Final touches. Technicians at Cape Canaveral ready GLAST for attachment to its launch vehicle.

ASTROPHYSICS

GLAST Mission Prepares to Explore The Extremes of Cosmic Violence

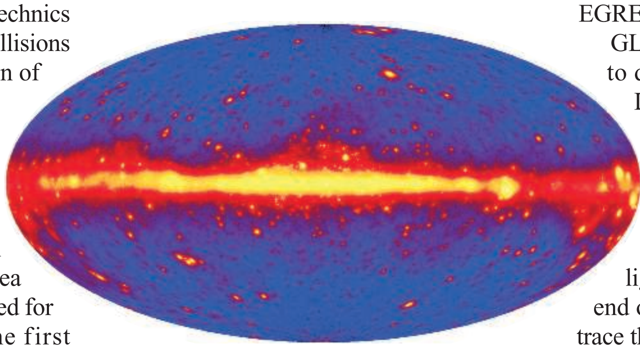
NASA's new gamma ray observatory will probe the most energetic radiation ever studied, the product of cataclysmic events deep in space

In July 1967, U.S. surveillance satellites looking for signs of a Russian nuclear test in space recorded two flashes of gamma radiation. Scientists quickly determined that the high-energy bursts did not come from a nuclear explosion, which would have generated a more sustained stream of gamma rays and also produced lower energy radiation detectable by other satellite instruments. Only years later did they realize that the flashes—named gamma ray bursts (GRBs)—originated in violent events deep in space. In scanning the heavens for an enemy secret, they had stumbled upon a cosmic one.

That serendipitous discovery opened a window on previously unknown phenomena whose signatures lay at the gamma end of the energy spectrum. Since then, astronomers have dispatched a number of gamma ray telescopes into space to glimpse the pyrotechnics unleashed by violent events such as collisions between neutron stars and the emission of particle jets by massive black holes.

Now, researchers are opening the window wider with a new telescope designed to record gamma radiation several orders of magnitude higher in energy than current instruments can detect. NASA's Gamma-ray Large Area Satellite Telescope (GLAST), scheduled for launch next month, will also be the first instrument of its kind to survey the entire sky several times a day, increasing the chances of finding and following extreme astronomical phenomena anywhere in the universe.

Researchers say GLAST's powerful combination of sensitivity and sweep will yield a rich harvest of data that could answer a host of astronomical questions such as how supermassive black holes behave and how cosmic rays originate. A tantalizing possibility is that observations from GLAST will help physicists discover the fundamental nature of dark matter, which makes up 10 times as much of the universe as the familiar matter of planets and stars. The mission represents a convergence of the quests to understand the large and the small, says Rene Ong, an astronomer at the University of California, Los Angeles. "We are just at the start of a very exciting time in astronomy and fundamental physics," he says, noting that unlike data from most previous missions, GLAST's will be available in real time to scientists—and the public—anywhere in the world starting a year after the launch.



Coming attraction. Simulated "gamma ray sky" shows how new observatory will view the universe.

Catching rays

Built over a decade at a cost of $690 million, GLAST is a feat of engineering. Its main instrument is a 3-ton detection system called the Large Area Telescope (LAT), which consists of two devices to track the direction and energy of incident gamma rays—energetic photons of extremely high-frequency electromagnetic radiation. The direction detector is a four-by-four matrix of towers that are essentially layers of tungsten and silicon stacked one on top of another. When a gamma ray slams into a tungsten layer, there's a chance its energy will be transformed into an electron and a positron that are propelled along the path the ray would have taken. As the two particles travel through silicon layers in the stack, they generate currents that reveal their direction. When they emerge from the bottom of the stack, the particles enter a chamber of cesium iodide—the telescope's energy-detecting device—producing a flash of light whose intensity shows how fast they had been moving and thus the energy of the gamma ray.

The stacked design gives LAT a much larger collecting area than previous gamma ray telescopes such as the Energetic Gamma Ray Experiment Telescope (EGRET), which flew on NASA's Compton Gamma Ray Observatory from 1991 to 2000. More collecting area means increased chances of a collision. And that's exactly what's needed in order to detect higher energy gamma rays, explains Steven Ritz, GLAST project scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, because they are so rare that a less sensitive instrument would miss them. As a result, LAT can detect gamma rays of up to 300 billion electron volts, 10 times EGRET's upper limit (see figure, p. 1009).

GLAST has a second instrument designed to detect lower energy gamma rays that LAT would not register. Called the GLAST Burst Monitor (GBM), it's a set of 12 sodium iodide disks and two bismuth germanate disks pointed in different directions, covering practically the entire sky. The disks produce light when struck by photons at the lower end of the gamma spectrum; scientists can trace the direction of the incident rays simply by noting which disk bears the brunt of the collision. GBM will detect rays between 10

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KeV and 25 MeV, overlapping with LAT's lower limit of 20 MeV. "Together, the two instruments give us vast energy coverage," says Ritz, adding that "if GLAST were a piano, it would have 23 octaves."

One of the challenges in designing the system was to ensure that it would run on the small amount of power available from the satellite's solar panels. Robert Johnson, a physicist at the University of California, Santa Cruz, who led the engineering of the tower array, says simplifying the electronics was part of the solution. "We ended up at 160 watts," he says. "That's a couple of light bulbs of power for over 900,000 channels."

Black hole, bright lights

Astronomers will be eagerly scanning GLAST data for clues to what goes on near monstrous black holes that sit at the centers of galaxies. Such objects can be as massive as hundreds of thousands or even billions of stars. As their enormous gravity sucks matter into a whirling disk around them, opposing jets of particles shoot away from their poles at nearly the speed of light. If a jet from such an active galactic nucleus (AGN) happens to be pointed at Earth, astronomers call it a blazar. The process generates radiation across the entire electromagnetic spectrum, including high-energy gamma rays.

The Compton Observatory identified 66 blazars during its time in orbit. Astronomers have since puzzled over how these beasts accelerate particles to such high speeds. GLAST is expected to find thousands of new blazars because of its sensitivity and periodic surveying of the sky, and the data it sends back should provide a sharper, more dynamic picture of these events than Compton did, says Ritz. He expects blazars and AGN to be a "bread and butter" topic for researchers analyzing GLAST data.

Alan Marscher, an astronomer at Boston University, agrees. Last month in *Nature*, Marscher and colleagues presented x-ray, radio, and visible light observations from a blazar, suggesting that the "accretion disk" spinning around the black hole had caused the magnetic field in the galactic center to coil into a spiral, leading to the emission of particulate jets from its core. He says GLAST will help him test the theory by observing how the brightness of gamma radiation from different blazars changes over time. "We expect time delays between the peaks in the flares at different gamma ray energies and relative to the flares in x-ray, visible-light, and radio emission," Marscher says. That signature, he says, could offer a deeper look into the heart of a blazar.

Outracing LHC?

Researchers involved with GLAST call the mission a unique marriage between particle physics and astronomy. Some are hoping to justify that description in grand fashion in the years to come by carving out a prominent role for GLAST in finding the elusive particle that constitutes dark matter.

As its name implies, astronomers cannot see dark matter; only its gravity gives it away. Many theorists think it consists of still-unknown "weakly interacting massive particles" (WIMPs). Detecting WIMPs is one of the goals of the Large Hadron Collider (LHC), the $5.7 billion underground accelerator at CERN that is expected to come on line this summer. But if the hypothesized particles do turn up there, physicists will still need to confirm that they make up the dark matter out in space. That's where GLAST would come in.

According to theory, in the rare event when two WIMPs collide, they annihilate each other and give off gamma rays. Such collisions are most likely in galactic regions where dark matter is densely concentrated.

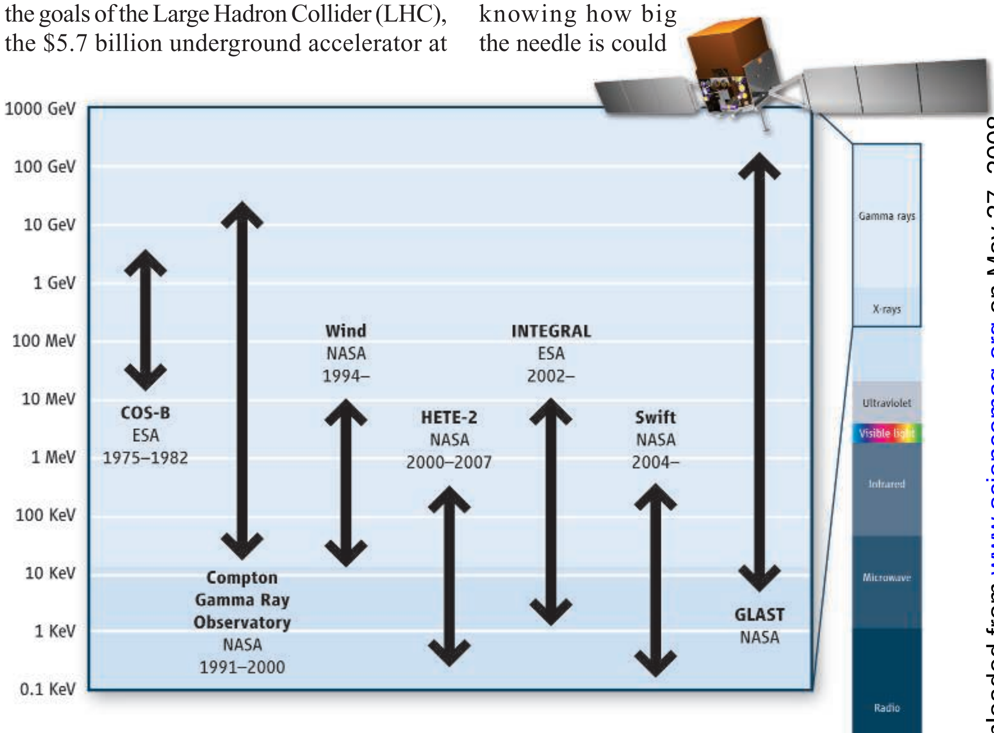
"We would look in those known directions to see if GLAST is picking up an excess of gamma rays," says Johnson, who started his career as a particle physicist before being completely "consumed" by the GLAST project a decade ago. He's now the co-convener of the mission's dark matter science working group. "The dream scenario is that we see the signature of dark matter before LHC turns on," he says with a chuckle. "But we'd be perfectly happy if they saw it first and determined the particle's mass, and then we went out and found it in space."

By the same token, observations from GLAST could help LHC in its quest to identify WIMPs, says Dan Hooper, a theoretical physicist at Fermi National Accelerator Laboratory in Batavia, Illinois. He says LHC will generate such a huge volume of data that any hint from GLAST about the energy released by an annihilating WIMP pair would help LHC scientists to focus their search. "If you are doing this needle-in-a-haystack search, knowing how big the needle is could be key," he says. However, Hooper cautions that gamma rays produced by WIMP collisions could turn out to be too faint for GLAST to see.

When the data start streaming in, researchers will be able to sink their teeth into them for insights into other fundamental problems. For example, says Neil Gehrels, deputy project scientist, GLAST might catch small, primordial black holes in a vanishing act, confirming a prediction by Stephen Hawking that such objects shrink by emitting radiation and eventually evaporate into a crematory flash of gamma rays.

"It could well be that the most interesting observations turn out to be something entirely new and unexpected," says Ritz. If that were to happen, as witnesses to the discovery of GRBs can testify, it would not be the first time.

–YUDHIJIT BHATTACHARJEE



Record breaker. GLAST's instruments can record gamma ray photons 10 times as energetic as the detectors aboard earlier satellites could handle.

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