GLORIA: A NEW NETWORK FOR CITIZEN SCIENCE ASTRONOMY

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Abstract

GLORIA is an innovative citizen science astronomy project, which will give free and open access to a growing collection of robotic telescopes via a Web interface. The project involves 14 institutions across 8 countries and is being funded by the EU under the FP7 eInfrastructures programme. In the initial phase, 17 telescopes around the world are being deployed for use by citizen scientists. The main aim is to involve the general public in carrying out astronomical research projects of their choosing and to provide all users with the tools necessary to plan and conduct their observations and to analyse and publish their data. It is critical to the success of the network that a global community of users grows to support it into the future. Special astronomical events are being broadcast live over the Internet, and high quality educational materials suitable for 16-18 year olds are being developed, in order to ensure a wide audience is being engaged. The key components of the project, along with a status report, are presented.

Keywords: Telescopes; astronomy; citizen science; education; e-science

1 INTRODUCTION

1.1 Citizen engagement in astronomy

'Participatory science' or 'citizen science' projects enable scientific research across many disciplines by harnessing the globally distributed computing power, data gathering power and brain power of many volunteers. The use of volunteers in the fields of ecological research and conservation is well-established. Examples of citizen science projects in these areas include 'Whale FM', 'Fossil Finders' and 'What's Invasive' among many others. The number of scientific papers published annually as a result of citizen science involvement has grown from a handful in the mid 1990's to more than 40 by 2010 [1].

The night sky is visible to all and astronomy can act as a gateway science to inspire everyone, but especially future scientists, engineers and computer programmers. There are many examples of citizens' participation in astronomy projects, especially when no specialised equipment is required. Meteor watches are often organised by amateur astronomy groups. NASA has created an Iphone app (Meteor Counter) that can be used to record timings and intensities of meteors during meteor showers and that automatically uploads the results to NASA for further analysis. This shows the potential of handheld sensors such as smart phones for live recording of bright transient phenomena in the sky. The Transit of Venus in June 2012 was a 'once in a lifetime' event that was used by several groups to organise large numbers of the general public to record the timings of the transit of Venus across the face of the Sun and to use the collected data to record a value of the Sun-Earth distance. In the case of the Hetu'u project, data collected by hundreds of school children from diverse cultural backgrounds around the globe returned a value within 1σ of the accepted one [2].

Many dedicated amateur astronomers contribute to discoveries in astronomy by monitoring the sky for new novae, supernovae, comets, asteroids and other transient sources. Typically these are individuals with advanced equipment, great expertise and enormous dedication. In certain cases, targeted campaigns for particular sources are coordinated by groups such as the American Association of Variable Star Observers (AAVSO). Results are usually notified through circulars such as those from the IAU Central Bureau for Astronomical Telegrams.

However, programmes of astronomical research carried out by a large number of citizen scientists and resulting in refereed publications have, until recently, been a rarity. This state of affairs changed dramatically with the development of Galaxy Zoo, which harnessed volunteers' ability to recognise galaxy shapes from Sloan Digital Sky survey data in order to produce more than 70 million galaxy classifications [3]. As a result, in the 5 years to the end of 2012, there are more than 70 refereed articles listed on the Astrophysics Data System (ADS) server from a search of keywords 'citizen science' or 'volunteer' or 'Galaxy Zoo'. The vast majority of these arise from the original Galaxy Zoo project [4], but more recently other Zooniverse projects such as Planet Hunters, Solar StormWatch and Milky Way [5] have featured. Another example is the 'Citizen Sky' programme of the AAVSO. For comparison, in the previous 5 year period (2003-2007), there was only 1 relevant publication found.

The stage is therefore well set for a new, broad-based approach to astronomical research that can involve collaboration between the general public, who need not have any special equipment, but simply a Web interface; the amateur community, whose project ideas and ambitions may stretch beyond their equipment resources or geographical location, and professional astronomers (Fig.1).

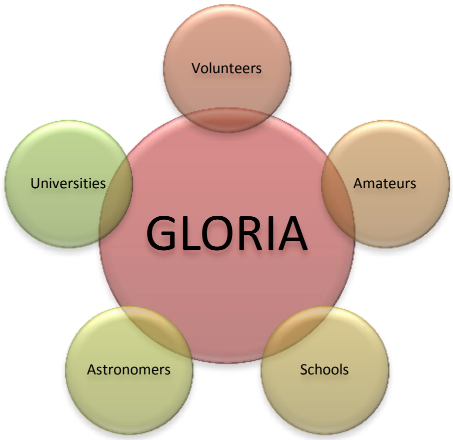

Fig. 1: The GLORIA project aims to provide the tools necessary for diverse communities to work together synergistically to create and share new astronomy knowledge.

1.2 Development of robotic telescopes

A large proportion of the effort in developing new ground-based astronomy facilities has traditionally been directed towards building larger aperture telescopes at professional observatories. However, at the other end of the scale, an increasing number of scientific programmes are being carried out by smaller instruments operated autonomously, sometimes in remote locations. Research goals requiring long time baselines or rapid response times are hampered by the inflexibility and limited availability of observing time on large telescopes. Considerable effort is therefore currently being devoted to developing robotic systems better suited to the specific scientific requirements of these types of programmes. Robotic telescopes have become increasingly sophisticated due to a variety of technological advances, in particular the Internet, the widespread availability of powerful, affordable computers since the early 1990s and the increasing sophistication of the amateur community, which has opened up new markets for manufacturers of components such as telescope mounts. A review of robotic telescope astronomy is given in Castro-Tirado, 2010 [6].

The main advantage of robotic telescopes lies in their flexibility, which allows variability to be studied in ways that are not possible with traditional facilities. Studies of active galactic nuclei, variable stars and extra-solar planetary transits greatly benefit from long-term monitoring programmes that robotic facilities can carry out so effectively. In addition, their rapid, automated response capabilities make them ideally suited to observations of transient sources like supernovae and gamma-ray bursts (GRBs). Whereas manually operated telescopes can respond on timescales of minutes at best, robotic telescopes can begin observing the target in seconds, opening up a previously unexplored regime in the time-domain study of GRBs. Other areas in which robotic telescopes excel are cosmological surveys and calibration tasks such as extinction monitoring.

1.2.1 Robotic Telescopes in Education

The primary driver for most astronomers to build robotic telescopes is to progress scientific understanding. However, some programmes have been developed that utilise the capabilities of robotic telescopes to also (or sometimes exclusively) harness students' enthusiasm for science and motivate them to pursue scientific studies. A notable example is the set of two Faulkes Telescopes (www.faulkes-telescopes.com) in Hawaii and Australia that permits students in Europe to observe during their school day. This manual mode is available for a fraction of the time, with the remainder being dedicated to scientific observations conducted autonomously.

The Bradford Robotic Telescope (BRT) is a robotic telescope system that also offers a rich and stimulating web resource that encourages children into scientific thinking by presenting them with ideas, games, simulations and puzzles [7]. Students are asked to explain astronomical phenomena and then to test their explanation with a scientific experiment. There is a robotic telescope at Teide Observatory in Tenerife to respond to students' requests for astronomical images. This facility presents wonderful opportunities for exploring the Universe, from seeing the colours of stars, to the changing shape of the Moon throughout the month. Fig. 2 shows a screenshot from the BRT website that allows students to use images taken by the telescope to determine the age of the universe.

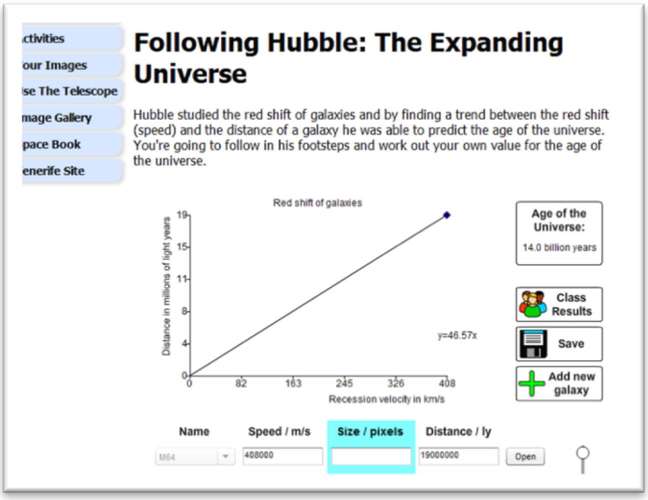

Fig. 2: Screenshot from the *schools.telescope.org* website of the BRT showing an activity to determine the angular size of galaxy images and hence plot the Hubble distance-redshift relation to determine the age of the universe. Image courtesy of the University of Bradford.

The potential of robotic telescopes as a catalyst for school pupils to engage with science and to pursue further scientific studies can be seen in the results of a recent pilot programme to bring the BRT into Irish schools (Fig. 3), sponsored by University College Dublin, Blackrock Castle Observatory, Forfas and the BRT.

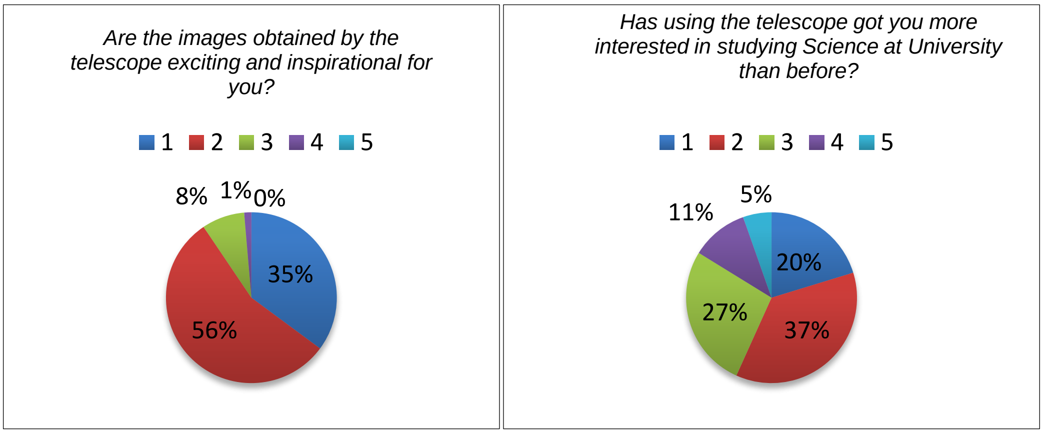

Fig. 3: Responses from 74 15-16 year old pupils in Ireland who were given access to the BRT and guided through the use of the telescope and the Hubble relationship activity by an experienced mentor and a graduate student in astronomy. The key to the legend is: 1 – Definitely; 2 - Probably yes; 3 - Not sure; 4 - Probably not; 5 - Definitely not.

2 GLORIA IN A NUTSHELL

GLORIA (*"**GLO**bal **R**obotic-telescopes **I**ntelligent **A**rray"*) is an innovative citizen science astronomy project, which will give free and open access to a growing collection of robotic telescopes via a Web interface. The project involves 14 institutions[1] across 8 countries and is being funded by the EU under the FP7 eInfrastructures programme. In the initial phase, 17 telescopes around the world (Fig. 4)are being deployed for use by citizen scientists. The main aim is to involve the general public in carrying out astronomical research projects of their choosing and to provide all users with the tools necessary to plan and conduct their observations and to analyse and publish their data. All the standards, software and documentation will be offered to the community under free licenses to use, distribute and modify (so-called copyleft licences).

The key elements of GLORIA are:

- Free and open access to the telescopes of the network to make observations, based on users' requests.
- A web interface and software that will allow anyone to add their own telescope to the network. The web access will also allow the user to directly control the telescopes. This may be a particularly attractive option for teachers and schools.
- Citizen science experiments, using data collected by GLORIA telescopes, or from other astronomical archives.
- Live web broadcasts of astronomical events and associated educational activities, including the Transit of Venus on June 5th/6th, 2012, the Aurora Borealis and the total solar eclipse of November 13th/14th 2012.
- Educational materials and web experiments that primarily target upper level (16-18 year old) high school students.

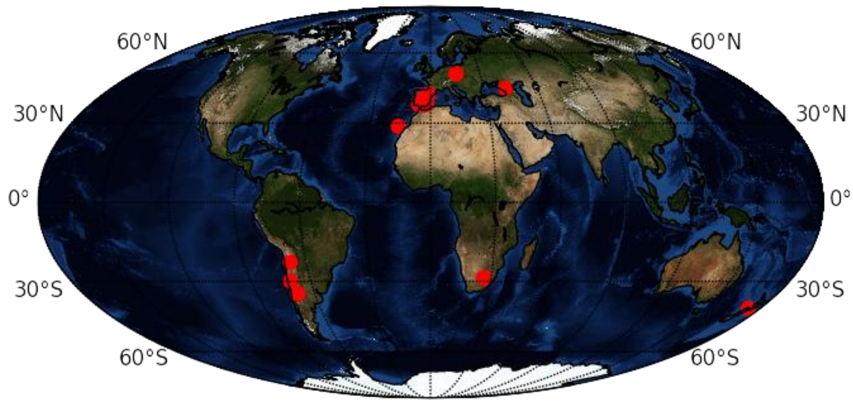

Fig. 4. Geographical locations of the initial 17 telescopes of GLORIA. More telescope information is provided in Table 1.

2.1 The telescopes of the network

GLORIA will create a completely robotised, autonomous **network** of telescopes. For each target, the selection of instrument as well as exposure settings will be decided automatically, without human intervention, based on information about telescope capabilities and the time slot which each telescope offers to the network. Putting together 17 telescopes in one network offers significant potential for automatically triggered follow-up observations. Such observations are obviously useful for transients of all kinds, including supernovae and gamma-ray bursts.

Thirteen of the telescopes (Table 1) are currently operational, with 2 (OM and TAD) already integrated into GLORIA.

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[1] For a full list of consortium members please see www.gloria-project.eu.

Table 1: The characteristics of each of the initial 17 telescopes in the GLORIA network

Name	Location	Aperture size (m)
BOOTES-1	Andalucia, Spain	0.3
BOOTES-2/TELMA	Andalucia, Spain	0.6
BOOTES-3/Yock-Allen	New Zealand	0.6
CAB-EVA1	Avila, Spain	0.5
CAB-CAB	Madrid, Spain	0.4
CAB-CAHA	Almeria, Spain	0.5
BART	Czech Republic	0.254 & 0.1
FRAM	Argentina	0.3
Pi of the Sky 1	Chile	0.07
Pi of the Sky 2	Huelva, Spain	0.07
Watcher	South Africa	0.4
C. Tololo	Chile	0.5
OM	Madrid, Spain	0.25
TAD	Tenerife, Spain	0.26
D50	Czech Republic	0.5
FAVOR	Russia	0.15
Mini-MegaTORTORA	Spain	0.07x9

2.2 Web interface

The user community will not only generate new science from archival data, but will also be able to control telescopes around the world, either directly, in ‘teleoperation’ mode, or via scheduled observations. The community will also make decisions about the network behaviour and priorities, that will give "intelligence" to GLORIA, while the drudge work (such as creating telescope schedules to satisfy various constraints) will be done by algorithms developed for the purpose.

2.2.1 Authoring tool

An authoring tool is being developed to allow a user to easily design and create their own experiments (Fig. 5). This authoring tool will enable users to easily design experiments by using a user-friendly web interface. The experiments may require the telescope(s) to make new observations, a so-called ‘on-line’ experiment, or may be an ‘ofline’ experiment utilising data previously acquired by GLORIA or, indeed, another system. Users will be able to design new experiments, integrate them into the network, by following the open methodology, and make them usable by all.

In the case of off-line community experiments, such as those available on Zooniverse, many thousands of users are expected to complete a data analysis or classification task. The requirement for such a large community to engage means that barriers to entry must be very low, allowing meaningful work to be done a few minutes after the site is first encountered. Such sites will be implemented as standalone microsites which will guide experienced users to the main GLORIA platform. Essentially they act as gateways to GLORIA.

During the lifetime of the GLORIA project, there will be demonstrators for at least one on-line and one off-line experiment. The on-line demonstrator experiment allows users to control the TAD telescope during daytime to take images of the sun and make a sunspot count. The off-line experiment will use images from the Pi of the Sky telescope to demonstrate the retrograde motion of Mars.

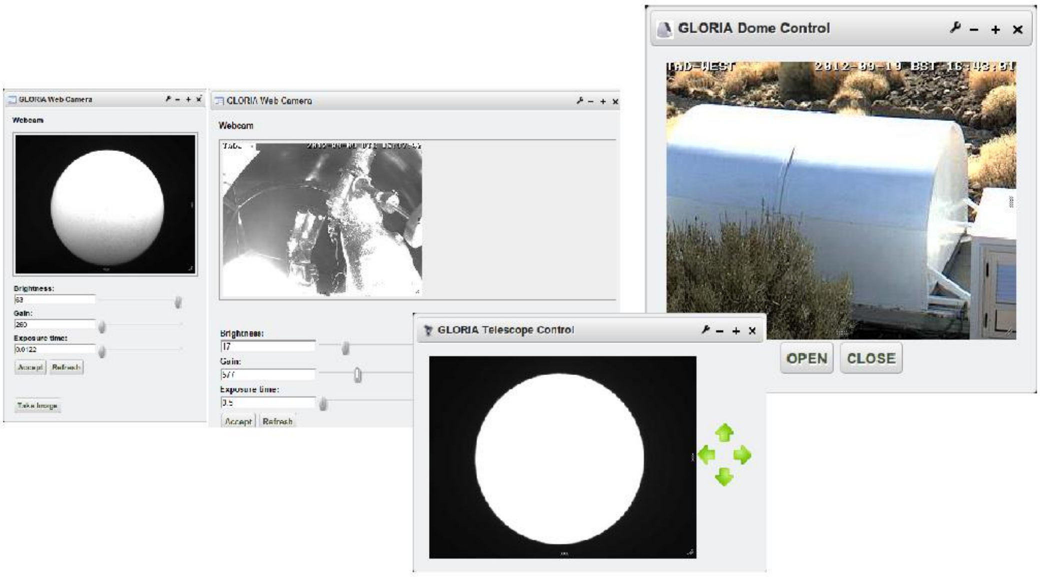

Fig. 5: A screenshot of the web interface showing the view from different webcams of the TAD telescope, including one that allows the user to view the roll-back roof (right).

2.2.2 Analysis tools

GLORIA seeks the collaboration of amateur astronomers and their telescopes. Some amateur astronomers are very active, with excellent instrumentation and observing locations. However, they may be limited in their ability to exploit and interpret their data scientifically. Interaction with professional astronomers and the use of powerful customized analysis tools will greatly improve the quantity, quality and reliability of the data collected with these instruments. GLORIA will benefit from their telescopes, the data they produce, and simply the extra knowledge, experience and ideas their presence brings to the community.

As examples, image viewing tools and curve fitting tools, all delivered via the Web interface, are being made available by GLORIA (Fig. 6). The image viewer FLORA is a javascript library which allows the display and manipulation of FITS (which is a standard astronomy image format) files in the browser and which also does point-source modelling. The intensity of light from a star as a function of time ('light-curve') can be fit to data via the Web interface to determine if, for example, there is a dimming of the light associated with the passing of a planet in front of the parent star.

2.3 Global scheduler

To practically implement these experiments, the following must be considered:

- **When** will the experiment be run?
  - **Fixed:** At a time chosen by the *user*
  - **Scheduled:** At a time chosen by the *system*
  - **Alert:** When triggered by an *external event*
- **How** will the experiment will be operated?
  - **Interactive:** Direct remote control of the telescope functions
  - **Batch:** The telescope receives a script, and executes it autonomously

Although a variety of telescope schedulers already exists, they are not *network* schedulers. The "Intelligent" aspect of the GLORIA concept is based on taking the next step - providing a single scheduler that optimises the use of the network as a whole.

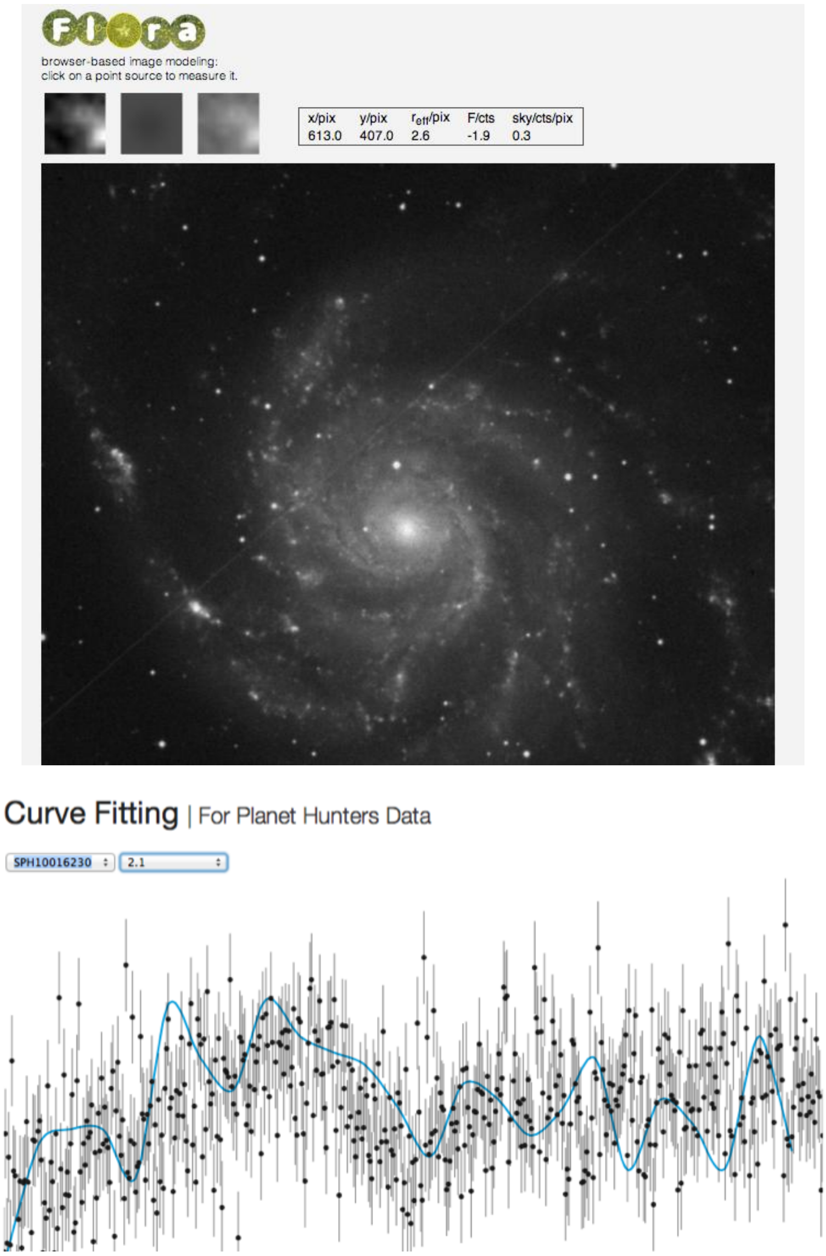

Fig. 6: Image viewing (top) and data analysis (bottom) tools are being made available to support scientific interpretation of data acquired by GLORIA.

Additionally, GLORIA is a network of *heterogeneous* telescopes, which also puts the project into new territory. GLORIA's scheduler accepts telescope-neutral Observing Plans as input, together with knowledge of the capabilities (and the available time-slots) of the network's telescopes provided by telescope owners. It then outputs a schedule for each, corresponding to the available time, and consisting of a sequence of Observing Blocks, which are Observing Plans converted to a telescope-specific form (calculated exposure times in seconds, etc.) and for a specific time. The scheduler is being designed to find a Pareto-optimal schedule for the network as a whole, rather than for individual telescopes.

2.4 Allocation of telescope time

The traditional method of allocating telescope time typically involves a 'Time Allocation Committee' which ranks proposals according to scientific merit and allocates time accordingly. This approach is not appropriate for a system that is primarily driven and supported by a user community rather than a single organisation. The time allocation approach being implemented in GLORIA will employ a meritocratic parameter associated with each user. The algorithm will use a combination of factors such as activity within the community, provision of support to user fora, rating by other users etc. Similar methods have been successfully used in many collaborative web sites such as YouTube. Care will be taken to ensure that younger and less experienced users are not frozen out by more experienced/profesional ones.

2.5 Live broadcast of astronomical events

In order to raise awareness among the general public of GLORIA's capabilities and generate interest in using the network, GLORIA is coordinating the live Web broadcasting of astronomical events (Table 2). The impact of these events to date has been high and is growing (Fig. 7). This aspect of the project represents a major effort in the development of Peer to Peer (P2P) or `distributed' broadcasting technology to allow many live feeds simultaneously without crashing a central server. A similar approach is being developed for the archiving of the large amount of data that will be generated by GLORIA. The promotional video for the total solar eclipse on November 13th/14th 2012 has been viewed more than 140,000 times.

A community activity, called 'Message to the Future' asked volunteers to take photos of daily life on planet earth during the Transit of Venus on June 5th/6th 2012 and to share them on the Flickr page of the same name. Some 485 photos were uploaded and form a resource for anyone to use in making time capsules, or other forms of archive, to preserve for the next observers of a Transit of Venus in 2117.

In addition, related educational materials, targeted at 15-18 year olds, and translated into the languages of the consortium, are being made available. For example, the images of the Transit of Venus June 5th/6th 2012, taken from Sapporo, Japan and Cairns, Australia (Fig. 8) are usable by students to measure the Sun-Earth distance via a web tool [8]. More detailed documents are also available for teachers or interested students. Linking with teachers through other European programmes, or on a one to one basis through national contacts, is a cornerstone element of the dissemination plan for this project. GLORIA is collaborating with 'Discover the COSMOS', an EU funded project, which is developing innovative ways to involve teachers and students in eScience through existing infrastructures.

The next live broadcast will be the Total Solar Eclipse on 13th November 2013 (14:20/14:30 UT) from Kenya.

Fig. 7: The three live broadcast events which have taken place so far and the number of page visits generated by each during the time window mentioned in the caption.

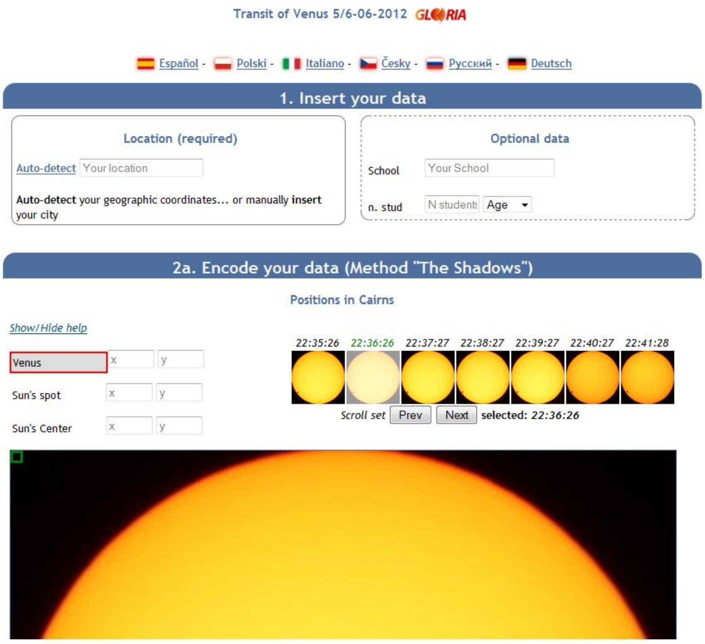

Fig. 8: Screenshot from the web tool (http://gloria-project.eu/venus-webcalc/) to measure the Sun-Earth distance using the Transit of Venus images taken from Sapporo and Cairns.

3 CONCLUSIONS

The GLORIA project started in October 2011 and has 3 years of financial support from the EU under the FP7 eInfrastructures programme. The funding for the existing telescopes in the 'start-up' phase of the network had previously been provided by national sources. The aim is to develop the network into a self-sustaining entity by the end of the EU funding period. A number of the telescopes will already be incorporated into the network during 2013.

4 ACKNOWLEDGEMENTS

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