



Fermi  
Gamma-ray Space Telescope

# A Statistical Approach to Recognizing Source Classes for Unassociated Sources in the Second Fermi-LAT Catalog

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on behalf of the Fermi-LAT  
Collaboration**

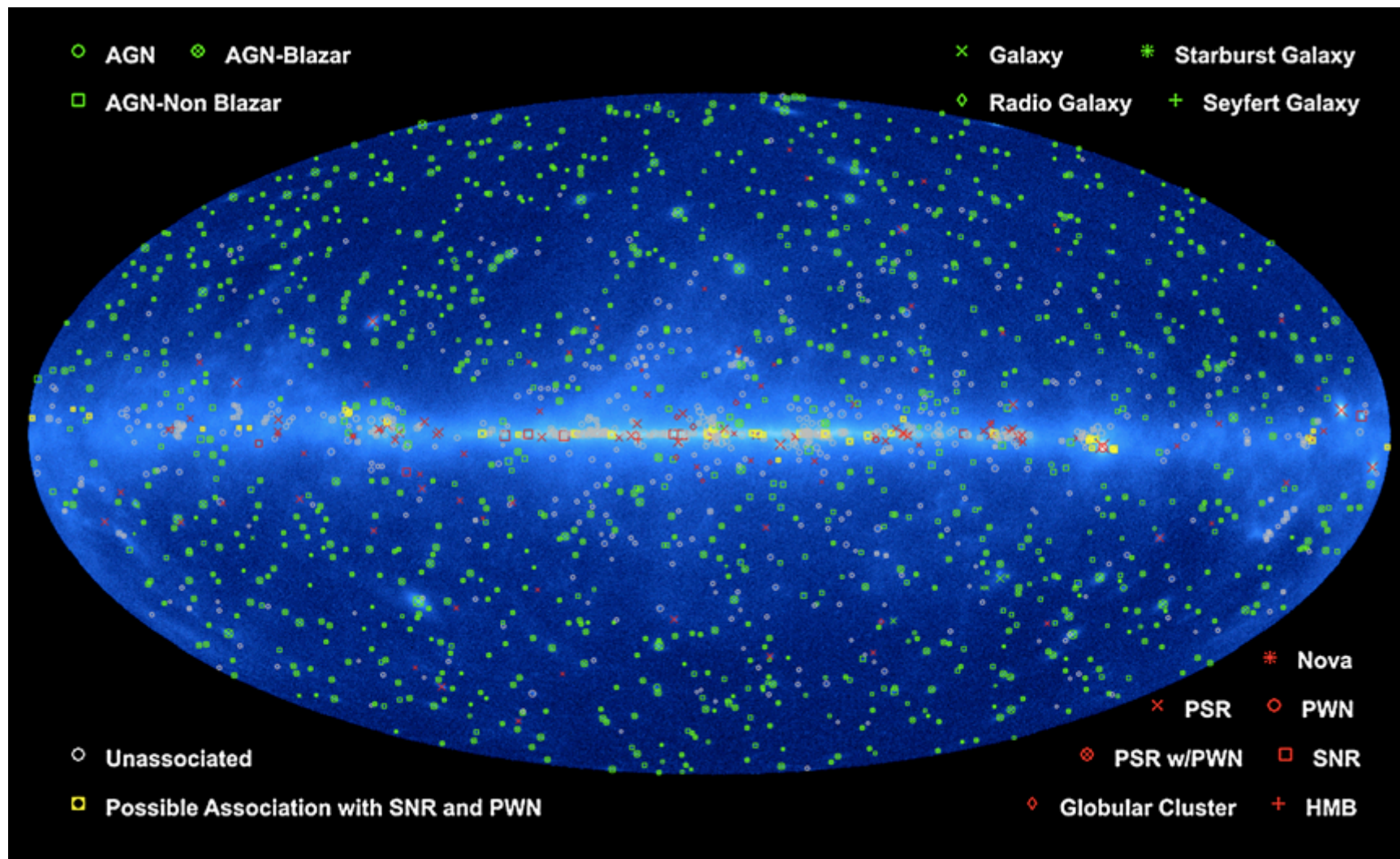


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# Unassociated Sources in 2FGL



1873 sources in 2FGL; 573 unassociated after all association efforts (~30%)



See Elizabeth C. Ferrara, poster 149.19 and <http://arxiv.org/abs/1108.1435>

# How to predict possible classifications



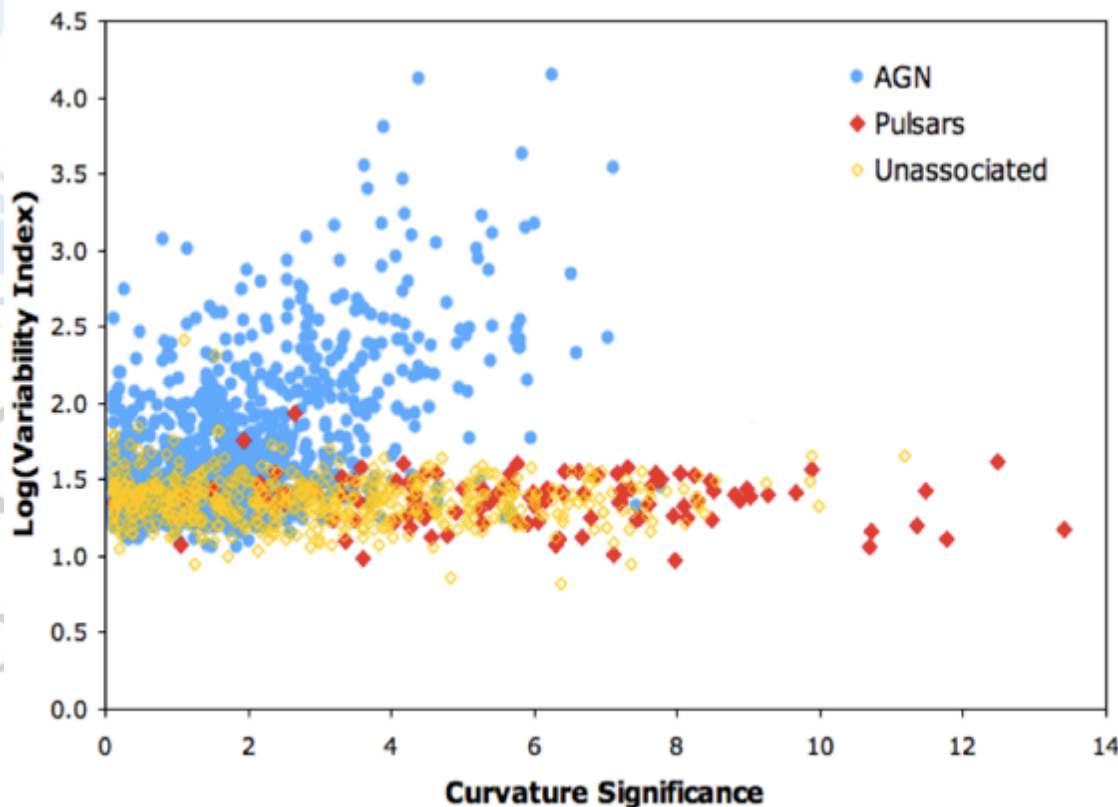
- **Implement statistical methods to determine likely source classifications for 2FGL unassociated sources**
  - **goal:** predict the likely classification of Fermi sources based solely on their observed gamma-ray properties
  - **principle:** use the properties of known objects to implement a classification analysis which provides the probability for an unidentified source to belong to a given astronomical class
  - **examples:** Classification Trees (this work) and Logistic Regression
  - **input sample:** all the associated AGN and blazars (1077 sources, 60% of total); all the associated/identified pulsar and pulsar-like objects (includes SNR and potential associations: 180 sources, 10% of total)
- **Classification Trees are a well-established class of algorithms in the general framework of data mining and machine learning**
  - **definition:** Classification Trees are built through a process known as binary recursive partitioning, an iterative process of splitting the data into partitions using *if-then* logical conditions
  - **advantage:** Classification Trees are especially flexible in handling sparse or uneven distributions



# Selection of the training variables



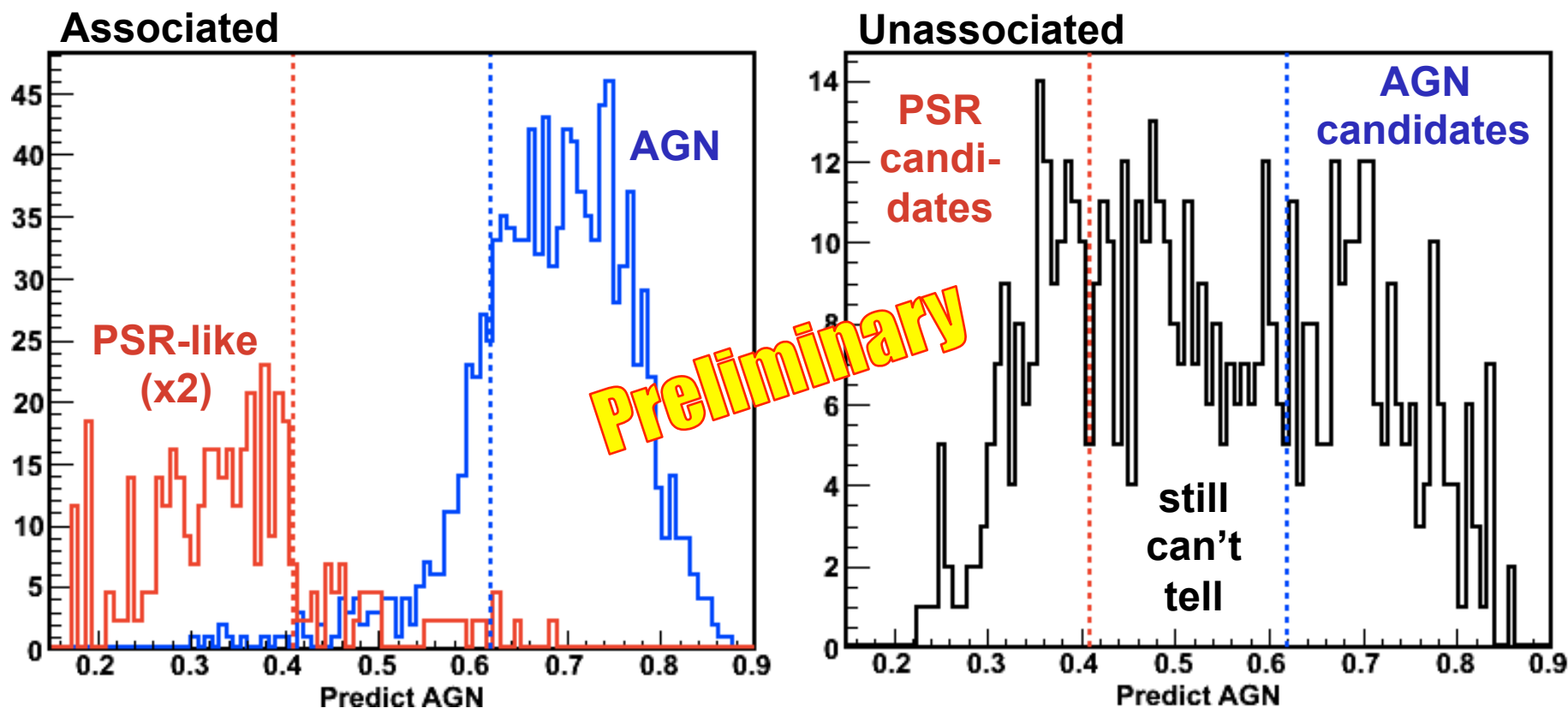
- This is a crucial step in the analysis:
  - physical considerations about the gamma-ray properties of each class
  - ensure that the selected variables are not dependent on the flux, the location or the significance of the source
  - avoid using the Galactic coordinates of the sources
- Ranking of the selected variables after training:
  - variability index (20%)
  - spectral index (16%)
  - curvature signif. (13%)
  - low energy flux (10%)
  - low and high energy hardness ratios (15%)
  - 3-band curvature (7%)
  - intermediate energy hardness ratios (10%)
  - 4-band fluxes (9%)



# Output of the training process



The result of the training process is the Predictor, a parameter describing the probability for any given source to be either an AGN or a pulsar-like source

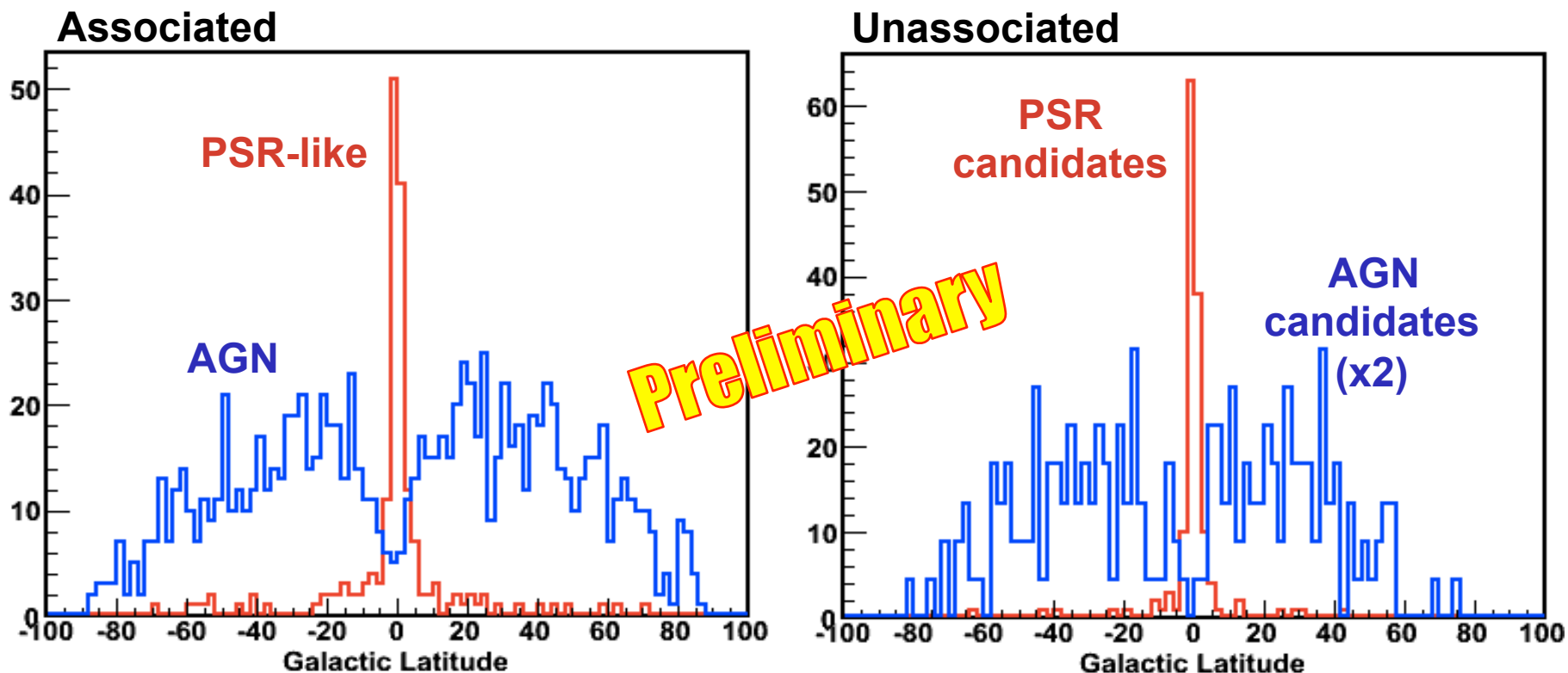


2 fiducial thresholds: **PSR candidates** -  $P < 0.41$ , **AGN candidates** -  $P > 0.62$   
 fiducial regions: 82% efficiency and  $< 5\%$  contamination on input samples

# Validation of the Classification Analysis



- 30% of input sources, randomly selected from AGN and pulsar samples, were set aside for internal validation (KS test and efficiency comparisons)
- the Galactic latitude distribution for pulsar and AGN candidates mirrors the expected one (as observed for the Associated sources)



- further validation will be performed using input from multi-wavelength observations (now in progress; was successfully implemented for 1FGL)

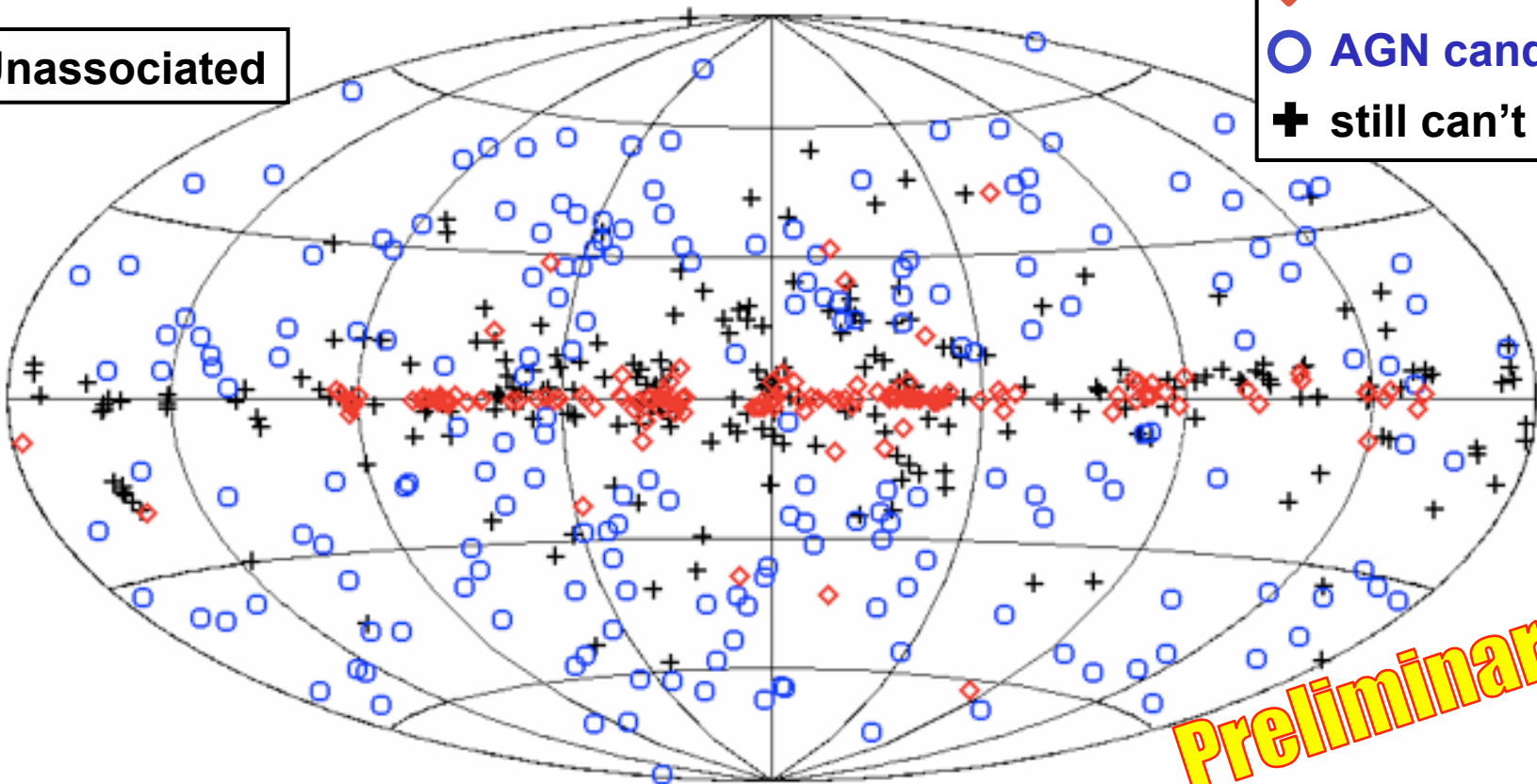
# Conclusions



- We implemented a method to predict likely source classifications for 2FGL unassociated sources, based solely on their gamma-ray properties
  - the performance of the method has been validated in several ways
  - the results from this technique have been used to help inform the next set of multi-wavelength observations

Unassociated

- ◇ PSR candidates
- AGN candidates
- + still can't tell



**Preliminary**