Evidence for New Force — May Be No. 6

This should be a time of respect for Sir Isaac Newton, what with the 300-year anniversary of his masterwork, the *Principia*. But part of his legacy, the theory of gravity, is certainly taking a beating.

In 1986, physicists reported on experiments that found gravity to be slightly weaker than the value predicted by Newton's theory — a discrepancy they took as a sign of a previously unnoticed fifth universal force. Now a team of Air Force physicists has detected minute *additions* to gravity, which may be manifestations of a sixth force, they reported last week at the American Geophysical Union's fall meeting in San Francisco.

"This is the first indication that there is an additional, attractive force," says Andrew Lazarewicz of the Air Force Geophysical Lab in Hanscom, Mass. "We see more gravity than there should be according to Newtonian law."

The Air Force team had originally set out to detect the controversial fifth force by making precise measurements with a gravity meter on and around a 2,000-foot television tower in Garner, N.C. Earlier experiments had suggested that this force causes objects to repel each other and that the strength of the effect depends on the composition of the material involved (SN: 1/3/87, p.6; 10/3/87, p.212). But the TV tower experiment detected an opposite, attractive force.

It isn't every day that scientists discover a new force. In fact, for the half-century before 1986, physicists confidently believed they could describe the universe in terms of four forces: electromagnetism and gravity, both of which can function over infinite distances; and the subatomic strong and weak forces, which cannot be felt outside the nucleus of an atom. The fifth and sixth forces, if they exist, differ from the others by acting over intermediate distances ranging between a few feet and hundreds of yards.

While these potential forces may become recognized additions to the four-member family of fundamental forces, many scientists believe the recent experiments are revealing a side of gravity, says Lazarewicz, who worked with Christopher Jekeli, Anestis Romaides, Roger W. Sands and group leader Donald H. Eckhardt. In this case, the new "forces" would not exist on their own but would be correction terms to the standard theory of gravity.

If so, they would be small corrections, much weaker than the main Newtonian component. As the Air Force researchers moved up the tower, they measured departures of 0.00005 percent from what Newton's theory predicted the gravity should be. Though minuscule, these discrepancies are 10 times greater than the smallest detection limits of the instruments, giving the group confidence in its results, says Romaides.

To be accurate in their calculations, the researchers had to include the gravitational attraction of the sun, the moon, the air surrounding the tower and even the water table below the earth's surface.

Other physicists were impressed by the experiment. "This is very compelling evidence that there have to be two additional terms [to gravity]," says Mark E. Ander of Los Alamos (N.M.) National Laboratory (LANL).

The Air Force results may seem to contradict the findings of previous fifth-force experiments, but theoretical physicists can explain why this new experiment detected the attractive rather than the repulsive force. "We have two effects that look incompatible but are, in fact, compatible with the only theory that we're taking seriously," says Frank Stacey of the University of Queensland in Australia.

Stacey and others believe that both attractive and repulsive forces fit neatly into new theories that have predicted two additions to standard gravity.

These theories have emerged from attempts to combine all the forces of nature into one Grand Unified Theory. In this work, theoretical physicists have always stumbled when they reached the standard theory of gravity. One of the main problems is that the gravity described by Newton and Einstein simply will not mix with quantum mechanics.

Undaunted, some theoreticians have constructed their own hypothetical force of gravity, molded to be amenable to quantum mechanics. To succeed, they have had to add new terms to the standard equations. Says theorist Mike Nieto of LANL, "It is a generic conclusion of quantum gravity that there will be new aspects to gravity, in particular that there will be a new repulsive force and a new attractive one."

To explain their results, the Air Force physicists hypothesize that the new repulsive force is stronger than its attractive counterpart at close range; but at a longer range, the attractive force can outdistance the other and dominate.

Therefore, the gravity experiments conducted deep within a mine measured the repulsive force, because the instruments were surrounded by dense matter. But these researchers made their measurements on the surface of the earth and on the TV tower. With their instruments removed from the dense earth, they could detect the longer-range, attractive force, says Romaides.

Though the Air Force observations conveniently match some of the predictions of quantum gravity theory, all involved caution that convenience does not constitute scientific proof.

Moreover, several gravity experiments in the last year have failed to measure any departures from standard gravity, and most scientists are unconvinced that there are any new forces at all.

But as more experiments turn up with positive results, scientists are beginning to take notice, says Nieto. "There have been many times in the history of physics where people have thought they've seen important things and they haven't; it was experimental error," he says. "The point is that there are so many people seeing funny things now. It sure looks interesting." — *R. Monastersky*

Solar cycle linked to weather

Atmospheric scientists have discovered a strong statistical link between the 11-year solar cycle and the weather here on earth — a finding that may eventually help explain why some winters are mild while others are unrelentingly harsh. The report was presented last week at a meeting of the American Geophysical Union in San Francisco.

Scientists have known about the solar cycle for more than a century and have long attempted to associate it with weather and a host of other phenomena. "The number of polar bears, the length of women's skirts, the stock market: Everything imaginable has been correlated with the solar cycle," says Harry van Loon of the National Center for Atmospheric Research (NCAR) in Boulder, Colo. "The field has been in ill repute."

The cycle is actually a minute variation in different properties of the sun. During the cycle maximum, ultraviolet and X-ray radiation increase, more sunspots appear on the surface of the sun and the total solar output is greatest.

Previous attempts to find a link between the cycle and the variations in weather have failed. When scientists look at the weather from one year to the next, temperature and air pressure and other aspects vary wildly, with no connection to the cycle. But Karin Labitzke, of the Free University in West Berlin, discovered in March that if she included only certain years, the stratospheric winter temperatures over the North Pole closely followed the solar cycle.

Labitzke grouped years according to a pattern of stratospheric winds over the tropics called the Quasi-Biennial Oscillation (QBO). During the west phase of the QBO, winter winds travel from west to east, and the opposite holds true for the east phase. On average, the wind reverses each year, but sometimes it misses a year.

During her recent visit to NCAR, Labitzke and van Loon probed deeper into this problem. By examining only the years of the western QBO they uncovered a remarkable correspondence between the solar cycle and the air pressure and temperature in certain areas, such as the eastern United States. For example, she says, "If the QBO is in the west phase, and we are in the solar minimum, the winter in Charleston [S.C.] will be normal or mild. And if we are in a solar maximum, the winter will be normal or cold."

Over the North Pole and extending down into Canada, this correlation appears strongest, measuring as great as 0.8 on a scale of 0 to 1. This means that the link between the solar cycle and the weather accounts for 64 percent of the variability in winter temperatures and air pressure in that region. Considering all the elements that affect weather, says van Loon, this is a huge correlation.

For other areas, the connection between solar cycle and weather is weaker or nonexistent. In general, a map of the areas of correlation is a blotchy affair with no apparent pattern. (The years of the eastern QBO also show correlations, but they are weaker than during the western phase.)

Statistical tests have indicated that there is an extremely low probability that these patterns are coincidental, says Labitzke. In computer runs, the correlations emerged out of random sequences a mere 25 out of 10,000 times.

Still, the data on the QBO go back only to 1953, limiting the researchers to 3 1/2 periods of the solar cycle, and Labitzke acknowledges that the pattern could fall apart during upcoming periods.

The disreputable history of solar-cycle correlations has made scientists wary of reports of new links. And no one can yet explain the mechanism of the correlation. They wonder how a small oscillation in several solar properties can exert such a drastic influence on earthly weather.

But the statistics are beginning to speak out to scientists. "I think it's really very convincing that there's something going on," says Brian A. Tinsley of the National Science Foundation.

Many people have wondered whether this correlation will help in making weather predictions. However, van Loon says, "This is purely statistics, and we don't understand the physical mechanism. Until we understand it, we should not use statistics to form predictions." Labitzke believes the most important effect of her find will be to force meteorologists to consider basic questions about the role of the QBO and the solar cycle. *– R. Monastersky*

Kids suddenly gain in grasp of symbols

When is an object not what it appears to be? When it serves as a symbol of something else.

The development of an infant's ability to see an object as a symbol is also not what it appears to be, says psychologist Judy S. DeLoache of the University of Illinois in Urbana-Champaign. Although researchers have often proposed that symbolic understanding develops gradually throughout childhood, there appears to be a rapid advance in an important type of symbolic thinking between 2 1/2 and 3 years of age, reports DeLoache in the Dec. 11 SCIENCE.

In that short span of six months, children become able to think of a small-scale model of a room in two ways at once—as a room in its own right and as a symbol of a larger room that it represents. This broadening of the scope of symbol use, says DeLoache, is a big step on the road to mature symbolic thought, in which virtually anything can stand for anything else.

She tested 16 infants between 30 and 32 months old and another 16 between 36 and 39 months old. The children were from white, middle-class families, and boys and girls were equally represented. Half the subjects in each age group watched as a miniature toy was hidden in a scale model of a room located next to a corresponding full-sized room, and half saw the larger version of the toy hidden in the room itself.

Given four trials, 3-year-olds found the analogous toy in the corresponding location nearly 80 percent of the time without error; 2½-year-olds were successful on only 15 percent of their searches, regardless of which hiding incident they witnessed. Both groups, however, located the toy that they actually saw being hidden 80 percent of the time.

To see if the three-dimensional nature of the model interfered with the younger children's appreciation of it as a symbol, the researchers tested 16 more 2 1/2-year-olds, once with the model and once after being shown a color photograph of where the toy was hidden. The same poor performance was noted in the former situation, but the children used the photographs to find the toy in the room nearly 80 percent of the time without error.

"This is a totally counterintuitive finding," says DeLoache. It is known, for example, that young children's memories for objects in a three-dimensional model are better than their memories for objects in a comparable photograph. But the only function of a photograph is as a symbol, she explains; it does not need to be thought of as a real object as well as a symbol. Thus, the 2 1/2-year-olds understood that the photographs represented the room and acted accordingly, whereas they treated the model only as a real object that could not be generalized to represent the room next door.

While this finding is intriguing, says psychologist Dennie Wolf of Harvard University, it is unclear why the younger children performed so much better with photographs. Youngsters of that age realize that a scale model represents a real house and that it is for dolls rather than for people, she notes. Further research must clarify whether some aspect of the experimental task influenced the results, or if the finding applies to most children, says Wolf. *– B. Bower*

Fanning flames in space

A flame, whether from a candle or a gas burner, is a remarkably simple, efficient way of transferring large amounts of energy to a specific location. Convection currents bring fresh chemical fuel into the flame's luminous combustion region and carry away hot products, giving the flame its distinctive profile. In the absence of gravity, however, no convection occurs, and flames are spherical. They eventually suffocate under a blanket of their own products. That drawback limits the potential usefulness of flames in space applications.

One way to direct hot combustion products so that they transfer heat efficiently is to keep the fuel under pressure in cylinders. But this solution requires bulky, heavy equipment. Now, two British researchers propose the use of electric fields as an alternative method for controlling flames in zero gravity. "There is little doubt," the researchers report in the Dec. 17 NATURE, "that this principle, using simple and lightweight equipment, could be applied to provide intense heating of small areas, making economic use of the oxygen available in the working environment."

A flame is the luminous product of chemical reactions taking place within a region of swirling, combustible vapors. Within the reaction zone, chemical reactions generate relatively large concentrations of short-lived charged particles, mainly electrons and positive ions. Felix J. Weinberg and F.B. Carleton of Imperial College in London suggest that a high-voltage "chimney" would push the charged particles so that the flame is directed toward the region to be heated. The resulting "ionic wind" would provide the required convection currents.

The researchers have successfully tested their scheme during brief periods of near-weightlessness on aircraft in parabolic flight. *– I. Peterson*