Finestres al cel

Laia Casamiquela[*1], *Víctor Moreno de la Cita*[*2], *Ignasi Pérez-Ràfols*[*3], *Santi Roca-Fabrega*[*4]

Abstract
We present an astronomy educational project intended for 16-year-old high school students that has been successfully deployed for 7 years under the Youth and Science Program of the Catalunya La Pedrera Foundation. The Youth and Science Program aims to encourage talented students to pursue careers in science and technology and a future as researchers. It consists of a two-week crash course covering all major topics in astronomy: stellar evolution, black holes, galaxy formation and evolution, cosmology, simulations, and gravitational waves, among many others. The classes focus on the relevant concepts in each of the aforementioned fields but without a detailed description of the math formalism or the most advanced concepts in modern physics, this to develop the students' intuition and interest in the wonders of the Universe without overwhelming them. Theoretical sessions are complemented with a set of practical sessions that help students to consolidate the concepts. All theory and practical sessions in this project are being compiled in an outreach book addressed not only to the students of this project but also to the entire amateur astronomy community.

Keywords
Astronomy course, High school, Observations, Practical sessions

[*] Authors sorted alphabetically, all contributed equally to the project
[1] Corresponding author: GEPI, Observatoire de Paris, PSL Research University, CNRS, Sorbonne Paris Cité, 5 place Jules Janssen, 92190 Meudon, France, laiacafl6@gmail.com
[2] Departament de Física Quàntica i Astrofísica, Institut de Ciències del Cosmos (ICCUB), Universitat de Barcelona (IEEC-UB), Martí i Franquès 1, 08028, Barcelona, Spain
[3] Institut de Física d'Altes Energies, The Barcelona Institute of Science and Technology, Campus UAB, 08193 Bellaterra (Barcelona), Spain
[4] Instituto de Partículas y Cosmología, Departamento de Física de la Tierra y Astrofísica, Facultad de Ciencias Físicas, Universidad Complutense de Madrid, Plaza de las Ciencias, s/n, 28040, Madrid

1. Introduction

Humans have looked up to the night sky since very early times. Indeed, the ancient Greek society already had a common widespread knowledge about the sky. Proof of this is the usage of constellations in the Iliad or the Odyssey to illustrate the directions of the hero's travels. More recently, in modern society, iconic figures such as Carl Sagan and Stephen Hawking have also instilled a widespread interest in astronomy. This has been supported by an extensive set of science fiction literature and filmography. Examples of the later are *Contact* or, more recently, *Interestellar* or *Don't Look Up*.

Nowadays, this interest in astronomy continues to grow, remarkably among young people [1,2]. As a direct consequence, we have seen the emergence of several outreach accounts in the social media with millions of subscribers that discuss science in general and astronomy in particular. Examples of such accounts are Quantumfracture (2.88M subscribers) or C de Ciencia (1.45 M subscribers). This growing interest is accompanied by a political will to disseminate the knowledge acquired by researchers, who are encouraged to increase their outreach activities. Indeed, most research grants now give merits to outreach activities (e.g., ERC programs[5]).

However, knowledge does not always flow from scientists to the general public but sometimes it flows both ways. This is known as citizen science and is widespread in astronomy. Leading the citizen science is the Zooniverse project[6] which originated from the GalaxyZoo project of the Sloan Digital Sky Survey Collaboration [3,4] and has now many publications[7]. Astronomy is particularly well suited for citizen science as there are numerous amateur societies whose members often have high-grade astronomical equipment (telescopes, CCD cameras, ...). Professional-Amateur Collaborations are encouraged by entities such as the Spanish Astronomical Society[8]. Amongst other activities they have the award Premio Javier Gorosabel de Colaboración ProAm en Astrofísica[9].

Despite all this, very little astronomy is taught as general education (elementary and high school), and young people often have to look for it elsewhere. For example, the Catalan curriculum [5] only includes one unit about "The Universe and the Solar System", in 1st of ESO (12-year-olds). This is within the "Biology and Geology" subject, often taught by by teachers withoun an background in astronomy and astrophysicss. Other than that, only the students that choose to study a scientific the scientific path at high school get to learn about Newton laws of gravity. Our project, Finestres al Cel, intends to cover this gap.

This paper is organized as follows. In section 2 we present the Youth and Science program, the framework we have used to deploy our project. The project itself is later presented in section 3, followed by a discussion on our ideas for the evolution of this project (section 4). Finally, we conclude in section 5.

2. Youth and Science program

Youth and Science is a program of excellence intended for 4th ESO students, which aims at fostering scientific and technological vocations among young people. For three years, selected students have the opportunity to experience research firsthand, both locally and internationally.

Figure 1. Long and short exposure composite of an observing night in MónNatura Pirineus. This shot was taken in the first observing night of the 2018 stay, in which the students are getting in contact with a telescope for the first time. The main telescope's dome is partially hidden behind a tree. Credit: V. M. de la Cita

During the first year, fifty selected students have the opportunity to have a unique experience and participate in a science research project at

[5] https://erc.europa.eu/
[6] https://www.zooniverse.org/
[7] https://www.zooniverse.org/about/publications
[8] https://www.sea-astronomia.es/
[9] https://www.sea-astronomia.es/premio-javier-gorosabel

MónNatura Pirineus[10] (figure 1). Each year the program offers five projects in different areas of science (physics, biology, chemistry...) designed by a team of expert scientists. 50 boys and girls from all over Catalonia are chosen in each edition to participate in this summer scientific camp. A total of ten students per project are chosen.

The Youth and Science Program does not end with the scientific stays at MónNatura Pirineus but continues for another two years with the research center stays and the international research stays. The goal of these two phases is to continue exposing students to science through a stay either at a research center or with an international science program.

The purpose of the second phase is for each student to join a research team in a scientific laboratory where they can work hand by hand with researchers and in international research groups. This phase also includes a unique option of international research stays with places reserved at prestigious science programs for students in the Youth and Science Program (such as the Research Science Institute at the Massachusetts Institute of Technology).

In order to participate in the second phase of the program, students have to write a scholarly article in the first quarter of the academic year immediately following the end of the first phase. The quality of this article will be a determining factor in securing a place in the next phase of the program.

In the final phase of the program, students should work on their own to find a research project to conduct during the summer after their 2nd year of baccalaureate. The purpose of this phase is for the students themselves to look for a research project on which to work that matches their preferences and scientific interests.

This program has been running yearly since 2008, and it is currently a reference in Catalonia, and students, teachers and schools alike look up to get involved with it, given its proven importance in developing young scientific careers. Due to its extensive trajectory, the number of former participants is large and they have created a network to keep in contact and build scientific relations, known as La Pedrera Science Academy Fellows[11].

3. The project: Finestres al cel

Finestres al cel (FCel) has been selected for seven years to be the astronomy and astrophysics project in the Youth and Science program. We, the authors of this paper, have led the FCel project since it started back in 2015. When we presented the first version of FCel we all were still Ph.D. students and the project was just a proof of concept. It worked well and got good reviews from the participants and the organizer; thus, the project was selected for a second year. From this second year onwards, we took advantage of both the insight we got from the previous versions and our increasing skills on teaching astronomy in the University or other educational centres to improve the project. An example of this increasing teaching skills by the leaders of the project is that two of us got the master of teacher formation (for middle and high school), and one of us is currently a science teacher in a high school.

As we mentioned before, this has been a successful project that in the last six years helped more than 60 students to find out if astronomy may become their vocation. One of the success' keys of the project is that we, the leaders, have an extensive, complementary and diverse background in the astrophysics fields and also a broad experience in outreach and educational activities in Spain and abroad.

After six years of feedback from the students, the organizers of the program, and from our own experiences, the project has evolved greatly. Unexpected difficulties and situations with the weather conditions that limited our practical lessons, and also with the material to be used, helped us to build a solid project with many alternative activities and lectures. The current version includes a large variety of activities, both in-class and practical exercises, that make use of many materials that are in general easy to get by amateur astronomy organization and high-schools. As a consequence, the program not only allows students to get a complete view of the current astronomical research but also to continue small research projects on their own.

Furthermore, the project is always under revision and change. In particular, we continuously update the activities to include unexpected and unique astronomical events

[10] https://monnaturapirineus.com/

[11] https://www.fundaciocatalunya-lapedrera.com/en/pedrera-science-academy-fellows

that become hot-topics in the public media. For instance, when the project started the gravitational wave astrophysics was only a theoretical idea; this changed after the first direct observation of gravitational waves in 2016 [6], when this became new field of experimental astrophysics. We are currently teaching this new field in our lectures as one of the important sources of information about the evolution of the universe, and we also invite experts on the subject to help us with teaching the details on this subject.

Aside of revising the project yearly, the project is very flexible to adapt for unexpected events. For example, the eleven year solar cycle forces us to include or remove from our program activities related with solar activity depending on the Sun's evolution. Other examples include the discovery of new comets or of observable supernovae.

Finally, in the last years we also incorporated new instrumentation we use to allow students learn about new fields in astrophysics, this is the case of the analysis of stellar spectra using a spectrograph (see figure 2).

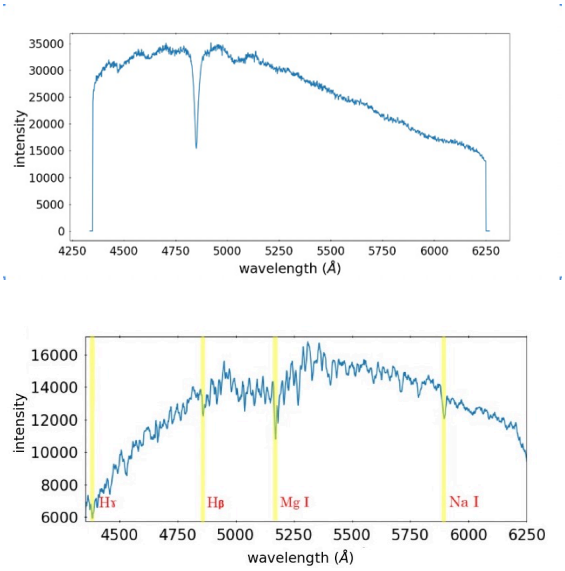

Figure 2. Two examples of spectra captured by the students with the program equipment. The spectrum in the top panel corresponds to Vega, an A-type star with few absorption lines. The spectrum in the bottom panel corresponds to Arcturus, a bright K-type star, much richer in absorption lines. The students highlighted the absorption lines that were able to identify. Credit: Joves i Ciència 2021

With respect to the educational plan within FCel, we moved from a traditional system to a new and modern educative model that is projects based. This was possible thanks to our new skills and the resources we gained when studying the education master and working in high-schools. In this new project, that is an evolution of FCel, we choose the object M13 as the central element of the whole educative event. M13 is a globular cluster visible from the Pyrenees' dark skies in summer that due to its complex nature immediately brings on questions related to many fields in astrophysics.

For instance, M13 allows us to talk about how can we make basic observations of single stars, how the galaxies form and evolve, and how simulations can help us to better understand the formation of stellar groups, among many others. Following the project-based educative model, we adapt our activities to the interests of our students while conducting them all the way through the many topics in the modern astrophysics.

4. Discussion

4.1. Reaching a wider audience

The success of our project in the last six years has encouraged us to expand the potential impact of our work to a wider audience. Our main goal now is to satisfy the need for knowledge about astrophysics that part of our society can have, in particular, high-school students and amateur astronomers. Therefore, we will create and publish a reference book based on the content of the FCel project.

It will include both theoretical and practical content, well beyond the typical outreach books: we want it to be an initial astrophysics course. It will also contain rigorous and up-to-date content on a wide range of astrophysics topics, including discussions on the newest hot-topics in research. In this book we aim to communicate with a plain language and emphasizing the points at which the scientific community is still working to understand.

Regarding the practical exercises, these will exemplify the concepts covered in the theoretical part and will be presented in plain language and with precise instructions for reproduction. Most of them will be reproducible using materials available in many centers of secondary and higher education, and that are easily owned by amateur astronomers. They may be used in the future as basis for work in high school science classes or high school research works. Moreover, the book will also include more specific topics and practices that require more specialized instrumentation.

These will be of interest to students with an advanced level in science and can encourage them to contact with amateur astronomy

centers and associations to access their instruments. They will do the same for the amateur astrophysics' community, which often lacks of ideas to take full advantage of the instruments they have. This book will also encourage collaborations between professional and amateur astronomers.

In conclusion, this material will allow the readers to think about questions such as "Is the universe infinite? Is there life on other planets? How do stars form?", mainly providing tools and objective information so that they can respond themselves.

To our knowledge, there is currently no such book available. Thus, as mentioned above, we aim at filling the gap between outreach materials for the general public (usually very superficial in content), and astrophysics text books (usually too advanced).

4.2. An outreach book on general astrophysics

In the last years we worked in a summary of the FCel theoretical and practical exercises, and this has become the skeleton of the book. Summarizing, its structure will be the following:

- **First part:** Modern astrophysics from the solar system to the Universe's large scale from a theoretical point of view. We initiate this part with by introducing the basic concepts in astrophysics and observational astronomy that are necessary to understand both the theory and the proposed practices. This includes the coordinate systems and transformations, the types of telescopes and the detectors. After this very first introduction we explain concepts that are related with the structure, formation and evolution of stars and black holes. Later we move to the formation of planetary systems, in particular the Solar system, but also to a more general view of planetary systems in other stars, i.e., exoplanets, and we also show how can we detect them. The exoplanets topic allows us to introduce and talk about another recent field in astrophysics that is the astrobiology. In the next sections we focus on the wide field of formation and evolution of galaxies and of the Universe itself (cosmology). In relation with the extreme environments that accompany the first instants of the universe and also several star formation and evolution processes, we also teach high energy and gravitational waves astrophysics, two relatively new fields. Finally, we dedicate a section to the description and use of simulations in astrophysics, a topic not well known to the general public and which has great importance and applications in current research.
- **Second part:** In this second part we give the details on the hands-on experiments and practices. This part includes all the activities we designed to settle the theory knowledge we give in the first part of the book. We include the following practices: (1) measurement of the Earth radius using the method use by Eratosthenes, (2) experimentation with distance scales, (3) validation of Titius-Bode's empirical law, (4) photometry of an open cluster, (5) stellar spectroscopy, (6) observation star forming regions, (7) construction of a cloud chamber to detect muons, (8) generation and analysis of an N-body simulation. These are eight hands-on exercises that are related to most of the topics described in the theoretical part, and which can be mostly undertook using accessible materials by high-schools and amateur astronomy associations. Some of them only need rudimentary materials (level, protractor) (1, 2 and 7). Others need a computer and access to public databases (3) or codes that we have designed ourselves and are available on public repositories (3 and 8). And others involve the use of more sophisticated instruments, such as telescopes, specialized cameras and spectrographs (4, 5 and 6). In this book we will also sort and group the practical sessions according to the necessary material and/or its increasing difficulty.

5. Conclusions

Our work within the Youth and Science program has been, on one hand, a constant source of motivation towards education of science; and on the other hand, a playground to test different ideas and proofs of concept. We have discovered which educational experiences work, which doesn't, and how to best present the different concepts of astronomy of our interest and knowledge. This has been done by intensively revising and evaluating the results of our educational activity. The current FCel project and its structure, captured in the outreach book, is the result of years of experience and iteration between four passionate astronomy teachers, 60 students and a supportive group of professionals from La Pedrera foundation.

Every year the stay in the MónNatura educational center surprises us with new challenges. Each generation of students strikes our methods and test our ideas in ways we have not foreseen. This interaction between trainers and trainees and the constant evaluation of the

results and impact of our activity is what keeps the project up-to-date and in constant evolution. Therefore, it is easy to foresee that in the future this project will require of new changes on its methodology, and will incorporate new practical sessions and probably new fields in astronomy yet to be discovered.

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