PSR J2021+4026: the pulsar in Gamma Cygni SNR

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On behalf of the Fermi LAT Collaboration

(Scineghe2010, September 9, 2010)
Over 60 gamma-ray pulsars are now known.
Looking at the Cygnus...
Fermi view of Cygnus

Maybe not so romantic, but…

ROI 10 degrees

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

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Zooming on PSR J2021+4026

- Located within G78.2+2.1 (Gamma Cyg SNR);

- SNR-PSR: is it a real association?

LAT+NVSS

Preliminary
High energy emission from $\gamma$ Cygni

• MILAGRO 4.2$\sigma$ excess (Abdo et al., ApJL 2009)

Saz Parkinson
Saint Cugat Forum on Astrophysics, 2010

VER J2019+409 map
(Å. 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=5.5x10^{-14}
  ➢ Char. age $\tau_c \sim 77$ kyr
  ➢ $E_{SD} \sim 10^{35}$ erg/s
  ➢ $B \sim 4x10^{12}$ 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 J202131.04−402645.

Figure 3. The 8 × 8 arcmin² 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 ~ 1.45x10^{-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

A real P3? ($\phi \sim 0.76$)

- $@0.067 \pm 0.004$
- FWHM = 0.14 ± 0.01

- $@0.547 \pm 0.006$
- FWHM = 0.13 ± 0.01

Background estimate based on prob that $\gamma$ from the source

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

Lightcurve evolution in energy

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

\[ \text{Counts/bin} \]

\[ \text{Pulsar Phase} 0 \quad 0.2 \quad 0.4 \quad 0.6 \quad 0.8 \quad 1.4 \quad 1.6 \quad 1.8 \]

\[ \text{Energy (GeV)} \]

\[ 0.3 \text{ GeV} < E < 1.0 \text{ GeV} \]

\[ 1.0 \text{ GeV} < E < 3.0 \text{ GeV} \]

\[ 3.0 \text{ GeV} < E < 10.0 \text{ GeV} \]

\[ 10.0 \text{ GeV} < E < 100.0 \text{ GeV} \]
Phase-averaged spectrum

- Sources modeled from 1FGL catalog
- Sources < 5° free, <9° free normalization
- Unbinned likelihood, PL+exp cutoff
  - $\Gamma = 1.817 \pm 0.016$
  - $E_{\text{cut}} = 2.67 \pm 0.06$ GeV
  - Flux (>0.1 GeV) = $1.69 \pm 0.06 \times 10^{-6}$ ph/cm²/s
  - $E_{\text{flux}} (>0.1$ GeV) $\sim 10^{-9}$ erg/cm²/s

Preliminary
Efficiency in gamma rays

- Assuming $d=1.5$ kpc, age of $6.6$ kyr $\ll t_c$
- 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