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Physicists plan search for the known unknowns

Gravity feels like a force you can trust. Every day, unwavering, it keeps your feet planted firmly on the ground.

But for many physicists, gravity is unsettling. It's the one force that doesn't fit into their quantum picture of the world. The best theory to describe it — Einstein's general theory of relativity — doesn't mesh with quantum mechanics.

What's more, general relativity breaks down in the singularities thought to lurk at the centre of black holes, suggesting to physicists that the theory is incomplete. So last week at the University of Arizona in Tucson, around 50 physicists met at a workshop called 'rethinking gravity', to confront these problems.

Over three days, participants debated what experiments they could use to hunt for flaws in the general theory of relativity, and asked whether dark matter or dark energy — the unknown stuff that cosmologists now reckon makes up 96% of the Universe — are clues to whatever deeper theory lies beneath.

Their proposals stretch from a table-top experiment so delicate that it can be sent off-kilter by a single piece of dust, to ambitious space missions to measure the gravitational ripples created when two black holes coalesce into one.

Theoretical progress in combining gravity and quantum mechanics has produced ideas such as string theory and loop quantum gravity. And although no theory has yet been proposed that physicists accept as compelling, efforts to develop alternatives have been bolstered by recent discoveries in cosmology.

Maps of the temperature of the cosmic microwave background, for example — the radiation left over from the birth of the Universe — have revealed two opposing influences on the Universe's structure. One helps matter to clump together, the other accelerates the expansion of the Universe. Taken with other evidence, these observations suggest the existence of dark matter and dark energy, respectively.

A modified theory of gravity might account for the effects — although not everyone is convinced that it will do so. "It's very easy to sit around in the coffee breaks and say, maybe there is no dark stuff and gravity is different," warns Sean Carroll of the California Institute of Technology in Pasadena, who works on alternative theories to produce expansion like that seen with dark energy. "But if you sit down to actually do something, there are rules you have to follow. It's harder than you might think."

On the launch pad

Five astrophysics projects are competing to be the first mission from NASA's 'Beyond Einstein' programme to fly. Conceived in 2002, the programme aims to address fundamental questions in cosmology (see *Nature* **420,** 593–594; 2002), and could help physicists in their understanding of gravity.

The five ideas are being reviewed by a panel convened by the US National Academies at the request of NASA and the Department of Energy. Mission teams presented their cases at a meeting in Newport Beach, California, this week, in their second meeting with the panel.

Of the two major missions under consideration, one will be built and operated jointly with the European Space Agency. Called the Laser Interferometer Space Antenna, or LISA, the project will search for gravitational waves.

The other large-scale proposal is Constellation-X, a powerful X-ray telescope to study the processes around black holes.

The three smaller proposals are the Joint Dark Energy Mission, being developed jointly by NASA and the Department of Energy; an inflation probe that will try to determine how the Universe expanded after its birth; and a probe to detect black holes.

The panel will consider the technical and management challenges as well as the missions' scientific merit. It is expected to report in September, to assist with NASA's funding plans for 2009.

Some worry that the missions face an uncertain future if they miss the top spot. But Michael Salamon, programme manager for Beyond Einstein, says that all of them will eventually go ahead. "NASA is committed to the entire Beyond Einstein programme", he says. "There is no 'winner takes all' scenario here." **J.H.**

SIDELINES

ON THE RECORD

"Isolating stem cells from the placenta is not more difficult than making a steak."

The editors of online 'how-to' guide makezine.com, in a blog entry on the joys of isolating your own amniotic stem cells at home.

SCORECARD

E. MINOR/AP

▲ **Ray guns**
US military researchers have turned science fiction into reality with their 'harmless' electromagnetic weapon that makes victims feel as if they are about to catch fire. This non-lethal way to disarm people could help save the lives of civilians and army personnel in battle zones such as Iraq, Pentagon officials claim.

▼ **Space tourism**
'Lucky' competition winner Brian Emmett has reluctantly given up his seat on a flight into space with cosmic tour operator Space Adventures after realizing that the prize, offered by software company Oracle, would come with a $25,000 tax bill.

NUMBER CRUNCH

110% is how much the price of US home heating oil rose between 2000 and 2007.

82% is how much petrol prices rose during the same period.

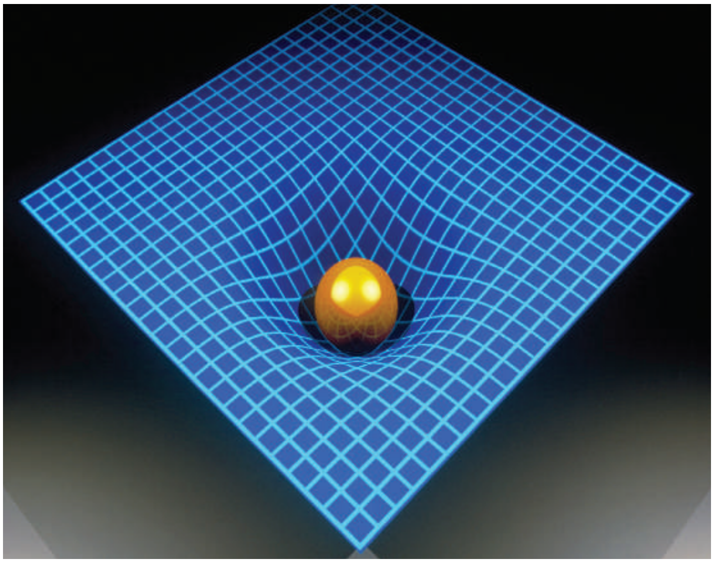
357% is how much ExxonMobil's profits grew between 2000 and 2006.

ZOO NEWS

The owners of a Malaysian fruit orchard have discovered why their guard dogs kept disappearing — a 7.1-metre python had eaten 11 of them before being captured by villagers.

Sources: Makezine.com, CNN, Los Angeles Times, Campaign for America's Future, Reuters

LAGUNA DESIGN/SPL



Curves in space: the theory that matter warps the shape of space and time doesn't mesh with quantum physics.

The hope now is that future experiments will detect some deviation from the predictions of general relativity, or some property of dark matter or dark energy, that will give theorists purchase on the problem. Daniel Holz of the Los Alamos National Laboratory in New Mexico says that, over the past decade, the balance of the field has shifted. "It's definitely experimentally driven at this point," he says.

For instance, Eric Adelberger presented work from his group at the University of Washington in Seattle that checked for anomalies in how the strength of gravity changes with distance. In most circumstances, general relativity gives a dependence that is the same as that familiar from Newton's law: gravity varies with the inverse square of the separation. But new physics, such as the existence of extra dimensions, could modify this behaviour at short range, where these dimensions are thought to operate.

"Processes in the vicinity of a black hole could affect the observations."

Adelberger's group measured the gravitational attraction between two parallel discs as they were brought to 55 micrometres apart, finding no significant deviation from Newton's law (D. J. Kapner *et al. Phys. Rev. Lett.* **98,** 021101; 2007). This set a new limit on the size of any extra dimension of 44 micrometres, some four times smaller than the previous best estimate.

Other experiments will probe different facets of the theory. In particular, researchers are interested in tests of general relativity that involve strong gravitational fields, such as those around black holes. "It's a regime where we haven't tested gravity," explains Dimitrios Psaltis, one of the conference organizers.

General relativity supposes that matter distorts the shape of space and time, similar to the way that a ball would sink into a rubber sheet. So far, experiments have mostly probed the gentle curvature around the Sun and planets.

The shape of space and time around a black hole is expected to depend on just two of the black hole's properties: its mass and spin. The Tucson workshop heard that it might be possible to check that a black hole's spin is the same at all radii by tracking hot blobs of infalling matter, or by observing X-rays reflected from the object's surrounding disk of dust.

However, Avery Broderick of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, who presented the results about infalling matter, cautions that processes in the vicinity of a black hole could affect the observations, making it a challenge to confirm whether any deviation is due to differences in gravity or the result of some overlooked astrophysics.

Physicists also hope to test general relativity's predictions about unusual cosmological events, such as mergers of black holes, by detecting gravitational waves. So far, the existence of such waves has only been inferred by measuring changes in the orbit of a binary system containing a radio-emitting pulsar, and ground-based detectors have yet to pick any up. The probable launch date of a proposed space-based detector remains uncertain (see 'On the launch pad').

But whether or not the next round of experiments helps to reconcile general relativity with quantum mechanics, the quest for such a glorious union will continue. "We know there's something we don't know, but we don't what it is," says Adelberger. "We just have to look as hard as we can." ■

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