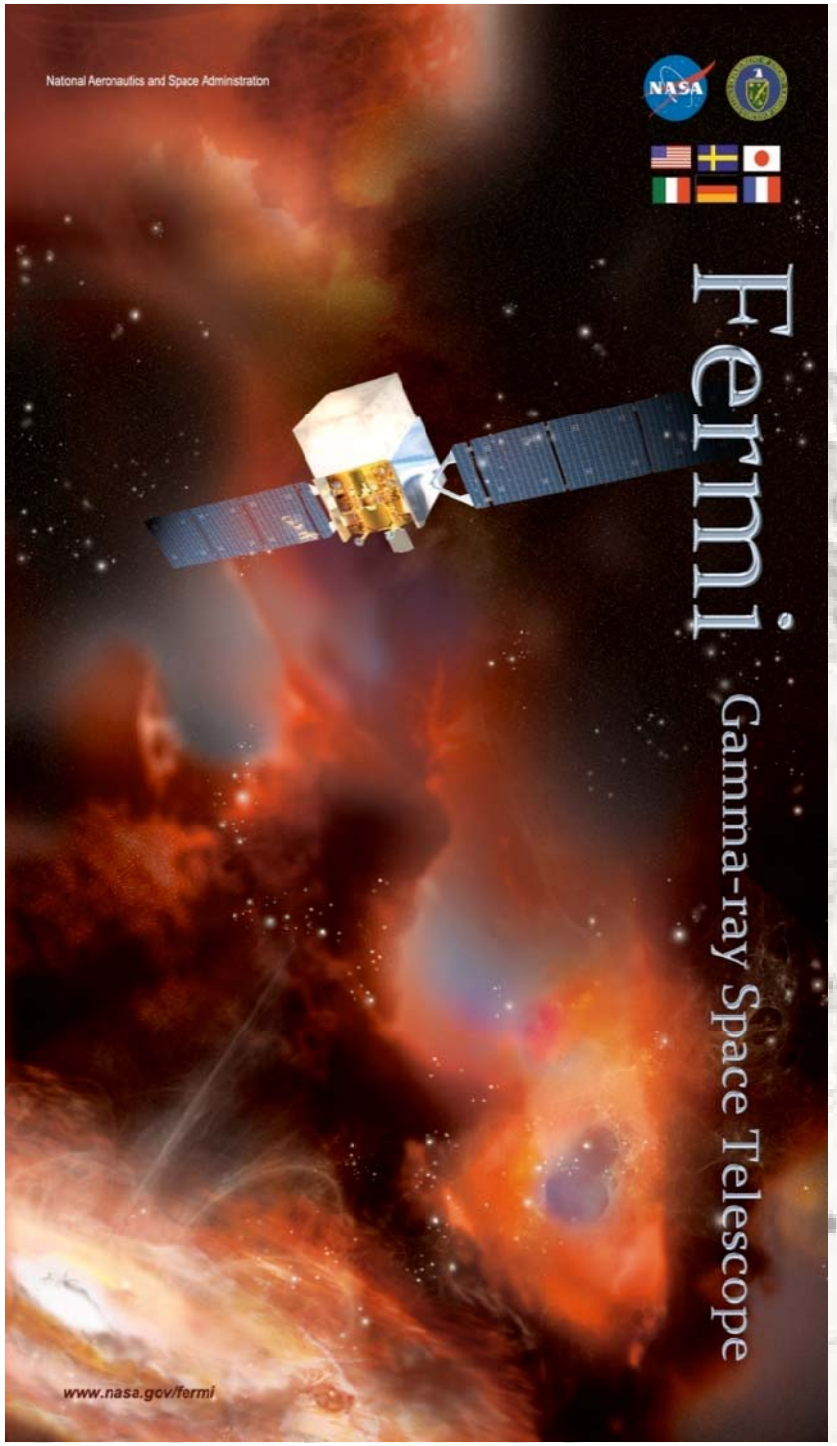


PSR J2021+4026:
the pulsar in Gamma Cygni SNR

Massimiliano Razzano
Università di Pisa & INFN

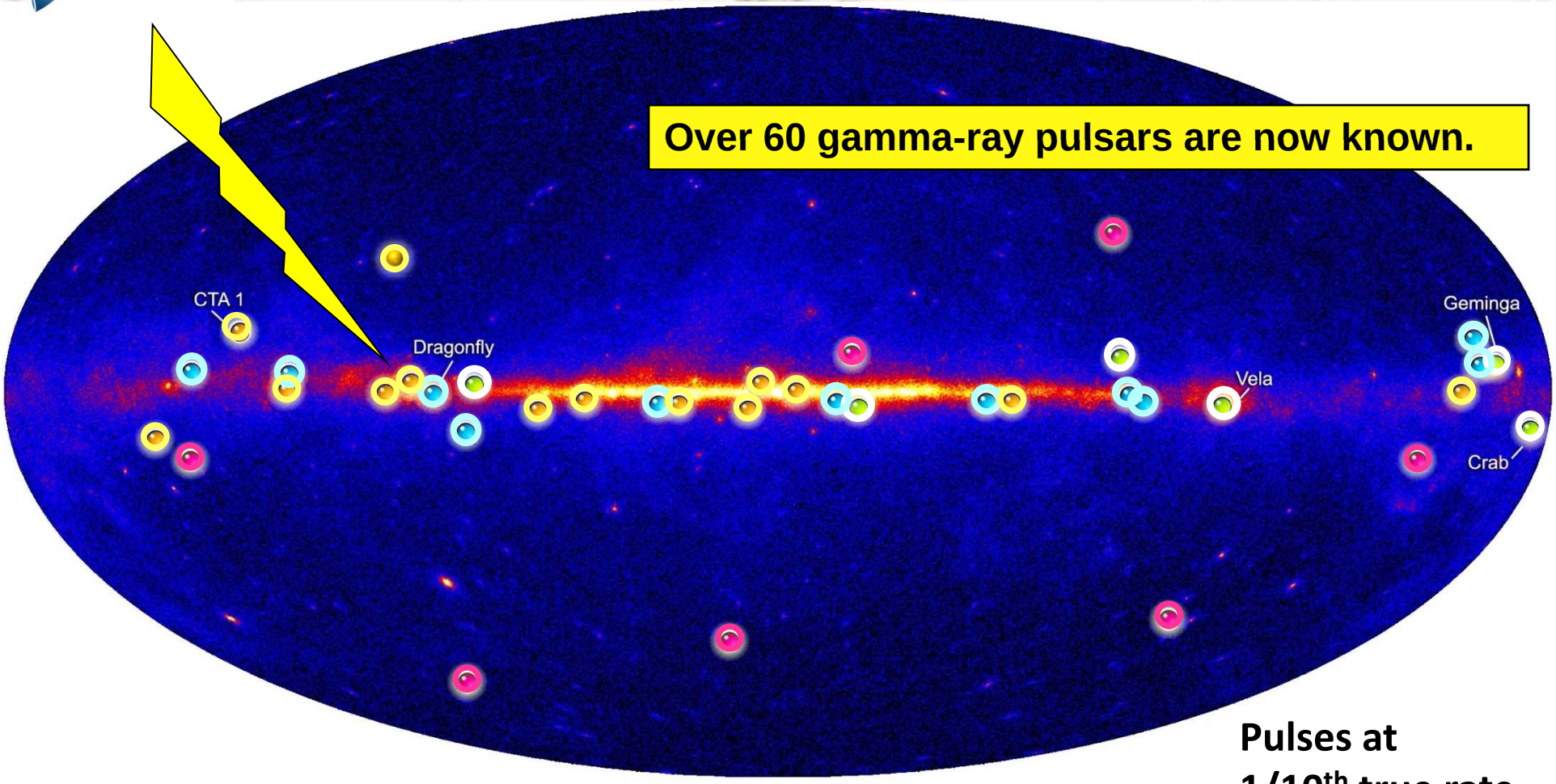
On behalf of the Fermi LAT Collaboration

(Scineghe2010, September 9, 2010)

The Pulsing γ-ray Sky

Fermi Gamma-ray Space Telescope

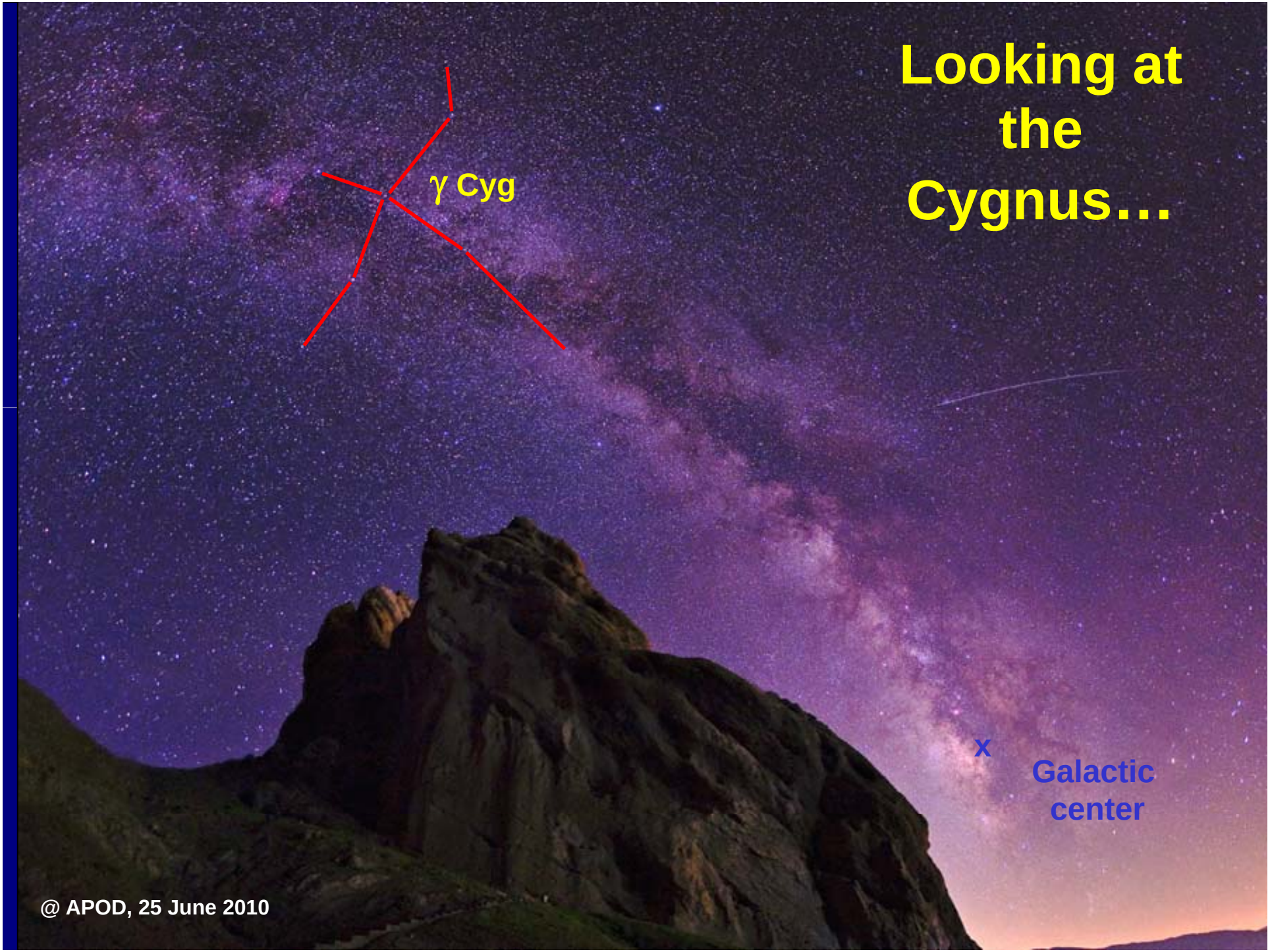
Over 60 gamma-ray pulsars are now known.



Pulses at 1/10th true rate

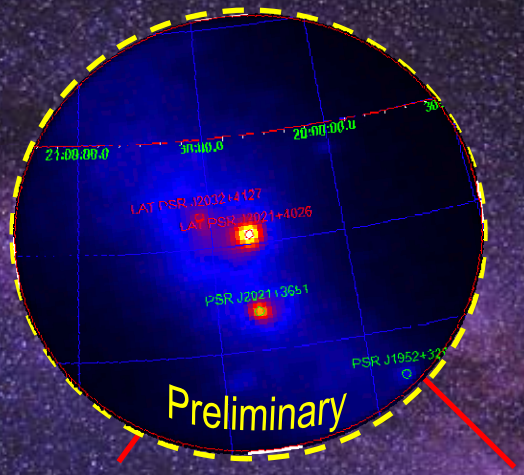
Fermi Pulsar Detections

- New pulsars discovered in a blind search
- Millisecond radio pulsars
- Young radio pulsars
- Pulsars seen by Compton Observatory EGRET instrument

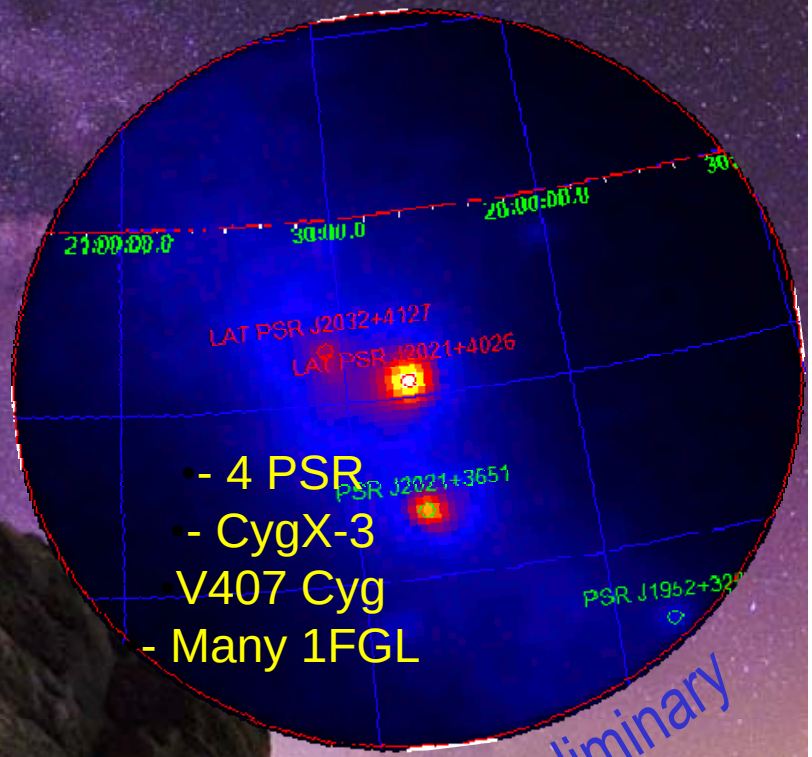

γ Cyg
Looking at the Cygnus…
x
Galactic center
@ APOD, 25 June 2010

Fermi view of Cygnus

Maybe not so romantic, but…



ROI 10 degrees



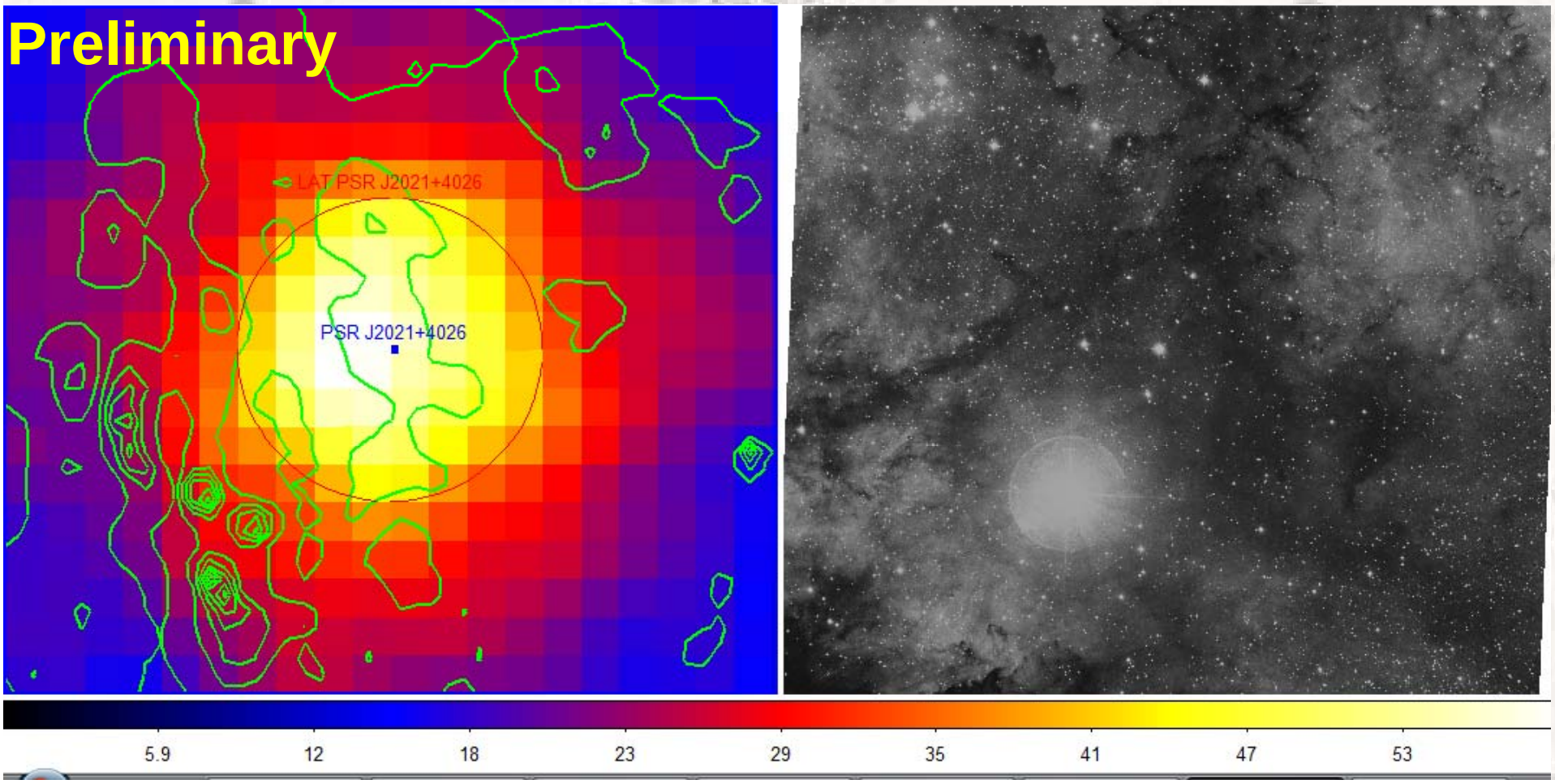
- 4 PSR
- CygX-3
- V407 Cyg
- Many 1FGL

Zooming on PSR J2021+4026

- Located within G78.2+2.1 (Gamma Cyg SNR);
- SNR-PSR: is it a real association?

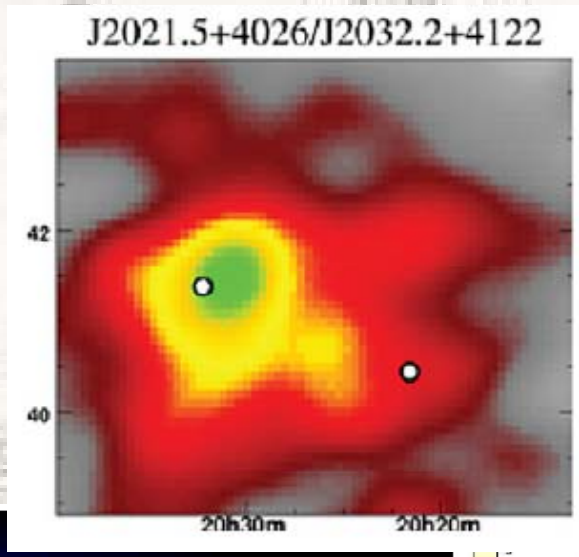
LAT+NVSS

0.1° DSS

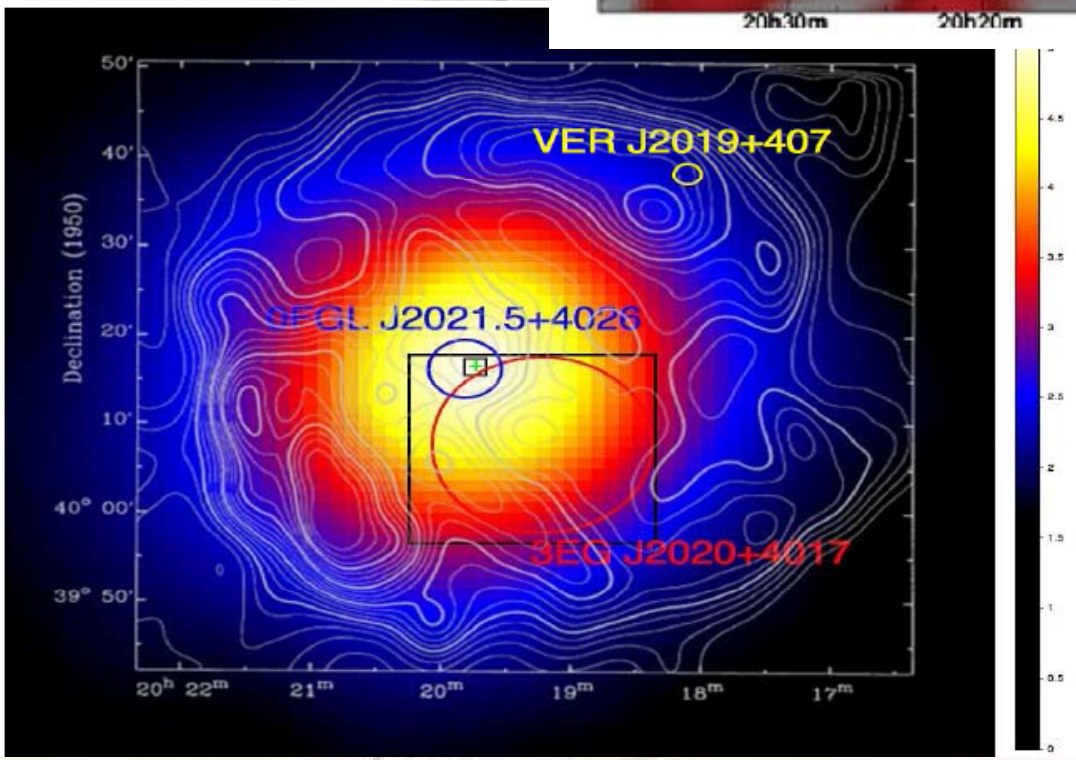


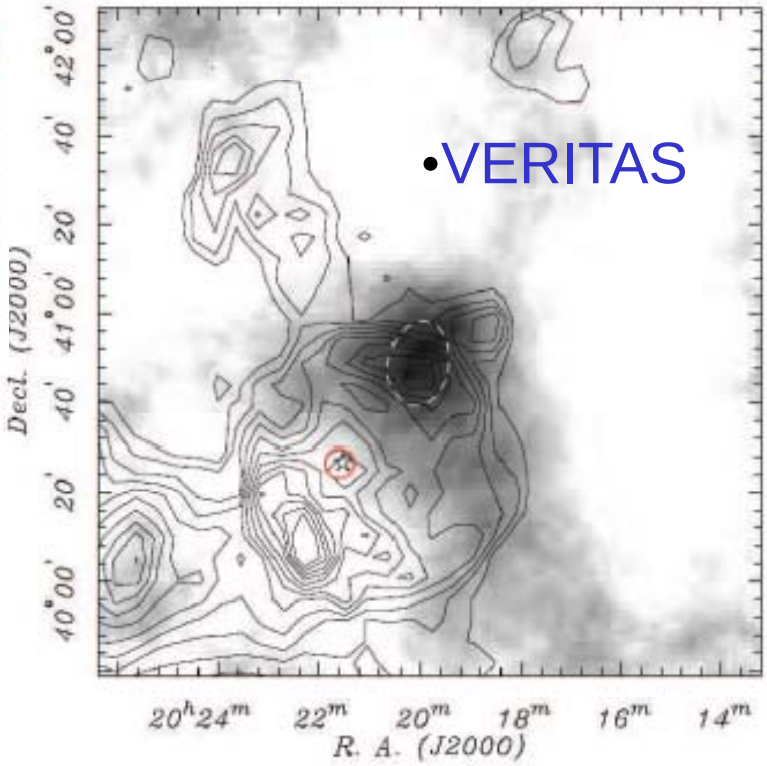
High energy emission from γ Cygni

•MILAGRO 4.2σ excess
(Abdo et al.,ApJL 2009)



Saz Parkinson
Saint Cugat Forum on
Astrophysics, 2010





(b)

VER J2019+409 map
(A. Weinstein,
2nd Fermi Symposium, 2009)

ID of PSR J2021+4026

Discovered by Fermi with blind searches,
(see talk by P. Saz Parkinson)

- Some useful quantities
  - P=265 ms
  - Pdot=5.5×10^{-14}
  - Char. age τ_c ~ 77 kyr
  - E_{SD}~ 10^{35} erg/s
  - B~4×10^{12} G

  - Distance=1.5 ± 0.4 kpc (IF is SNR-associated), Landecker et al., 1980

Searches for radio, optical and X-ray counterpart…

The quest for association

- **Best candidate is S21 (Weisskopf et al. 2006)**
  - **R.A.=20:21:30:55±1.18” , dec=+40:26:46.89 ±0.84” (Chandra)**
- **LAT timing position:**
  - **RA=20:21:29.85 ±0.01” Dec=+40:26:46.18 ±0.4” (syst ~2.5”)**

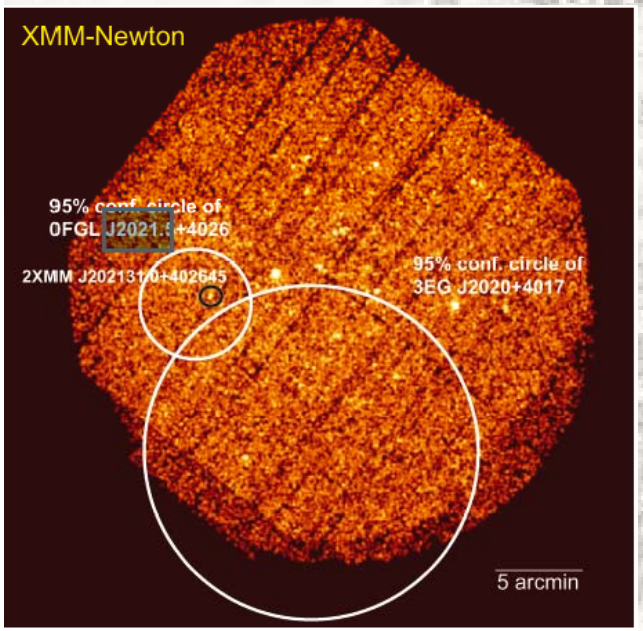


Figure 1. The image as observed by *XMM–Newton* in the energy range of 0.3–10 keV on 2003 December 1 with the MOS1/2 and PN data merged. The aim-point of this observation was towards the geometrical centre of SNR G78.2+2.1. The 95 per cent confidence circles of the γ-ray sources PSR J2021+4026 and 3EG J2020+4017 are illustrated as white circles. The small black circle indicates the position of 2XMM J202131.0+402645.

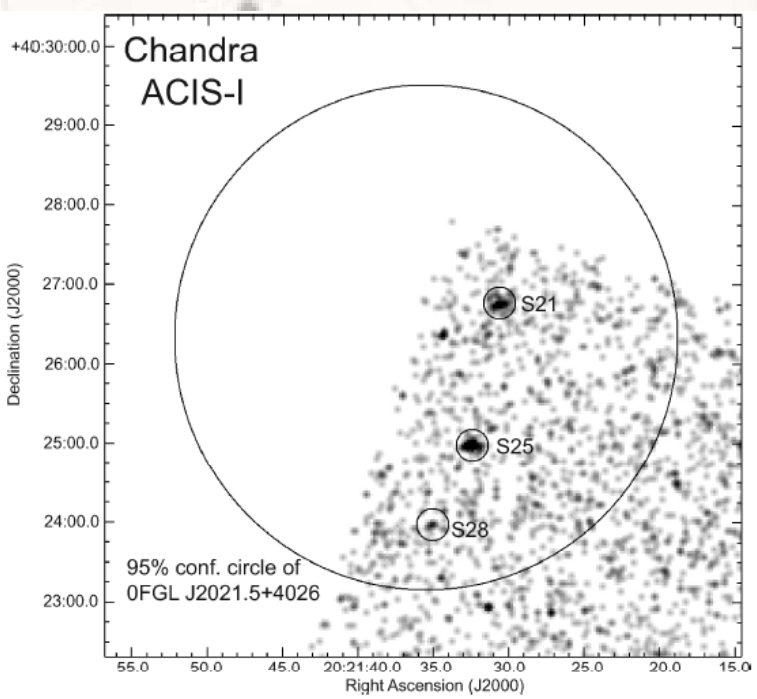


Figure 3. The 8 × 8 arcmin^2 field centred at the nominal γ-ray position of PSR J2021+4026 which is partly covered by a *Chandra* observation. The displayed image is in the energy range of 0.5–8 keV. Three sources located in the 95 per cent confidence circle of PSR J2021+4026 are labelled with the same designations as in Weisskopf et al. (2006).

A MNRAS paper on this PSR

- **Trepl et al., MNRAS, 405, 1339 (ext. auth)**

- **Archival multi-λ analysis**
  - **A XMM source (2XMM J2031.0+402645) confirms the Chandra S21 counterpart Fermi proposed in the discovery paper**
  - **Radio @ Urumqi Obs. → No detection, UL 0.1 mJy**
  - **Radio @NVSS → 2 features, beamed emission?**
  - **Optical @ DSS and USNO-B1.0 --> Nothing (~m>21)**
- **Fermi analysis (~ 1 yr)**
  - **Grid timing → consistent with the 2XMM src**
  - **XSpec spectral analysis (G ~1.85, Ecut ~ 3.86 GeV, F ~ 1.45×10^{-6})**
- **Modeling**
  - **Outer Gap (Cheng K.S.) → ζ ~90° α ~ 40°**

Timing solution for PSR J2021+4026

- **Best TEMPO2 timing solution derived directly from gamma rays**
- **Validity extends up to May 27, 2010**

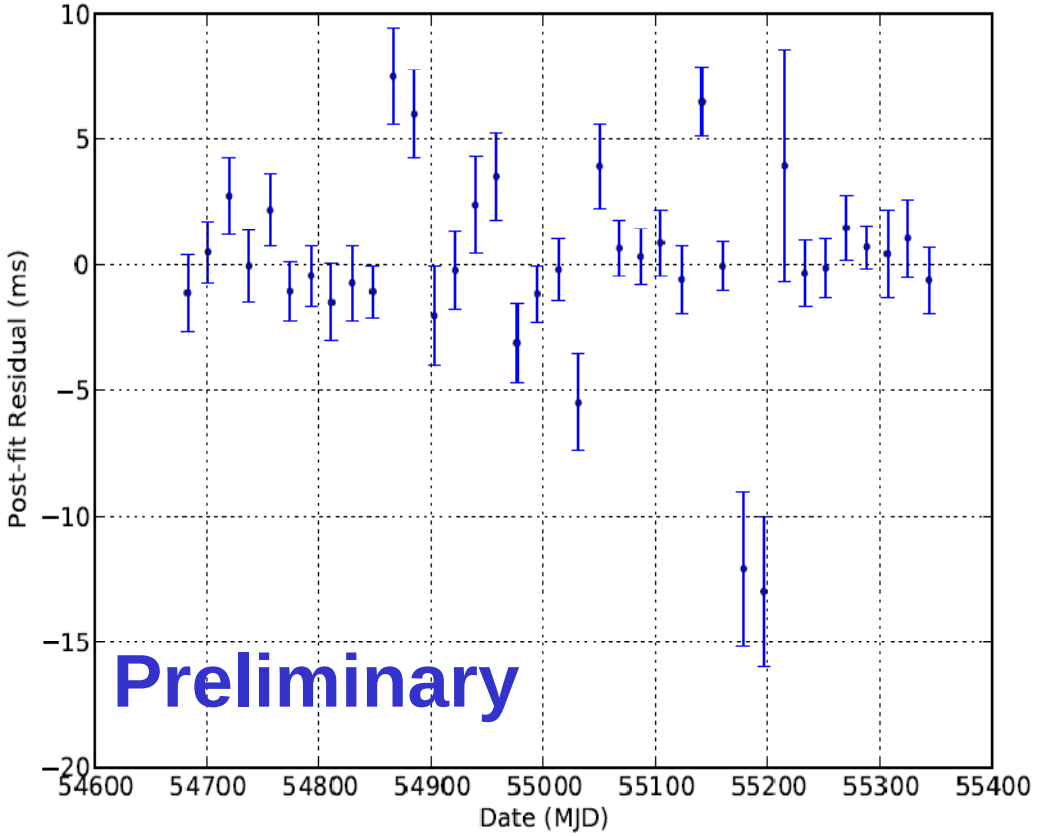
- **Quite noisy: rms is ~2500 us,**

- **Best timing position:**
  - **RA=20:21:29.85**
  - **Dec=+40:26:46.18**

Timing position is ~5” from S21,

but nearest X-ray sources→ likely counterpart

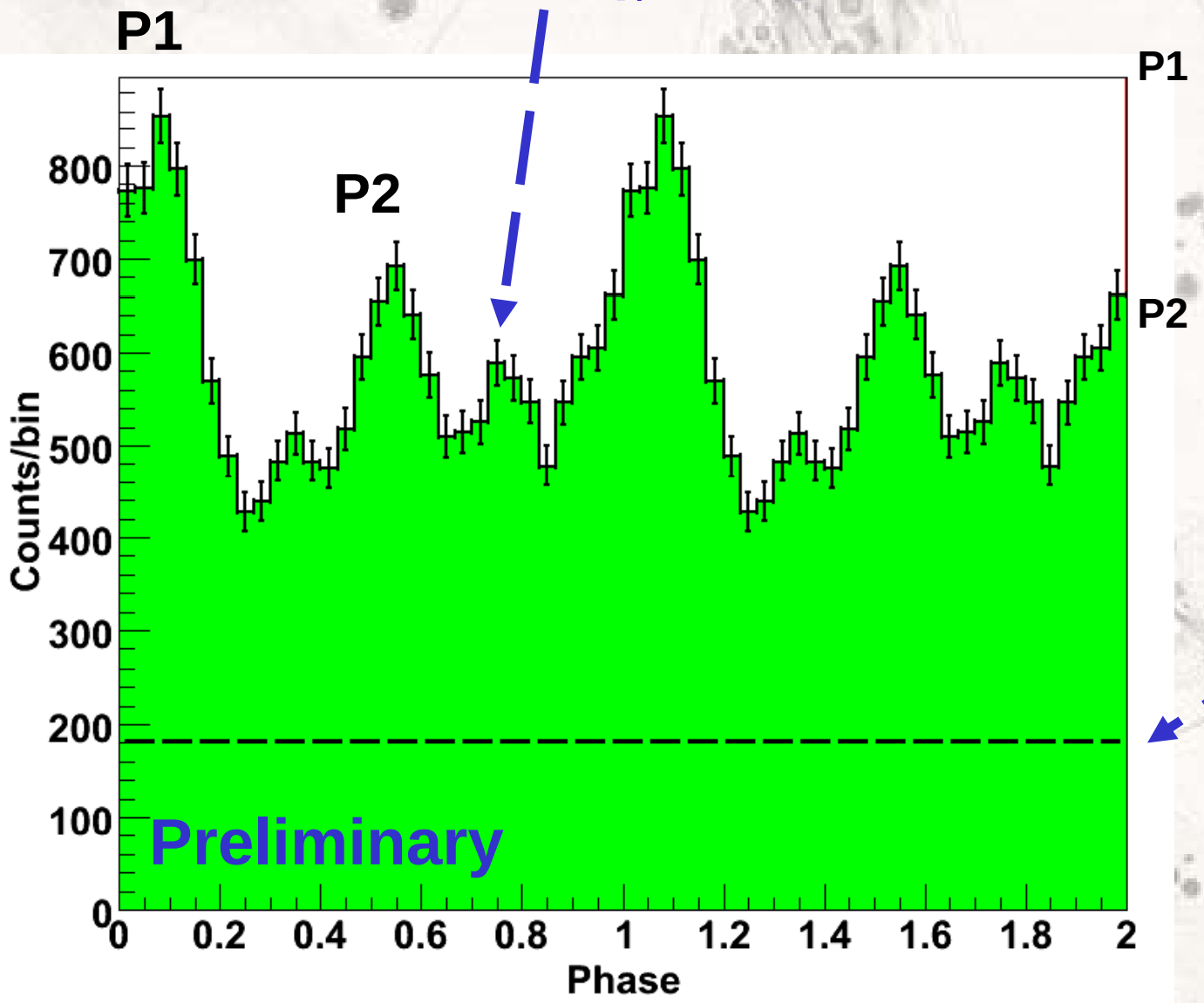
+systematics



Dataset and cuts

- ✓ **Diffuse class, zmax < 105°**
- ✓ **P6_V3_DIFFUSE**
- ✓ **Timing analysis:**
  - ✓ **Data from Aug 4, 2008 to 27 May 2010**
  - ✓ **Optimal ROI=0.9°, E>300 MeV**
- ✓ **Spectral analysis**
  - ✓ **Data from Aug 4, 2008 to Aug 8 2010**
  - ✓ **ROI=10°;**

Lightcurve at E>300 MeV



- @0.067 ± 0.004
- FWHM= 0.14 ± 0.01

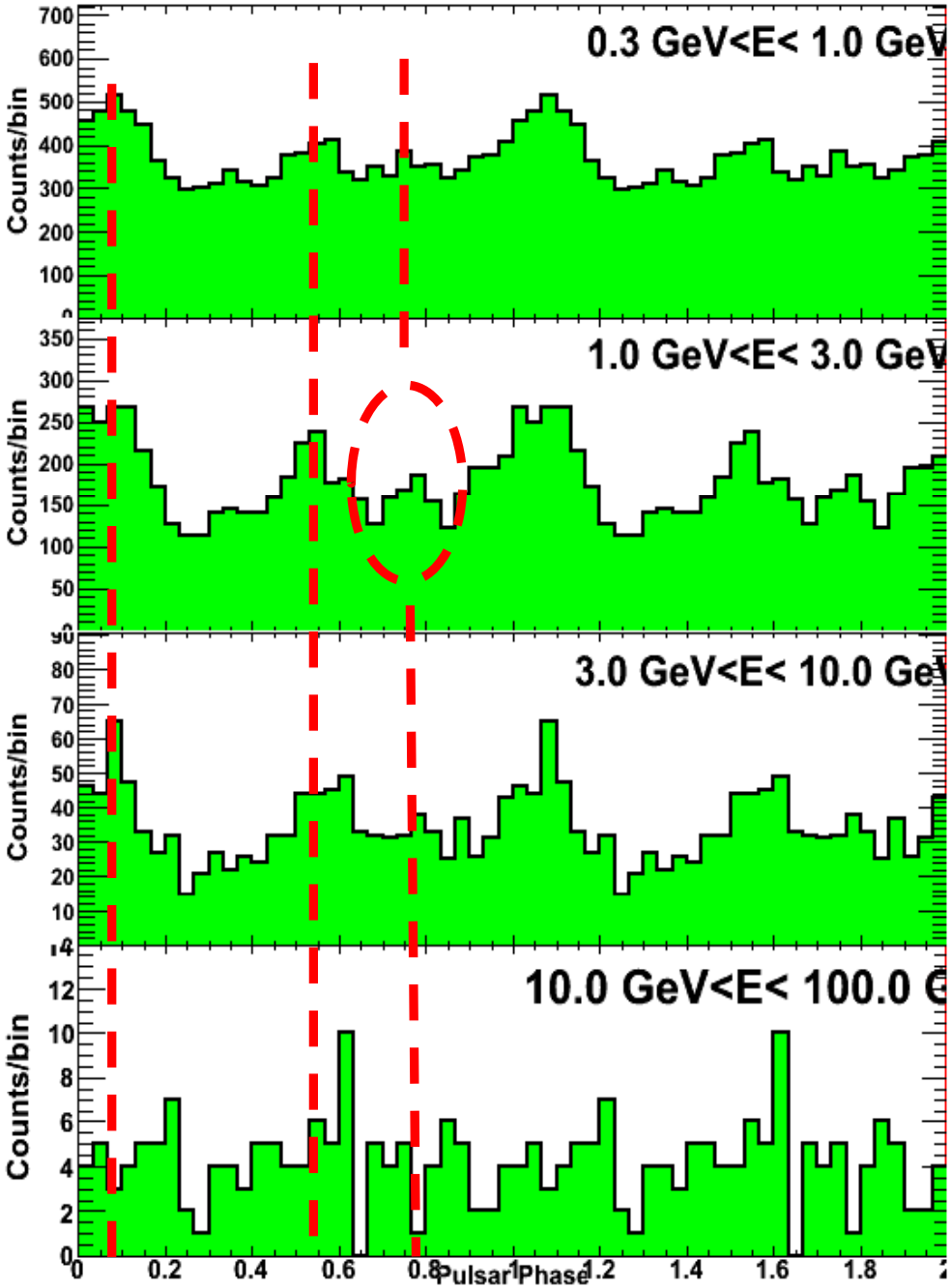
- @0.547 ± 0.006
- FWHM=0.13 ± 0.01

Background estimate

based on prob that γ from the source

$N_{bg}=\Sigma(1-p_i)$

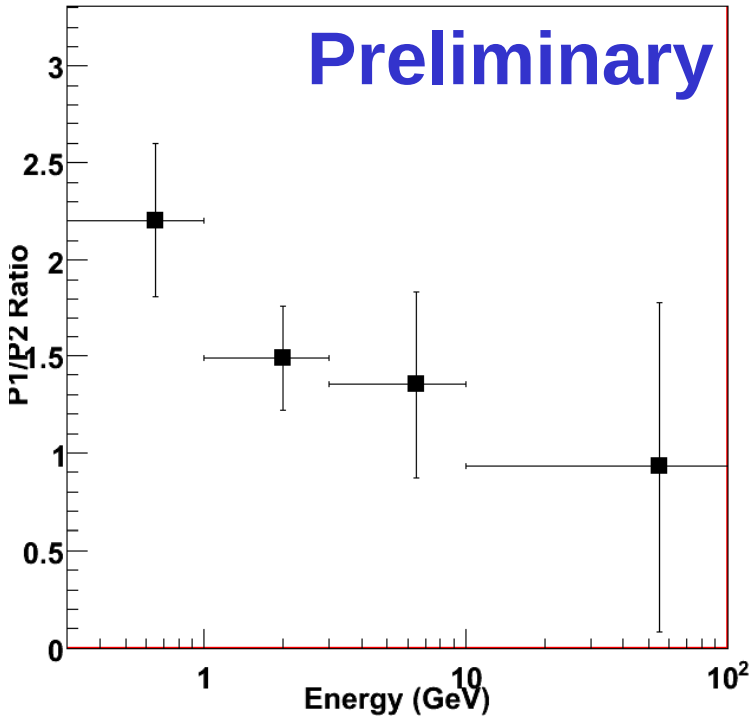
Preliminary



Lightcurve evolution in energy

- P3 seems to be more visible @ 1-3 GeV
- Investigating with timing and more data

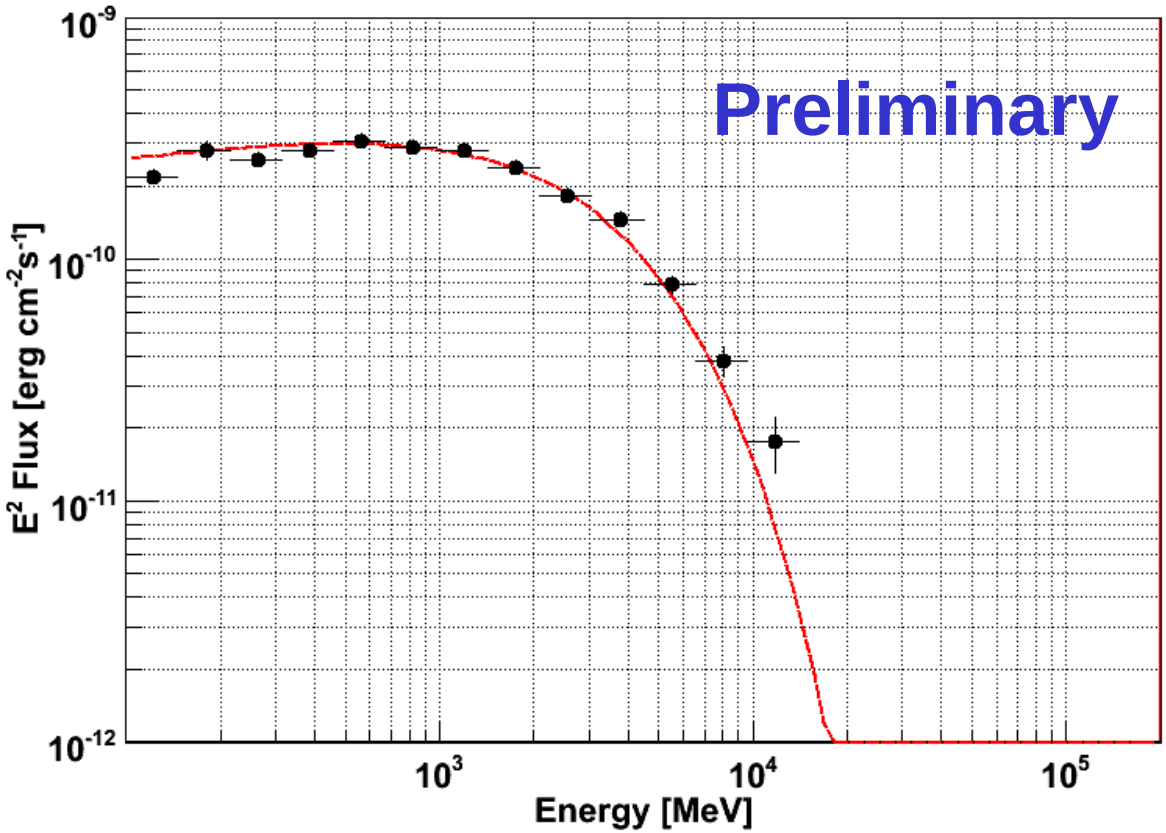
Preliminary



Phase-averaged spectrum

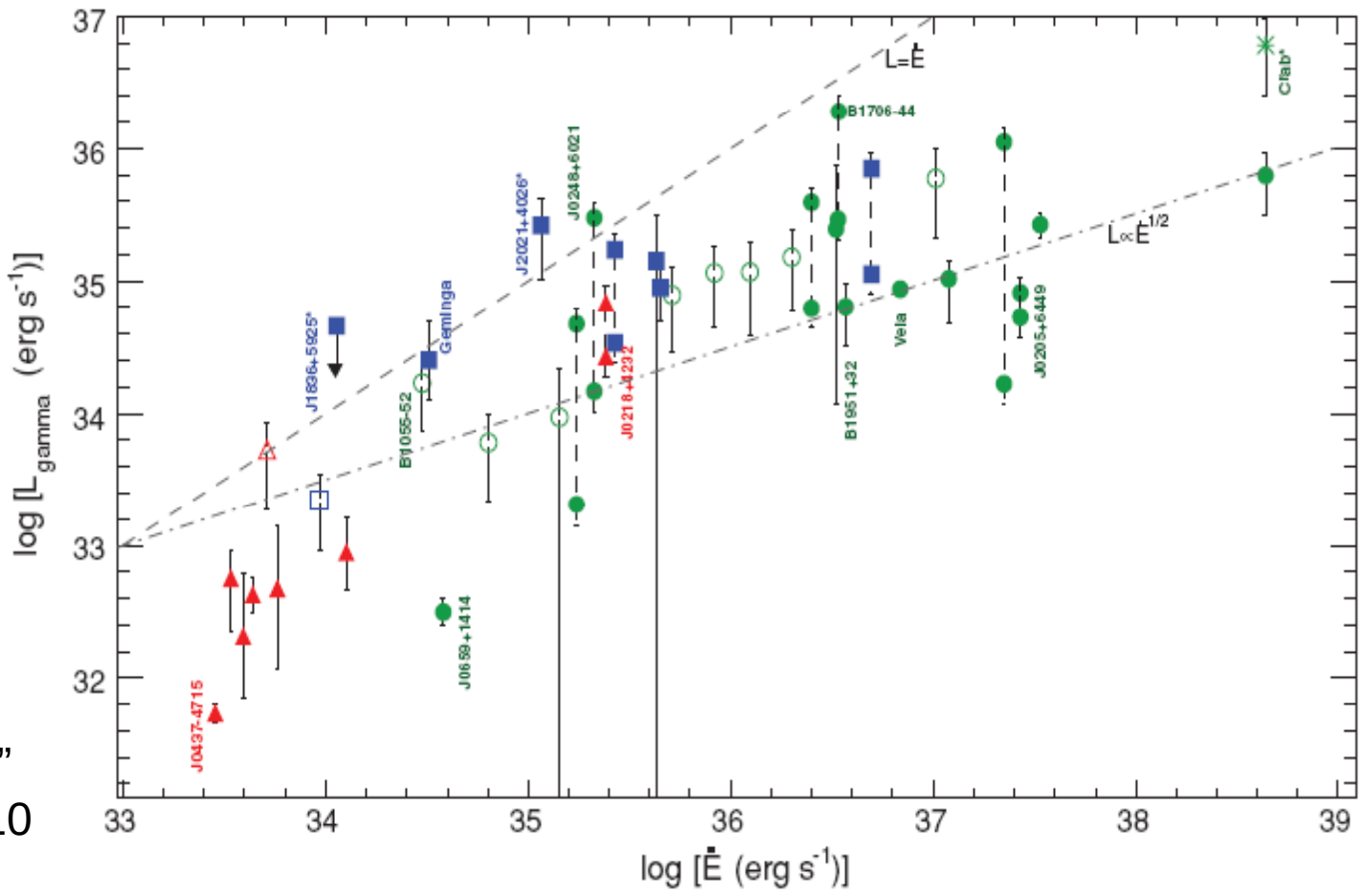
- Sources modeled from 1FGL catalog
- Sources < 5° free, <9° free normalization
- Unbinned likelihood, PL+exp cutoff
  - Γ=1.817 ± 0.016
  - Ecut=2.67 ± 0.06 GeV

    Flux (>0.1 GeV) = 1.69 ± 0.06 x 10^{-6} ph/cm2/s •
  - →E_{flux} (>0.1 GeV) ~10^{-9} erg/cm2/s



Efficiency in gamma rays

- Assuming d=1.5 kpc, age of 6.6 kyr <<t_c
- Interestingly, PSR J2021+4026 has a suspiciously large efficiency
- A foreground object would lead to a efficiency in line with other PSRs



from the
"pulsar catalog paper"
Abdo et al., ApJS 2010

Conclusions

- **PSR J2021+4026 is an interesting young gamma-ray selected pulsar**
- **Pulse profile shows two peaks separated by ~0.4 in phase**
- **Spectrum compatible with PL+exp cutoff**
- **Counterpart and association with SNR**
- **Large unpulsed component, due to magnetospheric emission? Can be interpreted by Two Pole caustics models**
- **X-ray observations suggest that a PWN should be very faint and small (See F. Giordano's talk)**
- **Analysis in process, paper is in preparation**