Highlights of Spanish Astrophysics VIII, Proceedings of the XI Scientific Meeting of the Spanish Astronomical Society held on September 8–12, 2014, in Teruel, Spain. A. J. Cenarro, F. Figueras, C. Hernández-Monteagudo, J. Trujillo Bueno, and L. Valdivielso (eds.)

The GLObal Robotic telescopes Intelligent Array for e-science (GLORIA)

A. J. Castro-Tirado[1,2], F. M. Sánchez Moreno[3], C. Pérez del Pulgar[2], D. Azócar[4], G. Beskin[5], J. Cabello[2], R. Cedazo[3], L. Cuesta[6], R. Cunniffe[1], E. González[3], A. González-Rodríguez[1], J. Gorosabel[1,7], L. Hanlon[8], R. Hudec[9,14], M. Jakubek[9], P. Janeĉek[10], M. Jelínek[1], O. Lara-Gil[1], C. Linttot[11], M. C. López-Casado[2], M. Malaspina[12], L. Mankiewicz[13], E. Maureira[4], J. Maza[4], V. F. Muñoz-Martínez[2], L. Nicastro[12], E. O´Boyle[8], E. Palazzi[12], P. Páta[14], M. A. Pio[15], M. Prouza[10], F. Serena[3], M. Serra-Ricart[15], R. Simpson[11], P. Sprimont[12], J. Strobl[9], M. Topinka[8], S. Vitek[14], and A. F. Zarnecki[16]

[1] Instituto de Astrofísica de Andalucía, P.O. Box 03004, E-18080 Granada, Spain
[2] Unidad Asociada Departamento de Ingeniería de Sistemas y Automática, Univ. de Málaga, Spain
[3] Universidad Politécnica de Madrid, Campus de Montegancedo, Madrid, Spain
[4] Universidad de Chile, Santiago, Chile
[5] Special Astronomical Observatory, Russian Academy of Sciences, Zelenchuk, Russia
[6] Centro de Astrobiología (INTA-CSIC), Ctra. de Ajalvir 4, 28850 Torrejón de Ardoz, Madrid, Spain
[7] Universidad del País Vasco, Bilbao, Spain
[8] UCD School of Physics, University College Dublin, Belfield, Dublin 4, Ireland
[9] Astronomical Institute, Czech Academy of Sciences, Ondrejov Czech Republic
[10] Fyzikální ústav AV CR, v. v. i. Na Slovance 1999/2, 182 21 Praha 8, Czech Republic
[11] University of Oxford, Oxford, UK
[12] Istituto di Astrofisica Spaziale, CNR, Bologna, Italia
[13] Center of Theoretical Physics, Warszawa, Poland
[14] Czech Technical University in Prague, Faculty of Electrical Engineering, Praha, Czech Republic
[15] Instituto de Astrofísica de Canarias (IAC), Via Láctea s/n, La Laguna, Santa Cruz de Tenerife, Spain
[16] Faculty of Physics, University of Warsaw, Warszawa, Poland

Abstract

GLORIA, funded under the auspices of the EU FP7 program in 2012–14, is a collaborative web–2.0 project based on a network of 18 robotic telescopes, which has become the first free-access network opened to the world for public outreach and specially for e-Science projects. On-line (solar and night) observations (experiments) as well as batch-mode (night) requests are possible. Educational material, applications (such as Personal Space) and complementary software have been also produced, besides the broadcast of several astronomical events during this period. GLORIA+ will exploit the full GLORIA potential in the years to come.

1 Introduction

In 2009, following the maturity in the field of Robotic Telescopes (see [1] for a review) we proposed to create a world-wide network of robotic telescopes (dubbed GLORIA as the GLObal Robotic telescope Intelligent Array), by devoting a fraction of the available observing time of existing instruments. This is not intended to compete with the very deep sky surveys planned towards the end of this decade, but our underlying idea was to attract a large number of users who will look at the sky and even help astronomers to achieve more scientific discoveries.

The GLORIA project has produced the first world-wide network of robotic telescopes free and open to ordinary people around the world. As observing time is limited, the users must prove their capabilities to get time, and compete via merit function score for access.

Hence GLORIA is indeed an "Intelligent Array" and it bases its intelligence on its community. Like most Web 2.0 projects, GLORIA implements a reputation-based scoring system to reward user contributions, driven by parameters such as the quality of gathered and processed images, time invested in the observations, etc, as well as the votes granted by the rest of the community, who finally evaluate the quality of the work done.

This project was initially designed for the 2012–2014 time interval. In Spring 2014 telescopes became operational for experimentation [2].

Finally, the GLORIA partners really believe in the enormous power of astronomy as a centre of interest in the scientific and human training of our young people.

In order to enroll newcomers and awaken interest in astronomy among children, during 2012–14 we organized the live Internet broadcast of 5 astronomical events: 4 eclipses and a transit of Venus, which were made from the GLORIA network, with associated activities in all schools of the partner countries, with the aim of getting students and teachers participating in research-based science education and improving their motivation to push the barriers of science education further [8].

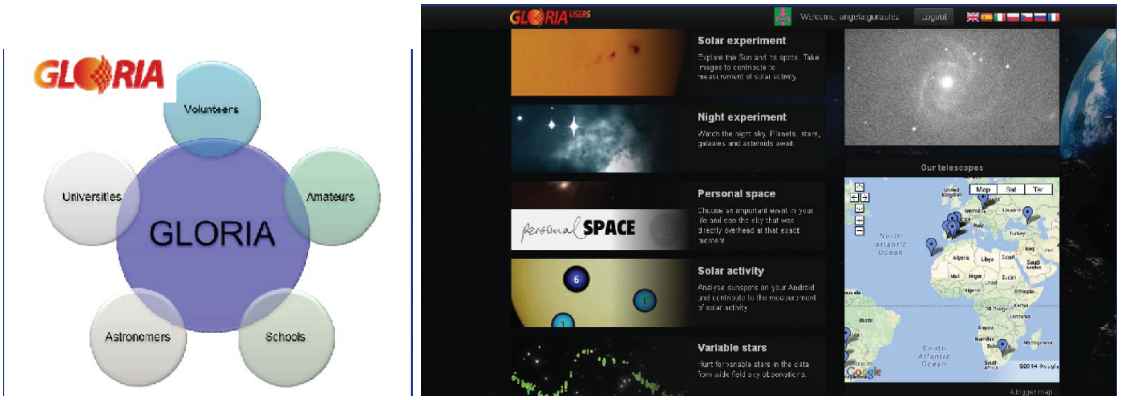

Figure 1: *Left*: The GLORIA community and the synergies amongst different GLORIA users. *Right*: User web interface showing the experiments available to GLORIA users in 2014.

2 GLORIA main facts

2.1 What is GLORIA?

GLORIA stands for "GLObal Robotic-telescopes Intelligent Array". GLORIA is the first free and open-access network of robotic telescopes of the world, through a web portal (http://gloria-project.eu). It is based on a Web 2.0 environment where users can do research in astronomy by observing with robotic telescopes, and/or analyzing data that other users have acquired with GLORIA, or from other free access databases, such as the European Virtual Observatory.

2.2 Who can access GLORIA?

The community is the most important part of GLORIA project. Access is free to everybody who has an Internet connection and a web browser. Therefore it is open not only to professional astronomers, but also to anyone with an interest in Astronomy. See Fig. 1 *(left)*.

2.3 Which services is GLORIA offering?

Many Internet communities have already formed to speed-up scientific research, to collaborate in documenting something, or as social projects. Research in astronomy can substantially benefit from attracting many star gazers. Indeed to catch some new celestial objects requires looking in the right place at the right moment. Our robotic telescopes can search the sky, but the vast quantities of data they produce are far greater than astronomers have time to analyze. GLORIA is a Web 2.0 structure, with the possibility of accomplishing real experiments. The community does not only generate content, as in most Web 2.0, but it is able to control telescopes around the world, either teleoperated or directly via scheduled observations (see [5] for a technical description of GLORIA).

Thus, the community can take decisions for the network which and the end is giving

Table 1: The 18 GLORIA Telescopes offered to the users as of 2014

Telescope	Diameter	Location	Partner
BOOTES-1A	0.15	Huelva (Spain)	CSIC
BOOTES-1B	0.30	Huelva (Spain)	CSIC
BOOTES-2/TELMA	0.60	Málaga (Spain)	CSIC, UMA
BOOTES-3/YA	0.60	Blenheim (New Zealand)	CSIC
CAB-CEB	0.50	Cebreros (Spain)	CAB/INTA-CSIC
CAB-CAHA	0.50	Calar Alto (Spain)	CAB/INTA-CSIC
BART	0.25	Ondrejov (Czech Rep.)	AUAV
FRAM	0.30	Malagüe (Argentina)	IP-ASCR
Pi of the Sky S	0.10	San Pedro de Atacama (Chile)	UNIWAR
Pi of the Sky N	0.10	Huelva (Spain)	UNIWAR
WATCHER	0.40	Boyden (South Africa)	UCD
C. TOLOLO	0.50	Cerro Tololo (Chile)	UC
OM (solar)	0.25	Madrid (Spain)	IAC
TADs (solar)	0.25	Teide (Spain)	IAC
TADn	0.25	Teide (Spain)	IAC
D50	0.50	Ondrejov (Czech Rep.)	AUAV
FAVOR	0.25	Zelenchuck (Russia)	SAO
MM TORTORA	0.10	Zelenchuck (Russia)	SAO

"intelligence" to GLORIA, while the drudge work (such as drawing up telescope schedules that satisfy various constraints) can be done thanks to algorithms developed for the purpose.

3 GLORIA telescopes and experiments

3.1 How many Robotic Telescopes are offered in GLORIA?

During the three years of the project lifetime GLORIA consortium 18 telescopes have been integrated (see Table 1), with 12 currently working in various scientific fields and in dissemination issues; another three instruments will commence operation this year and a further three will be installed towards the end of the project.

3.2 What is an experiment?

The GLORIA web interface allows research into a specific astronomical issue through an experiment, in which users are guided through the different tasks the research requires. There are two kinds of experiment: those that require a telescope (which we call "on-line experiments"), and another type ("off-line" experiments) which deal with data produced by the GLORIA network or taken from other databases, such as the European Virtual Observatory. See Fig. 1 (*right*).

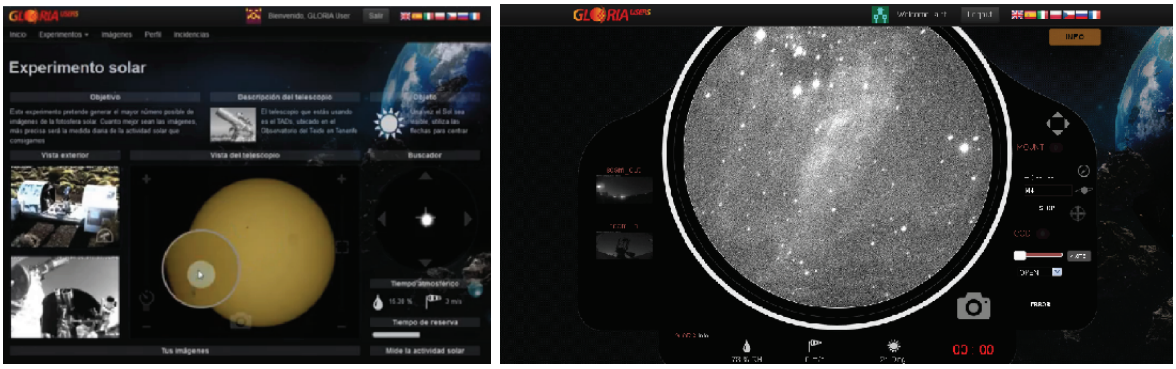

Figure 2: Snapshots of the two GLORIA web interfaces. *Left*: The Sun as observed by the 25-cm solar telescope at Observatorio del Teide. *Right*: The M 17 nebula as observed by the 60 cm TELMA telescope at the BOOTES-2 station in Algarrobo Costa (Málaga).

3.3 What kind of experiments have been considered?

During the lifetime of the GLORIA project, demonstrators for on-line and off-line experiments were produced [6]:

- On-line experiments: sun observations, interactive night sky observations, scheduled night sky observations. See Fig. 2.
- Off-line experiments (using archival images): evaluation of solar activity through Wolf number determination, variable star lightcurve analysis using LUIZA [9, 10].

On the top of them, we have also developed an application, dubbed "Personal Space", which allows to connect singular events in everybody´s life with the Cosmos, that increases the interest in Astronomy. See Fig. 3.

4 GLORIA objectives

4.1 A new concept for doing astronomy research more cost-effectively

The main idea is to do more and better research by allowing thousands of people to collaborate in doing science and making discoveries, by giving them access to professional research infrastructure.

To achieve this, a social network has been built in order to give free access to citizen scientists to: i) a growing number of telescopes; ii) a growing volume of data; iii) an unlimited range of astronomical scientific issues; and iv) a growing range of increasingly powerful software tools.

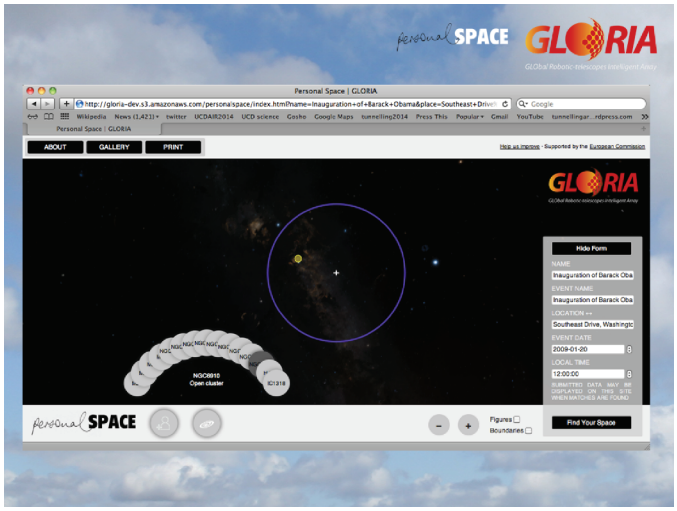

Figure 3: The personal space entry webpage (http://personal-space.eu).

4.2 To increase the number of telescopes and the number of scientists

The GLORIA network is designed to scale to an arbitrary number of telescopes. Basic tools are available for telescope owners on how to: i) robotize their own telescopes and ii) add their robotized telescopes to GLORIA (especially for scheduled observations). To achieve this, the GLORIA consortium has provided free/open software, free documentation and technical support to telescope owners.

4.3 To broaden the targeted areas of research

Anybody can design a web application for conducting research into some specific astronomical issues. Free software web components are being developed in order to carry out standard astronomy tasks. With these tools, professional and amateur astronomers can build up web applications (experiments) that invite others to focus on some particular astronomical target or research such as gamma-ray bursts [4, 7].

4.4 To increase the number of citizen scientists

To build up the community, GLORIA must attract and retain newcomers, both ordinary people and astronomers [3]. The main attraction is, of course, the offer of access at no cost to a network of robotic telescopes and the corresponding astronomical dataset.

4.5 To give free access to knowledge for everybody

All content generated by the GLORIA project or by GLORIA users is made available to all the community and protected by a copyleft license.

5 GLORIA+: the continuation of GLORIA into the future

GLORIA is created to last into the future as GLORIA+. As telescope maintenance is paid by their owners, the cost of the core part is moderate, and we expect GLORIA will be sustainable since 2015. The consortium believes that an economic model based on public and private funding could be adopted. Its strength will rely on the collaboration of the entire community. GLORIA+ is conceived as a distributed and central infrastructure which will run with the telescopes being maintained by their owners. The infrastructure for keeping GLORIA alive is basically a web server and a database, which will be hosted at certain institutions of the GLORIA+ consortium and maintained with national funding.

Acknowledgments

We thank the support of the EU FP7 program for collaborative projects and coordination and support actions (CP-CSA) through the grant 283783 which allowed GLORIA to become a reality. We are also grateful to our national institutions for their support and are indebted to the users who have helped us to improve the GLORIA outcome over 2012–14.

References

[1] Castro-Tirado, A. 2010, Robotic Astronomy 2009, A. J. Castro-Tirado, J. S. Bloom, L. Hanlon and T. Kotani (eds.), Advances in Astronomy, vol 2010, article ID 570489

[2] Castro-Tirado, A. J. et al. 2014, Robotic Astronomy 2013, J. C. Tello, A. Riva, D. Hiriart and A. J. Castro-Tirado (eds.), Rev. Mex. Astro. Astrophys. Conf. Ser. vol 45, 104A

[3] Hanlon, L. 2013, In: 7th International Technology, Education and Development Conference, see http://gloria-project.eu/wp-content/uploads/2013/10/hanlon-proceedings-inted2013.pdf

[4] Mankiewicz, L. 2013, Gamma-ray Bursts: 15 Years of GRB Afterglows, A. J. Castro-Tirado, J. Gorosabel and I. H. Park (eds.), EAS Publication Series 61, 483

[5] Pérez del Pulgar, C., Cedazo, R., Cabello, J. et al. 2012, In: Advances in Information Systems and Technlogies, Advances in Intelligent Systems and Computing, volume 2012, 293

[6] Piotrowski, L. W., Castro-Tirado, A. J., Cunniffe, R. et al. 2013, In: 33rd International Cosmic Ray Conference, see http://gloria-project.eu/wp-content/uploads/2013/10/icrc2013-0715.pdf

[7] Ricci, D., & Nicastro, L. 2013, Gamma-ray Bursts: 15 Years of GRB Afterglows, A. J. Castro-Tirado, J. Gorosabel and I. H. Park (eds.), EAS Publication Series 61, 263

[8] Serra-Ricart, M. and Pío, M. A. 2013, In: EDULEARN 2013, see http://gloria-project.eu/wp-content/uploads/2013/11/edulearn-2013.pdf

[9] Zarnecki, A. F., Piotrowski, L. W., Mankiewicz, L., & Małek, S. 2012, Proc. SPIE, 8454, 845408

[10] Zarnecki, A. F., Piotrowski, L. W., Mankiewicz, L., & Małek, S. 2013, Acta Polytechnica, 53, 58