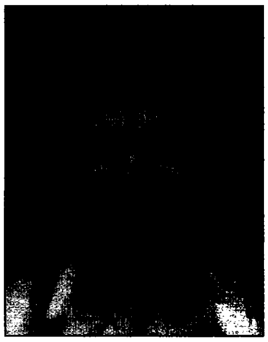
institutions. Located just a few miles down Interstate 95 from Princeton, his university has seen several of its biggest names alter their commutes recently. This year, in what Langacker calls a "devastating" loss, one of the world's most respected astrophysicists—Paul Steinhardt, who had been at Penn for 17 years—left the group of junior faculty he had been leading. In his move to Princeton, his family changed houses, but Steinhardt's wife, a professor of Chinese art history, was able to keep her position at Penn.



DAVID WEITZ
Pennsylvania to Harvard, 1999

"Penn was always extremely generous and supportive throughout my career there," says Steinhardt, "but they can't create an astrophysics department of the quality here out of the blue." Respecting Steinhardt's reasons for moving, Penn made no counteroffer, but it did swing into action when Princeton began recruiting materials scientist David Weitz. After a move from Exxon 3 years ago, Weitz had seen his reputation skyrocket as his research focus—the physical properties of biological materials, colloids, gels, and foams—became more familiar in academe.

The university put together a package worth more than $1 million, says Langacker, including a big salary increase, another faculty position in the field, and a center for "soft condensed matter" that Weitz would direct in exchange for a reduced teaching load. Ultimately, Penn lost out—when Harvard made "what I thought was a really outstanding offer," says Weitz, including a large amount of start-up money, a relocation package, and the chance to take all 10 of his students with him. "It's a job-seeker's market," says Weitz.

Just up the road, Rutgers University in New Jersey has seen its prized research group working on the high-profile topic of string theory—a mathematical quest for a unifying theory of particles and forces—become a hot commodity. Starting a decade ago, Rutgers built one of the premier groups in the field, luring four top theorists: Nathan Seiberg, Steve Schenker, Dan Friedan, and Tom Banks. But when string theory caught fire, other universities began eyeing this reservoir of talent. "What happened was they were successful—in some sense too successful," says Paul Leath, chair of the department of physics and astronomy at Rutgers. Seiberg has left for the Institute for Advanced Study in Princeton, and Schenker is at Stanford University. Banks is also considering leaving, says Leath. "We offered them everything you could imagine" to stay, says Leath, including sky-high salaries, new infrastructure, and fresh research funds.

Such bidding wars take a toll on universities, says one Nobel laureate. "I recognize that superstars can create real intellectual excitement and be a magnet so that a major new strength can be created," he says, but excessively lavish packages can "divert precious resources from others who could better use the money. I am not in favor of the 'free-agency' aspect of recruiting," adds this laureate.

Still, some physicists think the free agentry could be a sign of a broader stirring in the long-stagnant job market in physics, even though statistics compiled by the American Institute of Physics don't show any trend so far. "I was just in a committee meeting last week," says Tremaine, "and we realized that nine out of 10 people at the table either had moved in the last couple of years or were contemplating a move." Others note that the value of endowed academic chairs has risen with the stock market, increasing the odds that people can be attracted to fill openings that do exist.

For the departments on the losing side, there's another silver lining: the chance to recruit a new star. Toronto's Sinervo sweetened the package that had been put together for Mason and offered it to Louis Taillefer, a star materials scientist at McGill University in Montreal. Taillefer had no interest in leaving Canada, but "as soon as it became clear that Louis was mobile, other institutions moved in," says Sinervo, who then had the pleasure of outbidding McMaster University, Simon Fraser University, and the University of British Columbia. Taillefer now occupies Mason's former faculty slot in Toronto.

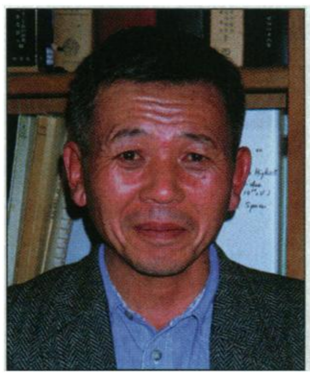
–JAMES GLANZ

GAMMA RAY ASTRONOMY

New Ground-Based Arrays to Probe Cosmic Powerhouses

Built at a tiny fraction of the cost of satellites, these telescopes should help unlock the mysteries behind these high-energy sources of photons

TOKYO—Gamma rays are a signature of the most powerful and puzzling phenomena in the universe—gamma ray bursts, supernovae, and the black hole–powered infernoes called blazars. But scientists' view of these high-energy photons has been blurry at best. Blocked by the atmosphere, they have been studied mainly from satellites, such as NASA's Compton Gamma Ray Observatory. But the satellite-based detectors have poor angular resolution, and the highest energy gamma rays elude them. To get a better view of the gamma ray sky, astronomers are going back to where it can't be seen directly—back to the ground.



CANGAROO kid. Japan's Tadashi Kifune leads new facility in Australia.

In a flurry of construction in deserts and on mountain peaks, they are building arrays of reflectors and light detectors designed to pick up the faint glow produced when gamma ray photons slam into the upper atmosphere. The University of Tokyo's Institute for Cosmic Ray Research (ICRR) has just gotten approval to expand its present single 7-meter telescope in the Australian outback, called CANGAROO, to an array of four 10-meter telescopes. The Max Planck Institute for Nuclear Physics in Heidelberg, Germany, is developing the components for an array of four 10-meter telescopes to be built in central Namibia. A second Max Planck physics institute, in Munich, leads a group including Spanish and Italian universities and institutes building a single 17-meter dish, called MAGIC, at the Roque de los Muchachos observatory on La Palma in the Canary Islands. And the Whipple Observatory of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, is expecting a funding decision within the next few weeks on a proposal to build seven 10-meter telescopes on Mount Hopkins in southern Arizona.

"This is a poor man's approach to gamma ray astronomy," says Trevor Weekes, principal investigator for the Whipple project, called VERITAS. VERITAS is the most expensive of the projects, but at $16.6 million, it is a fraction of the cost of a gamma ray satellite. Even at that bargain price, Weekes and his fellow gamma ray astronomers are

CREDIT: (BOTTOM) D. NORMILE

expecting a big scientific payoff. The arrays should allow astronomers to track down the sources of gamma emissions that are now mysterious, as well as to observe gamma rays at energies that are now invisible. And the global coverage should allow astronomers to keep a continuous watch for short-lived sources, such as gamma ray bursts.

Gamma rays also provide astronomers with a new window to look upon a universe now known mainly from optical, radio, and x-ray observations. "The feeling is that for our understanding of the evolution of the universe, as well as what is going on in specific processes, this nonthermal component is as important as the thermal component, and we know a lot less about the nonthermal universe," says Werner Hofmann, one of the leaders of the German project in Namibia, called HESS.

Satellites were the first choice for gamma ray observations because gamma rays from space "never get closer than 20 kilometers of us," Weekes says. But satellites have severe limitations. They are necessarily small, limiting the number of photons they can gather. And gamma rays with energies more than about 10 GeV (giga–electron volts, or 10 billion electron volts) elude the small satellite-based detectors, which work by absorbing gamma rays in a dense material or by tracking the electron-positron pairs that result from gamma ray interactions in a gas-filled chamber. Both limitations are a liability for researchers hunting down the rare numbers of TeV (trillion-electron-volt) gamma rays.

An array of arrays. New telescopes to indirectly detect incoming gamma rays are sprouting in Australia *(inset)*, Namibia, the Canary Islands, and Arizona.

SOURCES: INSTITUTE FOR COSMIC RAY RESEARCH, MAX PLANCK INSTITUTE, AND HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS; INSET: COLLABORATION OF AUSTRALIA AND NIPPON FOR A GAMMA RAY OBSERVATORY IN THE OUTBACK

Searching for a way around that problem, astrophysicists relied on the fact that gamma ray photons create a cascade of charged particles when they slam into the atmosphere. These charged particles create a faint glow of light, known as Čerenkov radiation. Atmospheric Čerenkov telescopes, as they are called, gather and focus this light on a camera or other light sensor. The pattern of the Čerenkov radiation leaves clues about the energy and direction of the original gamma ray photon. A Čerenkov telescope on the ground can be as large as funds allow, overcoming the sensitivity limits that plague satellite detectors, and the atmospheric Čerenkov technique has proven capable of detecting gamma rays of from about 200 GeV to 50 TeV.

Although the principle of the atmospheric Čerenkov telescopes has been known for decades, a major challenge was learning to discriminate between gamma rays, which are believed to come from point sources, and cosmic rays and other background noise. Weekes's group at the Whipple Observatory, which built a 10-meter gamma ray telescope in 1968, was the first to demonstrate convincingly that the ground-based technique could work. The technique was taken a step further by the German-Spanish-Armenian High-Energy Gamma-Ray Astronomy, or HEGRA, project in the Canary Islands. It used an array of six atmospheric Čerenkov telescopes and over 200 particle detectors, which caught the secondary charged particles directly. Completed in 1997, HEGRA demonstrated that two or more ground telescopes work better than a satellite in determining the origin of photons. "The Whipple first proved the concept of observing gamma rays from the ground," says Hofmann. "HEGRA proved the value of having an array of detectors."

One of the most significant discoveries by Weekes's group and others using first-generation ground-based telescopes were TeV gamma rays from certain supernova remnants. It had been thought, but never proven, that these remnants, which have pulsars at their cores, are filled with electrons accelerated to velocities close to the speed of light. Such electrons would collide with photons in the supernova cloud and send them winging off through space as gamma rays. This inverse Compton scattering, as the phenomenon is called, creates gamma rays with a distinctive energy spectrum. Observing this telltale energy signature confirmed the presence of electrons at TeV energies. "There is no other way that [the gamma rays] can be produced but by these electrons. There is no ambiguity," Weekes says.

While upholding one theory concerning supernovae, the atmospheric Čerenkov telescopes have so far failed to confirm that the supernovae are the source of the cosmic rays that bombard Earth from random directions. It had been generally accepted that cosmic rays, primarily high-energy protons and atomic nuclei, originate in the expanding shock wave of supernovae. Theory had further predicted that protons within the shock wave would interact with the gases of the interstellar medium and produce gamma rays. But the telltale energy spectrum of gamma rays produced by these hadronic collisions has never been observed, with the possible exception of one observation by the Japanese-Australian CANGAROO group. The next generation of atmospheric Čerenkov telescopes will be more sensitive and, in combination with planned space-based gamma ray detectors, should be capable of probing the entire gamma ray energy range.

Another surprise, from both ground-based and satellite telescopes, has been the detection of gamma rays from blazars, a special class of active galactic nuclei. AGNs, at the centers of some distant galaxies, are believed to consist of a black hole, a surrounding accretion disk of material falling into the hole, and relativistic jets of plasma ejected in two directions perpendicular to the disk. In blazars the jets are thought to point toward Earth, aiming potent gamma rays at us. But theorists have struggled to explain energies as high as those observed (*Science*, 14 November 1997, p. 1225). "We're at a loss to explain the mechanisms that produce these very great quantities of energy," says Charles Dermer, an astrophysicist at the Naval Research Laboratory in Washington, D.C. He hopes that gamma ray observations of AGNs made with the new generation of ground-based telescopes can be coupled with x-ray and ultraviolet observations to yield clues on how black holes extract energy from accretion disks and eject it in jets.

All in all, astronomers believe the new wave of ground-based instruments will throw wide open a new window on the universe. "The early 21st century," says Tadashi Kifune, primary investigator for CANGAROO, "will be the era of gamma ray astronomy."

–DENNIS NORMILE