communicate with itself—that is, to transfer information back and forth. The trick, he says, is to squeeze the computer down to the most compact possible size. Lloyd shows that a computer made of the most compressed matter in the universe—a black hole—would calculate as fast as a plasma computer. It would also communicate in precisely the same time that it takes to flip a bit—the hallmark of the ideal computer. Coincidence? Perhaps not, Lloyd says: "Something really deep might be going on."

At present, scientists have no idea how to turn a laptop into a black hole (Windows 98 jokes aside). But Laflamme says that just thinking about such extreme scenarios might illuminate deep physical mysteries such as black holes. "It's not just what insight physics brings to information theory, but what information theory brings to physics," he says. "I hope that, in the next 10 or 15 years, a lot of insight into physics will be due to quantum computing."

–CHARLES SEIFE

ASTROPHYSICS

Neutron Stars Imply Relativity's a Drag

Matter warps space; space guides matter. That, in a nutshell, is Einstein's general theory of relativity. Now three astronomers in Amsterdam may have confirmed a much subtler prediction of Einstein's: warped space-time with a twist.

The general theory explains how the sun's gravity curves the surrounding space (actually space-time), bending nearby light waves and altering the orbit of Mercury. The new finding, based on x-rays from distant neutron stars, could be the first clear evidence of a weird relativistic effect called frame dragging, in which a heavy chunk of spinning matter wrenches the space-time around it like an eggbeater. "This is an extremely interesting and beautiful discovery," says Luigi Stella of the Astronomical Observatory in Rome, Italy.

Peter Jonker of the University of Amsterdam, the Netherlands, and his colleagues Mariano Méndez (now at the La Plata Observatory in Argentina) and Michiel van der Klis announced their results in the 1 September issue of *The Astrophysical Journal*. To describe such exotic behavior of space-time, Jonker goes beyond the astrophysicist's standard image of a bowling ball resting on a stiff sheet.

"Frame dragging is comparable to what happens when you cover the ball with Velcro and rotate it," Jonker says. The effect occurs only in the immediate neighborhood of very massive, swiftly rotating bodies. To study it, astronomers have to observe distant neutron stars—the extremely compact leftovers of supernova explosions, whose near-surface gravity is so strong that they make ideal testbeds for general relativity.

Using data from NASA's Rossi X-ray Timing Explorer, Jonker and his colleagues found circumstantial evidence for frame dragging in the flickering of three neutron stars in binary systems. The flickering spans a wide range of x-ray frequencies. According to theoretician Frederick Lamb of the University of Illinois, Urbana-Champaign, the most prominent "quasi-periodic oscillations" probably come from orbiting gas that a neutron star tears off its normal-star companion. The hot gas accretes into a whirling disk and gives off x-rays as it spirals toward the neutron star's surface at almost the speed of light.

The new evidence comes in the form of less prominent peaks close to one of the main frequency peaks. These so-called sidebands showed up only after the researchers carefully combined almost 5 years' worth of data. The Amsterdam astronomers say the peaks could be due to frame dragging, which would cause the accretion disk to wobble like a Frisbee. The wobble frequency would imprint itself on the main frequency peak, just as amplitude modulations do on the carrier wave of a radio broadcast.

Some physicists, however, are unconvinced. Lamb says calculations done with his Illinois colleague, Draza Markovic, show that the frequency separation between the main signal and the sidebands is probably too large for the sidebands to have been caused by frame dragging. A similar false alarm occurred 3 years ago, he says, when Stella and Mario Vietri of the Third University of Rome cited a low-frequency, 60-hertz x-ray flicker in a couple of neutron stars as evidence of frame dragging (*Science*, 7 November 1997, p. 1012). The frequency of that earlier flicker clashed with theoretical calculations by Lamb's group and others. Lamb suspects that the flicker arises from a neutron star's intense magnetic field interacting with the accretion disk. Although the sidebands aren't as far out of step with theory, he says, "it's unlikely that [they] are produced by frame dragging."

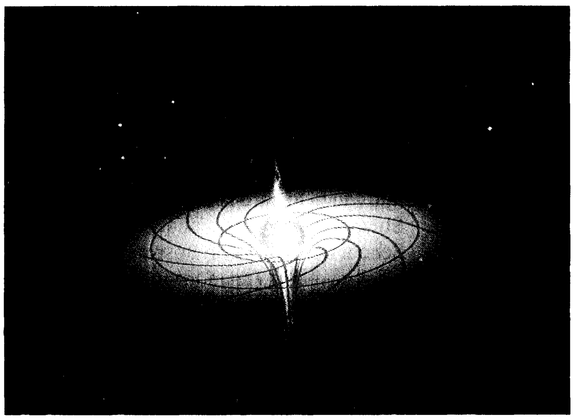
Even so, the sidebands are "a very important result," Lamb says. "The discovery of sidebands is a real breakthrough, regardless of what causes them. This may be the key to unlocking what is generating the main oscillations." They may also provide information on the mass, the radius, and the physical makeup of neutron stars.

But Stella says frame dragging can't be so lightly dismissed. Taken as a whole, he says, the sidebands and his earlier evidence "fall together in a very nice fashion. The frequency differences pose no problem at all." Indeed, in a paper submitted to *The Astrophysical Journal*, Dimitrios Psaltis of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, presents a model of a relativistically oscillating disk that overcomes the frequency problem.

The Amsterdam astronomers hope to use the Rossi satellite to study the neutron stars in more detail and look for sidebands in other sources. If the sidebands are indeed caused by frame dragging, Van der Klis explains, their frequency should shift along with that of the main oscillation in a specific way that will provide a decisive test of the hypothesis. "In principle," he says, "these kinds of observations could prove Einstein right or wrong."

–GOVERT SCHILLING

Govert Schilling is an astronomy writer in Utrecht, the Netherlands.



It's a wrap. According to general relativity, a massive neutron star (shown spinning counterclockwise) could warp and twist space-time in its near neighborhood.

CREDIT: ARTWORK BY JOE BERGERON, COURTESY *SKY & TELESCOPE*

ECOLOGY

Forest Fire Plan Kindles Debate

Forest fires burning in the western United States have already scorched over 2.5 million hectares this summer. Now a federal proposal to prevent them by paying loggers to cut smaller trees is generating heat among ecologists, who say the approach may not be right for all forests—or all fires.

Leaders of western states have sharply criticized the Clinton Administration for not doing enough to prevent the blazes, the worst in nearly a century. They say that re-

Thinning down. Ecologists are debating a plan to prevent uncontrollable burns, like this one in Montana, by clearing smaller trees.

cent policies, including suppressing wildfires and logging only mature trees, have allowed western forests to grow unnaturally dense with young trees and made them more vulnerable to fire. Reacting to that criticism, the Administration said last week that it will soon release a plan to dramatically expand an experimental approach to fire prevention that emphasizes aggressive cutting of smaller trees. Although officials of the Interior and Agriculture departments are still working out the plan's details, it is expected to include paying loggers nearly $825 million a year to remove trees too small to be commercially valuable from 16 million hectares of western forests.

The plan draws heavily from insights into fire control on federally managed lands made by ecologist Wallace Covington of the Ecological Restoration Institute at Northern Arizona University in Flagstaff. In one case, for example, the Forest Service paid professional loggers to remove 90% of the trees from a 36-hectare swath of low-altitude ponderosa pine in the Kaibab National Forest near Flagstaff. When a wildfire unexpectedly swept through the area last June, it burned the sparsely populated stand far less severely than the denser surrounding forest.

Pete Fulé, a member of Covington's team, says that drastic thinning of the plot is the reason. With less fuel, the flames could no longer leap from treetop to treetop, he says, and when the fire spread along the ground it ignited only the underbrush. Mechanical cutting is necessary, Fulé says, because thinning forests with controlled burns "has not proven effective, at least in many instances."

But environmentalists say the widespread logging would harm forests, not help them. And some scientists say other combinations of cuts and burns may achieve the same results with less disruption. Covington's approach "doesn't use as wide an array of possible tools as we're using," says Phil Weatherspoon of the Forest Service's Pacific Southwest Research Station in Redding, California. He is involved in an 11-site project that is examining various fire prevention schemes, from mechanical cutting alone to just prescriptive burns. Forest managers, he says, should get data on the potential costs and ecological consequences of various approaches before proceeding.

Heavy thinning also may not address other causes of the recent fires, says Bill Baker, a geographer at the University of Wyoming in Laramie. Before settlers began grazing livestock in western forests, he notes, grasses competed with the young trees that now clog the landscape. "What's missing [from Covington's approach] is an emphasis on restoring grasses," says Baker. "Without it I don't think it's going to work." And Tom Swetnam, an ecologist at the University of Arizona in Tucson, thinks hot, dry weather brought on by La Niña climate patterns may have contributed to the severity of this year's fires—not just the accumulation of combustible young trees. As a result, he says, "there is some danger that [Covington's model] might be overextrapolated in the West."

Covington and his supporters agree that it would be a mistake to treat all forests the same. "We've got a score of forests, all of which burn differently," says Steve Pyne, an environmental historian at the University of Arizona who is involved with Covington's project. But Pyne defends the Arizona site as representative of a common western ecosystem. "I think we understand why [ponderosa pine forests] are burning and what to do about it," says Pyne.

Despite their disagreements, both sides say that federal officials need to do more to prevent future wildfires. "The problem is not that we're doing too much, but that we're not doing enough," says Craig Allen, an ecologist with the U.S. Geological Survey in Los Alamos, New Mexico. The challenge is to come up with a plan flexible enough to fit all the nation's hot spots.

—JOHN S. MACNEIL

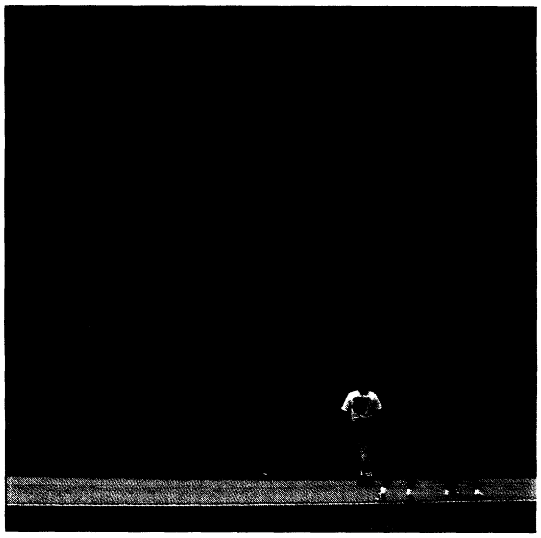
SEDIMENTARY GEOLOGY

Homegrown Quartz Muddies the Water

Next to volcanoes or earthquakes, mudstones are hardly a glamorous subject for geologists. But these widespread strata are an important source of hydrocarbons that migrate into petroleum deposits, and they can reveal much about Earth's history—if they are read correctly. Now a team of geologists has found that a telling feature of many mudstones may have been misinterpreted, throwing into question conclusions about everything from climate to ocean currents.

Mudstone consists mostly of clay, washed from the land to the sea. It also contains fine grains of quartz. The size and distribution of these grains can reveal how far they traveled from shore, the strength of the currents that carried them, or even whether they took an airborne journey from a desert. Such inferences assume that quartz silt, like the clay, came from the continents. However, Jürgen Schieber of the University of Texas, Arlington, and his colleagues show in this week's issue of *Nature* that in some mudstones, most if not all of the quartz silt may have formed in place, probably from the dissolved remains of silica-bearing organisms.

If this kind of homegrown, or authigenic, quartz silt is common, geologists may need to reexamine some of their reconstructions of past environments, including climate. A new "silica sink" could also affect the calculations of how much dissolved silica drifts between mudstone and sandstone. This migration is a prime concern of petroleum geologists, because silica can plug up the pores in rock that might



Look again. New ideas about quartz silt may make geologists rethink their analyses of ancient environments.

CREDITS: (TOP TO BOTTOM) D. KRAUSS/AP; J. SCHIEBER/UNIV. OF TEXAS, ARLINGTON