The Fingerprint of the Stars: An Astronomy Lab On Spectroscopy

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Keywords
Secondary School, High School, Experiment Activities, Spectroscopy, Activities for Young People

Summary

Many Portuguese schools are not equipped to carry out the mandatory experimental activities covered by the school curriculum. In order to remedy this deficiency, the Centro de Astrofísica da Universidade do Porto (CAUP) has developed hands-on laboratories, offering schools several different experimental activities. This article will focus on one of these experiments, in which students build a spectroscope and use it to analyse different spectra. Pupils learn not only the practical methods of science but also the astronomical and everyday applications of spectroscopy.

Introduction

Although the Portuguese school curriculum places considerable emphasis on experimental activities, many schools lack the materials and facilities required to carry them out. Thus, schools are often forced to bypass these activities, resorting instead to textbooks, PowerPoint or video presentations of the experiments they were supposed to conduct, and teaching the results that should have been obtained experimentally rather than completing the practical work. In recent years, some effort has been made by the Portuguese government to improve the conditions under which public schools operate (Almeida, 2009), but these programmes can only reach a handful of schools[1].

Since its creation in 1989 the Centro de Astrofísica da Universidade do Porto (CAUP) has set science outreach and promotion, and the teaching of astronomy at undergraduate level as two of its main goals. It became clear that CAUP could play an important role in providing the opportunity for students to perform the experimental activities that — according to the guidelines provided by the Ministry of Education — they were expected to conduct, and in particular those related to astronomy.

CAUP began to develop several experimental activities in 2006, activities which covered themes from the school curriculum, and forged a direct link to astronomy and space sciences. Today, six experiments covering different topics and catering to different age ranges are available at the Planetarium of Porto. These can be used as stand-alone activities, or to complement regular planetarium sessions. The experiments are guided by CAUP's outreach staff, all of whom have a high level of astronomy education.

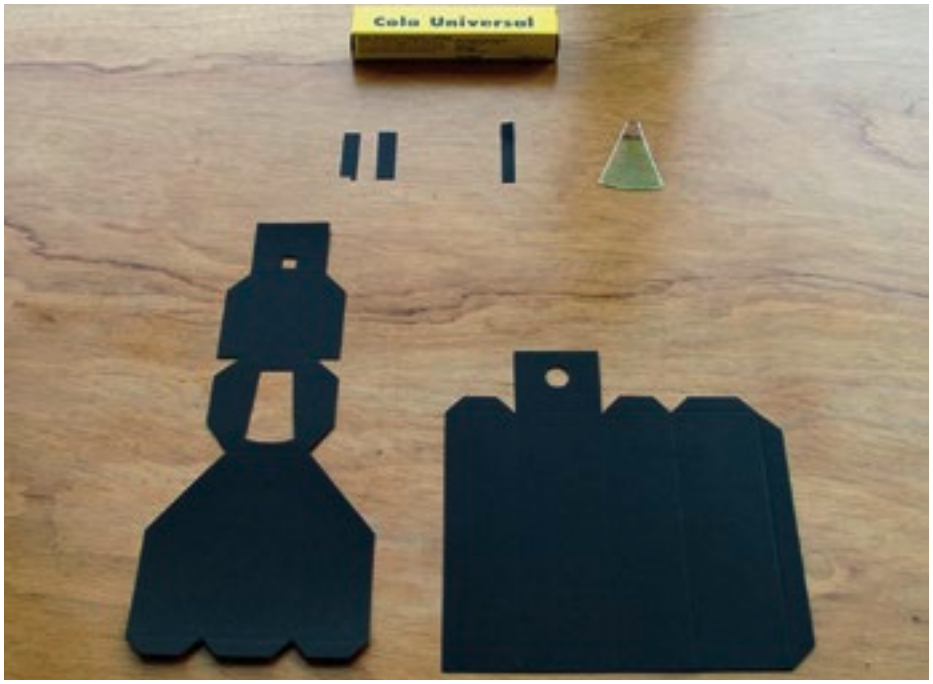

Figure 1. The material needed to assemble the spectroscope. Credit: Ricardo Cardoso Reis.

In the latest published results from the OECD Programme for International Student Assessment, which tests the general competence in reading, mathematics and scientific literacy of 15–16 year old students, Portugal ranked 34th in science[2], and is one of the worst performers among the OECD member countries. Although there is some controversy around what should be the exact role of experimental teaching in science learning, most researchers agree that experimental teaching is very important for at least some aspects of science education (Atkina, 2002)[3]. Therefore, if used appropriately, experimental activities may become a powerful tool for improving Portuguese students' scientific literacy.

The first activity, entitled "The Fingerprint of the Stars", debuted in 2007 and is targeted at students of around 15 years old. At this point in the Portuguese school system the topics covered in the physics and chemistry curricula, taken by high students in science and technology programmes include: the Universe, the nature of light, spectra and atomic structure.

Experiment description

This activity begins with an informal talk between the presenter and the students where a broad overview on the nature of light is presented. This checks that students have the necessary prerequisite knowledge and, if not, introduces them to the missing concepts. This talk also explains to students why spectroscopy is of the utmost importance for astronomy.

Students then proceed to build their own spectroscope from very simple materials: pre-cut pieces of cardboard, all-purpose glue and a slice of a compact disc (CD) with its reflective layer removed (Vieira, 2004; Figure 1). With this simple spectroscope, which students take home at the end of the experiment, students can observe spectra with a reasonable resolution (Figure 2), and, if the slit is carefully assembled, they can even observe the Fraunhofer lines in the solar spectrum.

Students are then asked to use the spectroscope they have built to observe several spectra from gas-discharge lamps containing a range of substances, from simple chemical elements like hydrogen or helium, to complex mixtures such as air or water vapour. A more accurate graduated spectrometer is also used as they are expected to perform some basic tasks of spectroscopic analysis, for example identifying the wavelength of a given hydrogen line (Figure 3).

Figure 2. A group of students observes the solar spectrum. Credit: Ricardo Cardoso Reis.

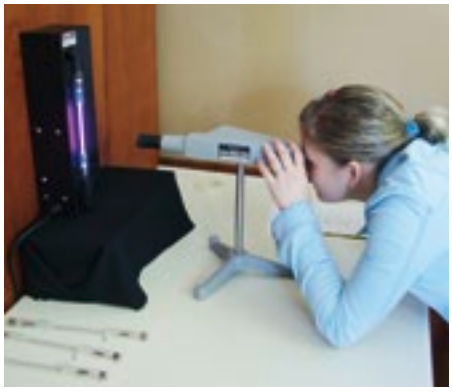

Figure 3. A student uses a spectrometer to observe the spectrum of a gas-discharge lamp. Credit: Ricardo Cardoso Reis.

Through their observations students see that different elements present different spectra, helping them understand one of the major applications of spectroscopy: the identification of the chemical composition of distant objects. Depending on the background knowledge of the target audience, some other applications of spectroscopy in astronomy may also be discussed, such as the Doppler effect and the redshift of distant galaxies; the radial velocity method for discovering exoplanets and the determination of gas pressure and temperature in a stellar atmosphere (Figure 4).

Considerable efforts have been made to make these sessions highly interactive, as students take the lead role in the experiments being conducted. Furthermore, throughout the entire session, they are encouraged to participate, by posing and answering questions, some of them requiring complex reasoning.

All this is done in an informal setting to encourage students to pose questions that they may not feel comfortable asking their teacher in a regular classroom setting. Furthermore, as these sessions are presented by people with formal university training in astronomy, students can get up-to-date and highly specific answers, which some teachers may not be able to offer.

In order to further cover the contents of school curricula, a few other related topics are also discussed during the experiment. For instance, the atomic structure of matter is easily brought into the discussion in order to explain how a gas-discharge lamp emits light.

Conclusion

With a growing number of visitors, The "Fingerprint of the Stars" experiment has been providing students with the chance to improve their knowledge and understanding of some major topics in their physics and chemistry curricula. This is done by experimenting first hand with the physical phenomena being studied, and interactively seeking further information. In turn, the presenter poses several questions and challenges that lead students to think about both the astronomical and everyday implications of the physics they are investigating, and also develop their scientific reasoning capabilities.

For most students who visit CAUP, this is the only chance they will get to perform an experiment on any spectroscopy-related subject. Thus, with this activity CAUP ensures that students from less well-equipped schools also have the opportunity to improve, through experimentation, their understanding of these subjects, which are apparently disconnected from everyday life, and potentially harder to grasp.

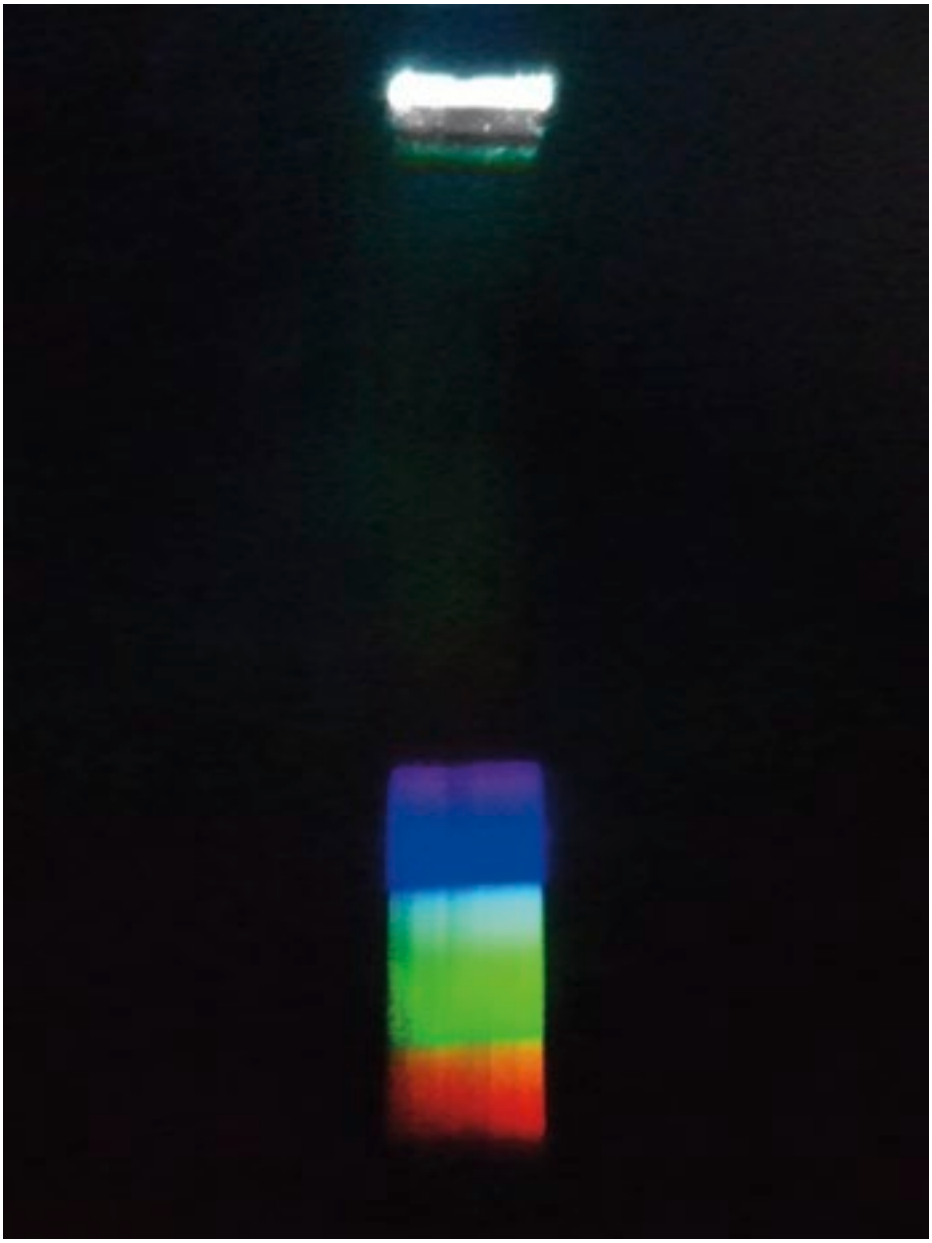

Figure 4. The solar spectrum observed with a student-built spectroscope. Credit: Ricardo Cardoso Reis.

Notes

[1] Parque Escolar, E.P.E., Schools included in the modernisation programme; available at www.parque-escolar.pt/pt/escolas/escolas.aspx, retrieved on 2012/10/12

[2] OECD Programme for International Student Assessment (PISA), *Science Proficiency 2009*, http://www.oecd.org/statistics/, retrieved on 2012/10/12

[3] Other sources on the importance of experimentation in science teaching include:

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Biographies

Pedro Mondim works in the Outreach Unit of CAUP, and is involved in many astronomy outreach activities for the general public and, especially, for students. He regularly presents planetarium sessions, develops new experimental activities and guides students in the hands-on laboratories.

Ricardo Cardoso Reis is an outreach assistant at CAUP, Ricardo works on most aspects of its strategy for astronomy outreach and promotion of scientific culture, by producing and presenting shows in the Planetarium of Porto, writing astronomy related news and press releases, presenting telescope observing nights (and days), and supervising hands-on activities. During the International Year of Astronomy 2009 (IYA2009) he was the coordinator of the global project Dawn of IYA2009 and a member of the task groups of Solar Physics, 100 Hours of Astronomy and Galilean Nights.

Filipe Pires is the head of CAUP Outreach Unit. He has a degree in astronomy from the University of Porto and is an expert outreach professional. He has worked at the Porto Planetarium since its construction in 1997.