:00AM (28) *Hyponormal pairs of Toeplitz operators.*
Raúl E. Curto, The University of Iowa (936-47-116)

9:30AM (29) *Extremal problems for moments of planar continua with fixed conformal centroid.* Preliminary report.
Albert Baernstein II*, Washington University, and **Richard S. Laugesen**, University of Illinois (936-31-197)

10:00AM (30) *A compact composition operator that is not Hilbert-Schmidt.*
Benjamin A. Lotto, Vassar College (936-47-163)

10:30AM (31) *Compact composition operators between weighted Bergman spaces on convex domains in C^n.*
Peter R. Mercer, SUNY College at Buffalo (936-47-74)

Special Session on Combinatorics and Graph Theory, I

9:00 AM – 10:50 AM **Room 117, Calloway Hall**

Organizer: **Bruce Landman**, University of North Carolina

9:00AM (32) *The power of 2 dividing coefficients in a series.* Preliminary report.
Fredric T. Howard, Wake Forest University (936-05-59)

9:30AM ▸ (33) *Sequences of weighted averages.* Preliminary report.
Neil J. Calkin, Clemson University (936-05-204)

10:00AM (34) *Antichains in the poset of integer partitions.*
Rod Canfield, University of Georgia, Athens (936-05-05)

10:30AM (35) *Filter sizes in distributive lattices.*
Dwight Duffus*, Emory University, and **Bill Sands**, The University of Calgary (936-06-175)

Special Session on Abelian Groups and Modules, I

9:00 AM – 10:50 AM **Room 112, Calloway Hall**

Organizer: **Ulrich Albrecht**, Auburn University

9:00AM (36) *Mixed groups and companion groups.* Preliminary report.
Steven T. Files, Wesleyan University (936-20-159)

9:30AM (37) *Baer-Kaplansky theorems for direct sums of self-small mixed groups.*
Bill Wickless, University of Connecticut (936-20-39)

10:00AM Discussion

Special Session on Noncommutatuve Algebra, I

9:00 AM – 10:50 AM **Room 119, Calloway Hall**

Organizers: **Ellen Kirkman**, Wake Forest University
James Kuzmanovich, Wake Forest University

9:00AM (38) *Enveloping algebras of Lie color algebras: Primeness versus graded-primeness.*
Jeffrey M. Bergen*, DePaul University, and **D. S. Passman**, University of Wisconsin (936-16-180)

9:30AM (39) *Orthogonal subcategories of the stable category.* Preliminary report.
Jon F. Carlson, University of Georgia (936-20-182)

10:00AM (40) *Global dimension four extensions of Artin-Schelter regular algebras.*
Tom Cassidy, University of Oregon (936-16-105)

10:30AM (41) *Module extensions over classical Lie superalgebras.*
Edward S. Letzter, Texas A&M University (936-16-173)

Special Session on Ergodic Theory, I

9:00 AM – 10:50 AM **Room 102, Guy T. Carswell Hall**

Organizer: **Idris Assani**, University of North Carolina, Chapel Hill

9:00AM (42) *Equivalence relations and the capturing property in topological dynamics.*
Joseph Auslander, University of Maryland, College Park (936-54-109)

9:30AM (43) *Integer sequences with big gaps and the pointwise ergodic theorem.*
Roger L. Jones*, DePaul University, **Michael Lacey**, Georgia Tech. Univ., and **Mate Wierdl**, University of Memphis (936-26-97)

10:00AM (44) *A finite approximation of the Conley decomposition.*
Fern Y. Hunt, National Institute of Standards and Technology (936-58-82)

10:30AM (45) *Weakly almost periodic L_1 contractions and coboundaries of non-singular transformations.*
Isaac Kornfeld*, North Dakota State University, Fargo and **Michael Lin**, Ben-Gurion University of the Negev, Beer-Sheva, Israel (936-28-66)

Invited Address

11:10 AM – NOON **Pugh Auditorium, Benson University Center**

(46) *A.e. multiple recurrence and Wiener Wintner dynamical systems.*
Idris Assani, UNC Chapel-Hill (936-28-234)

Invited Address

1:25 PM – 2:15 PM **Pugh Auditorium, Benson University Center**

(47) *Some mathematical problems related to the equations of the atmosphere and the oceans.*
Roger Temam, Indiana University (936-86-06)

Special Session on Combinatorics and Graph Theory, II

2:30 PM – 5:50 PM **Room 117, Calloway Hall**

Organizer: **Bruce Landman**, University of North Carolina

2:30PM (48) *A variation on the coloring criterion in finding the Ramsey number of a complete graph.* Preliminary report.
Richard H. Schelp, The University of Memphis (936-05-48)

3:00PM (49) *Some generalizations of the van der Waerden numbers.* Preliminary report.
Bruce M. Landman*, University of North Carolina at Greensboro, and **Tom C. Brown**, Simon Fraser Unversity (936-05-89)

3:30PM (50) *Geometrical and topological Ramsey numbers.* Preliminary report.
Heiko Harborth, TU Braunschweig, Germany (936-05-179)

4:00PM (51) *Infinite partition regular matrices – solutions in central sets.* Preliminary report.
Neil Hindman*, Howard University, and **Imre Leader**, University College London (936-05-35)

4:30PM (52) *Maximum jump numbers of regular matrices classes of zeros and ones.*
Bo Cheng, University of the Witwatersrand (936-05-176)

5:00PM (53) *A survey of configurations in BTDs and related BIBDs.* Preliminary report.
Margaret A. Francel, The Citadel (936-05-103)

5:30PM (54) *Some constructions of block designs.*
Malcolm Greig, Greig Consulting, and **Dinesh G. Sarvate***, University of Charleston (936-05-68)

Special Session on Abelian Groups and Modules, II

2:30 PM – 4:20 PM **Room 112, Calloway Hall**

Organizer: **Ulrich Albrecht**, Auburn University

2:30PM (55) *Test classes for freeness.* Preliminary report.
Andreas R. Blass*, University of Michigan, and **John Irwin**, Wayne State University (936-20-79)

3:00PM (56) *Cotilting modules and bimodules.*
Riccardo Colpi, Universita di Padova, and **Kent R. Fuller***, University of Iowa (936-16-36)

3:30PM (57) *A class of groups characterized by the ranks of their socles.*
Anthony J. Giovannitti, University of West Georgia (936-20-24)

4:00PM (58) *A-solvability and quasi-isomorphism.*
Ulrich F. Albrecht, Auburn University (936-20-149)

Special Session on Noncommutatuve Algebra, II

2:30 PM – 5:50 PM **Room 119, Calloway Hall**

Organizers: **Ellen Kirkman**, Wake Forest University
James Kuzmanovich, Wake Forest University

2:30PM (59) *Quantized primitive ideal spaces as quotients of affine varieties.* Preliminary report.
Kenneth R. Goodearl*, University of California, and **Edward S. Letzter**, Texas A&M University (936-16-147)

3:00PM (60) *Eulerian derivations.* Preliminary report.
Daniel R. Farkas, Virginia Tech, **Christof Geiss**, UNAM, **Edward L. Green***, Virginia Tech, and **Eduardo N. Marcos**, Univ. of Sao Paulo (936-16-87)

3:30PM (61) *Algebraic structure of the quantum Lorentz group.*
Timothy J. Hodges, University of Cincinnati (936-16-104)

4:00PM (62) *Canonical basis and Macdonald polynomials.*
Naihuan Jing, North Carolina State University (936-17-212)

4:30PM (63) *On the Krull-Schmidt-Azumaya theorem for integral group rings.*
Peter Hindman, University of Georgia, **Lee Klingler***, Florida Atlantic University, and **Charles Odenthal**, University of Toledo (936-16-200)

5:00PM (64) *Projective modules over hereditary Noetherian prime rings.*
Lawrence Sherwin Levy*, University of Wisconsin, Madison, and **J. Chris Robson**, University of Leeds, England (936-16-161)

5:30PM (65) *A family of Yetter-Drinfeld module algebras for the Taft algebras.* Preliminary report.
M. Susan Montgomery, University of Southern California (936-16-73)

Special Session on Recent Results on the Topology of Three-Manifolds, II

2:30 PM – 5:50 PM **Room 3, Calloway Hall**

Organizer: **Hugh Nelson Howards**, Wake Forest University

2:30PM (66) *Abelian subgroup separability.* Preliminary report.
Elizabeth S. Allman, University of North Carolina at Asheville, and **Emily Hamilton***, Emory University (936-57-203)

3:00PM (67) *Degenerations of representations and the boundary curve space of the Whitehead link.* Preliminary report.
Alan E. Lash, UCSB, and **Patrick D. Shanahan***, Loyola Marymount University (936-57-135)

3:30PM (68) *Non-mutant hyperbolic knots with unfaithful double branch covers.* Preliminary report.
Steven A. Bleiler*, Portland State University, **Bell Foozwell** and **Hyam Rubinstein**, University of Melbourne (936-57-115)

4:00PM (69) *Genus two 3-manifolds decompose into handle number one pieces.* Preliminary report.
Eric D. Sedgwick, Oklahoma State University (936-57-211)

4:30PM (70) *The $\lfloor 2\pi \rfloor$-theorem.*
Ian Agol, University of California, Davis (936-57-133)

5:00PM (71) *Holonomic parametrizations of knots.* Preliminary report.
Joan S. Birman*, Barnard College of Columbia University, and **Nancy C. Wrinkle**, Columbia University (936-57-168)

5:30PM (72) *Length multiplicities of hyperbolic 3-manifolds.*
Joseph D. Masters, University of Texas at Austin (936-57-134)

Special Session on Commutative Ring Theory, II

2:30 PM – 5:50 PM **Room 20, Calloway Hall**

Organizers: **David F. Anderson**, University of Tennessee, Knoxville
Evan Houston, University of North Carolina, Charlotte

2:30PM (73) *Commutative rings with zero divisors having no atoms.*
Bernadette Mullins*, Youngstown State University, and **Jim Coykendall**, North Dakota State University (936-13-169)

3:00PM (74) *Unique factorization rings with zero divisors.*
Ahmet G. Ağargün, Yildiz Üniversitesi, **Daniel D. Anderson***, The University of Iowa, and **Silvia Valdes-Leon**, University of Southern Maine (936-13-32)

3:30PM (75) *On the elasticities of Krull domains with finite cyclic divisor class group.*
Scott T. Chapman*, Trinity University, and **David F. Anderson**, University of Tennessee at Knoxville (936-13-127)

4:00PM (76) *Non-unique factorization in monoid domains.*
Hwankoo Kim, Univ. Tennessee, Knoxville (936-13-108)

4:30PM (77) *Elasticity properties preserved in the normset.*
Jim B. Coykendall, North Dakota State University (936-13-19)

5:00PM (78) *Weakly factorial algebraic orders.* Preliminary report.
Martine Picavet-L'Hermitte, Laboratoire de Mathematiques Pures, Universite Blaise Pascal (936-13-18)

5:30PM (79) *Splitting multiplicative sets in Dedekind domains.*
David F. Anderson Univ. Tennessee, Knoxville and **Jeanam Park***, INHA, Korea (936-13-107)

Special Session on Ergodic Theory, II

2:30 PM – 4:50 PM **Room 102, Guy T. Carswell Hall**

Organizer: **Idris Assani**, University of North Carolina, Chapel Hill

2:30PM (80) *Modulated ergodic theorems along sequences of density zero.*
Roger L. Jones, DePaul University, **Michael Lin**, Ben-Gurion University, and **James H. Olsen***, North Dakota State University (936-28-52)

3:00PM (81) *Factors of nonsingular Cartesian products.* Preliminary report.
Andres del Junco, University of Toronto, and **Cesar E. Silva***, Williams College (936-28-132)

3:30PM (82) *Transformations and singular sequences.* Preliminary report.
Andrew B. Nobel, University of North Carolina (936-60-113)

4:00PM (83) *The Krieger theorem for ergodic measure preserving Z^d actions.*
E. Arthur Robinson Jr*, George Washington Univ, and **Ayse A. Sahin**, North Dakota State Univ (936-28-67)

4:30PM (84) *Almost everywhere convergence and boundedness of Cesàro-α ergodic averages.*
Francisco J. Martín-Reyes*, Universidad de Málaga, and **María Dolores Sarrión Gavilán**, Univ. de Málaga (936-28-100)

Special Session on Spectral Theory of Differential Equations and Applications, I

2:30 PM – 5:50 PM **Room 101, Guy T. Carswell Hall**

Organizers: **Dominic Clemence**, North Carolina A&T University
Alexandra Kurepa, North Carolina A&T University

2:30PM (85) *Shape invariants of weak Dirac spinors and C^1 immersions.*
George I. Kamberov, Washington University (936-35-215)

3:00PM (86) *Variational analysis of the nonlinear Schrodinger equation.*
J. K. Shaw, Virginia Tech University (936-34-70)

3:30PM (87) *Second order opial inequalities and applications.*
Richard C. Brown, University of Alabama, **Victor Burenkov**, University of Wales Cardiff, **Steve Clark**, University of Missouri Rolla, and **Don Hinton***, University of Tennessee (936-34-93)

4:00PM (88) *The distribution of scattering poles.* Preliminary report.
Peter D. Hislop, University of Kentucky (936-35-63)

4:30PM (89) *Two-parameter spectral averaging and localization for non-monotoneous random Schrödinger operators.*
Gunter Stolz, University of Alabama at Birmingham (936-81-86)

5:00PM (90) *Perturbation theory for a Sturm-Liouville operator.* Preliminary report.
Don B. Hinton, University of Tennessee, and **Suzanne C. Melescue***, Arkansas State University (936-34-128)

5:30PM (91) *Numerical determination of continuous spectra for the Neumann Laplacian.*
John W. Neuberger* and **Robert J. Renka**, University of North Texas (936-35-08)

Special Session on Modern Methods in Set Theory and General Topology, II

2:30 PM – 5:20 PM **Room 10, Calloway Hall**

Organizers: **Winfried Just**, Ohio University
Paul Szeptycki, Ohio University

2:30PM (92) *Resolutions as a categorical property and as a mapping property.* Preliminary report.
Stephen Watson, York University (936-54-223)

3:00PM (93) *Special sets of reals.*
Tomek Bartoszynski, Boise State University (936-04-227)

3:30PM (94) *A countably compact space X such that X^ω is strongly collectionwise normal and X^2 is not pseudocompact.*
Oleg I. Pavlov, Ohio University (936-54-29)

4:00PM (95) *Small filters.* Preliminary report.
Claude Laflamme, University of Calgary (936-04-195)

4:30PM (96) *The topology of elementary submodels.* Preliminary report.
Franklin D. Tall, University of Toronto (936-54-50)

5:00PM (97) *Three reflection properties for cardinal functions.* Preliminary report.
Richard E. Hodel, Duke University, and **Jerry E. Vaughan***, University of North Carolina at Greensboro (936-54-196)

Special Session on Topology in Dynamics, II

2:30 PM – 5:20 PM **Room 17, Calloway Hall**

Organizers: **Marcy Barge**, Montana State University-Bozeman
Krystyna M. Kuperberg, Auburn University

2:30PM (98) *When do new chain recurrent points imply a tangency?*
Kathleen Alligood, George Mason University (936-58-206)

3:00PM (99) *Explosions at homoclinic tangency.* Preliminary report.
Evelyn Sander, George Mason University (936-58-199)

3:30PM (100) *Rational attractors and irrational continua for maps in the Lozi family.*
Chris Cleveland, Montana State (936-58-145)

4:00PM (101) *Dynamics forced by homoclinic tangles.*
Pieter Collins, University of California, Berkeley (936-58-157)

4:30PM (102) *The Horseshoe: Pruning and homoclinic families.*
André S. de Carvalho*, SUNY at Stony Brook, and **Toby Hall**, Univ. of Liverpool, UK (936-58-117)

5:00PM (103) *Isotopy stable dynamics relative to compact invariant sets.*
Philip L. Boyland,University of Florida (936-58-10)

Special Session on Operator Theory and Holomorphic Spaces, II

2:30 PM – 5:50 PM **Room 208, Guy T. Carswell Hall**

Organizers: **Tavan T. Trent**, University of Alabama
Zhijian Wu, University of Alabama

2:30PM (104) *Ext over the bidisk algebra.* Preliminary report.
Sarah H. Ferguson, Wayne State University (936-47-193)

3:00PM (105) *Disjoint invariant subspaces for cyclic subnormal operators.*
James E. Thomson* and **Robert F. Olin**, Virginia Tech (936-47-42)

3:30PM (106) *Non-cyclic cellular indecomposable subnormal operators.* Preliminary report.
Robert F. Olin, Virginia Tech (936-47-207)

4:00PM (107) *Semi-commutators and commutators of Toeplitz operators.*
Dechao Zheng, Vanderbilt University (936-47-85)

4:30PM (108) *Solving Poisson's equation with interior conditions.*
John E. McCarthy*, Washington University, **Elena Yu. Backhaus** and **Joel Fajans**, U.C. Berkeley (936-78-34)

5:00PM (109) *Weakly compact composition operators on VMO.*
Joseph A. Cima*, UNC, and **Alec L. Matheson**, Lamar University (936-30-51)

5:30PM (110) *A commutant lifting theorem on the polydisc.*
Joe E. Ball, Virginia Institute of Technology, **Wing Suet Li***, Georgia Institute of Technology, **Dan Timotin**, Romanian Academy of Science, and **Tavan Trent**, University of Alabama (936-47-229)

Saturday, October 10

Meeting Registration and AMS Book Sale and Exhibit

8:00 AM – NOON **Lobby, Benson University Center**

Special Session on Commutative Ring Theory, III

8:00 AM – 10:50 AM **Room 20, Calloway Hall**

Organizers: **David F. Anderson**, University of Tennessee, Knoxville
Evan Houston, University of North Carolina, Charlotte

8:00AM (111) *Powerful ideals in integral domains.*
Ayman Badawi*, Birzeit University, and **Evan Houston**, University of North Carolina at Charlotte (936-13-30)

8:30AM (112) *Commutative rings with finitely generated multiplicative semigroup.*
Daniel D. Anderson, The University of Iowa, and **Joe Stickles***, Marshall University (936-13-91)

9:00AM (113) *On the prime ideals in a commutative ring.*
David E. Dobbs, University of Tennessee (936-13-49)

9:30AM (114) *Dilworth and Sperner numbers of group rings.*
James S. Okon and **J. Paul Vicknair***, California State University, San Bernardino (936-13-96)

10:00AM (115) *Krull rings and the ring of finite fractions.* Preliminary report.
Thomas G. Lucas, University of North Carolina at Charlotte (936-13-120)

10:30AM (116) *Closures along admissible subsets.* Preliminary report.
Gabriel Picavet, Laboratoire de Mathematiques pures, Universite Blaise Pascal (936-13-17)

Special Session on Modern Methods in Set Theory and General Topology, III

8:00 AM – 10:50 AM **Room 10, Calloway Hall**

Organizers: **Winfried Just**, Ohio University
Paul Szeptycki, Ohio University

8:00AM (117) *Ulam stability and pathological submeasures.* Preliminary report.
Ilijas Farah, York University (936-04-201)

8:30AM (118) *Cardinal characteristics and ultrafilters.* Preliminary report.
Andreas R. Blass, University of Michigan (936-03-80)

9:00AM (119) *Almost* realcompact spaces.*
John J. Schommer*, University of Tennessee at Martin, and **Mary Anne Swardson**, Ohio University (936-54-190)

9:30AM (120) *A linearly fibered Souslinean space under Martin's axiom.*
Justin Tatch Moore, University of Toronto (936-54-154)

10:00AM (121) *Which partial orders extend to $\mathbb{Q}$?* Preliminary report.
Judith Roitman, University of Kansas (936-06-152)

10:30AM (122) *Why Boolean algebras?*
Andrzej Roslanowski, Boise State University (936-04-126)

Special Session on Boundary Value Problems, II

8:00 AM – 9:50 AM **Room 5, Guy T. Carswell Hall**

Organizers: **John V. Baxley**, Wake Forest University
Stephen B. Robinson, Wake Forest University

8:00AM (123) *Differentiation of solutions of Lidstone boundary value problems with respect to the boundary data.*
John M. Davis, Auburn University (936-34-26)

8:30AM (124) *Existence of multiple solutions for some n^{th} order boundary value problems.*
Johnny Henderson*, Auburn University, and **H. B. Thompson**, The University of Queensland (936-34-20)

9:00AM ▸ (125) *A self-adjoint second order equation on a measure chain.* Preliminary report.
Allan C. Peterson, University of Nebraska-Lincoln (936-39-90)

9:30AM (126) *Exact controllability and uniform stabilization for electromagnetic fields.*
Matthias M. Eller, Tennessee Technical University, and **James E. Masters III***, University of Virginia (936-35-189)

Special Session on Noncommutatuve Algebra, III

8:30 AM – 10:50 AM **Room 119, Calloway Hall**

Organizers: **Ellen Kirkman**, Wake Forest University
James Kuzmanovich, Wake Forest University

8:30AM (127) *q-wedge modulules for quantized enveloping algebras of classical type.* Preliminary report.
Kailash C. Misra, North Carolina State University (936-17-205)

9:00AM (128) *Down-up algebras.* Preliminary report.
Paula A.A.B. Carvalho, Universidade do Porto, Portugal, and **Ian M. Musson***, University of Wisconsin-Milwaukee (936-16-72)

9:30AM (129) *Tilting modules and cohomology.*
Brian J. Parshall, Univ. Virginia (936-16-208)

10:00AM (130) *Construction of noncommutative ruled surfaces.* Preliminary report.
David Patrick, University of Washington (936-16-184)

10:30AM ▸ (131) *Representation theory, generic and specific.*
Leonard L. Scott, University of Virginia (936-16-210)

Special Session on Recent Results on the Topology of Three-Manifolds, III

8:30 AM – 10:50 AM **Room 3, Calloway Hall**

Organizer: **Hugh Nelson Howards**, Wake Forest University

8:30AM (132) *The second homology group of the level 2 mapping class group and extended Torelli group of an orientable surface.*
Joel S. Foisy, SUNY Potsdam (936-57-58)

9:00AM (133) *Results concerning surface groups in surgered manifolds.*
Anneke Bart, Saint Louis University (936-57-21)

9:30AM ▸ (134) *Relatively-slice links and the lower central series of 3-manifold groups.*
Vyacheslav S. Krushkal, Institute for Advanced Study (936-57-220)

10:00AM (135) *Subgroup separability and the generalized word problem in Aut(F_n) and the braid groups.*
Oliver T. Dasbach, Columbia University, and **Brian S. Mangum***, Barnard College - Columbia University (936-57-164)

10:30AM (136) *Planar normal surfaces and the word problem.*
William H. Jaco*, Oklahoma State University, **Joachim H. Rubinstein**, University of Melbourne, and **Eric D. Sedgwick**, Oklahoma State University (936-57-222)

Special Session on Ergodic Theory, III

8:30 AM – 10:50 AM **Room 102, Guy T. Carswell Hall**

Organizer: **Idris Assani**, University of North Carolina, Chapel Hill

8:30AM (137) *Oscillation for discrete singular integral operators.* Preliminary report.
James T. Campbell* and **Mate Wierdl**, University of Memphis (936-43-230)

9:00AM (138) *Fractional Poisson's equation and ergodic theorems for fractional coboundaries.* Preliminary report.
Yves Derriennic, Université de Bretagne Occidentale, and **Michael Lin***, Ben-Gurion University of the Negev (936-28-65)

9:30AM (139) *Invariant measures for set-valued dynamical systems.*
Walter M. Miller*, Howard University, and **Ethan Akin**, CUNY (936-28-144)

10:00AM (140) *Factor maps between tiling dynamical systems.*
Karl E. Petersen, University of North Carolina at Chapel Hill (936-28-13)

10:30AM (141) *Universal estimation of ergodic transformations.* Preliminary report.
Terrence M. Adams*, Rhode Island College, and **Andrew B. Nobel**, UNC-CH (936-60-221)

Special Session on Spectral Theory of Differential Equations and Applications, II

8:30 AM – 10:50 AM **Room 101, Guy T. Carswell Hall**

Organizers: **Dominic Clemence**, North Carolina A&T University
Alexandra Kurepa, North Carolina A&T University

8:30AM (142) *Exact results for the m-Lambda function.* Preliminary report.
John C.D. Diamantopoulos, Ouachita Baptist University, Arkadelphia, AR (936-34-235)

9:00AM (143) *A spectral method for the solution of control problems.*
Mohsen Razzaghi, Mississippi State University (936-93-99)

9:30AM (144) *Extremal properties of eigenvalues.* Preliminary report.
Charlotte A. Knotts-Zides, University of Tennessee at Knoxville (936-34-123)

10:00AM (145) *Discrete Liapunov inequalities.*
Steve Clark*, University of Missouri-Rolla, and **Don Hinton**, University of Tennessee-Knoxville (936-39-198)

10:30AM (146) *An existence result for a class of sublinear semipositone systems.*
Alfonso Castro, University of North Texas, **Chhetri Maya** and **Ratnasingham Shivaji***, Mississippi State University (936-35-98)

Special Session on Topology in Dynamics, III

8:30 AM – 10:50 AM **Room 17, Calloway Hall**

Organizers: **Marcy Barge**, Montana State University-Bozeman
Krystyna M. Kuperberg, Auburn University

8:30AM (147) *Models of boundaries of Siegel disks.* Preliminary report.
Andrew O. Maner, **John C. Mayer*** and **Lex G. Oversteegen**, UAB (936-30-142)

9:00AM (148) *External impressions in non-locally-connected Julia sets.* Preliminary report.
Lex G. Oversteegen* and **John C. Mayer**, UAB (936-54-139)

9:30AM (149) *Exit points on the boundary of a Siegel disk.* Preliminary report.
James T. Rogers Jr., Tulane University (936-58-54)

10:00AM (150) *Blowup and fixed points.* Preliminary report.
Christopher W. Stark, NSF and University of Florida (936-57-218)

10:30AM (151) *How basins of attraction evolve as a parameter is varied.*
James A. Yorke*, University of Maryland, and **Helena E. Nusse**, University of Groningen (936-00-217)

Special Session on Operator Theory and Holomorphic Spaces, III

8:30 AM – 10:50 AM **Room 208, Guy T. Carswell Hall**

Organizers: **Tavan T. Trent**, University of Alabama
Zhijian Wu, University of Alabama

8:30AM (152) *Synthesis sets for $H^\infty + C$.* Preliminary report.
Pamela B. Gorkin*, Bucknell University, and **Raymond Mortini**, Universite de Metz (936-46-38)

9:00AM (153) *Schroeder's equation in several variables.*
Carl C. Cowen, Purdue University, and **Barbara D. MacCluer***, University of Virginia (936-32-84)

9:30AM (154) *Composition operators on transition Bergman spaces.* Preliminary report.
Thomas L. Kriete, University of Virginia (936-47-150)

10:00AM (155) *Commutant lifting on a two holed domain.*
Scott McCullough, University of Florida (936-47-138)

10:30AM (156) *Numerical ranges of composition operators.* Preliminary report.
Valentin Matache, University of Puerto Rico (936-47-22)

Special Session on Combinatorics and Graph Theory, III

9:00 AM – 10:50 AM **Room 117, Calloway Hall**

Organizer: **Bruce Landman**, University of North Carolina

9:00AM ▸ (157) *On the number of elements in matroids with small circuits or cocircuits.*
Tristan M. J. Denley and **Talmage J. Reid***, The University of Mississippi (936-05-101)

9:30AM ▸ (158) *Cycles for square matrices mod n.* Preliminary report.
Theresa P. Vaughan*, University of North Carolina at Greensboro, and **Ezra Brown**, Virginia Polytechnic Institute & State Univ. (936-15-119)

10:00AM ▸ (159) *Using graph theory to find the genus of fundamental regions of subgroups of $SL(2, Z)$.* Preliminary report.
Ezra Brown, Virginia Tech (936-05-111)

10:30AM ▸ (160) *Applications of Deza's theorem.* Preliminary report.
Andras Gyarfas, Computer and Automation Institute, Hungarian Academy of Sciences, **Andre Kezdy*** and **Jeno Lehel**, University of Louisville (936-05-172)

Special Session on Abelian Groups and Modules, III

9:00 AM – 10:50 AM **Room 112, Calloway Hall**

Organizer: **Ulrich Albrecht**, Auburn University

9:00AM Discussion

Invited Address

11:10 AM – NOON **Pugh Auditorium, Benson University Center**

▸ (161) *Unique and nonunique factorization in integral domains.*
David F. Anderson, University of Tennessee, Knoxville (936-13-69)

Invited Address

1:25 PM – 2:15 PM **Pugh Auditorium, Benson University Center**

▸ (162) *Structure of attractors.* Preliminary report.
Marcy Barge, Montana State University (936-58-233)

Special Session on Combinatorics and Graph Theory, IV

2:30 PM – 5:20 PM **Room 117, Calloway Hall**

Organizer: **Bruce Landman**, University of North Carolina

2:30PM (163) *Inverting random functions.* Preliminary report.
Mike A. Steel, University of Canterbury, and **Laszlo A. Szekely***, University of South Carolina (936-05-31)

3:00PM ▸ (164) *The cycling of partitions and compositions under repeated shifts.*
Jerrold R. Griggs* and **Chih-Chang Daniel Ho**, University of South Carolina (936-05-165)

3:30PM (165) *On k-ordered graphs.*
Jill R. Faudree, University of Alaska - Fairbanks, **Ralph J. Faudree**, University of Memphis, **Ronald J. Gould***, Emory University, **Michael S. Jacobson**, University of Louisville, and **Linda Lesniak**, Drew University (936-05-122)

4:00PM (166) *Total irredundance in graphs.* Preliminary report.
Teresa W.W. Haynes, East Tennessee State University, **Stephen T.T. Hedetniemi**, Clemson University, and **Debra J. Knisley***, East Tennessee State University (936-05-125)

4:30PM ▸ (167) *Progress on mod sum graphs.*
Boland James* and **Wallace Christopher**, East Tennessee State University (936-05-140)

5:00PM ▸ (168) *From isospectral graphs and domains to isospectral networks.* Preliminary report.
Tzong-Yow Lee, University of Maryland (936-52-16)

Special Session on Noncommutatuve Algebra, IV

2:30 PM – 5:50 PM **Room 119, Calloway Hall**

Organizers: **Ellen Kirkman**, Wake Forest University
James Kuzmanovich, Wake Forest University

2:30PM (169) *Exotic differential operators.* Preliminary report.
Thierry Levasseur, Université de Bretagne Occidentale, Brest, France, and **J. T. Stafford***, University of Michigan, Ann Arbor (936-17-75)

3:00PM (170) *Weighted quantum planes and related regular algebras.*
Darin R. Stephenson, Hope College (936-16-183)

3:30PM (171) *Line schemes.* Preliminary report.
Brad Shelton, University of Oregon, and **Michaela Vancliff***, University of Texas at Arlington (936-16-46)

4:00PM (172) *Some homological invariants of local PI algebras.* Preliminary report.
Quanshui Wu* and **James J. Zhang**, Univ. of Washington (936-16-236)

4:30PM (173) *Full embeddings of almost split sequences for split-by-nilpotent extensions.*
I. Assem, University of Sherbrooke, and **Dan Zacharia***, Syracuse University (936-16-110)

5:00PM (174) *A noncommutative version of Watanabe theorem.*
James J. Zhang, University of Washington (936-16-61)

5:30PM (175) *Phantoms in representation theory – remembrance of things finite.* Preliminary report.
Birge Huisgen-Zimmermann, University of California (936-16-146)

Special Session on Recent Results on the Topology of Three-Manifolds, IV

2:30 PM – 5:50 PM **Room 3, Calloway Hall**

Organizer: **Hugh Nelson Howards**, Wake Forest University

2:30PM (176) *Integral points on character varieties.*
Darren Long, U.C.S.B., and **Alan W. Reid***, University of Texas (936-57-136)

3:00PM (177) *The Yang-Mills measure in the Kauffman bracket skein module.*
Doug Bullock*, University of Maryland, **Charles Frohman**, University of Iowa, and **Joanna Kania-Bartoszynska**, Boise State University (936-57-162)

3:30PM (178) *Counting Heegaard genus and tunnel number.*
Martin G. Scharlemann, UCSB, and **Jennifer C. Schultens***, Emory University (936-57-214)

4:00PM (179) *Intrinsically chiral colored graphs.* Preliminary report.
Erica L. Flapan* and **David L. Li**, Pomona College (936-57-137)

4:30PM ▸ (180) *Simple closed curves and pseudo-Anosov maps.*
Shicheng Wang, Beijing University, **Ying-Qing Wu***, University of Iowa, and **Qing Zhou**, Easten China Normal University (936-57-160)

5:00PM (181) *Existence of essential laminations.* Preliminary report.
Rachel Roberts, Washington University (936-57-194)

5:30PM (182) *SL(2) characters of groups.* Preliminary report.
Feng Luo, Rutgers University (936-57-156)

Special Session on Commutative Ring Theory, IV

2:30 PM – 5:20 PM **Room 20, Calloway Hall**

Organizers: **David F. Anderson**, University of Tennessee, Knoxville
Evan Houston, University of North Carolina, Charlotte

2:30PM (183) *Overrings of Z[x].* Preliminary report.
Alan Loper*, Ohio State University - Newark, and **Francesca Tartarone**, Universita "La Sapienza" (936-13-62)

3:00PM (184) *On the polynomial equivalence of subsets E and f(E) of Z.*
Robert Gilmer, Florida State University, and **William W. Smith***, University of North Carolina at Chapel Hill (936-13-47)

3:30PM (185) *Integral domains for which every non-zero ideal is stable.* Preliminary report.
Bruce M. Olberding, Northeast Louisiana University (936-13-95)

4:00PM (186) *Strongly homogeneous rings extensions of a domain.*
Herman P. Goeters, Auburn University (936-13-23)

4:30PM (187) *Independent locally-finite intersections of localizations.*
Daniel D. Anderson and **Muhammad Zafrullah***, The University of Iowa (936-13-40)

5:00PM ▸ (188) *Prime producing sequences.*
Joe L. Mott, Florida State University (936-40-187)

Special Session on Ergodic Theory, IV

2:30 PM – 4:20 PM **Room 102, Guy T. Carswell Hall**

Organizer: **Idris Assani**, University of North Carolina, Chapel Hill

2:30PM (189) *Simplicial dynamical systems.* Preliminary report.
Ethan Akin, The City College (936-28-76)

3:00PM (190) *Measures that maximize weighted entropy for factor maps between subshifts of finite type.* Preliminary report.
Sujin Shin, University of North Carolina at Chapel Hill (936-28-153)

3:30PM (191) *Convergence of subsequential averages of admissible superadditive processes.*
Dogan Comez, North Dakota State University (936-28-155)

4:00PM (192) *Absolutely continuous invariant measures for piecewise C^2 and expanding mappings of general domains in R^N.*
Jiu Ding*, Univ. of Southern Mississippi, and **Aihui Zhou**, Chinese Academy of Sciences (936-58-07)

Special Session on Spectral Theory of Differential Equations and Applications, III

2:30 PM – 5:50 PM **Room 101, Guy T. Carswell Hall**

Organizers: **Dominic Clemence**, North Carolina A&T University
Alexandra Kurepa, North Carolina A&T University

2:30PM (193) *Uniqueness of steady states for thin film equations.*
Richard S. Laugesen*, University of Illinois, Urbana-Champaign, and **Mary C. Pugh**, University of Pennsylvania (936-34-112)

3:00PM (194) *Some remarks about the inverse scattering problem for first order systems on the line.*
Tuncay Aktosun, North Dakota State University, **Martin Klaus***, Virginia Tech, and **Cor van der Mee**, University of Cagliari (936-34-188)

3:30PM (195) *Spectral stability of encapsulated vortices in nonlinear wave equations.* Preliminary report.
Robert L. Pego, University of Maryland, and **Henry A. Warchall***, University of North Texas (936-35-94)

4:00PM (196) *Inverse problems for elastic media.*
Lizabeth V. Rachele, Tufts University (936-35-213)

4:30PM (197) *Some Opial and Lyapunov inequalities with nonhomogenous boundary conditions.* Preliminary report.
Richard C. Brown*, University of Alabama, **Arlington M. Fink**, Iowa State University, and **Don B. Hinton**, University of Tennessee (936-34-170)

5:00PM (198) *On sectorial operators and bouindary value problems.* Preliminary report.
Eduard R. Tsekanovskii, Niagara University (936-47-148)

5:30PM (199) *Ice-covered ocean wave guides and operator polynomials.* Preliminary report.
Boris P. Belinskiy, University of Tennessee at Chattanooga (936-34-15)

Special Session on Modern Methods in Set Theory and General Topology, IV

2:30 PM – 3:50 PM **Room 10, Calloway Hall**

Organizers: **Winfried Just**, Ohio University
Paul Szeptycki, Ohio University

2:30PM (200) *D-spaces give a new characterization of semistratifiabity.* Preliminary report.
William G. Fleissner, University of Kansas (936-54-78)

3:00PM (201) *Normal subspaces of finite products of ordinals.*
Adrienne M. Stanley, Purdue University (936-54-219)

3:30PM (202) *Ordered spaces with special dense subsets.* Preliminary report.
Harold R. Bennett*, Texas Tech University, **Robert W. Heath**, University of Pittsburgh, and **David J. Lutzer**, The College of William and Mary (936-54-118)

Special Session on Topology in Dynamics, IV

2:30 PM – 5:20 PM **Room 17, Calloway Hall**

Organizers: **Marcy Barge**, Montana State University-Bozeman
Krystyna M. Kuperberg, Auburn University

2:30PM (203) *Knotted orbits in steady fluid flows.* Preliminary report.
John Etnyre, Stanford University, and **Robert Ghrist***, Georgia Tech (936-58-174)

3:00PM (204) *Index bounds for self-mappings of two-complexes.*
Michael R. Kelly, Loyola University, New Orleans (936-57-106)

3:30PM (205) *Symbolic dynamics of the collinear three-body problem.*
Samuel R. Kaplan, Bowdoin College (936-34-41)

4:00PM (206) *The convergence of an algorithm for calculating topological entropy.* Preliminary report.
S. Baldwin* and **E. E. Slaminka**, Auburn University (936-58-231)

4:30PM (207) *Horseshoes and billiards.* Preliminary report.
Judy Kennedy, University of Delaware (936-58-228)

5:00PM (208) *Toral invariants analogous to continued fractions.* Preliminary report.
Robert F. Williams, University of Texas, Austin (936-58-60)

Special Session on Operator Theory and Holomorphic Spaces, IV

2:30 PM – 5:20 PM **Room 208, Guy T. Carswell Hall**

Organizers: **Tavan T. Trent**, University of Alabama
Zhijian Wu, University of Alabama

2:30PM (209) *Hermitian matrix completions of band matrices.*
Hugo J. Woerdeman, The College of William and Mary (936-15-121)

3:00PM (210) *Dirichlet spaces of $\mathcal{M}$-harmonic functions on the unit ball in $\mathbb{C}^n$.* Preliminary report.
Manfred Stoll, University of South Carolina (936-32-92)

3:30PM (211) *Sampling measures for Bergman spaces on the unit disk.*
Daniel H. Luecking, University of Arkansas (936-30-71)

4:00PM (212) *Loewner's theorem for kernels having a finite number of negative squares.*
Daniel Alpay, Ben-Gurion University of the Negev, and **James Rovnyak***, University of Virginia (936-47-88)

4:30PM (213) *Boundedness of higher order Hankel forms and factorization in potential spaces.* Preliminary report.
Sarah Ferguson, Wayne State University, and **Richard Rochberg***, Washington University (936-46-209)

5:00PM ▸ (214) *Compactness criteria for holomorphic composition operators on the Hardy and Bergman spaces of the unit ball in $\mathbf{C}^n$.*
Dana Dwight Clahane, University of California, Irvine (936-47-232)

Session for Contributed Papers

2:30 PM – 3:40 PM **Room 112, Calloway Hall**

2:30PM (215) *Path stability and nonlinear weak ergodic theorems.*
Yong-Zhuo Chen, University of Pittsburgh at Bradford (936-47-45)

2:45PM (216) *The beta-shift, expansions of 1, and pumping lemmas.* Preliminary report.
Kimberly C. Johnson, University of North Carolina at Chapel Hill (936-58-202)

3:00PM (217) *Shifts on Banach spaces.* Preliminary report.
M. Rajagopalan*, Tennessee State University, and **K. Sundaresan**, Cleveland State University (936-46-130)

3:15PM ▸ (218) *Tessellations of moduli spaces and the mosaic operad.*
Satyan L. Devadoss, Johns Hopkins University (936-55-131)

3:30PM ▸ (219) *A supplemental bibliography on mathematics within the scientific method.* Preliminary report.
G. Arthur Mihram*, Princeton, NJ, and **Danielle Mihram**, Univ of Southern California (936-98-143)

Robert J. Daverman
Associate Secretary
Knoxville, Tennessee

Mathematics Program at AAAS Meeting

The 1999 Annual Meeting of the American Association for the Advancement of Science (AAAS), January 21–26, 1999, in Anaheim, California, will feature many outstanding expository talks by prominent mathematicians. These include the following symposia (three-hour sessions) and invited talks sponsored by Section A (Mathematics) of AAAS.

- Massive Data Sets in Mathematics, Science, and Engineering, organized by **Joan Feigenbaum**.
- Innovations in Mathematics: Historical Perspectives, organized by **Karen V. Parshall** and **Joseph W. Dauben**.
- On the Unusual Effectiveness of Logic in Computer Science, organized by **Moshe Y. Vardi**.
- The Mathematics of Epidemics and Disease, organized by **Kenneth L. Cooke**.
- Internet Research As an Experimental Science, organized by **Walter W. Willinger**.
- Counting on Justice? The Use and Misuse of Statistics in the Courts, organized by **Mary Gray**.
- Frontiers of the Physical Sciences Lecture: "The Topology of DNA", **De Witt Sumners**.
- Topical Lecture: "Bringing Geometric Modeling to the Desktop: From 3D Scanning at Home to Transmission over the Internet", **Peter Schroder**.
- Topical Lecture: "Women in Mathematics: The Addition of Difference", **Claudia Henrion**.

Other symposia that will be of interest to mathematicians and mathematics educators include:

- NCTM Standards 2000 Draft: Reflecting on Progress and Looking Ahead.
- Frontiers of the Physical Sciences I, II.
- Modeling Evolution.
- Imaging Development: From Single Cells to Complex Organisms.
- Preparing University Faculty to Teach While Educating Future Teachers.
- Intellectual Capital and Knowledge Management.
- Perception, Illusion, and Brain.

The above symposia are only a few of the 150 or so AAAS program offerings in the physical, life, social, and biological sciences that will broaden the perspectives of students and professionals alike. Indeed, AAAS annual meetings are showcases of American science, deserving greater participation by mathematicians.

In presenting mathematics to the AAAS Program Committee, I have found the committee genuinely interested in more symposia on mathematical topics of current interest. The Section A Committee is looking for organizers and speakers who can present substantial new material in understandable ways.

For details of the program, see the October 9, 1998, issue of *Science* magazine. I invite you to attend our Section A Committee meeting, 8:00 p.m.–11:00 p.m., Friday, January 22, 1999, in the Anaheim Marriott's Newport Beach Room. The committee meeting is open to all who wish to stimulate interest and activities of the mathematical sciences within AAAS. Please send me, and encourage your colleagues to send me, symposia proposals for future AAAS meetings.

The AAAS wishes to acknowledge the AMS for its generous support.

— *Warren Page, Secretary of Section A of the AAAS*

Meetings and Conferences of the AMS

Associate Secretaries of the AMS

Western Section: **Bernard Russo**, Department of Mathematics, University of California, Irvine, CA 92697; e-mail: brusso@math.uci.edu; telephone: 949-824-5505.

Central Section: **Susan J. Friedlander**, Department of Mathematics, University of Illinois at Chicago, 851 S. Morgan (M/C 249), Chicago, IL 60607-7045; e-mail: susan@math.nwu.edu; telephone: 312-996-3041.

Eastern Section: **Lesley M. Sibner**, Department of Mathematics, Polytechnic University, Brooklyn, NY 11201-2990; e-mail: lsibner@magnus.poly.edu; telephone: 718-260-3505.

Southeastern Section: **Robert J. Daverman**, Department of Mathematics, University of Tennessee, Knoxville, TN 37996-1300; e-mail: daverman@novell.math.utk.edu; telephone: 423-974-6577.

The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. Up-to-date meeting and conference information is available on the World Wide Web at www.ams.org/meetings/.

Meetings:

1998

October 9–10	Winston-Salem, No. Carolina	p. 1553
October 24-25	State College, Pennsylvania	p. 1553
November 14–15	Tucson, Arizona	p. 1553

1999

January 13–16	San Antonio, Texas Annual Meeting	p. 1553
March 12–13	Gainesville, Florida	p. 1554
March 18–21	Urbana, Illinois	p. 1555
April 10–11	Las Vegas, Nevada	p. 1556
April 24–25	Buffalo, New York	p. 1556
May 19–22	Denton, Texas	p. 1557
July 12–16	Melbourne, Australia	p. 1557
September 25-26	Salt Lake City, Utah	p. 1558
October 2–3	Providence, Rhode Island	p. 1558
October 8-10	Austin, Texas	p. 1558
October 15-17	Charlotte, North Carolina	p. 1559

2000

January 19–22	Washington, DC Annual Meeting	p. 1559
April 1–2	Lowell, Massachusetts	p. 1559
April 7-9	Notre Dame, Indiana	p. 1560
April 14-16	Lafayette, Louisiana	p. 1560
June 12–15	Odense, Denmark	p. 1560
September 22-24	Toronto, Ontario, Canada	p. 1560
November 3-5	New York, New York	p. 1560

2001

January 10-13	New Orleans, Louisiana Annual Meeting	p. 1560
March 16–18	Columbia, South Carolina	p. 1561
March 30-31	Lawrence, Kansas	p. 1561
April 28-29	Hoboken, New Jersey	p. 1561
October 13-14	Williamstown, MA	p. 1561

2002

January 6-9	San Diego, California Annual Meeting	p. 1561

Important Information Regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 150 in the January 1998 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

Several options are available for speakers submitting abstracts, including an easy-to-use interactive Web form. No knowledge of TeX is necessary to submit an electronic form, although those who use LaTeX, or AMS-LaTeX may submit abstracts with TeX coding. To see descriptions of the forms available, visit http://www.ams.org/abstracts/instructions.html or send mail to abs-submit@ams.org, typing help as the subject line, and descriptions and instructions on how to get the template of your choice will be e-mailed to you.

Completed abstracts should be sent to abs-submit@ams.org, typing submission as the subject line. Questions about abstracts may be sent to abs-info@ams.org.

Paper abstract forms may be sent to Meetings & Conferences Department, AMS, P.O. Box 6887, Providence, RI 02940. Note that all abstract deadlines are strictly enforced. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

Conferences: (See http://www.ams.org/meetings/ for the most up-to-date information on these conferences.)

1999:

January 11–12: Short Course on Nonlinear Control, Hilton Palacio Del Rio, San Antonio, Texas. See pp. 1262–1266 for details.

June 13–July 1: Joint Summer Research Conferences in the Mathematical Sciences, Boulder, CO. See pp. 1435–1441 for details.

July 26–August 13: Summer Research Institute on Smooth Ergodic Theory and Applications, Seattle, WA. See pp. 1442–1443 for details.

Hotel Reservations

To ensure accurate assignments, please rank hotels in order of preference by writing 1, 2, 3, etc., in the spaces at the left of the form and by circling the requested room type and rate. If the rate or the hotel requested is no longer available, you will be assigned a room at a ranked or unranked hotel at a comparable rate. Participants are urged to call the hotels directly for details on suite configurations, sizes, etc. Reservations at the following hotels must be made through the MMSB to receive the convention rates listed. All rates are subject to a 15% sales occupancy tax. **Guarantee requirements: First night deposit by check (add to payment on reverse of form) or a credit card guarantee.**

☐ Deposit enclosed ☐ Hold with my credit card Card Number_____ Exp. Date _____ Signature _____

Date and Time of Arrival _____ **Date and Time of Departure** _____

Name of Other Room Occupant _____ **Arrival Date** _____ **Departure Date** _____ **Spouse** ☐ **Child** ____ **(give age)**

Order of choice	Hotel	Single	Double 1 bed	Double 2 beds	Triple 2 beds	Triple 2 beds w/cot	Quad 2 beds	Quad 2 beds w/cot	Suites Starting rates
	Marriott Rivercenter (co-headquarters)*	$121	$135	$135	$150	$150	$165	$165	$400
	Students	$95	$95	$95	$110	$110	$125	$125	N/A
	Marriott Riverwalk (co-headquarters)*	$119	$119	$119	$134	$134	$149	$149	$500
	Students	$91	$91	$91	$106	$106	$121	$121	N/A
	Hilton Palacio del Rio	$119	$119	$119	$139	$159**	$159	N/A	$500
	Students	$109	$109	$109	$129	$149**	$149	N/A	N/A
	Ramada Emily Morgan Hotel	$95	$105	$105	$115	$125	$125	$135	N/A
	Students	$85	$95	$95	$105	$115	$115	$125	N/A
	The Menger	$89	$99	$99	$99	$99	$99	$99	$186
	Students	$79	$89	$89	$89	$89	$89	$89	N/A
	La Quinta Convention Center	$89	$99	$99	$109	$119	$109	$119	N/A
	The Crockett Hotel	$85	$85	$85	$95	$105**	$95	$105**	$149
	Students	$75	$75	$75	$85	$95**	$85	$95**	N/A
	Holiday Inn Express Hotel & Suites	$81	$81	$81	$81	N/A	$81	N/A	all suites
	Students	$79	$79	$79	$79	N/A	$79	N/A	N/A
	Hampton Inn	$75	$75	$75	$75	$85	$75	$85	N/A
	Students	$65	$65	$65	$65	$75	$65	$75	N/A
	Red Roof Inn	$64.99	$64.99	$64.99	$64.99	$69.99	$64.99	$69.99	N/A

***Please note that the AMS Council and MAA Board of Governors will meet at the Hilton, NOT at the co-headquarters hotels. Please check updated announcements and schedules for locations of other committee meetings.**

****Limited Availability**

Special Housing Requests:.

☐ I have disabilities as defined by the ADA that require a sleeping room that is accessible to the physically challenged. My needs are: _____

☐ Other requests: _____

☐ If you are a member of a hotel frequent-travel club and would like to receive appropriate credit, please include the hotel chain and card number here: _____

If you are not making a reservation, please check off one of the following:

☐ I plan to make a reservation at a later date.

☐ I will be making my own reservations at a hotel not listed. Name of hotel: _____

☐ I live in the area or will be staying privately with family or friends.

☐ I plan to share a room with _____, who is making reservations.

San Antonio Advance Registration/Housing Form

Name _____

Mailing Address _____

_____

Telephone _____ Fax _____

Email Address _____

(Acknowledgment of this registration will be sent to the email address given here, unless you check the box to the right.)

Badge Information:

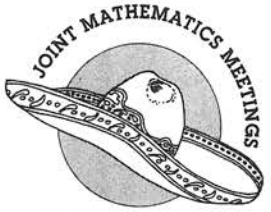
Name to appear on badge _____

Affiliation for badge _____

Nonmathematician guest badge _____
(please note charge below)

Membership
✓ all that apply

AMS	☐
ASL	☐
AWM	☐
CMS	☐
MAA	☐
NAM	☐



San Antonio ★ Texas
January 13–16, 1999

☐ **I DO NOT want my program and badge to be mailed to me on 12/9/98.**

☐ **I want acknowledgment of this registration sent by U.S. mail, not email.**

Registration Fees

Joint Meetings	**by Dec 21**	**at mtg**	**Subtotal**
☐ Member AMS, ASL, CMS, MAA	$160	$208	
☐ Nonmember	$248	$322	
☐ Graduate Student	$ 35	$ 45	
☐ Undergraduate	$ 20	$ 26	
☐ High School Student	$ 2	$ 5	
☐ Unemployed	$ 35	$ 45	
☐ Temporarily Employed	$120	$133	
☐ Developing Countries Special Rate	$ 35	$ 45	
☐ Emeritus Member of AMS or MAA	$ 35	$ 45	
☐ High School Teacher	$ 35	$ 45	
☐ Librarian	$ 35	$ 45	
☐ Nonmathematician Guest	$ 5	$ 5	
☐ Exhibitor	$ 0	$ 0	

$ _____

AMS Short Course on *Nonlinear Control (1/11–1/12)*

☐ Member, Nonmember	$ 80	$ 95	
☐ Student, Unemployed, Emeritus	$ 35	$ 45	

$ _____

MAA Short Course on *Mathematics in Finance (1/11–1/12)*

☐ Member of MAA	$125	$140	
☐ Nonmember	$175	$190	
☐ Student, Unemployed, Emeritus	$ 50	$ 60	

$ _____

MAA Minicourses (see listing on facing page)

I would like to attend: ☐ One Minicourse ☐ Two Minicourses
Please enroll me in MAA Minicourse(s) #_____ and/or #_____
In order of preference, my alternatives are: #_____ and/or #_____
Prices: $55 for Minicourses # 1, 3, 4, 6, 7, 8, 10, 12, 13, 15, 16
$75 for Minicourses # 2, 5, 9, 11, 14 (computer)

$ _____

Employment Register

Applicant résumé forms and employer job listing forms will be on e-MATH and in *Notices* in September and in *Focus* in October.

Employer—First Table	$200	$250
☐ Regular ☐ Self-scheduled ☐ Information Table		
Employer—Second Table	$ 50	$ 75
☐ Regular ☐ Self-scheduled ☐ Information Table		
☐ Employer—Posting Only	$ 50	N/A
☐ Applicant	$ 40	$ 75

$ _____

Events with Tickets	**Price Per**
AMS Banquet #___Regular #___Veg #___Kosher	$ 39
MER Banquet #___Regular #___Veg #___Kosher	$ 39
NAM Banquet #___Regular #___Veg #___Kosher	$ 39

$ _____

Student Activities (no charge):

☐ Mathchats

Total of Fees for Registrations & Events : $ _____

Payment

Registration & Event Total (total from other column) $ _____

Hotel deposit (only if paying by check) $ _____

Total Amount To Be Paid **$** _____

(Note: A $5 processing fee will be charged for each returned check or invalid credit card.)

Method of Payment

☐ Check. Make checks payable to the AMS. Checks drawn on foreign banks must be in equivalent foreign currency at current exchange rates.

☐ Credit Card. VISA, MasterCard, AMEX, Discover (no others accepted).

Card number: _____

Exp. date: _____ Zipcode of credit card billing address: _____

Signature: _____

Name on card: _____

☐ Purchase order # _____ (please enclose copy)

Registration for the Joint Meetings is not required for the Short Courses, but it is required for the Minicourses and the Employment Register.

Other Information

Mathematical Reviews field of interest # _____

How did you hear about this meeting? Check one:

☐ *Focus* ☐ *Notices* ☐ WWW ☐ Colleague(s) ☐ Special mailing

☐ I am a mathematics department chair.

☐ Please do not include my name on any promotional mailing list.

☐ Please ✓ this box if you have a disability requiring special services.

Mail to:

Mathematics Meetings Service Bureau (MMSB)
P. O. Box 6887
Providence, RI 02940-6887
Fax: 401-455-4004
Questions/changes call: 401-455-4143 or 1-800-321-4267 x4143

Deadlines

For room lottery and/or résumés/job descriptions printed in the *Winter Lists*, return this form by:	**Nov. 9, 1998**
For housing reservations, badges/programs mailed:	**Nov. 23, 1998**
For housing changes/cancellations through MMSB:	**Dec. 11, 1998**
For advance registration for the Joint Meetings, Employment Register, Short Courses, MAA Minicourses, & banquets:	**Dec. 21, 1998**
For 50% refund on banquets, cancel by:	**Dec. 30, 1998***
For 50% refund on advance registration, Minicourses & Short Courses, cancel by:	**Jan. 9, 1999***

***no refunds after this date**

SPRINGER FOR MATHEMATICS

OLEG A. IVANOV, St. Petersburg State University, Russia and **ROBERT G. BURNS,** York University, Ontario, Canada, (Translator)

EASY AS π?

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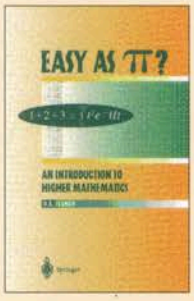

This book aims at introducing the reader to both the higher and the more fundamental developments of the basic themes of elementary mathematics. To this end most chapters begin with a series of elementary problems, behind whose diverting formulation more advanced mathematical ideas lie hidden. These are then made explicit and further developments explored, thereby deepening and broadening the reader's understanding of mathematics. The book arose from a course for potential high school teachers of mathematics taught for several years at St. Petersburg University, and nearly every chapter ends with an interesting commentary on the relevance of its subject matter to the actual classroom setting. However it can be recommended to a much wider readership, including university-level mathematics majors; even the professional mathematician will derive much pleasurable instruction from reading it.

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