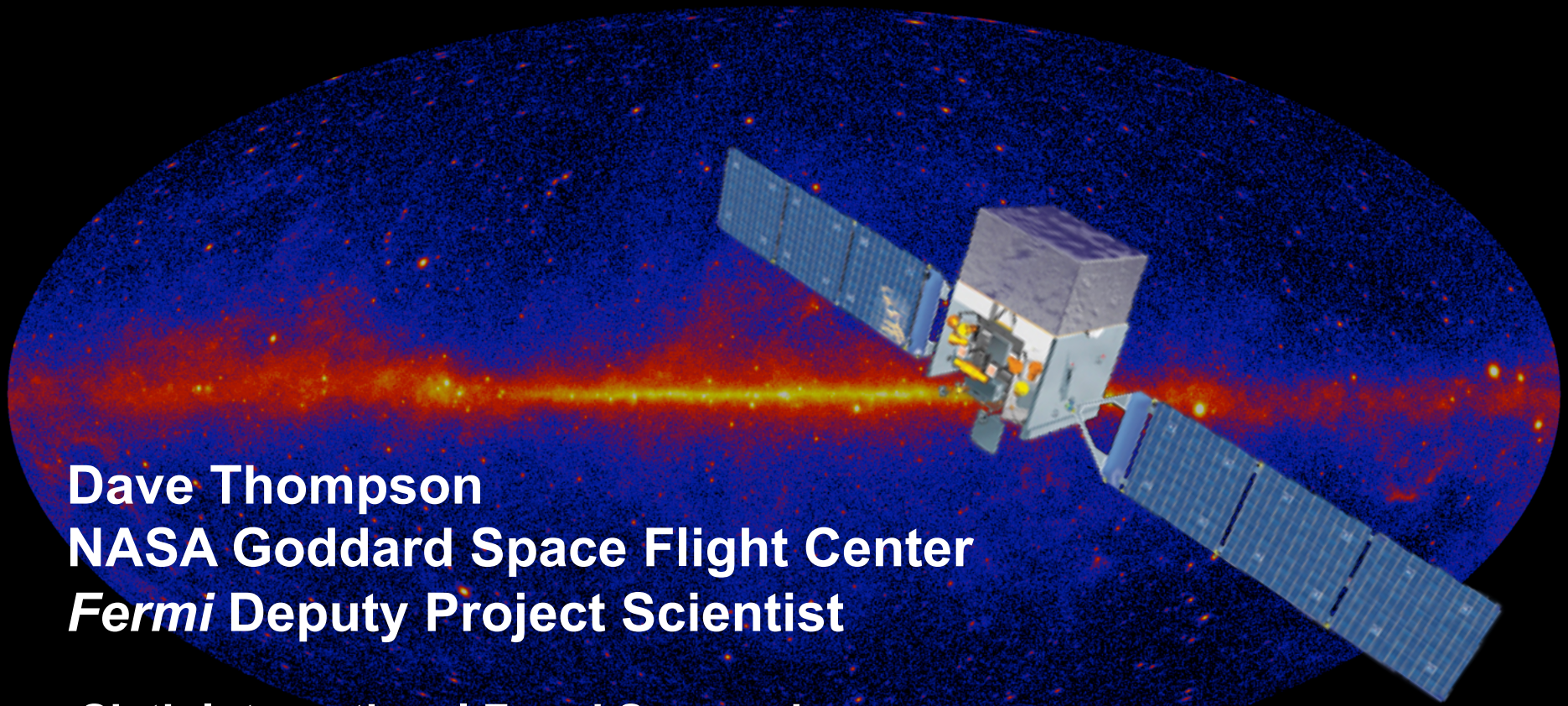
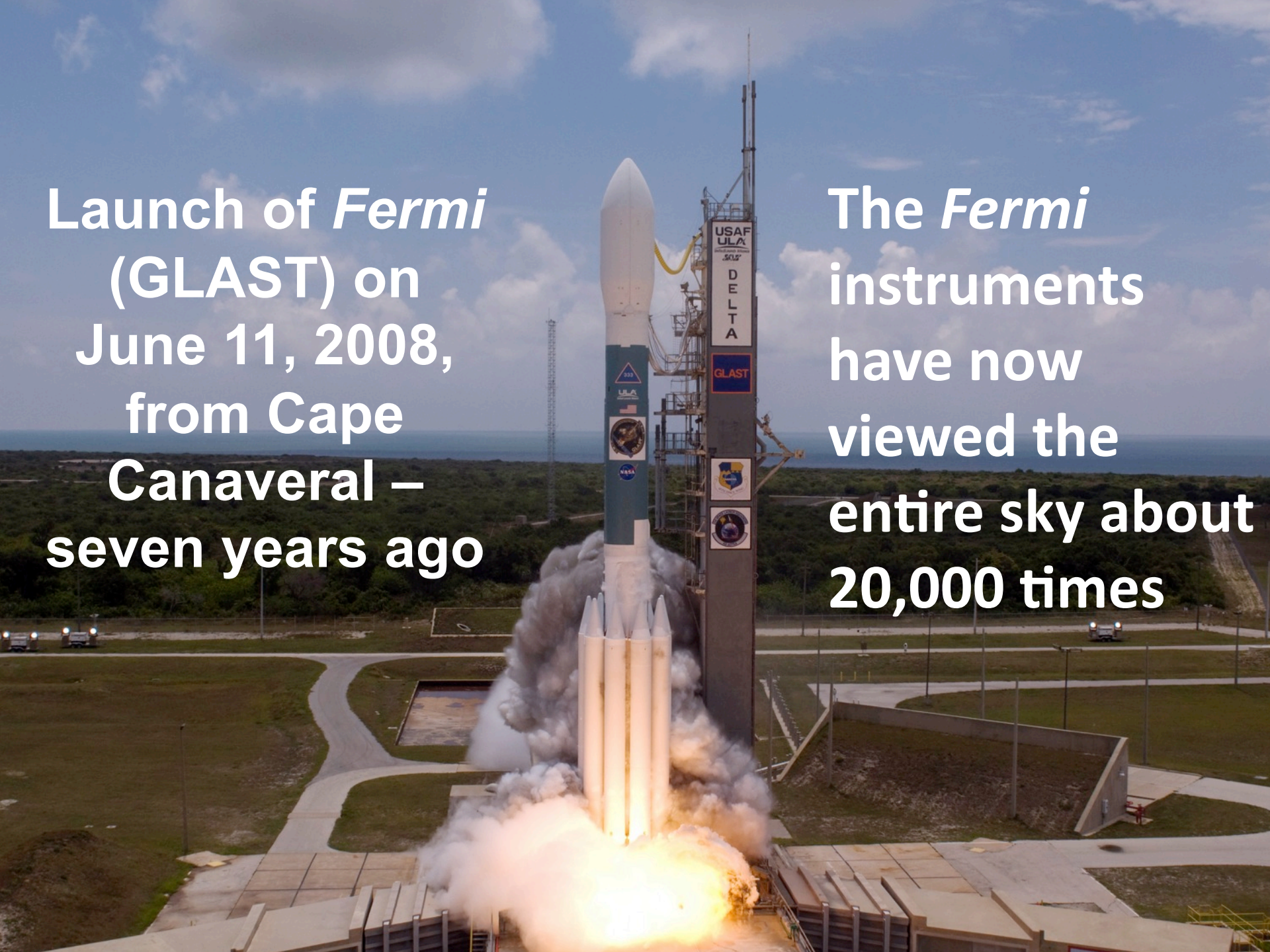
Taking the Long-Term View: *Fermi* Results from a Multi-Year Baseline



Dave Thompson
NASA Goddard Space Flight Center
***Fermi* Deputy Project Scientist**

Sixth International Fermi Symposium
Arlington, Virginia, November, 2015



Launch of *Fermi* (GLAST) on June 11, 2008, from Cape Canaveral – seven years ago

The *Fermi* instruments have now viewed the entire sky about 20,000 times

Outline

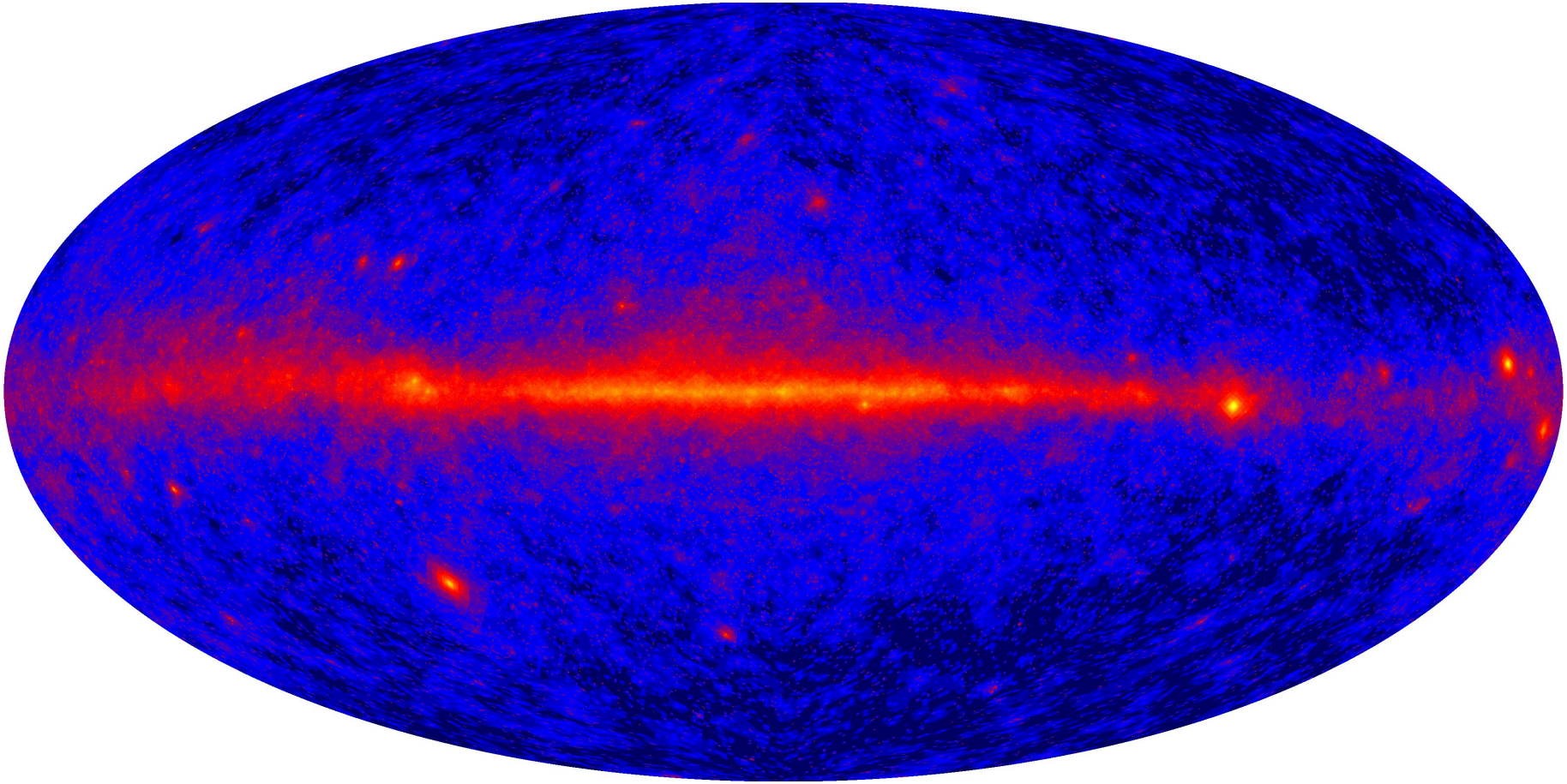
Three reasons that scientific discoveries continue to come from *Fermi*:

1. **Improved instrument performance**
   Pass 8 with the LAT (talk by Matt Wood on Friday) and Continuous Time Tagged Events from GBM
2. **Accumulation**
   For the LAT, a longer mission increases the energy reach, improves the statistical precision, and enhances variability measurements.
3. **Opportunities**
   The extreme phenomena seen with *Fermi* are often rare, so the longer mission increases the chances of seeing activity that gives meaningful insight.

Fermi LAT Data Accumulation:

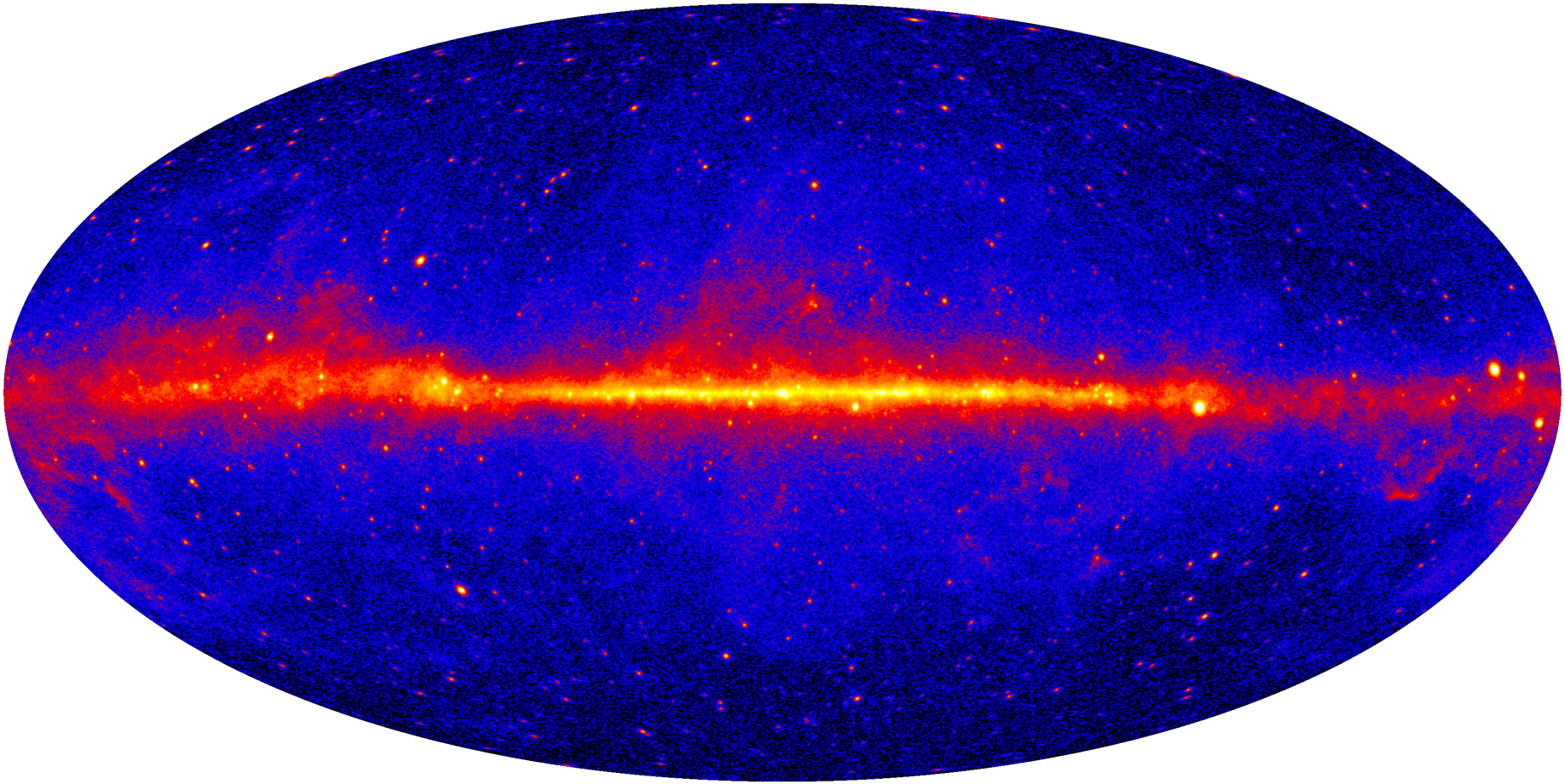
For most of the sky and most of its energy range, the LAT is limited by photon counting statistics, not background.

The First LAT All-sky Map



Energy Range: E>100 MeV Duration: few days

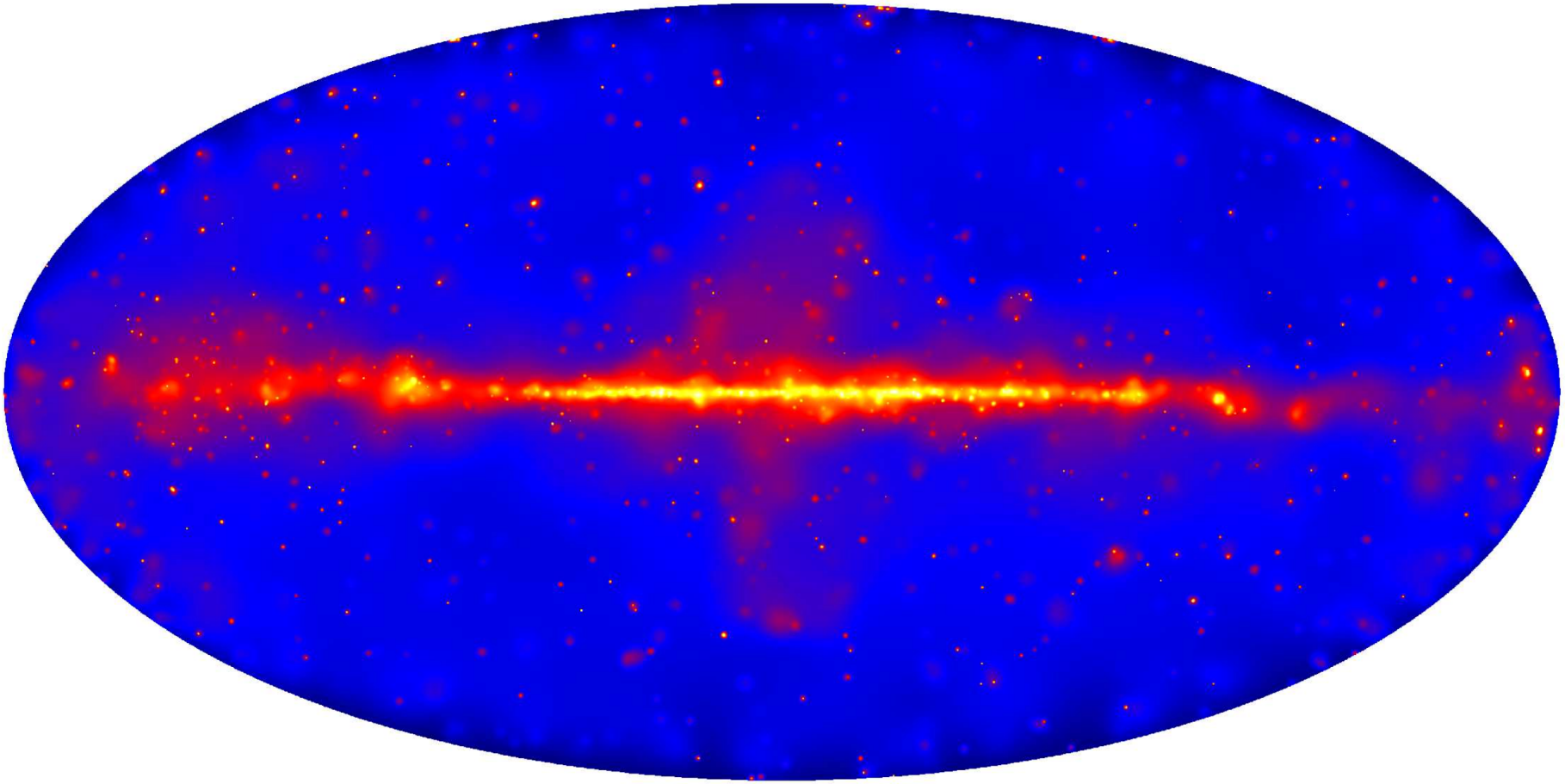
The 3FGL All-sky Map



Energy Range: E>1 GeV

Duration: 48 months

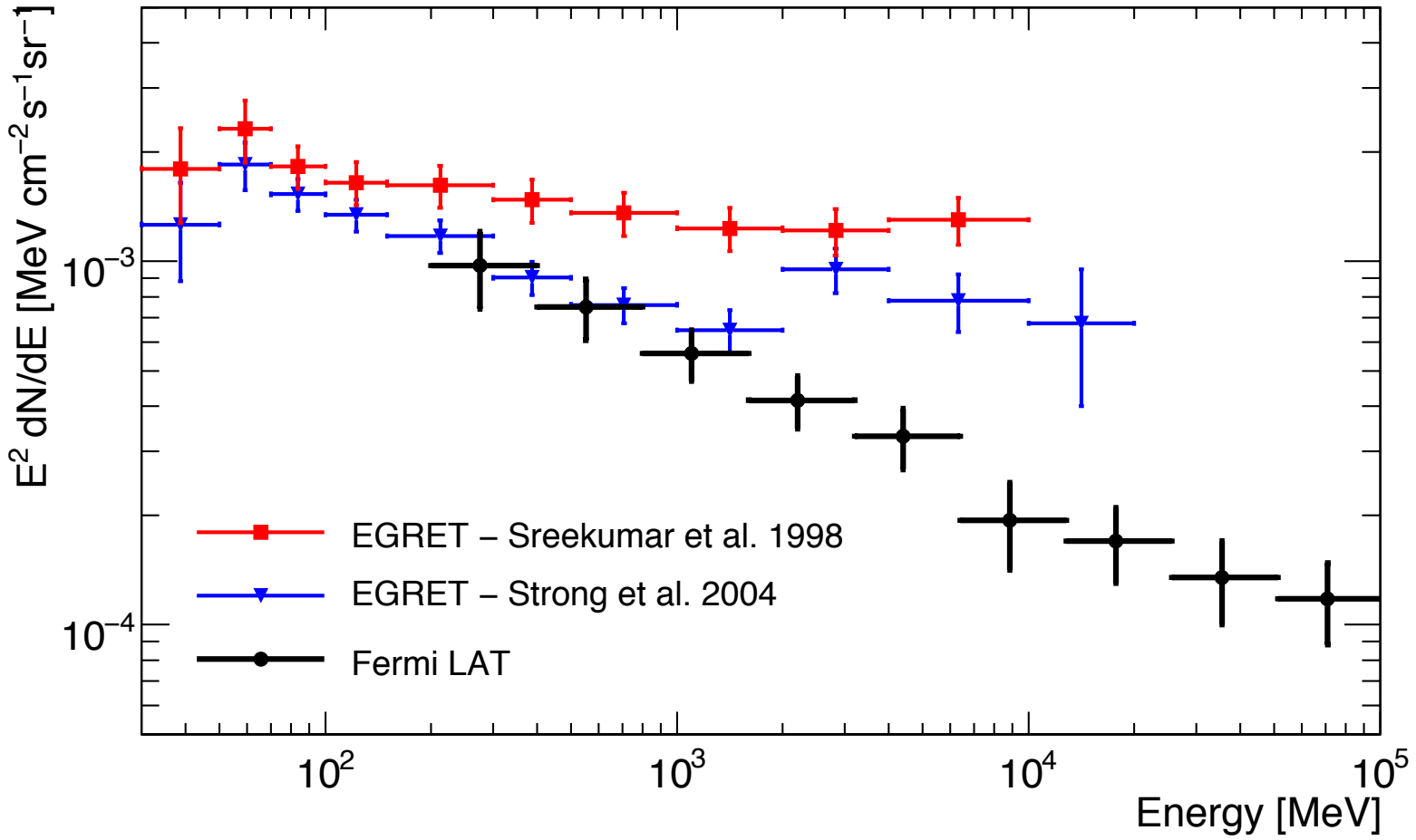
The 2FHL All-sky Map



Energy Range: E>50 GeV Duration: 80 months

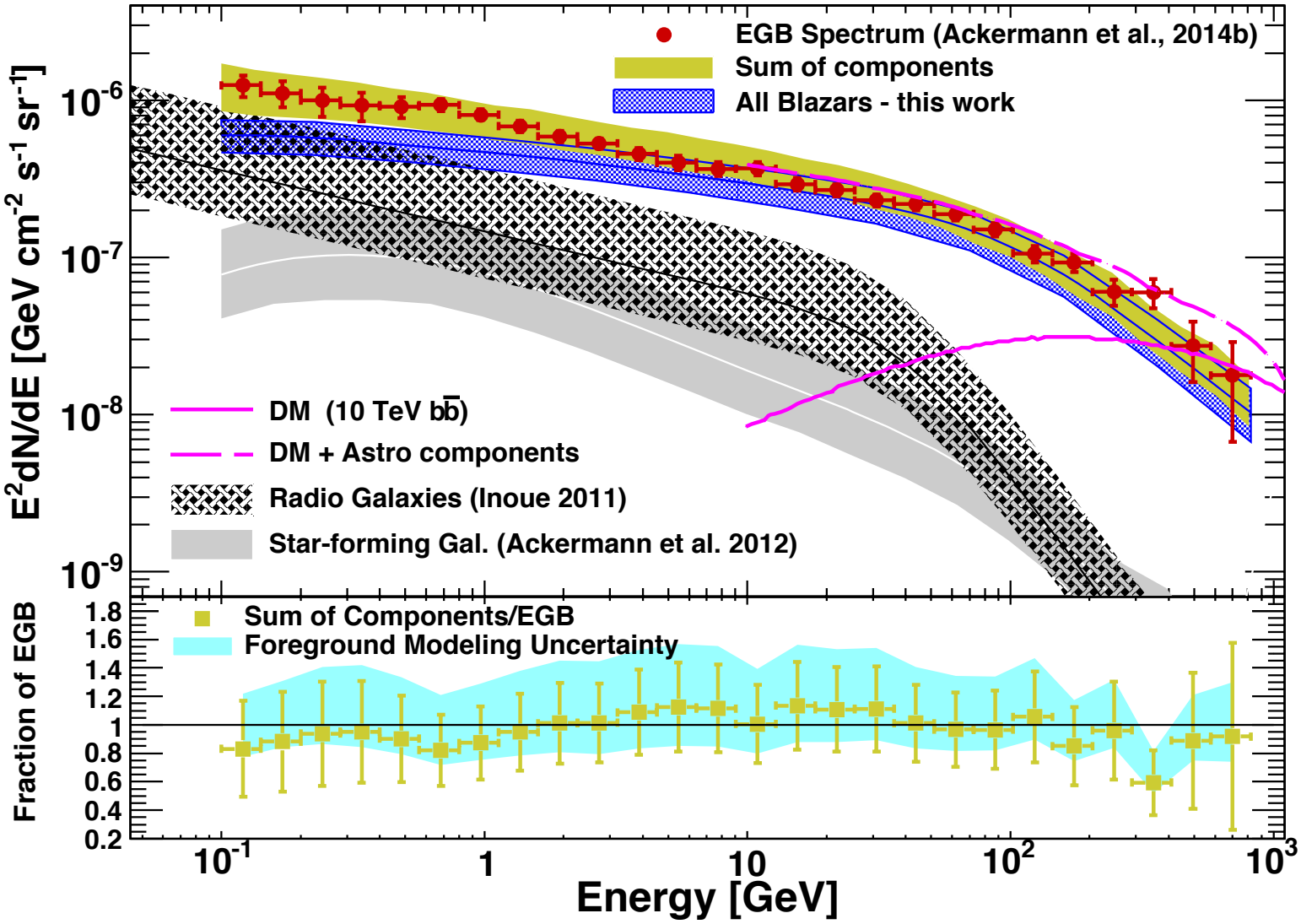
Talk tomorrow by Marco Ajello

Extragalactic Gamma-ray Background



Abdo, et al. 2010 – 10 months of data. Energies 200 MeV – 100 GeV

Extragalactic Gamma-ray Background

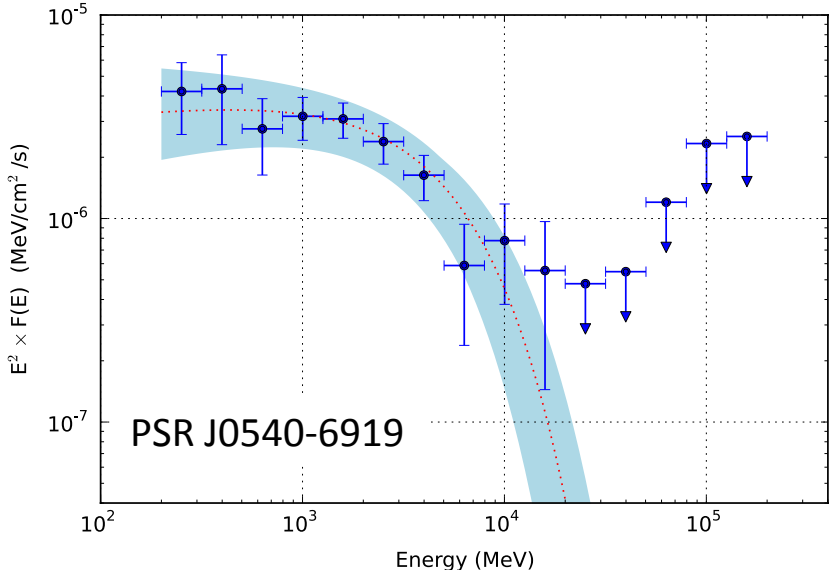


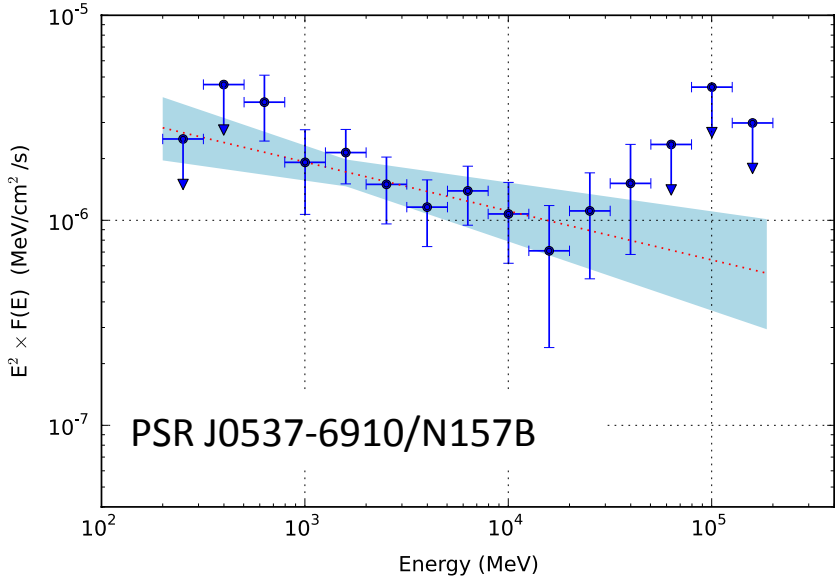
Ajello, et al. 2015 Energy Range: 100 MeV – 820 GeV Duration: 50 months

Resolving Sources in the LMC

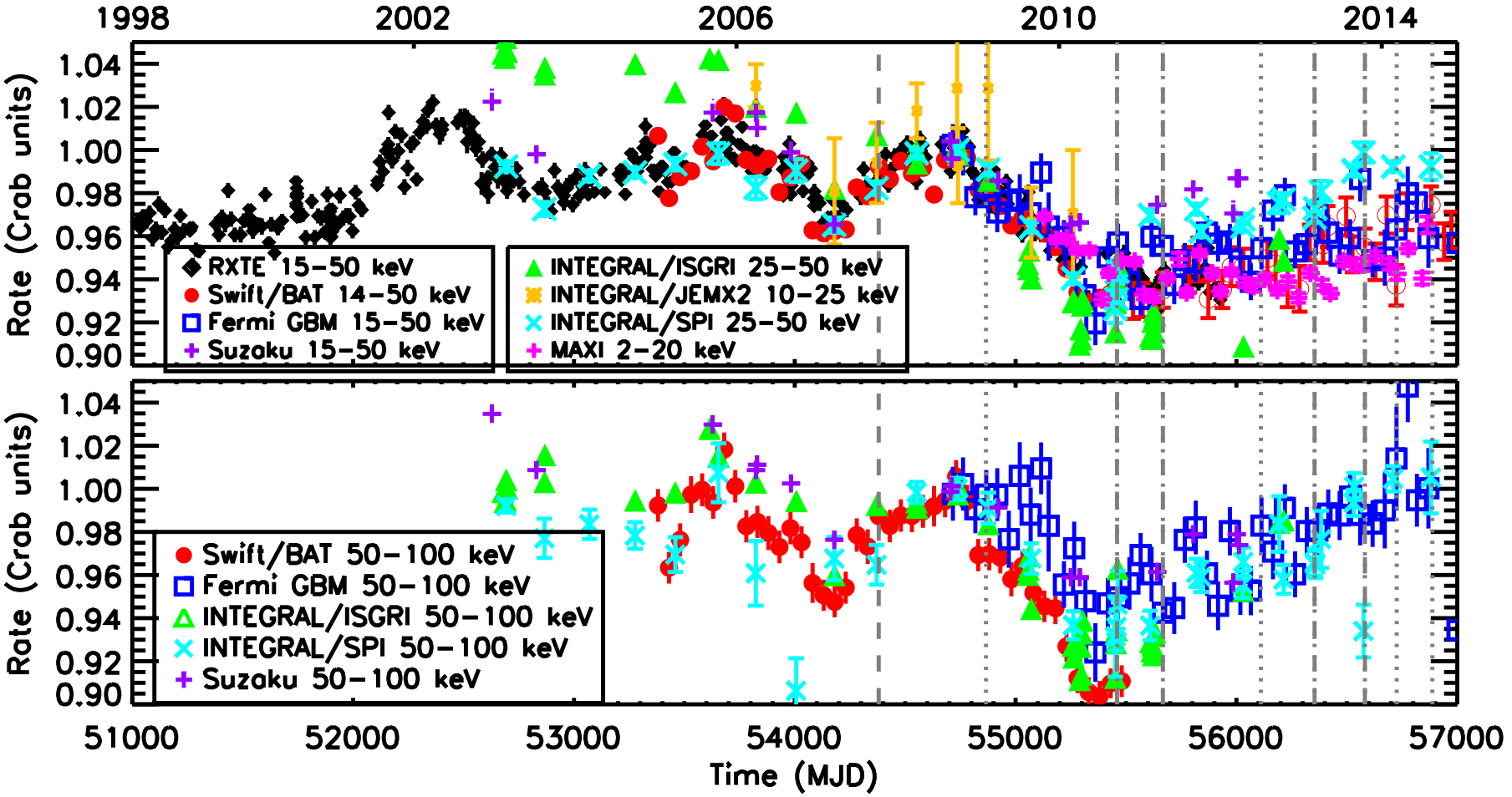
In the original 11-month LAT analysis of the Large Magellanic Cloud, the 30 Doradus region was unresolved, and the emission was attributed generically to it being a star-forming region (Abdo et al, 2010).

With 6 years of data, sources in this region are resolved. The source at the position of PSR J0540-6919 has a pulsar-like spectrum (and is a gamma-ray pulsar), while the spectrum of the source at the position of PSR J0537-6910 looks neither like a pulsar nor a pulsar wind nebula (Ackermann et al. 2015 – two papers).
Poster by Pierrick Martin.





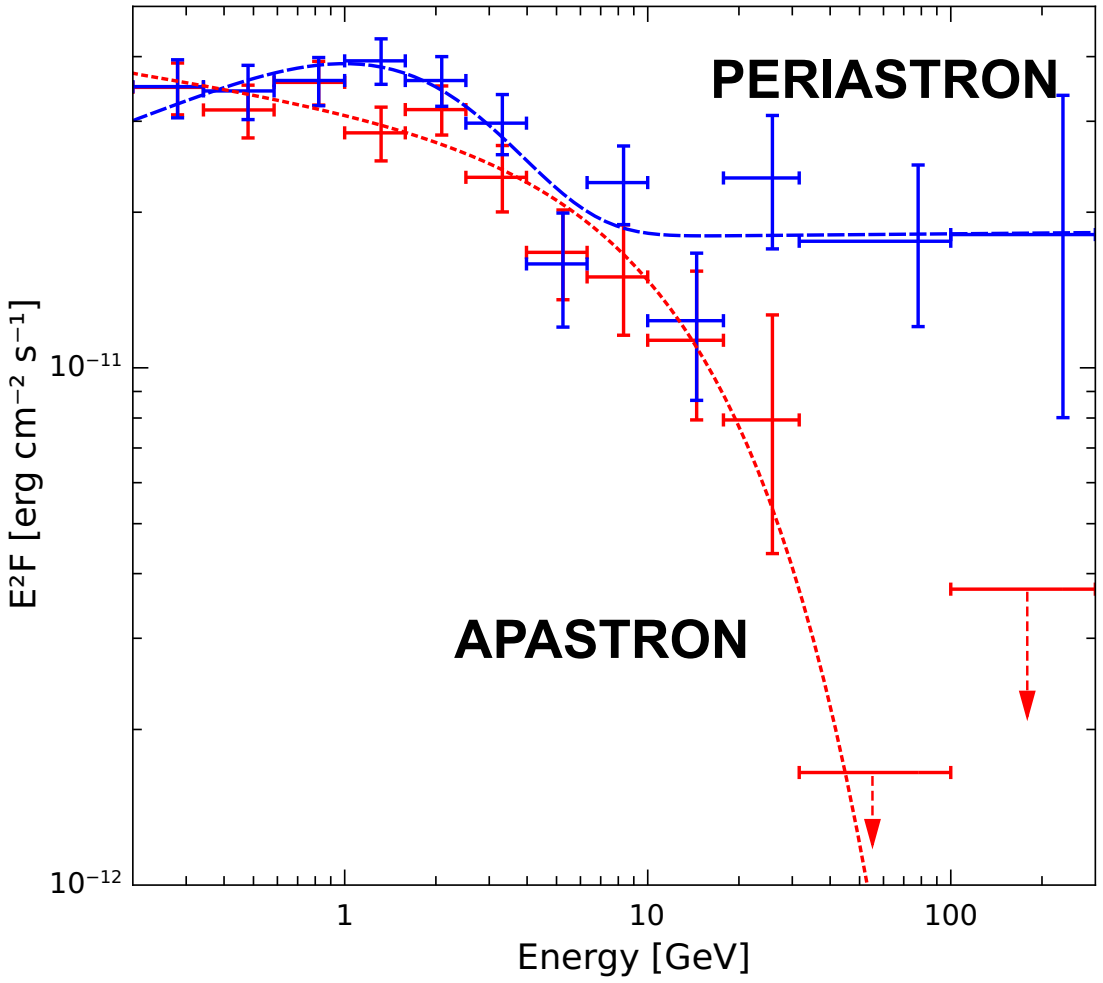
Long-term Variability – Crab Nebula



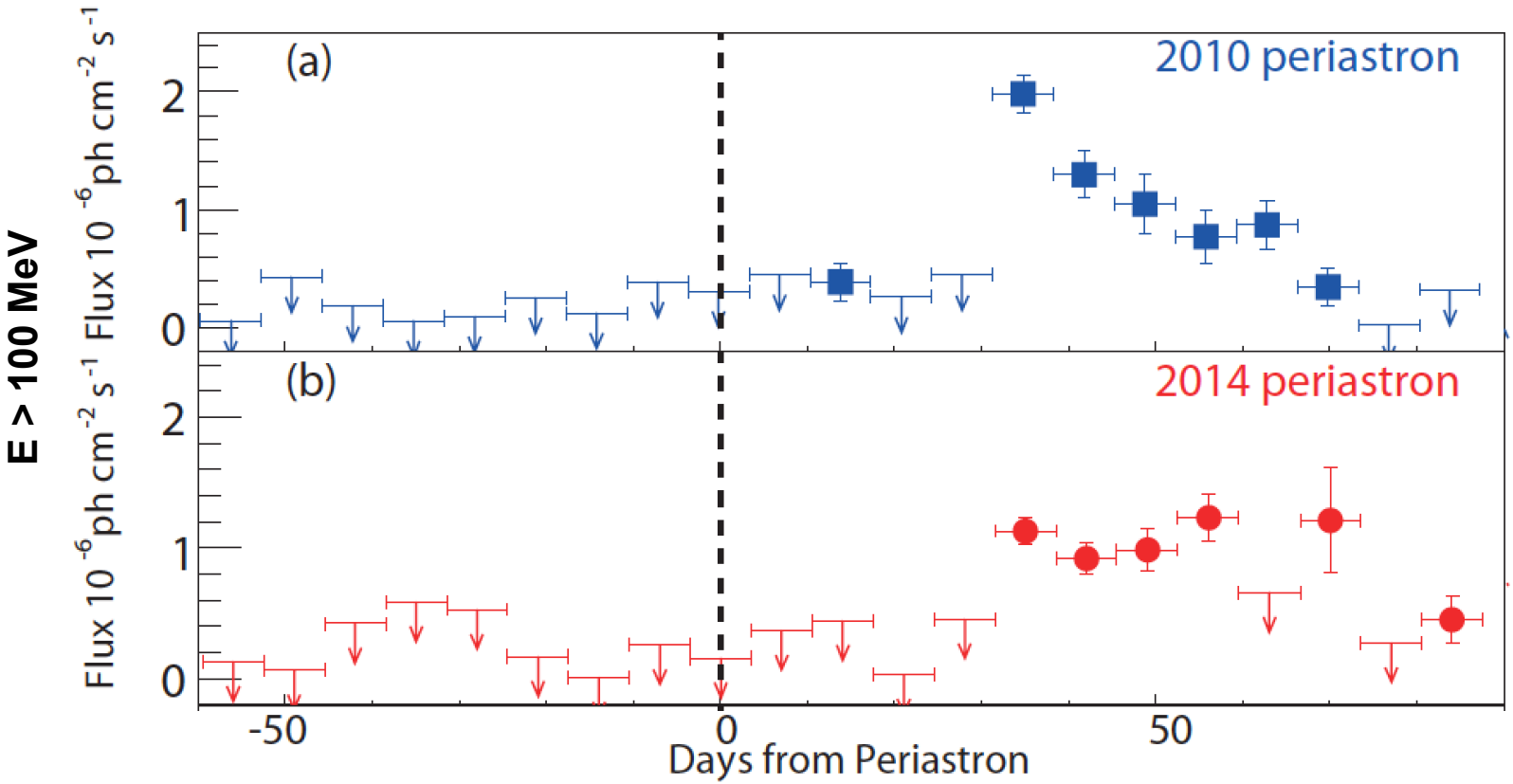
The *Fermi* GBM and other instruments have shown that the hard X-ray flux from the Crab Nebula is not a standard candle (figure courtesy of Colleen Wilson-Hodge).

Long-term Variability – Eta Carinae

Eta Carinae appears to be the only colliding wind binary system to produce significant gamma-ray emission. Fermi has seen two periastron passages of its 5.5-year period, but only one apastron (Reitberger et al. 2015). The spectrum clearly varies. Eta Car has not been reported as a TeV source. The next periastron passage will be in 2020.

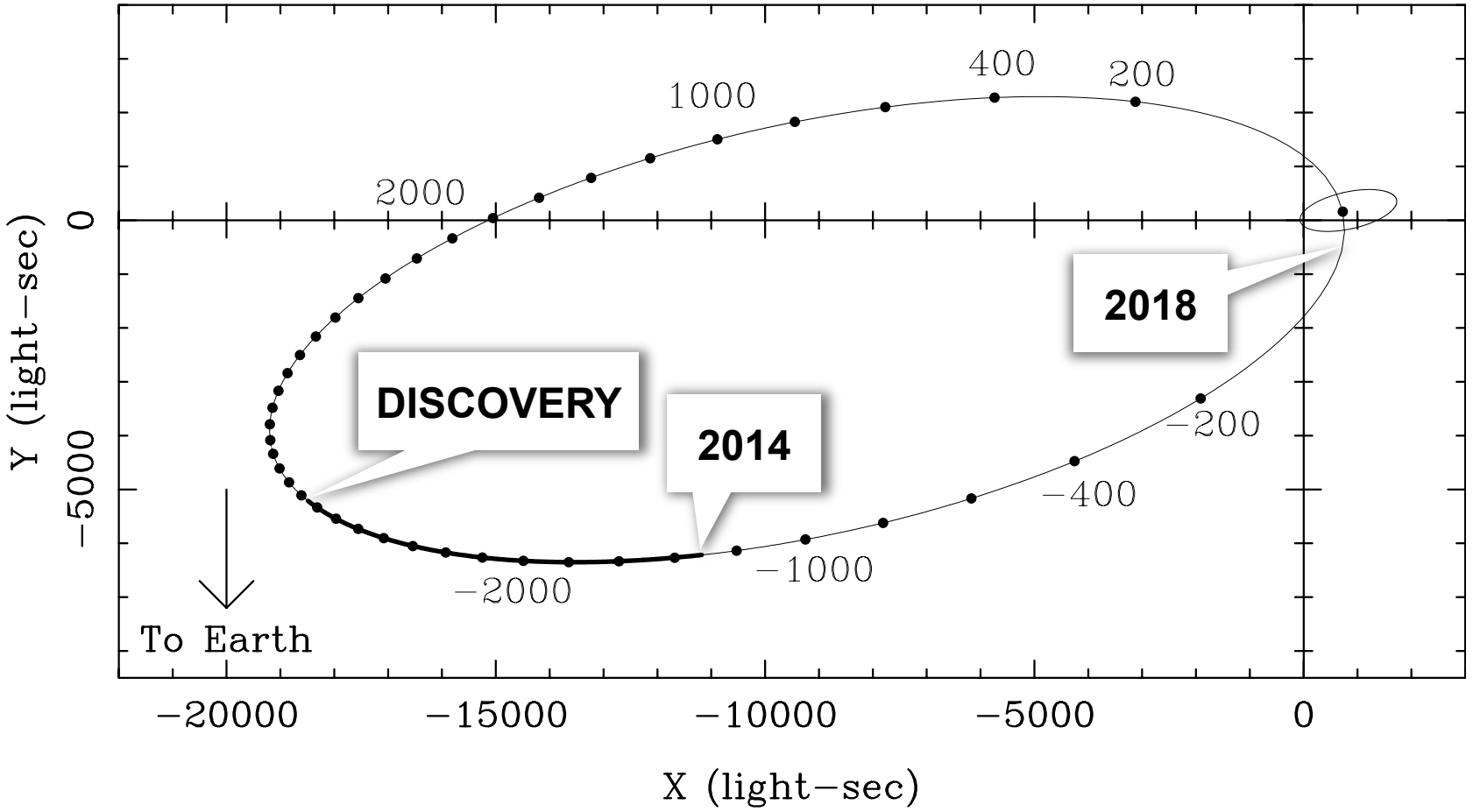


Long-term Variability – PSR B1259-63 System



PSR B1259-63 is a neutron star in orbit around a Be star, with periastron every 3.4 years. Gamma-ray flaring activity, representing 50% or more of the pulsar's rotational energy loss, has been seen about a month after periastron in 2010 and 2014, but with somewhat different characteristics (Caliandro et al. 2015). The next periastron will come in 2017.

Long-term Variability – PSR J2032+4127 System

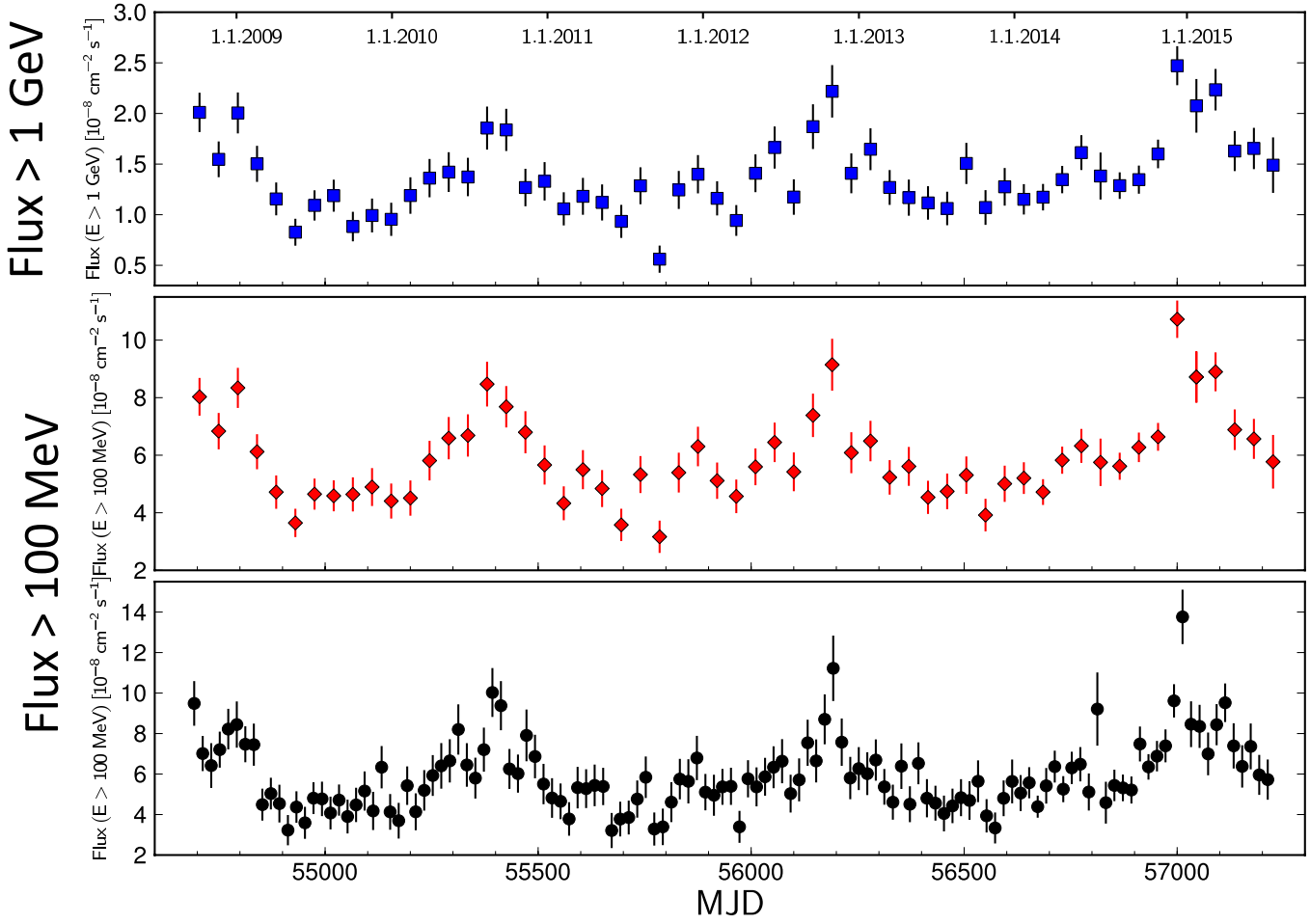


PSR J2032+4127 is a LAT-discovered pulsar also seen in radio, recently discovered to be in orbit around a Be star, with periastron every 25 years (Lyne et al 2015). Gamma-ray flaring activity may be expected near periastron in 2018.

Long-term Variability – Periodic Blazar?

Fermi **LAT sees apparent quasi-periodic variability from BL Lac object PG 1553+113 (Ackermann et al 2015). If this ~2-yr pattern continues, it might suggest a binary supermassive black hole system.**

Talk by Stefano Ciprini tomorrow.



Opportunities

Phenomena:

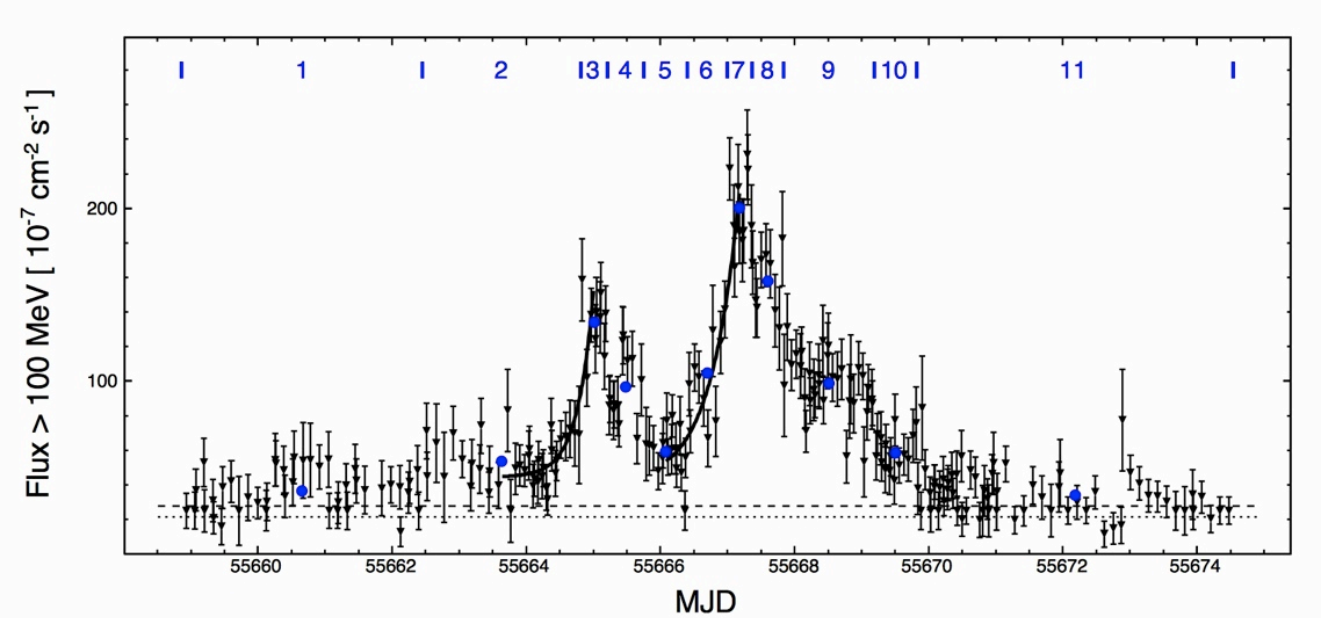
Unusual, extreme events often allow significant improvements in understanding.

Observations:

The multiwavelength/ multimessenger environment is constantly changing, enabling different science.

Crab Flares

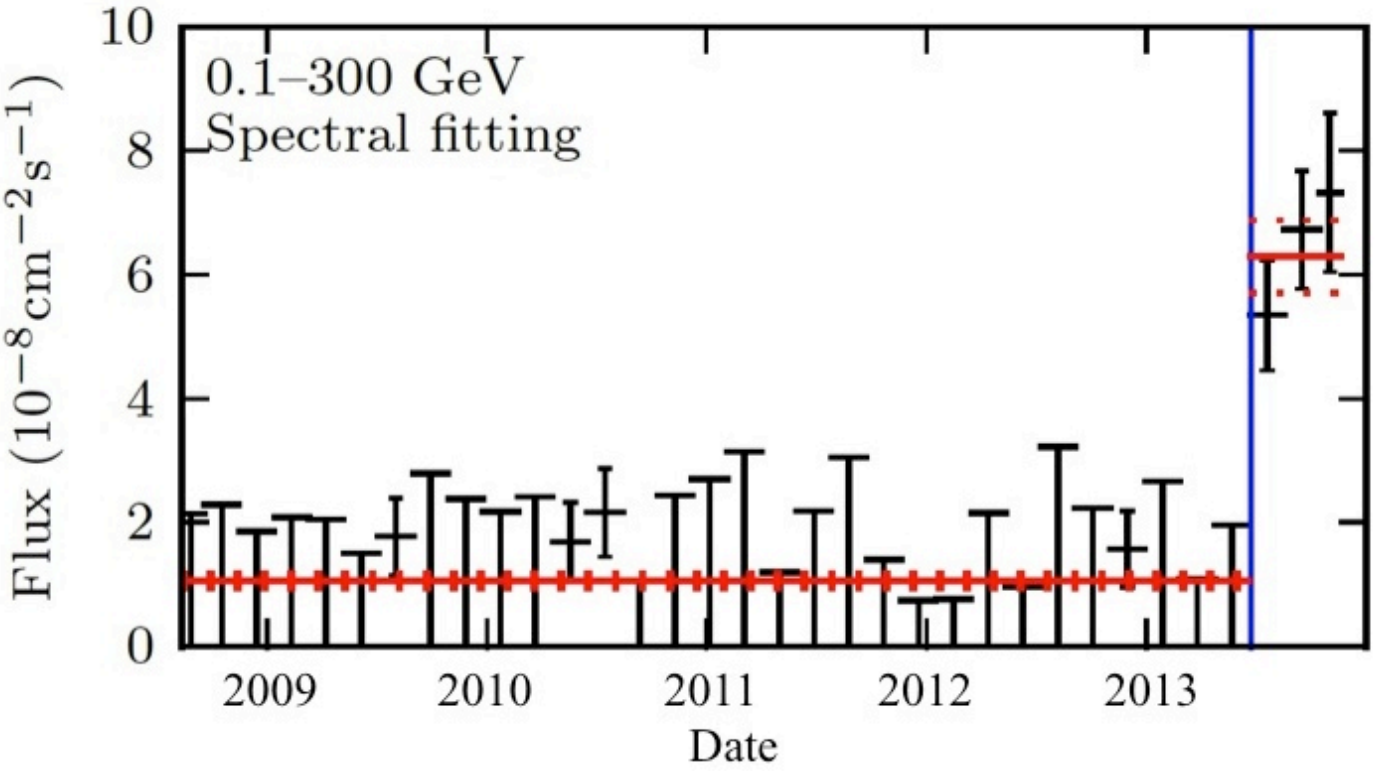
Intense, rapid gamma-ray flares from the Crab Nebula were a discovery: a site of fast acceleration of particles to very high energies.



Buehler et al., 2012

But now the Crab has gone quiet – no flares in the past year. Might they be different after a long pause? What if they do not return?

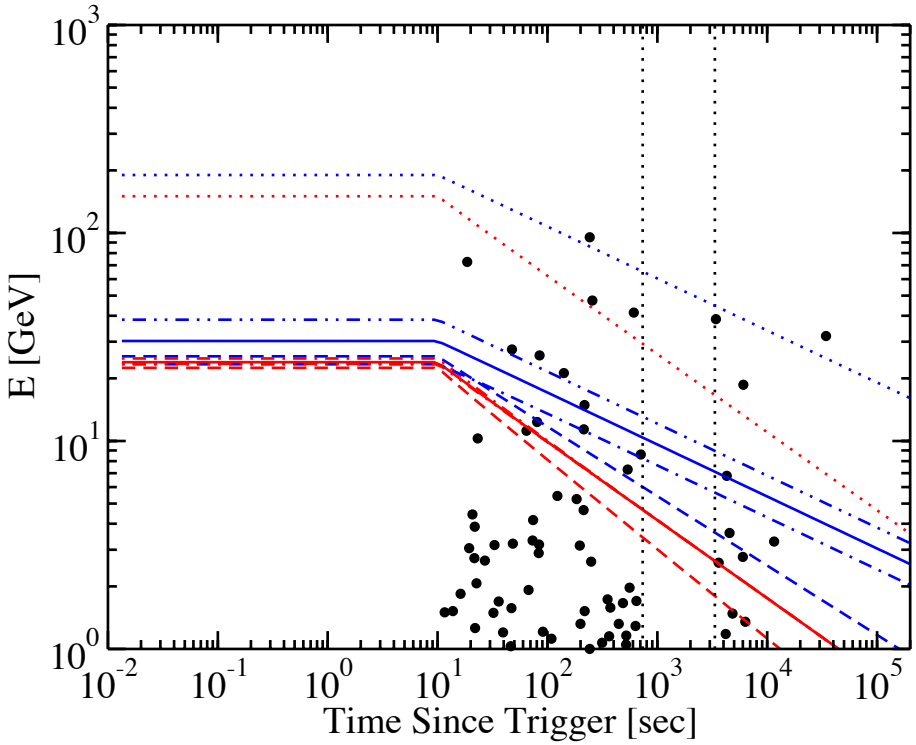
Pulsars in Transition - PSR J1023+0038



Stappers et al., 2014

The radio emission from this binary ms pulsar ceased at the same time the gamma-ray flux increased by a factor of five.

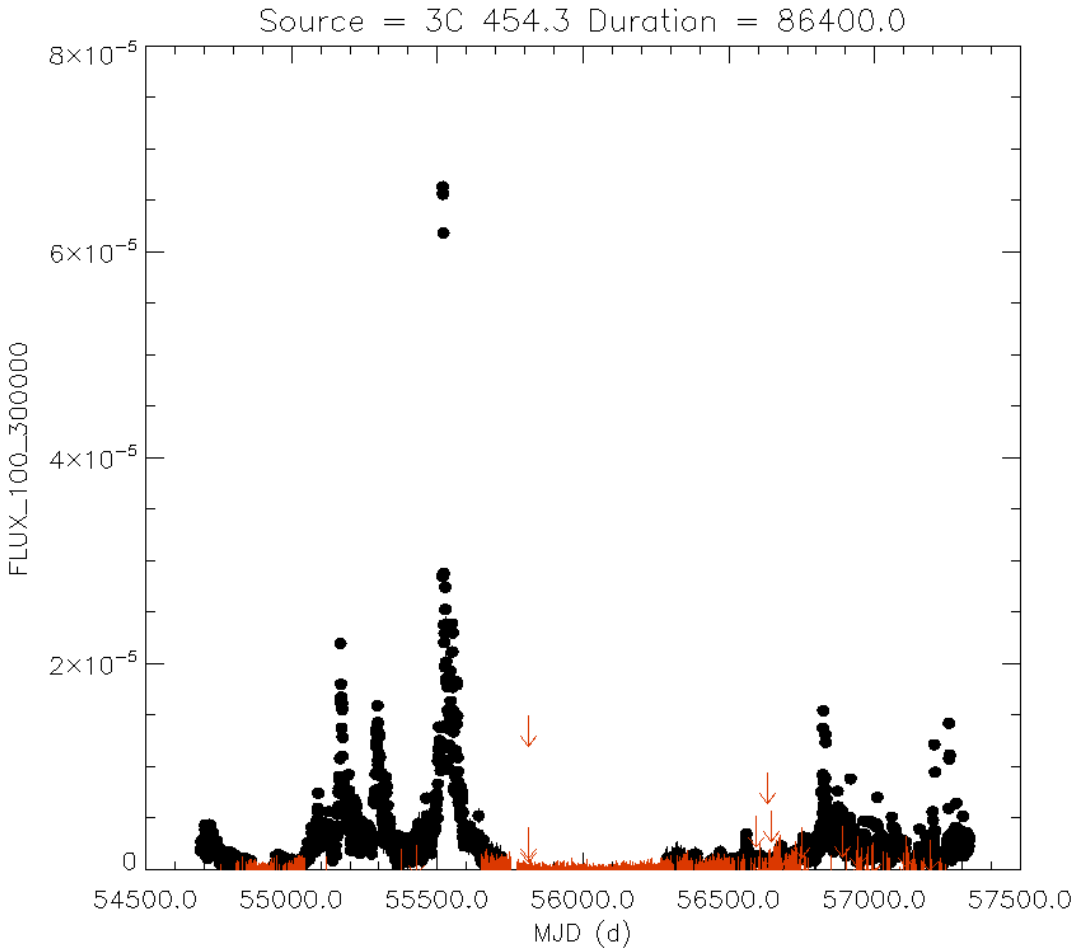
Gamma-Ray Bursts – GRB 130427A



Ackermann et al., 2014

The multi-GeV photons seen at late times are hard to explain in terms of the conventional synchrotron model for afterglow from an external shock.

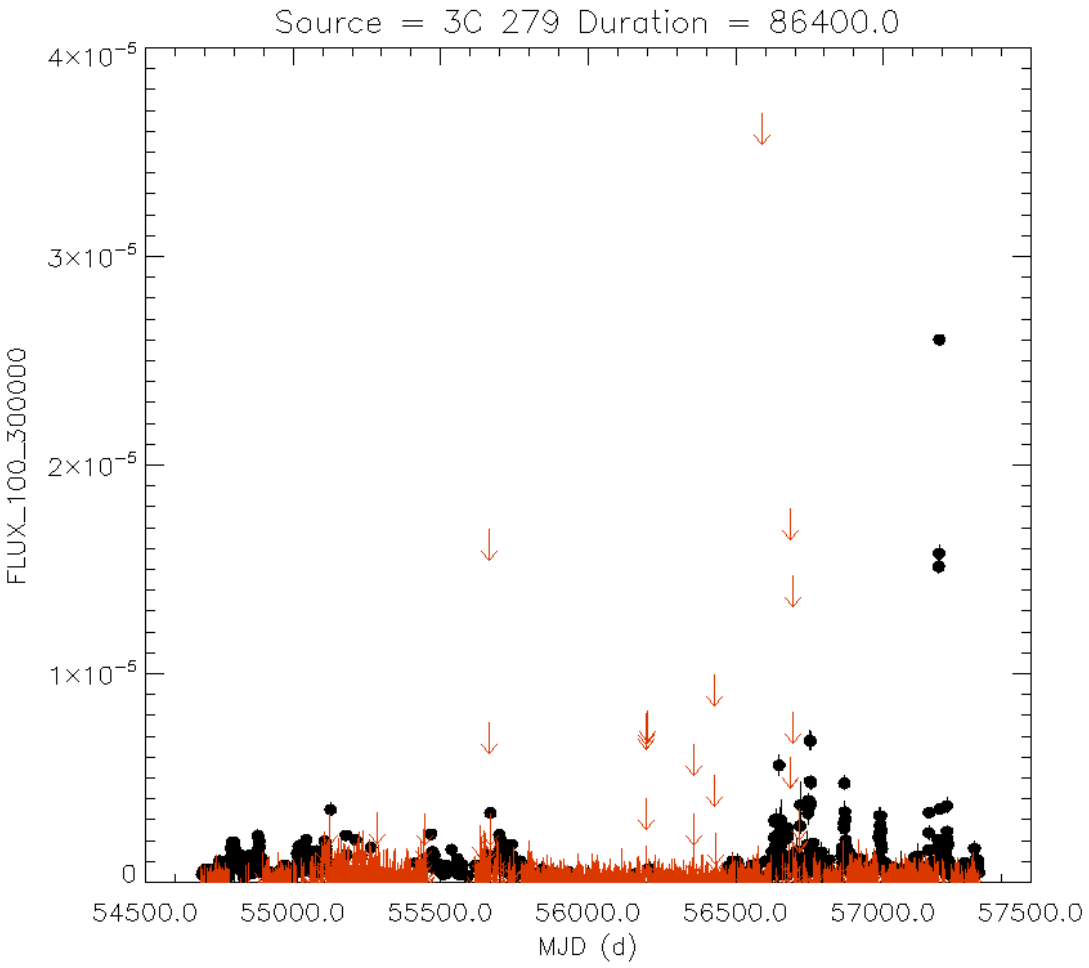
Giant Flares from Active Galactic Nuclei



Flares like the huge one from 3C454.3 in November, 2010, represent extremes of luminosity and variability. They challenge models of how and where such flares are produced.

From the public quicklook daily light curves at the FSSC, http://fermi.gsfc.nasa.gov/ssc/data/access/lat/msl_lc/.

Giant Flares from Active Galactic Nuclei



The second-brightest flare seen by *Fermi* LAT came last summer, from 3C 279. While not quite as bright as the one from 3C 454.3, it had faster variability.
Talk by Masaaki Hayashida tomorrow.

From the public quicklook daily light curves at the FSSC, http://fermi.gsfc.nasa.gov/ssc/data/access/lat/msl_lc/.

The Changing Observational Environment

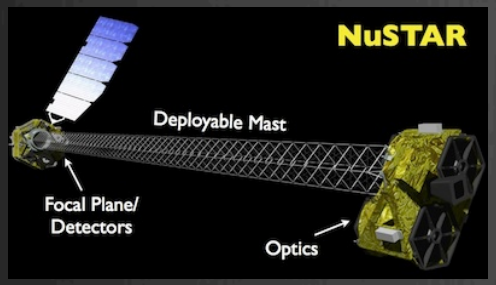
Other scientific facilities have long offered opportunities for *Fermi* scientific advances:

RXTE provided the key timing information for finding the pulsar in the LMC.

IR telescopes allowed measurements of the peak of the synchrotron emission component for many blazars and have provided a new tool for discovering blazars.

Although these resources are no longer available, new ones open up different opportunities.

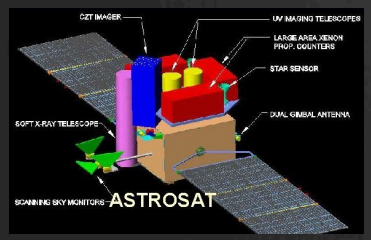
The Changing Observational Environment



NuSTAR's hard X-ray imaging was important in the study of GRB 130427A.

ROBOPOL is making optical polarization measurements of many LAT-detected AGN.

IceCube neutrino detections may be related to blazars/star-forming galaxies seen by LAT.



AstroSat, just launched by India, has a suite of X-ray telescopes.

High Altitude Water Cherenkov (HAWC)

HAWC, now operational, is a wide-field, full-time TeV telescope, providing complementary observations to those of the *Fermi* instruments. Several talks at this meeting about first results.

Advanced LIGO/Virgo

Advanced LIGO just started its first science run, and Virgo will be joining. The most likely source is thought to be merging compact objects, the same phenomenon producing short gamma-ray bursts seen by the *Fermi* instruments.

Summary

After seven years in orbit, the *Fermi Gamma-ray Space Telescope* continues to produce a broad range of scientific discoveries.

The performance improvements of the instruments, the accumulation of data, and the variety of opportunities offered by the survey mode of *Fermi* all contribute to the continuing scientific output.

We have every reason to expect a bright future for *Fermi*.