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The Holotheater at OAR

A new instrument for outreach in astronomy

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Abstract. Here, we present the new Holographic Theater of the Astronomical Observatory of Rome (OAR). Starting from the reasons why we decided to use holography for sharing astronomical content, the article will outline the features of the OAR Holographic Theater, its unique qualities, its potential, and how it is being used to give scientific subjects a fresh and engaging perspective. Finally, an attempt will be made to provide a forecast on how this type of technology can be useful in the field of outreach and scientific projects.

Key words. Outreach, Innovation, Technology, Holography

1. Introduction

Since the early 2000s, with the establishment of Astrolab, an educational and public outreach facility, the Astronomical Observatory of Rome has ventured into the field of science communication with new and innovative tools.

At the time, Astrolab was the only national structure of its kind dedicated to deepening knowledge of Astronomy, and it was designed as a virtual journey from Earth to the edges of the Universe. It used the best software and the best available optical and electronic technologies to create exhibits that allowed visitors to interact with the content presented throughout the experience.

Students, as well as science enthusiasts and the curious public, could experiment, measure, and get hands-on exposure to the themes and phenomena characterizing our Universe.

However, a structure that relies on technology as the fundamental means of conveying science must continuously evolve in line with technological and entertainment advancements. This reality led the OAR public outreach and education team to realize that only by constantly updating could Astrolab maintain its appeal. Over the years, significant investment was made in innovations and experiments to create new exhibits in line with the most powerful innovative technologies.

2. The Need for a Holographic Theater

This forward-thinking approach to innovation led to the creation of the "Observation Room," which allows visitors to virtually experience the act of conducting an astronomical observation. This new structure, realized around 2005-

2006, even before the term Virtual Reality was widely used, was created embodying the approach and philosophy of modern VR applications. Around 2010, interest in 3D content surged, and the team once again saw how this technology could be highly effective for presenting astronomical and astrophysical subjects. Numerous tests were conducted, including prototype 3D rooms, and different 3D systems were evaluated for efficiency: anaglyph, shuttering, linear polarization, and finally, circular polarization. The latter was chosen as the most efficient and practical technology for Astrolab, given its space limitations, maximum visitor capacity, health considerations, and the need to tolerate intermittent signals.

This brief overview of twenty years of innovations designed and tested with and for the Astrolab's audience demonstrates a growing interest in new technologies on the part of OAR's outreach group. As 2020 approached, the team faced the need to once again update the structure to meet the expectations of an increasingly tech-savvy audience, while also having an effective tool for presenting the latest astrophysics discoveries. Thus, the idea emerged to explore holography, which offers new tools for creating innovative scientific storytelling experiences.

3. Holography, History and Development

Holography, understood as the creation of a static 3D image, dates back to the 1970s, thanks to the studies of Dennis Gabor, who received the Nobel Prize in 1971 for this technique. Essentially, holographic technology takes advantage of the parallax effect between the viewer's eyes, allowing the distance between them to create two different images for each eye. This effect reproduces depth, similar to how human stereoscopic vision perceives it.

However, this process applies only to static images, achieved through complex optical procedures using laser projectors. The current challenge, by contrast, is to create holographic effects for moving objects.

Anyone thinking of holography will likely picture scenes from sci-fi movies that, since the late 1970s, have fascinated fans of the genre. Unfortunately, creating a 3D image in space with no physical support, as imagined in these movies, remains far beyond our technological reach. There are some experiments with modestly sized holographic projections, but we are nowhere near what the science fiction movies has showed for over forty years.

Today, however, we can achieve a highly sophisticated simulation of holographic projection (see (Muratori, 2015)(Muratori, 2006)). Modern projection systems and the latest materials that can intercept the projection beam allow us to create an image that, thanks to the near-complete invisibility of the projection medium, seems to float in the air. When video content is produced according to specific parameters, the illusion of observing a 3D image in space is complete. In other words, current holography is a "false holography," but when done well and with the right equipment, it creates a "great illusion".

4. Why a Holographic Theater in OAR

The Holographic Theater at the Astronomical Observatory of Rome (OAR) stems from the need to update Astrolab's exhibition space by exploring current market technologies and equipment that best highlight astronomical content. However, every upgrade requires funding to bring even the most exciting ideas to life, and the opportunity arrived with the SUSA (Smart Urban Sustainable Area) project. SUSA, aimed at fostering cooperation between science, institutions, and civil society, seeks to enhance the southern quadrant of Rome, an area with a high concentration of scientific institutes. Specifically, SUSA is dedicated to advancing science, creating development opportunities for businesses, and providing value to the local area.

Thus, building a holographic theater was perfectly aligned with SUSA's goals: to promote astronomy, engage Italian industry leaders in this sector, and create a final product intended for public outreach.

After experimenting with augmented reality in the Observation Room and using polarized 3D glasses in the 3D theater, holography seemed like the ideal tool for presenting our content.

5. How the OAR Holographic Theater is Made

The first step was identifying companies in Europe specialized in holographic systems. Ultimately, after primarily communicating with UK-based companies, the team found Naumachia, an Italian company based in Milan, which had experience in holographic solutions for major companies like CISCO, TIM, and RAI. After a series of emails, teleconferences, and an on-site visit to their studio in Milan, the decision was made to entrust Naumachia with building the holographic theater.

Currently, there are various techniques for creating holographic effects, such as fan screens (rotating LED-arm displays that generate images) and holographic projections on ultra-transparent materials like glass, folis, or silver-coated mesh. After extensive market research to determine which technical solution best suited the intended holographic application, the fan screen option was dismissed for several reasons: due to their high-speed rotation, fan screens required secure installations to prevent audience contact with moving parts; they allow viewing from only one side, as a supporting wall for the motor is required behind the fans; and when photographed or recorded, the image is completely lost. Silver mesh projection is suitable for large spaces like concert stages. Glass projections are limited to screens smaller than 2x2 meters, whereas the Astrolab room can accommodate projections over 4 meters wide. Consequently, the team chose the holographic foil solution. The project began by removing outdated exhibits from the Astrolab's fourth room, equipment that was technologically outdated and from the original installation twenty years prior, to create space for a true theater setup with a stage, holographic apparatus, seating for 30 viewers, and a control room to manage projections, lighting and audio (see Figure1).

What makes this setup unique is that it is a genuine stage rather than an exhibit. The science presenter steps onto the stage to perform his presentation, aided by 3d movies, professional lighting that follows their movements and an audio system to broadcast their explanations to the audience. However, this stage has greater depth than a traditional stage to house the equipment necessary for the holographic projection.

Between the audience and the stage is a large 4x2.4 meter LED wall, positioned horizontally in front of the stage and hidden by the stage's support structure. This large screen projects images managed by the control room upwards, where there is an ultra-transparent film (with over 99.9% transparency) positioned at a 45° angle. This foil captures the image and reflects it toward the audience (see Figure 2, where the support structure is shown during the Holotheater installation).

This setup creates the illusion that the image is floating in mid-air, as the projection goil is invisible to the audience (see (Menna, 2023). Additionally, the presenter on stage, positioned behind the foil, and skillful lighting that accentuates stage depth enhance the illusion that the image is hovering on the stage, next to the presenter (see Figure 3).

6. Potential of our Holotheater

Let's start with a fundamental point: a native two-dimensional image will never appear three-dimensional in the holographic theater. An image, however detailed, will always remain a flat, two-dimensional object. However, by following three basic principles, it is possible to create striking 3D content.

Images that are inherently three-dimensional, such as photos or videos of objects, animals, or people, native 3D CAD designs, or animated 3D drawings, appear as though they are truly in front of the audience with a realistic perception of depth thanks to this type of projection. Thus, it is essential to prioritize content that is natively 3D. There are now many software options capable of producing 3D images and animations, widely used in movie production or technology for modeling and movement representation.

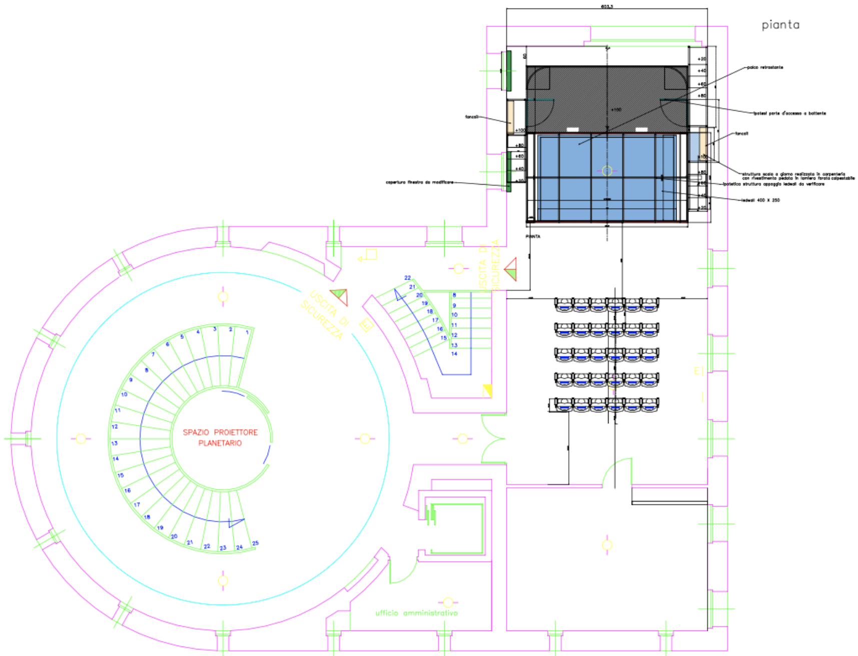

Fig. 1. Floor plan of the second floor of the Astrolab and the placement of the Holotheater and the audience seating within the fourth room.

Content should always use a black or transparent background. The entire stage of the Holographic Theater is outfitted with black curtains, background, and set elements to avoid interference with the projected holographic image. Even the best 3D subject displayed within an image or video with a colored background would lose its three-dimensional effect because the image's background would cover the stage backdrop, which otherwise contributes to the illusion of depth in projected subjects.

The final rule to achieve a more effective 3D effect is to project complete subjects that do not extend beyond the projection borders. Zooming in on a subject, whether it's an object or a person, that partially goes beyond the projection boundary drastically reduces the 3D effect because the perception of depth, which is automatically obtained by visually comparing the distance between the projection and the stage backdrop, is lost.

In conclusion, the ideal subject for a holographic projection is natively 3D, with a black background, and a projection within the projection boundaries. The best setup for astronomical images.

But the Holographic Theater is not only effective because it creates the illusion of depth in projected subjects. Being essentially a theater, it includes a stage where objects and people, like scientific presenters, can stand. With well-designed content based on carefully planned and tested storytelling, the presenter can move around the stage, point to projected 3D subjects, and simulate interactions with them to make the message even clearer and more engaging. The challenge is that the person on stage cannot see the projection, which is oriented toward the audience. Therefore, the

Fig. 2. Holotheater under construction in the fourth room of the Astrolab. The truss structure supporting the foil can be seen, as well as the horizontal suspended structure that holds the LED wall, which was already installed in the photo. The overall size of the entire structure is clearly perceptible.

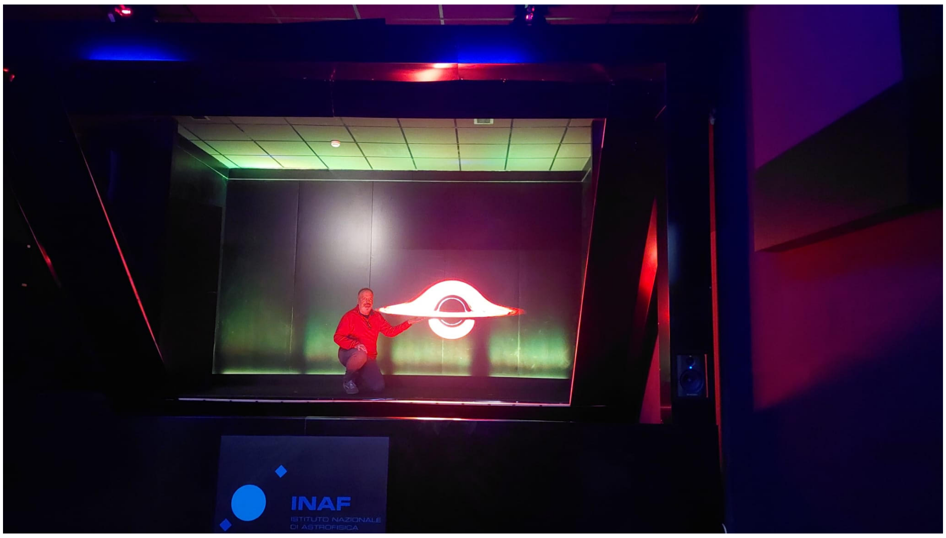

Fig. 3. Presenting a black hole hologram to the public at the Holotheater.

system is equipped with a hidden monitor visible only to those on stage, allowing the presenter to see in real-time what the audience is viewing and helping him find the right position and gestures relative to the 3D subjects currently being projected.

Finally, given the required stage dimensions, it is possible to project life-sized images of people. This allows a storytelling scenarios in which virtual individuals, not actually present on the stage, appear to interact with those onstage, making it seem as though they are genuinely present and interacting with the live presenter, thanks to the Holographic Theater.

7. The Telepresence

The ability to project human figures at real-life size, combined with the possibility of remotely connecting with distant individuals equipped with chromakey technology, adds to the Holographic Theater the potential to perform telepresence connections. The remote character appears as a hologram on stage and interacts in real-time with the real people next to their image.

To make this possible, the key element is the Holographic Theater and a fast internet connection. On the other hand, the remote subject only needs a simple PC equipped with a webcam and a green screen to serve as the background behind his figure. The rest of the work is done by the Holographic Theater's control room, which receives the full-body image of the remote person against the green background, makes the green background transparent, and projects the person, in the correct position and realistic proportions, close to the people on stage. Those on stage can see the remote interlocutor via the above mentioned monitor. Meanwhile, the remote person can see their image on stage, alongside the people present, thanks to the images captured by a camera placed behind the audience, which relays the scene in real-time.

This capability of the Holographic Theater opens a wide range of possible applications that only creativity can limit. It is possible to virtually invite speakers to present their discovery, even if the speakers are far away or perhaps on another continent. It is also possible to show a scientific instrument or any other content of interest in real-time and in 3D mode as if the instrument were on the stage.

8. The Future

With the spread of green studies across various INAF locations, the Holographic Theater of the Rome Astronomical Observatory could become the hub for a series of combined activities that add charm and realism to public events. Additionally, this type of equipment allows people to connect and share experiences where the movement of individuals or objects would be difficult to achieve due to organizational or logistical reasons.

Finally, it can also be a useful tool for scientific purposes, providing researchers with a new and power communication channel or means to disseminate their research.

9. Conclusion

After a year and a half of commitment, solution searching, and design work with a leading partner in the field of holographic instruments, the Rome Observatory has gained unique experience in this area, which is still underutilized in the outreach sector. The potential of such a tool is enormous. The future will surely bring new materials, more powerful projectors, and equipment that we cannot yet imagine, which will make holography even more effective for communicating scientific content. Therefore, it will be important to stay up-to-date on the technological advancements that will be available.

But even more important will be the creation of content, starting from the latest scientific discoveries in astronomy, and knowing how to tell those discoveries through holography. Thus, alongside technological innovation, it will be crucial to invest in ideas and projects aimed at telling science to the public.

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