The Sky as a Laboratory: 
an Astronomy education project 
of the University of Padova

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Abstract. “The Sky as a Laboratory” is an educational project of the Department of Physics and Astronomy of the University of Padova, aimed to give to the students of the last two classes of the high schools an original physical approach to astronomy and astrophysics. It is a tutoring program designed to improve science knowledge through Astronomy, based on a strict cooperation between scientists and teachers. Currently there are 30 high schools around all provinces of the region Veneto involved in this project, the winning strategy of which is the constant joint effort of high school teachers and astronomers in communicating science through astronomy. Their enthusiastic participation to the teaching and training activities excites each year attention for science in an arising number of students and suggests new ideas for future didactical experiments.

Keywords. Education, Astronomy, High Schools

1. Introduction
Most students, who start the study in Astronomy at the University of Padua, have the conviction that astronomy is essentially a qualitative and descriptive science. Their disappointment is quite heavy when they realize that astronomy practically consists of mathematics and physics applied to the study of celestial phenomena.

No doubt that the cause of this misunderstanding has its roots in the science education programs of the secondary school for the following reasons:

1. Astronomy is restricted to a small fraction of the Science program of the last year of the Sciences and/or Humanities High Schools.
2. Astronomy is never introduced in connection with Physics and Mathematics.

On the basis of this observation we decided to develop an educational project in Astronomy and Astrophysics, called “The Sky as a Laboratory”, designed to create a new form of science education for students of the last two years of the secondary school. This project has its force in the strict joint work of teachers and scientists and gives to the students the opportunity to experience directly the use of:

1. professional telescopes;
2. astronomical instruments like spectrographs and imaging cameras with CCD detectors
3. astronomical software for data analysis;
4. mathematics and physics for interpreting the collected observations
5. editing tools for producing scientific reports and presentations of their results.

2. The Sky as a Laboratory
The Sky as a Laboratory has three main goals:

1. to give to the students a physical and mathematical approach to astronomy;
2. to point out the interdisciplinary nature of astronomy, showing that most of the open questions on the interpretation of celestial phenomena are connected with other sciences, like e.g.: physics, mathematics, chemistry, geology and biology;
3. to offer guidelines to the students for the choice of their future field of study at the
university, giving them the possibility to identify and unveil their attitude and talent towards science.

The “Sky as a Laboratory” started on the scholastic year 2001 as a pilot project with the aim to weigh the interest of students and teachers for this new didactical experiment. At this stage only two schools, located not far from the Asiago Astrophysical Observatory, were involved in the project. In the wake of the success of this first experience, in 2002 we attempted to expand the project on larger scale in the region Veneto: we contacted teachers with a degree or a Ph.D. in astronomy working in the high schools of some selected provinces of the region and we started with them a close collaboration. Their institutes became officially didactical centers of the project (didactical poles) within each province and there the teachers itself gave to a selected group of voluntary students introductory lectures on fundamentals of astronomy and astrophysics. During this year the students had access for the first time to the facilities of the Asiago Astrophysical Observatory (Fig. 1) for carrying out observations at the telescopes. The success of this experiment resulted in a strong demand for the expansion of the reference school-network to all provinces of the region Veneto. Starting with the scholastic year 2003 the reference schools became 10. Since then around 350-400 students of 30 high schools are enrolled every year in the project. They attend 7, two hours long lectures of astronomy and astrophysics outside the normal school timetable and a thematic conference given by an astronomer of the Department of Astronomy of the University of Padova. More than 30 teachers and heads of institute are involved in the project. Around 150-170 students participate each year to the finals of the project and the best 50-60, divided in 4 small groups, are admitted to spend 3 days at the Asiago Astrophysical Observatory, where they carry out a run of observations on specific scientific programs at the 1.2m telescope. The time devoted to this activity, namely to observations, data reduction, data analysis and interpretation amounts to 35-40 hours for each group. The results of this activity are collected each year in a booklet containing 12-13 scientific reports.

3. The project in details

The Sky as a Laboratory officially starts each year at the beginning of October. During the first two months the students attend a course of 7 lectures (14 hours) of basics of astronomy and astrophysics (1 lecture per week). The subjects of the lectures are the following:

1. Blackbody radiation
2. The dual nature of light and the hydrogen atom
3. Magnitudes, colors and spectra of stars
4. The H-R diagram and the fundamentals of stellar evolution
5. Planets of the Solar System and search for extrasolar planets
6. Basics of physics of gaseous nebulae
7. Galaxies

Figure 1. Dome and telescope of the Asiago Astrophysical Observatory.
In November, when the students have already acquired some basic knowledge of astronomy and astrophysics, there is in each school a seminar of an astronomer focused on a modern research subject.

In December all students meet in Padua in the Aula Magna of the University, the same room where G. Galilei gave his lectures, for attending a special lecture given by an internationally well known astronomer.

A quiz test consisting of 42 questions and problems is scheduled in January. On the basis of the results of this test, to which participate 150-170 students, around 60 of them are admitted to a three days run of observations at the 1.2m telescope of the Asiago Astrophysical Observatory. Four observing runs at the Galileo 1.2 m telescope, equipped with a professional spectrograph and with modern CCD detectors, are scheduled during February. The typical number of participating students is 10-15 for each run. During this stay they acquire experience in the professional instrumentation, in obtaining data for a well defined scientific program, in their reduction, analysis and physical interpretation. All this activity must result in a written scientific report, that each group presents as a short seminar during a one day conference, organized each year in April at the Department of Astronomy. The conference is open to all teachers and students of the schools participating to the project. The written reports are collected each year in a printed booklet, published by the Department of Astronomy.

4. Training at the telescope

The Asiago Astrophysical Observatory has devoted to the project its 1.2 m telescope (D = 122 cm, F = 1950 cm), equipped with a Boller&Chivens Spectrograph. Four gratings with 150, 300, 600 and 1200 grooves/mm are available. They produce spectra with a resolution of 16.0, 8.0, 4.0 and 2.0 Angstrom respectively (using a slit width of 2 arcsec). A modern CCD detector Andor iDUS, 2048x512 pixel, pixel-size 13.5 μm, allows to obtain high quality spectra of relatively faint sources: magnitude 16-17 can be reached in 0.5-1 hour of total exposure time. The spatial scale on the CCD is 0.6”/pixel.

Both telescope and spectrograph are operated from a large control-room located at the ground floor of the dome. This room hosts also a set of 5 computers with Windows/Linux operating system and printers used by the students for online reduction of the data. All computers are equipped with professional astronomical software, like IRAF, MIDAS, DS9, SMongo, Sextractor, Galfit and Topcat. Up to 15 students can work at the same time in the control room. The students are grouped at the telescope on the basis of the different subjects of research, proposed by the tutor astronomer during a briefing with them and their teachers.

During the night the students observe the objects of their research program. If the weather conditions are adverse, data are extracted either from the local archive or from public astronomical archives (like SDSS, HST, DSS, 2MASS, etc.). During daytime the students reduce the data step by step under the astronomer’s direction. The analysis of the reduced data is performed using conventional astronomical software. The final interpretation of the observations is presented in the frame of the definition of the scientific case, and of its open questions, as pointed out by a complete bibliographical research on the subject of investigation, extracted from the NASA/ADS Abstract Service.

Examples of research subjects approached by the students are the following:

- **SOLAR SYSTEM**
  - Spectral analysis of absorption features of planets and satellites
  - Rotation curve and mass determination of planets
  - Spectral analysis of comets

- **STARS**
  - H-R and color-color diagrams of open and globular clusters
  - Light curves of variable stars
  - Spectral classification of main sequence stars
  - Temperature determination of stars
  - Classification of Supernovae

- **NEBULAE**
  - Temperature, density and chemical composition of Galactic gaseous nebulae
• Star formation rate in extragalactic HII regions

**GALAXIES**

- Morphology of nearby galaxies
- H-R diagrams of dwarf galaxies of the Local Group
- Stellar populations in galaxies
- Mass estimate of spiral and elliptical nearby galaxies
- Spectroscopy of active nuclei and starburst galaxies
- Photometric redshifts
- Optical counterparts of X-ray sources
- Star formation in spiral galaxies

As an example, it is reported the recent work by Monai, Pagotto, Artusi & De Luca (2009) entitled "Relations between stellar temperature, colour index and equivalent width of spectral lines" performed using archive data extracted from the Sloan Digital Sky Survey Data, Release 6 (http://www.sdss.org/dr6).

The students have firstly selected a sample of 26 stars having different color index $g-r$, then they have downloaded the spectra of such stars and have fitted the continuum of each spectrum with a Planck’s Black Body curve, using a script prepared by the astronomers for the interactive plotting programme SMongo (Fig. 2). The plot of the colour indices as a function of the inverse of the so derived temperatures, obtained using TOPCAT, is fitted by a linear regression with a high correlation factor (Fig. 3). This result shows that the color index of a star is directly related to its temperature. It is then possible to extract from the archives photometric information of a sample of e.g. 100 000 stars, to convert their $g-r$ colour index values into continuum temperatures and then to plot a histogram of temperatures, which gives a quantitative indication of the statistical distribution of stellar spectral types present in the sample (Fig. 4).

![Figure 2. Spectrum of a hot star. The red line is the best fit with a Planck’s equation.](image)
5. **Products of the project**

Until now The Sky as a Laboratory has produced the following bibliographical material:

- A website (http://www.astro.unipd.it/progettoeducativo/) collecting all information about the project and the slides of the lectures.
- Booklets containing the results of the researches carried out by the students during their observing runs at the Asiago Observatory.
- Scientific publications, like Ciroi et al. (2009a, 2009b).
- A book of astronomy for students of the high schools, written by the teachers and edited by the staff astronomers involved in the project (in press).

6. **Summary**

... In laboratory work: students can use real-life data; they can use the same computer languages and software packages that researchers use. The labs should be authentic mirroring real research, rather than aiming for a pre-determined cook-book result...They can learn that the astronomical knowledge is not produced by textbooks but by astronomers perhaps even by themselves! (Percy 2006).

The Sky as a Laboratory has demonstrated that it is possible to spread even complicated astrophysical concepts among strongly motivated students of the secondary school having a normal, basic knowledge of physics and mathematics. The success of this project is the result of the enthusiastic efforts of the teachers of the involved schools, and of the close collaboration between them and the staff of the Department of Astronomy of the University of Padua. Students who attend the full project, make an important unique experience for their life and for their future, whatever their professional choices are.
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