A Week-long Summer Programme in Astronomy for High-school Students

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The last four years have seen a considerable reduction in the number of candidates for the only Portuguese university degree course in astronomy. As a consequence, a number of measures were taken in order to increase the awareness of astronomy among high school students and to increase the number of students who ultimately decide to apply for the astronomy degree. Here, we present a week-long programme of experimental activities and lectures covering the major fields of astronomy, and an evaluation of its success.

Introduction

The University of Porto runs the only university astronomy degree course in Portugal and it has been accepting students since 1984. Although the intake of students per year has never been very high the lack of candidates has become a larger issue over the past few years. In 2012 there was a total of nine students enrolled in this degree and in 2013 the number reduced to just six. This has raised special concern since it could eventually result in a lack of qualified astronomers for Portuguese research institutions. A few other scientific degrees at the University of Porto, such as chemistry and engineering, are also experiencing lower enrolment numbers than usual but, notably, the same is not true of the physics degree course.

No significant population changes have been identified that could affect enrolment, leading us to believe that the decrease in the number of students enrolling is due to diminishing interest in this field among potential students. Alternatively, this could be due to a change in students' expectations regarding future employment, biasing them towards other degrees they believe to have better employment prospects. Such an argument is reinforced by the fact that Portugal has undergone a period of economic recession, with high unemployment rates, which may have led students to prioritise employment prospects when choosing a degree.

In light of this decline in astronomy students Centro de Astrofísica da Universidade do Porto (CAUP), which, together with the University of Porto, has the role of training new astronomers, has developed and joined several initiatives aiming to reverse the downward trend in student numbers. Some of these activities try to stimulate pre-university students' curiosity and interest in astronomy, whilst others debunk common myths about employability[1, 2]. This paper presents one such activity — a week-long summer programme — its evolution over the last three years and an analysis of the evaluation data captured from the programme.

The University of Porto already has a programme which introduces eleven to seventeen year olds to the university environment. This programme, entitled *Junior University*, has been running since 2005, with the primary model being week-long activities held in July, plus three subprogrammes (Ferreira Gomes, 2007 and Marques, 2010). Around 5000 students participate in the programme every year, making it the largest such initiative in Portugal.

For the youngest students, the *Try it in the Summer* subprogramme includes daily activities exploring different fields of knowledge including science, arts, philosophy and history. Students rotate across these daily activities during their week in *Junior University*. In 2015, there were six groups of different activities. CAUP has been participating in this programme for several years with a daily activity dedicated to the Solar System.

Students in the thirteen to fourteen age bracket can enrol in the Summer Workshops which are also made up of activities in different fields of study. The older students, on the other hand, participate in the *Summer Project* subprogramme. This subprogramme consists of week-long activities focused on a specific field of study with up to sixteen students in each activity. These students are usually fifteen to seventeen years old and in 2015 there were a total of 83 different activities for them to partake in.

With *Junior University* already in place, it was decided that a course in astronomy should be developed for interested students, taking advantage of the organisational effort already being invested by the University of Porto each year to run the larger programme.

Activity organisation

The astronomy course developed — entitled *Astronomy: from concepts to practice* — is intended to guide students through some of the main areas of astronomy. Students spend most of the time performing experiments and discussing the results, while an hour to an hour and a half is dedicated to lectures each day.

The first two days of the course serve a dual purpose as they deal with stars and exoplanets as well as the basic properties of light and how it is used in astronomy. The third day of the course is devoted to extragalactic astronomy, and the fourth to cosmology and the fundamental laws of physics. The theme of the last day of the course is astronomical instrumentation, with a focus on telescopes. The last day

also provides students with information regarding the training opportunities in astronomy available at the University of Porto. The weekly schedule of this activity is summarised in Table 1 and presented in more detail below.

Each day starts with a theoretical lecture providing mathematical tools and basic physics knowledge which students will need during the week. As the students are spread across three different school years and so have different levels of knowledge of physics and mathematics these lectures are a vital way of ensuring all students have the knowledge needed to get the most out of the course and the experimental activities that follow the lectures each day. The lectures are presented by CAUP researchers who also teach undergraduate and graduate courses in astronomy at the University of Porto.

The last day also starts with a lecture followed by experimental activities but the afternoon is spent in a brief presentation of the training opportunities in astronomy at the University of Porto and watching two shows at Porto Planetarium.

The course also includes a night sky observation. The observation is always scheduled for the first night but this is subject to change according to weather conditions. If weather conditions do not allow the observation to take place on any of the nights — something that has only happened once in three years — the students can still enjoy a demonstration of the night sky inside Porto Planetarium.

Description of the lectures and experimental activities

There are currently twelve experimental activities performed over the course of the week. Some of the experiments were adapted and expanded from programmes already available as hands-on laboratories for schools at Porto Planetarium but most of them were developed specifically for the course, inspired by resources available online and from the author's own work.

Some activities simply test physical and astronomical concepts and are then linked to work carried out by astronomers during discussion of the results, but wherever possible the experiments were developed

	Monday	Tuesday	Wednesday	Thursday	Friday
Theme	Stars, planets and properties of light	Stars, planets and properties of light	Galaxies and large scale structures	The fundamental forces of Nature	Observations and technology
Morning	Properties of light	Formation, evolution and death of stars	The Miky Way and other galaxies	Cosmology	Telescopes and astronomical observations
	The fingerprints of Stars	Comparing brightness	Colouring astronomical pictures	Gravity in action with a torsion balance	Building a sundial and an astrolabe
				Black holes' properties	
Afternoon	Parallax	Solar observation and rotation period	Building a Hubble sequence	Determining the speed of light	Presentation of astronomy training at Univ. Porto
	Searching for exoplanets	Light — our window on the Universe			Planetarium shows
Night	Night sky observation	Alternative date for night sky observation	Alternative date for night sky observation	Alternative date for night sky observation	Alternative date for night sky observation

Table 1. *The weekly schedule of the activities. The experimental activities are written in blue for clarity.*

Figure 1. *One of the pictures taken to simulate the transit method for detection of exoplanets. A small ball held by a thread is photographed at multiple positions while crossing in front of the bulb. Credit: Pedro Mondim and Pedro Pedrosa*

to be as similar as possible to experiments actually carried out by astronomers.

Monday — lectures
At the beginning of the week, each student receives a guide that provides, for each experiment they will perform, a short theoretical introduction, the experimental protocol and extra space for recording results, performing calculations and taking notes. The students are guided throughout their activities by the author, an astronomy outreach professional, and also by another guide with a college-level education in astronomy.

After a short introduction to the course, the week starts with a lecture on techniques used to measure astronomical distances, on the concepts of brightness, luminosity and magnitudes and also on stellar spectra and the Hertzsprung–Russell diagram.

Monday — activities
The fingerprints of stars
This activity, adapted from a hands-on laboratory experiment available at Porto Planetarium (Mondim, 2010), has the goal of showing the students the major role played by spectroscopy in astronomy and some of the information astronomers obtain from it.

Parallax
This activity, which was also adapted from a hands-on laboratory experiment available at Porto Planetarium[3], leads the students to think about how astronomers are able to measure distances, providing an example of one of the several available methods.

Searching for exoplanets
Exoplanets, whilst a major focus of modern astronomy, are not explicitly presented in any of the lectures but that is compensated for by a theoretical introduction to this activity, after which students use the transit method to determine the presence of a planet around a star and estimate its size (Figure 1). This activity was developed from scratch by the author but related experiments can be found elsewhere[4, 5].

Tuesday — lectures
The Tuesday lecture focuses on the techniques used to measure the velocity of an astronomical body, and then qualitatively describes the formation, evolution and death of stars.

Tuesday — activities
Comparing brightness
This activity was inspired by the work of Paul Doherty[6] and is used to allow students to better understand the concepts of magnitude and measurements of a star's brightness, which have already been presented in the first lecture.

Solar observation and rotation period
In this activity, students are shown some of the phenomena that take place in a stellar atmosphere (like sunspots and prominences) and how they can be used to determine a star's rotation period. The teaching of how to determine the rotation period is similar to the description available in protocols online[7], but makes use of digital images of the Sun.

Light — our window on the Universe
This activity was adapted from a hands-on laboratory already available at Porto Planetarium[3] and with it we expect students to be able to understand refraction, total internal reflection, specular reflection and diffraction and how these phenomena can be used to build astronomical instruments.

Wednesday — lectures
The Wednesday lecture presents a qualitative overview of the Milky Way's properties and dynamics as well as galaxy formation and interaction models.

Wednesday — activities
Colouring astronomical pictures
Most students have no idea how the astronomical pictures shown in the media are produced and imagine that astronomers always work with coloured pictures. This activity challenges these assumptions, explaining how coloured pictures are obtained and letting the students apply some techniques to compose coloured astronomical pictures. Several step-by-step guides to producing coloured images can be found online[8].

Building a Hubble sequence
Although the morphological classification of galaxies is discussed in this day's lecture, this activity reinforces the topic, challenging students to try and classify galaxies themselves. Afterwards, each student selects their favourite Hubble sequence and receives their own A3-sized copy of their chosen Hubble sequence.

Thursday — lectures
This lecture presents some basic cosmology concepts, and discusses the history and evolution of the Universe and the main properties of the fundamental forces of nature. Developing experimental activities for cosmology proved to be a challenge and therefore this day's experiments deal with just one of the topics of the lecture: the gravitational force.

Thursday — activities
Gravity in action with a torsion balance
While the effects of gravity are quite clear in astronomy, it is difficult to gain a reasonable idea of gravity's effects between small objects. This experiment allows students to actually observe such effects. They also compare gravitational and electric forces, doing some simple calculations. The torsion balance in this activity is based on the one described by John Walker[9].

Black hole properties
In order for students to better grasp the order of magnitude of the sizes and masses of black holes they use the Schwarzschild radius equation to estimate the properties of black holes.

Determining the speed of light
The entire afternoon is devoted to this activity, adapted from the work of Jan Paul Dabrowski and other collaborators at Gettysburg College[10]. Its aim is to better prepare students for the reports they will be required to write in school and university. This is done by having students determine the speed of light, using Rømer's method, and then write a report. This report is read by the author and discussed with each group the following day, providing detailed feedback and suggestions for improvement.

Friday — lectures
Friday's lecture is devoted to telescopes and astronomical observations and is somewhat longer than the others as several astronomical instruments are displayed and manipulated by the students during the lecture.

Friday — activities
Building a sundial and an astrolabe
This activity was developed to show students how astronomical concepts and data can be used to provide useful information for our daily lives, namely, time and orientation, and also how simple materials can be used to build astronomical instruments.

The sundial is built using a pre-cut piece of cardboard which has to be assembled and glued (Figure 2), while the astrolabe is built according to a technique described online[11].

Presentation of undergraduate and graduate astronomy programmes

As one of the main goals of this programme is to increase the number of students enrolling in undergraduate and graduate programmes in astronomy, at the end of the week we present them with the options available at the University of Porto. This presentation is led by the director of the astronomy undergraduate degree who also discusses the employment and career options for people with academic degrees in the field of astronomy.

The programme ends with two shows inside Porto Planetarium, one on dark matter and the other on the origins of life.

Evaluating the course

At the end of the week, just before the planetarium shows, each student completes a questionnaire to evaluate this programme. From 2016 students will also fill out an additional questionnaire on the first day to provide a baseline and allow for better evaluation of the programme's effects. The questionnaires are filled in anonymously and the students' comments over three years have led to several changes to the global organisation of the programme (described below) and in the theoretical lectures and experimental activities themselves. However, another important goal of these surveys is to understand if the activities have actually had any influence on the willingness of the students to enrol in undergraduate studies in astronomy.

All the students who participated in this programme — 89 over the three years the activity was held — were required to fill in the questionnaire on the last day of the activity. The number of students is higher than the maximum number of students officially allowed to attend a *Junior University* course (sixteen) as high demand has led to an increase in available vacancies for *Astronomy: from concepts to practice*. The average rating students gave to this programme was 4.57 on a 5-point scale.

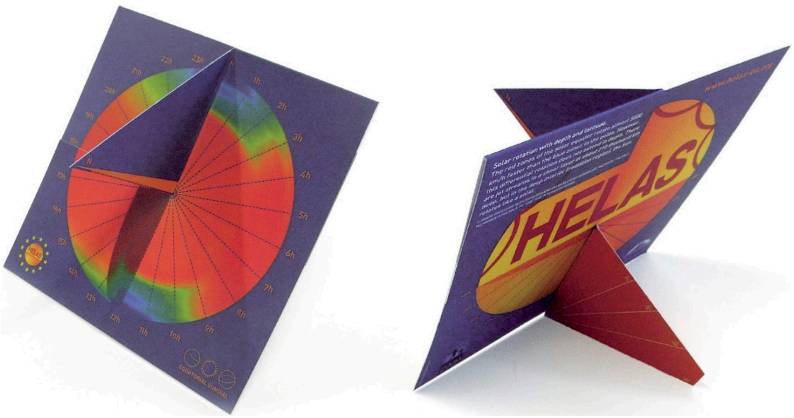

Figure 2. *Sundials built by the students during the last day of the programme. Credit: Paulo Pereira*

Effect on uptake and interest in astronomy

Analysing the survey results we have found that, of the students who attended the programme over three years, 43.8% had just finished a school year spanning ages fourteen to fifteen. In comparison, 38.2% had just finished a school year spanning ages fifteen to sixteen and only 18.0% had finished a school year spanning ages sixteen to seventeen.

Students were questioned about how this activity had changed their view of astronomy and if their perceived likelihood of applying for an astronomy undergraduate degree had changed. The results are shown in Figures 3 and 4. The percentage of students who stated that this activity had increased a lot or increased somewhat how much they like astronomy is remarkable (80.9%) and only one student over the three years said it had actually decreased his interest. Over 70% of participants reported that the effect of our programme had increased their perceived likelihood of enrolling in the astronomy degree, while this likelihood remained the same for 27% of the students and decreased somewhat for just 2.2% of students. However, it is not yet known if these effects are sustained over time and if students actually end up enrolling in the astronomy degree, as only a small number of those who participated in this programme have finished high school and applied to university-level degrees. So far, only eleven of our students have applied to university-level education; of these, four enrolled

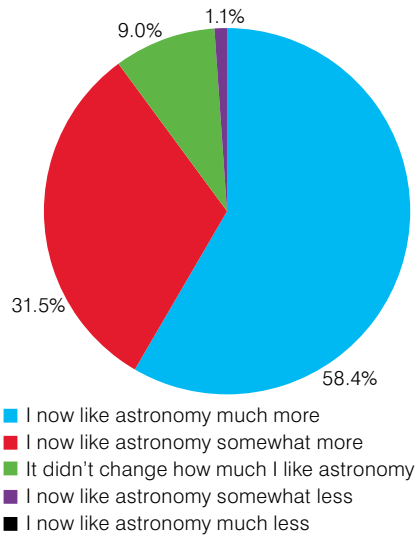

Figure 3. *Answers to the question "How did this programme change how much you like astronomy?" from surveys over three years.*

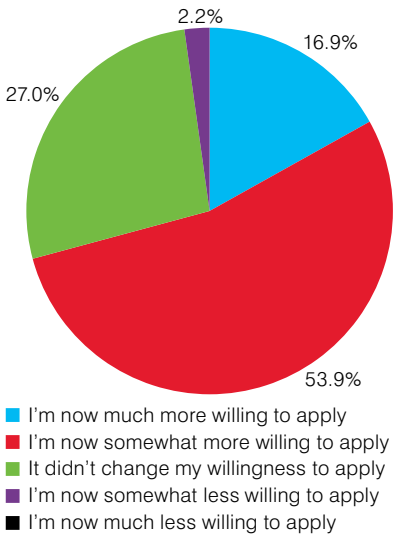

Figure 4. *Answers to the question "How did this programme change your willingness to apply to the astronomy degree?" from surveys over three years.*

in non-scientific degrees, two enrolled in aerospace engineering at another university, two enrolled in physics at another university and three enrolled in the physics degree at the University of Porto. It should be noted that one of the measures taken by the University to ensure the continuity of the astronomy training programmes was to merge the astronomy degree into the physics degree as an option available for students to choose in their last year. Thus, our students have been informed they should opt for the physics degree at the University of Porto when seeking a career in astronomy.

Updates to the course based on feedback

In the questionnaire, students were asked about the experimental activities and lectures and about several organisational aspects of the programme.

The results have led the author to implement several changes over the years. The cosmology lecture was replaced by a simpler version: it became essentially descriptive, with a very limited quantitative content, as the original version was deemed by the students to be too hard to grasp.

The extragalactic astronomy lecture was somewhat refocused towards galaxies, with just a couple of minutes dedicated to the large-scale structure of the Universe and it was also changed to present a more detailed description of Sagittarius A*, the central black hole in the Milky Way.

The lectures of the first two days were reorganised to allow a chapter devoted to star formation, evolution and death.

Regarding changes in experimental activities, the optics experiment was simplified, as it originally included a protocol for critical angle estimation that was not easily understood by the students. Two new activities were also developed and added, after the first year, to reduce downtime, as the author realised some activities took less time than expected.

Conclusion

This programme seems, based on evaluation so far, to provide a major boost to most students' willingness to apply for the astronomy degree and to improve their opinions about astronomy. The high rating the programme received (4.57/5) also shows that it meets or perhaps even surpasses the students' expectations.

This activity will be offered once again to students next summer for two weeks, with minor rearrangements to theoretical lessons and with a programming activity replacing the one using the torsion balance. The author expects to keep applying further changes to the programme in the following years according to the future feedback given by the students and the author's opinion of what could be improved in the different lectures and experimental activities.

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Notes

1 Webpage of the 2016 edition of Dia da Astronomia, in Portuguese, available at: http://www.astro.up.pt/formacao/index.php?WID=361&CID=17&Lang=pt

2 Webpage of the Show of Porto University in which CAUP participates, in Portuguese, available at: http://www.mostra.up.pt/

3 Porto Planetarium hands-on laboratories, in Portuguese, available at: http://planetario.up.pt/planetario/laboratorios.html

4 Detecting Extrasolar Planets (2007), available at: http://kepler.nasa.gov//files/mws/DetectingTransitsSSSmsGEMS.pdf

5 Bertone, S. and Melchior, A. L. 2011, Astronomy with SalsaJ — Discover an exoplanet: the transit method. Available at: http://www.euhou.net/index.php/exercises-mainmenu-13/astronomy-with-salsaj-mainmenu-185/269-discover-an-exoplanet-v15-269

6 Paul Doherty, Solar Brightness, available at: http://www.exploratorium.edu/wsw/progress_snacks/solar_brightness/

7 Teacher Guide, Activity 4: Rotation Period of the Sun (1999). Available at: http://www.spaceweathercenter.org/resources/05/solarscapes/Act4t.pdf

8 Levay, Z. *Create your own Color Hubble Images*. Available at: http://hubblesource.stsci.edu/services/articles/2005-02-10/

9 Walker, J. 1997, *Bending spacetime in the basement*. Available at: http://www.fourmilab.ch/gravitation/foobar

10 Dabrowski, J. P. et al. *Jupiter's Moons and the Speed of Light*. Project CLEA, Gettysburg College. Available at: http://www3.gettysburg.edu/~marschal/clea/roemerlab.html

11 The Editors of Publications International Ltd. *Science projects for kids: The Incredible Universe — Make an astrolabe*. Available at: http://lifestyle.howstuffworks.com/crafts/other-arts-crafts/science-projects-for-kids-the-incredible-universe6.htm

References

Ferreira Gomes, J. 2007, *Universidade Júnior*, a project to motivate school pupils, Proc. International Conference on Engineering and Computer Education, ed. Brito, C. R. et al., 199, available at: http://www.fc.up.pt/pessoas/jfgomes/documentos/documentos/Universidade%20Junior,%20a%20project%20to%20motivate%20school%20pupils%20-%20JF%20Gomes.pdf

Marques, J. & Restivo, M. 2010, *Working with young people at the University of Porto*, Proc. Joint International IGIP-SEFI Annual Conference 2010, available at: www.sefi.be/wp-content/papers2010/papers/2394.pdf

Mondim, P. et al. 2014, CAPjournal, 15, 28, available at: http://www.capjournal.org/issues/15/15_28.pdf

Biography

Pedro Mondim works at the Centro de Astrofísica da Universidade do Porto (CAUP), the association that manages the Planetário do Porto — Centro Ciência Viva and is the host institution for the Instituto de Astrofísica e Ciências do Espaço. He 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. He previously worked as a trader in investment banking, while finishing his Masters degree in astronomy, and is currently finishing a medical degree.