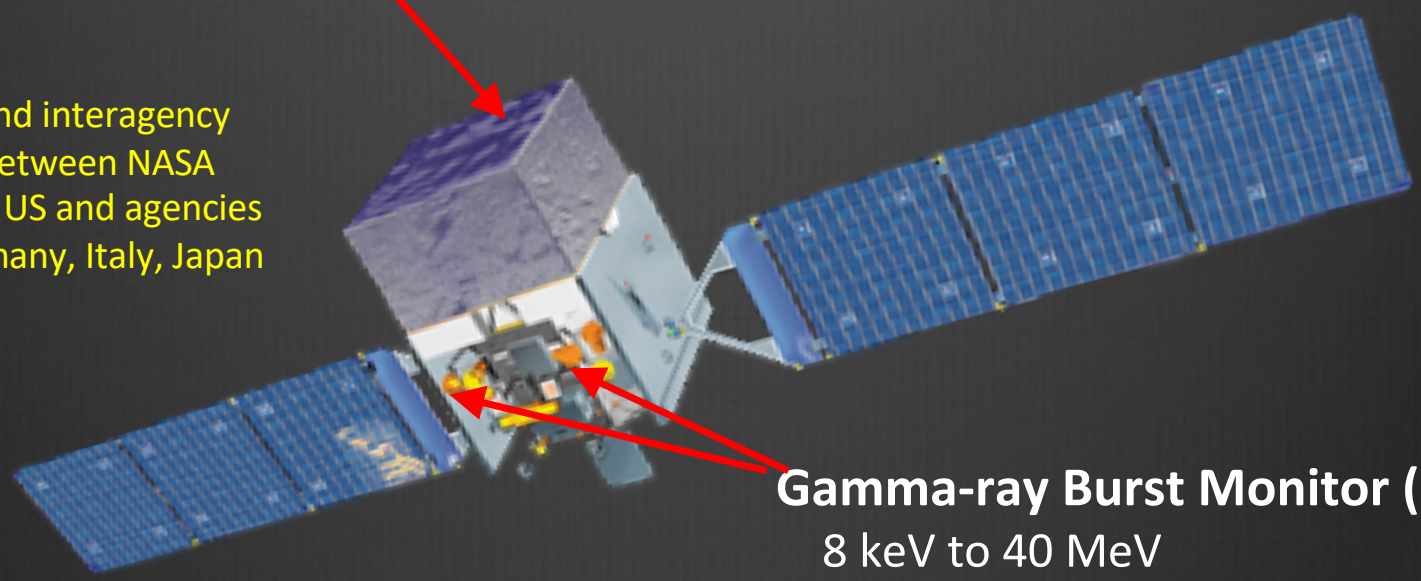
# The *Fermi* Observatory

## Celebrating 10 years of operations

**Probe class mission to study the extreme high-energy Universe**

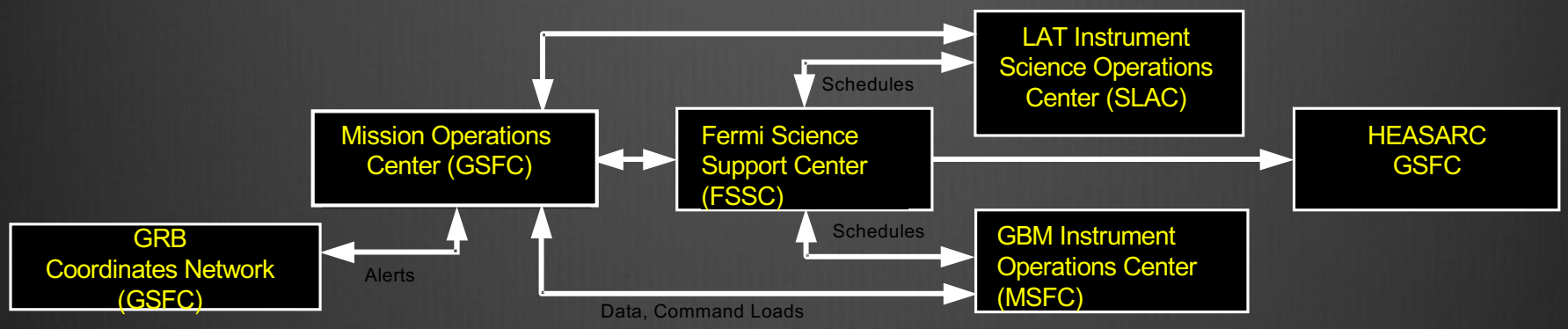
**Large Area Telescope (LAT):** 20 MeV to more than 300 GeV
observes 20% of the sky at any instant, entire sky every 3 hrs
absolute timing to ~300 ns

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
absolute timing ~2 μs

# Many Groups Working Together



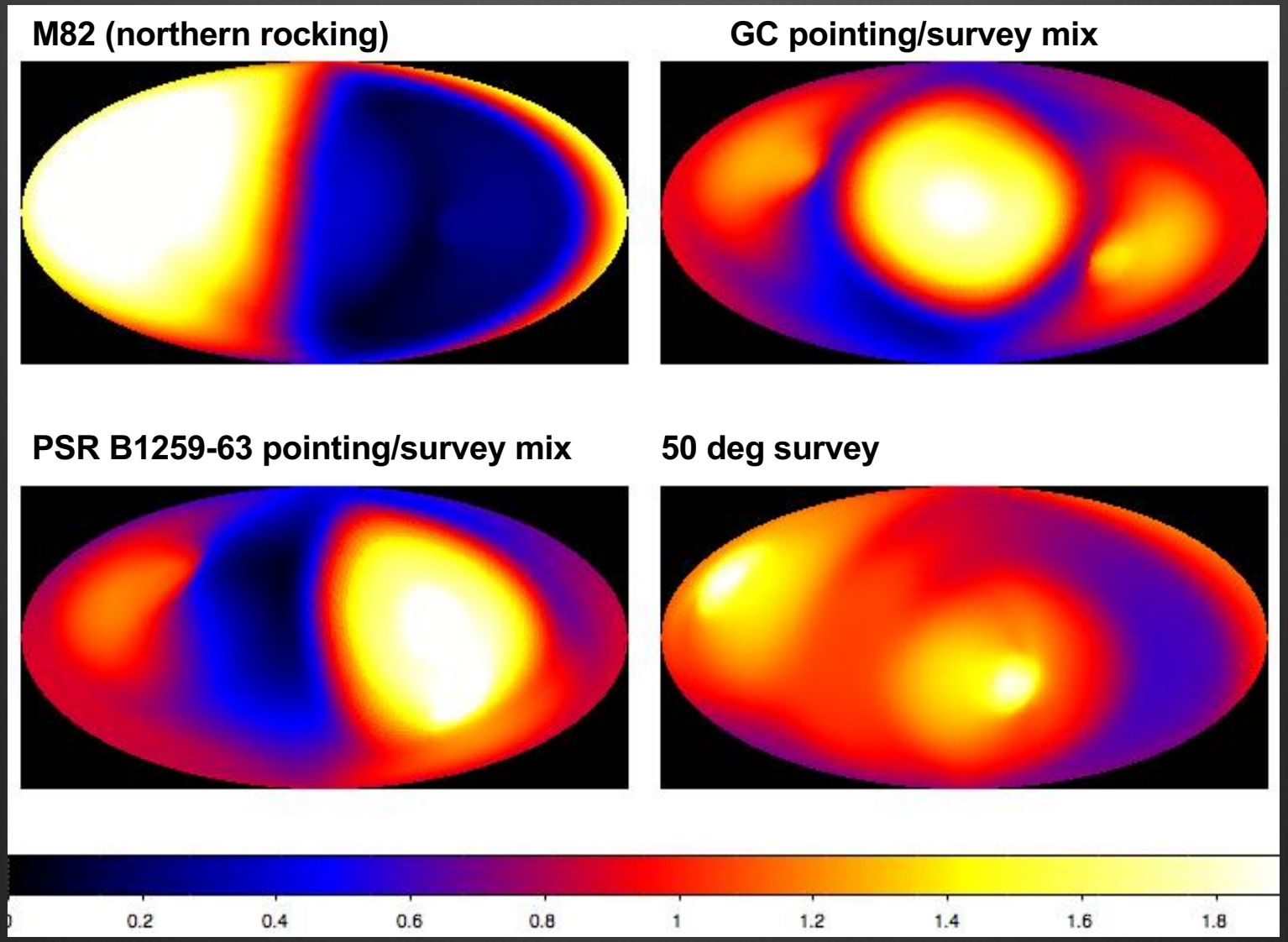

- At least 6 people on shift every day
  - Flight operations team – on call FOT (respond to observatory anomalies)
  - FSSC – duty scientist (respond to TOO requests etc)
  - GBM – Burst advocate (respond to GBM triggers)
  - LAT – Burst Advocate (short duration transients), Flare advocate (longer duration flares/transients), Data Quality Monitor

# Flight Operations

- >60 billion frames of science data
- >40, 000 Ku Passes (>6,000 hours)
- 700, 000 alerts
- Sky Survey ~90%
  ARR ~0.7%,
  ToO/pointed 9.3%
- 821, 790 commands uplinked

- John Nagy, Michele Tamoria, Aaron Nguyen, Mark Carter, Teresa Tropf, Tim Wasserman, Chris Craft, Martin Cornish, Terry Reed, Kurt Reifner, Rob Laverghetta, Shane Stezelberger, Brian Ratzlaff, Zachary Mason, Arhlene Hawkins, Ben Holt, Rishabh Maharaja, Bob Scheid, Jeff Devine, Ben Chinn

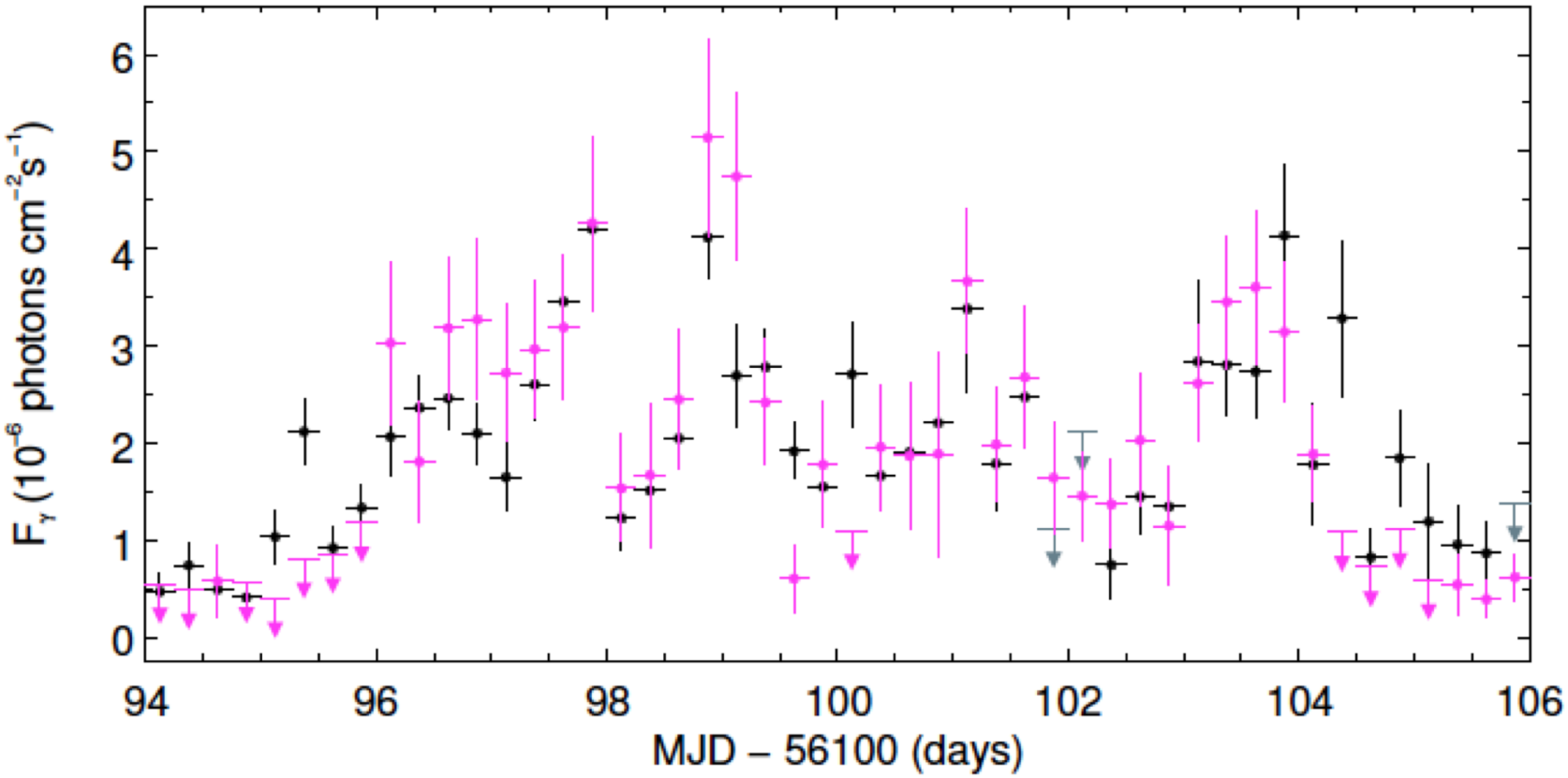
# Observations



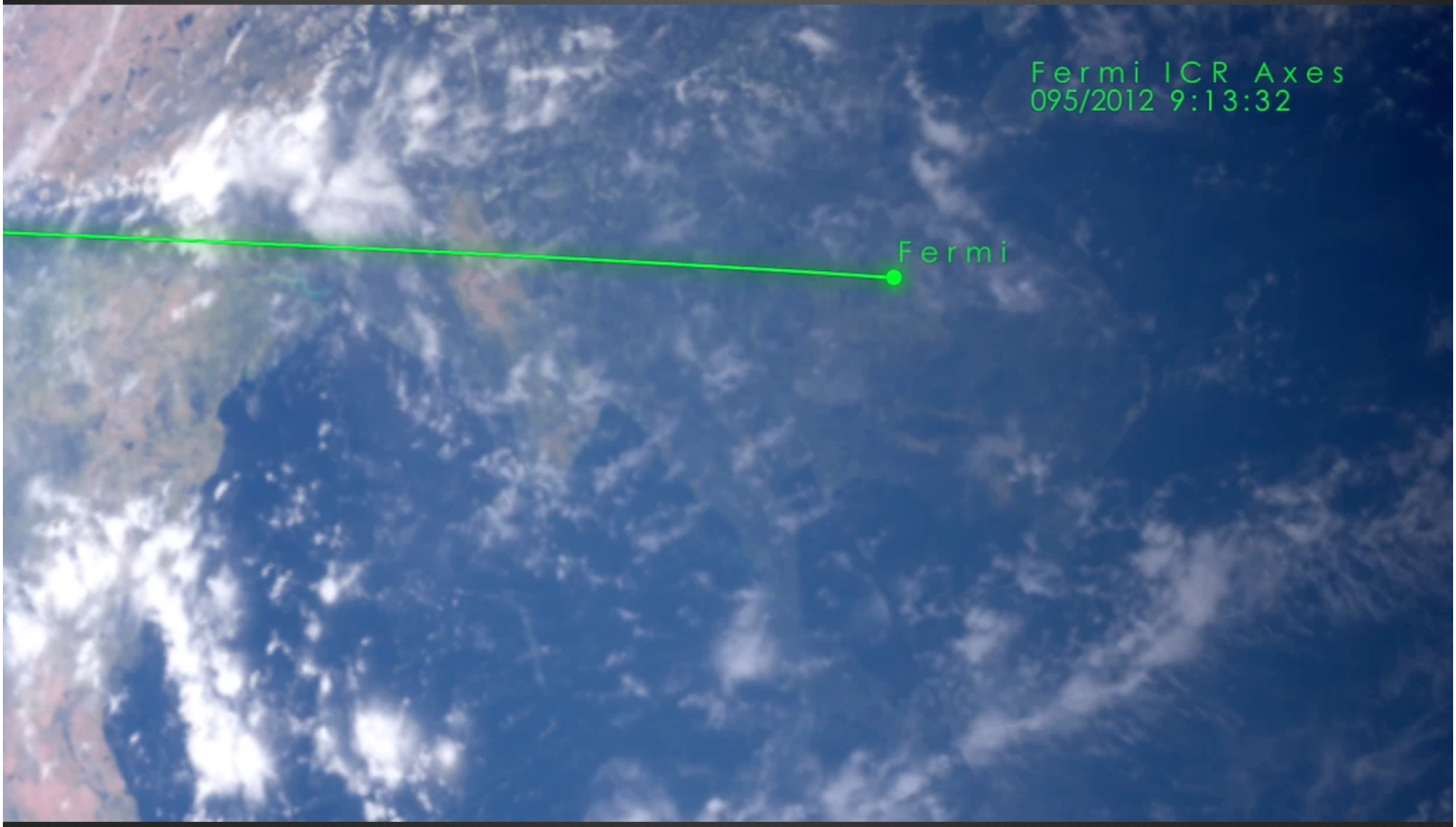

- Exposure at 10 GeV for selected observations in 2014

# S3 0218+35: A Gravitational Lens

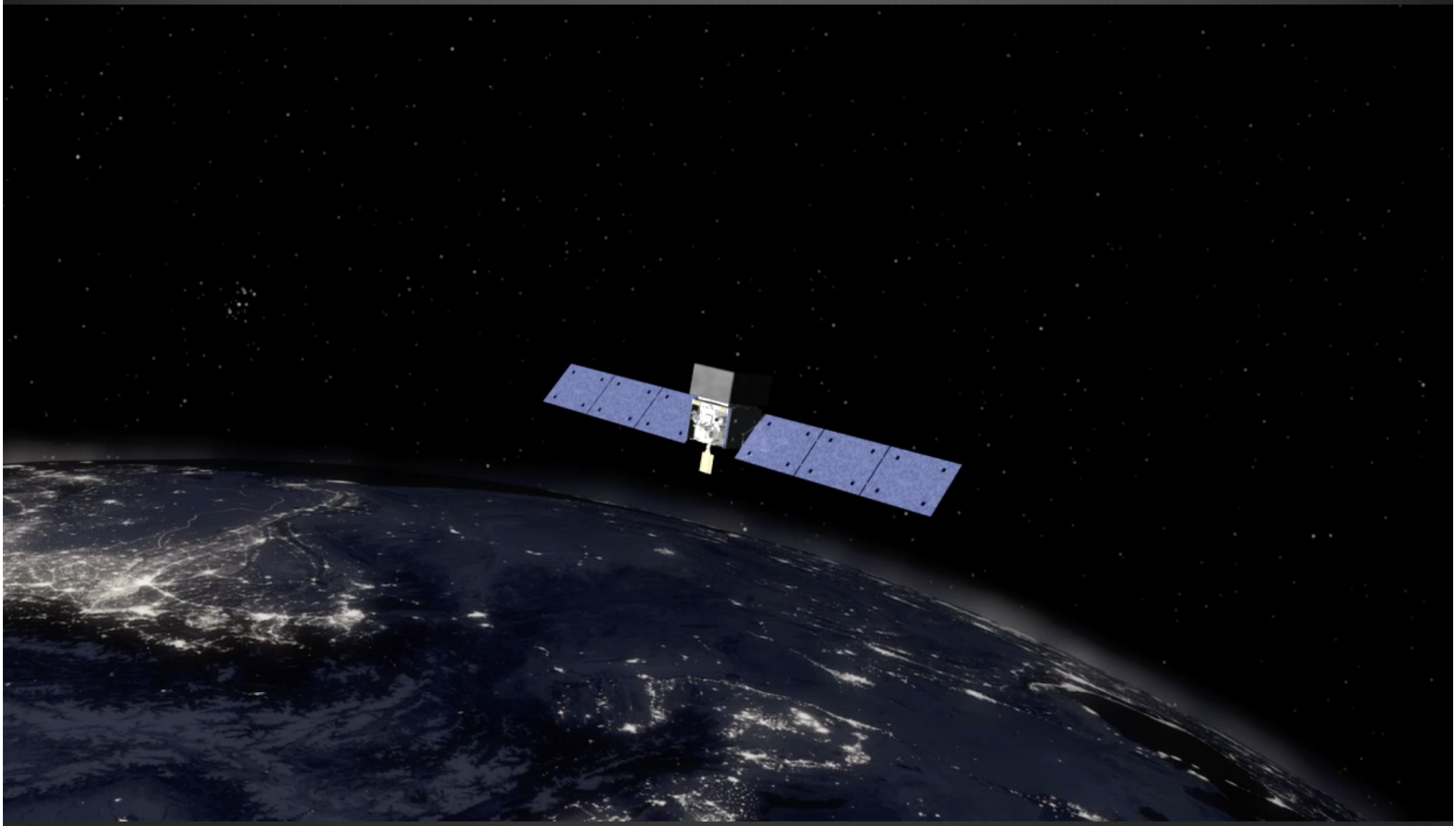
- Delayed flare expected ~10 days later based on prior radio observations - schedule Fermi-LAT pointed observation
- Shift flare by 11.5 days and scale by 1.16 to overlay delay



# Collision Avoidance



# We moved out of the way…

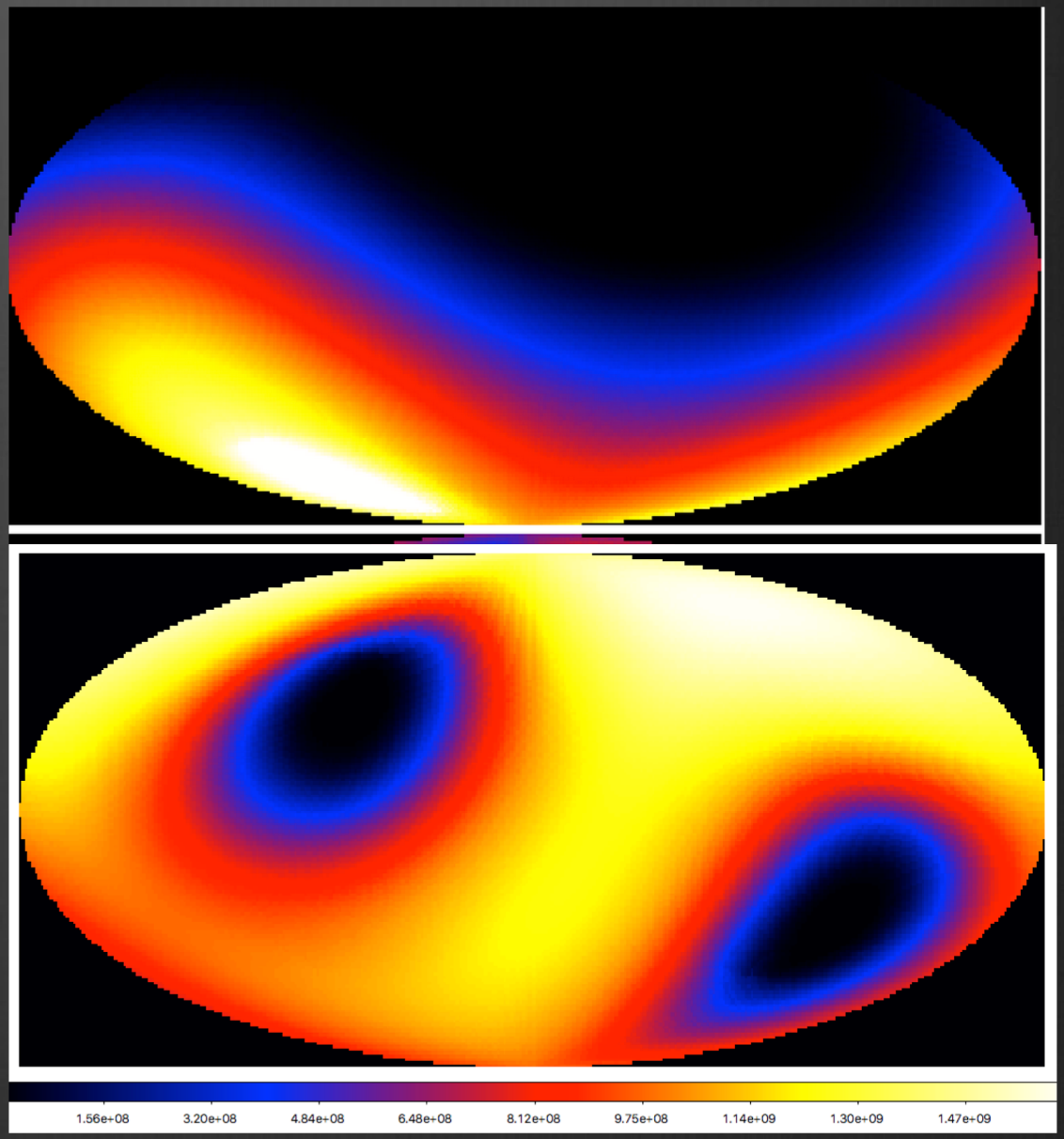


# Glitches etc

- Very smooth operations
  - Only 2 incidents that resulted in powering down instruments
    - 2009 – reboot of LAT and SC cpus (addressed with FSW patch)
    - 2018 – Failure in –Y Solar Array Drive Assembly (SADA) on March 16
- -Y SADA anomaly
  - Solar panel currently stuck at an angle of 17.5 deg, pointing downward
  - Resumed GBM operations on March 27
  - Resumed LAT observations on April 4

# Observations since Anomaly

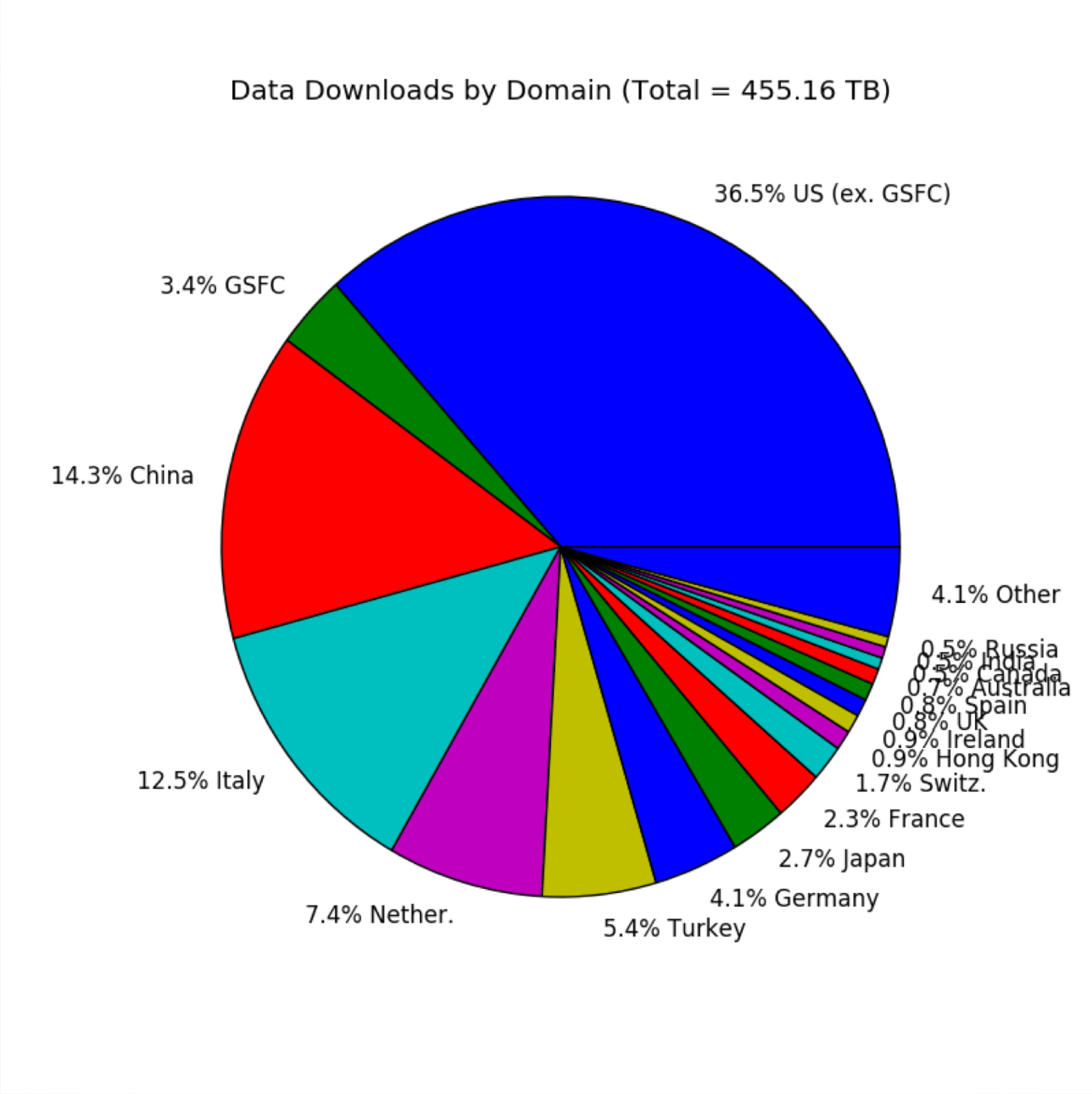
- Either single sided 50 deg rocking, point away from hemisphere with the Sun
- Or once per orbit sine profile
- In late November we will resume normal +50/-50 deg rocking profile for part of the time and sine profile for the rest



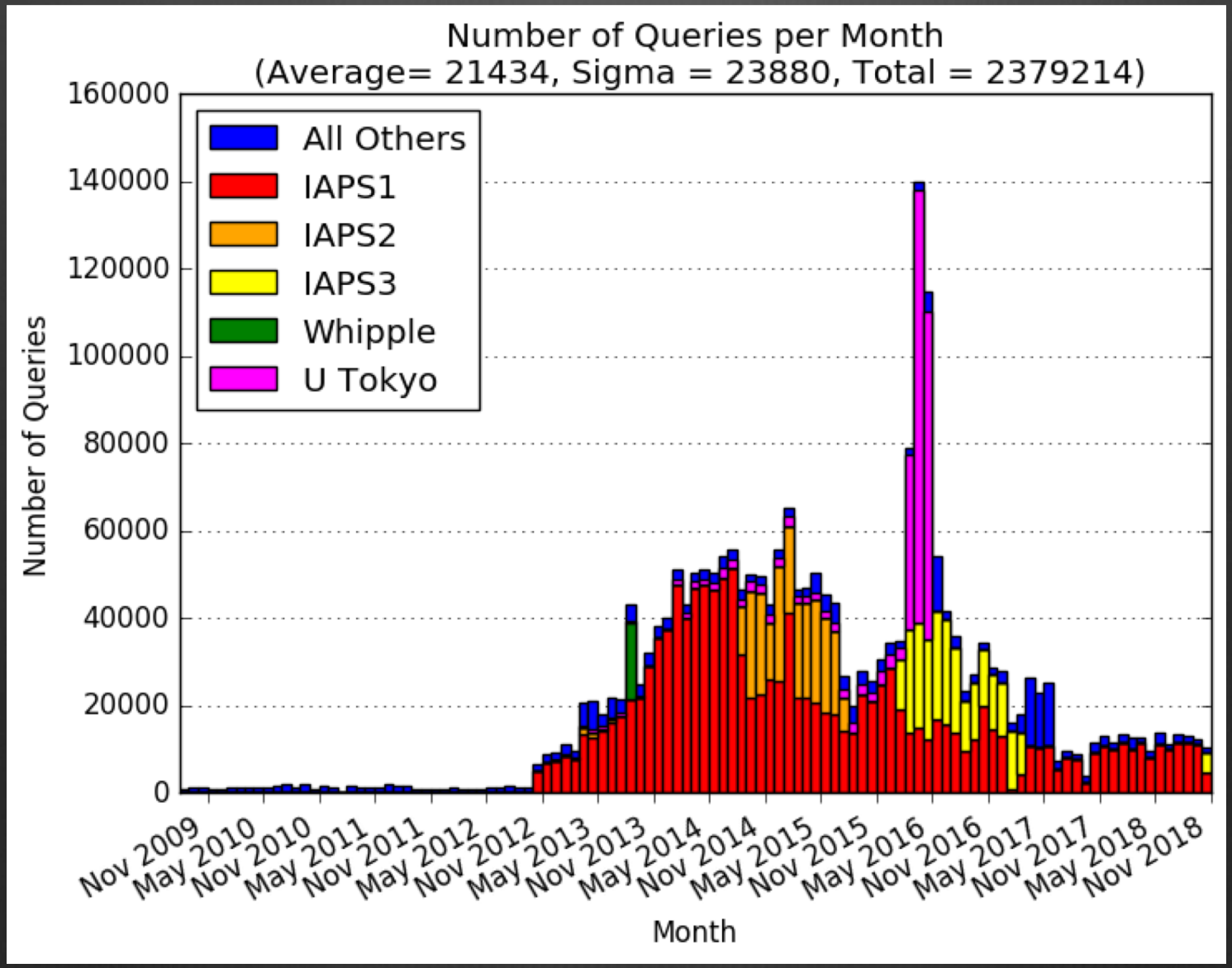
# Fermi Science Support Center

- 11 years/cycles of guest investigator program
  - ~1500 proposers (and ~220 reviewers)
    - primarily represents US Fermi user community. Worldwide user community is significantly larger than this

# Who is looking at Fermi Data from HEASARC?

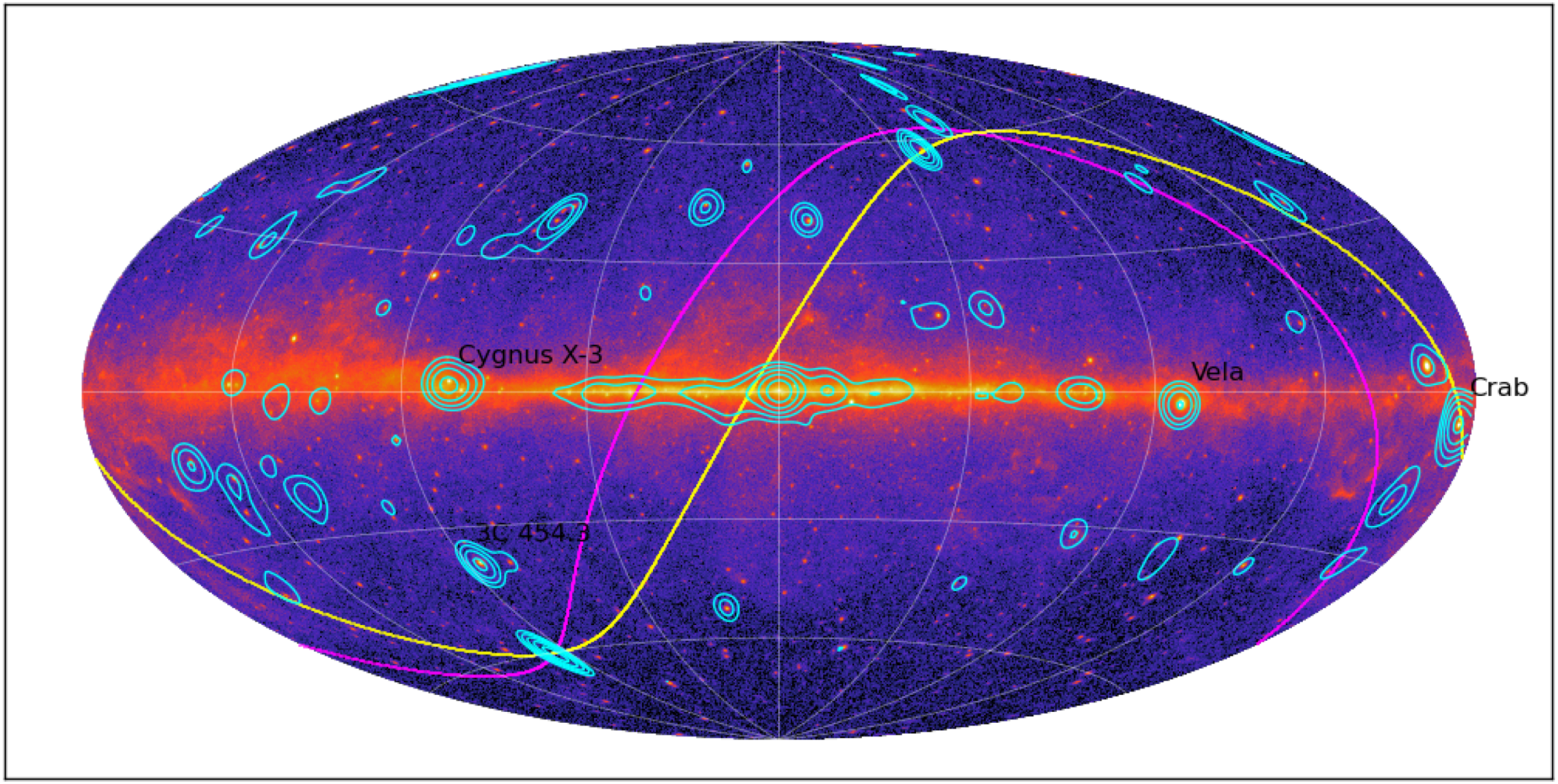


# Fermi-LAT Data Server




- Allows users to select a region of the sky for a specified time interval

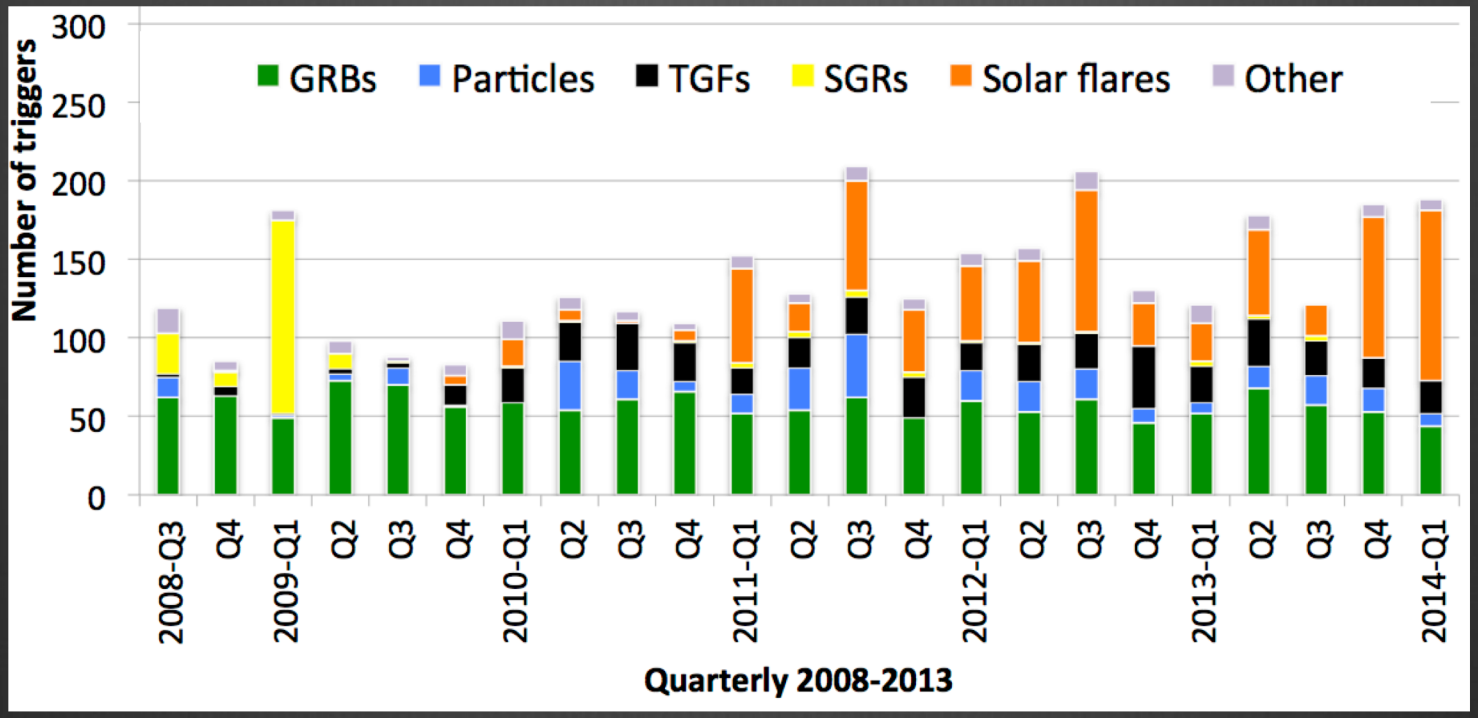
# Where are people looking?



# Analysis Workshops

- 2008-2010 sequence of 1-2 day analysis and proposers workshops
  - Stanford, Berkeley, UCLA, UCSC, Fermilab, Argonne, University of Chicago, University of Michigan, NYU, CfA, Boston University
- Topic Specific analysis workshops
  - Fermi-Swift GRB analysis workshop 2010
  - Solar Analysis workshop 2012
- Fermi School (1-2 weeks)
  - COSPAR Capacity workshop Bangalore 2009
  - Annual Fermi Summer School in Lewes, DE
  - + additional schools organized independently of the Fermi Project

# Fermi-GBM

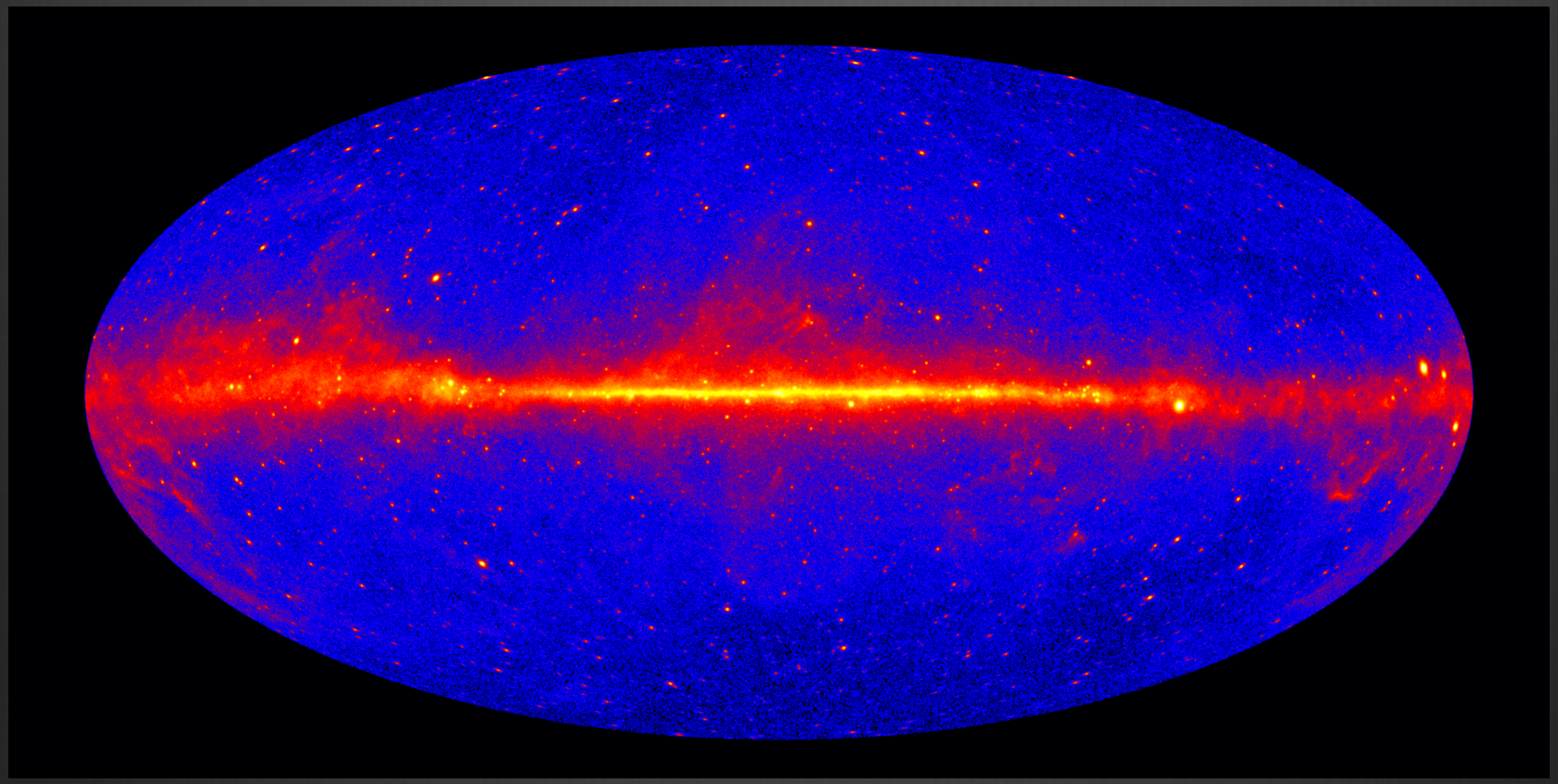



- Designed to detect short gamma-ray transients between 8 keV – 40 MeV
  - Most prolific detector of localized Gamma-Ray Bursts and terrestrial gamma-ray flashes
- Many operational improvements since launch
  - 2009 - Modified onboard trigger to improve sensitivity to TGFs
  - 2012 - Transition to collecting information about each individual gamma-ray

# Fermi-GBM: Recent activities

- GSPEC – modern replacement for Rmfit with backend to XSPEC
  - V0.9 release planned for Fall 2018
  - Part of a larger API that will allow users to write their own scripts to do automated batch processes
- Hourly CTTE data
  - Convenient, easier to get the right time interval
  - Removes timing glitches, improves latency
- Automated ground processing
  - Automated ground localization (RoboBA) since January 2016 with accuracy on the order of human analysis.
  - Working towards automation of the GBM BA process
  - prompt localization, duration and spectral analysis, and GCN reporting
  - Implementing an improved ground classification algorithm

# LAT

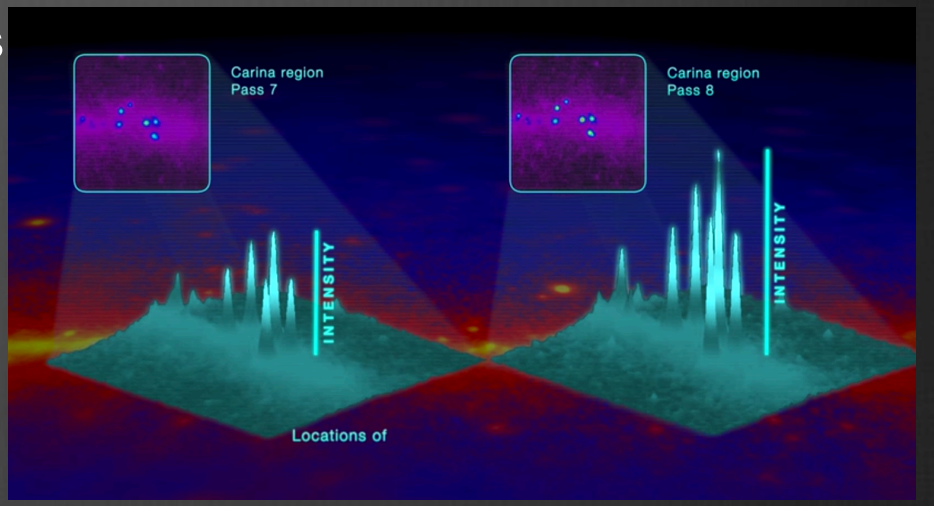


- Survey the entire sky from 20 MeV to >300 GeV
- 8 releases of high level analysis software
  - Each providing enhancements and new features
- Catalogs, diffuse models, transient search pipelines etc

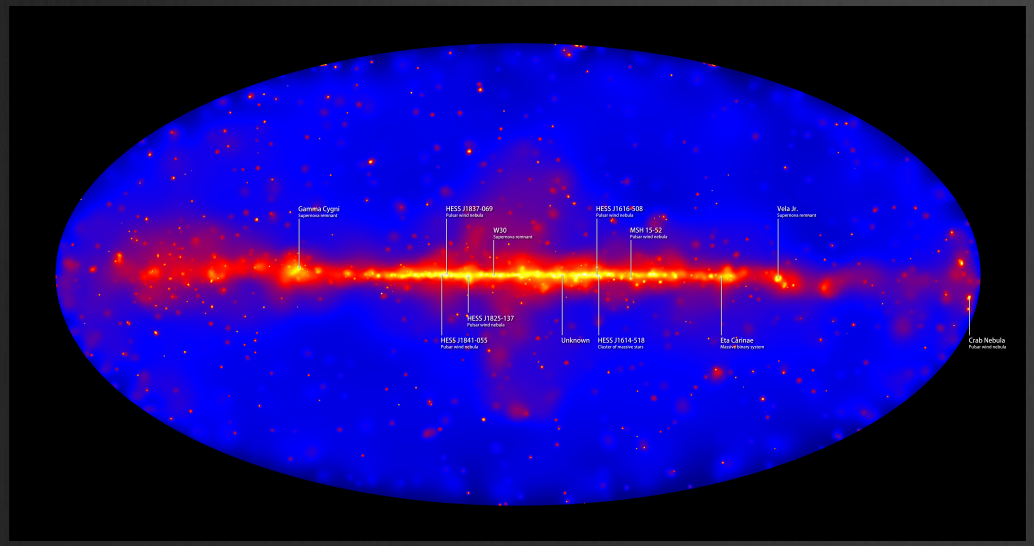
# Reconstruction improvements

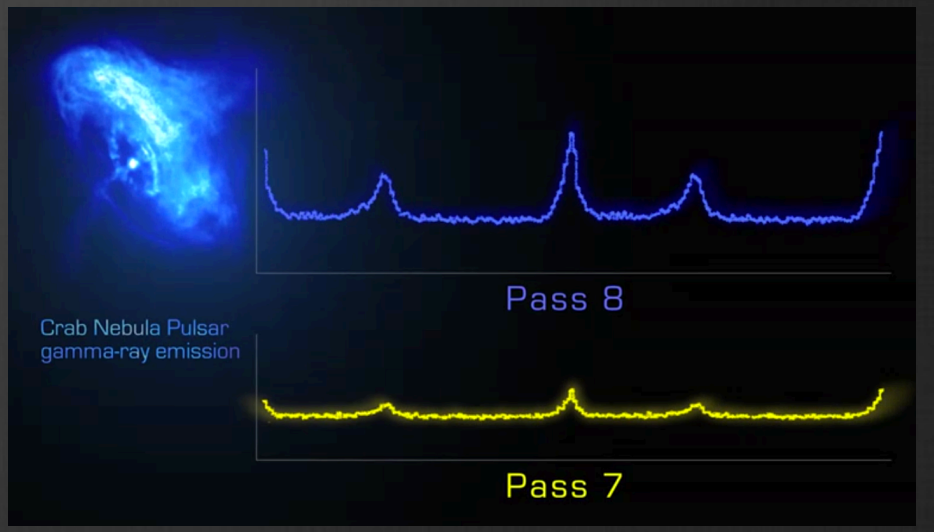
4 data releases, pass 6, pass7, pass7rep and pass 8

Pass 8 was a major revamp of the data processing pipeline produces sharper images (right) and more gamma-rays (lower right) **dramatically improving** Fermi Large Area Telescope performance.



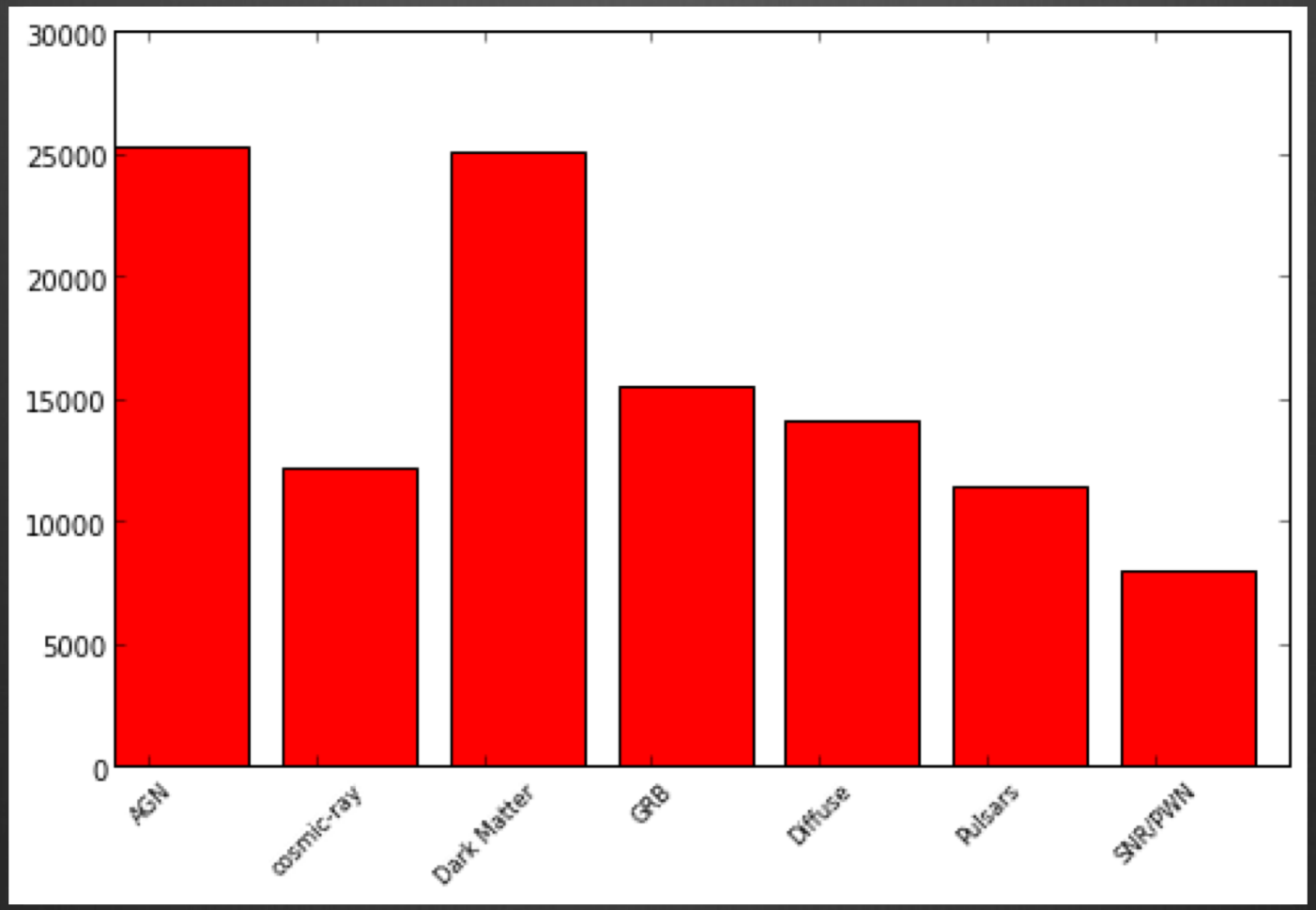

Expanded Fermi-LAT coverage to higher energies allows the **first census of the sky between 50 GeV and 2 TeV** (below).



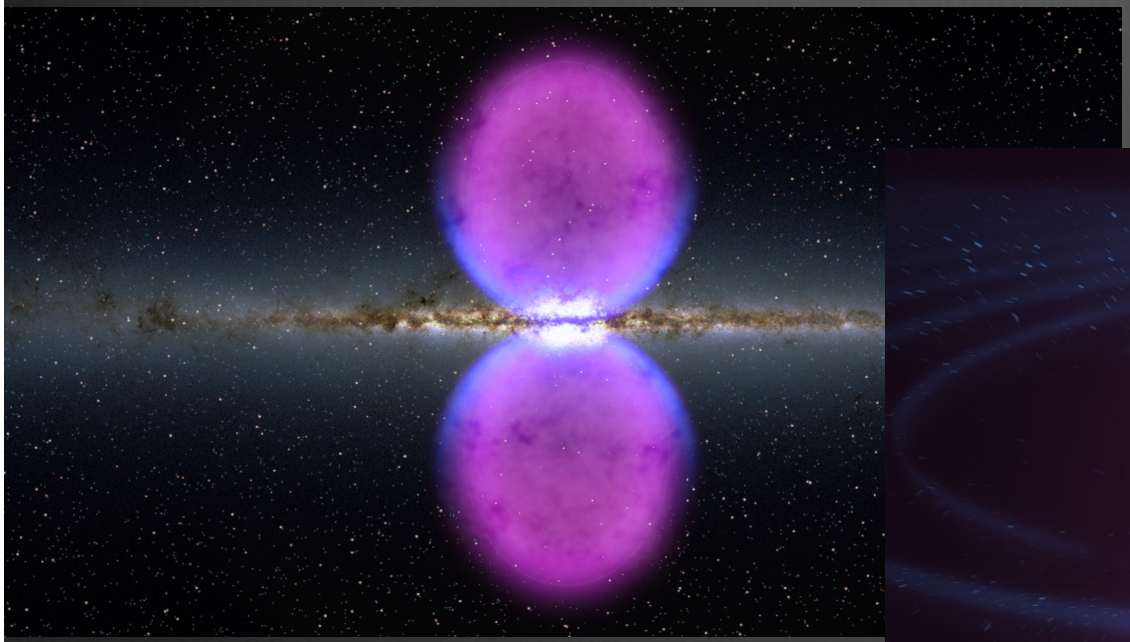

Another release coming soon, further reducing background!

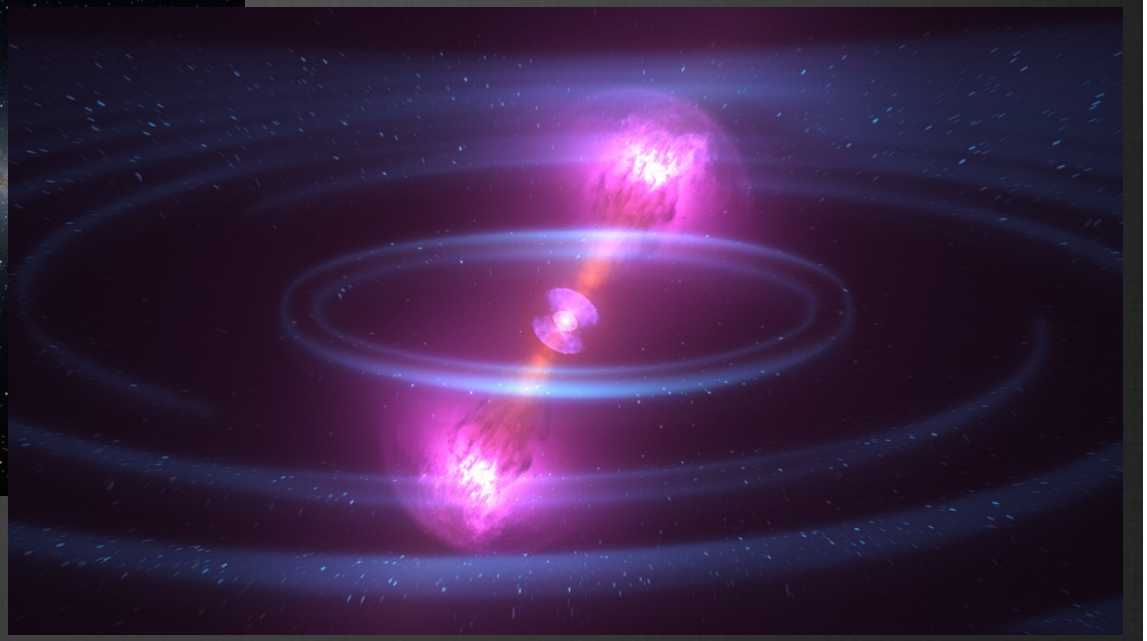
# Refereed Publications




- 3073 publications from Aug 2008 to Aug 2018 with 112, 381 citations

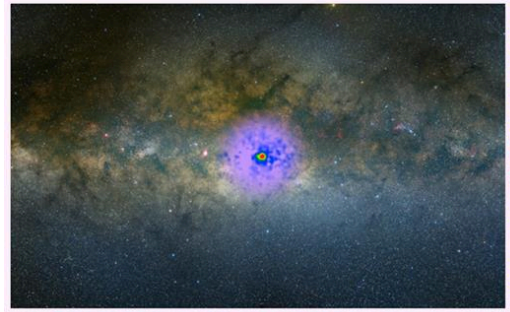
# Press and outreach

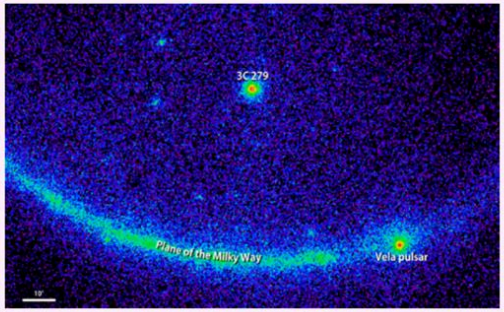


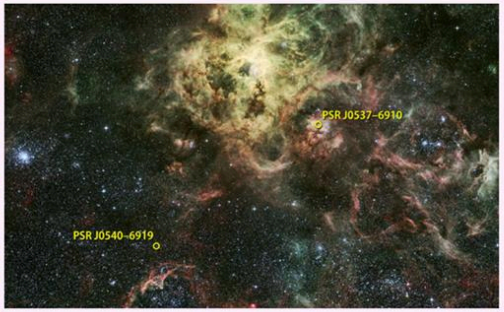


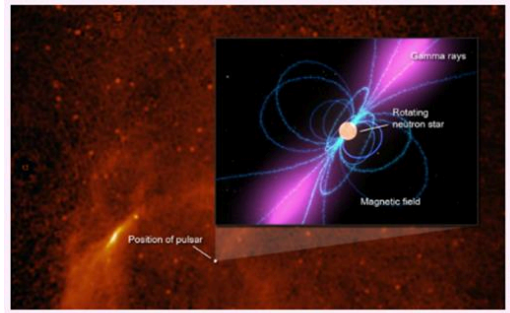
- ~65 press releases/features issued by NASA
  - Most are accompanied by video/animation
  - Total number of views of these animations is >10 million!

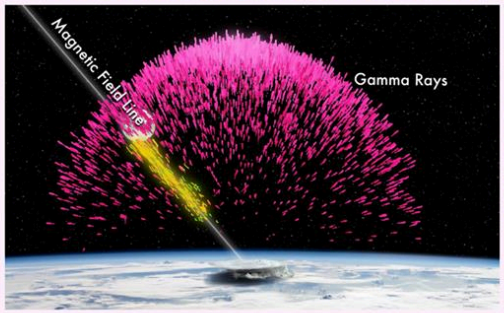
# Science Brackets

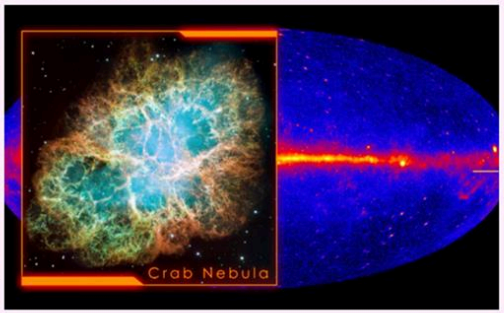


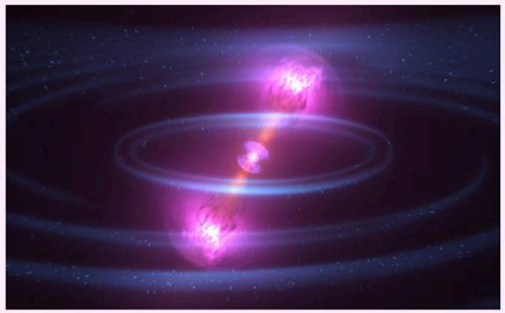


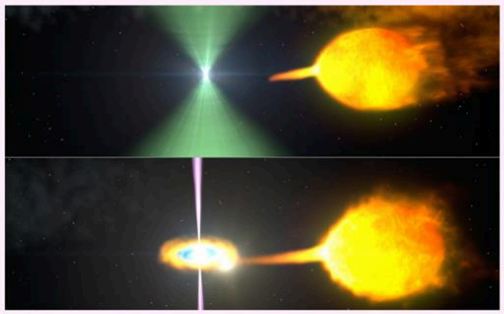



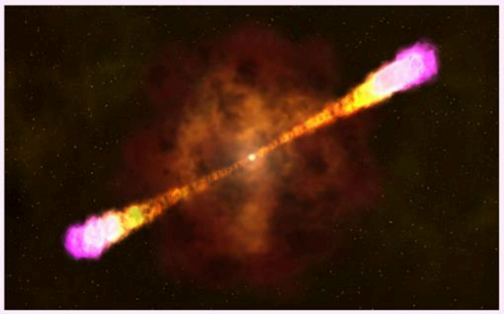


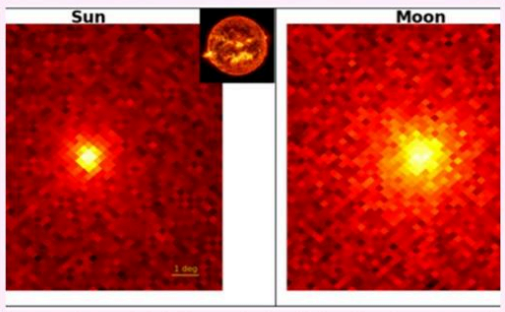



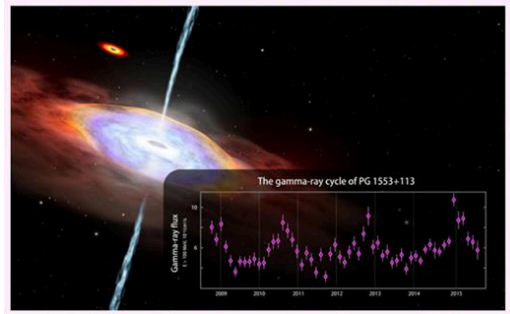



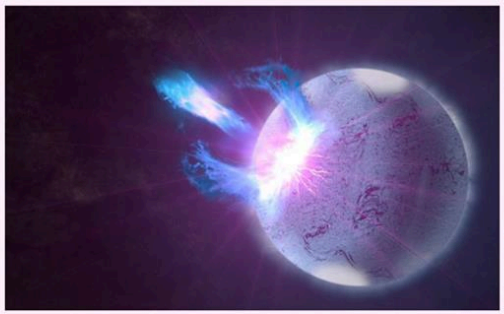



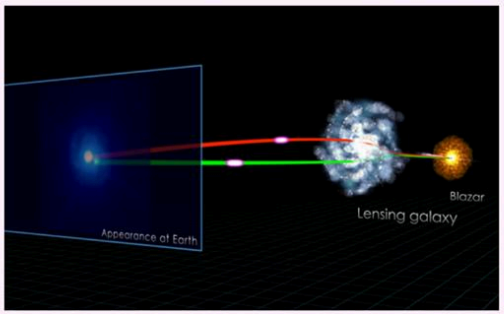


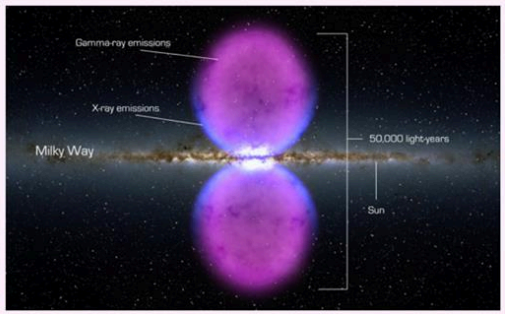




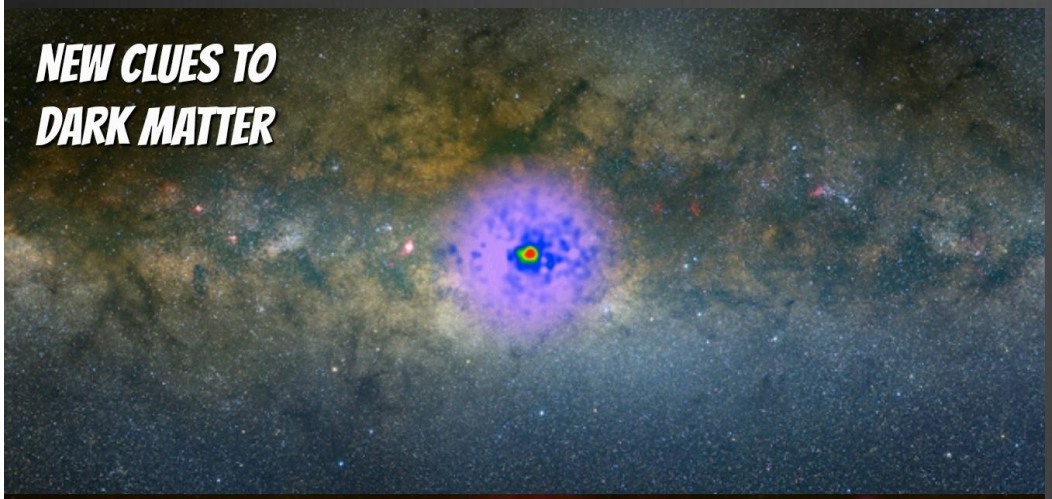



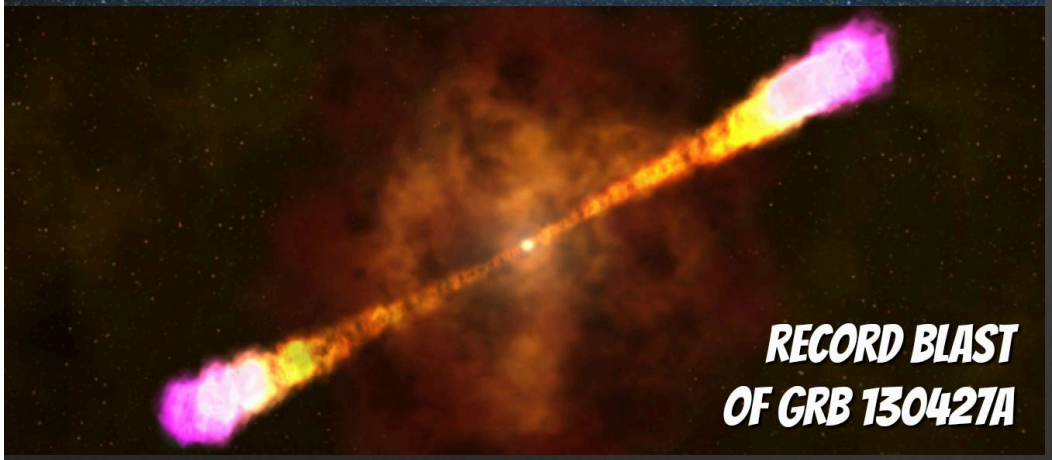


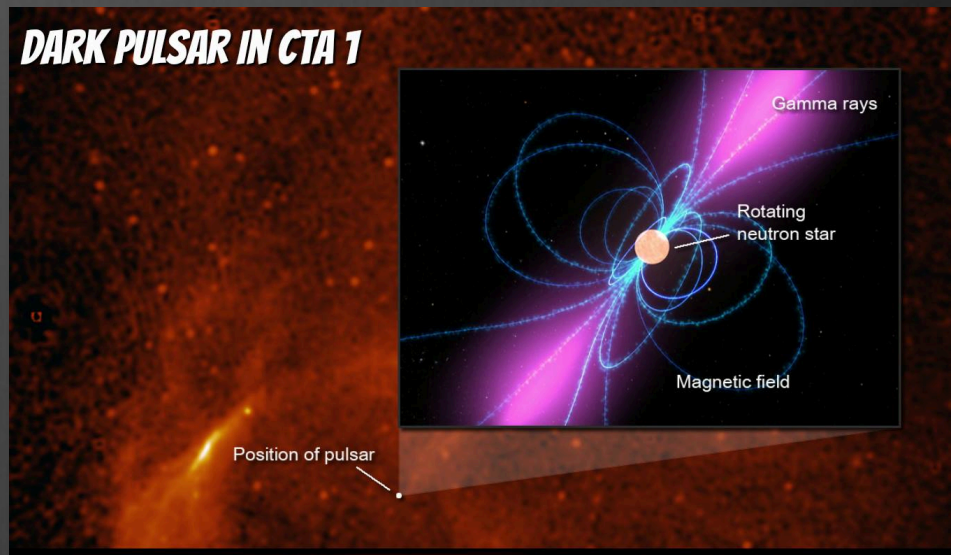



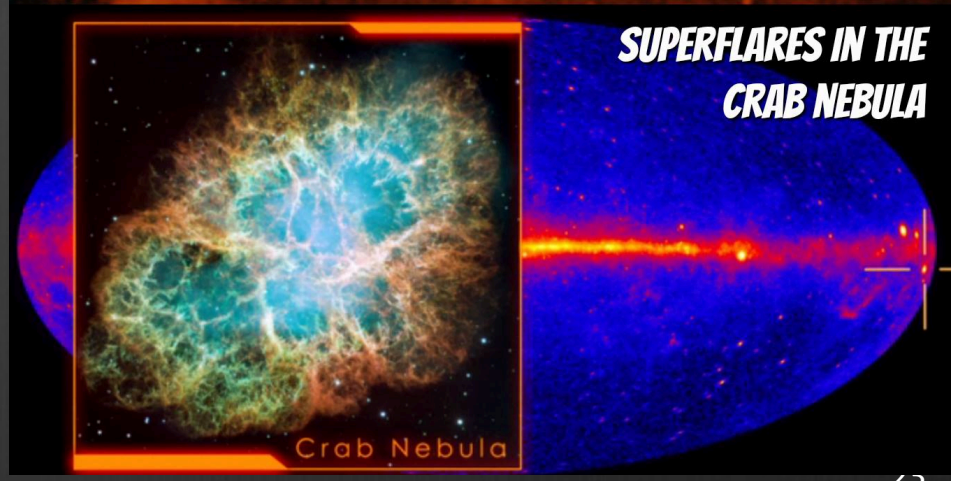
# Science Brackets

# Brackets – Fermi results go head to head



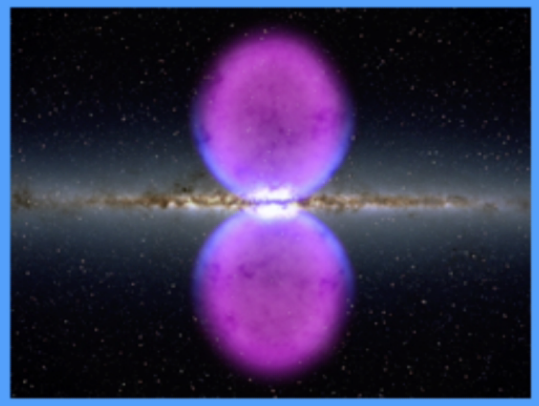



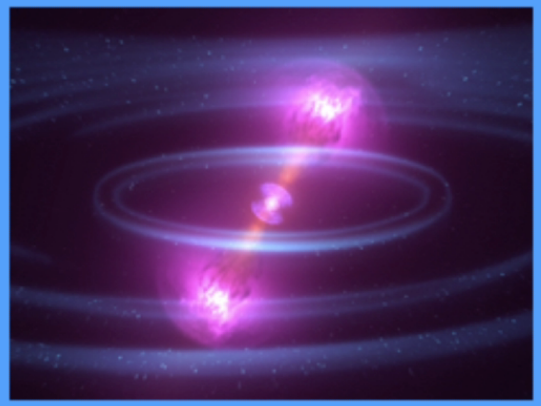



# Round 3: Down to 4…

# Science Playoffs!



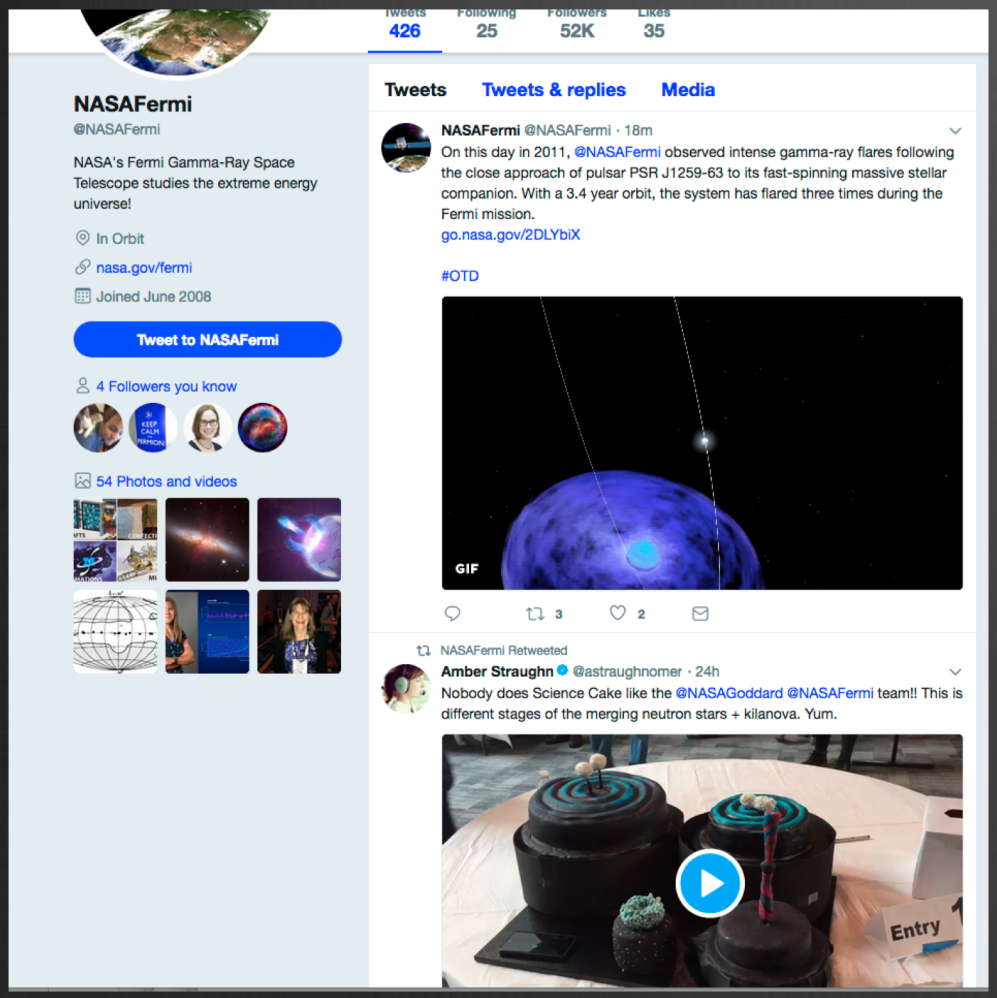
Fermi
Gamma-ray
Space Telescope



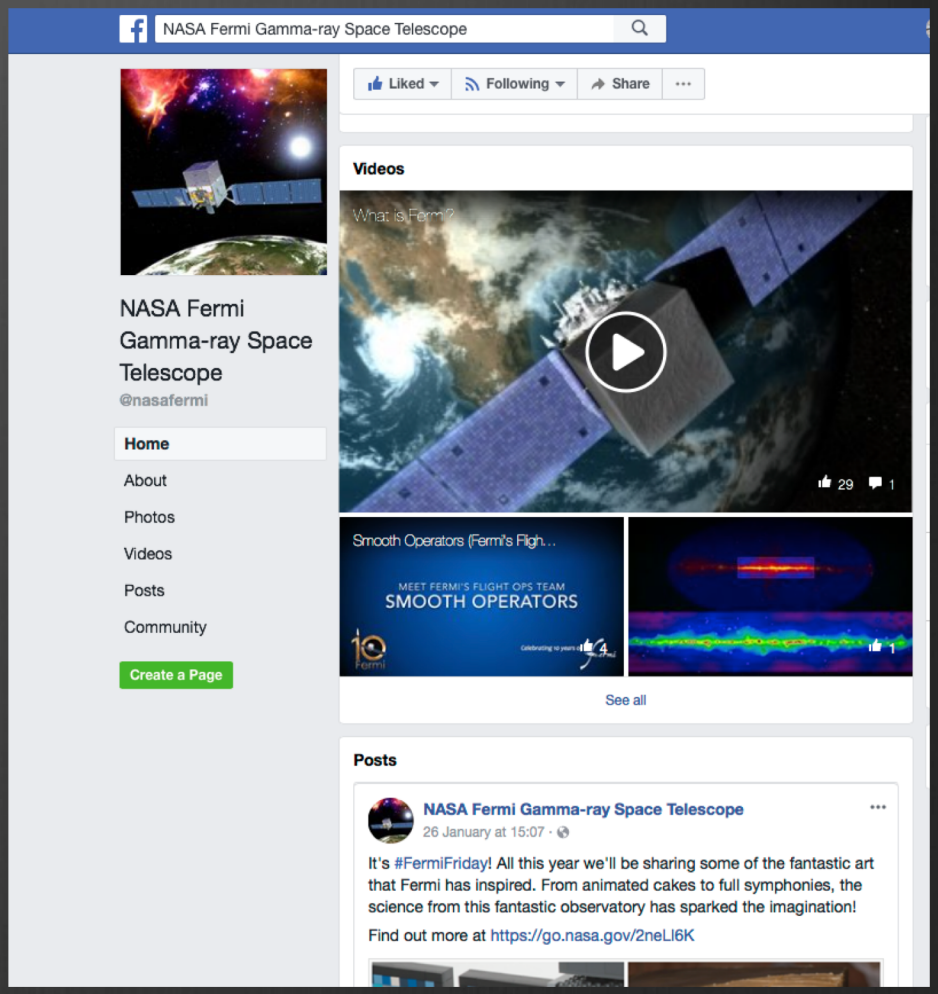
# Final Round!

# Join us on social media

Twitter @nasafermi




Facebook



# Most liked Facebook post

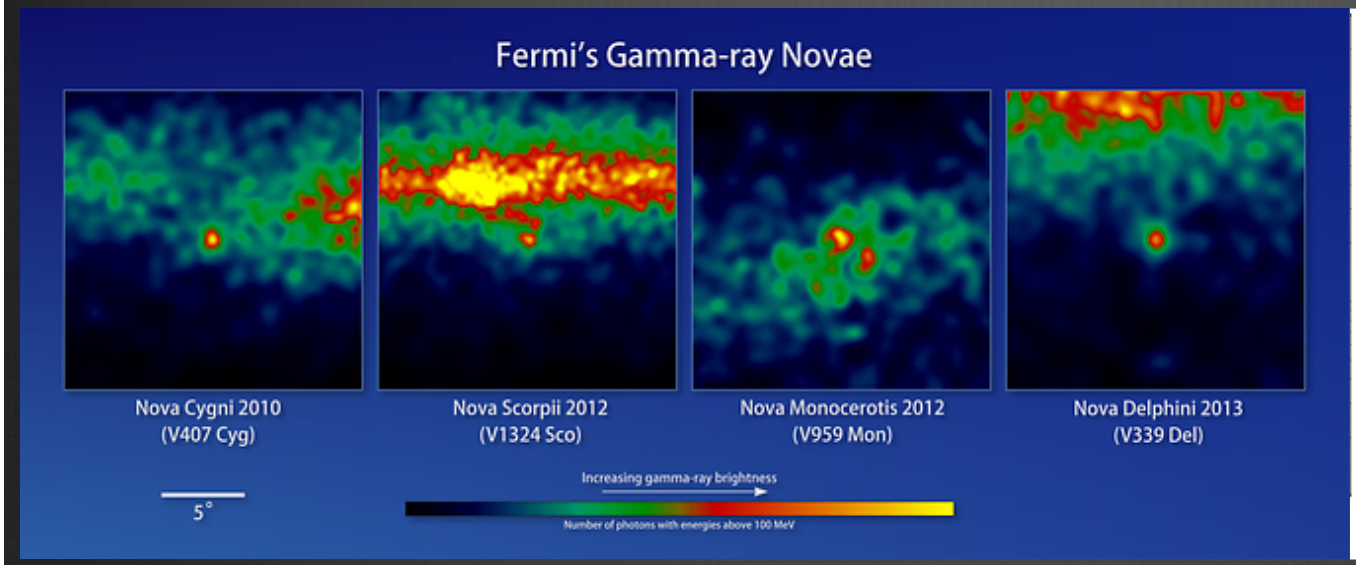
# The First 10 years has been fun

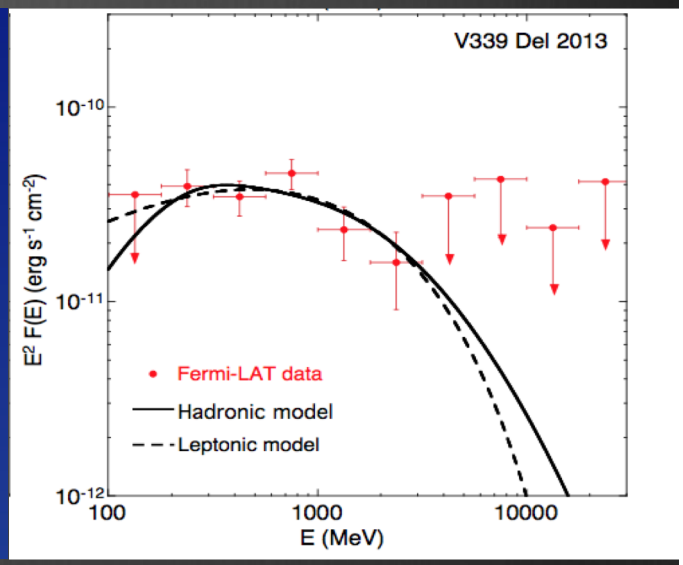
- Enhancements to pipeline processing and analysis software
  - Both instruments have better performance than ever
- Sky is constantly changing
  - Something new to see every day
- New observatories/experiments are creating new opportunities for Fermi
  - LIGO/Virgo, IceCube
  - CTA, LSST, SKA etc
- I'm looking forward to the next 10 years!

# Preparations for LIGO/Virgo O3

- Testing changes to the targeted search to make it both more sensitive and faster.
  - Preliminary results show the changes are improvements over O2 version
- Working with LVC to implement, in one of their pipelines, a way to read in and combine GBM sky localizations w/ LVC localizations and send out improved sky maps via GCN
- Using simulated signals, we are assessing the sensitivity dependence of the untargeted search on fluence and spectral shape.

# Novae




- Shocks in the expanding nova envelope produce gamma rays that appear 1-3 weeks after onset of optical outburst
- Fermi ToO in response to optical discovery resulted in ~8 new detections
- Synergy with radio observations that reveal shock sites

# Top 10 cited papers

1. The Large Area Telescope on the Fermi Gamma-Ray Space Telescope Mission
2. Fermi Large Area Telescope Second Source Catalog
3. Measurement of the Cosmic Ray e++e- Spectrum from 20GeV to 1TeV with the Fermi Large Area Telescope
4. Fermi Large Area Telescope First Source Catalog
5. Fermi Large Area Telescope Third Source Catalog
6. Searching for Dark Matter Annihilation from Milky Way Dwarf Spheroidal Galaxies with Six Years of Fermi Large Area Telescope Data
7. Giant Gamma-ray Bubbles from Fermi-LAT: Active Galactic Nucleus Activity or Bipolar Galactic Wind?
8. The Fermi Gamma-ray Burst Monitor
9. Dark matter annihilation in the Galactic Center as seen by the Fermi Gamma Ray Space Telescope
10. The Second Catalog of Active Galactic Nuclei Detected by the Fermi Large Area Telescope

# Top 10 cited papers (excluding catalogs and instrument papers)

1. Measurement of the Cosmic Ray e++e- Spectrum from 20GeV to 1TeV with the Fermi Large Area Telescope; Abdo, A.A., et al.
2. Giant Gamma-ray Bubbles from Fermi-LAT: Active Galactic Nucleus Activity or Bipolar Galactic Wind?; Su, M., Slatyer, T.R., & Finkbeiner, D.P.
3. Dark matter annihilation in the Galactic Center as seen by the Fermi Gamma Ray Space Telescope; Hooper, D., & Goodenough, L.
4. Evidence for Strong Extragalactic Magnetic Fields from Fermi Observations of TeV Blazars; Neronov, A., & Vovk, I.
5. Multi-messenger Observations of a Binary Neutron Star Merger; Abbott et al
6. Constraining Dark Matter Models from a Combined Analysis of Milky Way Satellites with the Fermi Large Area Telescope; Ackermann, M., et al.
7. Fermi Observations of High-Energy Gamma-Ray Emission from GRB 080916C ; Abdo et al
8. Searching for Dark Matter Annihilation from Milky Way Dwarf Spheroidal Galaxies with Six Years of Fermi Large Area Telescope Data; Ackermann, M., et al.
9. Spectrum of the Isotropic Diffuse Gamma-Ray Emission Derived from First-Year Fermi Large Area Telescope Data; Abdo, A.A., et al.
10. Pulsars as the sources of high energy cosmic ray positrons; Hooper, D., Blasi, P., & Dario Serpico, P.