Optical polarization as a method for the association of unidentified gamma-ray blazars

I. Liodakis[1], D. Blinov[2], K. Kokolakis[2,3], N. Mandarakas[2], G. Panopoulou[4], A. Pouliasi[2], V. Pavlidou[2,5]

[1]*Kavli Institute for Particle Astrophysics and Cosmology, Stanford University*

[2]*Physics Department, University of Crete*

[3]*Mineral Resources Engineering Department,Technical University of Crete*

[4]*Division of Physics, Mathematics and Astronomy, California Institute of Technology*

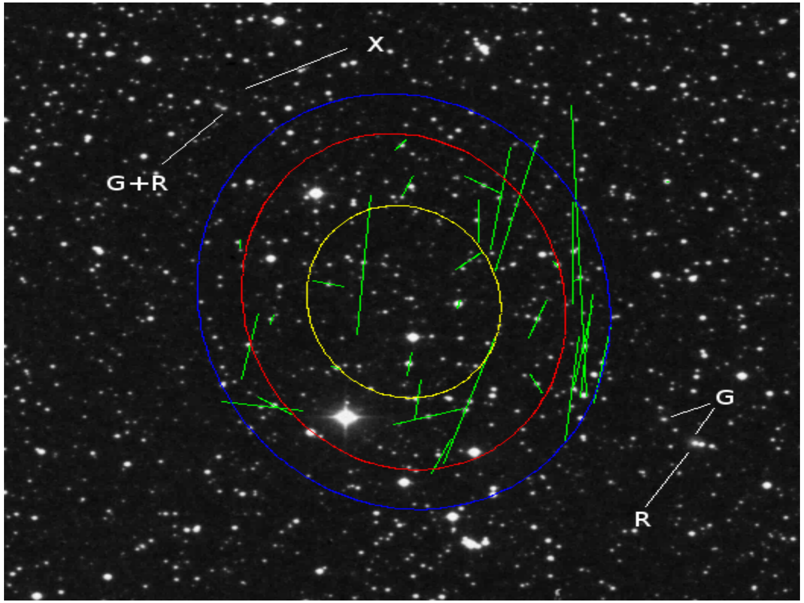
[5]*Foundation of Research and Technology-Hellas*

Using our knowledge of the population of γ-ray—loud blazars from the RoboPol survey we propose a new method for the association of gamma-ray loud blazars using as a discriminant their optically polarized emission.

Our theoretical benchmarking suggests that blazars tend to be significantly more polarized at high galactic latitudes than the field stars, making polarization a suitable probe for the identification of blazars in the unidentified γ-ray source fields of *Fermi*.

We observed several sources within the 3σ positional uncertainty of *Fermi* in three fields (namely **3FGLJ0336.1+7500, 3FGLJ0419.1+6636, and 3FGLJ1848.6+3232**) using the RoboPol polarimeter at the Skinakas Observatory 1.3m telescope.

Preliminary results would suggest a few blazar-like candidates within two of the unidentified fields. Upcoming observations will be able to reduce the polarization uncertainty and reveal the missing γ-ray loud blazars.



Polarization observations of sources within the 1,2 and 3σ positional uncertainty of *Fermi* for 3FGLJ1848.6+3232. The green lines show the relative polarization degree and the orientation of the polarization plane. The letters (G,R,X) mark nearby galaxies, radio and X-ray sources.

Introduction

Active galactic nuclei (AGN) are one of the largest class of γ-ray sources with blazars accounting for the vast majority of the AGN associations. Despite the advancements in angular resolution and localization Fermi has offered, roughly 1/3 of the detected sources are still unassociated with a lower-energy counterpart. Under these considerations, it is very likely that the unidentified fields (especially in high galactic latitudes) contain yet unknown blazars. We propose a new method for the association of gamma-ray loud blazars by using as a discriminant their optically polarized emission.

Feasibility of the Method

The first step to ensuring the validity of our method was to perform simulations that allowed us to quantify the probability of a blazar being significantly more polarized than the field sources. Starting from the statistically complete γ-ray loud sample of RoboPol (King et al., 2014, Pavlidou et al. 2014), we simulated the observations of random blazars at a random instants using the polarization distribution of each blazar (beta distribution, Angelakis et al. 2016). We compared that value to the average interstellar polarization of the field stars in a random orientation in the sky. The polarization of the stars in the field are drawn from the distribution of the star polarization in the polaris flare (Panopoulou et al. 2015). In order to cover areas of the sky with different average interstellar polarization, we logarithmically shift the distribution of the polaris flare stars to retain the same shape. **Our findings suggest that for high galactic latitudes where the interstellar polarization is expected to be <1%, roughly 80% of the time a blazar will have a polarization degree larger than five standard deviations from the mean of the field star distribution (Fig 1.)**

Observing strategy

To select suitable unidentified fields in order to demonstrate our method we have excluded all unidentified fields within 10^{o} from the galactic plane. This way we avoid fields with possible high degree of optical polarization as well as unidentified pulsars. We then removed any field that was not visible from the Skinakas observatory during the length of the observing season (April-November).

Additionally, we introduced a ranking parameter based on the γ-ray properties of the unidentified source. The ranking parameter is defined as the product of the long-term average γ-ray flux (>100MeV) and the variability index, divided by the positional uncertainty. This way we take into account not only the γ-ray flux, but also how variable is a source (also a discriminant of blazars) and how efficient it would be for an optical telescope to survey the uncertainty region.

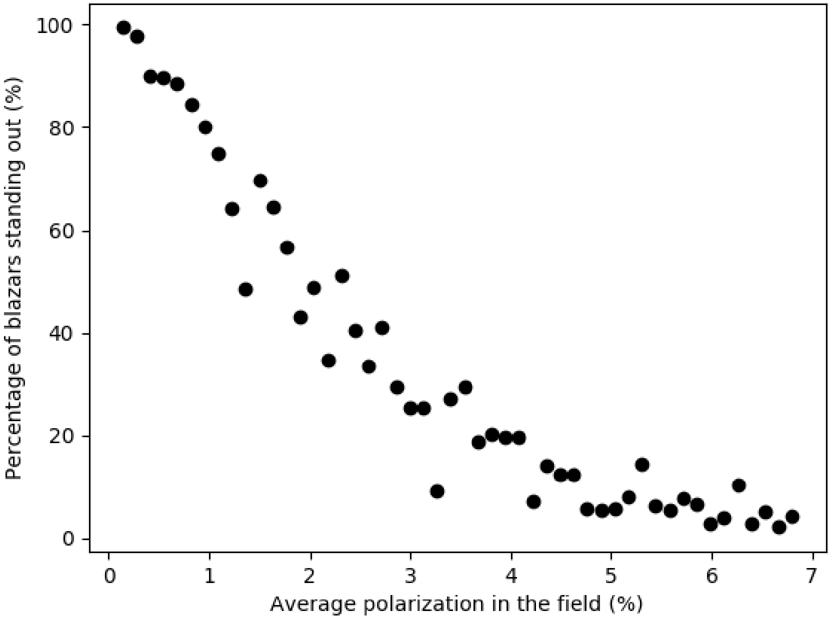


Figure 1: Percentage of blazars standing out in polarization more that 5σ from the mean of the field stars versus the average polarization in the field.

Observations

Based on the theoretical benchmarking of our method we have launched an observing campaign in order to find the missing blazars in the unidentified fields of Fermi. So far several sources have been observed in **3FGLJ0336.1+7500, 3FGLJ0419.1+6636, and 3FGLJ1848.6+3232**. While several more are expected to be observed by the end of the observing season in November. For each field we remove sources with a measurable proper motion (>3σ significant proper motion) in order to avoid observing stars. We also use photometric catalogs in order to find the optical magnitude of each source in the field and create a list of targets with R<17.5. Sources fainter than 17.5^m require significantly longer exposures making them inefficient targets. 3FGLJ0419.1+6636 showed ~6% interstellar polarization which according to our theoretical benchmarking suggests a low probability of detecting a blazar that thus was dropped from our sample. Figure 2 shows the Q-U plot for the sources observed in 3FGLJ1848.6+3232. In any Q-U plane an unpolarized source is expected to reside around (0,0) while a clustering of sources (in Fig 2. around [0.005,-0.0025]) would suggest interstellar polarization. The remaining sources should be intrinsically polarized, however, the relatively large error bars prevent us from drawing strong conclusions. The upcoming observations can help us reduce the uncertainty in our measurements and reveal potential blazar candidates for that field.

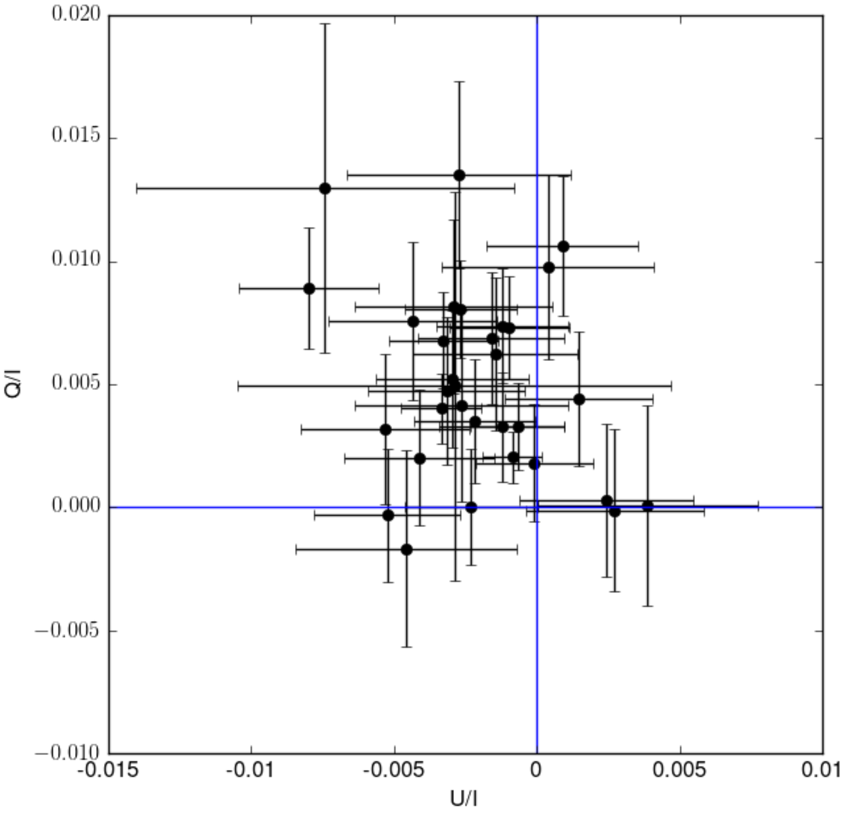


Figure 2: Q-U plot for the sources within the 3σ positional uncertainty in 3FGLJ1848.6+3232.

References

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