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EDITED BY
Michael S. Kirk,
NASA Goddard Space Flight Center,
United States

REVIEWED BY
João Manuel Fernandes,
University of Coimbra, Portugal
Ryan French,
University of Colorado Boulder, United States

*CORRESPONDENCE
Rebecca A. Robinson,
rrobinson@seti.org

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A mission-embedded outreach program for NASA's Multi-slit Solar Explorer (MUSE) mission: inspiring future generations of solar explorers beyond boundaries and backgrounds

Rebecca A. Robinson[1]*, Bart De Pontieu[2,3,4], Simon Steel[1], Pamela Harman[1], Vanessa Polito[2,5] and Meng Jin[2]

[1]SETI Institute, Mountain View, CA, United States, [2]Lockheed Martin Solar & Astrophysics Laboratory, Palo Alto, CA, United States, [3]Institute of Theoretical Astrophysics, University of Oslo, Oslo, Norway, [4]Rosseland Centre for Solar Physics, University of Oslo, Oslo, Norway, [5]Department of Physics, Oregon State University, Corvallis, OR, United States

In the wake of the Decadal Survey for Solar and Space Physics, it is clear that the general knowledge of these subjects in the US is deficient in comparison to other subfields of astrophysics. This is concerning because we rely on the Sun to survive, and understanding our relationship with the Sun is crucial for understanding our immediate space environment. With that, it is our responsibility as scientists and educators to advocate for and share the knowledge of our Sun and space environments as accessibly as possible. One way to do so is by developing mission-specific outreach programs that tackle fundamental science questions and topics that are relevant to the Sun-Earth system. As a new and budding example, we introduce a mission-embedded outreach program for NASA's Multi-slit Solar Explorer (MUSE) mission. This program officially began on 1 December 2024 and includes three main local partners: California Academy of Sciences, Chabot Space and Science Center, and the Boys and Girls Club of the Peninsula. Each partner's scope of work is shaped by their resources and expertise, and each remains committed to creating reusable and versatile outreach products. This manuscript will summarize the scientific goals of the MUSE mission, detail the MUSE outreach program, highlight our collaborations with other heliophysics missions (e.g., PUNCH), and provide a preliminary assessment of our contribution to the future of heliophysics outreach.

KEYWORDS

heliophysics, outreach, education, astronomy, space science, solar physics

1 Introduction

The Multi-slit Solar Explorer (MUSE) mission is the first medium-class NASA explorer that is designed to focus on the Sun, targeted to launch no earlier than July 2027. MUSE is led by the Lockheed Martin Solar and Astrophysics Laboratory (LMSAL) located in Palo Alto, California. The goal of the MUSE mission is to use cutting-edge technology to observe and understand the dynamic physical processes that heat the multi-million degree solar corona, are at the roots of the solar wind, and drive the instability of the solar atmosphere in the form of flares and coronal mass ejections (CMEs). It remains unclear which physical mechanisms dominate these various processes, and MUSE aims to improve our understanding of those processes in order to diagnose the extent to which each underlying mechanism can energize a stellar atmosphere and drive space weather events such as flares and CMEs.

Innovative technology onboard the MUSE mission includes a 35-slit spectrograph that will measure extreme ultraviolet (EUV) spectra in the solar corona much faster than other spectrographs, and at very high spectral resolution. The MUSE design draws inspiration from its predecessor, the Interface Region Imaging Spectrograph (IRIS; De Pontieu et al. (2014) and De Pontieu et al. (2021)) and addresses some of the challenges faced by single-slit spectrographs. These scan the solar disk slowly to obtain spectra over a large field of view. The cadence of spectroscopy from single-slit spectrographs is typically too low to capture the full evolution of large-scale dynamics events in the solar atmosphere. IRIS takes high-resolution images and spectra of the low solar atmosphere, but due to its single-slit design, is unable to capture the evolution of the plasma in dynamic events such as flares and eruptions over a large field of view. To address that challenge, MUSE will use its 35-slit spectrograph to effectively "freeze" snapshots of erupting plasma, measuring the spectra of large-scale erupting flares and CMEs in space and time. For details on the technical specifications and science goals of the MUSE mission, we refer the curious reader to two MUSE introductory papers: De Pontieu et al. (2022) and Cheung et al. (2022).

The MUSE Outreach program is a mission-embedded outreach initiative and is headquartered at the SETI Institute (also colloquially referred to as SETI) in Mountain View, California. This partnership with SETI allows the MUSE Outreach Program to benefit from SETI's engagement with several existing projects such as NASA's Community College Network (NCCN), the NASA Heliophysics Education Activation Team (HEAT), NASA's Astronomy Activation Ambassadors (AAA), Unistellar, and SETI's own Education Group. Reciprocally, SETI benefits from a strong partnership with the MUSE mission scientists and outreach specialists; the establishment of SETI's first Heliophysics Group is another byproduct of this intentional partnership between LMSAL and the SETI Institute. The MUSE Outreach proposal was confirmed during the MUSE mission's Phase C/D assessment in August 2024, and was officially granted funding from 1 December 2024 - the tail end of NASA's Heliophysics Big Year - until 30 June 2027.

The MUSE Outreach program has three main local partners in the San Francisco Bay Area of Northern California, as well as several satellite partners throughout the U.S. The three main partners are California Academy of Sciences in San Francisco, California, Chabot Space and Science Center in Oakland, California, and the Boys and Girls Club of the Peninsula, specifically the Moldaw-Zaffaroni Clubhouse in East Palo Alto, California. Satellite partners include the Center for Astrophysics: Harvard and Smithsonian, the Daniel K. Inouye Solar Telescope (DKIST), and the Montana Space Grant Consortium (MSGC). As previously mentioned, MUSE Outreach also engages directly with several NASA Science Activation (SciAct) projects, especially NASA HEAT, Aurorasaurus, and NCCN.

MUSE Outreach aims to address four main science themes that are complementary to the MUSE science goals. These themes are:

- Spectroscopy, "the science of rainbows"
- Magnetic explosions on the Sun
- Technology and Innovation in Advancing Solar Science and Space Weather
- Sun-as-a-Star, from Living with a Star to Living with Stars

Each theme touches on fundamental science concepts, the understanding and development of which are crucial to MUSE mission success. A goal of the MUSE Outreach Program is to package these science themes into lectures, public engagements, and original and heritage products in an accessible, sensitive, and thoughtful manner. The intent is to provide easily digestible science content for everyone and perpetuate the idea that science is fun, relevant, and important to our development as a society.

During the first several months of official operation, MUSE Outreach has collaborated with NASA's Polarimeter to UNify the Corona and Heliosphere (PUNCH) mission (Deforest et al., 2022; Deforest et al., 2025) to design MUSE versions of PUNCH Outreach heritage products (Morrow and DeForest, 2021). These efforts are ongoing and progressing. MUSE Outreach has also debuted several original products in collaboration with local partners, and is currently curating content for an upcoming 10-week internship program for the Boys and Girls Club of the Peninsula. This report serves as a checkpoint for early progress in the MUSE Outreach Program, highlights contributions by outreach partners, and notes the ways in which MUSE Outreach can address deficiencies in public knowledge of solar and heliophysics as identified by the most recent Decadal Survey for Solar and Space Physics.

2 Local outreach partners

The three main Bay Area partners benefit from close, active engagement with MUSE and SETI, as well as synergies among themselves. Each partner contributes to the MUSE Outreach program according to their resources, and their scopes of work are individually discussed below.

2.1 California academy of sciences

Located in San Francisco, California Academy of Sciences is California's oldest running museum and research institution for the natural sciences, and it currently welcomes more than one million visitors per year. One of their most prominent exhibits is the Morrison Planetarium, a 75-foot tilted dome with the ability to display seamless images of the cosmos. Their shows are produced in-house, many of which utilize OpenSpace software for cutting-edge visualizations of our known universe.

With the Morrison Planetarium as well as their flat-screen facilities in mind (including their Hohfeld Hall immersive presentation venue), California Academy will create an interactive program that centers MUSE science and innovation. The program will include state-of-the-art models, visualizations of the MUSE orbital trajectory, and updated solar visualizations. These visualizations and program will be available on platforms that are

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accessible to other museums and science centers (i.e., OpenSpace) so that each product can be disseminated across the US.

California Academy also hosts the monthly Benjamin Dean Astronomy Lecture series, and one lecture each year will be given by a MUSE mission member. Before each lecture, California Academy's planetarium engineers work together with the speaker to curate full-dome visualizations for use during the lecture. Afterward, California Academy's video production staff creates an associated video that can be used multiple times for outreach presentations. These videos and visualizations are intended to be shared with other museums and science centers as well as the general public.

2.2 Chabot space and science center

Chabot Space and Science Center was established in 1883 and is located in Oakland, California. Chabot is a multi-building science center with learning laboratories, classrooms, a full dome theater, full dome planetarium, outdoor amphitheater, and three permanent outdoor telescopes. Chabot also hosts the NASA Ames Visitor Center as a part of the exhibit hall.

The Galaxy Explorers internship program at Chabot consists of over 200 10th-12th grade students from the Oakland Public school system who receive training in STEM topics and career readiness. Throughout the internship, they work shifts on the museum floor acting as exhibit interpreters to enhance the guest experience. In addition, they are exposed to content following four different STEM Pathways: Astronomy, Digital Media, Engineering, and Environmental Monitoring. At the end of each semester, they complete a project pertaining to one of the STEM Pathways which may end up serving as a short- or long-term museum exhibit. Their voices in curating guest experiences are valued by Chabot leadership and crucial to interns' professional and personal development.

Under the guidance of Chabot's Youth Development Instructor, the Galaxy Explorers have been (and will be) creating products that pertain to the four MUSE science themes mentioned in Section 1. Recently, this semester's Galaxy Explorers unveiled their brand new *Solar Corner* located next to the center's permanent telescopes. This outdoor space was previously unused during the day, but is now full of original Sun-themed products and activities created by the Galaxy Explorers. MUSE Outreach plans to continue leveraging these original products for our own outreach goals as we continue to support Chabot's Galaxy Explorers.

Over the next several months, a subset of the incoming Galaxy Explorer interns will focus not only on the Sun in general, but on the MUSE mission specifically. MUSE Outreach Leadership will assist in training the new class of Galaxy Explorers so that they are prepared with MUSE science themes and mission basics. New products and activities will be tested and piloted as the new Galaxy Explorers move through the internship and complete their semester projects.

In addition to the Galaxy Explorers internship program, the MUSE Outreach Program also supports overnight events with the Scouts programs. Last year, Chabot hosted over 3,500 overnight participants who completed activities to earn Space Science Badges. Future events will feature MUSE- and Sun-related activities and corresponding Sun Science badges for the Scouts to earn. Chabot, with support from the SETI Institute, is developing Sun-focused scout packages for Juniors (4th and 5th graders) and Cadets (6th-8th graders) for use during the overnight events. These packages will be evaluated and reused for future Scouts events at Chabot, and can be repackaged for similar events nationwide.

2.3 Boys and girls club of the peninsula

The Boys and Girls Club of the Peninsula's Moldaw-Zaffaroni Clubhouse (hereafter denoted as BGCP) is located in East Palo Alto, California; just a short distance from LMSAL where MUSE is headquartered. Since MUSE and BGCP are neighbors, MUSE Outreach intends to foster a strong relationship between BGCP students and the MUSE Science team.

The MUSE Outreach Program aims to support BGCP by creating a 10-week high school internship program to be piloted during the Fall 2025 semester. MUSE Outreach will provide stipends, content, activities, dedicated MUSE Science mentors, and bus transportation for all interns. During the first half of the internship, BGCP interns will learn the basics of the MUSE science themes and visit outreach partners (i.e., California Academy of Sciences, Chabot Space and Science Center, SETI Institute, and Lockheed Martin Advanced Technology Center). The second half of the internship will be a continuation of their science training, and they will also spend a significant amount of time with their MUSE Science mentors at LMSAL.

Under the direction of their MUSE Science mentors, the BGCP interns will create their own MUSE Outreach products. These products will showcase what they have learned about the MUSE science themes, as well as why they believe MUSE science themes are relevant and important to their lives. They will present their outreach products to their community as a culmination of their hard work and training. Once piloted, this internship will be modified as necessary, repeated, and deployed to other interested Clubhouses.

3 Outreach products

The MUSE Outreach program is relatively new and as such, has not yet produced a large portfolio of products. However, MUSE is making good use of heritage products from the PUNCH mission and, at the time of this writing, has piloted the first original MUSE outreach activity. In addition, as mentioned in the previous section, each local partner is responsible for contributing their own outreach products. The following subsections provide descriptions of current and ongoing outreach initiatives.

3.1 Heritage products from PUNCH

- 3-hole PUNCH Pinhole Projectors: This product is a tool for teaching optics and encouraging safe eclipse viewing. It was designed, vetted, and field tested by the PUNCH Outreach program. We are in the process of printing a MUSE version with our own design (Figure 1) using updated text provided by the PUNCH team.
- Virtual Team Cards: This product aims to showcase the broad-spectrum workforce that is vital to NASA mission success. Participating members of the PUNCH team have used this

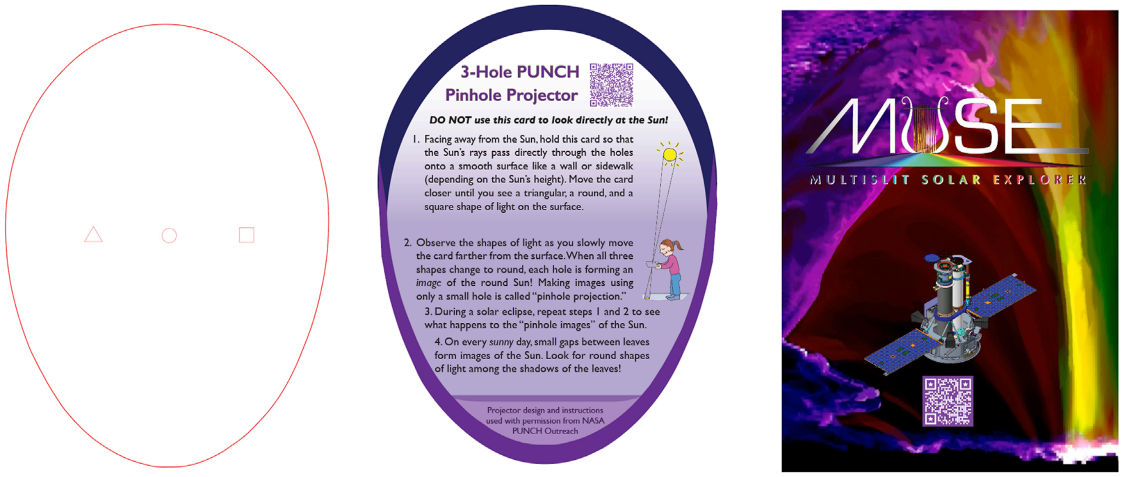

FIGURE 1
Inspired by PUNCH Outreach, MUSE 3-hole PUNCH Pinhole Projectors are ready to be printed. This product was developed to encourage safe solar eclipse viewing and to teach optics concepts in a hands-on, accessible manner.

product to demonstrate that they come from a variety of backgrounds and possess a wide set of skills and interests. The original PUNCH version includes a section called "Inspiring Animal" which allows participants to identify an animal that embodies one of their most valued traits. The MUSE team will follow suit with our own version, incorporating the electromagnetic spectrum to capture our theme of Spectroscopy. The MUSE version will include a section called "My Wavelength" which will allow participants to place themselves somewhere on the electromagnetic spectrum based on their self-reported personality traits and/or skills that they find beneficial to the MUSE mission team.

3.2 Original activities by MUSE outreach leadership

- SolArt - Visualizing the layers of our Sun: This is an original STEAM activity that combines art and solar science to teach the layers of the Sun, as well as how energy moves between those layers and extends into the solar wind. SolArt is an art project that uses the ancient water marbling method (Wolfe, 1990) to create a unique painting of the Sun in just a few minutes. Participants create a turbulent "solar wind" by swirling floating paint with a wooden skewer, then use a few more drops of paint to layer the Sun's atmosphere, surface, and interior on top. Then, they use their wooden skewer to "move energy" from the interior to the exterior of the Sun, effectively illustrating turbulent radial energy transport. The paint is then transferred to a piece of mulberry paper and left to dry. Once dry, each participant can take their own unique creation with them. This activity was piloted at the KIPAC + friends Community Day held at Stanford University in April 2025, and will be used for future events including the BGCP Internship Program. Figure 2 shows the front and back of a complementary postcard given to participants, including a QR code to a YouTube Shorts video that explains the science content as well as the painting activity itself. Figure 3 shows two photographs from KIPAC + friends Community Day, courtesy of SaM Fontejon/Fontejon Photography, Inc. These photographs depict the participants and their paintings, of which between 150 and 200 were created.

3.3 California academy of sciences

- Full-dome assets: The California Academy engineering team is working with speakers from the MUSE mission team to create full-dome presentations using solar assets in the OpenSpace universe. They are also working to integrate MUSE visualizations into OpenSpace.
- Flat-screen assets: In addition, the video production team is integrating MUSE content into flat-screen video assets to be enjoyed by the public when visiting the science center, including an interactive kiosk.

3.4 Chabot space and science center

- Spectroscopy and Invisible Light: The Galaxy Explorers have developed activities utilizing infrared cameras and ultraviolet solar beads to teach about different types of light, including invisible types. In addition, the Galaxy Explorers have curated a build-your-own spectroscope activity.
- Magnetic Fields: Using a magnet and iron filings scattered over an EUV photo of the Sun, the Galaxy Explorers can illustrate how active regions form over magnetic concentrations.
- Remote Sensing: The Galaxy Explorers have gamified remote sensing of the solar interior by creating the Solar Detective activity, whereby participants use experimentation with sound to identify hidden objects trapped between two opaque cups.

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FIGURE 2
Complementary postcard that accompanies the SolArt activity. (Top) The front of the postcard explains the different layers of the Sun, including temperature profiles, heat transfer, and magnetic dynamics. (Bottom) The back of the postcard includes a QR code to a YouTube Short that summarizes the SolArt project and allows participants to engage and learn at their own pace.

- Sunion: This activity teaches the layers of the Sun with an interactive "Sunion" (think "Sun onion") and participants can make their own paper version to take home.
- Solar Corner: All above activities (and more) are a part of Chabot's new *Solar Corner*, located outdoors and adjacent to their three permanent telescopes. The *Solar Corner* now

FIGURE 3
Pictures from the KIPAC + friends Community Day on 19 April 2025. This was our first time introducing the SolArt activity to the public, and between 150 and 200 participants created their own painting. Photographs courtesy of SaM Fontejon/Fontejon Photography, Inc.

includes permanent signage providing information about the Sun, and it is an area where visitors can gather, learn, and participate in guided activities.

3.5 Boys and girls club of the peninsula

- BGCP High School Internship: This 10-week internship will focus on the creation of an original outreach product supporting the MUSE mission. Interns will receive training in each of the MUSE outreach science themes, be exposed to working environments at the SETI Institute and LMSAL, visit Chabot Space and Science Center and California Academy of Sciences, and ultimately create their own outreach product that summarizes how MUSE science is relevant and important to their lives and community.

3.6 Evaluation of products

MUSE Outreach products and activities are evaluated by an external evaluation team based at the Planetary Science Institute. This team will perform qualitative and quantitative evaluations for all programs, activities, events, and products to ensure that MUSE Outreach is in alignment with proposed goals and metrics. These goals and metrics include meaningful engagement with 10,000+ participants and students, and adoption of our OpenSpace visualization assets by 25 museums, science centers, or art galleries. We also aim to achieve a significant (30%) increase in participant understanding of the importance of space weather to present-day society, participant understanding of stars and their planetary systems, participant interest in NASA Heliophysics exploration, audience perception that NASA is relevant and accessible, and subject matter expert (SME) comfort and interest in public engagement (Buxner et al., 2022; Mead et al., 2024). Data collection methods include feedback forms, surveys, interviews, participant video reflections, participant journal reflections, and site visits by our evaluation team (Buxner et al., 2011). Frequent checks with our evaluation team solidify our commitment to producing measurable results through our feedback pipelines.

4 MUSE outreach as a valuable public service

4.1 Response to the Decadal Survey

The Decadal Survey for Solar and Space Physics (Heliophysics) 2024–2033 (National Academies of Sciences, Engineering and Medicine, 2024) has exposed a lack of public understanding of solar and heliophysics, especially when compared to other subfields of astronomy. Section 4.1 includes a paragraph that reads: “While solar and space physics science is exciting and has important ramifications for life and society on Earth as well as in space, public awareness of the subject is lacking (while there is better awareness of astronomy). The public does not associate the subject with an independent scientific field or a professional community. Better communication, including a wider variety of appealing graphics and animations, will help to raise public awareness of the valuable science of solar and space physics.” According to HelioIndex, there are only 1,910 active heliophysics researchers registered over 61 countries (Young, 2025). Of these researchers, the largest group (29%) of them work in the United States; but if the US public does not recognize heliophysics as an independent scientific discipline, then this implies an even more bleak reality for other nations. Clearly, a lack of interest or knowledge of heliophysics is an international issue that impacts, and has impacted, the development of a global heliophysics workforce. In Chapter 4.3 of the Decadal Survey, the authors note: “Solar and space physics science has not been fully incorporated into U.S. education at either the K-12 or undergraduate level in the same way that astronomy and astrophysics, Earth sciences, and planetary science have been. Consequently, the recruitment of students and professionals into solar and space physics is less than it could be.”

These are sobering findings, but they ultimately serve as an encouraging reminder to continue investing in heliophysics outreach initiatives. Not only that, but we must intentionally design our outreach initiatives to bridge some of these educational gaps that learners face in U.S. schools and beyond. Fortunately, the MUSE Outreach Program has been designed to focus on four accessible science themes, to engage the local community, and to incorporate a variety of media such as art, computer visualizations, and hands-on activities.

Of course, the MUSE Outreach Program is not an education program, although it does align with the Next-Generation Science Standards (see Section 4.3). MUSE Outreach is designed to appeal to learners everywhere, whether we share MUSE science in schools, science centers, museums, or at public events. All products and activities produced under the MUSE Outreach umbrella will be deployable to planetariums and science centers nationwide and, when applicable, available in the OpenSpace database rather than remaining at their host institutions local to the Bay Area. Indeed, many MUSE Outreach products are intrinsically borderless (e.g., OpenSpace assets, virtual products, etc.) and can be deployed worldwide in order to address global deficiencies in heliophysics education and understanding. Section 4.5 of the Decadal Survey notes that "[t]he space science community needs to have a data bank of resources and materials to draw from that communicate to the public what solar and space physics is and how it affects society." Not only does MUSE draw inspiration from other missions (e.g., PUNCH) but MUSE products will be available to future missions and other entities nationwide. In this way, the heliophysics community may draw down resources as needed from within, rather than requiring even more resources to create something similar to what already exists.

For example, the first original MUSE Outreach activity, SolArt (see Figure 2) uses ancient painting methods that can be repurposed for a variety of lesson plans and performed almost anywhere. This project can be framed as a direct response to a call in Section 4.5 of the Decadal Survey: "One way to increase visibility is through so-called STEAM iniatives, or STEM plus art, by fostering […] visual art projects." SolArt is a quick, take-home visual art project that can serve several hundred participants during a single event, all of whom will have had the opportunity to create their own unique Sun painting to take home and cherish. Affixed to bedroom walls or refrigerators in their homes, that original artwork can serve as a reminder of not only the science behind the project, but of an encounter during which science became fun, engaging, accessible, relevant, colorful, and joyful.

MUSE Outreach is committed to fostering joy as well as scientific growth and workforce development; topics that seem inaccessible are not made more accessible by force, but by community and colorful storytelling. By paying close attention to our local community, taking the time to correct course when we miss the mark, and interpreting the excitement and relevance of MUSE science themes, the MUSE Outreach Program is endeavoring to improve the state of solar and heliophysics for the next Decadal Survey.

4.2 Heliophysics Big Ideas

The NASA Heliophysics Education Activation Team (NASA HEAT) has created an extensive framework for heliophysics education questions, including Heliophysics Big Ideas with specific introductory, intermediate, and advanced topics for students and learners of all exposures and abilities. The three Heliophysics Big Questions are:

1. What are the impacts of the Sun on humanity?
2. How do the Earth, the solar system, and heliosphere respond to changes on the Sun?
3. What causes the Sun to vary?

Each Heliophysics Big Question comes with a set of Heliophysics Big Ideas (HBIs), each of which encompasses an important aspect of heliophysics. Each heliophysics mission in NASA's fleet addresses its own subset of HBIs based on the mission science concepts and goals, and MUSE is especially aligned with four of them:

- HBI 1.2: The Sun is active and can impact technology on Earth via Space Weather
  One of the science goals of the MUSE mission is to closely observe the active solar corona in order to diagnose the origins and energies of magnetic explosions, coronal mass ejections, and the solar wind. As the launching pad of space weather phenomena, the solar corona generates the solar wind and releases plasma shock waves that can impact lunar and planetary systems including the Earth, the Moon, and Mars. Understanding the solar corona in better detail can improve our ability to predict space weather events, which helps us better predict its impacts on technology and human spaceflight. This HBI pertains to three of the MUSE Outreach science themes: Magnetic explosions on the Sun, Technology and Innovation in advancing Solar Science and Space Weather, and Sun-as-a-Star, from Living with a Star to Living with Stars.
- HBI 2.3: The Sun is the primary source of light in the solar system
  Sunlight energizes the daylight sides of all bodies in our solar system, but visible sunlight is not the only form of light emitted by the Sun. The MUSE mission is designed to use spectroscopy to observe the Sun in EUV light, which glows brightly in the solar corona. The 35-slit spectrograph onboard MUSE will allow us to disperse the EUV light into its spectra, providing the "fingerprints" of the environments that produced the light. This HBI pertains to the MUSE Outreach science theme of Spectroscopy.
- HBI 3.1: The Sun is made of churning plasmas, causing the surface to be made of complex, tangled magnetic fields
  Although scientists do not know exactly what causes the solar corona to be so hot, one prevailing theory is that such high temperatures come from energetic processes in the Sun's dynamic magnetic field. The magnetic field is generated by the constant churning motion of electric plasma, and these motions can cause tangled magnetic fields to reconnect with one another. When that happens, magnetic energy is released as heat, light, and particle acceleration. MUSE will observe these events in fine detail in order to better understand how magnetic fields can drive these sudden explosions. This HBI is exactly aligned with the MUSE Outreach science theme of Magnetic explosions on the Sun.
- HBI 3.2: Energy is created in the core and travels through the Sun into the Heliosphere
  Although MUSE is primarily designed to observe the solar corona, the processes that occur in the corona are a result of magnetic energy that is generated in the solar interior. This generation is made possible by temperature and opacity gradients that form as energy moves outward from the core. By tracking energetic events that occur in the solar corona, MUSE can join a suite of co-observing instruments (such as IRIS, Hinode, the Solar Dynamics Observatory (SDO), or ground-based observatories like DKIST) to understand the comprehensive layers of energy transfer from the interior to the corona. Of course, we cannot directly observe the solar interior; but surface observations allow us to infer conditions

in the solar interior. This HBI aligns with the MUSE Outreach science themes of Magnetic explosions on the Sun as well as Technology and Innovation in Advancing Solar Science and Space Weather. Not only will MUSE unveil important details in the solar corona, it will be one of many instruments observing the Sun's dynamic layers.

4.3 Next-Generation Science Standards

The MUSE Outreach program was designed with specific science themes which pertain to specific Heliophysics Big Ideas, as discussed in the previous section. The Heliophysics Big Ideas were developed to be in alignment with the Next-Generation Science Standards (NGSS; National Research Council, 2013), which were created by the National Research Council's (NRC) Framework for science proficiency. This framework includes three main dimensions: Practices, Disciplinary Core Ideas, and Crosscutting Concepts.

MUSE as a science mission, by nature, is in direct alignment with all of the Practices and Crosscutting Concepts listed in the NGSS framework. However, not all science missions have the same science goals or themes, and the MUSE Outreach science themes align with the following Disciplinary Core Ideas:

- Physical Sciences:
  PS1: Matter and its interactions
  PS2: Motion and Stability: Forces and interactions
  PS3: Energy
  PS4: Waves and their applications in technologies for information transfer
- Life Sciences:
  LS2: Ecosystems: Interactions, energy, and dynamics
- Earth and Space Science:
  ESS1: Earth's place in the universe
  ESS2: Earth's systems
  ESS3: Earth and human activity
- Engineering, Technology, and Applications of Science:
  ETS1: Engineering Design
  ETS2: Links among engineering, technology, science, and society

Together, the MUSE Outreach science themes pertain to all PS, ESS, and ETS Core Ideas, as well as one LS Core Idea. This alignment with NGSS, enhanced by a strong alignment with the HBIs, demonstrates that the MUSE Outreach Program is ready to deliver important and relevant education and outreach content.

5 Conclusion

NASA's Multi-slit Solar Explorer (MUSE) mission is targeted to launch no earlier than July 2027 and is being designed to observe the solar corona using a 35-slit spectrograph, which will drastically improve our ability to collect EUV spectra of dynamic coronal events including solar flares and CMEs. The accompanying mission-embedded MUSE Outreach Program is headquartered at SETI and focuses on four main science themes that accompany the mission goals.

The MUSE Outreach Program has three local partners in the Bay Area of California, including California Academy of Sciences, Chabot Space and Science Center, and the Boys and Girls Club of the Peninsula. Each local partner contributes outreach products and activities based on their resources and abilities. MUSE Outreach has already piloted one original activity in addition to products designed by Chabot Space and Science Center's Galaxy Explorers, and is continuing to develop heritage products originally designed by the PUNCH Outreach team.

MUSE Outreach addresses some of the key challenges outlined in the Decadal Survey for Solar and Space Physics (Heliophysics) 2024–2033, in that the program is designed to address some field-wide outreach and education deficiencies exposed in the report. In addition, MUSE Outreach is designed to align with the NASA HEAT Heliophysics Big Ideas, which themselves were designed in alignment with the Next-Generation Science Standards. With strong collaborators and a foundation firmly rooted in educational best practices, the MUSE Outreach Program is committed to excellence and relevance as the MUSE mission moves toward launch.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

RR: Writing – original draft, Writing – review and editing. BD: Funding acquisition, Resources, Conceptualization, Supervision, Project administration, Investigation, Writing – review and editing. SS: Funding acquisition, Conceptualization, Supervision, Project administration, Writing – review and editing. PH: Writing – review and editing, Conceptualization, Funding acquisition. VP: Investigation, Supervision, Writing – review and editing. MJ: Writing – review and editing, Investigation.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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