Optical and γ-Ray Variability of the RL NLSy1 Galaxy 1H 0323+342

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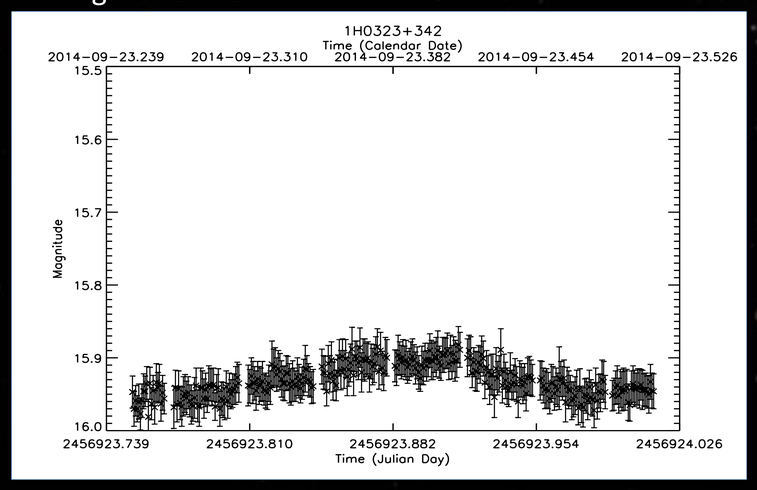
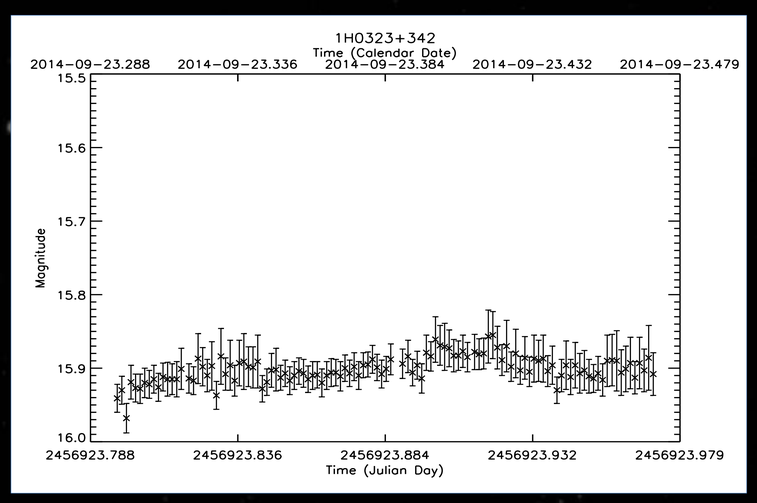
Abstract: Narrow Line Seyfert 1 (NLSy1) galaxies are a class of AGN first identified by Osterbrock & Pogge (1985). The optical spectra, for members of this class, contain narrower than usual permitted lines with FWHM(Hβ) < 2000 km/sec. Lines from both the broad line region (BLR) and narrow line region (NLR) are present in NLSy1s spectra, but the permitted lines from BLR are narrower than that found for Seyfert 1 galaxies. The detection by Fermi of strong and variable gamma-ray emission from the class of AGN known as radio-loud narrow-line Seyfert 1 galaxies (RLNLSy1s), provides strong evidence that these sources contain powerful jets oriented near the line-of-sight to the observer.

1H 0323+342 is one of the first RLNLSy1 galaxies detected with the 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 work, 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 existence of discrete events with durations ~15 minutes.

Figures 1 & 2 – Simultaneous Photometric data





The above simultaneous lightcurves demonstrate low-amplitude ($\Delta M_R < 0.05$) micro-variability for this source in a single night.

Data and Instrumentation: Our optical photometric data 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 our group's dedicated web pages (https://sites.google.com/site/jdmaune/seyfert-fields). Figures 1 & 2 display a single night of simultaneous (31" & 72", respectively) data on this source, demonstrating the reality of extremely low amplitude microvariability. Figure 3 displays the results of our MW monitoring program.

All of our optical polarimetric data were obtainded from the 72" (1.83 m) telescope at Lowell, using the PRISM instrument. Data were taken during several different runs between 2010 November and 2015 March. For a description of our polarimetric data reduction process, please see our poster titled "***The Population of RL NLSy1 Galaxies with Blazar-Like Properties***". Our photo-polarimetric data are presented in Figure 3 (panels 2, 3, & 4).

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 3 (bottom panel) along with the results of our optical monitoring of the target (top).

Figure 3

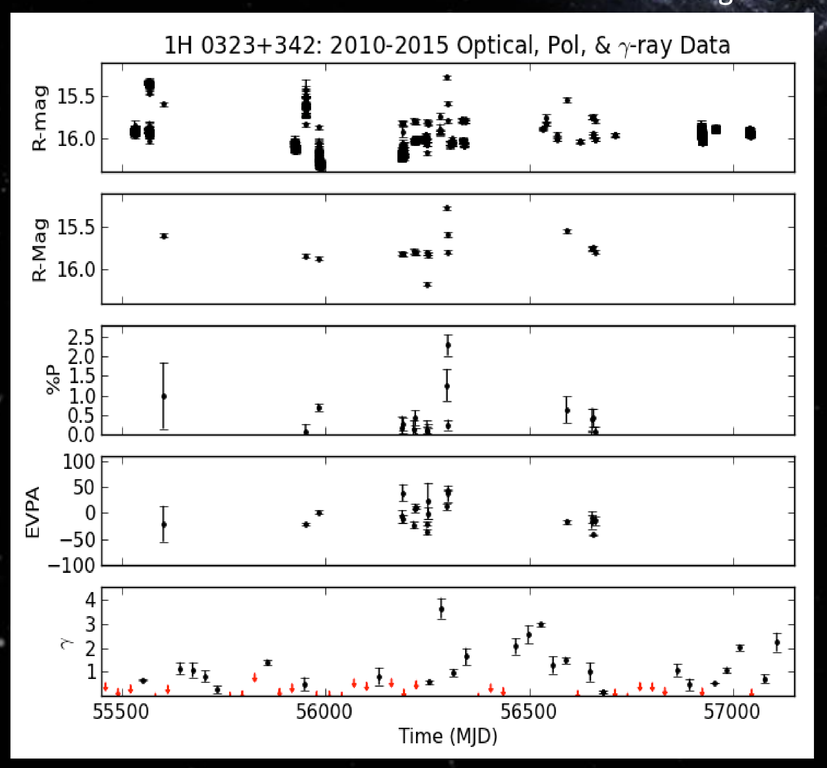


Figure 4 – Polynomial fits to Figures 1 & 2

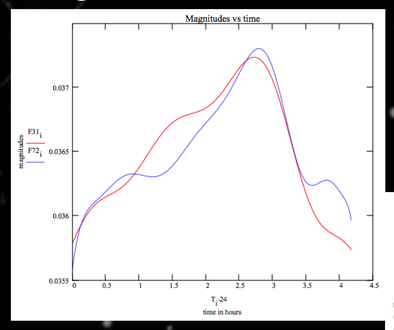
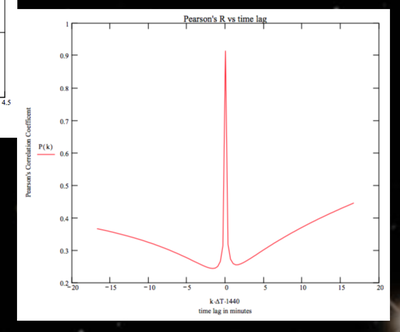


Figure 5 – Pearson's R correlation between LCs



Results: The simultaneous lightcurves in Figures 1 & 2 were converted to flux and fit with N = 16 polynomial, as illustrated in Figure 4. The Pearson's Correlation Coefficient was then found for these lightcurves, with a result of P(0) = 0.914 at zero time lag (Figure 5). This result demonstrates the reality of low-amplitude ($\Delta M_R \leq 0.05$) microvariability events.

The overall results of our multi-wavelength monitoring program are displayed in Figure 3. 1H 0323+342 has been observed to vary by approximately 1.1 magnitudes over the course of our ~5 year program, though the largest variation observed in a single night was $\Delta M_R = 0.14$. The maximum degree of polarization observed for this source was %P = 2.29 ± 0.27%,, with a minimum of ~0%.

1H 0323+342 is highly variable in the gamma-ray regime. The source was observed to undergo long (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/flux state by a matter of days near the middle of our monitoring period.