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An engaging solution for the outreach of cosmic-rays science? The innovative “Flashes” web-game!

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Introducing cosmic-ray science to the general public is a challenging task. In particular, the operating principles of Imaging Atmospheric Cherenkov Telescopes (IACTs) may result confusing and puzzling to students who wonder why these huge optical instruments cannot take beautiful images of astronomical sources. To overcome this issue and learn about IACT astronomy, we propose an innovative solution which is particularly modern and engaging: “Flashes”, an educational game on a web application developed ad-hoc by the cultural association PhysicalPub. “Flashes” is based on the physics behind the Cherenkov technique. Atmospheric flashes recorded by IACTs have different shapes depending on their source: hadron, gamma, muon or “else” (car flashes, sky background, electronic noise, and others). In our game, the player is presented with Cherenkov images from real scientific data and simulations, and must classify them according to their origin, trying to mimic the real image discrimination analysis. The game is divided into several sessions, each dedicated to one IACT among the main ones currently in operation: ASTRI-Horn, MAGIC, and LST-1 (Large-Sized Telescope prototype for the CTAO). In every session, the player has one minute to recognize the highest number of images and get the highest score. Several topics related to science education are involved, such as critical thinking, artificial intelligence, and uncertainty of science. “Flashes” supports multiple-player sessions and includes an introduction that educators may use for preparatory explanations. “Flashes” is accessible using a URL from any internet-connected personal device. It is completely free and does not require any account.

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1. Introduction

Outreach initiatives are important events for the general public, but also for the scientific community. While the social and cultural importance of these initiatives is well known, they are often surprisingly useful also for researchers themselves, forcing them to make a summary of their studies in a form that must be clear enough to be communicated to outsiders. In Italy there is a cultural association dedicated exactly to the realization of such events, focused on science communication and dissemination. Its name is PhysicalPub[1] and it collaborates with universities, research institutes, and other cultural institutions. PhysicalPub is entirely composed of volunteers and its associates include scientists, teachers, and several amateur astronomers and photographers. Thanks to the mix of very different backgrounds and skills, PhysicalPub realized in the past very complex events, managing several aspects, from the scientific content to graphics and communication, but also the most technical issues related to information technology and programming. The topics involved span different fields, as for example astrophotography [2], planetary formation [3], astronomical navigation [9], the large scale structure [13], and others. Recently, a new project was conceived and developed by this association, the realization of a web game with the purpose of communicating the science of Imaging Atmospheric Cherenkov Telescopes (IACTs), a fascinating field of astronomy which is unknown by the most of the public. Thanks to the collaboration with scientists of the three main IACTs currently in operation, (ASTRI [5, 6], MAGIC [4], and the CTAO [8]), this project is characterized by an unprecedented accuracy in the scientific content together with an excellent usability and a modern aspect, thanks to the smart hosting platform developed. Moreover, a peculiar characteristics makes this game still more unique and interesting, it is based on real scientific data provided by the three collaborations involved.
In this contribution we present the scientific field of IACT astronomy (section 2) and the characteristics of the game that we designed and developed (section 3). Lastly, a brief report of the very first experiences that we had with the public is reported in section 4. Section 5 is about the conclusion and future perspectives of this educative project.

2. Scientific background

The universe is filled with cosmic radiation, made of particles and electromagnetic waves. In the most energetic cases, up to 1 PeV and beyond, signals are far more intense than the maximum values achievable on Earth with artificial accelerators. There is a long list of candidate cosmic sources to produce such an enormous energy, as for example pulsars, supernova remnants, active galactic nuclei and others [16]. However, a lot of questions are still unanswered nowadays, regarding not only the processes of emission and acceleration, but also the propagation from the source to our planet. In addition the study of the energy at such a high level could in principle shed light on some of the most important open problems of our epoch in fundamental physics, such as the Lorentz Invariance Violations or the Dark Matter [14, 15]. For these reasons, the study of the cosmic radiation in the very high-energy range is an extremely important field in astronomy today, but the collection of such energetic signals is not easy at all. There are different techniques for the detection of cosmic radiation, both ground and space based. One of the most fascinating one is based on

[1]For more information visit the web page physical.pub.

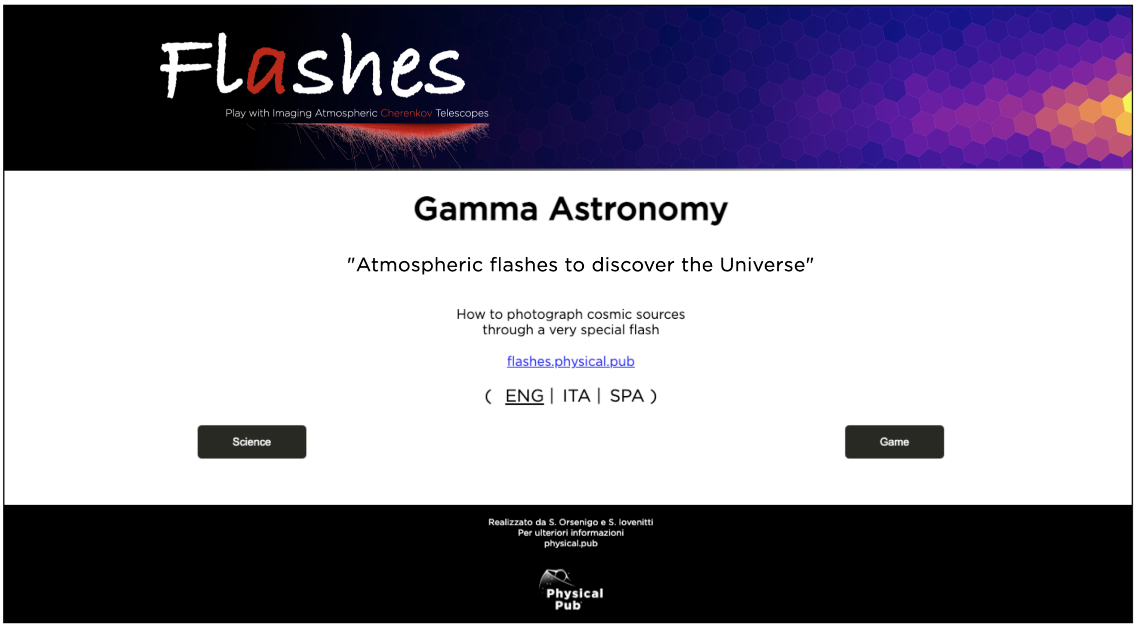

Figure 1: Landing page of the web application "Flashes". On the left there is a button to start the "scientific tour", similar to a slide presentation. On the right the button to start the game.

large reflector telescopes not designed for observing the signals emitted from cosmic sources, but rather their interaction with the Earth atmosphere. This is an indirect technique, but very effective, and the instruments involved are called IACTs.

2.1 IACT principles

The very high-energy cosmic radiation would be lethal for humans, but fortunately it does not reach the ground level thanks to the shielding action of our atmosphere. During the propagation in the air the original cosmic radiation is attenuated because of the progressive transformation of energy into massive particles[2]. This effect starts a cascade, resulting in an extended air shower of secondary particles. Due to the extreme initial energy, the speed of the particle shower is faster than the speed of light in the atmosphere. This stimulates air molecules to emit blue light according to the laws of a physics process called Cherenkov effect. Such emission is very faint and fast, about few ns only, and hence it is impossible to observe it by eye in the night sky. However, special telescopes endowed with large collecting areas and very fast acquisition systems can actually take images of these atmospheric flashes. They are the so-called IACTs, and they provide an indirect measurement of the incoming cosmic radiation.

2.2 Image discrimination

The images of the flashes recorded by IACTs offer the possibility to calculate the properties of the original cosmic radiation that started the atmospheric shower. The first important discrimination

[2]This process occurs even if the progenitor is not a massive particle but a ray of light. The quantum effect responsible for this phenomenon is known as *pair production* [17].

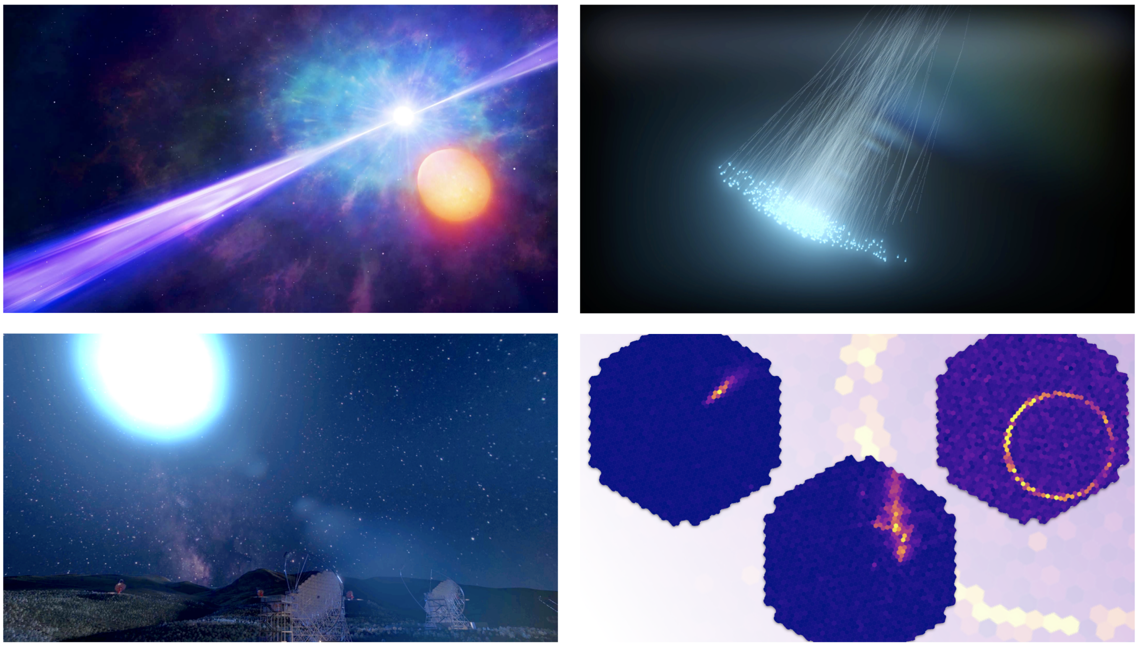

Figure 2: Four images shown in the preparatory "scientific tour". *Top left*, an artistic representation of a very high-energy cosmic source (Credit: University of Warwick/Mark Garlick). *Top right*, an extended air shower, *bottom left*, an atmospheric Cherenkov flash (Credit: CTAO). *Bottom right*, possible images recorded by an IACT (Credit: MAGIC).

regards its nature: was it a massive particle (*cosmic-ray* or hadron) or light (*gamma-ray*)? Gamma-ray flashes leave a footprint on the telescope cameras that is more elongated and narrow, while cosmic-rays usually produce larger and irregular shapes. Moreover, a further discrimination can be made among cosmic-rays, as there is a class of massive particle producing peculiar ring-shaped flashes, muons. The process of image discrimination is crucial for the correct elaboration of Cherenkov data, but it is undoubtedly not easy. In fact, besides cosmic signals, IACTs may detect also spurious events due to car flashes, headlamps, electric noise, thunderbolts and other uncategorized events that are discarded for scientific analyses.

3. The new "Flashes" web-game

In the past, the process of image discrimination illustrated in section 2.2 was carried out by expert scientists. Nowadays, this task is usually assigned to trained artificial intelligence algorithms. It should be noticed that such activity presents valuable characteristics for building educational games. First, it is based on images: a very powerful mean for conveying messages and long-lasting knowledge. Second, the faster you are, the more images you get: a race against time could be very exciting in a game context. Third, if you are fast but not accurate the result is not acceptable: everyone must choose a strategy, here individuality matters. Lastly, one player may be better than another simply for his good eye: this aspect offers the possibility of multi-player sessions without time limits. In light of these evaluations we decided to develop a web platform for hosting a game

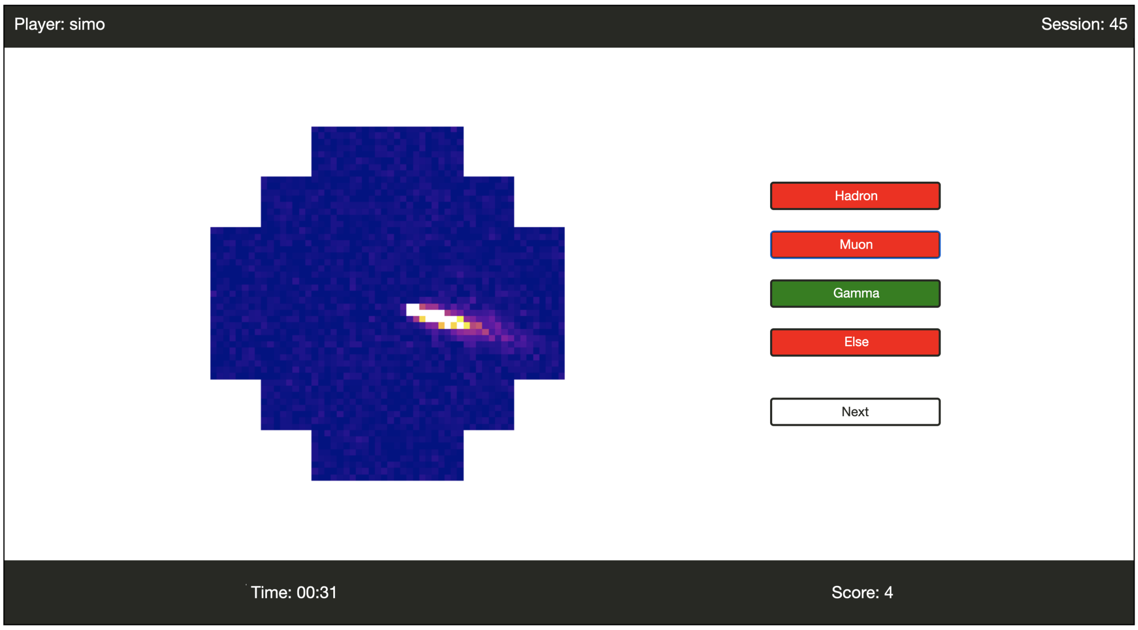

Figure 3: Screenshot of the game during the section dedicated to ASTRI. In the top bar there is the username and the session number. In the bottom the countdown and the score.

that mimic the real image discrimination analysis of IACTs[3], with the purpose of communicating the science of very high-energy cosmic radiation to both the general public and young students. The name of the game is just "Flashes" and thanks to the collaboration with ASTRI, MAGIC and the CTAO[4], the Cherenkov images presented in it are actually real data taken during scientific observations or simulations.

3.1 Development of the platform

"Flashes" is a web application designed and developed by PhysicalPub. It is based on a REST client-server architecture, composed of a back-end engine, coded in JavaScript using the runtime environment NodeJS, and a front-end written in ELM and transpiled to HTML and JavaScript. A SQL database is adopted for data management, while standard CSS is used for style sheets. Python was adopted for uniforming raw images provided by the IACTs involved.
The whole application is hosted on a Virtual Private Server (VPS) owned by PhysicalPub and publicly exposed on the internet using Apache. "Flashes" is accessible through the web-browser of any internet-connected personal device, simply resolving the url flashes.physical.pub/play, while a page with the full presentation of the project is available at the web address flashes.physical.pub.
A carbon copy of the VPS is installed on a portable local server, completely independent, made with a RaspberryPi 4 and a WiFi router, in order to make "Flashes" available on a dedicated local area network for in-person activities where the internet connection is absent or with a poor signal.
The usage of "Flashes" is completely free and does not require any account.

[3]Actually, similar games were also developed in the past by other teams in other contexts. See for example the following web links: INFN, ATLANTIS, CERN, and MSI.

[4]Also H.E.S.S. [10] will be added soon.

3.2 Design of the web-application and rules of the game

The web application is divided in two parts, "science" and "game", both accessible via the two buttons at the bottom of the main page, as it is shown in figure 1, where there is also the title of the game and the language selector (so far, only Italian, English and Spanish are available, but the platform is designed for adding more options in the future). The first part (left button) is equivalent to a slide presentation about the scientific background of the game. It is composed of a sequence of four images with explanatory captions. This part is designed not only to provide information to single players, but also for allowing educators to have an easy way for introducing their students to the game. In case of remote sessions, educators still may share their screen with students: the last image of the deck is a QR code pointing back to the main page, so it will be easy for remote users to land on the web application now, with their own devices. The second part (right button) actually stars the game. The player is asked for a username and a session code (in case of several players against each other, e.g. students of the same class) which is simply the number of a session previously opened by the educator. The game is divided into three sections, each dedicated to an IACT among the main ones currently in operation: ASTRI-Horn[5] Prototype telescope for the ASTRI project [7]. , MAGIC, and LST-1[6]. At the beginning of each section a cover page illustrates the characteristics of the telescope showing a picture of it with a caption. Afterwards, the player is presented with a sequence of images and must classify them according to their origin, choosing between hadron, gamma, muons or "else". In every section, the player has one minute to recognize the highest number of images and get the highest score. Correct answers give 1 point, wrong answers -0.5. At the end, a final ranking shows the score of all the users of the same session.

4. Experience with the public

In November 2022 we had the chance to present our game to the public for the first time, as an in-person activity in the context of the Genova Science Festival, in Italy. Visitors were guided by trained scientific animators through the preparatory part with an oral presentation using the slides on the platform (figure 4, *right*) and then across the three sections of the game. Players joined a unique common session using their own personal devices and played one against the others (figure 4, *left*). The access to our activity was free, without reservation, and without age limitations, although we recommended our game from the age of 12 onwards. With this modality it was very difficult to valuate the impact of our game and its effectiveness for educational purposes, however we saw that the public was very enthusiastic of the web application and that scientific explanations raised a lot of interest. Furthermore, we also found that "Flashes" provides the opportunity to discuss with people several additional topics related to science, as for example its intrinsic "uncertainty" aspect (triggered by the presence of the answer *else* among the options) or the importance of critical thinking. Such insightful discussions took place also at the end of on-line sessions, where single students or entire classes played remotely into the same session connecting with the animator using a video conference.

[5]

[6] Large-Sized Telescope prototype for the CTAO [18].

Figure 4: A detail of four students playing the game with their own devices (*left*) during the first experience of "Flashes" with the public in the context of the Genova Science Festival 2022 (*right*).

5. Conclusion

In this contribution we presented the new educational web-game "Flashes", developed by PhysicalPub, in the context of gamma-ray science and IACTs astronomy. We illustrated the game platform and its structure, but also the excellent feedback from the audience during its first public presentation. "Flashes" is completely free and available on the internet, it does not require an account or installation, and it can be used for activities both in presence and on line. Currently, a new section dedicated to H.E.S.S. [10] is under development. Meanwhile, we have an ambitious plan for the future. Answers from the audience could be collected and sent back to the IACTs which are provided new data every time, in order to help (statistically) in the analysis of their images. In this way, a simple educational web-game game could turn into a valuable experiment of citizen science.

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References

[1] Hillas A. M., 2013, APh, 43, 19.

[2] Iovenitti S., et al., 2021, ICRC proc., 36, vol. 395.

[3] Iovenitti, et al., 2021, Communicating Astronomy with the Public, proceedings.

[4] Barrio J. A.,et al., 1998, MPI-PhE 98–05.

[5] Scuderi S., et al., 2022, Journal of High Energy Astrophysics, 35, 52-68.

[6] Vercellone S., et al., 2022, Journal of High Energy Astrophysics, 35, 1-42.

[7] Scuderi S., et al., 2018, Proc. SPIE 10700.

[8] *Science with the Cherenkov Telescope Array*, The CTA Consortium, 2019.

[9] Iovenitti, S., et al., 2022, GIREP proceedings, IOP JPCS (*in publication*).

[10] Deil C., et al., 2008, AIP Conference Proceedings, 1085, 693–695.

[11] The CTA Consortium et al., 2011, Experimental Astronomy, vol. 32, 193–316.

[12] de Naurois M., and Mazin D., 2015, Comptes Rendus Physique, vol. 16, 610–627.

[13] Iovenitti S., et al., 2023, Il Nuovo Cimento C, 46, (*in publication*).

[14] Liberati S., 2013, Classical and Quantum Gravity, 30, 13, 133001.

[15] Garrett K., Duda G., 2010, Advances in Astronomy, 2011.

[16] Hillas A., 2003, Annual Review of Astronomy and Astrophysics, 22, 425–444.

[17] Jones, G. T., , 1999 Physics Education, 34, 5, 276–286.

[18] Mazin D., et al., 2017, American Institute of Physics Conference Series, 1792, 080001.

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