each hole powered quasars, while great whorls of more distant gas gradually collapsed inward to form the galaxy's stars. An opposing hypothesis holds that galaxies coalesced first, and then black holes slowly grew at their hearts. A popular third model, which astronomer Virginia Trimble of the University of California (UC), Irvine, calls the "potato-salad model," maintains that galaxies and their black holes matured simultaneously. "Of the three possibilities, this one always seemed the most intuitively obvious," says Trimble.

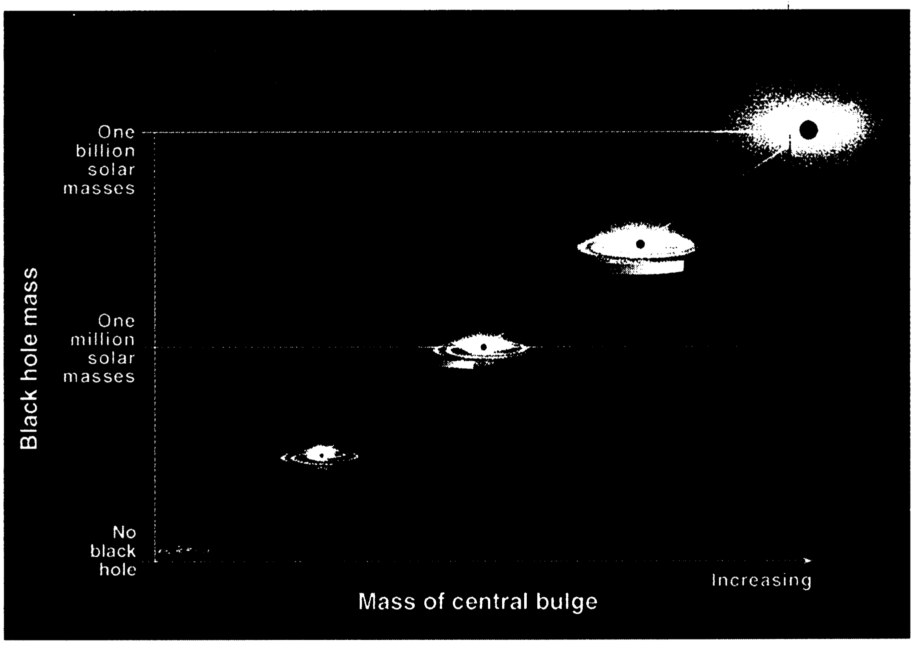
The best census to date of massive black holes justifies that intuition: Researchers reported here last week at a meeting of the American Astronomical Society that giant black holes and their host galaxies appear to be cosmic siblings that grew up at the same time. That conclusion rests on a newly unveiled relationship between the masses of black holes and how tightly gravity binds together the billions of stars around them.

A team of 15 astronomers used a spectrograph aboard the Hubble Space Telescope to peer at the centers of galaxies within 120 million light-years of the Milky Way. The team found eight new black holes and included six more new ones recently discovered by other scientists in its study, bringing the number of well-identified massive black holes to 33. That's enough for a good statistical analysis, says team member Richard Green, director of Kitt Peak National Observatory in Tucson, Arizona. "Our knowledge about black holes has moved beyond individual detections to a real look at the population," he says.

The spectrograph revealed the rapid orbital motions of stars in the core of each galaxy, providing a firm estimate of the mass of the hidden black hole. Those masses ranged from 3 million to 2 billion times the mass of our sun. Then the team went beyond previous analyses by examining how stars move throughout each galaxy's central "bulge," a spherical cloud containing billions of suns. Those stars are too distant to feel the gravitational pull of the black hole, says astronomer Karl Gebhardt of UC Santa Cruz. Instead, their orbits through space reveal the mass and compactness of the overall bulge. That's a measure of how tightly the galaxy's parent gas cloud collapsed in on itself in the young universe.

The team was surprised to find a near-perfect correlation between the orbital speeds of these far-flung stars in the galactic bulges and the masses of the black holes in the middle. The more massive the hole, the faster the stars throughout the bulge moved. "Normally, we don't see such a tight relationship," Gebhardt says. "It's a slap in the face that something fundamental is going on."

That something, says astronomer John Kormendy of the University of Texas, Austin,



In tandem. Orbital speeds of stars (curved arrows) suggest that black holes and galaxies grow up together.

CREDIT: ADAPTED FROM NASA AND K. GEBHARDT/LICK OBSERVATORY

almost certainly is an evolutionary partnership between galactic bulges and massive black holes. "If black holes are unusually massive whenever galaxies are unusually collapsed, then the black hole masses must be determined by the collapse process," Kormendy says. "The major events that made the bulges and the black holes were the same events." An alternative explanation for the partnership between bulges and black holes—that massive black holes arose first and then attracted massive bulges around them—is much less palatable, he notes. Baby black holes of such size would ignite powerful quasars, and their intense radiation pressures would drive apart the cocoons of gas around them rather than drawing them in tightly.

Other astronomers aren't quite ready to discard alternative scenarios. "The new correlation is impressive," says Andrew Wilson of the University of Maryland, College Park. "But I think we have a long way to go before we understand the symbiosis between black holes and galactic bulges." Trimble sounds another caution: "It's difficult to know whether they have studied a really representative sample of galaxies." If Hubble takes a broader census of black holes in galaxies chosen at random and finds a similar pattern, she says, more astronomers will find the case convincing.

The study raises another puzzle: Each black hole is about 1/500th as massive as the bulge of stars it inhabits. No one knows why that figure is so consistent from one galaxy to the next, although Kormendy views it as another indication that the growths of galaxies and black holes are intimately linked. Outpourings of energy from quasars may stall torrents of gas from feeding black holes when they reach a particular size in relation to their host galaxies, says astrophysicist David Merritt of Rutgers University in Piscataway, New Jersey. However, no models or computer simulations have yet shown how nature arrives at that magical ratio.

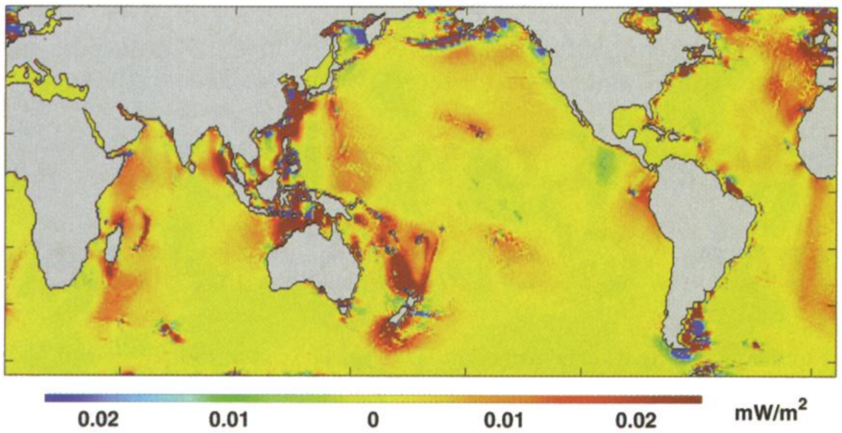
—ROBERT IRION

OCEANOGRAPHY

Missing Mixing Found In the Deep Sea

Climate modelers thought they could get away with a simple-minded ocean. In their simulations of how the sea's ponderous flows of water and heat affect climate, including future greenhouse warming, they assumed that something—they were vague as to what—evenly stirred the world ocean from top to bottom around the globe. But oceanographers gauging the tides of the world's seas from a satellite perch have found intense patches of tidally driven mixing deep within the open ocean. Once modelers include these patches, they should see some changes in model predictions of global warming. Climate prediction models "have a long way to go," says oceanographer Raymond Schmitt of the Woods Hole Oceanographic Institution in Massachusetts, before they match the tidal mixing of the real ocean.

The study of tides has already come a ways. "Tides are considered an old subject, a 'solved problem,' of no interest to most oceanographers," laments physical oceanographer Carl Wunsch of the Massachusetts Institute of Technology. Beginning early in the 18th century, it became obvious that the moon raises sea level by meters along the



Deep mixing. Stirring (red) occurs in the deep sea where tidal currents cross rugged sea floor.

CREDIT: (TOP) G. EGBERT AND R. RAY/*NATURE*

shore, although by only a few tens of centimeters in the open ocean. Where the water is shallow enough, thinking went, tidally induced currents drag on the bottom and stir the shallow seas and waters of the continental shelves. Thus, through the tides, the moon's orbital energy slowly trickles into stirring the shallow ocean.

But although tidal mixing seemed to be solved, some loose ends remained. It wasn't clear to everyone that the shallow ocean could account for the dissipation of all the tidal energy the moon imparts. And oceanographers had trouble with what they call the conveyor belt, which carries heat from the tropics to the poles. Dense, cold water sinks into the deep sea near the poles, travels to the tropics, and rises to the surface. To do so, it must mix with warmer, more buoyant waters along the way. Oceanographers have discovered one or two places where tidal currents flowing across a rough sea floor greatly enhance mixing (*Science*, 10 January 1997, p. 160). But they have found only a tenth of the mixing required to lift deep waters.

Oceanographers needed a global tide gauge, which they found in the TOPEX/POSEIDON satellite. Every 10 days for 7 years, it has measured the height of the tides over the world ocean to an accuracy of about 1 centimeter. In this week's issue of *Nature*, geophysicists Gary Egbert of Oregon State University in Corvallis and Richard Ray of NASA's Goddard Space Flight Center in Greenbelt, Maryland, report how they used TOPEX/POSEIDON altimeter data to map tidal currents, tidal energy, and finally where tidal energy was being dissipated and mixing the ocean. Shelves and shallow seas such as the Yellow Sea off Asia show up clearly as areas of strong tidal dissipation, but some deep-sea, rough-bottomed areas show considerable mixing as well—the ridge joining the Hawaiian Islands, the Mid-Atlantic Ridge, and ridges of the southwest Pacific, among others. All told, open-ocean tidal mixing seems to account for enough energy dissipation to keep the conveyor belt running.

"That's supportive of deep tidal mixing," says Wunsch. "The answer is interesting." It reaffirms the theoretical inference that "mixing is the driving force" behind the conveyor belt, says Schmitt. If not for tidal mixing in the deep sea, he notes, the ocean would fill to near the top with cold water and the conveyor would shut down. Because deep-sea tidal mixing determines the rate at which the conveyor runs, changes in the way tidal currents interact with the bottom could have changed the way the climate system worked in the past, Wunsch notes. The rearrangement of the continents and sea-floor ridges in plate tectonics may have altered tidal mixing, for example. And the uniform mixing of climate model oceans—in contrast to the actual patchy mixing—could skew model forecasts of ocean behavior and therefore greenhouse warming. Those are far-reaching conclusions to draw from imperceptible tidal bulges on the open sea.

–RICHARD A. KERR

CLINICAL TRIALS

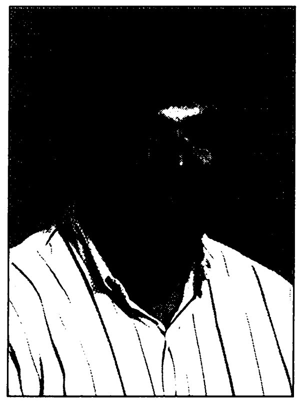
Harvard's Koski to Lead Human Subjects Office

As Congress steps up oversight of human clinical trials, the Administration is getting a high-level manager of its own to watch out for the interests of volunteers in U.S.-financed research. As expected, Secretary of Health and Human Services (HHS) Donna Shalala last week named anesthesiologist E. Greg Koski, 50, to run a new HHS Office for Human Research Protections (*Science*, 26 May, p. 1315).

One of Koski's first jobs when he takes over in September will be to conclude more than 170 pending investigations into alleged infractions of regulations governing human experimentation. Koski may also be swept into a debate on the adequacy of those regulations. Last week a bill, H.R. 4605, was introduced by Representatives Diana DeGette (D–CO), Henry Waxman (D–CA), and John Mica (R–FL) that would extend HHS's authority over patients in federally funded studies and certain private studies that are not now subject to federal monitoring. Arguing for a "comprehensive reform," the sponsors propose to bring all human research under a single standard, "independent of setting and funding source." They also would like to create a "nonprofit entity" to accredit the local Institutional Review Boards that examine and approve clinical trials.

Koski, an M.D.-Ph.D. associate professor at Harvard Medical School in Boston, has spent 30 years in the Harvard community, most recently as director of human research affairs for Partners HealthCare System Inc., which oversees the Massachusetts General Hospital in Boston and other Harvard-affiliated hospitals. As chief U.S. protector of research subjects, Koski will report directly to the assistant secretary of health, Surgeon General David Satcher. An agency reorganization that created his job at HHS also created a 12-person advisory panel—not yet named—that will give outsiders a chance to drive policy from the back seat.

Koski could not be reached for comment, but scientific leaders say they welcome him to Washington. Jordan Cohen, president of the Association of American Medical Colleges, said last week that Koski "is highly respected within the academic medical community and brings to the new office a strong track record in the area of human subject protections." The administration, he added, "is to be applauded for attracting a person of Dr. Koski's caliber." Cohen also supports H.R. 4605.



Clinical czar. Greg Koski will oversee federal efforts to protect patients.

But Vera Hassner Sharav, a leader of one of the patient advocacy groups that has faulted the government for weak enforcement of regulations, Citizens for Responsible Care and Research in New York City, offers a more wary endorsement of HHS's new scheme. Sharav says she is concerned that a boost in the status of the human subjects office, formerly headed by Gary Ellis, does not necessarily confer independence. "The new office," she says, "should be judged on its actions—on how vigorously and expeditiously it investigates allegations of research violations."

–ELIOT MARSHALL