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INTEGRATION OF THE WATCHER TELESCOPE INTO THE SIERRA STARS OBSERVATORY NETWORK – LESSONS LEARNED FOR GLORIA

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Abstract. The UCD Watcher robotic telescope is planning to participate in the Sierra Stars Observatory Network (SSON), a US-based organisation that provides astronomical images upon request to subscribing users, who are typically either amateurs or university/college students. Implementing the tasks required for the integration of Watcher to SSON, such as remote scheduling, file transfer, image quality validation and the provision of meteorological information, have provided useful experience for the GLORIA project. It has also become apparent that managing user expectations will be important for GLORIA.

Keywords: robotic telescope, gamma-ray burst afterglows, GLORIA, SSON.

1. The Watcher robotic telescope

The Watcher robotic telescope has been established at Boyden Observatory in South Africa (29° S, 26° E, altitude of 1387 m) as a collaboration between UCD (Ireland), AsÚ AVČR (Czech Republic), UFS (South Africa) and IAA (Spain) [1]. The telescope's location affords $\sim$ 200 clear nights a year and it has been in operation since 2006. The telescope is shown in Fig. 1. The current configuration consists of a 40 cm diameter mirror, with f/14.25 in a classical Cassegrain setup on a Paramount mount. The filter wheel allows use of standard B, V, R, I filters as well as no (clear) filter. Since 2009 the Watcher has been equipped with an Andor camera enabling fast EMCCD mode imaging (reaching 16th magnitude in the clear filter in just a 2 second exposure), but reducing the field of view to $8' \times 8'$ from $14' \times 14'$.

Watcher's observing time is dedicated primarily to rapid follow-up of gamma–ray burst (GRB) afterglows and also to undergraduate and Master's student projects. The telescope schedules and runs observations in a fully autonomous regime controlled remotely by the open-source RTS2 software [2], supported by an astrometry package and a photometry pipeline (WaLaPi) currently under test. Highlight observations from the successful programme of GRB afterglow follow-ups include prompt and early afterglow observations of GRB 041219A, GRB 060525A, GRB 080905B, GRB 120327 and GRB 120711A, with response times typically less than 1 minute and as short as 20 seconds in some cases.

2. GLORIA project

GLORIA stands for "GLObal Robotic-telescopes Intelligent Array" and will be the first free and open access network of robotic telescopes in the world [4]. It will provide a Web 2.0 environment where users

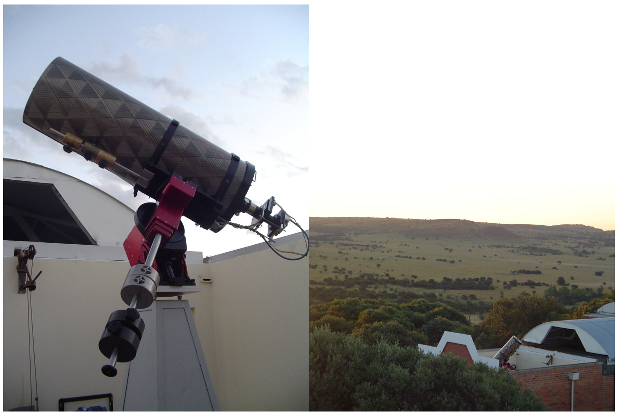
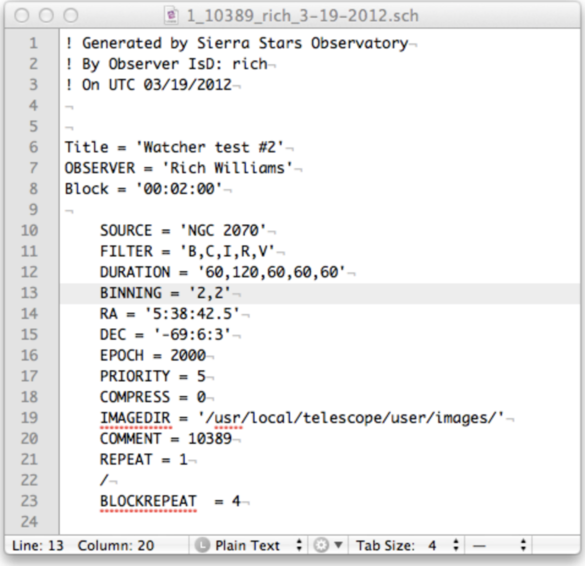


Figure 1. Two views of the Watcher robotic telescope.

(who may be students, citizens, amateurs or professionals) can do research in astronomy by observing with robotic telescopes. The GLORIA activities fit into two categories: 'online experiments' (taking images) and 'offline experiments' (working on acquired images from the archive to do scientific projects e.g. galaxy classification). The observations will be made through manual remote control or in fully automatic batch mode.

The observations can be done at a fixed time chosen by the user, or can be selected by the system scheduler, or can be triggered by an external alert, such as a GRB. The priority of the users' requests is determined based on a system that incorporates the user's experience, their previous work within GLORIA and their 'rating' within the community.

A key component of the GLORIA system is a global scheduler that will plan the observations of a heterogenous array of telescopes around the world. GLORIA's scheduler will accept telescope-neutral Observing Plans as input and then outputs a schedule for



```
! Generated by Sierra Stars Observatory
! By Observer IsD: rich
! On UTC 03/19/2012


Title = 'Watcher test #2'
OBSERVER = 'Rich Williams'
Block = '00:02:00'

    SOURCE = 'NGC 2070'
    FILTER = 'B,C,I,R,V'
    DURATION = '60,120,60,60,60'
    BINNING = '2,2'
    RA = '5:38:42.5'
    DEC = '-69:6:3'
    EPOCH = 2000
    PRIORITY = 5
    COMPRESS = 0
    IMAGEDIR = '/usr/local/telescope/user/images/'
    COMMENT = 10389
    REPEAT = 1
    /
    BLOCKREPEAT  = 4
```


FIGURE 2. Listing of a sample SSON observational request file to be parsed by Watcher.

each of the telescopes, based on their available time and capabilities. It is planned that the algorithm of multiple queues will be used [5]. The GLORIA web page will provide a forum for discussion, sharing results and starting collaborations on astronomical projects. Moreover, a number of interesting astronomical events, such as the 2012 Venus transit over the solar disk, will be broadcast live on the Internet with commentary.

Thanks to its open-access philosophy, GLORIA has ambitions to be a powerful and useful tool for education and outreach. So far, 17 telescopes are already, or are about to become, part of the growing network. To become a partner, telescopes must offer a fraction of their observing time for free to GLORIA. Ultimately, the aim is to have many users who supply telescopes to the network and, in return, gain access to other telescopes around the world, to further their own research goals and interests.

3. SSON

The Sierra Stars Observatory Network (SSON) provides astronomical images from selected telescopes for a fee to subscribed users, who are usually amateurs and university staff and students [6]. There are three robotic telescopes deployed in the USA: Sierra Star Observatory (61 cm in California), Mt. Lemmon (81 cm diameter in Arizona) and Rigel (37 cm in Iowa). Dark-subtracted and flat-field corrected images are delivered straight to the users to download from the central SSON archive.

Watcher was invited to join SSON in 2011, due primarily to its coverage of the southern sky. In late 2011 and early 2012, concerted efforts were made to implement the required components needed by SSON. Although straightforward in principle, various issues

FIGURE 3. A sample tweet showing Watcher's current weather condition from the on-site Davis weather station and the weather forecast for Boyden Observatory.

have arisen that have taught us lessons about the differing expectations from different types of users. These are discussed here in order to inform future discussions about incorporating new telescopes into the GLORIA network.

4. TELESCOPE INTEGRATION

The communication protocol must be general and simple, providing a bullet-proof interface layer that is essentially a black-box. The telescope does not need to know the details of the architecture of the scheduler and the scheduler does not need to know the internal details of the telescope, but just sends observational requests and awaits for a result and a status message. Any messages that are not understood are omitted. An example of an observation request from SSON is shown in Fig. 2.

Watcher receives the SSON requests prepared by the SSON scheduler from the FTP server on a daily basis, parses them and integrates them into its observation planner/scheduler and updates the queue of targets to be observed. Several constraints such as fixed time, minimal airmass or lunar distance can be input. At the end of the night Watcher returns a summary report of the night, reporting on the SSON-related observations and delivers images to the FTP server. The GLORIA processes may work in a similar way, however the communication feedback between the telescope and the global scheduler should be continuously updated in the real time, rather than once per day.

The astronomical images are then preprocessed, astrometry is performed and image quality is validated by an heuristic quality function that incorporates the zero-point, airmass and point spread function of stars in the image, cloud level and sky background. The latest available flat-fields are provided for each filter.

Watcher's status, with current meteorological conditions, weather forecast and current image quality, are updated on Twitter [7] as shown in Fig. 3.

Amateur astronomers' observing targets are typically different from GRB afterglows, which are point-source deep sky objects. Sources with large angular sizes, such as galaxies or nebulae are often found among the requested targets. This challenges the small field of view of Watcher, since there are often not enough catalogued stars in the image for successful astrometry and therefore for re-centring the image,

Figure 4. An example of a good quality image of the spiral galaxy M83 before application of the 'cross-pattern' algorithm.

if the pointing is initially off target. An example is shown in Fig. 4.

A centering 'cross-pattern' algorithm has been implemented when an observation of an extended astronomical object of a comparable apparent angular size to the field of view is requested. This algorithm determines a pointing correction to be applied to ensure the target is well-centred in the field. A series of test images is first made, including the target and adjacent fields. The correction is then applied and the actual target image is then taken.

5. Conclusions

Due to its exclusive location in the southern hemisphere, the fully robotized Watcher telescope is a cornerstone of the developing GLORIA project and in an experimental testing phase of joining the SSON, planned for full integration by the end of October 2012. The basic features of the GLORIA and SSON networks are summarized in Table 1 and their current geographical distribution in Fig. 5. The methods used by SSON-Watcher for the telescope–scheduler communication, the form and parsing of the observational requests, the modification of observing techniques used for targets predominantly selected by amateur astronomers, the telescope status broadcasting, including the usage of Twitter and the image validation, all have relevance for and potential applications to, the growing GLORIA telescope network.

Feature	SSON	GLORIA
number of telescopes	4	17
in countries/continents	2/2	8/4
total aperture size	$1.17\,\mathrm{m}^2$	$2.38\,\mathrm{m}^2$
real time scheduling	no	yes
request optimization	no	yes
request validation	yes	yes
free of charge	no	yes
ready to use	now	2013

Table 1. Comparison between the SSON and the GLORIA networks (including Watcher) as of mid-2012.

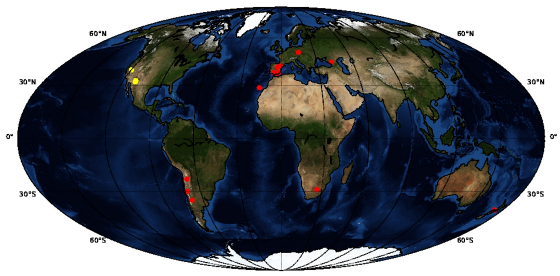


Figure 5. The world map of the locations of the current GLORIA (red dots) and SSON (yellow dots) robotic telescopes.

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[7] `http://www.twitter.com/WatcherTele`