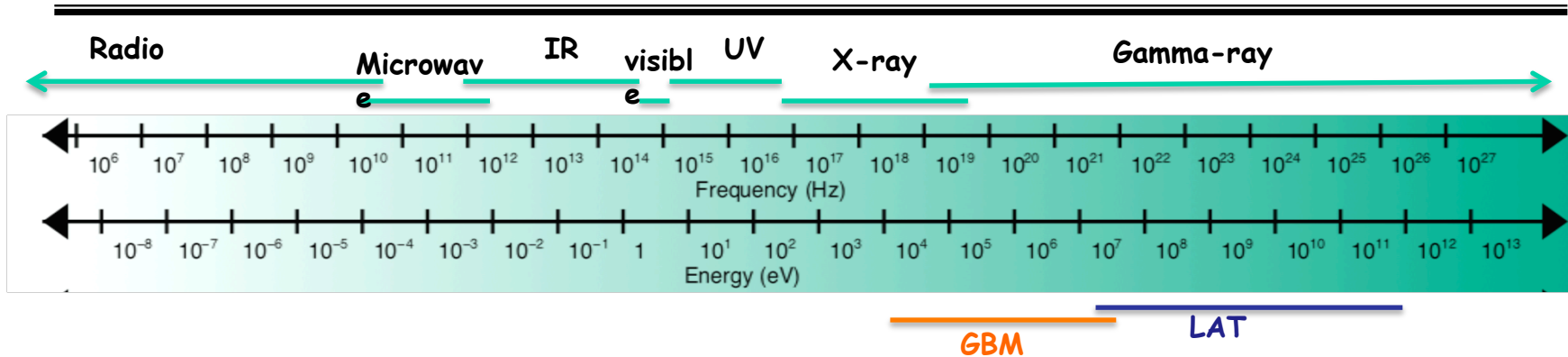


The Fermi Gamma-ray Space Telescope: Spacecraft, operations and mission

Julie McEnery
NASA/GSFC



Gamma-ray Astrophysics



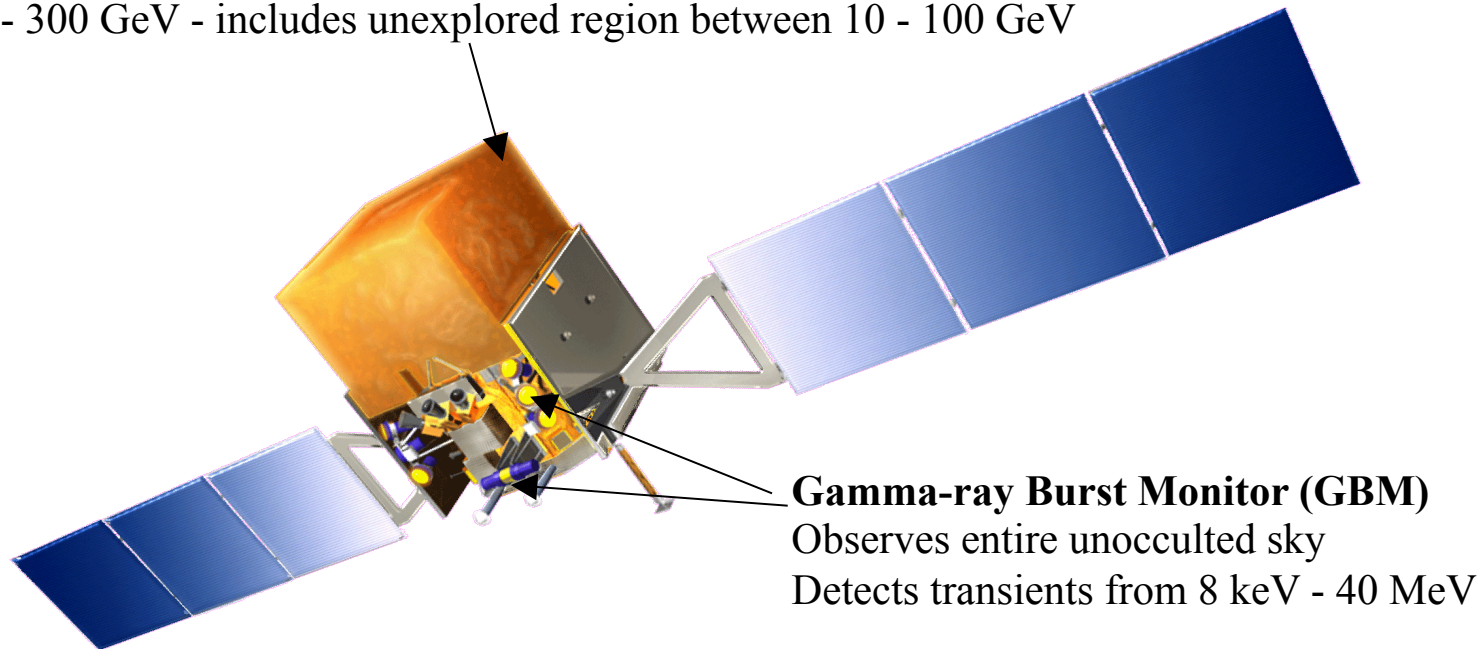
- **Gamma-rays cover a huge swath of the electromagnetic spectrum**
- **The gamma-ray sky is still very new**
- **High-Energy gamma-rays probe the non-thermal universe**
 - **Explore extreme environments hosting powerful particle accelerators**



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



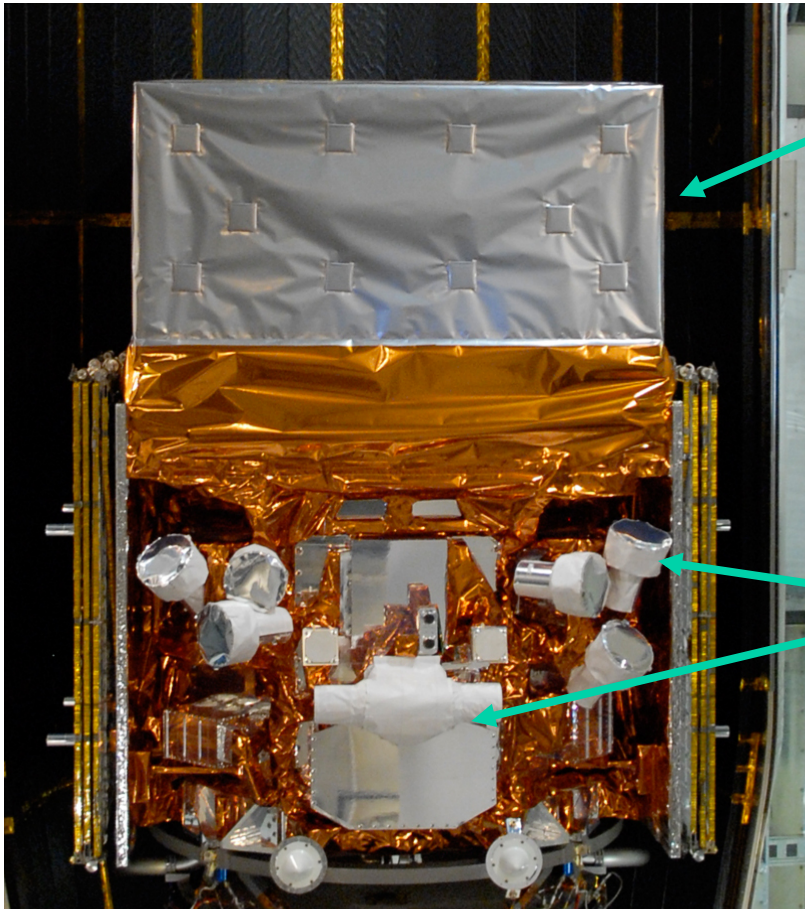
Gamma-ray Burst Monitor (GBM)

Observes entire unocculted sky
Detects transients from 8 keV - 40 MeV

- **Unique capabilities for GeV astrophysics**

- **Large effective area**
- **Good angular resolution**
- **Huge energy range**
- **Wide field of view**

Fermi Observatory



Large Area Telescope (LAT):

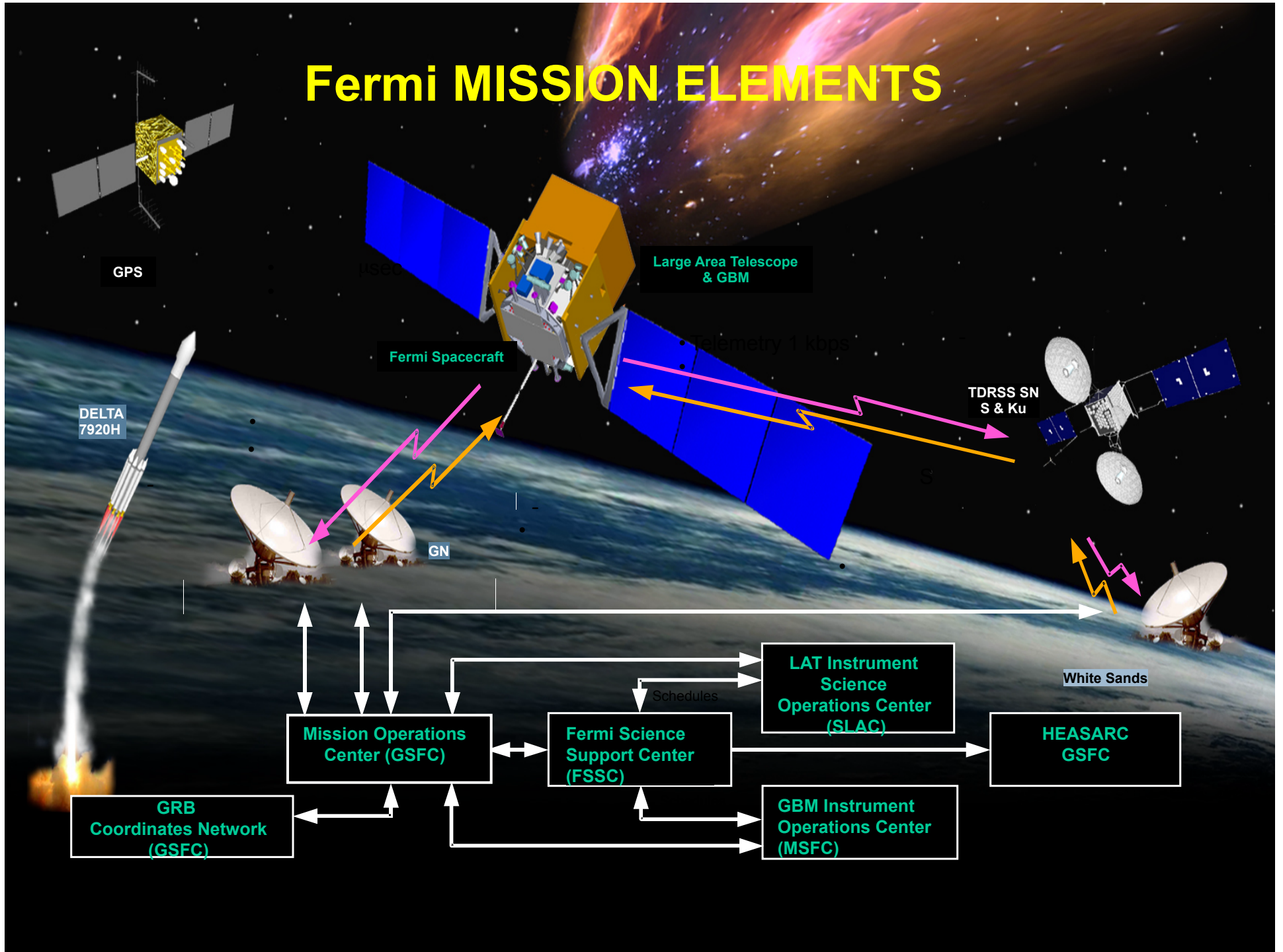
- 20 MeV - >300 GeV
- 2.4 sr FoV (scans entire sky every ~3hrs)

Gamma-ray Burst Monitor (GBM)

- 8 keV - 40 MeV
- views entire unocculted sky

Launched on June 11, 2008

Fermi MISSION ELEMENTS



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)**



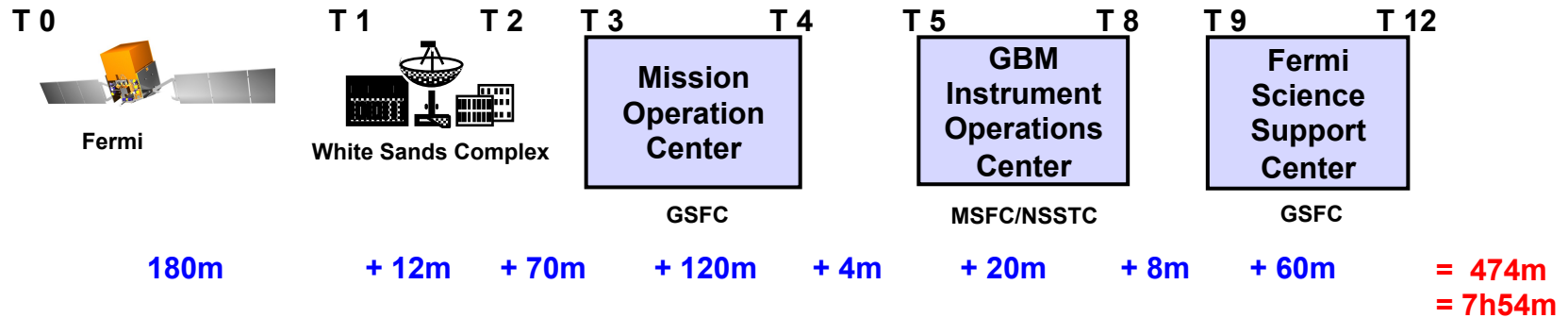


Raw Data

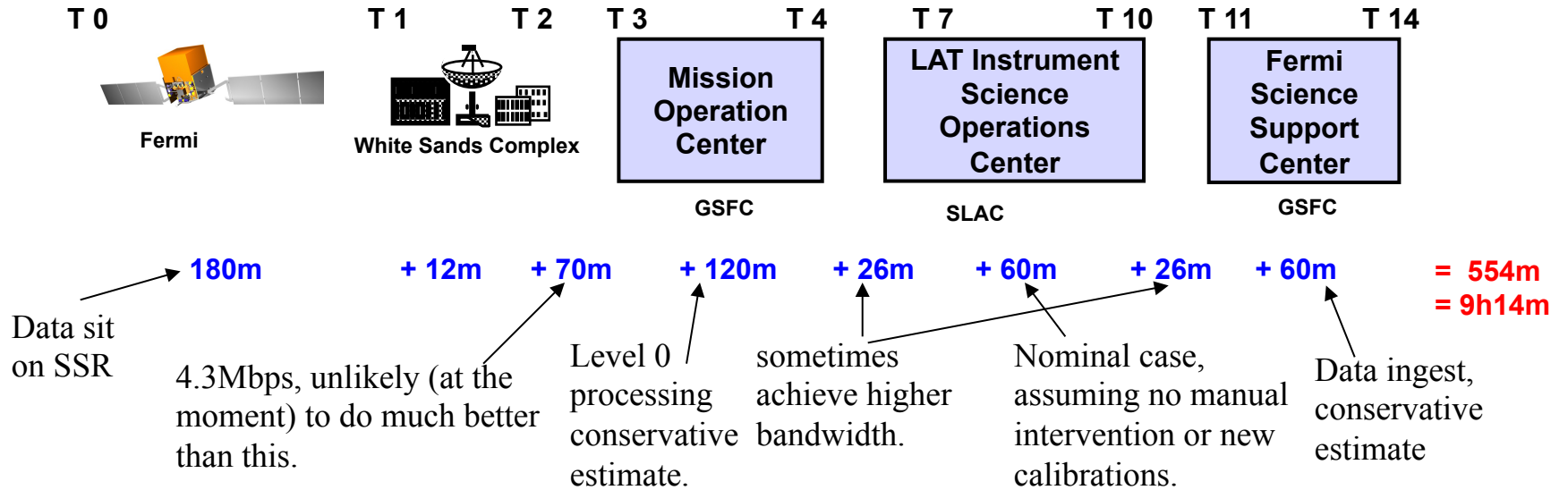
- **Data consists of**
 - **1.2 Mbps LAT data**
 - **26 kbps GBM data**
 - **51 kbps housekeeping data (from SC, LAT and GBM)**
- **The onboard solid state recorder (SSR) has two partitions, read out in parallel**
 - **Science (LAT+GBM data)**
 - **Housekeeping**
 - **Often arrives before science data due to smaller volume**

Data Latency

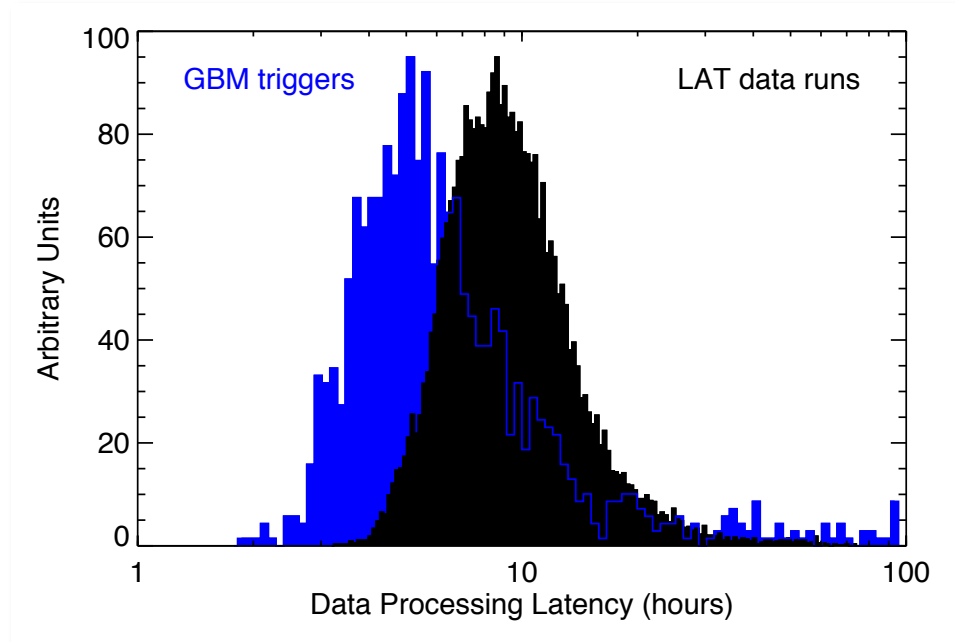
GBM DATA PATH



LAT DATA PATH

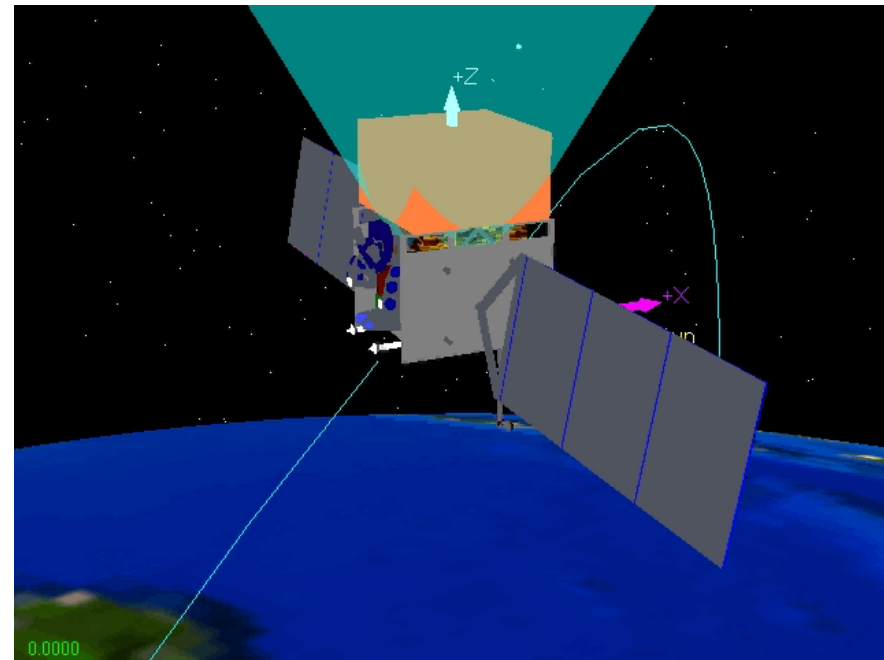
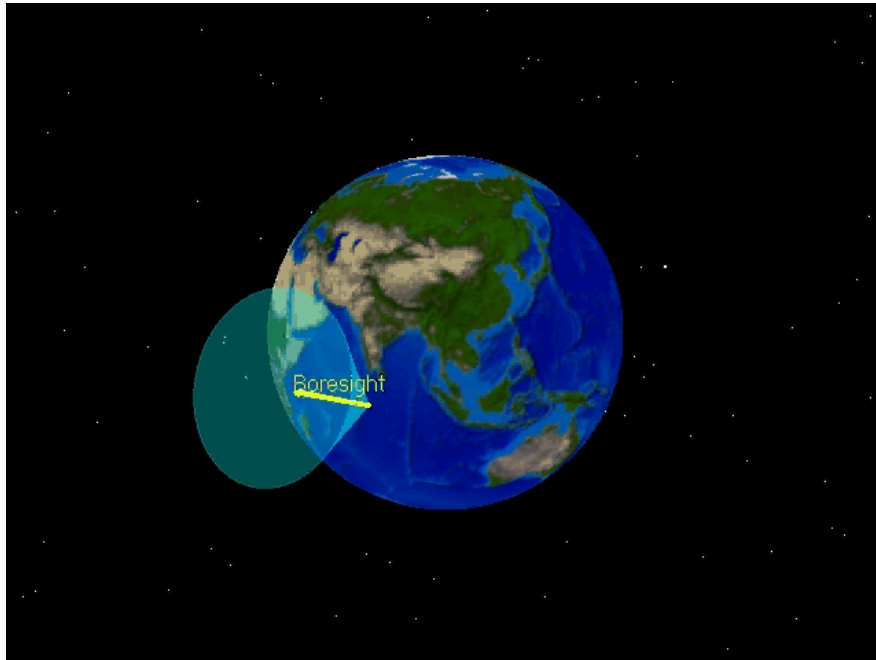


Data Latency



- **LAT - level 2 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



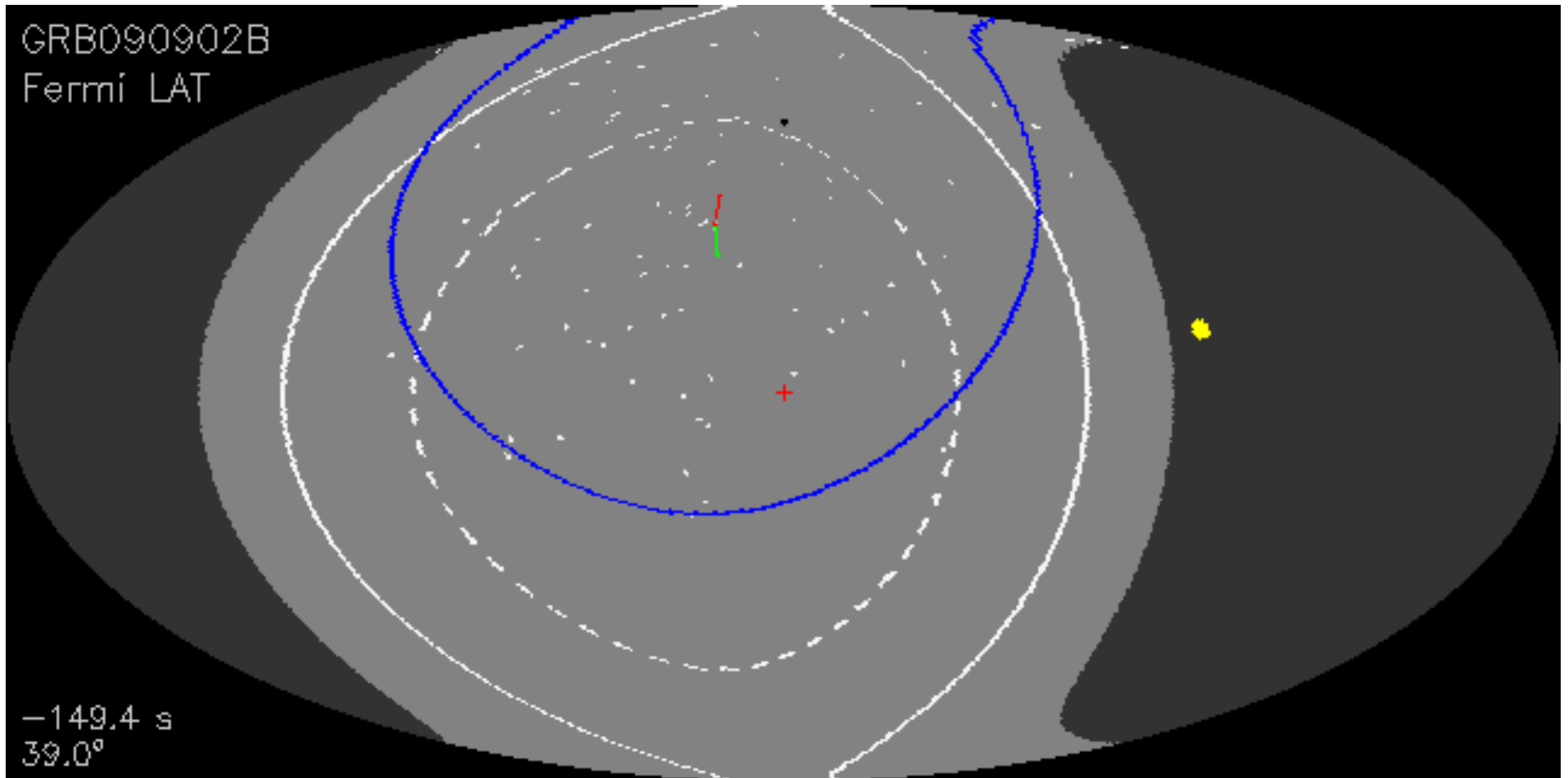
LAT exposure over
two orbits

00000 seconds

- 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.

GRB090902B - Autonomous repoint

- LAT pointing in celestial coordinates from -120 s to 2000 s
 - Dark region = occulted by Earth ($\theta_z > 113^\circ$)
 - Blue line = LAT FoV ($\pm 66^\circ$), 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.
 - 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)**
 - **Duration reduced to 2.5 hours (from 5 hours)**
- **5 Target of Opportunity Observations**
 - **3C 454.3**
 - **Crab Nebula flare (Sept 2010 and April 2011)**
 - **Cygnus X-3**
 - **Galactic Center**
 - **Sun**
- **2 modified survey mode observation**
 - **Two orbits south, 1 orbit north to enhance coverage during PSR B1259 periastron**
 - **Stay rocked south for 3 days to enhance observations of sun during solar activity**
- **LAT Calibrations**
 - **~<12 hours/year**

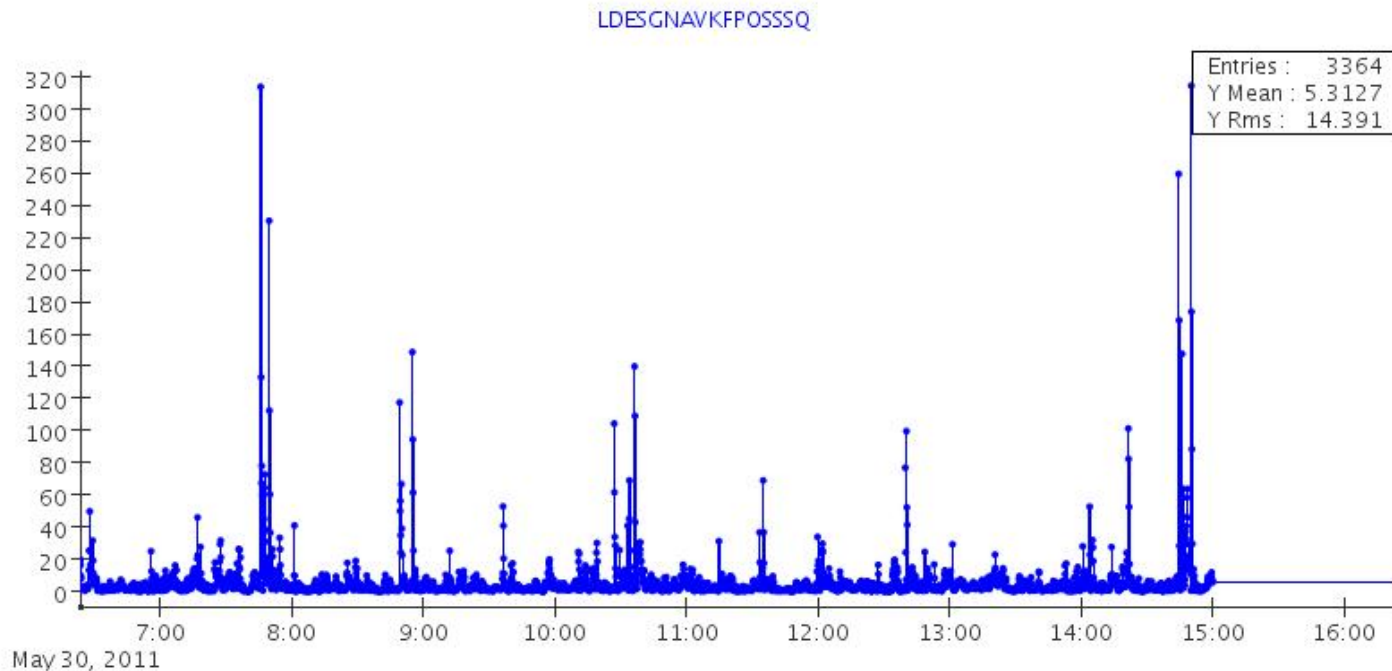


Where are we pointing (1)

- **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**

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





Spacecraft files (aka FT2 files)

- **These combine the orbit position and attitude information from the spacecraft.**
 - **Entries spaced every 30 s**

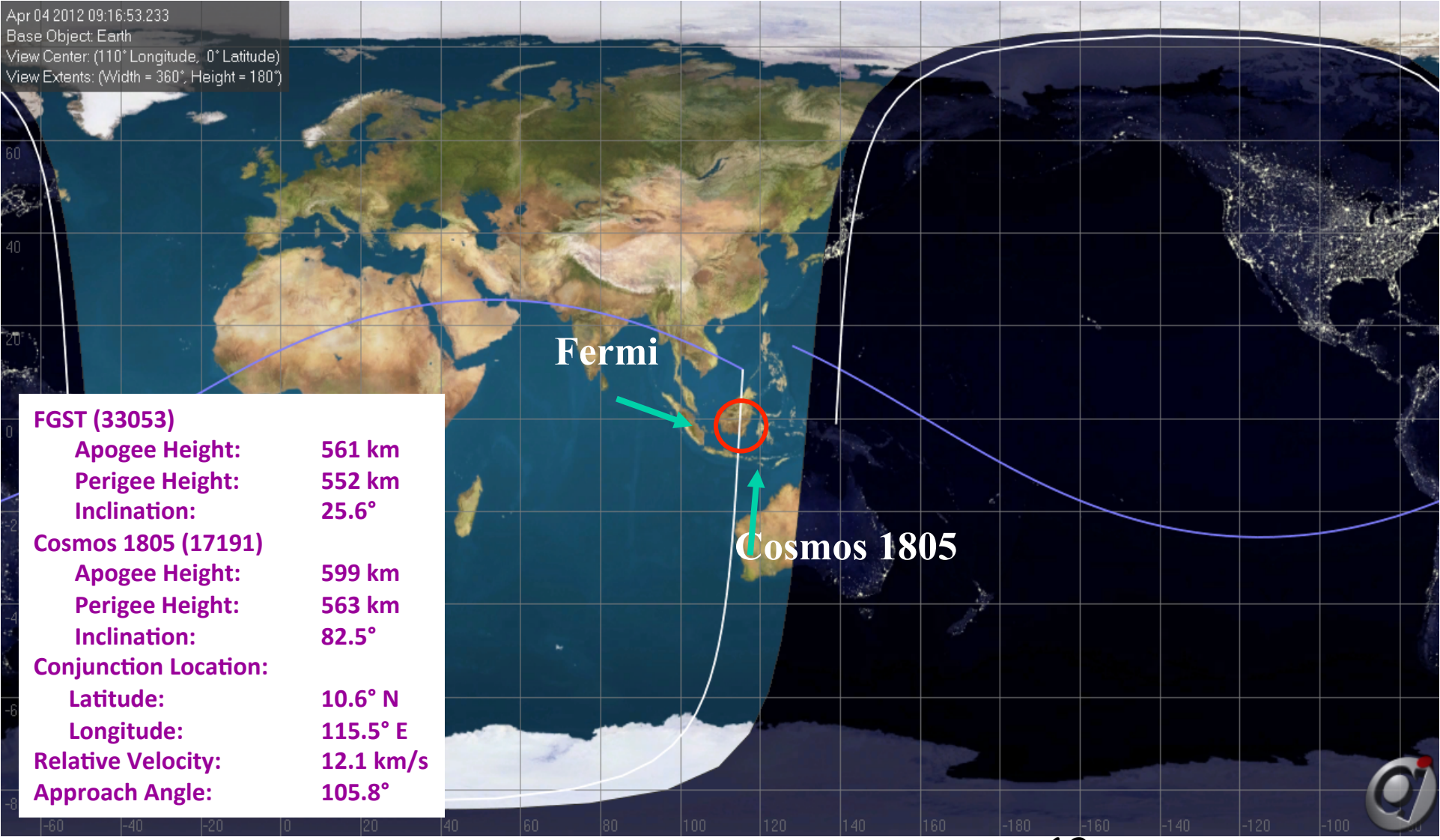


Absolute timing and orbit location

- **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 $\sim <20$ m**
- **Both of these are important when considering very short timescales**
 - **Millisecond pulsars!**

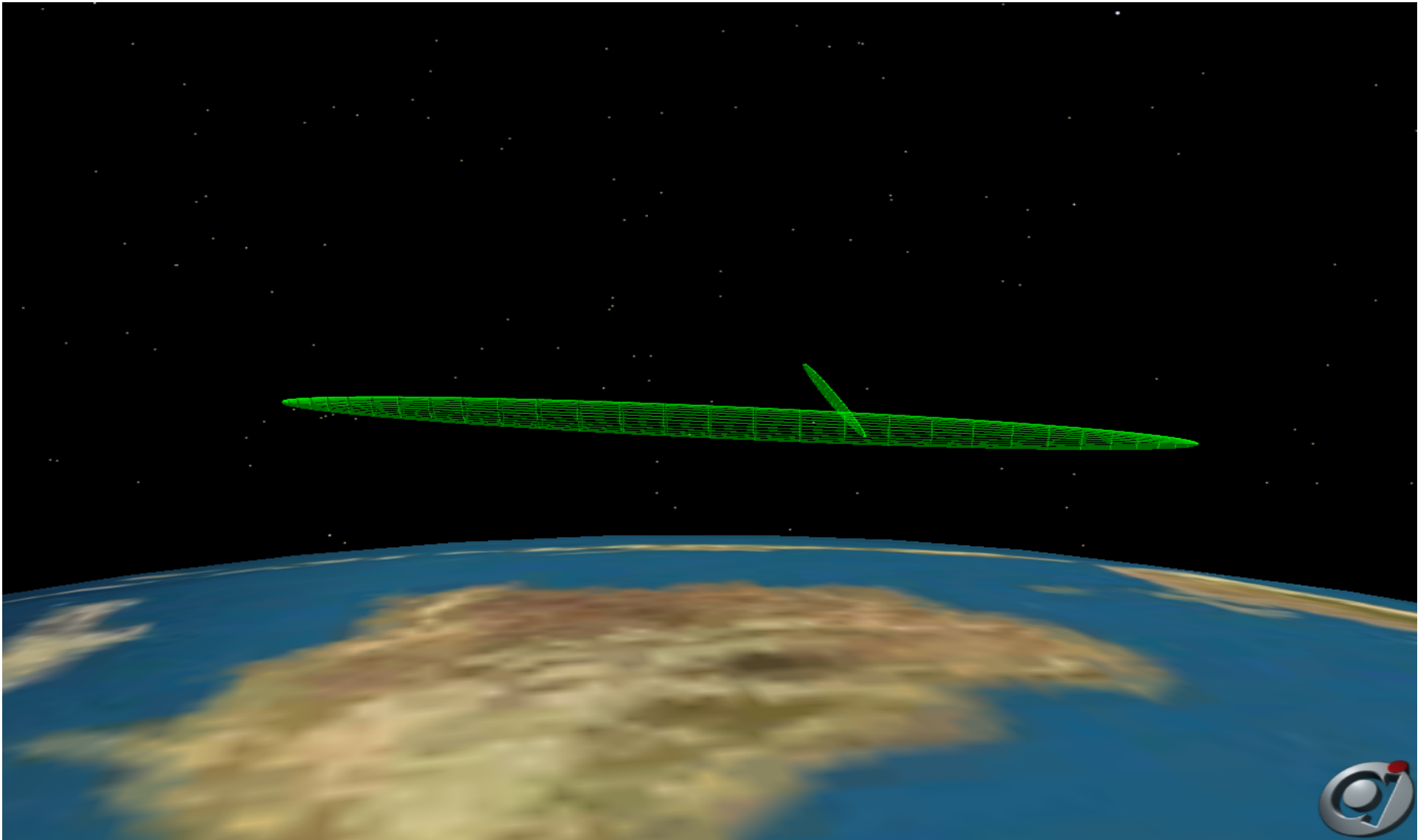
Last Month...

Apr 04 2012 09:16:53.233
Base Object: Earth
View Center: (110° Longitude, 0° Latitude)
View Extents: (Width = 360°, Height = 180°)



FGST (33053)	
Apogee Height:	561 km
Perigee Height:	552 km
Inclination:	25.6°
Cosmos 1805 (17191)	
Apogee Height:	599 km
Perigee Height:	563 km
Inclination:	82.5°
Conjunction Location:	
Latitude:	10.6° N
Longitude:	115.5° E
Relative Velocity:	12.1 km/s
Approach Angle:	105.8°

We moved out of the way





Fermi Science Support Center

 **GODDARD SPACE FLIGHT CENTER**

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+ [GSFC Homepage](#)
+ [Fermi Homepage](#)

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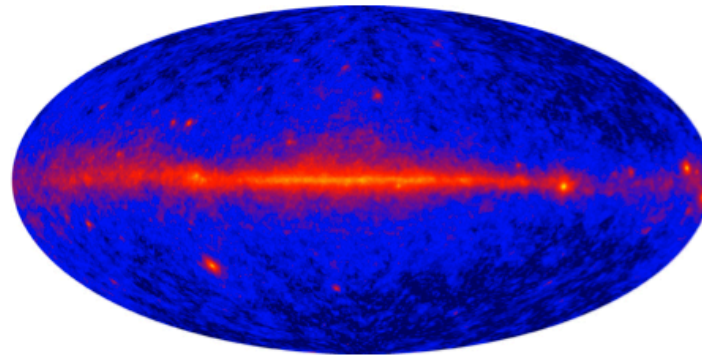
The Fermi Science Support Center (FSSC) runs the guest investigator program, creates and maintains the mission time line, provides analysis tools for the scientific community, and archives and serves the Fermi data. This web site is the portal to Fermi for all guest investigators.

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](#)



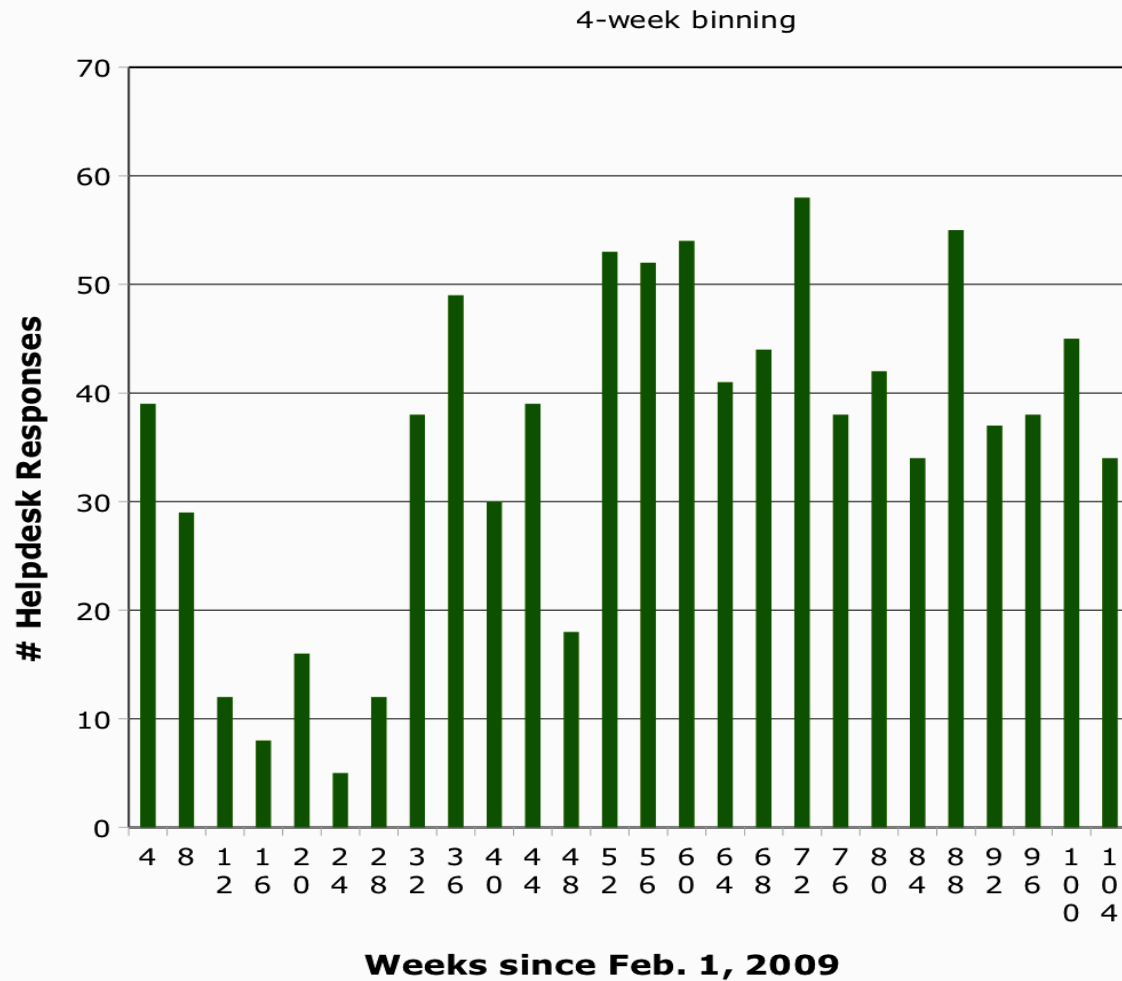
This all-sky view from Fermi reveals bright emission in the plane of the Milky Way (center), bright pulsars and super-massive black holes.
Credit: NASA/DOE/International LAT Team

Public data and extensive support for science Analysis Tools

<http://fermi.gsfc.nasa.gov/ssc/>

FSSC Supports Guest Investigator Analysis

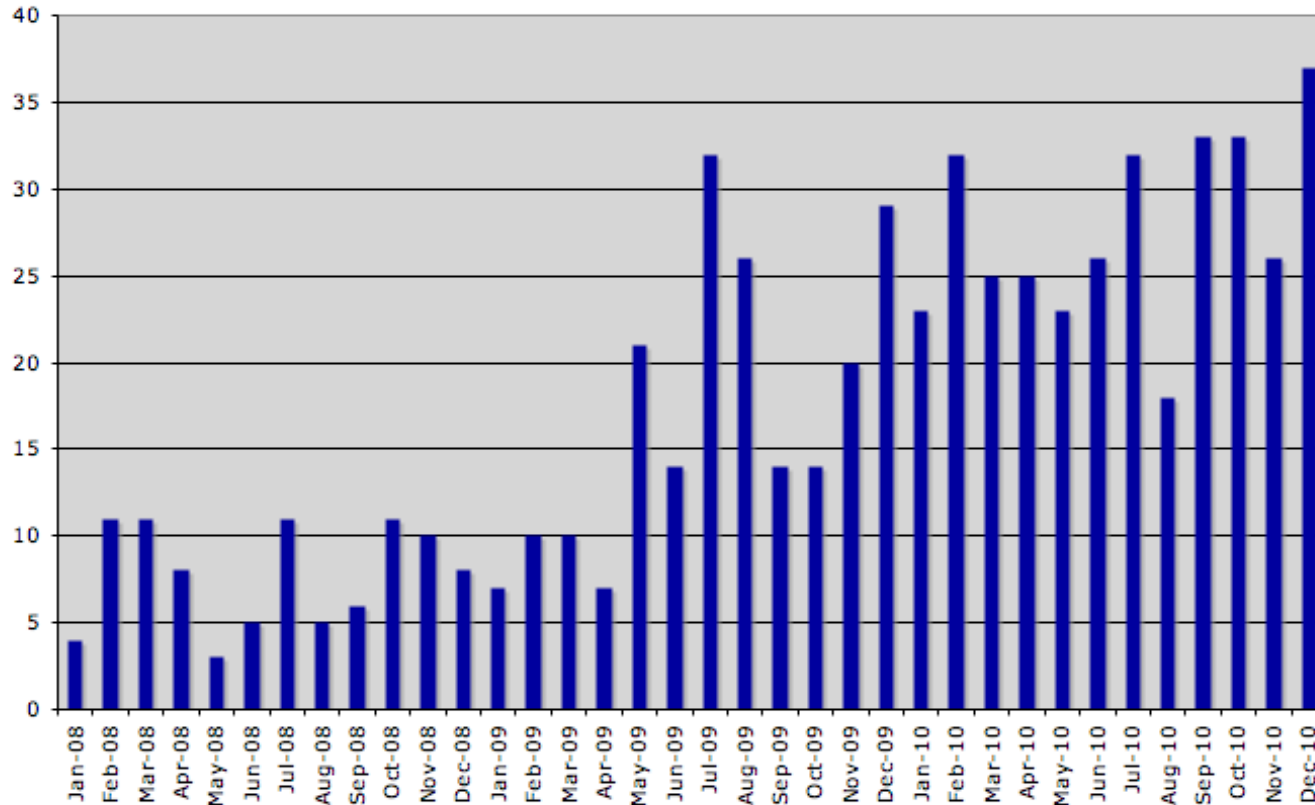
Queries to FSSC Helpdesk





Published Refereed Papers

Fermi Publications



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



Questions?
