

# Bringing frontline astronomy in the classroom: EU-HOU

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## Abstract

**The EU-HOU project ("Hands-On Universe, Europe. Bringing frontline interactive astronomy to the classroom") is in keeping with the general goal of renewing the teaching of science. A re-awakening of interest for science in the young generation is foreseen through astronomy and the use of new technologies, which should challenge middle and high schools pupils. The primary target group will thus be the school teachers, who will be involved through a pilot school scheme widely advertised.**

**The project is based on real observations, possibly acquired by the pupils themselves in classrooms thanks to either a European and worldwide network of automatic telescopes operated via Internet or didactical tools (Webcam system, radio telescope) developed within this project. These observations can be manipulated in classrooms with a specific software designed to be pupils friendly. They are integrated into pedagogical resources constructed in a close collaborative work between researchers and teachers. The resources developed in the course of this project are free and have been posted on the project Web site ([www.euhou.net](http://www.euhou.net)).**

**The EU-HOU project is funded at 44% through the European program MINERVA (SOCRATES) for a two-year period. More information on the project, the partner Institutions, the Pilot Schools that are collaborating with the project across Europe and the results of the experience can be found in the network URL: [www.euhou.net](http://www.euhou.net).**

**In this talk we should describe the results of the first two years of hard and very successful collaboration. Special emphasis will be made on the tools used in the Spanish Pilot Schools (URL: [www.mat.ucm.es/~aig/HOU\\_Espana/](http://www.mat.ucm.es/~aig/HOU_Espana/) ).**

**Keywords:** Innovation, Technology, Education, Astronomy, Physics, Mathematics

## 1. Introduction: Engaging youth in science

A clear disaffection for scientific studies at universities, in particular mathematics and physics, is currently observed in the occidental world, including most of the European countries. Very worrying for the future of our modern societies, such a complex situation cannot be reversed with a unique answer. However, it seems that renewing the teaching of science could largely contribute to increase the attraction for scientific subjects at universities. This undoubtedly requires a re-awakening of interest for science, the promotion of the learning of scientific method in order for pupils to feel that understanding can be a source of pleasure. Bringing the excitement of scientific discovery to the classroom is of uttermost importance for sustainable economy, which needs a critical number of scientists and engineers. Moreover, our society should keep science in its heart,

or will regress to barbarism. This is the overall goal of our project. It will be fulfilled through astronomy as a well-established source of motivation for science and technology learning, and by using new technologies for high and middle schools (Internet-controlled optical and radio-telescopes, Web-cam systems, didactic softwares...).

The overall objectives of the project are to identify, gather, organize and produce pedagogical resources ready to use in European classrooms and to coordinate and assist the implementation of these tools in a network of European Schools. In the 2004-2006 period, the EU-HOU team has carried out the following activities:

1. To produce new innovative pedagogical resources: users-friendly software, astronomical data, exercises, multimedia supports. These resources are trans-disciplinary in essence (astronomy, physics, mathematics, history, language...), and will be available in English and in the various European national languages. They are motivated by leading astronomical and space navigation projects and favour a connection with the European Research System.
2. To test the pedagogical use of the Faulkes Telescopes.
3. To develop new innovative observing tools (Webcam, radio-antenna...) to be used directly by pupils.
4. To create a European network gathering researchers and middle and high school teachers and hence promoting scientific and technological education. It will help to gear the education system to research and development both at European and at national level.
5. To set a specific Web site offering a free multilingual portal.
6. To organize workshops and teacher training sessions to train European teachers in the use of the tools and applications

In this way, we expect to cover the demand of teachers willing to introduce in their classrooms a new innovative way to teach science in order to stimulate pupils.

## 2. A new method for scientific education at Schools

The specific pedagogical concept underlying the project is the practical use (Hands-On) of real astronomical data in classrooms. The project does not aim at teaching comprehensive astronomy courses, but rather at challenging pupils in order to teach them what is a scientific work, how to apprehend data and interpret them within physics and mathematics courses. The objective is to form open-minded pupils able to think by themselves. The innovative aspects of this project are both technical and educational.

1. **Technical aspects:** With the availability of numerous astronomical databases, to be integrated soon in virtual observatories, high quality space and ground-based data are now easy to access, but because of their huge sizes, they are not directly usable in classrooms. Furthermore, the remote use of (automatic) optical and radio telescopes, and web-cameras have opened the possibility of allowing students to acquire directly data from astronomical instruments and analyse them in a classroom framework. Although astronomical observations are generally performed nightly, the existence of automatic telescopes around the world enables direct observations during classrooms thanks to longitude differences. Moreover, radio-observations are almost unaffected by poor meteorological conditions. Therefore, these facilities can be easily implemented on a very large scale within the current school practical organisation. The application of Information and Communication Technology to the development of pedagogical and didactical tools is then required. This includes the development of pupils-friendly software to manipulate and analyse astronomical data, adaptable to the different resources from each partner. This software, SALSAJ, is distributed freely through the project web (URL: [www.euhou.net](http://www.euhou.net)) in the different languages of the EU-HOU consortium members.
2. **Educational aspects:** The production of such pedagogical resources based on real astronomical data requires a good knowledge of the meaning and use of the data, therefore implies a close interaction between researchers and teachers. This is an important aspect of the project, which guarantees the scientific and pedagogical validity of the resources. High and middle school teachers with a scientific background constitute the main target of the project.

A media education is thus becoming effective, as pupils can work with different types of data (images, spectra, 3D images) and furthermore, can directly access observations (guided by their teachers); they will be able to collect their own data by themselves, on the Web, through automated telescopes, archives, local telescopes and cameras.

In addition, communication education is further favoured as pupils (and teachers) from all over Europe work on similar exercises; the venue of researchers in classrooms is encouraged.

### **3. Organization of the EU-HOU consortium (period 2004-2006)**

The European team is composed by eight institutions of France, Greece, Italy, Poland, Portugal, Spain, Sweden and United Kingdom: Université Pierre et Marie Curie, Philekpaideftiki Etaireia, Fondazione IDIS-Cittá della Scienza onlus, Centrum Fizyki Teoretycznej Polskiej Akademii Nauk, NUCLIO, Universidad Complutense de Madrid, Chalmers Tekniska Hoegskola, and Armagh Planetarium, respectively (see [www.euhou.net](http://www.euhou.net) for more details). The Université Pierre et Marie Curie acted as coordinator during the 2004-2006 period. The Centrum Fizyki Teoretycznej Polskiej Akademii Nauk will act as coordinator in the 2007-2009 period. The consortium produces the resources and coordinates the project implementation in the school system. They also coordinate the European-scale interaction and serve as connection with the European Research Space.

A major target group of the project is secondary school teachers. Calls for interest have been announced in the different partner countries. The teachers have access to the preliminary resources available on the Web server. The teachers of the pilot schools selected by the different partners adapt the multimedia outputs of the project in each national language and curriculum. They also test these resources in their classroom. From the most motivated teachers in scientific education, we identify an average of 3-4 of them per year, per country. They are trained, in English, in annual sessions at the European level of the project. In the short term, they serve as "Teacher Resource Agents" (TRA) for the training of teachers in their national language. Ideally, the TRA should aim at organising their sessions within the framework of their national educational system. They support the work of the pilot schools.

A Scientific Advisory Committee (SAC) has been set up with personalities of different countries known for their involvement in innovative scientific education or popularisation of science; they are external of the project. The SAC meets annually in order to discuss the report from the pedagogic coordinating committee, to review progress, pertinence and performance of the project, to formulate recommendations for the pedagogic coordinating committee and the coordinator, and define ways and priorities for the following year. SAC is asked to produce a concise report that is transmitted to all the national authorities through the national representatives of the pedagogic coordinating committee. These representatives ensure the acknowledgement of the project by their national authorities.

### **4. Tools developed/tested by the EU-HOU consortium**

The following tools have been either developed or tested during the project:

#### **4.1 Small radiotelescopes – Observing the 21cm line of HI**

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. In a short time, it is possible to detect the radio emission from neutral hydrogen gas in our own Galaxy, the Milky Way, and to map the distribution of this gas in the spiral arms.

The Swedish partner (Onsala Space Observatory, Chalmers University of Technology) has developed a prototype radio telescope which will be made available to pilot schools for real time observations via the Internet. Salsa Onsala is a 2.3 m radio telescope operating at a wavelength of 21 cm. At this wavelength, one can observe the HI emission from the spiral arms of the Milky Way (our galaxy). To detect cosmic signals while watching the telescope move in the webcam is a great thrill for both pupils and teachers.

The radiotelescope is a modified television antenna with a diameter of 2.3 m (see Fig. 1). This provides an angular resolution of about  $7^\circ$  at the frequency of the HI line (1420 MHz). The radio telescope is equipped with a newly designed receiver. The receiver has a bandwidth of 2.4 MHz and 255 frequency channels, so that each channel is 9.375 kHz wide. A good spectrum is obtained in just 30 seconds. The HI line profiles are processed in the classroom and from them, and simple kinematics concepts the students obtain the distribution of gas in the Milky Way: map the spiral arms



Fig 1: Salsa-Onsala (see [www.euhou.net/docupload/files/radiosweden.pdf](http://www.euhou.net/docupload/files/radiosweden.pdf))

## 4.2. Web Cam system

The Polish partner (Center for Theoretical Physics; Polish Academy of Sciences) has designed a low cost Webcam system which allows classrooms to perform themselves night observations. A complete software manual is available, together with pedagogical tools for studying the Sun, the Moon, planets, Deep Sky objects and the variability of the brightest stars. In the framework of the EU-HOU project, 20 Webcam systems will be provided to each partner country, for the pilot secondary schools.

The simplest setup consists of a webcam attached to a M42 lense through a special adaptive thread, which can be mounted on a standard photographic tripod with an universal head (see Fig. 2).

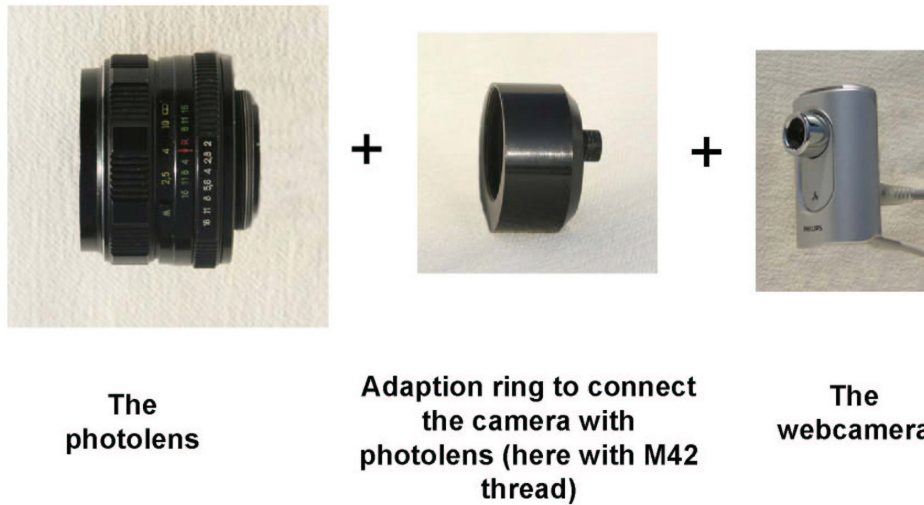


Fig 2: The simplest set-up system

Using other thread, webcam can be attached to an amateur telescope in order to register, with help of webcam CCD sensor, astronomical observations on a computer providing your school with a real, digital astronomical observatory! (see Fig. 3)...



Fig 3: WebCam system attached to an amateur telescope

This instrumentation can be used to observe solar spots and track the solar cycle, to observe Mercury and Venus transits, Solar System objects, stars, galaxies and nebulae. Students record the images in electronic format allowing them to carry out measurements on the data (see for more details, [www.cft.edu.pl/%7Elech/HOU/WebcamSystem/Webcam%20System%20Slide%20Show/index.html](http://www.cft.edu.pl/%7Elech/HOU/WebcamSystem/Webcam%20System%20Slide%20Show/index.html))

### 4.3 The Faulkes Telescopes

The Faulkes Telescope Project is the education arm of Las Cumbres Observatory Global Telescope Network (LCOGTN). LCOGTN operates a network of research class robotic telescopes. Currently there are two telescopes, one in Hawaii and the other in Australia. These telescopes are available to teachers for them to use as part of their curricular or extra-curricular activities and are fully supported by a range of educational materials and a team of educators and professional astronomers (see <http://faulkes-telescope.com> for more details). The EU-HOU pilot schools have access to observing time during 2005-2006.



The telescopes are enclosed within a novel clamshell building. The enclosure can open to expose the telescope to the whole sky. Due to this it is possible to move the telescope rapidly from one side of the sky to the other with a slew rate of at least 2 degrees per second. The telescopes can be used in real time and the teachers select their targets, filters and exposure time. Only imaging capabilities are available though new spectroscopic capabilities are under development. Telescope design is Altitude-Azimuth with Telescope Control System based upon that of the William Herschel Telescope. The Primary mirror diameter is 2m (see Fig 4) and the focal ratio f/10. The optics gives 12 arcmin diameter field for uncorrected telescope with images < 0.4 arcsec diameter from 0.3 to 2.5 microns.

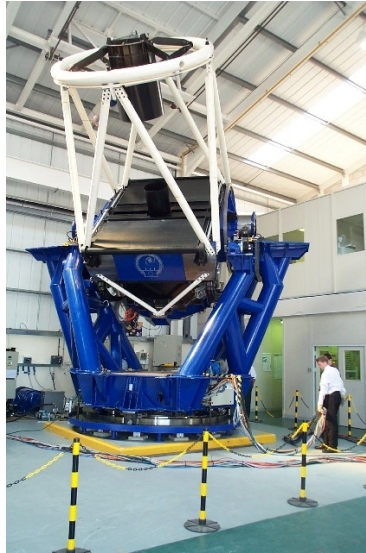


Fig 4: The Faulkes Telescope North

## 5. Image processing software: SALSJA

The software developed for the EUHOU program has been designed to be a multi-platform, multi-lingual experience for image manipulation and analysis in the classroom. Its design enables easy implementation of new facilities and basically requires no in-situ maintenance. For the software and each pedagogical resource, different levels of utilisation will be implemented (i.e. middle, high schools...). The software is freely distributed (see [www.euhou.net](http://www.euhou.net)).

The "Salsaj" window contains a menu bar (at the top of the screen on the Mac), tool bar, status bar, and a progress bar. Images, histograms, line profile, etc. are displayed in additional windows. Measurement results are displayed in the "Results" window. Windows can be dragged around the screen and resized. Histograms and plots are ordinary image windows that can be copied (to the internal clipboard), edited, printed and saved.

Salsaj allows multiple images to be displayed on the screen at one time. Salsaj supports 8-bit, 16-bit and 32-bit (real) grayscale images and 8-bit and 32-bit color images. 8-bit images are represented using unsigned integers in the range 0 to 255. 16-bit images use unsigned integers (0 to 65,535) and 32-bit grayscale images use floating-point numbers.

The following image formats are supported: TIFF (uncompressed), GIF, JPEG, BMP and FITS. In addition, access is provided (through the plugins) for reading "raw" files, images in ASCII format, and for loading images over the network using a URL. To import a raw file, you must know certain information about the layout, including the image size and the offset to the image data. Files can be saved in TIFF, GIF, JPEG, FITS, tab-delimited text, and raw formats.

Salsaj's functionality can be expanded through the use of plugins written in Java. Plugins can add support for new file formats or they can filter or analyse images. Plugins located in Salsaj's "plugins" folder are automatically installed in the Plugins menu.

## 6. Astronomical Exercises:

Several exercises have been developed within the project. Most of them are defined **to illustrate astronomical concepts** making use of data obtained with the project tools and processing them with the SALSaj software as:

- a.** Measuring the rotation curve of the Galaxy using the 21-cm line data recorded with **Salsa-Onsala**.
- b.** Measuring solar spots on the Sun and observing Solar System bodies with the **WebCam**. Determining sizes (from craters to planets).
- c.** Studying the orbital motion of Galilean Satellites with the **WebCam**.
- d.** Measuring distances to Cepheids; from observations with the **WebCam** to the determination of the period and the apparent magnitude.
- e.** Observing galaxies with the **Faulkes Telescopes**- Imaging and classifying galaxies, measuring spiral galaxies and determining the surface brightness of galaxies.
- f.** Observing jets from young and ancient stars with the **Faulkes Telescopes** and determining sizes and variability scales.

An exercise has also been defined to describe how the Doppler effect is used to detect exoplanets making use of the Salsaj software: "Seven steps for a dwarf star: from Doppler to exoplanets" .

There are however, another exercises that are defined over electronic pedagogical tools such as:

- 1. How to weight a galaxy.** This activity measures the mass of a spiral galaxy, viewed edge-on, using the same procedure employed by astronomers. It is surprising how just a few measurements and the knowledge of a few fundamental laws of physics make it possible to weigh the largest and most distant objects in the Universe, despite the impossibility of carrying out direct measurements and the fact that the only information available to us derive from a few photons which have travelled for tens and tens of millions of years. What is even more surprising is the fact that the simple measurement proposed here makes it possible to obtain experimental evidence for the well-known **dark matter**. Spiral galaxies contain a large amount of gas; the gas emits a spectrum of lines; if the galaxy is viewed **edge-on** (and not directly facing the observer, not perpendicular to the line of sight) and given that it rotates on its own axis, on one side the gas goes away from us and on the other, with respect to the centre, it draws closer to us (see Fig. 5). The lines emitted by a gas which moves with respect to the observer undergo the so-called Doppler effect, which shifts the observed frequency (see [http://www.euhou.net/index.php?option=com\\_content&task=view&id=118&Itemid=13](http://www.euhou.net/index.php?option=com_content&task=view&id=118&Itemid=13))

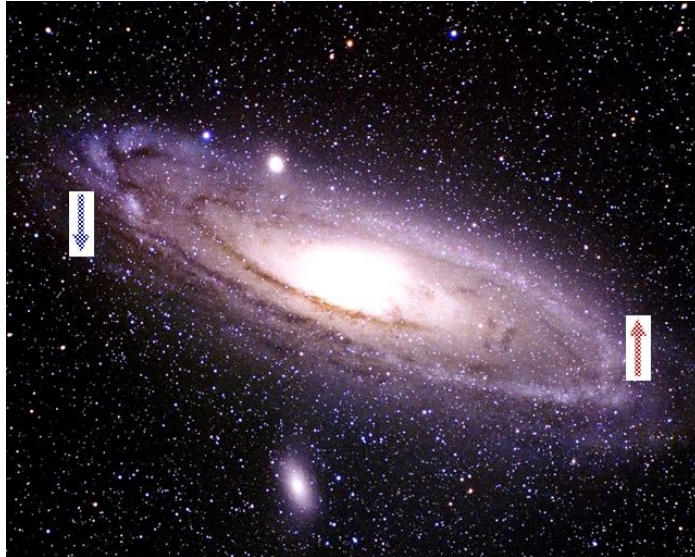


Fig 5: Rotation in a Spiral Galaxy

2. **The Life of Stars and their Spectra: Spectrj** is an electronic pedagogical tool for secondary schools that aims to provide a ready-to-use resource, inspired by real observations and research activities applying modern processing techniques. This tool presents an e-Lesson and a corresponding e-Exercise focused on the stellar spectra and their importance in astrophysics. Travelling through the pages of the lesson students get basic information on light and its spectra, on the stellar spectra and their classification into spectral types, and how they provide us with knowledge about the stars and their life. This lesson will be the theoretical base to understand the exercise. On the other hand, by doing the exercise students follow, in a simplified manner, the steps taken in a real research project. Students find the age of stellar systems in the neighbouring galaxy SMC by classifying and analysing the spectra of their stars.

## 7. Another approach: “The Solar System as a MathLab”

This electronic pedagogical tool is designed to teach mathematics using as motivation astronomy and space navigation. The tool contains some basic exercises built-in and also poses some open mathematical problems (geometry, combinatory) for teachers to explore with the pupils. As most mathematics teachers are not familiarized with astronomical concepts three introductory manuals are also made available for the teachers (see [www.mat.ucm.es/~aig/HOU\\_Espana/Traveller/inicio.html](http://www.mat.ucm.es/~aig/HOU_Espana/Traveller/inicio.html)). The application is split into two packages: **Sailing the Solar System** and the **Efficient Space Traveller**.

### /.1 Sailing the Solar System

Motivated by the COSMOS-I project to build a space-sail ship propelled by the radiation of the Sun, the application defines a Space Port at the Lagrange Point 1 from which solar vessels depart. The application trains the students in the Cartesian formulation of elliptic orbits in the plane and on the role of radiation pressure to compensate gravitational attraction. There are also exercises on simple geometry and iterative processes/converging series. Several levels of expertise are allowed:

1. Computing surfaces of simple polygons
2. Calculating the relations between semi-major, semi-minor axes and eccentricity in ellipses and the Cartesian formulation of ellipses.
3. Vectorial analysis of forces and velocities.
4. Equation of the straightline passing by two points.



5. Understanding the geometry behind the optimal coverage of plane surfaces (see Fig. 6).
6. Understanding the concept of launching window for space missions.

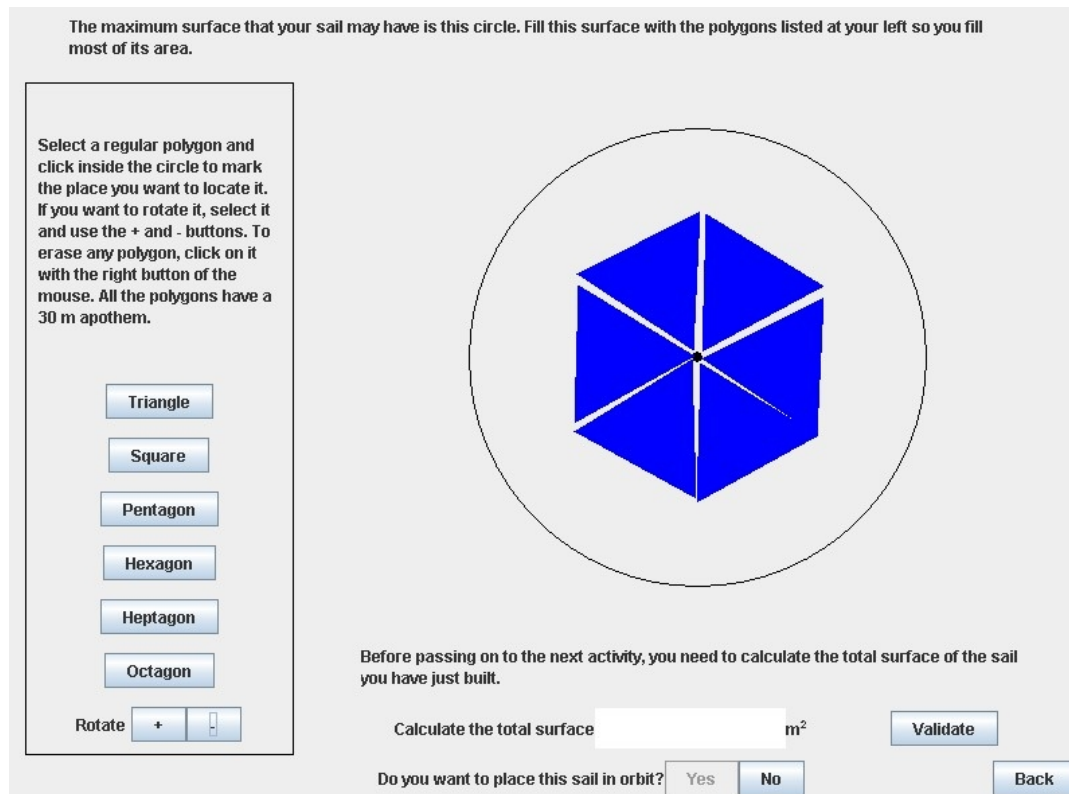


Fig 6: Optimal coverage of a circle with polygons tool

## 7.2 The Efficient Space Traveller

Motivated by space travel among extrasolar planetary systems, this application provides the students a 3D representation of the location of the known extrasolar planetary systems and their basic properties in Cartesian coordinates (see Fig. 7). This representation is used to train students in the conversion between Cartesian and Polar Spheric (astronomical) coordinates and simple vectorial algebra and combinatory. Space travel is used to pose the "space traveller problem": a new fuel is defined (the parsecol or amount of fuel needed to cover a distance of one parsec) and the students have to find the optimal way to travel among these systems with the minimal consume of parsecol. A simple heuristic is programmed in a graphic manner to help the students to understand the problem and open the possibility to train further heuristics with their teachers.

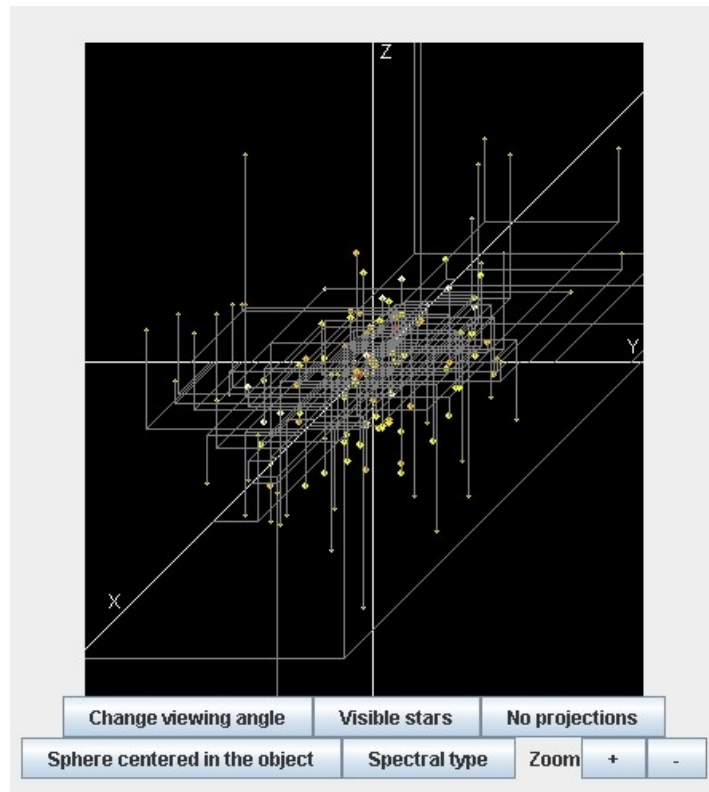


Fig 7: Cartesian representation of the location of the extrasolar planetary systems

## 8. Implementation in Spain

The project is being implemented in slightly different manners in the participating countries according to the local characteristics. During this 2004-2006 test period, the project has been implemented in Spain through the Universidad Complutense de Madrid, as part of the "Título Propio" of "Expert in Mathematical Education". This is an upgrading course for teachers that it is taken into account by the Education System for the teachers promotion. Thus teachers are trained directly from the University group. Teacher Resource Agents are those teachers being more active and having a good enough level of English to take benefit of the European Training Sessions.

The implementation is being a success though the maths and physics syllabus are very extensive and time very tight to easily implement extra-curricular activities. As a consequence, the prime target groups are the last years secondary courses (ages: 14-15 years old) instead of the higher upper school (*bachillerato*). The project is being implemented mainly in the Labs (Informatics, Mathematics and Physics Labs; also in the Astronomy Lab where available). Teachers have pointed out that it would be most useful to implement this kind of activities at earlier ages (12-13 years old) when pupils can get really engaged into science.

The teachers find the experience motivating. Also they find very interesting to learn about the levels and scientific knowledge across Europe and the different educational systems.

## **9. Summary**

In the 2004-2006 period, the EU-HOU project has developed the basic tools and outlined some main exercises. The project has been implemented in the pilot schools successfully. The materials produced by the EU-HOU team have been positively evaluated by the School System though obviously not all the materials have been tested in all the Schools.

The main objectives of the EU-HOU consortium for the next period, 2007-2009, are:

1. To adapt the resources to the national curricula of maths and physics.
2. To extend the implementation of the project within the Education System.
3. To extend the implementation of the project in Europe.
- 4.** To explore the use of new technologies for visualization and European-wide interaction among the Pilot Schools through the internet.

### ***Acknowledgements:***

We thank the MINERVA (Socrates) program from the Directorate of Education and Culture of the European Commission 113969 for funding a 44% of the project during the 2004-2006 period (grant number - CP - 1 - 2004 - 1 – FR -MINERVA- M).