QUANTUM MECHANICS

# The Subtle Pull of Emptiness

There's no such thing as a free lunch—except in quantum mechanics. Classical physics—and common sense—dictates that the vacuum is devoid not only of matter but also of energy. But quantum mechanics often seems to depart from common sense. A paper in the current issue of *Physical Review Letters* describes the first successful measurement of the ultimate quantum free lunch: the Casimir force, a pressure exerted by empty space.

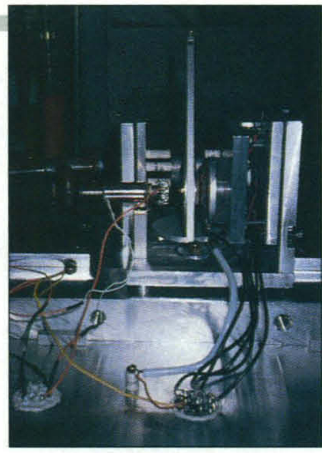
The measurement, by physicist Steven Lamoreaux of Los Alamos National Laboratory, confirms the strange picture of the vacuum conceived in the 1920s by pioneering quantum physicists Max Planck and Werner Heisenberg. Even at absolute zero, they asserted, the vacuum is seething with activity. This "zero-point energy" can be thought of as an infinite number of "virtual" photons that, like unobservable Cheshire cats, wink in and out of existence—but should have a measurable effect en masse. That's what Lamoreaux has now shown. "We're excited; it confirms a very basic prediction of quantum electrodynamics," says Ed Hinds of the University of Sussex in the United Kingdom.

For decades after Planck and Heisenberg described the zero-point energy, physicists preferred to ignore it. It's infinite, and to a physicist, "infinity's not a very useful quantity, so we get rid of it," says Charles Sukenik of the University of Wisconsin.

But an early clue that these infinite fluctuations can't be ignored came in 1948, when researchers at the Philips Laboratory in the Netherlands were studying the van der Waals force—a weak attraction between neutral atoms. At long distances, the van der Waals force weakened unexpectedly. Philips scientists Hendrick Casimir and Dik Polder found that they could explain the weakening when they pictured the force as resulting from correlated zero-point fluctuations in the electric field, which would propagate from atom to atom at the finite speed of light. Because of the lag, the chance that the atoms would feel each other's fluctuations while they were still correlated would fall off at longer ranges. This weakening, called the Casimir-Polder effect, was first accurately measured in 1993, by Hinds, Sukenik, and their colleagues.

Casimir had also realized that the zero-point energy should reveal itself more directly, as a very weak attraction between two surfaces separated by a tiny gap. Provided the gap was small enough to exclude some of the virtual photons, the crowd of photons outside the cavity would exert a minute pressure.

To measure it, Lamoreaux positioned two gold-coated quartz surfaces less than a micrometer apart, one of them attached to a torsion pendulum while the other was fixed. The surfaces created a "box" that allowed only virtual photons of certain wavelengths to exist inside it. Outside the box, a full complement of virtual particles was merrily winking away. The infinite zero-point energy on the outside of the box outweighed the infinite (but smaller) zero-point energy inside, forcing the surfaces together.




**Conjuring act.** Two closely spaced surfaces, one on a torsion pendulum, coax force from space.

By counteracting this subtle attraction with piezoelectric transducers, which exert a force when a voltage is applied to them, Lamoreaux was able to measure the force. The result: a value of less than 1 billionth of a newton, agreeing with theory to within 5%.

Hinds and others say the experiment should help physicists accept that the subatomic world is every bit as weird as quantum mechanics predicts. "We feel in our hearts that we really do understand how things work—even something as peculiar as vacuum fluctuations," says Hinds. Adds Sussex physicist Malcolm Boshier, who was on Hinds's Casimir-Polder team: "This is one of those experiments that is going to wind up in all of the textbooks."

**–Charles Seife**

*Charles Seife is a writer in Scarsdale, New York.*

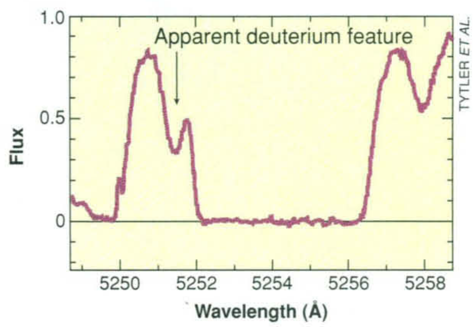
COSMOLOGY

# Clouds Gather Over Deuterium Sighting

CHICAGO—Three floors below the ballroom where Craig Hogan spoke at the 18th Texas Symposium on Relativistic Astrophysics, held here from 15 to 20 December, a pair of old headlines in a showcase illustrated the perils of drawing conclusions from limited data. Not that there was any resemblance between the topic chosen by the University of Washington, Seattle, astronomer—the amount of deuterium in the early universe—and the 1948 presidential election. But Hogan found himself in much the same position as the *Chicago Daily Tribune* the day after its famous DEWEY DEFEATS TRUMAN banner: Faced with new data, he graciously withdrew an earlier conclusion.

In the 1 March 1996 issue of *Astrophysical Journal Letters*, Hogan and his then-graduate student Martin Rugers had analyzed a gas cloud so far away that it likely contains material fresh out of the big bang. They concluded that it holds about one deuterium atom for every 5000 hydrogen atoms. That was a startlingly high value, because the more of this hydrogen isotope that emerged from the big bang, the lower the universe's total density of other ordinary matter must be (*Science*, 7 June 1996, p. 1429). Hogan and Rugers's value implied a universe so rarefied that it could barely contain the ordinary matter astronomers have observed by other means. But now, Hogan told the audience, a team led by David Tytler of the University of California, San Diego (UCSD), has obtained "clearly superior" data on the same cloud and failed to find the clues that had led Hogan and Rugers to their conclusion. "What we thought was a smoking gun of ... [high] deuterium is not there."

Limin Lu, an astronomer at Caltech who has made similar measurements and who heard talks by Tytler and Hogan at the symposium, agrees: "The case for high deuterium is basically gone." That may remove a puzzling discrepancy with values nearly 10 times lower, which Tytler and colleagues had measured in two other gas clouds. But Hogan's concession—unlike the *Chicago Daily Tribune*'s—isn't the last word, because some astronomers maintain that Tytler's own measurements are not airtight.




**Down on deuterium.** In this spectrum—the shadow of a distant gas cloud—a crucial peak in the apparent deuterium feature has vanished.

All sides in this dispute are using a single weapon: the 10-meter Keck Telescope on Mauna Kea, in Hawaii. Its light-gathering power allows astronomers to record the "shadows" cast by gas clouds billions of light-years away in the light of brilliant quasars at even greater distances. How much light the clouds absorb—and at which wavelengths—holds clues to their composition. But deute-