Gamma-ray Sky Observed with Fermi Large Area Telescope

RESCEU Symposium on Astroparticle Physics and Cosmology

Hongo Campus, University of Tokyo
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(SLAC/KIPAC Stanford University)

On behalf of the Fermi-Large Area Telescope Collaboration

Fermi LAT Collaboration

United States
- California State University at Sonoma
- University of California at Santa Cruz - Santa Cruz Institute of Particle Physics
- Goddard Space Flight Center – Laboratory for High Energy Astrophysics
- Naval Research Laboratory
- Ohio State University
- Stanford University (SLAC and HEPL/Physics)
- University of Washington
- Washington University, St. Louis

France
- IN2P3, CEA/Saclay

Italy
- INFN, ASI

Japanese GLAST Collaboration
- Hiroshima University
- Tokyo Inst of Technology
- ISAS/JAXA, RIKEN

Spain
- ICREA and Inst de Ciencies de l'Espi

Swedish GLAST Collaboration
- Kalmar University
- Royal Institute of Technology (KTH)
- Stockholm University

PI: Peter Michelson (Stanford U.)

Mission Scientist: Steve Ritz (NASA-GSFC)

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112 Collaboration Members and

~90 Affiliated, 37 Postdocs, 48 Grad. Students

Instr. Science Operation Center

SLAC National Accelerator Lab.

Mission Operation Center

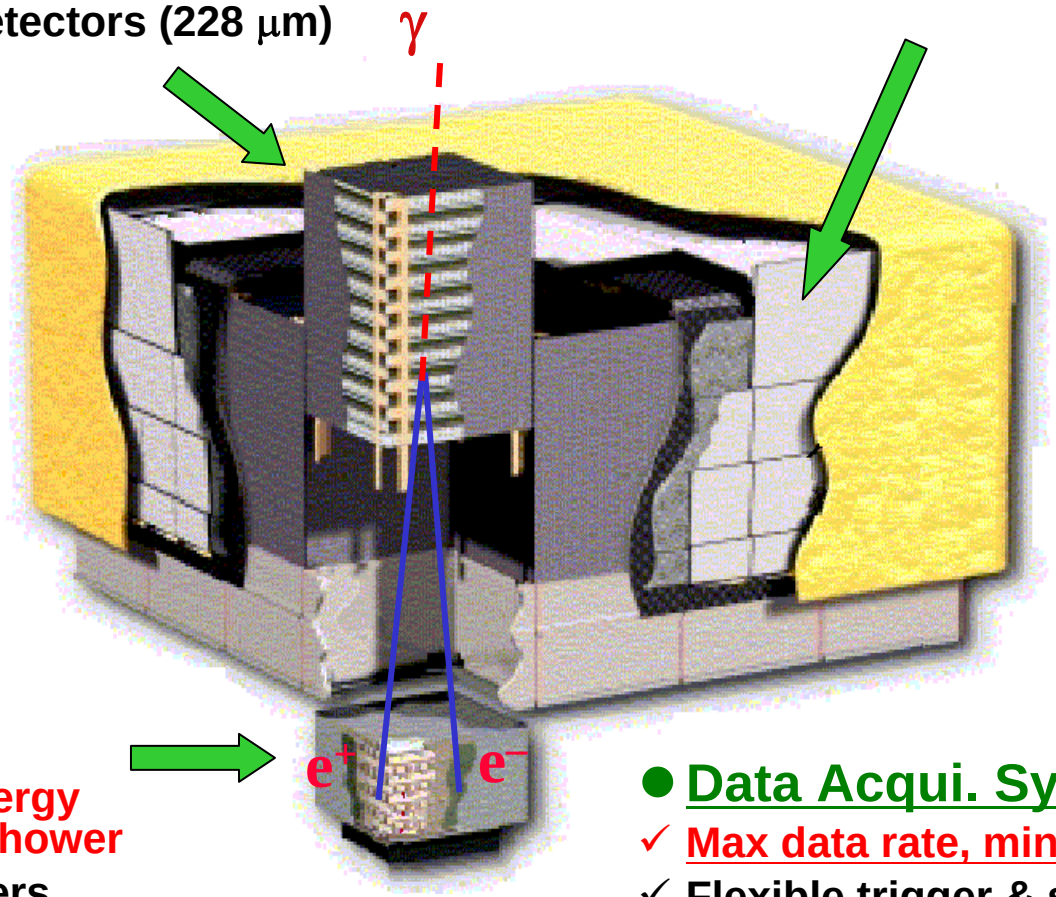
Goddard Space Flight Center

Fermi Science Support Center

Goddard Space Flight Center

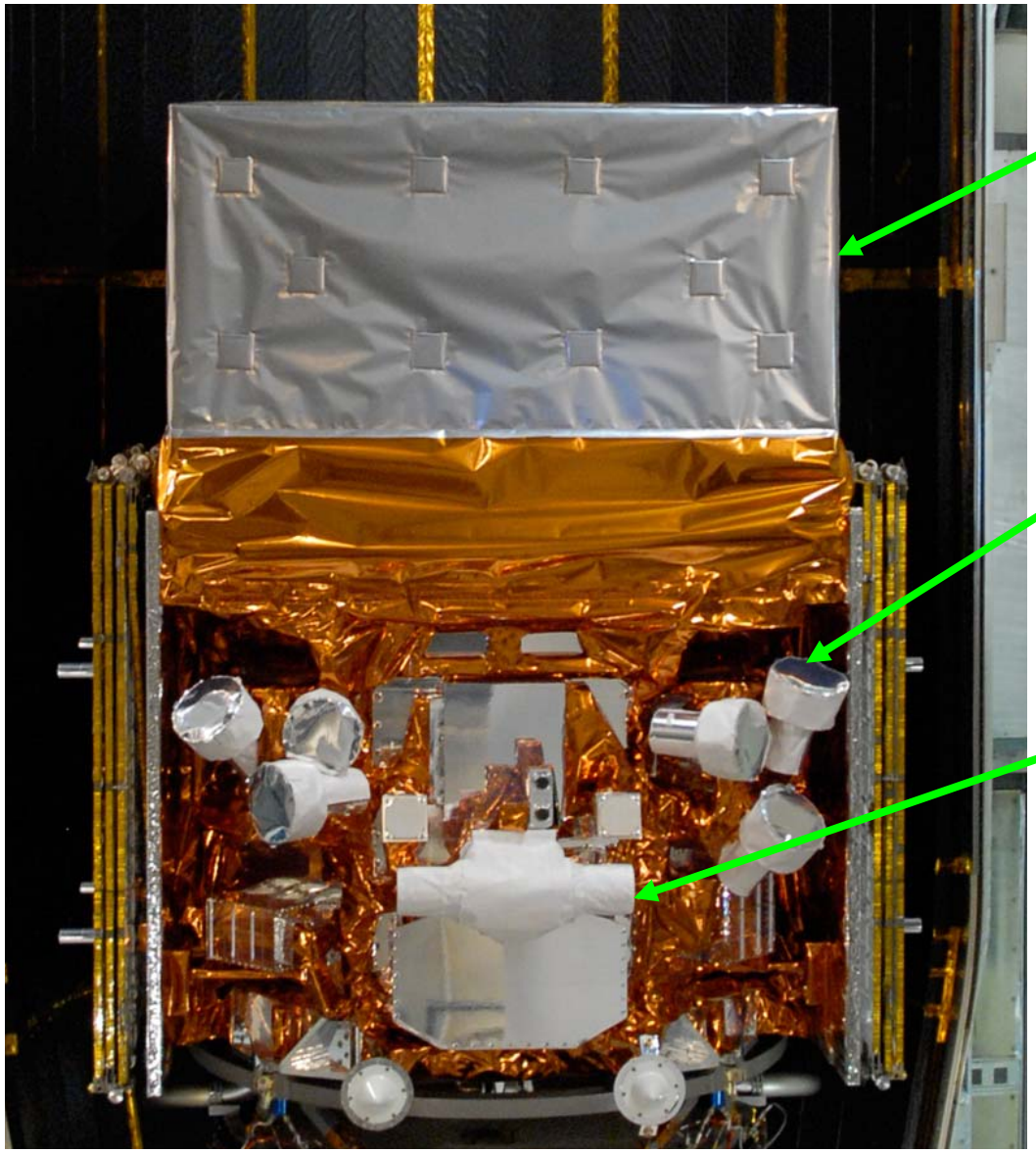
Large Area Telescope

- **Silicon Strip Tracker (TKR)**
  - ✓ Measure the photon direction
  - ✓ Identification of the gamma-ray shower
  - ✓ 36 planes of Si strip detectors (228 μm)
- **Anticoinc Detector (ACD)**
  - ✓ Reject charged cosmic rays
  - ✓ Plastic scintillator tiles and ribbons



- **Calorimeter(CAL)**
  - ✓ Measure the photon energy
  - ✓ Image the gamma-ray shower
  - ✓ CsI(Tl) crystals in 8 layers.
- **Data Acqui. System**
  - ✓ Max data rate, min dead time
  - ✓ Flexible trigger & software filters.

Fermi Observatory

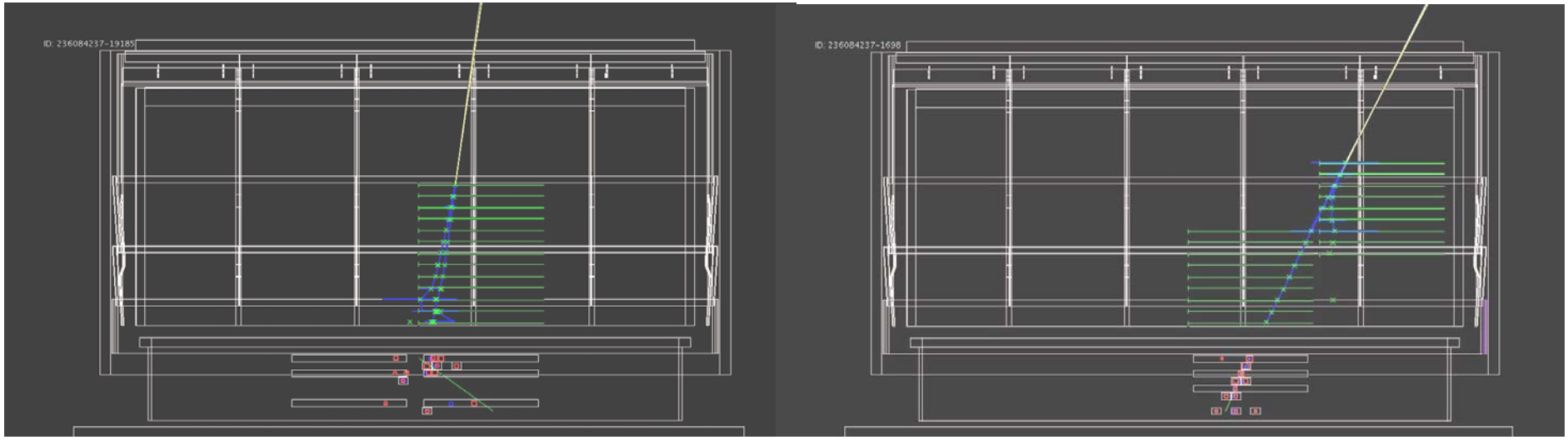


Large Area Telescope (LAT)

GBM
NaI Detector

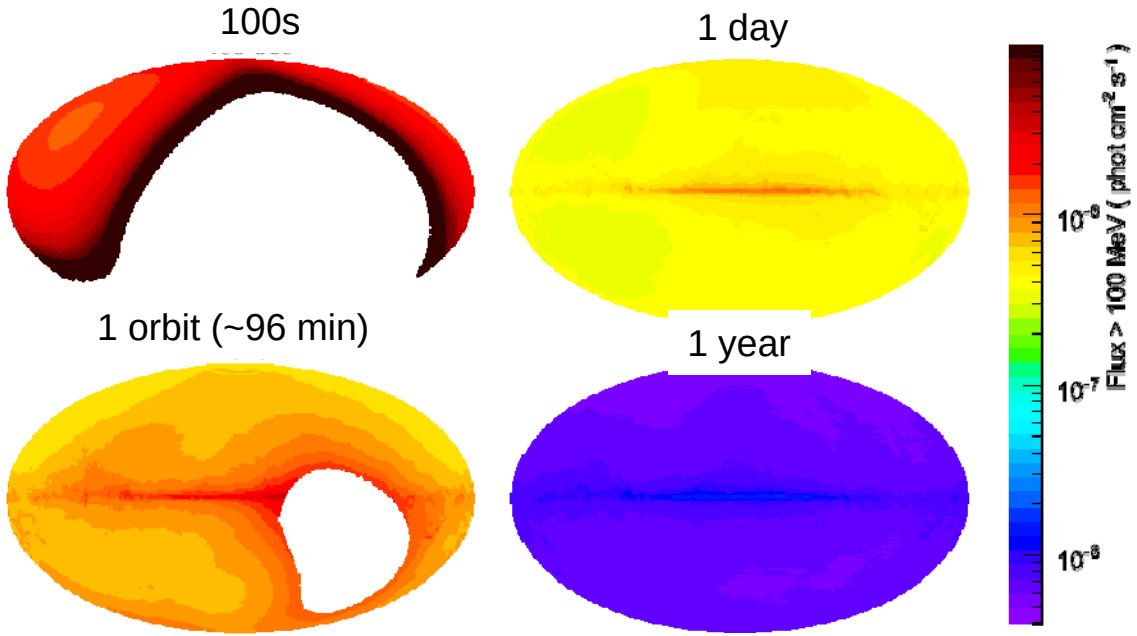
GBM
BGO Detector

Event Reconstruction on Ground



- **Pulse heights** at all TKR Si strips, CAL CsI logs and ACD tiles/ribbons with signals are recorded with **time stamps (dt~25us).**
- Candidate gamma-ray events are **reconstructed on ground** (see Figs).
- Charged particle cosmic-ray events are also sampled and recorded for monitoring and calibration purpose.

Sky Coverage per Orbit, Day and Year



LAT sensitivity in

100 s

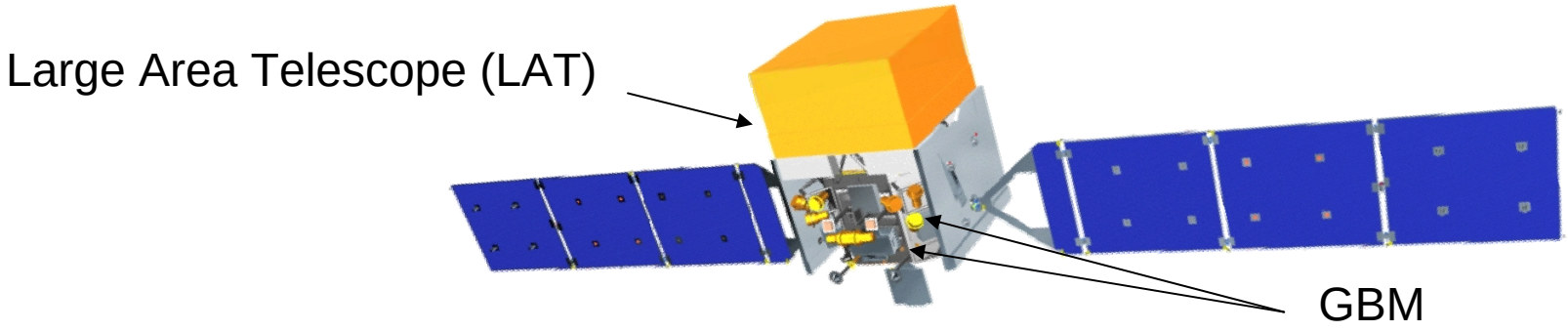
1 orbit (96 minutes),

1 day

1 year

- **In the nominal survey mode, the LAT observes the entire sky every two orbits (~3 hours).**
- **Each point on the sky accrues ~30 minutes exposure in two orbits.**
- **Can also perform pointed observations of particularly interesting regions of the sky.**

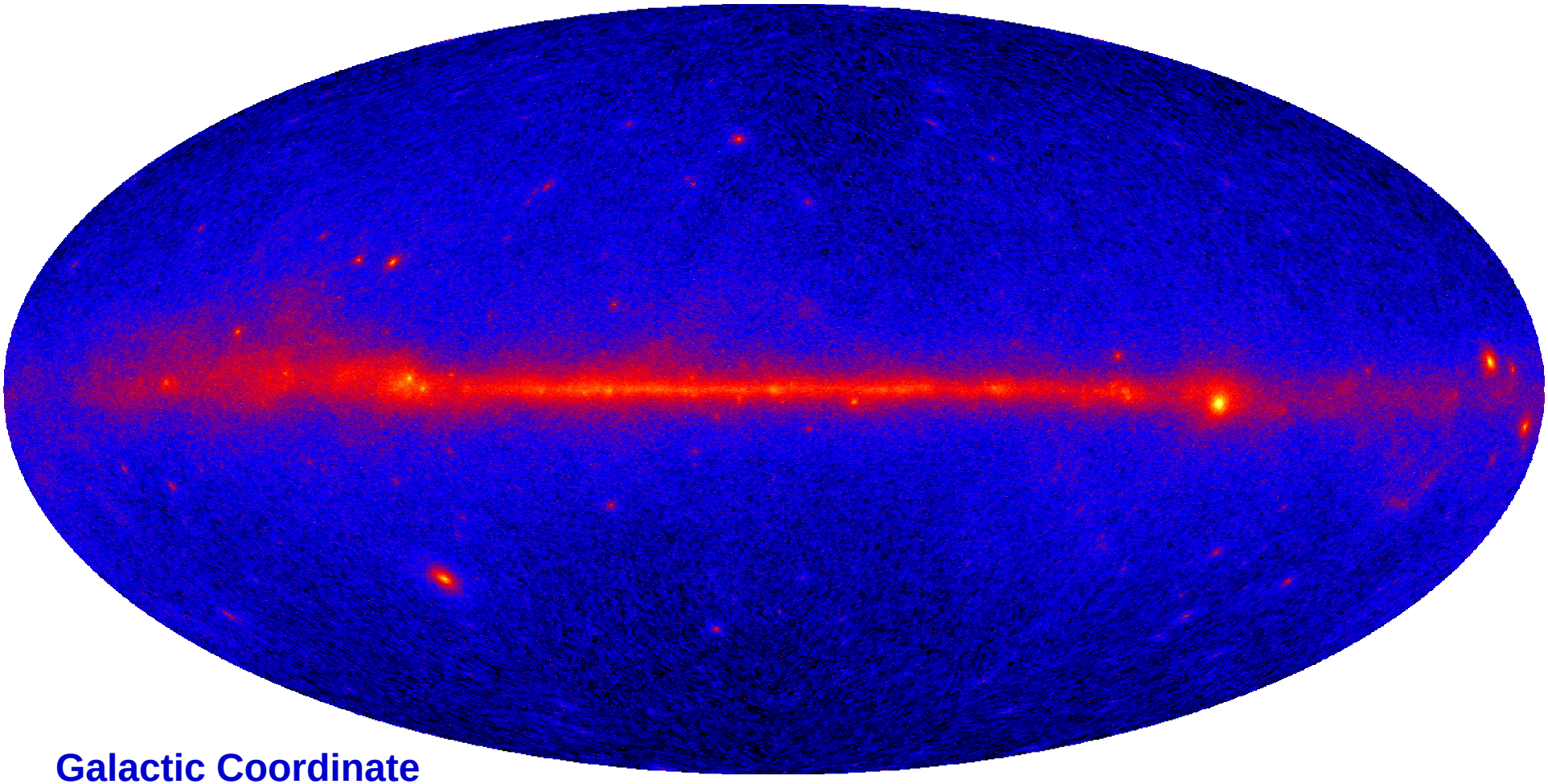
Fermi-LAT Key Features



- **Broad energy band: 20 MeV - 300 GeV**
- **Uniform exposure over the entire sky**:
  - combination of the large field-of-view (2.2-2.5sr)
  - rocking of the telescope axis (+/- 35 deg)
- **Wide coverage of temporal structure:**
  - state-of-art Data Acquisition system and
  - continuous survey operation
  - **sub-ms to ~1yr variability can be studied**
- **"Minimum-biased" data-set taken**
  - TDRSS downlink allows 400-500Hz where as the signal rate is ~1 Hz

Sample Skymap (23 days of data)

After a few days of data processing, we get a sky map like this.



Galactic Coordinate

Science Results Are Coming Out

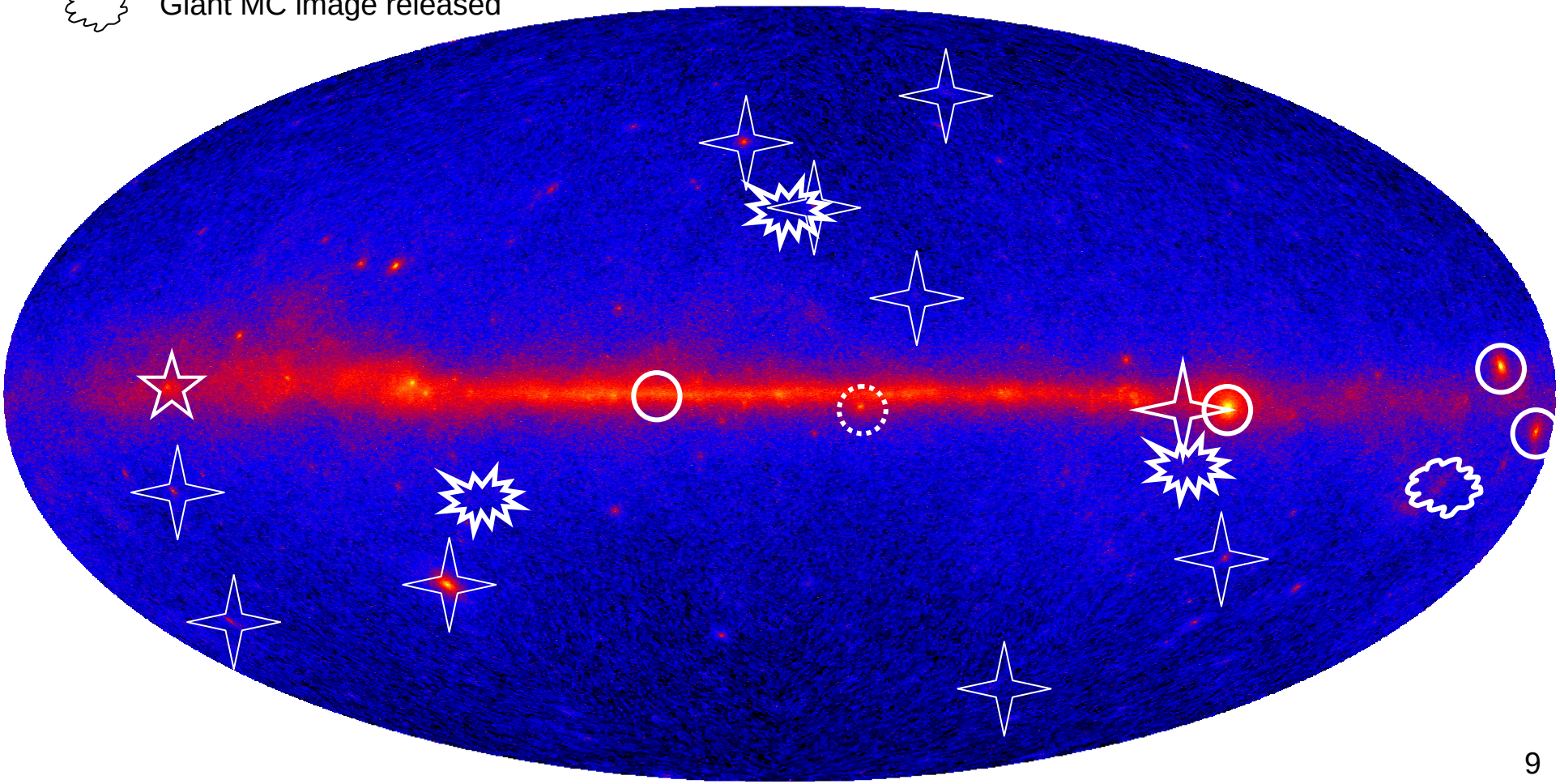
Pulse profile published or released

Glitch detection reported

Flare activity reported via ATel

Gamma Ray Bursts reported via GCN

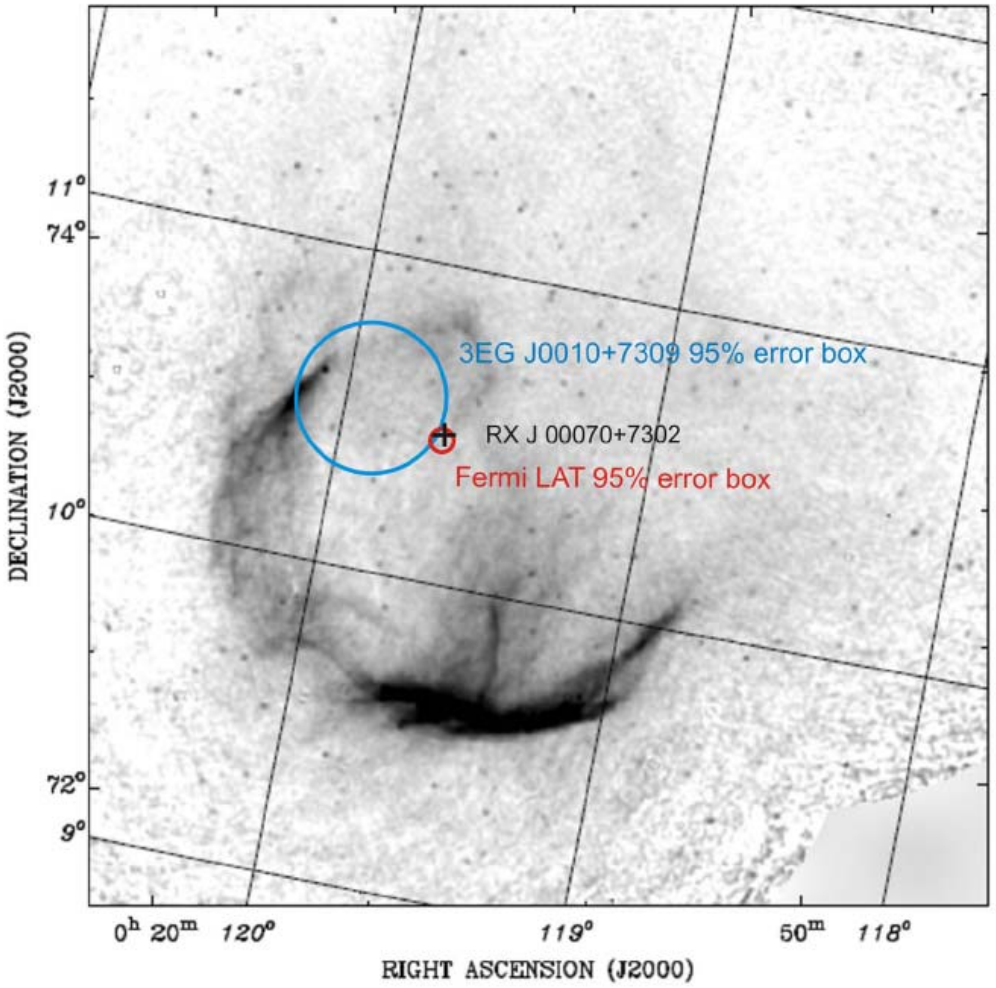
Giant MC image released

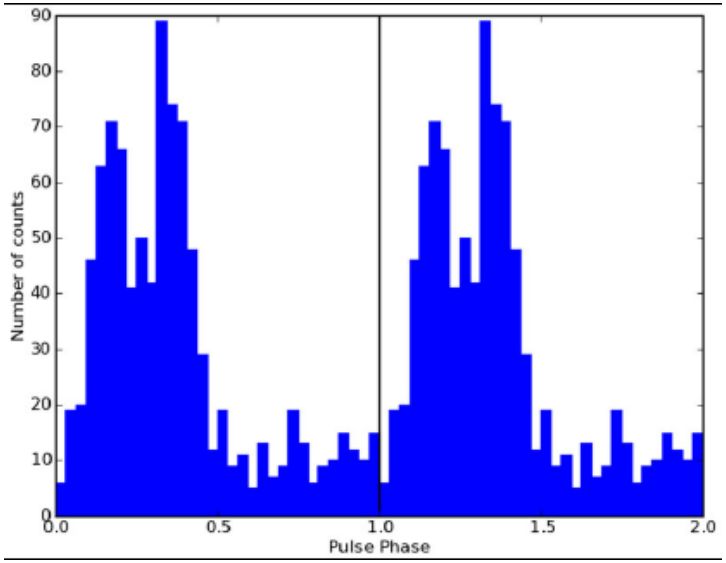


Publicly Released Results
as of
November 7, 2008

Discovery of γ-ray Pulsar in CTA-1

This is one of many radio quiet γ-ray pulsars yet to be discovered.





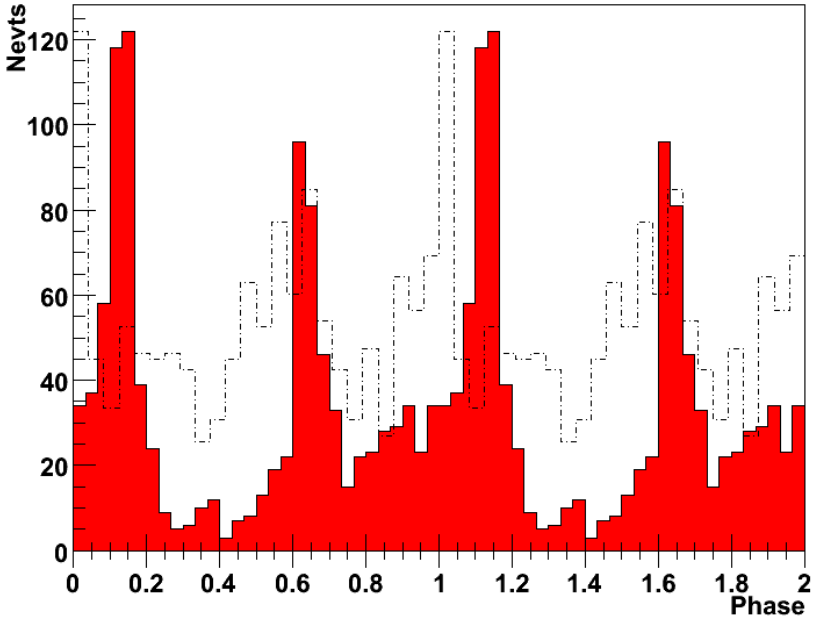
Period: 316.86ms
Period derivative:
3.614 x 10-13 s/s

Detailed Study on Known Pulsars

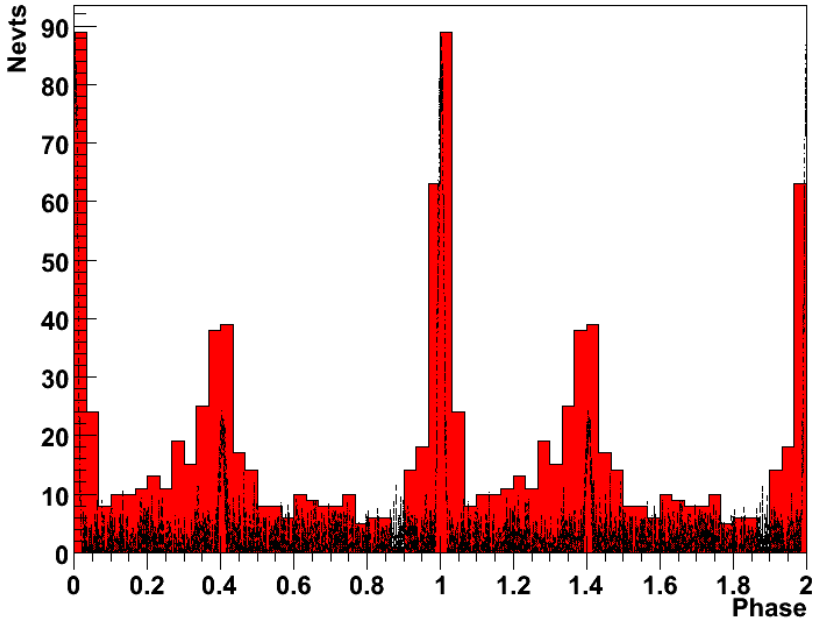
Fermi-LAT is expected:

- **To detect γ-rays from several millisecond pulsars.**
- **To make detailed analyses on the emission mechanism.**

Geminga: 16 days of data



Crab: 16 days of data

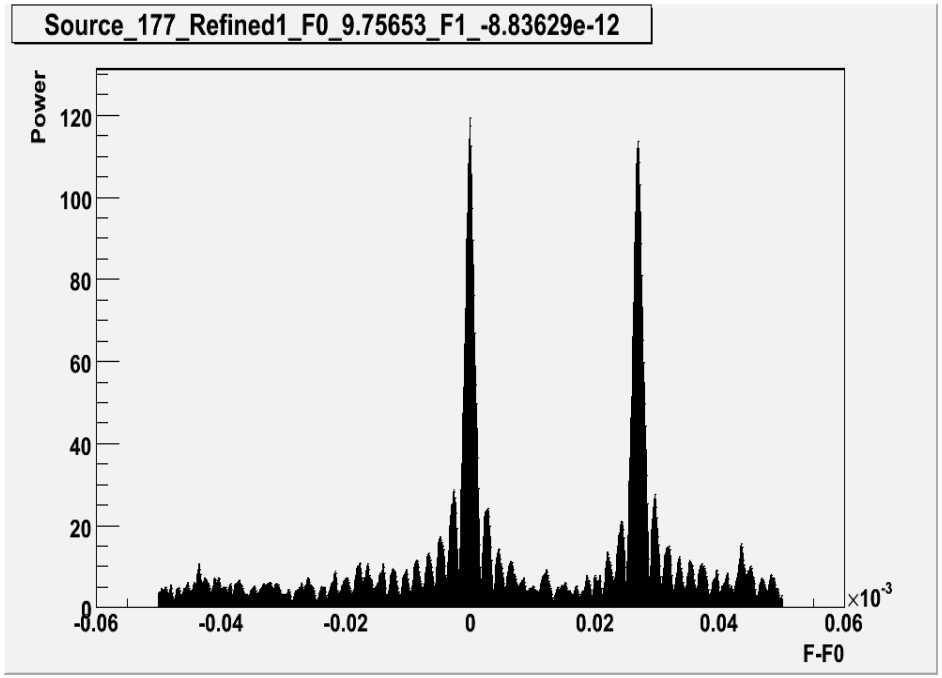


Long-Term Monitoring => New Possibilities

Discovery of A Glitch in PSR1706-44

Fermi-LAT will monitor:

- **Stability of known pulsars: Vela, Geminga, Crab, PSR1706-44 etc.**
- **To find timing glitches: Already found one in PSR1706-44**



A search around the known ephemeris has resulted in two highly significant peaks in the power spectrum.

Glitch occurred between 08:00 on 14 Aug and 06:00 on 15 Aug

This pulsar has been known to glitch (e.g. 1992, 1995).

GeV Gamma-Ray Bursts

GRB 080825C (the first detection with LAT):

Gammas up to 35 seconds (>5σ) 1.5 deg localization

GRB 080916C (a bright long burst in GeV):

Many γ's above 1 GeV. 0.13 deg localization

GRB081024B (a short "long" GRB with GeV emission):

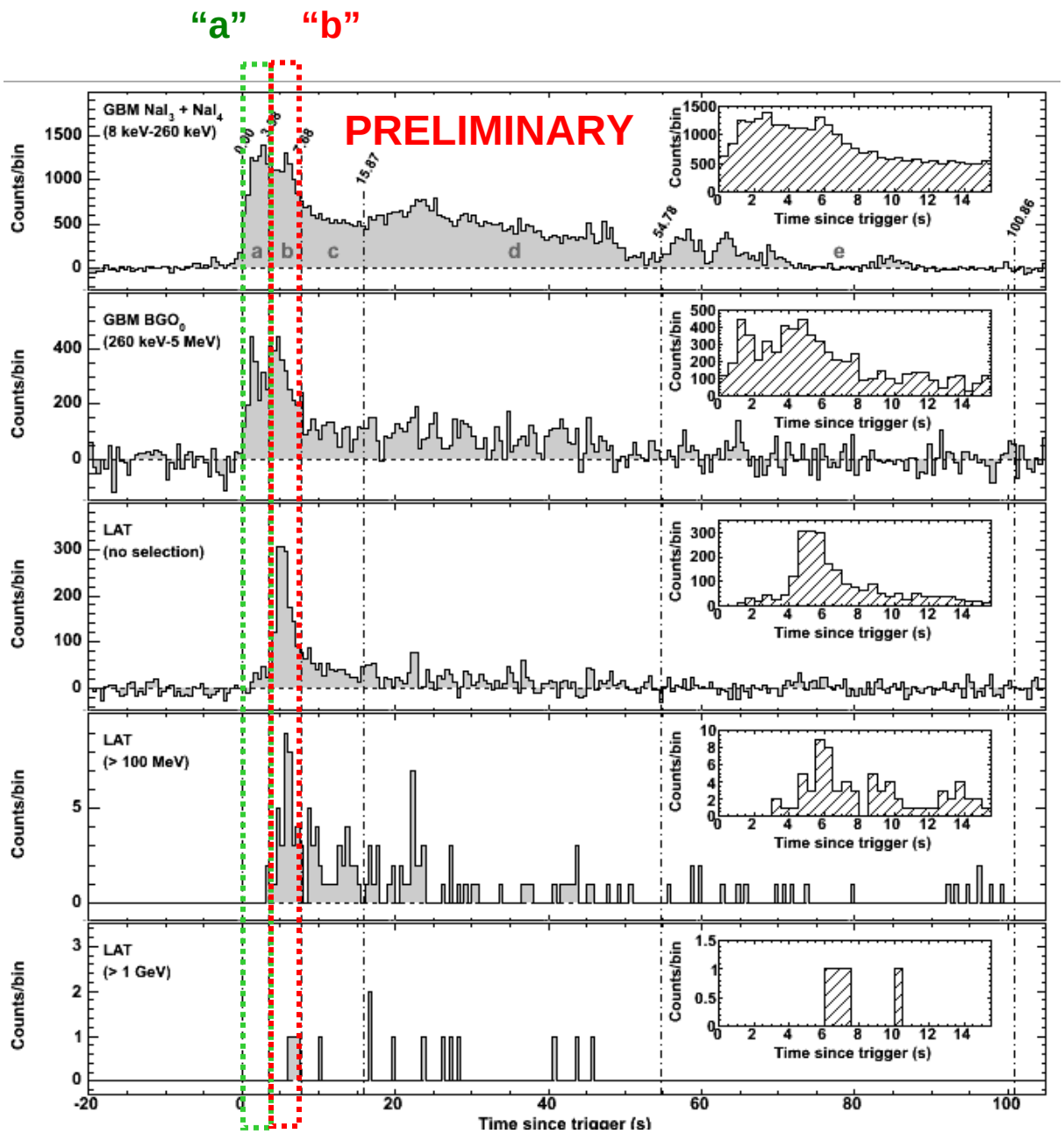
up to 3 GeV in the first 5 sec. 0.16 deg localization

Movie: click below

GRB080916CLR.mov

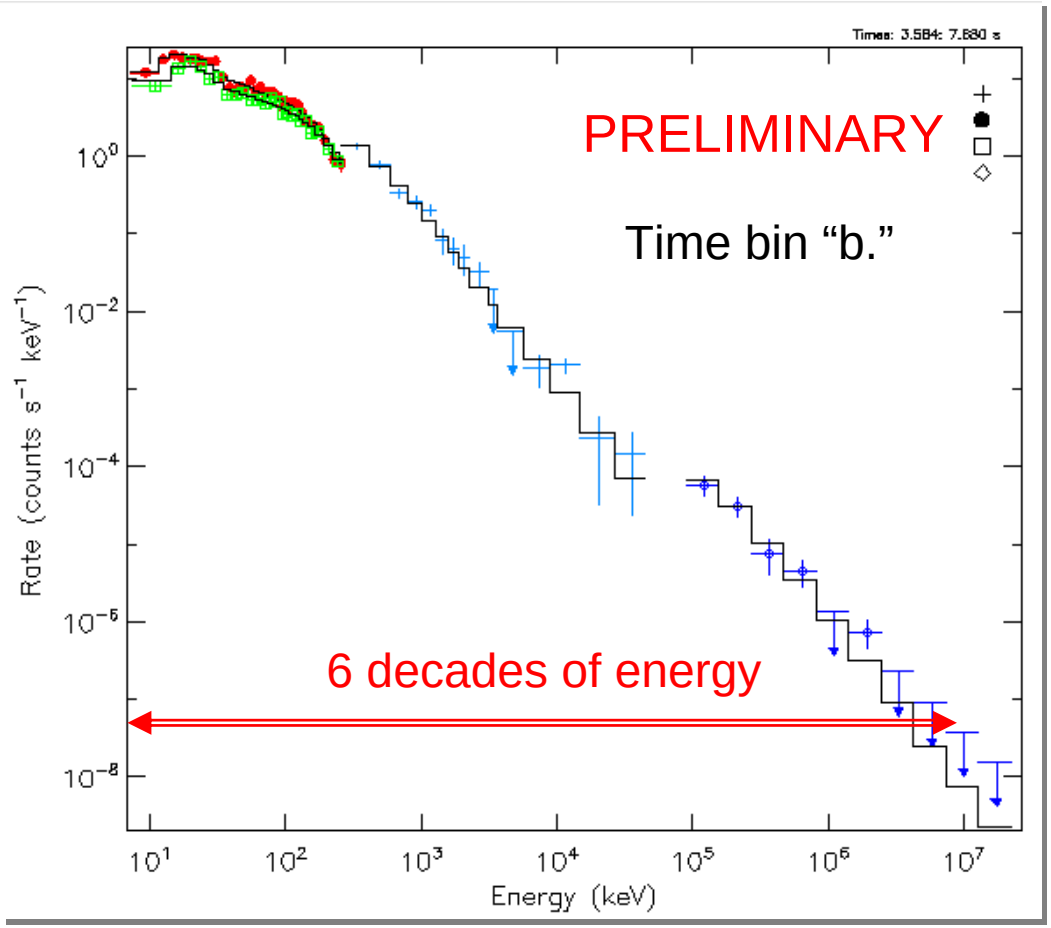
GRB 080916C
Light Curve

- **Feature in the LC:**
  - **Pulse in interval "a" disappear at LAT energies.**
- **Spectral evolution & time-lag?**
- **No z measurement.**
- **Stay tuned for a next GRB from LAT.**



Spectrum at the Main Peak "b"

- Fit the Band function from 10keV to 10 GeV
- No evidence of roll-off



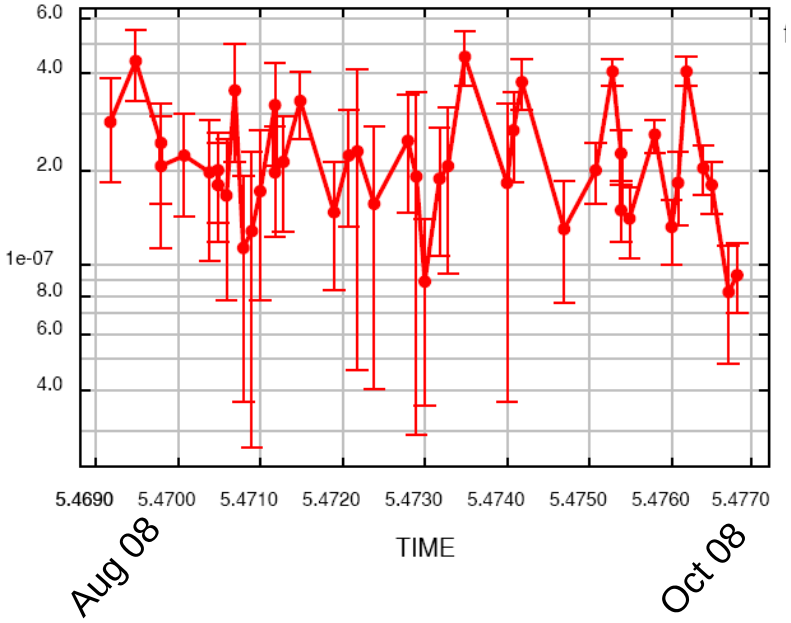
More info on the 3 GRBs can be found at http://fermi.gsfc.nasa.gov/ssc/data/access/

Active Galactic Nuclei

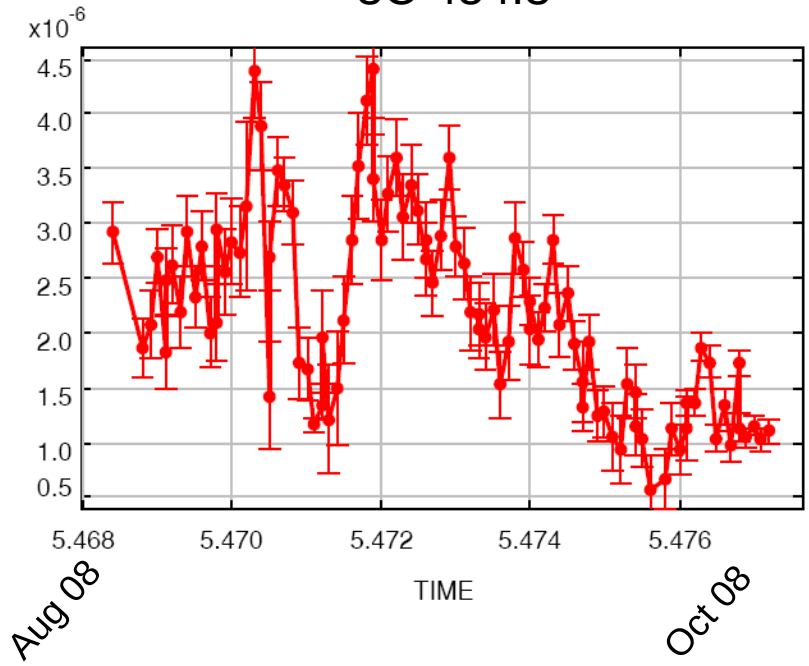
Fluxes from 22 AGNs posted at the Fermi SSC site

- You can monitor 22 AGNs and 1 Binary at Fermi Science Support Center. http://fermi.gsfc.nasa.gov/ssc/
- Sample data: Mrk 421 and 3C454.3 activity in the LAT energy from the url.

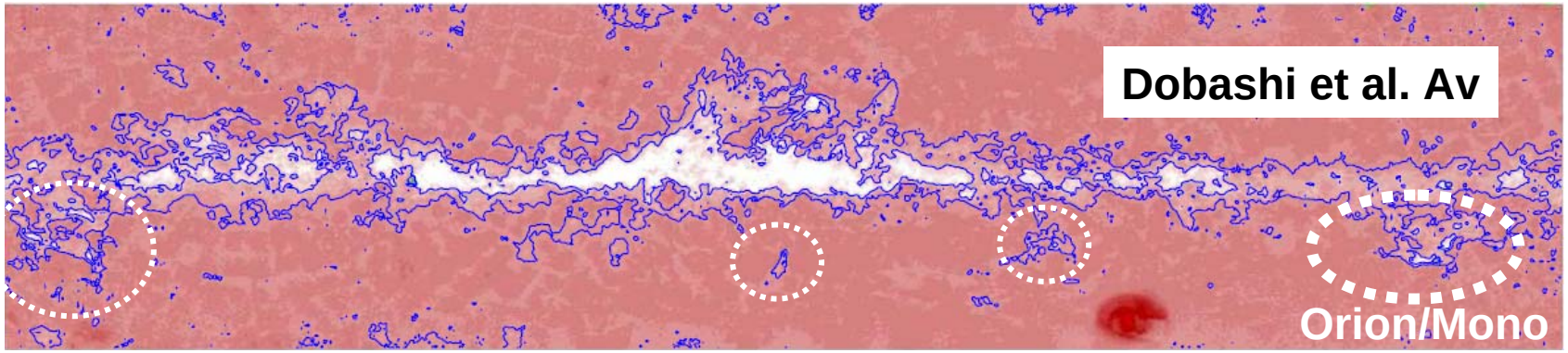
Mrk 421

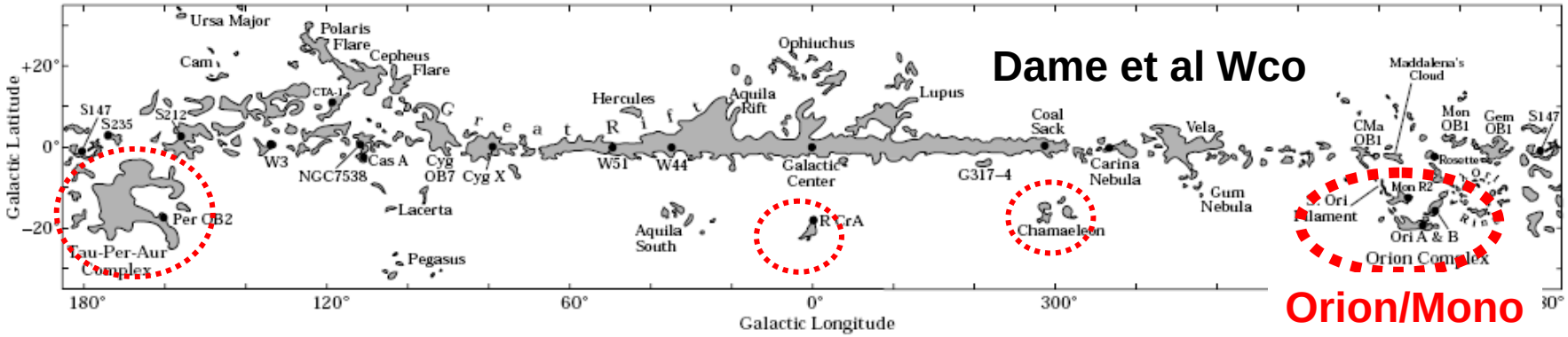


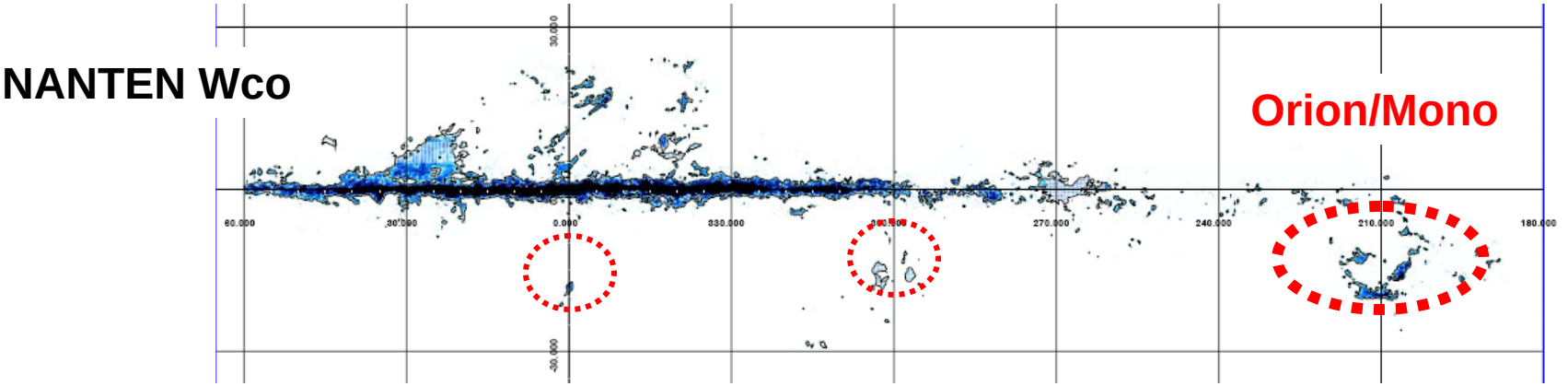
3C 454.3



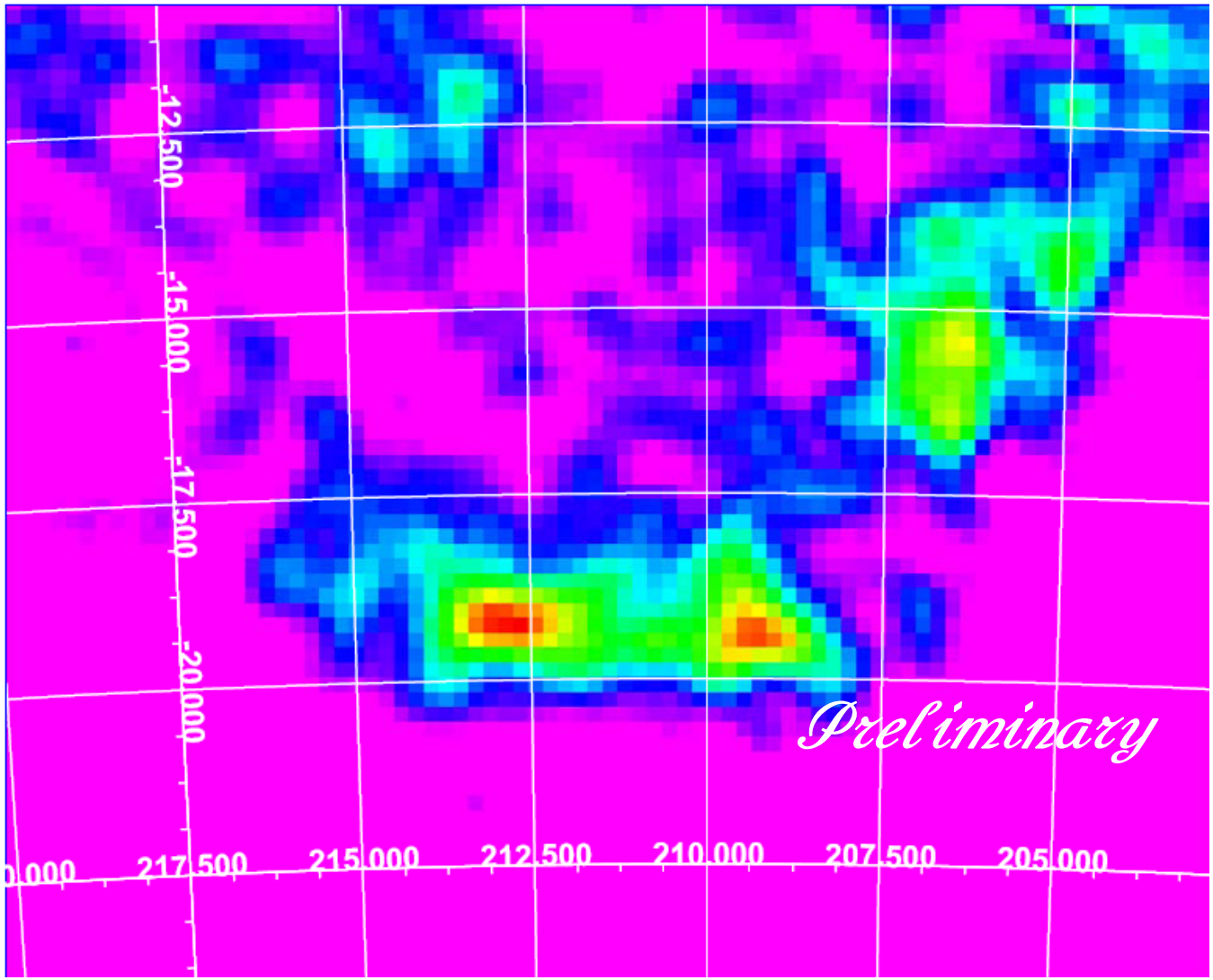
Interaction of Cosmic Rays with Clouds



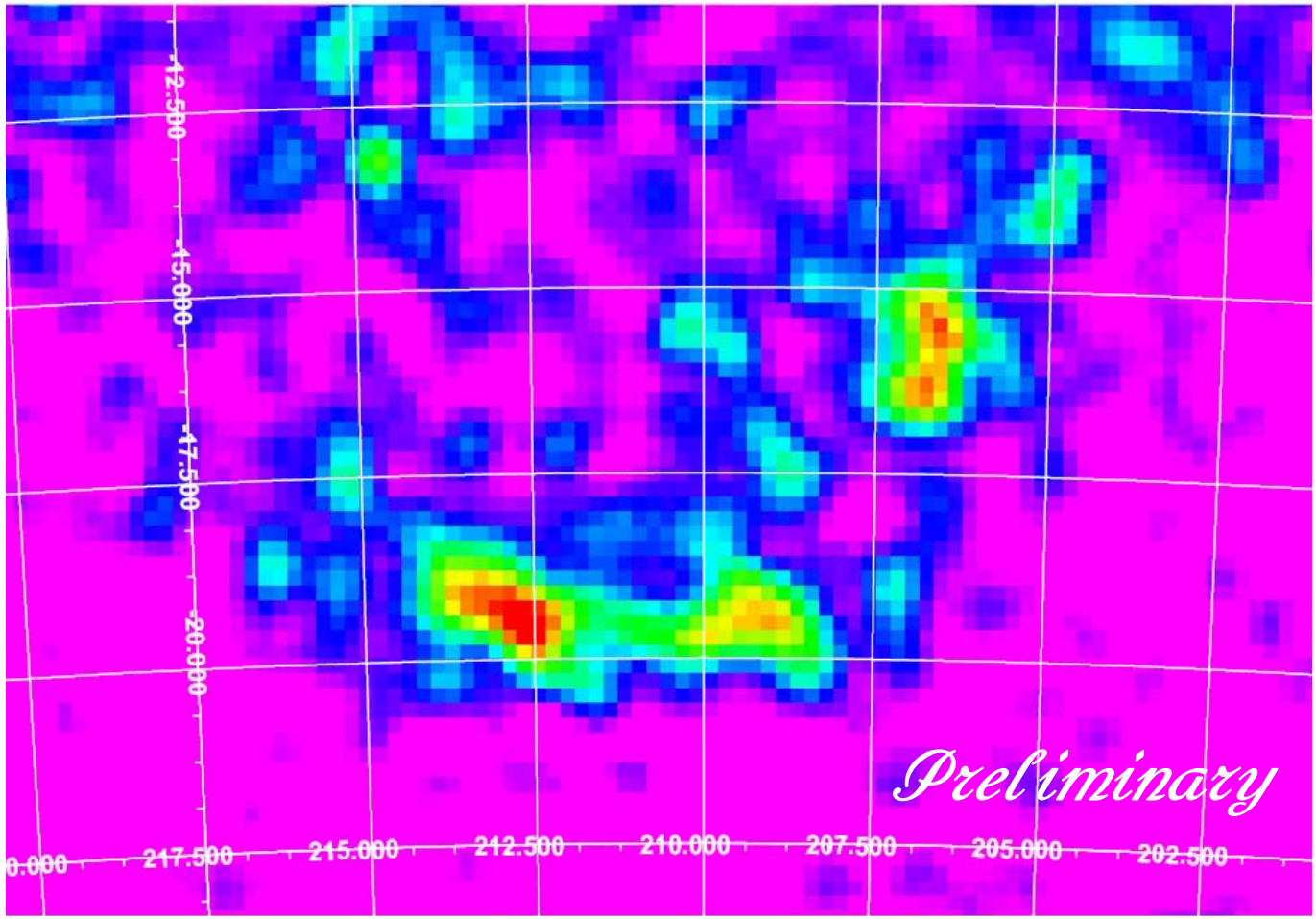




Orion Region: E > 100MeV

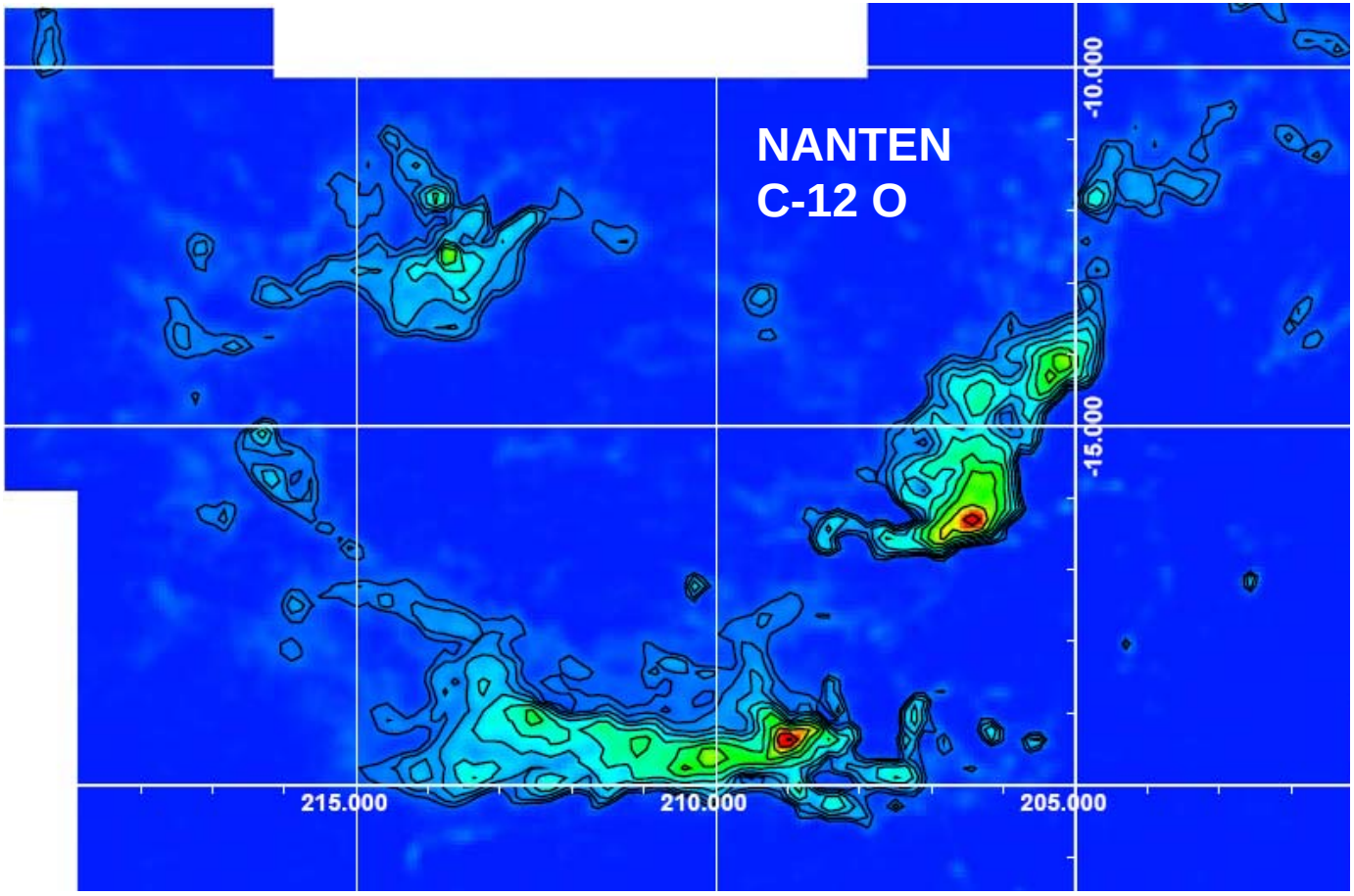


Orion Region: E>1GeV



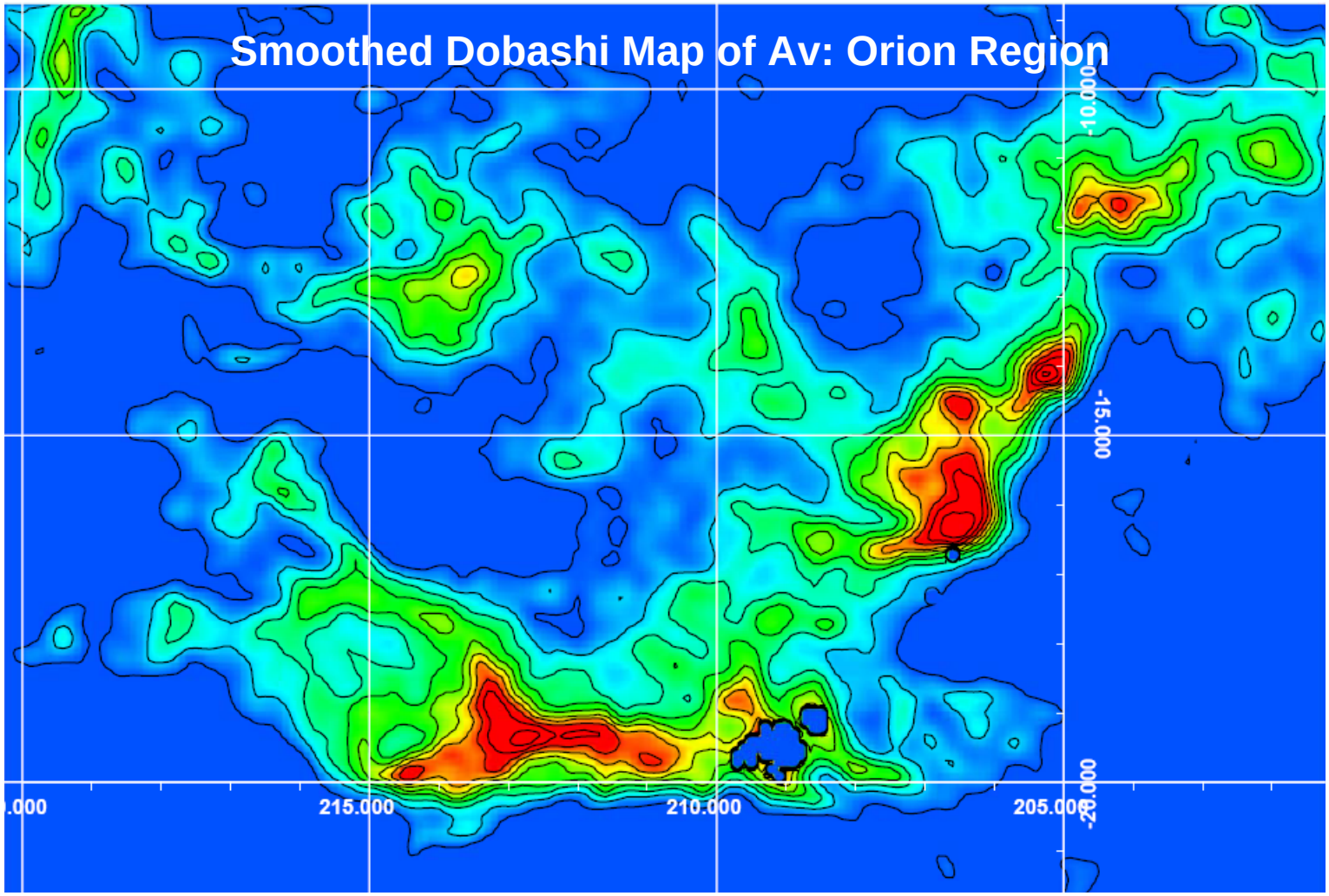
NANTEN has Observed Orion

in C-12 O, C-13 O and other mol. lines



Visual Attenuation Map by Dobashi et al.

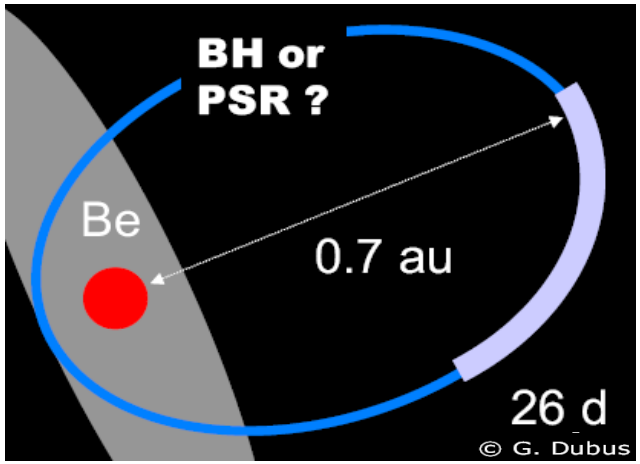
Arc-minute mapping of local clouds

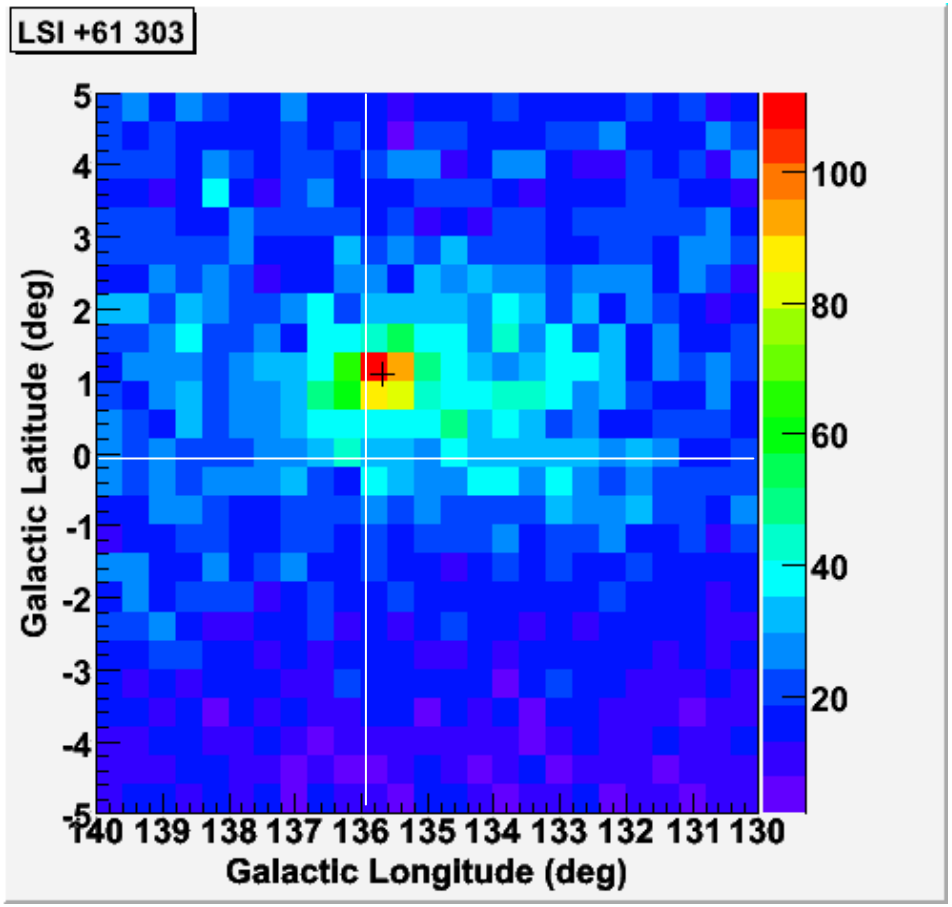


Binary Pulsars and Micro-quasars

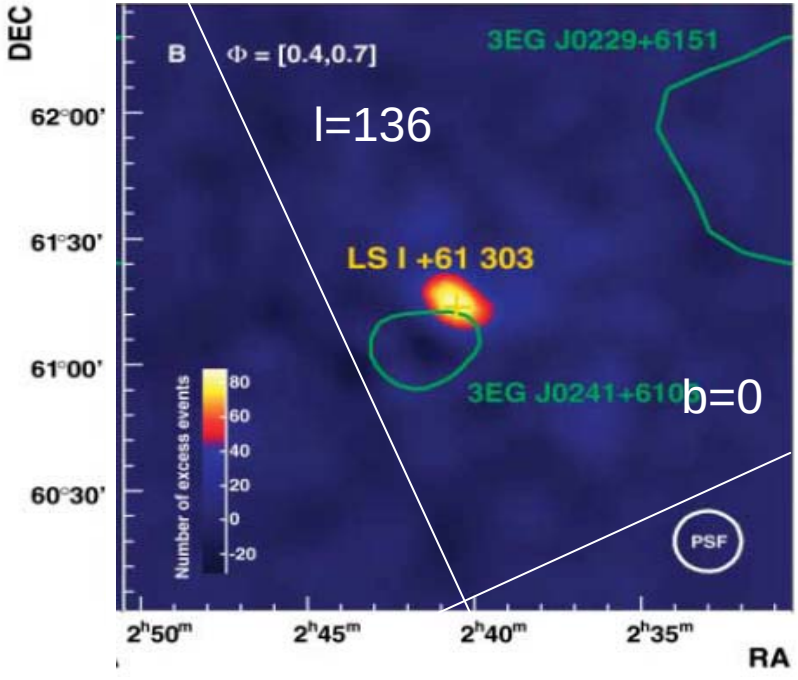
LSI +61 303

Several High-Mass X-ray Binaries will be detected.
Collaboration with Suzaku will be very important.



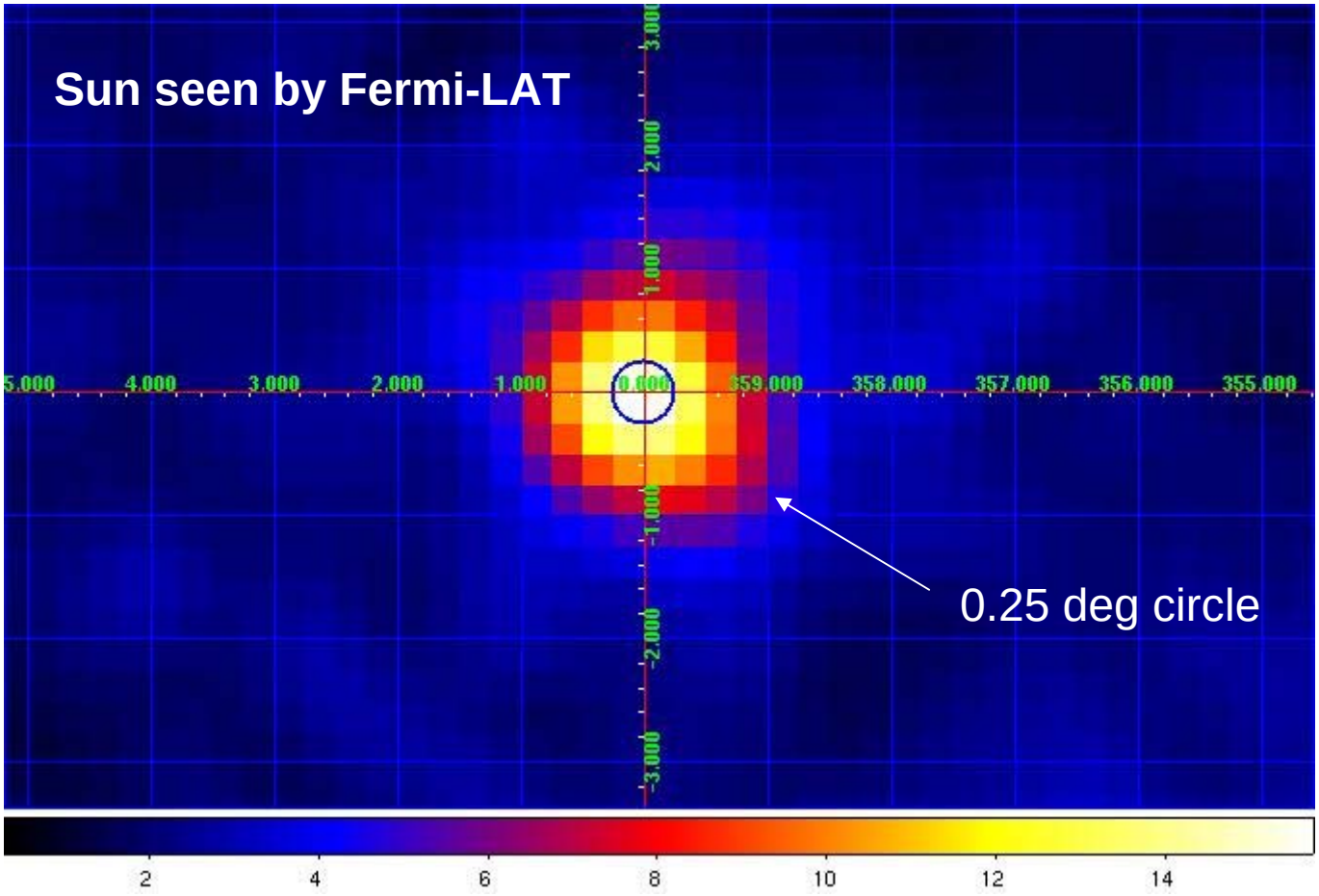


TeV Emission detected by HESS



Lots of Solar Physics to Come

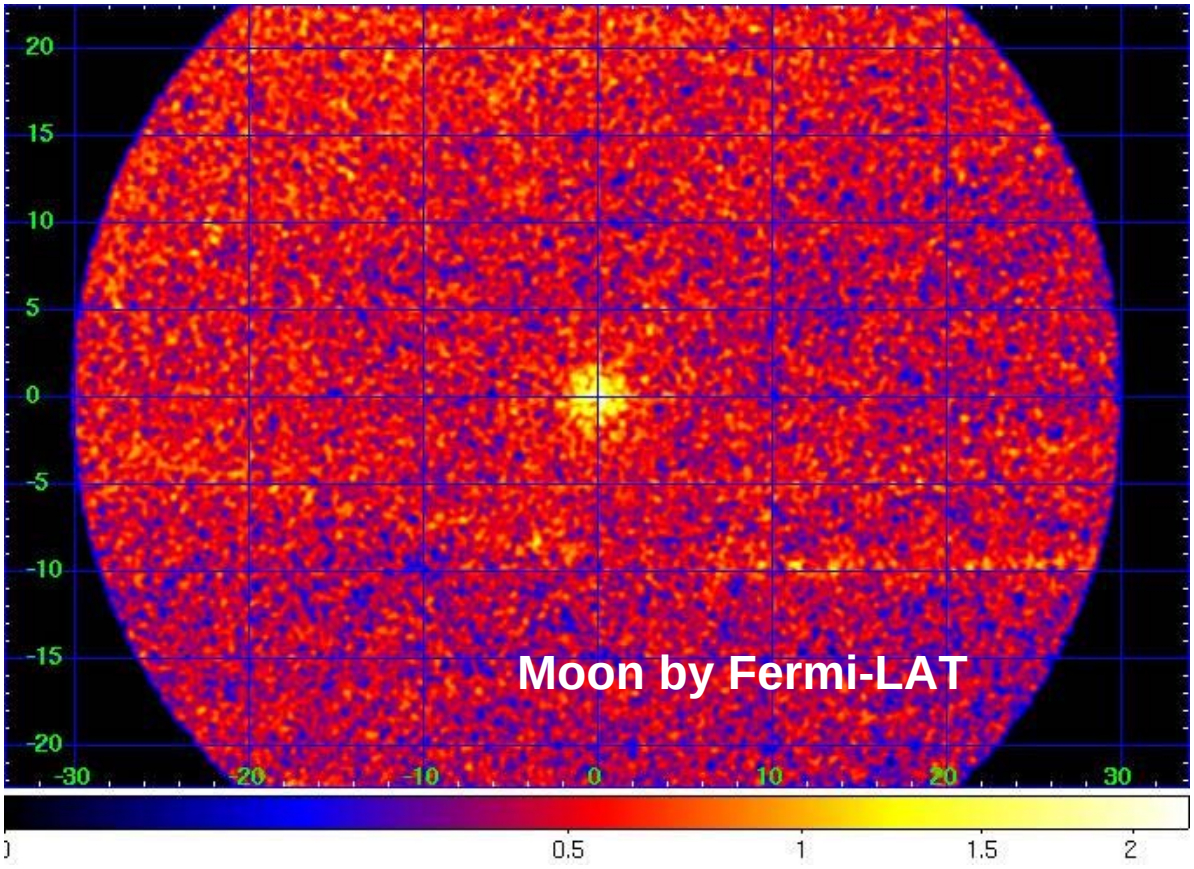
About 3 months; E>100MeV; 0.25 deg/bin



Even Moon Shows Up

Albedo gammas by Local Cosmic Rays

A grid with relative R.A. on x axis and relative DEC on y axis.
E>100MeV, 0.2 deg/bin



Future Plan

- **Fermi LAT Operation plan**
  - **Will operate mostly in the standard survey mode**
  - **Autonomous re-pointing for GRBs**
  - International participation in quick-look, GRB alert, Flare monitoring
- **GRB follow-up with optical telescopes**

  Telescopes in Asia play important role
- **AGN monitoring with optical telescopes**

  Regular monitoring of the monitored blazars
- **Public data release of the first year data in September 2009**
  - Analysis support plan through NASA SSC
  - Japanese local support through tutorials

- **Other important milestones**
  - A one-day symposium in Tokyo Inst. Tech in March
  - The 2nd Fermi Workshop in Washington DC (Nov. 2009)
  - Fermi-Guest Investigator Proposal (2nd round)

For KEK Review

The next slide will be used only in the
KEK Review of US-Japan Collaborative Programs
“GLAST-Large Area Telescope”
(to be presented by Takashi Ohsugi)

Contribution by Japanese Members

- LAT Calibration:
  - **Tracker calibration and trending**: H. Tajima (SLAC); 1 student (Hiroshima)
  - **Simulation (cosmic-ray):** T. Mizuno (Hiroshima) T. Kamae (SLAC)
- Science analyses:
  - **GRB**: H. Tajima(SLAC), T. Tanaka (JSPS) M. Hayashida (JSPS); N. Kawai, K. Asano, T. Nakamori (Tokyo Inst. Tech.); Y. Fukazawa, R. Yamazaki, T. Mizuno (Hiroshima); M. Ohno, R. Sato (ISAS); 2 students (Hiroshima and Tokyo Inst. Tech.)
  - **AGN**: J. Kataoka (Tokyo Inst. Tech); M. Hayashida (JSPS); T. Takahashi (ISAS)
  - **Pulsar/PWN**: N. Kawai (Tokyo Inst. Tech); 2 students (Tokyo Inst. Tech.)
  - **SNR/Stellar wind**: T. Kamae, Y. Uchiyama, H. Tajima (SLAC); H. Katagiri, H. Takahashi (Hiroshima); M. Ozaki (ISAS)
  - **Microquasar/Binary:** T. Tanaka (JSPS); H. Takahashi (Hiroshima), K. Makishima (U. Tokyo)
  - **Cosmic-ray interaction in clouds**: T. Kamae, Y. Uchiyama (SLAC); T. Mizuno (Hiroshima); Y. Fukui (Nagoya); 1 student (U. of Tokyo)
  - **Dark Matter signals**: T. Kamae (SLAC)
- Multiwave collaboration with non-Fermi scientists in Japan
  - **X-ray counterpart**: Suzaku team
  - **Cosmic ray model**: H. Honda (ICRR)
  - **CO and Av survey**: NANTEN2 (Nagoya U.), K. Dobashi (Tokyo Gakugei U.)