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for the AMEGO Team
https://asd.gsfc.nasa.gov/amego
Why Look in the MeV Range?

EGRET All-Sky Map Above 100 MeV

~200 Sources Detected
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Credit: EGRET Team

Fermi-LAT All-Sky Map Above 1 GeV

~3000 Sources Detected

Credit: NASA/DOE/Fermi LAT Collaboration
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COMPTEL All-Sky Map 1 - 30 MeV
Tens of Sources Detected
Credit: COMPTEL Collaboration
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Why Look in the MeV Range?
Guaranteed Discovery Space

The MeV range is prime discovery space. It is a key piece to the high-energy view of the Universe.

More than \( \frac{1}{3} \) of Fermi-LAT catalog sources peak below the Fermi-LAT band.

Achievable: Orders of magnitude improvement

Below 200 MeV AMEGO will dramatically improve sensitivity and will open a new window in the spectrum leading to the discovery of new sources and new source classes.

Note: Fermi-LAT optimized for 1 GeV
AMEGO will provide a well rounded portfolio of capabilities
MeV blazars have their peak power output in the MeV Band and are powerful probes of the growth of supermassive black holes.

- Large jet power and accretion luminosity
- Often found at very large redshift
- Harbor massive black holes ($10^9 M_\odot$)

AMEGO will measure AGN spectral energy distributions and variability:

- Determine the maximum particle energies, study magnetic field strength, jet content, & the $\gamma$-ray emission location.
- Differentiate hadronic and leptonic models with polarization.

See T. Venters’ talk at 17:00 today (8/10)
Extreme Conditions Around Compact Objects

Example 1: Soft Gamma-ray Pulsars

- Seen in hard X-ray but not Fermi-LAT, peak lies in MeV band
- 11 MeV pulsars known
  - Extremely energetic $\dot{E} > 10^{36}$ erg
- Possible “hidden” population of energetic soft gamma emitting pulsars

Example 2: Novae

- How do close binary star systems like classical novae eject mass during outbursts?
- Shocks in the expanding nova envelope produce gamma rays.

AMEGO will measure the energy spectrum below 100 MeV to determine the shock properties and identify novae missed by optical observations.
Element Formation in Dynamic Systems

Nuclear lines explore Galactic chemical evolution and sites of explosive element synthesis (SNe)

- **Electron-positron annihilation radiation**
  - \( e^+ + e^- \rightarrow 2g \ (0.511 \text{ MeV}) \)

- **Nucleosynthesis**
  - Giants, CCSNe \((^{26}\text{Al})\)
  - Supernovae \((^{56}\text{Ni}, ^{57}\text{Ni}, ^{44}\text{Ti})\)
  - ISM \((^{26}\text{Al}, ^{60}\text{Fe})\)

- **Cosmic-ray induced lines**
  - Sun
  - ISM

See X. Wang’s talk at 14:30 on Friday (8/11)

- \(^{56}\text{Ni}: 158 \text{ keV} 812 \text{ keV (6 d)}\)
- \(^{56}\text{Co}: 847 \text{ keV}, 1238 \text{ keV (77 d)}\)
- \(^{57}\text{Co}: 122 \text{ keV (270 d)}\)
- \(^{44}\text{Ti}: 1.157 \text{ MeV (78 yr)}\)
- \(^{26}\text{Al}: 1.809 \text{ MeV (0.7 Myr)}\)
- \(^{60}\text{Fe}: 1.173, 1.332 \text{ MeV (2.6 Myr)}\)
Searching for Dark Matter Signals

Example: *Axions*

Axions in neutron stars (hep-ph/0505090)
- emission process for axions with mass up to a few MeV
- production in Gamma Ray Bursts

Axions produced in supernovae (arXiv:1410.3747)
- core collapse supernova (SN1987A)

Current upper limits would be limited by the PSF below 100 MeV

See M. Meyer’s talk at 17:00 on Friday (8/11)
Challenges

From ~0.1 - 100 MeV two photon interaction processes compete: Compton scattering and pair production cross sections intersect at ~10 MeV.

Additionally, large backgrounds exist in this energy range.
\( \gamma \) converts to pair \((e^-/e^+)\) in a multi-layer Si-strip tracker (no additional conversion material).

- Trigger on signals in 2 consecutive Si-strip layers in coincidence with energy deposit in a calorimeter.
- \( \gamma \) direction is determined by measuring the position of the pair components as they pass through the Si-strip layers and a calorimeter.
- \( \gamma \) energy is determined by evaluating the energy deposited in the Si-strips and in the calorimeter.

Photon scatters a low-energy \( e^- \) in Si-strip. Scattered \( \gamma \) can be absorbed in the calorimeter.

- Trigger on signal in Si-strip in coincidence with energy deposit in the calorimeter.
- \( \gamma \) direction constrained to a circle or arc on the sky. Determined by position and energy measurements of a low-energy \( e^- \) and absorbed \( \gamma \).
- \( \gamma \) energy is determined by evaluating the energy deposited in the Si-strips and in the calorimeter.
**Tracker:** Incoming photon undergoes pair production or Compton scattering. Measure energy and track of electrons and positrons
- 60 layer DSSD, spaced 1 cm, Strip pitch 0.5 mm

**CZT Calorimeter:** Measure location and energy of Compton scattered photons
- Layer of 0.6 x 0.6 x 2 cm bar CZT

**CsI Calorimeter:** Extend upper energy range
- 6 planes of 1.5 cm x 1.5 cm bars
AMEGO Details

- Use of **well-tested, proven technologies** (Si tracker, CsI calorimeter, Plastic ACD, …)
- Designed to fit within a probe class budget:
  - Concept for the 2020 decadal review
- Designed to be **modular** for ease of development, testing, and integration.
- 10 year mission goal (similar to *Fermi*)

<table>
<thead>
<tr>
<th>Energy Range</th>
<th>0.2 MeV -&gt; 10 GeV</th>
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<tbody>
<tr>
<td>Angular Resolution</td>
<td>3° (1 MeV), 10° (10 MeV)</td>
</tr>
<tr>
<td>Energy Resolution</td>
<td>&lt;1% below 2 MeV; 1-5% at 2-100 MeV; ~10% at 1 GeV</td>
</tr>
<tr>
<td>Field-of-View</td>
<td>2.5 sr</td>
</tr>
<tr>
<td>Sensitivity (MeV s⁻¹ cm⁻²)</td>
<td>4x10⁻⁶ (1 MeV); 4.8x10⁻⁶ (10 MeV); 1x10⁻⁶ (100 MeV)</td>
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</table>
The MeV gamma-ray band has enormous scientific potential.

AMEGO is a probe class survey mission in consideration for the 2020 decadal review with sensitivity between 0.2 MeV and 10 GeV.

Detects MeV gamma-rays via pair production and Compton scattering and performs continuum, spectroscopy and polarization measurements.

AMEGO will open up a new window on the MeV sky and explore:

- Jets: Formation, Evolution, and Acceleration
- Extreme Conditions Around Compact Objects
- Element Formation in Dynamic Systems
- Dark Matter Signals

See talks by T. Venters, M. Meyer, and X. Wang for more details.
Backup Slides
Angular Resolution vs. Theta

Preliminary (see R. Caputo et al. ICRC 2017 for more details).
Angular Resolution vs. Energy

Preliminary (see R. Caputo et al. ICRC 2017 for more details).
Diffuse Backgrounds

Preliminary (see R. Caputo et al. ICRC 2017 for more details).
Effective Area vs. Theta

Preliminary (see R. Caputo et al. ICRC 2017 for more details).
Effective Area vs. Energy

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Sensitivity
In one week, assuming that the source is in the field of view for 10% of the time, AMEGO reaches an MDP of 5% (12%) in the 0.5 - 1 MeV (1 - 2 MeV) energy range.

\[
\text{MDP} = \frac{4.29}{\mu_{100} R_S} \sqrt{\frac{R_S + R_{BG}}{T_{\text{obs}}}}
\]

Preliminary (see R. Caputo et al. ICRC 2017 for more details).