# Blazar Counterparts for Low-Latitude Unidentified Sources: 1FGL J2015.7+3708 and 1FGL 2027.6+3335

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Summary: We present the associations for 1FGL J2015.7+3708 and 1FGL J2027.6+3335 in the Cygnus region based on correlated variability between Fermi gamma-ray light curves and OVRO radio light curves. The resulting spectral energy distribution shows a broad Inverse Compton component.

## Abstract

Previous studies in the Cygnus region proposed blazar counterparts for 1FGL J2015.7+3708 and 1FGL 2027.6+3335 [1,2,3]. Now, the analysis of 31 months of Fermi-LAT data reveals that the sources are variable, supporting the hypothesis of extragalactic origin of the gamma-ray emission. We present here the associations for 1FGL J2015.7+3708 and 1FGL J2027.6+3335 based on correlated variability between gamma-ray and radio light curves. We produce gamma-ray light curves from the LAT using the Fermi ScienceTools and obtain radio light curves at 15 GHz taken with the 40-m telescope at the Owens Valley Radio Observatory (OVRO). Simultaneous variability is seen in both bands for the two blazar candidates. The resulting spectral energy distribution shows a broad Inverse Compton component. Lastly, we resolve a third steady gamma-ray source in the region with spectral characteristics similar to known LAT pulsars.

## 1FGL J2015.7+3708 and 1FGL J2027.6+3335

- We perform an analysis of two unidentified sources in the Cygnus region: 1FGL J2015.7+3708 and 1FGL J2027.6+3335 [4]
- With a 31-month analysis of Fermi-LAT data, we find:
  - **1FGL J2015.7+3708** is spatially coincident with blazar B2013+370
  - **1FGL J2027.6+3335** is best fit by two sources: J2025+3342, a variable source spatially coincident with blazar QSO B2023+336 and J2028+3333, a steady source with spectral characteristics similar to LAT pulsars [6].

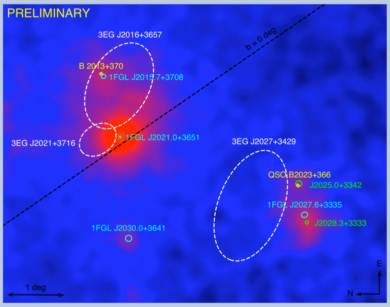


*Fig 1:* Smoothed Fermi-LAT counts map for E > 300 MeV of 1FGL J2015.7+3708 (left) and 1FGL J2027.6+3335 (right) in the Cygnus region. Contours indicate 95% c.l. error ellipses for EGRET [5, white] and Fermi 11-month catalog [4, cyan]. Green circles indicate the 95% c.l. error circle derived in this analysis, and yellow points indicate the catalog positions for the two blazars.

## Spectral Energy Distribution

- Spectral energy distribution for the average state and high-state of B2013+370 with radio, X-ray and gamma-ray data
- The flaring state in gamma-rays is consistent with a high state in X-rays (August 2010)
- The hard X-ray spectrum suggests a very broad Inverse Compton component
- Further analysis of optical data will be completed to better characterize the synchrotron emission component

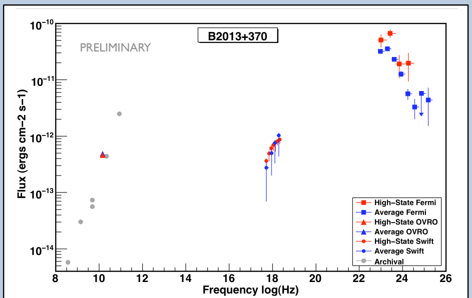


*Fig 2:* Spectral Energy Distribution for 1FGL J2015.7+3708 using OVRO (15 GHz), Swift XRT X-ray (2-10 keV) and Fermi Gamma-ray data (E > 300 MeV). The blue (average) points consist of archival XRT data from 2006, and an average over the 31 months of Fermi and OVRO data. The red (high-state) points consist of the Fermi and OVRO data from the entire month of August 2010, when there was a flare, and four concurrent XRT observations. The grey points are archival radio points from NED.

| | RA [deg] | DEC [deg] | $\sigma_{95\%}$ [deg] | TS | Fit | Flux (1-100 GeV) [$10^{-9}$ cm$^{-2}$ s$^{-1}$] | $\Gamma$ ($E_c$) | Counterpart |
|---|---|---|---|---|---|---|---|---|
| **1FGL J2015.7+3708** | 303.89 | 37.17 | 0.03 | 752 | Powerlaw | 8.93 ± 0.48 | 2.59 ± 0.05 | B2013+370 |
| **J2025+3342** | 306.26 | 33.70 | 0.05 | 280 | Powerlaw | 3.19 ± 0.33 | 2.94 ± 0.09 | QSO B2023+336, z=0.21 |
| **J2028+3333** | 307.08 | 33.55 | 0.03 | 1110 | Powerlaw with Exponential Cutoff | 9.13 ± 0.58 | 1.00 ± 0.08 (1.4 ± 0.2 GeV) | |

*Table 1:* Position and spectral parameters obtained in the analysis of 31 months of Fermi data.

## Variability and correlation studies

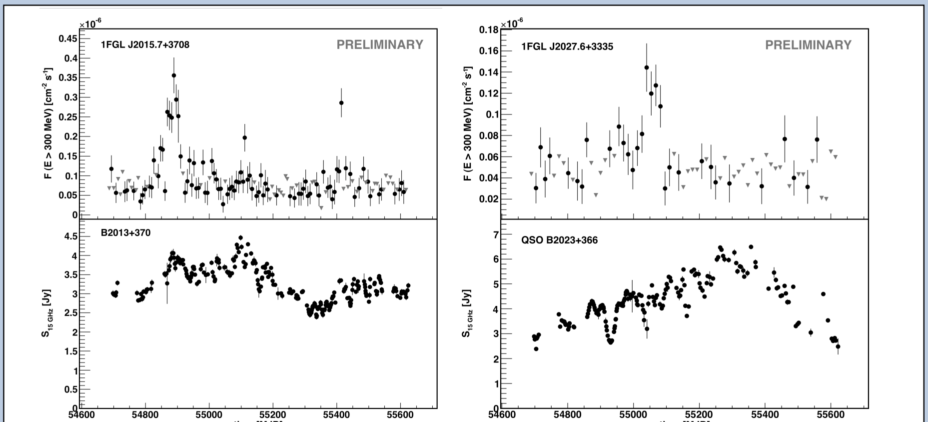


*Fig 3: Top:* Fermi-LAT light curves at E > 300 MeV for B2013+370 and QSO B2023+336 in 7-day and 14-day time bins, respectively. When the source was not detected, grey triangles show 90% c.l. upper limits. *Bottom:* 15 GHz radio light curve from the OVRO 40-m telescope. 1FGL J2015.7+3708 shows clear variability, and has three main flares in May and October 2009 and in August 2010. J2025+3342 is a week gamma-ray source and the light curve shows a hint of variability. The hypothesis of a steady flux is discarded with a probability of $3.5\cdot10^{-5}$ (4.1σ), supporting its identification as a blazar.

- **1FGL J2015.7+3708** is a strong gamma-ray source associated with B2013+370, and shows clear variability. The discrete correlation function between the gamma-ray and radio light curves shows the highest correlation at zero lag, although the significance of these peaks is still to be evaluated.
- **J2028+3333** is a weak gamma-ray source associated with QSO B2023+336 , and shows hints of variability. The hypothesis of a steady flux is discarded with a probability of $3.5\cdot10^{-5}$ (4.1σ).

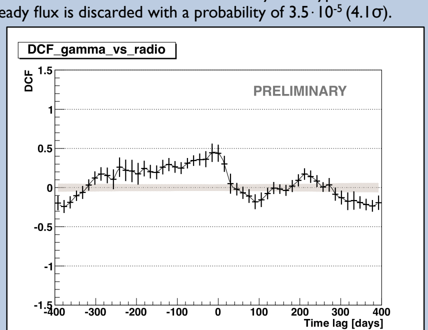


*Fig 4:* Edelson Discrete Correlation Function between Gamma-ray and radio light curves for 1FGL J2015.7+3708 (B2013+370)

## References

[1] Mukherjee, R. et al. 2000 ApJ 542, 704
[2] Halpern, J.P. et al. 2001 ApJ 551, 1016
[3] Sguera, V. et al. 2004 A&A 414,839
[4] Abdo, A. et al. 2010 ApJS 188, 405
[5] Mattox, J.R. et al. 2001 ApJS 135, 155
[6] Abdo, A. et al. 2010 ApJS 187, 460

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