X-ray flashes illuminate general relativity

Observations of rapid oscillations in the intensity of X rays emitted by gas striking a neutron star's surface provide a novel test of Einstein's general theory of relativity.

A typical neutron star—the extremely dense cinder left behind after a violent supernova explosion—consists of matter roughly equivalent to the sun's mass compressed into a ball only about 15 kilometers in diameter. General relativity predicts that such a concentration of mass would curve space-time in the star's vicinity so much that there would be observable effects in the behavior of gas plunging to the neutron star's surface.

Now, William Zhang of NASA's Goddard Space Flight Center in Greenbelt, Md., and his coworkers have uncovered evidence of such behavior in data from the Rossi X-ray Timing Explorer satellite. Zhang reported the findings this week at a meeting of the American Physical Society in Columbus, Ohio.

This is "the first evidence of a unique effect of general relativity in regions of strongly curved space-time—an effect that has never been observed before," says Frederick K. Lamb of the University of Illinois at Urbana-Champaign.

Zhang and his team studied a binary system in which the two stars are so close together that the neutron star's strong gravitational field pulls gas off the surface of its companion, an ordinary star. That gas circulates around the neutron star to form an accretion disk. Swirling inward, streams of gas eventually fall onto the neutron star's surface, generating temperatures as high as 100 million kelvins and emitting X rays.

Soon after the Rossi satellite's launch in 1995, researchers discovered that the intensity of such X-ray emissions could rise and fall more than 1,000 times per second. Lamb and other theorists proposed a more detailed picture of disk behavior to account for the rapid oscillations.

In the wide outer ring of the accretion disk, gas travels in nearly circular orbits, slowly spiraling inward. At a certain distance from the neutron star's surface, however, radiation from the star becomes so intense that it impedes the flow of the gas. Unable to orbit, gas inside that boundary plunges rapidly to the star's surface, creating a bright spot wherever it hits.

The researchers hypothesize that a clump of gas at the boundary between the accretion cloud's inner and outer regions would deliver extra gas to a particular spot on the neutron star's surface once every orbit. Observers detecting X rays from that spot would see corresponding oscillations in intensity, which reflect the characteristic orbital speed.

For reasons not yet understood, the rate of gas flow within an accretion disk can vary considerably. As the flow rate increases, the boundary between the outer and inner regions gets pushed closer to the neutron star. The frequency of the X-ray brightness oscillations increases to reflect the higher orbital speed at the new boundary.

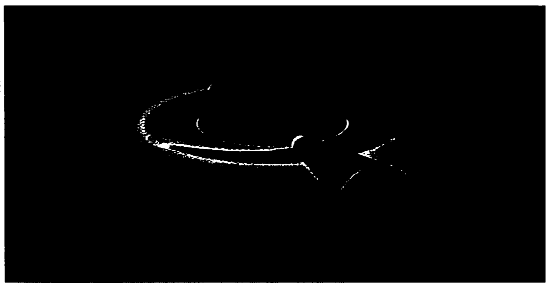
According to general relativity, however, the extreme curvature of space-time would prohibit stable circular orbits within a certain distance of the neutron star's surface. Calculations by Lamb and his colleagues predict that no matter how high the gas flow rate gets, the observed oscillation frequency eventually levels off.

Made more than a year ago, the prediction triggered a competition among groups observing different stars. Zhang's team is the first to detect such a leveling off in the data from one X-ray source.

Because the maximum attainable frequency depends only on the neutron star's mass and spin rate, researchers now have a new way to determine a star's mass. In this case, the observed maximum frequency indicates a mass 2.3 times that of the sun.

Nuclear physicists had expected that no compact star this massive could resist collapsing into a black hole. If the finding is confirmed, Lamb notes, "it tells us something new about superdense matter in neutron stars." —*I. Peterson*

Lamb



X rays beam out from a spot where gas strikes a neutron star's surface. The gas spills from a clump circling at the boundary between the accretion disk's inner (dark purple) and outer (lighter purple) regions.

Birds' eggs started to thin long before DDT

By combing museum collections for old birds' eggs, a researcher has found that thrush eggshells in Great Britain were thinning by the turn of the century, 47 years before DDT hit the market.

The pesticide, now banned in most countries, caused such dramatic shell thinning that populations of peregrines, ospreys, and other top predators began to decline.

Long before DDT was a glimmer in a farmer's eye, some other menace, as yet unknown, was sapping the strength of eggshells, claims Rhys E. Green of the Edinburgh office of the Royal Society for the Protection of Birds. In the April 22 PROCEEDINGS OF THE ROYAL SOCIETY OF LONDON B, he describes long, slow shell declines.

Eggshell thinning may have been an early consequence of industrialization, Green speculates. Acids formed when pollutants belch out of coal furnaces and smokestacks may have changed soil and water chemistry enough to reduce the availability of calcium, which is critical for eggshells. "Calcium can be a particularly bad pinch point," Green says.

Other research has linked acidified soil to frail eggs, he notes. J. Graveland of the Netherlands Institute of Ecology at Heteren reported in 1994, for example, that great tits lay weaker eggs as calcium-rich snails dwindle on acidified soils.

In an unusually broad survey, Green measured three museums' collections of well-labeled eggshells gathered since 1850 from four thrush species in Great Britain. Eliminating bad eggs still left Green several thousand to measure. "You get quite quick," he says.

From the weight and dimensions of the shells, he calculated an index of thickness similar to those developed for monitoring DDT effects. For two species, he also measured shell thickness by fitting a thin probe through the hole made to remove the material inside the egg in preparation for museum storage.

Both the index and the direct measurements show steady declines. Blackbirds (not the U.S. blackbird but *Turdus merula,* a cousin of the U.S. robin) have lost 7 to 10 percent on the shell index since 1850. Eggs from song thrushes thinned 6 percent, mistle thrushes 4 percent, and ring ouzels 2 percent. Only the ring ouzel leaves Great Britain for long migrations.

The research did not look for effects of weakened shells on bird populations, but Green points out that other species have withstood eggshell declines of up to 15 percent.

"I think he probably has something," says wildlife toxicologist D. Michael Fry, director of the Center for Avian Biology at the University of California, Davis. "There is a lot of scatter, but the trend is significant."

Acidification as a threat to eggshells sounds plausible to Lloyd Kiff, now science director at the Peregrine Fund in Boise, Idaho. More than 2 dozen recent studies show acid effects on songbirds abroad, but no research has been done in the United States, he says. "I don't know why someone hasn't picked it up and run with it," he adds. "We have similar conditions here." —*S. Milius*