Tower Study Hints at a "Sixth Force"

Little is seen of the "fifth force" repulsion, but the researchers do see a new kind of gravitational attraction; if true, the results make gravity more complicated than ever

Air Force scientists who climbed a North Carolina television tower to search for the so-called "fifth force" have netted unexpected dividends. According to their 11 December announcement at the American Geophysical Union meeting in San Francisco, they believe they have found signs of a "sixth force."

"We call it a sixth force because everyone is talking about the fifth. What this does is it throws a number of extra variables into the equation," says Andrew R. Lazarewicz, a member of the research team from the Air Force Geophysical Laboratory at Hanscom Air Force Base in Massachusetts.

Some theoretical physicists have hypothesized an additional fundamental force in nature besides gravity, electromagnetism and the strong and weak nuclear forces.

This fifth force would be similar to conventional gravity. But it would be much weaker than gravity, it would be repulsive instead of attractive, and it would be of limited range as opposed to gravity's unlimited range.

Also unlike gravity, the strength of the force would depend on the chemical composition of materials under its influence rather than on mass alone. (In technical terms the force would couple to baryon number, which just counts the protons and neutrons in the material without taking account of the energy binding those particles into atomic nuclei.)

Possible evidence for such a force has been detected by a few groups of experimenters, who chose locations where the gravitational influences of surrounding masses would be easiest to measure—such as mine shafts in Australia and a cliff face in the Cascade Mountains of Washington State. But other fifth force searches have netted negative results, and its existence is far from being considered a certainty.

Last July, the Air Force group began its own experiment on the approximately 600-meter tower in suburban Raleigh, a location chosen after a national search for a tall and stable platform that was surrounded by relatively flat terrain.

With additional help from a Defense Mapping Agency squadron from Cheyenne, Wyoming, the researchers logged precise elevations and positions within 5 kilometers of the tower's base and also took gravimeter readings at those survey points.

They continued that process on the tower itself, taking readings at average intervals of about 93 meters. Readings below the 190-meter level had to be disregarded because of difficulties in modeling corrections for the gravitational influence of the ground around the tower's base. In their final calculations, however, the scientists did take account of such factors as the gravitational attraction of the air surrounding the tower, changes in the water table, and the gravitational attractions of the sun and moon.

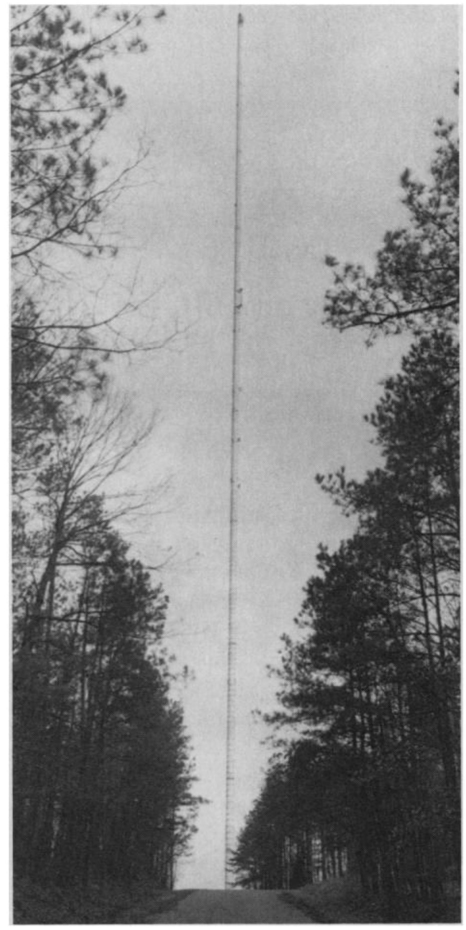
When all the perturbations had been accounted for, the team found "a significant departure" of up to 5 parts per million beyond what would be expected from applying Newton's laws of gravity. The magnitude of the effect was about ten times larger than what could be attributed to uncertainty, according to the announcement.

What was especially surprising was the sign of the effect. "We are seeing an attractive force that adds to gravity," says Anestis J. Romaides, another team member. "This is contrary to past experiments that indicate a force that is repulsive, that works against gravity."

Those results would appear to support an alternative hypothesis advanced by physicists at Los Alamos National Laboratory in New Mexico. According to Los Alamos theorist Michael Martin Nieto, there may actually be three kinds of gravity, with the force of each carried by a different quantum particle.

Familiar Newtonian gravity would exert its effects over an unlimited range via a massless particle called a "spin 2 graviton." At very limited range, there would also be a repulsive force expressed through a spin 1 graviphoton and an attractive mediated by a spin zero graviscalar.

In addition, the graviphoton and the graviscalar would have masses, although not much. In their 11 December announcement, written by division director Donald H. Eckhardt, the Air Force Geophysical Laboratory researchers actually calculated the rest masses of the proposed graviphoton and graviscalar, based on theory and their data from North Carolina.



Outdoor laboratory. *This television tower in suburban Raleigh provided a platform to measure how gravity varies with altitude.*

The rest mass of the graviscalar should be about 1 nanoelectron volt, they say, while the rest mass of the graviscalar should be about one-third of that. This is about 18 orders of magnitude less than the mass of a proton, the statement says, adding that "except for massless particles, no smaller particles are known."

Obviously, the evidence is still not as clear-cut as one would like. Although Lazarewicz says the "best fit" of the data taken at the tower would assume that there are two short-range particles, both he and Romaides acknowledge that their team did not detect any clear signs of a repulsive force such as might be carried by a graviphoton. Nor did their team attempt to compare the effects of a force on different materials. And in any case, he says, the prediction of particle masses is no better than "speculation on speculation,"

Nonetheless, he says, "we have seen an additional attractive force and we so far generally all agree we are seeing something —well enough to go ahead and throw it out to the world and see what happens."

Purdue University physicist Ephraim Fischbach, who was a member of the group that first drew attention to the possibility of a fifth force last year when they published a reanalysis of the classic Eötvös experiment, says that these new results are quite interesting—but tenuous. "I would be happy when I get into bed tonight if there were one experiment in the world that showed the existence of a fifth force at a level at which I could believe it," he says.

Fischbach is hardly alone in that sentiment. Even now, physicists are awaiting the results of a fifth force study conducted in a borehole into the Greenland ice cap. That study involved researchers from Los Alamos, Scripps Institution, the University of California at San Diego and other institutions and companies. Meanwhile, another kind of experiment, an attempt to measure effects of gravity on antiprotons, has been approved for the CERN accelerator in Switzerland in 1991. ■ MONTE BASGALL

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Superconductor's Critical Current at a New High

A new processing technique brings the copper oxide materials much closer to practical applications; meanwhile, there are controversial hints of superconductivity at 500 K

IN the high-temperature superconductivity symposium at the Materials Research Society's recent fall meeting in Boston,* two announcements stood out.

In the first, a team of researchers at Bell Laboratories reported a new fabrication technique that increases the critical current of bulk superconductor by a factor of 1000 at 77 K; this brings the new copper oxide ceramic materials to within about one order of magnitude of the current capacity needed for magnetic resonance imaging and other large-scale applications of superconductivity.

In the second, Ahmet Erbil of the Georgia Institute of Technology laid out his controversial evidence for a possible observation of physics' new Holy Grail: superconductivity at room temperature.

The new fabrication technique was described at the meeting by Sungho Jin, Thomas Tiefel, Richard Sherwood, and Bruce van Dover, all of Bell Laboratories' Murray Hill, New Jersey, facility.

Their starting point was the family of yttrium–barium–copper oxide ceramics discovered last February. With a superconducting transition temperature of around 90 K, these so-called 1-2-3 compounds are still the only confirmed superconductors that can operate at the 77 K boiling point of liquid nitrogen, a cheap and universally available coolant. With their granular, polycrystalline structure, however, these superconductors have proved to be disappointingly feeble as current-carrying devices.

Even though their electrical resistance is zero below the transition temperature, their supercurrents still have trouble in passing from crystal to crystal. No one quite knows why this should be. Impurities at the interfaces, perhaps? Misalignment of the crystal lattices? But the reality is that the materials lose their superconductivity at very modest current densities, no more than a few hundred amperes per square centimeter. Moreover, their performance deteriorates rapidly as the external magnetic field increases. At a field strength of 1 tesla, which is typical of what the material would encounter in practical applications, the critical current is only 1 to 10 amperes per square centimeter. It needs to be more like 100,000 amperes per square centimeter.

"In the last 10 months, the low critical current has been the biggest problem in the field. Now we've broken out of the mold."

On the other hand, this limit is clearly not a fundamental one. Single crystals of the 1-2-3 compounds have exhibited critical currents in excess of 10,000 amperes per square centimeter, and thin films have attained 100,000 to 1 million amperes per square centimeter. In both cases, moreover, the performance is relatively unaffected by external magnetic fields. So the capability is there. The trick is to eliminate whatever internal imperfections have been holding the bulk materials back.

Jin and his colleagues have taken a giant step in that direction by changing the way they process the bulk material.

The standard technique is to press yttrium–barium–copper oxide powder into the desired shape and then sinter it—that is, heat the powder until the individual grains fuse together. Instead of simply leaving it at that, however, Jin and his colleagues do something that would be commonplace for a metallurgist, but that is almost unheard of in a ceramics laboratory: they take the sintered powder all the way to 1300°C and melt it. Then they put the sample through a proprietary cooling regimen to bring it back to room temperature. (They also have to restore the superconductivity with a final heat treatment that replaces oxygen atoms driven out of the crystal lattice during the previous processing. However, this latter step is standard and has to be done for sintered samples also.)

This "melt-textured growth" process yields bulk superconductor that is considerably denser than its sintered counterpart, which is about 15% porous on a microscopic level. More important, it creates new crystals and crystal boundaries. Jin and his co-workers find that the processed material now consists of needle-like crystals several hundred micrometers long. These crystals are elongated in the good conduction direction—the 1-2-3 compounds are highly anisotropic in their ability to superconduct—and they are well aligned with one another, at least locally. The result is that the material has a much higher critical current than before: 7400 amperes per square centimeter at zero magnetic field, and 1000 amperes per square centimeter at 1 tesla.

The new processing technique was discovered only a few weeks before the Boston meeting, and the Bell Laboratories researchers are understandably jubilant. "It's a new milestone," says Gilbert Y. Chin, director of the facility's materials research laboratory, where the research was done. "In the last 10 months, the low critical current has been the biggest problem in the field. People were getting discouraged, thinking there was

*Materials Research Society 1987 Fall Meeting, 30 November to 5 December 1987, Boston, Massachusetts.