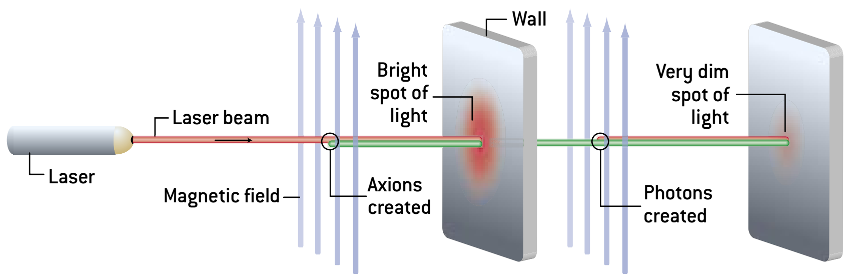
PHYSICS

A Hint of Axions

AN EXPERIMENT MAY HAVE SEEN AN ELUSIVE NEW PARTICLE BY GRAHAM P. COLLINS

Named after a laundry detergent and originally proposed to clean up a problem with particle physics, axions are curious critters. Axions produced during the big bang could be lurking all around us, contributing to the dark matter that constitutes 22 percent of the universe. Other axions, freshly formed inside the sun, could be streaming through us. And according to a paper published in March, laboratory-made axions might have been detected for the first time by an experiment in Italy known as PVLAS (*p*olarization of the *v*acuum with a *las*er).



LIGHT BEAM experiment that would confirm the existence of axions passes a laser beam through a strong magnetic field, converting some photons to axions (*green beam*). The axions penetrate a wall before passing through another magnetic field that converts some of the particles back to photons, which form an extremely faint spot on the far wall.

Axions are posited to have exceedingly low mass—less than a millionth that of an electron—and are electrically neutral. They interact only very weakly with other particles, making detection difficult. But physicists predict that a tiny fraction of any photons passing through a magnetic field will change into axions. (That is how the sun is predicted to produce them.) Indeed, the Italian experiment, based at the National Laboratories of Legnaro and led by Emilio Zavattini and Giovanni Cantatore of the INFN Trieste, saw evidence for axions in the behavior of a laser beam. The beam's polarization was rotated by 10 millionths of a degree after transiting 44,000 times back and forth through an extremely strong magnetic field. Such rotation is just the fingerprint expected if some photons converted to invisible axions, or more precisely, what physicists call axion-like particles.

From its data, the PVLAS group infers the mass of the putative axions and how strongly they interact. Puzzlingly, however, the results contradict other observations and do not fit with constraints deduced from astrophysics. In particular, the CERN Axion Solar Telescope (CAST) ran for six months in 2003 and failed to detect any axions arriving from the sun. That result would seem to rule out a large swath of possible masses and interaction strengths, including the values seen by PVLAS. Furthermore, if axions interact as strongly as PVLAS indicates, they should be produced in large quantities in stars, causing stars to grow old much faster than they are known to.

Such considerations "put the bar pretty high before one can accept the PVLAS results," says axion expert Pierre Sikivie of the University of Florida and CERN. On the other hand, he adds, "these people are very competent, and they have worked on it a long time." By all accounts, the PVLAS researchers have been careful to exclude effects that could be confounding the data; moreover, in work that is not yet published, the group has also obtained consistent results with a different laser. Some theorists have already proposed ways to reconcile the PVLAS results with those of CAST and other astrophysical limits.

Only further experiments will determine the truth. If the PVLAS results are correct, then axions should appear in an experiment known as "shining a light through a wall." The idea is this: A laser beam is sent through a strong magnetic field at an opaque wall. Some of the photons in the beam are converted to axions, which pass through the wall. On the other side, another magnetic field induces a small fraction of the axions to convert back to photons, which can be detected. Such an experiment, using a large, strong magnet and sensitive photon detectors, would convincingly confirm (or refute) the PVLAS results in a matter of minutes. Research groups, including the PVLAS team, are gearing up to perform that experiment. By the end of the year the axion could be a firm addition to the particle menagerie—or back on physicists' most-wanted list.

SAVING A SYMMETRY

Physicists originally proposed the axion as part of a scheme to explain why the strong nuclear force preserves so-called CP symmetry, which relates the properties of particles and antiparticles. Calculations using the Standard Model of particle physics showed that the strong force could preserve CP only if a certain parameter in the theory was zero, and yet quantum effects tend to make the parameter nonzero. In 1977 Helen R. Quinn and Roberto D. Peccei, then at Stanford University, showed that by changing the parameter into a quantum field, its value would be driven to zero by a natural process. A side effect of the new field would be the existence of a new particle—the axion.

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