SOCIETY OF PHYSICS STUDENTS
An organization of the American Institute of Physics

SPS Chapter Research Award Proposal

Project Proposal Title	Our First Radio Telescope
Name of School	Calvin University
SPS Chapter Number	0951
Total Amount Requested	2000

Abstract

Calvin University's Society of Physics Students is seeking to build our university's first radio telescope used for student's exploration, and research. This telescope will be maintained by an interdisciplinary team of students which will also serve as an outreach instrument to get students involved in astronomy and science in general.

Proposal Statement

Background and Overview of Proposed Project

Calvin University's Society of Physics Students is a group of dedicated, ambitious students who seek to rebuild a 2.8 m, parabolic reflector radio telescope for use in student instruction, exploration, and, ultimately, research. In the early 2010s, a complete amateur radio telescope was donated to Calvin University with the supposition that it would be used to usher in an era of radio astronomy at Calvin. A decade later, this dish would be collecting dust, rusting, and missing several key components—perhaps lost in a facility cleanup.

Earlier this year, the whim of a curious students to vitalize radio astronomy at Calvin transformed into an exciting opportunity for students and professors alike when the project received departmental clearance to return the telescope to working order. Work began in mid-July and we recently assembled the dish atop the science building. Forthcoming design work on the feed horn and superheterodyne receiver will be inspired by MIT's Small Radio Telescope (SRT) project.[1] The completed telescope will examine the 21 cm (1420.4 MHz) hydrogen line (HI) emission and serve as a teaching tool for radio astronomy to Calvin undergrads and the general public. We are requesting funds to build necessary components such as a superheterodyne receiver, radio-frequency transparent paint, a construction of a driving mechanism and more.

We have several specific interests we hope to cultivate through our work with the telescope. First, we strive to provide a greater understanding and accessibility of science for both students and non-students alike. Our dish is located in the vicinity of our long-established optical observatory and will receive the same visitors on regular observing nights. Observing nights are free, public events held every weekday night when the sky is clear. Visitors can probe the heavens with Calvin's optical telescope, exploring objects we can see with the unaided eye (like Saturn or the moon), and some we cannot (like the Ring Nebula or the Andromeda Galaxy). What about invisible light, like radio? What we will offer is a logical abstraction of visible wavelength astronomy; instead of solely focusing on the incredibly narrow optical band, we will use similar light collection principles to open our eyes to an invisible, yet very real, part of our universe. By doing so, the public can see firsthand how astronomy, like many scientific disciplines, relies on simple observations to lay the rigorous foundations for more complex observations. This significant connection is a subtle way the project and a radio telescope will work to renew wonder and curiosity in science—to slowly reestablish a trust of science in our greater community.

Second, our mission is to provide an opportunity for undergraduates from all STEM backgrounds to engage in a real-world application of their education through radio astronomy. While the details of specific applications are not yet established, imminent work on the telescope will feature component construction, electronics design, public engagement, and data acquisition, filtering, and analysis—all of which incorporate valuable, practical skills to our members' post-undergraduate pursuits. We are not particular about who can benefit from our organization; our only request is that members are curious and long to satisfy their curiosity. This has far-reaching implications in terms of social dynamic and inclusivity. For example, we are truly fortunate to have a capable, ethnically-diverse group of students working on this project.

Looking ahead, we will be promoting the radio project to students next fall, ideally when the telescope is fully operational. No one wanting to learn more about, or practice radio astronomy will be turned away on the basis of sex, religion, race, color, ethnicity, sexual orientation, or national origin as it is both immoral and hypocritical of our unique origins. We recognize that, through our ethnically-diverse backgrounds, we enter situations with conscious and unconscious biases, and that the inherent value of others is irrespective of our agreement (or lack thereof) with their personal beliefs. Therefore, we say intellectual diversity should promote humility in ourselves, curiosity towards our peers, and lead us to question our presuppositions. It should prompt openness to ideas that we do not fully understand and foster curiosity while we seek to understand. It should welcome the notion that all people harbor life experiences that shape how they approach questions and how they perceive the world.

We believe our project aligns well with the objective of SPS, to help "students transform themselves into contributing members of the professional community." In doing so, we recognize that the students in the project who will not necessarily go out in the world and become professional radio astronomers. But through the project will be able to engage the general public on matters of astronomy, specifically relating to its relatability and credibility. Other sections of this proposal also speak of the aims to reestablish trust and comprehension (and a healthy dose of awe) in astronomy, especially among people not actively engaged in STEM. This could include members of the Grand Rapids community or non-STEM students taking an introductory astronomy class. The possibility for outreach is immense and aligns with the objective of SPS moving forward into the next decade.

Expected Results

When our telescope is fully operational, we will focus our attention on the HI emission from the milky way and from other bright radio sources (the galactic center, Cassiopeia A, M87, etc.).[2][3] The HI line is an effect of the conservation of an electron's angular momentum, where quanta of light are released at a very specific frequency following the excitation of a hydrogen atom. This frequency can be used to the radio astronomer's advantage in a few distinct ways. First, since the frequency of emission is so precise, the signals we receive could be one of two things: excited hydrogen clouds from the milky way or "radio galaxies", or a continuous emission source like a supernova remnant. We should be able to detect and map bright sources like Cassiopeia A or Cygnus A (two very bright supernova remnants) with our telescope. Additionally, since there is one and only one frequency for the HI line, deviations in the frequency relay information about the radial movement of the source. If the frequency is higher, the source is approaching the earth; if the frequency is lower, the source is retreating from the earth. This simple fact can be (and has been) used to map the rotation of the Milky Way. These are two examples of student-led projects we plan to pursue with our completed telescope.

Description of Proposed Research - Methods, Design, and Procedures

The structure of our work is split between small teams and larger assemblies. Assemblies are used for directing efforts and disseminating results, while teams are used for development and accomplishing specific tasks. For example, we recently assembled the dish on the roof of the science building as a large group. This is contrasted by teams who have been assigned to address specific tasks (like antenna support, feed horn design, etc.) as a way of decentralizing objectives while promoting accountability. In terms of additional responsibilities, only the organization director has obligations outside of standard meetings. Student leadership will formally expand as we grow as an organization.

During the academic year, we expect to hold one assembly (meeting) a week during which we will develop components for the telescope, learn the essential theory behind radio astronomy, and, importantly, promote radio astronomy in an accessible and enjoyable way for those who are curious. This effort approximately equates to 0-2 hours per week per student. This winter, we will design a feedhorn and feedhorn support and reinforce theory and data manipulation practices with measurements with our small feed horn telescope. Should we be awarded this grant, we will attempt to complete the superheterodyne receiver before the term's end in late April.

The summer is a more challenging time to coordinate work on the telescope. As a result, there will be fewer members who could work on the telescope next summer, but those who are at Calvin could work more hours per week given an increase in free time. It cannot be estimated how much can be done at this time, but our efforts will return to the consistent 0-2 hours per week per student come autumn 2023. We will paint our telescope in the summer or autumn depending on availability. We hope to have the first data (albeit not calibrated) in September 2023. Enduring work will be technical in nature.

We would like several of our short-term goals to perpetuate and grow in complexity over time. These include cultivating public engagement, renewing telescope architecture, and reinforcing good research and data analysis habits. Novel objectives include engaging in student-led radio astronomy research and expanding the range of frequencies that can be observed. Ultimately, we hope to expand our operation to include another radio telescope. This would allow us to correlate the detections from our dishes to improve the resolution and pointing accuracy of our overall measurements—this setup is called an interferometer and would be the next step after mastering the current telescope.

Plan for Carrying Out Proposed Project

- Personnel - Members of our chapter of SPS and other interested students in various STEM majors will contribute significantly to the project.
- Expertise - We are supported by the entire Physics and Astronomy Department at Calvin. Specifically, our faculty advisor received his PhD for work in radio astronomy and is a very capable source of help.
- Research space - The dish will reside next to our existing optical telescope dome. A coaxial cable will run from the dish to a computer located inside the observatory dome.
- Contributions of faculty advisors or the department (equipment, space, etc.) - Our department has provided us with an old radio dish, seed funding to kickstart the project, and encouragement to undertake the project. Additionally, we have roof space designated for the radio telescope when it is complete.

Project Timeline

Date	Objective
11/15/22	Submit SPS proposal Ongoing self-study and small group projects
1/15/22	Convene for discussion on purchase
1/16/22	Submit purchase orders
2/16/22	Assemble and tests arrived parts
3/6/22	Collect first signals from radio telescope, collect data for iterative improvement and calibration
5/1/22	Begin writing interim report
5/31/22	Submit Interim report
9/1/22	Reconvene for school, first academic year meeting
10/1/22	Split into groups working on improvements.
11/1/22	Finish calibration and collect first data
11/15/22	Start first observation project
12/1/22	Start writing report
12/31/22	Submit final report

Budget Justification

We are actively supported by the Calvin University Physics and Astronomy department which will buy small parts to stimulate our progress (<$100). We also have a preexisting 2.8 m dish that we using to build this radio telescope. Additionally, we have the initial low noise amplifier setup (different from the low noise amplifiers inside the receiver) from a related feed horn telescope.

Many parts on our budget are components to build necessary radio teslecope parts and were originally defined in a document by the MIT Small Radio Telescope project. We will be building, from scratch, the first feed horn prototype, the receiver, and the PC interface. The low noise amplifiers are small, expensive parts used for boosting the signal in processing.The A/D converter and local oscillator are two parts in our budget that are challenging to source. As such, they are estimates based on similar products that will not work for this system. Other expensive parts on our budget relate to shielding sensitive parts and specialized radio frequency components.

Bibliography

[1] “SRT: The Small Radio Telescope.” MIT Haystack Observatory.
[2] Owen, Biretta, & Eilek. “M87 as a Radio Galaxy.” NRAO, January 7, 1999.
[3] "21-centimetre radiation." Encyclopedia Britannica, November 19, 2020.