A Radio Multi-Survey Catalog of *Fermi* Sources

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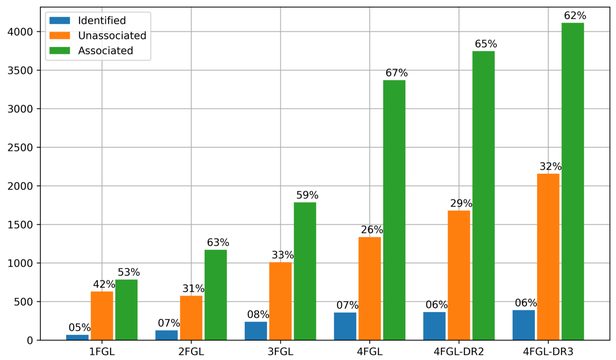
Abstract

Approximately 1/3 of all point sources discovered by the *Fermi Gamma-Ray Space Telescope* have no known counterpart in any other electromagnetic regime. As *Fermi's* associated and identified sources make up some of the most energetic systems in the sky, significant effort has been put into determining the nature of these **unassociated sources**, whether they be pulsars, activate galactic nuclei, or perhaps even more exotic phenomena.

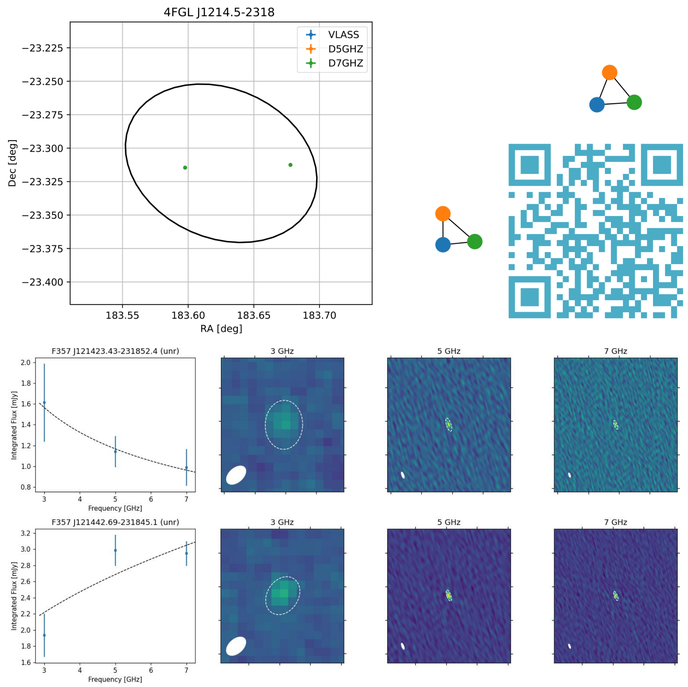
This poster describes efforts by this group to leverage existing radio catalogs to shed new light of these mysterious objects. Radio measurements have typically been one of the most powerful tools for the analysis of *Fermi* fields, and we continue that trend with this work



The Prototype

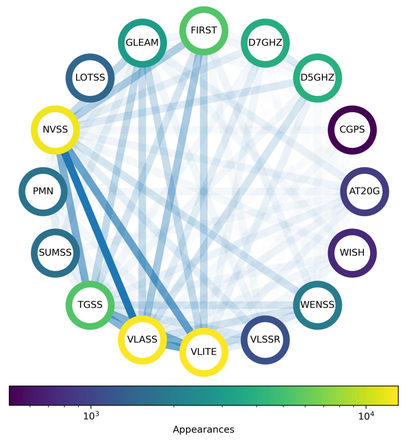
With each major release of the *Fermi* point source catalog (FGL), we performed dedicated C-band (5 and 7 GHz) observations on all new unassociated sources. The 4th catalog (4FGL) was released around the time that the first epoch of VLASS finished observing, and as such we could use it to augment our existing dedicated observations with new data at 3 GHz.

Using a graph/network approach to link sources based on uncertainty scaled distances, we generated our F357 catalog. Any source found at more than one frequency can be fit for a spectral index, giving immediate insight into the nature of the radio source and allowing for new selections of follow-up candidates. Alongside our catalog we also provide diagnostic images such as those shown here. Scan to QR code to read the paper.



Interconnectivity

It was quickly realized that this method could be extended to other catalogs. Especially in the Northern sky, a deep survey such as VLASS can act as a linchpin in our graphing system, providing linkages anywhere in the sky to find sources at multiple frequencies. As such we assembled a variety of catalogs and began to link them together.

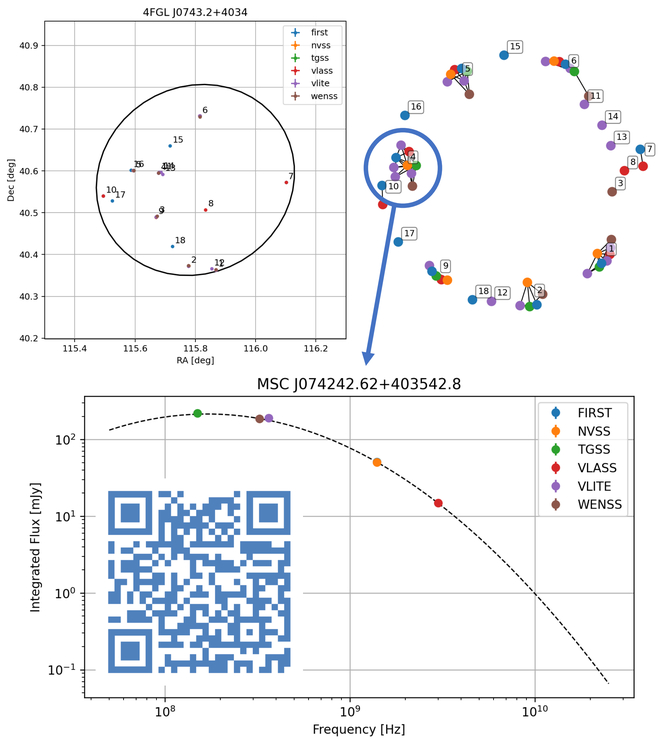


The MSC Catalog

The Multi-Survey Catalog (MSC) is the culmination of the work described above. Expanding the network approach to take in a significantly increased number of catalogs (16 in total), we gain both an expanded sky coverage, as well as a dramatically expanded frequency coverage. While F357 was limited to 3-7 GHz, the MSC spans from 100 MHz up to 20 GHz.

For every Fermi field (including the associated and identified ones, for the sake of rigor), we network sources inside the *Fermi* positional uncertainty ellipse, then fit the spectrum to the best degree we are able. For a significant number of sources there are even enough data points to fit for spectral curvature (such as the example to the right). We then assemble this fit, as well as the network member names, into a single catalog, provided alongside diagnostic images and sub-selection catalogs.

The intent is that this catalog serve as a first step, from which others can set their own selection criteria and perform observations to match those specific needs. Several use-cases are described in the Paper (which can be found by scanning the QR code), and some are illustrated in the next panel.

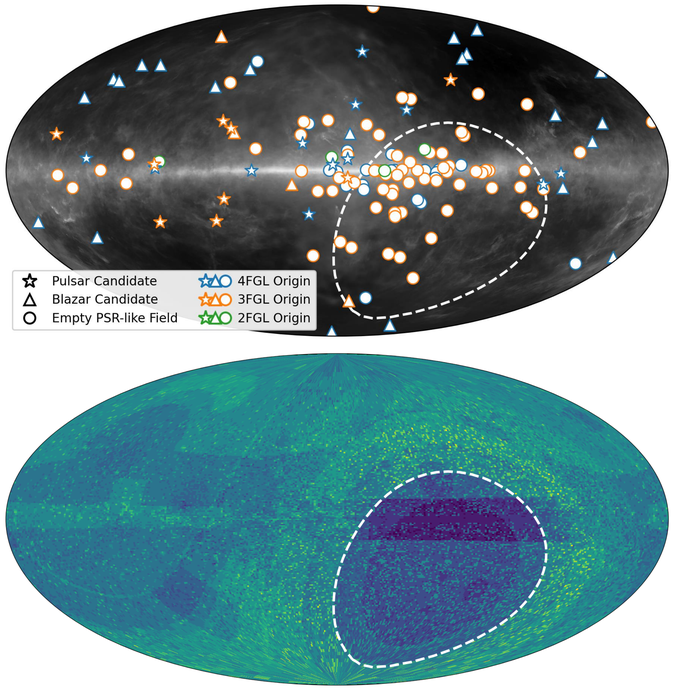


Targets on the Sky

There are a variety of ways to select interesting targets from the data provided in the MSC. As we especially take an interest in pulsars and their canonically steep spectra (Bates et al. 2013), one can select for sources with steep spectra and "pulsar-like" gamma-ray properties.

Similarly, one can look for flat-spectrum radio sources in *Fermi* fields noted by machine learning techniques (e.g., Amanpreet et al. 2019) to be likely blazars.

Finally, some number of fields are devoid of radio sources. To some extent this is biased by the overall summed sky coverage of our catalogs (shown to the right on the bottom). But the existence of these Super-Empty Fields in the North implies some of these sources are more mysterious.



Citations:
Bates, S.D., Lorimer, D.R., & Verbiest, J.P.W. 2013, MNRAS, 431, 1352
Kaur, A., Falcone, A.D., Stroh, M.D., et al. 2019, ApJ, 887, 18