VLASS White Paper – Early Integration of Broader Impacts - EPO

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Introduction

As this committee reviews white papers presenting science cases for a new Karl G. Jansky Very Large Array Sky Survey, it is important to also consider ways in which the general public could be involved through citizen science efforts, and how more robust programs might engage middle/high school teachers, undergraduate faculty, and K-16 students in research. This paper presents the case for planning public participation projects in tandem with efforts to design and implement any sky survey.

The Karl G. Jansky Very Large Array is one of the most sophisticated research instruments of our time. The scientific discoveries that will be made in the coming years using the VLA are exciting to think about, and the VLA Sky Survey (VLASS) provides an opportunity to showcase the vast potential of a new and improved telescope. Sharing this exciting opportunity with students and the general public, through strategic education and public outreach (EPO), will allow NRAO to maximize on its investment, while inspiring the next generation of science, technology, engineering, mathematics (STEM) professionals.

NRAO has a rich history of supporting a variety of successful EPO efforts. In its mission statement, NRAO states, "In partnership with the scientific community, we also train the next generation of scientists and engineers, and promote astronomy to foster a more scientifically literate society." As a federally funded institution, NRAO is asked to not only address intellectual merit requirements, but also those of broader impacts (NSF, 2013). VLASS provides an opportunity for NRAO and its partners to do both.

As with any successful building project, a great deal of time, money, and effort can be saved with adequate early planning. Integrating EPO efforts, whether it is for citizen science, student research, or social media must take place from the beginning, and in concert with the development of science cases for a VLASS.

Rationale

A recent Pew poll showed 85% of scientists view the public's lack of scientific knowledge as a major problem, and nearly 50% believe the public has unrealistic expectations of scientists (The Pew Research Center, 2009). Further, 51% of high school students say they may be discouraged from pursuing a STEM career because of a "lack of understanding of the subjects or what people in these fields do" (Science Daily, 2010). And of those who end up pursuing a STEM degree in college, just 40% complete a degree in a STEM field (Drew, 2011). There is a disconnect between the practice of science and the public's understanding of it.

NRAO can make a difference. There is evidence that students who participate in original scientific research are more likely to both enter, and maintain a career in science when compared to students who do not have these experiences (Markowitz, 2004; Roberts & Wassersug, 2009). In addition, students who participate in authentic science experiences show significant increases in conceptual knowledge, question and hypothesis development, modeling, and logical argumentation (Charney et al., 2007). There is little doubt that exposing learners, and engaging them in the practice of science will improve science literacy. Recognizing the need for renewed efforts along this front, the new *5-Year Federal Science, Technology, Engineering, and Mathematics (STEM) Education Strategic Plan* (2013) establishes (1) increasing and sustaining youth and public engagement in STEM to support a 50 percent increase in the number of U.S. youth who have an authentic STEM experience each year prior to completing high school; and (2) enhancing the STEM experience of undergraduate students in an effort to graduate one million additional students with degrees in STEM fields over the next 10 years; as two of its primary goals.

In meeting the needs of the Nation, the National Radio Astronomy Observatory has a unique opportunity, through the VLASS, to engage the public in the "doing" of radio astronomy.

Public participation in astronomical research is an expanding enterprise and radio astronomy should feature more prominently in it. Numerous projects that engage non-scientists in the analysis of large data sets demonstrate significant benefits to both the science research and STEM education communities. These types of projects typically fall into one of three categories; (1) citizen science where large data sets are made available to the general public for analysis, or the public acquires data and submits it to a large centralized database for analysis; (2) student research projects where learners sometimes access more sophisticated instruments to collect data, or use existing archives, and work through the scientific process to conclusion and presentation of their work; and (3) a "hybrid" of citizen science and student research projects. Any of these 3 models could be employed with VLASS data. The case studies presented below may provide inspiration for VLASS public participation projects.

Hybrid Citizen Science-Student Research Project Examples:

Pulsar Search Collaboratory - In 2007, the NRAO in partnership with West Virginia University, created the first radio astronomy citizen-science style program, and proved the viability of engaging the public in radio astronomy research. The Pulsar Search Collaboratory (PSC) is designed to interest high-school students in science, technology, engineering, and mathematics (STEM) related career paths by helping them to conduct authentic scientific research. The PSC teaches students to analyze astronomical radio data acquired with the 100-m Robert C. Byrd Green Bank Telescope for the purpose of discovering new pulsars.

Factors that set the PSC apart from other interactive citizen science programs are: 1) the PSC targets middle/high school aged children, not the general public; 2) students are working with radio data, not optical data. Furthermore, the PSC data are not images. Diagnostic pulsar plots contain much more information than optical images. To extract science from the data, the students must understand the basics of observational radio astronomy, the nature of pulsars and their signature in the plots, and the sources of radio frequency interference that can be easily mistaken for a pulsar. As a result, students participating in the project receive significant training to prepare for the data analysis process. In addition, real-time contact, both face-to-face and virtual, between pulsar scientists and participants has been key to the success of the PSC.

The benefits of the PSC to the astronomical community and to the students and teachers are substantive. Since the PSC began, in 2007:

- Seventeen hundred students have been exposed to research through the PSC;
- One hundred-six teachers and 191 students from 18 states have participated in summer workshops;
- Eight hundred and fifty six students are full PSC members (416 girls, 439 boys);
- As of 10/30/2013, PSC students have analyzed 2,111,940 pieces of data;
- Six pulsars and one transient object have been discovered by PSC students (Rosen et. al., 2012)
- External evaluation studies of the PSC indicate that the PSC significantly ($p<0.05$) increases student interest in science, engineering and computer science careers. The PSC also increases students' self-efficacy in and identification with science research—this effect is enhanced in girls (Rosen, R. et al, 2010) (http://www.pulsarsearchcollaboratory.com/)

The PSC model could easily be replicated in future public participation projects.

Hands-On Universe Asteroid Search – The initial search used data from the Supernovae Cosmology Project, the same data used by the recipients of the 2011 Nobel Prize in Physics, to hunt for asteroids. Numerous main belt asteroids were discovered by high school students, including a Kuiper belt object identified as1998 FS144 (Morelli, 2006; Pack, 2000). These efforts lead to the development of the **International Asteroid Search Campaign** (IASC). IASC student participants search optical CCD images for asteroids, near earth objects, and supernovae (Miller 2008). The project provides teacher training workshops and shows teachers how they can integrate the IASC into the classroom. Students learn about asteroids, transient phenomena (like supernovae), and the basics of optical astronomy, and have discovered five Main Belt asteroids. (http://iasc.hsutx.edu)

Citizen Science Examples:

SETI@home - In a sense, radio astronomy began the astronomy citizen science revolution with the venerable SETI@home, where personal computers connected to the Internet are used to analyze radio data to search for extraterrestrial intelligence. This program allows the public to participate by providing CPU cycles but it is not interactive with the individual. (http://setiathome.berkeley.edu/)

Stardust@Home - Asking the public to actively participate in large-scale data analysis began with Stardust@Home in 2006. Stardust@Home trained participants online to identify images of interstellar dust particles. Participants engaged in data analysis of interstellar dust, and reported their findings to a centralized database. (http://stardustathome.ssl.berkeley.edu)

Galaxy Zoo - Galaxy Zoo began in 2007 and engages the public in the classification of optical galaxy images from the Sloan Digital Sky Survey and Hubble Space Telescope. Over 800,000 people have participated in Galaxy Zoo and Zooniverse spin-off projects and the project has resulted in numerous scientific publications. (https://www.zooniverse.org/publications)

Student-Teacher Research Project Examples:

Spitzer Space Telescope Research Program for Teachers and Students – The Spitzer program partnered teachers and high school students with a mentor scientist to conduct research using the Spitzer Space Telescope. A wide variety of research was conducted leading to various publications, including the discovery of young sun-like stars in their early stages of development (Guieu et al., 2010). The Spitzer Program concluded and transitioned into the **NASA-IPAC Teacher Archive Research Program** (NITARP). Again, NITARP partners teachers and students with a mentor scientist, but this time, to conduct research using various astronomy databases. This effort, too, has lead to a variety of contributions to professional astronomy and related publications. (http://nitarp.ipac.caltech.edu/)

Arecibo Legacy Fast ALFA - The Arecibo Legacy Fast ALFA (ALFALFA) extragalactic HI survey actively engages faculty and undergraduate students at 18 principally undergraduate institutions (plus Cornell) in the U.S. and Puerto Rico through the Undergraduate ALFALFA Team (UAT). The UAT incorporates a multi-faceted program of student training, faculty development, and public outreach centered on the ALFALFA survey. Key elements include support for summer research by undergraduates, travel to present results at AAS meetings, and especially, an annual workshop held at Arecibo each year which includes lectures and activities designed to provide scientific and technical background as well as sessions of science observing with the telescope.

During the first six years of the program, 183 undergraduates have participated in UAT activities, including 106 students who attended the workshops at Arecibo and 47 who have traveled to Arecibo to conduct observations. More than 120 students have been involved in UAT-related undergraduate research either in the summer or during the academic year, including a large number of undergraduate thesis students. Furthermore, faculty and students at multiple UAT institutions are collaborating on a common research project (the UAT Groups of Galaxies Project) to quantify the impact of environment on galaxies in groups. Members of the UAT identify analysis methods and needed software and commit to producing and sharing software tools and analysis results. Students have written and documented many of the software tools, and a number have been incorporated in the general ALFALFA-IDL pipeline and toolkit package distributed to the larger ALFALFA collaboration.

The success of the UAT illustrates the efficacy of using a scientific legacy-class survey, its organization, and follow-up science, as a framework for engaging undergraduate students in research and training far beyond the boundaries of a single campus. The UAT can serve as a template for engaging undergraduate students and faculty in VLASS. (http://egg.astro.cornell.edu/alfalfa/index.php)

Beyond directly involving the general public or K-college learners in radio astronomy research efforts, there are also a variety of EPO products that can be generated to help VLASS projects convey the importance of their science to a broad audience. Early planning can allow for the creation of a products and efforts, including smartphone interactive tools (e.g. Transient Events iPhone App - http://www.lsst.org/News/enews/iphone-app-1007.html), NRAO social media integration, video explaining operation of the VLA and VLASS (e.g. https://public.nrao.edu/explorer/vla/TheVLAExplorer.php), etc. These types of mass media products can significantly enhance the reach and impact of the VLASS.

Conclusion

In this white paper we do not suggest a specific scientific survey. However, considering Broader Impacts-EPO for the VLASS from the outset, and in concert with the development of the science effort, is essential. Whether it's citizen science, engaging teachers and students in authentic research projects, or some combination, integrating the planning for EPO activities and the science could result in a product with far reaching benefits.

The authors of this white paper strongly urge the creation of a Broader Impacts-EPO “tiger team” now, and suggest that these experts be fully engaged in the development and implementation of VLASS projects moving forward.

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