The fifth force: Pulling both ways

For 300 years physicists have believed that the force of gravity is the same for all substances. In Isaac Newton's words, it was the "quantity of matter," not the nature of the substance, that counted in determining the sizes of gravitational forces. Now some scientists have a highly controversial suspicion that the nature of the substance does matter (SN: 1/3/87, p.6).

The suspicion began with anomalies found in a series of measurements of gravity in mines and wells done in Australia several years ago. It is supported now by a new measurement done in a well in Michigan. Meanwhile, various laboratory experiments testing the earth's attraction for different chemical substances have come up positive and negative, the most recent being negative. As controversy continues, physicists are doing what they always do in such a situation — planning more experiments.

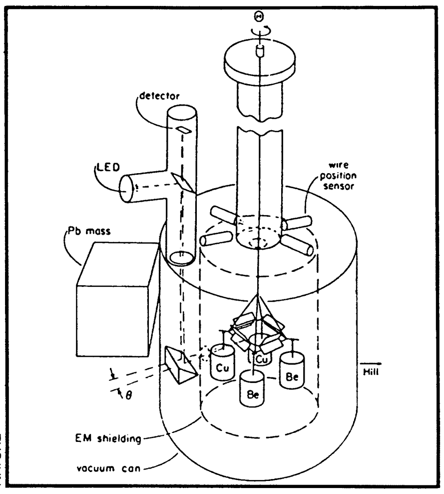
The Australians who did the original work, Frank Stacey of the University of Queensland in Brisbane and his collaborators, had found that in the mines, Newton's universal gravitational constant appeared slightly larger than the value determined by centuries of measurement in laboratories. To explain the discrepancy they suggested that a "fifth force" — or, as some have called it, a negative component of gravity — is at work. This would overthrow a lot of established physics, and the suggestion got a very negative reaction at first. It still does.

Now, however, a measurement done in a well in Manistee County, Michigan, in different geological and geographical surroundings, supports the Australian work. Albert T. Hsui of the U.S. Air Force Geophysics Laboratory in Bedford, Mass., and the Massachusetts Institute of Technology reports in the Aug. 21 SCIENCE that the Michigan work shows a similar apparent increase in the gravitational constant. As a possible explanation he quotes Stacey's suggestion of a fifth force and writes, "If the validity [of the work] can be confidently established, its implication for the laws of fundamental physics will be profound."

To be compatible both with these observations and with known physics, the fifth force would have to be medium-range, operating over distances between 10 and 1,000 meters or so. It would have to be 100 times weaker than ordinary gravity. It would be repulsive, and its strength would depend on the number of neutrons and protons in an object and so on the chemical elements present.

"Although a fifth force of this size certainly wouldn't change our everyday lives," says James E. Faller of the Joint Institute for Laboratory Astrophysics at the University of Colorado in Boulder, "it would have quite a profound effect on the way we think about our world."

Interested physicists have been busy doing new experiments and checking to see whether the fifth force is compatible with the classic experiments of the past. Early in 1986, Ephraim Fischbach of Purdue University in West Lafayette, Ind., brought widespread attention to the fifth force by publishing a reanalysis of an experiment done 70 years ago by Roland von Eötvös (SN: 1/18/86, p.38). Until then physicists had regarded the Eötvös experiment as a demonstration that gravity takes no notice of the differences among substances. Fischbach reanalyzed Eötvös's data to show that they are compatible with the existence of the fifth force.



NATURE

The Stubbs et al. experiment.

Galileo, back in the seventeenth century, also determined that gravity affects all substances in the same way. He is said to have done it by dropping balls off the leaning tower of Pisa. In the latest new experiment on this subject, Faller and graduate students Timothy M. Niebauer and Martin P. McHugh have redone the experiment in a modern guise. They dropped pieces of uranium and copper in evacuated towers — Faller calls them "20-centimeter leaning towers." (A vacuum is necessary to get rid of air resistance, which could affect different objects differently as they fall.) Mirrors on the weights allowed a laser to track their fall. The experimenters report in the Aug. 10 PHYSICAL REVIEW LETTERS that they found no difference in the earth's attraction for the the two weights to an accuracy of 5 parts in 10^{10}.

Unlike Fischbach's result, theirs supports Galileo and traditional physics. With respect to the relative strength and range of a possible fifth force, they conclude, "This experiment extends the...region over which the usual gravitational laws are valid."

However, the record of the last year includes at least one positive result in an experiment of this sort. Peter Thieberger of Brookhaven National Laboratory in Upton, N.Y., used a hollow copper sphere that he made neutrally buoyant so that it floated just submerged in water. He reasoned that, if the fifth force exists, the attraction of a large mass of earth for the copper will differ from the attraction of the same mass for the water, and the sphere should move in the water. Using a cliff of the New Jersey Palisades as an attractor, he found that the sphere did move. "This observation is consistent with a substance-dependent, medium-range force...," Thieberger concluded in the March 16 PHYSICAL REVIEW LETTERS.

The same journal also included a negative result by C. W. Stubbs and colleagues at the University of Washington in Seattle. In this case four samples, two of copper and two of beryllium, were arranged at the corners of a square and hung by a single wire in a torsion balance. If a large mass to the side of the apparatus (a hill on the campus) attracted copper and beryllium differently, the wire should have twisted. The negative results of the experiment, they conclude, "make it very unlikely that the geophysical and Eötvös anomalies have a common origin in a 'new force.' "

"It is always difficult to draw definite conclusions from such delicate experiments," comments E. Iacopini of the Scuola Normale Superiore in Pisa, Italy, reviewing the situation in the Aug. 13 NATURE. Iacopini describes two forthcoming experiments. In one of them, in which Iacopini will participate, a half-beryllium, half-copper sphere will fall in an evacuated chamber. If the earth's attraction for copper is different from its attraction for beryllium, the sphere will rotate somewhat about its axis as it falls. An arrangement of mirrors and lasers will measure that motion.

The second of these experiments, by Edoardo Amaldi of the University of Rome and his collaborators, involves the gravity-wave detector that belongs to the University of Rome and is set up at the CERN laboratory in Geneva, Switzerland. Gravity waves are cyclic disturbances of gravitational forces that propagate through space. They are gravity's analog to radio waves, and astrophysicists expect them to come from several kinds of astrophysical events. If they do, they should make the detector vibrate.

This experiment will attempt to excite the detector artificially. Near the detector, the experimenters will set up a "gravitational dipole," a hollow cylinder of which half is iron and half beryllium. This dipole will rotate at the detector's resonant frequency, 915 hertz. If the fifth force exists, the rotating dipole should excite the antenna, producing a signal that should be evident.

Summing up the situation, Iacopini remarks, "It is too early to draw any conclusions, but in a year or so there will be many experimental results."

— *D. E. Thomsen*