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Teaching astronomy in basic education

Investigative sky patrol through automatic meteor imaging

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Abstract. Observing meteor showers plays a fundamental role in analyzing meteoroid streams and understanding their origins, in addition to having direct relevance to astronomy and the safety of space navigation. However, there is a significant knowledge gap in this area in the Southern Hemisphere. This limitation motivated the development of this project, which combines scientific research with basic education through Citizen Science. The PatrICIA Project (Investigative Sky Patrol by Automatic Imaging, in Portuguese Patrulhamento Investigativo do Céu por Imageamento Automático) proposes the investigation of meteors using records from an all-sky camera, while promoting the active involvement of high school students in data collection and analysis. Thus, the objective of this work is to collect and analyze data on the entry of meteoroids into the Earth's atmosphere, expanding scientific knowledge on the subject and strengthening the teaching of astronomy in basic education, since astronomy is not a subject frequently covered by teachers in the classroom. The results also point to an increase and strengthening of confidence in science and in the work of scientists among the students participating in this study, as they became fully involved in the scientific investigation process through citizen science at school.

Resumo. A observação de chuvas de meteoros desempenha um papel fundamental na análise das correntes de meteoroides e na compreensão de suas origens, além de ter relevância direta para a astronomia e a segurança da navegação espacial. No entanto, existe uma significativa lacuna de conhecimento nessa área no hemisfério sul. Essa limitação motivou o desenvolvimento deste projeto que alia pesquisa científica à educação básica por meio da Ciência Cidadã. O Projeto PatrICIA (Patrulhamento Investigativo do Céu por Imageamento Automático) propõe a investigação de meteoros utilizando registros de uma câmera all-sky, ao mesmo tempo em que promove o envolvimento ativo de estudantes do ensino médio na coleta e análise de dados. Assim, o objetivo deste trabalho é coletar e analisar dados sobre a entrada de meteoroides na atmosfera terrestre, ampliando o conhecimento científico sobre o tema e fortalecendo o ensino de astronomia na educação básica, uma vez que a astronomia não é um conteúdo frequentemente trabalhado pelos professores em sala de aula. Os resultados apontam também para o aumento e fortalecimento da confiança na Ciência e no trabalho do cientista pelos alunos participantes deste estudo, pois estes se envolveram totalmente no processo de investigação científica através da ciência cidadã na escola.

Keywords. Teaching of Astronomy — Dissemination — Meteorites, meteors, meteoroids

1. Introduction

The interest of the general population and students of basic education in astronomy topics has been sparked mainly when astronomical phenomena occur or discoveries about the universe are made, generally disseminated in an exaggerated sensationalist tone by the media (Langhi 2011).

In fact, the desire and need to expand the limits of knowledge, encompassing places as distant as the limits of the cosmos, in the eagerness to explore space and time, is still preserved within humanity. Some of these sensationalist news stories and fiction films show images of meteor falls and address the possibility of devastating impacts on Earth by bodies from space (for example: asteroids, meteorites, and comets). This fear of mass destruction by celestial objects is growing when considering new discoveries of meteor showers, asteroids, and comets in the Solar System through research in the field of Astronomy.

There is a growing discovery of potentially hazardous objects with orbits close to Earth's orbit (NEOs – Near Earth Objects), as well as new radiants of meteor showers in the Northern Hemisphere, where we already have a fairly consistent characterization of these showers. However, there is a great lack of studies of this nature in the Southern Hemisphere, which justifies the importance of this study within the scope of Citizen Science.

2. When Citizen Science Goes to School

Citizen Science has been a new form of interaction between citizens and professional scientists and more specifically in this project, professional astronomers. Citizens can then participate in various formal activities developed in the world's leading research centers.

With this, an opportunity for engagement with Science and the Scientific Method is provided to the population. However, the participation of amateurs in scientific activity is not new: the figure of the professional scientist only emerged in the 19th century. In recent decades, with the use of digital technologies, it has become common for researchers to invite the public to cooperate (Irwin 2018).

The individual who participates in a citizen science project, therefore, collaborates with formal institutions in various ways, with numerous thematic areas available to follow, resulting in improvements for society in social, environmental, politically, and other conditions (Marques & Lopes 2017).

In this research, the authors promoted activities involving high school students and ordinary citizens in the study of meteors.

3. Meteors, Citizen Science, and School: Deep Impacts

Meteors (popularly called "shooting stars") are seen in the upper layers of the atmosphere, resulting from their light emission due to the high temperature caused by friction with the air and due to the ionization of atmospheric gas, since meteoroids penetrate at high speeds when coming from space. These generally originate from comets and asteroids (or fragments thereof), which penetrate the Earth's atmosphere at a total of at least 40,000 tons per year, resulting in an average of 76 kg per minute (the equivalent of the mass of a person falling on our planet every minute). However, more than 99 percent are completely consumed by friction, becoming meteoritic dust in the atmosphere, and can perform an important meteorological function, such as condensation nuclei, for example. However, some are large enough not to be completely pulverized, which is devastating to the ground. If found, these "extraterrestrial" rocks are called "meteorites", according to Boczko (1984).

Astronomical events such as meteor showers and possible impacts of comets and asteroids often arouse the curiosity of students, who overwhelm their teachers with questions about astronomy and the possibility of bodies from space falling to Earth. Teachers, in turn, are not always prepared to provide satisfactory answers, as their initial training in undergraduate studies did not allow them direct contact with the astronomy content (Langhi & Nardi 2012).

Another justification for this study is based on the fact that official government documents in Brazil, which parameterize national education, especially the National Common Curricular Base (BNCC), recognize that astronomy is interdisciplinary, since the subjects related to it are addressed in other disciplines (Brasil 2016). Therefore, the interdisciplinarity of Astronomy was considered in this research, since several contents of Meteorology, Mathematics, Geography and Physics are directly linked to the present proposal of meteor patrolling and its teaching in basic education.

In addition, studies on alternative conceptions in astronomy demonstrate that most of the population and teachers continue to persist with their personal common-sense explanations of celestial phenomena, often laden with myths and fears, their personal ideas being different from scientific concepts (Langhi 2011), highlighting the failure of science teaching in basic education. In fact, one of the most frequent questions from students is about meteors and the possibilities of destructive impacts. This highlights the existence of the problem regarding the population's (including teachers') lack of knowledge about these concepts, which justifies the need to include this topic in citizen education.

It is important to note that there is little research on meteor patrolling in the southern hemisphere; therefore, there is no teaching material for teachers on this topic published in Brazil. Therefore, this project assumes the premise that academic knowledge and the results generated by this research will also be used through educational and scientific outreach activities, fulfilling the research/teaching/extension triad.

Furthermore, the immersive involvement of high school students in the stages of the scientific work process, or the so-called "scientific method," can strengthen students' confidence in science and in the work of scientists, as the students themselves act as protagonists in the observation, collection, and analysis of data. Therefore, considering the current dissemination of science´s denial currents and movements opposed to science, this project assumes vital importance for the development of a citizen who understands how science works and values it. And this can only happen if the student engages in such activities, that is, Citizen Science, according to Carrara & Langhi (2022) and Andrade et al. (2025).

Therefore, what motivated this study was: a) most meteor studies are located in the northern hemisphere, b) the possibility of recovering probable meteorite falls, c) the teacher's lack of training in astronomy, d) the students' and the population's interest about meteors and e) the need to strengthen confidence in science.

4. Methodology

This project was developed and implemented using activities for the local community that visits a non-formal educational space, the Didactic Astronomy Observatory of Unesp, but also mainly for high school students who passed through the same Observatory and were invited to participate in the project. These activities were carried out within the scope of Citizen Science aimed at Investigative Sky Patrol through Automatic Meteor Imaging (whose acronym in Portuguese is PatrICIA, Patrulhamento Investigativo do Céu por Imageamento Automático de meteoro).

Through the methodological principles of Citizen Science, as promoted by the International Meteor Organization (IMO), the volunteers selected and guided by the authors of this paper were trained to analyze images of meteors captured by a station composed of a camera specially prepared for this function. For now, the analyses of this type cannot be performed by Artificial Intelligence, requiring the action of humans.

The captured images are kindly provided thanks to a partnership established with the BRAMON (Brazilian Meteor Observation Network) and the Ícaro Project, maintained by Luciano Diniz and Demilson Quintão, amateur radio operators who run this station with an all-sky camera. These images, captured by a ZWO ASI224MC camera with a wide-angle lens (all-sky), are archived in time-lapse format lasting approximately two minutes. Each frame contains metadata such as date, time, temperature, exposure time, and camera sensitivity. To validate the records, each visible meteor was compared with a sky simulation on the same day and time using Stellarium software, allowing confirmation of its position and extraction of relevant astronomical data, such as magnitude, angular length, and possible association with known meteor showers.

Therefore, the analysis of the records allowed the collection of meteor data according to the IMO format (Rendtel & Arlt 2017), including the time of occurrence, type (sporadic or shower identified with the official acronym), maximum apparent magnitude, angular length, and sky conditions.

5. Results

This paper presents a partial analysis of the records, conducted by five high school students who participated in this project. From the frame-by-frame evaluation of the videos obtained by the All-Sky camera, it was possible to identify and classify several meteors, indicating their parameters, stored in a spreadsheet on Google Docs.

As an example, we present here the analysis of the month of January 2022 (from the 1st to the 31st). Images of 76 meteors were captured, most of which were sporadic (identified by the acronym ESP in the data tabulation), that is, they were not part of a known meteor shower.

Analyzing the information studied in the recording videos, it is concluded that the average magnitude was approximately 3.2 and the average length of the resulting meteor trail is close

to 3.8 degrees. In January 2023 (from the 1st to the 31st), only 14 meteors were captured, since there were many cloudy and rainy nights, which makes it difficult or impossible to observe and identify meteors.

The captured meteors, mostly sporadic, have an average magnitude of 1.8 and an approximate length of 4.2 degrees. With these data, it is possible to conclude that in January 2023, we had brighter meteors than in January 2022, since the average magnitude number was approximately 43.75 percent lower than in the previous year.

Analyzing the captures made and recorded, in 2022 a total of 612 meteors were identified, with an average apparent brightness of 2.8 and a length of 2.4 degrees. The days in which it was not possible to capture meteors were due to factors such as: heavy rain, cloudy sky or an excessively bright full moon that prevents the visualization of faint meteors. Most meteors are recorded after midnight: between 4:00 and 5:00 AM there is a greater number of meteors, and between 6:00 and 7:00 PM there is a smaller number of identified meteors, as twilight obscures them for most of the year. Another finding was that July had the highest number of meteors recorded for analysis, while December was the month with the fewest captures. This difference can be explained by the fact that December and adjacent months have more cloudy periods. The most frequent meteor showers were the Alpha Capricornids (CAP) and Piscis Austrids (PAU). Apparently, meteors of greater magnitude (less bright) tend to have a smaller angular length.

6. Considerations

Despite the promising results, there are still some limitations in this study, such as the interval between captured frames and adverse atmospheric conditions, which reduce the number of meteors observed. For future work, it is recommended to install new cameras in different regions, expanding the coverage of observations, as well as expanding the project to involve a larger number of students and teachers. Observing meteor showers is highly relevant, since carefully observing sporadic meteors presents the possibility of discovering previously unknown showers (Izecson et al. 2008).

The data collected and analyzed are of great importance, as they can help teachers, researchers, scientists, and students to have understanding of the characteristics of meteors, especially those observed in the southern hemisphere. In addition, the results obtained here showed how citizen science can bring the teaching of astronomy closer to the reality of students, encouraging critical reflections and providing students with a real experience in scientific research, motivating them to trust science more.

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