Fermi Gamma-ray Space Telescope Motivation for a Medium-Energy Observatory (1-100 MeV)

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Outline

Fermi Gamma-ray Space Telescope **capabilities (and limitations) for E<100 MeV astrophysics.**

Some *Fermi* results that are encouraging for medium-energy gamma-ray studies.

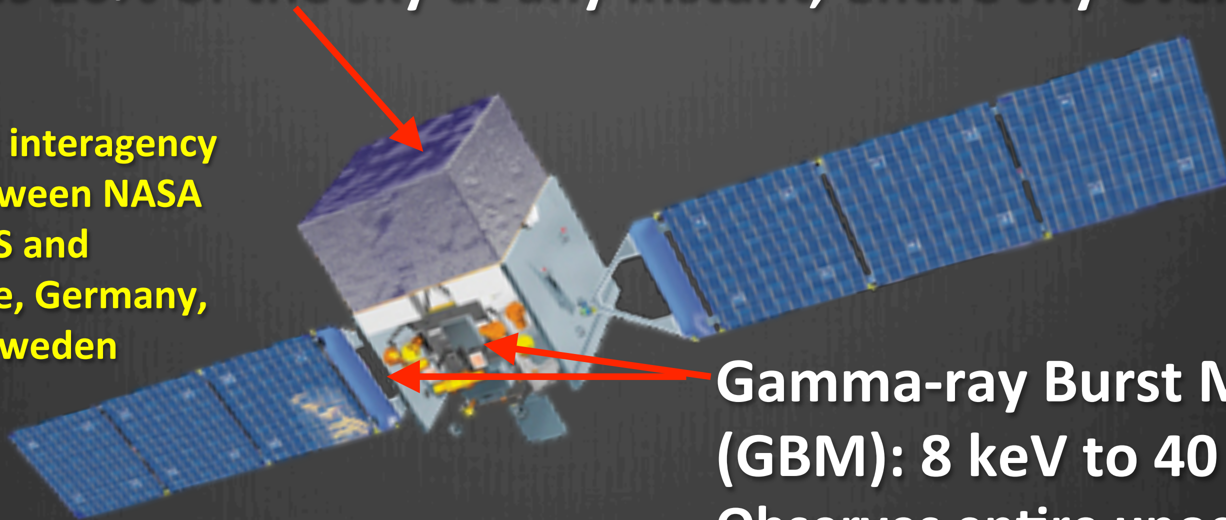
Some *Fermi* non-detections that suggest opportunities for medium-energy work.

Fermi Capabilities

The *Fermi* Observatory

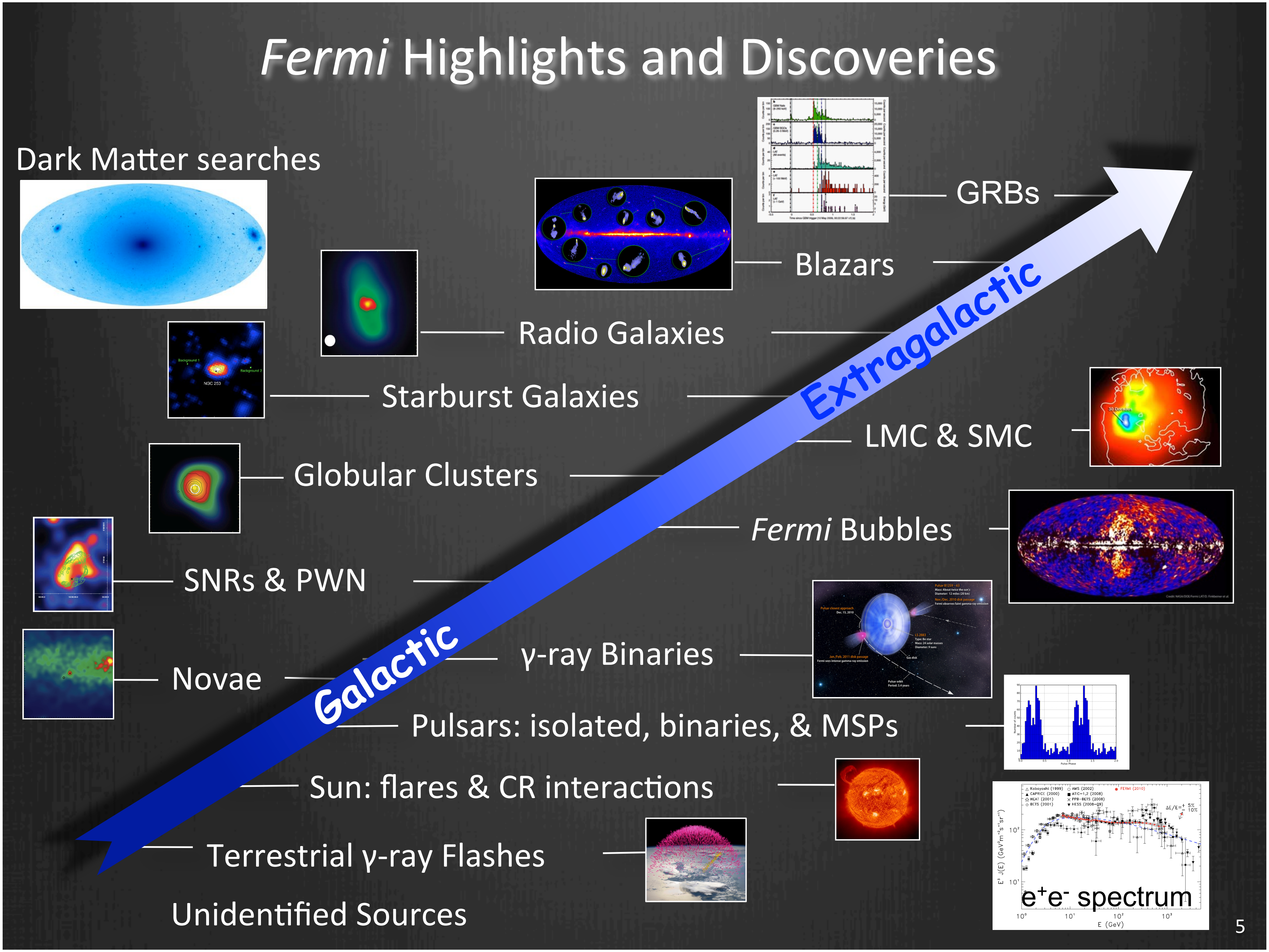
Large Area Telescope (LAT): 20 MeV to more than 300 GeV.
Observes 20% of the sky at any instant, entire sky every 3 hrs

International and interagency collaboration between NASA and DOE in the US and agencies in France, Germany, Italy, Japan and Sweden



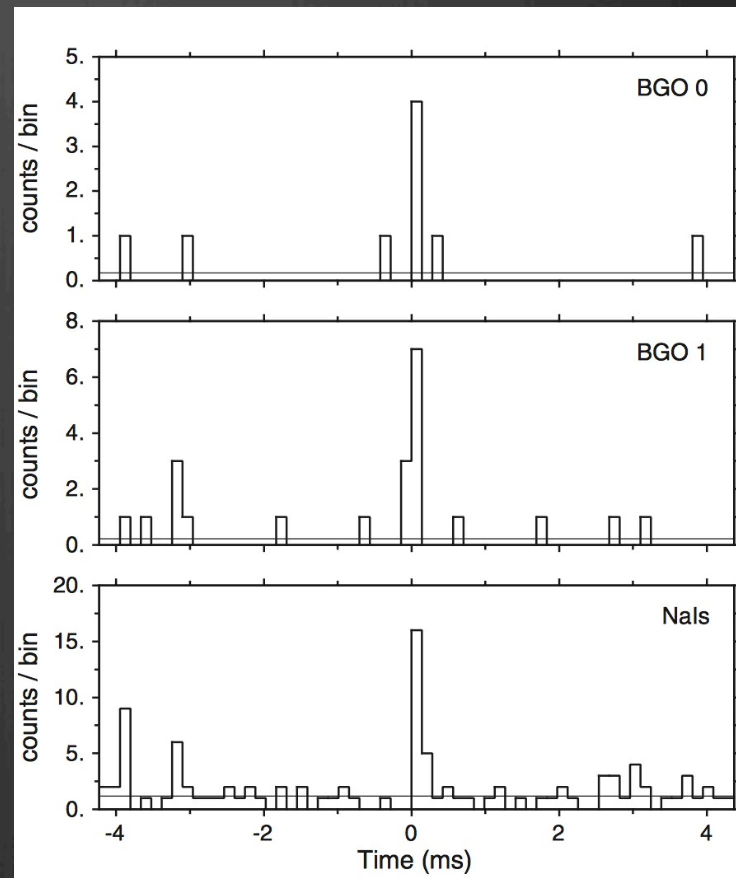
Gamma-ray Burst Monitor (GBM): 8 keV to 40 MeV.
Observes entire unocculted sky

- **Both instruments can tag individual gamma rays with 1 microsec accuracy.**
- **All the *Fermi* gamma-ray data become public immediately**
- **Analysis software, documentation, catalogs, and background models are available from the *Fermi* Science Support Center at Goddard, http://fermi.gsfc.nasa.gov/ssc/**
- **The *Fermi* instrument teams use GCN Notices, Astronomer's Telegrams, a weekly blog, and email lists to inform the community of sky activity**


Fermi Highlights and Discoveries
Dark Matter searches
GRBs
Blazars
Radio Galaxies
Starburst Galaxies
Extragalactic
LMC & SMC
Globular Clusters
Fermi Bubbles
SNRs & PWN
γ-ray Binaries
Novae
Galactic
Pulsars: isolated, binaries, & MSPs
Sun: flares & CR interactions
Terrestrial γ-ray Flashes
Unidentified Sources
e⁺e⁻ spectrum

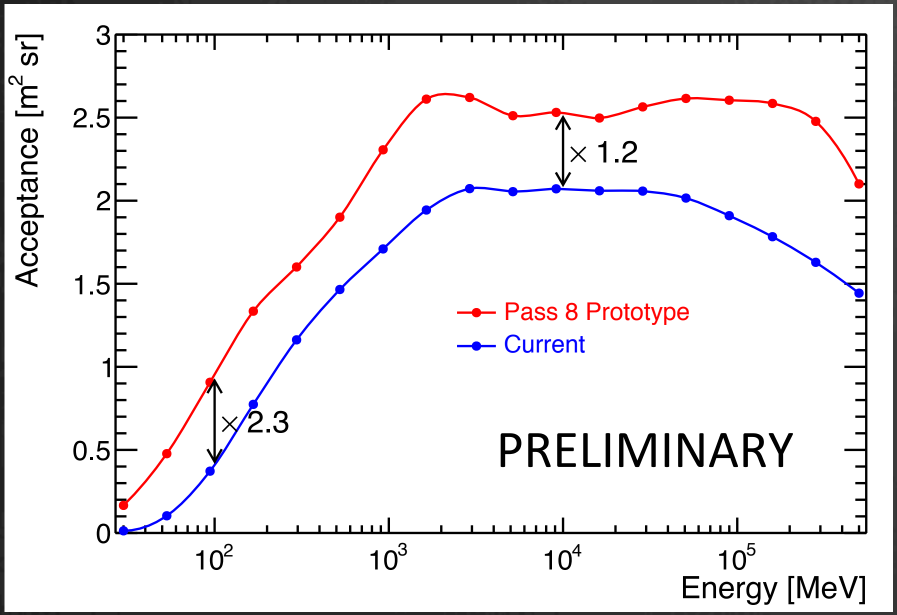
Short Transients Detection with the Fermi GBM Time Tagged Events

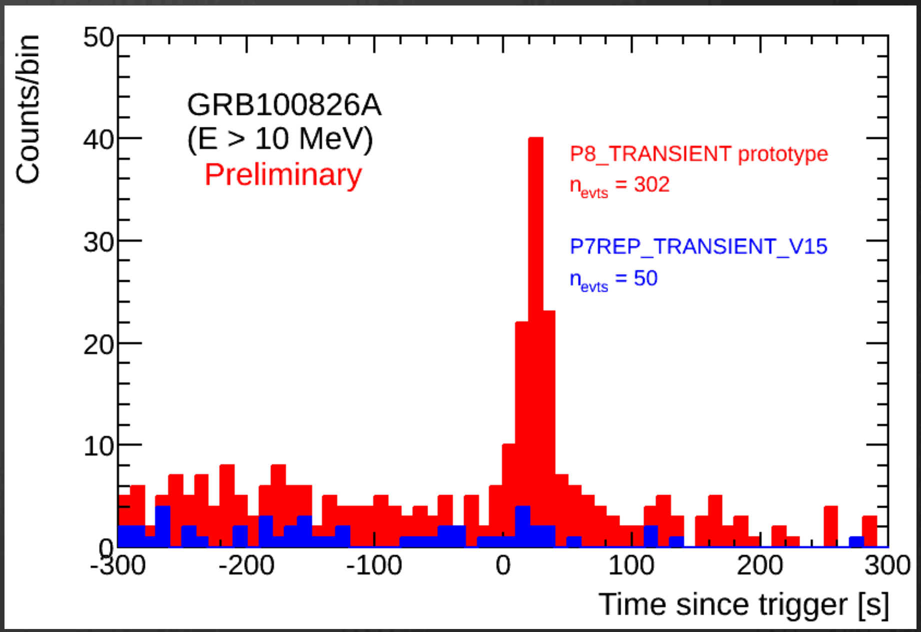
- The GBM originally accumulated data in time bins, switching to individually time-tagged photons when a burst was detected.
- Switching to Continuous Time-Tagged Event (CTTE) Mode has enhanced the GBM sensitivity to short transients.
- The rate of Terrestrial Gamma-ray Flashes like the one shown here has increased by an order of magnitude (Briggs et al. JGR, 2013)
- The rate of short Gamma-ray Bursts is expected to double.



LAT Analysis Upgrades: Pass 8

- A major upgrade of the LAT (aka Pass 8) is nearing completion
  - Complete revamp of LAT event reconstruction algorithms
  - More than double the acceptance (effective area x solid angle) below 100 MeV
  - Retroactively update entire *Fermi*-LAT data archive





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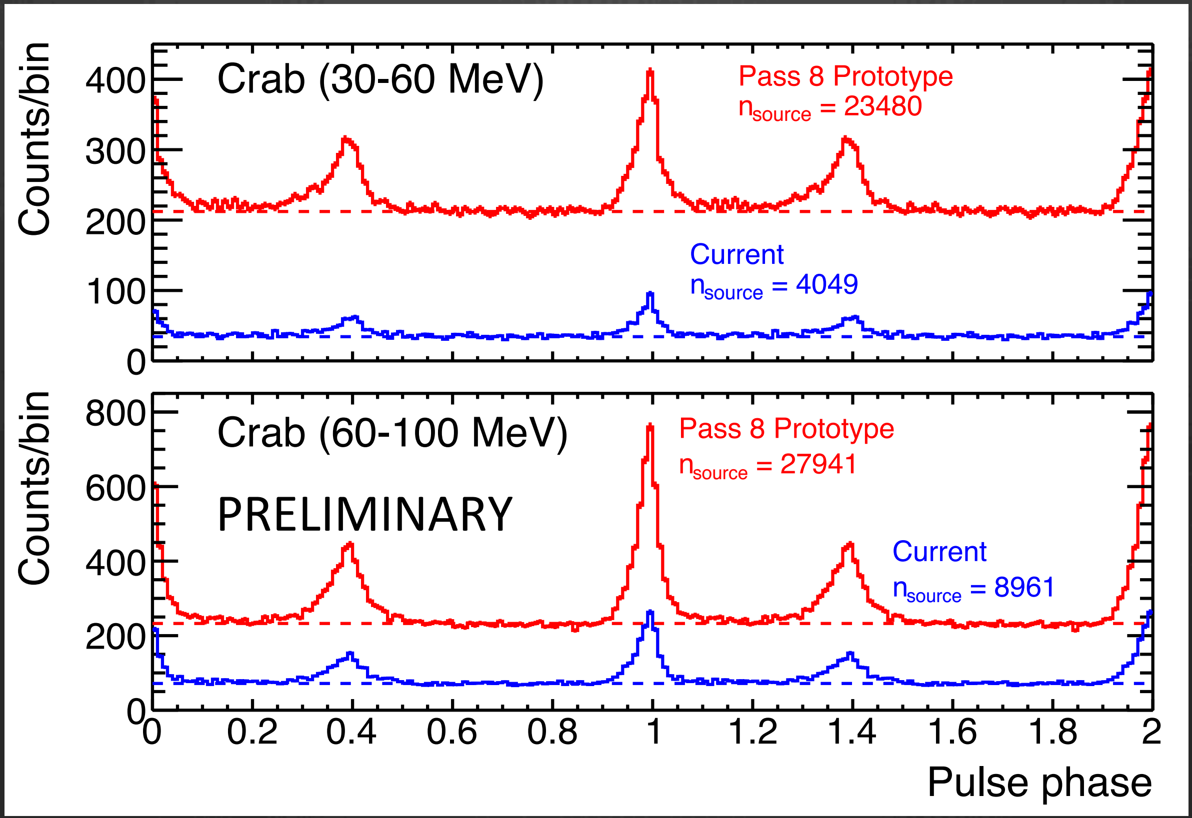

Fermi GBM and LAT are capable 1-100 MeV instruments, but…

GBM is primarily a transient instrument. It does have source monitoring ability using Earth occultation, but those results are all < 1 MeV.

LAT was optimized for astrophysics in the GeV energy range. Sensitivity falls off below 1000 MeV, and background rejection is significantly more difficult below 100 MeV.

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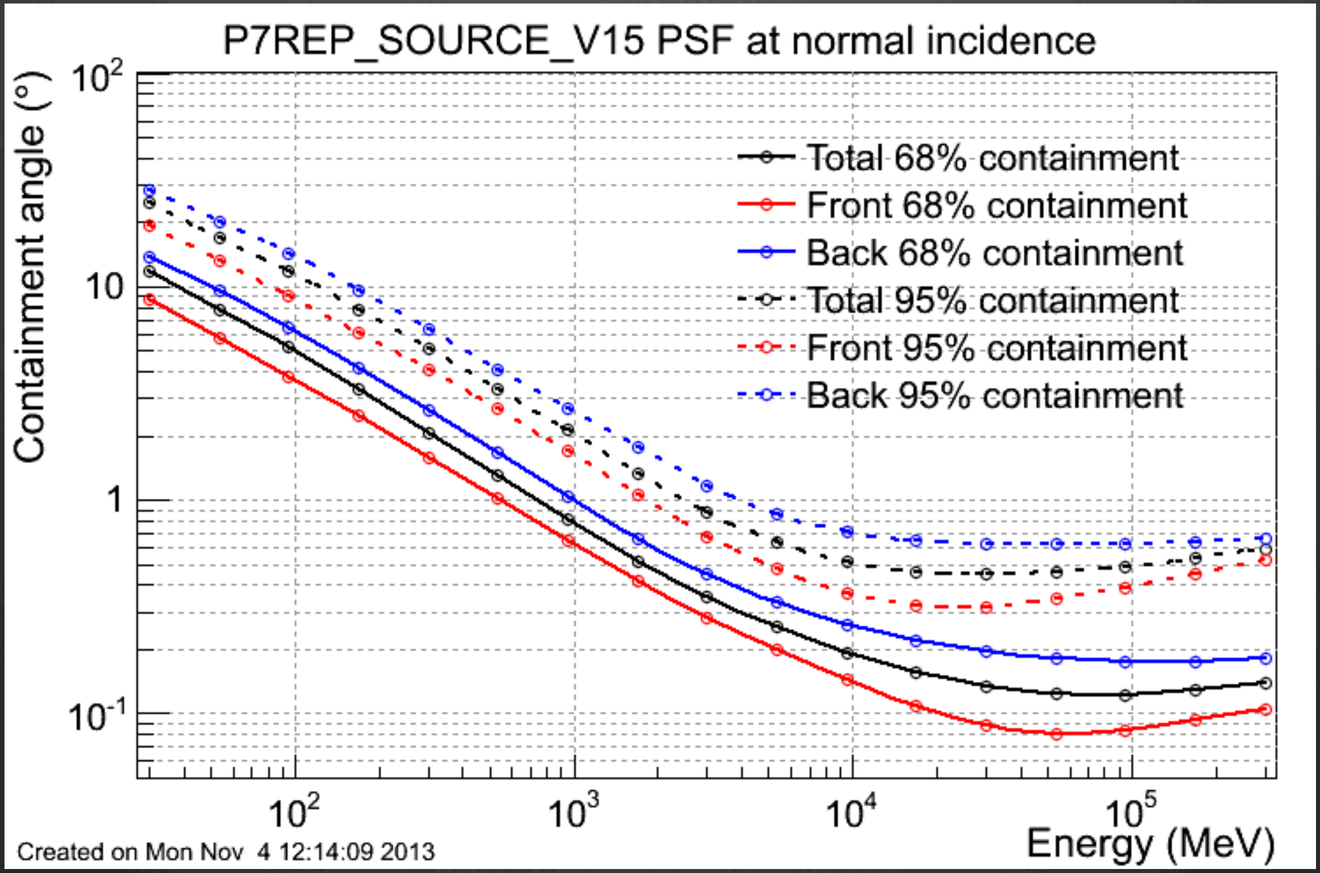


At 30 MeV, photons from a point source are spread out over hundreds of square degrees. Source confusion is a major problem.

Medium-Energy Motivation from *Fermi* LAT Results

Basic Premise: For any astrophysical source, we cannot expect to have a full understanding of its properties without observing the part of the spectrum where it has a peak energy output.

Without such a measurement, any estimate of source energetics is just an approximation.

Without this measurement, spectral modeling of the source physics will be incomplete.

We therefore examine the LAT spectra in the 3FGL catalog. Any source with a photon power-law spectrum steeper than E^{-2} has its peak energy output below 100 MeV.

RESULTS

Over 2/3 of the 3FGL sources have power-law spectra (E>100 MeV) steeper than E^{-2}

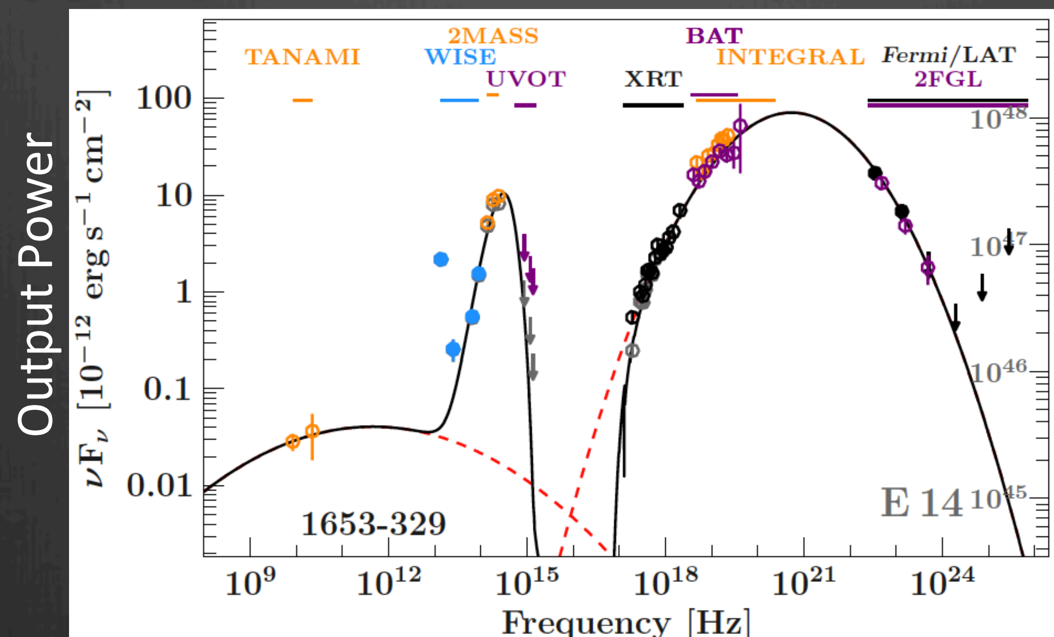
Over 600 of these have spectra steeper than $E^{-2.5}$

These include many Flat Spectrum Radio Quasars, the most distant and most energetic LAT sources, as well as many of the unidentified sources, representing discovery space.

These LAT results guarantee a significant scientific return for any lower-energy instrument with reasonable sensitivity.

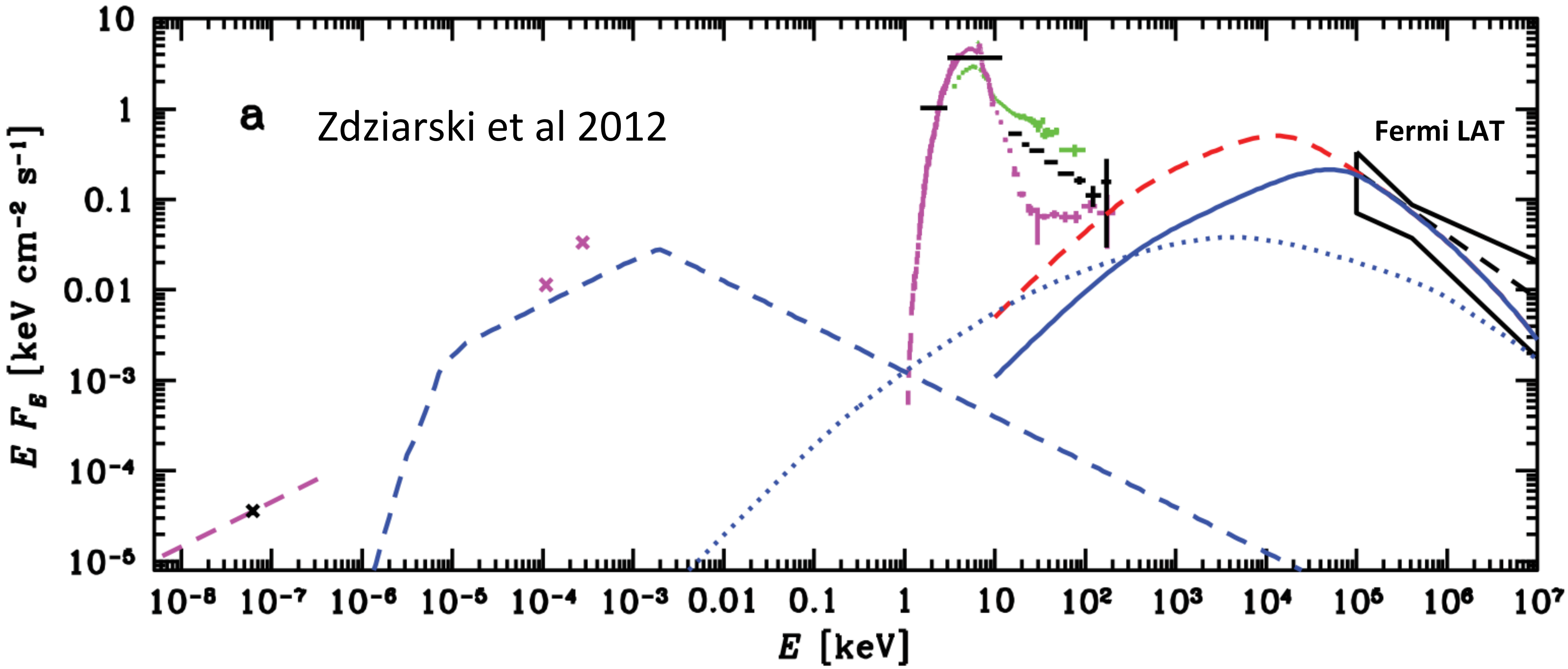
Example: FSRQs and IceCube Neutrinos

Two very high energy neutrinos detected by the IceCube detector at the South Pole may originate from gamma-ray-bright active galaxy jets pointed towards us (Krauß et al. 2014, A&A).



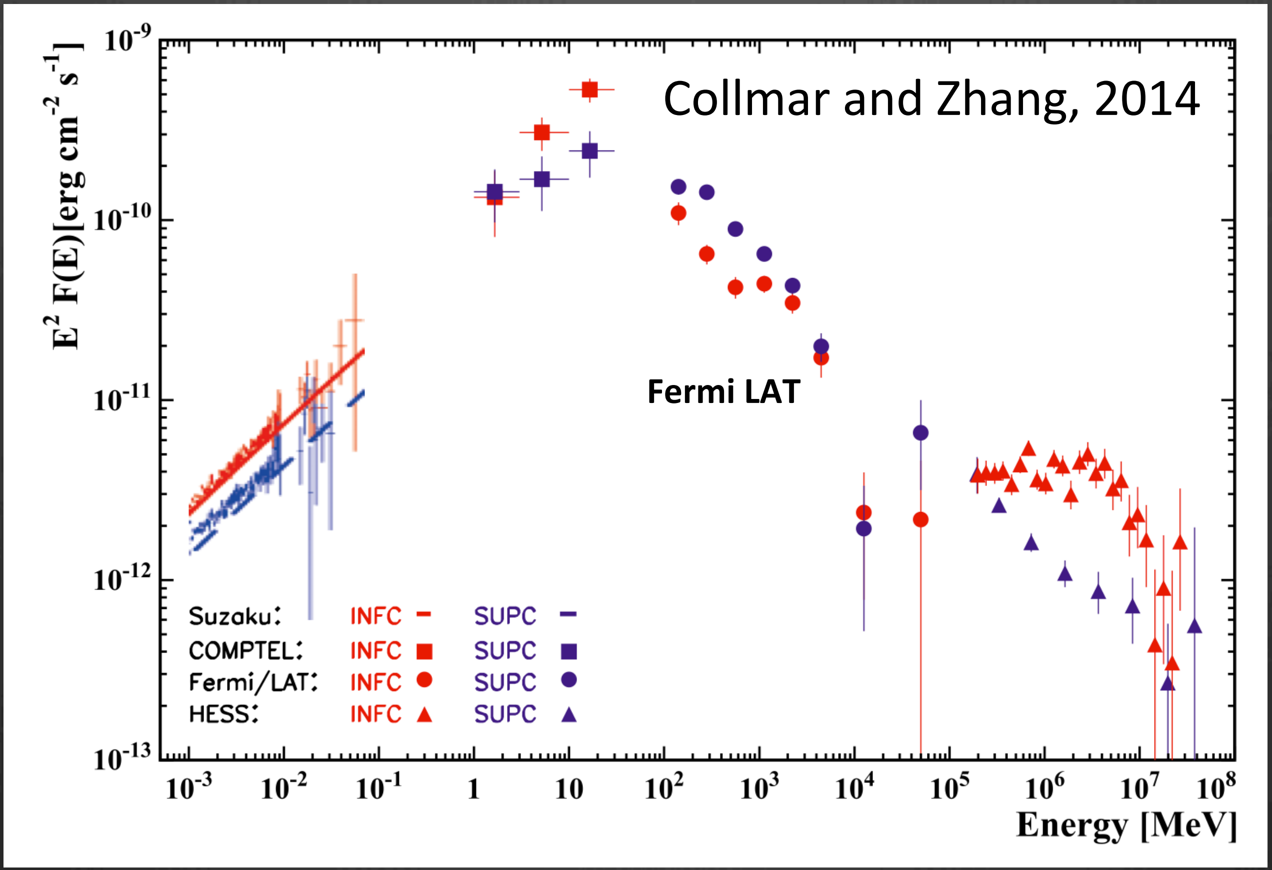
Six bright active galaxies in the same part of the sky as the two neutrinos "Bert" and "Ernie". Modeled output power, assuming a proton blazar, allows a calculation of the number of neutrinos we expect IceCube to see. Rate of expected electron neutrino detections is consistent with IceCube results. IN NOT ONE CASE IS THE PEAK OF THE SED MEASURED.

Example – Cygnus X-3



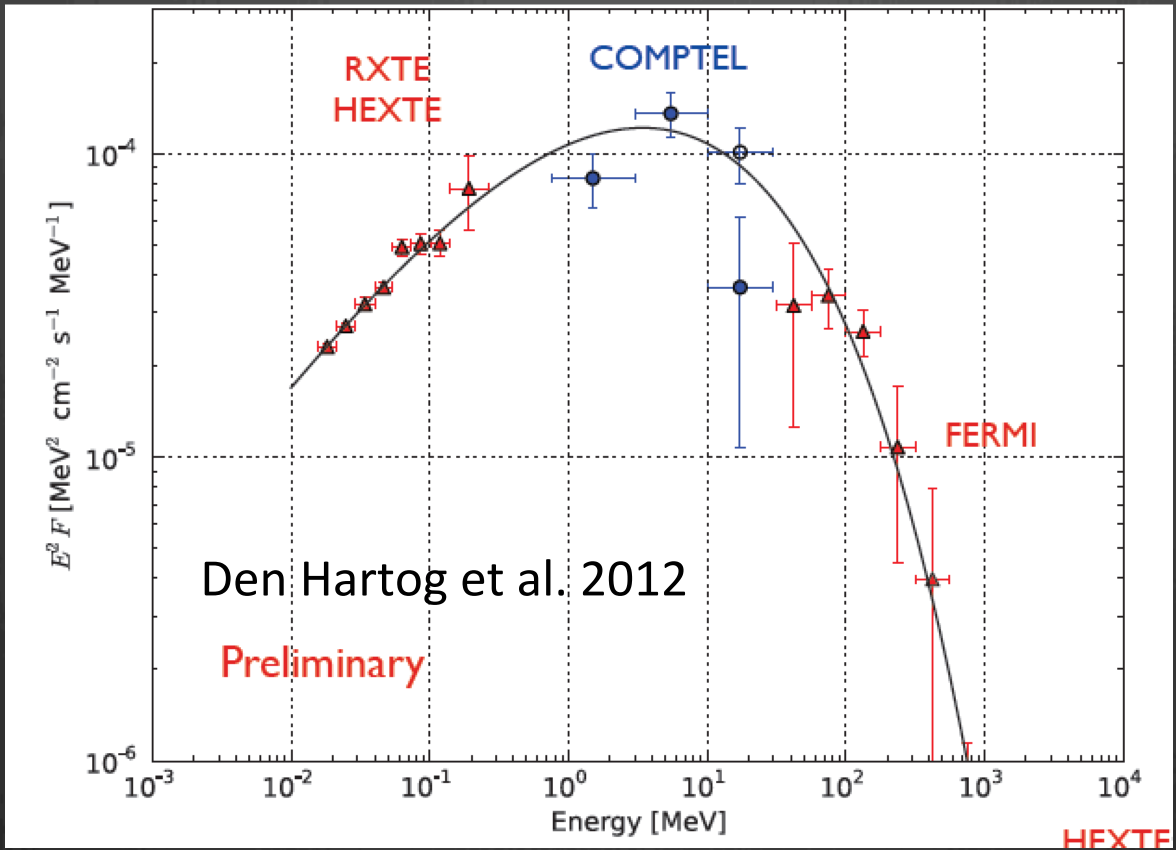
X-rays and gamma rays are separate components (the gamma rays are only seen when the X-rays are in a soft state). The peak of the gamma-ray component lies below 100 MeV, and its position is critical to modeling this nonthermal emission.

Example – High-mass Binary LS 5039



The complex keV to TeV spectrum varies during the 3.9-day orbital period (Red – inferior conjunction; Blue – superior conjunction). The MeV results are from COMPTEL, so not contemporaneous with recent observations.

Example – Pulsar PSR J1513-5908



Although most high-energy pulsars have flat spectra in the LAT energy range, this one is only weakly detected above 100 MeV. It may represent a new class of pulsars.

OTHERS

V407 Cygni – nova

Cen A – radio galaxy

M31 – normal galaxy

M82 – starburst galaxy

Gamma-ray bursts

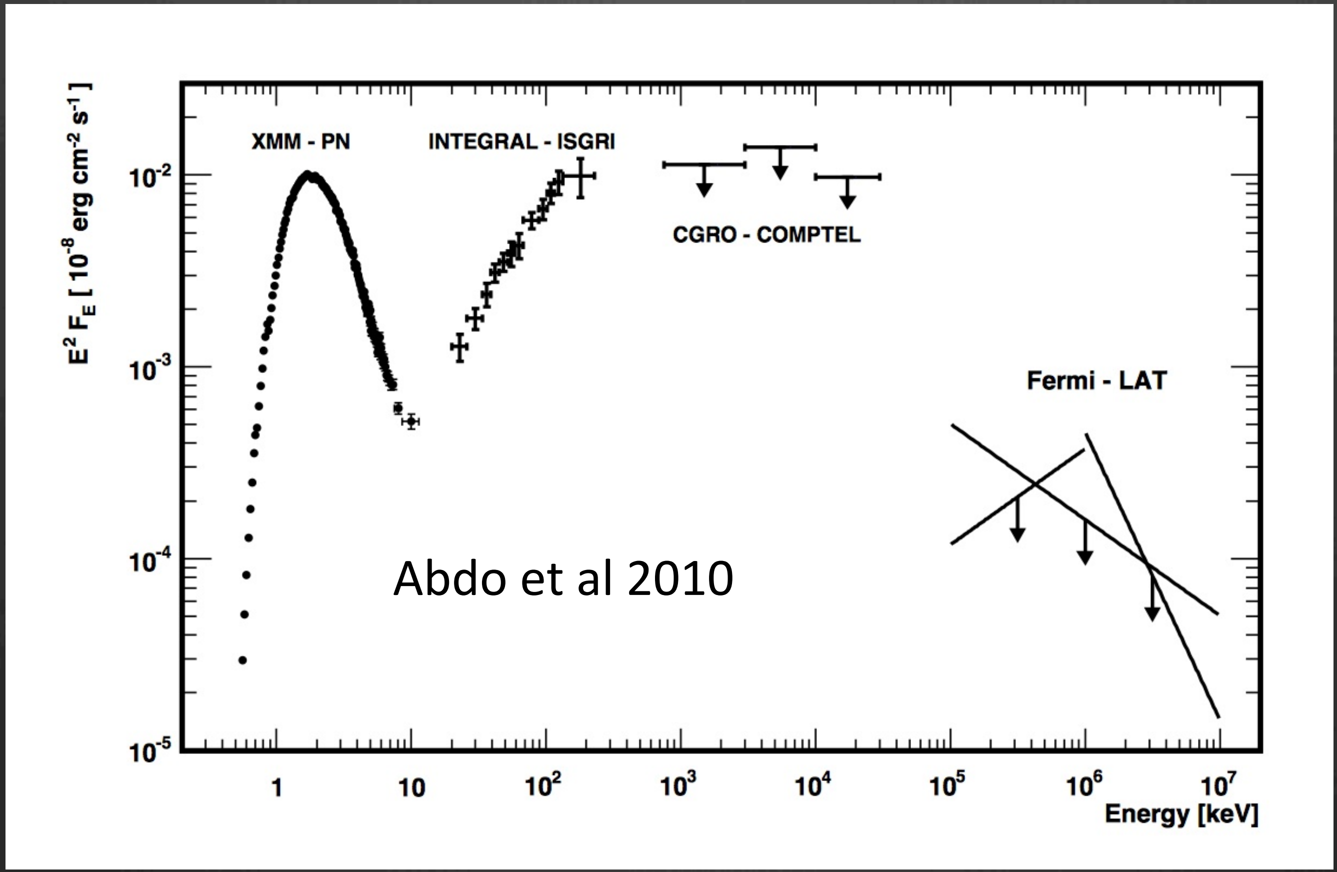
Medium-Energy Motivation from *Fermi* LAT Non-detections

Start from lower energies and extrapolate upward. We examine the Swift BAT spectra in the 70-month catalog (Baumgartner et al 2013). Any source with a photon power-law spectrum flatter than E^{-2} has its peak energy output above 200 keV. If such a source is not seen by Fermi LAT, then its spectrum must turn over in the medium-energy range.

There are over 400 BAT sources with a spectrum flatter than E^{-2}

Example: SWIFT J1913.3-5010, a Seyfert 2 galaxy, has a photon power-law index of 1.46 and an energy flux of 2 x 10^{-11} ergs s^{-1} cm^{-2}. It is not seen by the LAT.

Example – Magnetar 4U 0142+61



Fermi GBM shows emission up to 300 keV (Hermsen, 2013). Somewhere above that energy, the spectrum must break.

Summary

A simple phenomenological analysis of Fermi source detections and non-detections reveals a broad range of scientific opportunities for a medium-energy gamma-ray observatory.

The 1-100 MeV energy band is clearly a "crossroads" range where many sources have changes in their spectral shape. Such spectral breaks are important to determining the physics of the sources.

Backup