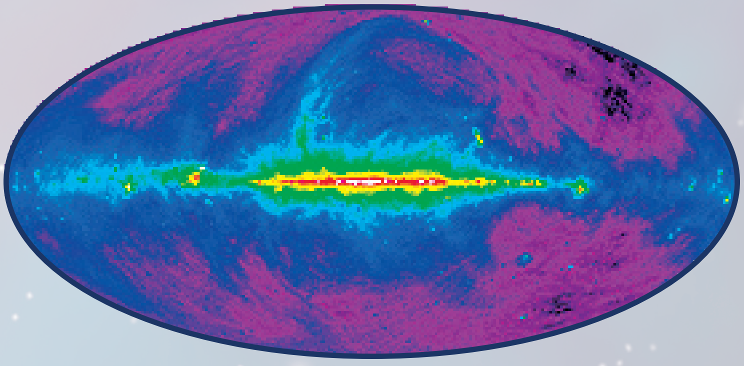
National Aeronautics and Space Administration

GLAST

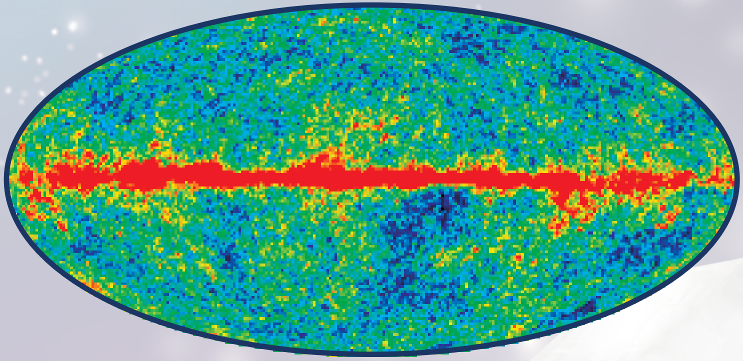
Gamma-ray Large Area Space Telescope

Windows On The Universe

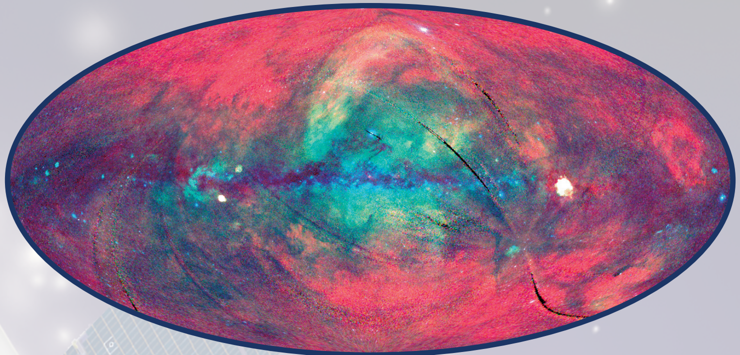


Radio Continuum: 408 MHz, Bonn, Jodrell Bank, and Parkes

Optical: Axel Mellinger, University of Potsdam, Germany

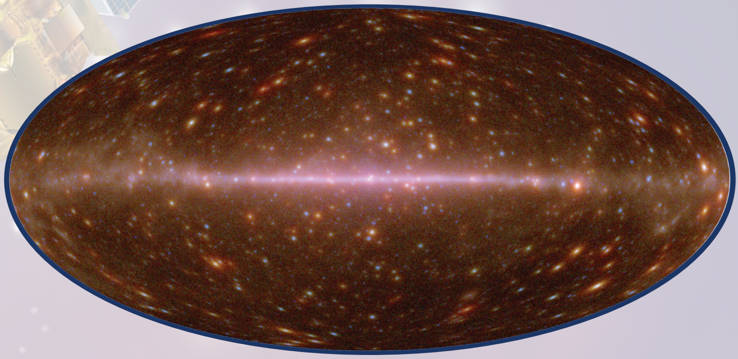


Microwave: W-band 94 GHz, NASA and the WMAP Science Team



X-Ray: 0.25, 0.75, 1.5 keV ROSAT/PSPC

Near Infrared: 1.25, 2.2, 3.5 micron wavelength COBE/DIRBE



Simulated gamma-ray sky as seen with GLAST after one year of operations - Seth Digel, Stanford

The images above depict the sky as seen at different energy ranges. In each image, the Milky Way Galaxy dominates, and can be seen as a roughly horizontal band of light across the middle. At the lowest energies (radio, microwave and infrared), most of the emission is from cold objects such as dark clouds of dust and gas and the greatly cooled radiation left over from the Big Bang. In the optical and ultraviolet, we see stars and hot gas. X-rays reveal more exotic neutron stars, supernova remnants, and black holes. At gamma-ray energies, the diffuse glow of the Galaxy is peppered with hot spots from the highest-energy emitting black holes, pulsars, and supernova remnants. Outside the Galaxy (above and below the band in the image), the sky is sprinkled with active galaxies, whose supermassive central black holes are furiously gobbling down matter.

The Exotic Universe We Call Our Home

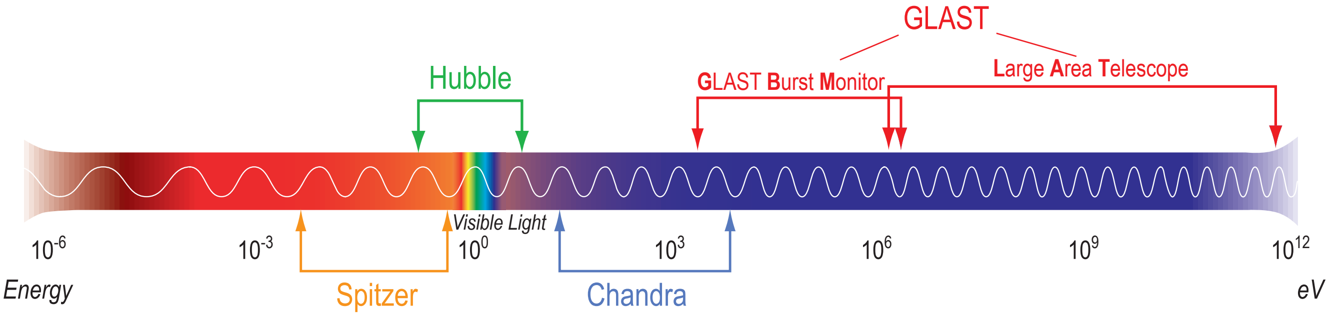
Imagine a Universe where light is so energetic that it flies through space like arrows, slicing through telescope mirrors as if they were made of paper. No ordinary telescope can catch this light.

Imagine a Universe so exotic that particles of light smash into each other at such fantastic energies that they can actually form matter in the process; where a single explosion releases more energy than our Sun will in a billion years; where black holes accelerate sub-atomic particles to nearly the speed of light in jets stretching thousands of light years, beyond the confines of entire galaxies.

This is the gamma-ray Universe, a Universe invisible to our eyes yet, quite literally, all around us. This is our Universe, which we will see at long last in unprecedented clarity with a new observatory called GLAST, the Gamma-ray Large Area Space Telescope.

Gamma rays are the most energetic form of light, capping the electromagnetic spectrum that runs from low-energy radio waves, through the infrared and visible band, and onward to higher-energy ultraviolet, X-ray, and gamma-ray radiation. Gamma rays, in fact, are millions to billions of times more energetic than visible light. As hot as the Sun is, it shines primarily in visible light, a fiery orange-yellow ball. It takes an event as powerful as a massive star explosion or the escapades of the most massive black holes to generate gamma rays.

Figure: Electromagnetic spectrum showing the range of energy detected by GLAST compared to NASA's Great Observatories currently in operation.



Scientists are eager to learn more about the gamma-ray Universe. The enormous energies involved teach us valuable lessons about fundamental physics and the forces of nature. And the exotic gamma-ray sources themselves – ancient black holes, matter-antimatter annihilation, spinning neutron stars, immense solar flares, colossal star explosions – reveal secrets about the structure and evolution of the Universe.

GLAST will address major questions in astronomy, cosmology and physics, such as the early history of star formation, the origin of black hole particle jets, the nature of dark matter, and the source of gamma-ray bursts (GRBs), the most powerful explosions in the Universe. GLAST, planned for launch in 2008, is a mission that connects many scientific disciplines. This booklet describes the unique science goals of GLAST, a satellite that partners NASA with the U.S. Department of Energy and institutions in France, Germany, Italy, Japan, and Sweden.

GLAST will address major questions in astronomy, cosmology, and physics.

A New Era of Discovery...

With their tremendous energies, gamma rays travel through the Universe largely undisturbed. Dust and gas clouds? No problem. Gamma rays fly through the type of material that blocks X-rays and most lower-energy radiation from reaching us. This means GLAST will be able to observe gamma-ray sources near the edge of the visible Universe -- that is, ancient radiation that has taken over 10 billion years to reach us.

The irony is that most gamma rays, after traversing the Universe, stop cold when they interact with molecules in the Earth's thick atmosphere. This is good news for our health, because gamma rays, like X-rays, can penetrate our bodies and damage our cells. Miles of dense atmosphere protect us from gamma radiation, so all but the most energetic gamma rays must be detected by detectors lofted above the atmosphere. Signals from the highest-energy gamma rays, which are rare, do penetrate into the atmosphere. Large ground-based observatories can detect these types of gamma rays.

Scientists have collected gamma-ray data from sounding rockets, high-altitude balloons, and satellites since the 1960s. The most successful gamma-ray mission to date was NASA's Compton Gamma Ray Observatory (CGRO), part of the "Great Observatory" series. CGRO operated from 1991 to 2000 and, with its four separate instruments, surveyed nearly the entire stretch of the gamma-ray Universe – an energy band roughly a million times "wider" and a million times more energetic than what Hubble can detect. GLAST will be equipped with two main instruments: the Large Area Telescope (LAT) for detecting high-energy gamma rays from a variety of sources, and the GLAST Burst Monitor (GBM), which will detect gamma-ray bursts, and other energetic flares. The LAT is a successor to CGRO's Energetic Gamma-Ray Experiment Telescope (EGRET), which detected the higher-energy end of the gamma-ray band. EGRET has provided the basic sky map at gamma-ray energies; now the LAT will zoom in for discovery and adventure. The GBM follows the path of CGRO's Burst and Transient Source Experiment (BATSE) instrument which detected over 2700 GRBs during its nine-year lifetime.

The LAT will zoom in for discovery and adventure.

Discovery and adventure truly do await us. EGRET detected 271 gamma-ray sources, and over half of these sources remain unidentified with known objects. Are they distant and dim quasars, among the first galaxies to form in the Universe? Do these sources represent exotic new phenomena closer to home? GLAST's LAT will likely determine the nature of these sources and find thousands more, solving decades-old mysteries about the Universe and, without a doubt, stumble upon yet more mysteries to solve in years to come.

Journey to a Black Hole...

GLAST will transport us – virtually – to the environs of black holes. These objects are a key target of observation for GLAST's Large Area Telescope (LAT).

Black holes are regions in space where matter is so compact and gravity is so strong that nothing, not even light, can escape once it crosses the theoretical border called the event horizon. Stellar-mass black holes form from collapsed stars at least ten times more massive than our sun. Our Milky Way galaxy likely has thousands of these black holes; more than a dozen candidates have been identified. Supermassive black holes form in galaxy cores and can contain the mass of millions to billions of suns confined to a region no larger than our solar system.

GLAST will transport us to the environs of black holes.

Black holes create gamma rays in particle jets. One unsolved mystery about black holes is how these objects, notorious for drawing matter in, can also push matter away in jets moving over 99 percent light speed. These jets, which can be prodigious sources of gamma rays, are often seen in quasars, extremely distant galaxies with bright cores fueled by a central, supermassive black hole. The jets often shoot clear out of the galaxy core to distances of tens or even hundreds of thousands of light years. One type of quasar particularly bright in gamma rays is called a blazar. Blazars are thought to be quasars with a jet shooting right at us, as if we are staring down the barrel of a gun.

Using the LAT, scientists will observe blazars and other black hole systems with particle jets to learn how these jets form. We know that matter spirals into a black hole by forming an accretion disk, a flat ring around the black hole that glows brightly in radio waves, optical light and, as it gets very close to this mysterious void, in X-rays. The theory of jet formation says that magnetic fields surrounding the black hole somehow channel some of the matter from the inner

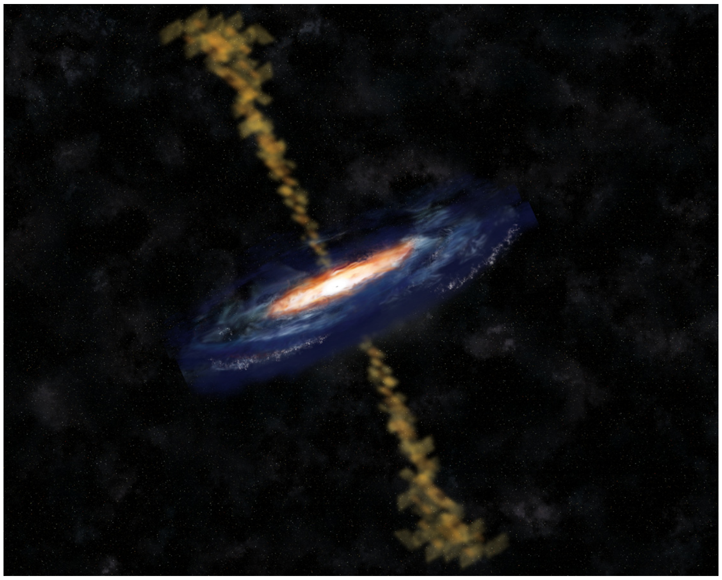


Illustration of an Active Galaxy - Aurore Simonnet NASA E/PO SSU accretion disk to the poles of the black hole. This matter, spared eternal doom in the black hole, races away from the accretion disk in a highly collimated jet. The matter then collides with other material in the region to create gamma rays.

The LAT will zoom in on the jet phenomenon to test this theory. The LAT will also search for previously unknown physics in these jets, because the collision energies are considerably larger than those created in giant particle accelerators on Earth. GLAST scientists' efforts will complement the work of particle physicists as they search for clues to the nature of subatomic forces.

How can black holes, notorious for drawing matter in, accelerate jets of matter to nearly light speed?

Journey to the Early Universe...

According to Einstein's theory of general relativity, a black hole represents a point where time, as we define it, comes to a standstill. So, in our study of black holes, we learn about one endpoint for time. Yet we can also learn about the beginnings of time.

Light detected from quasars and blazars is often quite old, having traveled for billions of years. This is because quasars formed when the Universe was very young, and they reside at cosmological distances. Gamma rays from these sources are therefore messengers from the early Universe.

Astronomers hope to study the early history of black hole and star formation in the Universe by studying the gamma rays from blazars and measuring their distribution through cosmic time. Another technique capitalizes on the unique ability of gamma rays to collide with starlight and literally disappear, creating particles of matter and antimatter. The process is called pair production. Two photons annihilate, creating a pair of matter and antimatter particles, specifically electrons and anti-electrons (also called positrons). Only in the realm of gamma-ray energies do we see this phenomenon.

Gamma rays from quasars and blazars are messengers from the early Universe.

Gamma-ray disappearance is proportional to starlight abundance. Tracing the disappearance of gamma rays, therefore, is tantamount to measuring the amount of light produced by stars and galaxies through the years. For example, in the early Universe there were fewer stars, so fewer gamma rays from distant blazars are annihilated. As the Universe slowly created more and more stars, more gamma rays were annihilated.

The LAT is expected to detect thousands of blazars, measuring the energy of their gamma rays. It will also provide accurate locations of these blazars, so that other telescopes, such as ground-based optical and infrared observatories, can determine their distances. This will be like sending a spaceship into these regions billions of light years away and collecting samples of starlight, era by era, until the present time.

Of Dark Matter, WIMPs, Supersymmetry, Exotic Physics

Gamma rays may reveal something else about the early Universe: the nature of dark matter and the fundamental forces, two of the most important questions in modern physics. Scientists find that over 95% of the matter and energy in the Universe is of a form that cannot be detected by current instruments. We can only detect about 5% of the stuff that's out there – that is, the stuff that radiates energy. The Universe is largely composed of dark matter and dark energy.

Dark energy is the name given to a mysterious force that appears to be accelerating the expansion of the Universe. It acts like some type of anti-gravity force. Dark matter, scientists say, seems to be a type of matter that has a gravitational attraction (that is, it attracts ordinary matter) yet doesn't shine like ordinary matter. We infer the presence of dark matter by virtue of its effect on the hot, glowing ordinary matter gathered around it, yet we cannot detect it directly. Scientists have proposed many theories of what this dark matter could be.

Scientists on the trail of dark energy often turn to certain types of star explosions, called Type Ia supernovae, as a means of calculating the expansion rate of the Universe. These explosions serve as standard candles, beacons of known energy spaced throughout the Universe from present time back to the first era of star formation. Recently, some scientists have come to regard gamma-ray bursts as probes of the early Universe as well, and gamma-ray bursts are much brighter than Type Ia supernovae. GLAST's observations of gamma-ray bursts may provide additional clues to the expansion rate of the Universe and the dark energy that seems to be pulling it apart.

Gamma rays may reveal the nature of dark matter and the fundamental forces.

GLAST may also help determine whether dark matter takes the form of WIMPs, short for Weakly Interacting Massive Particles. These are theoretical elementary particles, heavier than protons or neutrons. The "lightest supersymmetric particle," or LSP, is one type of WIMP. Two LSPs could collide and annihilate, emitting gamma-ray radiation at a unique energy. If GLAST detects a strong gamma-ray signal at this energy, it would provide dramatic evidence for the existence of WIMPs.

Supersymmetry, a theory in modern physics that states that all particles have undiscovered counterparts, is a consequence of many theories that attempt to unify General Relativity, the theory of gravity and the large scale, and quantum theories of subatomic forces and the small scale. These are the two pillars of modern physics. Some theorists have also suggested that WIMPs (in a form other than LSPs) formed in the Big Bang and have since decayed, like radioactive particles, emitting gamma rays in the process. The LAT could detect this gamma-ray signature, if it truly exists, in its deep survey of the diffuse gamma-ray background radiation that pervades the Universe.

The Gamma-Ray Milky Way...

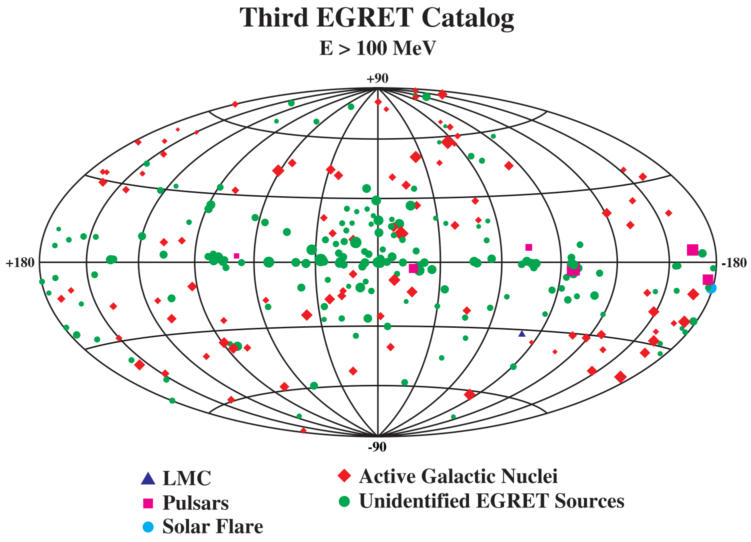
Astronomers don't have to look across the Universe for gamma-ray sources. Our own Milky Way galaxy glows in gamma rays formed when energetic charged particles called cosmic rays hit interstellar gas and dust. The Milky Way also has a few individual powerhouses in the form of pulsars and supernova remnants. However, the nature of most of the gamma-ray sources in our galaxy remains a mystery.

Gamma-ray pulsars are rotating, magnetized neutron stars that "pulse" with gamma rays with each rotation. As with other neutron stars, these objects are the core remains of stars once several times more massive than our Sun – stars that had spent their nuclear fuel and exploded as supernovae. Pulsars were the first objects detected at gamma-ray energies, back in the 1970s.

GLAST may identify several hundred gamma-ray emitting pulsars, vs. only seven known today.

While pulsars are known to pulse across the entire energy spectrum, from radio waves through X-rays, only seven have been identified as gamma-ray emitters. GLAST may identify several hundred more, providing scientists with the statistics to understand what makes these objects tick. Many questions abound. For example, scientists say that pulsars generate X-rays and gamma rays by flinging material from on and around their surface into space. GLAST will help determine where and how this acceleration takes place, as well as determine the shape of the particle beam. By knowing the fraction of the sky that a pulsar beam illuminates, scientists can calculate the number of pulsars in our galaxy and how often they are born.

The EGRET instrument on the Compton Gamma-Ray Observatory detected 271 gamma-ray sources, of which 170 have not been otherwise identified. Some scientists say that a fair number of them are gamma-ray pulsars in the Milky Way galaxy, strung along the Gould Belt, a prominent collection of star-forming regions. GLAST should determine if this is true.



A map in galactic coordinates of the discrete sources detected by the EGRET experiment onboard NASA's Compton Gamma-Ray Observatory.

The more pulsars the merrier, scientists agree. Nearby pulsars and black holes serve as laboratories to test general relativity, Einstein's theory of gravity. Both of these sources, being highly compact objects, have strong gravitational fields. Thus, they distort light, space, and time in ways predicted by Einstein. Their compact yet massive presence creates a gravitational well in space. Light must climb out of this well on its journey toward Earth. Thus far, Einstein's predictions of the behavior of matter and energy around black holes and pulsars have held true. But can Einstein's theory hold up under tighter scrutiny as scientists study more pulsars and black holes with GLAST? Or will we uncover the need for a new theory of gravity, just as discrepancies in Isaac Newton's gravity law gave way to general relativity? GLAST, in its study of gamma-ray pulsars and expected detection of micro-blazars (local, stellar-size versions of blazars), will provide tests of general relativity in the years to come.

Inclement Weather...

The Milky Way is home to some nasty weather, such as fierce stellar winds and fast-flying bits of matter called cosmic rays. This cosmic-ray "hail" moves at nearly light speed, the fastest moving matter in the Universe. These tiny particles – usually electrons, protons or heavier atomic nuclei – can individually contain energies as high as that of a major league baseball pitch. Solar winds form as massive stars fling off electrons and protons in spectacular flares. GLAST will study stellar winds and cosmic ray production throughout the Galaxy.

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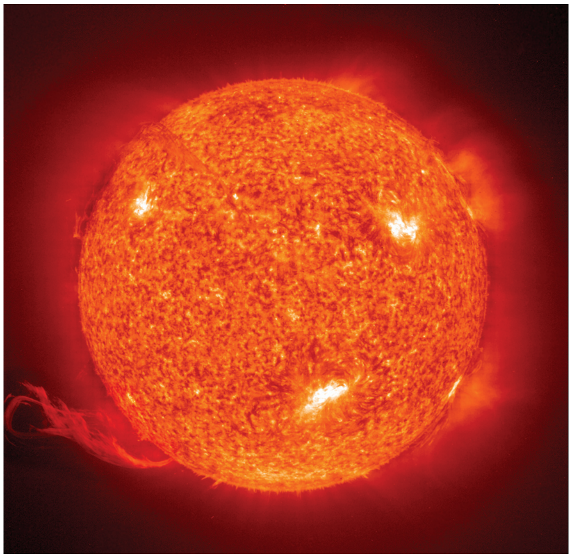
Cosmic rays can generate gamma rays when these particles smash into each other or into dust and gas in the interstellar medium of the Galaxy. Most scientists agree that the vast majority of cosmic rays are created in supernova remnants. The particles either come flying out of the explosion like shrapnel; or these particles, perhaps already present in the region around a supernova remnant, are accelerated to nearly light speed by the explosion's shock waves. Yet direct observational evidence is lacking. GLAST, with its ability to see the gamma-ray light created by cosmic rays, may be the first instrument to detect the sites of cosmic-ray proton production. GLAST will also be sensitive enough to detect cosmic-ray interactions in several nearby galaxies.


An extreme ultraviolet image of the active sun from the SOHO mission's EIT experiment.- ESA/NASA/SOHO/EIT

Through cosmic-ray mapping, GLAST will advance our understanding of hidden gases in our own Milky Way galaxy, particularly in star-forming regions. Dense, star-forming interstellar clouds are largely made of cold molecular hydrogen gas, which is very difficult to detect directly. Hot gas may glow in X-rays, but cold gas tends to be dark. Cosmic rays create gamma-ray "sparks" as they pass through these clouds. Cold hydrogen clouds are not "dark matter," but they contribute nonetheless to our overall understanding of star formation and the distribution of ordinary matter.

GLAST may observe stellar flares from other suns.

The Sun can occasionally produce gamma rays during large solar flares. Here, magnetic fields accelerate protons and electrons to high speeds through a mechanism not completely understood. GLAST may resolve the location of particle acceleration and the processes involved for local solar flares. GLAST may also observe stellar flares from other suns, particularly massive stars in dense, star-forming regions. There, stellar winds from neighboring stars can smack into each other, creating a bright source of gamma rays. Unidentified gamma-ray sources detected by EGRET in the 1990s could very well be from powerful stellar winds.

All This, and Gamma-Ray Bursts Too...

GLAST carries an instrument called the GLAST Burst Monitor (GBM), dedicated to observing gamma-ray bursts. These bursts are the most powerful explosions known in the Universe. Most of these bursts are likely from the early Universe, occurring billions of light years away. They are surprisingly common, detected by satellites at a rate of about one per day. Yet the bursts are random and brief, lasting from a few milliseconds to about a minute before fading forever, never to be seen again at the same spot. The leading theories state that gamma-ray bursts originate from massive "hypernova" explosions or from the mergers of black holes or neutron stars.

NASA's Swift satellite, launched in 2004, has helped to identify the location and nature of the bursts by detecting hundreds of bursts and "swiftly" turning its telescopes to study the bursts in detail. Whereas Swift observes lower-energy gamma rays from any given burst, GLAST's GBM and LAT will observe a wide

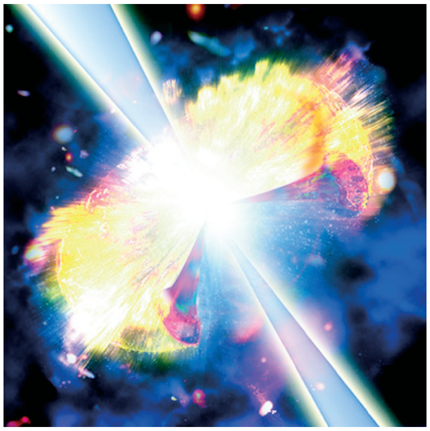


Illustration of a hypernova - David Armbrecht, Spectrum Astro

range of gamma rays, including higher-energy photons. Thus, GLAST may reveal important clues about gamma-ray bursts not seen by other satellites. For example, the CGRO EGRET instrument saw high-energy gamma-ray emission more than one hour after one gamma-ray burst, a real mystery. GLAST will detect a multitude of bursts to look for high-energy emission, both during the burst and as an "afterglow." It will be possible to combine the data from Swift and GLAST for many bursts to give information over a broad range of gamma-ray energies and time scales.

GLAST's GBM and LAT may uncover exotic physics in the gamma-ray burst phenomenon. Quantum gravity is a working theory that attempts to fold Einstein's theory of gravity, called general relativity, into quantum mechanics. In quantum mechanics, three of the four fundamental forces – electromagnetism, the strong nuclear force, and the weak nuclear force – have a particle that transmits the force: a photon, gluon, and W and Z particles, respectively. There is no evidence, however, of a particle for the fourth fundamental force, gravity. Quantum gravity predicts the existence of such a particle, called a graviton. GLAST will not detect gravitons, but it may find evidence of their existence.

Signs of quantum gravity might be seen in exceedingly distant and energetic gamma-ray bursts. Light travels at a constant speed in a vacuum. Some models of quantum gravity predict that the most energetic photons travel more slowly than lower-energy photons. This would be due to the effect of gravitons tugging at the highest energy photons. The effect is analogous to how light travels more slowly through water than through air. Gravitons are thought to be millions of times smaller than atoms. Lower-energy electromagnetic radiation (with longer wavelengths) cannot "see" the gravitons, like a giant stepping over ants. The gravitons are too small. Yet the highest-energy gamma rays (with exceedingly short wavelengths) might interact with the gravitons. The shorter the wavelength (and thus the higher the energy), the greater the potential for interaction. The effect would be miniscule, only measurable in photons that have traveled for billions of years. If the LAT detects higher-energy photons arriving a fraction of a second later than the lower-energy photons seen by the GBM, this could provide evidence for quantum gravity. One needs the highest energies and the greatest distances, afforded only by gamma-ray bursts, to detect this.

By studying gamma-ray bursts at different distances, GLAST may find evidence for quantum gravity.

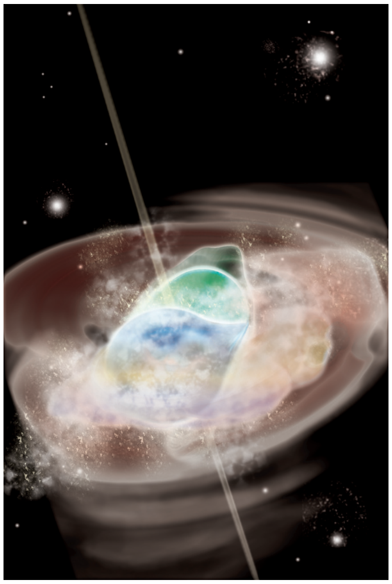


Illustration of Merging Neutron Stars
Aurore Simonnet, NASA E/PO SSU

Teamwork Below, With Ground-Based Observatories...

Not all gamma rays are created equal. Some are imparted with such high energies that they can penetrate deep into the Earth's atmosphere. These are gamma rays with tens to hundreds of times more energy than those that GLAST can observe well. Astrophysicists detect these highest-energy gamma rays with large, ground-based observatories. The gamma rays themselves don't quite reach the detectors. Instead, the gamma rays collide with molecules in the atmosphere and create an air shower of secondary particles and photons. The ground-based observatories detect the air showers and computers reconstruct the gamma-ray collision that caused the shower.

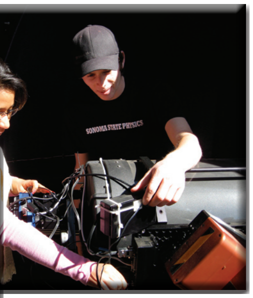
The highest-energy gamma rays are rare; however, in the past few years, new ground-based gamma-ray observatories have confirmed over 50 sources that produce such energetic photons. GLAST may help ground-based gamma-ray observers find more. What is needed to observe these rare gamma rays is a large collecting area, far larger than that of the GLAST satellite. (It is too expensive to launch that large and heavy a telescope into space.) Ground-based observatories – scattered across several continents, including the Australian outback, Namibia in southern Africa, the dry desert regions of North America and an island in the Atlantic Ocean– often have collecting areas as large as 10^4 meters across. Ground-based observers also have the opportunity to take daylong or weeklong observations of a single source. GLAST, with its enormous field of view, can notify the ground-based observatories with the location, for example,

Very Energetic Radiation Imaging Telescope Array System (VERITAS) Observatory, Amado, Arizona, U.S.A.

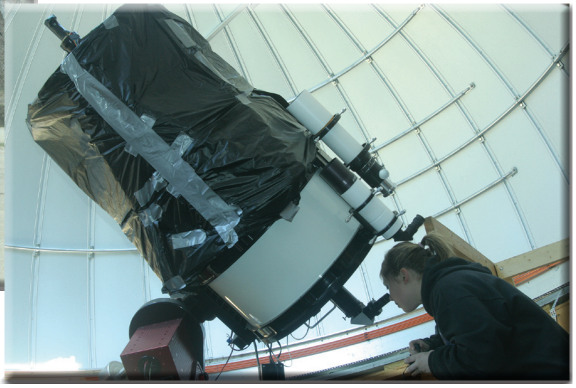
of flaring black hole systems. The ground-based observers can then turn their detectors to that part of the sky to collect the signature of photons too rare for GLAST to collect in significant amounts for analysis. Thus, we extend our view of the gamma-ray Universe by at least tenfold in energy.

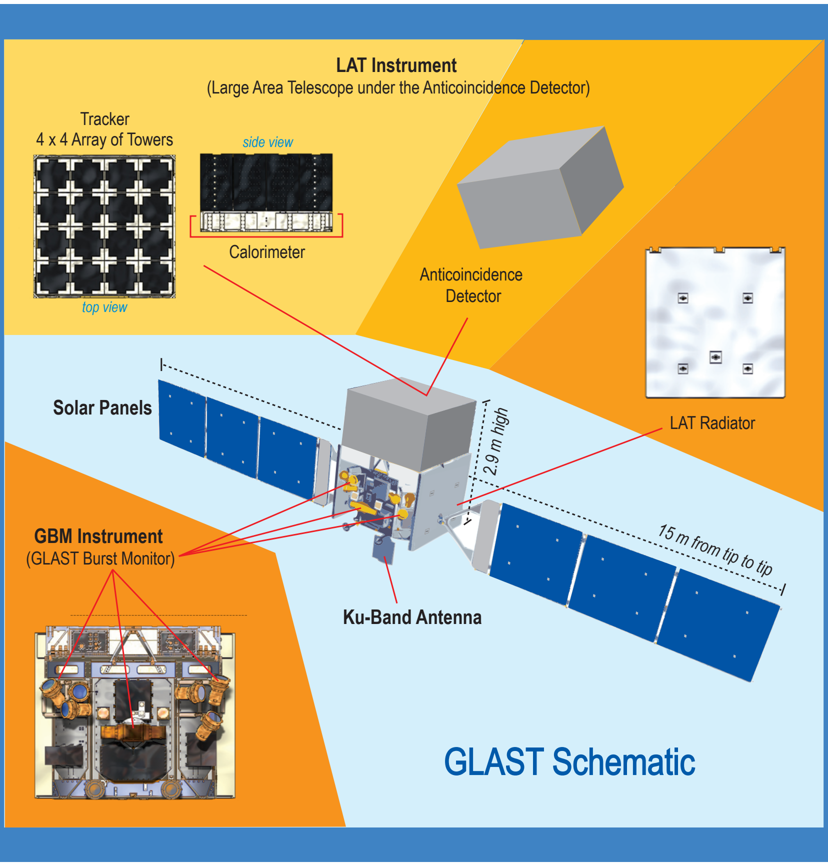
The GLAST project has formed partnerships with both the National Optical Astronomy Observatory (NOAO) and the National Radio Astronomy Observatory (NRAO) to enhance GLAST science. Coordinating GLAST observations with dedicated time on radio and visible-light telescopes will open the door for major discoveries spanning the electromagnetic spectrum. In addition, GLAST will notify scientists around the world nearly instantly the moment it detects a gamma-ray burst through the Gamma-ray Burst Coordinates Network. This system e-mails scientists and alerts automated telescopes that a burst is occurring. Remember, bursts fade quickly. Gamma-ray bursts typically last only for seconds. The burst alert system enlists other observatories, either on the ground or in space, to turn to the source of the burst to capture whatever information they can.

The GLAST project is also sponsoring the Global Telescope Network (GTN), a collaboration among observatories and individuals who will use automated telescopes to observe astronomical targets of interest to the mission. These ground-based telescopes will peer at distant galaxies, gamma-ray bursts, and black holes, providing information to scientists on how these objects change with time. Besides supporting the science goals of GLAST, the GTN will be used by amateur astronomers as well as high school and college students, partnering them with scientists and giving them an opportunity to contribute critical data to the ever-expanding realm of scientific inquiry.



Sonoma State University students at the GLAST optical robotic telescope, CA (above) and Holton high school students at the Elk Creek telescope, KS (left, below.)





New Collaborations, New Science

By merging the study of the very small with the very large, GLAST represents a new age in astronomy: particle astrophysics. Both disciplines – particle physics and astrophysics – come with their own teams of specialists, scientists, and engineers. The cooperation between these vastly different fields has made the development of GLAST into one of the broadest collaborative efforts ever undertaken in astronomy. It takes many experts to build a satellite so diverse and that can have such a tremendous influence on many fields of research. GLAST represents a collaboration of astronomers, physicists, and engineers at NASA, the U.S. Department of Energy, U.S. universities, and institutes and universities in France, Germany, Italy, Japan, and Sweden.

GLAST represents a new age in astronomy: particle astrophysics.

The Gamma-ray Large Area Space Telescope

NASA and General Dynamics

GLAST observatory in the General Dynamics clean room.

Top Row: Chip Meegan (MSFC), Peter Michelson (Stanford), Steve Ritz (GSFC).

Bottom row: Bill Atwood (UCSC), Dan Blackwood (NASA), Rick Harnden (NASA), Neil Johnson (NRL).

Conclusion

Today, the field of gamma-ray astronomy is about where X-ray astronomy was in the 1980s. Since then, X-ray astronomy has grown to be a critical part of astronomy and a key to understanding high-energy events previously invisible to earthbound observatories. It has even spawned a Nobel prize for Riccardo Giacconi, a pioneer in the field. In the coming decades, gamma-ray astronomy will grow into an equally mature enterprise. GLAST is at the forefront of this new frontier, playing a pivotal role in the future of high-energy science.

Credits:
Written by: Lynn Cominsky, Sonoma State University & NASA's *GLAST* Mission, California.
Christopher Wanjek, NASA/GSFC, Maryland.
Special thank-yous go to the following for their useful additions, suggestions and comments:
Neil Gehrels, Steve Ritz, Julie McEnery and David Thompson NASA/GSFC, Maryland.
Chip Meegan, NASA/MSFC, Alabama.

Cover art and layout by:
Aurore Simonnet, Sonoma State University.
GLAST spacecraft concept by General Dynamics

GLAST Mission

GLAST System	Lead Institution	Other participants
Large Area Telescope	Stanford University, and Stanford Linear Acceleration Center (SLAC)	• **USA:** NASA/GSFC, Ohio State University, UC Santa Cruz, Naval Research Laboratory, University of Washington. • **France:** IN2P3, CEA/DAPNIA Saclay. • **Italy:** ASI, INFN, INAF. • **Japan:** Japan GLAST collaboration. • **Sweden:** Royal Institute of Technology, University of Stockholm.
GLAST Burst Monitor	NASA/MSFC	• **USA:** University of Alabama/Huntsville, LANL. • **Germany:** Max Planck Institut für Extraterrestrische Physik, Garching.
Spacecraft	General Dynamics	NASA/GSFC
Education and Public Outreach	Sonoma State University	NASA/GSFC, NASA/MSFC, Stanford University, UC Santa Cruz, TOPS Science Inc., Tom Lucas Productions, WestEd, California Academy of Sciences, Astronomical Society of the Pacific and AstronomyCast.
Mission Management	NASA/GSFC	

Large Area Telescope (LAT) Performance Summary

Energy Range	20 MeV - 300 GeV
Peak Effective Area (in range 1-10 GeV)	> 8,000 cm^2 at 10 GeV
Energy Resolution 100 MeV-10 GeV on-axis	< 10%
Energy Resolution 10-300 GeV on-axis	< 20%
Angular Resolution 100 Mev on-axis	< 3.5
Angular Resolution 10 Gev on-axis	< 0.15
Field of View	> 2sr
Point Source Sensitivity (>100 MeV)	< 6x10^{-9} ph cm^{-2}s^{-1}
Source Location Determination	< 0.5 arcmin

Burst Monitor Performance (GBM) Summary

Trigger Threshold	<1 ph cm^{-2}s^{-1}
Low-Energy Detectors	
Material	Sodium Iodide
Number	12
Area per detector	126 cm^2
Thickness	1.27 cm
Energy range	10 keV to 1 MeV
High-Energy Detectors	
Material	Bismuth Germanate
Number	2
Volume per detector	1609 cm^3
Energy range	150 keV to 30 MeV

GLAST Mission Website:
http://www.nasa.gov/glast

Education and Public Outreach Website:
http://glast.sonoma.edu/

www.nasa.gov