Fermi LAT observations
of gamma-ray pulsars in the Cygnus region

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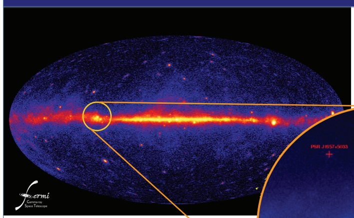
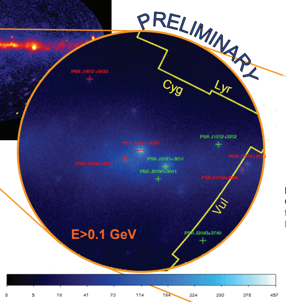
An updated summary on the pulsars detected in this region, one of the most interesting of the gamma-ray sky

The Cygnus region has long been known as one of the most complex and interesting regions in the gamma-ray sky, containing pulsars, supernova remnants, the Cygnus-OB2 association and the Cyg X-3 microquasar. In particular, the bright LAT-detected gamma-ray pulsars account for a large part of the gamma-ray emission from this crowded region, as exemplified by J2021+4026 (Gamma Cygni) and J2021+3651 (the Dragonfly). We report updated results from 2.5 years of Fermi LAT observations of gamma-ray pulsars in the Cygnus region, as well as a study of unidentified sources in the region that are good pulsar candidates.

Unveiling new gamma-ray pulsars in Cygnus



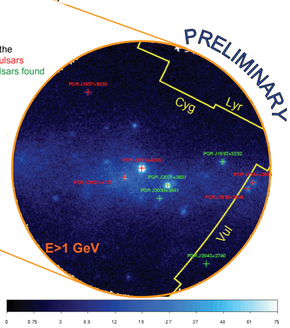
Fermi 1-year skymap above 300 MeV



Located on the Galactic plane at ~80° from the Galactic center, the Cygnus region is one of the most complex and interesting portions of the gamma-ray sky.

Both COS-B and EGRET detected several unidentified sources in this region. Now Fermi LAT is unveiling their nature and discovering remarkable new sources, such as: pulsars, the Cyg X-3 microquasar, the V407 Cyg nova, and new extended sources such as the Gamma Cygni supernova remnant (SNR) or the diffuse emission from the "Cygnus cocoon". Most of these sources are discussed with more details in separate contributions at this Symposium (see References).

Maps of the sky within 15° of the Gamma Cygni SNR, showing pulsars found in blind searches and pulsars found by folding radio ephemerides



Fermi observations revealed that the Cygnus region is crowded with many new gamma-ray pulsars. Some have been discovered by folding gamma rays using the radio ephemerides, while others have been found in blind searches

PSR Name	*Photon flux (>0.1GeV)* (>100 MeV 10^{-8} ph cm^{-2} s^{-1})	*P* (ms)	*$\dot{P}$* (10^{-15})	*Char. Age* (kyr)	*$\dot{E}_{SD}$* (10^{34} erg s^{-1})	*Notes and references*
J1952+3252	17.6 ± 1.9	39.5	5.8	110	374	EGRET pulsar in CTB 80 SNR [1],[2],[3]
J1954+2836	11.9 ± 1.6	92.7	21.2	69.5	104.8	[4]
J1957+5033	3.3 ± 0.5	374.8	7.1	837.7	0.5	[4]
J1958+2846	7.65 ± 1.6	290	222	21	35.8	[5],[3]
J2021+3651	67.4 ± 0.4	104	95.6	17	338	In the "Dragonfly" PWN (G75+0.1) [6],[7],[3]
J2021+4026	152.6 ± 4.9	265	54.8	77	11.6	In the Gamma Cygni SNR [8][9][5][3]
J2030+3641	6.5 ± 0.1(*)	200.1	6.5	487	3.2	[9][10]
J2032+4127	6.0 ± 2.3	143	19.6	120	26.3	Radio counterpart discovered at GBT [5][11]
J2043+2740	2.4 ± 0.1	96.1	1.3	1200	5.6	[12][3]

Summary of properties of gamma-ray pulsars in Cygnus
within 15° of the Cyg SNR, including pulsars found with blind searches or folding radio ephemerides. (*) Preliminary.

Searching for new pulsars

The Cygnus region hosts several unidentified sources that might turn out to be pulsars. We tried to select some potential unidentified sources suitable for blind searches. We started from a very basic approach considering all sources in the region and with no association.

The first parameter we considered is the ***variability index V***, an important criterion since pulsars have been shown to be less variable than most other sources. Assuming the variability in the first year of observations, as reported in the first LAT source catalog [14], a index V>23.21 means that the source is variable at a 1% confidence level.
As an additional criterion, we used the ***curvature index C***, defined in 1FGL as a measure of the departure of the spectrum from a power law. This could be an useful parameter, given the fact that LAT pulsars show a power law with a cutoff. As an example, considering the 5-bands spectra of the 1FGL catalog, at a 1% confidence level, a spectrum Is significantly different from a power law if C>11.34.
As an example, we ran these simple selection cuts on the 1FGL sources, finding that the top source is 1FGL J2030.0+3641 (V=3 and C=31.1), which was later discovered as a radio pulsar by GBT [10], or 1FGL J2030.9+4411 (V=3.9, C=29.2). We are going to apply the same filtering to the 2FGL catalog, in order to select possible interesting sources for blind searches.

References

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[16] Tibaldo, "The Fermi LAT view of cosmic rays and interstellar gas in the Cygnus X region", Poster
[17] Tibaldo, "The Fermi LAT unveils a coocon of freshly-accelerated cosmic rays in the Cygnus X", Talk
[18] Cheung, "Fermi LAT Discovery of Gamma-ray emission concurrent with the nova in the Symbiotic binary V407 Cygni", Talk

An intriguing pulsar

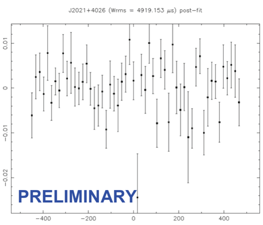
PSR J2021+4026 is a 265 ms pulsar found by Fermi LAT using blind searches based on the time-differencing technique [5]. This discovery help to better clarify the nature of the unidentified source 3EG J2020+4027, thought to be associated with SNR 78.2+2.1, a.k.a. the Gamma Cygni SNR.
Unfortunately, so far this pulsar lacks a radio counterpart, and observations with Chandra and XMM show a potential X-ray counterpart [8,9,15], but no pulsations have been detected so far.

Therefore, gamma rays are still the best way to study this source. First of all, light curve and spectral analyses are fundamental for investigating its emission mechanism and for constraining its beaming geometry. Moreover, timing this pulsar in gamma rays is the best way of arriving at an accurate position for the gamma-ray source and possibly confirm the most plausible X-ray counterpart.

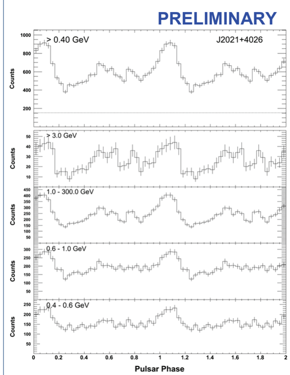
We present here updated results on PSR J2021+4026, based on a dataset ranging from Aug 4, 2008 to March 12, 2011.

We built a timing solution based on gamma-rays within an ROI of 0.7° and E>400 MeV, using Pass6 data and filtering events belonging to the 'diffuse' class.

Following timing procedure reported in [13], we integrate 17 days for each Time of Arrival (TOA), resulting in a total of 55 TOAs



Timing noise residuals associated to the timing solution based on 2,6 years of observations



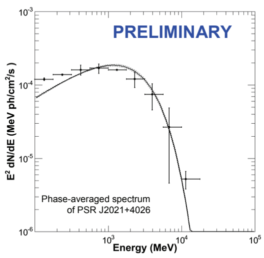
Using the same cuts on gamma rays, we built light curves in various energies.

Two broad peaks separated by ~0.5 in phase are visible at all energies.
An interesting feature is the third peak showing up at higher energies (>1 GeV).

Light curves of PSR J2021+4026 in various energy bands

We used the standard binned gtlike tool for studying the phase-averaged spectrum of PSR J2021+4026.
We fit the data with a power law with an exponential cutoff (PLEC) in the form:

$$dN\gamma/dE \sim E^{-\Gamma} \; exp\left(\frac{-E}{E_0}\right)$$



	PLEC
Spectral index Γ	1.33 ±0.02
Energy cutoff E_0 (GeV)	1.75 ± 0.05
Photon flux >0.1 GeV (10^{-6}ph cm^{-2} s^{-1})	1.07 ± 0.01

PRELIMINARY