Remembrances of Edward G. Effros

Edited by Palle Jorgensen

"Life can only be understood backwards; but it must be lived forwards"

—Søren Kierkegaard—translated from Danish by Palle Jorgensen

Edward George Effros (1935–2019), Distinguished Professor of Mathematics at UCLA, died on December 21, 2019. His degrees are from MIT and Harvard (PhD with a thesis directed by Professor George Mackey). He joined UCLA in 1980, after nearly 20 years as a Professor at the University of Pennsylvania. He was famous internationally for his profound and pioneering research in operator algebras and representation theory. Of special note is his deep work in what now goes by the name "Operator Spaces," the quantized theory of Banach spaces. His most recent and penetrating work is in Quantum Information. His academic honors include a Guggenheim Fellowship and being an invited speaker at the International Congress of Mathematicians. E. G. Effros was an *AMS member* since 1963, *AMS Fellow* since 2014.

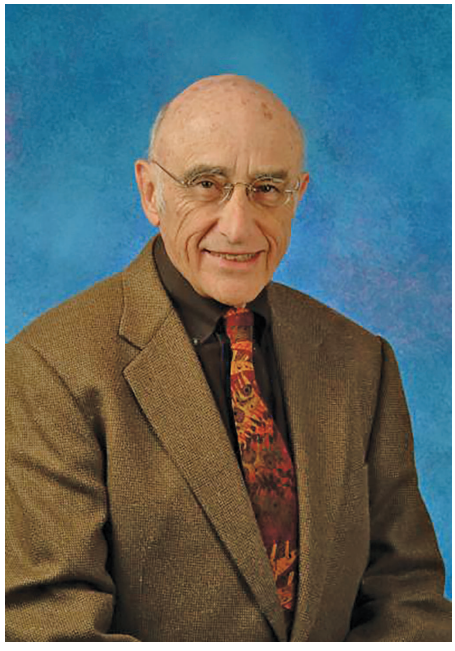

Figure 1. Ed Effros (LA, 2006).

Introduction

Claude (Chaim) Schochet

I got to know Ed Effros in 1979–80 at UCLA during a Special Year in Operator Algebras. That was its official billing, but I think that the UCLA faculty looked upon it as "Recruit Effros" year, for the following year he officially left Penn and joined the UCLA Math Department, where he stayed for the rest of his career.

The Special Year was run by Ed and Masamichi Takesaki. Fred Greenleaf, Richard Herman, Li Bingren, and I were there for the year, and various visitors stopped by, including Vaughan Jones in the spring. [He had just finished his PhD and had a first result on the index of subfactors, and he started his work with Herman on finite group actions on UHF algebras.] I was definitely the junior one of the group. [Speaking of young, I remember Effros commenting one day that when he went to a conference he was

Palle Jorgensen is a professor of mathematics at the University of Iowa. His email address is palle-jorgensen@uiowa.edu.

Claude Schochet is a professor of mathematics at Israel Institute of Technology. His email address is clsmath@gmail.com.

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always especially glad to see Dick Kadison in attendance, for then he knew that he wasn't the oldest one there!]

Ed and Masamichi ran a seminar for the whole year on A. Connes' brilliant paper "Sur la théorie noncommutative de l'intégration" which culminated in his proof of the Index Theorem for foliations. The result is one of four cited in Connes' Fields Medal (1982) citation. The paper is very difficult. I remember that at the beginning of the year the goal of the seminar was to understand the *proof* of the theorem. By the end of the year, the goal had shifted to trying to understand the *statement* of the theorem. Various visitors gave talks (for instance Vaughan gave a talk on foliations, a subject he had learned from Haefliger and Connes), but the regulars gave most of the talks. I don't think I realized it at the time, but running this seminar was extraordinarily difficult. I credit Ed and Masamichi with making it look easy.

It turned out that Cal Moore was leading a seminar at Berkeley on the same paper and also having difficulty. Cal and I eventually teamed up and wrote a book-long exposé of the result. Along the way we generalized Connes' result to foliated spaces. That generalization has proved very useful, most recently in our current work on tilings. So what I learned from Ed, Masamichi, and the others in the UCLA seminar turned out to be critical in my career. I owe Ed and Masamichi a big thanks for including me.

Figure 2. Vaughan Jones needs a tie (1992).

Ed was invariably warm, gentle, and helpful. I came to UCLA with a haphazard background in C^*-algebras and virtually no background in von Neumann algebras. Ed took all that into account, helping me repeatedly with my many many questions. I remember him sitting me down one day and explaining to me just why the fact that the associated von Neumann algebra of the foliation was Type II was central to the story. That was the fundamental fact that brought this Index Theorem into really new territory, very different from the classical Atiyah-Singer theorem or its generalization to families.

Figure 3. Ed, Karen Kadison, Dick Kadison (Norway, 1997).

Ed's and Masamichi's relationship with Li Bingren must have been fascinating. In 1979 there were very few mainland Chinese visiting US universities. Bingren would come to the seminars, work on his own, and nod politely when you spoke to him. I thought that his English was so limited that he wasn't understanding the lectures, and I had no idea about his French, the language of the paper. Several months into the year, Bingren was listed as a speaker in the seminar. I went and was astonished. Bingren gave a clear talk in English and, more amazingly, gave every indication that he understood the paper as well or better than anyone in the room.

After the Special Year I would run into Ed at conferences (starting with the Kingston conference that summer) or when stopping by UCLA. I remember being there once when his identical twin brother came walking down the hall. It was the first time that I had ever seen an identical twin of someone that I knew well, and it was very disconcerting. He had many of Ed's mannerisms—the way he stood, the way he cocked his head while listening,... it was spooky! But there really was only one Ed!

Ed continued to do research for most of his life. I was particularly influenced by his work with Kaminker on homotopy and shape theory. He also wrote various expository works, which I especially valued. His CBMS lectures on Dimensions and C^*-algebras opened the door for many people to the world of AF algebras and their dimension groups [Eff81]. In Math. Intelligencer (1989) he wrote a paper entitled "Why the circle is connected: an introduction to quantized topology" [Eff89]. Here's what I said in Math Reviews:

"The author takes the reader on a brief tour of a fragment of the theory of C^*-algebras, starting from general philosophical comments ["*Now when Heisenberg noted that, he was really scared.*" P. A. M. Dirac] and culminating with a more-or-less self-contained proof that the reduced C^*-algebra of the free group on two generators is connected: it has no nontrivial projections. The focus of the article is on the strength that one obtains by quantizing classical (read commutative) functional analysis and generalizing it to the noncommutative setting. This is a lovely article, exactly the sort of article one would hope to find in the Intelligencer. Compliments to the author and to the editor."

Ed was a wonderful person and a brilliant mathematician. We will all miss him.

Claude Schochet

Obituary for Professor Edward G. Effros

Masamichi Takesaki

I was deeply saddened by the news of Ed's passing and naturally I started to think about his work and my own interactions with him.

I first became aware of Ed as a rising young operator algebraist in 1963 through his work on the conjugate space of a C^*-algebra, a topic which I had also worked on. I was very pleased to find his work because at that time there were rather few papers in the field of operator algebras and I was heartened to know that there was someone far away from me but working in a closely related field.

I first met him in person at the famous Baton Rouge international conference on operator algebras and applications in the spring of 1967. He was the first speaker of the conference and delivered a beautiful talk which impressed me very much despite my limited understanding of English. Ed's exceptional expository skills meant that he was often chosen to deliver the first talk and hence set the tone at many conferences.

Figure 4. Richard Herman, Masamichi Takesaki, Ed (Japan, 1983).

Ed was a very innovative mathematician who worked in and created a very broad range of new areas in the field of operator algebras. He was a mathematical explorer in the true sense: he never hesitated to plunge deep into some unknown field whenever he felt there was something new waiting to be explored. His independence of mind was evident as a graduate student when he chose against the advice of his supervisor at Harvard, George Mackey, to write his thesis in operator algebras. Although our early academic works are closely related, our interests diverged somewhat in later years, with Ed driving crucial developments in an extraordinary range of topics within operator algebras. I was deeply impressed by his creativity and have been strongly and positively influenced by him throughout my career.

He was not only a beautiful lecturer, but also an excellent author of mathematical research articles: he had a distinguished style of creative, elegant, and joyful writing. It is simply a joy to read his papers.

Although I feel that I am not well-equipped to comment on the full range of Ed's mathematical output, I think that I should at least attempt a summary from my own perspective. Probably one can divide his mathematical achievements into the following areas:

1. His contribution, from the mid 1960s to the mid 1970s, to consolidating and expanding the "Mackey philosophy" through his work on (for example) the Effros Borel Space of von Neumann algebras on a separable Hilbert space, the Direct Disintegration of von Neumann algebras and/or representations of

Masamichi Takesaki is professor emeritus of mathematics at UCLA. His email address is mt@math.ucla.edu.

Figure 5. Uffe Haagerup, Ed (Odense, 1992).

C^*-algebras, and the Operator Algebraic Structure Analysis of Compact Convex Sets (a significant contribution to the Choquet School) [Eff65, Eff08].

2. Nuclear C^*-algebras and related topics in the mid 1970s. Among many important contributions by Ed in this area, he and his collaborator, Man-Duen Choi, proved the equivalence of the nuclearity and the approximation of the identity map by completely positive finite rank maps for a C^*-algebra [CE76a, Eff81].
3. Dimension Groups in the early 1980s, where Ed and his coauthors David E. Handelman and Chao Liang Shen gave a beautiful characterization of the dimension groups of AF C^*-algebras as Riesz groups [EHS80].
4. Operator spaces and quantized functional analysis, from the mid 1980s onwards. It is my impression that Ed viewed this work as his most important contribution to mathematics, regarding it as the quantization of analysis [Eff89, Eff09, ER94].

Ed was not only very creative and talented, but also very generous in sharing his ideas with others, resulting in many joint works as well as distinguished visitors to UCLA. This generosity had a critical influence on my own mathematical development. In 1968, I visited the University of Pennsylvania where Ed and his colleagues (including Erling Størmer, a fellow visitor) were evaluating a set of far-reaching claims being made by Tomita; they were skeptical of the claims, and Ed suggested to me that I work through them and write up my own account. The resulting theory is now known as the Tomita-Takesaki Theory of von Neumann algebras. I deeply appreciate my Philadelphia colleagues' flat but friendly rejection of Tomita's claim and Ed's suggestion of writing up my own account.

Ed lived his whole life according to the principles of humanity and warm thoughtful help to others when necessary. For instance, when I arrived at Philadelphia International Airport with my family in the summer of 1968, Ed was kindly waiting there for us to provide any help which may have been needed upon landing. This was my first trip abroad with my family, and I didn't know anything about Philadelphia at that time, so it was a great relief to be met by someone whom I knew. I felt Ed's warm personality and was deeply touched.

Figure 6. Masamichi and Kyoko Takesaki (2004).

Ed's mathematics is also guided by the same principle of humanity and generosity. I admired him very much and felt that we were privileged to have him at UCLA. I am deeply thankful to have been his colleague. We all miss him badly now.

I pray here for the peaceful rest of his soul.

Masamichi Takesaki

A Brief Bio of Ed

Rita Brickman Effros

My husband, Ed, was born in Queens, and grew up in Great Neck, NY. One of his earliest memories was in the 5th grade, when the teacher taught an old trick for checking a long column of addition called "casting out nines." Ed was mesmerized by this apparent "magic" and from that moment on, his ambition was to become a mathematician.

As many of you know, Ed was a twin. He was born 10 minutes ahead of Dick, and he used that seniority to tease his brother on many occasions. They were truly identical, which led to confusion on the part of all family members. Actually, their mother had put little bracelets on them when they were infants to help her keep them straight, but alas, she removed them at bath-time, so who knows which is the real Ed!

Ed managed to finish MIT in three years, and then earned his PhD at Harvard. After a postdoc at Columbia, he moved to the University of Pennsylvania. In May, 1967, we met on a blind date, and married four months later. We were married for 52 years, but it could have been 53 years: Ed, the typical absent-minded professor, had gotten my phone number a year earlier from another friend. But he put it into the dark recesses of his briefcase and forgot about it, until he got my number again, this time from a friend of his brother's wife.

Our two children, Rachel and Steve, were born in Philadelphia, where we lived for 14 years. During that time, Ed met an Immunologist at one of his Penn committee meetings. He came home all excited about the fairly new field of immunology, so much so, that I decided to focus in that field when entering graduate school at Penn.

In 1979, our family relocated to LA, where Ed had been recruited by the UCLA mathematics department, and I eventually joined the faculty of the Geffen School of Medicine. Even though I am a scientist, I have never been able to understand the complicated areas of mathematics that so inspired Ed. Years ago, he told me he was working on something called C^* algebra, and for many years, I assumed he was saying SEA-STAR algebra. Until I actually saw one of his papers, I thought he was interested in oceanography!

Ed was extremely supportive of my own work, but try as he might, he could not stay awake during my "dress rehearsal" for my thesis defense. Nevertheless, he stayed awake during his many hours of childcare while I was completing my graduate work, and beyond, when I had to be away on business.

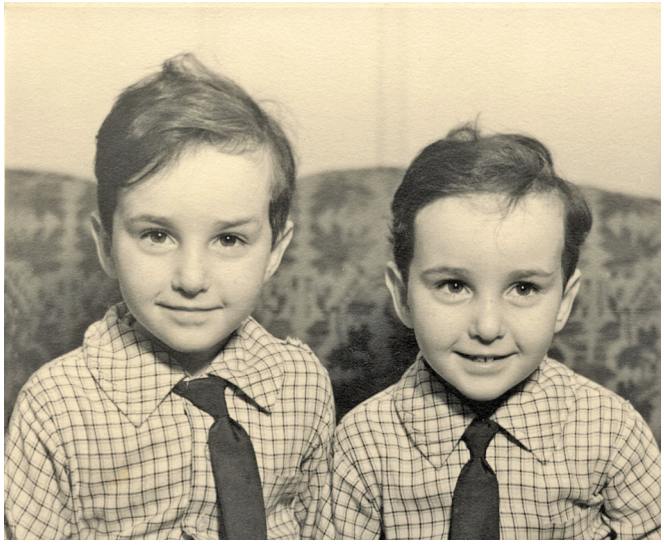


Figure 7. Ed/Dick or Dick/Ed? (Queens, NY, 1940).

Over the years, Ed and his twin, Dick, have played many jokes on family and friends. But one incident truly highlighted how similar they were. Ed was walking up a large staircase of a hotel, and he saw Dick and waved to him. At that moment, he realized that he was waving to himself in a full-length mirror! Even he could not tell the twins apart! One memorable twin story occurred when Ed was spending some time at MSRI in Berkeley. His brother came to meet him after one of the lectures. As he was waiting, one of the mathematicians, who did not know that Ed was a twin, came over to greet Dick, thinking he was Ed. This

Figure 8. Ed and Rita (soon after marriage) and a very young Dick Kadison (Philadelphia, 1967).

Rita B. Effros is professor emerita of pathology & laboratory medicine at the David Geffen School of Medicine at UCLA. Her email address is rita.effros67@gmail.com.

person did not quite believe that it was not really Ed. So, a colleague asked Dick to explain what an Operator Space was—this would prove that this could not possibly be Ed. Dick, being a physician, said, without missing a beat, "An operator space is where a surgeon does his work." So both twins shared a sharp mind and a great sense of humor! Looking at the book that Ed wrote on Operator Spaces with Zhong-Jin Ruan, I now realize how important this area of mathematics is.

One of the joys about being married to a mathematician was experiencing the amazingly close international community of colleagues. We have made so many dear friends both in the US and abroad—all through the math connection. As part of this community, we have visited/lived in so many places. It has been a pleasure to join math colleagues at conferences all over the world, including Berkeley, Paris, Oslo, Istanbul, Beijing, Hong Kong, Copenhagen, Stockholm, New Zealand, Warwick, Japan, Sicily, Montenegro, Croatia, Italy, Wales, and Israel.

In June 2019, we decided to relocate to Portland, Oregon, where our children and grandchildren live. We had spent several summers here, and began to really love the city, which is on the Willamette River and features numerous beautiful bridges. Unfortunately, Ed only lived to enjoy this place for six months, but being so close to our family was a real joy for him. Besides me, Ed is survived by our daughter, Dr. Rachel Effros; son, Stephen Effros (wife, Suzanne); granddaughters, Lila and Eva; brothers, Dr. Richard Effros (wife, Gail) and Robert Effros; numerous nieces, nephews and cousins; and many dear friends.

Rita Brickman Effros

Ed Effros: From His Colleagues at UCLA

Dimitri Shlyakhtenko and Sorin Popa

Edward Effros (December 10, 1935–December 21, 2019) was a professor at the UCLA Department of Mathematics and a world-renowned mathematician. He is known for his pioneering work in functional analysis with his research touching many mathematical subjects, including C^*-algebra theory and operator algebras, descriptive set theory, Banach space theory, and quantum information.

Figure 9. Ed's sixtieth birthday party: Bill Arveson, Jerry Kaminker, Pat Kaminker, Ed, Zhong-Jin Ruan, Rita, Cathy Olsen, Marc Rieffel (Canada, 1996).

Early in his career, Ed used descriptive set theory notions to show that one cannot classify factors explicitly, due to a nonsmoothness obstruction in the spirit of Mackey's similar results for representations of infinite groups. More importantly, he suggested that one could apply the same methods in other areas of mathematics. This triggered many subsequent developments, and indeed, owing to the work of Kechris and his colleagues, Borel classification theory is now a very active area in logic.

Effros's work with Hahn in the 1960s, on transformation groups and the primitive ideal space of group C^*-algebras, was very influential. In particular, Effros and Hahn made a deep conjecture that triggered a lot of work,

Dimitri Shlyakhtenko is a professor of mathematics at UCLA. His email address is shlyakht@math.ucla.edu.
Sorin Popa is a professor of mathematics at UCLA. His email address is popa@math.ucla.edu.

by many people, culminating with a complete solution, in 1979, by Gootman and Rosenberg.

The 1970s were marked by two extraordinary developments in operator algebras: the classification of amenable von Neumann algebras and the birth of noncommutative topology, with the introduction of algebraic topology-like invariants, such as Ext, K-theory, and later KK-theory. Ed made major contributions to both directions. On the von Neumann algebra side, he introduced the notion of semidiscreteness proving it equivalent to amenability, a characterization that was key in Alain Connes final classification of amenable von Neumann algebras. On the C^*-algebra side, he did ground-breaking work, with Lance and separately Choi, on nuclear C^*-algebras (a C^*-version of amenability). In particular, they proved that nuclearity is equivalent to matrix approximability. This was followed by another breakthrough: the proof of the completely positive lifting theorem for nuclear C^*-algebras, an essential ingredient in the Brown-Douglas-Fillmore Ext-theory and later the KK-theory of Kasparov. From that same period, his idea of a C^*-algebraic shape theory was one of the most influential in the theory of C^*-algebras over the last three decades.

Effros is perhaps most famous for his work on what he called a "quantized" theory of Banach spaces. In that he was very much influenced by Takesaki's discoveries and the subsequent meteoric career of Alain Connes. Quantized versions of algebraic topology and probability theory would soon appear. But for Effros, the most influential person was perhaps Arveson, who took the first step in the quantization of functional analysis.

Just as any Banach space can be realized as a linear space of bounded functions (a "concrete Banach space"), one can define a quantized Banach space to be a linear space of norm-bounded Hilbert space operators. For this purpose one must consider the norms of matrices over the space. This is due to the fact that a matrix of operators has a natural norm which cannot be calculated from the norms of its matrix entries. The appropriate morphisms in this theory are the linear mappings that are completely bounded, i.e., they induce uniformly bounded mappings on the matrix spaces. Arveson was perhaps the first to recognize the importance of these notions. In his study of noncommutative function algebras, he succeeded in proving the noncommutative analogue of the Hahn-Banach theorem.

As is well known, there is a more elementary ordered version of the Hahn-Banach theorem which is concerned with positive linear mappings of ordered Banach spaces. There is a corresponding theory of completely positive mappings, in which one recognizes the ordering on matrices of operators. Effros and Choi characterized the operator systems (the quantized versions of Kadison's function

Figure 10. The Popa family (UCLA, 1990).

spaces, the "duals" of compact convex sets). This framework was essential to Effros's groundbreaking work with Lance and Choi on the classification of C^*-algebras. In particular, they introduced the von Neumann analogue of semidiscreteness. As acknowledged by Connes, the latter provided an important key to his characterization of the injective von Neumann algebras. This was followed by the proof of the completely positive lifting theorem for nuclear C^*-algebras, an essential ingredient of Kasparov-Voiculescu's KK-theory.

The category of operator systems is the appropriate context for studying matrix convexity. In particular, Effros and his student Winkler proved an operator analogue of the Hahn-Banach Separation Theorem. This played a key role in the Helton-McCullough theory of free semialgebraic sets. Paulsen and his collaborators have recently turned to the category of operator systems, in which they study such notions as quotients and dual spaces.

Although Arveson proved the "first theorem of quantized Banach space theory," he did not complete the theory. What was missing was the analogue of axiomatizing Banach spaces as abstract vector spaces with norms. One need only realize how awkward it would be if one only handled concrete Banach spaces. Thus it is not obvious

that the dual of $C(X)$ can be thought of as a subspace of $C(Y)$ for some space Y, where it is immediate that it is an abstract Banach space.

Effros assigned his student Zhong-Jin Ruan the task of axiomatizing such matrix normed spaces. The relevant morphisms are linear mappings which induce uniformly ("completely bounded") mappings of these matrix spaces. This characterization result is essential to proving that the dual and various tensor products of operator spaces are operator spaces. The related completely positive mappings determine the channels in quantum information theory.

A wide range of mathematicians, including Pisier, Haagerup, Ruan, and Junge, have taken up operator space theory. It would seem that virtually all of Banach space theory is amenable to quantization. In particular, Effros and Ruan have shown that Grothendieck's tensor product program has quantum analogues for studying mapping spaces. The classical and quantum versions of the Grothendieck inequality are equivalent to various forms of Bell's famous inequality in entanglement theory (see the work of Tsirelson). Specialists in quantum information theory now maintain that operator spaces provide an essential tool in their discipline. The Effros-Ruan book *Operator Spaces* is regarded as the fundamental text in this subject. Since then other major monographs have appeared, including several by Pisier, and a major work by Brown and Ozawa. In this context, Effros's work with Haagerup, Ruan, and Junge on local reflexivity has proved to be particularly important.

Effros's last work concentrated on Quantum Information theory. One of his notable achievements was a greatly simplified proof of several of Lieb's famous inequalities related to this subject.

Dimitri Shlyakhtenko

Sorin Popa

Jonathan Rosenberg

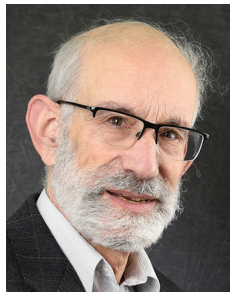
Though I haven't been in much contact with him for many years now, Ed Effros had a big influence on my career and I miss him as a friend and mentor. I first met him when I was in grad school at Berkeley as a student of Marc Rieffel in the years 1973–76, and when I finished my PhD, I took a position at Penn largely because of Ed's being there. We talked quite a bit about many things, mathematical and otherwise, but we only wrote one paper together [ER78]. This paper was, to be honest, not among the greatest work of either of us, but we enjoyed working on it together, and it's gratifying to note that it has since led to some important developments in the Elliott program for classification of simple C^*-algebras.

However, the paper [ER78] gives me a chance to mention one of the things I most remember and cherish about Ed, which was his sense of humor. I remember that I was scheduled to give a seminar talk about this paper, and the announcement was supposed to read

C^*-algebras with approximately inner flip
time: 3:00

However, this was garbled in transcription and came out as "C^*-algebras with approximately inner flip time, 3:00." We both had a good chuckle about this. Ed also once told me that someone, who having heard about the "Effros Borel structure," assumed that he was a collaborator of Émile Borel (who was born in 1871), and on seeing him in person was amazed to discover that he didn't look at all as if he was 100 years old!

As regards Ed's mathematics, the work of his that probably had the deepest impact on my own career was his memoir with Hahn [EH67]. In retrospect, this was the start of a very large body of work on the structure of C^*-crossed products, a subject now well documented in the book [Wil07]. It was through listening to Ed lecture and chatting with him that I came to appreciate the significance of the Effros-Hahn work. And it was Ed's being at Penn that motivated Elliot Gootman to come to Penn for a sabbatical, where with Ed's encouragement we worked on trying to prove the conjecture in the Effros-Hahn memoir [GR79]. So I owe Ed a deep debt of gratitude. All of those in the operator algebra community will miss him.



Jonathan Rosenberg

Jonathan Rosenberg is the Ruth M. Davis Professor of Mathematics at the University of Maryland. His email address is jmr@math.umd.edu.

Figure 11. Ed with Zhong-Jin Ruan and Ruan's son at Lake Michigan, Chicago, Illinois, 1994.

Zhong-Jin Ruan

I feel very sad to lose Ed.

I was a PhD student of Ed Effros at the University of California at Los Angeles (UCLA) when I first met him in fall 1984. He was a great mathematician, extremely bright. He was a great teacher as well, very patient and kind to his students. He was always smiling and encouraging. His devotion to mathematics inspired me. He was also fun to be around. I came from China and received a BA degree in mathematics from Nankai University in Tainjin in 1982. That same year, I studied functional analysis and operator algebras from Professors Joel Anderson and Richard Herman at the Department of Mathematics at the Pennsylvania State University. I became interested in this field. Professor Herman recommended me to study with Ed at UCLA. In the first year at UCLA, among other things, Ed asked me to read his papers while I was gradually building up knowledge. After I passed my second language test, in fall 1985, Ed gave me a question: "How to recognize characterization of operator spaces?" In spring 1986, under Ed's guidance, I discovered a matricial norm characterization for operator spaces (i.e., subspaces of C^*-algebras). This turned out to be a fundamental result in operator spaces which helped me complete my PhD thesis in 1987. Special thanks go to Ed who carefully mentored and coached me for my doctoral studies. His impact was far-reaching on me. Special thanks also go to Rita who always warmly welcomed me with wonderful meals.

As a well-known mathematician, Ed's research style was unique. He loved talking. His humorous conversations came with math ideas. He would provide careful proofs, offer pioneering ideas with great vision. He was always energetic. After discovering the characterization of operator spaces, Ed and I started to collaborate for more than 15 years. Among these years, we incorporated some important topics and applications into a book, entitled *Operator Spaces*, published by Oxford University Press in 2000 [ER00].

In the book, Ed and I were concerned with a more recent innovation, the quantization of Banach space theory. Our goal has been to explain the deep analogy between linear spaces of bounded functions and linear spaces of bounded operators. Fact: every operator space may be realized as a subspace of some C^*-algebra. The question is which kind of and under what conditions can operator spaces be identified with a subspace of C^*-algebras? It turned out that our operator spaces have important applications to the study of harmonic analysis on quantum groups. The book is a summary of our long-time collaboration. Our work along with the work of Vern Paulsen and David Blecher established the foundation for operator spaces.

Ed visited Illinois in the summer of 1994 while we were writing the book. The photo (Figure 11) brings back memories of wonderful stories Ed used to tell. On one day, I had to go out. I asked Ed to help watch over the turkey that was roasting in the oven. He happily responded, "Sure. I would stop the turkey walking out of the oven if it stepped out." Ed and Rita taught me how to cook turkey for the Thanksgiving holiday and their recipe became our family tradition. To me, Ed was my advisor and research collaborator. More importantly, he was a father-like dear friend.

Zhong-Jin Ruan is a professor of mathematics at the University of Illinois. His email address is z-ruan@illinois.edu.

Zhong-Jin Ruan

Marius Dadarlat

Ed Effros's life's work is truly remarkable and will no doubt continue to have a profound impact. He obtained fundamental results in a wide array of areas. But since his extraordinary mathematical achievements have been

Marius Dadarlat is a professor of mathematics at Purdue University. His email address is mdd@purdue.edu.

Figure 12. Maria Dadarlat, Steve Effros, Rachel Effros, Zhong-Jin Ruan, Ed, Marius Dadarlat and Iunia Dadarlat (Berkeley, 2000).

summarized earlier in this article, I will confine myself to adding some personal recollections.

In the Fall of 1990, following the collapse of the totalitarian regimes in Eastern Europe, I had the good fortune and honor of becoming one of Ed's graduate students. He, along with Sorin Popa, was instrumental in opening the doors of the UCLA Math Department for three aspiring students from Romania. I met Ed for the first time when two of us, myself and Florin Radulescu, arrived at LAX. The third, Florin Boca, joined us a couple of weeks later. With his infinite generosity, Ed arranged for affordable hotel reservations, picked us up from the airport, and in the days that followed, assisted us in finding long-term accommodation. Do I need to add that he even called a couple of utility service companies once it became apparent that our command of English was probably insufficient to secure a contract? I will let you guess who provided us with glasses and cookware.

Ed was liberal with his time and he offered me invaluable guidance and support. And his wit and humor were splendid. To my request for a good problem, he replied that if he knew one he would work on it himself. He used this as a pretext to introduce me to his vision of mathematical development. In truth, Ed was driven by a boundless curiosity as he was always in search of new insights and problems that he would wholeheartedly share with others. He encouraged me to continue to explore ideas from algebraic topology in the realm of operator algebras. When graduation time came, I proposed a 30-page thesis. Ed thought it was perhaps too short. After many more hours spent in the library, I had news that Ed found satisfactory: a recent dissertation supervised by a distinguished UCLA math professor was just 14 pages long.

Ed was also a brilliant conversationalist. With a mind that was perpetually young, he would fascinate the people around him with his views and insights into notable current events in mathematics, politics, or society at large. During a dinner occasioned by a colloquium talk at Purdue, Ed's charming and inspiring personality even succeeded in enchanting my mother—who does not speak or understand English.

I owe Ed and Rita deep gratitude for the generous friendship they showed me and my family over the years. We will all miss Ed dearly.

Marius Dadarlat

Research, Edward Effros and Man-Duen Choi: Completely Positive Maps

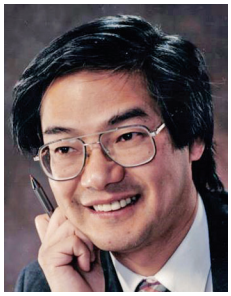
Man-Duen Choi

Originally, the notion of completely positive linear maps was introduced by W.F. Stinespring (1955), and promoted by W.B. Arveson (1969). Then Effros in collaboration with Man-Duen Choi, took up the further tasks (as a series of six papers [CE76b, CE76a, CE77a, CE77c, CE77b, CE78] in 1974–1978) to show that completely positive linear maps are natural morphisms in the category of C^*-algebras.

Indeed, many intrinsic C^*-algebraic constructions, such as tensor products (extended to crossed-products), finite-dimensional approximations (covering nuclear C^*-algebras), and various algebraic topological features (including injectivity and liftings, as fully explored in the Brown-Douglas-Fillmore extension theory) have been feasible in the setup of completely positive linear maps. Henceforth, more substantial results and generalizations of completely positive linear maps were established by mathematicians like A. Connes, K. Davidson, U. Haagerup, V. Paulsen, G. Pisier, Z.J. Ruan, G. Witsttock, and others.

Man-Duen Choi is a professor of mathematics at the University of Toronto. His email address is choi@math.toronto.edu.

On the other hand, as initiated by K. Kraus in the early 1970s, theoretical physicists have become interested in completely positive linear maps in connection with quantum mechanics. Consequently, the mathematical research has been widely recognized in the pioneering papers of the structure of quantum information. Surprisingly, in the beginning of this 21st century, the study of quantum information has grown to a very hot field in physics, because of the sudden building of quantum computers. Notably, the recent progress of quantum information, in terms of quantum channels (alias, trace-preserving completely positive linear maps) on matrix algebras, has provided the most natural setting for noncommutative geometry and noncommutative probability, as well as noncommutative harmonic analysis in all kinds of real practices.



Man-Duen Choi

Dan Voiculescu

My first contact with Ed Effros was in the late 1970s around the time I got my doctoral degree from the University of Bucharest. At the time, I received a short handwritten note from Ed, who was a professor at Penn. The work of Ed and Man-Duen Choi on completely positive liftings for nuclear C^*-algebras and my work about a noncommutative Weyl-von Neumann type theorem, when put together, had an important consequence. By an observation of Bill Arveson, these were the two results needed to prove for a C^*-algebra that the Brown-Douglas-Fillmore Ext semigroup of a C^*-algebra was a group. The Ext of Brown-Douglas-Fillmore was constructed from unitary equivalence classes of injective homomorphisms of the C^*-algebra into the Calkin algebra under orthogonal sums and had been shown by them to be a group in the case of commutative C^*-algebras. My result dealt roughly with the unity element in the semigroup while the Choi-Effros result was needed to get the existence of inverses. It was the beginning of extending the Brown-Douglas-Fillmore theory beyond the commutative, to noncommutative C^*-algebras.

Dan Voiculescu is a professor of mathematics at UC Berkeley. His email address is dvv@math.berkeley.edu.

Figure 13. Ioana Voiculescu, Ed, Gilles Pisier, Cecile Delesalle, Dan Voiculescu (Paris, 1999).

In addition to the pleasure of receiving the sample of Ed's fine handwriting I also enjoyed that my work had connected with work which was quite different in style. My paper, though an operator algebra paper, had some of the flavor of my background in single operator theory (it also solved one of Halmos' ten problems). On the other hand the completely positive lifting Annals paper of Choi and Effros in its style pointed to a background in Grothendieck's functional analysis work.

Soon I also got acquainted with the Effros-Handelman-Shen paper and another Choi-Effros paper. The first paper was about the structure of dimension groups of inductive limits of finite-dimensional C^*-algebras (AF-algebras). This was a major early step in the classification of C^*-algebras. The second paper was a key contribution to the theme of amenability in C^*-algebras. It was also in the form which subsequently played an important role in the development of K-theory in C^*-algebras, in particular the extension of the Brown-Douglas-Fillmore theory which culminated with the bivariant K-theory of Gennadi Kasparov. Not long after that I also met Ed in person. I greatly enjoyed both his elegant mathematical ideas and his humor. It was always a pleasure to see him.

Years later, Ed had relocated to UCLA and I was at UC Berkeley. In the Fall of 1991, Ed spent his sabbatical in Berkeley. What Ed had not foreseen when planning the sabbatical was the devastating East Bay Hills Fire at the end of October. The house he rented was close to the historic Claremont Resort hotel, which we watched on TV for a few days as the fire came closer and closer to the landmark building, but fortunately at the very last moment stopped. The disaster also reached the operator algebra group in Berkeley as Bill Arveson's house burned. Ed and Rita, after staying at Marc Rieffel's house during the fire, were fortunate to be able to return to the house near the

Claremont. It was there, a month later, that my wife Ioana and I had one of the warmest Thanksgiving dinners with a large part of the extended Effros family. Smiling, Ed had told me in advance that I would meet his twin brother who is a medical doctor and that they were indistinguishable when they dressed the same way. I could not verify the claim completely, the last condition for indistinguishability not being met.

Ed was a wonderful mathematician and a wonderful person. We greatly miss him.

Dan Voiculescu

Jerry Kaminker

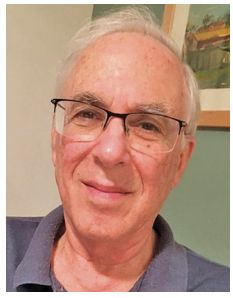
I was able to spend a quarter at UCLA in the fall of 1982 and got to know Ed and Rita. Ed had come up with the idea of adapting Borsuk's shape theory to a noncommutative setting with the goal of extending Elliott's K-theoretic classication of AF-algebras to more general direct limits. In the course of this he introduced noncommutative versions of notions such as projectivity and semiprojectivity. Ed thought that these ideas could be applied to developing the relation between C^*-algebras and topological dynamical systems in a way parallel to that between von Neumann algebras and ergodic theory. This was developed by Ian Putnam and many others over the years. Ed and I worked out some computations and he taught me a lot. Actually, I felt he was trying to brainwash me into having the correct view of mathematics and I often wish he had been more successful.

It is worth mentioning that Ed would have been very pleased to see that Alain Connes has recently been led to use operator space theory in his work relating noncommutative geometry to physics.

Ed had very high standards, both mathematically and in life. However, it was also his sense of humor which brings back memories of him. There were many instances, but one that lingers was when my wife Pat and I were having dinner with Ed and Rita. We were talking about food and diets. Pat said that her mother told her to "always leave the table hungry." Ed responded "my mother told my brother and me to eat until it hurts." This was typical of words of wisdom which have helped guide us over the years.

It was really a pleasure to know Ed and Rita and their children. His insights and opinions, both mathematical and otherwise, were great to hear and we will really miss him.

Jerry Kaminker is a visiting professor of mathematics at UC Davis. His email address is kaminker@math.ucdavis.edu.



Jerry Kaminker

Effros and Convexity Theory

Fred Shultz

Kadison in his AMS Memoir showed that if $\mathcal{A}$ is a unital C^*-algebra, and K its compact convex set of states, then the space A of self-adjoint operators in $\mathcal{A}$ (as an ordered Banach space) is isomorphic to the space $A(K)$ of continuous affine functions on K. Surprisingly, much of the algebraic structure of $\mathcal{A}$ is also determined by K. For example, affine homeomorphisms of K induce Jordan isomorphisms.

Effros in the years immediately following his 1962 PhD had many papers that explored a similar duality of ordered linear spaces and their state spaces in various contexts. I first became familiar with Ed's work from his paper "Order ideals in a C^*-algebra and its dual" [Eff63]. Erik Alfsen and I read this thoroughly at the start of our investigation of compact convex sets that are state spaces of C^*-algebras. Among other results, that paper (and a related paper of Prosser) established a correspondence of norm closed one-sided ideals of $\mathcal{A}$, norm closed order ideals of A, and the w^*-closed faces of K. Ed then wrote a series of papers on simplexes. The state space of a C^*-algebra $\mathcal{A}$ is a simplex iff the algebra is abelian, or equivalently, iff $A = \mathcal{A}_{sa}$ is a vector lattice (and then also A^*). The Choquet simplexes that occur in this way are precisely those with closed extreme boundary. If K is a Choquet simplex, then Ed shows many of the results from the C^* duality paper discussed above carry over. For example, there is a 1-1

Fred Shultz is professor emeritus at Wellesley College. His email address is fshultz@wellesley.edu.

correspondence of closed order ideals in $A = A(K)$ with closed faces of K (and maximal closed order ideals of A with extreme points of K). He defines closed sets of a "structure topology" or "facial topology" on the set $E(K)$ of extreme points of K as the intersections of closed faces with $E(K)$. If this topology is carried over to the set of maximal closed order ideals, this is the Jacobson hull-kernel topology. In the second paper of this series, Ed shows this topology has the Dirichlet property: structurally continuous functions on $E(K)$ admit a unique extension to an element of $A(K)$. In the first of those simplex papers, Ed thanks Erik Alfsen (and Robert Phelps) for introducing him to the theory of simplexes. Then in the early 1970s Ed and Erik exploited similar themes in their paper "Structure in real Banach spaces." Here the duality of a real Banach space and its dual is exploited in geometric terms. The key notion is that of an M-ideal, which generalizes the two-sided ideals of a C^*-algebra. There is also a connection with the theory of Banach lattices (L-spaces and M-spaces) that played an important role in Ed's papers on simplex spaces. But the heart of this paper is a beautiful geometric characterization of M-ideals in terms of the "3-ball property" which describes how intersections of triples of balls meet the ideal.

I met Erik Alfsen shortly after he and Ed finished their paper "Structure in real Banach spaces" [EG69], and I began a long collaboration with Erik. I got to know Ed initially vicariously via Erik's recounting of their collaboration. Later I met Ed in person, and heard his many beautiful talks at conferences (often the keynote talk). His talks were always informative, often creative, and very enjoyable. Ed always went out of his way to be friendly, and conveyed a sense that he had read your papers and enjoyed your work. Erik Alfsen would have found a way to say more elegantly how much we will all miss Ed.

Fred Shultz

Gilles Pisier

I first met Ed in Houston, probably in the Fall 1990. I drove from Texas A&M in College Station to attend a series of named lectures that he was scheduled to give at the University of Houston, over a week. This had been initiated by Vern Paulsen and David Blecher who had been independently developing their own ideas on operator spaces. This was going to be my introduction to operator spaces of which I knew next to nothing at the time. Of course I was attracted by the name Effros. His huge reputation was already all around functional analysis when I started doing research for my thesis in 1972. Convexity was a major theme of research around Choquet at Paris VI and Ed's work on that topic was highly regarded there. Also there was the celebrated "Effros-Borel theory" that was quite impressive and intimidating to the French student that I was back then. While I was no longer a beginner in 1990, my perception was still that I was going to meet a great man of science, a great father figure from the past, so it was a big surprise to find how warm, lively, and totally unpretentious he was. He was witty and could be very funny. We became friends almost instantly and he behaved in such a way that I immediately forgot his seniority. In retrospect, it is amusing to remember that although I instantly liked Ed, I was very reluctant to accept operator spaces which he was promoting like a great preacher in his lectures. I remember he was very enthusiastic and excited. There was a rather small audience, and I felt he was trying to convert me while I was secretly being very skeptical. I had no problem accepting completely bounded maps, to which I had been previously exposed, but the duality of operator spaces and their new projective tensor product were giving me trouble. All this did not seem "natural" to me. It was only a few months later that I suddenly saw the light! I owe that to Christian Le Merdy who was my PhD student at the time. Stimulated by his interest and feeling the need to catch up with him, I invested the necessary amount of time and energy to understand how operator space duality works, and all of a sudden all the things that Ed had preached about fell into place. With delay his lectures made perfect sense and I was converted. I have worked on the subject ever since. I was coming from a different field (Banach spaces) but I immediately felt comfortable and very welcome by all the people I met in the operator algebra community after this initial meeting with Ed. I invited him to visit Paris VI University for a month in the 1990s. There, it was amusing for me to watch the reaction of some people for whom

Gilles Pisier is an A.G. and M.E. Owen Chair and Distinguished Professor of Mathematics at Texas A&M University. His email address is pisier@math.tamu.edu.

Figure 14. Bob Powers, Ed, Teo Banica (Monastery conference in Italy, 1996).

he had been a major figure some 30 years earlier when he was working on convex sets and Choquet simplexes. They were a bit surprised to see him brought back by the latest generation of Paris VI recruit, as the shining star of a completely different subject. This was the beginning of a 25-year period of fruitful exchanges, with mutual invitations, each one of us giving special lecture series in the other's department, organizing jointly several conferences, and cultivating all sort of links. After meeting Rita, we all (with my companion Cécile by my side) became intimate way beyond our professional activity. We both miss him dearly.

Gilles Pisier

Robert Powers

Ed Effros was a great researcher and a scholar. When I arrived at Penn in 1967 he was here. Soon I learned that I did not have to spend long hours in the library looking stuff up. I would simply ask Ed. He was a fountain of knowledge. I remember after he left Penn I submitted a paper to a journal for publication and then I had to retract it when Man-Duen Choi told me that a much better result had been published by a Russian years ago. If Ed had been at Penn that never would have happened. When it comes to letters of recommendation most people put their money on the letters from the top leaders but I always paid my most careful attention to Ed's letters. Ed took these evaluations seriously and I found his to be the most useful. I remember when a prominent mathematician retired Ed said, "Now we all move up a notch." As all who knew him knew he had a great sense of humor. His work with Choi on completely positive idempotent maps and how they define a multiplication has had an enormous effect on my own research. Ed Effros was always a great friend to graduate students in analysis.

Robert Powers is a professor of mathematics at the University of Pennsylvania. His email address is rpowers@sas.upenn.edu.

Robert Powers

Former PhD Students of Ed Effros (in chronological order):

Robert Busby; Maurice Dupre; William Green; Patricia Kenschaft; Dong Chi; C.-L. Shen; Y.-T. Poon; Z.-J. Ruan; Marius Dadarlat; Kevin McClanahan; Soren Winkler; Eduard Vaysleb; Corran Webster; Ping Ng; Dmitri Nikshych; Vrej Zarikian.

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Palle Jorgensen

Credits

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