

Review

A Search for Blazar-Like Radio-Loud Narrow-Line Seyfert 1 Galaxies

Hugh R. Miller ^{1,*}, Jeremy D. Maune ¹, Joseph R. Eggen ¹, Clay S. Turner ¹, Elizabeth C. Ferrara ¹, Diana O. Gudkova ¹ and Amy M. Battles ²

¹ Department of Physics and Astronomy, Georgia State University, Atlanta, GA 30302, USA; maune@astro.gsu.edu (J.D.M.); eggen@astro.gsu.edu (J.R.E.); turner@astro.gsu.edu (C.S.T.); Elizabeth.C.Ferrara@nasa.gov (E.C.F.); diankald@gmail.com (D.O.G.)

² Department of Physics, Georgia Gwinnett College, 1000 University Center Ln, Lawrenceville, GA 30043, USA; acambe2@ggc.edu

* Correspondence: miller@chara.gsu.edu; Tel.: +1-404-413-6023

Academic Editors: Jose L. Gómez, Alan P. Marscher and Svetlana G. Jorstad

Received: 2 September 2016; Accepted: 23 February 2017; Published: 21 March 2017

Abstract: We report the results of an observational program to investigate the gamma-ray and optical variability properties of the vRL NLSy1 galaxies listed in the Yuan et al. sample. We have identified 17 members of the Yuan et al. sample possibly associated with gamma-ray sources based on a combination of their optical polarization and optical variability and their gamma-ray properties. Eight have previously been associated with gamma-ray sources. We find nine additional members that we predict are excellent candidates to be associated with gamma-ray sources in the future. All 17 sources have many properties in common with flat spectrum radio quasars (FSRQs), suggesting that they may, in fact, constitute a new subclass of FSRQs.

Keywords: blazar; narrow line seyfert 1 galaxy; gamma-ray source

1. Introduction

During the past decade, the Fermi Gamma-Ray Space telescope has identified a small number of very radio-loud narrow-line Seyfert 1 galaxies (vRL NLSy1) associated with gamma-ray sources (e.g., PMN J0948+0022, Abdo et al. [1]). These objects exhibit the familiar double-peaked SED that is typical of that seen for blazars (Abdo et al. [2]). Their detection has, for the first time, suggested that a number of vRL NLSy1s may have properties that are similar to those of FSRQs. Since Seyfert galaxies have long been known to have host galaxies with spiral morphologies, this would be the first time that a blazar-like object (with a relativistic jet oriented close to the line of sight to the observer) has been found to reside in a spiral galaxy (Abdo et al. [1]).

Yuan et al. [3] and Komossa et al. [4] have identified a sample of vRL NLSy1 galaxies with $R > 100$, where R is defined as the ratio of flux at the 5 GHz regime to the optical flux in the B band. Indeed, it should also be noted that all gamma-ray-detected vRL NLSy1s presently are included in this sample. This raises the possibility that there may be additional vRL NLSy1s in this sample that may also be found to be future gamma-ray sources. If this is true, what might the properties of these gamma-ray detected vRL NLSy1s be? How might they be different from presently known blazars? Do they, in fact, make up a new class of blazars?

2. Observational Program

Motivated by the gamma-ray detection of a few of these galaxies and by the questions posed above, we initiated an observational program jointly at gamma-ray and optical wavelengths to fully investigate the properties of the galaxies listed in the Yuan et al. sample. The goal of this

dual wavelength program is to identify additional members of this sample that exhibit blazar-like characteristics and which would be prime candidates to monitor as future candidates to be associated with gamma-ray sources.

As the first step in initiating this program, we identified the basic properties of the vRL NLSy1 galaxies included in the Yuan et al. sample. Kellerman et al. [5] has defined radio-loud as $R > 10$, as opposed to “very” radio-loud which corresponds to $R > 100$ in the Yuan et al. sample. Osterbrock and Pogge [6] identified the following properties for NLSy1 galaxies: (a) contain a disk-like host galaxy (spiral?); (b) contain a low-mass central supermassive black hole (SMBH) that is near the Eddington accretion rate; (c) exhibit a $\text{FWHM(H-beta)} < 2000 \text{ km/s}$ (Goodrich [7]); and (d) exhibit a strong emission from FeII. Thus the Yuan et al. sample is made up of objects that simultaneously satisfy both the Osterbrock and Pogge criteria as NLSy1 galaxies and the Yuan et al. definition of very radio-loud AGN.

If some members of this sample are truly blazar-like objects, they should demonstrate some of the classic characteristics of this class of AGN. Strittmatter et al. [8] were among the first to list the following observational properties for BL Lac objects: They (a) exhibit a featureless optical spectrum; (b) exhibit a non-thermal spectral energy distribution (SED); (c) are highly variable on all observed timescales and wavelengths (including microvariability); (d) exhibit highly variable polarization; and (e) are radio-loud (and many are detected at gamma-ray wavelengths). We have therefore chosen to use the unique blazar-identifying optical properties of large amplitude and rapid optical flux variations (including microvariability), significant and variable optical polarization, and radio loudness ($R > 100$) as the primary indicators for a blazar candidate in the sample. We further define microvariability as discrete events occurring on timescales of minutes to hours, or doubling times on similar timescales (Miller, Carini and Goodrich [9]); however, we do not include simple linear trends spanning several hours.

Utilizing the 1.3 m SMARTS telescope located at CTIO and the 31 in NURO, 42 in Hall, and 72 in Perkins telescopes at Lowell Observatory, we began, in 2010, a program to photometrically and polarimetrically monitor each member of the Yuan et al. sample for the blazar-like properties of strong and variable optical polarization and optical microvariability. In addition, we have used the Fermi Gamma-Ray Space Telescope (Fermi) to detect and monitor the members of this sample for gamma-ray emission. The presence of gamma-ray emission (in addition to the property of very radio-loudness) is a key element indicating the presence of a relativistic jet oriented near the line of sight to the observer.

The gamma-ray data used in this work was collected with the Large Area Telescope (LAT), which is the primary instrument aboard the Fermi (1) space telescope. The spacecraft has been operating in all-sky scanning mode almost continuously since its launch in 2008, which allows the LAT to cover the entire sky once every 3 h in an energy range of 20 MeV to several hundred GeV. Our data were reduced and analyzed using ScienceTools v9r33p0, instrument response functions P7REP, and the standard background and galactic model. The reader is referred to Eggen [10] for the details of this analysis.

Our data were downloaded from the Fermi website on 20 February 2014. For each source, we analyzed a circular region in the sky that was 15 degrees in radius, centered on the target, and covering an energy range of 100 MeV to 300 GeV. Please see Eggen, Miller, and Maune [11] for details concerning event class selection and pointing cuts. The gamma-ray light curves for each source were constructed from 66 bins, each of which was 30.5 days long. The first bin began on 4 August 2008. Normally, a positive gamma-ray detection of a Fermi source requires a test statistic $TS > 25$ (Mattox et al. [12]). Our results from this analysis are divided into two classes: those objects that are firmly detected at gamma-ray energies with a $TS > 25$ in Table 1, and those in Table 2 that were detected with $9 < TS < 25$. A more detailed summary of these procedures is found in Eggen [10].

To date, using the radio and optical criteria discussed above, we have confirmed the previous gamma-ray detection of eight members of this sample with $TS > 25$ (See Table 1 as blazar-like NLSy1 galaxies. In addition, we have also identified nine additional members of this sample with $9 < TS < 25$

which we expect to be prime candidates for future gamma-ray detection. This second group of objects also exhibits variability and polarization properties consistent with those commonly detected for blazars. The details of these results are discussed below.

Table 1. Objects in the sample that were detected at gamma-ray energies (Foschini et al. [13], and references therein). (1) Object Name; (2) Right Ascension; (3) Declination; (4) Radio-Loudness; (5) Binning Number; (6) Gamma-ray Test Statistic; (7) Gamma-ray Flux.

Object ID	R.A.	Dec.	Log(R)	Bin#	TS	Flux(err)
1H 0323+342	51.2096	34.143	2.50	53	280.31	36.19(2.73)
J0849+5108	132.492	51.1414	3.16	35	790.76	26.34(2.20)
J0948+0022	147.221	0.349773	2.93	53	402.14	39.81(2.32)
J0956+2515	149.208	25.2545	3.56	20	95.95	10.24(2.34)
J1443+4725	220.827	47.4324	3.03	49–53	27.81	1.49(0.06)
PKS1502+036	226.292	3.40703	3.53	43	36.60	9.58(2.71)
J1644+2619	251.177	26.3204	2.73	46–50	52.25	4.24(1.04)
PKS2004-447	301.98	−44.579	3.80	13–24	53.77	2.26(0.52)

Table 2. Objects with $25 > TS > 9$ gamma-ray detections. (1) Object Name; (2) Right Ascension; (3) Declination; (4) Radio-Loudness; (5) Bin Number; (6) Gamma-ray Test Statistic; (7) Gamma-ray Flux.

Object ID	R.A.	Dec.	Log(R)	Bin#	TS	Flux(err)
J0100+0200	15.1342	−2.01278	1.77	8	9.65	5.87(0.56)
				25	9.52	3.17(2.23)
J0706+3901	106.605	39.031	1.21	23	10.30	0.76(0.15)
				66	10.50	1.10(0.36)
J0804+3853	121.038	38.8969	1.18	34–36	10.77	8.49(0.15)
J1102+2239	165.597	22.6558	1.28	15–20	14.57	1.29(0.81)
J1146+3236	176.726	32.6145	2.19	5	12.61	3.58(1.66)
J1246+0238	191.709	2.67123	2.38	55–66	17.13	1.58(0.60)
J1713+3523	258.269	35.3926	1.05	22	12.03	6.21(0.23)
IRAS2018-2244	305.268	−22.5884	1.57	9	9.42	2.24(1.89)
J2314+2243	348.732	22.7236	1.25	50	11.59	5.05(2.54)

3. Results

In order to test our ability to identify additional blazar-like members of the Yuan et al sample, we first analyzed the optical microvariability and polarization, and the gamma-ray observations for the previously identified members of the sample associated with gamma-ray sources.

PMN J0948+0022. As shown earlier by Eggen et al [11], this object exhibits extraordinary optical variability on timescales of minutes to years (see Figure 1). It also rivals the most extreme microvariability that is observed for blazars, as shown in Figure 2, where the flux is observed to double on timescales of less than 4 h. Figure 3 shows the long-term optical variability (R-mag), polarization (P), position angle (EVPA), and gamma-ray flux, where all of these exhibit large-scale variations. Therefore, using our criteria defined above, we find conclusive evidence supporting the classification of this member of the sample as a blazar.

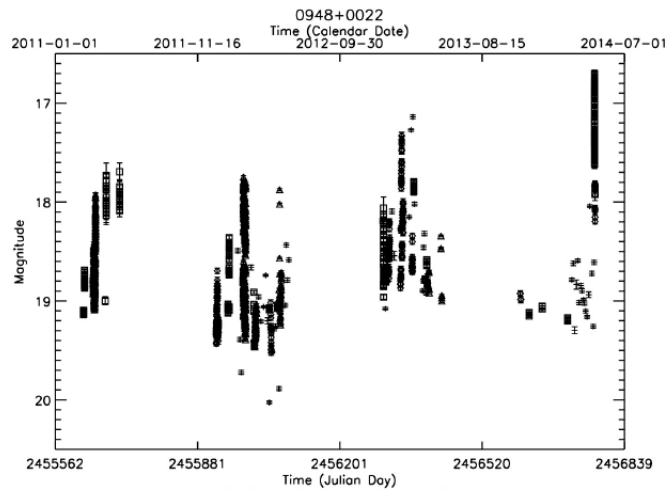


Figure 1. Multi-year light curve of J0948+0022.

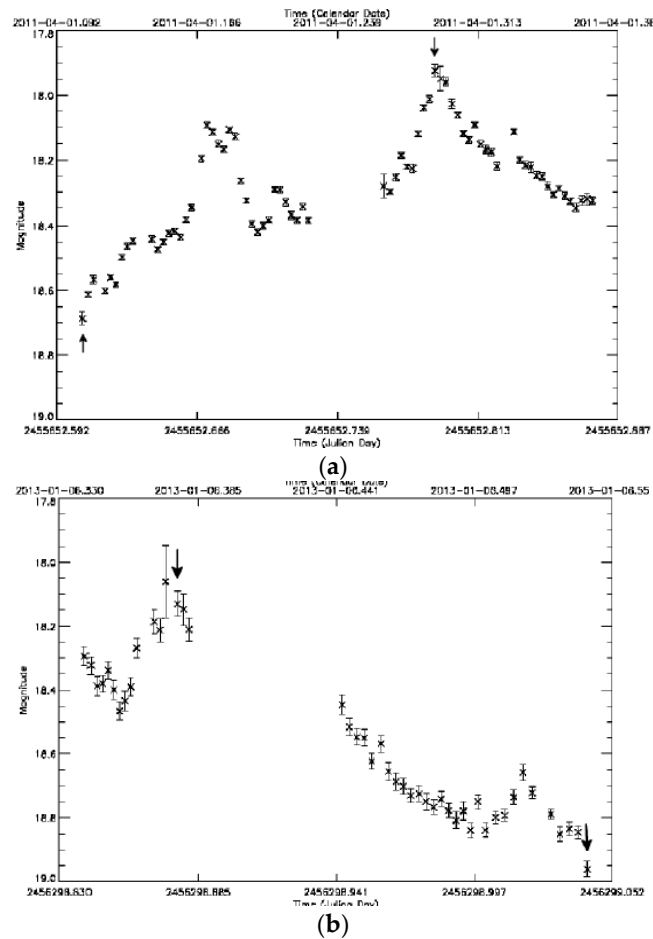


Figure 2. (a) Intra-night light curve of J0948+0022. The light curve share a ~ 1.0 magnitude range. The object is in an excited state showing a flux doubling time of 4.39 ± 0.19 h. The arrows indicate the extreme range during this observation. All data was obtained in the optical R band; (b) Intra-night light curve of J0948+0022. The light curve shows a ~ 0.8 magnitude range. The object is in an excited state showing a flux doubling time of 3.60 ± 0.23 h. The arrows indicate the extremes. A low amplitude ~ 0.10 mag event with a duration of a 1.4-h is centered near ~ 2456299.01 JD. All data was obtained in the optical R band.

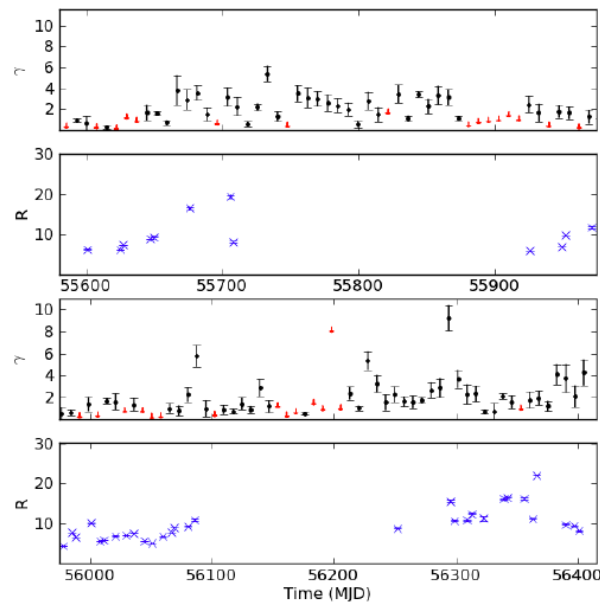


Figure 3. Quasi-simultaneous gamma-ray and optical R-band data for J0948+0022.

J0849+5108. Maune et al. [14] have demonstrated that this object also exhibits enormous variability on all timescales at both optical and gamma-ray wavelengths (Figure 4) and it also exhibits a high degree of polarization ($P = 12\%$). Figure 5, which displays the multiwavelength variability, shows that there appears to be a close relationship between the occurrence of the gamma-ray and optical flares observed during April 2013. This event was followed by a radio flare observed a few months later which may be related to these earlier optical and gamma-ray events.

1H 0323+342. The observational results for 1H 0323+342 are similar to those found for the above two objects and are summarized in Miller et al. [15]. This includes the rapid, low-amplitude microvariations shown in Figure 6.

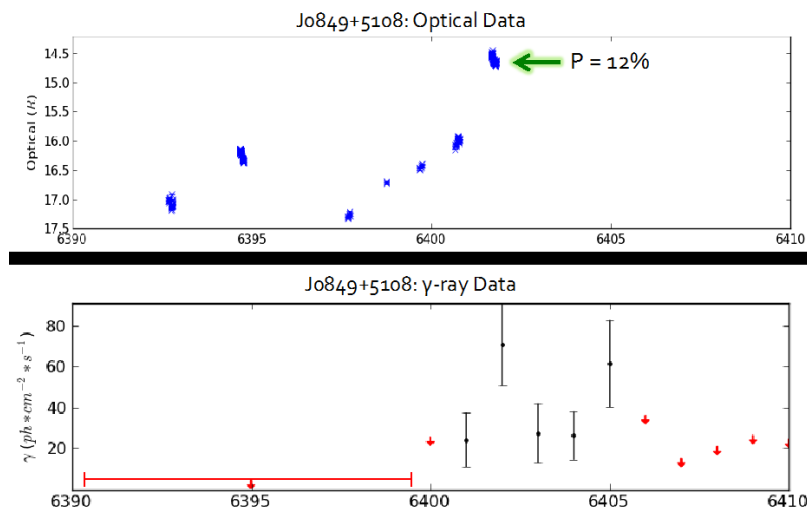


Figure 4. Rapid, large-amplitude gamma-ray and optical variations for J0849+5108.

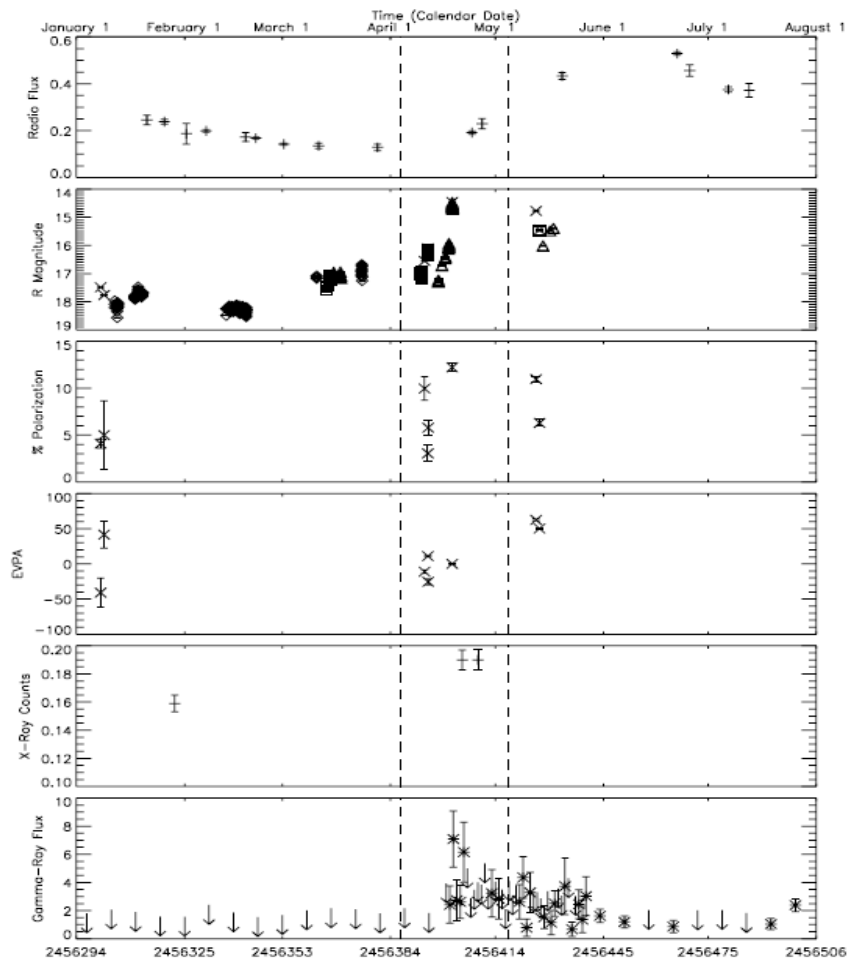


Figure 5. Multiwavelength observations of J0849+0022 from the year 2013, combining data from the Owens Valley Radio Observatory, Lowell (optical R band), Swift (X-ray), and *Fermi* (gamma-ray) telescopes. The dotted lines indicate a period in which there was a gradual 30% increase in IR flux, reported by Mexico’s National Institute for Astrophysics, Optics, and Electronics (Carrasco et al. [16]).

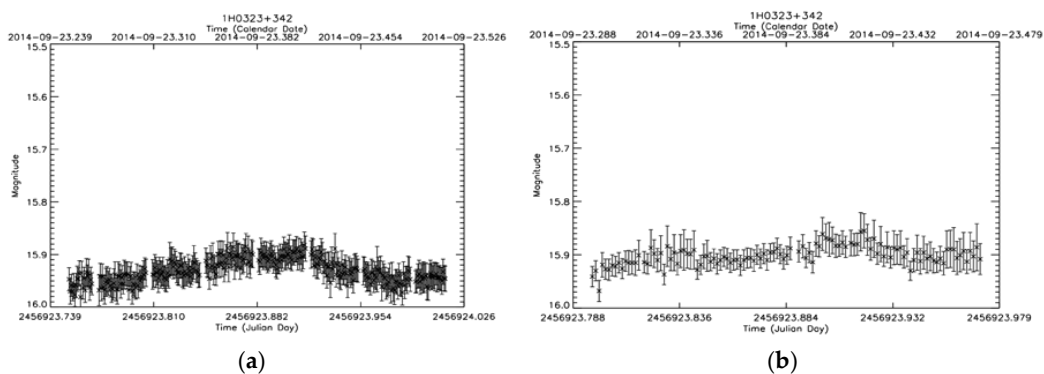


Figure 6. Intra-night light curves (LC) of 1H 0323+342. The LC taken using the 72-in is shown as (a), and the LC taken with the 31-in is shown as (b). Both light curves are plotted on a 0.5 magnitude scale. Microvariability remains detectable for this object, albeit on a much smaller scale than for J0849+5108 or J0948+0022. Data was obtained in the optical R band.

The remaining members of the Yuan et al. sample, included in Table 1, exhibit similar but less dramatic variability behavior compared to that shown for the preceding objects. This demonstrates

that the criteria outlined in Section 2 of this paper are good predictors of blazar-like characteristics for the members of this sample. We also investigated the microvariability for the remaining members of the Yuan et al. sample and failed to detect any cases of microvariations.

Modifying our newly defined criteria for prime candidates for future gamma-ray detection defined above, we searched the Yuan et al. sample for members which satisfy this ($9 < TS < 25$) criteria and which also have $R > 25$. We also investigated if these objects also exhibit significant optical polarization with both rapid optical variability and microvariability. Listed below in Table 2 is our list of objects that satisfy these criteria and which we predict will be the most blazar-like vRL NLSy1 galaxies in this sample. These nine objects are excellent candidates to be detected at gamma-rays with a $TS > 25$ in the near future.

We have also performed a statistical study of the microvariability for the 17 members of our sample of blazar-like vRL NLSy1s in an effort to compare them with other radio-loud AGN. We have constructed a histogram of the number of microvariability events versus the amplitude of the observed microvariations for these 17 objects included in our sample (Figure 7). We then compared this histogram to similar histograms constructed for radio-selected (RBL) and X-ray-selected (XBL) blazars (Miller and Noble [17]). (Note that FSRQs are included in RBLs.) In all three histograms, the distributions for small-amplitude events are quite similar. However, both the RBL and vRL NLSy1 histograms show a significant number of large-amplitude events while no large-amplitude events are found in the XBL histogram. Miller and Noble [17] performed a Kolmogorov-Smirnov (K-S) test on the RBL and XBL histograms and found that there was only a 2.2% chance that they were drawn from the same parent distribution. A K-S test comparing the RBL distribution to that found for the vRL NLSy1s found that there was an 89% probability that these two distributions were drawn from the same parent distribution (Maune [18]). Therefore, the comparison of the histograms demonstrates that the character of the distribution of the microvariations is most similar to that found for the RBL blazars, strongly suggesting that the gamma-ray-loud vRL NLSy1s are closely related to the RBL blazars.

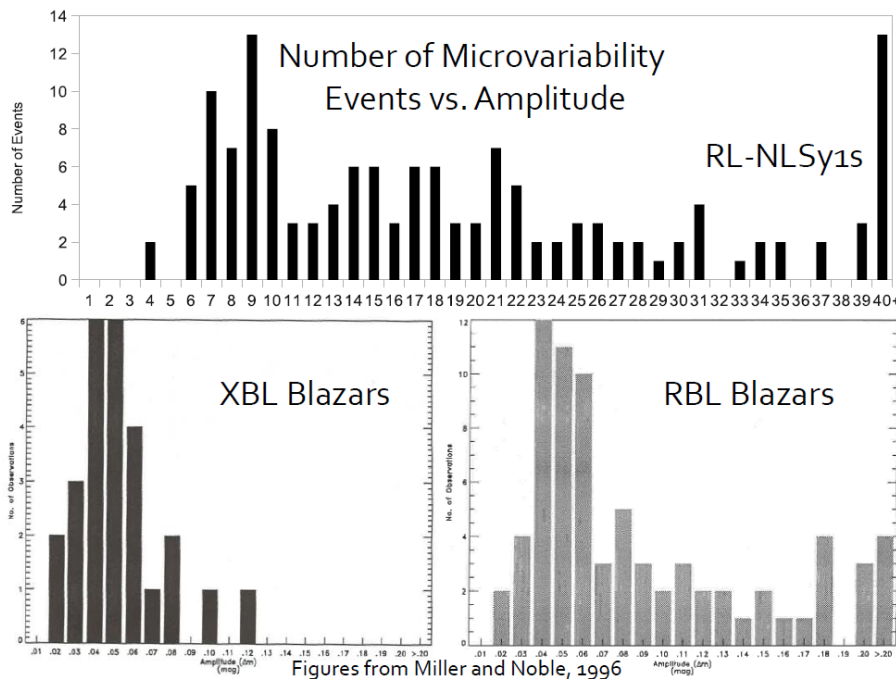


Figure 7. Histograms showing the number of microvariability events vs. amplitude. The top figure is reproduced from Maune [18] and uses a scale of 0.01 magnitude on the x -axis. The bottom two figures were originally printed in Miller and Noble [17] and use a one-magnitude scale. Note that the XBL sample was generally brighter than the other two, allowing for a bias in the detection of excess low-amplitude events.

We also have found extraordinary large-amplitude microvariations for two members contained in this sample (J0948+0022 and J0849+5108), which rival the most extreme behavior observed for any known blazar. In addition, we observed an optical orphan flare at optical wavelengths that had no detected gamma-ray counterpart. This also supports the possibility that gamma-ray-loud vRL NLSy1s are closely related to the RBL blazars.

In addition, the duty cycle for the gamma-ray-detected vRL NLSy1s studied in the present sample was found to be $DC = 0.42$ which is similar to the $DC \sim 0.45$ found for the RBL blazars (Carini, Miller and Noble, [19]). Previously, the duty cycle for a sample of radio-quiet NLSy1s was found to be $DC \sim 0.02$ (Ferrara, E.C. [20]). This clearly indicates that vRL NLSy1 galaxies exhibit quite different variability properties than those observed for normal NLSy1s. This also provides additional support for the hypothesis that the vRL NLSy1s have many properties in common with the RBL blazars. It should also be pointed out that no vRL NLSy1 has, to date, been detected at TeV energies, and that the duty cycles for XBL blazars are significantly different from those found for the vRL NLSy1s. All these properties suggest that vRL NLSy1s seem to be closely related to RBL blazars.

4. Conclusions

We have identified nine new gamma-ray-loud members of the Yuan et al. sample, all of which exhibit blazar-like properties. Our investigations have also shown that some (but not all) vRL NLSy1s in this sample exhibit blazar-like properties, including provisional gamma-ray detection, and variability of the optical polarization and flux (including microvariability). It was also found that radio-loudness by itself is a poor indicator of whether a member exhibits blazar-like properties. It was further determined that at least a gamma-ray detection with ($9 < TS < 25$) is likely required as a predictor of blazar-like properties for any object in this sample. We also found that microvariability, duty cycle and optical polarization for those gamma-detected objects in this sample are consistently RBL-like when detected, suggesting, to date, that all vRL NLSy1 blazars are RBL-like. This suggests that this subclass of NLSy1s then is likely to have masses for the central SMBH similar to those found for RBL blazars, leading to the conclusion that they have significantly more massive SMBHs than normal, radio-quiet NLSy1s. This is consistent with recent results reported by Baldi et al. [21] utilizing spectropolarimetric observations of RL NLSy1 galaxies, and earlier estimates of the black hole masses for NLSy1 galaxies (Marconi et al. [22]). This was independently suggested by Calderone et al. [23] who found black hole mass estimates for a sample of RL NLSy1 galaxies of at least a factor of six to ten times larger than earlier estimates based on single-epoch virial methods. This also means that Eddington ratios for these objects are correspondingly lower. Thus the present results suggest that the narrowness of the lines detected in their spectra may be explained as an orientation effect rather than an intrinsic property. Decarli et al. [24] have suggested that the observed optical spectrum of vRL NLS1 galaxies is due to the fact that these sources have a disk-like BLR and we are observing the BLR $\sim$ pole-on, with the line of sight to the observer near the axis of the relativistic jet. If this is the case, then there is little or no component of the velocity directed toward the observer which can cause Doppler broadening in a cylindrical-like BLR. Therefore, the mass of the central SMBH for these objects could be closer to that of FSRQs (a sub-class of RBLs) than that of radio-quiet NLS1 galaxies.

This study also raises a number of other questions. Do vRL NLSy1 galaxies in the present sample exhibit the giant-amplitude intraday X-ray variability commonly observed for NLSy1s (Boller et al. [25]), or do they exhibit smaller-amplitude intraday X-ray variations closer to that of FSRQs? Does the morphology of the host galaxy play a significant role in the formation of relativistic jets? How do vRL NLSy1 galaxies differ from normal RBL blazars (other than morphology of the host galaxy)? If the vRL NLSy1 galaxies are part of the population of RBL blazars, then are there XBL analogues to these objects, and if so, why have they not been detected?

Acknowledgments: The authors thank GSU for support through the RPE program and the Lowell Observatory and Cerro Tololo Interamerican Observatory for observation time. H.R.M. thanks the NSF for partial support during 2010–2012.

Author Contributions: All authors participated in collecting the observational data, analysis, discussion and writing of this manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Abdo, A.A.; Ackermann, M.; Ajello, M. Fermi/Large Area Telescope Discovery of Gamma-Ray Emission from a Relativistic Jet in the Narrow-Line Quasar PMN J0948+002. *Astrophys. J.* **2009**, *699*, 976–984. [CrossRef]
2. Abdo, A.A.; Ackermann, M.; Ajello, M. Radio-Loud Narrow-Line Seyfert 1 as a New Class of Gamma-Ray Active Galactic Nuclei. *Astrophys. J.* **2009**, *707*, L142–L147. [CrossRef]
3. Yuan, W.; Zhou, H.Y.; Komossa, S.; Dong, X.; Wang, T.; Lu, H.; Bai, J. A Population of Radio-Loud Narrow-Line Seyfert 1 Galaxies with Blazar-Like Properties? *Astrophys. J.* **2008**, *685*, 801–827. [CrossRef]
4. Komossa, S.; Voges, W.; Xu, D.; Mathur, S.; Adorf, A.; Lemson, G.; Duschl, W.; Grupe, D. Radio-loud Narrow-Line Type 1 Quasars. *Astron. J.* **2006**, *132*, 531–545. [CrossRef]
5. Kellerman, K.I.; Sramek, R.; Schmidt, M.; Shaffer, D.B.; Green, R. VLA observations of objects in the Palomar Bright Quasar Survey. *Astron. J.* **1989**, *98*, 1195–1207. [CrossRef]
6. Osterbrock, D.E.; Pogge, R.W. The Spectra of Narrow-Line Seyfert 1 Galaxies. *Astrophys. J.* **1985**, *297*, 166–176. [CrossRef]
7. Goodrich, R. Spectropolarimetry of ‘Narrow-Line’ Seyfert 1 Galaxies. *Astrophys. J.* **1989**, *342*, 224–234. [CrossRef]
8. Strittmatter, P.A.; Serkowski, K.; Carswell, R.; Stein, W.; Merrill, K.M.; Burbidge, E.M. Compact Extragalactic Nonthermal Sources. *Astrophys. J.* **1972**, *175*, L7–L13. [CrossRef]
9. Miller, H.R.; Carini, M.T.; Goodrich, B.D. Detection of Microvariability for BL Lacertae Objects. *Nature* **1989**, *337*, 627–629. [CrossRef]
10. Eggen, J.R. Optical Polarimetry and Gamma-Ray Observations of a Sample of Radio-Loud Narrow-Lined Seyfert 1 Galaxies. Ph.D. Dissertation, Georgia State University, Atlanta, GA, USA, 2014.
11. Eggen, J.R.; Miller, H.R.; Maune, J.D. The Variable Optical Polarization and Fermi Observations of PMN J0948+0022. *Astrophys. J.* **2013**, *773*, 85–94. [CrossRef]
12. Mattox, J.R.; Bertsch, D.L.; Chiang, J.; Dingus, B.L. The Likelihood Analysis of EGRET Data. *Astrophys. J.* **1996**, *461*, 396. [CrossRef]
13. Foschini, L.; Berton, M.; Caccianiga, A.; Mathur, S. Properties of Flat-Spectrum Radio-Loud Narrow-Line Seyfert 1 Galaxies. *Astron. Astrophys.* **2015**, *575*, A13–A50. [CrossRef]
14. Maune, J.D.; Eggen, J.R.; Miller, H.R. The Extreme Optical Variability of J0948+0022. *Astrophys. J.* **2013**, *762*, 124–130. [CrossRef]
15. Miller, H.R.; Turner, C.; Eggen, J.; Maune, J. Optical and Gamma-Ray Variability of the vRL NLSy1 galaxy, 1H 0323+342. *Galaxies* **2017**, *5*, 7. [CrossRef]
16. Carrasco, L.; Recillas, E.; Porras, A.; Carraminana, A. NIR Flare of the Radio-Loud Narrow-Line Sy1 SBS 0846+513. *Astronomer’s Telegram*. 2013, p. 5085. Available online: <http://www.astronomerstelegam.org/?read=5085> (accessed on 1 March 2017).
17. Miller, H.R.; Noble, J.C. The Microvariability of Blazars and Related AGN. In *Blazar Continuum Variability, Proceedings of the ASP Conference Series, Miami, FL, USA, 4–7 February 1996*; Astronomical Society Pacific: San Francisco, CA, USA, 1996; Volume 110, pp. 17–29.
18. Maune, J.D. The Detection of Microvariability in a New Class of Blazar-Like AGN. Ph.D. Dissertation, Georgia State University, Atlanta, GA, USA, 2014.
19. Carini, M.T.; Miller, H.R.; Noble, J.C. Microvariability in Seyfert Galaxies. *Astron. J.* **2003**, *125*, 1811–1816. [CrossRef]
20. Ferrara, E.C. The Variability Characteristics of Broad and Narrow Lined Seyfert 1 Galaxies. Ph.D. Dissertation, Georgia State University, Atlanta, GA, USA, 2000.
21. Baldi, R.D.; Capetti, A.; Robinson, A.; Laor, A.; Behar, E. Radio-Loud Narrow-Line Seyfert 1 under a Different Perspective: A Revised Black Hole Mass estimate from Spectropolarimetry. *Mon. Not. R. Astron. Soc.* **2016**, *458*, L69–L73. [CrossRef]
22. Marcone, A.; Axon, D.; MaioLino, R.; Nagao, T.; Pastorini, G.; Pietrini, P.; Robinson, A.; Torricelli, G. The Effect of radiation Pressure on Virial Black Hole Mass Estimates and the Case of Narrow Line Seyfert 1 Galaxies. *Astrophys. J.* **2008**, *678*, 693–700. [CrossRef]

23. Calderone, G.; Ghisellini, G.; Colpi, M.; Dotti, M. Black Hole Mass Estimate for a Sample of Radio-Loud Narrow-Line Seyfert 1 Galaxies. *Mon. Not. R. Astron. Soc.* **2013**, *431*, 210–239. [[CrossRef](#)]
24. Decarli, R.; Dotti, M.; Fontana, P.; Haardt, F. Are the Black Hole Masses in Narrow-Line Seyfert 1 Galaxies Actually Small? *Mon. Not. R. Astron. Soc.* **2008**, *386*, L15–L19. [[CrossRef](#)]
25. Boller, T.; Brandt, N.; Fink, H. Soft X-Ray Properties of narrow-Line seyfert 1 Galaxies. *Astron. Astrophys.* **1996**, *305*, 53–73.



© 2017 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).