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CONNECTING CLASSROOMS TO THE MILKY WAY

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Abstract. 'Connecting Classrooms to the Milky Way' is a project of the EU-HOU Consortium (Hands-On-Universe, Europe), involving 11 European countries. It is supported by the lifelong Learning Programme of the European Community. The main goal of this project was to set up the first network of small radio-telescopes dedicated to education all around Europe and directly accessible from a simple Web interface. Any classroom connected to Internet via any Web-browser can now remotely control one of the radio-telescopes and observe the HI emission coming from our Galaxy. The interface also provides the users with simple tools to analyse the data: (i) derive the Milky-Way rotation curve and (ii) map the spiral arms HI distribution. A special emphasis has been made to enable the young generation to understand the challenges of these wavelengths, which are currently at the frontline of the new instruments with the development of the ALMA (Atacama Large Millimeter Array) and SKA (Square Kilometer Array) projects.

Keywords: Galaxy: kinematics and dynamics, Miscellaneous: Science Education

1 The EUHOU-MW project

This project is part of the COMENIUS European Commission Lifelong Learning Programmme (2010-2012). It is coordinated by Anne-Laure Melchior and Roger Ferlet (University Pierre et Marie Curie, UPMC), in the framework of the EU-HOU consortium whose objectives are to (i) raise the attractiveness of science education, (ii) participate to the development and modernisation of learning technics in EU schools and (iii) promote scientific methods/knowledge. The EU-HOU consortium has been structured through the 2004-2006 MINERVA project that involved 8 European countries. This first project was then followed by a COMENIUS Programme (2008-2010) involving 14 European partners. The actual project was built in the perspective of the future large radio-submillimeter facilities (ALMA [i] , SKA [ii]). It involves 11 countries and is focused on radio-astronomy. The consortium has delivered educational material (updated versions of the SalsaJ software, exhibition on Radio-Astronomy, pedagogical resources including kinesthetic activities), organised teachers training sessions, and built a radio-telescope network for teachers and schools. In this article, we emphases the activities developed by the coordinator's team at Univ. Pierre & Marie Curie, in France, supported by the European partners for the deployment of a network of radiotelescopes and its dissemination in European schools.

2 Radio-astronomy Network

We will focus here on one aim of *Connecting Classrooms to the Milky Way* that was to develop the first European network of radio-telescopes for education, enabling European schools to explore the Milky Way via the HI emission line with Internet (with a simple web browser). The scientific goals are (i) to derive the Milky-Way rotation curve and to discuss the need of dark matter and (ii) to map the Milky-Way spiral arms structure, enabling to discuss our place in the Universe. In order to do so, we provide the teachers with multilingual

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[i] `http://www.almaobservatory.org/`
[ii] `http://www.skatelescope.org/`

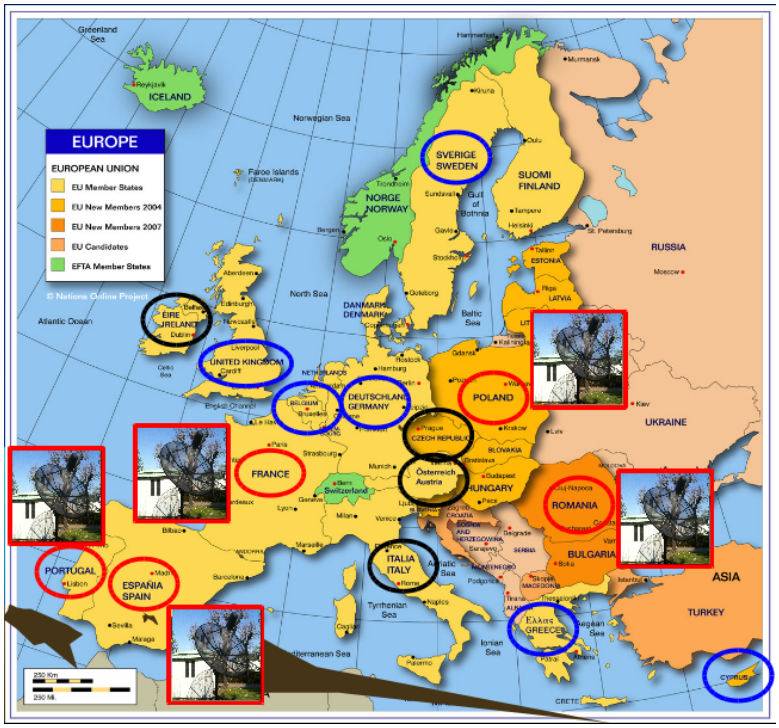

Fig. 1. Network of radio-telescope and countries involved in the present COMENIUS project (red and blue).

tools: a scheduling system to remotely access the five T3m radio-telescopes[iii], archives to retrieve and/or analyse previous observations, and a simulator of observation enabling to perform (off-line) the exercise with high quality data (LAB[iv] survey, Kalberla et al. (2005)). The Internet Control Web page of the EU-HOU-MW radiotelescope network is accessible from the project Web site `http://www.euhou.net/`.

Any teacher can go to this page and register. Once he has open an account (under the control of a local administrator), he can book a free time slot on any antenna of the network. The connection to the *Observer* page (the remote control interface) will be possible during this time slot only. Simple inputs are required: position on the sky, observing frequency, integration time. The interface provides the users with interactive maps in Az/El and Galactic Long/Lat coordinates. A Webcam shows the telescope moving in real time. Once the observations are done, the spectrum is displayed and the user can remove a baseline and/or redo an observation. This spectrum can then be directly retrieved from the *Archive*, where more analysis can be performed. The user can select some peaks in the HI spectra. These peak velocities, together with the Galactic coordinates of the pointed region, can be translated into a rotation velocity and a radius (by simple geometric arguments) and/or into a x/y position in kpc on the face-on Galaxy plot. Those two outputs are directly computed by the interface from the selected peaks and compared to professional data outputs and to some modelling of Galaxy potential wells and spiral arms (see Fig. 2 and 3).

3 The EU-HOU-MW Web Interface

In order to remotely control the antenna, we used the java control system delivered with the antenna and the receiver: `http://www.haystack.mit.edu/edu/undergrad/srt/oldsrt.html`. The EU-HOU interface was designed in javascript, php and python, like a wrapper which uses the original control system commands. The *Account manager*, the *Scheduler*, the analysis tools, the administration tools, the communication protocols have been written by A. Radiguet, the software engineer of the project (Orsay IUT). The telescope outputs are also connected to a SQL database to archive the data and post-process or download them. A central server hosts

[iii] Actually, six antennas are connected. UPMC acquired a slightly smaller antenna for the 2009 International Year of Astronomy, which has been used as a prototype to develop the present network. Both french antennas are on the Paris Observatory campus.

[iv] `http://www.astro.uni-bonn.de/en/download/data/lab-survey/`

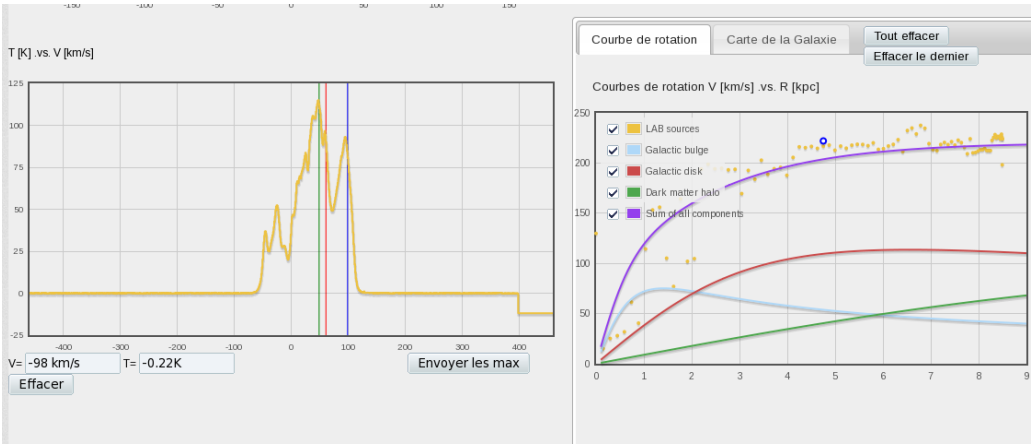

Fig. 2. Milky-Way rotation curve (**right panel**) derived from HI observations (**left panel**) with the EU-HOU-Simulator.

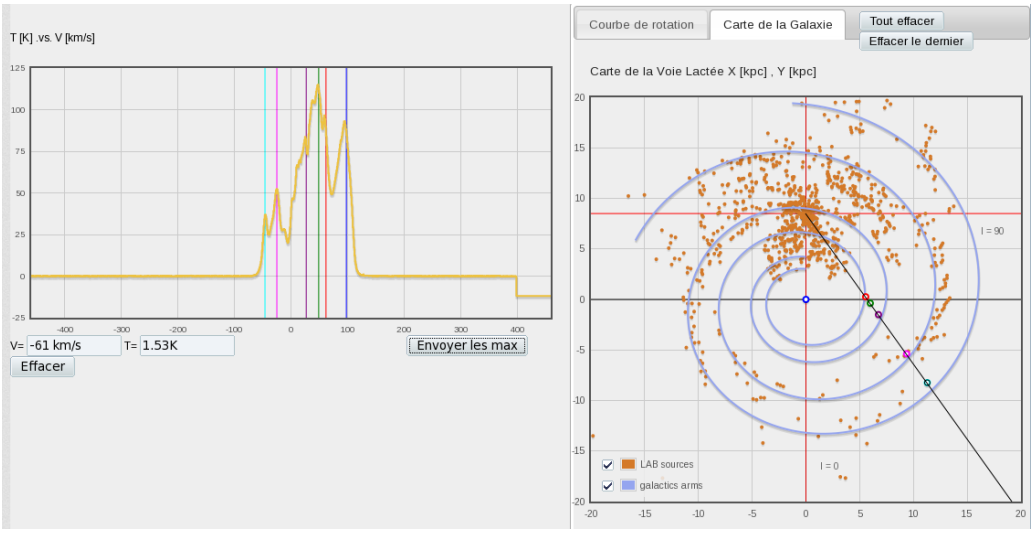

Fig. 3. Milky-Way spiral arms derived from HI observations with the EU-HOU-Simulator.

the *Archive*, the *Scheduler*, the *Account manager*, the homepage and the identification protocols to authorise the connection to each antenna. The *Observer* pages are hosted on local computers directly connected to the antenna in France (Paris), Poland (Cracovia), Portugal (Pampilhosa), Romania (Craiova) and Spain (Madrid).

4 Pedagogical support

Although a lot of efforts have been dedicated to the development of tools easy to use by secondary schools pupils, these tools lack the pedagogical and science explanation that could benefit to the learners. In parallel, Alexander Rudolph, an astronomer and astronomy education researcher, has worked on the pedagogical material which can be proposed to secondary school teachers along with the EU-HOU-MW Web interface. The challenge was two-fold: 1) because the observations of redshift and blueshift are made from the moving platform of the Solar System from within the rotating Galaxy, it is difficult to conceptualize the relative motion of the Sun and observed HI clouds for different quadrants of the Galaxy; and 2) the principles of a rotation curve computation and of the Galactic spiral structure determination are not easy to understand. To address these difficulties, a kinesthetic activity has been developed in order to explain the rotation of the Milky Way, the Galactic System of coordinates, as well as the blue and red-shifts of the velocities along different lines of sight. This activity has been video-taped by the *Centre de Production Multimedia* at UPMC, and is currently translated. After this attractive introduction, the teachers are led through the technical calculations of the rotation curve velocities, now with some intuitive understanding of the mathematics to support their understanding, and are

Fig. 4. Top panel: Homepage of the radio-telescope network remote control interfaces. **Bottom panel:** Account manager.

then introduced to the Web interface and are asked to reproduce the phenomena observed with the kinesthetic activity with the EU-HOU-MW simulator.

An exhibition presenting the radioastronomy and its challenge has also been prepared in the course of the project. It explains some important concepts to understand basics of radioastronomy, such as the wavelengths, cosmic radio-sources and the use of radio-wavelengths in the world surrounding us.

5 Future prospects

The use of this radio-telescopes network can also be extended to introduce University students to radio-astronomy. For this dedicated purpose, we do not use the remote control interface, but the original java software, which is more flexible. Observations like the antenna temperature calibration and pointing on the Sun are then possible. These calibrations can be analysed with a python library we purposely prepared.

Synergies exist with several research institutes, outside the EU-HOU-MW network which have acquired the same kind of small radio-telescope for outreach or education purposes: Bologna (Italy), Madrid (Spain), Hanoi (Vietnam), Green Bank (USA). In France, the Paris Observatory (Nançay) and the Observatoire Midi-Pyrénées (Toulouse) will also install these small radio-telescopes in 2012/2013. Any of these other telescopes can easily be integrated into the EU-HOU-MW antenna network.

The Web interface is now fully operationnal and the concept has been demonstrated. Much more material can be added to the webpages to illustrate the radio-astronomy principles (heterodyn receiver, interferometry, continuum/line observations) as well as the astronomy topics concerned (Galaxies structure and content: dust,

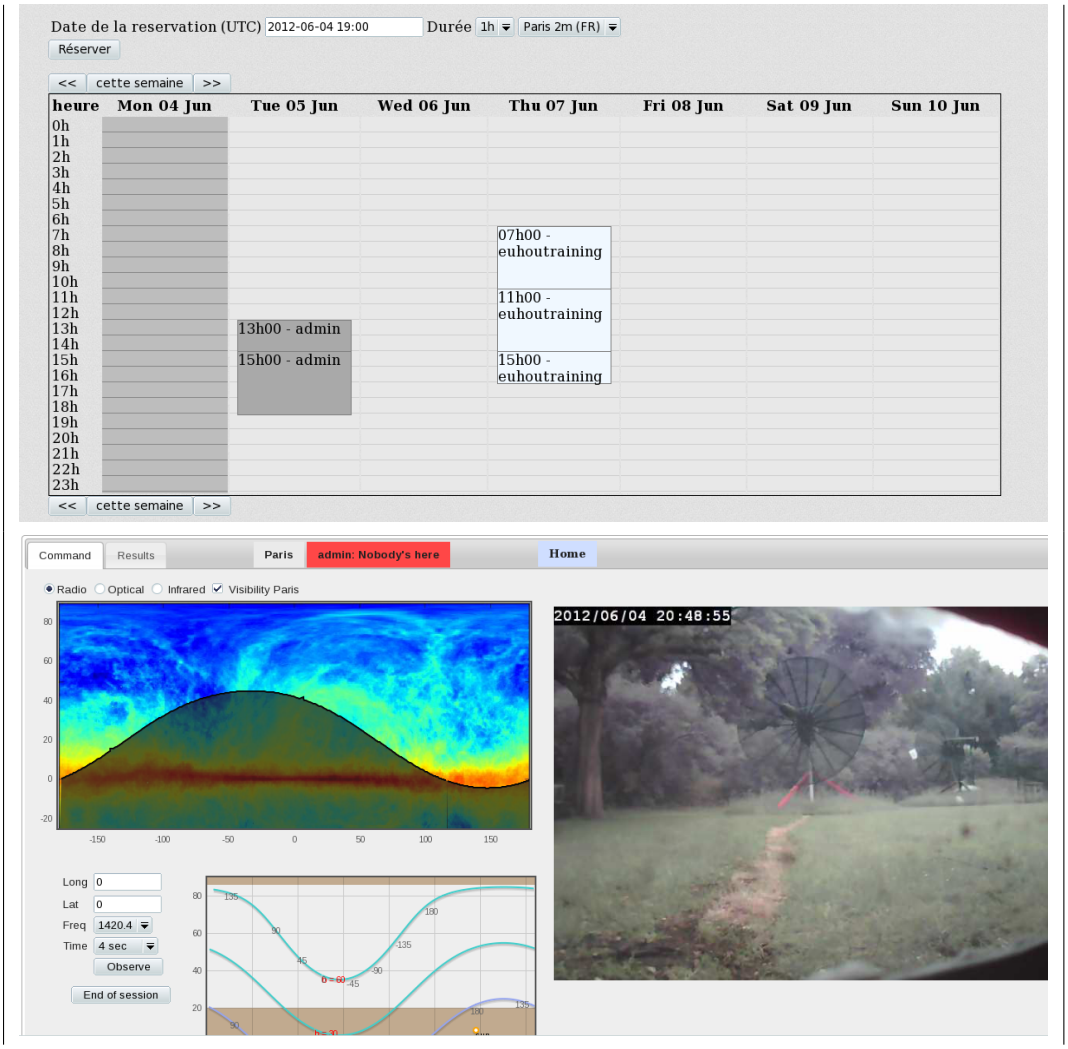

Fig. 5. Top panel: Telescopes booking interface. **Bottom panel:** Remote control interface.

gas, stars, dark matter...). This tool will thus evolve, enabling secondary school pupils to explore different subjects and to get a better idea of the golden age open by the new generation of instruments like ALMA and SKA. Besides showing students what real science can be, the project might inspire some of them for doing science and consider a scientific carrier.

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