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Investigation and Identification of High–Energy Sources on Astronomical Archival Plates

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Many types of astrophysical sources exhibit long–term brightness changes. The astronomical plate archives represent the unique data source for such studies. There are about 3 million astronomical photographic plates around the globe, representing an important data source for various aspects of astrophysics. The main advantage is the large time coverage of 100 years or even more, as well as good sampling. The recent digitization efforts, together with the development of dedicated software, enables for the first time effective data mining and data analyzes by powerful computers with these archives. We will present the recent status of such efforts, and then we will focus on the astrophysical aspects with emphasis of application in high-energy astrophysics (HE) (where many HE sources do have optical counterparts accessible by plates). The importance of the astronomical data archives as additional data source for such analyzes will be discussed. Examples of HE objects investigated on the astronomical plates will be presented.

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1. Introduction

The high–energy sky is rich in variable and transient objects. The study of the long-term activity of astrophysical objects is an important but not easy task in general. In many cases we need very-long term optical light curves covering more than one decade, and in some cases even more than several decades, as some duty cycles in some types of astrophysical targets can be so long (e.g. in binary blazars). For the time being, the astronomical plate archives represent a suitable source, as they can provide up to several thousands of photometric points covering up to 100 years or so.

2. Astronomical plate archives and high–energy sources

A large fraction of high–energy (HE) sources exhibit optical emission. Despite of this, the knowledge of long–term activity of many optical counterparts of high–energy sources is still very limited. It is evident that the use of data gained from data mining in astronomical plate archives can be important. In this paper we show a few examples.

In Fig.1 we show an example of the study of the intermediate polar and INTEGRAL hard X–ray source TV Col on the astronomical astrograph plates from the Bamberg Observatory, showing the behavior of the object and rare active states (outbursts) of the system, some of them unknown before.

In addition to investigations performed over last years, we have started analyzes of selected optical counterparts of high–energy sources on southern archival plates located at the Bamberg Observatory. As an example, the appearance of the microquasar V4641 Sgr both in quiet as well as in flaring state is shown in Fig. 2. The preliminary results obtained from these plates confirm the presence of the optical flaring activity (Fig. 9). This is a part of the project performed at the Bamberg Observatory (Figs. 3 and 4).

The long–term light curve of microquasar CI Cam is shown in Fig. 3. We also show the light–curve of cataclysmic variable and bright and hard INTEGRAL X–ray source V1223 Sgr (Fig.4). The long–term light curve of the microquasar and bright X–ray source Sco X-1/V818 Sco based on the Sonneberg sky patrol data shows an interesting feature of the long-term high and low state (Fig.7).

There are three basic types of astronomical plates: direct images, multiple images, and spectral images (with objective prism). The spectral plates offer the unique possibility to study the spectral features and spectral changes using the astronomical plates taken with the objective prisms, i.e. analyzing the low-dispersion spectra. Here new dedicated algorithms have been recently developed and tested (Fig.8), allowing automated classification of objects as well as searches for the objects with unique spectra and investigations of the spectral changes.

We note that the plates can be also used to identify and to classify the yet undetected INTEGRAL gamma–ray sources, as in several plate archives there are numerous high–quality plates covering the fields along the galactic equator (e.g. Sonneberg Field Patrol, Leiden Franklin Adams plates). This approach is based on the fact that a large fraction of the sources has optical counterparts and exhibit measurable light variability. We have started such extended study at the Bamberg Observatory with quite promising results which will be reported later.

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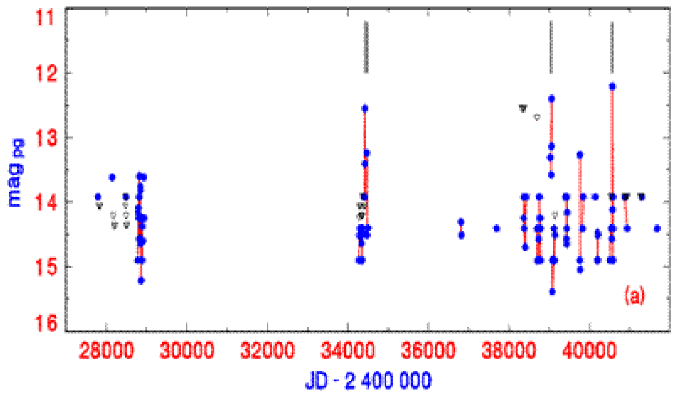

Figure 1: Example on an optical light–curve based on measurements on astronomical archival plates. The curve shows the brightness evolution of TV Col (Hudec et al., 2005), where 12 optical flares have been observed so far, five of them on archival plates from the Bamberg Observatory. TV Col is an intermediate polar (IP) and the optical counterpart of the X-ray source 2A0526-328 (Cooke et al. 1978, Charles et al. 1979). This is the first cataclysmic variable (CV) discovered through its X-ray emission. The object was recently confirmed as INTEGRAL IBIS hard X–ray source.

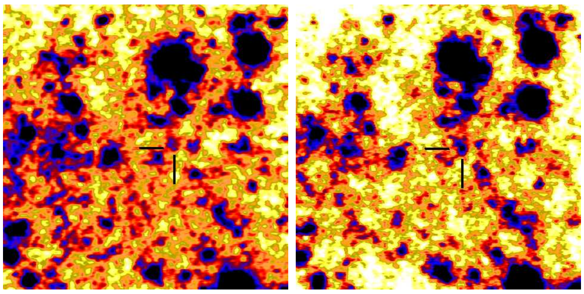

Figure 2: The appearance of the microquasar V4641 Sgr on the digitized sky patrol archival plates from the Bamberg Observatory. The object is shown both in the minimum light (plate SUD 0181, left) as well as in maximum light (plate SUD 8332, right).

3. Conclusion

The examples of results of investigations of HE objects on astronomical archival plates shown in this paper confirm that the astronomical plate archives represent a suitable data source for the analysis of the long–term activity of many categories of astrophysical sources including optical counterparts of high–energy sources. The novel computer–based methods including plate scanning and evaluation by dedicated sophisticated software play a major role here.

Acknowledgments

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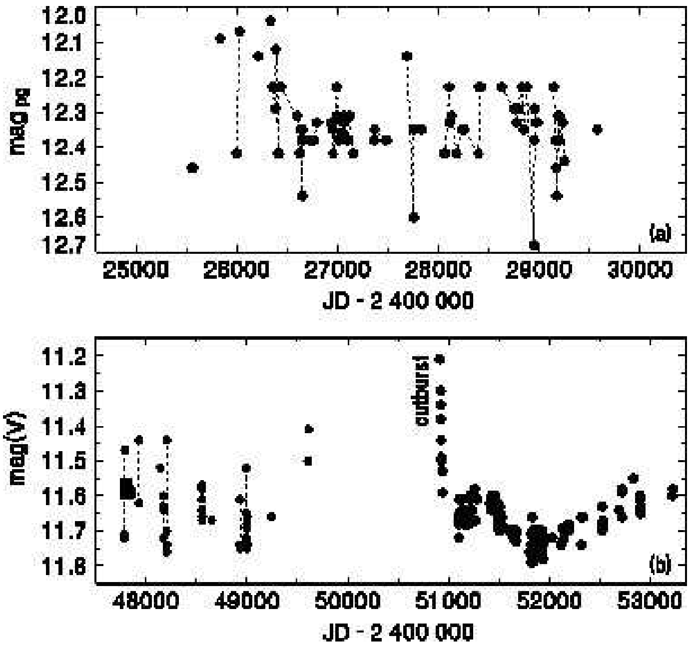

Figure 3: Upper panel: Photometric history of the microquasar CI Cam according to the Bamberg photographic observations in the blue band (similar to the B band) (years 1928 – 1939). Points are connected by line in densely covered segments. Typical uncertainty is 0.05 mag. Bottom panel: Photoelectric and CCD photometry (1985 – 2004) (Bergner et al. 1989, Simon et al. 2007)

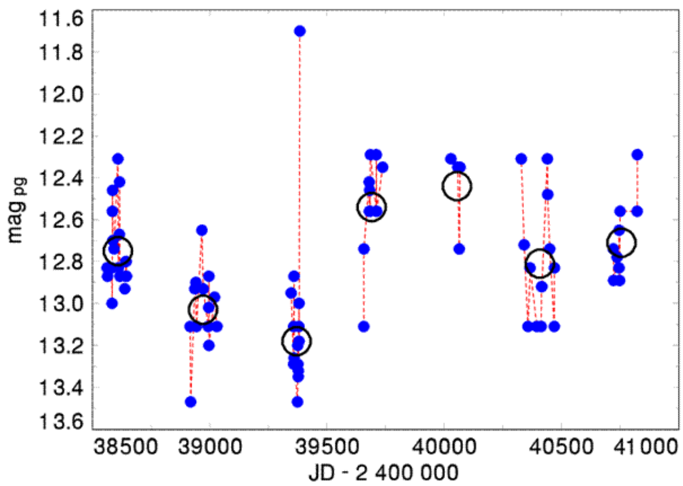

Figure 4: Segment of the long-term light curve of the intermediate polar V1223 Sgr (85 data points). This is the brightest cataclysmic variable detected in hard X–rays by the ESA INTEGRAL satellite (IBIS gamma–ray telescope). Sampling of Bamberg photographic plates is similar to the one expected from ESA Gaia satellite. Closed circles – individual observations. Large open circles – annual averages. The outburst is not included in the annual mean.

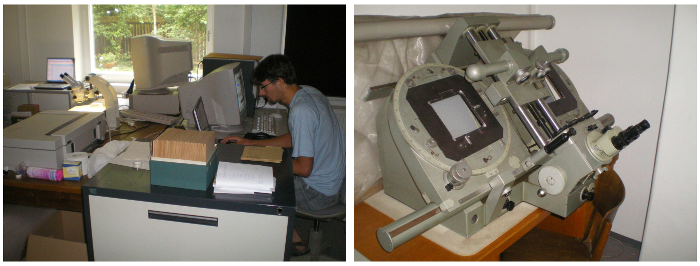

Figure 5: The newly reconstructed laboratory of the astronomical plate archive at the Bamberg Observatory (left) and the Bamberg Observatory blink microscope (right).

Figure 6: The Bamberg plate archive – one of the plate cabinets (left) and the arrangement of the plates in the cabinets in Bamberg (right).

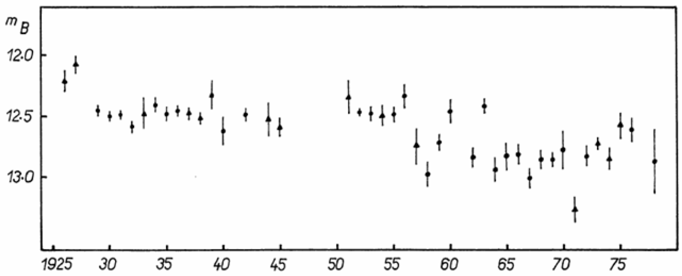

Figure 7: The long–term (over 50 years) optical light evolution of V818 Sco, the optical counterpart of very bright X–ray source Sco X-1. Annular mean values are given. Error bars show the standard deviation of the mean. Time axis is displayed in years (Hudec 1981). The two different brightness levels are clearly visible.

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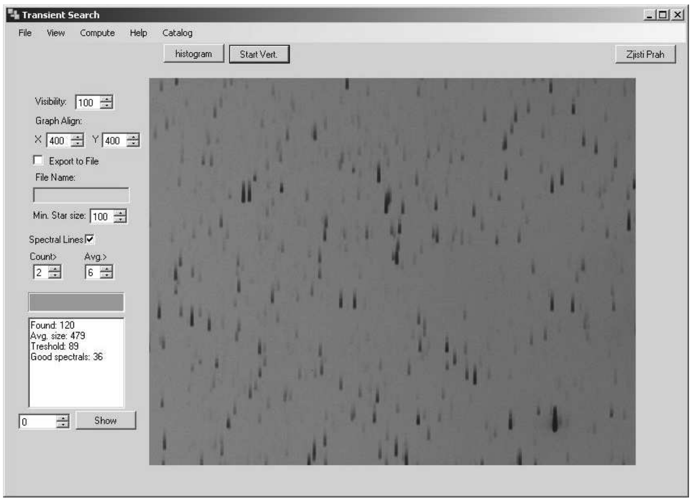

Figure 8: The automated analysis of a part of the digitized astronomical spectral Schmidt plate from the Sonneberg Observatory plate archive.

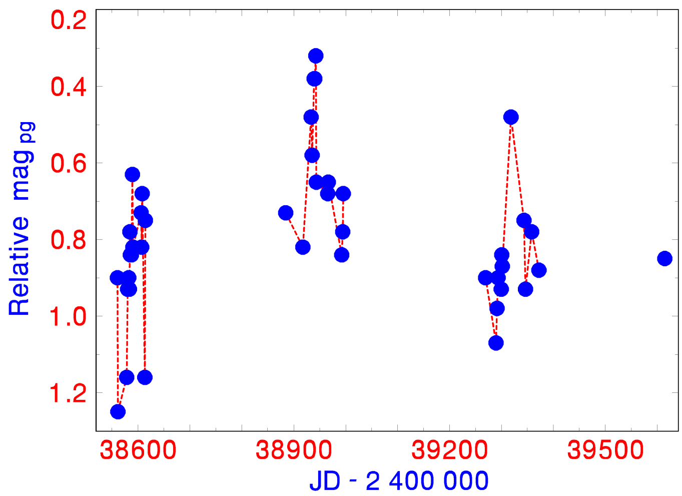

Figure 9: The optical light curve of the microquasar V4641 Sgr on the blue-band sensitive photographic plates from the archive of the Bamberg Observatory (1964–1967). The exposure time was 60 min. Typical uncertainty is 0.05 mag. Magnitudes are displayed with respect to the star GSC 0684802768.

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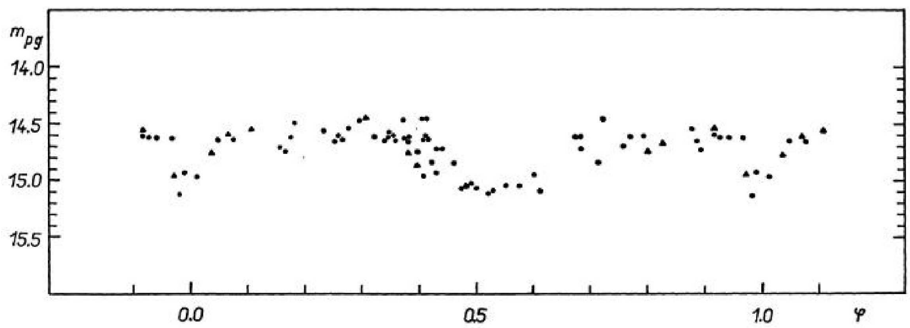

Figure 10: The optical orbital modulation of HZ Her, the optical counterpart of Her X-1, during its rare inactive state. Circles denote the observations between JD 2428630 and JD 2429789. Triangles mark the data between JD 2427543 and JD 2427657 (Hudec & Wenzel 1976). This curve shows the behavior of the object in rare inactive state which can be investigated only with historical data.