Dr. Raymond L. Johnson: A Mathematical Journey and Some Reflections on African Americans in Graduate Mathematical Sciences Programs in the US

Tasha Inniss, Raymond L. Johnson, and Sherry Scott

1. Introduction

Dr. Raymond L. Johnson has had a productive career as both a research mathematician and as a mentor to African American students pursuing advanced degrees in the mathematical sciences. While he served as chair of the Department of Mathematics at the University of Maryland, College Park, his bold and transformational efforts resulted in more than ten African Americans earning doctoral degrees in the mathematical sciences. Because he was instrumental in and intentional about recruiting talented African American students for the doctoral program at Maryland, he was awarded the Presidential Award for Excellence in STEM Mentoring (see Figure 1).

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Figure 1. President Barack Obama meets with the 2012 winners of the Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring (PAESMEM) in the Oval Office, June 17, 2015.

This article is broken into two parts. The first part, written by Johnson himself, highlights his academic and mathematical journey, while the second part is structured as an interview in which Johnson discusses some of his views and experiences in the fight to increase the number of African American mathematicians.

2. My Career at Maryland

Maryland used a device called the "two-man committee" to help new assistant professors make their way through the profession. The committee was supposed to meet with the new person, advise them on publication strategies, and present their case when it was time for them to be considered for promotion. I was told there was such a committee, but it never met with me. I was surprised then when I got a letter two years into my appointment pointing out that I needed to have publications to be considered for promotion a couple of years hence. I had, in fact, published my thesis and had another paper in the pipeline. One of my committee members had assumed I was not publishing and had not asked what I was doing.

My thesis director, Jim Douglas, had written an article on how to prove backwards continuation in time for solutions of the heat equation. It is known that if you know the solution u of the heat equation at some time T, you can calculate it for every time larger than T because there is a representation formula $u(x, t+T) = W(x,t) * u(x,T)$, where W is the Gauss-Weierstrass kernel,

$$W(x,t) = \frac{1}{\sqrt{4\pi t}} e^{-x^2/4t}.$$

If you are making numerical approximations and make an error ϵ in your computation, the error in future times will be bounded by some multiple of ϵ and you can be sure the approximation is reasonable.

But you cannot compute $u(x,t)$ for $t \le T$. Forward continuation is stable and straightforward; backward continuation is unstable and requires some a priori assumption. Douglas had proved that if you assumed the solution had a nice representation formula, then while you could not say that the backwards approximation would have an error bounded by a multiple of ϵ, you would have Hölder dependence; it would be bounded by a multiple of ϵ^δ for some $\delta > 0$. Numerically this means that an approximation would not necessarily be of the same order, but you would lose a fixed number of digits, and so further approximations could be understood.

One way to express all of this is that if $||u(\cdot, T)|| \le \epsilon$, then $||u(\cdot, t+T)|| \le C\epsilon$ for forward continuation.

The best you can hope for with backwards continuation is to make some further assumption on the function u, and perhaps you can say that there is a $\delta > 0$ such that if $||u(\cdot,T)|| \le \epsilon$, then $||u(\cdot,t)|| \le C\epsilon^\delta, 0 < t < T$.

The a priori assumption Douglas made was that there was a measure μ such that $u(x,t) = \int W(x-y,t)d\mu(y)$. There were results going back to D. V. Widder that showed that this could happen if, for example, the solution was nonnegative.

Avner Friedman's book on parabolic partial differential equations was published in 1964 and contained a proof of the existence and properties of the fundamental solution $\Gamma(x,t)$ of a parabolic second-order equation. My thesis extended the method of Douglas to solutions of general linear second-order parabolic equations with $\Gamma(x,t)$ taking the place of the Gauss-Weierstrass kernel W. I showed that solutions had the same backwards continuation estimates as solutions of the heat equation had, perhaps with a different value of δ.

Before my last year at Rice, Jim Douglas took a job at the University of Chicago. I could have stayed at Rice and chosen a new thesis director, but I thought I could save time if I went with Douglas. It was somewhat easier because I had an NSF (National Science Foundation) graduate fellowship, which would continue to support me. My wife, Claudette, worked at the Social Security Administration and secured a transfer to a comparable job in Chicago. We spent 1967–68 in Chicago. Douglas had to prod me to finish because life was very enjoyable in Chicago.

In 1968, I was hired as an assistant professor at the University of Maryland at College Park. The first thing I had to do was get my thesis in a form suitable for publication. I had my thesis defense in the summer of 1968, before I arrived at College Park, but at the time, Rice did not have winter graduations. I paid to have it typed and presented it to Rice University, which awarded my degree in the summer graduation in 1969. I then wrote it up in a form suitable for publication in the *Transactions of the American Mathematical Society*.

I also had to choose a research direction. One possibility was to consider higher-order parabolic equations, but I was practically sure the same methods would work in the same way. Another possibility was to extend my thesis result to systems of equations, where Eidelman had constructed a fundamental solution, but again, I thought little new work would be needed.

I decided to focus on the question of when solutions admitted a representation of Widder's type. My next paper assumed various mixed $L^{p,q}$ bounds on the solution and showed that there was a distribution f such that $u = W * f$, where this means $u = \langle W(x-\cdot), f\rangle$ taken in the sense of distributions, and f need not be a measure.

I submitted this paper to the *Journal of the London Mathematical Society* because an editor there, T. M. Flett, had proved similar results for an elliptic equation and because I thought I was more anonymous in England.

During the reviewing process for this paper, my two-man committee was changed. John Benedetto was appointed to it, and he asked me what I was doing. I explained the paper in process and what I hoped to do after it was accepted, if it was. He presented my case to the tenure committee, and I received tenure soon thereafter.

I later learned that this type of mixed weight condition had been considered by many people (Besov, Taibleson) and the distributions were in a class eventually called the Besov spaces. They were a generalization of spaces of Lipschitz- or Hölder-continuous functions. A function is Hölder continuous of order α if $|f(x+h)-f(x)| \le Ch^\alpha$ for all $x, h > 0$. The quantity $f(x+h)-f(x)$ is a first difference and is denoted $\Delta_h f$. The Besov spaces are functions whose higher-order differences divided by various powers of h belong to L^p spaces in x and L^q spaces in h with a modification of Lebesgue measure. They were first studied using a definition involving these differences, but it had been discovered that they could also be characterized by properties of solutions of the Dirichlet problem in the upper half-space (Flett) or properties of the solution of the heat equation (Taibleson). There were papers in Russian by Besov and papers in English by Flett and Taibleson. I could read Russian but only learned of the Besov spaces later. My initial introduction had been from the papers of Flett, which I had successfully generalized. Taibleson had also considered the spaces, but I was unaware of his work at the time I started working on the problem.

I had a slight difference in focus. The earlier authors had been interested in the properties of functions in the Besov spaces, using the new approaches to consider questions like trace theorems (if u is in a Besov space of a certain order and you restrict it to a lower-dimensional subspace, is it still in a Besov space and if so, of what order) and extension theorems (if a function u is in a Besov space on R^n, can you construct an extension of it to R^{n+1} and to what Besov class will it belong?). I wanted to know if mixed norm conditions characterized uniquely an initial distribution, gave a representation $u = W * f$ as above, and determined the Besov class to which it belonged. I made an assumption, which I never verified, that if there was such a representation, my results and Douglas's results would apply to the backward continuation problem. However, I thought it would be easier to check the mixed norm estimates than to know exactly when you had the type of representation theorem needed to make the theorem apply. There is also an operator-theoretic approach to these problems; my first student, Alton Wallace, extended the operator-theoretic approach to parabolic equations. I later learned that he was the second African American student to have an African American thesis director; Albert Bharucha-Reid directed Tepper Gill's thesis at Wayne State University. Tepper and I were later colleagues at Howard University.

Parenthetically, there was later a great extension of the Besov spaces to $0 < p < 1$ and consideration of atomic and molecular decompositions of the Besov and Hardy spaces. My second student, Sue Sands, wrote a paper on the parabolic version of some of these results. I did not work directly on the extensions, although I used them in some of my later work.

I realized that work on Besov spaces had brought me to harmonic analysis, and I began to study uses that could be made of the Besov spaces. My first application involved the distinction between homogeneous and inhomogeneous Besov spaces. The inhomogeneous spaces are invariant under multiplication by characters (if $f \in X, \chi_h f(x) = e^{-ixh} f(x) \in X$), the homogeneous spaces are not. I showed what the character invariant subspaces of the Besov spaces were. Character invariance becomes translation invariance on the Fourier transform side; I wasn't always precise in my verbal description, but I was in the mathematical description.

I appropriately focused on producing papers during my early career. I did not pay enough attention to making sure people at, e.g., NSF knew what I was doing. I did get lured into trying to help a group of African American graduate students through the program. I was not successful, partly because I had not been involved in recruiting them and did not know their strengths and weaknesses. In hindsight, it was not a good use of my time. I did not pursue any collaborations during this period, but as a new assistant professor and an African American, people were not exactly beating on the door to work with me.

After I received tenure, I had a sabbatical and applied to the Mittag-Leffler Institute to participate in their 1973–74 special year on partial differential equations. It was my first time in Europe at an institute with many young mathematicians who were very friendly, and I had a productive year. It was not my specialty, and I ended up getting thrown into the deep end of the pool. Lars Hörmander, who had just published his paper with Duistermmat on Fourier integral operators, was the director of the Institute for the fall semester (Lennart Carleson was on leave), and he arrived with N papers to be presented by the N individuals visiting the Institute. None of them were really in my area, so I ended up with the last paper on his list, which was his paper on pseudodifferential operators presented at an AMS meeting in about 1968. I had to learn it all from scratch but succeeded in presenting it in two lectures to the assembled group, who probably knew it much better than I did, but who didn't complain about my report. I kept the notes and gave a similar talk when I returned to Maryland.

When we returned from Sweden, my wife and I had Jim Donaldson over for dinner several times, and he showed me his draft plan for a doctoral program at Howard. I do not know the plan's genesis, but it was fully formed when I read it. After several discussions, he invited me to join the faculty.

I went to Howard in 1976 in a class that included James Curry and Gerald Chachere from Berkeley, James Joseph, and myself. I can't speak with great authority on Jim Donaldson as chair. He was on sabbatical at NYU the first year, and George Butcher was acting chair, but Jim came back by my second year.

My difficulties were always with the administration, not from the chair's office. Curry, Chachere, and I wanted to be able to come into the office on weekends. We would need a key to the building in order to do that. We had to petition the administration (we met with a Vice President, whose name I do not recall). He explained that our safety would be our responsibility, and allowed us to get a key to the building (I was younger then). We were not even allowed to use the Xerox machine (faculty at Maryland could make their own Xerox copies), and computers were not prevalent in those days.

I can say that Jim was an excellent judge of mathematicians and made many outstanding appointments. He seemed to know every graduating doctoral student and which ones would be a good fit for Howard.

After a year, Curry took a postdoc at MIT, and after two years, I went back to Maryland. Chachere and Joseph remained on the faculty at Howard.

In our exit interview, I told Jim that I felt that even as an African American, an associate professor, and one of 80 faculty at Maryland, I would have more influence there than I would as a full professor and one of 25 faculty at Howard. Jim tried to reassure me that different people at Howard had different amounts of influence, and while I understood that and the reasons for it, I thought the unpredictability was part of the problem.

I returned to Maryland in 1978, and my path to full professor was smoother than my path to associate professor, perhaps because I had shown a willingness to leave, but more because John Benedetto understood what I was doing and could explain it to the other faculty. I was promoted to full professor in two years. What motivated me to pursue this promotion? I believe it was that Howard thought I was good enough to be a full professor and I was very invested in my research program at that time. I had two further opportunities to leave Maryland and can explain why I turned them down. I was approached about applying to head the MAA (Mathematics Association of America) Office of Minority Affairs, later headed by Bill Hawkins. At the time of the approach, I had been graduate chair and was contemplating running for chair. I felt I could do more good for the students I had recruited by staying at Maryland. The same reason applied when, after completing my term as chair, I was offered the position of Deputy Director at MSRI (Mathematical Sciences Research Institute). I would have enjoyed working with William Thurston, Director of the Institute, but I felt that I needed to be at Maryland to help as many of our recruits finish as possible.

There aren't many collaborations on my resume, and that is one of my disappointments. If I had made more of an effort, I might have had a more far-reaching resume. Finally, after I had stepped down as chair and had long been away from my areas of interest, Bob Warner and I started a project on spectral synthesis. It had generally been studied in L^1, but we decided to see if we could get better results by studying synthesis in H^1, a subspace of L^1 that was known to give better results for mapping questions. Many operators that map L^p into L^p, $p > 1$, do not map L^1 into L^1, but do map H^1 to H^1. We showed that one could get close to answering some old open questions in spectral synthesis and published two papers, one after Bob had died.

For most of my career, if you ask me which of my papers was the most interesting, I would say the last one. That remains true today.

3. Interview of Dr. Johnson

Q1: *Since the world's viewing of Mr. George Floyd's murder on May 25, 2020, there has been a good deal of discussion in the media about systemic racism. Where do you think we stand with regards to diversity, inclusion, equality, AND equity in the mathematical sciences? Has there been any real progress; if so, in what sense?*

Johnson: There continues to be intermittent progress at intermittent places. Most programs do well when someone takes care of them and then wither when there is no one to propel them forward. I think especially of Maxwell Reade's[1] recruiting of African American students from Historically Black Colleges and Universities (HBCUs) to the math program at the University of Michigan around the late 1960s and early 1970s, and Lee Lorch's[2] mentoring work at Fisk University from 1950 to about 1955 before he was run out of the country by the House Unamerican Activities Committee (HUAC).

Q1a: *The phrase "when someone takes care of them" implies that the program depends on one key person?*

Johnson: Yes and for this reason, it's difficult to maintain/sustain a program. Phil Kutzko has found a successor for the Math Alliance (a national community of math science faculty)—namely David Goldberg at Purdue University—so that program should continue. However, Lee Lorch had six undergrads at Fisk University go on to graduate school, but Fisk has not had any since his time there in the 1950s. In general, the key person for leading the program needs a good group of supporting people so that the important second (and subsequent) efforts

[1] https://record.umich.edu/articles/obituary-maxwell-reade/
[2] https://www.youtube.com/watch?v=_mcpiVui54w

are effective and sustained. Also, programs need persons in positions of power who understand the African American culture. For example, the program head needs to understand the nuances of covert racism (e.g., racism experience by African Americans vs. other people of color) and microaggressions that students might encounter. In addition, many students will come from HBCUs so the program head must understand those institutions and their academic programs, so they can properly evaluate those students' math background (e.g., see response in Q6).

Q2: *Many would agree that desire (along with hard work) is one of the most important ingredients for success with diversifying a graduate mathematical sciences program. Most importantly, we should note that there is no magic formula. That being said, in your experience and from your observations, what are some other key common characteristics of a successful program?*

Johnson: I think there are common elements in all the programs that have been successful.

One is getting a "large" (the specific number depends on the institution) body of African American students. There is always tremendous pressure, partly self-inflicted, on a single individual or a few minorities in a program.

The second thing is to treat students as individuals. The best (worst) example of this was in 1998 when, after retiring from an administrative role, Don Lewis worked hard to recruit a group of African American students to the University of Michigan PhD program. An African American math transfer student from Michigan told me that at the orientation for new graduate students, the graduate chair told the African American students that the department knew the students were not as good as the other students in the program, but the department would work to help them succeed. He undid all of Don's good work with this one sentence. Many of those students left (the student who shared the story with me came to Maryland and got her doctorate with us). This was clearly a different statement and tone than given by Maxwell Reade to the African American students he recruited to the University of Michigan in the late 1960s to early 1970s. Reade told them they would be admitted to the doctoral program, and even if they were not successful, they could still leave with a master's degree. A master's degree is worth something and was worth considerably more when Reade was making this offer.

The third thing is to encourage the students to form their own community. The students understand that they must join the larger mathematics community on their campus as a whole, but some hesitate to form a minority community. Richard Tapia at Rice University has always worked to get his recruits to form a community, and we did the same at Maryland.

Q2a: *What are some positive or negative signs/indicators that a prospective African American student might consider when looking for a graduate mathematical sciences program?*

Johnson: If the department currently only has white students, then this should be a concern. A prospective African American student should visit the school and department and gauge if there is a genuine "supportive feeling" during the visit. If the African American student is treated as just filling a diversity recruitment need or if the diversity recruitment is not an integral part of the overall graduate program, then this is a bad sign. That is, the program designed to recruit and retain African American students should not be separate from the rest of the graduate program. A definite positive sign is clear evidence of a group support system in several key positions—e.g., the graduate school staff, graduate director, department chair, department and university administration—all working together to successfully diversify the program and make that diversity an essential and fundamental part of the graduate program, department, and university.

The program should make it easy for the African American student to talk unfiltered to other students, faculty, and staff other than the recruiters. For example, the prospective African American student should have a chance to meet with the student body (not just select students) without the recruiters present, so that they can candidly discuss the program. The best source of information comes from other African American students and other students in general.

Also it's a good sign if the African American student can begin to identify someone who might want to be their thesis advisor, and the African American student should discuss this process and possible options for advisors with other students. Another key concrete tell is the type and amount of financial support that is being offered. If the monies for the program are primarily based on external grants this hints of a lack of institutional support. Funding from the institution attests to the amount of buy in and support on behalf of the institution. Remember that funds from the schools can be on the order of 3 trillion vs. grant funds of 3 billion (see quote in response to Q3a). Regardless of the amount or scale of monies the school has, if diversifying their program is a priority, then the monies should be focused accordingly.

Note that data such as retention/graduation rates (versus just enrollment rates) are good to look for, but such data can be difficult to obtain and perhaps misleading. Similarly, retention/support strategies/programs might be difficult to identify.

Q3: *Key supportive leadership, such as the department chair, can change rather quickly. Moreover, the tenure of these*

leadership positions can be short, e.g., only two or three years. Hence, a supportive environment can become less supportive and move more so towards the status quo or might even become toxic in a matter of two years. What are some ways for addressing this "instability point"?

Johnson: Perhaps we were lucky at Maryland because the department chair's term was five years, and the program was able to run for five years before starting to wither. The main variable is whether key people and the institution/department are genuinely interested in recruiting minority students or giving lip service to the concept of diversity. More often, I see lip service instead of work to implement change.

Unfortunately, there is no way to be sure leadership is committed to improving things. You will always hear the right words, but it can be challenging to detect if they mean what they're saying.

It is probably most important for African American students to just be aware that the atmosphere can change quickly and be prepared to leave if necessary. They should definitely look for written and clear structure, specifications and objective rules for measuring progress towards completing the program and graduating, so if the leadership/administration changes, they have some structure/rules to protect them. For example, details about how many and which exams are required for PhD students as well as the doctoral exam procedures and requirements should be clearly written down. It helps to identify someone who will know and be honest about such issues.

Q3a: *The idea of "lip service instead of work to implement change" brings to mind a "quick fix/throw money at the problem" tactic. In particular, alumni donations and their influence can be tricky to manage and sustain in a positive and productive manner especially with regard to diversity. For example, I think of Bloomberg's 150 million dollar donation to Johns Hopkins University (in May 2021) and the opposition by a top alumnus donor to the tenure of Dr. Nikole Hannah-Jones (an African American woman) at UNC School of Journalism at Chapel Hill (in summer 2021). Can you comment on these types of issues?*

Johnson: I have seen both sides of issues like these. I remember at an advisory board meeting at NSF, James Rosser, President of California State University at Los Angeles, a very smart man, leaned over to me and whispered, "Everyone is so interested in NSF funding. NSF has a budget of 3 billion dollars (that lets you know how long ago this took place), while colleges spend 3 trillion dollars per year." I realized that the money was in the universities, and we largely spent the University of Maryland at College Park's own money in our effort. Grants like GANN (Grants in Areas of National Need) come and go, but university assistantships and fellowships are there as long as the university funds them. It is good for a program to have a lot of money, but I foolishly turned down a chance to pursue grants that might have let us get even more African American students at Maryland. I felt like it wouldn't be good for mathematics if we had "sucked all the oxygen out of the room." We had funded a large proportion of African American doctorates with univeristy funds and could have applied for grant funding, but I didn't think it would be healthy if most of the African American doctorates came from our one institution. When I made this decision, I did not realize how much the program would eventually wither. We probably should have struck while the iron was hot and gotten as many people through as possible.

We never had the kind of negative attention an alumnus brought to UNC, but neither did we have the positive support Don Lewis told me about at Michigan, where a member of the Board of Trustees had engaged with him about improving their freshman mathematics program. As a result, Don Lewis expanded Uri Treisman's freshman preparation program to the entire freshman program at Michigan. Treisman originally worked with underrepresented groups; Don's program at Michigan was for all students and added other new ideas like involving postdocs and graduate students in addition to faculty and undergraduate students. In this way, the freshman class instruction came from a four-person team teaching and collaborating with the students. Attention from the Board can be helpful when it is not used against the university's long-term interests as it was at UNC.

Q4: *What difficulties/adversities with faculty and leadership did you experience as department chair? Any particular/specific backlash?*

Johnson: There wasn't backlash as much as there was disbelief. Faculty genuinely believed that minority students could not succeed in mathematics. I saw this repeatedly even after many of our students had graduated ("but they were exceptional"). I didn't see it from faculty who had advised some of our minority students, but I saw it from most of those who had not.

Q5: *What key allies did you have?*

Johnson: I started this effort when I was graduate chair. Many of the students were recruited by my successors: Rebecca Herb, Karsten Grove, and William Goldman. They deserve much of the credit for recognizing talented students. There were faculty who were supportive, including most of the thesis advisors of our African American graduate students, such as John Benedetto. Most of the faculty were indifferent or unaware. This was a priority of the upper administration, but the indifference applied there as well. They were happy to brag about our math department's accomplishments, but not enough to provide extra money.

Harry Truman supposedly said about Washington, "If you want loyalty, get a dog." I felt that the people who had had minority graduate students were allies; the rest of the faculty were indifferent. Like I said if you want allies...

Q6: *Are there any specific/personal incidents that come to mind?*

Johnson: I have many stories, but I will mention only one with a name since Karen died almost two years ago. As graduate chair, I received an application from a very talented African American student from Spelman College named Karen King. I could tell she was brilliant, but the mathematics graduate admissions committee rated her at a level that would not qualify her for an assistantship or fellowship.

I suppose I could have just overridden them, but I did not want to do that. Instead, I took the problem to the chair, Nelson Markley, and explained my discomfort. He was also chair of the campus-wide Graduate School Fellowship Committee. He told me to send her folder over to them because they were used to looking at a broader range of schools. I did, and the fellowship committee awarded her a fellowship, which is the holy grail of funding since it came from the university and did not require teaching, and ranked her at the highest level possible. Our committee recognized its mistake, but if Nelson had not been so placed, we could have lost one of our best students and the first one of the Spelman to Maryland pipeline.

The second incident came when I was chair and got a phone call from a colleague. He said he had a brilliant student; he had encouraged the student to apply to many highly rated schools, but the student had been turned down at every school, including Maryland. Being aware of the calibration problem, I went down to look at the file (probably the only time I ever did that as chair). I discovered that one of the three letter writers had clearly not known the student well. The student was a male, but the letter writer said that "she" was one of the best students he had ever had. I called my colleague back and asked if we could get another letter from a different writer. He arranged it, and the student received an assistantship and completed his doctorate.

A pure form of the calibration issue (committees that evaluate students from HBCUs without understanding the academic programs of those schools) showed up after I had left the chair's office and returned to the faculty. Another brilliant Spelman student I met on some trips there while serving on an Advisory Board was completing her degree a couple of years early with excellent grades. By then, we had a track record of Spelman students succeeding in the Maryland program. I was astonished when I received an email from the student. She said that she wanted to come to Maryland for the doctoral program but was offered a Fellowship in Applied Mathematics at Princeton, yet only an assistantship at Maryland. I passed the information on to the appropriate person; she was awarded a Fellowship and easily completed her degree at Maryland.

Do you have a summary statement or concluding remarks/requests?

Increasing and graduating African Americans with PhDs in the mathematical sciences can be done! The recurring theme is that it requires a genuine and concentrated departmental and institutional commitment and effort in a positive supportive environment. In particular, the program needs key persons, faculty or staff, who understand the specific obstacles encountered by the students, and successors who can sustain the work.[3]

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Credits

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[3]*For additional information, consider the following:* `https://nam-math.org`, `http://www.mathad.com`, *and* `https://www.math.umd.edu/~rlj/fineddrft.html` *as an initial start.*