Second Workshop on Robotic Autonomous Observatories
ASI Conference Series, 2012, Vol. 7, pp 117 – 122
Edited by Sergey Guziy, Shashi B. Pandey, Juan C. Tello &
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New improvements in robotic telescopes at CAB

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Abstract. The Robotic Telescopes at the Centro de Astrobiologa (CAB, CSIC-INTA) are scientific installations dedicated mainly to observe and characterize exoplanets through the analysis of their transits. Over the last year, we have improved several characteristics of these telescopes. We have put great efforts into improving the accuracy of the observations through improved observation techniques and methods of analysis and data reduction. A new CCD with better QE and linearity has been installed. Also, a new Str$\acute{}$ongrem filter has been set to provide enhanced capacities to the telescope. Finally, the primary and secondary mirror have been re-coated. In the case of the methodology to analyze the data, we have improved the tables of focus versus temperature and the procedures to compensate for the deviations on the image focusing. Although the main use of these telescopes is scientific, a significant amount of observation time is dedicated to outreach programs. We have developed an educative program based on simple scientific projects that students can carry out. In this paper we will go over these improvements and the new projects of Public Outreach.

Keywords : robotic telescopes – exoplanets – scientific outreach

1. Introduction

Robotic telescopes are a new tool for astronomy that are mostly used to study nearby and brilliant objects. They are also a perfect tool to support scientific projects that require constant monitoring of the sky (Baruch 1992). Then, robotic telescopes are very useful in observations that do not require an operator (Steel & Marsden 1996; Street et al. 2003). In this case a great amount of data is generated but can be reduced and analyzed automatically.

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Figure 1. Telescopes at the Observatory of Calar Alto.

One of the astrophysical topics for which robotic telescopes have been widely used is the search and characterization of exoplanets (Mayor & et Queloz 2004). The study of extrasolar planets is in the vanguard of the present investigation of astrophysics and is of great interest to the field of astrobiology (Henry et al. 2000; Charbonneau et al. 2000). The method of transit detection is based on obtaining differential photometry to detect changes in the light curves of stars (Konacki et al. 2003; Alonso et al. 2004; Pollacco el al. 2008). For this type of study a great amount of observation time is required.

With these characteristics, robotic telescopes have also become one of the most important tools in practical education and the teaching of astrophysics. They represent a way to reach the public efficiently due to their particular configuration and the technical innovation that they represent (Baruch et al. 1992). Impressive images and scientific results in top astrophysics are good examples of their potential.

The Centro de Astrobiología (INTA-CSIC) operates three robotic telescopes with the aim of discovering and characterizing exoplanets (Cuesta 2008b). At present time, only one of these (installed at the Observatory of Calar Alto, Almería) is dedicated to science (see Fig. 1) while the other two are dedicated to activities of public outreach.

2. Telescope improvements

During the last year several features of the CAB's robotic telescopes at Calar Alto Observatorio have been changed in order to improve the quality of the data (Cuesta et al. 2008; Eibe et al. 2011). First of all, a new CCD camera has been installed. With more or less the same total number of pixels (4008×2672, $9\ \mu m/pixel$ to 3056×3056, $12\ \mu m/pixel$; ie. $\sim 1.1\ 10^7 pixels$ to $\sim 9.3\ 10^6 pixels$) and area covered ($24 \times 16\ arcmin^2$, $0.37\ ''/pixel$ to $25 \times 25\ arcmin^2$, $0.5\ ''/pixel$), the typical noise of the camera is reduced from $10e^-$ to $7e^-$ and the QE increases from 45% to 64%, with better wavelength response (see Fig. 2). Also, the linearity of the CCD is better for

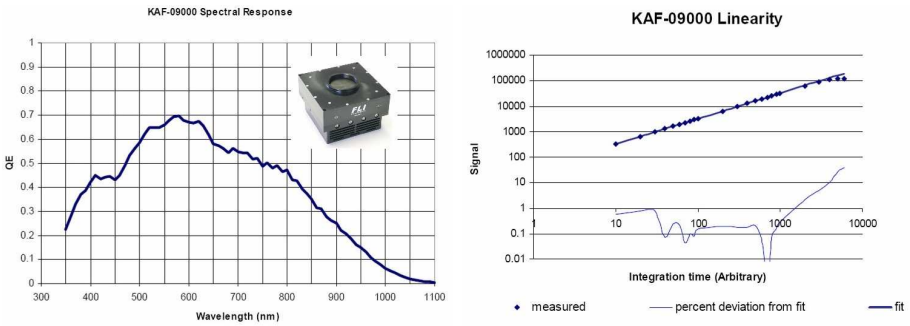


Figure 2. Spectral response and linearity for the CCD camera (from Finger Lakes Instrumentation).

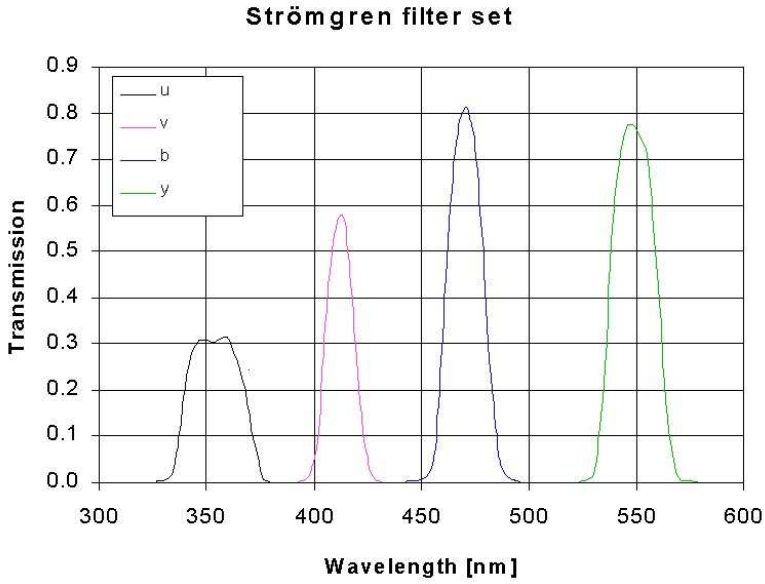


Figure 3. Strömgren filter response (from Andover Corporation).

a more extended range (see Fig. 2) which is critical in our case that high precision is required. Hence, with this new camera we are able to reduce significantly the exposition time with the corresponding reduction on thermal emission and deviations on tracking.

On the other hand, the telescope is provided with four new filters in order to increase the fields of Astronomy in which it can be useful. This new filters are a set of Strömgren filters (see Fig. 3).



Figure 4. Mirror re coating process made at the Observatory of Calar Alto (Almería, Spain).

3. Quality of data

One of the most important parts of a telescope is the primary mirror. A good reflective and clean surface is critical to increase the efficiency of the telescope and the quality of the data obtained. Both, primary and secondary mirrors have been re coated during the last year (see Fig. 4). Then we were able to reduce the exposition time by about a factor 1.5 after this process.

On the other hand, for robotic telescopes that have to work all the night on their own, a complete set of focus values for each value of temperature is the best way to reach a high quality on the data. Also during the last year a large amount of effort has been put into obtaining these tables for each filter used: UBVRI, and get the linear approximation. (see Fig. 5).

Finally, we have created a new pointing model that compensates for a variety of systematic mechanical errors including unusual mount flexure, incorrect location and drive train peculiarities. The procedure consists in a fine-alignment using an All-sky pointing mesh. The idea of this procedure is to take a large collection of images which cover the entire sky. Each image is solved for its WCS solution against the Hubble GSC to form an error mesh. The mesh is then used to refine pointing information from the telescope encoders during all slewing and tracking. The final goal is to be able to maintain a star on the same pixel during all the night.

4. An educative project with robotic telescopes

The ability of robotic telescopes to generate a large amount of data with little effort and budget compared to the big telescope and space missions has been fully proven. The case of exoplanets and their transit light curves are a good example. This can

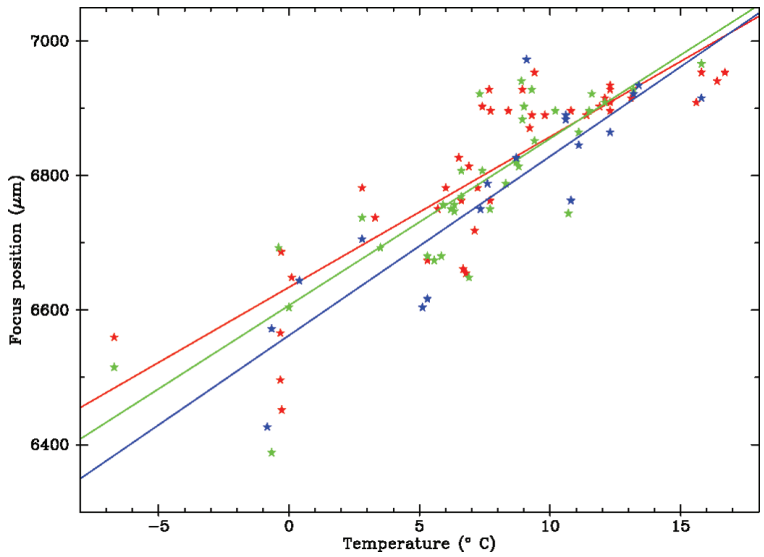


Figure 5. Variation of focus versus temperature and the corresponding linear fitting for each one of the filters used: R (red), V (green) and B (blue).

be exploited to create an outreach project (Cuesta 2008a). With this objective we are developing a series of tools and methodologies to provide the general public with the means to participate in the study of exoplanets. This is an activity based on interactive work with actual observations. User tasks are completed in three phases:

- Choosing the best light curves. One of the major problems in analyzing these light curves is the choice of those with the best conditions based on three criteria: have better temporal resolution, cover most of the transit, and have better photometric precision.
- Integrate light curves. Having chosen a set of light curves with the best conditions it is necessary to join them. This gives a considerable increase in the SNR. To correctly add the curves they must fit perfectly within the time scale of the orbital period of the exoplanet.
- Fit a model for transit. Using a transit model, and with information provided to the user, it is possible to determine orbital parameters and some other characteristics of the planet. Careful fitting is essential at the beginning and end of transit and its depth. Some important information of the planet may be derived and the user can learn how to get it.

The activity is aimed at the general public. It is an exercise for which no special preparation is required; people may only have clear concepts on exoplanet transit light curves. The available tools provide the rest. The work environment is an interactive website where the user must be registered to gain access to a desk with all the tools.

Each user will initiate a project to characterize an exoplanet's light curves set. He can use a database of existing transit observations or request a new observation. All light curves, both from the database and requested by users, will be public and usable by all registered users. Also, several users could start their projects on the same exoplanets. With the results of all the projects from all users a comparative study will be done. This is a good example of collaborative science.

5. Conclusions

A wide improvement of the characteristics of the observatories of the group of Robotic Telescopes at Centro de Astrobiología have been carried out during the last year, both technical, with new hardware, and with new analysis methods that are more robust and efficient. The result is a better quality of the data that allows the system to reach values of accuracy about 2 milmag which is critical to study exoplanets transits. Also, an educational project using the robotic telescope have been developed.

Acknowledgments

The authors would like to acknowledge financial support from the Spanish program AYA2009-14000-C03-02 starting in 2010.

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