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CLASSIFICATION OF VARIABLE OBJECTS FOR SEARCH FOR GRB CANDIDATES ON BAMBERG PHOTOGRAPHIC PLATES

René Hudec[a,b,*], Fabian Kopel[c], Robert Macsics[c], Markus Hadwige[c], Ulrich Heber[d], Walter Cayé[c]

[a] *Astronomical Institute, Academy of Sciences of the Czech Republic, Ondřejov, Czech Republic*

[b] *Cech Technical University in Prague, Faculty of Electrical Engineering, Prague, Czech Republic*

[c] *Dientzenhofer Gymnasium, Bamberg, Germany*

[d] *Dr Remeis Observatory, University of Erlangen, Bamberg, Germany*

[*] corresponding author: `rhudec@asu.cas.cz`

Abstract. We report on an ongoing study based on blink-comparison of more than 5000 Bamberg Observatory Southern Sky Patrol Plates performed within a continuation of a student high school project (Jugend Forscht). After a detailed analyses and classification, 6 non-classified objects were identified as emulsion defects, 19 as asteroids, 37 as variable stars, and 6 as real OT-GRB candidates.

Keywords: astronomical photography, astronomical photographic plate archives, Gamma-Ray Bursts, optical transients, variable stars, asteroids.

1. Introduction

In this paper we report on further results of an ongoing study based on extended blink-comparison of Bamberg Observatory Southern Sky Patrol Plates performed within a German high school student project (Jugend Forscht) in the last year (2011–2012). The Bamberg Observatory (Bavaria, Germany) was deeply involved in variable star research in the past. The Bamberg Observatory photographic sky surveys (Hudec, 1999) were used to deliver observation data for these studies. The Bamberg plate archive contains 40 000 plates from Northern (18 000) and Southern (22 000) Surveys; the relevant time periods are 1928-1939 (North) and 1963–1976 (South). The southern patrol was taken from the Boyden Observatory observing station in South Africa for variable star research. The northern patrol was performed in Bamberg directly. The past works in variable star research in Bamberg focused mostly on discoveries and classification of new variable stars. For more details on the motivation of the work and the related background, see Hudec et al., 2001.

2. The method

The blinkmicroscope investigations of thousands of pairs of selected high-quality sky patrol plates were performed in the past under the direction of Prof. W. Strohmeier, former Director of the Bamberg Observatory, and his collaborators, mainly R. Knigge and H. Abt. They investigated more than 2500 pre-selected southern sky survey plate pairs (with magnitude limits and overall quality above average) where one plate pair represented about 5 hours of work at the blinkmicroscope. Each plate represents 13×13 square degrees, about 1 hr exposure time, and has a limiting magnitude of about 15 (for southern plates), i.e., enough to detect brighter OTs (Optical Transients) and OAs (Optical Afterglows) of GRBs. Taking into account the large field of view (FOV) of the plates that were used (the northern plates are 35×35 degrees), this is one of major sky survey programmes in the past.

We have re-analysed the objects recorded in 6 measurement books for southern sky surveys, with emphasis on detailed investigation of non-classified objects suspected to occur only once (i.e., visible only on one plate and below the limit of other plates).

The datasets that were analysed involved a total of 5004 southern sky patrol plates (always blinked as a pair of plates, i.e., 2502 blink comparisons), each plate representing 13×13 square $= 169$ square degrees and 60 min exposure time. This represents in total 845676 square degrees (i.e., 21.14 full sky spheres) monitored for 60 minutes, i.e., almost full day and full sky sphere coverage. It is obvious that although the statistical probability of having a real GRB OT candidate in our sample is low, it is not negligible. The estimated observed GRB rate by GRBM is about 1.3/day (Guidorzi, 2011), but the intrinsic GRB rate is higher as the estimated rate is influenced by instrument sensitivity. Hence one can expect there was at least one GRB inside the investigated plate sample.

3. Object classification

Object classification was an important part of the investigations performed in the last year. In this section we show examples of originally non-classified objects, now classified by us to different types/categories, namely known and newly-detected variable stars (Fig. 1), asteroids (Fig. 2), emulsion faults (Figs. 3 and 4), and genuine OT candidates (Fig. 5).

The light variation is clearly demonstrated. The object indicated on the right picture is a real one,

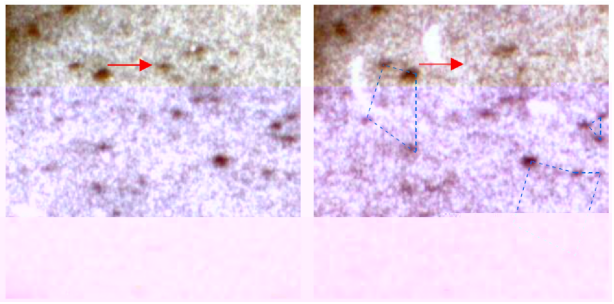

Figure 1. Example of a newly-detected (previously unknown) variable star: maximum (left) and minimum (right).

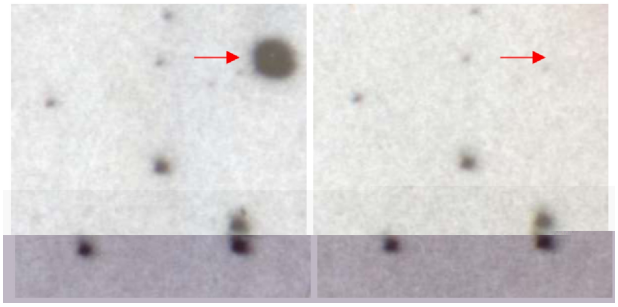

Figure 2. Example of OT images identified as asteroids (here Vesta). The image size is approximately 1×1 mm.

despite being close to the plate background, as it is visible on more plates, and there is a faint star at this position. The image size is approximately 4 mm × 4 mm.

4. The catalogue

The creation of a catalogue represents an important part of our work in the last year. Due to the large number of objects and because of the scattered information at different places, a clear review and picture was difficult. We therefore decided to put all the information into one volume, namely the catalogue. The catalogue is divided according to classification types of non-classified objects, namely previously known and newly discovered variable stars, asteroids, emulsion defects, and true OT-GRB candidates. The catalogue includes images of digitized neighborhoods of the objects, DSS images, computer-generated images, images provided by ImageJ, as well as all available information for the candidate object, such as observing site, celestial position, exposure date and time, Julian date, plate information, etc.

5. Results

We have made a detailed analysis of the 6 Measurement Protocols of Prof. Strohmayer and his collaborators, representing the results of analyses of about 5000 selected southern sky patrol plates. We have

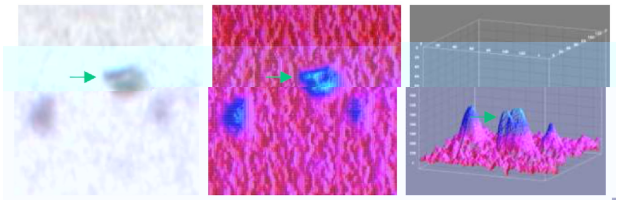

Figure 3. Identification of emulsion defects by surface plots and 3D imaging. The image size is approximately 0.6×0.6 mm.

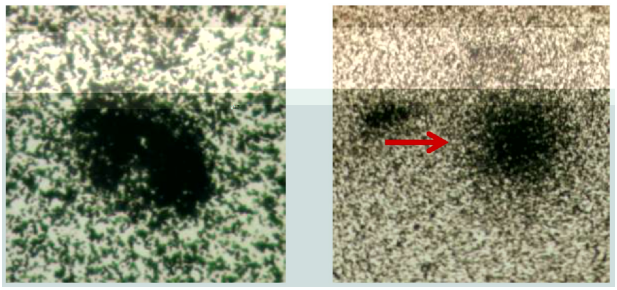

Figure 4. Detailed analyses with the Sonneberg Observatory Zeiss Microscope: Emulsion defect (left) and real OT image (right). The image size is $\sim 0.3 \times 0.3$ mm.

re-discovered the 63 non-classified objects on the original plates. The surrounding areas (sub-windows 873 × 873 arcsec) of these objects have been scanned and analysed.

The detailed analysis of the discovery plates confirmed that 4 of these objects are in fact variable stars, as they were present on both the discovery and on the comparison plate, with different magnitudes. Plates from the Bamberg archive covering the same position but at different times were used for this study.

In addition, the OT positions were investigated both on Stargazer and on DSS images, uncovering a total of 7 already known variable stars and 25 newly detected variable stars. This study was based on analyses of objects available at or close to the OT positions on deeper image (DSS) or in catalog (Stargazer). Verification on deeper images and/or in catalog was always used to avoid false detection of faint stellar images.

The detailed asteroid search performed with an online tool (`http://ssd.jpl.nasa.gov/sbfind.cgi`) identified 19 OT as asteroid images. We note that a similar study by Bedient 2003 has indicated that out of 24 OT candidates identified by Ross (1929) 6 represent asteroids mis-classified as suspected variable stars.

The 6 objects were identified as emulsion defects based on a profile study with ImageJ as well as the Large Zeiss plate microscope at the Sonneberg Observatory. In this study, deviations from star images and/or profiles were investigated in great detail under high magnification and/or reflected light microscope.

The remaining 6 objects can be considered as real

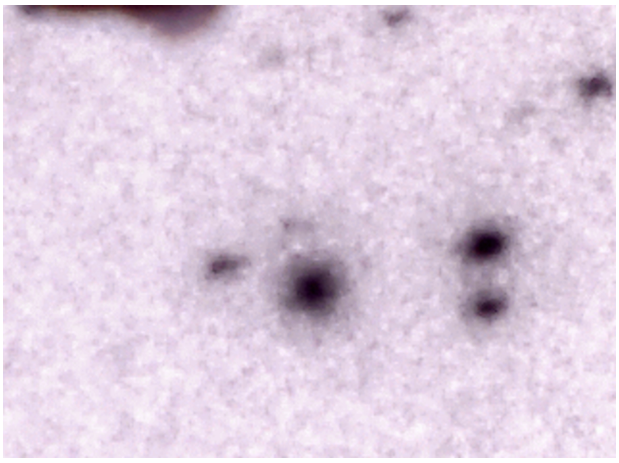

FIGURE 5. One of 6 real OT-GRB candidates (image taken by a USB plate microscope, which was used for rapidly obtaining images of the objects under high magnification).

OT/GRB candidates. Their coordinates were measured to enable detailed analyses of their positions with modern CCD telescopes. In addition, their magnitudes were measured and were found to lie between 10.8 and 13.5 magnitude (B). Because of the absence of quiet counterparts for all these objects in DSS, we can conclude that the brightening amplitude was larger than 6.5, with very fast light change typically > 2–3 mag in one day.

We have selected the plates in the Bamberg plate archive covering the positions of these candidates just before or just after the OT times, and in most cases there was nothing one day before or one day after down to typical plate magnitude limit of investigated plates of $M_B = 15$.

Very recently, we have obtained deep images of our OT candidates, in 2 cases taken in different filters. This data is undergoing a detailed analysis at the moment of writing this article, and the details will be reported later in a separate paper. The later paper will also give more details and a Table of all 6 GRB/OT candidates, as the investigation of these objects (especially with larger instruments) is still ongoing.

The OT is the bright object in the centre of the image. For these candidate objects, all the alternative explanations namely for known types of astrophysical objects, asteroids, and emulsion defects, could be excluded. The image size is 1×1 mm.

6. Conclusion

We have re-analysed the Bamberg Observatory Southern Sky Surveys measurement logs, and have re-detected and investigated relevant non-classified objects as possible OT candidates. The study continued with a detailed OT classification, which has been explained in the paper. In addition the candidate objects were scanned and investigated by advanced computer programs.

This study won 1 place in the Jugend Forscht (Youth Research) high school regional competition in Oberfranken in 2012, and in addition 1st place in the Jugend Forscht 2012 competition in Bavaria and 3rd place in the all-German Jugend Forscht 2012 competition, as well as the award for best astronomical project. Fabian, Robert and Markus are (now) 18 year-old-students. The project was proposed by Rene Hudec, and was supervised by Rene Hudec and Uli Heber.

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