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3D Constellations

Accessibility resources for astronomical outreach

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Abstract. We understand the concept of constellations from an essentially visual resource: the night sky. Therefore, a barrier arises for the inclusion of visually impaired people. This concern is amplified when we bring the discussion to spaces of scientific dissemination, such as museums and planetariums. The Brazilian Law for the Inclusion of People with Disabilities (No. 13.146/2015) guarantees that a blind person has the right to receive information and access cultural goods in an appropriate format. Considering these issues, in 2024 we began a project to develop tactile materials. In this work, we present the accessibility resources for astronomical dissemination already produced and their application during an accessible observation night at the Interactive Science Museum (MIC, São José dos Campos). We also discuss the results of an evaluation experiment of tactile resources in a dark room during the event "7th Peering at the Moon through Telescopes," organized by the Astronomy and Space Physics Observatory of the University of Vale do Paraíba (UNIVAP), are also considered.

Resumo. Compreendemos o conceito de constelação a partir de um recurso essencialmente imagético: o céu noturno. Sendo assim, surge uma barreira para a inclusão de pessoas com deficiência visual. Essa preocupação é ampliada quando trazemos a discussão para espaços de divulgação científica, como museus e planetários. A Lei Brasileira de Inclusão da Pessoa com Deficiência (nº 13.146/2015) assegura que a pessoa cega tenha o direito de receber informações e acessar bens culturais em formato adaptado. Tendo em vista estas questões, em 2024 iniciamos um projeto para a elaboração de material táctil. Neste trabalho, apresentamos os recursos de acessibilidade para divulgação astronômica já produzidos e a sua aplicação durante a uma noite de observação acessível no Museu Interativo de Ciências (MIC, São José dos Campos). Também são discutidos os resultados de uma experiência de apreciação dos recursos tácteis em uma sala escura, durante o evento "7° Espiando a Lua na Luneta", organizado pelo Observatório de Astronomia e Física Espacial da Universidade do Vale do Paraíba (UNIVAP).

Keywords. Teaching of Astronomy – Miscellaneous

1. Introduction

Astronomy is widely considered as an essentially visual science. Thus, the images obtained through observatories and space telescopes are not accessible to people with visual impairments, as pointed out by Bernardes (2009). Furthermore, as highlighted by Dominici (2008), we are all "blind to astronomy". Considering the whole electromagnetic spectrum (Figure 1), we notice that visible light to our eyes corresponds only to a small fraction of it. Celestial objects can be emitting light from radio to gamma ray frequencies, that are beyond human visual perception. The information captured in these different ranges is converted into images because it seems "natural" for visual people, but also could be adapted into sound or tactile resources, for example.

In this sense, accessibility in astronomy emerges as a significant concern, prompting reflection on how to broaden participation beyond the imagetical approaches. Beside formal classes, this discussion should be taken to spaces where astronomy is taught and disseminated, such as museums and planetariums. The Brazilian Law for the Inclusion of People with Disabilities (Law Nº 13.146, article 42, Brasil, 2015), guaranties that persons with disabilities have full access to cultural and leisure spaces, which implies in the obligatory offer of accessible resources. In particular, according to Solima (1998, 2000), the social function of a museum is to contribute to the cultural development of the community as a whole. A museum space does not fulfill its social function if the information does not reach everyone. Furthermore, there is a growing importance in exploring multisensory experiences in the production and dissemination of knowledge. As pointed out by Addis (2002), the involvement of different senses can make the communication more comprehensible for all.

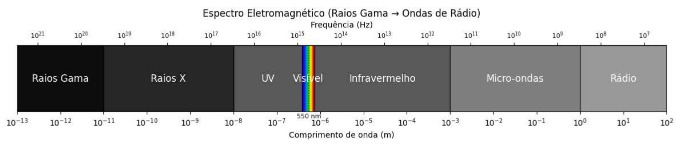

Figure 1. Representation of the electromagnetic spectrum from radio waves to gamma rays. Visible light is the small range of frequencies represented in colors. Thus, we are all blind to larger part the electromagnetic information coming from the Universe. Credits: W. Melo.

Bernardes (2009) points to the lack of teaching materials as a barrier in the teaching and learning of astronomy; this is even more worrying when we talk about accessible materials. In Brazil, according to Santos (2020), investment in the development of materials for teaching astronomy to visually impaired people seems to be lower when compared to other countries. Nevertheless, there has been a growing number of new initiatives in Brazil around this topic, mainly since 2015 when the Brazillian law For the Inclusion of People With Disabilites was approved (Correia et al. 2025). In the international scenario, the interest increased since 2009, that was the International Year of Astronomy, endorsed by UNESCO.

Backing to Brazil, one of the first initiatives was the work of Dominici et al. (2008), where tactile material to promote accessible nights of observation were developed. We can also highlight the initiative called "Accessible Universe"[1], a university extension program of the Federal University of Rio de Janeiro (Lorenz-Martins et al. 2024). The project focuses on the production of teaching resources adapted in different convenient support formats for elementary school students with visual impairments.

Furthermore, there are other initiatives such as the work of Almeida et al. (2020), which described the creation of a tactile model of solar system for visually impaired students, showing the differences in temperature of planets and its relative distances from the sun. The material was presented at an Astronomy exhibition for visually impaired people in Juazeiro do Norte-CE during the National Science and Technology Week of 2018.

Accessible astronomy for includes also insert diverse people in the scientific carrers. A good example was two workshops holded by the Astronomical and Educational Association "Henrietta Swan Leavitt" in The Canary Islands (Spain), in collaboration with the STEAM Program and Department of Special Needs (NEAE) of the Government of the Canary Islands. They culminated in the discovery of the variable star UCAC4 459-092739 by a group of visually impaired students (Bolãnos-Santana et al. 2024), done through sonification techniques.

During 2024, we started an outreach project at the Interactive Science Museum (MIC) of São José dos Campos (SP), in which we are developing tactile constellations to make accessible planetarium sessions and observation nights.In this work, we present the development of the material and tests during two public events. In Section 2 we described the adopted metodology, while the results as presented and discussed in Section 3. The conclusions can be found in Section 4.This project is developed from a universal design perspective. That is, even though the resources generated are tactile, they are not exclusively for use by the visually impaired. They are for everyone.

2. Methodology

The creation of tactile material focused on visually impaired people should follow a series of guidelines regarding comfort in handling, the clarity with which the information is presented, the language used during communication (MLA 2005, p. 40, for example), and the mediation of the content itself. Taking this into account, the initial development of this work was based primarily on Dominici et al. (2008), the "Accessible Universe" project (UFRJ, Lorenz-Martins et al. 2024), and the three-dimensional resources for teaching astronomy developed by Dr. Anderson Trogello (e.g., Trogello 2025).

Dominici et al. (2008) produced a tactile kit containing 2D constellations, celestial maps of cities in the southern and northern hemispheres, a three-dimensional model of the Orion constellation and a celestial sphere, each item having been evaluated by a specialized team from the Dorina Nowill Foundation for the Blind. [2]. In turn, Trogello (2025) produced three-dimensional models of constellations, where we can observe the relative distances between the stars of different constellations, solving the problems found in the Orion constellation in Dominici et al. (2008). However, the models were not developed for tactile appreciation. The "Accessible Universe" initiative (Lorenz-Martins et al. 2024), with the support of the Benjamin Constant Institute[3], seeks to create tactile materials for teaching various astronomy topics, including developing textbooks for wide distribution throughout the country.

Since the material is intended to be part of planetarium shows and public stargazing nights, in this work we opted to produce tactile resources for constellation identification and understanding. In the following sections. In the following sections, we present details of the material's production, taking into account best practices for communicating with visually impaired audiences.

2.1. 2D Constellations

For the creation of tactile constellations, which we call 2D here, we selected twelve of the zodiac constellations and Orion, according to the convention of the International Astronomical Union (IAU). The latter was included after research on the constellations most frequently discussed during planetarium sessions at MIC.

We followed the production scheme of Dominici et al. (2008): using high-grammage A4 sheets, printed asterisms of the constellations (which were transferred to the sheets with carbon paper), sewing thread, and adhesive tape. The imaginary lines were then sewn onto the sheet. While Dominici et al. (2008) used relief paint to represent the stars, in this work we glued rhinestones of several sizes to differentiate among the relative brightness in the sky of each star.

In addition to the individual constellations, two celestial maps were produced: one centered on the south pole and the other on the north pole. This makes it possible to touch all the constellations in both hemispheres and verify their relative positions. In this case, the maps were traced onto fabric, the constellation lines were sewn on, and the stars were represented by beads, also sewn on and all the same size.

The requirements for choosing materials, in addition to low cost, include the use of different textures for each piece of information contained in the material. The requirements for choosing materials, in addition to low cost, include the use of different textures for each piece of information contained in the material. The resulting materials can be seen in Figure 2.

2.2. 3D Constellation

We also developed a 3D model of one constellation. We chosen the Southern Cross constellation because it is simple, as its asterism has few stars.The development began with determining the distances of the stars from Earth. For this, we used the SIMBAD astronomical database[4], from which proper motion data were collected, which we used to calculate the distances of the five stars that make up the asterism.

After testing several assembly options, and observing the same 3D constellation made by A. Tragello in wood, with a laser cutting machine, we decided to test 3D printing. As we said before, the wooden constellation is not suitable for tactile appreciation. This is because the material can hurt the hands due to the sharp edges. In addition, it was necessary to practice the recommendation of placing different textures for each information. In the developed constellation, the stars on the cover (which represents the projection onto the celestial sphere) are embossed,

[1] https://universo-acessivel.pages.dev/

[2] The Dorina Nowill Foundation for the Blind, located in São Paulo, is a Brazilian philanthropic institution that aims to facilitate the inclusion of blind and visually impaired children, youth, and adults through free and specialized services. https://fundacaodorina.org.br/

[3] The Benjamin Constant Institute (IBC), based in Rio de Janeiro and linked to the Ministry of Education, specializes in education for blind and visually impaired people. https://www.gov.br/ibc/pt-br

[4] https://simbad.u-strasbg.fr/simbad/sim-basicIdent=m33&submit=SIMBAD+search

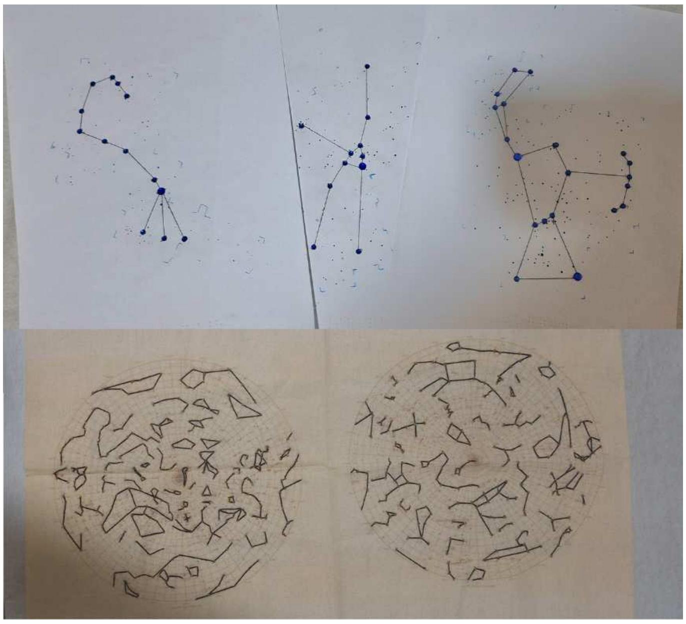

Figure 2. Top: Tactile (2D) representations of the constellations of Scorpio, Taurus and Orion. Bottom: Star charts for both hemispheres.

different sizes to symbolize the difference in magnitude, as can be seen in Figure 3. On the back of the cover, the stars are represented spherically and with the distances to scale.

Note that on the front the stars are represented as "star-shaped," while on the back they appear spherical. This is an opportunity to present the effects of the atmosphere on what is seen in the night sky, as well as to discuss the physical mechanisms that occur in stars. As pointed out by Dominici et al. (2008), visually impaired audiences tend to be surprised to discover that the "star shape" they have been tactilely exposed to throughout their lives is not the actual shape of a star.

Figure 3. Three-dimensional representation of the Southern Cross constellation, where the stars are shown with their relative distances to scale.

3. Results

The resulting 2D and 3D constellations were presented at science outreach events, where we were able to test them with visually impaired and sighted individuals. In this article, we will present the results obtained during the event the "Astronomy in Our Hands", event that occurred in 2024 at MIC. In 2025, a "Dark Room Experience" was offered during the "VII Observing the Moon Through the Telescope", an event at the Astronomy and Space Physics Observatory of the University of Vale do Paraiba (Univap). The analyzes considered the people's interaction with the developed materials, with an emphasis on the understanding of the presented constellations and the material's suitability for astronomical teaching and outreach.

3.1. Astronomy in Our Hands event - Accessible night observation

The materials were first presented in 2024, during the first accessible night sky observation at MIC: the "Astronomy in Our Hands" event. The 2D constellations were arranged on a table for attendees to handle, placed in an open environment, as shown in Figure 4. The table was next reflecting and refracting telescopes available for the observations. At that time, we had not yet created the 3D constellation.

Figure 4. Table with 2D constellations displayed

The main purpose of this exhibition treach visually impaired audiences, so that they could test the materials. The Museum announced in an Instagram post that it would be an accessible observation night and a group of blind people were invited. However, at the end of the event, neither the invited group nor the target audience attended. One of the explanations given later by the group was the difficulty in accessing the museum. This observation reveals that, in addition to barriers in the communication and dissemination of scientific information, there are also architectural and urban barriers that prevent people with disabilities from accessing cultural and leisure spaces.

It is worth noting that the sky was cloudy that night, which prevented visitors from using telescopes for observation. However, the tactile constellations caught the attention of non-visually impaired public, revealing that the material fits within the principle of universal design which, according to article three of Brazilian Inclusion Law, refers to the development of resources and products without the need for subsequent adaptation, that can be used by all people.

As the event ended, a woman approached the table and was surprised to learn that the material was accessible. She told us that her husband has low vision and was present at the event, but outside the Museum, not participating in the activities. The husband, whom we will refer to simply as "the person" here for privacy reasons, was invited to touch the 3D constellations. When asked why he wasn't participating in the activities the answer was "I felt this space wasn't for me, so I stayed outside." This statement reveals the immediate need to make cultural and leisure spaces accessible to everyone. The person already had some knowledge of astronomy. He considered the 2D constellations easy to understand and that the guided activity helped him to comprehend them (Figure 5). Furthermore, he was able to touch the telescopes, learning how light is captured by different type of instruments; it's worth noting that the guidance was also important at this part.

However, when testing the 2D constellations, several people made erroneous observations, such as: "How cool, the Three Marys are right next to each other." To eliminate this confusion, it became necessary to develop the 3D model to explain the distances between the stars. This work resulted in the development of the Southern Cross constellation as described in Section 2.2.

Figure 5. A person with low vision exploring the tactile constellations during the accessible night observation event promoted by MIC.

3.2. Dark Room experiment

To test the 2D and 3D constellations simultaneously, we conducted a darkroom experience during the "VII Observing the Moon Through a Telescope", promoted by the Physics and Astronomy Observatory of Univap. Inside the Observatory's auditorium, 2D and 3D constellations were arranged on a table as well as a tactile moon and the tactile star charts. Next to the table, a reflecting and a refractor telescopes. The experience involved 40 participants, all of whom were not visually impaired and divided in groups of 10 people per session.

Initially, people entered with the auditorium with the lights on and the objects were covered with a dark cloth. In the sequence, it was explained how the activity would work, the objectives and the motivation of it. Then, the lights were turned off, the cloth was removed and the participants were invited to touch the objects on the table, talking with each other about their impressions and with mediators guiding them. This mediation was essential, especially for the 3D Southern Cross constellation, as it involves some important astronomical concepts for effectively understanding the material, such as: distance and magnitude of stars. It should be noted that, at the beginning of the session the participants could not see anything. However, as their eyes adjusted to the darkness, they began to see some of the materials.

In a third stage, the lights were turned on and everyone could see what they were touching. At this moment, the materials were explained, as show in Figure 6, and the participants were invited to answer an evaluation form, which contained some questions about the experience. We characterize this activity as an action of citizen science, where the community participates actively in the research.

3.2.1. Analysis of the answers to the questionnaire

Of 40 participants, 17 responded to the evaluation form, representing 42.5% of the total. The form had 12 questions, 9 of which were multiple choice and 3 were open-ended. The questions aimed to evaluate the effectiveness of the material with the audience and to gather suggestions for improvement. It's worth noting that no visually impaired individuals attended the experience and the event; in other words, 100% of the participants were sighted. However, a person with a hearing impairment participated and shared with the team their satisfaction at finding a science outreach project committed to accessibility. Furthermore, it is worth to point out that participants of different ages took part in the activity, with the majority being between 35 and 59 years old.

Regarding the understanding of the 2D and 3D materials, most participants understood that they were constellations and that the 3D model was easy to understand, especially the differences in distances and magnitudes of the stars. It is worth highlighting that 100% of the participants responded that they

Figure 6. Explaining the materials at the end of the dark room experiment.

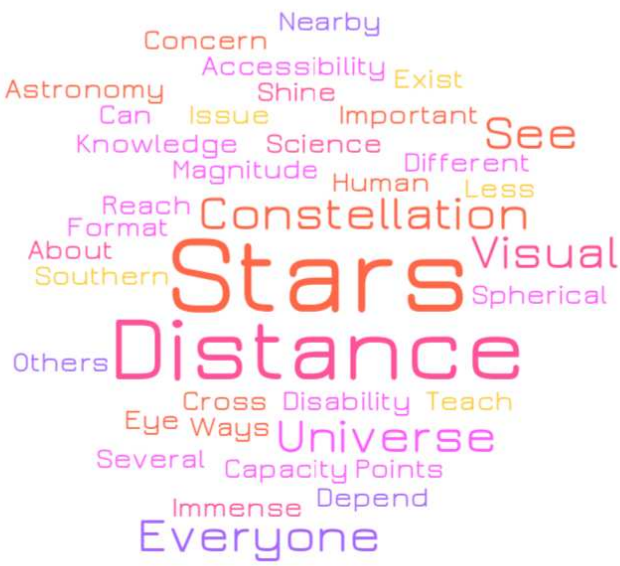

Figure 7. Word Cloud with answers for the question "What did you learn from this activity?".

were well guided by the person who mediated the activity, reinforcing the importance of mediation in the construction of the main concepts presented during the activity.

Considering the essay questions, one of the them was about what the participant learned from the activity. The results can be seen and analyzed through a word cloud, as shown in Figure 7, where the largest word being the most frequent and the smallest the least frequent. The answers of the questionnaire are still under analysis, also including responses obtained during subsequent events, not presented here.

4. Conclusion

This work sought to describe the development of accessibility resources for astronomical outreach, as well as their application in the two events, the "Astronomy in Our Hands" at the MIC and Dark Room Experiment at Univap. The obtained results indicated that the tactile models facilitated the understanding of the constellations, that mediation is important for better comprehension of the materials, and that these resources attract both people with and without visual impairments.

The development of 2D and 3D constellations and their corresponding results reinforce the need to rethink astronomical outreach practices, especially in spaces such as museums, planetariums, and observatories, valuing resources that consider universal design and break with the dependence on essentially visual representations.

Although the results were satisfactory, there remains a need for continuous refinement of the materials. As a continuation of this work, further testing with groups of visually impaired participants is proposed to improve the resources. The accessibility materials that are being developed in the project constitute a tool for democratizing access to astronomy and science in general, and reaffirm that inclusion, when placed at the center of the educational resource development process, transforms the ways in which we engage with and learn about the night sky. Furthermore, they increase our sense of community, seeking to always including all of us.

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