RevMexAA (Serie de Conferencias), **45**, 110–113 (2014)

THE ROLE OF ROBOTIC TELESCOPES AND GLORIA IN HIGH ENERGY ASTROPHYSICS: IMAGING AND LDS SPECTROSCOPY

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RESUMEN

Presentamos y discutimos el rol de los telescopios robóticos, incluyendo la red GLORIA, en la astrofísica de altas energías, al igual que estrategias relacionadas. Numerosos proyectos de satélites se enfocan en la astrofísica de altas energías, desde rayos-X a rayos gamma, sin embargo, una gran porción de los objetos astrofísicos de altas energías emiten también luz óptica, la cual es en muchos casos, variable. La observación de estas fuentes en longitudes de onda ópticas puede proveer información valiosa para el análisis multiespectral de varias categorías de fuentes celestes de Altas Energías. Muchos objetos tienen magnitudes brillantes y por lo tanto pueden ser observados por observatorios robóticos en la superficie terrestre, y por lo tanto estas observaciones pueden contribuir a las investigaciones y análisis de fuentes de altas energías. Además de imágenes directas, la espectroscopía de baja dispersión (LDS) representa una estrategia óptima para los telescopios robóticos, tomando en cuenta resultados anteriores de sondeos extendidos de LDS con telescopios y placas fotográficas.

ABSTRACT

We present and discuss the role of robotic telescopes including GLORIA network in high–energy astrophysics, as well as related strategies. Numerous satellite projects focus on high energy astrophysics from X-rays to gamma-rays, however, a large fraction of objects of high-energy astrophysics emits also optical light, which is, in many cases, variable. The observation of these sources at optical wavelengths can provide valuable inputs for multispectral analysis of various categories of celestial high-energy (HE) sources. The magnitudes of numerous objects are bright and can be hence accessed by robotic ground-based observatories, hence these observations can contribute to investigations and analyses of HE sources. In addition to direct imaging, the Low dispersive spectroscopy (LDS) represent important optional strategy for RTs, taking into account the results from past extended LDS surveys with photographic telescopes/plates. .

Key Words: telescopes — spectroscopy — surveys

III Workshop on Robotic Autonomous Observatories (Torremolinos, Malaga, Spain, 7-11 October 2013)
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Introduction

The networks of ground–based robotic telescopes (like GLORIA) offer scientifically valuable contribution to numerous projects in high–energy astronomy and astrophysics. A large fraction of objects of high–energy astrophysics emits also optical light, which is, in many cases, variable. For example, most of optically identified INTEGRAL gamma-ray sources are brighter than mag 20, and more than half are brighter than mag 15. The observation of these sources at optical wavelengths can provide valuable inputs for multispectral analysis of various categories of celestial high-energy (HE) sources. As the magnitudes of numerous objects are relatively bright and can be hence accessed by small robotic observatories, these devices can effectively contribute to investigations and analyses of HE sources.

Some types of high–energy astrophysical objects (e.g. blazars, cataclysmic variables, gamma-ray bursters, flare stars, etc) exhibit rare flares for which satellite observations are important. These events cannot be monitored by satellites itself in most cases but can be effectively monitored by robotic telescopes (RT) generating ToO (Target of Opportunity) triggers for satellites with ToO regime.

Networks of RTs such as GLORIA can play an important role in these activities. GLORIA stands for "GLObal Robotic-telescopes Intelligent Array". GLORIA is the first free and open- access network of robotic telescopes in the world. It is a Web 2.0 environment where users can do research in astronomy by observing with robotic telescopes, and/or by analysing data that other users have acquired with GLORIA (http://gloria-project.eu/), or from other free access databases, like the European Virtual Observatory (http://www.euro-vo.org).

These monitors, in contrast to alert telescopes,

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can deliver optical photometric data for objects prior and during the active/flaring states wide-field (WF) coverage is important to cover as many sources as possible. There is a scientifically justified need to have this mode in robotic (i.e. autonomous remotely controlled) telescopes (RT). RT with reasonably large field of view (FOV), performing regular sky surveys, or with an attached WF camera, can serve as a monitoring device. In some cases, even post-flare monitoring is important as shown by magnetar candidate GRB070610 optical flares (Castro-Tirado et al., 2008) in order to (1) detect the optical flares, (2) detect possible recurrence (this is a very difficult task, but important one, which can be performed only by robotic instruments as the recurrence cannot be predicted). Similar coverage can be provided even for the past (up to 100 years) using the digitized sky patrol photographic plates as data source.

1. THE RT SUPPORT OF HIGH–ENERGY ASTRONOMY

The HE sources belong to both galactic as well as extragalactic sources. In the following we will very briefly discuss both groups.

1.1. *Types of HE sources*

There are numerous categories of galactic HE sources, most important ones are listed below. 1. Cataclysmic Variables (CVs) and related objects. Example: GK Per 2. LMXRB (low mass X-ray binaries). Example: HZ Her = Her X-1 3. HMXRB (high mass X-ray binaries). Example: Cyg X-1 4. X-ray transients 5. New types of sources.

The fact that there are numerous CVs among the gamma-ray sources observed by the ESA INTEGRAL satellite (perhaps up to 10% of all INTEGRAL gamma-ray sources) represent one of interesting new findings over the last decade. Moreover, few symbiotic stars (SSs) were also identified with INTEGRAL gamma-ray sources.

1.2. *Extragalactic HE sources*

Numerous celestial HE sources belong to the category of extragalactic sources; the most important types are listed below. 1. AGN 2. Blazars 3. Optical Afterglows and Optical Transients of Gamma-Ray Bursts (GRBs) 4. SNe 5. LBV (Luminous Blue Variables in external galaxies). They are worth study as they can at some active states mimic the light behavior of optical afterglows of GRBs. Several examples of the blazars detected in gamma-rays by the INTEGRAL satellite are given and discussed later in this paper.

2. OBSERVATIONS OF HIGH–ENERGY SOURCES BY ROBOTIC TELESCOPES

Many RT can implement automated monitoring of selected high–energy sources, however a care must be taken on an appropriate planing which should reflect the nature of the targets. There are various modes of optical observations required for the HE sources. The situation is very complex, as the sources belong to various categories. The goals below represents the tasks in photometry which is typical for most RT in operation, however, some RT are equipped also by low-dispersion spectral (LDS) devices able to deliver valuable data for certain astrophysical objects with prominent, strong, and/or variable spectral features, as required newly by the ESA Gaia mission.

There are also completely newly detected types of optically variable HE sources. The optical counterpart of GRB070610/SWIFT J195509+261406 may serve as an example (De Ugarte Postigio et al., 2007, Castro-Tirado et al. 2008). The This GRB was detected on 10 June 2007 20:52:26 UT by Swift/-BAT as a normal burst (Pagani et al. 2007), with T90 = 4.6 s, photon index 1.76 ± 0.25, and fluency $(2.4 \pm 0.4)10^{-7}$ erg/cm^2 (Tueller et al. 2007). XRT detected an X-ray counterpart 3100s later (Pagani et al. 2007b) with a column density consistent with the Galactic. Stefanescu et al. (2007) reported the detection of a variable optical counterpart, de Ugarte Postigo et al. (2007) confirmed the detection with observations from the 1.5m OSN. D.A. Kann et al. (2007) suggested a Galactic origin, based on unusual flaring activity and location near the galactic plane: l=63.3 deg, b=-1 deg. About 40 optical flares peaking at up to I mag 14. The emission between flares slowly decreased until it disappeared with no detectable quiescent source.

V407 Cyg represents another new type of hard-gamma ray eruptive variable (Hudec, 2011, Munari et al., 2011). V407 Cyg is a symbiotic binary harboring a Mira variable, of 745 day pulsation and a possible orbital period of 43 years, at a distance of 2.5/3.0 kpc In addition to a possible previous one in 1936 (when the object was noted for the first time by Hoffmeister (1949), V407 Cyg has been discovered in large outburst by Nishiyama and Kabashima (2010) on 2010 Mar 10.8 UT. Such a scenario was highly reminiscent of the recurrent nova RS Oph. The outburst of V407 Cyg has since then been detected also in gamma-rays (Cheung et al., 2010) and in radio (Nestoras et al., 2010) and observed in the infrared (Munari 2011 and references therein).

Optical Transient (OT) in Pegasus (OT

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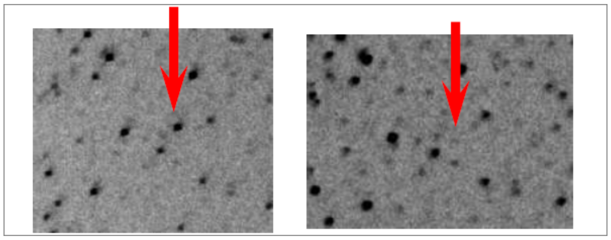

Fig. 1. The historical 1942 optical flare of OT in Pegasus as detected on the Sonneberg Observatory Sky Patrol Plates. Left: 1942 flare, Right: comparison plate.

Fig. 2. Baker–Nunn camera photographic frame, 5 x 30 degrees, example of database able to extend wide–field optical coverage back in time.These archival images represent suitable very extended database to search for OTs like illustrated in the Fig. 1

J213806.6+261957) represents a rare type of dwarf nova (DN) with very long recurrence times (67 years) but very large amplitudes (Hudec, 2010). The optical transient/cataclysmic variable in Pegasus, reported in CBET 2273 and CBET 2275 (designated VSX J213806.5+261957 or OT J213806.6+261957) was detected in the extended study of Sonneberg Observarory Archival Sky Patrol Plates (more than 3000 plates analyzed, taken during the years 1928 to 2004) in another (historical) large optical outburst (peak on 1942 Nov 30) at mag(B)=9.8 (+-0.5), illustrated in Fig. 4. The star was found in a superoutburst from 1942 Nov 30 till 1942 Dec 11, being fainter than mag(B) 13 on 1942 Nov 10 (and before this date) and on 1942 Dec 28 (and after this date). Only 2 outburst are known (1942 outburst found by Hudec, 2010, based on analyses of 2000 Sky patrol plates). Only very few such objects are known so far. There is a good chance for such targets to be detected by Gaia (Alert System) or other types of sky patrol. Dramatic spectral changes detectable by Gaia BP/RP photometers are also expected.

Another important role of robotic telescopes in HE astrophysics is in satellite projects outside high–energy astrophysics. The ESA Gaia project may serve as an example. Albeit its main goal is the ultra precise astrometry, Gaia will monitor all celestial objects down to magnitude 20 over a 5 years time period. However, the photometric sampling will not be optimal; hence the supplementary observations provided by ground-based robotic telescopes are expected to provide a valuable contribution. The main goal of these supplementary observations are as follows: (1) confirm triggers (e.g. optical transients, flares, brightenings, etc.) detected by Gaia satellite (2) provide additional photometric data with more dense sampling than provided by the satellite. The HE objects such as LMXRB, HMXRB, and Optical Afterglows and Optical Transients of GRBs can serve here as an example, together with various types of cataclysmic variables including SNe.

The peculiarity of ESA Gaia, where a substantial fraction of data will be as ultra–low dispersion spectra, raises a question about the role of focal devices with dispersive elements, i.e. on a spectral alternative. This is fully scientifically justified, as the spectral type of Cepheids, Miras and Peculiar Stars is known to change significantly with time. For example, all classical Cepheids definitely vary their spectral types. At maximum, they all have types around F5–F8. At minimum, the longer the period, the later is the spectral type (to K2) (Samus, 2008). The long–term behavior of spectral types of various variable celestial objects (so far only poorly investigated) may be a significant goal not only for ESA Gaia, but also for robotic ground–based optical telescopes equipped with corresponding dispersive elements. Especially RT equipped with LDS focal devices can provide valuable contribution to Gaia spectral alerts.

2.1. *Photographic LDS Surveys*

The LDS mentioned above represent additional tool (to direct imaging) tool to investigate HE sources. The LDS technique was often used in the past in various photographic sky surveys with objective prism. The data are still available in photographic plate archives and can be digitized and analysed by dedicated software and powerful computers (Hudec and Hudec, 2014).

3. CONCLUSIONS

The HE objects exhibit optical (and mostly variable emission) accessible by robotic observatories. For many of these sources there is a lack of optical data. The optical data provided by automated ground-based optical telescopes are important for multispectral analyses of the sources, contributing to better understanding of related physical processes. Even small apertures may contribute as some sources are brighter than magnitude 12. In addition to that, robotic telescopes may play an important role also in satellite projects outside HE astrophysics, as shown

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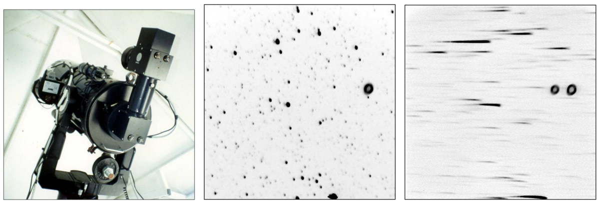

Fig. 3. The BOOTES low dispersion prism spectrograph constructed at the Astronomical Institute in Ondřejov (left), and a CCD image without (middle) and with (right) prism. This type of devices greatly extends the possibilities of RT in astrophysical analyses, especially in investigation of strong and prominent emission features by Low dispersion spectroscopy (LDS).

Fig. 4. LDS photographic sky survey plate. This type of archival data is suitable, after digitization, to provide extended statistical studies and real modeling for CCD based low dispersive spectrographs used with RTs.

on the example of the ESA Gaia, namely as devices confirming the satellite triggers, as well as delivering additional well sampled photometric data for particular objects. In addition to direct imaging, LDS may be performed with RTS yielding additional scientific information. These procedures may be effectively tested with digitized sky LDS spectral surveys.

Acknowledgements We acknowledge grants provided by the Grant Agency of the Czech Republic, 13–33324S and 13–39464J. GLORIA is supported by European Commission Seventh Framework Programme (FP7/2007–2013) under grant agreement no. 283783.

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