ASTROPHYSICS WITH DIGITIZED ASTRONOMICAL PLATES: SEARCH FOR SUPERMASSIVE BLACK HOLE BINARIES

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ABSTRACT

In the history of X–ray astronomy, astronomical archival plates, mostly those from two major plate collections (Harvard and Sonneberg) helped to identify and to analyse first stellar X–ray sources. Novaday, there are efforts to digitise the astronomical plate archives and to use these data for various scientific projects. These data may easily provide monitoring over very extended time intervals (up to more than 100 years) with limiting magnitudes up to 23 and are expected to provide very valuable supplementary information to recent and even to future satellite data from various spectral bands.

Key words: Astronomical archives, astronomical plates, astronomical photography.

1. INTRODUCTION

At the early stages of stellar X–ray astronomy, astronomical archival plates helped to identify and to analyse optical counterparts of celestial X–ray sources such as Sco X-1/V 818 Sco, Her X-1/HZ Her, and others (e.g. Hudec and Wenzel, 1976, 1986, Hudec and Meinunger, 1977). The nearly 3 millions astronomical archival plates located at different observatories (Hudec, 1999) still represent a unique database for various scientific projects including X–ray astronomy as well as satellite experiments. The plates represent thousands of exposures for any celestial position, reaching monitoring intervals of up to few years of continuous monitoring - i.e. tens of thousands of hours. Each of the plates cointains valuable information about thousands and often even tens of thousands star images recorded on the plate. The photographic sky monitoring is available for more than 100 years and some of the archives have very high quality plates with limiting magnitudes of up to 20 ... 23 (direct imaging) and /or 17....19 (spectral with objective prism). However, only the recent development of photographic scanners and powerful computers allows an efficient extraction of scientific data. Some of the archives already have devices for digitisation of plates and few of them have already started extended digitisation of the plates (e.g. Sonneberg Observatory - about 180 000 plates already scanned). There are attempts to create an European Plate Centre in Brussels, Belgium (the UDAPAC project, see de Cuyper et al., 2001). Analogous efforts exist also in the US (Castelaz and Cline, 2005).

2. THE SCIENCE WITH ASTRONOMICAL PLATES

Archival and sky patrol plates represent a valuable tool in investigations and identifications of various types of high energy sources such as blazars/quasars, X-ray binaries, X- and gamma-ray transients, cataclysmic variables, etc. Many of X-ray sources emit also optical light and can be hence analysed on archival plates. It is obvious that the automated evaluation of sky patrol plates has large potential in: (i) providing extended (more than 10 years) monitoring intervals with good (daily or weekly measurements) sampling, (ii) allowing long-term evolution and changes to be studied, (iii) searching for optically variable AGNs-QSOs-blazars and other objects, (iv) providing their light curves with good sampling, (v) searching for their flares, (vi) providing simultaneous and quasi-simultaneous optical data for satellite campaigns, even back in time, (vii) monitoring of objects as base for proposals for ToO (Target of Opportunity) for satellite high energy observations, and (viii) providing extended database for identification and classification of sources.

The detection and investigation of very large amplitude flares from AGNs may serve as an example. There is increasing evidence that some AGNs may exhibit very large amplitude flares exceeding mag 10 (Hudec et al. 1999). These large flares are however rare so very large fractions of monitoring times (of order of thousands hrs or more) are required to detect them. This can be accessed easily on plates but hardly by other methods.

Identification of high-energy sources is another example

of use of archival plates. The recent high-energy satellites, especially those observing in X-rays, provide a large number of detected sources. The identification of them is an important but not easy task. Astronomical plate archives can help essentially. Some of the X-ray objects detected by recent analyses can be very easily rediscovered and further studied - even back in the history - on high quality direct and spectral archival plates.

3. THE SOFTWARE FOR PLATE ARCHIVES

Until recently, the data recorded on archival plates were accessible only by special procedures. The recent wide digitisation of plate collections offers significantly easier access by computers. However, there is still a gap between the digitised archive and the scientific use. Special software is required to fill this gap. The robust program able to provide realiable and automated astrometry and photometry of all objects on the plates is a difficult tasks and still a matter of further development.

The second type of plate software is specific to particular plate type and particular project. For example, if we search for optical prompt emission (including orphans) from GRBs, we need to look for short-living transient phenomena lasting minutes or less, analogous to the event observed for the GRB990123. However, on long-exposed deep images and plates, it is very difficult to look for brief transients since the OT image is hidden by typically tens to hundreds of thousands stellar images with similar appearance. The methods of comparing plates and/or comparison with catalogues is still not very effective and reliable. We have developed novel method using multiply exposed astronomical plates and based solely on the information recorded in the plate itself. Such plates are available and are relatively numerous in various sky plate archives, e.g. at the Royal Observatory Brussels. These plates contain several (typically 2 to 10) identical star field images on the same plate. This means, each star inside the FOV of the telescope, is represented several times. Such plates have been obtained by multiple exposures on the same plate with tiny shifts between the exposures. It is difficult to find transient objects on these plates by classical methods. However, using digitisation, dedicated novel algorithms and software programs, and powerful computers, it is relatively easy, effective and reliable to identify the OT candidates.

4. SEARCHES FOR SUPERMASSIVE BLACK HOLE BINARIES

The project of searches for supermassive black hole binaries represent another example of an dedicated scientific project of recent astrophysics based on the astronomical plates. In this project, we have gathered data from the literature and observational campaigns in order to establish long-term optical light curves of the selected blazars - binary black hole candidates - to study periodic behavior in their light curves and other interesting features (intense outbursts, flares, quiescent level behavior). However, there are several crucial data gaps that disable to confirm periodicity or a BBH model (that has already been built up for several of these blazars). Therefore we intend to go to databases of astronomical plates (e.g. Sonneberg Observatory, Germany (about 280,000 plates), Harvard College Observatory, USA (about 500,000 plates),UKSTU plate collection ROE Edinburgh, UK (18,000 very deep plates), and Observatory Leiden, NL (40,000 plates)) to fill in these gaps. Within this project, we intend to reach the following results: (i) improve historical light curves of candidates, (ii) periodicity and light curve analysis, (ii) confront the new light curve of the selected blazars with the corresponding theories, (iii) establish a detailed model at least of one of the candidates, (iv) draw statistical conclusions, (v) provide the data to wide scientific community. The nature of the project requires the availability of data sets covering very long time intervals, hence digitized archival plates are the obvious choice (Hudec, 1999).

5. CONCLUSION

The astronomical plate archives represent a very important data source for various aspects of astrophysics in general and for X–ray astronomy in particular. The recent efforts to scan the plates and to develop related software packages for scientific evaluation of plates represent a promising basis for future computer-based analyses.

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REFERENCES

Hudec R., Vrba F. J. and Luginbuhl C. B. 1999, BL Lac Phenomenon, ASP Conference Series, 159, 115.

Hudec R. and Wenzel W. 1976, Bull. Astron. Inst. Czech., 27, 325.

Hudec R. and Wenzel W. 1986, Astron. Astroph., 158, 396.

Hudec R. and Meinunger L. 1977, Mitt. Veraend. Sterne, 8, 10.

Hudec R. 1999, Acta Historica Astronomiae, 6, 28.

Castelaz M. V. and Cline J. D. 2005, Bull. Amer. Astron. Soc., 206, 2404.

de Cuyper J.-P. et al. 2001, ASP Conference Proceedings, 238, 125.