

A New Generation of Gamma-Ray Telescopes Prepares To Plumb the Nonthermal Universe

Supernovae. Active galactic nuclei. Gamma ray bursters. Pulsars. The mysteries of these and other spectacularly violent phenomena of the heavens may be unlocked with the help of four new atmospheric Čerenkov imaging telescopes, which are set to go on-line in the next few years in the US, Namibia, Australia, and the Canary Islands. The telescopes will look for showers of Čerenkov radiation triggered by high-energy gamma rays plowing into Earth's atmosphere.

Only a handful of very high-energy gamma-ray emitters have been observed—the most famous being the Crab Nebula, a supernova remnant with a pulsar at its center. So far, the data points to accelerated electrons as the source of the gamma rays. That, however, makes the question of where the far more abundant cosmic protons come from all the more puzzling. "Protons are the big question," says Trevor Weekes, a pioneer gamma-ray astronomer and spokesman for VERITAS (Very Energetic Radiation Imaging Telescope Array System), the planned US Čerenkov telescope array. "The hope is to find a signal from a supernova remnant, where gamma emission comes unambiguously from the acceleration of protons. It would pin down the origin of cosmic rays." Scientists also expect to discover many more, and new types of, gamma-ray sources, and to use gamma-ray signals for probing extragalactic light to learn about star and galaxy formation.

Narrowing the gap

Gamma rays can be traced back to their sources, unlike charged particles, which make up the bulk of cosmic radiation and whose paths get randomized by interstellar magnetic fields. But they can't penetrate Earth's atmosphere, and instead produce pairs of relativistic electrons and positrons. Moving faster than light in the atmosphere, those particles emit

With more and bigger atmospheric Čerenkov imaging telescopes, astronomers hope to learn much about gamma-ray sources, and to use such sources to learn about galaxy evolution.

a bluish flash—Čerenkov radiation. Most of the pairs' energy goes to gamma rays, however, which again give rise to electron-positron pairs, and so on. The showers die out five or so kilometers above Earth.

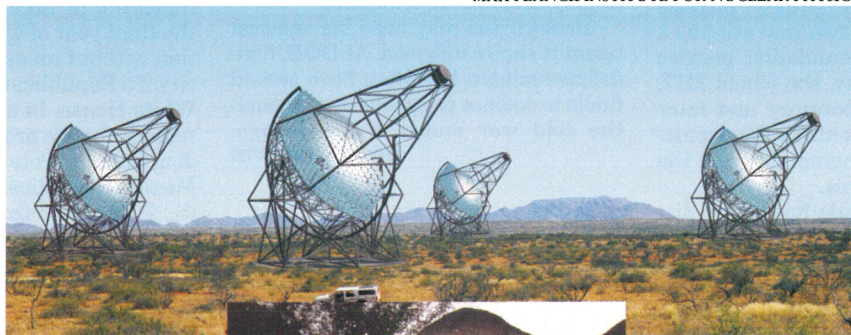
The Čerenkov showers are imaged using tiled spherical mirrors, with

gamma-ray sources can be pinpointed to a few hundredths of a degree.

Figuring out whether gamma rays hail from protons or electrons is tricky, and requires using simultaneous optical, x-ray, and radio data. Eventually, astronomers hope to correlate gamma-ray and neutrino observations, says Weekes. "By putting the two signals together, we should be able to tell a lot about what's going on—we don't expect neutrinos from electron sources."

With the next generation of atmospheric Čerenkov imaging telescopes, the idea is to take a small

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THE FOUR ATMOSPHERIC ČERENKOV IMAGING TELESCOPES that will make up the first phase of the HESS project, superimposed on a photo of their future site in Namibia (top). In the US, Native Americans object to siting the VERITAS array near a sweat lodge where they perform purification ceremonies and other rituals (bottom).

hundreds of photomultiplier tubes at the focal plane to catch the flashes. The intensity, broadening, and shape of the Čerenkov light images are used to calculate the energy and direction of the incident gamma rays, and to pick out showers caused by gamma rays from the more numerous signals triggered by cosmic radiation. The locations of

technological step for a big scientific payoff. Three of the new facilities will be arrays of 10-meter-class Čerenkov detectors, and a fourth will be a single, 17-meter telescope. All four are expected to be roughly ten times more sensitive (able to spot objects that are fainter or further away) than existing Čerenkov telescopes, and to have better background rejection, a bigger collection area, better angular resolution, better energy resolution, and a lower energy threshold.

Gamma rays are more abundant and less attenuated at lower energies, so with the reduced thresholds—about 50 GeV for detection and 100 GeV for spectral resolution for the arrays, and down to 10 GeV for the biggest telescope—the new facilities should detect more sources and, in particular, be more sensitive to extragalactic signals. They will also partially close a gap: The current generation of ground-based Čerenkov telescopes cuts off at about 250 GeV, and space-based telescopes register gamma rays only up to about 20 GeV. Says Patrick Fleury, a French astrophysicist who is involved in both the German-led HESS (High Energy Stereoscopic System) and GLAST, the gamma ray observatory NASA plans to launch in 2005, "It's frustrating to observe objects that manifest above

[the energy gap] from the ground and below [it] from space. It's often occurred—it's the case for [the blazars] Markarian 421 and 501." Narrowing the gap in observation energies, he adds, will give more constraints on cosmic accelerators, allowing better checks between observations and theories.

Comparable competition

The planned arrays will vary in detail, but be comparable in capability, according to scientists on the projects—VERITAS, HESS, and the Japanese-Australian CANGAROO III (Collaboration between Australia and Nippon for a Gamma Ray Observatory in the Outback).

VERITAS is planned as an array of seven 10-meter telescopes arranged in a hexagon, 100 meters to a side, with one telescope at the center. It will be built near its predecessor, the 32-year-old Whipple Gamma Ray Telescope, in the mountains not far from Tucson, Arizona. Most of the \$21 million for construction is expected to come from the Smithsonian Institution, the National Science Foundation, and the Department of Energy, with about 10% coming from partners in the UK and Ireland.

But before the project can go ahead, a resolution is needed to a site dispute with Native Americans, who have a sweat lodge near where astronomers want to build VERITAS. "We are connecting to our spirituality and bringing our Indian community together. We don't want the telescope anyplace nearby," says sweat lodge keeper Cayce Boone. "We would fight it all the way." For its part, the VERITAS team hopes the two communities can coexist. "We don't want to disturb the sweat lodge," says Weekes.

Last fall, the National Forest Service, which manages the land, rejected the VERITAS site request, but it's now reconsidering. As a backup, the telescopes could be built a bit to the west, where, says Weekes, the array wouldn't be as well shielded from artificial light. The forest service is expected to rule on the sites later this year. VERITAS is scheduled to see first light in 2005.

In Namibia, meanwhile, the local community is enthusiastic about hosting HESS (named in honor of Victor Hess, who discovered cosmic radiation in 1912). It will be the country's largest scientific project, and University of Namibia physicist Riaan Steenkamp, for one, hopes it will convince more students to stay home for university.

HESS will be built on the Khomas Highland, about 100 km southwest of Namibia's capital, Windhoek. Construction on the first four 12-meter telescopes starts this summer. They'll form a 120-by-120-meter square, and are scheduled to go on-line in 2002. The plan is to expand to 16 telescopes. Germany is putting up about three-quarters of the building costs, with most of the rest coming from France. The project also has partners in Armenia, the Czech Republic, Ireland, Italy, Namibia, South Africa, and the UK.

And at a former rocket-launching range in Woomera, 500 km north of Adelaide, in Australia, the first of four 10-meter telescopes planned for CANGAROO III is already up and running. A square array with 100-meter spacing, CANGAROO III is scheduled to be completed by 2004.

Construction on the larger, single telescope, MAGIC (Major Atmospheric Gamma Imaging Čerenkov Telescope), is also well under way—it's supposed to start collecting data next year on La Palma in the Canary Islands. In opting

for a larger, single telescope, the project gives up energy resolution to buy a lower energy threshold. In the long run, however, the German-led team, which has partners in a half dozen countries, hopes to expand MAGIC into an array of three telescopes.

More is better

If the planned telescopes are so similar, why build four of them? For one thing, astronomers like to search the skies in both the northern and southern hemispheres—VERITAS and MAGIC, in the north, will focus more on extragalactic gamma-ray sources, while HESS and CANGAROO III, in the south, will have a better view of our galaxy. And scientists from the four experiments plan to collaborate to watch time variations in gamma-ray sources. What's more, the price is right, says HESS's Heinrich Völk: At about \$3 million per telescope, or \$12 million to \$48 million per array, "It's not efficient—politically, organizationally, or financially—to build a big, global experiment."

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Jordan Will Likely Host Middle East Synchrotron Light Source

Jordan is the first-choice site for a synchrotron light source intended to promote peace and science in the Middle East. That outcome of a vote this past April by representatives from 10 of the project's 11 member states is expected to be ratified in late June at a meeting in Amman, Jordan. However, supporters of opening the facility in Armenia, the backup site, continue to campaign for a fresh vote.

Envisioned as a topnotch international facility, SESAME (Synchrotron-light for Experimental Science and Applications in the Middle East) will be an upgraded reincarnation of BESSY I, a synchrotron donated by Germany. Science programs are being planned in, among other fields, biology, physics, materials science, environmental science, and

archaeology. (See PHYSICS TODAY, August 1999, page 54, and February 2000, page 52.)

"At all levels, we are highly committed to this project," says Khaled Toukan, president of Jordan's Al-Balqa' Applied University and a member of the SESAME council. "We want it to be a success, because we want our country to become a center of science in this region, and an active member of international science." Jordan's King Abdullah II has pledged \$1 mil-

