Explore most powerful sources of acceleration in the universe
Gamma Rays

- Energy = $h \times$ frequency  \hspace{1cm} (h=4.1 \times 10^{-15} \text{ eV-sec})
  - Radio $10^{-9} - 10^{-8}$ eV
  - TV $10^{-7}$ eV
  - Infrared $.1 - 1$ eV
  - Visible $2 - 5$ eV
  - X-rays $10^3 - 10^5$ eV
  - Gamma Rays $>10^6$ eV

Gamma Rays can’t be reflected by mirrors
Wavelength $<<$ interatomic distances
Why do we need a satellite?

Atmosphere:

For $E_\gamma < \sim O(100)\text{ GeV}$, must detect above atmosphere (balloons, satellites, rockets)

For $E_\gamma > \sim O(100)\text{ GeV}$, information from showers penetrates to the ground (Cerenkov)
How are gamma rays generated?

Accelerated particles interact with matter, magnetic field or photon fields.
16 towers arranged in a 4 x 4 configuration
GLAST Collaboration

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- Boston University, Boston, Massachusetts
- University of Udine, INFN, Italy + new French and Italian collaborators

&> 30 Institutions
International Collaboration

Si-Pb Tracker

CsI Calorimeter

Delta II
7920 H

Large Area Telescope
2560 kg, 600 W, \(1.73^2 \times 1.06\) m

Anti-Coincidence Detector

Gamma-ray Burst Monitor

International Collaboration
Gamma Converts in Tungsten Foil

Whenever 3 planes in a row are hit, then read out the event and store its information.
ACD Rejets Charged Cosmic Rays

ACD (plastic scintillator) for background rejection

- A charge particle interacts with the ACD scintillator and produces light.
- A $\gamma$ usually goes through the ACD without making any signal.
Silicon Strip Detector

Strip-shaped PN diode

200 micron wide

400 micron thick high purity silicon

9 cm

VLSI amplifier
Balloon Flight Engineering Module
Since there are at least 3 hits in a row, the event is triggered.

Problem: In the GLAST orbit there are $\sim 10^5$ times more cosmic rays than photons!
Physics Motivation for GLAST

- Active Galactic Nuclei (AGN)
- Gamma Ray Bursts (GRB)
- Diffuse Galactic $\gamma$-ray background
- Dark Matter (or its absence “MOND”)
- Diffuse Extragalactic $\gamma$-ray background (relics from the Big Bang)
- Pulsars
- Cosmic rays
- Solar flares
Active Galactic Nuclei

Up to $10^4$ times the luminosity of typical galaxy in a volume of one cubic parsec!
(1 pc = $3.1 \times 10^{18}$ cm ~ 3 light years)
(assuming isotropic emission)

Changes in Luminosity in a fraction of a day!

Radiation is emitted at all frequencies!

Energy and time resolved spectra

Possibility to study flares

Study mechanisms of acceleration and cooling

Formation of extragalactic jets from black hole accretion disk
Gamma Ray Bursts

We already know that they occur at cosmological distances, implying energies up to $10^{54}$ ergs during burst emission (if we assume isotropic model).
Optical Afterglow

GRB 971214 – 12 billion light years away (z = 3.42)!
(about 5.9 trillion miles for light to travel)

2 days after burst

2 months after burst
EGRET Sky map

Point sources

Third EGRET Catalog
E > 100 MeV

EGRET Gamma Ray Emissions > 100 MeV

Cosmic background…
What is the point source contribution?

271 sources
169 unidentified
Search for Dark Matter

WIMP annihilations could produce such structure.

$10^{-5} \text{ ph cm}^{-2} \text{ sec}^{-1} \text{ sr}^{-1}$ for $E_g > 1 \text{ GeV}$

Contours of photon intensity after subtraction of “best estimate” of Galactic diffuse model. Data suggests presence of a galactic halo (Dixon et al. 1998).
Halo WIMP annihilations

Good particle physics candidate for galactic halo dark matter is the LSP in R-parity conserving SUSY

If true, there may well be observable halo annihilations

Example: $X$ is $\tilde{\chi}^0$ from Standard SUSY, annihilations to jets, producing an extra component of multi-GeV $\gamma$ flux that follows halo density (not isotropic) peaking at $\sim 0.1 \, M\tilde{\chi}^0$ or lines at $M\tilde{\chi}^0$. Background is galactic $\gamma$ ray diffuse.

Although calculation for $\gamma$-rays is less uncertain than for other signals (multi-GeV antiprotons, positrons) a null result will not likely constrain SUSY parameter space.

If SUSY uncovered at accelerators, GLAST may be able to determine its cosmological significance quickly.
Indications for Dark Matter

1) Rotation curves of spiral galaxies go to a constant tangential velocity $v$ at large radii.

$$\frac{v^2}{r} = \frac{GM_{\text{galaxy}}}{r^2}$$

when all galaxy mass is within the radius $r$. So $v$ should decrease with $r$, but it doesn’t!! Hence maybe there is invisable Dark Matter.

2) Particle Physicists like looking for Dark Matter. Maybe Dark Matter is SUSY Wimps (neutralinos), or Axions. Theoretically predicted particles that would have been made in the Big Bang.
MOND

“Modified Orbital Newtonian Dynamics” (Sci Am August, 2002)

But is it Dark Matter or Modified Newton?  
http://www.astro.umd.edu/~ssm/mond/

Change Newtonian acceleration when the acceleration is very small:

\[ \text{Acceleration} = \frac{GM}{r^2} \rightarrow \sqrt{\frac{GM}{r^2} \times a_0} \text{ when Acceleration} < a_0 \]

\[ \frac{v^2}{r} = \sqrt{\frac{GM_{\text{galaxy}}}{r^2} \times a_0} \quad v^4 = GM_{\text{galaxy}} \times a_0 \]

1) Galaxies’ tangential velocity is now a constant at large radii.

2) If we assume \( M_{\text{galaxy}}/\text{Lum measured} \sim 2 \), then \( a_0 \sim 2 \times 10^{-8} \text{ cm/sec}^2 \) seems to be the same number for all spiral galaxies looked at!

3) An experimental regularity called “Tully Fisher” \( V^4 \propto \text{Lum} \) is explained.

4) The Hubble Constant = \( 7 \times 10^{-8} \text{ cm/sec}^2 \) (is \( \sim a_0 \) just a coincidence?)

GLAST will set limits (or see the it!) on how much of certain forms of Dark Matter can be trapped in our Galaxy. If no Dark Matter, maybe MOND?
Which orbit?

Low Earth Orbit (LEO)
200-500 miles (320–800 km)
(must travel fast)

Geostationary Orbit (GEO)
~22000 miles (~35000 km)
(higher background)

Communication satellite

GLAST
The South Atlantic Anomaly (SAA) is a dip in the Earth's magnetic field which allows cosmic rays and charged particles to reach lower into the atmosphere and interfere with communication with satellites, aircraft, and the Space Shuttle. The geologic origin is not yet known.

The enhanced particle flux in the SAA also strongly affects X-ray detectors, which are in essence particle detectors. The ROSAT PSPC had to be turned off during passage through the SAA to prevent severe damage. While the ROSAT HRI could be left on during the passage, it could collect no useful data. The light blue and green bands at the top and bottom of the image are due to an enhanced particle flux above Earth's auroral zones (particle belts).
GLAST timeline

• 1997 Test Beam
validation of measurement principles and technology choices.

• 1999/2000 Test Beam
full engineering model including compact front end electronics
E. do Couto e Silva et al SLAC-PUB-8682 (2000), accepted for publication in NIM A

• 2001 Balloon Flight
Next step in full flight software development and improvements based upon 1999/2000 test beam experience

• 2003/2004 Calibration Beam tests
Full calibration of instrument and response matrices

• 2006 March, Launch
## Gamma Ray Astronomy in Space

<table>
<thead>
<tr>
<th>Mission</th>
<th>Range</th>
<th>Detector</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSO-III (1967)</td>
<td>50 MeV - 0.5 GeV</td>
<td>Proportional Counter</td>
<td>Hint of Galactic diffuse emission</td>
</tr>
<tr>
<td>SAS-2 (1972)</td>
<td>30 MeV - 0.2 GeV</td>
<td>Spark Chamber</td>
<td>Galactic diffuse emission</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>~10 Galactic sources</td>
</tr>
<tr>
<td>COS-B (1975)</td>
<td>50 MeV - 5 GeV</td>
<td>Spark Chamber</td>
<td>~25 sources</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 extragalactic source (3C273)</td>
</tr>
<tr>
<td>EGRET (1991)</td>
<td>20 MeV - 30 GeV</td>
<td>Spark Chamber</td>
<td>271 sources including</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>169 unidentified sources</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 Gamma Ray Bursts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6 pulsars</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>~70 AGN</td>
</tr>
<tr>
<td></td>
<td>EGRET</td>
<td>LAT (min)</td>
<td>Improvement</td>
</tr>
<tr>
<td>------------------------</td>
<td>------------------------</td>
<td>-------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Energy</td>
<td>20 MeV - 30 GeV</td>
<td>20 MeV - 300 GeV</td>
<td></td>
</tr>
<tr>
<td>Surface</td>
<td>1500 cm²</td>
<td>&gt; 8000 cm²</td>
<td>&gt; 6</td>
</tr>
<tr>
<td>Field of view</td>
<td>0.5 sr</td>
<td>&gt; 2.0 sr</td>
<td>&gt; 4</td>
</tr>
<tr>
<td>Sensitivity (1yr)</td>
<td>~ $10^{-7} \gamma$ cm$^{-2}$ s$^{-1}$</td>
<td>&lt; 6 $10^{-9} \gamma$ cm$^{-2}$ s$^{-1}$</td>
<td>&gt; 20</td>
</tr>
<tr>
<td>Localization</td>
<td>15'</td>
<td>&lt; 0.5'</td>
<td>&gt; 30</td>
</tr>
<tr>
<td>Deadtime</td>
<td>100 ms</td>
<td>&lt; 100 µs</td>
<td>&gt; 100</td>
</tr>
</tbody>
</table>

- Large area
- Low instrumental background
Field of View $\sim 30\times 30\text{deg}^2$

Area $\sim 0.5\times 0.5\text{m}$

$\sim 1\text{ meter}$

Spark Chamber

(Invented by Fukui and Miyamoto)

Calorimeter

Field of View $\sim 140\times 140\text{deg}^2$

Area $\sim 1.4\times 1.4\text{m}$

Silicon Strip Detector

Calorimeter
Identification of Sources

LAT 95%
5σ LAT source
r = 7'

3EG1911-2000
r = 0.3'

EGRET 95%

Rosat or Einstein X-ray source
1.4 GHz VLA radiosource
LAT Science capabilities - sensitivity

**200 γ bursts per year**
- prompt emission sampled to > 20 µs
- AGN flares > 2 mn
  - time profile +ΔE/E ⇒ physics of jets and acceleration

**γ bursts delayed emission**

all 3EG sources + 80 new in 2 days

⇒ periodicity searches (pulsars & X-ray binaries)
⇒ pulsar beam & emission vs. luminosity, age, B

**10^4 sources in 1-yr survey**

⇒ AGN: logN-logS, duty cycle,
  emission vs. type, redshift, aspect angle
⇒ extragalactic background light (γ + IR-opt)
⇒ new γ sources (µQSO, external galaxies, clusters)