The Long-term Optical Monitoring of VHE Blazars

Kurtanidze Omar, Chigladze Revaz, Nikolashvili Maria, Kurtanidze Sofia

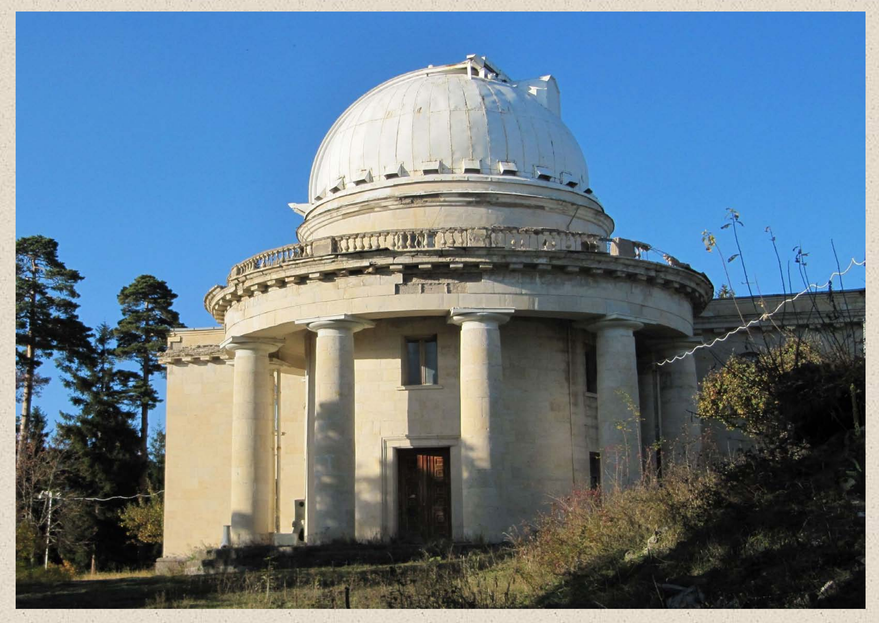
Abastumani Observatory, Mt. Kanobili, 0301 Abastumani, Georgia

To study optical variability of extragalactic objects, namely VHE sources, in Abastumani Observatory we are conducting a long-term monitoring of selected blazars using 70-cm (f/3, SBIG ST6 and Apogee Ap6E) meniscus and 1.25-cm Ritchey-Chretien (f/13, Apogee Ap6E) dedicated telescopes and Calar-Alto Observatory (123-cm and 220-cm, 1999-2003, Spain) telescope. During last twenty years we collect ~400 000 CCD frames (3 500 nights). This extensive monitoring campaign over 100 blazars during 1st five years were carried out in BVRI bands and later on from 2002 mainly in R band to enhance the sampling. The frames have been reduced using Daophot II and the homogenous sample of lightcurves have been generated. The amplitudes of long-term variability are within 0.3-4.5 magnitudes. Few sources show Intra-day variability within 0.1-1.0 magnitudes, while intra-night/micro-variability is below 0.05-0.60 magnitudes. The results of multi-wavelength campaigns (VLBA, OVRO, ALMA, UMRAO, Effelsberg 100-m, WEBT, ATOM, SMARTS, FERMI/LAT, AGILE, SWIFT, HESS, VERITAS, MAGIC and etc.) are also presented. To extend optical photometric, polarimetric and spectral survey of fainter sources with high temporal resolution, we are considering purchase of two meter class telescopes.

Introduction

The history of the optical variability of Blazars begins with the identification of the radio source VRO 42.22.01 (1968) with the “variable star” BL Lacertae discovered in the late of 1920s by Hoffmeister. They are variable along the whole emission spectrum from radio to TeV bands. The 3rd catalog of EGRET (20 MeV-30 GeV) showed that among extragalactic sources discovered most sources are blazars. The blazars are the most prominent class of associated sources in FERMI/LAT, HESS, VERITAS and MAGIC catalogues. They were among the first sources detected at TeV energies and have remained the largest source population for TeV gamma-ray astronomy.

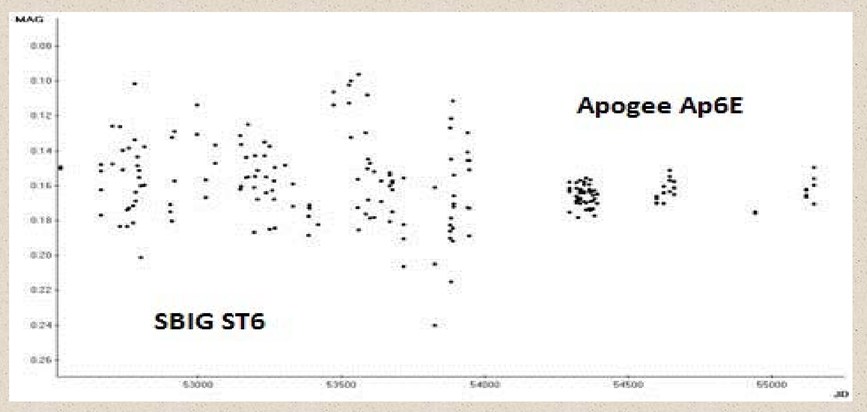
One of the distinguishing characteristics of the Blazars, which includes BL Lacertae objects, high polarization quasars (HPQ) and optical violently variable (OVV) quasars is that their flux densities are highly variable at all wavelength from radio to TeV. Blazars are also characterized by high apparent luminosities, short variability time-scales and apparent superluminal motion of jet components.

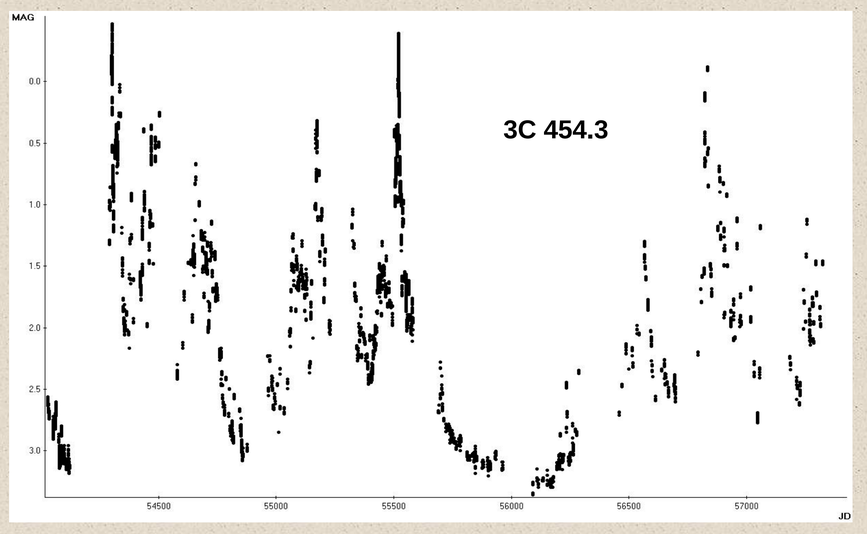


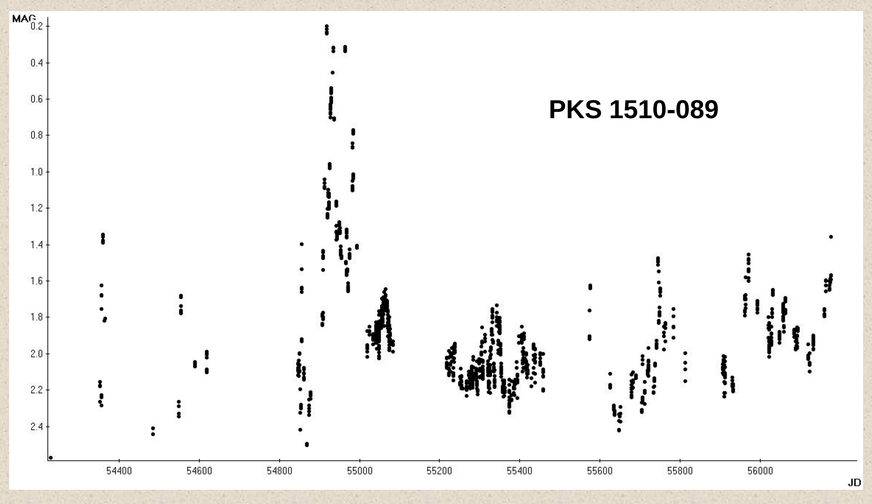
Observations and data reduction

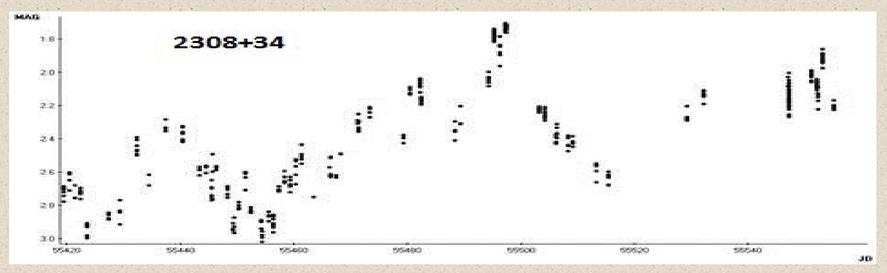
Abastumani Observatory is located at a latitude of 41.8 deg. and a longitude of 42.8 deg. on the top of the Mt. Kanobili (1700 m, ~150 nights per year, 1/3 with seeing <1 arc sec). The mean values of the night sky brightness are B=22.0, V=21.2, R=20.6 and I=19.8. The Abastumani Monitoring Program (1997-2006) was carried out using ST-6 CCD camera attached to the Newtonian focus of the 70-cm meniscus telescope (f/3, FOV is 15x11 sq. arc minute), Ap6E camera at 125 cm telescope (2005-2006, f/13, FOV is 5x5 sq. arc minutes). From September 2006 Ap6E camera was attached to the prime focus of 70-cm telescope. We are using combined filters of glasses that match the standard B, V (Johnson) and Rc, Ic (Cousins) bands well. Reference sequences in the blazar fields were calibrated by the Landolt's equatorial standard stars.

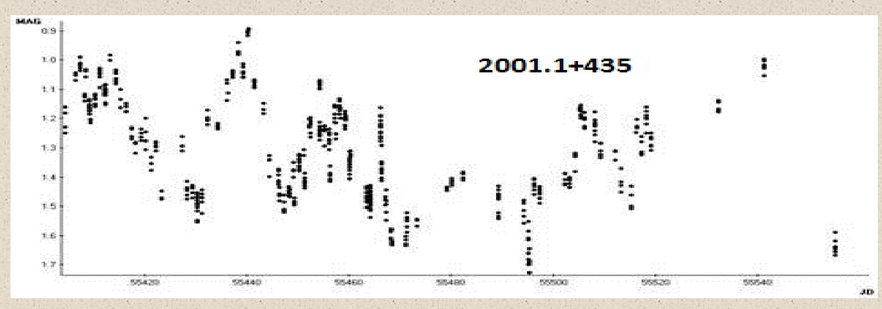
In the frame of the Program from 1997 to 2020, during more than 3500 observing nights, about 40000 frames were collected for over 100 target sources. Most frequently observed sources are BL Lacertae, 1ES 1959+650 and S5 0716+710, 3C 454.3, W Comae, Pg 1553+113, Mrk 421. Mrk 501, 3C 66A, OJ 287, PKS 1510-089, 1ES 0502+675, 1011+596, 2308+34, 2001.1+435 and others. All these images were reduced using DAOPHOT II. The differential photometric accuracy is 0.02 mag. (rms, star like sources) during 180 sec exposure at R=15.0. The list of target sources was compiled from different catalogues, while twelve X-ray BL Lac objects were selected from the catalogue of Perlman. Later on, most of these X-ray sources were identified as TeV ones. During photometric monitoring most easily task is to study IH and ID variability. We participated in many ground-based and space telescope MW campaigns (VLBA, OVRO, ALMA, UMRAO, Effelsberg 100-m, WEBT, ATOM, SMARTS, FERMI/LAT, AGILE, SWIFT, HESS, VERITAS, MAGIC and etc.) and over two dozen selected sources were studied in detail along the whole emission spectrum (3C 454.3 (6 publications), PKS 1510-089 (6), Mrk 421 (5), Mrk 501 (4), 1ES 0502+675,3C 279 (2), S5 0716+710 (2), BL Lac, OJ 287, OJ 248, 1ES 1517+656, 1ES 2344+514, 1ES 1011+496, Pg 1553+113, B3 1633+382, 4C 71.07, W Comae, 3C 66A, AO 0235+164, 4C+21.35 and others) that resulted in a publication of over 70 papers in HI factor journals. The LC of selected sources are presented.











Conclusions

The observed maximum variability amplitude of radio detected sources (BL Lacertae) reaches 6.0 magnitude in R band, while for TeV sources below 2 magnitude. To obtain the full timescales and amplitudes of variability it is required to conduct much more denser coverage of selected sources with dedicated 2-m class telescopes to achieve higher temporal resolution and photometric accuracy.

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