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THE GLOBAL ROBOTIC TELESCOPES INTELLIGENT ARRAY FOR E-SCIENCE (GLORIA)

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RESUMEN

GLORIA es un proyecto web-2.0 colaborativo basado en una red de telescopios robóticos de acceso libre que está abierto al público y enfocado a la divulgación astronómica y sobre todo a Ciencia Ciudadana.

ABSTRACT

GLORIA is a collaborative web-2.0 project based on a network of robotic telescopes, which has become the first free-access network opened to the world for public outreach and specially for e-Science projects.

Key Words: education — public outreach — telescopes

1. INTRODUCTION

Nowadays, research in optical astronomy poses two main challenges; 1) the immensity of the sky to be scrutinized and 2) the huge amount of astronomical data being gathered with current instrumentation. In fact, astronomers are facing great difficulty in finding the resources to analyze the increasing flood - insufficiently power software tools, and limited time (8 hours on average in a normal working day). The sky comprises 4×10^4 square deg, and future professional projects (such as LSST) intend to observe a very significant fraction of it on a regular basis.

In order to meet these, an increasing number of astronomical projects have begun to try to foster citizen participation in science, helping to analyse data using collaborative (so called Web 2.0) Internet applications.

In 2009, following the maturity in the field of Robotic Telescopes (see Castro-Tirado (2010) 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 would create 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. A GLORIA user's productivity will be measured automatically thanks to the collaboration of the rest of the users of the network.

Hence GLORIA is indeed an "Intelligent Array" and it bases its intelligence on its community.

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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. By 2015 the consortium will produce a standard for adding new telescopes and experiments to this network. Unlike other private, profitable ongoing initiatives, the GLORIA network will provide a free, twofold service to the Community:

1. Giving citizens (including professional and amateur astronomers) free access to a network of at least 18 robotic telescopes spread over four continents and both hemispheres. In the case of professional astronomers, GLORIA could be useful for those of developing countries who lack astronomical facilities in their own nations.

2. Giving citizens easy web access to all data collected by the robotic telescopes.

Besides providing the possibility of nearly continuous monitoring of an object thanks to the worldwide nature of the network, the following additional objectives will be pursued:

1. GLORIA will enable more telescopes to join the network by producing standards, software, and documentation oriented towards teaching professional and amateur astronomers to automate and eventually robotize their telescopes and how to integrate them into the GLORIA network beyond 2014.

2. GLORIA will enable new research projects to be undertaken by producing standards, software, and documentation oriented to teach amateur and professional astronomers how to design new GLORIA web experiments.

3. GLORIA will encourage participation in order to increase the size of its community of citizen scientists.

4. GLORIA will give free access to knowledge to everybody (see Fig. 1). All knowledge (software, manual, standards, documents, astronomical images, data, etc) produced by the GLORIA consortium and by the community will have copyleft licenses.

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

Fig. 1. The GLORIA community and the synergies amongst different GLORIA users.

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 partnersćountries, 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 (Serra-Ricart and Pío 2013).

With these activities, GLORIA is becoming widely known and we hope it will help to increase scientific vocations among young people, ensuring the future competitiveness in research and development in Europe and beyond.

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. 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 (http://www.euro-vo.org).

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.

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

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 objetcs 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 Pérez del Pulgar et al. 2013 for a technical description of GLORIA).

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

2.4. *How does GLORIA face its challenges?*

GLORIA project is defining free standards, protocols and methodology for:

1. Controlling Robotic Telescopes: and all related instrumentation i.e. cameras, filter-wheels, domes, etc.

2. Giving Web access to the Network in order to access to an arbitrary number of robotic telescopes via a web portal (gloria-project.eu).

3. Conducting On-line experiments, being able to design specific web environments for controlling telescopes for research in some specific scientific issue.

4. Conducting Off-line experiments, being able to design specific web environments for analyzing Astronomical meta-data produced by GLORIA or other databases.

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,

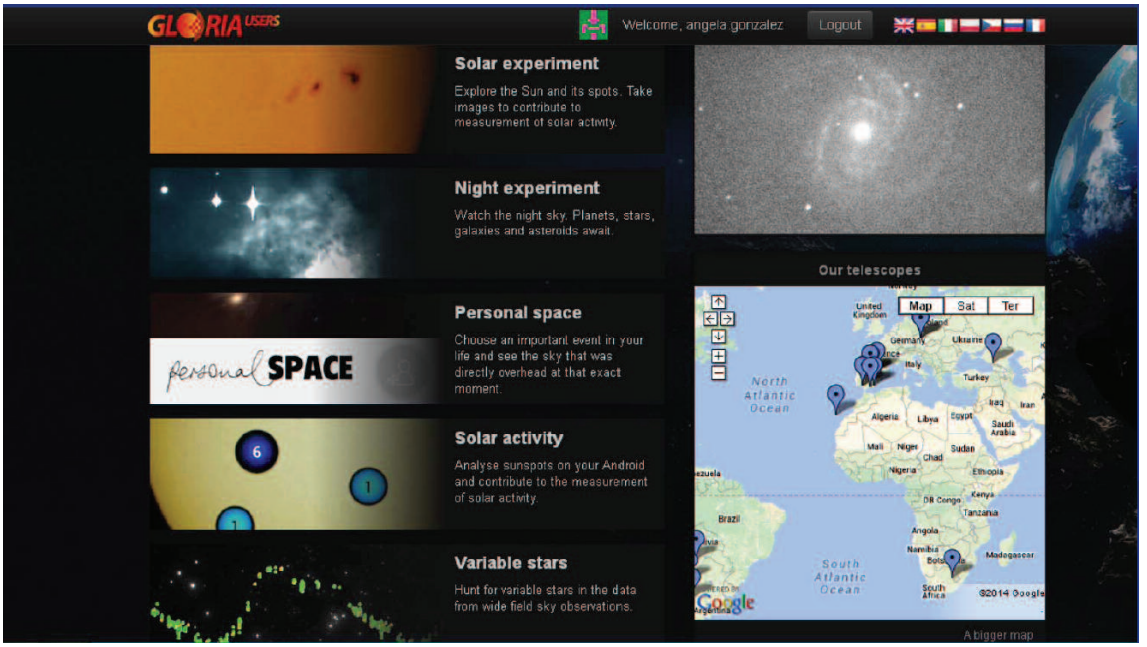

Fig. 2. User web interface showing the experiments available to GLORIA users in 2014.

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. 2.

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 (Piotrowski et al. 2013):

- On-line experiments: sun observations, interactive night sky observations, scheduled night sky observations. See Fig. 3-4.

- Off-line experiments (using archival images): evaluation of solar activity thru Wolf number determination, variable star lightcurve analysis using LUIZA (Zarnecki et al. 2012, 2013).

On the top of them, we have also developed an application, dubbed "Personal Space" (personalspace.eu), which allows to connect singular events in everybody´s life wih the Cosmos, that increasing 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.

The provided service relies on free access to: i) a world-wide expensive infrastructure of robotic telescopes; and ii) a free database of astronomical images taken by the members of GLORIA robotic telescope network.

The Web 2.0 feature is based on the fact that the GLORIA network is a meritocracy. The collaboration of each user is validated for the rest of the community and measured automatically by an index called Karma.

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

Fig. 3. A snapshot of the web interface showing the Sun as observed by the 25-cm solar telescope at Observatorio del Teide.

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. The benefits to the telescope owners are that they will be able to trade time on their instrument for time on other telescopes, perhaps better, perhaps in distant timezones (to observe during local daytime), or in different latitudes (to observe objects never visible from their location), or simply to observe when their own telescope is closed by bad weather. Telescope owners will be able, if they wish, to restrict the use of their telescope to research some specific topic in astronomy, and will benefit from the person-power of GLORIA network for research. The Web 2.0 aspect of the network implies that users who contribute a telescope gain karma as a function of its availability, quality, and by the new scientific discoveries he/she will support and the votes of the rest of the community.

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 (Mankiewicz 2013, Ricci and Nicastro 2013). Once a give experiment is validated, it can be introduced into the GLORIA network and the whole community can start researching in the new area. Thus, GLORIA is producing a standard methodology for building up astronomy experiments on the web, and those who add experiments to GLORIA increase their karma as a function of its quality, potential for scientific discoveries and interest by the rest of the community.

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 (Hanlon 2013). The main attraction is, of course, the offer of access at no cost to a network of robotic telescopes and the corresponding astronomical dataset. Broadcast of astronomical events is of utmost importance and is already proven by the GLORIA partners that these events awaken the interest of many thousands of people who followed and watched the live video we produced. School activities around these events in all the countries of the GLORIA consortium were also arranged. Keeping the high quality of the network of robotic telescopes as well as the related astronomical database developed in the context of the GLORIA project (dubbed Sadira) was another goal.

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 licence. Although all documents are freely available, authorship will be recognized. This content includes: i) software for robotic telescopes to allow anybody to robotize their own telescope and to integrate it into GLORIA network; ii) experiment software components and new experiments to allow anybody to design a specific experiment and to publish it in the GLORIA network; iii) images and multimedia content to allow anybody to disseminate science or to make scientific discoveries by using images taken on behalf of somebody else.

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 beyond 2014. 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

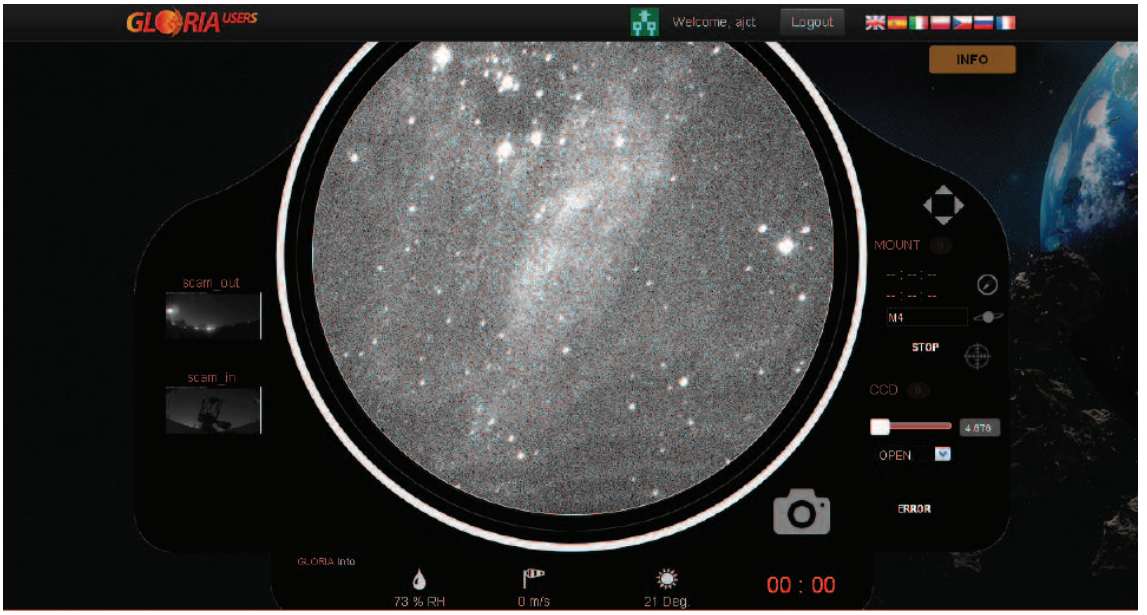

Fig. 4. A snapshot of the web interface showing the M 17 nebula as observed by the 60 cm TELMA telescope at the BOOTES-2 station in Algarrobo Costa (Málaga).

is basically a web server and a database, which will be hosted at certain institutions of the GLORIA+ consortium and maintained with national funding.

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Fig. 5. The personal space entry webpage.

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