Mem. S.A.It. Vol. 96, 137

Memorie della

From virtual present to real future

New technology to describe the future of high-energy astronomy

F. Di Giacomo[1], S. Bardelli[1], L. Daricello[2], A. De Blasi[1], and A. La Barbera[3]
The remaining authors can be found at the end of the paper.

[1] Istituto Nazionale di Astrofisica – Osservatorio di Astrofisica e Scienze dello Spazio, via Gobetti 93/3 40129 Bologna, Italy e-mail: `federico.digiacomo@inaf.it`
[2] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Palermo, Piazza del Parlamento 1, Palermo, Italy
[3] Istituto Nazionale di Astrofisica – Istituto di Astrofisica Spaziale e Fisica Cosmica di Palermo, via Ugo La Malfa 153, Palermo, Italy
The remaining affiliations can be found at the end of the paper.

Received: 6-11-2024; Accepted: 25-01-2025

Abstract. In the coming years, between Chile and the Canary Islands, the CTAO will become the world's largest ground-based gamma-ray observatory, with over 60 telescopes of three sizes. While prototypes are ready and major infrastructures are under construction, the long timeline of such a large project makes it difficult to convey its full scope to the public. Virtual technologies help bridge this gap, offering an immersive glimpse into CTAO's future, where Italy plays a key role. As part of the CTA+ project, funded by the European Union through NextGenerationEU and led by INAF, a public engagement initiative is using emerging digital tools to share CTAO's scientific and technological goals with the wider community. We briefly present the multimedia outputs, focusing on a planetarium show designed to leverage the "wow effect" to engage audiences. This effort highlights both the future of gamma-ray astronomy and Italy's strong contribution to this major international observatory.

Key words. New technology, VR, planetarium show, very high energy astrophysics, CTAO

1. Introduction

Recent years have seen a significant rise in awareness regarding the vital role of public engagement in scientific endeavors. Having realized that science education and outreach researchers are fundamental to scientific activities, researchers are increasingly emphasizing the widespread dissemination of their projects (Jensen & Buckley 2014). In parallel, educators in the scientific community are striving to identify optimal strategies that inspire, inform, engage, and educate diverse audiences. By pushing the boundaries of what is possible in the real world, emerging new technologies such as virtual reality (VR) present exciting opportunities to transform and extend public engagement practices (Bondell & Myers 2021).

While the potential of virtual reality has begun to be exploited in some scientific contexts, the possibility of these technologies to transform public outreach practices is largely unexplored (Evangelou & Kotsis 2019, Wolter 2023). The need for evidence-based inquiries into the opportunities and challenges of VR in public engagements is evident. One promising avenue is the potential enhancement of public engagement with science through VR experiences. However, substantial gaps exist in understanding the dynamics between VR use and public engagement, as well as in elucidating the specific benefits of VR technology.

Technologies that merge real and virtual worlds hold immense potential for reshaping learning paradigms by linking novel perceptual experiences to abstract concepts (Southgate 2019). This potential has spurred interest in investigating both the advantages and limitations of physical and virtual learning environments. VR's unique affordances extend beyond visualizations, offering immersive contexts that foster spatial skills, practical learning, and inquiry-based education—particularly beneficial in most complex scientific domains (Ibáñez & Delgado-Kloos 2018).

In this context, and within the framework of the PNRR CTA+ project (PNRR M4C2 IR0000012 CTA+)(website CTA+ 2023) funded by the European Union and led by the Italian National Institute of Astrophysics (INAF), a public engagement project has been funded to use new technology to describe the science, the technology and the Italian contribution within the Cherenkov Telescope Array Observatory (CTAO)[1], the world's largest ground-based gamma-ray observatory. Among the various multimedia products, currently being developed by a professional company (ASSA - Vitruvio Virtual Reality) in the field of new technology, there is the creation of a virtual reality experience, a planetarium show and a 360° immersive video. Thanks to these three products, users will be able to immerse themselves in the future of gamma-ray astronomy, explore the two CTAO's array sites, climb onto the telescopes to explore and discover the characteristics of their cameras, and uncover the secrets and peculiarities of the main celestial sources that these telescopes will observe.

[1] https://www.ctao.org/

2. The project

Describing the scientific and technological characteristics of the Cherenkov Telescope Array Observatory (CTAO) project was a meticulous and innovative effort. The approach we have chosen has resulted in a series of engaging experiences and educational resources designed to bring the wonders of high-energy astronomy closer to the public.

First, together with a company expert in in the creation of virtual products, we developed a cutting-edge virtual reality (VR) experience. This immersive platform allows users to step into the southern and northern sites of the CTAO, to walk virtually around the telescopes, and to engage in different activities to uncover the intricate technology and scientific marvels of the CTAO. The development of this exhibit involved meticulous planning, including the creation of a detailed storyboard outlining all possible user interactions within the virtual environment. In addition we crafted interactive activities and challenges to further delve into the characteristics and scientific significance of the CTAO. In this way the user can enter meta rooms where they construct telescopes models and unravel the mysteries of celestial objects such as Active Galactic Nuclei (AGN) or Supernovae (SN).

In the second phase of our work, we created a highly immersive planetarium show that will capture the attention of a wide audience, both students and the simply curious, and explore the scientific goals of CTAO. This show not only sheds light on how Cherenkov telescopes work, but also provides insights into the future of high-energy astronomy, engaging users in a fascinating exploration of cosmic wonders.

Finally, we oversaw the production of a 360° immersive video which, like the previous ones, describes the characteristics linked to the

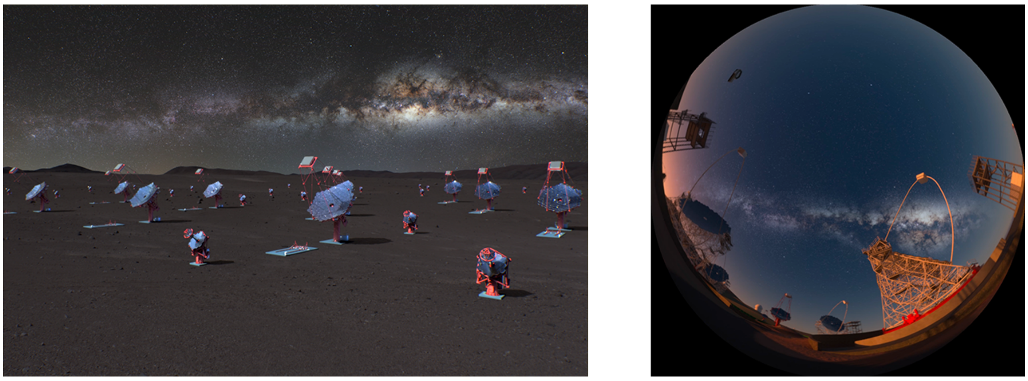

Fig. 1. The image on the left shows a rendering of the Cherenkov Telescope Array Observatory (credit: CTAO). The one on the right is a rendered representation of the array optimised for planetarium.

CTAO. This video is ideal in the case of events with a large influx of audiences where the previous multimedia contributions are not applicable.

3. The main objectives

Our approach to public engagement is centered around the use of new technologies and immersive techniques to enhance public understanding and interest in gamma-ray astronomy.

First, we want to take advantage of the "*wow effect*" and fascination of new technologies to engage the public as efficiently as possible. Secondly, our efforts aim to cultivate increased scientific awareness among the public. Through detailed and attractive explorations of the CTAO's features and scientific objectives, users gain a deeper understanding of astronomical phenomena and the cutting-edge technologies utilized to explore the universe's most extreme realms.

An essential aspect of our approach is the active involvement of the public. Interactive games and challenges embedded within the VR exhibit and planetarium show encourage active learning and discovery. Users have the opportunity to delve into the functioning of the Cherenkov Telescope Array Observatory and explore the scientific targets that will be studied, fostering a sense of ownership and curiosity.

Furthermore, our work involves a comprehensive analysis of the strengths, limitations, and educational potential of three key approaches: interactive VR, VR films, and planetarium experiences. This analysis aims to identify the most effective strategies for engaging the public and effectively conveying the future of gamma-ray astronomy. The main purpose of our study is to identify the best way to engage the public. Wishing to improve how new technology might be used in informal learning and public outreach contexts, we set up our research design as an exploratory case study of presenting a VR tour, a planetarium show and an immersive video at scientific events, like the European Research Night or scientific festivals.

4. The realization of the planetarium show

For the realization of the planetarium show, we transformed the VR scenes by optimizing and adapting them to the specific features and functionality that planetariums offer. This adaptation process was fundamental to ensuring an engaging and informative experience, which adapts to all audiences and various occasions.

The first step of our work was to adapt the storyboard to the characteristics and needs of the planetarium to describe in detail the contents, scenes and animations to be shown during the show. Using the original drawings of

Fig. 2. Representation of *Cicer-One*, the robotic assistant that guides users in the virtual environment. Thanks to its screen, visitors can interact with it, obtain some information on the CTAO and discover characteristics of very high energy astrophysics. In addiction Cicer-One can project videos and infographics.

the various telescopes, we created 3D models of the telescopes, aiming for a high level of realism. These are conceived and designed to capture the attention of users by transmitting at the same time essential knowledge on high energy astrophysics and the CTAO.

At the beginning of the experience, users find themselves inside a spaceship in space. In the scene there is a robot, called *Cicer-One*, which accompanies visitors in the virtual environment and can provide the user with a series of general information and concepts on the CTAO project, its characteristics and scientific objectives.

To allow flexibility and customization, we have developed a series of scripts and contents that the various planetarists will be able to choose based on the audience and the objectives of the event. These scripts have been designed to offer a wide range of themes and ideas (for example, scripts will allow us to analyze only the science or only the technology or to focus only on some parts of the CTAO), related to high energy astrophysics and the CTAO. This flexible approach allows us to maintain a high level of engagement and knowledge transmission, while ensuring a unique and memorable experience for every viewer. Through this strategy of content creation and adaptation, we have managed to transform the planetarium space into a dynamic and interactive stage, where high-energy astronomy and the discoveries of the CTAO come to life in a compelling and accessible way for all. This work, which began in spring 2024, was iterative and collaborative, involving continuous feedback and adjustments to further refine the experiences. This approach has allowed us to address technical challenges, improve user experience and refine the delivery of educational content. As a result, the planetarium show has evolved into excellent tool for audience engagement, seamlessly blending immersive technology with educational goals.

One of the main advantages of the planetarium is its ability to offer an immersive experience, although less immersive than VR. The presence of a planetarist leading the experience allows viewers to ask questions, thus increasing the overall interactivity and engagement of the experience. The planetarium activity is particularly suitable for large contexts and large audiences, like festivals, big events etc. Furthermore, the presence of an expert operator able to create and modify the script is important to adapt it to the specific public, like children, schools, adults, stakeholders, etc. This flexibility is a significant advantage to reach a larger and diverse group of audiences.

5. The evaluation of the impact

Having three types of virtual products that describe the CTAO, we asked ourselves which multimedia tool - virtual reality, immersive video, or planetarium show - is most effective in conveying the complex scientific content related to high-energy astrophysics and the CTAO. Specifically, we aim to understand the impact of these tools on learning outcomes and audience engagement. In order to answer this question, our idea is to present these three products in various contexts, including science festivals (e.g., Genoa, Naples, Bergamo) and public events like the European Researchers' Night. These events provide a different type of audience (age, background, interest, etc.). In these events the evaluation will be conducted exclusively through post-experience tests, administered immediately after the participants have carried out one of the three experiences. In this approach we assume that our audience has no prior knowledge of the CTAO, the Cherenkov effect, or high-energy astrophysics. This assumption is crucial because it allows us to conduct, exclusively, post-experience tests without needing to establish a baseline through pre-tests, which would be impractical in the dynamical environments where these activities will be showcased. The test will consist of a maximum of ten questions divided into three sections. The questions will be identical for all three experiences, with the aim of reducing question-induced bias. Furthermore, they will be designed to be independent of the product viewed, ensuring an objective and consistent evaluation of the different experiences. The first section includes preliminary context questions to gather demographic information such as age, gender, and educational level. The second section contains questions about the scientific content, directly related to what presented in the experience, covering concepts of high-energy astrophysics and details about the CTAO. The third section includes feedback questions on the experience, asking about the overall experience, including aspects such as enjoyment, clarity, and engagement.

The support through which the tests will be subjected to the different participants will depend on the type of event. At events with a high influx of people, such as the European Researchers' Night, we will conduct direct interviews with participants. Responses will be recorded and transcribed later, allowing for rapid data collection in a fast-paced environment. In more controlled settings such as schools or smaller events, we will use digital forms to collect responses. This method ensures ease of data collection and analysis. To encourage participation in the evaluation, especially in high-traffic and voluntary settings, we will offer small incentives such as gadgets or diplomas/badges of honour. This approach aims to increase response rates and ensure a broad and representative sample. The collected data will be analyzed to assess the effectiveness of each multimedia tool in conveying scientific content, the level of engagement and satisfaction among participants, and differences in responses based on demographical variables.

By adopting this comprehensive and flexible methodology, we aim to gather meaningful insights into the impact of VR, immersive videos, and planetarium shows on public understanding and engagement with high-energy astrophysics and the CTAO.

6. Conclusion

We estimate that all the virtual products will be optimized by the end of 2024. Once finished, we intend to introduce the virtual reality (VR), planetarium show and 360° video to a variety of audiences. This will allow us to explore the involvement of participants and understand which of these three products is most suitable for transmitting different contents and narrating the future and characteristics of high energy astrophysics.

The presentation of our multimedia products represents a crucial moment for our scientific dissemination project. We want to evaluate the effectiveness of each products in engaging the public and conveying complex concepts related to high energy astrophysics in a clear and engaging way. Virtual reality offers an unprecedented immersive experience, allowing participants to virtually explore the CTAO's array sites. This mode of interaction could be particularly effective in conveying the complexity of astronomical discoveries and engaging the audience on an exciting journey through the universe. The planetarium show, on the other hand, offers an immersive visual and narrative experience. Through advanced graphical representations and captivating narratives, we can present the future of high energy astrophysics in a way that is accessible even to non-experts. Finally, 360° video offers the possibility of exploring an immersive environment without having to use specific devices such as VR viewers or with a shorter turnaround time. This option could be more accessible to a wider audience, allowing for effective dissemination even among those who are not familiar with the most advanced technologies.

Authors

La Parola V.[3], Paganini L.[4,5], Wolter A.[5] and on behalf of INDACO group.

Affiliations

[4] Politecnico di Milano – Dipartimento di Matematica, Piazza Leonardo da Vinci 32, Milano

[5] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Brera, Via Brera 28, Milano, Italy

Acknowledgements. This project was funded by the European Union, NextGenerationEU under the project IR0000012 “Cherenkov Telescope Array Plus” (CUP: C53C22000430006; CIG: 99989778D8) of ”Piano Nazionale Ripresa e Resilienza” Missione 4 - Componente 2 - Linea di Investimento 3.1 “Fondo per la realizzazione di un sistema integrato di infrastrutture di ricerca e innovazione.

We also thank the Cherenkov Telescope Array Observatory for the support provided in this project. The models used in the realization of the various experiences were kindly made available by CTAO, which also offered a fundamental contribution in reviewing the contents of the VR and planetarium experiences.

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