SMARTS Optical Spectroscopy of Blazar 3C 454.3

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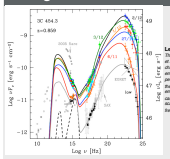
Daily BVRJK light curves may be found at http://www.astro.yale.edu/smarts/glast/index.html

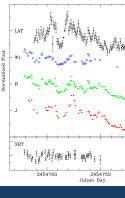
Abstract

We report ongoing spectroscopic observations of 3C 454.3 using the Small and Moderate Aperture Research Telescope System (SMARTS) 1.5m telescope + RC Spectrograph located at Cerro-Tololo Inter-American Observatory (CTIO). Spectra have been obtained roughly every 14 days from August 2008 through December 2010, during which 3C 454.3 has undergone several prominent optical and γ-ray flares. We find that while the equivalent width (EW) of 3C 454.3 varies, the line flux remains approximately constant. This result suggests that the Broad Line Region (BLR) is photoionized by the accretion disk rather than from the highly variable relativistic jet. We find the strength of the MgII line to be consistent with a line flux of ~ 2.0 x 10^{-14} erg $s^{-1}cm^{-2}A^{-1}$ to within a factor of 2. This finding also implies that accretion disk does not vary strongly on timescales of at least 2.5 years.

Background



Left: *The SED of 3C 454.3 (Bonnoli et al. 2011) shows the characteristic shape of blazar emission. The two prominent humps/peaks are thought to arise as the result of synchrotron emission in the lower frequency case and inverse Compton scattering in the higher frequency peak.*

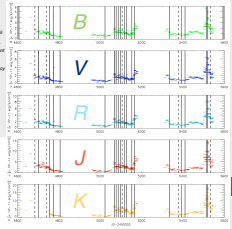


Methods

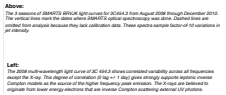
Table 1. 3C 454.3 Observation Log

UT Date	JD (-2450000)	V	σ_V	EW_{MgII}	F_{MgII}
22 Aug 2008	4701.66	15.094	0.007	8.689	1.287
13 Oct 2008	4753.66	15.418	0.008	7.638	0.8263
03 Nov 2008	4771.66	15.332	0.013	19.46	0.9716
04 Dec 2008	4803.55*	16.144	0.011	15.7	0.5548
09 Jul 2009	5022.83	16.398*	0.018	15.79	0.9263
26 Aug 2009	5098.78	14.955	0.008	3.501	1.156
01 Sep 2009	5078.68	15.213	0.010	5.806	1.021
11 Sep 2009	5088.63	15.308	0.007	6.776	1.022
23 Sep 2009	5097.63	15.434	0.007	7.079	1.249
11 Oct 2009	5116.51	15.330	0.008	8.922	1.257
22 Oct 2009	5127.50	15.319	0.008	8.397	1.137
01 Nov 2009	5132.50	15.495	0.015	9.673	0.9914
29 Nov 2009	5160.55	14.486	0.007	6.521	1.356
18 May 2010	5325.92*	15.305	0.008	7.535	0.9757
13 Jul 2010	5361.78	15.956	0.010	14.57	0.9068
31 Jul 2010	5408.77*	15.903	0.013	15.69	1.196
11 Nov 2010	5512.52	14.426	0.007	2.561	1.149
17 Nov 2010	5518.53	14.664	0.009	1.34	4.289

Above: *The spectroscopic observation log of 3C 454.3. Dates marked with an asterisk mark observations that are not simultaneous with photometry (at < 1 day in all cases).*

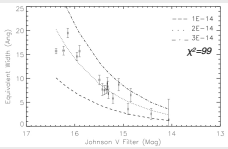


Above:
The 3 seasons of SMARTS BRVJK light curves for 3C454.3 from August 2008 through December 2010. The vertical red lines mark the dates where SMARTS optical spectroscopy was done. Dashed lines are omitted from analysis because they lack calibration data. These spectra sample factor~of 10 variations in jet intensity.

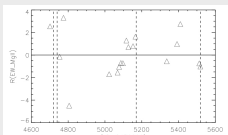


Left:
The 3008 multi-wavelength light curve of 3C 454.3 shows correlated variability across all frequencies except the X-ray. This degree of correlation (0 lag +/- 1 day) gives strongly supports leptonic inverse Compton models as the source of the higher frequency peak emission. The X-rays are believed to originate from lower energy electrons that are inverse Compton scattering external UV photons.

Results



Above:
The lines represent predictions of the EW of the MgII emission line if the line flux were held constant at values of 1-, 2-, and 3 x 10^{-14} erg $s^{-1}cm^{-2}A^{-1}$. The line flux does not vary significantly; the observed EWs are consistent with a line flux that varies by no more than 50% over the 2.5 year time frame of observation.



Above:
The residuals of the measured MgII EW. The vertical dashed lines mark the approximate dates of the four most prominent multi-wavelength flares, which can be seen in panel at left. There is no obvious trend of EW with flares, supporting the idea that the accretion disk is the photoionizing source, and that it varies modestly over 2.5 years.

Physical Implications

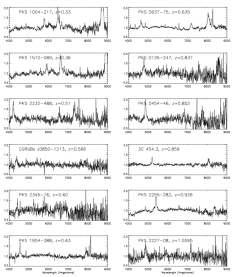
- Small variations in the MgII line luminosity suggests the accretion disk is photoionizing the broad emission-line clouds.
- Over the 2.5 year time frame of the SMARTS monitoring, the accretion disk emission appears to gave varied slightly (by a factor of 2 or less) in the optical/ near-infrared, far less than the factors of 10 variations in the jet emission.
- The jet variability cannot be caused by large mass injections through the accretion disk because that would cause the disk luminosity to change more dramatically than is observed. Therefore the tremendous variability observed in the jet luminosity must be intrinsic to the jet (local shocks, change in Doppler factor, etc.).

Next Steps

3C 454.3

- Extended flare correlation analysis.
- Constraints on the disk luminosity via upper limits imposed from minimum ionizing flux necessary to produce observed emission lines.
- Constraints on the disk luminosity from disk-jet decomposition.

Yale-SMARTS Spectroscopy Program



Above:
A representative sample of the hundreds of SMARTS spectra available for approximately 20 blazars . As can easily be seen from just this subset of data, there are many emission lines of varying ionization states that can be investigated further.

Yale-SMARTS Monitoring Program

- SMARTS Cliff Photometric Monitoring of Fermi Blazars, Bonning et al., in prep.
- Time Variability Analysis of SMARTS Monitoring of Fermi Blazars, Chatterjee et al., 2011arXiv1101.3815C
- Correlated Variability in the Blazar 3C 454.3, Bonning et al., 2009, ApJ, 697, 81

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