Radio observations of the Milky Way from the classroom

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We present the project to introduce the first European network of radio telescopes for education. It enables pupils to detect spectral line emission of neutral hydrogen in the Milky Way at a wavelength of 21 cm. Any classroom connected to Internet via any web-browser can remotely control one of the radio-telescopes, observe and analyse obtained spectra: derive the Milky-Way rotation curve and recognise spiral arms in hydrogen distribution. Doing exercises pupils, guided by their teachers, learn the basics of radio astronomy research, use scientific method to explore and interpret the attained spectral data. A range of attractive educational materials are prepared to help in disseminating the scientific knowledge in the classroom and demonstrate the modern information technology.

1 Introduction

Even with a small radio dish it is nowadays possible to detect line emission from neutral hydrogen (HI) from the Milky Way at 1420 MHz (21 cm). Hydrogen, the simplest atom of the universe, is everywhere and in large quantities also in the Galaxy. Having an access to a radio telescope pupils at schools, guided by their teachers, can obtain, analyse, and interpret the HI spectra.

Using Doppler effect spectral observations can reveal distribution and orbital velocity of hydrogen clouds. They can be used to construct the rotation curve of the Milky Way and show the need of dark matter. They can reveal spiral arms and help to recognize the location of Solar System in the Galaxy. Mapping the HI across the plane of the Galaxy reveal the 3D (disk like) structure of the Milky Way. Radio astronomical observations can be carried out during day time and even in poor weather conditions. This makes them ideal for teaching astronomy interactively in the classroom.

The project to introduce radio astronomy at schools was founded by the lifelong Learning Programme of the European Community within project of the EU-HOU Consortium Hands-On-Universe, Europe: "Connecting Classrooms to the Milky Way". It was executed by various institutions in 11 countries: Belgium, Cyprus, France, Germany, Greece, Poland, Portugal, Spain, Sweden, Romania, United Kingdom. Within this project A radio telescope enabling HI observations was installed in Poland, at the Astronomical Observatory of the Jagiellonian University. The instrument was acquired from the U.S. (CASSI Corp.) and is composed of 3-meter radio dish, digital FFT spectrometer, motors for steering (Fig 1) and software to control it. It is now a part of European network of radio telescopes for education. Similar antennas are installed in 4 other European countries. Each instrument is equipped with a user-friendly web interface which allow to control it remotely, by a web browser.

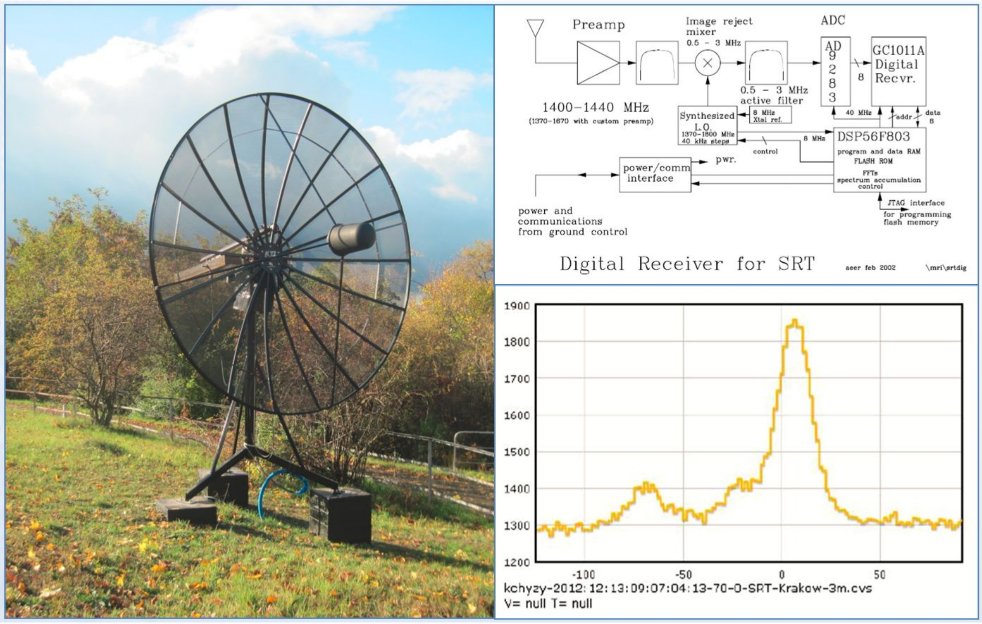

Fig. 1: Krakow's educational radio telescope (left) has digital FFT spectrometer (top-right) and can deliver HI spectra with visible spiral arms of the Milky Way in half a minute angular distance (bottom-right).

The EUHOU radio astronomy project was designed by researchers and teachers together which guarantee both the scientific quality and the pedagogical relevance. Teachers obtain new teaching tools using up-to-date technology. They are supported in hands-on experiments by materials and FORUM platform where they can contact astronomers and school teachers (http://www.pl.euhou.net, http://www.oa.uj.edu.pl/hou). The web interface for controlling the network of radio telescopes is directly accessible on the website and also free to use. School pupils performing radio astronomical observations can acquire transversal skills and competencies in mathematics, physics, computer sciences, writing and reporting. The hands-on approach requires an active participation of the pupils, which is an essential step in the learning process.

2 Project approach

The proposed radio observations of HI line emission are straightforward. Observations are based on choosing in HI spectra the hydrogen clouds with the highest Doppler shift to calculate distance and velocity of the clouds (the tangential method). Before observations teachers should go to the main page of the web site and register (http://euhou.obspm.fr). They can use a scheduling system to book a free time slot on any available antenna of the network, including the Krakow's one. The interface provides interactive maps of sky visibility to help in choosing the best time to observe the plane of the Galaxy.

During observations a web-cam shows the telescope moving in real time (Fig. 2). Once the observations are done, the spectrum is displayed. The user can change the integration time or choose different central frequency of the spectral band and repeat

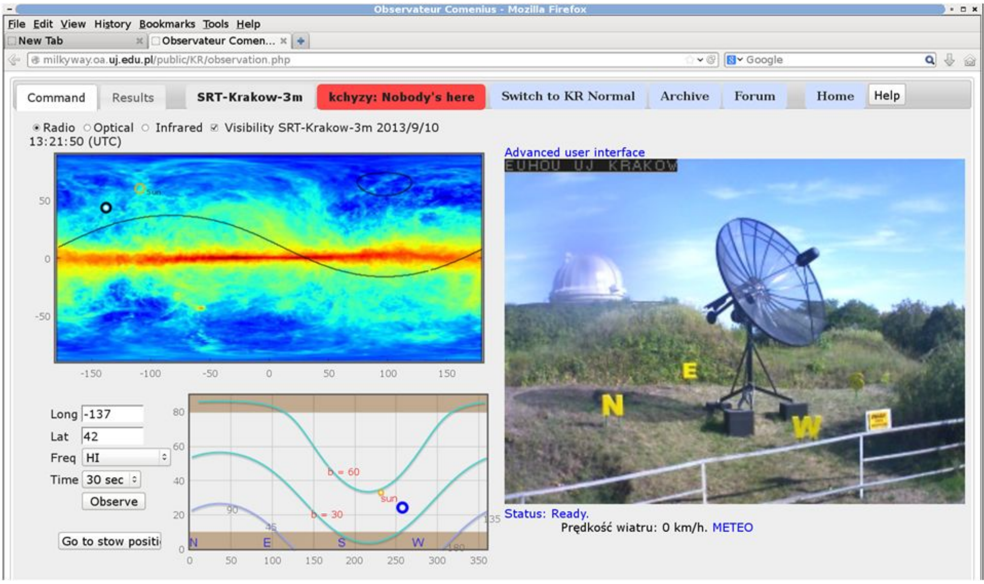

Fig. 2: Observing web page which enable on-line steering of the 3m Krakow's radiotelescope and see it by a camera.

the observation or choose other direction in the sky. First reports from pupils show that on-line steering of the astronomical instrument via internet from the classroom is highly exciting and motivates them to do the whole exercise.

All observed spectra are automatically archived at the server in Paris (Fig. 3). In any time the data can be retrieved from the SQL database and analysed. The files are stored in FITS and CSV (comma separated values) formats. The latter can be easily used in any spreadsheet program. The archive makes access to all data from all radio telescopes in our network. The user can use the spectra obtained by other observers and combine them with his/her own data to shorten the time of carry out the exercise or to enhance the statistical power of the results.

The archive interface has also tools to analyse the spectra. The linear trend in he spectra (the baseline) can be first fitted and then removed. The spectra are compared to professional ones obtained by larger instruments and convolved to the resolution of the Krakow's radio telescope. In this way the user can control results and avoid interpreting bad spectra, contaminated by radio interference or any spurious signal. The user can select peaks in the HI spectra and automatically translate their positions to rotation velocity according to the tangent method. Having radius and velocity the interface can present the plot of the rotation curve and the location of the HI clouds on the two dimensional plot of the Galaxy (Fig. 3). This is the easiest and fastest way to analyse the obtained spectra.

More advanced users (from senior secondary schools) can reduce the spectra and produce final results completely by themselves. This is recommended way of doing the exercises. For example the spectra from the archive in the CSV format can be loaded to a spreadsheet program. Pupils can calculate Doppler shift, plot spectra, recognize peaks, calculate distances and velocities of the clouds and construct the rotation curve. The prepared templates of such spreadsheets are available from the project site (http://www.oa.uj.edu.pl/hou).

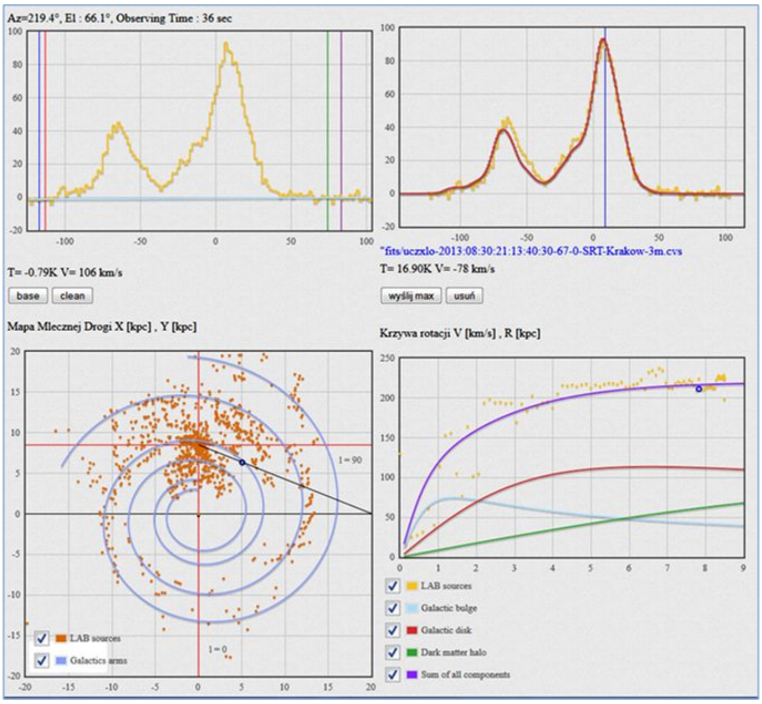

Fig. 3: The archive enables online analysis of the HI spectral data, determination of the rotation curve and distribution of the HI clouds.

Along with explanation of the observing exercise also pedagogical materials explaining the science and consequences of the observational results are available on the website of the project (Fig. 4). To address difficulties in understanding the rotation of the Galaxy and used the Galactic coordinates system, a kinesthetic activity has been developed. The activity has been video-taped and is available from our website. After this novel introduction, the teachers are led through the technical calculations of the Doppler shift and the rotation curve velocities, now with some intuitive understanding of the mathematics to support their understanding. An exhibition presenting the radio astronomy principles and general astronomy concepts as galactic structure and rotation, mass content and dark matter are available for teachers too. Besides showing pupils "how science works", the radio astronomy project might inspire some of them for doing science and consider a scientific carrier.

3 Summary and conclusions

"Connecting Classrooms to the Milky Way" is a project to set up the first network of small radio telescopes dedicated to education. Five such radio instruments are spread over Europe and directly accessible from a simple web interface. One of such instrument was acquired, assembled and is now operated by the Astronomical Observatory of the Jagiellonian University.

The aims of the project are as follows:

- Wide dissemination of science among young people in an attractive form.

Fig. 4: Radio exhibitions and kinesthetic exercise at schools.

- Promote scientific methods/knowledge.
- Delivery of educational materials prepared by researchers and teachers.
- Improve the quality of in-classroom science education.
- Promote experimental science teaching, present the Milky Way structure and kinematics by on-line observations of the neutral hydrogen by a radio telescope.
- Demonstrate in the classroom the modern information technology: computer control devices at a distance via the internet, transfer of data and information on the network, use a browser and Java software, use a spreadsheet for calculations and graphs.
- Reach young people concerned science and stimulate their passion.

All teachers and astronomy amateurs are encouraged to use the prepared pedagogical resources and the network of the radio telescopes.

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