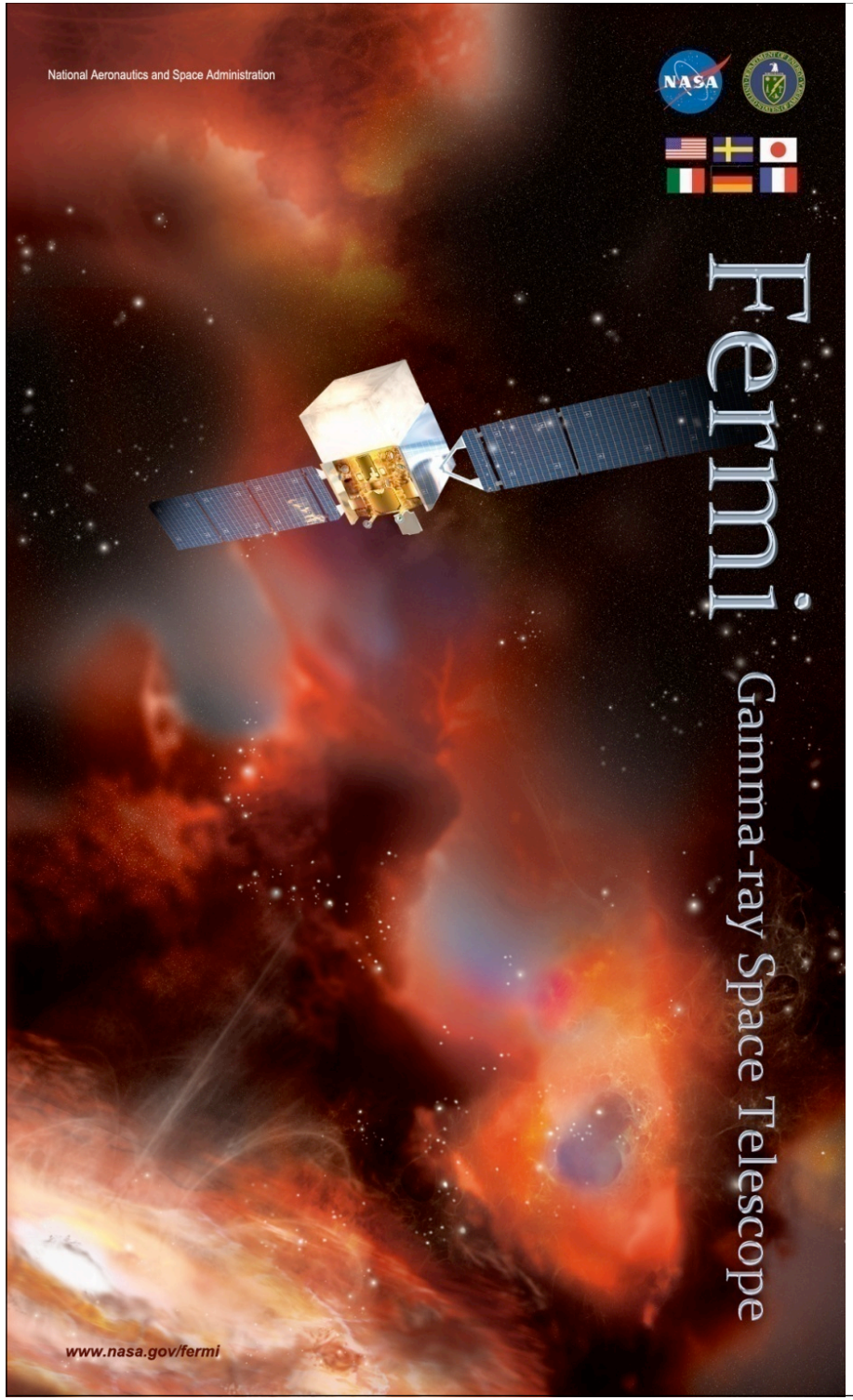

Black Hole Universe

Fermi Gamma-ray Space Telescope

Fermi-LAT Observations of Galactic Transients and and the MeerKAT/KAT-7 connection (or from YHz to GHz).

Stéphane Corbel

(University Paris Diderot / CEA Saclay / Institut Universitaire de France)

on behalf of the Fermi LAT collaboration

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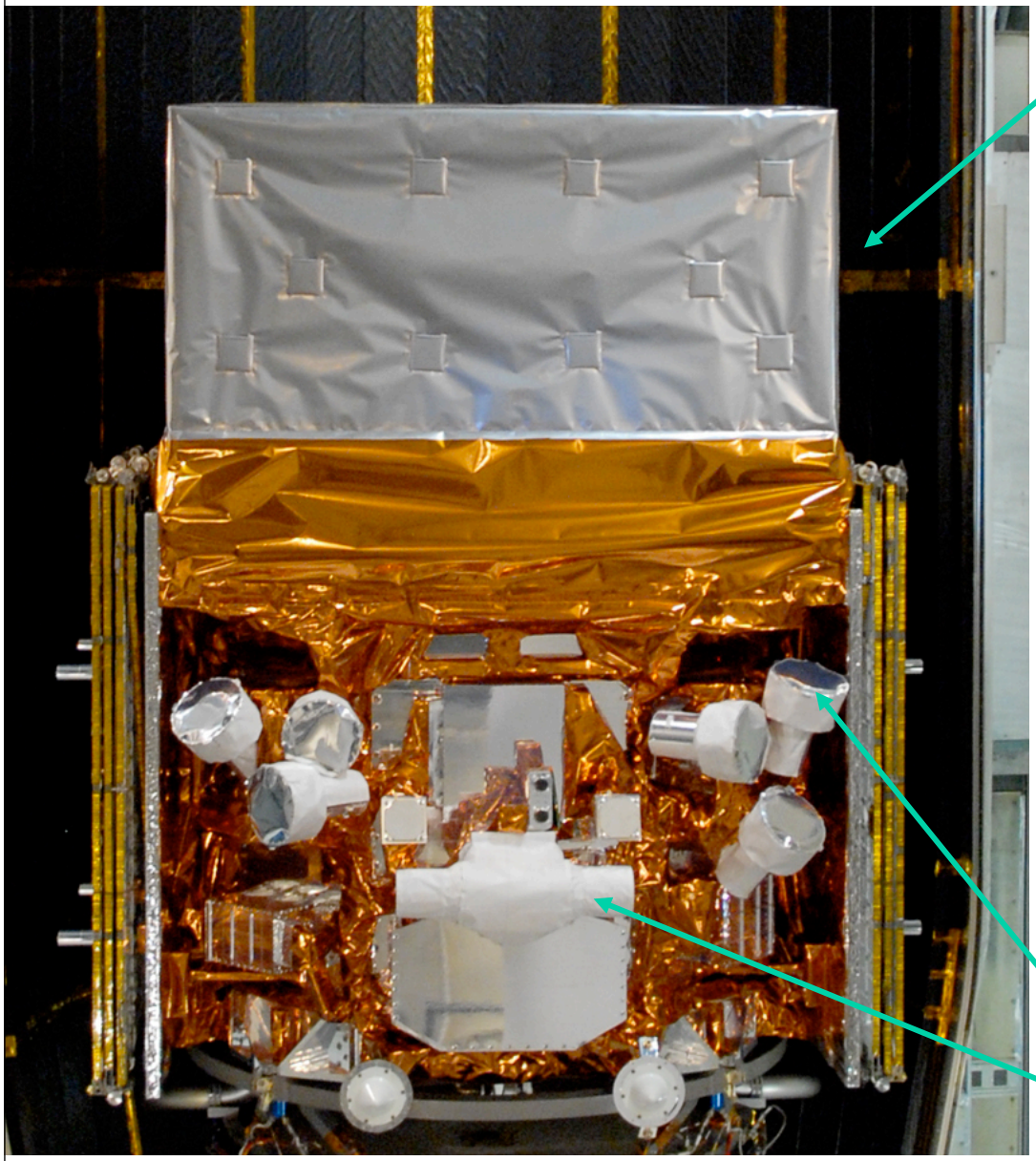
The Fermi Gamma-ray Space Telescope



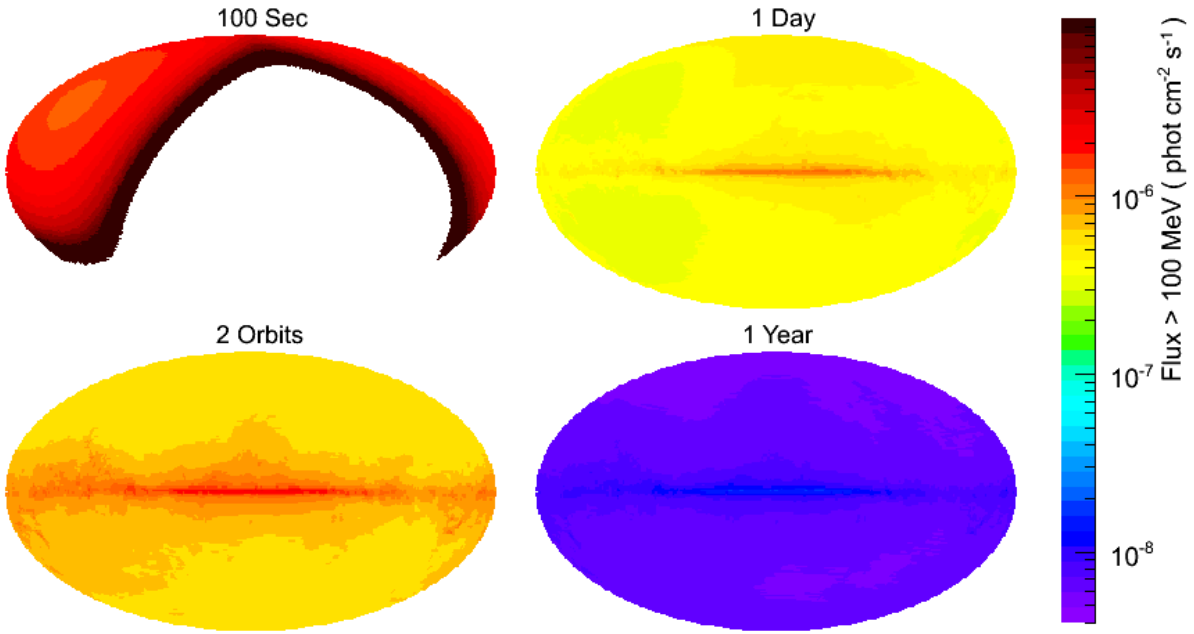
Large Area Telescope (LAT)

KEY FEATURES

- **20 MeV → >300 GeV photon energies (very different from MeerKAT)**
- **2.4 Steradian field of view**
- **Operated in scanning mode,**
- **Source location capability : 1-10 arcmin.**

Gamma-ray Burst Monitor (GBM)
NaI and BGO Detectors
8 keV - 40 MeV

All Sky Coverage

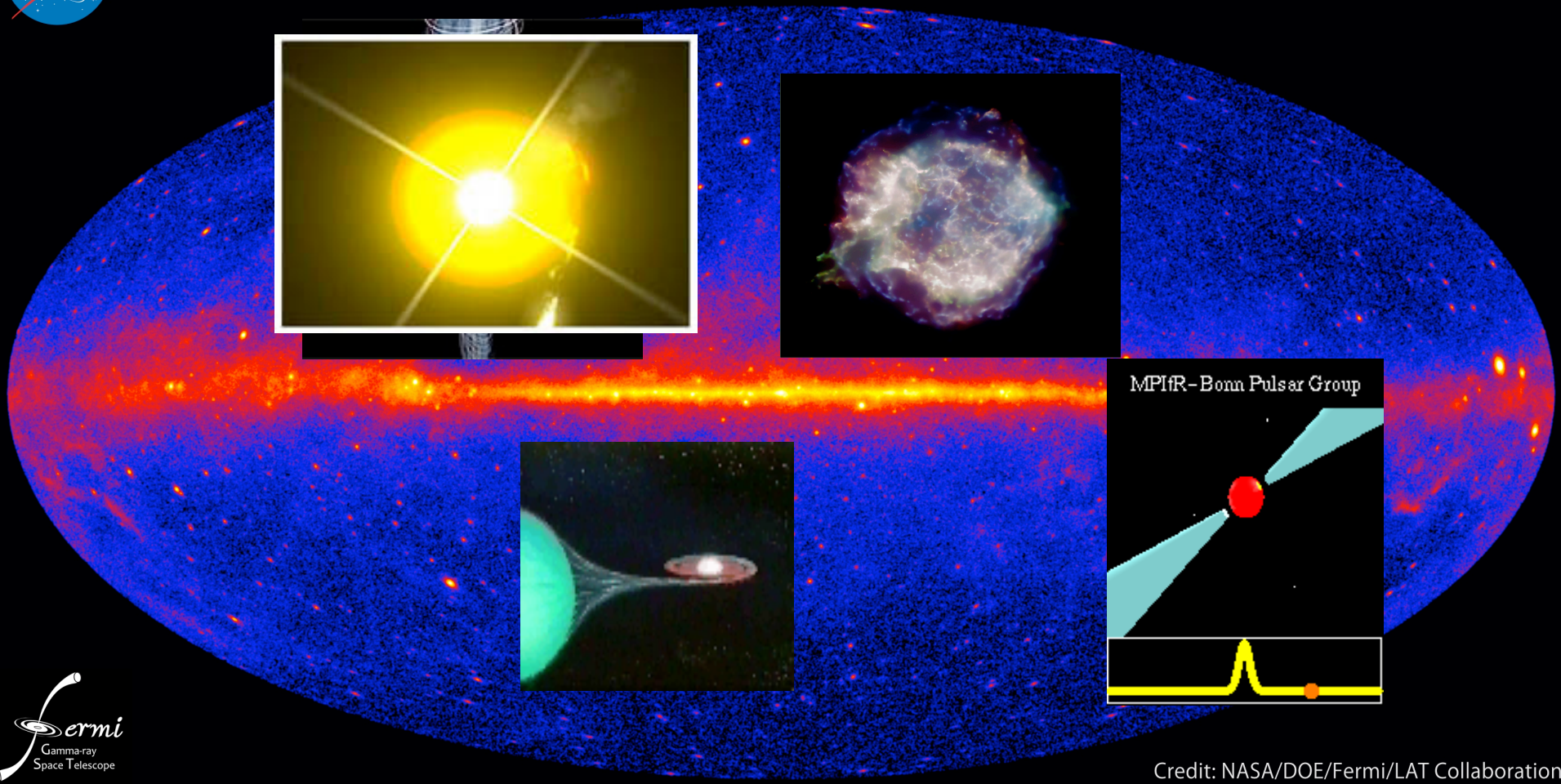


LAT sensitivity on 4 different timescales: 100 s, 1 orbit (96 mins), 1 day and 1 year

- **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.**

The >1 GeV Sky

Fermi two-year all-sky map

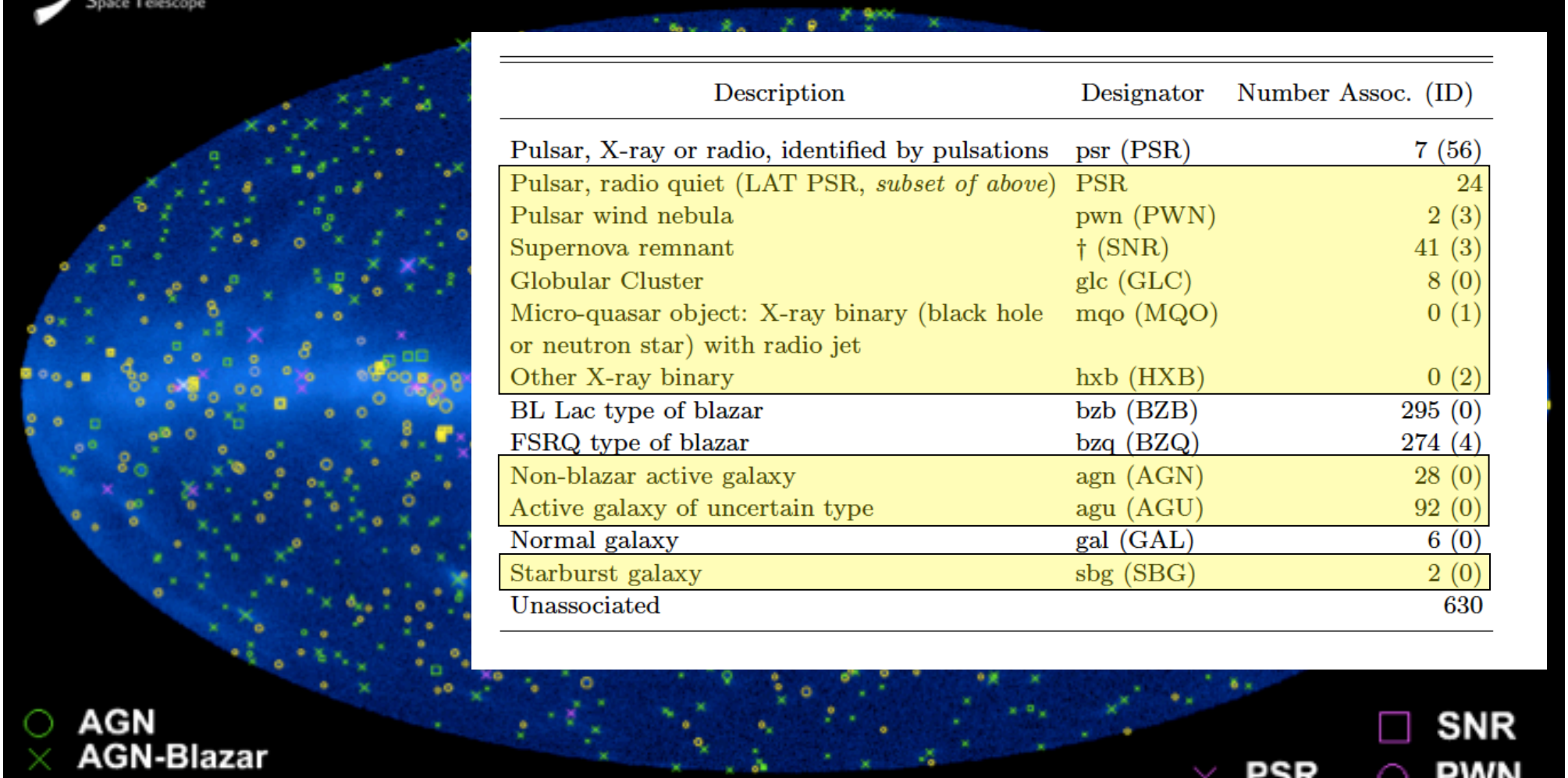


Credit: NASA/DOE/Fermi/LAT Collaboration

Two years catalog to be released soon.

The Fermi LAT 1FGL Source Catalog

1,451 sources

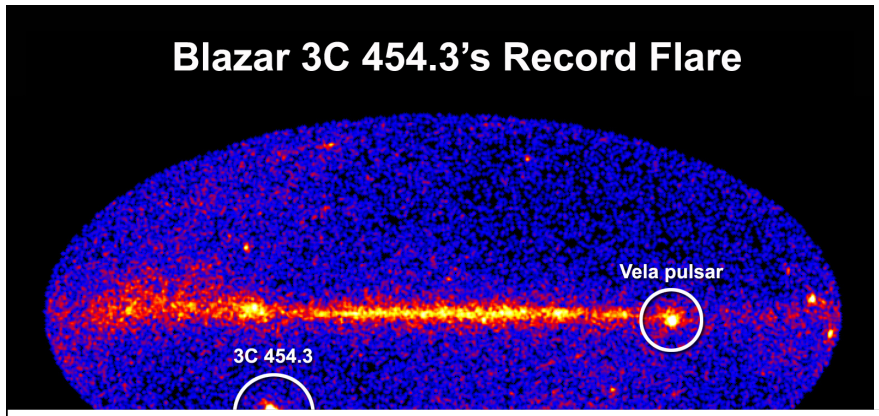


Description	Designator	Number Assoc. (ID)
Pulsar, X-ray or radio, identified by pulsations	psr (PSR)	7 (56)
Pulsar, radio quiet (LAT PSR, *subset of above*)	PSR	24
Pulsar wind nebula	pwn (PWN)	2 (3)
Supernova remnant	† (SNR)	41 (3)
Globular Cluster	glc (GLC)	8 (0)
Micro-quasar object: X-ray binary (black hole or neutron star) with radio jet	mqo (MQO)	0 (1)
Other X-ray binary	hxb (HXB)	0 (2)
BL Lac type of blazar	bzb (BZB)	295 (0)
FSRQ type of blazar	bzq (BZQ)	274 (4)
Non-blazar active galaxy	agn (AGN)	28 (0)
Active galaxy of uncertain type	agu (AGU)	92 (0)
Normal galaxy	gal (GAL)	6 (0)
Starburst galaxy	sbg (SBG)	2 (0)
Unassociated		630

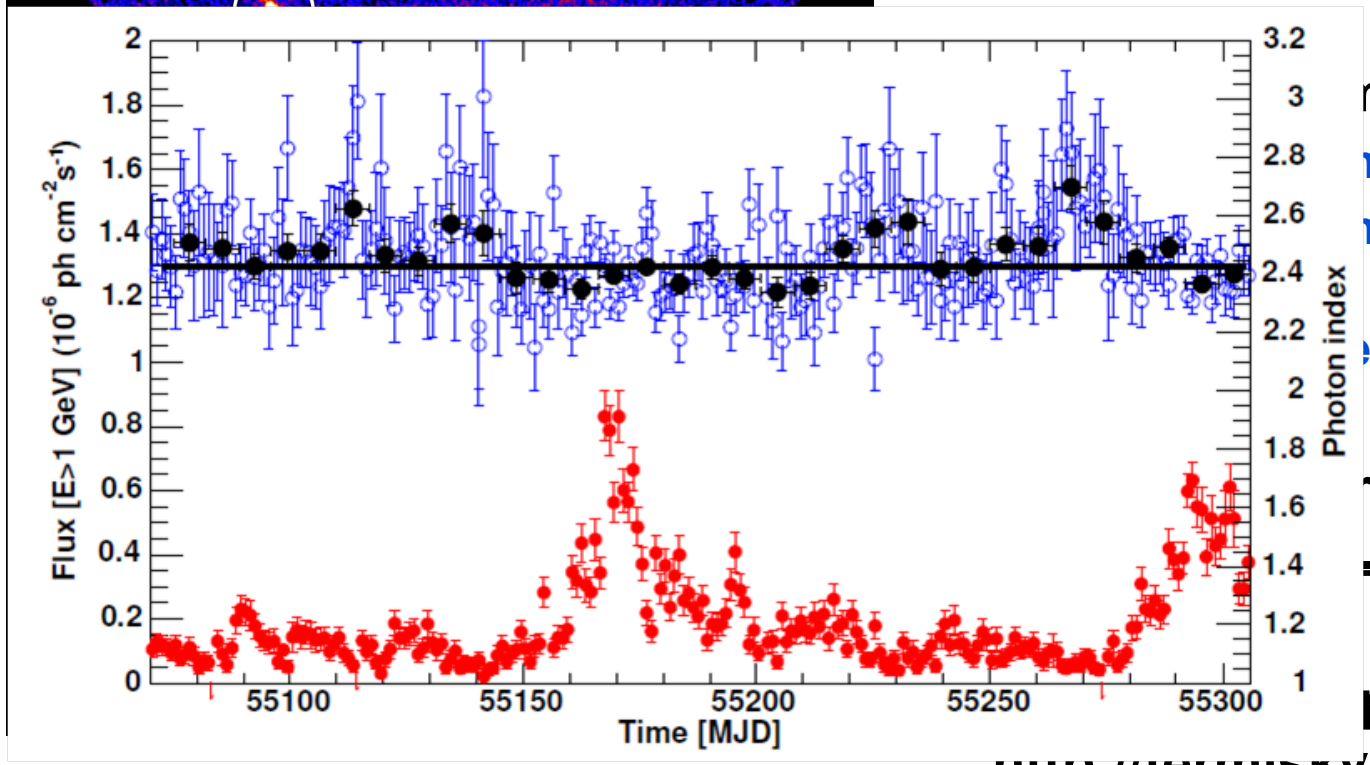
AGN
AGN-Blazar
AGN-Non Blazar
No Association
Possible Association with SNR and PWN
Possible confusion with Galactic diffuse emission
Starburst Galaxy
Galaxy
SNR
PSR
PWN
PSR w/PWN
Globular Cluster
HXB or MQO

Credit: *Fermi* Large Area Telescope Collaboration

The flaring and variable sky



- **Automated search for flaring sources on 6 hour, 1 day and 1 week timescales.**
  - **LAT scientists perform follow-up analyses, produce ATels, and propose ToOs**



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new gamma-ray blazars

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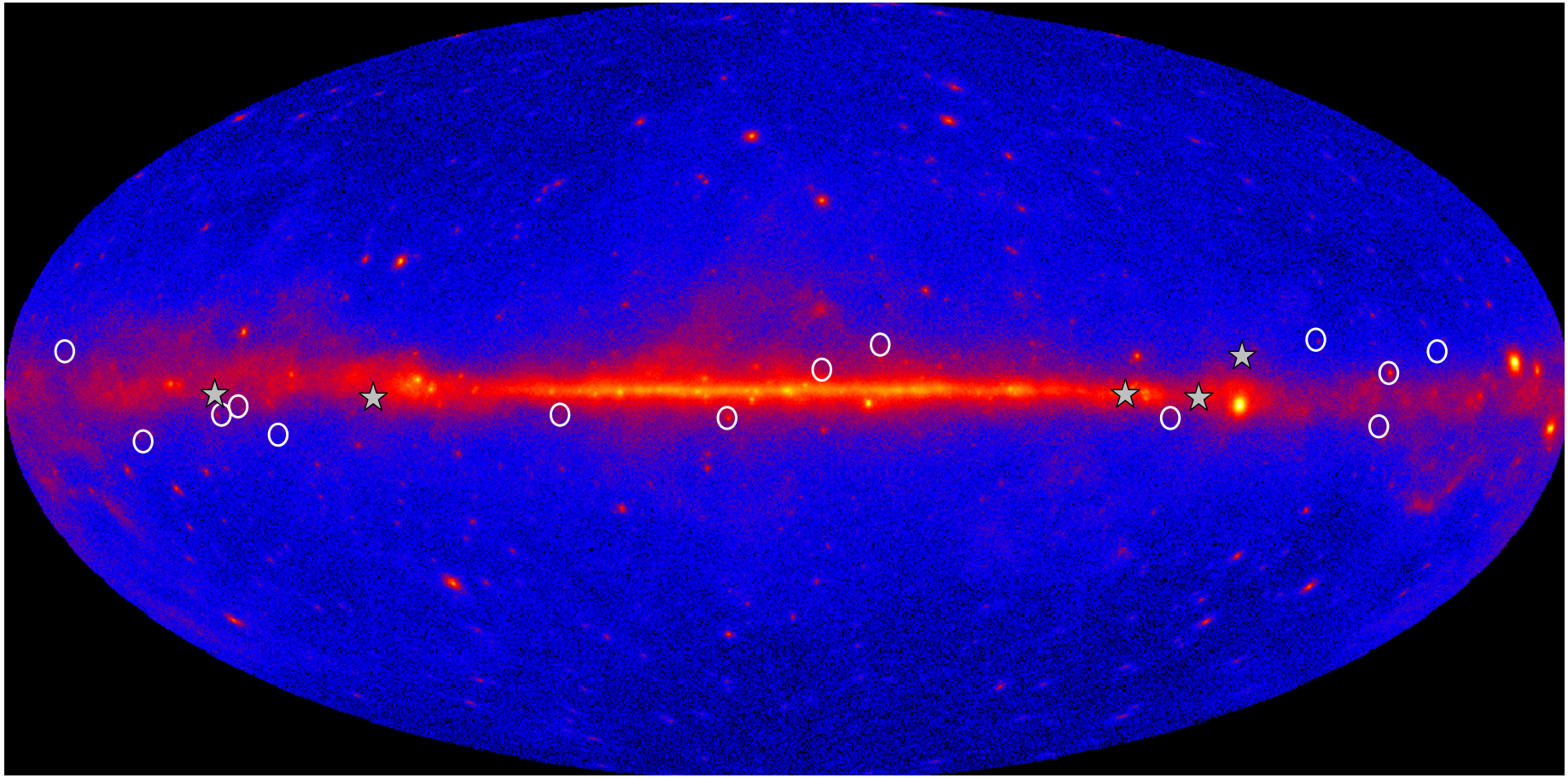
rves through FSSC
.gsfc.nasa.gov/ssc

pecial Reports :
http://fermisky.blogspot.com

Fermi-LAT Galactic Plane Transients

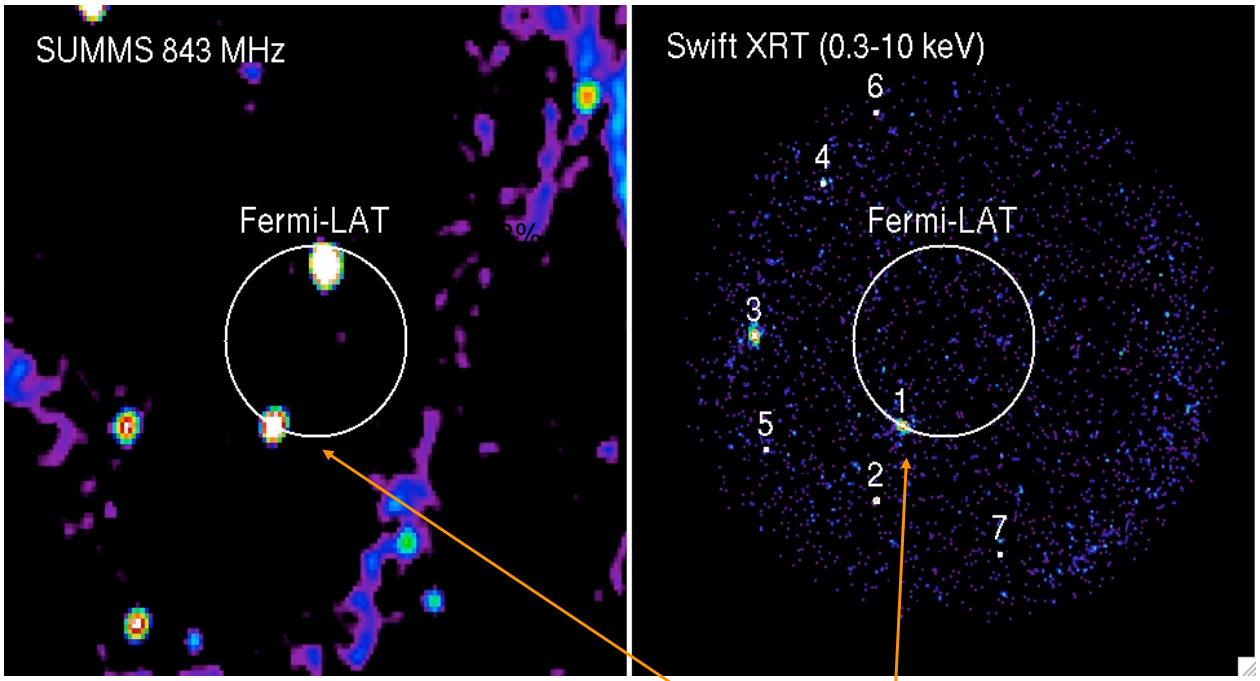


○ Low Galactic latitude blazars in 1st LAT AGN Catalog

☆ LAT Galactic plane ($|b|<10^{o}$) transients from daily search*

*Excludes flaring from known sources like Cyg X-3 and Crab

Counterpart Search - Fermi J0910-5041



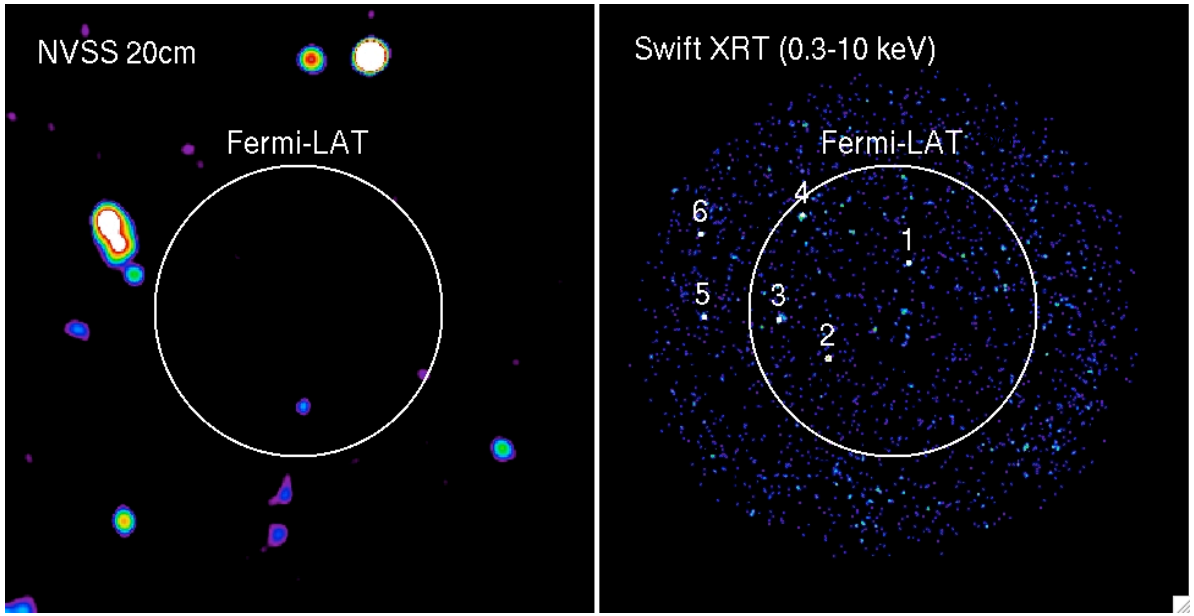
Fermi J0910-5041
(Cheung et al. ATel #1788)

- Gal. latitude, b = -1.2°
- October 15, 2008 (10σ), 2 day gamma-ray flare
- Gamma-ray flare 10x larger than average flux
- Swift TOO within 1 day

LAT 95% error circle contains Swift XRT source (Landi et al. ATel #1822) coincident w/ flat-spectrum radio source in AT20G & SUMMS (Sadler ATel #1843)

- Background blazar? Blazar gamma-ray activity typically more 'long lived'
- Galactic origin? More follow-up necessary

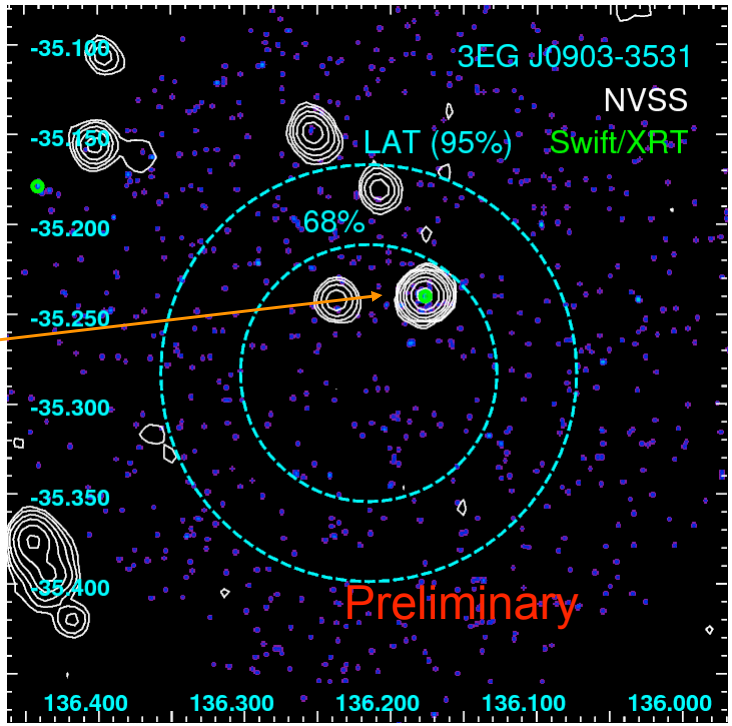
Counterpart Search - 3EG J0903-3531



3EG J0903-3531
(Hays et al. ATel #1771)

- Gal. latitude, b = +7.7°
- October 5, 2008 (10σ), 3 day gamma-ray flare
- 5x above 3EG flux
- Swift TOO within 2 days

Updated LAT 95% error circle (8 months) contains a flat-spectrum radio source that is detected with Swift/XRT



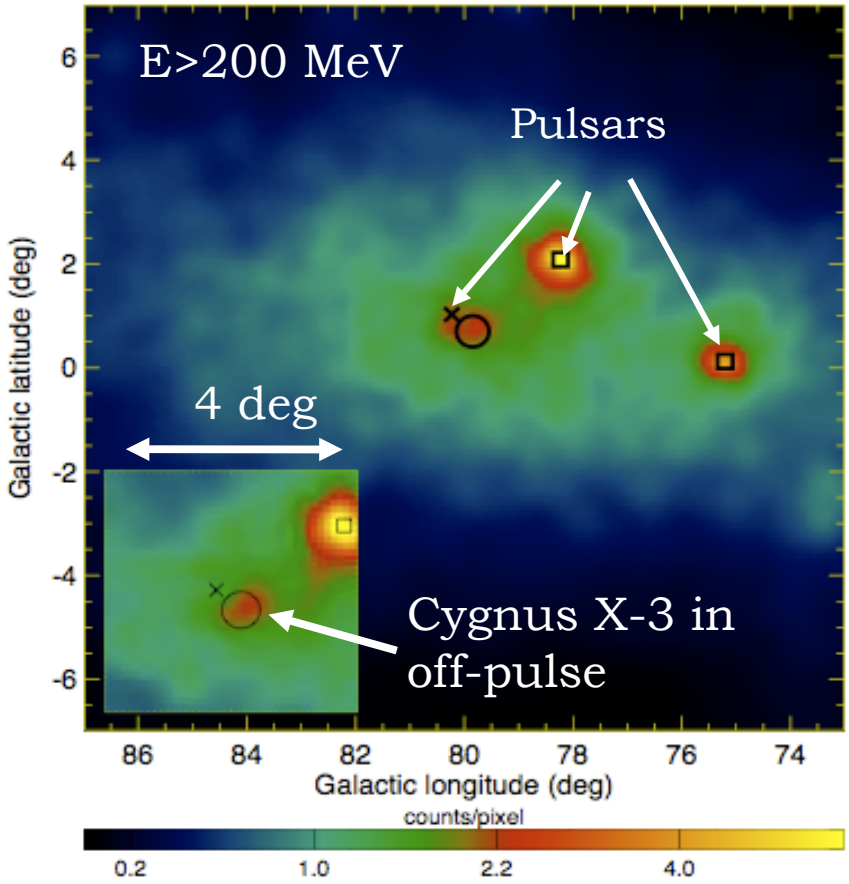
Other bright Galactic plane transients

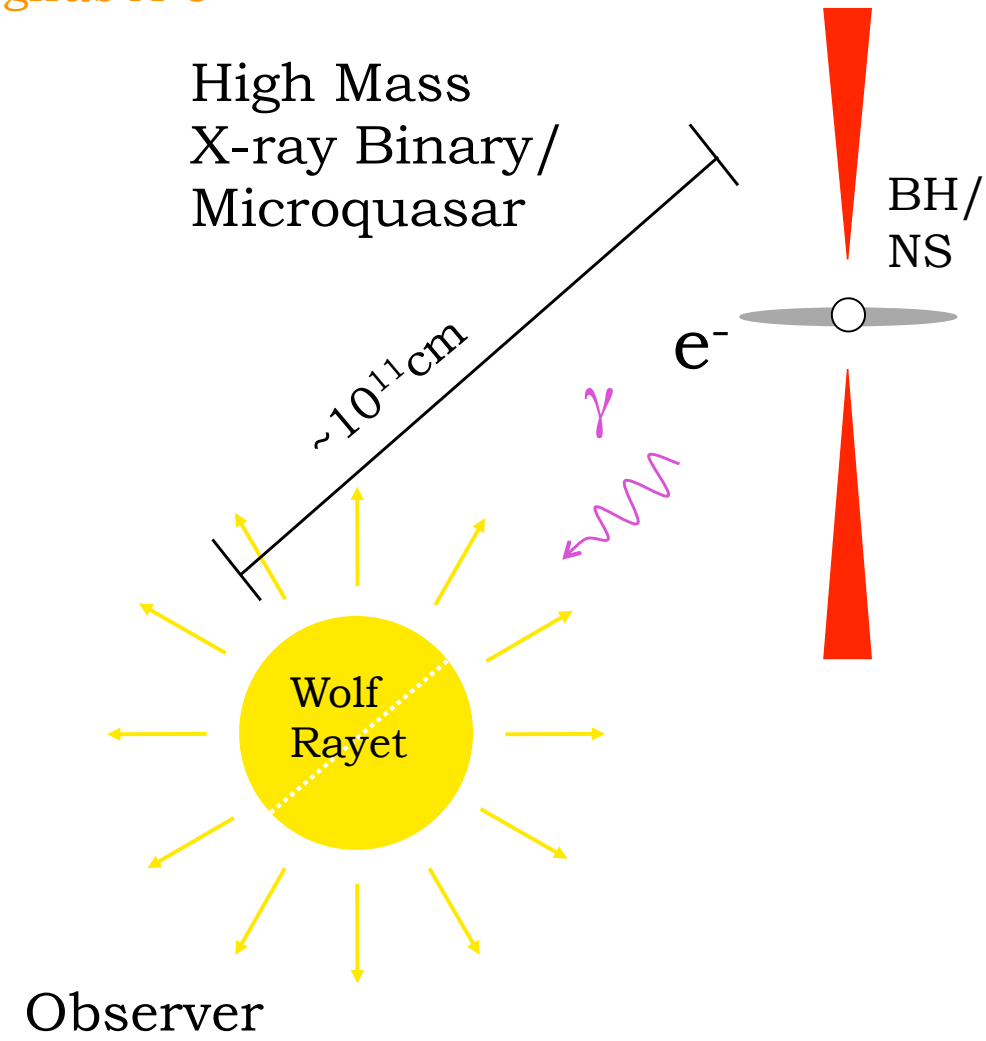
- Fermi J1057-6027 (Yasuda et al. Atel #2081) – no ID
- Fermi J0109+6134 (Vandenbroucke et al. 2010) - blazar

Microquasar: Cygnus X-3

First secure gamma-ray detection of Cygnus X-3

high significance source and binary modulation

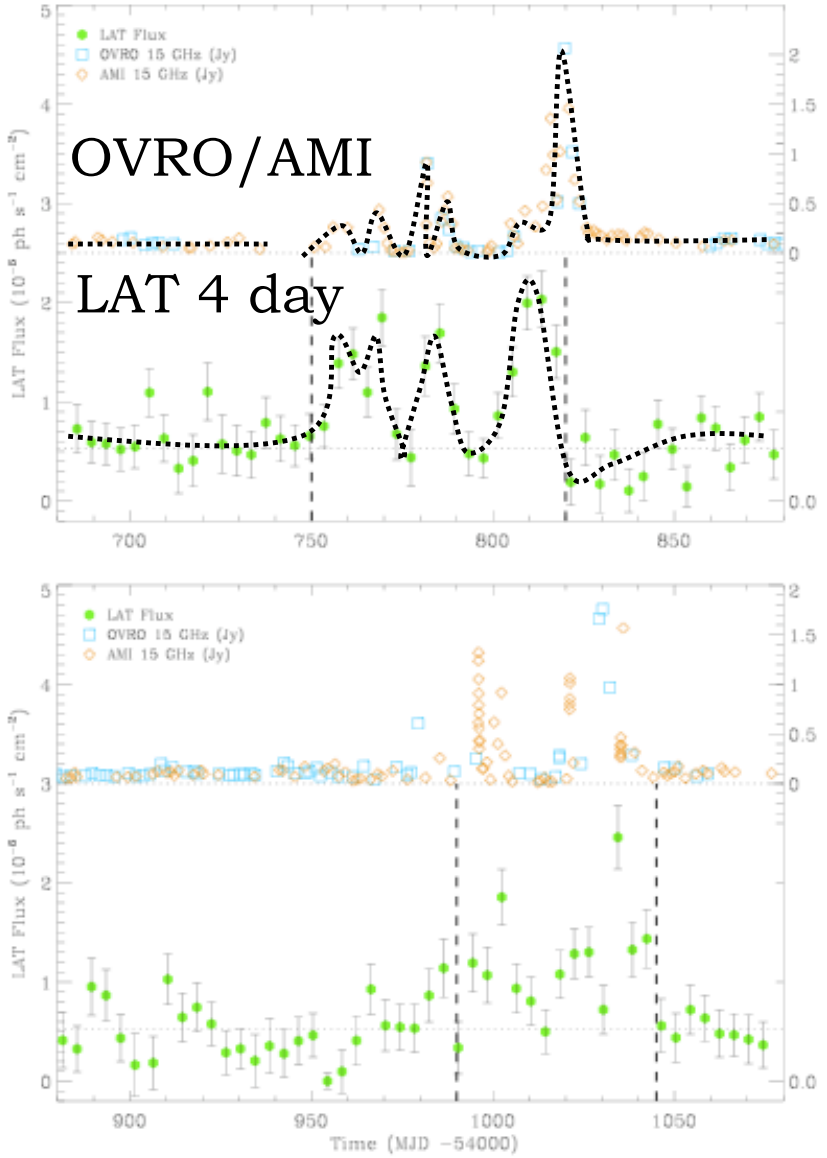




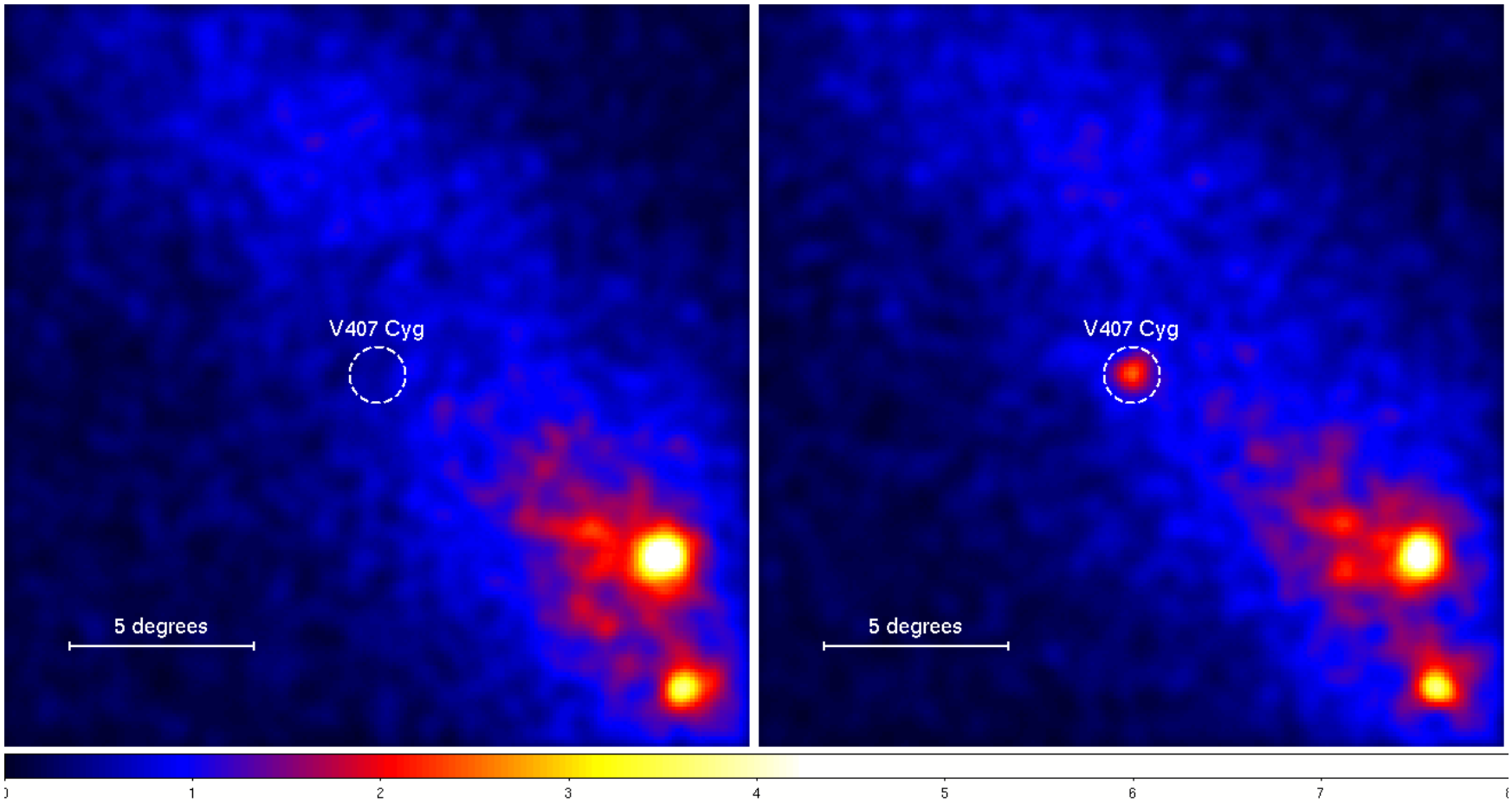
Abdo et al. Science 326, 1512 (2009)

Connection to Jet Activity

- **LAT active periods correspond to radio flares**
  - **Possible radio lag is not well constrained by correlation analysis**
- **Expect high energy electrons somewhere along the jet to scatter the stellar radiation field (UV) via inverse Compton**
  - **Superior conjunction favored for gamma-ray production**



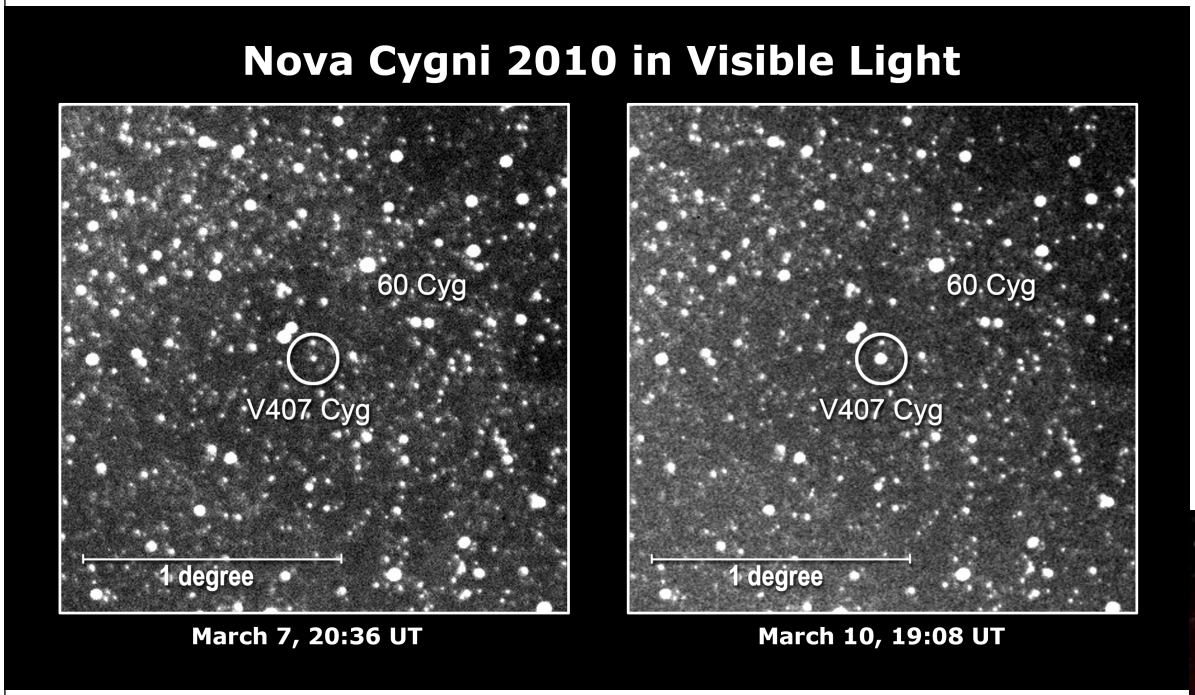
March 2010 - a Galactic plane transient



- *First γ–ray detection of a nova*
- *White dwarf in binary system*

Abdo et al. 2010 Science, 329, 817

V407 Cygni: a variable star

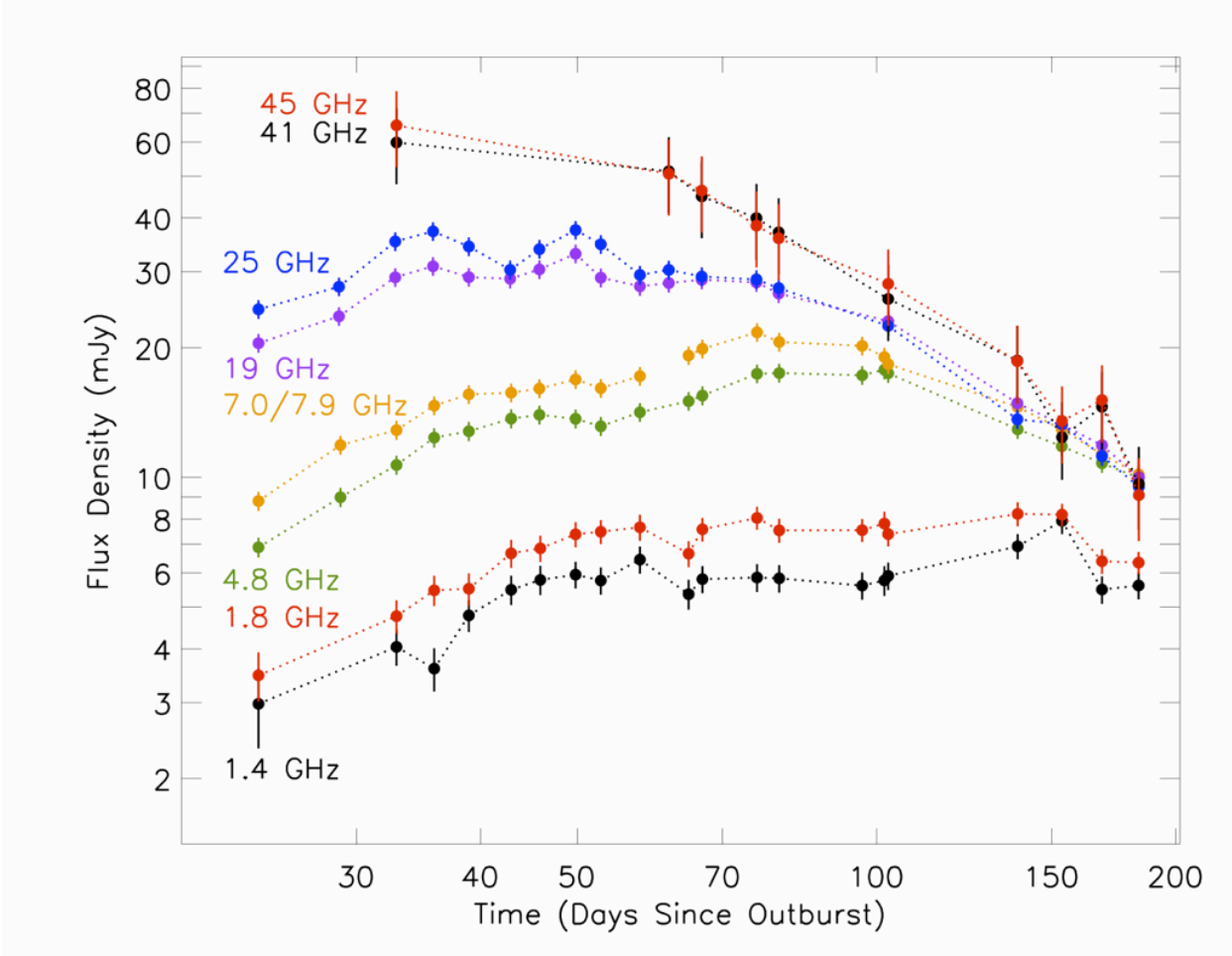


Symbiotic binary:
small white dwarf (WD) star and large red giant (RG) star orbiting each other closely

Variability can come from the binary motion, pulsations of the red giant (IR/optical), accretion disk around the white dwarf (UV)

Nova thermonuclear runaway on WD surface

Panchromatic Lightcurves



EVLA Nova team. Krauss et al.
https://safe.nrao.edu/evla/nova/

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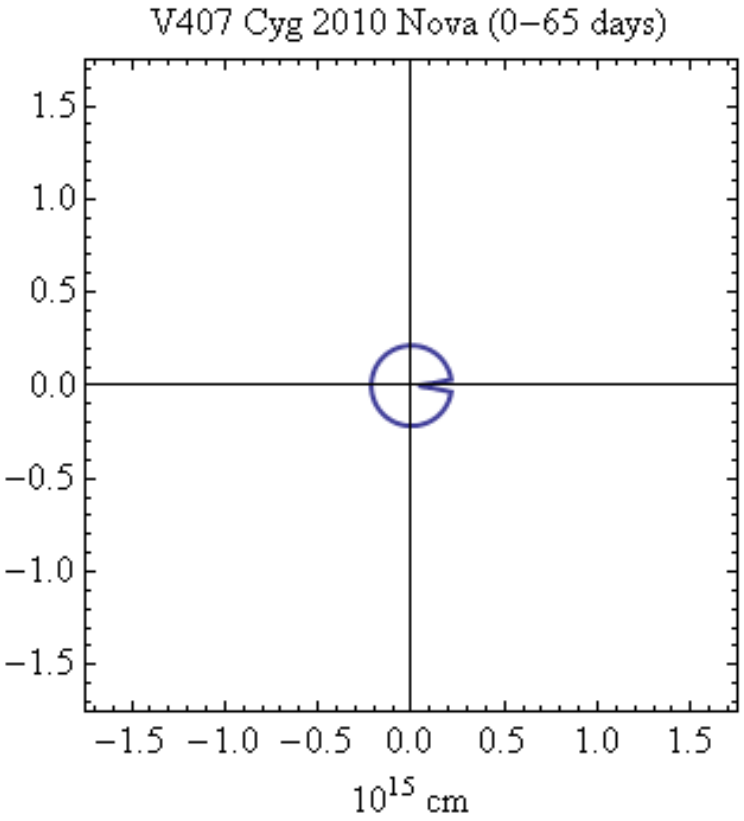
Nova γ-ray and X-ray Evolution



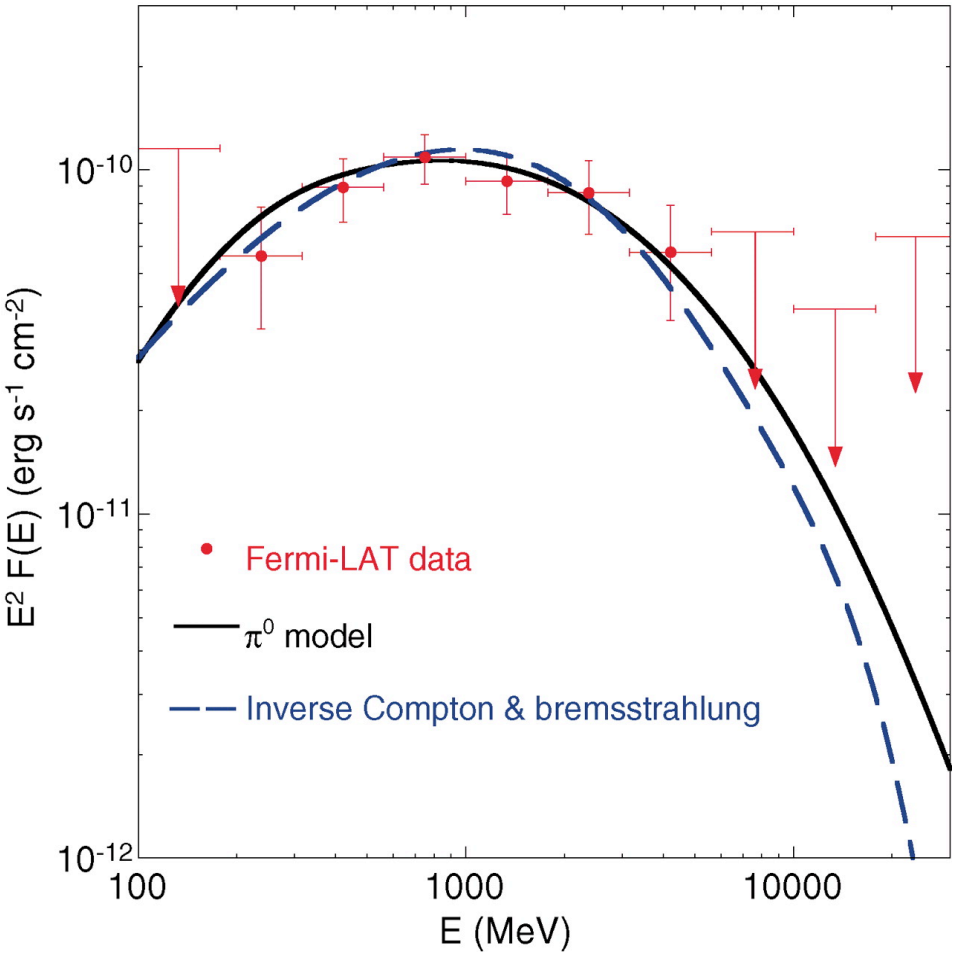
White dwarf at center

Credit: S. Razzaque

- Nova shell initially freely expands into asymmetric dense medium : Shell expansion is nonuniform in space
- Shell toward RG slows down quickly
  - Gamma rays peak early when efficiency for pion and inverse-Compton processes is favorable
- Shell decelerates slowly away from RG
  - Later X-rays peak, flux increasing with volume of shock-heated gas

γ-ray Spectrum and Energetics

15-day average



Gamma-ray emission process could be:

- ***pion:*** accelerated p's collide with ambient material producing π^0 with prompt decay
- ***inverse Compton:*** accelerated electrons up-scattering infrared photons from the red giant

Energetics:

Kinetic energy of the shell: ~10^{44} erg

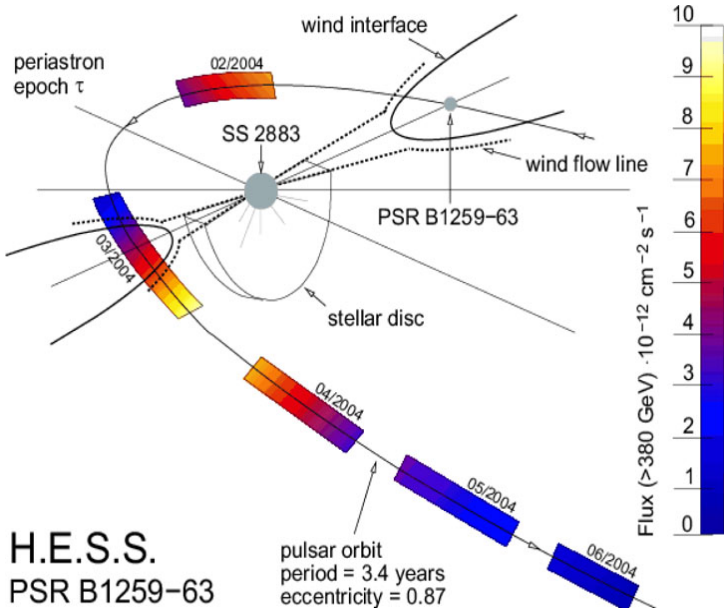
Total energy in γ-rays: ~4 x 10^{41} erg

This means 0.4% efficiency for leptonic scenarios

Or 9% for hadronic (similar to Fermi SNR)

Other Fermi/LAT γ-ray transients

- γ-ray flare from the Crab nebula !!! Poor standard candle ?
- Blazars in flaring period, but no major change in radio.
- Periastron passage of PSR B1259-63

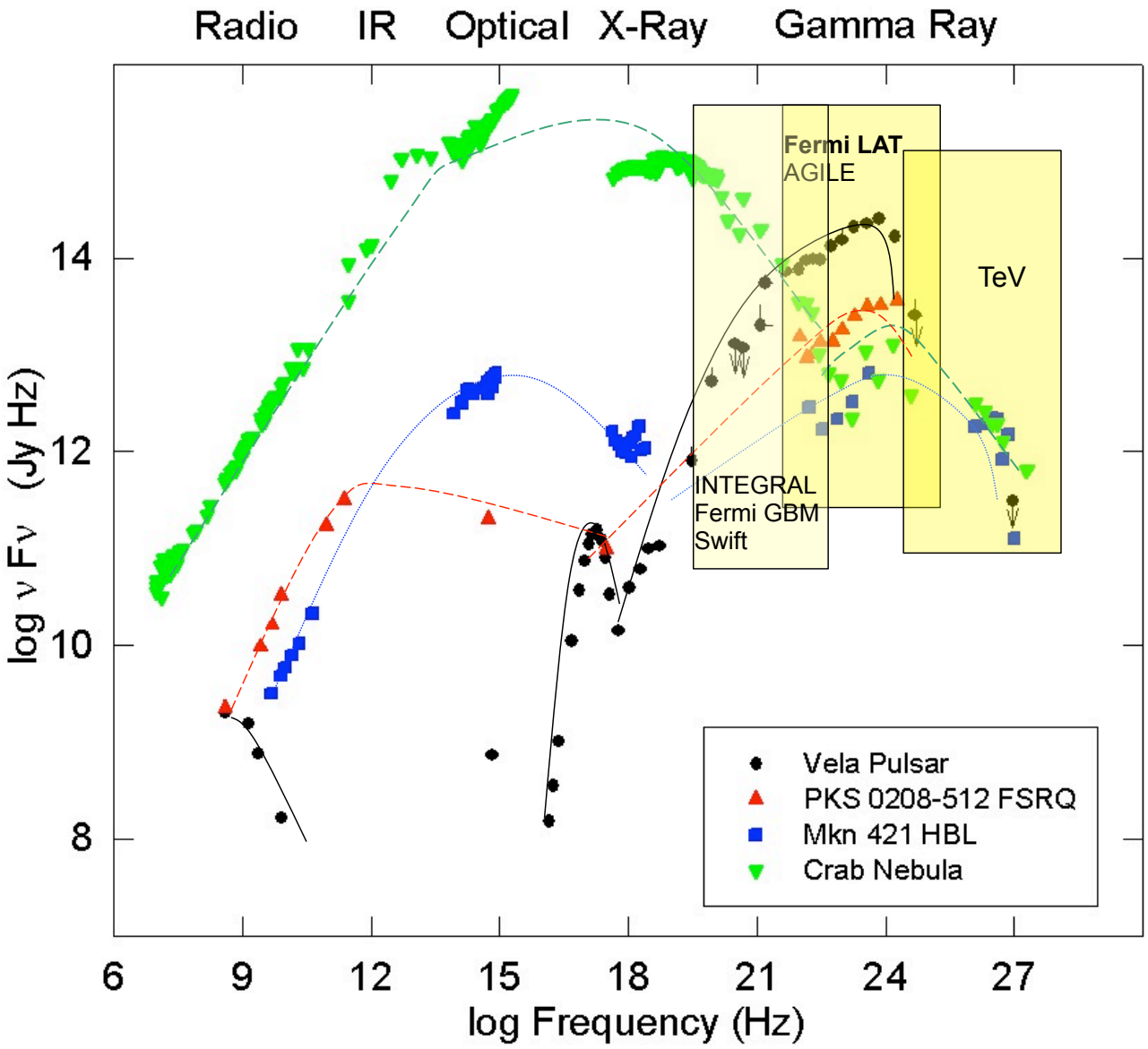


- AGILE flare of microquasar Cyg X-1, not seen by Fermi

Gamma-Ray/Radio Synergy

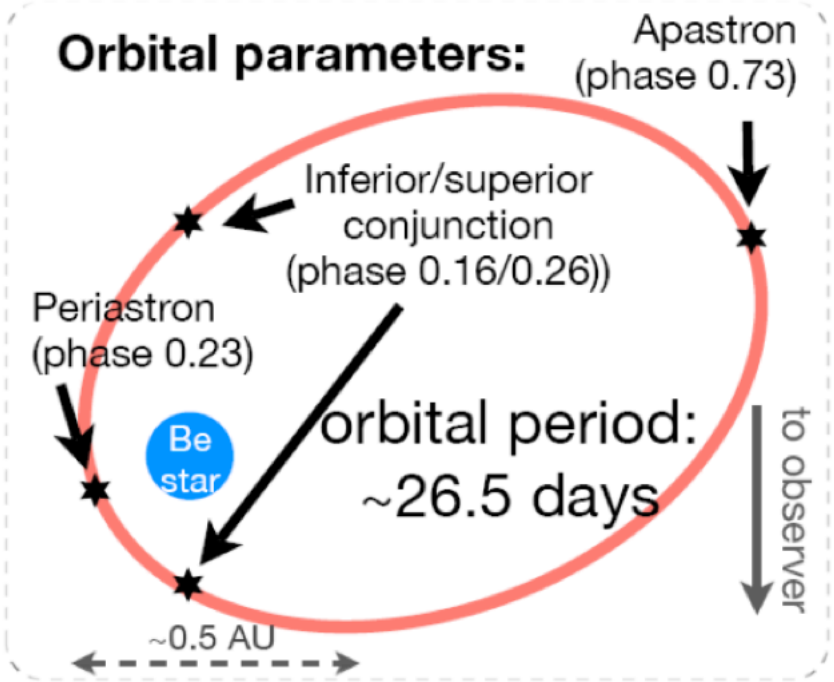
- **Gamma rays often represent a significant part of the energy budget of a source; therefore, gamma-ray studies can be critical to understanding physical processes in such objects**
- **Radio observations offer timing and spatial resolutions vastly superior to anything possible with gamma-ray telescopes; therefore radio is often the key to understanding source structure.**
- **Gamma-ray and radio observations can complement each other, making a great team.**
- **MeerKAT: a very sensitive radio interferometer in the Southern hemisphere + broadband capabilities.**
- **Large science prospect and γ-ray/radio synergy: GRBs (many), CVs (1), XRB (1 (+1?) mq + 5 gamma-ray binaries) + unknown transients**
- **VLBI capabilities**

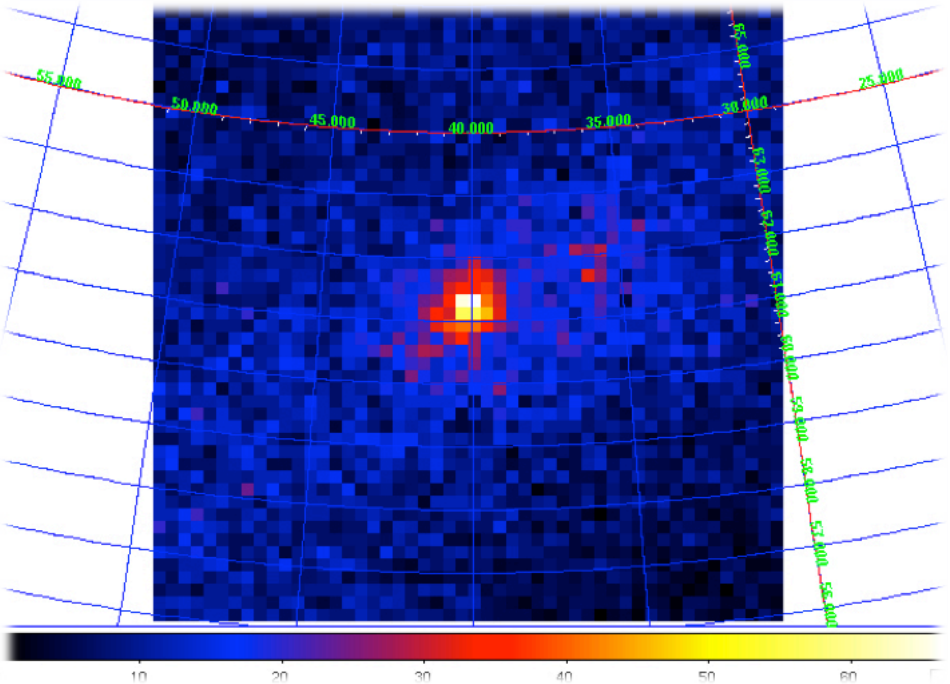
Known Gamma-ray Sources – Multiwavelength Objects

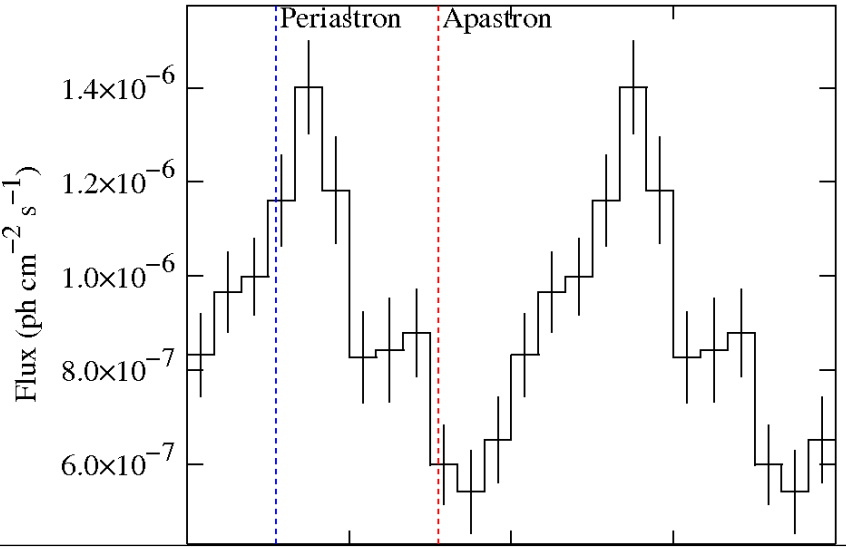


- **Gamma-ray sources are nonthermal, typically produced by interactions of high-energy particles.**
- **With different interactions, the same particles produce radio emission.**

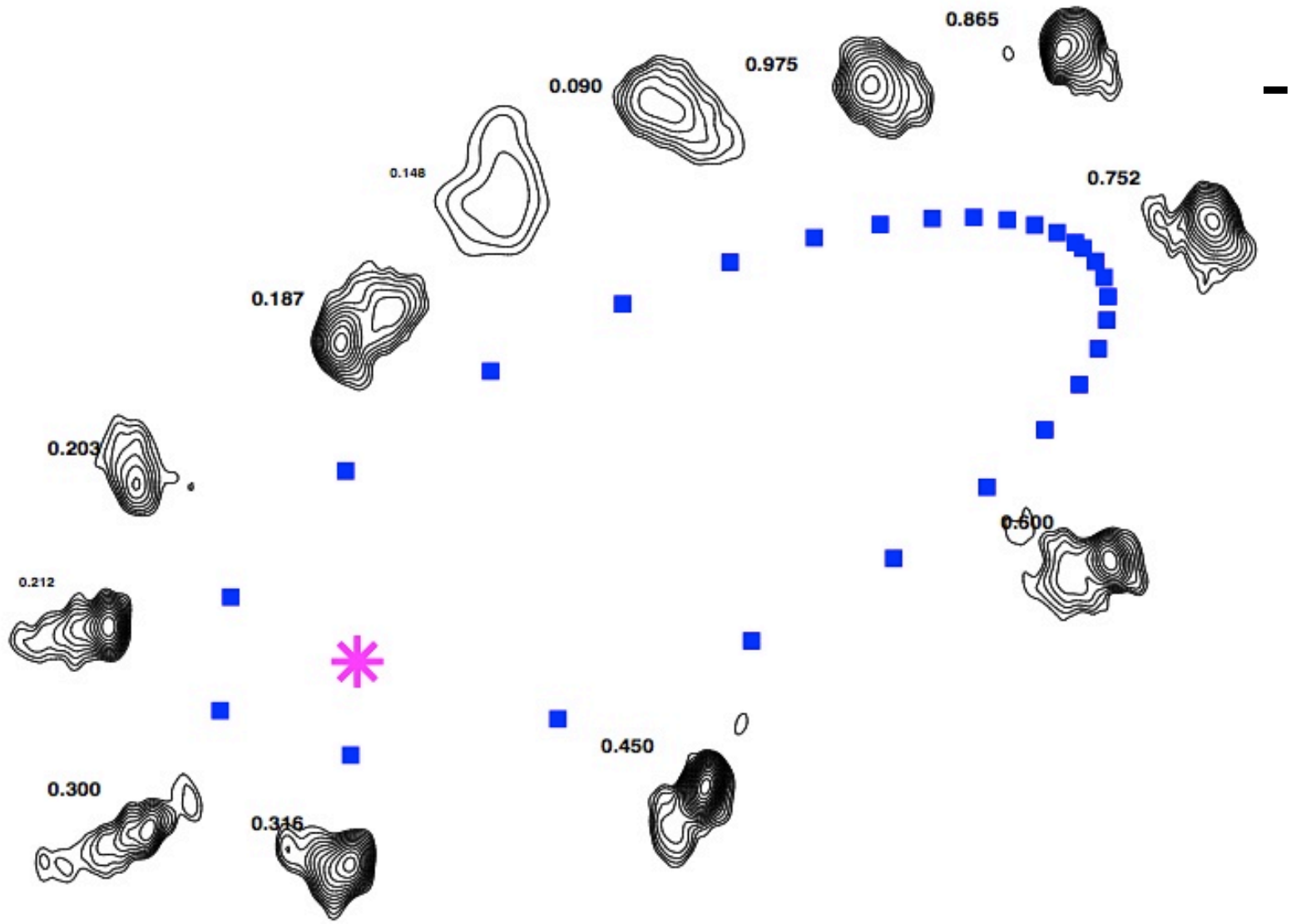
High-Mass X-ray Binary – LSI +61°303







Fermi LAT observations showed a clear 26-day modulation.



VLBA observations by Vivek Dhawan, Amy Mioduszewski, & Michael Rupen (2006) suggest that it is a pulsar in orbit around the Be star. The Fermi LAT spectrum also appears pulsar-like.

Conclusions

- Fermi highlights various populations of known transients: X-ray and γ-ray binaries, GRBs + new population : CVs, PWN,

- Some Fermi-LAT Galactic plane γ-ray transients still unidentified (some could be unidentified blazars, but not sure for all)

- Cyg X-3: Probing the relativistic jets of a microquasar. Other candidates ?

- V407 Cyg first γ-ray nova (white dwarf in binary system): Fermi acceleration in nova shell; interaction with massive red giant wind plays important role

- Almost all of these transients had radio associated radio emission ! Fermi is on for some time. Crucial role for MeerKAT. A very sensitive radio interferometer in the South! Fermi data always there !!

- Broadband MW observations are very important to set-up in advance. For example, ALMA Early CfP (same hemisphere as MeerKAT), maybe too earlier yet ! A synergy to explore with other radio transient project (e.g. VAST, Lofar TKP).