

# Outer Space is Not Empty Space

Teacher's Guide

RET Program 2004

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## 1. Purpose:

The elements that make up our universe were formed via fusion in stars, a process which continues today. These elements met one another in nebulae, on planets and in other places, reacting to form compounds. This unit uses self guided lessons to teach students how atoms are formed and how radio telescopes are used to detect them.

## 2. Overview:

"Outer Space Is Not Empty Space" combines Astronomy, Chemistry, Physics, Physical Science, and Earth & Space science. The educational vehicle used is a Webquest which consists of nonlinear Power Point presentations through which the students navigate. They are self-paced with numerous links to external websites from which the students can continue their research. Each Webquest is accompanied by an assessment worksheet.

One of the goals of this learning unit is to encourage teacher and student use of two unique learning opportunities: the Small Radio Telescope (referred to as the "SRT" in this teacher's guide) and Haystack's 37m Radio Telescope.

The SRT was designed by engineers and scientists at M.I.T.'s Haystack Observatory specifically for student educational use at the University or Secondary School level. One can get a complete overview of

this instrument by accessing the SRT web pages at the Haystack Observatory web site at:

<http://web.haystack.mit.edu/SRT/index.html>

It is possible to purchase an SRT for student or amateur use. This information can be found at:

<http://web.haystack.mit.edu/SRT/HowToBuy.html>

More detailed information regarding teacher and student use of the SRT for this RET project can be found in section 9 of this teacher's guide.

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### 3. Outline of PowerPoint Web Quests:

#### 3.1 Introduction

3.1.1. Astrochemistry Basics - How do scientists study matter from millions of miles away?

3.1.2. Fuzzy Stars - What do astronomers look at besides stars?

3.1.3. Radio Telescope Basics - How do Radio Telescopes work?

#### 3.2 Light

3.2.1 Reading Spectral Lines - What do we learn by reading spectral lines?

3.2.1 Mechanisms of Radio Wave Emission - How are radio waves generated?

3.2.2 Masers - What are they? How do they work? What do they reveal about different regions of space?

#### 3.3 Matter

3.3.1 Chemistry Review - What types of chemical reactions happen in space?

3.3.2 Nuclear Synthesis - Where did all these atoms come from?

3.3.3 Dark Matter - What is dark matter and how can scientists study something they can't see?

## 3.4 Atmosphere

- 3.4.1 Introduction of the Ionosphere - What is the Ionosphere and why is it important?
- 3.4.2 Auroras - What causes the Northern and Southern Lights?
- 3.4.3 The Ionosphere as Plasma - Why does the Ionosphere behave the way it does?

#### 4. **Suggestions for use:**

This unit can be used in several different science classes including physics, astronomy, chemistry, and earth science. In each case the students, not the teacher, will be responsible for accessing and making sense of the material.

For this unit, each student will need his or her own computer. Students can also work in small groups if necessary. Each group will simply navigate through a webquest reading information, making connections, and continuing their research with the internet. Students can print out a copy of the worksheet and use it as a guide to the webquest.

#### 5. **Hands-On Activities**

- 5.1. Energy of Rotation
- 5.2. Spinning Tabletop Molecules
- 5.3. Spinning PVC Molecules

#### 6. **Integration with Mass. and N.H. Educational Frameworks**

Note: Since the two RET participants in 2004 are both New Hampshire Science Teachers and M.I.T. Haystack Observatory is in Massachusetts, the integration information will be offered for **both** state guidelines.

The reference for the New Hampshire Science Frameworks is taken from the state Education website:

<http://www.ed.state.nh.us/education/doe/organization/curriculum/Assessment/Science.htm#Introduction>

The reference for the Massachusetts Science Frameworks is taken from the state Education website:

<http://www.doe.mass.edu/frameworks/>

For both the Massachusetts and the New Hampshire state educational frameworks, the standard will be listed and then the component of this project that addresses the standard will be listed. The Framework number will be

listed along with the written framework along with the manner or section in which this unit supports that specific framework goal.

### 6.1. Integration with the Massachusetts Science Frameworks

Note: The Massachusetts frameworks for this unit were taken from the Mass. state K-12 Curriculum Frameworks.

<http://www.doe.mass.edu/frameworks/scitech/2001/>

#### Earth and Space Science - Grade 9 or 10 (Mass. Frameworks)

Standard number	Standard	Components of this project that address the standard
1.2	Describe the components of the electromagnetic spectrum and give examples of its impact on our lives.	Several of the powerpoints have an overview of the E/M spectrum.
1.3	Describe the characteristics of waves (wavelength, frequency, velocity, amplitude).	The Amazing Spectral Lines pp has an overview of frequency and wavelength
1.4	Describe the nature of the continuous emission and absorption spectrum that indicates the composition of stars.	Amazing Spectral lines ppt has detail about emission vs. absorption spectra.
1.6	Explain how the layers of the atmosphere affect the dispersal of incoming radiation through reflection, absorption, and re-radiation.	Intro. To the Ionosphere ppt. has introduction to layers of the atmosphere and their characteristics.
3.16	Explain how the magnetic field of the earth is produced	Intro. To the Ionosphere ppt. has introduction to magnetic fields of the earth.
4.1	Explain the Big Bang Theory and discuss the evidence that supports it (background radiation, and Relativistic Doppler effect ~ red shift).	Students can measure the red/blue shift of our galaxy by taking rotation measurements of the galaxy
4.7	Compare and contrast the various instrumentation used to study deep space and the solar system, e.g., refracting telescope, reflecting telescope, radio telescope, spectrophotometer.	The SRT can be used as a hands-on instrumentation activity to measure the sun's radio waves.

Standard number	Standard	Components of this project that address the standard
1.3	Describe the four states of matter (solid, liquid, gas, plasma) in terms of energy, particle motion, and phase transitions.	
2.3	Identify the major components of the nuclear atom (protons, neutrons, and electrons) and explain how they interact.	Chemistry basics covers the components of the nuclear atom.
2.4	Understand that matter has properties of both particles and waves.	
2.5	Using Bohr's model of the atom interpret changes (emission/absorption) in electron energies in the hydrogen atom corresponding to emission transitions between quantum levels.	Astrochemistry basics ppt explains basic atomic absorption and emission via blackbody radiation theories.
2.6	Describe the electromagnetic spectrum in terms of wavelength and energy; identify regions of the electromagnetic spectrum.	Mechanisms of Radio Wave Emission identify parts of the E/M spectrum and their characteristics.

Standard number	Standard	Components of this project that address the standard
3.4	Recognize that matter exists in four phases, and explain what happens during a phase change.	
4.2	Recognize the measurable properties of waves (e.g., velocity, frequency, wavelength) and explain the relationships among them.	Basic wave characteristics of wavelength, and frequency are covered in the Mech. Of Radio Wave Emission ppt.
4.4	Distinguish between mechanical and electromagnetic waves	
4.6	Recognize the effects of polarization, wave interaction, and the Doppler effect.	
6.1	Describe the electromagnetic spectrum in terms of wavelength and energy, and be able to identify specific regions such as visible light. *	Mechanisms of Radio Wave Emission identify parts of the E/M spectrum and their characteristics.
6.2	Explain how the various wavelengths in the electromagnetic spectrum have many useful applications such as radio, television, microwave appliances, and cellular telephones.	
6.4	Recognize and explain the ways in which the direction of visible light can be changed.	

Standard number	Standard	Components of this project that address the standard
6.1	Identify and explain the applications of light in communications, e.g., reflection, refraction, additive, and subtractive color theory.	
6.2	Explain how information travels through different media, e.g., electrical wire, optical fiber, air, space.	
6.3	Compare the difference between digital and analog communication devices.	
6.4	Explain the components of a communication system, i.e., source, encoder, transmitter, receiver, decoder, storage, retrieval, and destination	

## 6.2. Integration with the New Hampshire Science Frameworks

Note: The New Hampshire frameworks for this unit were taken from the N.H. state K-12 Science Curriculum Frameworks. This can be found at:

<http://www.ed.state.nh.us/education/doe/organization/curriculum/Assessment/Science.htm#Introduction>

N.H. Standards (cont'd)

**K-12 Broad Goals for Science Education  
Proficiency Standards**

Goal or Curriculum Standard	Stated Goal(s)	How met within project
K-12 Broad Goals for Science Education	Students will demonstrate an understanding of, and be able to practice, the basic processes which scientists use to obtain and continually revise knowledge about the natural world.	
	Students will use problem-solving strategies to investigate and understand the natural world.	Many of the powerpoint presentations have a investigative trail for the student to follow.

**1a. Curriculum Standard  
Proficiency Standards**

1a. Curriculum Standard	•Design and conduct a controlled scientific investigation	Student designed SRT or 37m telescope experiment
	•Use technologies as tools in conducting investigations, e.g. microscopes, computer, calculator	<ul style="list-style-type: none"> <li>• Student designed SRT or 37m telescope PC based experiment.</li> <li>• Use of Excel in plotting, graphing, interpreting collected SRT data</li> </ul>

N.H. Standards (cont'd)

**2a. Curriculum Standard  
Proficiency Standards**

Goal or Curriculum Standard	Stated Goal(s)	How met within project
2a. Curriculum Standard	Students will demonstrate an increasing ability to use measuring instruments to gather accurate and/or precise information	Any of the Experiments with the SRT or the 37m telescope will involve student use of measuring instruments.
	<ul style="list-style-type: none"> <li>• Measure with both analog and digital electronic devices, e.g. voltmeter, oscilloscope, and pH meters</li> <li>• Describe ways in which technology has improved measuring instruments and their accuracy</li> </ul>	<p>SRT telescope controls and 37m remote control involve interpreting values and their meanings.</p> <p>Several of the PP presentations show remote access to many optical or radio telescopes.</p>

N.H. Standards (cont'd)

2b. Curriculum Standard  
Proficiency Standards

Goal or Curriculum Standard	Stated Goal(s)	How met within project
2b. Curriculum Standard	<b>Students will demonstrate an increasing ability to use technology to observe nature.</b>	
	<ul style="list-style-type: none"> <li>•Explore nature with technology, e.g. microscopes, telescopes, computer probes, and spectroscopes</li> <li>•Gather information that can only be obtained by using a technological tool, e.g. pH, voltage, amperage, blood pressure, etc.</li> </ul>	<p>Any of the SRT lessons will show use of technology with PC control of the small radio telescope.</p> <p>Logging data with the SRT command file and then importing the data into MS Excel uses "technological tools".</p>

2c. Curriculum Standard  
Proficiency Standards

Goal or Curriculum Standard	Stated Goal(s)	How met within project
2c. Curriculum Standard	Students will demonstrate an increasing ability to analyze, synthesize, and communicate scientific information using technology.	
	<ul style="list-style-type: none"> <li>•Manipulate data on a database, e.g. rearranging, sorting, selecting, using a spread sheet</li> <li>•Analyze data graphically with technological assistance, e.g. graphing calculator</li> <li>•Communicate data through an electronic</li> </ul>	<p>Lessons 6 &amp; 7 of the SRT lessons show students how to:</p> <ul style="list-style-type: none"> <li>• Import the SRT data table into MS Excel</li> <li>• Analyze the data w/Excel</li> <li>• Graph the data w/Excel</li> </ul>

	medium, e.g. camera, tape recorder, computer modem •Quantitatively analyze experimental data	
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N.H. Standards (cont'd)

2d. Curriculum Standard  
Proficiency Standards

Goal or Curriculum Standard	Stated Goal(s)	How met within project
2d. Curriculum Standard	<b>Students will demonstrate an increasing ability to understand how technology is used to synthesize new products.</b>	
	Plan and conduct a scientific research project using technology  Create a model by locating and utilizing appropriate software programs	Students can plan an experiment using the SRT or the 37m telescope by: <ul style="list-style-type: none"> <li>• Making a prediction of the outcome of the experiment.</li> <li>• Determining the object to "see" in the radio telescope w/reference to the objective and the hypothesis for the experiment.</li> </ul> Students can hypothesize a model and then prove/disprove the model with SRT or 37m experiments.

N.H. Standards (cont'd)

Earth/Space Science:  
**4a. Curriculum Standard**  
 Proficiency Standards

Goal or Curriculum Standard	Stated Goal(s)	How met within project
<b>4a. Curriculum Standard</b>	Students will demonstrate an increasing ability to understand that the Earth is a unique member of our solar system, located in a galaxy, within the universe.	
	<ul style="list-style-type: none"> <li>•Use a model to describe the location and motion of the Earth and its Moon in the solar system</li> <li>•Identify the other planets in the solar system on a diagram or in the night sky, and describe their motions, as well as the motion of the planetary moons and comets</li> <li>•Describe the characteristics of Earth and other planets in the solar system in terms of their ability to support life</li> <li>•Describe the current scientific theory relating to the origin and geologic evolution of the Earth and the solar system</li> </ul>	After doing several lessons of the SRT, use the SRT to record the radio energy at the center of the Milky Way (near the constellation Sagittarius) compared to almost any other direction of the plane of our galaxy.

N.H. Standards (cont'd)

Earth/Space Science:  
**4b. Curriculum Standard**  
 Proficiency Standards

Goal or Curriculum Standard	Stated Goal(s)	How met within project
4b. Curriculum Standard	<b>Students will demonstrate an increasing ability to understand that the Earth is a complex planet with five interacting systems, which consists of the solid Earth (lithosphere), air (atmosphere), water (hydrosphere), ice (cryosphere), and life (biosphere).</b>	
	Identify the composition and physical characteristics of the atmosphere	PowerPoint presentations of: <ul style="list-style-type: none"> <li>• Introduction to the Ionosphere</li> <li>• Ionosphere as Plasma can both be used to provide basic information on the Ionosphere.</li> </ul>

N.H. Standards (cont'd)

Physical Science:

**5f. Curriculum Standard**

Proficiency Standards

Goal or Curriculum Standard	Stated Goal(s)	How met within project
5f. Curriculum Standard	<p><b>Students will demonstrate an increasing understanding that energy can be transmitted by waves, using light and sound as examples</b></p>	
	<ul style="list-style-type: none"> <li>•Distinguish among amplitude, wavelength, and frequency of longitudinal and transverse waves</li> <li>•Conduct investigations to demonstrate the properties of reflection, refraction and diffraction of light</li> <li>•Identify and distinguish among the various forms of electromagnetic radiation, e.g. visible light, microwaves, X-rays</li> <li>•Determine the speed of a wave using wave length and frequency.</li> </ul>	<ul style="list-style-type: none"> <li>• Several of the PowerPoint presentations deal with basic wave nature of energy transfer via waves and the duality of the wave/photon theories.</li> <li>• PowerPoints of the Introduction section or the section on Light both have lessons on the relationship of frequency and wavelength and the different parts of the Electromagnetic Spectrum.</li> </ul>

## 7. THE SMALL RADIO TELESCOPE

The SRT lesson is designed as a step by step guide to using the SRT. Students should be able to follow the lessons on their own and, in the course of a week, become proficient radio telescope operators. The lesson begins with an introduction to the SRT Software and contains lessons on:

- 7.1.1.1. Pointing the Telescope
- 7.1.1.2. Doing an npoint scan
- 7.1.1.3. Setting the Frequency
- 7.1.1.4. Recording a Data File
- 7.1.1.5. Understanding your data
- 7.1.1.6. Importing data into MS Excel
- 7.1.1.7. Graphing Data in Excel
- 7.1.1.8. Command Files

8. The 37m users' guide is geared toward the teacher taking the lead with students working with the teacher. The 37m is one of the world's major research grade radio telescopes and hence must be used with adequate preparation and care.

