PHYSICS

Relativity Passes a Tough Cosmic Test

Continents drift, empires rise and fall, stock markets whipsaw, but photons just keep rolling along. That reassuring idea—that the speed of light is independent of the velocity of the light source—has been a central postulate of special relativity for almost a century. Now, a rigorous test has shown that it is indeed true, to at least 20 decimal places.

On 29 April, at the April meeting of the American Physical Society in Long Beach, California, astronomer Kenneth Brecher of Boston University will report how he confirmed Einstein's assumption by studying distant gamma ray bursts, violent explosions at the edge of the observable universe. Astronomers see the bursts as fleeting pulses of high-energy radiation, some less than a millisecond long, which they plot as peaked graphs of brightness versus time known as light curves.

Nobody knows what gamma ray bursts are or where they get their staggering power. Even so, Brecher says, it's safe to assume that any matter capable of emitting such energetic radiation must be hurtling through space at relativistic speeds, at least a few percent of the 300,000-kilometer-a-second speed of light. And if the explosion flings particles in many directions, sources of the radiation must start out moving at different velocities with respect to Earth.

If the speed of light did depend on the motion of the source, Brecher says, that "velocity dispersion" would give some photons slightly higher speeds than others. During the billions of years it takes the photons to reach Earth, those tiny differences would smear out the light curve of a gamma ray burst, spreading the peak over a longer time.

By analyzing the light curves of a number of gamma ray bursts with extremely rapid brightness variations, Brecher found that any light speed differences must be smaller than 3 billionths of a millimeter per second. "The speed of light is really constant to a precision of one part in 10^{20}," he says.

Bradley Schaefer, an astronomer at Yale University who has used gamma ray bursts to test other tenets of relativity, points out a possible weak point in Brecher's argument: velocity dispersion. "How do you know that the gamma rays aren't emitted by things that have the same velocity?" he says. "You can concoct some finely tuned scenarios where that is not the case." That's possible, Brecher says, but he thinks such scenarios—in which gamma rays reaching Earth all came from particles with the same velocity relative to us—would have to be hopelessly contrived.

Why do astronomers bother torture-testing a theory that almost nobody doubts is true? Schaefer describes the relativity tests as "anomaly searches." "We push as hard as we can, hoping that something breaks," he says. "Who knows what kind of subtle discrepancies we may find? That would be big news and would lead to a new important step" in physics. Brecher agrees: "No one expects great deviations, but one should test the theories as well as one can."

—GOVERT SCHILLING

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ASTRONOMY

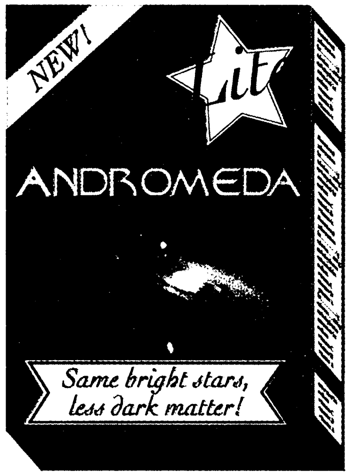
Milky Way Looks Like Big Kid on the Block

Fellow citizens of the Milky Way, take heart. No longer do you have to settle for second best. If two British astronomers are right, our underdog galaxy is, in fact, the heavyweight champion of the neighborhood.

The neighborhood in question is the Local Group, a collection of some 30 galaxies in a region of space about 8 million light-years across. For decades, astronomers have believed that the heftiest of those galaxies is Andromeda. Earlier estimates put its mass at about twice that of the Milky Way, because it is larger and brighter and contains twice as many globular star clusters—spherical collections of hundreds of thousands of stars. But that's "poor evidence," says astronomer Wyn Evans of Oxford University in the United Kingdom. Measurements of brightness, he points out, focus on the visible disk of a galaxy while ignoring the spherical halo of dark, unseen matter that surrounds it. Because Andromeda's disk is more massive than its counterpart in the Milky Way, astronomers assumed that Andromeda's total mass, including the halo, would also be larger.

Evans and astronomer Mark Wilkinson of Cambridge University decided to put that assumption to the test. Together they analyzed velocity measurements of 37 objects that orbit Andromeda, such as small satellite galaxies and outlying globular clusters and planetary nebulae. Because the objects lie far from Andromeda's center, their speeds are determined by the galaxy's total mass—including the dark matter in the halo. From the speeds, Evans and Wilkinson estimate that Andromeda has a total mass of 1.2 trillion solar masses, about half the mass of the Milky Way, the duo reports in a paper slated for publication in the *Monthly Notices of the Royal Astronomical Society*. "Although the central region [of Andromeda] is certainly bigger and brighter," Evans says, "the total mass turns out to be much less."

"This is a surprising result," says Piet van der Kruit of the University of Groningen, the Netherlands. "Although there is no direct proof, everyone assumes that the proportion between the visible and the dark mass is more or less the same for every galaxy." If Andromeda really does have a lightweight halo, van der Kruit says, astronomers may have to develop a more complicated picture of how galaxies evolve.



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So far, few are rushing to change their minds. "This is a really interesting attempt to determine the mass of [Andromeda]," says Paul Hodge of the University of Washington, Seattle, a leading expert on the Andromeda galaxy, "but I'm a little bit nervous about using the distant, outlying possible satellites." Sidney van den Bergh of the Dominion Astrophysical Observatory in Victoria, Canada, agrees. "I don't believe it yet," he says. "It all depends on the objects you use." Van den Bergh, who has discovered many satellite galaxies of Andromeda and of the Milky Way, says that two of the most distant satellite galaxies cited by Evans and Wilkinson—Pegasus and IC 1613—may not really be part of the Andromeda subgroup. In that case, their velocities may reflect forces other than the gravity of Andromeda, which could make them useless for estimating the galaxy's mass.

Evans concedes that "our error bars are pretty large." But he says new data further support the findings. "Since we submitted our paper, we have acquired additional Keck Telescope measurements on five faint dwarf galaxies that were discovered only in 1998 and 1999," he says. The velocities of the new satellites also point to a skimpier Andromeda.

A final answer must wait for more and better velocity measurements, Evans says. NASA's Space Interferometry Mission and the European Space Agency's Global Astro-