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NEWS

COSMOLOGY:
Astronomers See a Cosmic Antigravity Force at Work

James Glanz

Seemingly in defiance of common sense, space itself appears to be permeated by a repulsive force that is counteracting gravity on large scales. That, at least, is the reluctant conclusion of an international team of astronomers who have used the brightness of distant exploding stars called supernovae to gauge how cosmic expansion has changed over time. Gravity should have gradually slowed that outward rush. But as team member Alexei Filippenko of the University of California, Berkeley, announced at a meeting near Los Angeles last week,* the dimness of the supernovae--pointing to unexpectedly great distances--implies that cosmic expansion has actually sped up in the billions of years since the stars exploded.

"My own reaction is somewhere between amazement and horror," says Brian Schmidt of the Mount Stromlo and Siding Spring Observatory in Australia, who leads the group, called the High-z Supernova Search Team. "Amazement, because I just did not expect this result, and horror in knowing that [it] will likely be disbelieved by a majority of astronomers--who, like myself, are extremely skeptical of the unexpected." But after intense efforts to account for the dimness with prosaic effects such as dust in the cosmos or some intrinsic dimness of those remote explosions, says Schmidt, the team concluded with a statistical confidence of between 98.7% and 99.99% that cosmic expansion is receiving an antigravity boost.

Astronomers expressed caution over what would be a momentous turn of events, saying there could be still-undiscovered differences between galaxies now and billions of years ago--and hence in the brightness of the supernovae they host. "Even the most conservative explanations for the results are quite amazing," says Rocky Kolb, a cosmologist at the University of Chicago who attended Filippenko's talk. A cosmic repulsion "would be such a fundamental result that I think everyone should reserve judgment." No one, however, is arguing with the data themselves: Just last month, an independent team presented data from another set of distant supernovae that suggested, more tentatively, an acceleration of roughly the same amount (*Science*, 30 January, p. 651). "This is what the observations are telling us," says Filippenko.

The discovery of an accelerating universe would have a major impact on the reigning theory of how the big bang got started. In the simplest version of this theory, known as inflation, the universe contains just enough matter to make it geometrically "flat"--a mass density that would also slow the cosmic expansion to a halt, given infinite time. Earlier supernova results and other measures have shown no sign of the gravitational brake that so much mass would apply (*Science*, 31 October 1997, p. 799). But because both matter and energy can curve space-time, a mysterious background energy--which Albert Einstein named the cosmological constant, or lambda--might make up the deficit and flatten the universe again. This background energy would push rather than pull, speeding up the cosmic expansion over time.

Physicists do not have a good explanation for the source of the energy; it could somehow be related to the fleeting "virtual" particles that quantum theory says wink in and out of existence in empty space. But some cosmologists have been drawn to the concept, in part because it would be compatible with more refined versions of inflation that would not require a radical overhaul of the theory. So astronomers have gone looking for lambda by trying to detect its influence on cosmic expansion.

The High-z team probes the expansion with distant supernovae. The team electronically subtracts images of the same regions of the sky, taken weeks apart, to find new supernovae of a class called type Ia, thought to occur when a white dwarf star rips so much material from a nearby companion star that the dwarf suddenly explodes like a giant thermonuclear bomb. They then record the gradual brightening and fading of each one with the Hubble Space Telescope or with ground-based instruments.

Although type Ia's do not all reach exactly the same peak brightness, the variation can be corrected for: Those that fade more quickly are less luminous. The correction allows type Ia's to serve as approximate "standard candles," whose apparent brightness is a measure of their distance. The team compares those distances to the "redshifts" of the light--a measure of how fast cosmic expansion is sweeping the supernovae outward--to gauge the expansion when they exploded, as much as halfway back to the big bang.

What the team found left many of its members "stunned," says Berkeley's Adam Riess, lead author on the paper being prepared on the results. The 14 distant type Ia's in the study turned out to be, on average, 10% to 15% farther away than they would be even in a low-density universe, in which the expansion would have slowed very little. "Not only don't we see the universe slowing down; we see it speeding up," says Riess. If the universe is indeed flat, then the results imply that it contains roughly twice as much energy in the cosmological constant as in matter.

That conclusion survived detailed corrections for any dust that might be veiling the supernovae and making them look more remote than they are. It also survived another test, which Riess and Filippenko did in tandem with the other supernova team, led by Saul Perlmutter of Lawrence Berkeley National Laboratory in California. To see whether the distant supernovae behave the same way as closer ones, they compared how the spectral fingerprints of distant and nearby supernovae change during the explosion. No significant differences turned up, Riess says.

Group members stress that their findings still need careful scrutiny by the astronomical community. "To be honest, I'm very excited about this result," says group member Robert Kirshner of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts. But for all the group's vigilance, he says, it's still conceivable that some "sneaky little effect" is mimicking the acceleration. "It's a remarkable result," says Marc Davis of Berkeley, who is not part of either group, but he agrees, "it's clearly going to take some time to digest this."

That certainly goes for theorists. Kolb, for one, says that the universe is starting to look like a cosmic version of the Marx brothers movie *Monkey Business*, in which more and more people show up in a ship's stateroom, leading to chaos. The universe already contains visible and dark matter as well as radiation; now there's a mysterious new guest. "It's crazy," he says. "Who needs all this stuff in the universe?"

Martin Rees of the University of Cambridge, Britain's Astronomer Royal, sees it differently. Like Kepler, who was troubled that planetary orbits were ellipses and not perfect circles, theorists who long for a simpler universe might just be missing "the really big picture," he says. Newton's theory of gravity ultimately made sense of elliptical orbits, and some missing concept may ultimately make sense of a seemingly baroque universe. Cosmic simplicity's aesthetic lure, says Rees, "may seem, in retrospect, as shallowly motivated as was Kepler's infatuation with circles."

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