The stimulation of the fifth force

Nearly three years of ingenious searching may not yet have uncovered evidence that the fifth force, a kind of correction of newtonian gravity, is real, but the search itself has been rewarding.

THE reality or otherwise of the fifth force, the supposed short-range correction to newtonian gravitation, may still be an open question, but there is little doubt that the search for evidence mounted in the past three years has been extraordinarily stimulating. Both experimentalists and theoreticians have done wonders of ingenuity. The flurry of excitement shows vividly how the publication of arresting inferences from intriguing data can have a value going beyond the interest of the original claims. No doubt it is a necessary condition for this benefit that the data should be convincing and the inferences made from them inherently plausible, conditions amply satisfied by Fischbach's re-examination of the Eötvos data of the 1920s.

On balance, the experimentalists seem to have responded the more ingeniously to the challenge of the fifth force. There have been novel designs of torsion balances and, more particularly, novel ways of placing them near perturbing masses, on cliff faces or on the edges of dry docks, for example. But a measurement now reported by C.C. Speake and T.J. Quinn, from the International Bureau of Weights and Measures in Paris (*Phys. Rev. Lett.* **61**, 1340; 1988) seems to point the way to more sensitive measurements of the gravitational attraction between masses separated by laboratory distances. That could be important because Newton's constant of gravitation, *G*, is one of the least accurately known of the fundamental constants.

Speake and Quinn have been operating on a huge scale, at least by the standards of most precision measurements, having arranged to measure the gravitational attraction between objects of different composition (lead, carbon and copper), each of mass 2–3 kg, and moveable attracting objects with mass no less than 1–78 tonnes (and made, alternately, of lead and brass). As the fifth force is supposed to depend on the composition of the attracting materials, it is necessary to be able to ring changes such as are made possible by this array of materials.

The alternative attracting masses apparently consist of motorized trolleys that can be trundled into position beneath a sealed tank containing the balance. The balance itself consists of a rigid beam with equal arms. The novelty is the suspension for the beam, which pivots on flexible strips rather than a knife-edge, thus avoiding the familiar problems in precision measurement of knowing just what allowance to make for the elasticity of a supposedly rigid support.

The enclosing tank is first evacuated and then filled with nitrogen at roughly atmospheric pressure, chiefly so as to damp oscillations of the balance. Test objects are weighed under the influence of one or other of the attracting masses. To minimize the effects of geometrical shape, the trolleys made of lead (in reality, there are two each, each carrying nearly half a tonne) consist of layers of lead interspersed with wood to give them nearly the same geometrical shape. Similarly, the 2–3 kg test masses are enclosed in stainless-steel cans of nearly equal shape so as to reduce the corrections due to buoyancy. There is a system of gimbals to ensure that masses can be interchanged accurately (and automatically) on the balance pans.

In essence, the measurement is a null measurement: the balance beam is kept horizontal by a servo-system, regulating electrical currents passed through two coils interacting with two magnets mounted at each end of the beam. Known sources of vibration are reduced as far as possible by the design and then at least partially excluded by filtering the output from the servo-system.

Even so, the system seems not to have been entirely free from trouble. Outgassing from the stainless-steel cans seems always to have been a problem (accounting for changes of pressure of the order of one per cent an hour). But the most persistent source of uncertainty in four series of measurements seems to have been the difficulty of excluding dynamical changes caused by external sources of heat. The wooden layers interleaved with lead insulated that pair of trolleys more efficiently than the brass trolleys from the laboratory floor, providing a systematic difference with composition that might have trapped less careful investigators. Speake and Quinn estimate that their mass differences have a sensitivity of 1 nanogram, corresponding to a force of 10^{-11} N.

The authors are no doubt right to say that their measurements should be readily capable of improvement, and that a tenfold improvement of sensitivity should be possible by paying more attention to the exclusion of design of the effects of external heat. And the result of what they have done so far? Sadly, the persisting errors are comparable with the mean values, which is another way of saying that they are not significant. The authors claim that they can only exclude the possibility that the fifth force at short distances is greater than about one per cent of ordinary gravitation, which of itself does not do much to advance the cause.

Much the same has emerged from an analysis of past measurements of the position of planetary orbits conducted by C. Talmadge from Purdue University and three colleagues at the Jet Propulsion Laboratory at Pasadena, California. The argument is simple: if the force between a planet and the Sun is not a simple inverse function of the square of the distance, Kepler's Third Law (relating orbital period to semi-major axis and, crucially, in which the mass of the planet does not enter) should not be strictly correct. In practice, Talmadge and his colleagues say, Kepler's Law is rarely verified directly; people measure the orbital period of a planet directly, then calculate the semi-major axis from the supposed value of the constant in the equation — the product of the solar mass and the gravitational constant.

The group seizes the opportunity of using accurate data for the positions of planets derived from sighting shots by passing spacecraft as well as from the longer series of data based on radar-ranging measurements of the objects of the Solar System. Evidently there is a substantial volume of data not fully made use of in previous analyses. One of the unexpected byproducts of the exercise is the discovery that the data can be made to yield more accurate estimates of the anomalous rates of precession of the orbits of the planets out to and including Jupiter.

But, sadly, the outcome for the main purpose of the calculation is again disappointing. From information about the distance of the orbit of a particular planet, it is obviously possible to obtain information about the strength of the fifth force in some region spanned by the average position of the orbit. Sadly, again, the estimated errors of the estimates Talmadge and his colleagues have derived are comparable with, or greater than, the estimates themselves, so that only extreme values of the parameters defining the fifth force (if there is one) can be confidently excluded. But, in a sense, "So what?". Observers will remark that the hunt for this still elusive phenomenon has already been worthwhile, whatever the eventual outcome.

John Maddox