

The identical Voyager probes launched in 1977 and are still travelling.

stories of discovery, excitement and public engagement. He describes the extension of the Voyager mission to the heliopause, where the Sun's energy is overpowered by interstellar forces. Ed Stone, who has been chief scientist for Voyager since its inception, evinced the excitement of a self-confessed non-party animal. "I can still remember taking the data home every night, and putting the plots on the refrigerator," he tells Bell. "I couldn't stop thinking about them, wondering what would happen next."

Voyager 1 is now more than 130 astronomical units (AU) from the Sun (1 AU is the distance between the Sun and Earth, around 150 million kilometres), and Voyager 2 is at more than 107 AU. They continue to take readings of the heliopause.

Thanks to astronomer Carl Sagan, one of Bell's heroes, both probes contain messages from Earth: gold-plated copper phonograph records encoded with 115 images of scenes from Earth, audio greetings in 55 languages, and 90 minutes of music from Bach to Chuck Berry, along with playing instructions. This message in a bottle is one of the mission's best-known attributes, and Bell explains well its publicity value and how it represents a feel-good sentiment about the possibility of encountering interstellar life.

The Voyagers demonstrate the remarkable advances in robotic space exploration over the past almost 40 years, and suggest that subsequent missions may yield even more exciting results. Such follow-ups as the Galileo mission to Jupiter, Huygens–Cassini to Saturn and New Horizons to the Kuiper belt including Pluto may herald even more ambitious missions — to Titan, for instance, where they might sail on a hydrocarbon sea, or to Jupiter's moon Europa, to explore an ice-covered liquid-water ocean that has the potential to harbour life.

I believe that NASA's greatest achievement is the Apollo Moon programme. The odyssey of the Voyagers certainly vies for second place. Bell appropriately quotes historian Stephen Pyne: "The Voyagers were special when they launched. They have become more so thanks to their longevity, the breadth of their discoveries, the cultural payload they carried, and the sheer audacity of their quest." ■

Roger D. Launius is associate director for collections and curatorial affairs at the Smithsonian Institution's National Air and Space Museum in Washington DC. e-mail: launiusr@si.edu

MATHEMATICS

Groping in the dark for glimpses of beauty

Amir Alexander relishes two accomplished accounts of the life mathematical.

One evening in 2009, French mathematician Cédric Villani stepped into his children's room. He locked the door, turned off the light and began to pace, pondering the statistical properties of plasma. A few metres away, his wife, Claire, was in the kitchen, cooking dinner for the family. The contrast, Villani concedes in his engaging *Birth of a Theorem*, was "a bit much", yet immediately after dinner he returned to the dark room to grapple for hours with his elusive proof.

Anyone reading that anecdote will feel sympathy for Claire as she tries to preserve family normality. Anyone who has seriously engaged with mathematics will also understand her husband. Perhaps more than any other field, mathematics pulls the practitioner away from the 'normal' world of things and people into a strange alternate universe, in which we catch glimpses of beauty and coherence, but spend most of our time groping in the dark. In *Birth of a Theorem*, Villani offers one way of straddling that divide; in *Mathematics Without Apologies*, fellow mathematician Michael Harris presents a very different one. Together, they provide an unmatched perspective on life in this "problematic vocation" by two of its leading practitioners.

Birth of a Theorem is the story of Villani's quest to give a full mathematical account of Landau damping. Whereas gas becomes increasingly disordered over time as entropy increases, plasma spontaneously stabilizes, with no increase in entropy. Soviet physicist Lev Landau was the first to mathematically describe this improbable phenomenon, but he used a simplified model that left many unconvinced. Working closely for several years with mathematician Clément Mohout, Villani succeeded, and he was awarded a Fields Medal in 2010.

Villani's quest takes him across the world, from Lyons, France, to Princeton, back to Paris and on to Hyderabad in India. At every stop, he talks to local mathematicians, demonstrating that, for all its abstractness, mathematics can be an intensely social activity. The book is sprinkled with brief, telling

Birth of a Theorem: A Mathematical Adventure

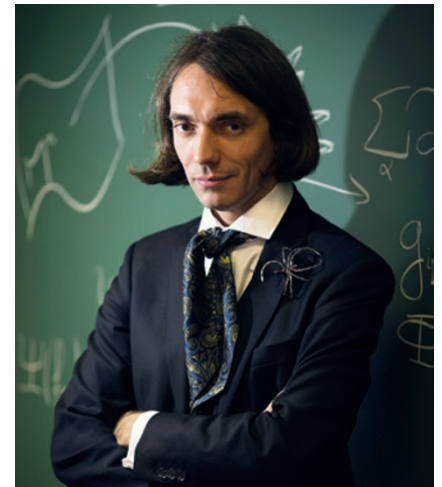
CÉDRIC VILLANI

Bodley Head/Faber and Faber: 2015.

Mathematics Without Apologies: Portrait of a Problematic Vocation

MICHAEL HARRIS

Princeton Univ. Press: 2015.



Cédric Villani studies the maths of plasmas.

portrayals of mathematicians and physicists past and present. The grumpy, grey-haired Étienne Ghys of Lyons and Chinese expat Alice Chang of Princeton alternate with the autocratic Lev Landau in 1960s Moscow and the ever-present shadow of Albert Einstein at the Institute for Advanced Study in Princeton. Much of Villani's e-mail correspondence with Mohout is reproduced, chronicling moments of triumph and despair.

Charismatic and flamboyantly dressed, Villani is the opposite of the 'mathematical hermit' and annoyed by the stereotype. He attends a recital by one of his children, joins his family at the American Museum of Natural History in New York and travels a long way to attend a concert by rock band Têtes Raides. Yet he studies the mathematics of galaxy formation during the recital, works out a step in his proof on the bus from the museum, and explains his research to a stranger who drives him back from the concert. The mathematical life, in his telling, is a delicate dance between the demands of the 'real' world and the ▶

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▶ allure of the mathematical one.

If *Birth of a Theorem* is the personal record of a single-minded quest, *Mathematics Without Apologies* is a kaleidoscope of philosophical, sociological, historical and literary perspectives on what mathematicians do, and why. Do they pursue their work for the public good? Harris dismisses that as a pose, useful for grant applications and little else. Is it the absolute truth of mathematical demonstrations that drives the field? That, Harris contends, is a conceit of philosophers: practising mathematicians seek insight, not certainty. What about the lauded beauty of mathematics? Perhaps, Harris concedes, but when mathematicians talk about beauty, what they mean is pleasure. A 2012 sociological survey found that 91% of pure mathematicians cited it as a key attribute of the field. Mathematicians, Harris concludes, do what they do because of the enormous pleasure it brings them.

Pleasure is not an explanation likely to satisfy funding agencies. Yet Harris makes no apologies. He is concerned that the field has made a Faustian bargain with the institutions that provide the material conditions for mathematical research. Leading mathematics departments have trained an army of quantitative analysts, or quants, to implement the algorithms that govern financial trading practices. The impersonal, unchallengeable equations of higher mathematics, he worries, contribute to a moral vacuum at the heart of high finance.

Harris's insider view reveals a community in which each mathematician is placed in an informal but strict hierarchy, depending on acknowledged brilliance and accomplishments. He takes a playful detour, arguing that each of US writer Thomas Pynchon's 'non-linear' novels is organized around a different conic section, such as a parabola. Throughout the book, he verbally spars with an imaginary "performing artist" while trying to explain the mysteries of number theory.

But, like Villani, Harris returns repeatedly to the chasm between the human world and the mathematical one — a tension that in his own life has proved fruitful. Stuck in a professional cul-de-sac in the 1990s, Harris experienced a revelation: a dream showed him a new mathematical path, which led to his ascent up the mathematical hierarchy and transformed his life.

For him as for Villani, mathematical insight at its deepest core remains an irreducible personal experience. ■

Amir Alexander is the author, most recently, of *Infinitesimal*. He teaches at the University of California, Los Angeles. e-mail: amiralex@ucla.edu

SOCIAL SCIENCE

Aid's inconvenient truth

Erin Bohensky applauds a documentary revealing how disaster relief can have disastrous impacts.

At the start of Raphael Barth's provocative documentary *Aftermath*, a bottle of Coca-Cola lands on a pristine beach. The image calls to mind the satirical 1980 film *The Gods Must Be Crazy*, in which the lives of Kalahari Desert tribal peoples are changed irreversibly by modernization. Barth's is the true story of how foreign aid delivered to inhabitants of the Nicobar Islands after the 2004 Indian Ocean tsunami became a second disaster.

Barth's film focuses on social ecologist Simron Singh and his work with these indigenous peoples. In setting out to help them, Singh grapples with two questions: why is aid so dysfunctional, and how can science help people in crisis?

Singh first visited the islands in 1999 to research Nicobarese culture, and befriended many in the community. After the tsunami, they asked him for help. Singh mobilized funding from the Austrian Science Fund to support rehabilitation research. In the film, he — with community spokesperson Prince Rasheed Yusoof and local reporter Denis Giles — watches aid pour in from hundreds of non-governmental organizations (NGOs). In effect, the tsunami engineers the perfect social experiment, revealing what happens when cash and unneeded commodities are funneled to a remote indigenous community. There was "no way back", Singh admits.

The donations, Barth shows, are mismatched to needs and context. The community wants tools; donors bring blankets. Houses and schools rebuilt with aid are ill-ventilated "boiling chambers". A government initiative provides European-style dwellings housing just five or six people, fragmenting the large joint family groups traditional among the Nicobarese. "Who is helping whom?" Singh asks. "Are the victims helping the organizations to reproduce themselves?"

How can the messy problem of ineffective aid be fixed? Development analyst Ben Ramalingam has argued that we must understand development as a complex system to address underlying causes rather than treat symptoms. *Aftermath* shows Singh and colleagues in Vienna creating the Sustainable Indigenous Futures (SIF) fund in 2005, to



Aftermath: The Second Flood

DIRECTOR: RAPHAEL BARTH
Golden Girls/Filmtank/
TwoPair/Tata Institute
of Social Sciences/
ORF: 2014.

provide financial aid directly to the community. As they soon learn, however, even well-directed intervention is no substitute for empowerment. Nominated community members struggle to abide by NGO norms of accountability. "A Nicobarese cannot become a project officer in ten days," Yusoof concedes. The community shuns Singh when the SIF stops sending money. In 2009, Singh and the SIF establish a partnership with a local NGO, the Tata Institute of Social Sciences, to reinstate resource-based livelihoods such as fishing in the islands.

Is the global aid enterprise learning from its mistakes? Perhaps. Extreme events can be catalysts for change. One young Nicobarese man leaves to pursue a higher degree, noting how the tsunami has shaped his aspirations. Yusoof is building a community tourist resort to generate income locally. Through such proactivity, resilience is built.

Finally, we see Singh, meticulously sorting slides, promising to document it all for the Nicobarese. But he questions the current paradigm of aid based on Western capitalist values. He even asks whether people in crisis need assistance at all. Scientists, he proposes, can help most by bringing together scientific and local ways of thinking to guide NGOs' actions on the ground.

Aftermath is a gritty, honest picture of two communities: the Nicobarese and aid agencies. Raw moments such as a ceremonial pig butchering, or a glimpse of the ethical and administrative conflicts that can trap development agencies in operational gridlock, are delivered unflinchingly. Ultimately, the Nicobarese have hope. "The aid has stopped," Yusoof concludes. "Now the real normal life starts, and we are happy." ■

Erin Bohensky is a senior research scientist in livelihoods and adaptive development at the Commonwealth Scientific and Industrial Research Organisation in Townsville, Australia. e-mail: erin.bohensky@csiro.au