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LATEST ACHIEVEMENTS FROM BELOGRADCHIK OBSERVATORY

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Abstract. We present some of the resent (since Sept. 2020) instrumental developments at Belogradchik Astronomical Observatory, Bulgaria, and show examples of the first results. More specifically these include the first blazar polarization results, obtained with our new filter-based linear polarimeter, as well as the first transient event identification attempt, with the new wide-field camera.
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1. INTRODUCTION: BELOGRADCHIK OBSERVATORY

Belogradchik Astronomical Observatory is located at the NW part of Bulgaria, near the town of Belogradchik (at the northern outskirts of the Balkan mountain) at 610m altitude. The Observatory has been built in 1965 and since 1969 has operated a 60cm equatorial Cassegrain telescope, the largest instrument of its class in the Balkan peninsula at the time it was mounted. Throughout the first years the telescope has been equipped with electrophotometers as light detectors, but during the last 20 years mostly CCD's, equipped with standard UBVRI filters have been used (e.g. Strigachev & Bachev, 2011).

2. POLARIMETRIC MEASUREMENTS

Linear polarization measurements at Belogradchik Observatory were initiated mostly for purposes to study blazars. Blazars are a type of active galactic nuclei, in which most of the optical emission comes from a jet that happens to be pointed in the direction of the observer (Urry & Padovani, 1995). This emission is produced via synchrotron processes by relativistic particles in magnetic field and is linearly polarized (e.g. Rybicki & Lightman, 1986).

We used polarization filters, mounted on a double-barrel (7x7) filter set, so the polarization filters could be combined with any of the other photometric filters

(UBVRI). Instead of the normally used 4 polarimetric filters (oriented at 0, 45, 90, 135 degrees), our setup included only 3 filters, oriented at 0, 60 and 120 degrees. Still, the polarization parameters of the source can be derived, however the calculation is somehow more difficult, as the standard Stokes parameters, which would significantly facilitate the calculations, this time cannot be used.

Thus, if consider the light from a polarized source to consist of entirely polarized (I_p) and non-polarized (I_{np}) parts, then the measured intensities through the 3 polarization filters will be:

$$I_0 = \frac{1}{2} I_{np} + I_p . cos^2 \theta$$
$$I_{60} = \frac{1}{2} I_{np} + I_p . cos^2 (\theta - 60)$$
$$I_{120} = \frac{1}{2} I_{np} + I_p . cos^2 (\theta - 120)$$

We solve numerically the equation above for I_{np} and I_p. To assess the errors of these values, the equations have been solved repeatedly, varying the measured intensities within their respective measurement errors. Then for the polarization rate and the orientation (electric vector polarization angle, *EVPA*) one gets:

$$p[percent] = 100 \frac{I_p}{I_p + I_{np}}$$
$$EVPA \equiv \theta$$

As of the end of 2022 more than 20 blazars have been monitored polarimetrically, some of which on the intra-night time scale (e.g. Bachev, 2022a, 2022b, 2022c; Bachev & Strigachev, 2022). Some of our polarimetric measurements have already been published in major international journals even of the rang of *Nature* (Jorstad et al., 2022). Many of these objects showed significant changes and high polarization rates. For example, the blazar S4 0954+65 showed polarization rate of about 39% during the night of June 5, 2022 (Bachev, 2022a).

One of the most polarimetrically studied objects was BL Lacertae, the prototype of the blazar family. For this object, during its unprecedented 2020-2021 outburst we detected significant intra-night changes, not only in flux but also in polarization (Bachev et al., 2022). Figure 1 presents some of the results.

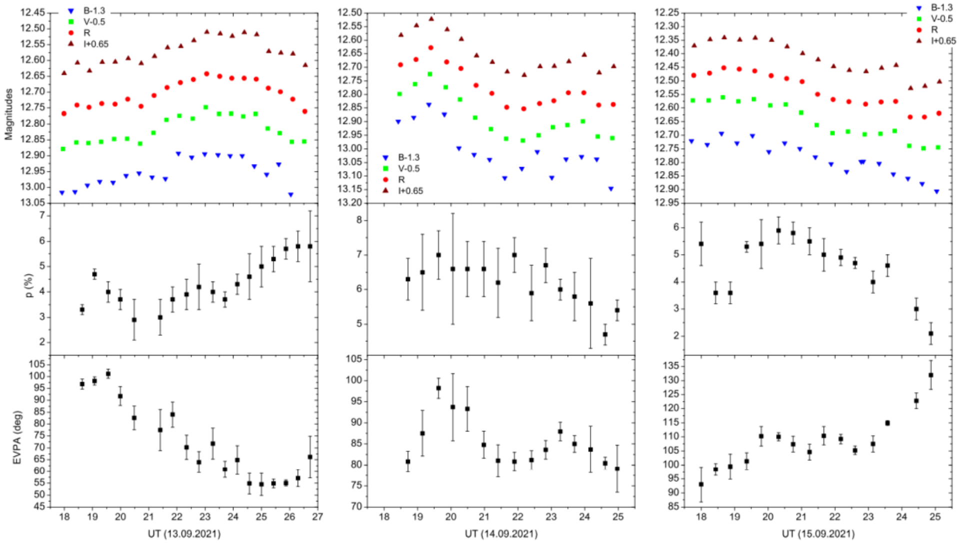

Figure 1: Intra-night multicolor and R-band polarimetric observations with the 60cm Belogradchik telescope. BVRI light curves (top panel) are shown together with polarization rate (middle panel) and EVPA (bottom panel) for each night. Significant variability in both flux and polarimetric parameters can be seen (Bachev et al., 2022).

3. WIDE-FIELD IMAGING

Another addition to the Belogradchik Observatory equipment is recently attached to the 60cm telescope an 8” F/2 *Celestron* Rowe-Ackermann Schmidt Astrograph for wide-field (around 3 degrees with the used *ZWO* ASI071MC CMOS) imaging, Figure 2. This instrument is intended mostly for fast optical identifications of transient events (GRB, neutrino or GW events, etc.), whose location is known only approximately. The idea is that if a transient, detected in other wavelengths or by other multi-messenger detectors would have an optical counterpart, we might be able to detect it and thus identify the source. Other activities may include comet imaging, educational purposes, etc.

One of the first attempts to identify an optical counterpart of a transient event was a gamma-ray burst (GRB201020B), detected by *Fermi* satellite (Fermi GBM Team, 2020) and located with a 3-degree error. *Master* network detected shortly after the *Fermi* trigger a 13.7 mag object in the field (Lipunov et al., 2020) and thus the object was identified. Unfortunately, our observations could have taken place only about 4 hours later, when the object apparently had faded (Figure 3).

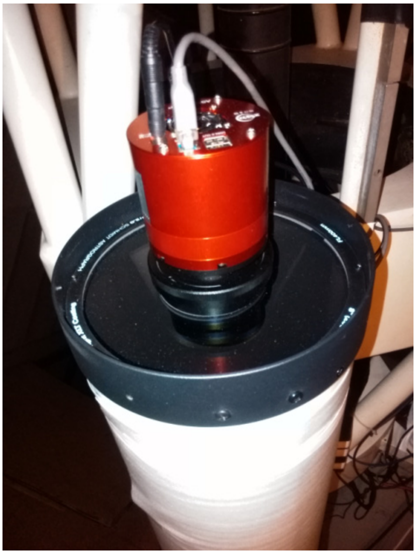

Figure 2: The 8” F/2 Rowe-Ackermann Schmidt Astrograph for wide-field imaging and transient identification, attached to the 60cm telescope.

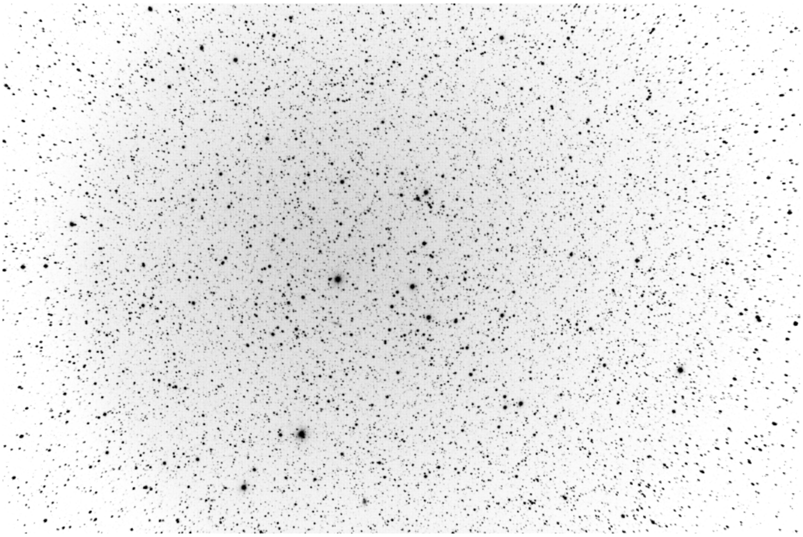

Figure 3: The 3-degree field of the GRB201020B event, observed with the 8” F/2 astrograph. About 4 hours after the Fermi trigger the optical counterpart has already faded and is not seen in the frame.

4. CONCLUSIONS

With these new capabilities to perform optical polarimetry and wide-field imaging we aim to place Belogradchik Observatory among the small, but actively participating in wide international campaigns observatories. Nowadays, a small observatory with a generally modest equipment, located not at an excellent for astronomical observations conditions, can effectively contribute to astrophysical science only via wide co-operation with other similar astrophysical centers. We believe that the new additions at the Belogradchik Observatory, as well as other planned in the near future will help to retain our position of a modern astrophysical center throughout the 21st century.

Acknowledgements

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