Optical Variability of the TeV Blazar PG 1553+113 with Sampurnanand Telescope

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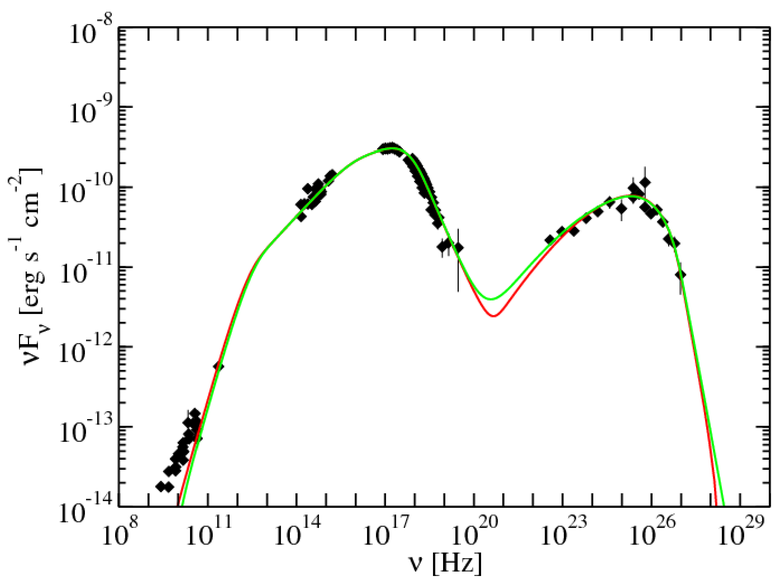
Abstract

We report the optical flux variability of PG 1553+113 on intra-night using VRI data collected over 9 nights from 15 March to 14 June, 2019 employing Sampurnanand Telescope, ARIES, Nainital. We monitored the blazar quasi-simultaneously for 4 nights in the V and R bands and 3 nights in the V, R, I bands and examined the light curves (LCs) for intra-day flux and colour variations using two powerful tests: the power-enhanced F-test and the nested ANOVA test. The source was found to be significantly (> 99%) variable in 2 nights out of 9 in R-band, 1 out of 7 in V-band, and 1 out of 3 nights in I-band. No temporal variations in the colours were observed on IDV timescale. During the course of these observations the total variation in R-band was 0.35 mag observed. We discuss possible physical causes of the observed flux variability.

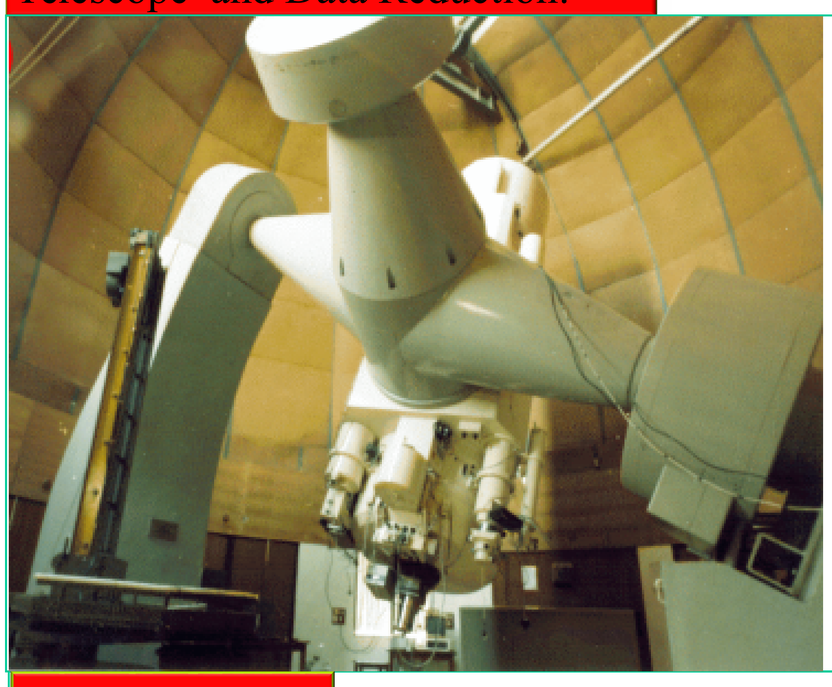
Introduction

Blazars are a subclass of radio-loud AGNs.

- ➢ Make angle of < 10^0 between the LOS & the emitted jet from the source.
- ➢ Display rapid flux variability in the complete EM spectrum.
- ➢ Show variable polarization in radio to optical bands.
- ➢ Emission in all wavelengths is non-thermal (predominantly) .
- ➢ Broadband SED is characterized by two broad humps.



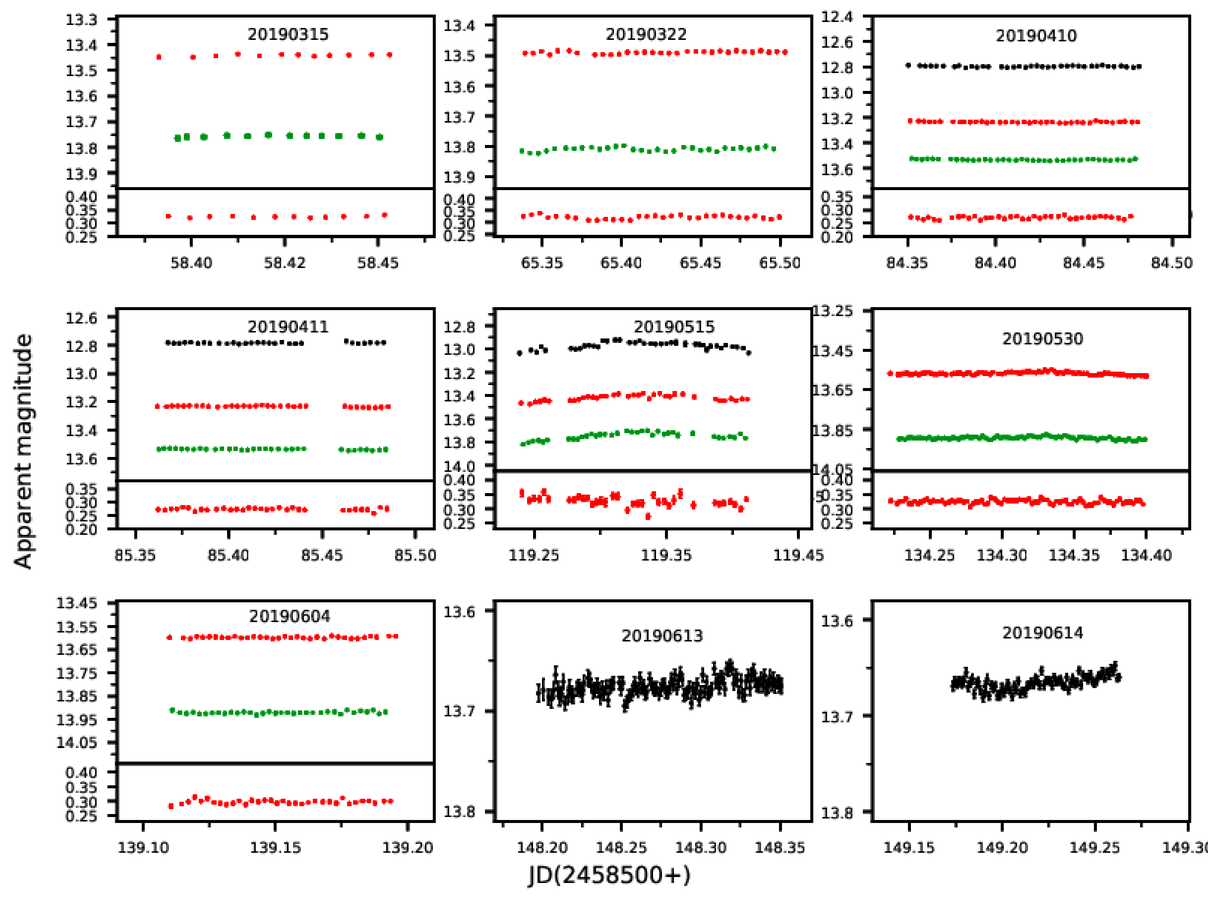
Telescope and Data Reduction:



1.04 m Sampurnanand Telescope (ST)

The pre-processing of the raw images was done using the standard routines available in the Image Reduction and Analysis Facility (IRAF) and aperture photometry was done by DAOPHOT software packages.

Results:



- ➢ R-band: 2/ 9
  V-band: 1/7
  I-band: 1/3
- ➢ No color variation found
- ➢ Amplitude variation is increased with frequency

Observation date	Band	*Power-enhanced F-test*			*Nested ANOVA*			Status	Amplitude
yyyy-mm-dd		DoF(ν_1,ν_2)	F_{enh}	F_c	DoF(ν_1,ν_2)	F	F_c		%
20190515	V	35, 70	6.53	1.93	6, 28	10.36	3.52	V	11.86
	R	35, 70	3.13	1.93	6, 28	8.57	3.52	V	9.05
	I	35, 70	3.21	1.93	6, 28	3.75	3.52	V	8.24
	V-R	35, 70	0.82	1.93	6, 28	1.44	3.52	NV	–
20190530	V	81 ,162	1.29	1.55	15,64	1.25	2.33	NV	–
	R	81 ,162	1.26	1.55	15,64	1.89	2.33	NV	–
	V-R	81, 162	0.82	1.55	15,64	1.36	2.33	NV	–
20190604	V	33, 66	1.88	1.96	5, 24	1.01	3.89	NV	–
	R	33, 66	0.75	1.96	5, 24	0.94	3.89	NV	–
	V-R	33, 66	0.91	1.96	5, 24	1.04	3.89	NV	–
20190613	R	123, 246	1.97	1.43	23,96	2.65	2.00	V	3.95
20190614	R	81. 162	0.47	1.55	15.64	1.57	2.33	NV	–

Analysis Techniques

Power-enhanced F-test: *(de Diego, 2014)*

$$F_{enh} = \frac{s^2_{blz}}{s^2_c},$$

where

$$s^2_c = \frac{1}{(\sum_{j=1}^{k} N_j) - k} \sum_{j=1}^{k} \sum_{i=1}^{N_i} s^2_{j,i}$$

s^2_{blz} is the variance of the (blazar – ref star) DLCs

s^2_c is the combined variance of the (com. star – ref star) DLCs;

N_j is the number of observations of the jth comparison star

Nested Anova test *(de Diego et al., 2015)*

Nested ANOVA Test compares the variances of means between the groups to the variances of means within the groups. It uses all the comparison stars as reference stars to generate DLCs.

A light curve is considered as variable (V) only if significant variations were found by both the tests, otherwise we conservatively declare it non-variable (NV).

Intraday Variability Amplitude *(Heidt & Wagner, 1996)*

$$Amp = 100 \times \sqrt{(A_{max} - A_{min})^2 - 2\sigma^2}$$

Duty Cycle(DC):

$$DC = 100 \frac{\sum_{i=1}^{n} N_i (1/\Delta t_i)}{\sum_{i=1}^{n} (1/\Delta t_i)} \text{per cent}$$

N_i = 1 if IDV was detected, otherwise N_i = 0

Discussion

- ➢ Significant intraday flux variations were detected in V, R, and I band LCs only on 2019, May 15 and variability amplitude in range of 8-12 %, and the bright and faint magnitude is 13.2 and 13.55 in R band, respectively
- ➢ We found no temporal V − R color variation on IDV timescale.
- ➢ DC is 22.22%, 14.28%, 33.33% in R, V, I band, respectively.
- ➢ At optical wavelengths, TeV HBLs are less variable and their variability amplitudes are very small as compare to X-ray and Gamma-ray.