or 4, he says. Longini and his colleagues found the mean to be about 2, although in some runs there were no secondary cases.

No simple answers

Earlier this month, a group of smallpox modelers met behind closed doors with officials from the Department of Health and Human Services at the John E. Fogarty International Center, part of the National Institutes of Health in Bethesda, Maryland, to compare and discuss their work. Some of those who attended say that there were great differences among the models. Not surprisingly, their gloominess had a major effect on the chances of success for the ring vaccination strategy. Longini, for instance, says his model shows that ring vaccination, even when it's started only after the 25th case of smallpox, can contain an epidemic almost as well as mass vaccination, provided that at least 80% of those exposed can be found and vaccinated. But a model by Edward Kaplan and colleagues at Yale University comes out more in favor of mass vaccination, others say.

"There are serious disagreements, and they're well founded," says Fogarty's Ellis McKenzie, who organized the meeting. But such differences can help clarify the debate, he asserts. "One of the important things modeling forces you to do is put all your assumptions on the table, which is extremely helpful." Until now, he adds, U.S. epidemiologists and public health officials have not been very interested in how mathematical models could aid disease control—in contrast to their counterparts in the United Kingdom, where the field has been thriving. Now, that attitude has changed, as has almost everything since 11 September.

–MARTIN ENSERINK

ASTROPHYSICS

For Whom the Stars Toll

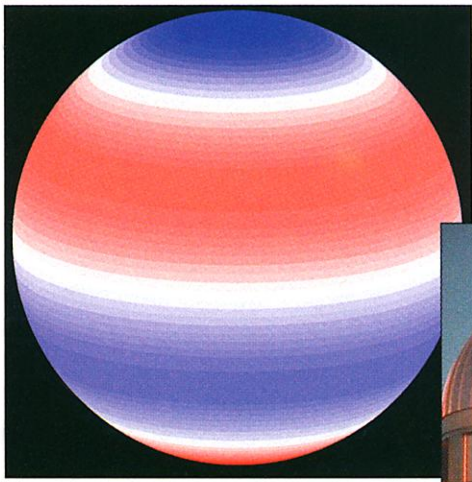
In the new field of asteroseismology, researchers are hoping to peer into stars by studying tiny oscillations of their gaseous surfaces

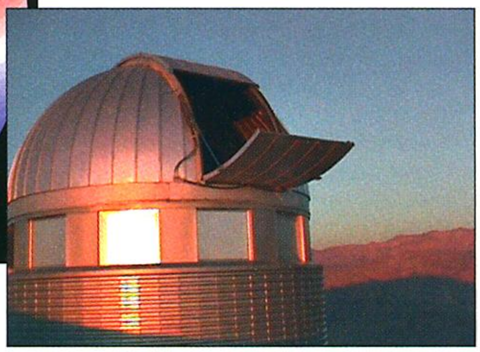
It is said that a blind musician can recognize a Stradivarius from its sound and even sense the occasional crack in its top plate. Similarly, astronomers hope that they will soon be able to detect the provenance and health of stars by listening to their sound.

For decades, solar physicists have extracted huge amounts of data about the interior of the sun by studying vibrations of its surface, a field that has become known as helioseismology. Over the past few years, astronomers have detected, across vast distances, similar vibrations in a few other stars. Earlier this month, a team reported for the first time the existence of vibrations in a giant star, 10 times the size of our sun. The new field of asteroseismology is taking off, and researchers hope it will provide a wealth of data on the size, density, temperature, age, structure, and chemical composition of stars. "Asteroseismology will become an extremely important tool in astrophysics," says Douglas Gough of Cambridge University.

The complicated oscillations of the sun's surface that physicists first spotted in the 1960s have periods of about 5 minutes. They are now known to be caused by turbulence and convection of hot gas in the outer mantle of the sun. The surface responds to these motions by ringing like a bell, at frequencies determined by the sun's physical properties and internal structure. These movements of the sun's surface are now tracked daily by satellites such as the U.S.-European Solar and Heliospheric Observatory (SOHO).

Astrophysicists are eager to know if their model of how the sun works also applies to other stars, but detecting similar oscillations at such distances has proved extremely difficult. It's little wonder: The quivering undulations of the solar surface have an amplitude of less than 25 meters and move at velocities well below 1 meter per second. And for distant stars, which appear as mere points of light from Earth, motions of different parts of the star tend to cancel each other out, giving an overall impression of a motionless surface. As a result, 10 years ago asteroseismology seemed like wishful thinking.





Starquake. Oscillation patterns on Xi Hydrae, such as that above, were spotted using the Leonard Euler telescope in Chile.

CREDIT: (LEFT) ESO

But in spring 1994, a team led by Hans Kjeldsen of the University of Aarhus in Denmark succeeded in detecting oscillations in the star Eta Bootis, 38 light-years from Earth. This star is larger and more massive than the sun and so should oscillate more slowly. By measuring subtle changes in the relative intensities of spectral lines, Kjeldsen and his colleagues deduced temperature changes of a few hundredths of a degree with periods of about 20 minutes. Other astronomers looked for corresponding Doppler shifts in the light from the star's heaving surface but were unable to confirm the findings, mainly because the star rotates quickly, making Doppler measurements more difficult. "Not everyone believed our results," says Kjeldsen.

The breakthrough came in 1999 and 2000, when astronomers finally measured minute variable Doppler shifts in the light from nearby stars Procyon and Beta Hydri. Detecting a star's surface moving at just 50 centimeters per second had become possible thanks to extremely sensitive spectrographs that astronomers had also used to look for extrasolar planets. In fact, for the observations of Beta Hydri, the team headed by Tim Bedding of the University of Sydney, Australia, also included the renowned planet hunters Geoff Marcy of the University of California, Berkeley, and Paul Butler, now at the Carnegie Institution of Washington in Washington, D.C.

Soon afterward, astronomers at the University of Geneva, Switzerland, detected vibrations on Alpha Centauri A, our sun's nearest stellar neighbor. They used the CORALIE spectrograph on the Swiss 1.2-meter Leonard Euler telescope at La Silla, Chile, which is also used for planet hunting. "It's a fantastic instrument," says Kjeldsen. "The results are just amazing." The surface of Alpha Centauri A was clocked at just 35 centimeters per second.

But what about stars very different from our sun? For giant, slowly oscillating stars, astronomers need to keep their spectrographs extremely stable and well calibrated over long periods and might need more than one instrument to keep watching during several oscillations. This month, a large collaboration of European astronomers announced using the Euler Telescope and a similar instrument at La Palma in the Canary Islands to observe the old giant star Xi Hydrae twice per hour for a month. It oscillated, they found, once every 3 hours. "Eventually, we hope to deduce the internal structure of stars in each possible evolutionary stage," says team member Conny Aerts of the Catholic University of Leuven, Belgium.

Gough says it's not yet possible to deduce detailed stellar properties from asteroseismology data. "But right now, we have so few measurements of this kind that any new observation is of interest, especially for an evolved star" such as Xi Hydrae. "The observed frequencies fit the theoretical expectations, and that's comforting," he says. Already, other groups are focusing on stars with special properties, such as compact dwarfs and stars with low abundances of heavy elements, and later this year the Euler Telescope will be equipped with a much more sensitive spectrograph.

The big breakthroughs, however, will have to await the launch of dedicated asteroseismology satellites. From space, sensors will be able to measure tiny brightness fluctuations rather than Doppler shifts, enabling them to scan many more stars for vibrations and study fainter stars. In December, Canada will launch a small asteroseismology satellite called MOST, and 2 or 3 years later, Denmark and France hope to launch their own missions, dubbed Rømer/MONS and COROT.

But these space pioneers will likely be eclipsed by an orbiting observatory called Eddington that the European Space Agency plans to loft in 2007 (see p. 1585). "Its final design could benefit from the preliminary results of the other missions," says Gough. "Without any doubt, space observations are going to transform this field, just like they did with helioseismology." **–GOVERT SCHILLING**

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

SUSTAINABLE DEVELOPMENT

Cash-Strapped Fund Struggles To Make Science a Priority

Earlier this month, donor nations failed to agree on a budget for the Global Environment Facility. The crisis could undermine nascent efforts to strengthen its science base

CAMBRIDGE, U.K.—When a pair of ecologists unveiled an ambitious proposal 5 years ago to triple the size of South Africa's Addo Elephant National Park, they had no trouble convincing peers that the idea was sound. As a recipe for sustainable development, their plan offered all the right ingredients: thousands of new ecotourism jobs for the depressed Eastern Cape region; a refuge for more than 400 bird species, including the world's largest gannet colony; ample breeding grounds for elephants; and hundreds of kilometers of new fencing to protect six of the country's seven biomes, from the spectacular coastal dunes in Alexandria to the fragile Sundays River estuary. All that ecologists Graham Kerley and André Boshoff of the University of Port Elizabeth needed to drum up were political support and the $40 million it would take to make the Greater Addo National Park a reality.

Their quest for a Greater Addo came to a satisfying conclusion earlier this month, when the governing body of the Global Environment Facility (GEF) approved a $5.5 million grant. Even before the decision was made, the megafund's promise of support had provided the leverage that Kerley and Boshoff needed to convince South African National Parks and the government to embrace their proposal and to raise the rest of the money from private donors. To enthusiasts, this is exactly what GEF is all about: getting environmentally sound initiatives off the ground.

Taking off. GEF funding was crucial to starting work on Greater Addo National Park and its famous gannetry.

But many other projects in GEF's pipeline were not so lucky. At a parallel meeting earlier this month, the fund's donor nations failed to agree on GEF's next budget. The United States has resisted calls to increase GEF's 4-year funding from $2.2 billion to $3.2 billion to cope with a mandate recently broadened to cover desertification and persistent organic pollutants. A Treasury Department official attributes the reluctance to pony up funds to what the United States views as GEF's inadequate monitoring of whether grant money is spent wisely, as well as an intention to catch up on arrears: The United States currently owes the fund $220 million. The uncertainty leaves dozens of projects in limbo, including 16 that have already been delayed by funding shortfalls. In addition, GEF's Scientific and Technical Advisory Panel (STAP) had to cancel some of its initiatives, including a workshop on how to clean up organic pollutants.

The belt-tightening has brought to a boil what many STAP members view as the fund's most pressing issue: weak scientific underpinnings of many projects. "Given that resources are scarce, it is absolutely critical that scientific input is sought as a basis for GEF policymaking," says new STAP member Leonard Nurse, a coastal ecologist at the University of the West Indies. Adds Al Hammond, senior scientist of the World Resources Institute, who recently took part in a major outside review of GEF's operations: "If we are serious about getting scientific advice, then we have to change the system."

Since being set up a decade ago to fund the United Nations Conventions on Biological Diversity and Climate Change, GEF has spent $4.2 billion on more than 1200 projects and catalyzed an additional $12.7 billion in matching funds from governments and private investors. It funds proposals from the U.N. Development Programme, the U.N. Environment Programme, and the World Bank, which will oversee the Greater Addo project.

In the run-up to its meeting held earlier this month in Washington, D.C., GEF's governing council commissioned a major review

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