"Standard model" safe as physicists can't find misbehaving light particles

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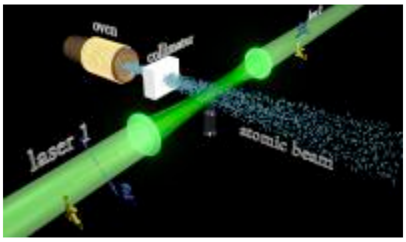
Physicists say they have confirmed to a near certainty that particles of light obey a basic distinction between two types of building blocks of the universe.

This distinction, between particles called "bosons" and "fermions," has long been assumed, but never quite proven by physicists. It is tied in turn to many assumptions behind the "standard model," a working model of reality that underpins mainstream physics.



A beam of hot barium atoms exits an oven and passes through a collimator before hitting overlapping laser beams. If photons sometimes act like fermions, every once in a while a barium atom would absorb two photons and subsequently emit a flash of light. (Credit: Damon English/UC Berkeley)

If the boson-fermion dichotomy proved wrong, "the consequences would be far-reaching, affecting our assumptions about the structure of space-time and even causality itself," said physicist Damon English of the University of California, Berkeley, one of the investigators in the study.

One possible consequence of this breakdown would be the possibility of "receiving a flash of light before it was emitted," he added.

The researchers set up an experiment in which the building blocks of light—which are bosons—were given some 10 billion opportunities to act in a way characteristic of fermions, but apparently never did.

Bosons are special in that they can all occupy an identical "quantum state," a set of characteristics that includes location. As a result, for instance, any number of particles of light can be in the same space. Fermions can't do this—which is why, since most ordinary atoms consist of fermions, it seems obvious to most people that two objects can't be in the same place at once.

English and colleagues bombarded barium atoms with particles of light, called photons, from two identical laser beams. They looked for signs that the barium had absorbed two photons of the same energy at once.

Generally speaking, events of this sort are common. The incoming light would kick one of the atom's electrons, or electrically charged particles, into a higher-energy state.

But the specific variety of electron energy jump being sought in this experiment was one that can only be triggered by bosons, not fermions.

The reasons for this come down to math, including a consideration of the “spin” of particles, English said. Many fundamental particles behave in some ways as though they were spinning, although the exact relationship of this “spin” to ordinary spin, such as that of a top, is hard to pin down.

The electron energy jump in question would have taken the atom from having a spin of zero to a spin of one, according to conventional physics. This means that the arriving photons must also have had a combined spin of one. This is mathematically impossible for equal-energy photons, unless they follow the equations that describe fermions, English explained.

Consistent with these ideas, the required energy jump never happened, English said—though no physical principle except the boson-fermion distinction should prevent it. The energy jump would have been detected when the atoms emit a particular color of fluorescent light, the researchers noted.

Similar conclusions about the boson-fermion distinction were reached by a 1999 experiment by scientists including the principal investigator in the new study, Dmitry Budker of the Berkeley National Laboratory in Berkeley. But the new tests improved the precision of the results by about 3,000 times, the scientists said, thus constraining the chance of bosons acting like fermions to less than one in a hundred billion in the system tested. The findings are published in the June 25 issue of the journal *Physical Review Letters*.