Second Workshop on Robotic Autonomous Observatories
ASI Conference Series, 2012, Vol. 7, pp 1 – 6
Edited by Sergey Guziy, Shashi B. Pandey, Juan C. Tello &
Alberto J. Castro-Tirado

Summary of the conference

A. F. Źarnecki
Faculty of Physics, University of Warsaw, Hoza 69, 00-681 Warsaw, Poland

Abstract. In this article, summary of the oral presentations and discussions made during the conference have been summarized.

Keywords : robotic astronomy – autonomous observatories – Gamma Ray Burst (GRB),

1. Introduction

Robotic autonomous observatories have become more and more popular tool for doing high level scientific research in astronomy, astrophysics and cosmology. Over a hundred such observatories are currently in operation all over the world, in all continents (see Fig.1), additional ones are in design or construction phase (Hessman 2012).

Many projects were presented at this conference, showing large progress in the field over the last two years. In this summary, I will point to selected contributions, trying to indicate the most important developments as well as results, which seemed most interesting to me.

2. Scientific goals

Robotic telescopes are a must in the search for optical emission from Gamma Ray Bursts (GRBs). This is because fast reaction to the GCN alert from the satellite (re-pointing of the telescope to the GRB position) is crucial and delay due to the human factor had to be eliminated. However, searching for GRBs is the main goal only for about 30% of the projects. Other research goals, which profit from the robotic operation of the instruments include all-sky surveys, object monitoring, exoplanet, supernovae and asteroid searches. There is also a growing number of telescopes used for education.

Robotic observatories can play an important role in understanding sources of

Figure 1. Robotic telescope projects worldwide. Updated from Hessman (2012).

AGN short scale and long scale variabilities. Several models were proposed: accretion disk instability, supernova and starbursts, as well as gravitational micro-lensing. With precise data coming from observational campaigns aimed at monitoring large sample of AGN of different types or smaller samples of a certain class over long period of time, validity of these models can be tested. In case of FRII-type radio sources additional information can be used to provide disc inclination measurement. Results from the first year of dedicated observations were presented in Zola et al. (2012).

Highly variable optical emission is also observed from low-mass X-ray binaries (LMXBs) and cataclysmic variables (CVs). However, profiles of the individual outbursts (and/or high/low states) can be heavily affected by insufficient sampling. Robotic monitoring of these objects can significantly increase number of early outburst detections and increase number of observations following the outburst. Large fraction of events can be easily detected even by small-aperture, wide-field monitors (Simon 2012).

Global robotic telescope networks are also involved in the study of micro-lensing events and exoplanet searches. Monitoring of a large number of objects with high precision and good temporal resolution is mandatory here. However, automatic follow-up of the discovered transient by other telescopes in the network is also crucial for obtaining high quality continuous light curve (Castro-Tirado et al. 2012).

Robotic telescopes are also well suited for multi-wavelength observations, including detailed spectral analysis with a set of narrow-band filters or dedicated spectrograph. Automatic determination of red-shift for a huge number of objects can open new "exotic" research possibilities as study of the Barionic Acoustic Oscillations and constraining the equation of state of the Dark Energy (Granzer et al. 2012). Such observations can be also used for detailed study of Milky Way structure, galaxy evolution, galaxy clusters, SNe or GRBs (Karpov et al. 2012). Detailed analysis of the spectral lines evolution with time can reveal unique information on variable or fast rotating stars, as the surface temperature distribution or magnetic field (Weber et al. 2012).

Celestial objects are not the only interest for robotic observatories. More and more attention is devoted to Near Earth Objects (NEOs) also as a part of Space Situation Awareness (SSA) programs. Discovery and follow-up observations of "cosmic debris" is very important for safety of future space missions. High quality observations with robotic telescopes, which allow for precise tracking of NEOs, can help filling "blank pages" in debris catalogs and improve precision of their orbit determination (Muiños et al. 2012).

Robotic observatories and remote telescopes can also play an important role as an outreach tool, promoting astronomy and science in general amongst people of all age groups. Direct access to the telescope or operating the telescope system remotely in real-time is a unique and memorable experience for children and students (Smith et al. 2012). However, this is also the case when they are invited to take part in a true research project, where they can help in the analysis of real, high quality data, and contribute to important scientific outcome. Internet technologies opened wide possibilities for citizen science projects of this kind (Klotz et al. 2012).

3. Recent developments

New instruments, which are currently in the construction or design phase, will largely improve measurement sensitivity, precision and coverage. Also important for robotic telescopes is fast response time, and high temporal resolution. Two other features, which become standard in the new designs is the possibility of performing multi-wavelength and/or polarization measurements.

Good example of the project which aims at the best possible measurement precision is the PLATO Antarctic observatories project (Storey J. W. V. et al. 2012). At cost orders of magnitude lower than for the space mission, selected locations in Antarctica offer observation conditions much better than at any other place on the world. Total winter-time atmospheric seeing is about 0.25 arcsec (median). However, for such a location fully autonomous robotic telescope is a must.

Observational conditions are just one of the factors determining the measurement precision. In most cases, largest errors are due to instrumental effects, related to the shutter performance, CCD response and noise, image distortions and photometry algorithms (Eibe M. T. et al. 2012). Empirical estimation and periodic checks of readout chain parameters is the only way to reduce the impact of these effects. With the proper choice of reference stars photometry accuracy of the order of $0.002-0.003^m$ can be obtained. For wide field-of-view devices star image distortion can be very large. Parametrization of the point spread function (PSF) shape variation over the

CCD surface can help reducing both the photometry and astrometry errors (Piotrowski & Zarnecki 2012).

For optical observations of GRBs at least two approaches are possible. The first one is to observe the whole field of view of the space born gamma ray detectors. This permit to record whole optical prompt emission of the identified GRB, provided the burst is bright enough to be detected by a wide field-of-view instrument (Zaremba et al. 2012) The other option is to follow up the triggers coming from satellites. A number of dedicated robotic telescopes with rapid response capability has been build with this goal. While the initial part of the light curve is lost, what is measured should be still enough to reconstruct phenomenological properties of prompt emission and unveil a physical nature of the GRB phenomenon, at least for the long bursts (Gendre et al. 2012).

As mentioned above, more and more robotic telescopes are capable of doing spectral analysis. One of the solutions is to split incoming light and take simultaneous images with multiple CCD cameras equipped with different photometric filters (Karpov et al. 2012). With this approach fast optical transients, as GRBs, can also be studied. More precise spectral analysis is possible with use of narrow-band filters. T250 telescope at Javalambre will use a set of 56 filters, allowing for red-shift determination with precision up to $\Delta z \sim 0.3\%$ (Granzer et al. 2012). All filters can be simultaneously located in the filter tray. However, each can be used only for one out of the 14 CCD sensors covering telescope FoV. Reconstruction of the complete spectra is only possible by combining images taken at many different pointings. Most precise reconstruction of the spectra for selected object, including detailed time variation measurements (as Time-Series Doppler Imaging) can be obtained with use of fiber-fed échelle spectrograph. The STELLA/SES robotic telescope provides such a measurement with resolution $\lambda/\Delta\lambda = 50{,}000$ (Weber et al. 2012).

Recently, new window to the understanding of the GRB phenomena was also opened by the MASTER-Net telescopes: first polarization measurement of the prompt optical emission was made for GRB100906A (Lipunov et al. 2012). Much progress is also observed in the software and web applications for robotic telescopes. Control over the robotic observatory becomes easier and easier with usage of standard tools. New tools are being developed for running telescopes, infrastructure monitoring and environmental data access, as well as for reviewing alert response and on-line image processing results (Karpov et al. 2012).

4. Robotic telescope networks

Robotic autonomous observatories became a standard tool in astronomy. In most cases they are more efficient and reliable than those depending on "on-line" human control (on site or remote). However, even more possibilities open, if we connect a number of robotic telescopes in a network. This is of special importance in case of

GRB studies, as time and position of the burst are completely random. With network units located at different parts of the globe, chances of making optical GRB observations significantly increase, depending much less on the local weather conditions or time of the day. Successful examples of such an approach include MASTER-Net (Lipunov et al. 2012) and BOOTES Network (Castro-Tirado et al. 2012).

The idea is to create a dedicated network of telescopes and a social network for doing research. Members of the GLORIA community will be able to propose new observations or observations strategy (so called "on-line" experiments). Rules for assigning the observing time will take into account user's "karma", which should reflect user's reputation, based on the responses from the community. All users will also be able to access and analyze data collected by telescopes, and propose dedicated studies ("off-line" experiments) which can involve other community members. We also hope that we will be able to attract more telescope owners, both professionals and amateurs, to join the network

5. Summary of the summary

Second Workshop on Robotic Autonomous Observatories was a very successful meeting. We had almost 50 oral and about 20 poster presentations during the conference. I apologize for covering only a small and arbitrary selection of subjects in this short summary. One should also mention that there was a lot of time left for fruitful discussions, which should result in further development in the field and new collaborations. I hope we will see many new interesting results at the next meeting.

Acknowledgments

We are very grateful to organizers for inviting us to the beautiful town of Torremolinos and for perfect preparation of the meeting. This work has been financed by the Polish Ministry of Science and Higher Education in 2009-2011 as a research project.

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