

Learning from the master of complexity

French physicist Didier Sornette tells **Edwin Cartlidge** how complexity theory can be used to predict catastrophes such as stock-market crashes and earthquakes

Having a flair for prediction can make you a lot of friends, as Didier Sornette has found out. Since publishing a book earlier this year entitled *Why Stock Markets Crash*, in which he proposes that crashes can be anticipated months or even years before they happen, Sornette has received between 10 and 20 e-mails a day from people eager to know the fate of the world's markets. These e-mails have come not just from small-time investors, but also from some of the world's top fund managers and market analysts.

Sornette bases his analyses on the science of complexity, which describes both natural and man-made systems – such as the Earth's crust, the body's immune system and financial markets – in terms of the collective behaviour of their constituent parts. Financial markets, for example, consist of many traders continually telling one another what they think about the future of the market. Although the evolution of such systems cannot be predicted in detail, Sornette believes it is possible to foresee major transitions, such as a large earthquake or a stock-market crash.

"My papers on finance have been downloaded by professionals from around the world," says Sornette, who is a research director at the French national centre for scientific research (CNRS) in Nice and a professor of geophysics at the University of California, Los Angeles (UCLA). "These include employees at the US Federal Reserve, the Bank of Japan and the Deutsche Bank in Germany."

One prediction that has aroused particular interest was contained within a paper he published last December with Wei-Xing Zhou, also at UCLA (*Quantitative Finance* 2 468). According to Sornette and Zhou, the relative buoyancy of the US market over the past eight months will come to an end within a month or two, and the market will then start to decline.

Although his research has not been universally acclaimed by fellow academics, in science or economics departments, Sornette believes it is right that he sticks his neck out and makes risky predictions. "I think by taking risks you make progress in science," he says. He points out that some of his correspondents have made money from what he has told them; indeed, he himself made a 400% profit after he predicted that a mini crash would occur on the US stock market in October 1997.

Belief in the collective

Sornette graduated from the Ecole Normale Supérieure in Paris in 1981 and, after doing a masters thesis at the University of



Financial doomsayer – Didier Sornette believes the US stock market is about to take a nosedive.

Nice, went on to study the statistical physics of interfaces, the propagation of waves in random media, chaos and turbulence. He started his work on complex systems in earnest in the late 1980s, studying how materials such as concrete or metal alloys rupture under stress. He observed that small defects known as microcracks form at weak points in the material and that over time these microcracks multiply and combine, eventually causing the material to rupture.

What excited Sornette was that these cracks, which are not correlated to begin with, break the material through positive feedback – microcracks weaken the structure, which leads to more microcracks and to fusion between existing cracks. Such collective behaviour underlies all complex systems, and is manifest in what are known as

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“emergent phenomena” that act as a sign of impending collapse. In the case of materials under stress, Sornette discovered that the accelerating growth of the cracks is punctuated by a series of acoustic emissions that occur more and more frequently as the material gets closer to the point of rupture (a phenomenon that Sornette has called a log periodic power law).

Sornette put this discovery to use about 10 years ago while working for the French aerospace company Aerospatiale. By placing a rocket's pressure tanks under stress, recording the acoustic emissions, working out their

log periodicity and then extrapolating forward to the point of rupture, he and his colleagues were able to calculate the maximum stress that the tanks were able to withstand.

He has since applied this principle to the stock market. Here the traders play the role of elements of the material that are subject to failure, and the stock price is analogous to the elastic energy stored in the material. According to Sornette, individual traders tell neighbouring traders that they believe a fall is approaching, which creates a more gloomy outlook among the traders in general, which in turn increases the number of pessimistic interactions, and so on. This process continues until a critical mass of traders has been persuaded that the market is going to crash, and then the market does indeed crash.

Sornette believes this behaviour says something fundamental about human nature. "It is not a problem to be wrong if you are wrong with a crowd," he says. "It is okay for fund managers to lose money if everyone has lost money, and this is reflected in how their incentives are calculated. That is why it is very rare for people to go it alone."

According to Sornette, since August 2000 the Standard and Poor 500 Index in the US has been experiencing an "antibubble", a period of overall decline in the share price with a series of more minor ups and downs – the log periodicity – superimposed on the downward trend. By extrapolating these fluctuations as he did with the materials under stress, Sornette and Zhou have calculated that the market will decline significantly from about now until the Summer of 2004 (the slight recent upward trend was

merely a positive fluctuation, they say). He first made the prediction last September, and has updated it every month since, displaying the updated version on his website.

Whether or not the prediction is borne out remains to be seen, of course, but Sornette does have a couple of successes under his belt: he and Anders Johansen of UCLA correctly predicted that an antibubble would occur on the Nikkei index in 1999 and that the NASDAQ exchange would crash in April 2000. But they wrongly predicted that the US market would crash in December 1997 and October 1999.

Although Sornette's work has attracted a good deal of attention from financial professionals, it has received a more muted response among academic circles. "In finance and economics departments my work is basically ignored," he says. "They know our work is very strong and very serious, but we are not part of the mainstream."

Sornette has certainly earned himself a reputation as something of a maverick within the geophysics community. The orthodox view among geophysicists is that large earthquakes are simply individual smaller earthquakes that have grown. But Sornette believes that major quakes may instead be caused by many smaller tremors acting collectively. He says that stress patterns created

by small earthquakes link fault lines, thereby increasing stress in the crust and generating further minor quakes. Eventually a large fraction of the faults become interconnected and a slight disturbance then spells disaster. Again, he believes this critical state can be predicted by looking for a log-periodic power law – fluctuations in the aggregate shift of the Earth's crust over time.

"Other geophysicists find some of my work on earthquakes hard to swallow," he says. "This is understandable because earthquake prediction is a difficult problem. It is much more complicated than working out what will happen to a piece of concrete under stress, for example. You do not know where the material begins and ends – a plate

is coupled with the underlying crust and mantle as well as with other plates."

But how does Sornette manage to carry out such a wide range of research? "I have a very understanding wife [who is also a geophysicist]," he replies. "While I am in the US I work 13–15 hours a day, seven days a week, although I work a bit less in France."

To sustain this pace, he says he takes plenty of exercise, from windsurfing and skiing to cutting down trees and digging holes in his garden. And for recreation, he simply switches fields. "When I work on finance my hobby is to work on earthquakes," he explains. "And when I work on earthquakes my hobby is to work on rupture phenomena."

● www.ess.ucla.edu/faculty/sornette

INDUSTRY

Laser expert lights up entertainment

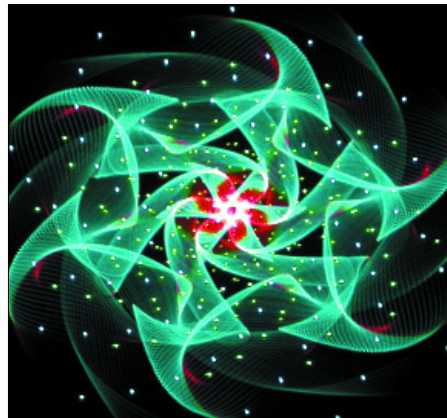
Lasers have fascinated Floyd Rollefstad from the time he first encountered one in high school. Not only was he interested in the science underpinning lasers, but also in their artistic potential. He expressed that interest by setting up small laser shows for his friends while he was studying for bachelor's and master's degrees in physics from the University of North Dakota.

Then, hoping to explore the possibilities of using light for medical applications, he stayed at the university to take some biological courses. But in 1977 another career opportunity presented itself. "A so-called Laserium had started in Los Angeles," he says. "I saw that I could do similar work and that it could be a viable business."

To pursue that possibility, Rollefstad founded Laser Fantasy International (LFI) as a one-man company. In the following year he produced his first planetarium show in Chicago. And today, a quarter of a century after that event, the firm has become a global leader in laser entertainment.

Based in Bellevue, Washington, since 1982, LFI has co-developed the yttrium aluminium garnet (YAG) laser for entertainment, has pioneered multiplex colour modulation and trace elimination for laser graphics, and has developed a self-contained YAG laser system for road shows. The firm sets up laser-based corporate promotions, educational projects and entertainment spectacles for organizations as diverse as Microsoft, Nintendo and the Seattle Mariners baseball team, in locations as far afield as Calgary, Kyoto and Las Vegas.

Last October, wishing to spend more of his time on the creative side of the business, Rollefstad sold LFI to entrepreneur Robert Baldrige, while remaining as the firm's vice president of technology development. "I saw LFI as an exciting business with profit potential," says Baldrige, who had previously



Light fantastic – Laser Fantasy International puts on shows for a wide range of organizations.

owned a printed-circuit company for 11 years. "It was an ideal situation. Floyd did not enjoy the business side and I do. So he could stick around and use his creativity."

Baldrige plans to focus that creativity on developing innovative technologies and new markets. "We are looking not only to be the laser entertainment experts but also to expand into multimedia to broaden the scope of our business," Baldrige says. He wants to apply lasers in new ways, including developing their use in theatres. He also wants to put more emphasis on the firm's international work.

Rollefstad could hardly imagine those ambitions when he founded LFI. "Getting started was pretty difficult because of a lack of money and not knowing very much about business," he remembers. "It took about a year before I could make any money at the first small planetarium." Only after he had moved himself and his firm to Seattle in 1982 to set up a show in that city's Pacific Science Center did he expand beyond working in one planetarium at a time. But as he became more accustomed to the business,

LFI developed laser shows for international expositions in Canada and Australia, installed a laser projection system at a theme park in South Korea, and co-designed, produced and installed a light show in the Las Vegas Hilton hotel.

During the same period, the firm also set up an educational division to produce "edutainment" shows for schools. Subjects of these shows have included public health, space science, ecology and history.

Despite those initiatives, LFI's growth began to flatten out in the early 1990s. "It has not grown any more since then, mainly because I was the only person calling the shots, and I was uncomfortable with making more than I could handle," Rollefstad says. "I am probably fairly strong on the right and left sides of my brain; that was critical in being the leading force for innovation in the industry and having good, solid technical products. I was also able to do the management and business aspect of the job, but it was not my favourite."

In his new role overseeing technology and development, Rollefstad will monitor advances in what has become a very competitive field. "We have a small group and probably will not come up with earth-shaking developments from the technical point of view," he says. "Marrying laser display technology with entertainment is probably where I will be putting in most of my work."

Even though he did not fully embrace the business aspects of running a technical company, Rollefstad's background in physics gave him some valuable non-scientific skills. "The training helped me to look at things from a systems approach," he says. "And knowing how lasers work is important in determining whether things are possible when customers ask for them."

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