ANCIENT TECHNOLOGY

Archimedes' fabled sphere brought to life

Curator recreates a 2,000-year-old model of the Universe.

BY JO MARCHANT

A mechanical model of the Universe attributed to the ancient Greek mathematician and polymath Archimedes has been reconstructed after more than two millennia. The metallic globe, which reproduces the motions of the Sun, Moon and planets across the night sky, is on display for the first time, at a museum in Basel, Switzerland.

The model, built by Michael Wright, a former curator at the Science Museum in London, is largely the product of erudite guesswork. But astrophysicist Mike Edmunds of Cardiff University, UK, says that it is a reminder that geared machines in antiquity were probably more complex than historians often assume.

Several ancient writers and poets describe mechanical models of the heavens[1], which they often attribute to Archimedes. The earliest and clearest of these appears in a dialogue[2] written by Roman author Marcus Tullius Cicero in the first century BC. One of Cicero's characters, Philus, describes how the Roman general Marcus Marcellus in 212 BC led an attack on Archimedes' home city of Syracuse (during which the mathematician was killed). As his troops ran the city, Marcellus took only one thing for himself: Archimedes' mechanical sphere.

When Philus later saw a demonstration of the device, he concluded that "the famous Sicilian had been endowed with greater genius than one would imagine it possible for a human being to possess". Solid globes marked with star constellations were common at the time. But Archimedes' invention, Philus notes, also included the Sun, Moon and the five known planets, displaying as it turned "those various and divergent movements with their different rates of speed".

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Nature Video: watch Wright's model of the sphere in action.
go.nature.com/wl1t41

Michael Wright's machine models the heavens.

ADAM LEVY/NATURE

Historians once thought that Cicero's description was fabricated or exaggerated. But studies of a relic known as the Antikythera mechanism, found on a shipwreck from the first century BC, have changed that view. The device turned out to be a clockwork calendar that could model the movements of celestial bodies and predict solar and lunar eclipses — and thus proved that complex geared astronomical devices did exist in antiquity; it consisted of more than 30 bronze gearwheels inside a wooden box the size of a phone book (see *Nature* **444,** 534–538; 2006).

Most specialists have concluded that Cicero was describing a similar machine. But Wright — who has previously built two working models of the Antikythera mechanism — points out that descriptions of Archimedes' device use the Latin word *sphaera* (*sphaira* in Greek). "The Antikythera mechanism is not a sphere; it's a shoebox," he says.

Other scholars counter that 'sphere' could have been a generic term for astronomical models, regardless of their shape. But Wright retorts that in Cicero's description, when the globe turned, "the Moon was always as many revolutions behind the Sun on the bronze contrivance as would agree with the number of days it was behind it in the sky". This implies that the device turned once each day, he says, which makes no sense for a flat dial.

Wright built his machine with similar techniques to those that Archimedes might have used. He engraved pictures of the Greek constellations on the surface of the 20-centimetre-wide globe and mounted it in a wooden box, which hides the portion of the globe below the horizon at any given time.

As the globe is turned by hand, 24 gearwheels hidden inside drive curved pointers on the outside. Those marking the Sun and the Moon move at a constant speed, whereas the planets meander, moving back and forth with respect to the fixed stars, just as in the real sky.

No one knows whether Archimedes truly came up with such a device, but Wright argues that he was perfectly positioned to do so. The ancient scholar was a brilliant mathematician and famous for building ingenious machines.

The model is at the Basel Museum of Ancient Art and Ludwig Collection, as part of an exhibition of artefacts from the Antikythera wreck. ■

1. Edmunds, M. G. *Contemp. Phys.* **55,** 263–285 (2014).
2. Cicero, M. T. *De Re Publica* Vol. 213 (transl. Keyes, C. W.) 40–44 (Loeb, 1928).

NUMBER THEORY

Maths whizz solves a master's riddle

Terence Tao builds on an online collaboration to attack the Erdős discrepancy problem.

BY CHRIS CESARE

A maths puzzle that resisted solution for more than 80 years — including computerized attempts to crack it — seems to have yielded to a single mathematician.

On 17 September, Terence Tao, a mathematician at the University of California, Los Angeles, whose body of work earned him the prestigious Fields Medal in 2006, submitted a paper to the arXiv preprint server claiming to prove a number-theory conjecture posed by mathematician Paul Erdős in the 1930s (T. Tao. Preprint available at http://arxiv.org/abs/1509.05363; 2015).

"Terry Tao just dropped a bomb," tweeted Derrick Stolee, a mathematician at Iowa State University in Ames.

Like many puzzles in number theory, the Erdős discrepancy problem is simple to state but devilishly difficult to prove. Erdős, who died in 1996, speculated that any infinite string made up of the numbers 1 and –1 could add up to an arbitrarily large (positive or negative) ▶

value by counting only the numbers at a fixed interval for a finite number of steps.

Tao's proof shows that these sums can, in fact, grow infinitely large for any arbitrary sequence, although it does not provide a way to calculate their value for a given instance.

The proof has not yet undergone rigorous peer review, but experts have expressed no concern over whether it will survive a critical look. "I'm completely confident," says Gil Kalai, a mathematician at the Hebrew University of Jerusalem.

Tao's proof comes after years of attempts to solve the problem by hand and computer. The most recent campaign began in December 2009 and gathered steam in 2010. Mathematician Tim Gowers at the University of Cambridge, UK, suggested focusing on Erdős's problem for the fifth PolyMath Project, an online collaboration in which mathematicians work together on a single mathematical puzzle. Tao was one of several dozen participants.

The effort fizzled out in 2012, but participants did manage to show that proving the conjecture for a certain family of sequences was good enough to prove it in general. That family has arbitrary 1s and −1s only in the spots indexed by prime numbers.

In February 2014, researchers presented a computer proof for a special case of the conjecture: they showed that it is always possible to find a sum that is bigger than 2 (B. Konev and A. Lisitsa Preprint available at http://arxiv.org/abs/1402.2184; 2014). However, they failed to prove that there is always a sum bigger than 3. Tao's proof demonstrates that there is always a sum bigger than any finite number.

RICHARD HARTOG/LOS ANGELES TIMES/GETTY

Terence Tao solved a major number-theory puzzle after being inspired by a comment on his blog.

No one else managed to make major progress after the computational attempt. Tao had been working on a different problem early in September, when a timely comment on his blog suggested that the problem might be related to the Erdős conjecture. "At first, I thought the connection was only superficial," says Tao. But he soon realized that combining the commenter's fresh insight with previous results could lead to a solution. He submitted his paper less than two weeks later and included an acknowledgement thanking the commenter, Uwe Stroinski, a maths instructor in Reutlingen, Germany, who holds a PhD in mathematics from the University of Tübingen.

Tao has submitted his proof to the open-access journal *Discrete Analysis*, run by Gowers. The journal, which was founded in early September, provides conventional peer review but accepts only papers that have already been posted on arXiv, thereby avoiding major publishing costs. "Tim's journal is a promising experiment in completely open-access publishing," says Tao.

Erdős, who wrote a letter recommending Tao for admission to Princeton University in New Jersey, often offered cash prizes for solving the problems he posed. He set the prize for the discrepancy problem at US$500. Since his death, others have taken it upon themselves to award those prizes on his behalf.

When asked whether he would accept the prize were someone to offer it, Tao demurred. "It was traditional to not actually cash the prizes that Erdős did award while he was alive," he says. "People usually framed the cheque instead." ■