Teaching astronomy and astrophysics with Hands-On-Universe and SalsaJ: stars, planets, exoplanets and dark matter

Suzanne Faye[1] and Michel Faye[2]

[1]Lycée Chaptal,
45 boulevard des Batignolles, 75008 Paris, France

[2]Lycée Louis-le-Grand,
123 rue Saint Jacques, 75005 Paris, France
email: `mfaye2@wanadoo.fr`

Abstract. How can teachers and researchers contribute to a new world-wide way to teach astronomy ? The Hands-On-Universe group proposes multi-media tools, from remote telescopes to image processing, inspired by the most recent research activities in astronomy and astrophysics. Teachers and students can learn, in a quantitative way, to analyse images and spectra using free data sets and softwares available at the website www.eu-hou.org.

Keywords. Hands-On-Universe, Eu-HOU, SalsaJ, stars, planets, exoplanets dark matter

1. What you can read on the web

Hands-On Universe (HOU) is an educational program that enables students to investigate the Universe while applying tools and concepts from science, maths, and technology. Using the Internet, HOU participants around the world request observations from an automated telescope, download images from a large image archive, and analyse them with the aid of user-friendly image processing software.

2. The EU-HOU project "*Hands-On Universe, Europe*"

Bringing frontline interactive astronomy to the classroom is one of the goals 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-school pupils. The primary target group are firtsly the school teachers, who are be involved through a pilot school scheme widely advertised.

Multi-media tools have been developed for real-time observations, allowing the teachers and their pupils to experience the thrill of discovery.

The webcam systems for backyard celestial observations in the visible spectrum have been produced in Warsaw by the Polish partner.

The radio telescopes allow teachers and pupils to open a new window of the electromagnetic spectrum on Universe. A prototype has been developed in Onsala by the Swedish partner. The European research network `RADIONET` also provides a ccess to a telescope in Jodrell Bank (UK).

A world-wide network of optical telescopes is available through the Internet to the pilot schools of the project.

The specific pedagogical concept underlying the project is the practical use (*Hands-On*) of real astronomical data in classrooms. Exercises on measuring distances in the
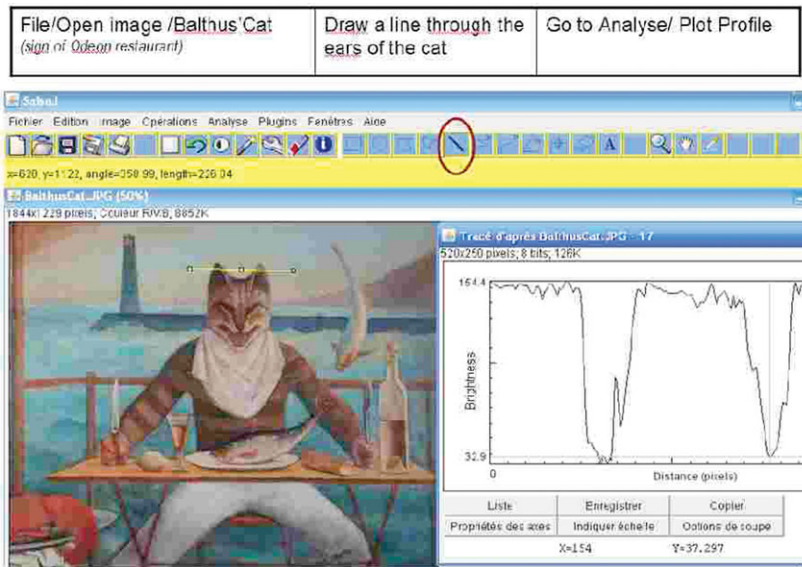
715

| File/Open image /Balthus'Cat (sign of Odeon restaurant) | Draw a line through the ears of the cat | Go to Analyse/ Plot Profile |

Figure 1. Using Balthus' cat for a simple experiment: (1) open the file with the image; (2) draw a line through the ears of the cat; (3) Click on the Analysis/Plot profile for a quantitative analysis.

Universe, stellar structure and evolution, the Doppler effect studied with optical and radio spectroscopy, extra-solar planets, dark matter and the Solar System as a mathematical laboratory will help teachers and their pupils to better understand the cosmos and to develop the key skills necessary to contribute as a member of European society.

Data are available with each exercise, or can be acquired on-line –or requested and obtained within days–from dedicated observing sites in Europe and worldwide t hrough the Internet. The exercises proposed are inspired by research activities (European research wherever possible), prepared by researchers, adapted and tested by teachers and educators from the different partner countries. These exercises do not aim at teaching comprehensive astronomy courses, but rather at challenging pupils in order to teach them what is a scientific process, how to apprehend data and interpret them within physics and mathematics courses.

3. Happy Hands-On-Universe

We advice beginners to choose a funny picture and to draw profiles, as an introduction to various scientific applications, such as the comparison of the structure of planets and stars, or as spectroscopic profiles. At the UNESCO Headquarters, during the Symposium, we proposed a famous painter's cat, from a nearby restaurant in Paris.

You can get a first training in `SalsaJ`, a free software to be downloaded from the website of the project (`www.eu-hou.net`) in various European languages, such as English, French, Greek, Italian, Polish, Portuguese, Swedish, Spanish.

As an illustration, we give three examples, one for beginners, and two for more advanced students.

3.1. *To compare stars and planets: SalsaJ Plot Profile*

Open the files with images of the Moon and the Sun, select the position of the line, and check the profile. The teachers can then explain the differences: in the Moon there
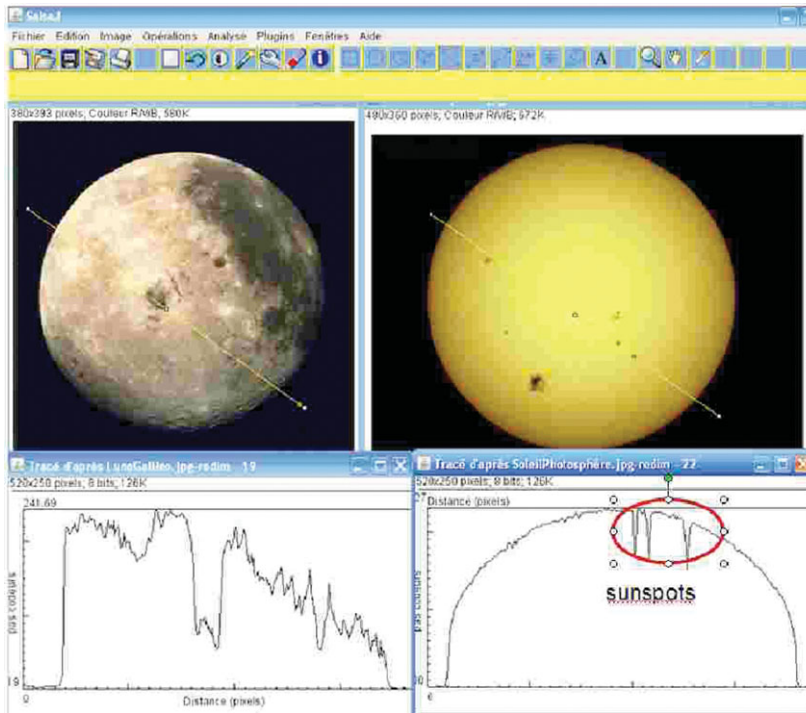
Figure 2. Comparing the light profiles of the Moon and the Sun from public images.

is no atmosphere (sharp drop in the profile), and many mountains and valleys (jagged line). In contrast, the Sun appears to have a smoothly declining profile, indicative of its gaseous/plasma atmosphere. If the profile happens to cross a sunspot, one can explain its structure, umbra/penumbra and the rôle of magnetic fields, etc.

The next step would be, paying tribute to Galileo, to test the differences sketched above with images of the Galilean moons. Which ones have atmospheres? Which ones have a rocky/icy surface? One could also use an image of Jupiter or Venus.

3.2. *Question: where is Saint-Exupéry's Petit Prince living now ?*

Clearly, in the 20th century, he lived on an asteroid; but now, in 21st century, he has chosen to live on an exoplanet. See at our web site www.eu-hou.net, exercise *Seven steps for a dwarf star, from Doppler to exoplanets* (exercise and data sets in collaboration with Roger Ferlet, CNRS, Institut d'Astrophysique de Paris). This exercise will allow you to uncover the exoplanet where the *Petit Prince* has migrated.

3.3. *Dancing with a galaxy*

In collaboration with Alessandra Zanassi (Science City, Naples) and Alessandro Pizzella (Padova University), we propose measuring Edwin Hubble's redshift and Vera Rubin's dark matter in a very exciting activity. The spectrum of a galaxy (here NGC 7083) shows a main/central Doppler shift, due to Hubble's redshift, and lateral ones, due to the rotating arms of the galaxy. These lateral ones are the same from pixel number 16, rather near of the core, to pixel number 256, the edge of the picture.

Figure 3. Using a real data set of radial velocities to infer the presence of an exoplanet.

Figure 4. Use the two-dimensional spectrum of galaxy NGC 7083 to measure the redshift of the galaxy and infer the presence of dark matter.

We can now use Newton's law whereby the centrifugal force must be equal to the gravitational one for a system in equilibrium, and write

$$\frac{mV^2}{r} \;=\; G\frac{m\,M}{r^2}.$$

Since we measure that the radial velocity in pixel 16 is the same as in pixel 256, this equation implies that

$$\left(\frac{M}{r}\right)_{\text{pixel number 16}} \;=\; \left(\frac{M}{r}\right)_{\text{pixel number 256}},$$

which in turn implies that

$$\frac{M(\text{pixel}\,256)}{M(\text{pixel}\,16)} \;=\; \frac{256}{16} \;=\; 16.$$

That is, the mass of the galaxy at the position of pixel 256 is 16 times larger than at pixel 16, while its luminosity is much fainter at the outer position (pixel 256) than at pixel 16. How can this be ? What V. Rubin found was that something unknown, dark and massive, was giving the "extra" mass and yet is not visible. This is called dark matter !

We hope that these simple examples will tease you and will lead you to perform these experiments with students. Teaching astronomy this way can be summarised as
```
F-HOU = Fun-HOU = France-HOU = Friends of HOU
```

Browse `www.eu-hou.net`, download data sets and programs, and enjoy !

References

Rubin, V. 1996, *Bright Galaxies / Dark Matters* (New York: AIP Press)
Saint-Exupéry, A. de 1943, *Le Petit Prince* (New York: Reynal & Hitchcock)