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New-School 'Aether' May Shed Light on Neutron Stars

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Among scientists, it is widely believed that there is no such thing as an aether – a medium pervading all space that allows light waves to propagate, similar to how sound needs air or water – but a part of its spirit may live on. A group of University of Maryland (UM) physicists have proposed a modern spin on the aether of old and have used it to make new predictions about the behavior of neutron stars.

Physicists once thought light waves propagated in a special medium, the "luminiferous aether." This implied that the speed of light would depend on the reference frame of the observer, but experiments performed at the turn of the 20th century established that light in a vacuum always travels at the same speed, independent of the reference frame. Maxwell's electromagnetic theory of light, together with Einstein's discovery of special relativity, provided the explanation: there is no such aether, and all reference frames are equivalent.

The UM group proposes, however, that an aether concept may still have a place in physics: not representing a medium for light waves, but a universal preferred frame of reference that is physical in nature. As such – although the new aether retains the spirit of the old – there are few similarities between the two.

The UM researchers – Christopher Eling, Ted Jacobson, and Coleman Miller – describe their aether as a preferred state of rest at each point of spacetime. This preferred state would not be the result of something known, such as a gravitational field or cosmic background radiation, but may, they say, arise from the structure of empty space in quantum gravity theory.

The new aether violates Lorentz symmetry, the principle stating that the laws of physics must have the same form no matter the reference frame. In other words, if a person drops a ball while standing in their house, in a moving train, or in a rocket shooting through space, the laws of physics describing the ball's motion are the same within each frame. This concept is one of the foundations of special relativity.

The UM team says their work provides a framework in which to test whether relativity holds within the context of very strong gravitational fields. In “weak field” situations – such as the gravitational bending of light and the orbits of the planets around the Sun – experiments have upheld relativity in gravitational physics. But experiments to probe relativity where gravity is much stronger, such as near neutron stars, are not yet as accurate, because of both limited observations and incomplete knowledge of the properties of dense nuclear matter.

The UM team use the new aether to make concrete predictions about neutron stars that differ from those generated by general relativity, Einstein’s theory of gravity. The group's calculations show that the maximum mass of neutron stars would be smaller than in general relativity and the increase in wavelength, or “redshift,” experienced by photons emitted from the stars' surfaces must be 10 percent larger.

“Our quantitative predictions allow strong field violations of relativity to be characterized and tested in the extreme gravitational environment of a neutron star,” said Jacobson to *PhysOrg.com*.

Upcoming experiments that may provide more insight into relatively at work in strong-gravity situations include x-ray detectors capable of tracking the movement of elements in disks around black holes, which will map out the shape of spacetime around a black hole; highly sensitive space- and ground-based detectors that will “see” gravitational waves; and devices that will yield improved measurements of neutron-star masses and the redshift of photons emitted from their surfaces as they escape the stars' gravitational fields.

This research is discussed in the August 17, 2007, online edition of *Physical Review D*. In their prior work on the subject, the UM group carried out a similar analysis for non-rotating black holes, and found that the deviations from general relativity would be very hard to detect. They say the case of spinning black holes would likely produce more dramatic effects, but it is more difficult and remains to be studied.

Citation: Christopher Eling, Ted Jacobson, and M. Coleman Miller “Neutron stars in Einstein-aether theory” *Phys. Rev. D* 76, 042003 (2007)