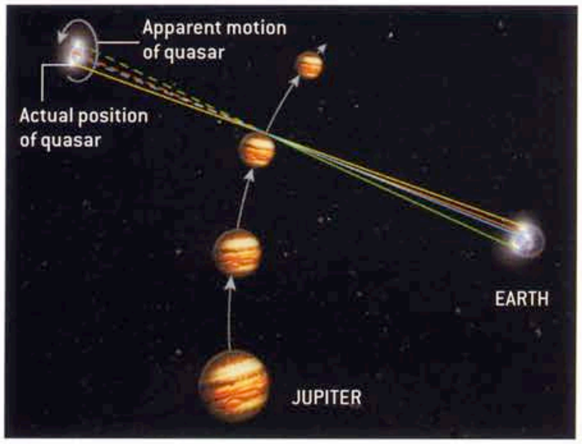
news SCAN

PHYSICS

A Tale of Two C's

GRAVITY SPEED TEST RAISES SOME RELATIVISTIC EYEBROWS **BY GEORGE MUSSER**

The hardest thing to prove is something you think you already know. How can you be sure that you're proving it, rather than merely reasserting your belief? So it is with the latest test of Einstein's general theory of relativity—a measurement of the speed at which changes in a gravitational field propagate. If the sun suddenly shattered into a million pieces, this speed would determine how many minutes of blissful ignorance the denizens of Earth would have until our orbit went haywire. In Einstein's theory, the speed of gravity (abbreviated c_g) exactly equals the speed of light in a vacuum (c).



LIKE A LENS, Jupiter bends the light rays from a distant quasar. The yellow ray is unaffected by Jupiter and takes a direct path to Earth; the dotted lines show the illusory paths of the ray. Jupiter's motion causes the quasar image to trace out a circle. Relativistic effects skew the circle (*not shown*).

Lo and behold, that is what a physicist-astronomer duo announced at the American Astronomical Society meeting in January. Einstein, they concluded, was right once again. Yet most relativity researchers are skeptical. "It's a beautiful experiment that gives a very nice new confirmation of general relativity, but it's still unclear whether it's testing the speed of gravity," says Steven Carlip of the University of California at Davis.

No one questions the basic experimental setup, devised by Sergei Kopeikin of the University of Missouri and Edward Fomalont of the National Radio Astronomy Observatory. The idea was to look for the effect that a nearby celestial body has on the light rays from a more distant object. The nearby body should bend the light rays, temporarily shifting the image of the distant object. In a famous (if controversial) expedition in 1919, English astronomer Arthur Eddington detected the deflection of starlight by the sun. Just over a decade ago high-precision radio astronomy—in particular, very long baseline interferometry, which links together far-flung radio dishes into a single globe-spanning telescope—saw the minute bending caused by Jupiter.

Since then, radio interferometry has gotten 10 times more precise. So Kopeikin and Fomalont went one step further: to look not only for the bending caused by a static body but also for relativistic effects caused by the motion of that body. Such effects depend on the ratio of the body's velocity to c. For Jupiter, which orbits the sun at 13 kilometers a second, the ratio is about one part in 20,000. That seems awfully small, but the researchers calculated that geometric factors would magnify any effects to detectable levels.

Last September they put their plan into action when Jupiter passed close to the line of sight between Earth and a quasar. The quasar image scooted 1,300 microarcseconds across the sky—with a 50-microarcsecond skew, just as expected from relativistic effects.

So far, so uncontroversial. The fun begins when you ask which relativistic effect was operating. There are oodles of possibilities, and Einstein's notoriously subtle equations do not specify which mathematical term corresponds to which physical effect. Kopeikin and Fomalont contend that the dominant effect was the propagation of gravity. As Jupiter travels, its gravitational force on the ray varies, and the variation takes a little while to travel through space to the ray. To isolate this effect, the scientists constructed an alternative version of relativity, in which c_g could differ from c. They were then able to infer a value for c_g from the data, without presuming it. The two c's turned out to have the same numerical value, with a precision of 20 percent.

But others, notably Clifford M. Will of Washington University, take a different approach to extending relativity and attribute the observed skew to the better-known relativistic effects of time dilation and length contraction. From the vantage point of Earth, Jupiter's moving gravitational field looks slightly flattened, which alters the amount of light deflection that we perceive. This flattening depends on c but not on c_g. The propagation of Jupiter's gravity does play a role, but Will argues that it corresponds to a different (and much smaller) term in the equations. If so, Kopeikin and Fomalont cannot infer a value for c_g.

The disagreement will not be easy to

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In Newton's theory of gravity, the speed of gravity (c_g) is infinite; if the sun blew up, Earth's orbit would change instantaneously. But Einstein's special theory of relativity wouldn't look too kindly on that. To preserve the distinction between cause and effect, the speed of light (c) must be the ultimate speed limit. Special relativity also suggests that c_g cannot be less than c: if it were, gravity would behave differently for different observers. Unfortunately, Newton's theory of gravity cannot accommodate a finite c_g without making orbits unstable. The conflict between Newton's theory and special relativity led Einstein to devise an entirely new theory of gravity, general relativity.

resolve. Most researchers lean toward Will's approach, which builds in consistency with other experimental tests. Some go so far as to say that the entire debate is pointless, because there are tests that have higher precision, but others think Kopeikin and Fomalont could be probing something unique. Sorting things out will take more theoretical work as well as direct measurement of gravitational radiation. No mainstream physicist doubts that c_g equals c. But in science, it is not enough to be right. You have to be right for the right reasons.