IDEAS Grant Program: School of Galactic Radio Astronomy CURRICULUM

1. The curriculum consists of modules arranged by topic and by type of celestial object. To keep the program consistent with the theme of scientific inquiry, the modules of the curriculum are arranged in sections similar to a refereed paper. Each module contains the following sections: Introduction, Observations, Results, and Discussion. The modules vary in difficulty and depth giving teachers flexibility in their classroom instruction. For example, a teacher during Space Week who wants to show their students what the Moon looks like in the visible as well as radio, may use the *Close to Home* module. Another teacher presenting a lesson on the electromagnetic spectrum may choose the *Radio Waves from Space* module, rather than a specific object.

a) The Curriculum Modules.

The curriculum modules we intend to develop are summarized in Tables1 and 2, followed by brief explanations of each. Table 1 lists modules by topic and Table 2 lists modules by celestial object. The explanations describe how the data taken with the PARI 4.6-m radio telescope will be utilized by the teachers/students.

Table 1. Modules by Topic

Module Title	Topic
What's Between the Stars?	Radio emission from interstellar clouds
Detecting Radio Waves	How radio telescopes and their detectors work
Radio Waves from Space	How different type of radio emission are produced
Mapping	Constructing a contour map; a Math exercise
Waves and Energy	Concept of energy per second emitted by a radio source

Table 2. Modules by Celestial Object

Module Title	Celestial Object
What Does the Center of the Milky Way Look Like?	Galactic Center
Star Formation, Interstellar Dust, and Gas	Orion Nebula
Collapsed Stars	Pulsars
Expanding Shell of Matter	Cassiopeia A
Close to Home	Moon and Sun

Description of the Curriculum Modules

The descriptions of the modules listed in Tables 1 and 2 are brief and not intended to be comprehensive. All participants will take data that can be used to construct images or spectra. The depth of use of this data by teachers/students depends on the grade level.

"What's Between the Stars?"

Students are familiar with the visible night sky. The goal of this module is to expand their vision of the night sky. The introduction to the lab includes a description of visible images of the center of the Milky Way Galaxy, or the Orion Nebula. The students will download the images from the SGRA website. The observations, using the PARI 4.6-m radio telescope, will consist of mapping 21-cm emission from either the center of the Milky Way or Orion. Results will be a comparison of the visible and radio maps, and a discussion of the difference.

"Detecting Radio Waves "

The goal of this module is to introduce students to the technology of antennae and receivers, and the basics of telescopes. The introduction to the module is a description of electromagnetic waves (e.g. wavelengths, frequencies, speed of light), and how an antenna detects an EM wave. The introduction also describes telescopes as light gathering instruments that can resolve small angular sizes. Observations will be made of several radio bright celestial objects, producing maps. Results and discussion will emphasize the detection of the radio waves over vast distances.

"Radio Waves from Space"

Similar to visible light, radio waves from celestial objects can be observed in emission, absorption, or as a continuum. The introduction to this module describes the mechanisms for the production of the radio waves. Observations will be spectra of a radio emission line object, an absorption line object, and a continuum source. This module is different from the others in that it measures spectra, rather than mapping the spatial extent of an object. Spectroscopy may be most appropriate for the upper grades. Results and discussion concentrate on interpreting the observations in terms of the different types of radio wave radiation.

"Mapping"

The goal of this module is to develop mapping and graphing skills, which are important in scientific inquiry. After an introduction on the concept of contour maps, students will set out to observe a radio source (e.g. Orion Nebula). They will sample the brightness of the source at regular spatial intervals over the area of the object. Without the use of a computer, the students will work together plotting the intensities by hand, developing a contour map. Results and discussion center on the contour map that was produced and how well it represents the actual object.

"Waves and Energy"

Radio waves carry energy, and also represent the amount of energy in the source of radio waves. The goal of this module is to have the students understand how much energy some of the celestial radio objects emit. The students will measure the overall 21-cm brightness of a celestial object. Results will use their measurement, and some given properties (such as distance) to calculate the amount of energy emitted by the object they observed. Discussion will compare that energy to the Sun, and their own local electric company generators!

“What Does the Center of the Milky Way Look Like?”

The goal is to compare a 21-cm radio map of the center of the Milky Way to visible images, emphasizing the striking differences in visible absorption and radio emission of electromagnetic radiation. Observations at 21-cm include mapping the Galaxy’s center, and downloading visible images from the SGRA website. Results and discussion center on the differences in 21-cm and visible maps.

“Star Formation, Interstellar Dust, and Gas”

The goal of this module is to teach students about the existence of gases and dust in the interstellar medium, and in particular in regions of star formation. The introduction includes visible images of the Orion Nebula and star formation theories. The students will make a 21-cm map of the Orion Nebula to compare with the visible images. Results and discussion will emphasize the extent of the gases and dust, and the importance in the formation of stars.

“Collapsed Stars”

The goal of this module is the study of the last stages of a star’s existence. Students will be introduced to pulsars. The flux from pulsars is low at frequencies that can be measured with the 4.6-m radio telescope. So, data from the PARI pulsar timing project, measuring the flux from pulsars at 400 MHz using one of the PARI 26-m radio telescopes, will be made available for students to download. This is the only module that does not include direct observation with the 4.6-m radio telescope. Results and discussion will center on the mechanism that can produce fairly regular millisecond to second pulses from a celestial object.

“Expanding Shell of Matter”

The goal of this module is to measure the extent of a supernova remnant, and the energy needed to produce it. Students will map Cas A, one of the brightest radio sources in the sky, at 21-cm. They will compare the radio map to visible images, and the discussion will include the reasons for the differences.

“Close to Home”

The sun and the Earth’s moon are bright at radio frequencies. Students are familiar with both the sun and moon in the visible. The students will make a 21-cm radio maps of sun and moon. Results and discussion will show how such a familiar object can appear in the radio part of the spectrum.

b) National Education Standards Addressed

The goals for school science that underlie the National Science Education Standards (1996 National Academy of Sciences National Research Council, ISBN 0-309-05326-9) are:

- "To educate students who are able to experience the richness and excitement of knowing about and understanding the natural world;
- To use appropriate scientific processes and principles in making personal decisions;
- To engage intelligently in public discourse and debate about matters of scientific and technological concern; and
- To increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers."

The modules described above are designed to meet these goals. The SGRA provides an exciting environment for students to explore the world around them using the scientific method. The students will observe for themselves natural processes from which they can engage in intelligent discussion. The scientific literacy of the students participating in SGRA will be enhanced as the students' technological skills developed and their deductive thought processes are sharpened.

Standards for content, teaching, professional development, assessment, program, and system describe the conditions necessary to achieve the goals. The development of the National Science Education Standards is based on the principles that science is for all students, learning science is an active process, school science reflects the intellectual and cultural traditions that characterize the practice of contemporary science, and improving science education is part of systemic education reform.

All of the SGRA curriculum modules address content, teaching, professional development, and program standards.

Content Standards

The sections of Table 6.10, Content Standards, Grades 9-12 from the National Science Education Standards that pertain to physical sciences is reproduced below. Review of the modules shows that the Unifying Concepts and Processes, Science as an Inquiry, and Science and Technology are completely met, considering the close tie between the technology using the 4.6-m radio telescope and remote astronomical observations made with that telescope. In Physical Science, we address structure of atoms, structure and properties of matter (as a gas), conservation of energy and increase in disorder, and interactions of energy and matter. In Earth and Space Science, we address energy in the Earth system in the "Waves and Energy" module.

TABLE 6.10. SECTIONS OF CONTENT STANDARDS, GRADES 9-12

Unifying Concepts And Processes	**Science As Inquiry**	**Physical Science**	**Earth and Space Science**	**Science and Technology**
Systems, order, and Organization	Abilities necessary to do scientific inquiry	Structure of atoms	Energy in the Earth System	Abilities of technological design
Evidence, models, and	Understandings about scientific	Structure and Properties of	Geochemical cycles	Understandings about science and

explanation	inquiry	matter		technology
Change, constancy, and measurement		Chemical reactions	Origin and evolution of the earth system	
Evolution and equilibrium		Motions and forces	Origin and evolution of the universe	
Form and function		Conservation of energy and increase in disorder		
		Interactions of energy and matter		

Teaching Standards

The six areas of teaching standards (National Science Education Standards 1996) are the planning of inquiry-based science programs, actions taken to guide and facilitate student learning, assessments made of teaching and student learning, development of environments that enable students to learn science, creation of communities of science learners, and planning and development of the school science program. Teachers using SGRA have already taken the steps to meet each of these areas. They are developing an exciting environment that enables students to learn science, and developing a new and unique lesson plan for their school science program.

Professional Development

Through its training workshop, SGRA provides teachers the opportunity to develop a practical understanding and ability and technological proficiency. The workshops allow for professional growth and development clearly connected to their school science program. So, teachers gain the knowledge, understanding, and ability to implement the curriculum modules presented by SGRA.

Program Standards

Six areas of program standards (National Science Education Standards 1996) are: consistency of the science program with the other standards and across grade levels; inclusion of all content standards in a variety of curricula that are developmentally appropriate, interesting, relevant to student's lives, organized around inquiry, and connected with other school subjects; coordination of the science program with mathematics education; provision of appropriate and sufficient resources to all students; provision of equitable opportunities for all students to learn the standards; development of communities that encourage, support, and sustain teachers.

The program standards relate to opportunities for students to learn and opportunities for teachers to teach science. The mission of SGRA is to provide the opportunity for all students to learn, which is consistent with the Program Standards. In the “Mapping and Graphing” module, the study is coordinated with mathematics education.

In summary, SGRA addresses many of the National Science Education Standards by means of a dynamic and exciting program of learning. Teachers and students are given the opportunity to develop a lifelong interest and understanding of the basics of scientific inquiry.

Software for data analysis must meet three basic requirements. First, it must be economical; schools are often on tight budgets and cannot invest in expensive software. Second, the software must be able to do the analysis. Third, it must be user friendly. Two image analysis packages satisfy these requirements. The *Sky Image Processor* (SIP; http://www.phys.vt.edu/~jhs/SIP/) is a JAVA based tool that can be used with any net browser, and is not installed on the user’s computer. So, students can run this from school, home, the library, or any place they can acquire an Internet connection. The other image processor is *IRIS* (http://www.astrosurf.com/buil/us/iris/iris.htm#intro), which is free, and needs to be installed on the participants’ computer. The installation takes just a few minutes. We will distribute copies of IRIS to teachers at the training workshops, and show them how to use both SIP and IRIS. Both image analysis software packages are capable of image construction and analysis, as well plotting scans for the radio spectroscopy.

The T1 high speed Internet access is an essential component of the project. Without it, access to SGRA will be prohibitively slow, particularly for realtime control of the radio telescope, data and image download, and atlas and catalog searching. T1 connection minimizes delays that may frustrate the teachers/students and maximizes class time for learning, rather than pausing for Internet communication. For example, the OBSERVING page of the SGRA website is designed as a control room at an observatory. Controls include options of source selection, coordinate entry, slew, set, and guide selection, and tracking. We prefer not to use a direct satellite link that uses 14-14.5 GHz. We are a radio telescope facility, and we would like to limit radio noise pollution at the site. For example, some astronomical sources may be observed at 12-15.4 GHz, and the satellite link would jam our receiver with signals 260 dB above the astronomical signals we wish to detect. Also, most of these satellite services are time-share and a single T1 connection is divided among 24 users. The best solution for Internet service and success of the SGRA is T1 connection service .

We will use free software called Virtual Network Computing (VNC; http://www.uk.research.att.com/vnc/) to allow access to the telescope controls over the Internet. All other features of the SGRA website will be accessible by any web browser. VNC is a password protected remote display system that allows the user to view and control a computing 'desktop' environment not only on the machine where it is running, but from anywhere on the Internet and from a wide variety of machine architectures. Download of VNC by teachers will be made available on the SGRA webpage, and at the teacher training workshops.