PROCEEDINGS OF SCIENCE

A riddle to solve Centaurus A: learning about Gamma Rays

Anna Wolter,[a,*] **Valentina La Parola,**[b] **Laura Paganini,**[a] **Adamantia Paizis,**[c] **Antonino La Barbera,**[b] **Giuseppe Fiasconaro**[b] **and Martina Cardillo**[d] **for the INDACO collaboration**

[a] *INAF - Osservatorio Astronomico di Brera, Via Brera 28, 20133 MILANO, Italy*
[b] *INAF - Istituto di Astrofisica Spaziale e Fisica Cosmica, Via Ugo la Malfa, 153, 90146 Palermo, Italy*
[c] *INAF - Istituto di Astrofisica Spaziale e Fisica Cosmica, Via A. Corti 12, 20133 Milano, Italy*
[d] *INAF - Istituto di Astrofisica e Planetologia Spaziali Tor Vergata Via del Fosso del Cavaliere, 100 - 00133 Roma, Italy*

E-mail: anna.wolter@inaf.it

The paramount importance of studying very high-energy (VHE) astronomical phenomena is straightforward for the scientific community. Conversely, it might be difficult, for both the general public and school students, to grasp how much information can be encoded in electromagnetic emission invisible to our eyes. On the other hand, it is fascinating to describe how our Earth's atmosphere can be exploited as an instrument to intercept the highest energy photons that can be studied today, via the Cherenkov emission of particle showers. To this aim, a dedicated group has been established within the Italian Istituto Nazionale di Astrofisica (INAF) since 2020, in order to foster Public Engagement for two Cherenkov Telescope projects: ASTRI, an INAF-led project, and CTAO, an international observatory in which INAF is a major contributor. The group, known as INDACO (INaf for the Dissemination of Astri and Cta Observatory), has a vast repertoire of activities. We will focus here on a case study: a laboratory dedicated to primary and middle school pupils based on "learning-by-doing" and "education through play". The game consists in reconstructing the multi-wavelength image of the well-studied active galaxy Centaurus A by solving challenges and riddles in order to gain the additional information and material. By playing with the different emission bands, the role of the VHE one becomes clearer. We present the design of the activity, together with feedback and lessons learned of this pilot project. We extrapolate our experience to the fields of outreach in the astrophysics of the invisible Universe.

38th International Cosmic Ray Conference (ICRC2023)
26 July - 3 August, 2023
Nagoya, Japan

*Speaker

PoS(ICRC2023)1608

1. Introduction - Key points for outreach

Outreach and dissemination are crucial ingredients of modern science. Not only, in fact, most researches are conducted thanks to public investments, but also a scientific citizenship is necessary to make people aware of the rapidly changing state of the art of discoveries, allowing the social community to live responsibly in our world. Many different specific aims can be envisaged, especially for large projects that might involve several stakeholders and many categories of public. However, many outstanding nodes for communication are inherent to the project and do not depend on the specific task/target. We will review here a few of the main intricacies of the Very High Energy Astrophysics (VHE) dissemination and describe how we, as INDACO group, have started tackling them.

- **VHE sources**

  One of the challenges is to be able to explain in a simple way how the most powerful sources in the Universe work, and if they are really able to accelerate particles. We are also telling a story about Cosmic Rays, which are not "rays" at all, and sometime make up the noise of our observation. Of course we talk about black holes and supernova remnant, which are somewhat known, but also about more exotic names as Gamma-ray binaries or Pulsar Wind Nebulae and the role of all these sources as PeVatrons.

- **The atmosphere**

  One nice twist is the harmless exploitation of our atmosphere, which is instrumental for the survival of most species on Earth, and often subject of "green" campaigns for conservation. We can proudly explain that the terrestrial atmosphere is actually the largest detector we can use in Astronomy: this is the place where very energetic photons from celestial sources are traced via a transformation that goes from an incoming photon of wavelength a thousandth of the size of an hydrogen nucleus, to a detectable light of wavelength 3 thousand billions (3×10^{12}) times larger, that we can collect with a relatively simple optical telescope.

- **Cherenkov Light**

  The production of blue-UV light from the Cherenkov phenomenon is exploited by ground based Imaging Atmospheric Cherenkov Telescopes (IACTs) since many decades. However, upcoming projects like the ASTRI Mini-Array and the CTAO are going a step beyond, making this science available to a larger audience of scientists, not all experts of the field. Also, the sensitivity of the instruments will open up a large discovery space, and a larger fraction of the public will be interested in the specific results and in the technology that allowed them. We are confronted therefore with tasks like explaining why particles in the atmosphere can move faster than light (not everyone will listen to the "in a medium" part of the sentence), and why we need an optical telescope to look at the most energetic part of the celestial sources' emission spectrum.

2. INDACO

The INDACO group (acronym of "INAF per la Divulgazione di ASTRI e CTA Observatory") was born in 2020 as an INAF outreach group to serve as reference for the ASTRI Mini-Array project[1] and for the INAF participation to the international project CTAO[2].

Figure 1: The logo of the INDACO group

Our logo is shown in Figure 1. About 15 people, mostly on a voluntary basis, participate in regular online meetings, in which the various activities are selected, discussed, and verified during and after their realization. Smaller groups of interested parties work on specific tasks. Our main aim is to make INAF known as an actor in the TeV community, by telling the "TeV science" to different publics, both from the scientific and technological point of view. Presenting the people who work on the projects with different tasks, e.g. not only astronomy but also engineering, electronics, information and communication technology (ICT), and so on, will give an overview of the diverse capacities necessary to a large project and possibly stimulate participation in STEM (which stands for: science, technology, engineering and mathematics) studies in the new generations.

Up to now, we have decided to target mainly students, from the primary and secondary levels, with the possibility of opening to Universities in the future. To this end, we have participated to a number of Science Festivals proposing different laboratories with hands-on activities. For the involvement of a larger public, participation to conferences, events and congresses is targeted to both the general public and interested scientists, but also to the community of outreach officers. Last but not least, we are working on social media campaigns to bring interest on our activities and traffic to the websites of the projects.

A comprehensive description of our work in the first two years of INDACO is presented in [1], albeit in Italian only.

In the future we will have a novel opportunity to address other fields like innovative technologies (Augmented Reality and Virtual Reality) or a dedicated theatrical play, also thanks to PNRR[3] fundings.

[1] ASTRI means Astrofisica con Specchi a Tecnologia replicante Italiana; more information in the website: http://www.astri.inaf.it

[2] Cherenkov Telescope Array Observatory; more information in the website: https://www.cta-observatory.org

[3] Piano Nazionale di Ripresa e Resilienza; proposal PNRR IR0000012 – CTA+

Figure 2: Everything is read to start!

3. A case study: a laboratory for primary and middle school

Astronomy is attractive and fascinating: it has the great advantage of beautiful images that both inspire awe, wonder and enthusiasm, and portray the Universe as a fascinating place worthy of exploration.

Images represent a language that can speak to young pupils with immediacy. Every different energy band has its peculiarities which are mainly based on the kind of instrument that we use to see that particular light, and therefore ultimately on the physical/chemical interaction a given (color of) light has with different materials.

With this in mind, in 2022 we presented a laboratory to the "Festival della Scienza" in Genova (one of the largest European Science Festivals) under the general theme of "Languages" (see Figure 2 for the location, ready to welcome the classes). The aim was to explain how different wavebands convey different information about an astronomical source, and how only by looking at all of them together can one see the complete picture. Every different "color" of light speaks its own language: we can learn to understand them all. Our aim is also to bring to the notice of new audiences the relatively new observational window of the very high energies and the work we are doing with Cherenkov Telescopes. Before the presentation to the Festival, a pilot version of the project had been tested in a selected school in order to tune the activity to the audience.

The main aim was to involve students by entertaining them, making them work with their own hands on a small project that required a few simple quests, in order to pave the way for all the different typical emission of a celestial source to bring them ultimately to know about the ASTRI

Figure 3: *Left*: Infrared testing with a IR camera; *Right*: The three wonderful Student Animators: Mattia Sotgia, Amira Eldomiaty, Olindo Bonifazi.

Figure 4: Boxes with material

Mini-Array project lead by INAF, and about IACTs in general. We describe briefly the setup and the outcome.

We decided to base our laboratory on four different images of the same (active) galaxy, each of them holding a different secret. To "earn" the image with information, each team had to solve a simple puzzle, linked to the wavelength in use. For instance, to win the Infrared card, the players had to use an Infrared camera with which they could observe a hidden number indicating where the next clue was (see Figure 3 *Left*). The hints and the construction material were held in different boxes (see Figure 4).

The hunting activity lasted about an hour for each round (see Figure 5). When all the clues where solved, and all the boxes emptied, each group had the material to reconstruct the galaxy appearance and to learn more about the different wave-bands (see Figure 6 for an example of the radio card). To guide the participants through the experience there were three facilitators, chosen and instructed by the Festival organizers amongst interested University students, whom we had met to give them the material for an introductory part and explanations for carrying out the hands-on laboratory. Daily sessions, devoted to classes in the mornings and to free participation of families

Figure 5: Various phases of the work done by the students

in the afternoons, took place for the entire duration of the festival, namely from October 20th to November 2nd 2022. The total attendance reached nearly 2.000 participants from both primary and middle high-schools.

We published a dedicated article [2], describing the activity and gauging the outcome of the laboratory in the online INAF magazine, devoted to Education: EduINAF. The activity has also been presented to the a symposium dedicated to Communicating science through Art at the European Astronomical Society annual meeting [3].

Feedback was collected through small post-it notes, where the participants could write their opinions and feelings on the activity (see an example in Figure 7). The response has been generally enthusiastic, especially as regards the several riddles and the need to complete one level in order to move to the next one, which inevitably grew into lively team work and competition among groups.

We also kept in close contact with the Student Animators who brought the activity to life for the participants and who gave us very useful feedback. Mainly: the fact that some activities were a

Figure 6: Example of recto and verso of the High Energy card, that shows also the ASTRI telescope.

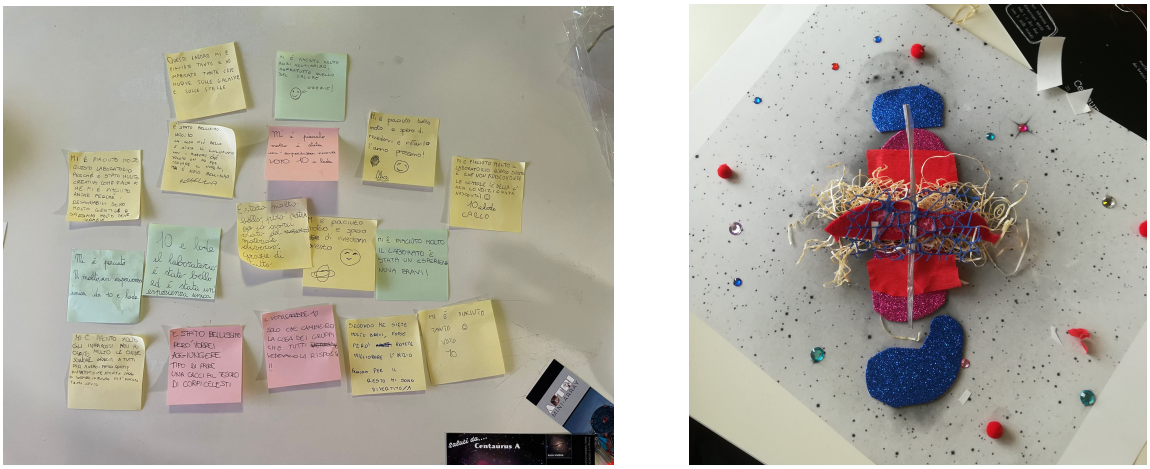

Figure 7: *Left*: A few samples of the feedback from the participants: from "I have learned a lot about stars" and "The Animators were wonderful" to "I want to come back again next year! But give us more diversified material...". *Right*: An example of the reconstructed Cen A.

little too difficult for the youngest pupils, who nevertheless engaged and enjoyed the game with just some extra help from the tutors (see Fig 3 *Right*). For more grown-up pupils (middle school), the conclusive part (i.e. the actual building of their own Centaurus A galaxy) was the least appreciated one. A lesson learnt is that the game is apt also for older student, but a different activity should be envisaged as a conclusion, possibly including computer assisted games or activities.

4. Conclusions

The laboratory aims to teach how to observe from different points of view, a useful skill not only in science but also in all multicultural contexts. Collaboration and dialogue are stimulated and manual skills are exploited to share the scientific context (learning-by-doing). The laboratory allowed participants to discover the existence of an invisible Universe and showed that the only way to understand it in its entirety is to gather all the information available (whether from different lights,

matter or other channels), without prejudices or pre-selections. The puzzles pushed the participants to share their personal experiences and knowledge which, however, are not enough by themselves, but need to be completed with those of others. The prize is to see the Centaurus A galaxy in its entirety. Each language has a content that deserves to be discovered, in an experience of sharing and inclusion.

As regards the high energy domain of Astrophysics, and especially the very high energies gamma ray band, we showed also that some information (images) is less detailed than others, because our current detection techniques are less developed. The aims of this laboratory are valid in many different context, and they naturally foster an important step forward within the collaborations of ASTRI Mini-Array and CTAO.

In summary, Astronomy is precious to favor critical thinking, to foster curiosity, to learn to work in a group, and especially to enjoy doing it! The gist is to associate a smile to research, because emotions last longer than notions.

Acknowledgments

The INDACO group acknowledges financial support by INAF. This work was conducted in the context of the ASTRI Mini-Array Project. We gratefully acknowledge support from the people, agencies, and organisations listed here: http://www.astri.inaf.it/en/library/. This work was conducted in the context of the CTAO project. We gratefully acknowledge support from the people, agencies, and organisations listed in the site https://www.cta-observatory.org/.

This paper went through the internal ASTRI and CTAO review processes.

References

[1] [Wolter, A. et al. 2023] *Gruppo INDACO: Report della divulgazione per i progetti ASTRI e CTA - Anni 2021-2022* INAF Technical Report https://doi.org/10.20371/INAF/TechRep/276

[2] [La Parola, V. et al. 2023] *Alla scoperta dei linguaggi dell'Universo* https://edu.inaf.it/approfondimenti/insegnare-astronomia/festival-scienza-2022-laboratorio-centaurus-a/

[3] [La Parola, V. et al. 2023] *When science meets art, a galaxy is born - Multiwavelength astronomy for kids* (No. 1469) at EAS Meeting, Krakow, 10-14 Jul 2023 SS39a : Sci-Art: Communicating Science Through Art https://k-poster.kuoni-congress.info/eas-2023/gallery#/poster/01f1619e-6cb2-4246-bb22-01d4d966be90