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Optical and Gamma-Ray Variability of the vRL NLSy1 Galaxy, 1H 0323+342

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Abstract: 1H 0323+342 was one of the first vRLNLSy1 galaxies detected at gamma-rays with the Fermi-LAT and is one of the brightest of this class observed at optical wavelengths. We report the results of monitoring the optical flux, polarization and the gamma-ray flux of 1H 0323+342 during the past ~5 years. In some cases, the optical flux has been monitored on timescales as short as ~minutes simultaneously with two telescopes, demonstrating, for the first time, the reality of microvariability events with durations as short as ~15 min for this object.

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

1. Introduction

Recently, Fermi has identified a small number of very radio-loud narrow-line Seyfert 1 galaxies (vRL NLSy1) as gamma-ray sources (Abdo et al. [1]). These objects exhibit many properties similar to those seen for blazars (Abdo et al. [2]). 1H 0323+342 was one of the first vRLNLSy1 galaxies detected at gamma-rays with the Fermi-LAT and is one of the brightest of this class observed at optical wavelengths. As such, it is an attractive object to monitor at both optical and gamma-ray wavelengths. In this paper, we report the results of monitoring the optical flux, polarization and the gamma-ray flux of 1H 0323+342 during the past ~5 years. In addition, the optical flux has been monitored on timescales as short as ~minutes, simultaneously with two telescopes, demonstrating, for the first time, the existence of microvariability discrete events with durations ~15 min.

2. Observational Program

Optical photometric observations were obtained using the 31″ NURO, 42″ Hall, and 72″ Perkins telescopes at Lowell Observatory in Flagstaff, Arizona. R-band magnitudes were derived via aperture photometry of in-field comparison stars. These comparison stars were selected for their photometric stability, and have been repeatedly re-tested to ensure this property. The finding charts, with comparison star R-band magnitudes, can be found on GSU's dedicated web pages (https://sites.google.com/site/jdmaune/seyfert-fields). Figure 1 displays a single night of simultaneous (31″ & 72″, respectively) observations of 1H 0323+342, demonstrating the reality of extremely low amplitude microvariability. Figure 2 displays the results of our MW monitoring program. All of our optical polarimetric data were obtained using the 72″ (1.83 m) telescope at Lowell Observatory, equipped with the PRISM instrument. Observations were obtained during several different observing runs between November 2010 and March 2015.

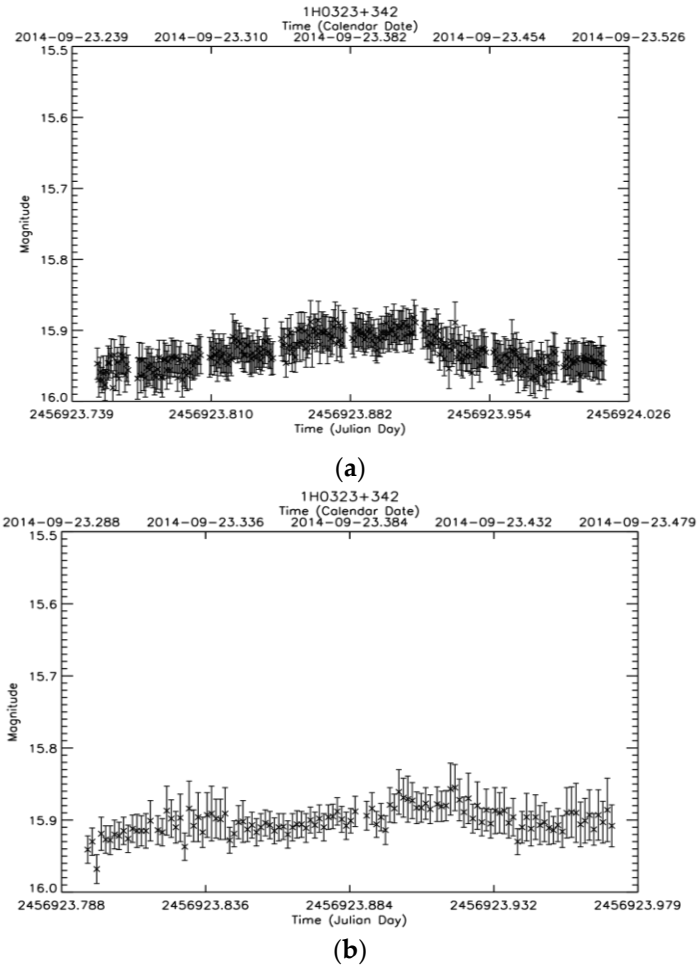

Figure 1. Intra-night R-band light curves of 1H 0323+342. Both light curves are plotted on a 0.5 magnitude scale. Microvariablity is clearly detectable for this object.

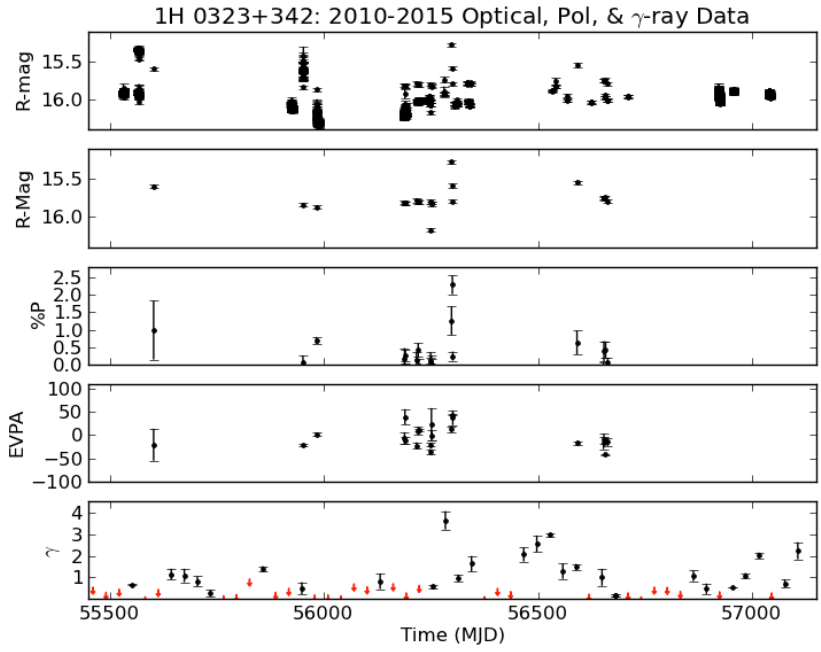

Figure 2. Quasi-simultaneous gamma-ray and optical R-band data for 1H 0323+342.

Gamma-ray data were obtained through the Fermi public data server, and were collected using the Large Area Telescope (LAT) over the entirety of its mission lifetime. The data were reduced and analyzed using ScienceTools v9r33p0 and instrument response functions P7REP_SOURCE_V15. The data were binned in 30.5 day increments, and a likelihood analysis was performed on each bin. The resulting gamma-ray lightcurve is co-plotted in Figure 2 (bottom panel) along with the results of our optical monitoring of the 1H 0323+342 (top).

3. Results

Following the technique employed by Carini, Miller and Goodrich [3], simultaneous observations of 1H 0323+342 were obtained using the 31-in and 72-in telescopes at Lowell Observatory (Figure 1). A cross correlation analysis of the light curves was performed. The Pearson's Correlation Coefficient was then calculated for these lightcurves, with the result of P(0) = 0.914 at zero time lag. This demonstrates, for the first time, the reality of very low-amplitude ($\Delta MR \leq 0.05$) microvariability events for 1H 0323+342. Previously, Paliya et al. [4] and Paliya et al. [5] reported detecting the presence of intranight optical variability (INOV) for 1H 0323+342. These results report the presence of low-level linear trends occurring during a single night, but not microvariations. Microvariability, as identified in Miller, Carini and Goodrich [6], refers to discrete events occurring on timescales of minutes to hours, or doubling times on similar timescales; but does not include simple low level linear trends spanning several hours.

In Figure 2, our multifrequency and polarimetric monitoring observations spanning from 2010 to 2015 are presented. 1H 0323+342 was observed to vary by approximately 1.1 magnitudes over the course of our ~5 year program, although the largest variation observed in a single night was $\Delta MR = 0.14$. The maximum degree of polarization observed during this period for this source was $P = 2.29\% \pm 0.27\%$. 1H 0323+342 is highly variable at gamma-ray wavelengths. The source was observed to undergo long periods (several consecutive months) of non-detectability punctuated by shorter periods of activity. A gamma-ray high-flux state was observed to precede an optical polarimetric flare by a matter of days near the middle of our monitoring period, occurring as the polarization reached its maximum noted above. Although there seems to be a quasi-coincidence in the occurrence of this gamma-ray/optical flare, the data are too sparsely populated to allow the rigorous analytical support of this possibility. In addition, there is an optical flare near ~MJD 56000 which has no obvious gamma-ray counterpart, and there is a gamma-ray event which has no optical counterpart near MJD 56500. This suggests that there is no strong evidence of a gamma-ray/optical correlation of events.

4. Conclusions

We have, for the first time, demonstrated the reality of microvariability events for 1H 0323+342 with an amplitude of ~0.05 mag. We have reported the first long term monitoring of the optical flux and polarization and the gamma-ray flux for this vRL NLSy1 galaxy. Although this object exhibited more than 1.0 mag variation during this monitoring program, no strong correlation was found between the optical and gamma-ray flux variations. However, the data sampling may be too sparse to fully address this question.

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

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