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Verifying the Associations of Fermi Source 3FGL 2015.6+3709

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Overview

The Large Area Telescope (LAT) is the main instrument onboard the Fermi Gamma-Ray Space Telescope (Fig. 3), which surveys the entire gamma-ray sky eight times each day. More than 3000 gamma-ray sources have been detected by the LAT since its launch in 2008. Until recently, source 3FGL J2015+3709 has been associated with the blazar B2013+370 on the basis of GeV variability[3]. However, a new analysis reveals a second association with the pulsar wind nebula (PWN), VER J2016+371, within 6 arcminutes of the blazar[1]. When analyzed at energies above 30 GeV, the gamma-ray source shows an abrupt spectral hardening and the localization shifts to agree with that of the PWN. Both the PWN and blazar contribute to the source detected by the LAT catalog, indicating that the previous single-object association is insufficient in representing a complete picture of 3FGL J2015+3709 .

Key Findings

- **A double-object association for 3FGL J2015+3709 has been verified.**
- **The PWN, which is known to emit TeV gamma rays, dominates the source's energy spectrum at higher energies (Fig. 4).**
- **The position of the source is incident with the PWN at energies above 30 GeV (Fig. 5).**
- **The age of the PWN is shown to be roughly 1000 years, restricting previous age estimates of VER J2016+371 to their lower limits.**

Fig. 1

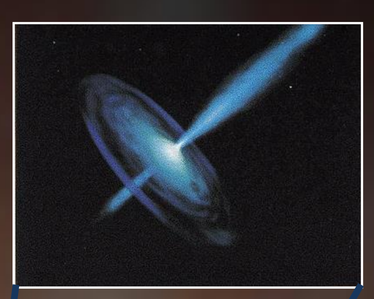

Fig. 2

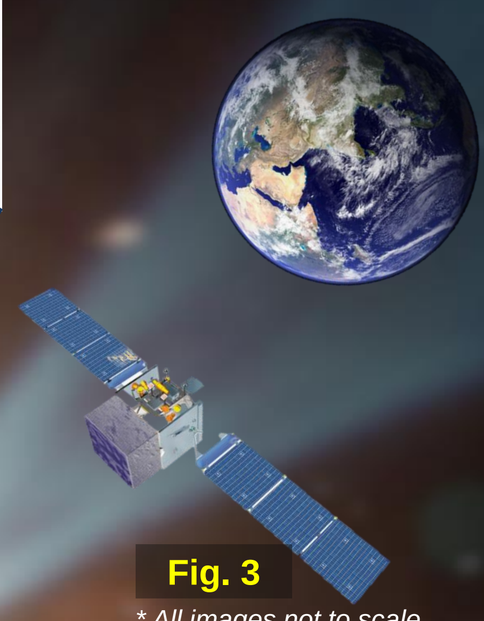

Fig. 3

** All images not to scale*

***Fig. 1** is an example of a Pulsar Wind Nebula (the Crab Nebula shown here). PWN are clouds of charged particles that have escaped along the B-fields of pulsars.*

***Fig. 2** is an example of a blazar, a class of active galactic nuclei with jets pointed in the direction of the observer.*

The Fermi LAT (Fig. 3) orbits Earth and collects images of 'sources', areas from which gamma rays are emitted. In this case, two objects were seen as one 'source' due to proximity.

Impact

As a result of our work, we now have a Python script that can be used to analyze other Fermi sources. Our work also shows that, despite having over 2000 associated Fermi sources, some associations may prove to be more complicated than single-object associations with further analysis.

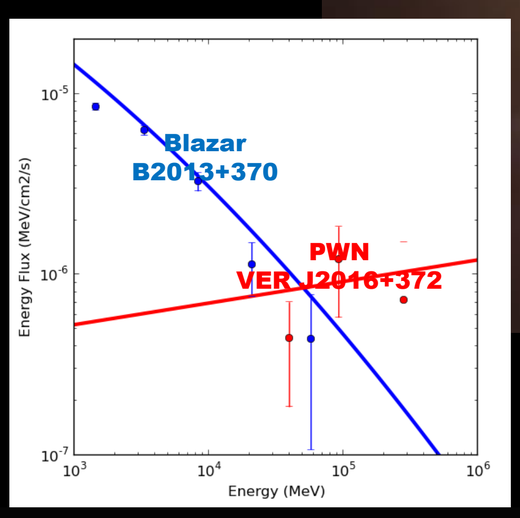

Fig. 4: Spectral Energy Distribution of 3FGL J2015+3709 showing the contribution of each source as a function of energy.

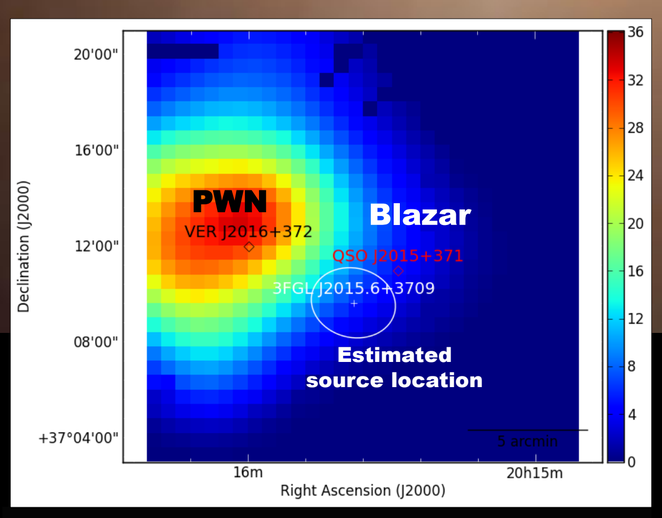

Fig. 5: Test-Statistic map revealing the most probably location of source **3FGL J2015+3709** at 30 GeV.

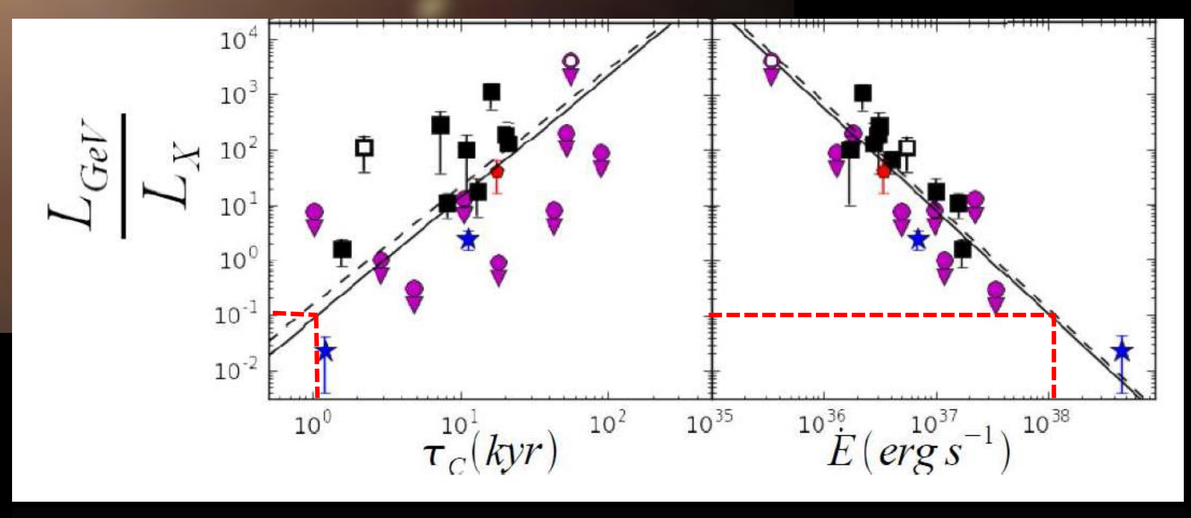

Fig. 6: A graph from Acero et al.[2] depicting a linear relationship between the gamma-to-x-ray ratio and the age (left) and spin-down energy (right) of the parent pulsar. The red lines represent **VER J2016+371**, with x-ray data from Matheson et al.[4]

Acknowledgements

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Referenced papers:

[1] Acero, F. et al. 2015, arXiv:1501.02003 [astro-ph.HE]
[2] Acero, F. et al. 2013, ApJ, 773, 77
[3] Kara, E. et al. 2012, ApJ, 746, 159
[4] Matheson, H, S. Safi-Harb, & R. Kothes. 2013, ApJ 774, 33

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