WEEKLY | NEWS IDEAS INNOVATION

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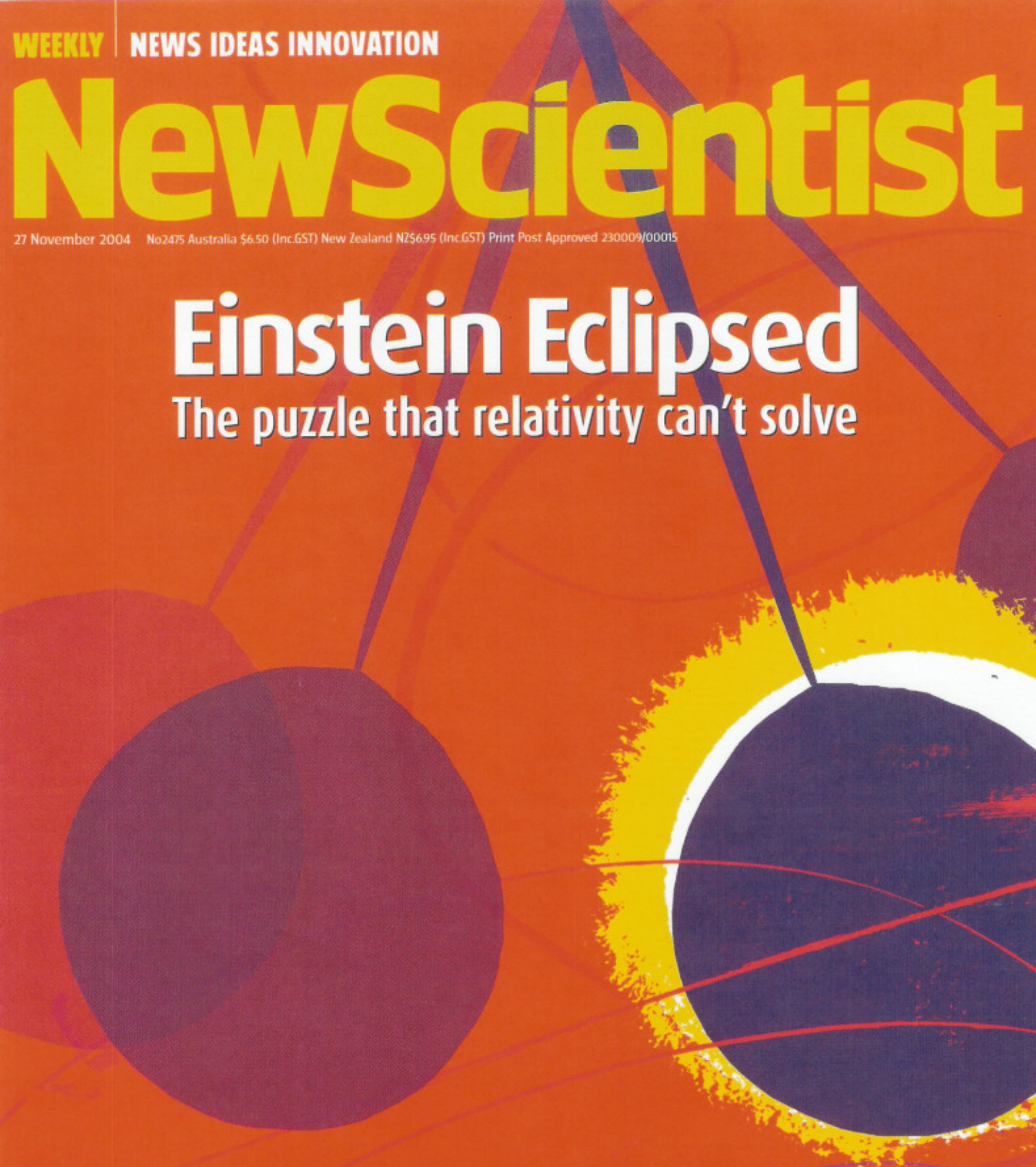
Einstein Eclipsed

The puzzle that relativity can't solve



FREEDOM FIGHTERS

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MOVE OVER DNA

Life's errand boy bids for power

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Shadow over gravity

Watch your grandfather clock next time there's an eclipse. It might be trying to tell you something, says **Govert Schilling**

NOTHING is more captivating than a total eclipse of the sun. Darkness races across the surface of the Earth. The sky turns stale blue. Temperatures drop. Dogs bark. And then, of course, there is the alien beauty of the sun's pearly white corona surrounding the black silhouette of the moon.

But there may be more to an eclipse than meets the eye. Swinging pendulums go wild as if some mysterious force were tugging on them. Sensitive gravimeters give readings that fluctuate violently. Gravity itself seems to quiver a bit. Or so say a small band of physicists who claim that these mysterious phenomena hint at a fundamental flaw in Einstein's general theory of relativity.

Needless to say, such claims have proved controversial. Celestial alignments, pendulum experiments, Einstein bashing – it all smacks of fringe science that deserves to be ignored. Surely there must be some conventional explanation.

Yet when physicist Chris Duif of Delft University of Technology in the Netherlands published a review in August this year of the various explanations that physicists have put forward, he concluded that they all fail to make sense of the bizarre findings. So now researchers are planning to pack up their pendulums and chase eclipses across the globe in the hope of settling the debate once and for all.

The first indication that something might be wrong came 50 years ago, in the summer of 1954. At the School of Mining in Paris, engineer, economist and would-be physicist Maurice Allais carried out an impressive series of pendulum experiments. Allais's original aim was to investigate a possible link between magnetism and gravitation. What he found was much stranger.

Let go of a pendulum and it will start swinging because gravity tugs down on it. Einstein's general theory of relativity explains this relentless tugging geometrically: every mass bends the fabric of space-time around it, so other masses slide down into the dimple in space-time. Walk into a room and you subtly distort space-time, pulling everything gently towards you.

Left to swing freely, a pendulum will always trace the same path through space. But because of our planet's rotation, the plane in which the pendulum swings appears to rotate slowly with respect to a laboratory on Earth. This effect was first demonstrated by French physicist Léon Foucault in 1851.

Surprisingly, Allais saw the pendulum's rotation rate increasing and decreasing in the course of a day, which was mysterious enough. Then, during a partial eclipse of the sun on 30 June 1954, one of Allais's assistants noted that the pendulum went mad. At the start of the eclipse, the pendulum's swing plane suddenly started to rotate backwards (see Graphic, page 31). It veered furthest off course 20 minutes before "maximum eclipse", when the moon smothered a large fraction of the sun's surface. Afterwards, the pendulum's swing went back to normal. It was as if the pendulum had somehow been influenced by the alignment of the Earth, the moon and the sun.

In an improved version of his experiment four years later, Allais placed two pendulums 6 kilometres apart. During June and July that year, both displayed the same erratic rotation. The work caught the attention of Wernher von Braun, the pioneering rocket engineer. Spellbound by these apparent gravitational anomalies, he urged Allais to publish his results in English and not just in French (*Aero/Space Engineering*, vol 9, p 46).

Einstein eclipsed

The scene was set for a repeat experiment during the partial solar eclipse of 22 October 1959. Again Allais saw his pendulum swing wildly. What's more, similar effects were observed during an eclipse in 1961 by three Romanian scientists who were completely unaware of Allais's results.

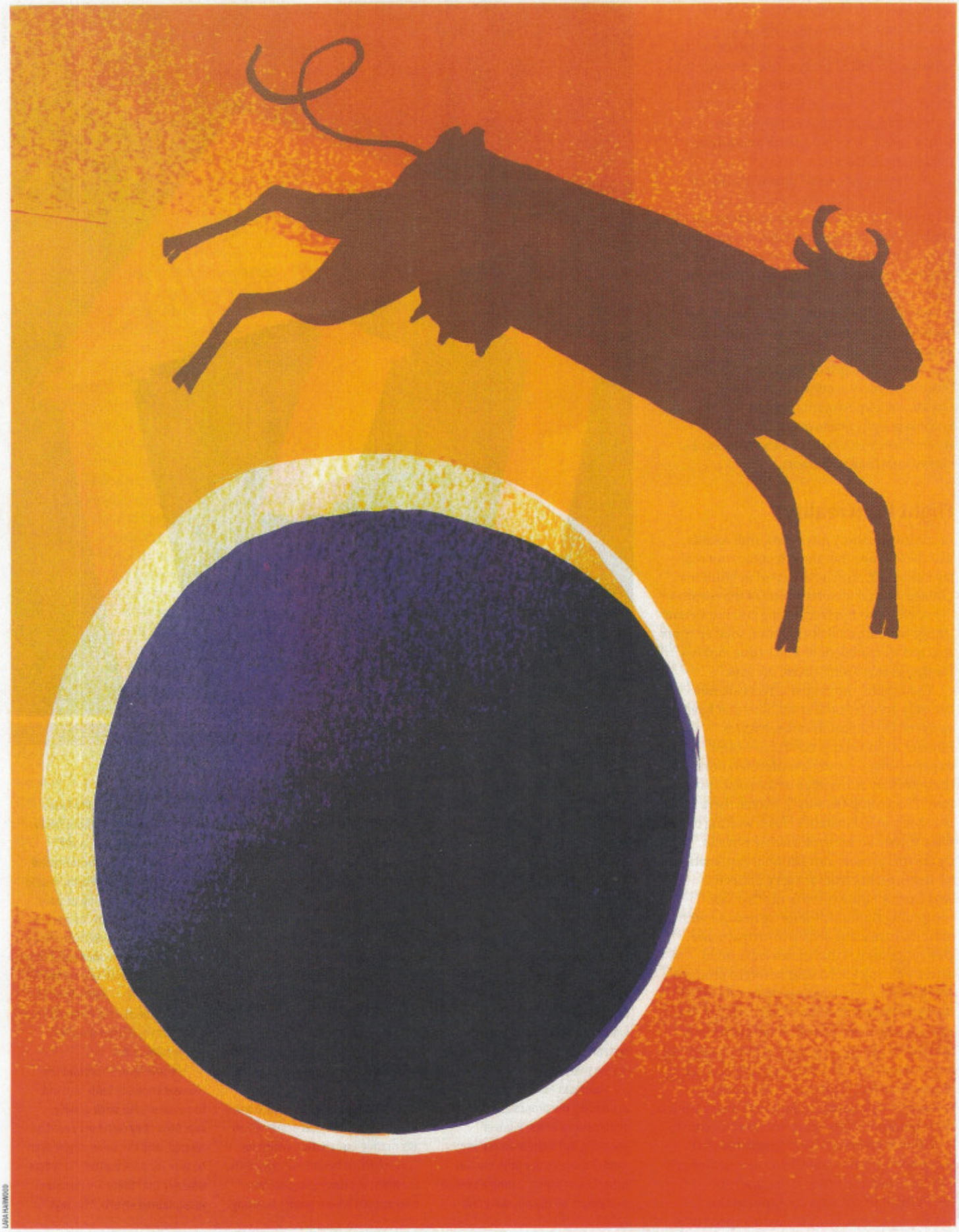
To Allais, the mysterious behaviour sounded as if it could signal the collapse of Einstein's general theory of relativity – a view he still holds today at the age of 93 and with the 1988 Nobel prize for economics under his belt. In particular, he claims that the pendulum results point to the existence of the ether, the hypothetical substance through which light waves were once thought to propagate.

Belief in the ether was widespread among physicists in the late 19th century. But experimenters were unable to prove its existence and Einstein built his theory of relativity on the assumption that the invisible substance does not exist.

Yet Allais has never given up on the ether and believes that it somehow affects swinging pendulums on Earth, though he offers no explanation why. Hardly anyone agrees with him. Still, he remains defiant. "In the history of science, every revolutionary result meets with very strong opposition," Allais says. "Relativists say I'm wrong without providing any demonstration. Most of them haven't even read what I wrote." Given the fact that the vast majority of his publications are in French, that may not be too surprising.

Still, a small number of scientists did read what Allais wrote and tried to repeat his experiment. In 1970 Erwin Saxl, who founded the company Tensitron, and Mildred Allen of Mount Holyoke College, Massachusetts, studied the behaviour of a pendulum before, during and after a total eclipse. Like Allais, they noted large irregularities at the onset of the eclipse. And in a paper they concluded that "gravitational theory needs to be modified" (*Physical Review D*, vol 3, p 823).

Saxl and Allen used a completely different setup from Allais. He had measured changes in the swing direction of a "paraconical" pendulum, a short, stiff version of the famous Foucault pendulum. Instead, Saxl and ▶



LARA HARWOOD

Allen measured changes in the period of a torsion pendulum, a massive disc suspended from a wire attached to its centre. Rotating the disc slightly causes the wire to twist. When it is released, the disc continues to twirl, first clockwise, then anticlockwise, with a fixed period. But not during an eclipse, when Saxl and Allen's pendulum sped up significantly.

Needless to say, most physicists do not want to believe there is something up with relativity. Surely there must be some other explanation, they say, perhaps an error with the instruments. Certainly, the jury is out over whether gravity really does go berserk from time to time. During a solar eclipse in India in 1995, D. C. Mishra and M. B. S. Rao of the National Geophysical Research Institute in Hyderabad observed a slight but sudden drop in the strength of gravity as measured by an extremely accurate gravimeter. But similar experiments carried out by Finnish geophysicists on 22 July 1990, when the eclipsed sun rose above Helsinki, showed nothing of the sort.

Flight from reality?

According to many physicists, null results like these prove that the effects are not real. Jay Pasachoff, an eclipse expert at Williams College, Massachusetts, is one of the sceptics. "There are enough fascinating and important things to be studied during total solar eclipses that it is too bad people waste time looking for things that aren't there," he says.

Then again, the eclipse effects are not the only gravitational anomalies that have surfaced in the past decades. NASA's Pioneer 10 and 11 spacecraft have been experiencing a mysterious deceleration on their journey to the edge of the solar system (see "Pioneering the way"). Maybe there really is a skeleton in Einstein's closet waiting to be discovered and to revolutionise physics. Or are there more conventional explanations?

Instrument errors are very unlikely, says Duif. All the experiments that saw something significant were carried out with extreme care using sensitive instruments. One suggestion is that increased human activity during a solar eclipse might produce small seismic disturbances that could affect the instruments. But, says Duif, that doesn't explain why scientists observed gravimeter anomalies during an eclipse in March 1997 in a very remote area of north-east China, while an experiment in Belgium found nothing on 11 August 1999, when millions of Europeans left their homes to observe the total solar eclipse.

Other researchers have suggested that the observations could be due to atmospheric effects. When the moon's shadow hits the Earth, it produces a cool spot in the atmosphere, which moves with a speed of a

LARA HAWKINS

Pioneering the way

According to physicist Chris Duif of Delft University of Technology, the mysterious behaviour of pendulums during solar eclipses may be related to another gravitational enigma: the Pioneer anomaly. In 1998, physicists and engineers at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, discovered that the unmanned space probes Pioneer 10 and 11 are slowly veering off their expected course, as if the solar system is tugging a bit too hard on the two craft.

Fuel leaks and heat radiation are among the proposed explanations of the Pioneer anomaly, but despite extremely careful analyses the problem has never been solved. During a special conference on the anomaly last May in Bremen, Germany, a wide variety of unconventional solutions were discussed, but no clear consensus emerged. Scientists from JPL and the universities of Bremen and Cologne have now proposed a European Space Agency mission to study the mysterious deceleration in more detail.

Some astronomers think the Pioneer anomaly is evidence of a minor but important flaw in the laws of gravity. According to Newton's laws, the strength of gravity falls with the inverse square of distance. But Mordehai Milgrom of the Weizmann Institute of Science in Rehovot, Israel, has proposed an alternative explanation which he calls modified Newtonian dynamics. In MOND, the inverse square law only applies where gravity is strong. Where it is weak, gravity fades more slowly with distance (*New Scientist*, 20 July 2002, p 28).

Modifying the inverse square law, some physicists claim, would also explain the motion of stars and galaxies without the need to invoke huge amounts of unseen dark matter in the universe. It may even point the way to a successful merger of general relativity with quantum mechanics – something scientists have been unable to accomplish so far.

If the eclipse effect and the Pioneer anomaly both turn out to be connected with gravity, says Duif, they could very well be related, and the same might even be true for dark matter. "It seems unlikely that there are dozens of unexplained effects," he says.

few kilometres per second. The resulting pressure changes and air-mass movements behave in ways that might possibly explain the observations, according to calculations by Tom Van Flandern of the Meta Research corporation in Washington DC and Xin-She Yang of the University of Wales Swansea in the UK (*Physical Review D*, vol 67, p 022002).

Duif believes this model cannot account for the effects observed with pendulums. He says that a dense mass of air moving through the atmosphere does not change gravity enough to knock a pendulum significantly off-course.

Still, Duif doesn't want to jump to conclusions. "It is likely that the reported anomalies will turn out to be due to a combination of effects and instrumental errors," he says. But he concedes that there is a slight chance some other force is at work. Given the potential implications, Duif thinks that further experiments are justified. The problem, of course, is money. After all, who wants to invest in a wildly unconventional and controversial topic like this?

Enter Thomas Goodey, an independent researcher based in Brentford, Middlesex, in the UK. Goodey trained as a mathematician at the University of Cambridge but he is not now affiliated with any university or institute. Using his own money and some private sponsorship, he is determined to settle the issue once and for all by repeating the experiments of Allais with several pendulums during an eclipse. "It's possible to build much more accurate and sensitive equipment than in 1954," he says. "With 20 to 100 times better resolution and accurate electronics the effect should be very clear."

Acid test

Goodey is convinced that Allais never received the attention he deserves. He believes Allais's big mistake was to publish almost exclusively in French. "If he had reported his results in English from the beginning, that would have made a big difference." Goodey has begun to translate Allais's publications, but his major work *l'Anisotropie de l'espace* is still only available in French (www.allais.info).

Over the next few years, Goodey plans to travel the world with 12 newly constructed pendulums. In May, he presented his strategy at a meeting of the Society for Scientific Exploration in Las Vegas and invited physicists to join him. Several leapt at the chance.

On 8 April 2005, when an annular eclipse occurs in Latin America, Goodey will team up with Héctor Múnera of the National University of Colombia in Bogotá. And when another annular eclipse crosses Portugal and Spain on 3 October next year, he plans to work with José Borges de Almeida of the University of Minho in Braga, Portugal.

Pendulum experiments will not only be carried out during solar eclipses, but also during lunar eclipses, which are visible from a much larger area of the globe. Indeed, Saxl and Allen recorded a weak effect in their torsion pendulum during a lunar eclipse.

"Gravitational anomalies are not just confined to eclipses"

Goodey speculates that the anomalies are somehow related to an observer being near the line that connects the centres of masses of the sun and the moon. During a total solar eclipse, the sun-moon line intersects the surface of the Earth at two points on roughly opposite sides of the globe. According to Goodey, observations at the "anti-eclipse" point where no eclipse is visible because it is night-time might carry much greater weight.

After all, at these points there would be no environmental eclipse-related effects that could spoil the experiments. In fact, Goodey and astronomer Dimitrie Olenici of the Suceava Planetarium in Romania carried out a dry run of the experiment last month in Malaysia at the anti-eclipse point of a lunar eclipse which occurred on 28 October.

During this dry run, Goodey detected no effect. He is now looking forward to two solar eclipses next year. He will use several pendulums at each location. And the eclipse of 22 September 2006 will be an acid test, he says. That's because the position of the sun and moon as observed from the island of St Helena in the South Atlantic will be almost identical to the situation in Paris in 1954. "It's an ideal case," says Goodey. "I'd be disappointed if we didn't see any effects."

Some argue that Goodey is not the right person to give the final verdict on the Allais effect. "Apparently, his starting point is to prove that the effect is real," says Duif. "I hope he turns out to be critical enough." Goodey's Portuguese collaborator has even accused the scientific community of covering up results that contradict the established theory. Duif is now considering teaming up with colleagues in Barcelona to carry out independent experiments next year.

Meanwhile, Allais himself is convinced that experiments will eventually prove him right. As for the theory behind the mysterious pendulum effects, he says bluntly: "My philosophy is that all theories are conditional and will eventually disappear. But all the facts remain. Facts are the main thing." ●

Govert Schilling is an astronomy writer based in the Netherlands

Further reading: "A review of conventional explanations of anomalous observations during solar eclipses" by Chris Duif www.arxiv.org/gr-qc/abs/0408023

SWING STATES

Maurice Allais reported bizarre pendulum effects during two partial solar eclipses in Paris in the 1950s