The Population of Radio-Loud NLSy1 Galaxies with Blazar-Like Properties

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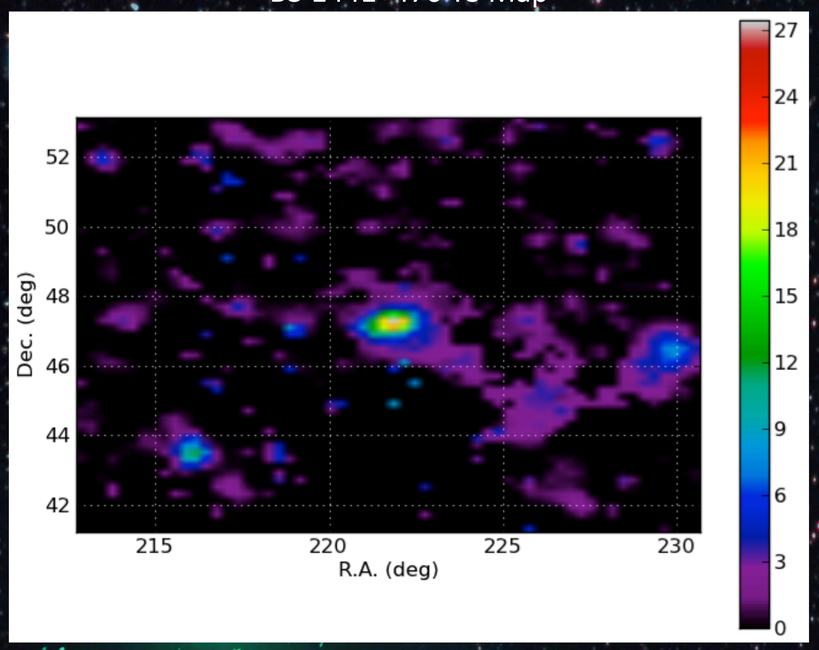
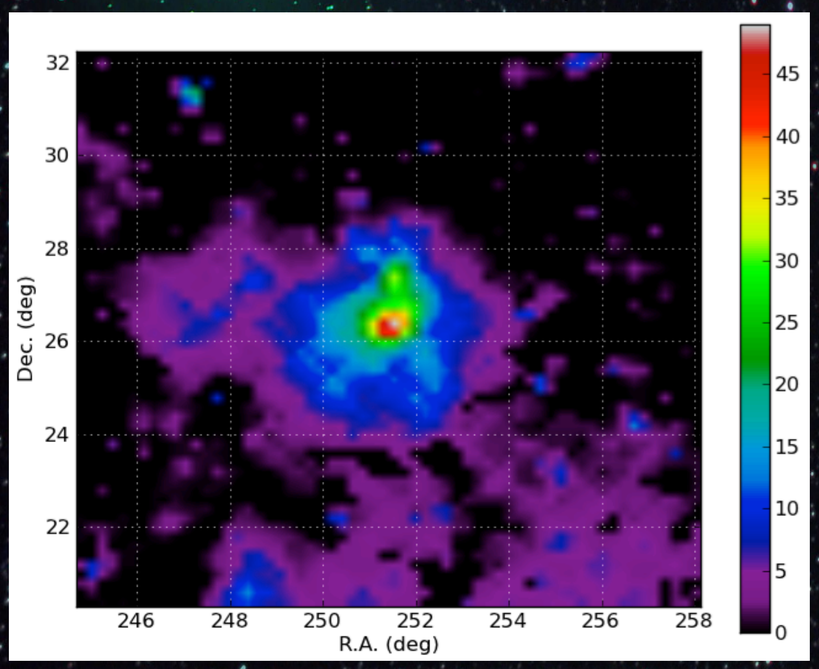
Abstract: We report on an investigation of the blazar-like properties for a subset of a sample of radio-loud NLSy1 galaxies. Using the properties of rapid and large amplitude optical and radio variability, rapid and large amplitude variations in the optical polarization and position angle, and choosing a sample that is very radio loud (R > 100), we find that one can identify a sample of NLSy1 galaxies which exhibit properties, such as gamma-ray emission, that are thought to be characteristic of the presence of relativistic jets oriented near the line-of-sight to the observer. As a result, we report the identification of newly-discovered gamma-ray-loud NLSy1 galaxies found in the Fermi database.

B3 1441+476 TS Map

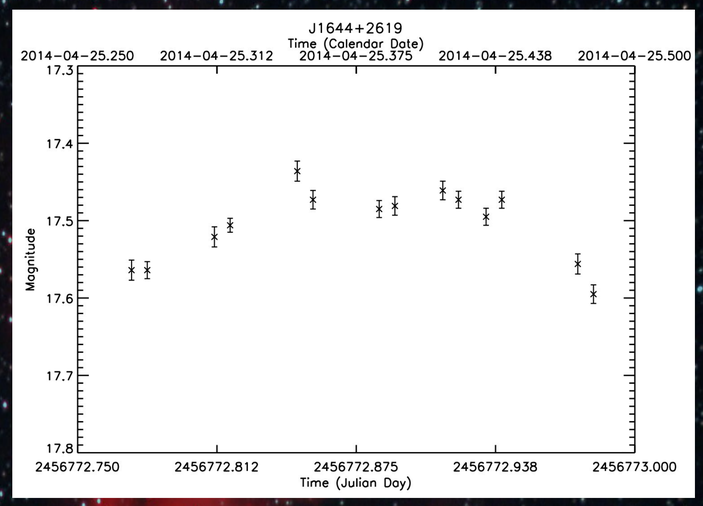


FBQS J1644+2619 TS Map



Data and Instrumentation: Optical photo-polarimetric data were obtained using the Perkins 1.83 m telescope at Lowell Observatory in Flagstaff, Arizona, with the PRISM instrument. Data were taken during several different runs between 2011 Feb and 2014 June, in the R-band. The polarimetric observations consisted of a series of 3-5 measurements of the Q and U Stokes parameters per object. Each series consisted of four images, taken at different instrumental position angles – 0°, 45°, 90°, and 135° – of the waveplate. As the camera has a wide field of view (approx. 14' x 14'), we are able to use field stars for both instrumental and interstellar polarization corrections. The statistical bias towards higher polarization values has also been corrected for. Polarized and un-polarized standard stars are used to calibrate polarization Position Angle (P.A.) and instrumental polarization. PKS 2004-447 is, unfortunately, too far south to be monitored from Lowell.

Gamma-ray data were obtained through the Fermi public data server, and were collected using the Large Area Telescope (LAT) during the first 66 months of its operation. The data were reduced and analyzed using ScienceTools v9r33p0 and instrument response functions P7REP_SOURCE_V15. The LAT detections for each source were made with 1-month (30.5 days) time bins for all sources except B3 1441+476 (5 months), FBQS J1644+2619 (5 months), and PKS 2004-447 (7 months). Optimum time bins were selected after performing a lightcurve analysis of the entire 5.5-year dataset for each source. TS maps were also computed for each of these objects, so as to rule out contributions from un-modeled field sources. Example TS maps for the two new gamma-ray sources detected by our group (red text in Table 1) are shown to the left.



Results: All but four of the the thirty-three sources monitored at Lowell Observatory have displayed some evidence of polarimetric variability (ΔP > 1.0%), and all but three have displayed evidence of micro-variability. In general, sources with high duty cycles tend to have a greater degree of polarimetric variability and *vice versa*, though exceptions are not uncommon.

In general, the RL NLSy1s are faint at gamma-ray wavelengths, with regular detections in month-long bins for only a few sources. The two sources indicated in red in Table 1 were each only active during a single period during the first 5.5 years of the Fermi mission. The most active source was PMN J0948+0022, which was detected in 46 of 66 consecutive month-long bins. Most sources were not detectable above TS = 25 for several months, such as BZU J0849+5108, which did not break the TS > 25 threshold for 24 consecutive months. We have also detected an additional ***nine*** sources (of 34 total) at the 9 < TS < 25 level, and it remains to be seen if these (or other) RL NLSy1s will become detectable as Fermi continues its monitoring operations.

Table 1 – Multiwavelength Data for Select RL NLSy1

Object ID	R-band Min/ Max	Duty Cycle	%Pol Min/Max	log(R)	TS value
1H 0323+342	16.36/15.31	0.21	0.00/2.20	2.50	289.5
BZU J0849+5108	18.57/14.46	1.00	3.06/15.44	3.16	810.2
PMN J0948+0022	20.77/16.70	0.95	0.90/12.31	2.93	412.2
7C 0953+2529	16.10/15.39	0.10	1.44/10.52	3.56	100.3
B3 1441+476	19.18/17.94	0.10	0.00/2.87	3.03	28.9
PKS 1502+036	18.34/17.81	0.40	0.11/2.80	3.53	37.4
FBQS J1644+2619	17.23/17.90	0.47	0.19/1.90	2.73	56.9
PKS 2004-447	--/--	--	--/--	3.58	58.28