The Fermi Gamma-ray Space Telescope: Spacecraft, operations and mission

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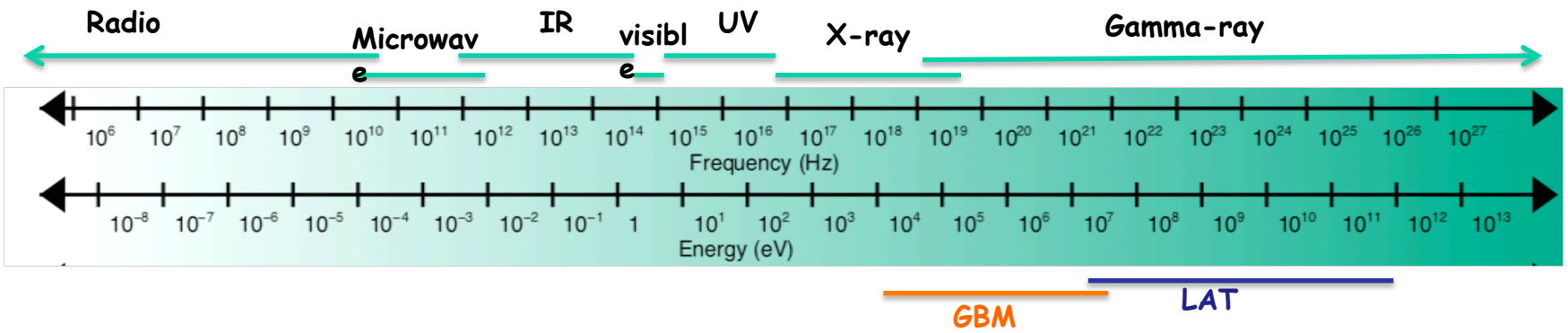
Gamma-ray Astrophysics



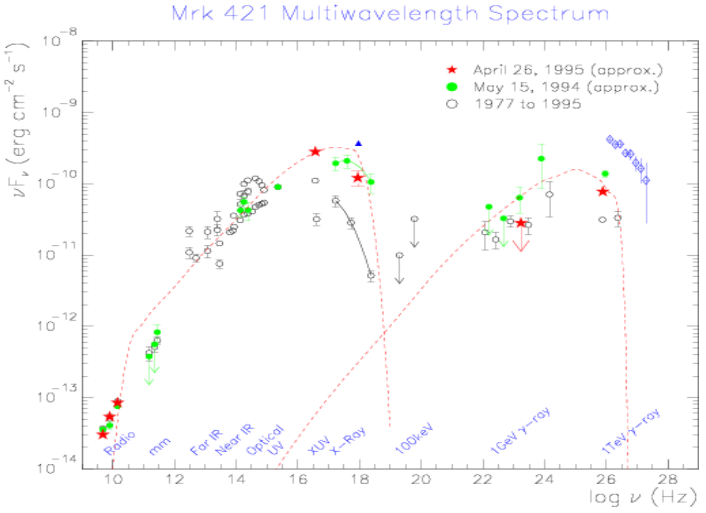
- Gamma-rays cover a huge swath of the electromagnetic spectrum
- The gamma-ray sky is still very new
- High-Energy gamma-rays probe the non-thermal universe
  - Explore extreme environments hosting powerful particle accelerators

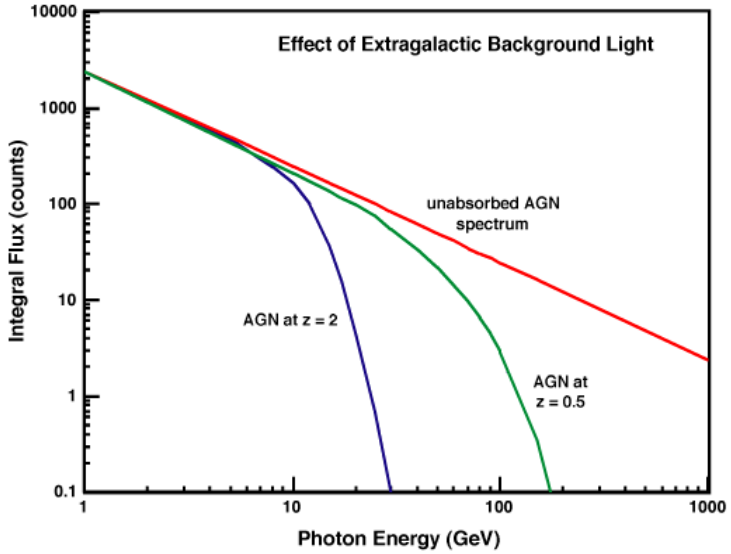
2

Why High Energy Gamma-Rays?

- **High energy gamma-rays explore nature's accelerators - "Where the energetic things are"**
  - **natural connections to UHE cosmic-ray and neutrino astrophysics**

High energy photons often produced in a different physical process to the lower energy emission -> Independent handle on the physical conditions.





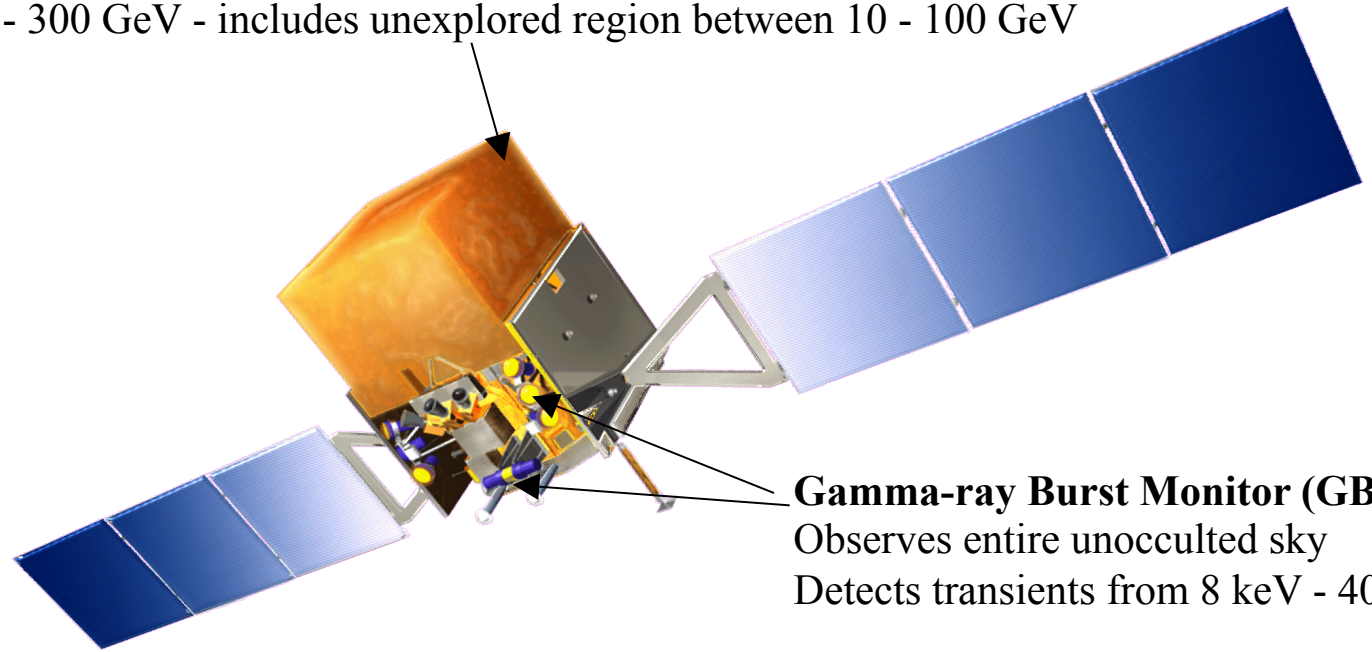
High energy gamma-rays can be attenuated by pair-production with lower energy photons

•Probe conditions in emission regions (gammas need to get out)

•Explore the optical/UV diffuse background

The Fermi Observatory

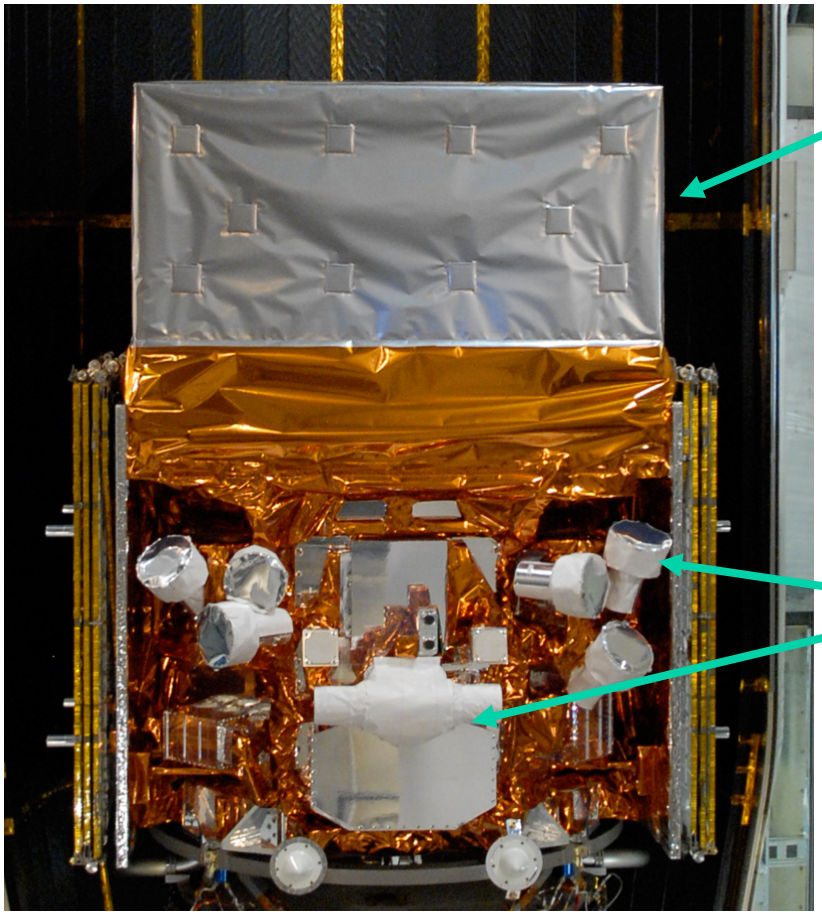
Large Area Telescope (LAT)
Observes 20% of the sky at any instant, views entire sky every 3 hrs
20 MeV - 300 GeV - includes unexplored region between 10 - 100 GeV



Gamma-ray Burst Monitor (GBM)
Observes entire unocculted sky
Detects transients from 8 keV - 40 MeV

- **Huge improvement over previous missions in this waveband**
  - **Increased effective area**
  - **Improved angular resolution**
  - **Broader energy range**
  - **Wide field of view**

Fermi Observatory



Large Area Telescope (LAT):

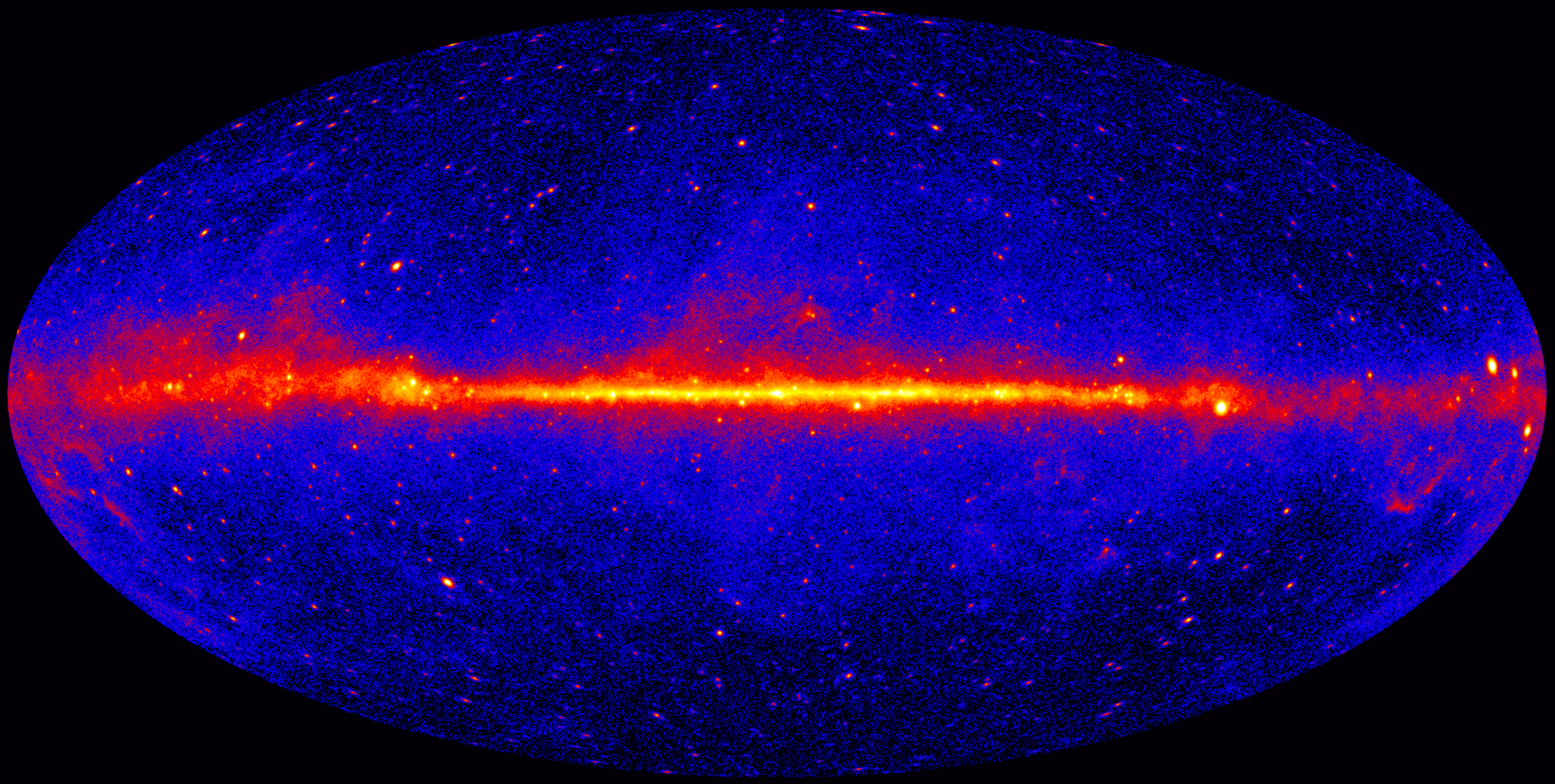
- 20 MeV - >300 GeV
- 2.4 sr FoV (scans entire sky every ~3hrs)

Gamma-ray Burst Monitor (GBM)

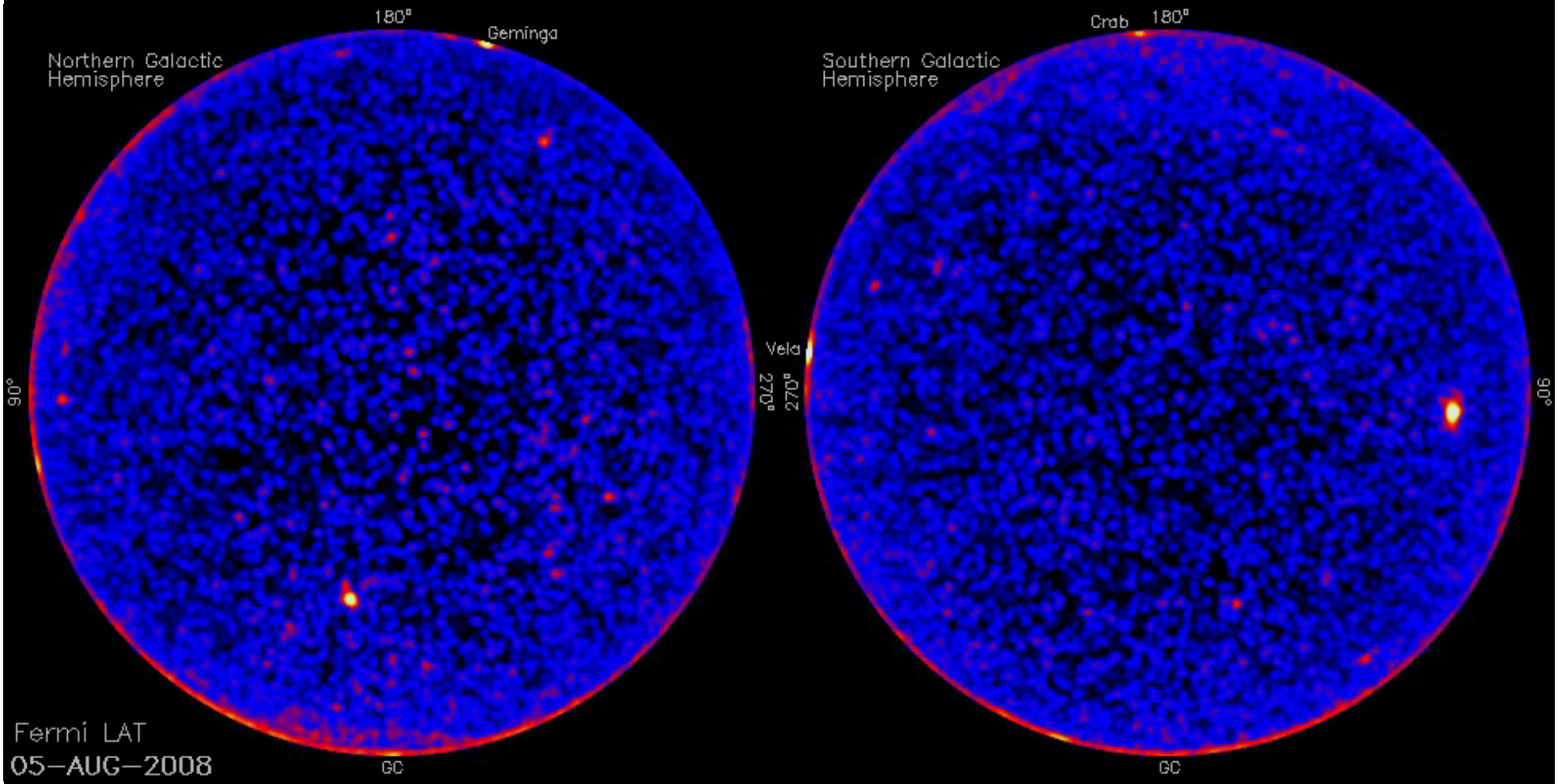
- 8 keV - 40 MeV
- views entire unocculted sky

Launched on June 11, 2008

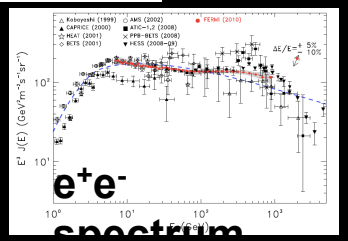
The >1 GeV Sky

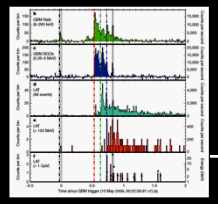


The Variable Gamma-ray Sky

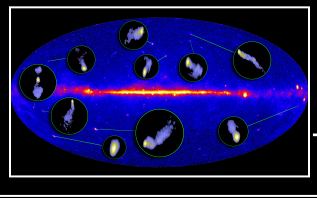


Fermi Highlights and Discoveries

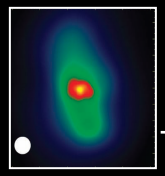




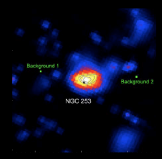
GRBs



Blazars

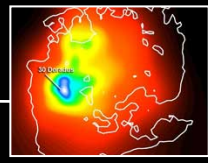


Radio Galaxies

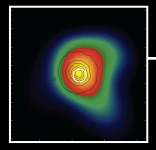


Starburst Galaxies

Extragalactic

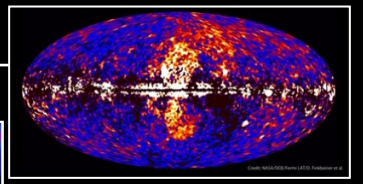


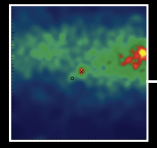
LMC & SMC



Globular Clusters

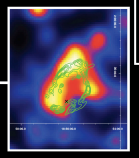
Fermi Bubbles

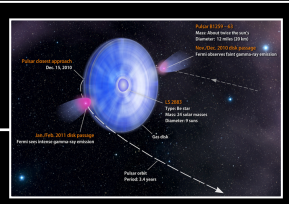




Nova

SNRs & PWN

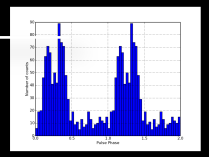




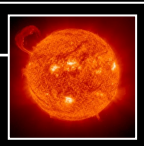
γ-ray Binaries

Galactic

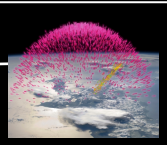
Pulsars: isolated, binaries, & MSPs



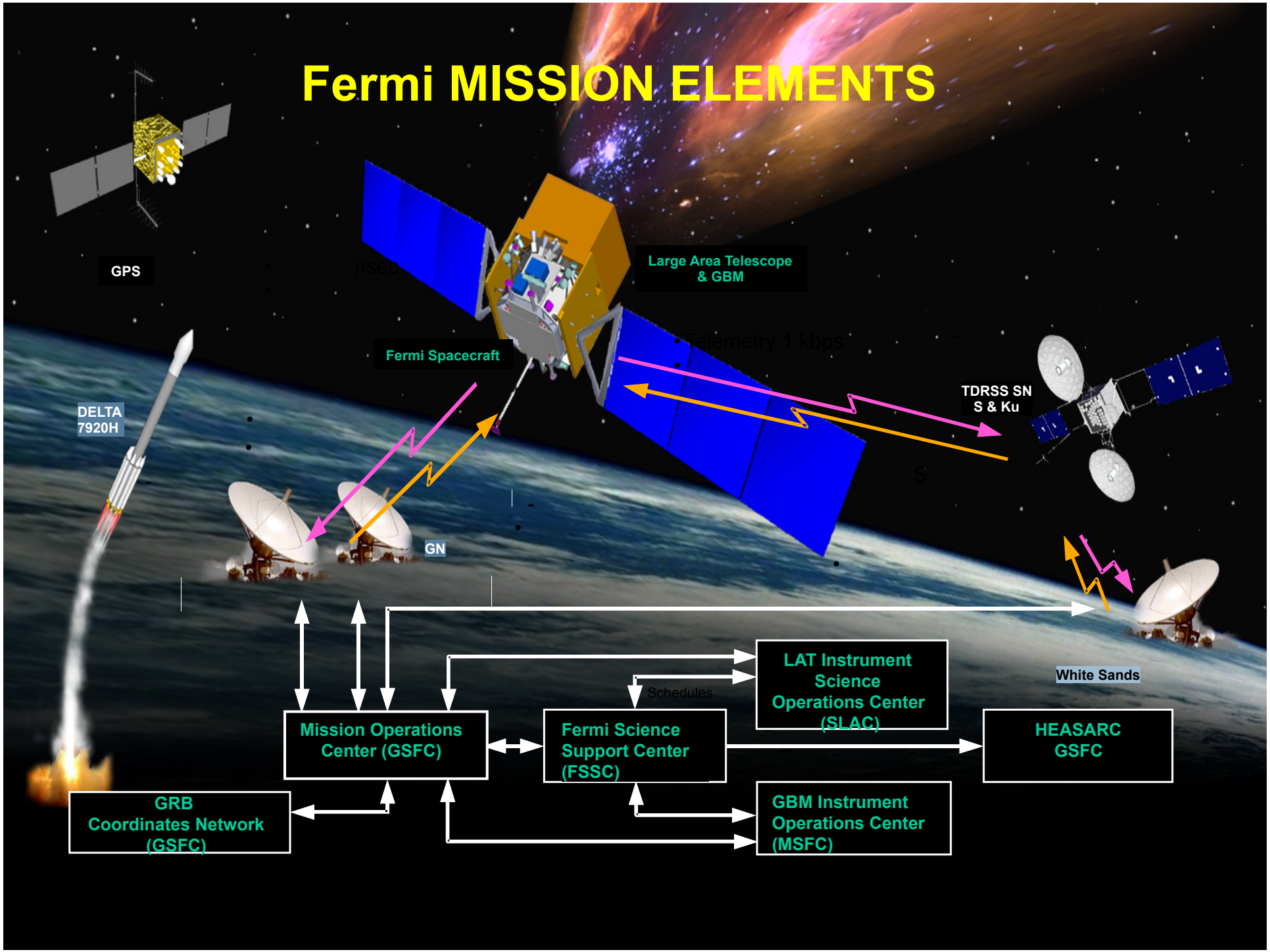
Sun: flares & CR interactions



Terrestrial γ-ray Flashes



Unidentified Sources (577/1873)


Fermi MISSION ELEMENTS
GPS
Large Area Telescope
& GBM
Fermi Spacecraft
TDRSS SN
S & Ku
DELTA
7920H
GN
White Sands
LAT Instrument
Science
Operations Center
(SLAC)
Schedules
Mission Operations
Center (GSFC)
Fermi Science
Support Center
(FSSC)
HEASARC
GSFC
GRB
Coordinates Network
(GSFC)
GBM Instrument
Operations Center
(MSFC)

Launch!

- Launch from Cape Canaveral Air Station 11 June 2008 at 12:05PM EDT
- Circular orbit, 565 km altitude (96 min period), 25.6 deg inclination.
- Communications:
  - Science data link via TDRSS Ku-band (40 Mbps, 8-10, 10 min contacts per day)
  - S-band via TDRSS (8kbps) or ground stations (1.26 Mbps)

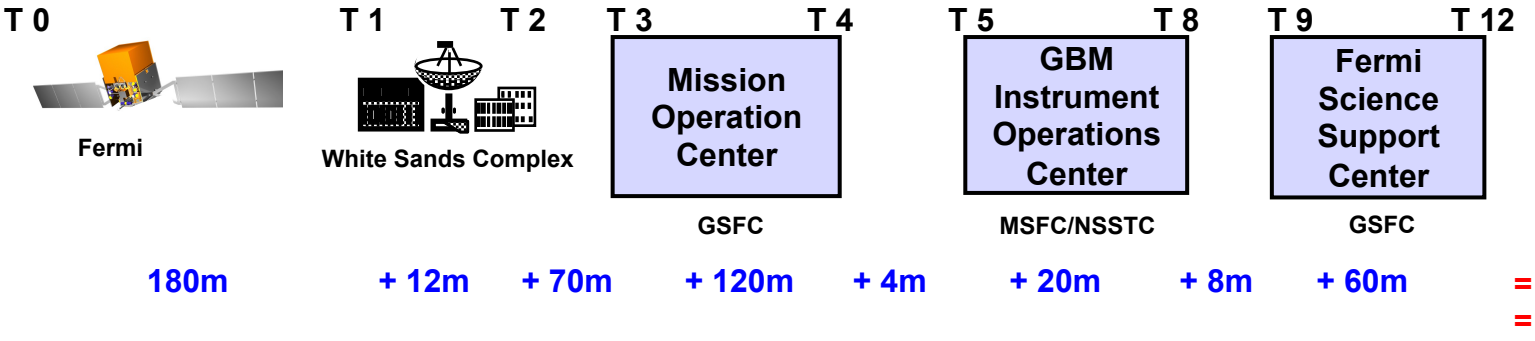
Raw Data

- **Data consists of**
  - **1.5 Mbps LAT data**
  - **0.5 Mbps GBM data**
  - **51 kbps housekeeping data (from SC, LAT and GBM)**

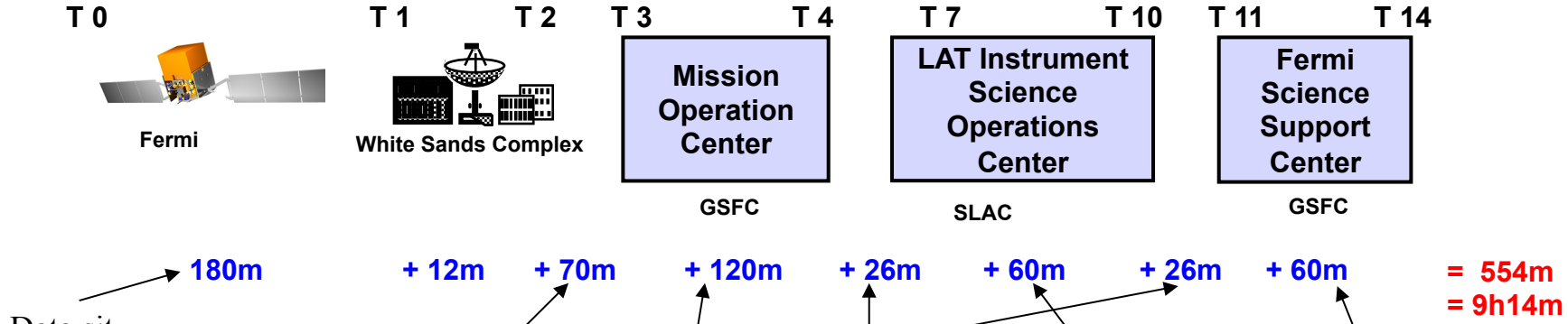
- **The onboard solid state recorder (SSR) has two partitions, read out in parallel**
  - **Science (LAT+GBM data)**
  - **Housekeeping**
    - **Often arrives before science data due to smaller volume**

Data Latency

GBM DATA PATH



LAT DATA PATH



Data sit on SSR

4.3Mbps, unlikely (at the moment) to do much better than this.

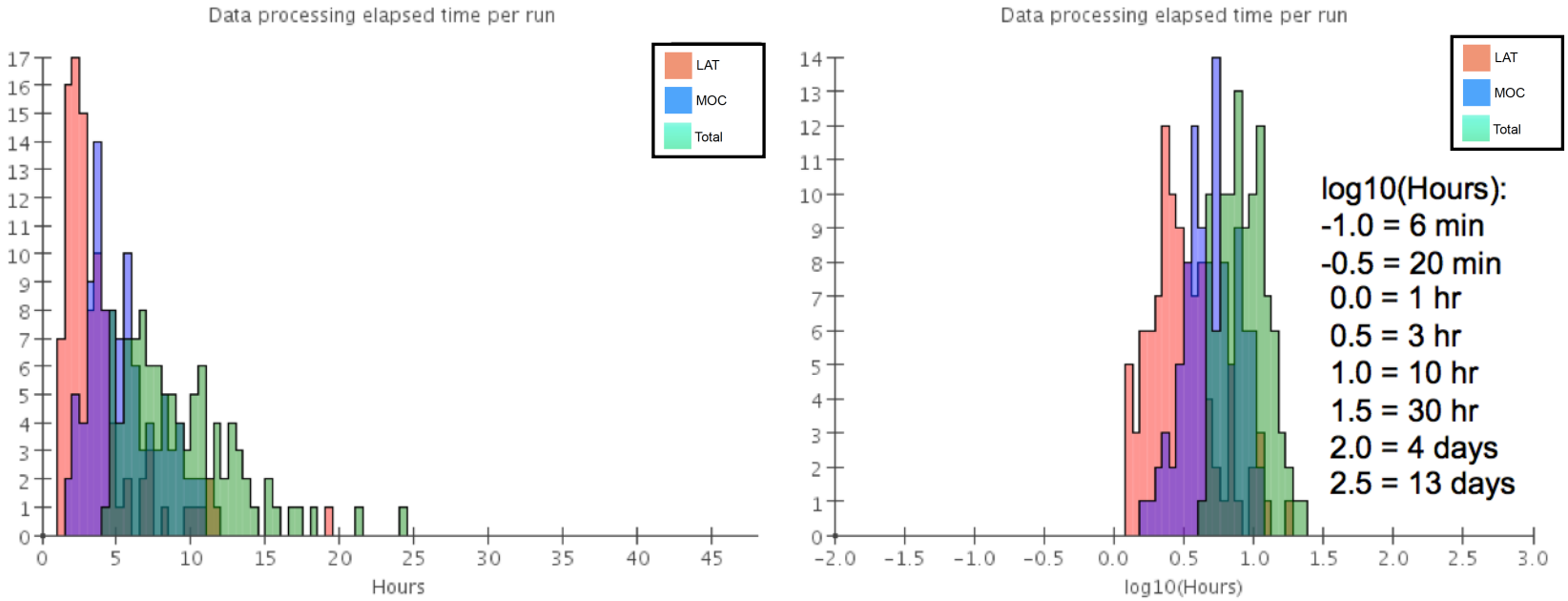
Level 0 processing conservative estimate.

sometimes achieve higher bandwidth.

Nominal case, assuming no manual intervention or new calibrations.

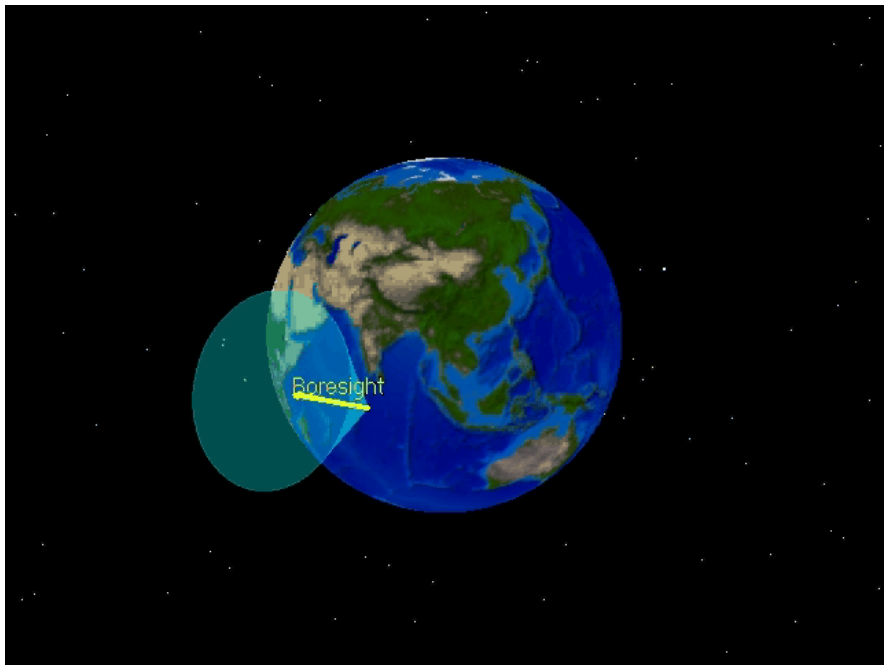
Data ingest, conservative estimate

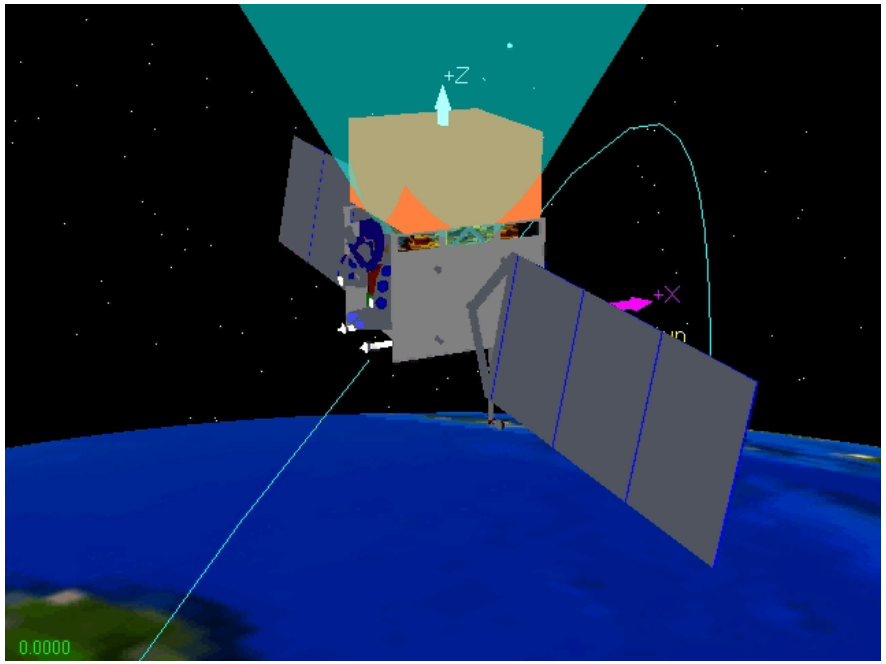
Data Latency



- **LAT - requirement: <72 hours from detection of gamma-ray photon to availability in public archive**
  - **Typical latency is ~8 hours**
  - **Everyone gets access to the data at the same time.**
- **GBM Data is delivered to FSSC within 24 hours for routine data taking.**
  - **GRB, Solar flares, TGFs - times, fluxes, location delivered in near real time.**

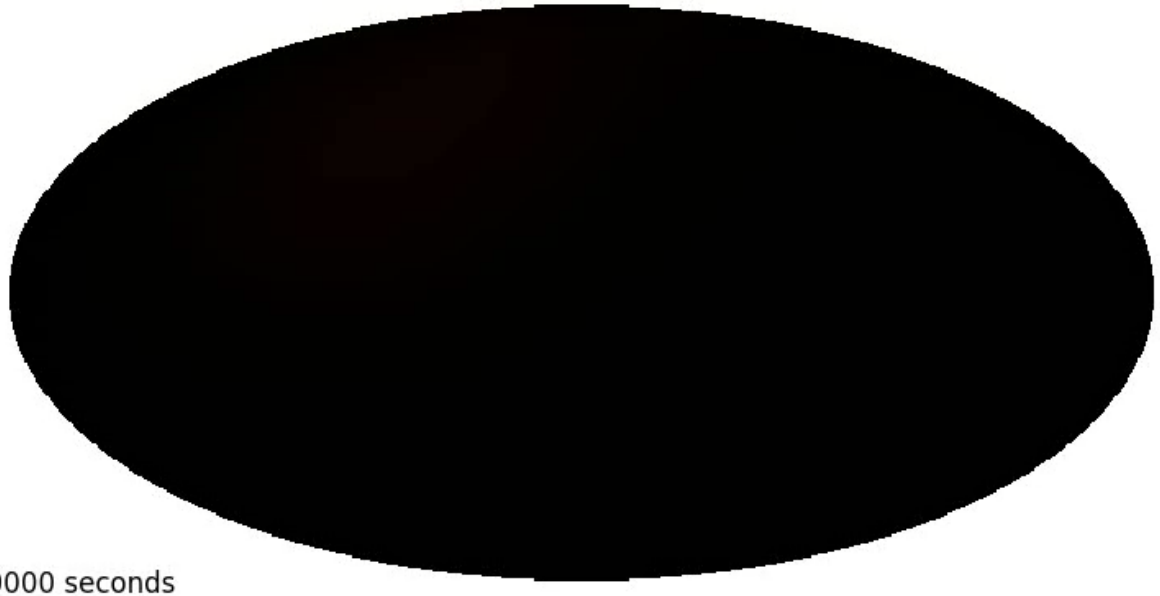
Survey mode





- Rock north for one orbit and south for the next
- Cover entire sky and always keep LAT FoV away from the Earth limb
- Rotate about Z-axis to keep sun off the LAT radiators (on +-Y faces

All Sky Coverage

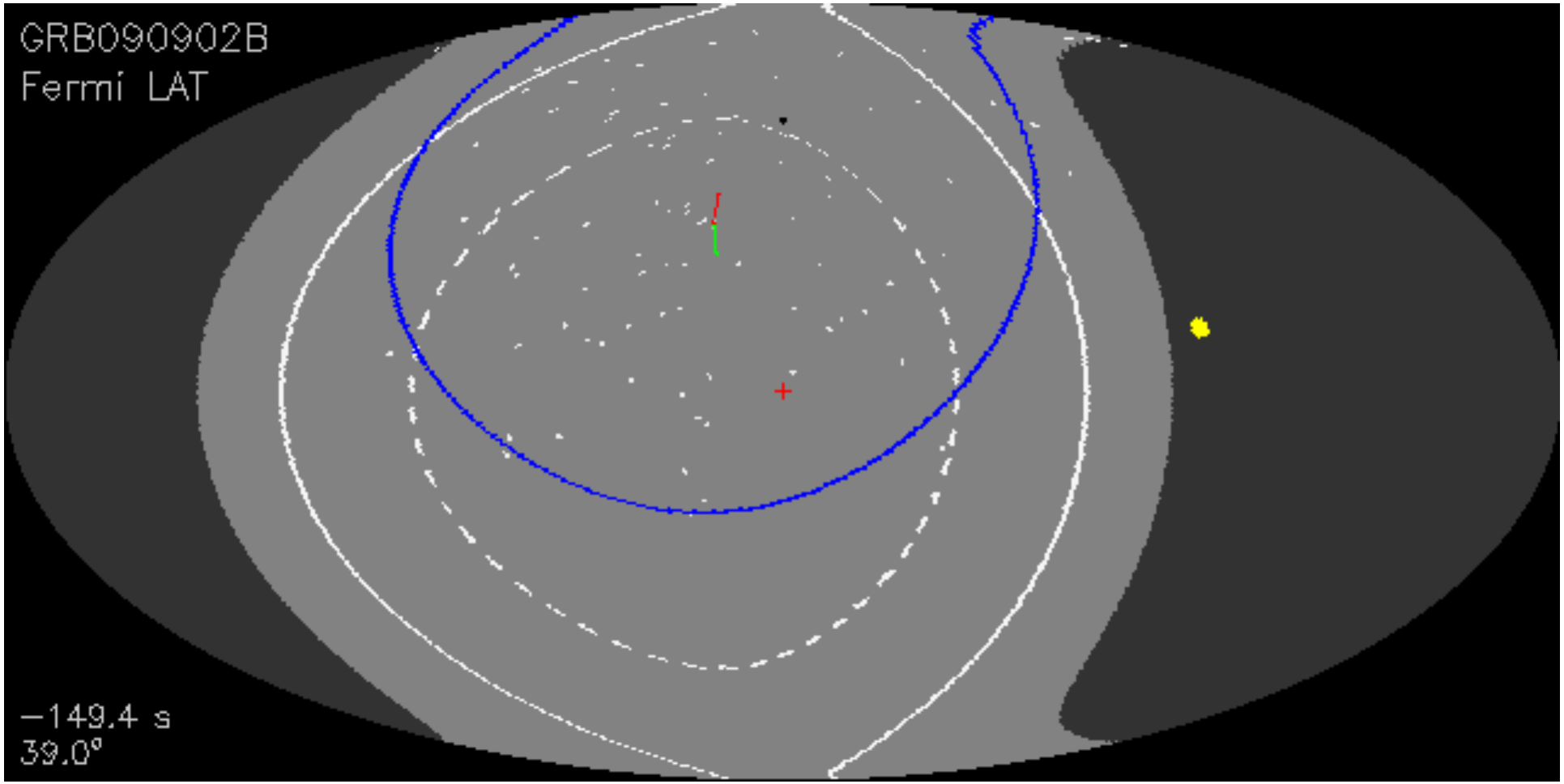


LAT exposure over two orbits

- In survey mode, the LAT observes the entire sky every two orbits (~3 hours).
- Multiwavelength observations in coordination with the LAT are limited only by the ability to coordinate to other observations in other wavebands.
- Can also perform pointed observations of particularly interesting regions of the sky.
  - Requirement to be able to slew 75 deg in less than 10 mins (to catch GRB)

GRB090902B - Autonomous repoint

- **LAT pointing in celestial coordinates from -120 s to 2000 s**
  - **Dark region = occulted by Earth (θz>113°)**
  - **Blue line = LAT FoV (±66°), White points = LAT events**



Observation modes

- **Normal Survey mode (default)**
  - 1 orbit rock north, 1 orbit rock south, repeat
  - Covers entire sky every two orbits (~3 hours)
  - Efficient observing, LAT boresight stays away from the Earth.
- **Modified survey (improve exposure up to 2x)**
  - N orbits rock north, M orbits rock south, repeat
  - Covers entire sky every N+M orbits
  - Efficient observing mode
- **Target of Opportunity (improve exposure up to 4x)**
  - Allows rapid initiation of pointed mode observations
  - Boresight traces earth limb while target is occulted.
  - Least efficient observing mode (Significant occultation of LAT FoV by Earth)
- **Pointed mode (improve exposure up to 4x)**
  - Planned pointed mode observation
  - Perform small segment of sky survey while target is occulted.
  - Somewhat inefficient observing mode (some occultation)

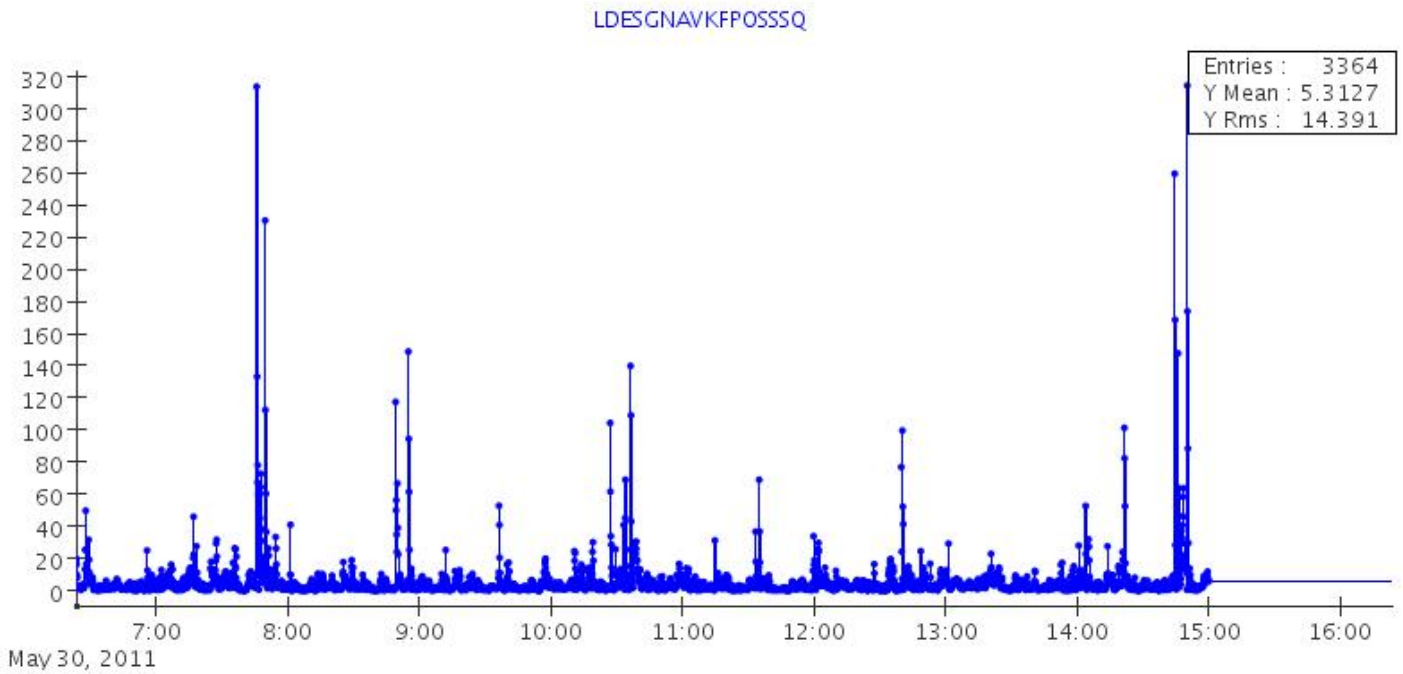
Observations summary

- Almost exclusively in nominal data taking in survey mode
  - 50 deg rocking angle from May 27 2009 onwards
- ARRs (~2/month)
  - 2.5 hours duration (5 hour before Nov 2010)
- Target of Opportunity/pointed mode observations
  - Crab nebula, Sun, flaring blazars, galactic center
- Modified survey mode observation
  - PSR B1259 periastron, sun
- LAT Calibrations
  - ~<12 hours/year

- For past and planned future observations see:
  - http://fermi.gsfc.nasa.gov/ssc/observations/timeline/posting/

How do we know where we are?

- **GPS**
  - **Propagate orbit model, refine orbit solution using GPS location data, data lying close to predicted location given higher weight (Kalman filter)**
    - **Filtered solution robust against outliers or GPS outages**
    - **Filtered solution more accurate than any individual GPS meas.**
  - **Orbit location (from filter) reported at 1 Hz**



Where are we pointing

- 3 star trackers (2 active, 1 spare)
  - Acquires, tracks and identifies up to 6 bright stars in its FoV
- Also have set of 4 gyroscopes that measure angular rates of the spacecraft
  - Used to propagate attitude solution during star tracker outages (and between updates)
- Propagated solution from the gyros is corrected by attitude measurements from the star trackers (similar to orbit location)
  - Solution is robust to outliers and outages in star tracker measurements
  - Track the residuals between star tracker measurements and propagated solution (always tiny compared with LAT psf)
- Attitude solution reported at 5 Hz
- This defines the spacecraft attitude, NOT the LAT
  - Before use, correct for offset between the spacecraft and the LAT

Spacecraft files (aka FT2 files)

- These combine the orbit position and attitude information from the spacecraft.
  - Entries spaced every 30 s
- LAT_MODE – describes spacecraft observation mode
  - 3: pointed mode
  - 4: Maneuver mode
  - 5: survey mode

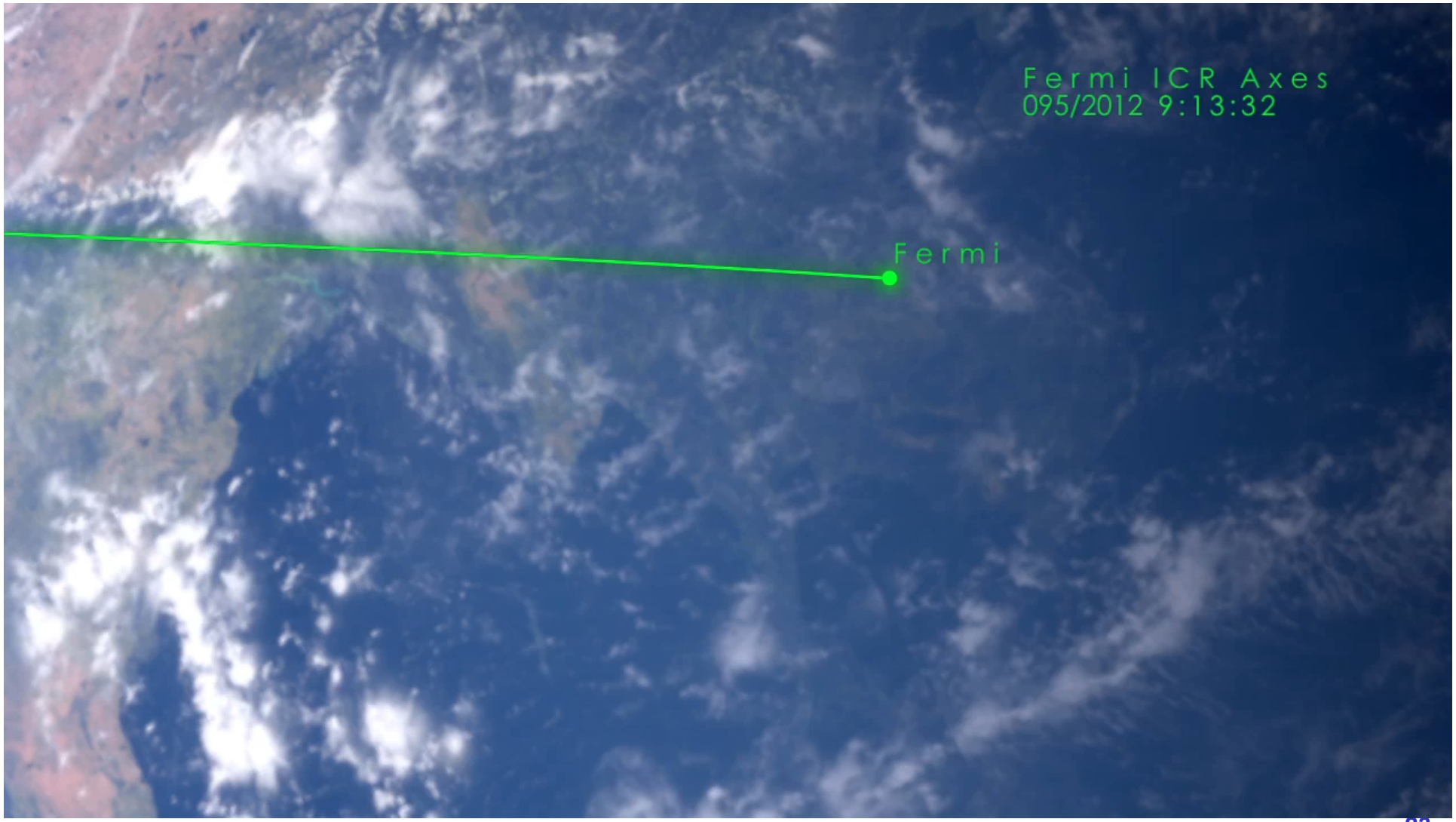
Absolute timing and orbit location

- GPS also provides an absolute timestamp
  - Used to calibrate an onboard oscillator.

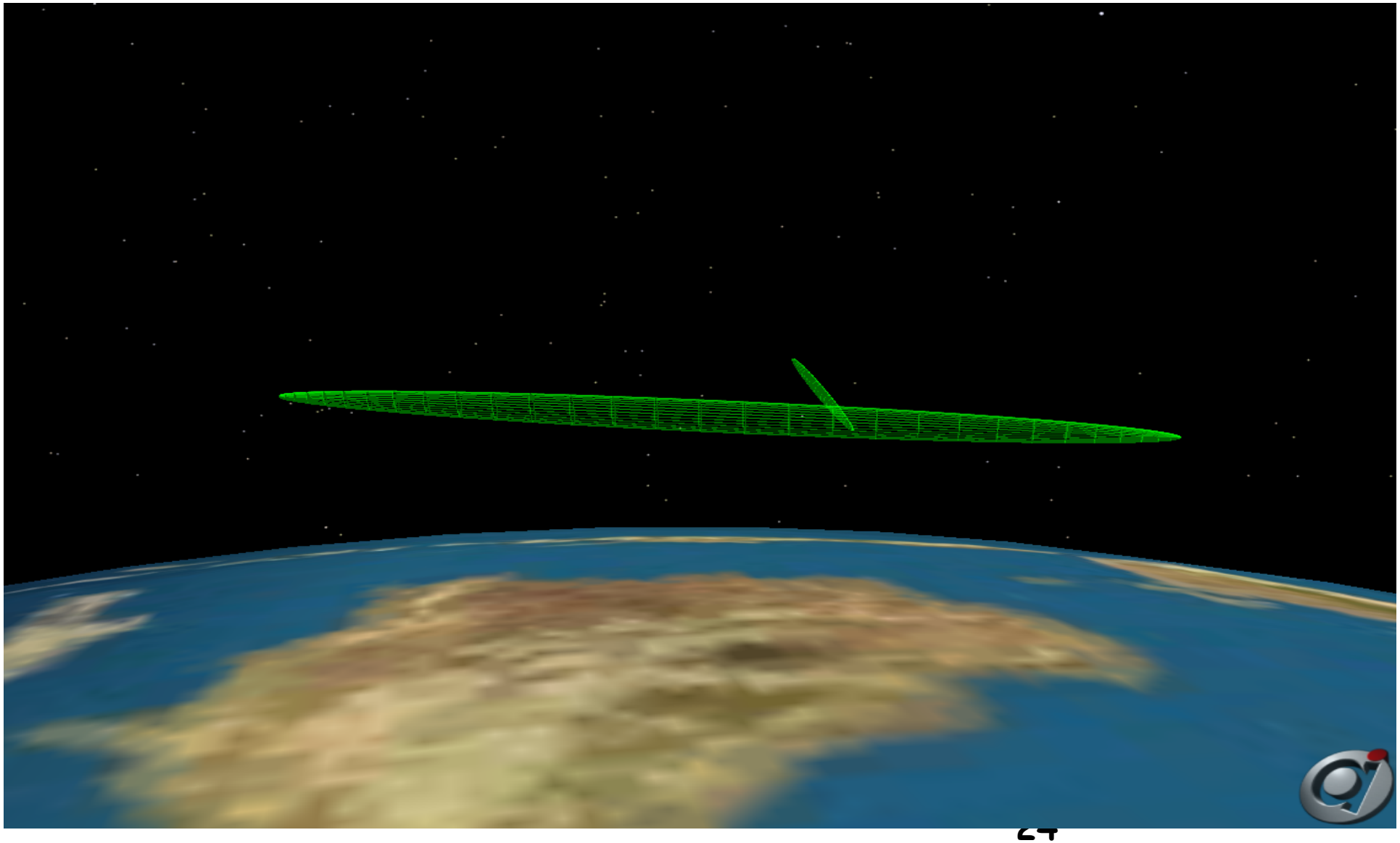
- Absolute timestamps are accurate to <300 ns (verified in ground test, and on orbit).
- Orbit position determination good to ~<20 m

- Both of these are important when considering very short timescales
  - Millisecond pulsars!

April 2012



We moved out of the way



Flight Operations Team

- **7 people**
  - **Responsible for operating the observatory and monitoring the health and performance of Fermi**

Fermi Science Support Center

GODDARD SPACE FLIGHT CENTER

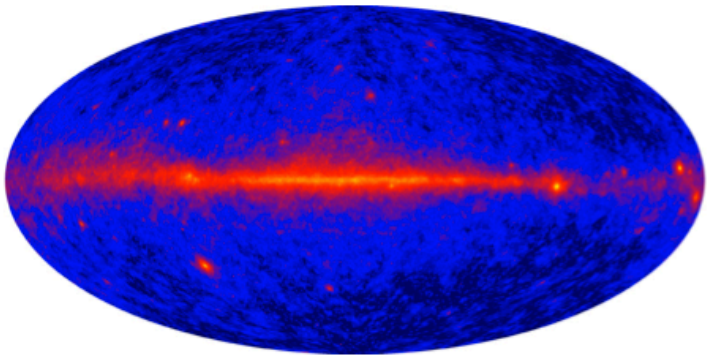
+ NASA Homepage
+ GSFC Homepage
+ Fermi Homepage

SEARCH Fermi: Search + GO

Fermi
Science Support Center

HOME | RESOURCES | PROPOSALS | DATA | HEASARC | HELP | SITE MAP

The Fermi Science Support Center (FSSC) runs the guest investigator program, creates and maintains the mission time line, provides analysis tools for the scientific community, and archives and serves the Fermi data. This web site is the portal to Fermi for all guest investigators.



This all-sky view from Fermi reveals bright emission in the plane of the Milky Way (center), bright pulsars and super-massive black holes.
Credit: NASA/DOE/International LAT Team

News

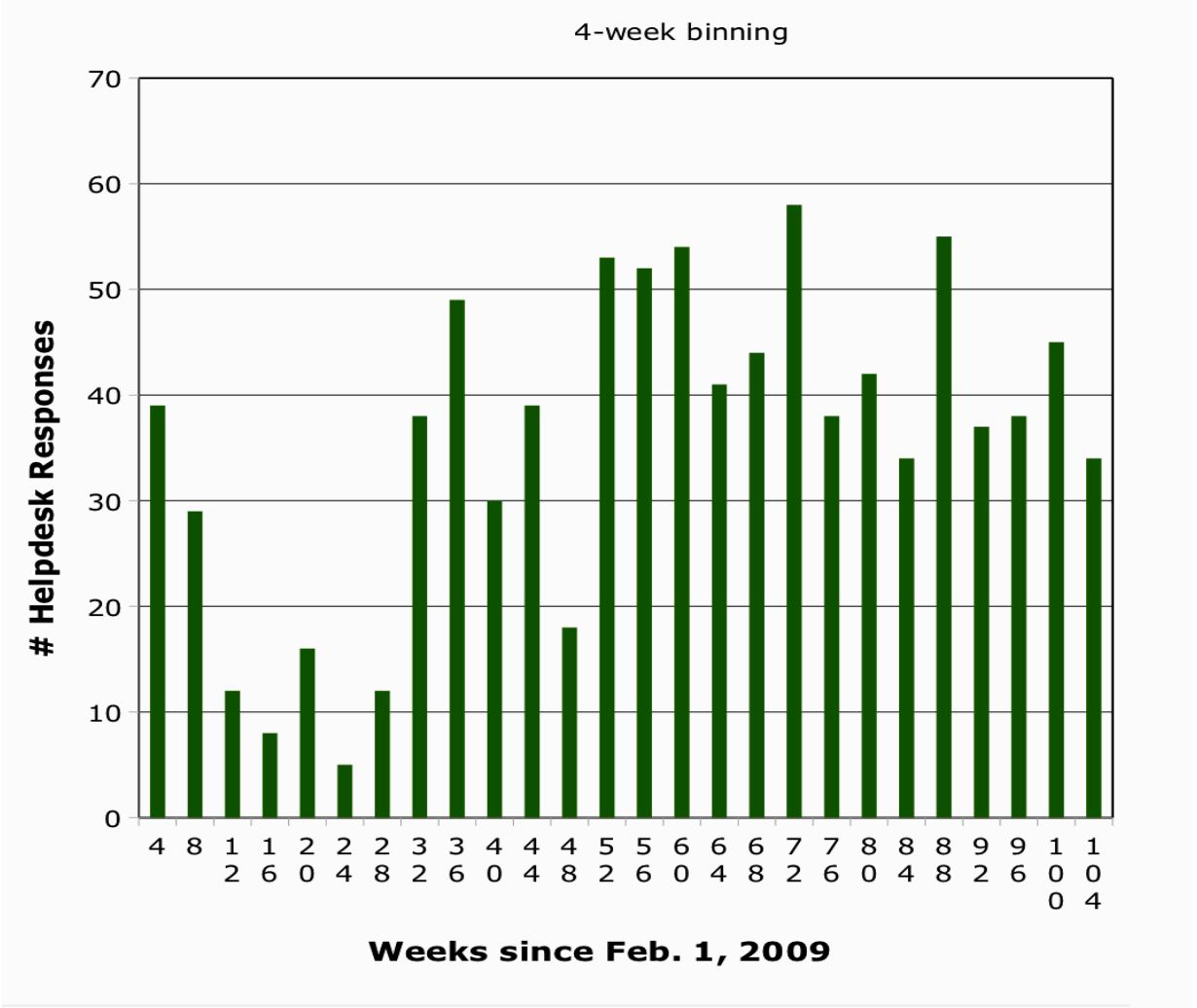
April 13, 2010
Multiwavelength Coordination is Important
The recent ToO on 3C 454.3 serves as a reminder of the need for community input on multiwavelength coordination with Fermi. In evaluating the impact of a ToO, we review scheduled or ongoing multiwavelength observations that have been reported to the FSSC. To ensure your planned observations are taken into consideration, please provide details via our multiwavelength reporting page.
+ Learn More

Public data and extensive support for science Analysis Tools
http://fermi.gsfc.nasa.gov/ssc/
FSSC Supports Guest Investigator Analysis

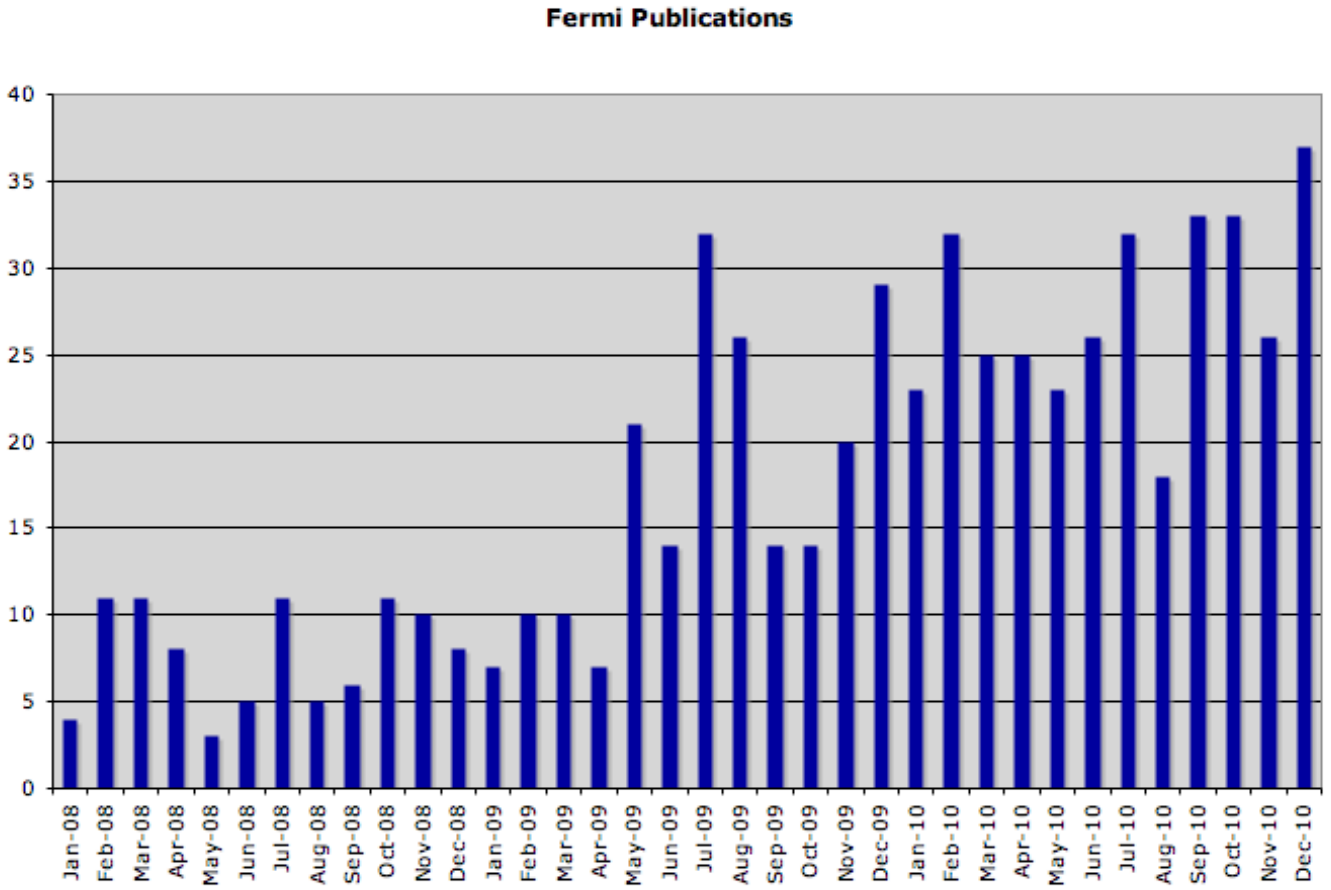
Science Support Center Team

- 6 scientists and 4 programmers/support staff
  - Planning/scheduling observations (including target of opportunity)
  - Software development
  - Data/software repository
  - User support
    - Documentation
    - Help desk
    - …

Queries to FSSC Helpdesk



Published Refereed Papers



See: http://fermi.gsfc.nasa.gov/cgi-bin/bibliography_fermi for a full list of Fermi-related publications

Questions?