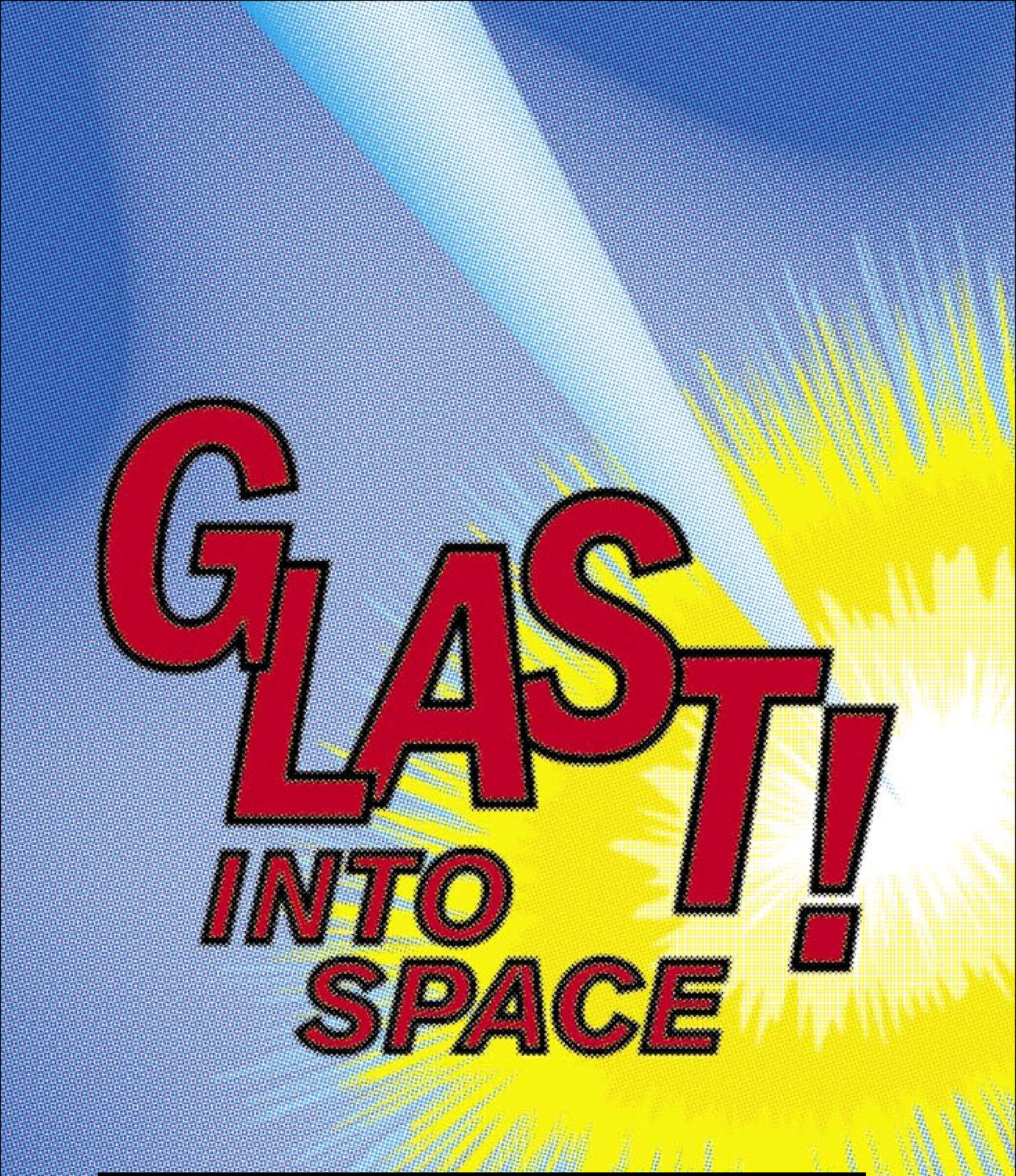
GLAST! INTO SPACE



Particle physics detectors in space will record gamma rays in search of dark matter, the evolution of stars, and nature's most powerful particle accelerators. **By Heather Rock Woods**

Supermassive rotating black holes can emit particle jets that radiate in gamma rays.

Illustrations: Sandbox Studio

Roughly once a day, the universe is rocked by mighty explosions. We don't fully understand what causes the explosions, but we can detect the results: brief, intense bursts of gamma rays, the most energetic photons in the universe. The bursts can show up at any time, in any part of the sky.

Soon a powerful new observatory will be orbiting the Earth, capturing gamma rays that come from bursts and various other sources. The Gamma-ray Large Area Space Telescope (GLAST) will explore the high-energy frontier in space to help solve the mysteries of dark matter, supermassive black holes, and the evolution of stars.

Gamma rays are bards, carrying tales at light speed from the farthest reaches and earliest days of our universe. They are the progeny of wild and violent events, of particles that have been accelerated to fantastic energies, and of dark matter annihilations.

"We're interested in listening to the stories gamma rays are telling us," says Steve Ritz, mission project scientist at NASA's Goddard Space Flight Center.

The joint Department of Energy and NASA project is a true collaboration of particle physics know-how with particle astrophysics savvy. Particle physicists can catch gamma rays so energetic that they defy telescope mirrors and lenses. Particle astrophysicists know where to go to hear the tales, and how to interpret them. And if gamma rays can tell us anything about the identity of dark matter, and many scientists think they can, the results will be spectacularly important to both communities.

The gamma-ray sky

Humans can't see gamma rays. Our eyes only detect photons—that is, particles of light—in a narrow range of energy hovering around two electronvolts. Gamma rays are photons at the extreme end of the electromagnetic spectrum, 100,000 electronvolts (100 keV) and up. They are electrically neutral and always travel at the speed of light.

GLAST will take high-resolution pictures of the invisible gamma-ray sky. Together, the Large Area Telescope (LAT) and the GLAST Burst Monitor (GBM) instruments will investigate the 10 keV to 300 GeV energy range, which includes some x-rays. The observatory will be launched into space to escape Earth's atmosphere, which blocks intense gamma radiation from reaching Earth's surface. The observatory will complete an orbit every 95 minutes, and can view the entire sky in two orbits.

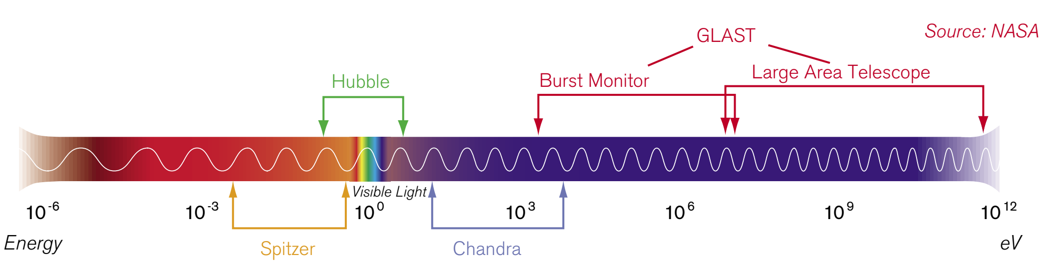
"If you put on gamma-ray glasses, you will see bright point sources, and you will also see a diffuse glow in our galaxy," says Rob Cameron, manager of a group at Stanford Linear Accelerator Center that will operate LAT and process its raw data.

The glow shows up on maps as a bright stripe across the plane of our galaxy. In our galaxy, charged cosmic rays frequently crash into interstellar gas, creating a gamma-ray haze, akin to the misty glow of the Milky Way viewed from Earth on a dark night.

GLAST will work synergistically with observatories operating at different wavelengths, as well as with ground-based telescopes that detect flashes of light in the upper atmosphere made by the most intense gamma rays, energetic enough to plow into the upper atmosphere before perishing.

"You get the most science out by using other kinds of telescopes—optical, radio, x-ray, on the ground, in space—at the same time as GLAST is observing," says Roger Blandford, director of the Kavli Institute for Particle Astrophysics and Cosmology, based at Stanford University and the Stanford Linear Accelerator Center.

GLAST's LAT is the successor to an instrument called EGRET onboard a NASA observatory that provided the first real look at the gamma ray sky and produced spectacular results and discoveries.



Electromagnetic radiation, carried by photons, occurs over a large range of energies, including low-energy radio waves, mid-range visible light, and high-energy gamma rays. NASA missions are looking at different parts of the spectrum: the Spitzer Space Telescope searches in infrared energies, the Hubble Space Telescope observes primarily in visible light, the Chandra X-ray Observatory works with x-rays, and GLAST (with DOE) will look for gamma rays.

"GLAST is an enormous leap in capability over EGRET," says GLAST principal investigator Peter Michelson of Stanford. "It has a broader energy range, better sensitivity, greater clarity. The discovery reach is enormous, and it has the capability to follow up on EGRET measurements and questions."

In one or two days, it will cover the entire sky with the same sensitivity EGRET had after 15 months, allowing GLAST to make observations significant to a broad range of science topics.

Understanding cosmic accelerators

Only the most powerful accelerators in the universe can accelerate particles to energies where they radiate gamma rays. GLAST will help determine how these different accelerators work.

GLAST will observe thousands of active galaxies that emit vast amounts of energy, each with a supermassive black hole at its center. Some emit the energy as jets of particles, bursting forth perpendicular to the plane of the galaxy. The particles radiate gamma rays, which GLAST will see if the jets point directly toward Earth.

"By watching gamma rays, we're watching black holes digest and burp matter," says Michelson. "We will learn a lot about the black holes by watching that."

Pulsars are another kind of cosmic accelerator. Giant stars run out of fuel, get violently crushed by gravity, explode brilliantly as supernovae, and leave a collapsed core as heavy as our sun yet only 10 kilometers across. This extremely dense core—a pulsar—rotates quickly, shaking off electromagnetic radiation in periodic pulses, like flashes of light from a lighthouse.

"We expect to see hundreds of gamma-ray pulsars with LAT and learn details of the emission mechanism," says Cameron.

The search for dark matter

The matter we are familiar with, which radiates photons of various sorts, accounts for only four percent of what exists in the universe. The rest of the matter—called dark matter—does not emit photons. Yet GLAST hopes to find, confirm, or set limits on dark matter by collecting high-energy photons. How could that be possible? Theories predict that when high-mass dark matter particles collide, they destroy each other but create gamma rays with an energy specific to the masses of the colliding particles. With careful analysis, GLAST researchers expect to pick out this dark matter "signature."

A leading candidate for dark matter is a theoretical particle called the neutralino. Neutralinos are part of the hypothesized supersymmetry family that particle physicists call upon to unify the electromagnetic, weak, and strong forces. To learn what makes up a large portion of the universe while simultaneously explaining subatomic occurrences of dark matter will unify particle physics and astrophysics like never before.

Ancient starlight

"Astronomy is a time machine," says Michelson. "GLAST will see some very old photons that come from when the universe was young."

Some of the gamma rays will have traveled for more than 10 billion years, packing with them information about what it was like when they departed, like an elderly refugee carrying a photograph of her hometown, taken when she was a young child.

Gamma rays speed virtually unimpeded and unchanged through the universe. However, there is a small probability that they will interact with starlight and other photons of lower energy and be converted into other particles. GLAST will measure this attenuation in gamma rays to learn how many stars existed in a particular region when a gamma ray flew through.

"GLAST will help us know how long the stars have been shining," says Ritz.

Puzzling gamma-ray bursts

Gamma-ray bursts have no obvious counterpart in other parts of the electromagnetic spectrum.

"Just for a few seconds, those sources in gamma rays are brighter than the entire universe—all stars, galaxies, all radiation in that second," says Michelson. "Then it goes away and is never seen."

Scientists expect to witness some 200 bursts a year, using both GBM and LAT to find them, track where they came from, and determine their energy.

"The engine that powers these explosions is not yet clear," says Ronaldo Bellazzini of INFN Pisa and head of the Italian part of the GLAST collaboration. Candidates include the birth of black holes from massive star collapses, and the mergers of black holes or neutron stars.

Researchers hope the bursts will reveal more about dark energy, the mysterious force that is speeding up the expansion of the universe. GBM can detect bursts that occurred very long ago, extending the known history of past expansion rates.

The oldest bursts might also allow scientists to find signs of gravitons, the postulated particles that transmit gravity. Graviton effects might slow down the highest-energy gamma rays ever so slightly in the course of billions of light-years, making them arrive just after lower-energy gammas from a burst.

Surviving in space

Almost immediately after EGRET's results started streaming in, a few physicists from SLAC and Stanford "talked about what the next technology for a high-energy gamma ray mission might be," recalls Elliott Bloom, co-chair of the SLAC/GLAST Physics Department.

EGRET used 1960s technology, and it was clear to particle physicists that detector technology for colliding beam experiments was the better way to go.

Bill Atwood, then at SLAC, now at University of California, Santa Cruz, went to the whiteboard in Bloom's office and drew what was essentially the design of LAT. Within hours, he also had a simulation showing it would work. But as the particle physicists learned, sometimes the hard way, everything has to work in extreme cold, extreme heat, in vacuum, and survive a noisy, jarring launch.

"In space there's no way to wiggle a cable or replace a board. Everything goes through a very rigorous testing process before it's flight-qualified," says SLAC's Jana Thayer, who commissions and tests LAT data and trigger systems.

The collaborating groups worked relentlessly to build LAT, the main instrument, which contains the largest area silicon detector ever built for space or ground. The 1.8-meter-cubed instrument tracks the direction and energy of the gamma rays and identifies the unwanted charged particles streaming through the detector.

Early this year, LAT will travel from SLAC to the Naval Research Laboratory (NRL) for final "shake and bake" tests where the complete instrument will be exposed to launch and space conditions, "to make sure no pieces fall off," says SLAC's LAT project manager, Lowell Klaisner.

NRL will then send the LAT to SpectrumAstro, a private company that will bundle the instruments, solar wings, communications, and other parts to make the GLAST observatory spacecraft. The spacecraft will fit in the nose cone of a Delta 2 rocket, and will be launched in fall 2007 from Kennedy Space Center to the cheers of GLAST collaborators from around the world.

A unique collaboration

In addition to the technical and scientific efforts to build, launch, and do science with the observatory, the mission has faced two more challenges: building a strong collaboration from researchers in different fields, and forging strong working ties between DOE and NASA in the biggest and most integrated joint project between the two.

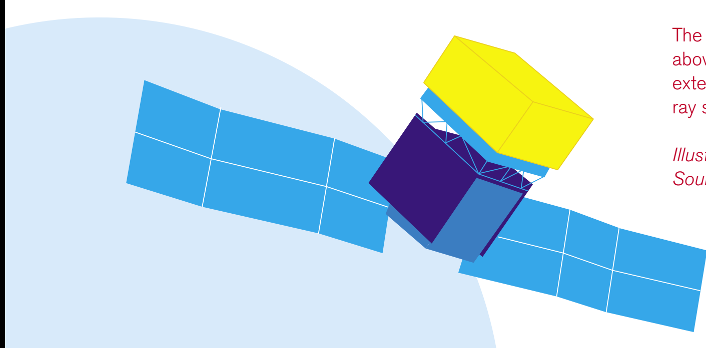
"People lost their labels pretty quickly, and just became scientists, that's why this project is so good," says Ritz.

The overall mission is managed by NASA's Goddard Space Flight Center. It is funded by NASA, the US Department of Energy, and international partners. Stanford and SLAC are the lead institutions for LAT, and NASA's Marshall Space Flight Center is the lead for GBM. Collaborators also include researchers from other US institutions, as well as from Italy, France, Sweden, Japan, and Germany.

To make the collaboration work, researchers and agencies adapted to new styles. For example, particle physicists usually share their data among collaborators only, while astrophysics experiments typically make the data available to the wider scientific community for analysis. For GLAST, the first year's data will be analyzed mainly within the collaboration. After that, data will be publicly available. Throughout the mission, the community will be notified immediately about bursts and other transient events.

NASA and DOE will continue the collaboration after launch. NASA will download the observatory's data, then send it to the Instrument Science Operating Center at SLAC. ISOC will look after the health and safety of LAT, work with NASA to operate it, and process the raw data to reconstruct incoming gamma rays.

With GLAST basking in the light of gamma rays, physicists will have a new window to the mysterious and mighty processes that ignite the gamma-ray sky. The view will be spectacular.



The GLAST observatory will orbit 550 kilometers above Earth, with its solar power panels extended and its detectors facing the gamma-ray sky.

Illustration: Sandbox Studio
Source: NASA