

advances made in collection and storage during the Spanish Civil War, Vaughan established several effective blood depots — one in a bar in Slough, which always attracted donors. She initiated a mobile service, using ice-cream vans to collect and deliver blood around the country. One contemporary commentator, Major General W. H. Ogilvie, considered the greatest medical advance of the Second World War to be not penicillin, but the blood-transfusion service.

For me, the outstanding hero is Arunachalam Muruganatham, an innovator in sanitary products from southern India. It is an area where menstruation is considered shameful and dirty, many women cannot afford commercially produced pads, and public toilets and running water are rare. The lack of basic hygiene and the use and reuse of inadequate washable rags can lead to girls and women missing out on education and employment, and contracting gynaecological infections.

Muruga, as he is known, noticed his wife using newspapers and cloth during menstruation, and decided to experiment with alternatives. He carried a football filled with goat blood under his clothes so that he could release the liquid as he moved, and gain some sense of the practical difficulties. Ridiculed even by his family, he persevered, and designed machines to manufacture affordable pads, encouraging local communes and factories to produce and sell them. Muruganatham's story has featured in a 2013 documentary by Amit Virmani, *Menstrual Man*, and a 2018 Bollywood feature film by R. Balki, *Pad Man* (see S. Priyadarshini *Nature* 555, 27–28; 2018).

*Nine Pints* is highly readable and informative, but the chatty style grates at times, and there are a few irritating duplications. And the title — a nod to the volume of blood in a human body, which is variable and related to body size — seems strangely static for a dynamic biological fluid with many vibrant contexts. ■

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## PHYSICS

# Black-hole fever

Richard Panek on two books tackling the counter-intuitive weirdness of these gravitational beasts.

In the late nineteenth century, physicist Ernst Mach wrote that when Isaac Newton published his theory of gravity in his book *Principia* (1687), it disturbed his fellow natural philosophers. The reason? It “was founded on an uncommon unintelligibility”: two objects interacting without physical contact. Mach was trying to show how an affront to common sense gains respectability through familiarity. By his own era, gravity had become “common unintelligibility”.

Black holes — gravitational beasts that warp space and devour light — have undergone a similar trajectory. In the 1980s, they still seemed like science fiction. Since then, advances in technology and theory have transformed them into scientific (near) certainties. Now, two books — *Einstein's Monsters* by astronomer Chris Impey, and science journalist Seth Fletcher's *Einstein's Shadow* — trace that transition without losing sight of how weird their subject is.

In *Einstein's Monsters*, Impey provides a history of black holes and an overview of investigations into their supremely counter-intuitive behaviour. The possibility of their existence arose from the idea that gravitation is a force of attraction between bodies of matter. If light were matter, as British philosopher John Michell and French mathematician Pierre-Simon Laplace argued in the eighteenth century, it would be subject to Newton's laws. And if Newton's laws were correct, an object with sufficient mass could overwhelm light's mass, creating a “dark star”. Laplace even provided a mathematical foundation for such a thing, in 1799. That year, however, polymath Thomas Young demonstrated that light acts as a wave. Laplace dropped his idea.

Albert Einstein's 1905 paper on the photoelectric effect, suggesting that light travels as both waves and packets of matter (photons), might have revived the dark star — had he not, ten years later, rendered obsolete the idea

## Einstein's Monsters: The Life and Times of Black Holes

CHRIS IMPEY  
W. W. Norton (2018)

## Einstein's Shadow: A Black Hole, a Band of Astronomers, and the Quest to See the Unseeable

SETH FLETCHER  
Ecco (2018)

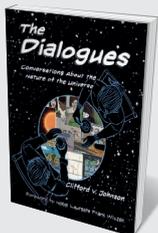
of gravitation as a force mysteriously operating without physical contact. In Einstein's universe, light follows curves in space-time created by the presence of objects with mass. Within months of Einstein's 1915 presentation of his general theory of relativity, astrophysicist Karl Schwarzschild found a solution for Einstein's equations: an object needn't be huge to trap light, as Michell and Laplace had assumed; it just needs to be sufficiently dense.

Impossibly so, thought many physicists, including Einstein. Such an object could result only from mass collapsing into a state of infinite density — a singularity. And infinities don't lend themselves to enthusiastic scientific endorsements. Just because a “monster” is mathematically feasible doesn't mean it exists.

However absurd, the possibility lurked, and some theorists love lurking absurdities. From the 1920s, they had the benefit of quantum mechanics, an understanding of the subatomic Universe in which previously unimaginable density makes sense. Theorists in the 1930s calculated that the mass of a star determines its eventual fate — and that those fates include a neutron star or a dark star.

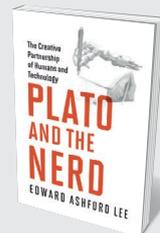
A neutron star was fine: quantum mechanics could account for a creature wherein a few cubic centimetres of matter weighs one billion tonnes, and the nuclei of adjoining atoms abut one another. A dark star was different. The ugly, infinity-dependent singularity at its heart defeated both general relativity and quantum mechanics.

For black holes to become commonly ▶



### The Dialogues

Clifford V. Johnson MIT PRESS (2018)  
Physicist Clifford Johnson aims to spark curiosity about science through discourse. In this thought-provoking graphic novel, he optimizes the rule of ‘show, don't tell’, encouraging engagement with concepts from the multiverse to immortality in everyday social scenarios.



### Plato and the Nerd

Edward Ashford Lee MIT PRESS (2018)  
Technology and creativity are irrefutably intertwined. Computer scientist Edward Ashford Lee explores both the potential impact of the digital revolution on human evolution and how technology's “real power comes from partnership with humans”.

► unintelligible, observations had to catch up. From mid-century, astronomers looked at the Universe in electromagnetic wavelengths from radio waves to  $\gamma$ -rays, and identified distant objects that generated geysers of radiation — a match for theoretical black holes. Theorists such as Stephen Hawking tried to divine what happens at the event horizon — the boundary between this Universe and whatever lies beyond the gravitational field.

Further advances, such as the Hubble Space Telescope, made the evidence overwhelming. Supermassive black holes probably occupy the centre of every galaxy and determine galactic growth. Over about 50 years, black-hole studies have gone from obscurity to a thriving industry. Theorists, Impey writes, are “in a golden age”, and observers “are harvesting massive black holes on an industrial scale”.

The harvest of two black holes is the subject of Fletcher’s book. One lies in the relatively nearby Virgo A galaxy. The other, the supermassive candidate Sagittarius A\*, is at our Galaxy’s heart. Observations of black holes have generally relied on indirect evidence, given the constraints of attempting to ‘see’ a black object on a black background at distances of up to several billion parsecs.

The evidence for Sagittarius A\* includes numerous studies over the past 20 years, revealing the zigging and zagging of nearby stars and gas under its apparent influence. But the Event Horizon Telescope (EHT) has tried to observe it directly.

Fletcher, chief features editor at *Scientific American* (which shares a publisher with *Nature*), tells this story. To bring such an observation into the realm of the possible, a telescope would need an aperture the diameter of Earth. By using very-long-baseline interferometry — combining observations from multiple, far-flung radio telescopes — the EHT team conceived an apparatus effectively covering the Western Hemisphere. For one week in April 2017, that network focused on the centre of the Milky Way to extract images such as the blazing radiation that should be generated by matter heating up to billions of degrees as it orbits the black hole at velocities approaching the speed of light.

Fletcher secured close access to the EHT collaboration, particularly director Sheperd Doeleman. Its results aren’t public yet, leaving a hole at the heart of Fletcher’s narrative. He compensates with a compelling behind-the-scenes story of scientists struggling as much

with funding and competition as with the challenges of seeing Sagittarius A\*.

Both books address the seeming absurdities of their subject with authority and wit. Fletcher characterizes the EHT as a “distributed Babel, constructed on as many as a dozen high perches”. And after describing a death spiral between two black holes, each 10 million times the mass of Earth and hurtling around each other at half the speed of light, less than 200 kilometres apart, Impey concludes: “This isn’t an orbit, it’s insanity”.

Maybe. But if history is any guide, it won’t seem so for long. Improvements to gravitational-wave detectors such as the Laser Interferometer Gravitational-Wave Observatory should make the detection of black-hole collisions routine, inspiring a new generation of theorists to address the incompatibility of general relativity and quantum mechanics. As these two books make clear, the study of black holes has progressed rapidly from “No way!” to “Oh, wow.” The next step is: “What now?” ■

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## NEUROIMAGING

# The brain decoders

Chris Baker enjoys a clear-eyed account of the promise and pitfalls of brain imaging.

Since the advent of neuroimaging in the 1980s with positron emission tomography (PET), the sight of a living human brain in action has captivated scientists and the public. The emergence of functional magnetic resonance imaging (fMRI) in the early 1990s was a watershed. MRI scanners were already common in hospitals and, unlike PET, fMRI does not expose people to radioactivity. By measuring activity in the brain at the scale of a few millimetres, these scans seem to promise profound insight into the workings of the brain. That has led to wild claims that the technique could enable mind reading — actually knowing a person’s precise thoughts.

Russell Poldrack tackles these claims head on in *The New Mind Readers: What Neuroimaging Can and Cannot Reveal about Our Thoughts*. RUSSELL A. POLDRACK Princeton University Press (2018)

Experimental psychologist and neuroimaging pioneer takes readers through three decades of fMRI, its promise and limitations. From the race between groups in Minnesota, Massachusetts and Wisconsin in 1991 to show that MRI measures of blood oxygenation can reflect functional brain activity, to the development of techniques for decoding what

someone is looking at, Poldrack surveys the history and biological basis of the technique and its potential application in areas as diverse as law and psychiatry.

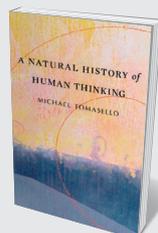
Poldrack is an ideal guide. As director of the Stanford Center for Reproducible Neuroscience in California, he actively advances fMRI methods. His enthusiasm for them is clear, as is his frustration at how their data have been misinterpreted and abused.

The technique has revolutionized neuroscience. Thousands of fMRI studies are published each year on topics ranging from perception to decision-making. For example, we now know that the pattern of blood flow



## Technically Wrong

Sara Wachter-Boettcher W. W. NORTON (2018)  
Technology permeates life, from grocery shopping to dating apps. Yet we rarely question its design or aims. Web consultant Sara Wachter-Boettcher proffers a damning critique of the ethical dilemmas it poses, and why we need to demand more accountability from tech creators.



## A Natural History of Human Thinking

Michael Tomasello HARVARD UNIV. PRESS (2018)  
Drawing on 20 years of comparative studies on humans and great apes, psychologist Michael Tomasello theorizes that human cognition arose from social cooperation. Language and culture, he posits, also grew from our ancestors’ need to work collaboratively.