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Editors: J. C. Tello, A. Riva, D. Hiriart & A. J. Castro-Tirado

CESAR: AN EDUCATIONAL PROJECT WITH AN ASTRONOMICAL NETWORK

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RESUMEN

Un buen proyecto de divulgación científica debe contar con una vertiente educativa que incluya la realización de experimentos con una metodología basada en la enseñanza por investigación, permitiendo a los estudiantes explotar todo el potencial del proyecto. La red de telescopios de proyecto CESAR es una excelente herramienta educativa que proporciona un amplio conjunto de actividades a los estudiantes, como son el estudio de la magnetosfera de Júpiter o la emisión procedente de cuásares, usando radiotelescopios; el descubrimiento y seguimiento de planetas extrasolares o supernovas, usando telescopios ópticos; y el estudio de las manchas solares o de la rotación solar utilizando telescopios solares.

ABSTRACT

A good outreach project must have an educational aspect that includes experiments in an inquiry based teaching methodology, enabling students to exploit the full potential of the project. The CESAR telescope network is an excellent educational tool that provides a comprehensive set of activities to students, such as the study of Jupiter's magnetosphere or the origin of the emission from radio sources, using radio telescopes; the discovery and follow-up observations of extrasolar planets or supernovae, using optical telescopes; and the study of the solar dynamics and activity using solar telescopes.

Key Words: telescopes

1. THE CESAR PROJECT

CESAR (Cooperation through Education in Science and Astronomy Research) is a joint educational project developed by the European Space Agency (ESA), the Spanish National Institute for Aerospace Technology (INTA) and Ingeniería y Servicios Aeroespaciales (INSA). Its objective is to provide students from European High Schools and Universities with hands-on experience in astronomy research through a multiwavelength observational programme. This programme not only should be didactically valuable but also produce real scientific results. In addition, CESAR shall contribute to promote Space Science and to stimulate European students' interest in STEM (science, technology, engineering and mathematics) related careers through astronomy research.

2. THE ASTRONOMICAL NETWORK

To achieve its objective CESAR comprises an astronomical network of one radio telescope, two reflector telescopes, two refractor telescopes and two solar telescopes. These instruments are the core of the so-called CESAR Observatory which is hosted by ESA's European Space Astronomy Center (ESAC) in Villafranca del Castillo (Madrid) and serves as a control centre to operate all equipment remotely from one single place.

Fig. 1. CESAR Webcams Pannel.

The CESAR Observatory comprises of the following elements (Fig. 1)

- CESAR Main Control Centre (C-MCC), from which all instruments are controlled and the collected data are transferred to for archiving and distribution to the users. The C-MCC is located at ESAC and will be split in two modules: the Control Module (C-MCC-CM) and the Data Archive (C-MCC-DA).
- CESAR ESAC Radio Telescope (C-E-RT), also

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known as VIL-1 Antenna, is a Cassegrain 15-meter parabolic main reflector fed with an S-Band transmitter and S-Band receiver (S/S) and located at ESAC.

- CESAR Cebreros Optical Telescope (C-C-OT) is a 50cm reflector telescope located at ESA's Cebreros Satellite Tracking Station (Ávila).
- CESAR Robledo Optical Telescope (C-R-OT) is a 30cm reflector telescope located at the Training and Visitors Center (TVC) of the NASA's Madrid Deep Space Communications Complex (MDSCC) in Robledo de Chavela (Madrid).
- CESAR ESAC Solar Telescope (C-E-ST) is a 9cm H-alpha telescope together with a 10cm refractor installed at ESAC to perform solar observations.
- CESAR Robledo Solar Telescope (C-R-ST) is a 9cm H-alpha telescope together with a 10cm refractor installed at the TVC of the NASA's MDSCC to perform solar observations.

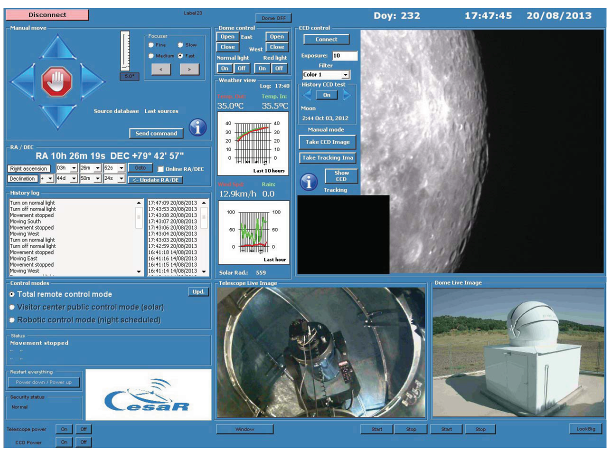

Fig. 2. C-R-OT Remote Control Pannel.

CESAR architecture shall be flexible enough to accommodate future instruments (optical or radio telescopes) should this programme be joined by new partners in the future.

2.1. *Observing Modes*

Depending on the instrumentation, there are different options for observation: remote, robotic or both. It is planned to provide web-access control to schools and universities through the Internet, so that they can, using web-based control tools, both carry out real-time remote observations and schedule queue-based robotic observations. In optical astronomy, the instrumentation consists of a telescope with a filter wheel and a CCD camera, and the observing modes are

- C-C-OT: Robotic operation only. Observations are performed robotically so users schedule them in a queue-based mode.
- C-R-OT: Both remote and robotic operation. It is possible to perform both real-time remote observations (Fig. 2) and queue-based robotic observations.

In radio astronomy, the instrumentation consists of a radio telescope and a power meter. The C-E-RT has only remote operation so it is possible to perform real-time remote observations. Finally, in solar astronomy, the instrumentation consists of two sets of a solar telescope with an H-alpha filter and a CCD camera and a refractor telescope with a white light solar filter and a CCD camera. For both telescopes, C-E-ST (Fig. 3) and C-R-ST, the observing modes are the same, remote and robotic, so it is possible to perform both real-time remote observations and queue-based robotic observations. From an educational perspective, remotely and robotically controlled observatories have pros and cons. As a pro, we can consider the availability of remote access to observatories with free access to scientific instrumentation and to have neither time nor space limits. Possible cons are non-tangible instrumentation, virtualization of the procedures and ICT dependent activity.

3. THE EDUCATIONAL APPROACH

As mentioned before, the aim of CESAR project is to provide students with a hands-on experience in Space Science and to stimulate their interest in STEM disciplines, in particular in Astronomy. Observations allow students to learn, with first-order scientific tools, the basics of an astronomical research. Students will control the telescopes via the Internet by connecting from their classroom to the Main Control Centre (C-MCC). They also will learn how to gather data, what that data means, and how to analyse and store it. Finally, the results of data analysis will be added to the Data Archive (C-MCC-DA). The educational approach of CESAR project is based on an Inquiry-Based Science Education (IBSE) methodology. An IBSE learning environment will raise students' interest in science, presented as an open activity. Inquiry-learning activities should be set in an Educational Programme so as to help students build a sense of teamwork, with job involvement, self-responsible teams, task-related decisions and effective organization. The CESAR Educational Programme will provide students (and teachers) with

- Physical basics of multiwavelength astronomy;
- Teachers Training Program;
- Classroom resources;

Fig. 3. C-E-ST dome at ESAC.

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• Remote observation procedures and robotic scheduling protocols;

• Support astronomer during real-time observations;

• Data analysis in a Virtual Observatory (VO) environment (VOPlot, VOSpec, SalsaJ);

• Database didactic exploitation;

• Final Year Projects for undergraduate students.

3.1. *Observational Programmes*

Students are able to control the CESAR astronomical network, acting as astronomers do. This way is highly recommended to motivate students through the participation in real ongoing astronomical research. There are currently several observational programs that participants can join

3.1.1. *Optical Astronomy*

• *Photometric detection and confirmation for extrasolar planets.* The program consist of characterize exoplanets by the Transit Method. The goal is to detect new exoplanets, and especially to characterize known exoplanets by photometric measurements and systematic monitoring of their transits.

• *Supernovae in Nearby Galaxies Monitoring.* The program consists of the systematically monitoring of a selected group of spiral galaxies that lie less than 300 million light years from our Milky Way, in hopes of capturing the rise in light from a supernova outburst.

• *Minor planet lightcurves and NEO confirmation.* Lightcurves of minor planet yield constraints on their spin axis and 3-D shape. These quantities are pre-requisites to any detailed analysis of the physical properties of minor planets, such as their albedo or density. From many lightcurves (10 to 20), taken over several years, the 3-D shape of any asteroid can be reconstructed. However, by combining random, sparse in time, photometry measurements of asteroids with at least one dense lightcurves, such as CESAR telescopes will produce, a spin solution and 3-D shape can be derived. Also, regular acquisition of lightcurves of minor planets will contribute to the actual effort of studying their properties.

3.1.2. *Radio Astronomy*

• *Spectral Index Calculation.* The spectral index of a source can hint at its properties and indicates whether the radio emission has a thermal or non-thermal origin (Fig. 4). Thus, using the positive sign convention, a spectral index of 0 to 2 at radio frequencies indicates thermal emission, while a steep negative spectral index typically indicates synchrotron (non-thermal) emission.

• *Jupiter Magnetosphere Study.* The radio emission coming from Jupiter is thermal emission of the planet plus the non-thermal emission coming from high energy electrons trapped in its surrounding magnetosphere. Due to a misalignment of spin and magnetic axes of Jupiter, the non-thermal intensity varies with the rotation of the planet. Since the rotation period is about 10 hours, systematic observations will allow students to measure the periodic power variation, also known as Beaming Curve.

• *Follow up of X-rays Binaries Outbursts.* The program consists of the monitoring of a special type of X-ray binaries, also known as microquasars, at radio wavelengths. Some of them show radio bursts and their study can give us information about the black hole/neutron star, accretion rate, etc. Students will measure the radio fluxes of a few selected microquasars to obtain a long-term dataset, searching for flares.

3.1.3. *Solar Astronomy*

• *Sun morphology and dynamics.* The program consists of observing the Sun through different solar

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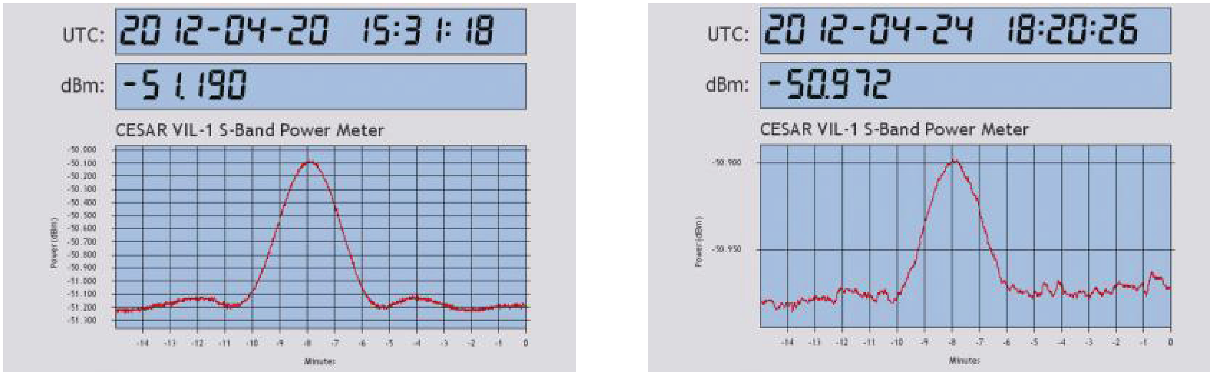

Fig. 4. Power meter measurements in S-Band of M1 (Crab Nebula, left) and 3C273 (right).

filters to identify its physical characteristics and to determine the differential rotation by studying the sunspots on its surface. It is also interesting to observe planet transists in order to measure the Sun-Earth distance (Fig. 5).

• *Solar activity.* The program consists of analyzing solar magnetic storm activity, including coronal mass ejections, prominences, flares and sunspots; and also describing the eleven-year solar cycle and the significance of sunspots.

• *Sun-Earth interaction.* The program will study, as a whole, the system comprised of the Sun, Earth's upper atmosphere, their magnetic fields, and geospace. The changes to this dynamic system, commonly known as space weather, have important implications on Earth. Space weather effects may induce some climate shifts, modify the ozone layer, change the propagation of radio and radar signals in and through the ionosphere, and produce significant effects on any object or person outside the atmosphere.

4. CURRENT STATUS

Nowadays there are several ongoing activities (1) in CESAR Observatory, the commissioning of the telescopes and the database design is almost finished, (2) in software development, a common User Interface for remote operation and a VO compliant data analysis tool are being developed, (3) CESAR Website[2] beta version is being tested (Fig. 6) and (4) in CESAR Educational Programme, lessons plans and other educational resources are being developed. The first Teacher Training Course is planned for the next Academic Year 2014/15.

5. CONCLUSIONS

The CESAR astronomical network is an excellent educational tool to train students in space science providing them with first-hand experience in astronomy research in an IBSE learning environment, having the opportunity to use Internet and computer technologies in conducting observational programs and in generating valuable scientific data.

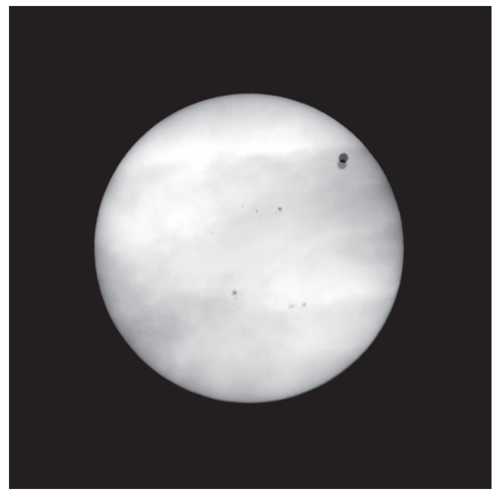

Fig. 5. Venus transit observation in 2012 from Canberra and Svalbard.

Fig. 6. CESAR Website-Beta Version.

[2]http://cesar-programme.cab.inta-csic.es/index.php