Interviews with Researchers Who Started their Career in Physics but Moved to Finance

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Since the end of the Bretton Woods system on August 15, 1971, the financial markets have undergone dramatic changes in almost every possible respect. The type of products they offer, the way they operate, and the impact they have on the economy and society as a whole have changed beyond recognition.

While predominantly driven by economics, these changes would be impossible without the development of quantitative methodologies, often borrowed from physics and other sciences, and the enormous growth of computational power in recent decades.

For the better part of the twentieth century, the theoretical frameworks underpinning finance and science have developed in parallel. As early as 1900, Louis Bachelier developed the first scientifically rigorous framework for describing market moves, while Vincent Bronzin derived formulas for pricing complex derivatives in 1908. Bachelier based his analysis on the Brownian motion concept, which also describes the random drifting of particles suspended in a fluid, to explain stock market fluctuations. It is worth noting that Albert Einstein's analysis of Brownian motion came about five years after Bachelier's work. However, practitioners and researchers in these fields did not communicate much, if at all, and a state of mutual indifference continued for some seventy years or so.

However, since the 1970s, specifically since 1973, when Black and Scholes' seminal paper was published, modeling methodologies in finance and science became much more aligned and coherent. Scientific and technological advances have impacted high-frequency trading, derivatives trading, hedging, and asset management, in particular. For example, given the fact that the characteristic times for high-frequency trading are extremely short (on the order of milliseconds or even microseconds), it is not surprising that the most advanced quantitative methods are needed to execute it successfully. Likewise, the industrial-strength risk management of a massive derivatives book requires the most advanced computational methods, which are suitable for solving multi-factor stochastic differential equations via advanced Monte Carlo methods in real time. The required methodologies are similar to those used in physics to study heat transfers, random walks, and related phenomena, which allows finance to borrow the sophisticated methods developed in the second half of the twentieth century for various physical applications, such as building nuclear reactors and the like. These methods have proven to be extremely powerful for executing algorithmic trading, pricing options, and similar tasks.

In general, quantitative methods have profoundly changed the nature of finance over the last fifty years or so. In order to deploy these methods successfully, both sell-side firms (banks), and buy-side firms (hedge funds) now employ 'quants' (quantitative analysts) in large numbers. The future for quantitative methods in finance seems to be bright, as long as firms use them appropriately, thoughtfully, and within a well-established regulatory framework. For the transformation of finance from a qualitative to a quantitative discipline to be successful, it was necessary to "import" a significant number of scientists from physics, mathematics, computer science, and sister fields to work as quants.

Note that the guest editors of this Special Issue, "Physics and Financial Derivatives," as well as the Editor of *The Journal of Derivatives*, have a similar background in physics, and subsequently many years of work in finance. Therefore, we decided to ask all interviewees the same 12 questions, which, at least to us, seemed to be necessary for gaining a better understanding of the connection between modern physics and finance, at both the professional and human levels. To achieve this, the editors invited various people with a suitable background to answer a questionnaire, and we are grateful to those who have agreed. Although encouraged to respond to all the questions, the interviewees were not required to do so. We asked the interviewees to answer the following questions:

(1) Please explain your education and work experience in Physics.
(2) What "calculations" prompted you to move from physics to finance?
(3) What, in your opinion, is the most valuable contribution of physics to finance?
(4) Which skills of your physics years did you find most useful for working in finance?
(5) Is there a specific achievement in finance of which you are most proud? If so, can you relate it to your physics background, or does it relate more to the post-physics skills you developed?
(6) You have observed and participated in the organization structure of a scientific organization (i.e., a research lab or a university) as well as that of a financial institution. What differences and similarities do you see in the people and organizations and, specifically, in the people who reach leadership positions? For example, is the old dictum—"There is no democracy of people in science but there is democracy of ideas."—applicable to finance?
(7) Have you found that there are specific roles or capabilities valuable to the financial world for which physicists are NOT well suited?
(8) Have you ever observed benefits that the physics world has received from finance?
(9) Is the value of physics to finance less than what it once was? Or do you expect the contributions of physics to finance to continue?
(10) Much has changed in finance and all other careers since you left physics. If you were facing that choice again now as a young physicist, would you choose finance as it is today? Or an alternative career such as coding for blockchain, cryptocurrencies, AI/ML, social media, cybersecurity, etc.? Or would you stay with physics?
(11) Will finance continue to hire physicists? Or will this trend weaken or expire altogether?
(12) In terms of prestige and recognition, are positions in physics and finance similar? When you moved to finance, was it a time of frustration or excitement?

Below we publish those interviews with several former physicists who have made a successful transition from physics and applied mathematics to finance. While the interviewees joined the field at different times—Derman, Gershon, and Lipton early on, while Antonov, Lorig, Tankov, and Guerrero more recently—their experiences are equally instructive. We hope that the readers will benefit from learning about their career trajectories and accomplishments.

QUESTIONS AND ANSWERS

(1) Please Explain Your Education and Work Experience in Physics

Emanuel Derman: I grew up in Cape Town, South Africa, the child of Polish Jewish immigrants who respected education and modesty. In South Africa, the British education system prevailed, and at University, at age 16, you decided forever what you were going to do for the rest of your life—BA meant the humanities, B.Sc. meant science, B.Com meant commerce. Medical School meant simply medical school straight out of high school. I took a B.Sc. though I wished I could study

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more humanities, but there wasn't time for that in any formal way.

So, in my first year in 1962 I took physics, chemistry, pure math, and applied math, each of them a full one-year course with no electives. In my second year, I happily dropped chemistry and working with hand-operated balances, and in my third year I dropped pure math, graduating with a degree in physics and applied math. Then I took an honors year in applied math, because although I liked physics, the applied math people in those days at that place seemed to do theoretical physics more professionally than the physics department. I studied differential geometry, general relativity, and unified field theories, not to mention advanced mechanics, Hilbert spaces, and so on.

It became apparent to me that if you were serious about theoretical physics then you had to go abroad, and so, in 1966, with a fellowship from Columbia University, I arrived in NYC. In those days, there was no email and no practical way of making long-distance calls to South Africa, so I communicated with my family, friends, and relatives via airmail letters whose round trip to South Africa and back took about two weeks. Initially, I felt very isolated, and then I grew to love NYC.

Columbia did physics professionally, by which I mean everything that seemed advanced and esoteric and new and puzzling in quantum mechanics from the South African viewpoint was regarded as just mundane technical stuff you had to know how to use in America. I knew little modern physics when I arrived and spent a few soul-taxing years catching up. Eventually I got a PhD in theoretical elementary particle physics, writing a paper on the then-as-yet-unseen parity-violation in electron-proton scattering that later helped establish the correctness of the Standard Model.

There followed a period of peripatetic physics, which is the way most of us had to do it in the 1970s: during the post-Sputnik fear of Russian expertise the American physics departments filled up with young tenured professors, and by the time my generation arrived university positions were scarce indeed. Those of us that didn't give up had, for the most part, to become wandering postdocs, taking a two-year job here followed by a two-year job there, with no retirement benefits, until either you did give up or you landed in a tenure track job or a national lab somewhere. I spent two years at the U. of Pennsylvania, two more years at Oxford, UK, and two more at Rockefeller University in NYC, often having a wonderful time when research went well, getting depressed when things went badly. Finally, I did land a tenure-track position at the University of Colorado at Boulder. My wife was a molecular biologist at Rockefeller University, and she was unable to find a position in Colorado. So, after a year at Boulder, I threw in the towel and returned to NYC to be with her and my two-year old son. I didn't want to live like that anymore.

Doing physics was wonderful. I wanted to learn about the way the universe worked, to discover some of those secrets myself. It was also scary: there were occasionally colleagues and professors one met or heard of who could do things you knew you could never do. But my whole attitude to understanding the world was influenced by my studies in physics: learn the theory, interact with experimentalists, struggle to get the intuition behind the theory. I think everyone who wants to model anything in the world should at least learn Newtonian mechanics very well, and see what a good theory is really like. If they still have energy after that, they should learn Electromagnetic Theory and its history of productive leapfrog between theory and experiment. Everyone in the modeling world can (and should) learn that stuff.

Alexander Lipton: I was born in Moscow, the capital of the Soviet Union, to a family of lawyers. Among the extended family, we proudly count several distinguished physicists and mathematicians, who inspired me from a very young age. After passing entrance exams, I started my studies at the fabled Mathematical High School # 2 for mathematically gifted children and graduated from it, *Summa Cum Laude.*

Upon graduation from high school, I was fortunate to be accepted to the Department of Mechanics and Mathematics of Moscow State University. At the time, it was the best department of mathematics in the whole Soviet Union, and, arguably, in the world. (From what I hear, it is still excellent.) I was deeply impressed and motivated by several of my teachers, such as the legendary Profs. A. N. Kolmogorov, I. M. Gelfand, V. I. Arnold, Ya. G. Sinai, A. G. Kostuchenko, and A. T. Fomenko, to mention but a few. All of them were remarkable both as researchers and teachers. After receiving my MSc, *Summa Cum Laude*, I accepted the position of research scientist at the Soviet Academy of Sciences.

At the same time, I started to work on my PhD dissertation at Moscow State University. My thesis was (or seemed to be) somewhat abstract, the title being

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"Spectral Properties of Degenerate Systems of Differential Equations." However, many years later, some of the methods I developed in my thesis became very handy when I studied algorithmic trading, see Lipton et al. (2014). This fact is a neat illustration of the profound interconnectedness of mathematical, physical, and financial phenomena. At the Academy of Sciences, I was captivated with and rigorously studied oscillations of the Earth's magnetosphere. For my work on this topic, I received "The Best Young Geophysicist Award" by the Academy. The work on the magnetosphere resulted in my life-long fascination with magnetohydrodynamics. While still in Russia, I wrote a book on the subject with an emphasis on thermonuclear fusion, which is still in print today; see Lifschitz (1989). One of the motivations for writing this book was a natural desire to put my thoughts on the subject in order. The other was an aspiration to learn English since it became clear to me that there was no future for my family and me in the Soviet Union.

At the end of 1988, I left the country of my birth for the US. As my first destination was Boston, I went to MIT to talk to some of the academics whom I knew by reputation. Professor Bruno Coppi, who read my book, offered me a research position in his group, which I gladly accepted. At the same time, I started to look for tenure track jobs, and, after a postdoc position at the University of Massachusetts, and my fair share of rejections, I landed a job at the University of Illinois, where I spent about seven years, long enough to get a full tenured professorship. At the same time, I worked as a consultant at the Los Alamos National Laboratory, where I continued research on fluids and plasmas.

At the University of Illinois, I became fascinated with fluid dynamics and astrophysics and wrote several papers on the subject, which were very well received by the scientific community. Surprisingly or not, subsequently, I was able to use some of the ideas developed in these papers in mathematical finance, specifically for studying stochastic volatility models.

In 1996, I started to develop an interest in financial mathematics. In 1997, I took a leave of absence from the University of Illinois and moved to New York (for the actual reasons, see my answer to the next question). I started as a quant for Bankers Trust, the leading derivatives trading investment bank, which was acquired by Deutsche Bank in 1999. I was lucky to hit the ground running and began to work with several brilliant colleagues on many exciting topics of the day, including passport options, which are quantitatively different from calls, puts, and other options known for at least two hundred years. We were the first to publish a definitive paper on the subject; see Hyer et al. (1997). I continued to work on this topic for a couple of years and eventually proved that the value of a passport option is half the value of a lookback put. For my work in this direction, I received the very first Quant of the Year Award by Risk Magazine in 2000.

While at Bankers Trust, I became interested in foreign exchange and started actively working on it. In 2001, I had enough results under my belt to write a book on the subject, which continues to be the standard reference in foreign exchange derivatives to this day; see "Mathematical Methods for Foreign Exchange: A Financial Engineer's Approach." After Deutsche Bank bought Bankers Trust, I stayed at DB for a couple of years but eventually moved on to Credit Suisse. Shortly afterward, I joined Citadel Investment Group in Chicago, where I became a managing director and head of capital structure quantitative research.

From Citadel in Chicago, my career trajectory took me to Merrill Lynch in London, where I initially headed the credit analytics group. In 2008, at the height of the Global Financial Crisis, Merrill Lynch was bought by Bank of America. I stayed with the Bank of America and became the co-head of the Global Quantitative Group. While in London, I kept my connections with academia as an honorary professor, first at the Imperial College, and then at Oxford, supervising several PhD students, including Ioana Savescu, currently an MD at BofA, and Vadim Kaushansky, now at Citadel.

After spending 10 years with BofA, I left it in 2016 to start developing my ideas about banking and the financial ecosystem in earnest. Advancing these ideas made me an expert on blockchains and digital currencies, including central bank digital currencies and stable coins. Jointly with Adrien Treccani, I am finishing a book on the topic; see *Blockchain and Distributed Ledgers: Mathematics, Technology, and Economics.*

In 2018, I co-founded, with S. Karkal, A. Angelovska-Wilson, and I. Hines, a new company called Sila, which develops a new financial system based on the stable coin concept and digital wallet & payments. Sila aims to transform the existing banking and payment system in its entirety and make it more accessible, rational, and efficient.

I also went back to my academic roots and became a Connection Science Fellow at MIT, and, more recently,

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a Visiting Professor and Dean's Fellow at the Hebrew University of Jerusalem.

My varied career in mathematics, physics, and finance taught me that universal mathematical constructs and the way of thinking rooted in physics permeate mathematics, physics, and finance, and make them virtually the same. There is one caveat, though. One needs to understand how to formulate the problem. Otherwise, one can find himself/herself in a vicious circle when people address the problem they can solve, rather than the one they need to solve.

David Gershon: My father was a chemist at the Weizmann Institute for Science in Israel and I grew up in a scientific atmosphere. After I skipped a class in high school, my new physics teacher brought me a book about modern topics in physics such as quantum physics and the theory of relativity and since then I was profoundly enchanted with physics. I did my PhD in theoretical physics in a field called "Superstrings" with Shimon Yankielowic, who was one of the prominent researchers in string theories in Tel Aviv University. My dissertation was about duality properties in string theories and their reflection in some phenomenological aspects. During my PhD program, I was very curious to understand the financial markets and so I received my MBA in 1990. At that time, I heard that Wall Street was looking for promising physicists and mathematicians and was offering very high salaries for such people. I joined the PhD program in Finance at Kellogg School of Management and from there I went to work on Wall Street. I worked on mortgage derivatives in NationsBank, currency derivatives at Deutschebank and emerging markets derivatives during the stormy period of the 1997–98 crisis for Barclays Bank NY. I made a lot of money trading various derivatives on Latin American, Asian, and even African currencies. During my work in NY, I always tried to be analytical in my trading approaches and developed for myself pricing methods and risk models for my trading activities. My colleagues used to attribute my success as a trader to the fact that I was a theoretical physicist. In 1998, I was asked by Barclays' global head of derivatives to relocate from NY to London to head the currency exotic derivatives business for the bank globally.

London was the capital of the world in currency derivatives and the volumes of exotic options were enormous compared to NY. Yet, pricing options was very difficult. The only known pricing model was the Black-Scholes (Brownian motion) model, but is was usually very much off market and therefore traders used to communicate with their interbank brokers all day long in order to receive every single option quotes and gauge themselves accordingly. Inexperienced option traders had huge difficulties in pricing options and one could often see arbitrage prices between banks. To settle the problem, option traders used to believe that pricing options is like art, a matter of opinion and that arbitrage prices stem from a difference of opinions. As a physicist, it did not make sense to me and I decided to investigate if there was a "market price" for options. In mid-1998, I started to collect data from the five interbank brokers we used in my desk. I received daily all the quotes (bid and offer prices) they had anonymously, about 150 options per day. Every day before going home, I phoned all of my brokers and each one dictated to me all the quotes of the day. Very soon I discovered that there was a consensus price for any option, quoted by the majority of the top tier banks. However, some mispricing always happened by less experienced traders and their off market quotes made the final price (i.e., best bid and best offer) quoted by the brokers differ significantly from the consensus price. Moreover, the same effect happened with the bid-offer spread. Hence when ignoring the mispricing by inexperienced traders, I had a database of the consensus price for thousands of options.

My next task was to develop a mathematical model that matched the consensus prices – bid and offer prices- of my huge database of exotic options. The first task was to invent a volatility smile model. In 1999, I created first a volatility smile model, which depended on three parameters only. About nine months later, I had an exotic option pricer that matched the bid and ask prices of my database. In order to create these models, I used all of my deep understanding and experience in options trading and risk management.

In 1999, it was very unlikely for a bank to use a model different than Black Scholes for risk management systems and consequently the global head of derivatives decided not to use my model in our system.

In 2000, I left Barclays and started SuperDerivatives, Inc. (the inspiration is of course from Superstrings), with the aim to generate transparency in option pricing among all the financial institutions. I decided to use the internet as the technological platform. It was the first time that a professional financial system was delivered over the web and SuperDerivatives is considered one of the first FinTech companies. The SuperDerivatives system was launched in January 2001, with real time pricing and by mid-2001 I already had top tier clients such as Merrill

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Lynch, Citibank, and Bear Stearns. Although it was a 'black box,' within two years almost all the banks that traded options were clients of SuperDerivatives and it was referred to as the benchmark prices for options. The price transparency generated by the company ignited the creation of options markets in many countries, such as Indonesia, Thailand, The Philippines, Poland, South Africa, and more. According to the BIS, the volume of options tripled from 2002 to 2005.

Over the years, the company became a world leader in derivatives technology, data, pricing, and risk management. In 2014, I sold the company to InterContinental Exchange (ICE). In 2017, I was appointed a finance professor at the Hebrew University and in 2018, I donated the funds to establish the Gershon Fintech Center at the Hebrew University Business School.

Matt Lorig: I have a BS in physics from the University of Minnesota and a PhD in physics from the UC—Santa Barbara. Like any other physicist, I have extensive course work in classical mechanics, quantum mechanics, electrodynamics, and field theory. However, my research interest changed from physics to finance mid-way through graduate school. As such, I never delved too deeply into physics research.

Peter Tankov: I have studied physics up to bachelor level and then switched to mathematics/mathematical finance. I have never worked as a physicist.

Alexandre Antonov: I received my Masters degree at Moscow institute for Physics and Technology (FizTech) and a PhD degree at Landau Institute for Theoretical Physics in Moscow. Right after that, in 1998 I joined the startup Numerix – now it is a large and well respected company. The company was partially founded and almost fully "powered" by young PhDs from the Landau Institute.

Alberto Bueno Guerrero: I have a degree in physics from the University of Granada (Spain), with the specialty of theoretical physics. When we were finishing the degree, some professors made an offer to us to stay at the University as research assistants, but without any guarantee of being able to start an academic career. I did not like the proposal and decided to apply to a permanent position as a secondary school math teacher in the public education system. Once I obtained this place, I realized that I was going to let go of all the mental training that I received during the degree, so I decided to pursue a new degree in Economics at UNED.

(2) What "Calculations" Prompted You to Move from Physics to Finance?

Emanuel Derman: It was relatively simple—no calculations. When I wanted to move back to New York, there were no permanent physics jobs I could get. AT&T Bell Labs was hiring physicists to do financial modeling, and the oil industry was hiring them to do energy research. I was offered and accepted a job at Bell Labs in Murray Hill, NJ. I worked there for five years, drifting more and more into developing computer languages for financial modeling. I loved writing little languages and compilers, but I didn't really like the industrial world and its managerial hierarchy, and when Goldman Sachs came knocking on my and other people's doors, I finally accepted a job there. I liked working in Manhattan again too.

Alexander Lipton: The "calculations" were rather straightforward. In 1997, my wife graduated from the University of Chicago with two degrees—a PhD in chemical physics and an MBA. As it was a golden time for physicists in finance, she quickly found a job on Wall Street. This decision sealed our fate. She had to move to New York to become a fixed income trader. So, I decided to give her a chance, take a leave from my tenured professorship, and move to New York, too. The excitement and pull of quantitative finance were so intense that, after extending my leave of absence twice, I finally decided not to return to the university and stayed in investment banking for twenty years.

David Gershon: While I always felt that nothing can be more fascinating than theoretical physics ("decipher the secrets of the universe"), the financial reward of working on Wall Street is very attractive. In the days when I worked at banks, successful people earned very significant amounts of money. Having this kind of wealth allowed a very high standard of living that academic people could not afford, even remotely.

Matt Lorig: My interest in finance began during graduate school. A friend of mine convinced me to take an introductory finance course with him and—much to my surprise—I found that I enjoyed it immensely. With my interest piqued, I began reading academic papers on finance. At some point, I stumbled across Vadim Linetsky's papers *A Path Integral Approach to Financial Modeling* and Pricing options on scalar diffusions: an eigenfunction expansion approach. Having had extensive course work in electromagnetism, quantum

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mechanics, and field theory, I was quite familiar with path integrals and eigenfunction expansions. As such, reading Vadim's papers revealed to me that my physics background could be useful in finance.

Upon discovering that Vadim held a PhD in physics, I wrote to him to ask how he made the transition from physics to finance. I do not remember exactly what Vadim told me, but he mentioned that my university (UC—Santa Barbara) had just hired Jean-Pierre Fouque to lead a PhD program in mathematical finance. I looked into Jean-Pierre's research and learned that he was using singular and regular perturbation techniques to find approximate solutions of partial differential equations (PDEs) that arise when pricing options in a multiscale market setting. As I was familiar with perturbation methods from my physics training, this further solidified my interest in finance. Eventually, I approached Jean-Pierre about doing research with him. He agreed to take me on as a student and, although I officially remained a student of the Physics Department and earned a PhD in physics, my thesis work focused on further developing multiscale methods for pricing options.

Peter Tankov: I was interested in the dynamics of 'complex systems' like financial markets and inspired by the fact that these systems may be described with a formalism similar to that of physics (heat equation, Hamilton-Jacobi equation, and so forth).

Alexandre Antonov: Well, Numerix was a sort of half-way between a university and a bank—money-wise, science-wise, etc. One important aspect was also the fact that mathematical finance was a rapidly growing science with a much bigger exposure than my theme of quantum integrable systems in theoretical physics.

Alberto Bueno Guerrero: Once I graduated in Economics, I started the PhD courses. My main interest was in monetary policy, and I planned to carry out my work prior to the PhD on this subject. However, the professor suddenly abandoned the doctoral program to fill a position in the United States. So, I decided to do my work in one of the other courses I was following: Term Structure of Interest Rates. Thus I discovered this fascinating mathematical object, a curve subjected to stochastic shocks that determines interest rates at different terms, as well as all the wonderful mathematical theory involved (arbitrage, martingales, SDEs...) that caught me to this day.

(3) What in Your Opinion is the Most Valuable Contribution of Physics to Finance?

Emanuel Derman: The idea that you think of an idea or mechanism that might drive the system or world you are trying to model, which you then represent in mathematical language, and then try solve it analytically and examine how well the solutions agree with the world as you examine it.

Physicists look for meaning and then try to encode it in mathematics. They don't simply look for regressions between data series.

I like these two statements attributed to Dirac:

- *I am not interested in proofs. I am interested in how Nature works.*
- *I understand what an equation means if I have a way of figuring out the characteristics of its solution without actually solving it.*

Take the first one seriously but not too literally; it means don't get carried away by rigor and the axiomatic approach, an unfortunate trend in quantitative finance.

Take the second one seriously indeed. Try to understand the behavior of your model before you actually solve it.

Of course, if all you are doing is regressions, you can ignore both.

Alexander Lipton: I think that contributions of physics to finance are manifold. The principal one is the usage of the scientific method per se. The strong impact of the quantitative way of thinking in finance is palpable and is in sharp contrast with economics, particularly macroeconomics, which, for all practical intents and purposes, is "not even wrong." At best, it is useless, and at worst harmful.

David Gershon: Physicists introduced methodologies and accuracy to finance and made it a common practice. Most physicists typically try to create a realistic model for financial products and if they know all the facts and factors and model the outcome reasonably well, the results of the model might be surprisingly close to reality.

Matt Lorig: Physicists have contributed to so many distinct areas of finance that I would be hard-pressed to name a single result as being most important. However, many physicists (Gatheral, Henry-Labordere, Jaimungal, Lipton, and others) have contributed to the

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development of asymptotic approximations in finance. Such approximations often eliminate the need to perform time-consuming computationally intensive Monte Carlo simulations.

Peter Tankov: The most important contribution is people, the scientists who in the early days of finance came and transformed it into a quantitative field. Compared to mathematicians, physicists often use an experimental, data-driven approach, which is very important since it helps to avoid being lost in abstract concepts with no relation to reality. In terms of concepts, the most important contribution is in the field of asymptotic methods, methods to obtain explicit approximations for quantities that are otherwise very difficult to evaluate.

Alexandre Antonov: No doubts, the diffusion equation.

Alberto Bueno Guerrero: In my opinion, the most valuable contribution of physics to finance is the Brownian motion. Although it was discovered by Robert Brown, a Scottish botanist, it was Albert Einstein who gave a physical interpretation to this phenomenon.

Since its introduction in finance, the Brownian motion (BM) has been part of many of the most important theoretical developments in the continuous time modeling of financial markets, such as the Black–Scholes model and its generalizations in the equity world or Heath–Jarrow–Morton (HJM) models in the interest rates world. Even today, many of the new developments (fractional BM, stochastic strings, ...) have their roots in the Brownian motion.

(4) Which Skills of Your Physics Years did You Find Most Useful for Working in Finance?

Alexander Lipton: I think that my ability to solve hyperbolic, elliptic, and, especially, parabolic equations, both analytically and numerically, helped me a lot. Also, the epistemological approach that I learned while working as an applied mathematician and physicist proved to be very valuable. In essence, finance boils down to manipulations with random variables, which is, in no small degree, what physics does, so the skills acquired in my previous life are naturally instrumental in the current setting.

David Gershon: The desire to obtain a realistic model for various situations/products; the pragmatic approach, where if a lot of data is missing then some intelligent shortcuts have to be selected; the very good sense of testing the outcome and having a good feel about how realistic it is.

Matt Lorig: The PDEs that arise in option pricing are quite similar to the PDEs that arise in quantum mechanics. As such, the tools from physics that I use most frequently in my research are the tools I learned to find approximate solutions of Schrodinger's equation—specifically Fourier transforms, eigenfunction expansions, perturbation methods, and spectral representations of linear operators. Some of the methods I learned in my classical mechanics courses have also been useful from time to time. For example, I have used calculus of variations to solve some static hedging problems.

Peter Tankov: Compared to my mathematician colleagues, my physics training makes me more focused on the result of the computation rather than the computation itself and helps to develop intuition about this result.

Alexandre Antonov: Ability to solve differential equations, plus a general mathematical apparatus as well as a rapidity in a scientific "digging," without going to microscopic details, as do mathematicians which can slow down the process. (Joking!)

Alberto Bueno Guerrero: I could say that the most important skill is the knowledge of PDEs or the use of computational methods, but I think that in reality, the most important skill is of a more fundamental type and is the conviction that natural phenomena, and in this case financial ones, can be described quite accurately by mathematical models, which can help us understand them better and provides us with valuable information.

It is true that finance, as a social science, is more difficult to describe accurately through mathematical models, but that does not mean that we have to abandon our objective, but instead that we will have to refine our basic assumptions and the mathematics used.

(5) Is There a Specific Achievement in Finance of Which You are Most Proud? if so, Can you Relate it to Your Physics Background, or Does it Relate More to the Post-Physics Skills You Developed?

Emanuel Derman: When I ran the Quantitative Strategies group at Goldman Sachs in the 1990s, we had an eclectic and interesting life. We built software and models for the volatility traders to manage their global books of vanilla and exotic options; we did research on hedging and valuation and volatility trading; we visited clients to explain the sometimes unintuitive behavior of options in terms they could understand; and we published easily accessible but still academic-quality research papers, on topics from the Black-Derman-Toy model to local volatility to variance swaps. I think I'm most proud of managing to run an interdisciplinary group like this that straddling the line between business and academia, providing insight to both groups. Groups like that don't really exist anymore.

It took a lot of not-inborn political skill on my part—the knee-jerk reaction in most trading firms is not to divulge anything to anyone, even when that isn't necessary. I had to push slowly but firmly to get the value of research recognized, both as an aid to traders and to clients, who do care about it. The people who were in my group still tell me that they didn't realize then what a good life they had, shielded by me from the pressures of people who thought only short-term.

Alexander Lipton: I am proud of being a coinventor of the local-stochastic volatility model, as well as a very potent Lewis-Lipton formula for pricing options in the stochastic volatility framework. I think that my work in fluid dynamics and plasma physics helped me a lot in being able to formulate and solve the corresponding problems.

David Gershon: I am most proud about the fact that I generated transparency in option pricing, which transformed the options market completely. In retrospect it seems like 'mission impossible,' but yet I did it. I am also proud that I discovered there is a market price for options and disproved the belief that pricing options is a matter of opinion; that both mid-market price and bid-ask spread require pricing models; and that the volatility smile can be modeled with three parameters. (In the 1999 version of the smile, the inputs were the at-the-money volatility and the 25-delta risk reversal and butterfly).

Matt Lorig: The contribution to finance that I am most proud of is the paper Explicit Implied Volatilities for Multifactor Local-Stochastic Volatility Models, co-authored with Stefano Pagliarani and Andrea Pascucci https://doi.org/10.1111/mafi.12105. In this paper, we consider a very general class of local-stochastic volatility models, which includes most well-known diffusion models (SABR, Heston, Three-Halves, CEV, quadratic local volatility, etc.). In order to compute explicit approximations for option prices and implied volatilities, my co-authors and I combined a variety of methods that would be familiar to physicists—namely semigroup methods, perturbation techniques, and Dyson-Phillips series.

Peter Tankov: I would not say that my greatest achievement is related to my physics background, but I did use concepts from physics (in particular, classical mechanics and asymptotic methods from mathematical physics) in my quant finance papers.

Alexandre Antonov: A development of the SABR model with a free boundary—for which I've received a Quant of the Year Award by Risk magazine. It is related to both physics and the post-physics skills: differential equations and the Bessel processes.

Alberto Bueno Guerrero: Until now, the achievement I feel most proud of is the stochastic string framework, based on the original work of Pedro Santa-Clara and Didier Sornette and developed together with my co-authors Javier F. Navas and Manuel Moreno.

One of the most important ways of progress of theoretical physics has been through generalizations of preexisting theories. Consider, for example, the General Theory of Relativity, as a generalization of the Newtonian Gravitation Theory. What we did in our work was to demonstrate that the stochastic string model, reformulated with continuous semimartingales, generalizes the HJM models (multifactor and infinite-dimensional), thus becoming a very general model for the dynamics of the term structure of interest rates. This also allowed to include other related aspects, such as the valuation and hedging of options, which we have been developing in several papers, some of them still waiting to be published.

(6) You Have Observed and Participated In The Organization Structure of A Scientific Organization (i.e., A Research Lab or A University) as Well as That of A Financial Institution. What Differences and Similarities Do You See in The People and Organizations and, Specifically, in The People Who Reach Leadership Positions? For Example, is The Old Dictum—"There is No Democracy of People In Science but There is Democracy of Ideas"—Applicable to Finance?

Alexander Lipton: I was able to carefully observe operations of a university as a full tenured professor and of a quant organization as co-head of the Global

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Quantitative Group at BofA, which at the time was one of the largest on Wall Street. I have to say that universities are more democratic, at least as far as tenured faculty are concerned. For a while, "a democracy of academic ideas" was in danger, not least because publishing of critical scientific papers became extremely hard, mostly due to deficiencies of the refereeing process. However, because several web depositories such as SSRN and arXiv (where I am a moderator) are readily available, it is currently much simpler to publish a fundamental idea, than it has ever been. Of course, publishing garbage is effortless, as well. In banking, a democracy of ideas strongly depends on a particular institution. If people cannot push their ideas through, they tend to vote with their feet and move to other institutions for recognition and appropriate compensation. In this regard, finance is much more dynamic than academia.

David Gershon: During the '90s, Wall Street was a tough environment and discipline and behavior codes were very important. However, if you came up with a great idea that generated a lot of money you would have been rewarded for it. You could be fired easily, but on the other hand, if you were a great producer you would have been rewarded very generously compared to any other work environment. In order to be a senior manager on Wall Street, you needed to have great political skills and be loyal to your boss in addition to being a top professional.

Peter Tankov: I only have an outside view, but it seems that outside the very best teams, the 'democracy of ideas' is much less developed in finance than it is in physics; sometimes it is very difficult to put into question an existing method because of financial considerations (other methods are more costly), trading environment constraints, or pressure from hierarchy.

(7) Have You Found That There are Specific Roles or Capabilities Valuable to the Financial World for Which Physicists are NOT Well Suited?

David Gershon: Wall Street is a very stressful environment. Talented physicists that cannot cope with the stress cannot succeed there. There are less stressful environments for physicists, such as consulting firms and other financial services boutiques.

Matt Lorig: My formal education, which I believe is typical of any physicist trained in the American university system, did not include any coursework on measure theoretic probability, stochastic processes, or optimization. These topics are fundamentally important for anybody that works in finance. This is not to say that physicists are poorly suited to work in finance, but rather that physicists will need to supplement their training by learning some mathematics they may not be familiar with.

I would add that my physics training did not include anything that would resemble rigorous mathematics. I believe it is fair to say, prior to making the transition to finance, I never once questioned the viability of changing the order of integration or passing a limit through an integral. While mathematical rigor may not be essential in industry, it is certainly important for anybody who wishes to do academic research in mathematical finance. The tools that are needed to do rigorous mathematics are actually quite different from the tools that are needed to do mostly formal physics computations. As such, when I made the transition from physics to the academic field of mathematical finance, the most challenging aspect of this move was learning to do rigorous mathematics. In fact, I still struggle to rigorously prove formal results. Thankfully, I have found some very talented co-authors who help me with this.

Alexandre Antonov: Maybe deep programming skills, especially for theoretical physicists!

Alberto Bueno Guerrero: The fact that a person acquires an education in physics usually increases his skills, which would lead to access to a greater diversity of roles. However, due to the type of intellectual and lonely work which a physicist faces during his formative years, it is possible that some physicists lack the management or leadership capabilities, which may require social skills that have not been specially trained during the years of study.

(8) Have You Ever Observed Benefits that the Physics World has Received from Finance?

Alexander Lipton: Yes, but there are not that many, as far as I can see. True, Louis Bachelier described the Brownian motion before Einstein, but physicists completely ignored his work. More recently, some of the work on pricing American puts found applications to Stefan problems, while my work on the efficient usage of the method of heat potentials found several applications

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in physics, including the integrate-and-fire neuron excitation model.

David Gershon: I think that the biggest contribution of finance to physics is the intensive use in stochastic processes for various uses. As a result, physicists started to model many complex random processes in physics (e.g., results of experiments, accelerators equipment, and turbulence) with two- or three-factor stochastic processes.

Matt Lorig: I cannot think of any concepts from finance that have had an impact in the world of physics. However, the Simons Foundation has donated millions of dollars to support basic research in mathematics, physics, and computer science. So, in that sense, finance has provided a very tangible benefit to physics.

Peter Tankov: The financial system is a complex system that is an interesting object of study from the physical point of view; the whole domain of 'econophysics' is, in my view, a domain of physics that was inspired by finance.

Alexandre Antonov: Maybe some sponsorship from former physicists having become rich from finance. I don't think that some scientific results from finance have influenced the physics.

Alberto Bueno Guerrero: Although I do not know of any method or tool from the world of finance that has been used successfully in physics, I could cite as a beneficial aspect the creation of a new field of knowledge known as econophysics. Although its borders are somewhat diffuse, econophysics studies economic and financial problems with the help of methods and tools from physics. The creation of this new field of knowledge has expanded the field of research of many physicists and has resulted in many scientific articles of financial content being published in physics journals, as is my case.

(9) Is the Value of Physics to Finance Less than What it Once Was? Or do You Expect the Contributions of Physics to Finance to Continue?

Alexander Lipton: I think that, at present, the value of physics is much less than it used to be, due to the prevalence of data science, artificial intelligence, and similar approaches to quantitative finance. While undeniably useful, these approaches have to be strongly fortified by the scientific method. So, at some point, finance would have to rely on physics again.

David Gershon: I believe that finance is about to go through a phase transition in the coming years with the to-be-introduced new sophisticated methods to deal with big data and computer learning. This will bring a new type of physicists to finance and will see a very significant contribution of physicists and computer scientists to finance.

Matt Lorig: Compared to when I made the transition from physics to finance, there seems to be a great demand today for people with strong data science skills and less demand for people with a strong background in analytic methods. Consequently, the kinds of physicists that are best suited for careers in finance these days are the physicists that have experience handling large data sets—namely high energy experimentalists.

Peter Tankov: In my view, the experimental and data-driven approach of physics is still very relevant for finance: as we advance in our understanding of the financial system towards such aspects as market microstructure, the beautiful abstract mathematical models become less relevant and we have to rely ever more on the data. A specific domain where financial engineers and physicists will increasingly need to collaborate in the future is climate finance (evaluating and managing the risks posed to the financial system by climate change).

Alexandre Antonov: Possible, but less than in the beginnings of mathematical finance.

Alberto Bueno Guerrero: We might think that as new methods of physics are used in finance, it is more difficult for new ideas to be incorporated, but taking into account the incredible variety of mathematical techniques developed to deal with problems in physics, it seems difficult that we are currently in a stage of exhaustion, especially if we consider that help can come from the most unexpected fields. It is possible to find contributions to finance coming from the Orthogonal Polynomials Theory used in quantum mechanics or from the Differential Geometry of General Relativity. For example, in one of my papers in collaboration, we use the Theory of Operators on Hilbert Spaces, also well known in quantum mechanics.

In the academic field, at present, there is a growing trend in the publication of articles on quantitative finance based on techniques from machine learning, with very promising practical results. However, this type of work, based only on inductive reasoning, lacks the axiomatic-deductive method, which in my opinion is what allows a true knowledge of the object of study.

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For example, Kepler had data that allowed him to determine that the planets follow elliptical orbits, but thanks to Newton, today we know why.

For this reason, I believe that the contribution of physics will continue to be important at least in the scientific part of finance, helping to develop physical-mathematical models that provide the understanding that machine learning techniques do not provide.

(10) Much has Changed in Finance and All Other Careers Since you Left Physics. If You were Facing that Choice again Now as a Young Physicist, would you Choose Finance as it is Today? Or An Alternative Career such as Coding for Blockchain, Cryptocurrencies, AI/ML, Social Media, Cybersecurity, etc.? Or Would You Stay With Physics?

Emanuel Derman: I would do whatever interested me the most at the time. I went into physics out of a passion for the subject; it wasn't just a career but a vocation. Later, by serendipity and force of circumstance, I got very interested in finance and loved options theory too.

Alexander Lipton: I would either stay with physics or choose an alternative career working with distributed ledger, artificial intelligence, and related concepts. After all, this is what I am doing at present.

David Gershon: Personally, I would do the same now. In retrospect, Wall Street for me was just the preparation to my entrepreneurial career. I gained skills, knowledge, and wealth to start my own company, which eventually turned my life in a very positive way.

Matt Lorig: When I made the transition from physics to finance, I did so for three reasons. First, the skills I had obtained from studying physics were well-suited for the financial industry. Second, I enjoyed thinking about the kinds of problems that arise in finance. And lastly, I had a sense that I would be able to have a successful academic career working as a financial mathematician (at the time, I had no interest in leaving academia for industry).

These days, with the growth of tech companies like Facebook, Google, and Amazon, the appeal of working in industry is far greater than it was when I left physics. As such, while my interests and skills match better with the financial industry than they do with the tech industry, if I were a student or researcher looking to move away from physics today, I would take the time to learn some of the skills that tech companies routinely demand from their employees. If I found, for example, that I was truly interested in artificial intelligence or machine learning, I would consider working for a tech company.

Peter Tankov: If I had to make this choice now, I would probably choose AI/ML.

Alexandre Antonov: I would stay with physics. The mathematical finance is less sparkling than before, and the other themes seem to be less scientifically involved.

Alberto Bueno Guerrero: I think it depends on the vital goals. If the goal is to reach knowledge and satisfy your curiosity (which was mine when I was young), I would prefer to follow the path I have followed, starting with theoretical physics and then moving on to mathematical finance. However, if the goal is to achieve a better standard of living and perhaps a well-paid job (which, given my family situation, is closer to my current goals), then I would devote myself to machine learning, big data and possibly quantum computing, all focused on finance.

(11) Will Finance Continue to Hire Physicists? Or Will this Trend Weaken or Expire Altogether?

Emanuel Derman: There are two kinds of classic quants, as a friend of mine calls them, p-quants and q-quants. I was a q-quant—trying to figure out the right price for things by replication. The q-probability that emerges from replication models isn't a genuine probability, it's a pseudo-probability whose components add up to 1. P-quants, in contrast, try to model processes by estimating the true probabilities of their occurrences, and so statistics, regressions, machine learning, AI, pattern-seeking, play a much bigger role.

Everyone thinks they're a quant now, but most of them are really p-quants. With the growth of vast amounts of electronic data, there's much fodder for this area, and the number of p-quants will keep growing. In addition, whereas once upon a time only a physicist could model and program and solve—all of those skills were in one person—nowadays finance training has changed and you don't need to go to a physics department to find that. So, I foresee fewer physicists in the long run, and more statisticians, computer scientists, and people trained in finance.

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Alexander Lipton: I think that finance, mainly, the buy-side, will always continue to hire physicists, but the trend is going to slow. Thankfully, right now, there are many more areas where people with a physics background can find gainful employment, such as computer engineering, fintech, biotech, and others.

David Gershon: I believe the trend will continue because usually physicists bring some added value to financial organizations, but it also depends on the number of PhD graduates in finance, with strong math backgrounds from good universities.

Matt Lorig: There will always be a need in finance for people with excellent analytical skills. And, physics has historically been an attractive choice for students with strong computational abilities. But, due to the allure of working at tech companies like Google and Facebook, the strongest undergraduate students are now choosing to major in computer science rather than physics. If this trend continues, we will see a decrease in the number of extremely bright students graduating with physics degrees. Over time, this will lead financial institutions to hire more computer scientists and fewer physicists.

Peter Tankov: Finance will continue to hire physicists, although not as many as before since there are many specialized quantitative finance degrees now. The banks usually place more importance on the degree, so they will hire quantitative finance students, but the hedge funds are more interested in the intellectual potential of the candidate, so they will hire bright people with different technical backgrounds, including physicists. Besides, there are still many former physicists in high-level roles in the finance industry; they will also contribute to this trend.

Alexandre Antonov: I think they will ,but less, again, given a current finance simplification.

Alberto Bueno Guerrero: Apparently, some years ago, the incorporation of complex mathematical techniques into the financial world and the lack of this type of knowledge among many economists, led financial companies to value physicist profiles when hiring. I was trying for years to get a quant position in a financial company. This situation began to change since the emergence and proliferation of Masters in Quantitative Finance, which led to financial companies becoming more confident in the type of skills of graduates of these studies.

The current trend in the industry seems to be more focused on techniques from machine learning and big data than from the world of physics, although it is possible that the arrival of quantum computing techniques improves the situation for physicists.

(12) In Terms of Prestige and Recognition, are Positions in Physics and Finance Similar? When you Moved to Finance, was it a Time of Frustration or Excitement?

Alexander Lipton: I do not think so—it seems that a great physicist has a greater prestige than an excellent quant. Still, when I moved to finance, I was extremely excited and continue to be at present.

David Gershon: I guess that the biggest factors that affect the prestige are the organization and the role in the organization. For example, I believe that the prestige of a professor in finance in MIT and a professor in physics in MIT is the same, but the prestige of a physicist doing post-doc at a top tier university is less that the prestige of a portfolio manager at a top tier hedge fund.

Matt Lorig: Moving from physics to finance was tremendously exciting for me for a number of reasons. First, I had not taken a single course on finance in high school or in college. So, the entire field of finance was completely new to me. Second, I really wanted to pursue an academic career and, having seen a number of very talented postdocs at the Kavli Institute of Theoretical Physics struggle to find academic jobs, I was quite certain that an academic career was unlikely if I continued along the physics path. I was delighted to discover that, at least compared to physics, academic jobs in finance were plentiful. Third, it was very motivating to discover that, with only a basic understanding of stochastic calculus and the fundamental theorems of asset pricing, I was able to use my physics training to begin writing academic papers. Lastly, I had a fantastic thesis adviser who was not only enjoyable to work with, but also very well-connected and happy to introduce me to his colleagues. The more established researchers that I connected with as a graduate student were not only impressively intelligent, but also quite friendly and willing to talk with me about research. As a young academic, feeling as though I was part of a community rather than fighting to get into a community was tremendously motivating.

Peter Tankov: In the academic world, the community of physics is much wider than that of

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quantitative finance. From this point of view, there is probably more prestige in being a celebrity physics professor (a Nobel Laureate, say) than a famous finance professor. However, at junior levels, a PhD in quantitative finance offers more prospects: young physicists struggle to find jobs, while for a PhD graduate in finance the industry option is always there.

Alexandre Antonov: Indeed, my move to finance was a (slight) frustration from the scientific point of view, but an excitement from prestige (and also moneywise).

Alberto Bueno Guerrero: Although I have not really had a job in physics or finance, I can speak from the point of view of the possession of academic degrees. In this sense, the people who know me, value my training as a physicist (especially as a theoretical physicist) much more than my training in finance. In fact, my experience tells me that some people in everyday treatment think that being a physicist, you are something like a person with extraordinary intelligence, which, at least in my case, is a wrong assumption. However, this small contribution to my self-esteem is one of the rewards that make the years of hard work worthwhile.

As for social prestige, it is obvious to me that it is greater in the case of finance. Probably, anyone can name a successful man or woman of finance, but, except for Albert Einstein and some well-known disseminators, very few people would identify a prestigious man or woman dedicated to physics.

When I moved to finance, I always had a feeling of excitement. In the academic field, doing research in mathematical finance has been, and continues to be a source of intellectual enjoyment. On the side of the financial industry, whenever I have applied to a quant position in a financial institution, I considered the possibility of working in a quant department to be fascinating.

Final Editors' Remarks

The words of these impressive interviewees speak for themselves. As we read their remarks carefully, we note several disclosures and revelations that strike us as most interesting. First, we admire the diverse forms of success that these friends have achieved in terms of gaining awards, discovering key financial insights, writing important papers and books, and starting and running thriving businesses. A second observation is the distinction between interviewees by generation. Those who moved to the financial world prior to the year 2000 generally had worked in physics, in academia or industry or both, after receiving their advanced degrees. They then moved to Wall Street firms such as Goldman Sachs, Merrill Lynch, Credit Suisse, and others. The younger generation, in contrast, did not join industrial or financial firms. Largely they remained in academic positions with a focus on mathematical finance rather than physics. Indeed, employing the advanced physics education to gain finance faculty positions appears to be an effective strategy to defeat the "wandering postdocs" dilemma Emanuel Derman described.

As a third, final, and extended comment, we provide our own context of "physicists in finance" to highlight additional interviewee insights while also adding a new perspective. For roughly the past three decades, ex-physicists have been "one type" of employee for financial firms. As our interviewees express here, physicists bring a disciplined approach to financial questions and problems. They search for "underlying truth" in the creation, trading, and risk management of financial products that they may express mathematically. But the "physics type" of employee has limitations. We have never known a competent ex-physicist salesperson. One insight that required both years and experience for us to learn is that all financial and industrial firms must have good, preferably great, sales and marketing. The physicist's attributes, such as dogged focus on details and unquenchable curiosity to be expert in narrow topics, are generally counterproductive for success in sales. Naturally, there are other necessary "types" of employees that productive organizations must have including leadership, management, accounting, legal, human resources, et cetera. Our point is that diversity of skills is critically important and that the "physics type" is one of several necessary constituents.

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BIO's

Emanuel Derman

Emanuel Derman is a professor at Columbia University, where he directs their program in financial engineering. He was born in South Africa but has lived most of his professional life in Manhattan. He started out as a theoretical physicist, doing research on unified theories of elementary particle interactions. At AT&T Bell Laboratories in the 1980s he developed programming languages for business modeling. From 1985 to 2002 he worked on Wall Street where he co-developed the Black-Derman-Toy interest rate model and the local volatility model. He is the author of *The Volatility Smile* (Wiley 2017) and *Models.Behaving.Badly* (Free Press 2011) one of Business Week's top ten books of 2011. He is also the author of *My Life As A Quant* (Wiley 2004), also one of Business Week's top ten of 2004, in which he introduced the quant world to a wide audience.

Alexander Lipton

Alexander Lipton is co-founder and chief technical officer of Sila, Partner at Numeraire Financial, partner at Investimizer, visiting professor and Dean's Fellow at the Hebrew University of Jerusalem, and Connection Science Fellow at MIT. He sits on Boards of Directors of Sila, and Zilliqa, and on Advisory Boards of several organizations, including Clearmatics, Endor, Katalysen, Sygnum, and UCL Centre for Blockchain Technologies.

In 2016, he left Bank of America Merrill Lynch, where he served for ten years in various senior managerial roles including Quantitative Solutions executive and co-head of the Global Quantitative Group. Earlier, he held senior managerial positions at Citadel Investment Group, Credit Suisse, Deutsche Bank, and Bankers Trust. In parallel, Alex held several prestigious professorial appointments at École Polytechnique Fédérale de Lausanne, NYU, Oxford University, Imperial College, and the University of Illinois. Before switching to finance, Alex was a full professor of Mathematics at the University of Illinois and a Consultant at Los Alamos National Laboratory.

In 2000 Alex was awarded the first ever Quant of the Year Award by Risk Magazine. Alex published eight books and more than a hundred scientific papers. His most recent book "Financial Engineering—Selected Works of Alexander Lipton" was published in May of 2018. He is currently working on his next book (with Adrien Treccani) "Blockchain and Distributed Ledgers: Mathematics, Technology, and Economics," which will be published in the first half of 2020.

David Gershon

David Gershon is the founder of the new Gershon Fintech Center at the Hebrew University of Jerusalem. Prof. Gershon is a 25-year expert in the FinTech industry and is viewed by many as one of the leading experts in FinTech. In 1999 while living in London, he founded SuperDerivatives, Inc., the first platform for option pricing over the web for the professional market, which generated global transparency in option pricing and later became one of the world leading vendors in derivatives and financial data. Gershon was CEO and chairman of SuperDerivatives until its acquisition by the Intercontinental Exchange in 2014.

Prior to SuperDerivatives, Gershon had a rich career as a trader on Wall Street and in the City of London and his last role was global head of exotic options at Barclays Capital in their London headquarters.

Prof. Gershon has been awarded numerous awards such as CEO of the Year by Acquisition International in 2016 and ranked among the Top 50 most influential people in Financial Technology by the Institutional Investor magazine from 2004 to 2015 consecutively. In 2016, he was declared one of the "Game Changers" in the financial industry by Finance Monthly magazine, which stated that "Gershon is the person that brought transparency into the options and transformed the options market." In 2012, he was included to the Market Data Hall of Fame by Incisive Data magazine.

Prof. Gershon is among the world experts in option models and pricing. In 2016, he published a universal model for option pricing, which remarkably reflects option pricing in all asset classes (currencies, interest rates, commodities, and equities).

Matt Lorig

Matt Lorig is an associate professor in the Department of Applied Mathematics at the University of Washington and the director of graduate studies for his department's Masters and PhD programs in Applied Mathematics, as well as its Masters program in Computational Finance and Risk Management.

Prior to joining the University of Washington, Professor Lorig was a postdoctoral researcher and lecturer at Princeton University in the Department of Operations Research and Financial Engineering. He holds a PhD in Physics from the University of California at Santa Barbara and a BS in Physics from the University of Minnesota.

Professor Lorig's primary areas of research are financial mathematics and applied probability. Among the topics he has studied are robust pricing and replication of financial derivatives, asymptotic behavior of implied volatility, optimal investment, static hedging, algorithmic trading, and optimal bookmaking for sports betting markets. Preprint versions of Professor Lorig's publications can be found on his arXiv author page.

In 2016, Professor Lorig was a co-recipient of the SIAM Activity Group on Financial Mathematics and Engineering (SIAG/FME) Early Career Prize. He currently serves as an associate editor at Applied Mathematical Finance as well as SIAM Journal on Financial Mathematics.

Peter Tankov

Peter Tankov is professor of quantitative finance at ENSAE Paris, the French national school for statistics and economic administration, having previously worked

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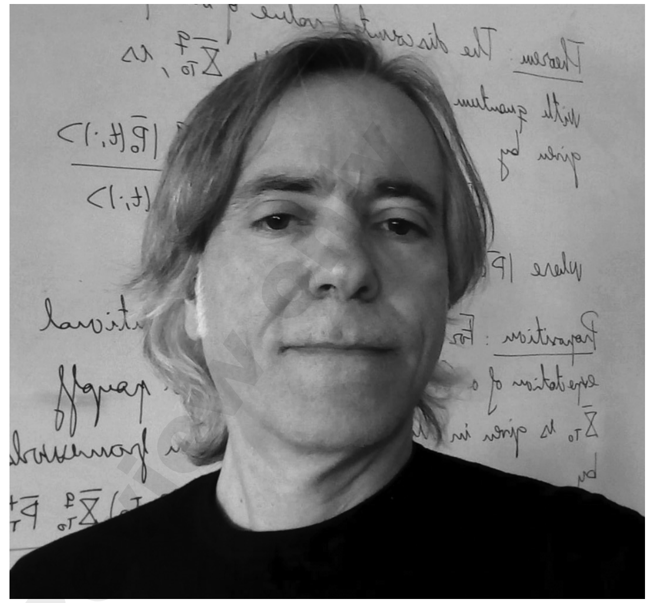
at Paris-Diderot university and Ecole Polytechnique (France). He studied physics at St. Petersburg State University and applied mathematics at Ecole Polytechnique and obtained his PhD in quantitative finance from Ecole Polytechnique. He is the author of a widely read book on financial modeling with jump processes and over 40 research papers on various aspects of quantitative finance. His current interests include energy finance, stochastic models for renewable energy, and climate finance.

Alexandre Antonov

Alexandre Antonov currently works as chief analyst at Danske Bank. He received his PhD degree from the Landau Institute for Theoretical Physics in 1997. His activity is concentrated on modeling and numerical methods for interest rates, cross currency, hybrid, credit, and CVA/FVA/MVA. Antonov is a published author for multiple publications in mathematical finance and a frequent speaker at financial conferences. He has received a Quant of Year Award of Risk magazine in 2016.

Alberto Bueno Guerrero



Alberto Bueno Guerrero holds a BSc in Physics (Theoretical Physics), a BSc in Economics (Quantitative Economics), and a PhD in Finance. He is currently doing research in mathematical finance, having published articles in prestigious journals such as *The Journal of Derivatives and Physica A*. He works as an economics teacher at IES Francisco Ayala, a secondary school in Granada (Spain). Eleven years ago, his life changed drastically when his wife gave birth to triplets, doubling his family.

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