by Jennifer Ouellette

Physicists Graduate from Wall Street

Over the past decade, the number of Ph.D. physicists employed in the financial community has increased dramatically. Once considered something of an anomaly on Wall Street and in banking, physicists—and their fellow Ph.D.'s in mathematics, computer science, and engineering—have become a critical element to successful investment strategies, gradually replacing many employees who lack strong statistical and analytical backgrounds. Today, quantitative methods are commonplace on Wall Street, despite concerns about their predictive accuracy, and the proliferation of Ph.D. physicists in financial activities has made competition for these lucrative positions more intensive than ever.

"Investing is increasingly becoming dominated by physicists, mathematicians, electrical engineers, and programmers," says Adrian Cooper, founder and president of Wall Street Analytics (Palo Alto, CA), where roughly one-third of the employees are Ph.D. physicists. Peter Carr, who heads the Equity Derivatives Research Group at Bank of America Securities (New York, NY), recalls that all of his interviewers for his first position at Morgan Stanley were physicists.

Physicists in finance generally fall into two categories: those attempting to predict the stock market to achieve superior return, and—more commonly—those who use quantitative methods to assess and manage investment risk, a group known as quantitative analysts, or "quants." Investment banks are highly leveraged institutions, with book assets that often greatly exceed the value of the firm. Their goal is to maintain a neutral position—a balance between gainers and losers—as various assets in a portfolio rise and fall in value.

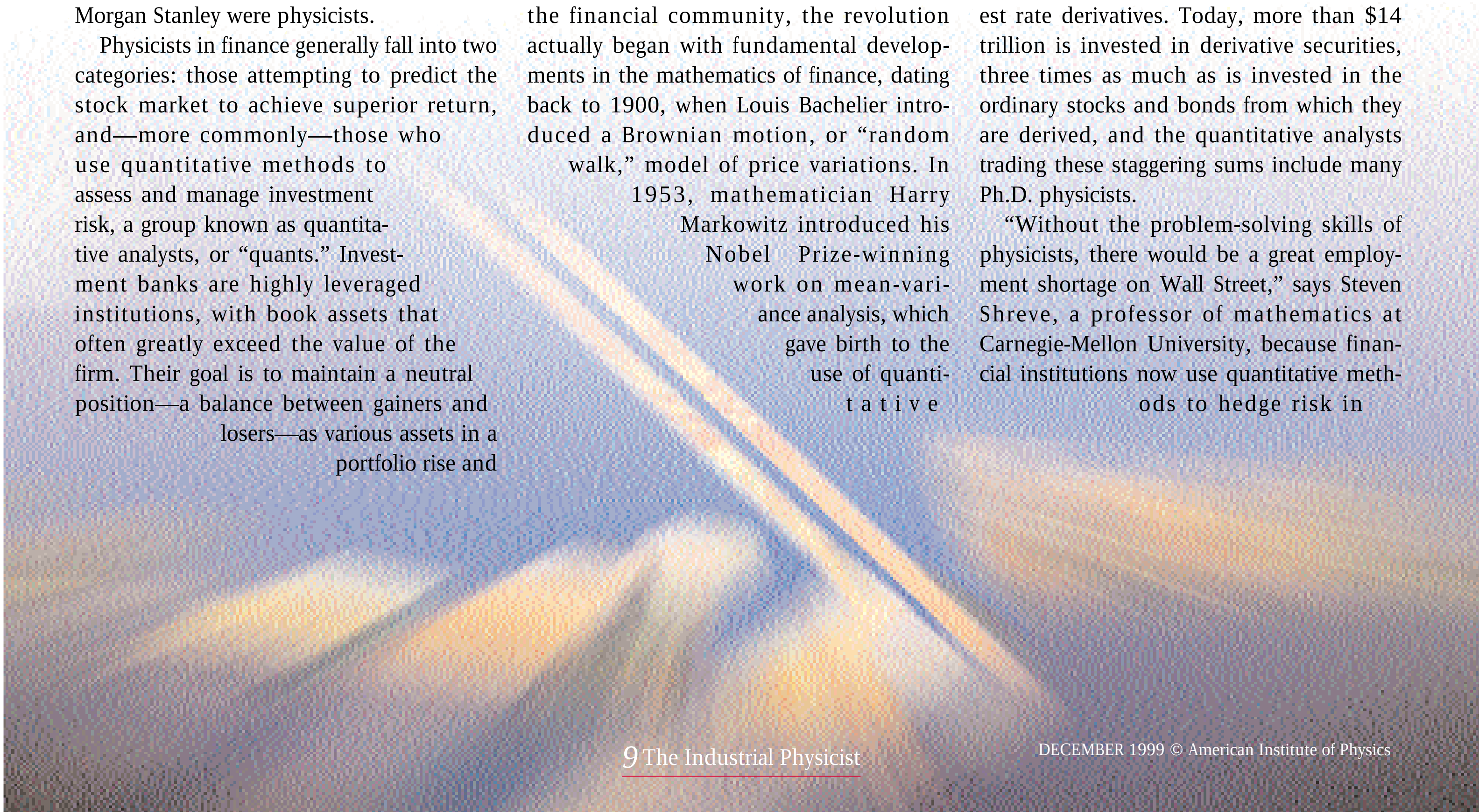
Hence, "risk management is more technical than ever," says Neil Chriss, a vice president and portfolio manager at Goldman Sachs Asset Management, who heads a fledgling master's program in financial mathematics at New York University. "The need to control risk has become a computationally intensive problem, involving the ability to price many different assets quickly."

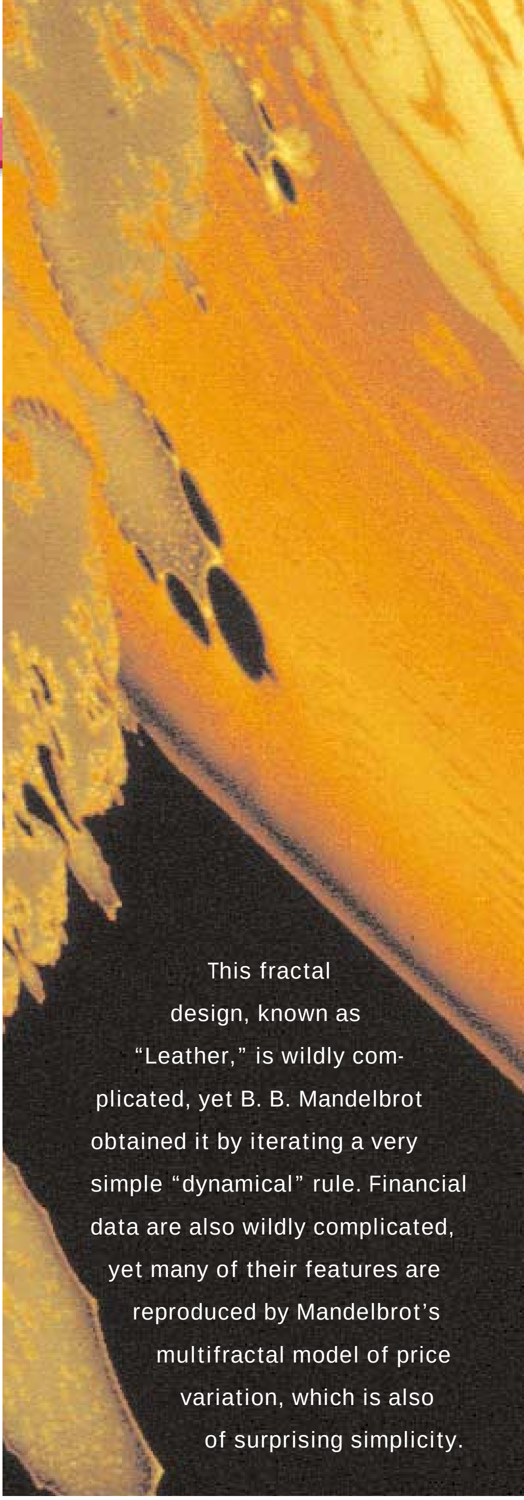
Not surprisingly, the problem-solving skills of physicists are useful in this capacity, as are their abilities to view a problem in a broader context, separate small effects from larger ones, and translate intuition about how something works into formal models. "Bond traders will try to persuade you that there's an emotional aspect that must be understood behind certain bonds, but that really isn't the case," says Cooper. "A bond is a mathematical instrument which performs according to precise characteristics, and in order to analyze it properly, you need people capable of understanding the math behind those characteristics."

Although physicists have helped foster the widespread use of quantitative methods in the financial community, the revolution actually began with fundamental developments in the mathematics of finance, dating back to 1900, when Louis Bachelier introduced a Brownian motion, or "random walk," model of price variations. In 1953, mathematician Harry Markowitz introduced his Nobel Prize-winning work on mean-variance analysis, which gave birth to the use of quantitative methods for predicting the stock market. Then, in the 1960s and early 1970s, Benoit Mandelbrot—now widely known as the "father of fractals" and an IBM Fellow Emeritus at IBM's T. J. Watson Research Center—proposed a model of price variations that eventually evolved into the concept of fractional Brownian motion in multifractal time. Among other conclusions, Mandelbrot, who worked at IBM from 1958 to 1993, demonstrated that wealth acquired on the stock market is typically acquired during a small number of highly favorable periods—a finding markedly different from the Brownian model, which predicts small gains consistently over time.

A major turning point occurred in 1973, when economists Fischer Black and Myron Scholes devised an equation to calculate the value of options in simple derivative dealings, best described as an option to buy a stock in the future at a specified price. (The term derivative is used because the value of the contract derives from the value of the underlying stock.) The Black-Scholes approach was later extended and applied to more complex derivatives, particularly interest rate derivatives. Today, more than $14 trillion is invested in derivative securities, three times as much as is invested in the ordinary stocks and bonds from which they are derived, and the quantitative analysts trading these staggering sums include many Ph.D. physicists.

"Without the problem-solving skills of physicists, there would be a great employment shortage on Wall Street," says Steven Shreve, a professor of mathematics at Carnegie-Mellon University, because financial institutions now use quantitative methods to hedge risk in





This fractal design, known as "Leather," is wildly complicated, yet B. B. Mandelbrot obtained it by iterating a very simple "dynamical" rule. Financial data are also wildly complicated, yet many of their features are reproduced by Mandelbrot's multifractal model of price variation, which is also of surprising simplicity.

Benoit Mandelbrot

trading derivative securities and other financial instruments. "Physicists didn't create that fact, but they helped build the human resource needs of the banks."

The demand for financial-modeling systems has driven the formation of numerous start-up companies, many founded by Ph.D. physicists drawn to the industry by the technical challenges and potential monetary rewards. (Base salaries on Wall Street can be as much as three times that of traditional physics positions.) Cooper earned his Ph.D. in theoretical physics from Stanford University, but found himself comparing the career satisfaction and financial rewards of Ph.D.'s his age who had followed the traditional career path with those who had gone into finance. "It was pretty clear which direction was more appealing," he says. Cooper went on to found Wall Street Analytics, which develops software for modeling financial systems for mortgage-pool investments.

Nigel Goldenfeld, professor of physics at the University of Illinois, Urbana-Champaign (UIUC), earned his Ph.D. from the University of Cambridge in England and specializes in statistical, theoretical, and computational physics. His first Ph.D. student at UIUC ended up working for Goldman Sachs, which sparked Goldenfeld's interest in the physics of finance. Convinced he could improve on the calculation techniques used, he founded NumeriX in 1996 with fellow physicists Alexander Sokol and Mitchell Feigenbaum and entrepreneur Michael Goodkin. NumeriX is a New York-based venture that markets fast numerical software products for derivative-risk management.

Physicists attempting to predict the stock market look for patterns in the data of stock prices and foreign-exchange markets. The Prediction Company (PC), based in Santa Fe, New Mexico, is perhaps the best-known company focusing on this sector of finance. The company develops advanced forecasting technologies for prediction and computerized trading of financial instruments, based on the assumption that the stock market is not completely random but has short-term pockets of predictability. "Our task for models is to detect the mispricing of an asset, and make a trade based on [that]," says Norman Packard, one of PC's founders.

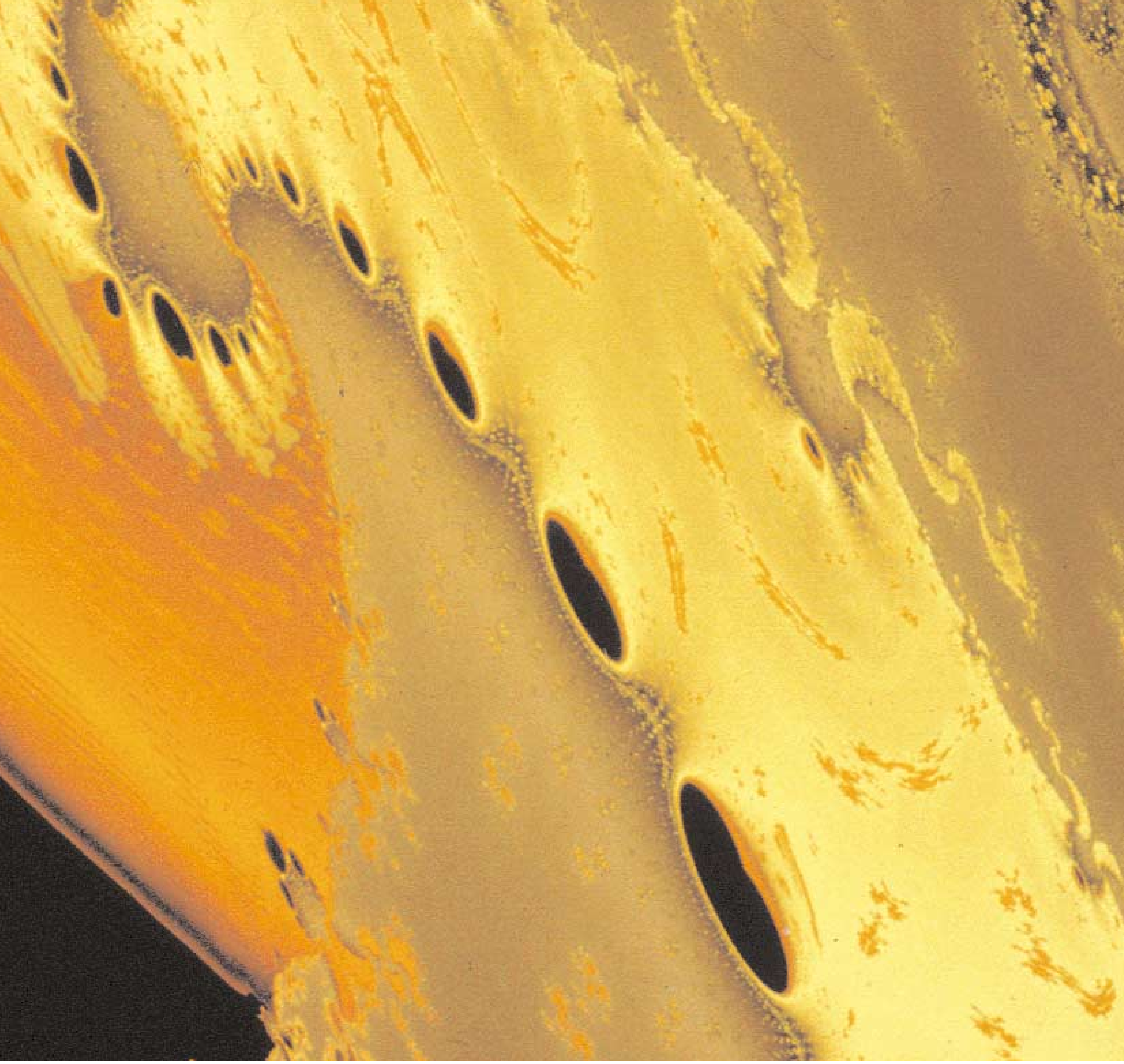
Along with fellow high-energy physicist Doyne Farmer, Packard developed a computerized system for beating the roulette wheel in the 1970s based on the then-emerging field of chaos theory. They subsequently sold it to other entrepreneurs for further development. The pair then concluded that financial markets offered another example of a complex system that might be amenable to predictive technology. They founded PC in 1991, and within a year, the company had signed an exclusive agreement to provide predictive signals and automated trading systems to O'Connor and Associates (now part of Swiss Bank), a highly successful Chicago-based trading firm that had made millions in derivatives trading using the Black-Scholes equation.

The skeptics, however, still remain unconvinced. "If they could do it, they wouldn't be wasting their time with a company. They would just be sitting there buying and selling IBM share options," Cooper says.

Prevailing attitudes among academics toward physicists working on Wall Street have changed in the last decade. Emanuel Derman, who earned his Ph.D. in physics from Columbia University in the 1970s, is now a managing director at Goldman Sachs and head of its Quantitative Strategies Group. He finds that the financial world is no longer viewed as a second-rate "alternative" career for physicists unable to obtain positions in academia and industry. Instead, finance now is a highly desirable first choice, as evidenced by the number of tenured professors who have left their academic positions for more lucrative careers in finance.

Ironically, physicists interested in pursuing careers in finance today may have become victims of their predecessors' success. "It used to be a gravy train for physicists and other mathematically oriented people, but now the job market has become saturated," says Carr. Few financial houses are hiring additional quants, and today the ability to solve differential equations and perform basic programming isn't enough to land a job on Wall Street. New Ph.D. physicists also need a basic understanding of options, pricing theory, interest rate theory, and other foundations of finance to be considered. "The stakes are higher than they've ever been in terms of the level of knowledge expected for entry-level [quant] positions," says Chriss.

This increased competitiveness has spurred the formation of numerous master's degree programs in computational finance (also called financial engineering or mathematics in finance) at institutions around the country. Carnegie Mellon University pio-



neered the concept in 1994 with a 12-month program combining coursework from four separate academic departments: mathematical sciences, statistics, computer science, and business.

Other schools have followed suit, including Purdue University, the Massachusetts Institute of Technology, Columbia University, Cornell University, the University of Michigan, the University of Chicago, and New York University. At UIUC, students are able to complete an accelerated master's in finance program in conjunction with their physics Ph.D.'s.

Although he supports the rationale for master's programs in computational finance, Cooper argues the need to preserve the traditional focus of university physics programs. His primary concern is that the growing emphasis on finance as a career option for physicists could undermine graduate education and turn Ph.D. candidates into mortgage traders too early in their development. Several universities are mulling the possibility of running physics and finance graduate programs in tandem. "These are the universities that have been entrusted to pass on the learning that has taken generations to amass in physics, mathematics, and other subjects," Cooper says. "If the physics departments aren't protecting the subject of physics, who is going to do it?" But Packard believes the threat of a "brain drain" is not limited to finance. "Financial markets are the least of physics' worries," he says. "The field is facing an even more severe brain drain from a number of other areas, such as electronics and computer engineering."

As successful as today's financial models have been, there remains substantial room for improvement. Although pleased at the increased trust placed in quantitative methods by the financial community, Thierry Kaufmann, a theoretical physicist who heads Purdue's computational finance master's program, admits that existing models are not 100% accurate, which poses serious potential consequences. "Sometimes excessive trust is placed in these quantitative results by people who lack the proper background and make very risky decisions based on them," he says. "They can lose a lot of money."

Although the models used for equity derivatives have proven fairly robust, many surprises still take place in markets heavily dependent on bonds and interest-rate movements and in volatile foreign-exchange markets such as Indonesia. Part of the problem, says Goldenfeld, is that many models were created with an eye to being easily calculable. Hence, these models are not faithful to the complexities of real market dynamics. "It's no good having people help you calculate if you're using the wrong model," he says. "You're getting the wrong answer faster and more accurately. You want to be able to get the right answer fast and accurately."

Among the sharpest critics has been Mandelbrot himself, now Abraham Robinson Professor of Mathematical Sciences at Yale University, who believes that the current models seriously underestimate the frequency of large fluctuations in stock value. For example, Alcatel, a French telecommunications equipment manufacturer, experienced severe volatility in its stock prices last year, which fell 40% in one day, fell another 3% over the next three days, and then rebounded by 10% on the fourth day. "The classical financial models used for most of this century predict that such '10 sigma' precipitous events should never happen," Mandelbrot says, with estimated probabilities of a few millionths of a millionth of a millionth of a millionth. In reality, such spikes occur quite regularly—as often as every month—with probabilities closer to a few hundredths. Far from varying continuously, as such models tend to assume, prices oscillate wildly, often discontinuously, at all time scales

"Volatility, far from being a static entity to be ignored or easily compensated for, is at the heart of what goes on in financial markets," Mandelbrot concludes. Underestimating the frequency of 10 sigma events, a technical term for enormous price fluctuations, can have serious global economic implications, as evidenced by last year's fears of damage to financial markets worldwide brought on by heavily leveraged trading by a hedge fund called Long Term Capital Management. This potential threat was narrowly averted by a bailout of the hedge fund paid for by major investment houses.

Even academic physicists are beginning to look more critically at some of the prevailing modeling assumptions used by the financial community. "It's becoming its own discipline," says Derman. In fact, financial markets provide an excellent practical field of study for those interested in the behavior of complex and nonequilibrium dynamical systems because there is a wealth of data available.

"Previous attempts to look at complex systems, in my view, have not been successful because people have operated at a level of generalities rather than rolling up their sleeves and doing honest spadework," says Goldenfeld. "What's happening now is exactly what I had hoped: people are digging in and trying to understand the financial markets from a physicist's perspective rather than that of a financial economist."

However, he remains a strong proponent of the value of firsthand experience with financial markets when studying such systems. "Thermodynamics was invented by engineers who wanted to make steam engines, not by people thinking about quantum states and other abstract concepts," Goldenfeld says.

For further reading:

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