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Learning radio astronomy by doing radio astronomy

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Abstract

PARTNeR (*Proyecto Académico con el Radio Telescopio de NASA en Robledo*, Academic Project with the NASA Radio Telescope at Robledo) is an educational program that allows high school and undergraduate students to control a 34 meter radio telescope and conduct radio astronomical observations via the internet. High-school teachers who join the project take a course to learn about the science of radio astronomy and how to use the antenna as an educational resource. Also, teachers are provided with learning activities they can do with their students and focused on the classroom implementation of the project within an interdisciplinary framework. PARTNeR provides students with firsthand experience in radio astronomy science. Thus, remote radio astronomical observations allow students to learn with a first rate scientific equipment the basics of radio astronomy research, aiming to arouse scientific careers and positive attitudes toward science. In this contribution we show the current observational programs and some recent results.

1 Introduction

The NASA Deep Space Network (DSN) consists of three radio communications facilities around the world: the Goldstone Deep Space Communications Complex (GDSCC) in the U.S.A., the Madrid Deep Space communications Complex (MDSCC) in Spain, and the Canberra Deep Space Communications Complex (CDSCC) in Australia. They are placed approximately 120 degrees apart in longitude to enable constant communication with deep space missions and Earth-orbiting satellites despite Earth's rotation. Each complex includes several parabolic dish antennas with 26, 34 and 70 meter in diameter. Some antennas are also equipped with extremely sensitive receiving systems for the purposes of radio astronomy.

In 2001, after nearly 40 years of operation,it was decided that one of the 34 meter diameter antennas located at MDSCC would no longer be used for monitoring missions. Rather than dismantle it, NASA and the Spanish *Instituto Nacional de Técnica Aeroespacial* (INTA, National Institute for Aerospace Technology) signed an agreement to use it as educational

Figure 1: DSS 61 antenna.

tool to bring science to Spanish students. The INTA *Centro de Astrobiología* (CAB, Center for Astrobiology) manages the use of the antenna and deals with users on project-related scientific, technical, or educational matters. In 2004 the conversion of the antenna into a radio telescope was completed, allowing also remote access and control of this unique scientific instrument.

2 A remotely controlled radio telescope

The project allows teachers and students from all over Spain to remotely control via the Internet the antenna to perform radio astronomical observations from their own classroom. It is mainly devoted to high school and also undergraduate students. The main objective of the project is to train students in both general science and engineering basics providing them with firsthand experience in radio astronomy science in an innovative learning environment, having also the opportunity to use the latest Internet and computer technologies in conducting experiments and in generating scientific data.

The radio telescope is located at the MDSCC at Robledo de Chavela, near Madrid, Spain. The antenna has a parabolic dish 34 meters (110 feet) in diameter, is nine stories high, and weighs 380 tons (850 000 pounds). Known as Deep Space Station 61 (DSS 61), the antenna was used by the NASA Deep Space Network to track robotic planetary missions such as the Mariner missions, Voyagers 1 and 2, Galileo, and others (see Fig. 1).

The antenna was transformed into a radio telescope, implementing the hardware and software needed to achieve remote operation. There are two working radio frequency bands: S Band (centered at 2.25 GHz in frequency) and X Band (centered at 8.45 GHz). There is a radio frequency receiver (power meter) in each band to measure the continuum radio flux coming from celestial sources. There are two software programs to remotely control the antenna. The super user's program is named HERACLES (*HERramienta de Análisis y Control Local en Entorno Superusuario*, Tool for Analysis and Local Control in a Super User Environment), and it is intended for controlling all the devices and processes taking

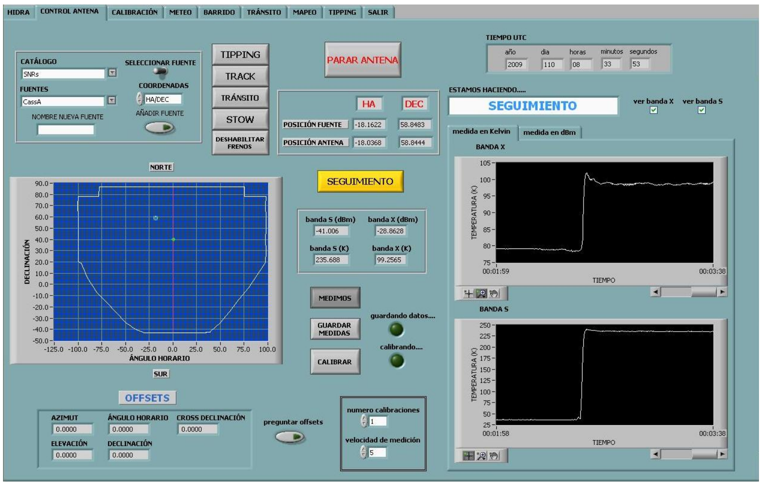

Figure 2: HIDRA interface.

place during observations. The other one is named HIDRA (*Herramienta Interactiva para la Docencia de la Radio Astronomía*, Interactive Tool for Teaching Radio Astronomy) and it is the user's program (see Fig. 2). During observations HERACLES is used by PARTNeR's support astronomer and HIDRA is used by students.

The technical requirements for carrying out remote observations are quite simple: ADSL Internet connection with 1 Mb minimum speed, Windows or Linux platform, Remote desktop connection software and Skype. A group of students, led by a previously trained teacher, performs remote radio astronomical observations in radio continuum S and X Bands. This activity is done in teaching time via the Internet, and supported and monitored by PARTNeR staff. Students remotely control the radio telescope by connecting from their classroom to PARTNeR Remote Operations Control at CAB-LAEFF campus facilities, where PARTNeR team pass control of the antenna to the students, allowing them to use HIDRA program to gather data. Voice communication between students and PARTNeR's support astronomer is made using Skype, providing students with guide and help from the technical or scientific issues that arise during observing sessions.

3 Teachers training course

Teachers participating in PARTNeR project attend a training course, which consists of two parts. The first one is an on line training with the courses "Physical Fundamentals of Radio Astronomy" and "Introduction to Radio Astronomy", both of them available at the PARTNeR website. In this distance part, teachers learn about radio astronomy fundamentals and how a radio telescope works.

The last one is a 2 day onsite training course (first at MDSCC and then at CAB facilities) where they learn more about the basics of radio astronomy and radio telescope operation, are taught how to organize and perform a radio astronomical observation using

HIDRA remote control user's software and are given guidelines to implement the project in the classroom as a different tool to fulfill the curriculum. Teachers receive specific preparation in the fields related to radio astronomy. These courses are mandatory for the request of observing time in DSS 61. After training, teachers can request time to perform observations with students.

4 Teaching support material

To turn the remote observations into a real teaching and learning experience, teachers must have the necessary educational resources that enable appropriate implementation of the project in the classroom turning observations in just another activity within the teaching-learning process. Teachers are provided with learning activities designed to align with Spanish educational curriculum which may be adapted to fulfill the curriculum at their classrooms. These resources are focused on the implementation of the project in an interdisciplinary framework in order to teach scientific topics related with astronomy and radio astronomy in a comprehensive way.

The contents have been articulated through lesson-plans, which are a sequence to perform in the classroom, preferably working in small groups, with the goal of training students to organize, plan and conduct the remote observations. They work together learning team participation and solving problem skills. All material is available on the project website.

5 Scientific programs

Students are able to operate the antenna, participating in scientific programmes as radio astronomers do. This way is highly recommended to motivate students through the participation in a real ongoing radio astronomical research. We summarize below the scientific programmes that currently participants can join. Nevertheless, any other project can be held after an evaluation by the Scientific Committee. Teachers can make proposals to apply for observing time and students can be involved in the proposal. Hence, students should learn about how to make a scientific proposal for observation, and if awarded with time, how to deal with the observations. Later on, they can rely on the scientific and technical advice from PARTNeR staff for later analysis procedures and data reduction.

5.1 X-ray binaries monitoring

The aim of this project is the monitoring of X-ray binaries, also known as microquasars. An X-ray binary consists of a compact object (black hole or neutron star) and a *normal* star, swallowed by the compact object. Some of these systems show radio bursts and their study can give us information about the black hole/neutron star, accretion rate, etc.

Students perform observations of a few selected microquasars to obtain a long-term data set of their radio fluxes, searching for flares. Students will then participate in a *radio burst patrol*, providing a valuable dataset to the scientific community.

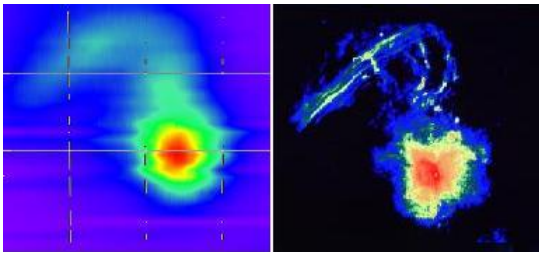

Figure 3: Radio map of the Galactic center obtained with PARTNeR radio telescope (*left*) and VLA (Very Large Array) radio map of the same region (*right*).

5.2 Quasar radio emission variability

This project focuses on some of the most puzzling objects in the Universe, quasars. Quasars or quasi-stellar objects appear to resemble point sources of light like stars, but their radiation emission is much more intense, putting out more energy per second than the Sun does in centuries. The source of this intense energy emission astrophysicists believe it to be super massive black holes many times the mass of our Sun. The study involves collecting data on quasars that are flickering or scintillating and explores the effects of the interstellar medium on this scintillation process. The objective is to build an extended-time set of data on selected quasars showing significant variability, thereby laying the groundwork for meaningful interpretation of the data. Thus, adding the new data to the growing database will allow students to confirm the periods of fluctuation.

5.3 Radio maps of extended sources in the Galactic plane

Most of the material of our Galaxy is located at the Galactic plane and students can map some of these radio sources (see Fig. 3), specially supernova remnants, i.e. the resulting structure from the gigantic explosion of a massive star; and HII regions, i.e. a cloud of gas and plasma in which star formation is taking place.

5.4 Jupiter magnetosphere radio emission variability

The radiation at radio wavelengths coming from Jupiter is thermal emission of the planet plus the non-thermal emission of 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. The rotation period is about 10 hours so observing Jupiter systematically, students can measure the periodic power variation also known as Beaming Curve.

5.4.1 Jupiter: project 24

The campaign was designed to both mark the 400 years since Galileo used his telescope to first observe Jupiter and make a valuable contribution to the International Year of Astronomy

Figure 4: Jupiter: project 24 logo (*left*) and Jupiter: project 24 data results (*right*).

2009 (IYA09). To celebrate Galileo's discoveries, on November 2009 and on May 2010 we successfully conducted the Jupiter: project 24, 24 hours of continuous radio observation of Jupiter using the radio telescopes of NASA's DSN (see Fig. 4). Two of these antennas were operated by students from GAVRT (Goldstone Apple Valley Radio Telescope) and PARTNeR educational programs. This was the first time that such a long continuous series of ground-based radio observations of Jupiter at a single frequency has been undertaken in an organised way. The project objective is to seek non-thermal variability caused by other causes unrelated to the Jovian magnetic field, such as variations in solar activity or possible changes induced in the planet for the great impact observed by an amateur astronomer near Canberra in July 2009.

6 Conclusions

PARTNeR is an inquiry based approach to science education, promoting trough observations scientific literacy as astronomy, astrophysics and radio astronomy because they are disciplines very attractive to students.

The operational phase of the project started in 2004. Thus far, more than 100 high schools, seven universities and six societies of amateur astronomers have been involved in the project. Also, eight teacher-training courses have taken place, with 120 Spanish and Portuguese high-school teachers attending them. Up to now, 130 radio astronomical remote observations have been performed with more than 2 500 students involved.

Since the antenna was converted into a radio telescope for educational purposes of radio astronomy, the benefits that have accrued to NASA and INTA by allowing this first rate scientific instrument to be used by Spanish students have been many. Thus, PARTNeR gives students a unique opportunity to command a 34 meter radio telescope via the internet making up an approach to the usage of ICT (Information and Communication Technologies) in an interdisciplinary framework and functions as NASA and INTA's outreach effort in disseminating scientific knowledge and keep on inspiring the next generations of scientists and engineers to specialize in spacecraft tracking, space science and radio astronomy.