High-energy γ-ray astronomy comes back to Earth

Planned ground-based telescope array could shed light on dark matter and the origin of cosmic rays.

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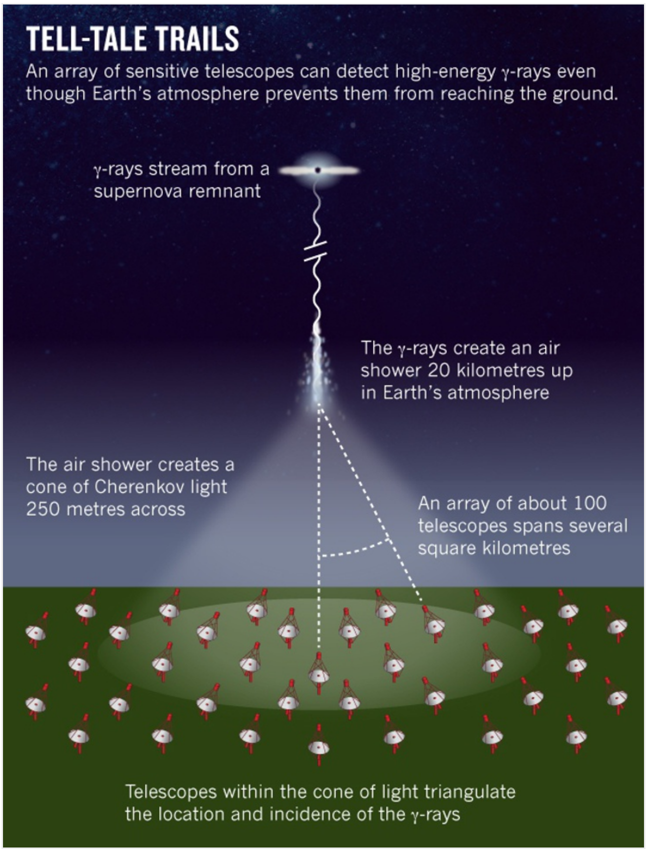
With Earth's atmosphere acting as a near-total shield against high-energy γ-rays, astronomers have traditionally relied on space telescopes to detect them. But plans that will be presented in early July at the International Cosmic Ray Conference in Rio de Janeiro, Brazil, indicate that γ-ray astronomers are betting their future on an ambitious ground-based telescope. On dark, moonless nights, the proposed Cherenkov Telescope Array (CTA) would capture the fleeting trails of blue light that are produced when γ-ray photons, emitted by collapsing stars or gas-guzzling black holes, are absorbed in the upper atmosphere.



"For high-energy γ-ray astronomy, the future is on the ground," says Rene Ong, an astroparticle physicist at the University of California, Los Angeles, who is part of the CTA consortium of more than 1,000 physicists and engineers from 27 countries. Proponents of the CTA say that it would be able to solve two mysteries: the origin of ultra-high-energy cosmic rays and the nature of dark matter. The facility could also test theories of quantum gravity, they say.

In the 1950s, astronomers pioneered the technique of tracking γ-rays by their atmospheric signature (see 'Tell-tale trails'). Three operational ground-based arrays consisting of just a few telescopes have since identified more than 150 high-energy γ-ray sources.

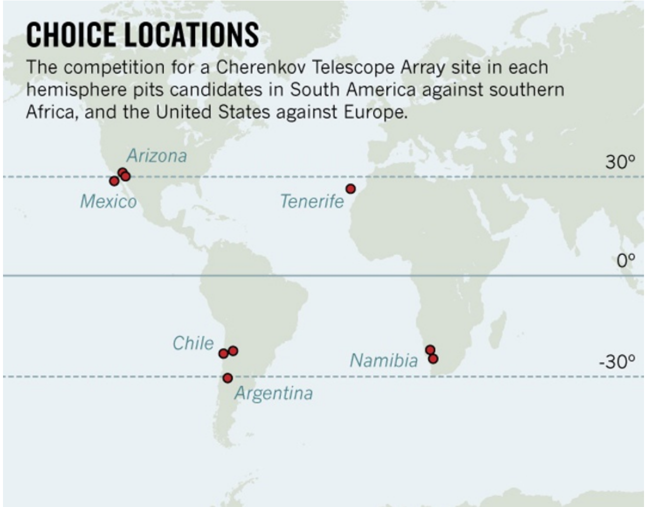
The CTA would have the energy range, sensitivity and angular resolution to find many more. It would consist of two sites, one in the Northern Hemisphere and one in the Southern, each with dozens of telescopes spread over about ten square kilometres. Together, they could identify an estimated 1,000 high-energy γ-ray sources. With a construction start in 2015, the facilities are projected to carry a price tag of €200 million (US$268 million).

The arrays would build on the range of energies up to 100 gigaelectronvolts (GeV) already mapped by the Fermi Gamma-ray Space Telescope, and could cover energies up to 100,000 GeV, a region that has never before been imaged. To achieve the same coverage in space, "you would have to fly an instrument the size of a football stadium," says CTA spokesperson Werner Hofmann of the Max Planck Institute for Nuclear Physics in Heidelberg, Germany. But the CTA's upper-energy limit is still only one-millionth of the highest energy cosmic rays detected so far.

Astrophysicists suspect that the mechanisms that launch the mysterious cosmic rays also emit high-energy γ-rays. And given that cosmic rays — which consist of protons or atomic nuclei — can be bent by galactic magnetic fields on their way to Earth, γ-rays present a more promising way to trace and image the sources because they have a more direct path. These sources have so far proved elusive for cosmic-ray detectors such as the Pierre Auger Observatory in Argentina.

Another motivation for the project is to further the understanding of dark matter, which is thought to make up more than 80% of the Universe's matter. The CTA would be sensitive to the photons given off by the annihilation of dark matter particles, in an energy region much higher than those probed by direct detection experiments and the Large Hadron Collider at CERN, Europe's particle-physics laboratory near Geneva in Switzerland. Hofmann says that the CTA will also be able to test theories of quantum gravity, some of which predict that the speed of light depends on the energy of a photon. By comparing arrival times for photons across an unprecedented energy range, astronomers would be able to see if there is variation in the speed of light, as some theories predict.

Design plans suggest that the CTA would consist of telescopes of three sizes: four 23-metre telescopes (to image the faint trails of lower-energy γ-rays) surrounded by dozens of 12-metre and 2–4-metre telescopes (to capture the rare highest-energy rays). The collaboration's next step is to select sites for the facilities (see 'Choice locations'), a decision due by the end of 2013. There is fierce competition for the Southern site. Notable candidate countries include Argentina, which already hosts the Auger observatory, and Namibia, which is near the South African site of the Square Kilometer Array, a planned network of radio telescopes.



Although funding is not yet secure, Germany has already agreed to support the CTA. The project has also done well in US competitive peer reviews, with the US National Science Foundation in Arlington, Virginia, paying for the production of a prototype telescope. Still, Ong says that it will be vital to convince policy-makers that γ-ray astronomy is as good from the ground as it is in space. "That's critical, because this is a very large project," he says.

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References

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