

## Optical Polarization and FERMI Observations of Radio-Loud NLS1 Galaxies

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We report on our results for a small sample of radio loud NLS1s for which we obtained measures of optical polarimetry and gamma ray flux. We discover evidence of slight (< 3%) polarization in a few sources, as well as variability in the gamma ray flux as measured against the 1FGL catalog. These objects and other RL NLS1s will be added to our long-term blazar monitoring program, so that we may better characterize their behavior in terms of optical polarization and optical/gamma ray energies.

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## 1. Introduction

Recently, much work has been done in the community on a small but interesting subclass of AGN, the very radio loud NLS1s ( $R > 50$ ). Several of these objects have been observed to possess blazer-like properties [1], including rapid variability and the emission of gamma rays, as detected by the FERMI/LAT instrument. As part of our ongoing program, we are now reporting on a limited sample of RL NLS1s. We have observed these objects in the optical utilizing polarimetry and photometry, searching for evidence of micro-variability (timescales  $< \sim$ day) [4]. We also utilize the public data available from the FERMI/LAT instrument to determine if and to what degree these objects are gamma ray loud. These properties will be compared to other extra-galactic relativistic jet sources, such as blazars.

## 2. Data and Instrumentation

Optical polarimetric data were taken using the Perkins 1.83 m telescope at Lowell Observatory in Flagstaff, Arizona, with the PRISM instrument supplemented by a polarimeter with a rotating half-wave plate. Data were taken between Feb 07 and Feb 10, 2011 in the R-band. The observations consisted of a series of 3-5 measurements for the Q and U Stokes parameters per object. Each series consisted of four images, each taken at different instrumental position angles –  $0^\circ$ ,  $45^\circ$ ,  $90^\circ$ , and  $135^\circ$  – of the waveplate. As the camera has a wide field of view (approx.  $14' \times 14'$ ), we are able to use field stars for both instrumental and interstellar polarization corrections. Polarized and unpolarized standard stars are used to calibrate polarization Position Angle (P.A.) and instrumental polarization (typically 3%-5%) [3], respectively.

Gamma-ray data were obtained through the FERMI-LAT public data server. The Large Area Telescope (LAT), on board the Fermi Gamma-ray Space Telescope, is a pair-conversion detector sensitive to gamma-rays in the 20 MeV to several hundred GeV energy range [2]. Since its launch in 2009, the instrument has worked almost continuously in sky-survey mode, which allows coverage of the entire gamma-ray sky every 3 hours. The data were reduced and analyzed using ScienceTools v9r15p2 and instrument response functions P6\_V3\_diffuse. We utilized the aperture photometry procedure as described at the FSSC website, as well as a sky annulus to subtract background noise. Photon fluxes in Table 2 are calculated using data for from MJD 55593 to MJD 55621 (Feb. 01 to Mar. 01, 2011).

## 3. Preliminary Results

Inspection of the optical polarimetry results shown in Table 1 reveals that 3 of our 7 sources possess an approximately 1% polarization at the  $2\text{-}\sigma$  level, 2 objects were detected at a lower confidence, and 2 were not seen to possess any significant polarization. It should be noted that, while many of our measures of polarization appear to give a null result, simultaneous measure of polarization for field stars for nearly all targets returned values of  $< 1\%$ . The lone

exception being the Feb 07 measure of J0948, for which the average percent-polarization for field stars was 1.18%. Additionally, the polarization results for 3 of the objects (1H 0323, J0948, and J1505) were confirmed on a second night of observations.

Interestingly, a recent publication by Ikejiri et al. [5] indicates that J0948 possessed a polarization level of 18.8% in March-April 2009. We note that despite the large discrepancy between their value and ours, this is not unusual for blazars observed over a long period, as can be seen for other objects in the aforementioned work.

**Table 1 – Polarization data**

Date	Object ID	% Polarization	EVPA (deg)
Feb 07	1H 0323+342	0.75±0.48	-1.74±18.45
Feb 10	1H 0323+342	0.74±0.91	-31.91±35.32
Feb 07	J0948+0022	1.85±1.48	-89.83±22.85
Feb 10	J0948+0022	1.47±2.09	-52.29±40.73
Feb 07	J1047+4735	0.22±0.83	77.74±106.63
Feb 07	J1435+3131	1.73±0.44	43.73±7.33
Feb 07	J1505+0326	3.94±2.14	-39.26±15.52
Feb 10	J1505+0326	2.80±1.48	-23.71±15.10
Feb 07	J1633+4718	1.34±0.31	-47.83±6.72
Feb 07	J1644+2619	1.49±1.38	-12.01±26.59

Aperture photometry of the  $\gamma$ -ray data for the month of February indicated 3 promising targets: J0948, J1505, and J1633. Subsequent likelihood analysis of the same data set showed J0948 and J1505 to be marginally detected with fluxes of  $6.15894e-08 \pm 3.22036e-08$  and  $1.26395e-07 \pm 5.80033e-08$  photons/cm<sup>2</sup>/s and Test Statistic values of 14.16 and 12.16, respectively. Table 2 compares the fluxes for these objects over this time period to that reported in the FERMI /LAT 1-year Source Catalog. J0948+0022 and J1505+0328 are both shown to be variable at gamma-ray energies.

**Table 2 – FERMI Data**

Object	Feb 01 – 28, 2011	1FGL Catalog
	Flux (photon/cm <sup>2</sup> /s)	Flux (photon/cm <sup>2</sup> /s)
J0948+0022	6.16E-08 ± 3.22E-08	2.52E-09 ± 3.89E-010
J1505+0328	1.26e-07 ± 5.80e-08	1.09E-09 ± 2.98E-010
J1633+4718	no detection	no detection

#### 4. Conclusions

Our observations indicate modest to low-level measures of optical polarization for 5 of the very radio loud NLS1s in our sample. Additional observations will be required to confirm these results and monitor the objects' states of polarization, optical

variability, and gamma ray variability. Accordingly, we plan to integrate these and other RL NLS1s into our long-term blazar monitoring programs.

## 5. Acknowledgements

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## References

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