LISTENING TO SPACE: RADIO ASTRONOMY TEACHER'S GUIDE

Listening to Space: Radio Astronomy is a planetarium presentation designed to teach your students how astronomers can learn secrets of the universe that cannot be seen with our eyes or an optical telescope. We will learn what radio waves are, what they teach us, how a radio telescope works, and how we transform radio waves so that we can 'see' and 'hear' them.

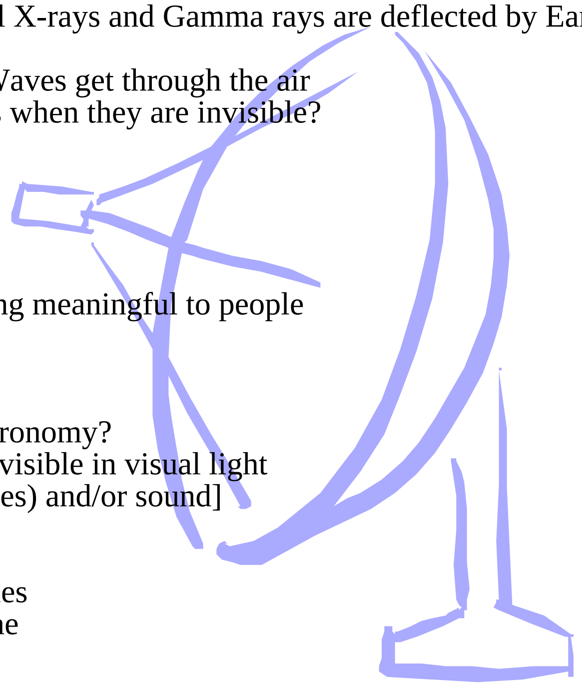
This Teacher's Guide is designed to help you prepare your students for their upcoming visit to the Northern Stars Planetarium when it visits your school. This guide contains background information about radio astronomy for you and worksheets for your students.

PROGRAM OUTLINE

I. How do we know what we know about the universe?
   A. Light tells us everything
   B. What is light?
      1. Colors are different wavelengths
      2. Couldn't there be longer and shorter wavelengths? Yes!
      3. A quick look at the spectrum
         a. Shorter wavelengths: UV, X-rays, Gamma Rays
         b. Longer wavelengths: infrared, *radio waves*
      4. Why radio waves and not the others?
         a. Most infrared and UV, all X-rays and Gamma rays are deflected by Earth's atmosphere
         b. Visible light and Radio Waves get through the air

II. How do we 'see' or 'hear' radio waves when they are invisible?
   A. Radio Telescopes
      1. How do they work?
      2. Problems
         a. faintness of signals
         b. human interference
   B. Turning the signals into something meaningful to people
      1. Diagrams and charts
      2. Pictures
      3. Sounds

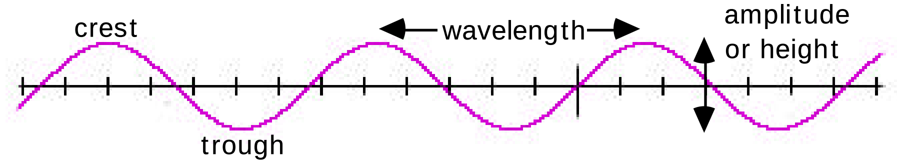
III. What have we learned from Radio Astronomy?
   A. Objects and Activities that are invisible in visual light
   B. Examples [in radiographs (pictures) and/or sound]
      1. Sun
      2. Planets
      4. Milky Way and Other Galaxies
      6. Supernovae, Quasars, Nebulae



VOCABULARY

AMPLITUDE   Amplitude in a wave refers to the amount of energy in a wave. In a sound wave, amplitude is a measure of loudness. In a light wave, it's a measure of brightness.

ANATOMY OF A WAVE:



ARECIBO RADIO TELESCOPE The largest single dish (1,000 foot diameter) telescope.

ARRAY When multiple radio telescope are electronically connected together.

ELECTROMAGNETIC SPECTRUM The entire range of 'light.' Visible light is only a small portion of the electromagnetic spectrum. The full range is divided up according to wavelengths. In order of *increasing frequency* and *decreasing wavelengths,* it goes: Radio waves, infrared, visible light, ultraviolet, x-rays and gamma rays.

FREQUENCY Frequency is a measurement of the number of waves that pass a fixed point in one second. Frequency is measured in units of 'cycles per second' called hertz.

INTERFEROMETER When two or more radio telescopes (perhaps miles apart) are electronically connected together and pointed at the same radio source. This increases resolution. The name interferometer arises from the way the two separate signals come together. The signals that neatly overlap reinforce and strengthen the image, while signals that do not overlap 'interfere' with each other and simply cancel each other out.

LIGHT Light is a form of energy that has both wave and particle properties. Light is emitted in 'packets' of energy called photons and travels at 300,000 km/second (186,000 miles/second). Light is actually more than just what we see – the entire range of light covers radio waves, infrared, visible light, ultraviolet, x-rays and gamma rays. This entire range is known as the electromagnetic spectrum.

VOCABULARY Continued:

LOBES Jets of visually invisible material ejected millions of light years out of some galaxies. Visible only with radio telescopes.

PULSARS Strong radio sources that pulse rapidly out of the cores of some dead stars.

QUASARS The most distant and energetic objects ever discovered.

RADIOGRAPH A visualization of what a part of the sky would 'look' like if we could actually see radio waves.

RADIO SOURCE Any object in space that emits detectable radio waves.

RADIO TELESCOPE An instrument designed to detect natural radio waves emitted from objects in space.

RADIO WAVES The part of the electromagnetic spectrum with the lowest frequency and the longest wavelengths. We can detect radio waves with wavelengths between 1 millimeter and 30 meters. Radio waves carry low levels of energy and are invisible to the human eye.

RESOLUTION The limits of detailed structure that can be observed. For example, modern radio telescopes can observe detail as small as one arc-second. (one arc-second is 3600th of one degree of arc. In human terms, that's the size of a dime viewed from two miles away!)

WAVELENGTH The distance between crests or peaks of adjacent waves.

SOME IMPORTANT PLACES & NAMES IN RADIO ASTRONOMY

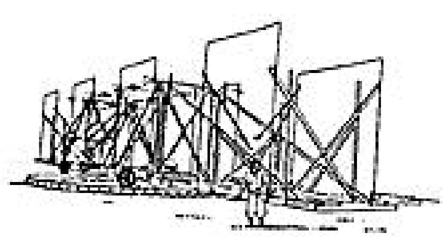
Arecibo Radio Telescope The largest radio telescope in the world. The dish is 1,000 feet in diameter and lies nestles between several hills in Puerto Rico.

Green Bank, West Virginia The National Radio Astronomy Observatory is located there, where many interesting radio telescope are located.

Karl Jansky The father of radio astronomy. He discovered radio emissions coming from the Milky Way while working on a radio communications system for Bell Telephone Laboratories in 1931.

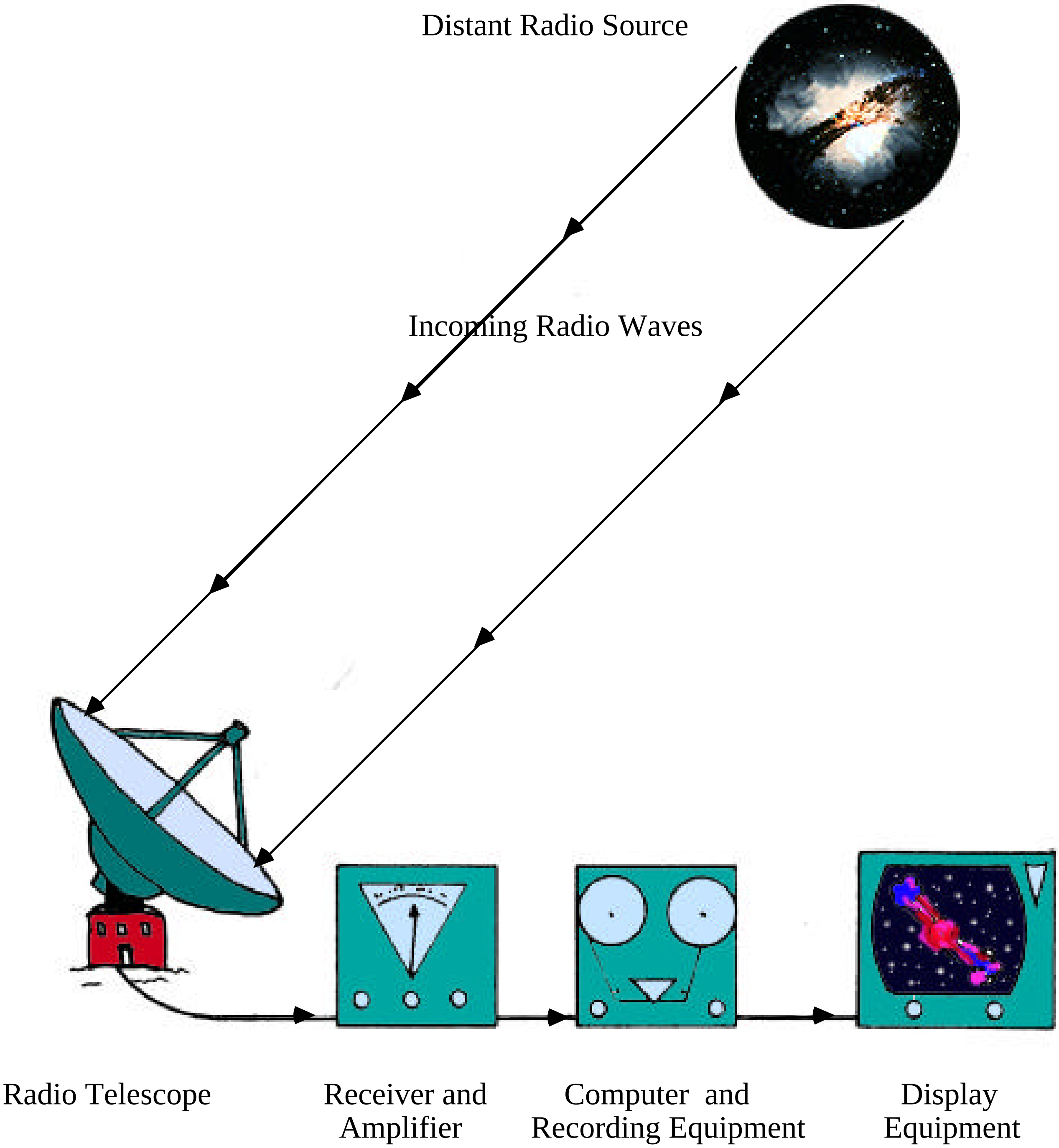
VLA Very Large Array An array of twenty-seven 82-foot diameter radio telescopes, all connected to form one large telescope. It covers an area of about 20 miles by 20 miles in the New Mexico desert. The VLA is effectively the largest radio telescope in the world (Arecibo is the largest single dish, while the VLA uses 27 smaller ones covering a larger area.).

Parkes CSRIO Radio Telescope A 64-meter moveable dish telescope in Australia.



Karl Jansky's First Radio Telescope, 1931.

HOW A RADIO TELESCOPE WORKS



TRUE OR FALSE

1. Radio waves are an invisible form of light. (T)

2. X-rays are a form of radio wave. (F – X-rays are an invisible form of light, but they are a high frequency/short wavelength/high energy form of light. Radio waves are a low frequency/long wavelength/low energy form of light.)

3. Radar and Microwaves are both forms of radio waves. (T – Microwaves represent high-end radio waves and Radar is just below microwaves – see diagram on page 7)

4. When you listen to the radio, you are actually hearing radio waves. (F – Radio waves are used by both radio and TV to carry signals, but what you hear and see are generated by electronics in your radio and TV that read the signals carried in the radio waves. If you could actually hear radio waves, you wouldn't need a radio!)

5. Radio Telescopes are really just large directional radio antennas. (T)

6. Radio Telescopes can also be used for communications if so desired. (T – They were used to communicate with the Voyager Space Probes, for example.)

7. Using a Radio Telescope with a dish the diameter of a football field, if we observed one of the strongest radio sources in the sky, the energy received would only be enough to heat one gram of water 0.001 Celsius. (T – Radio signals are all very, very weak.)

8. Radio Telescopes can only receive signals, they cannot send signals. (F – They have sent signals to space probes as well as intragalactic greetings to any aliens who care to listen!)

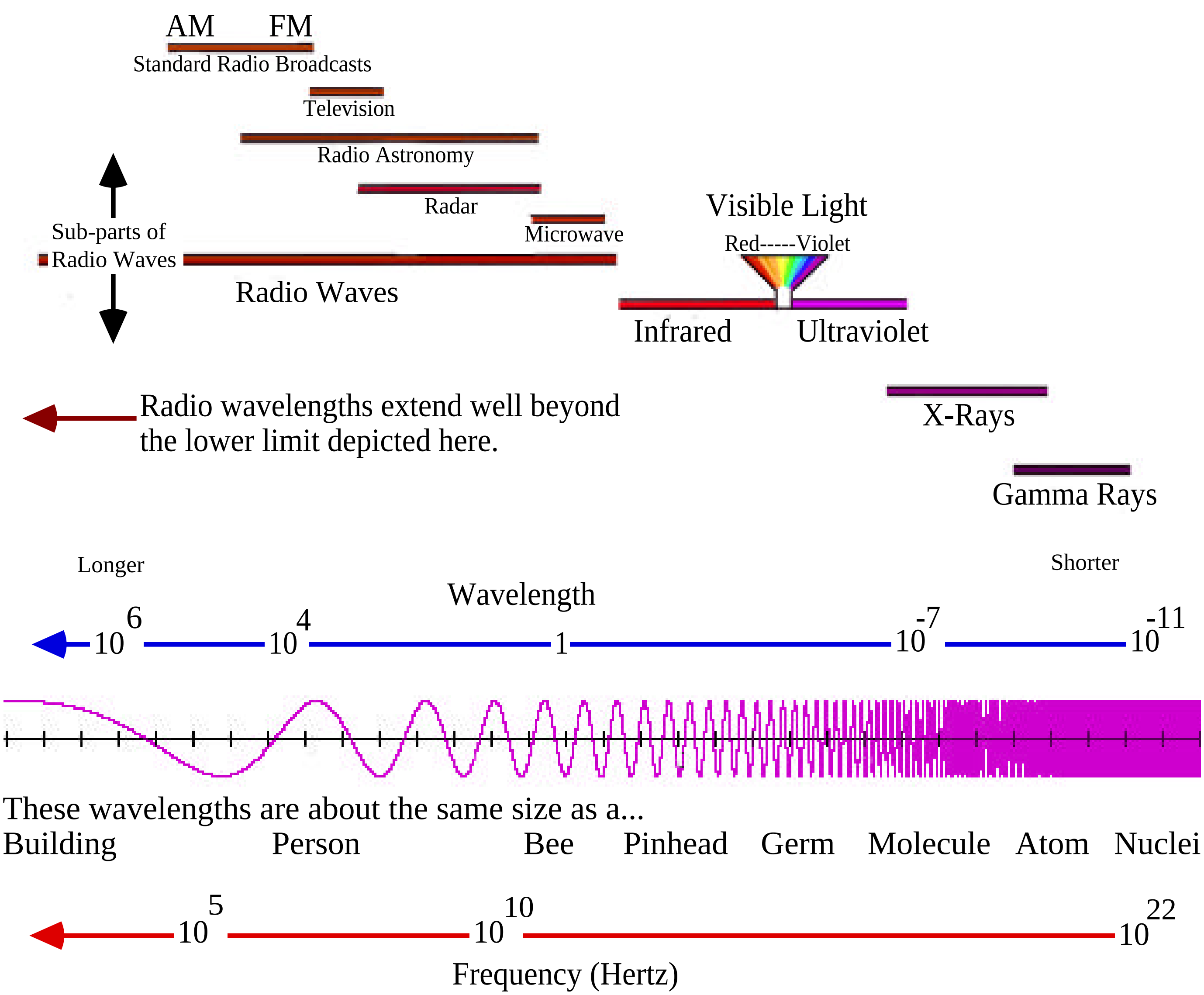
9. The largest single radio telescope dish is 500 feet in diameter. (F – Arecibo Telescope in Puerto Rico is 1,000 feet in diameter – that's bigger than 3 football fields end-to-end!)

10. The first radio signals from space were discovered in 1931. (T – by Karl Jansky, but the study of radio signals didn't begin in full until after World War II.)

11. Radio Telescopes, like their optical cousins, can only be used on clear, dark nights.
(F – Actually, they can be used day or night, clear or cloudy.)

12. Quasars, discovered first by Radio Telescopes, are the most distant and the most powerful objects ever discovered. (T)

THE ELECTROMAGNETIC SPECTRUM



$10^{6} = 1{,}000{,}000$

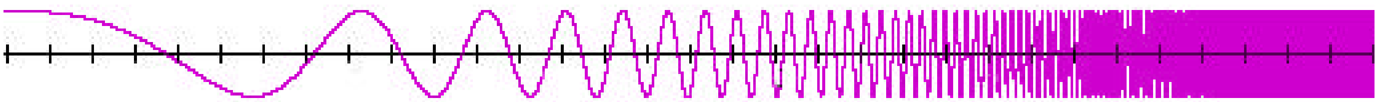
$10^{-6} = 0.000001$

ACTIVITY: UNDERSTANDING THE ENERGY OF WAVELENGTHS AND FREQUENCY

When you study the electromagnetic spectrum, you find that the different types of radiation are determined by wavelength.

Longest --------------------------------wavelengths------------------------------------Shortest

RADIO INFRARED VISIBLE LIGHT ULTRAVIOLET XRAY GAMMA



Lowest Energy Highest Energy

The problem most students have is that they tend to think that large things require a greater expenditure of energy to create than smaller things do. This is not the case with creating waves. What requires more energy is not creating big waves, but creating a lot of smaller waves (i.e. a higher frequency). Frequency is the number of waves found in a given distance. The higher the frequency, the greater the energy requirements.

If we counted the number of radio waves in a distance of one meter, depending on the wavelength of the particular radio transmission you picked, you might find 1,000 waves (wavelength of 1 mm) or only 1 wave (wavelength of 1 meter) or only 1/30th of a wave (wavelength of 30 meters).

If we measured the number of visible light waves in a distance of one meter, we would find millions and millions of individual waves.

If we measured the number of X-rays or Gamma rays in a distance of one meter, we would find billions and trillions of individual waves.

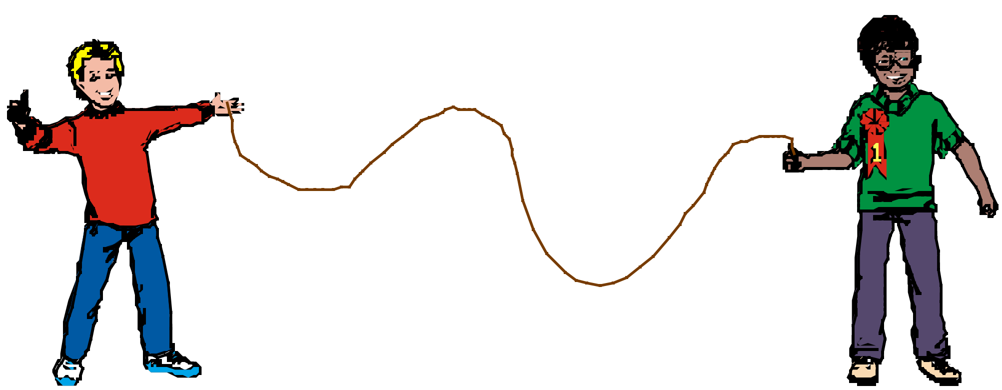
What takes the most energy is creating lots of small waves.

WAVE LENGTH DEMONSTRATION

To illustrate the energy levels of different wavelengths to your students, all you need is a long jump rope (2-3 meters or 6-9 feet) and a volunteer.

Directions:

1. Tie one end of the jump rope, about waist high, to a chair or door or something solid.
2. Have the volunteer hold the other end, letting the rope arc down a little more than half way to the floor.
3. With one quick up and down motion of the hand, have your volunteer make one wave move across the rope (this might represent a radio wave, i.e. low energy).
4. With two quick up and down motions of the hand, have your volunteer make two waves move across the rope. Were these two waves as long as the first? Did they have the same wavelengths as the first? Which took more energy on the part of the volunteer to create – the first single wave or the two shorter ones?
5. With three quick up and down motions of the hand, make even shorter wavelengths and more waves. Does this require more energy or less?
6. Try to make even more energetic waves.
7. Try to make even less energetic waves than the first (step 3). Does the lower energy wave even have enough power to make it to the other end of the rope? Which has more power, short waves or long waves?



RADIO ASTRONOMY WORD SEARCH

Find the following words hidden in the puzzle below. They are written horizontally, vertically and diagonally. Good luck!

ANTENNA ARECIBO ARRAY DISH ENERGY

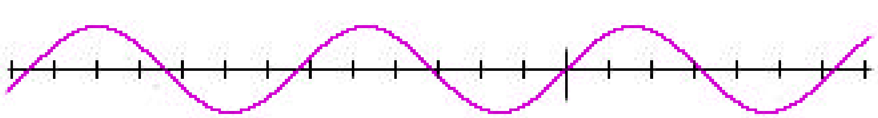
FREQUENCY GALAXY GASES INVISIBLE JANSKY

JUPITER LIGHT LOBES PULSARS QUASARS

RADIOGRAPH SATURN SOURCE SPECTRUM STARS

SUN TELESCOPE WAVELENGTH

W	S	P	Q	M	N	P	U	L	S	A	R	S	A	Q	U
I	A	S	G	U	R	A	D	I	O	G	R	A	P	H	R
N	R	V	T	I	A	A	O	G	U	G	A	S	E	S	E
V	E	H	E	A	F	S	N	H	R	O	R	L	S	O	H
I	C	Z	L	L	R	J	A	T	C	N	R	H	A	X	D
S	I	L	E	H	E	S	U	R	E	D	A	L	T	X	P
I	B	C	S	L	Q	N	K	P	S	N	Y	Z	U	F	Y
B	O	N	C	Z	U	X	G	S	I	E	N	E	R	G	Y
L	C	L	O	B	E	S	L	T	U	T	H	A	N	I	F
E	J	A	P	G	N	D	I	S	H	N	E	C	J	P	E
H	I	L	E	U	C	A	R	E	C	I	F	R	G	H	A
J	A	N	S	K	Y	S	P	E	C	T	R	U	M	Y	J



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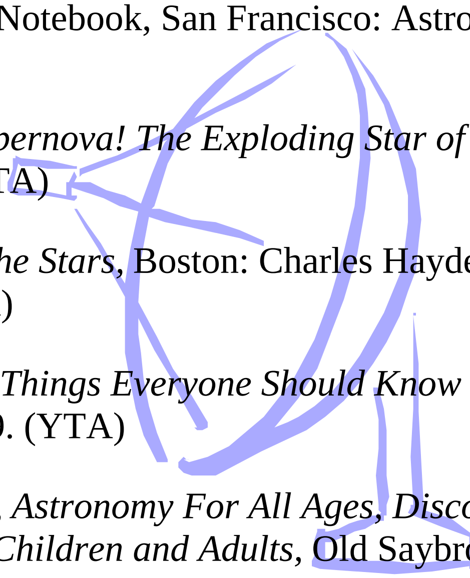

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PLANETARIUM PROGRAM EVALUATION

After the Northern Stars Planetarium has visited your class, please take a moment to fill out this evaluation. Your suggestions are very valuable to us!

Mail the completed evaluation to :......................Northern Stars Planetarium
15 Western Ave.
Fairfield, Maine 04937
Or Email To :..info@northern-stars.com

1. Show Name: ____

2. Group grade/age level:____

3. Was the material presented at an appropriate level for your class? ________________________

____

4. Was the amount of material discussed: Enough Overwhelming Not Enough

5. Should any parts of the presentation be developed further? _____________. If so, which parts?

6. Was there sufficient time for questions and answers? Yes No

7. Were you studying astronomy or another related subject at the time of the planetarium's visit?

Yes No

If so, was the planetarium visit helpful? ____

8. Was the Teacher's Guide helpful in preparing your class for the planetarium visit? Yes No

Which parts were most helpful? ____

Which parts were least helpful? ____

9. Did the presenter present the material in a clear and understandable fashion? ______________

10. How would you rate the overall program given to your class in the planetarium? ____________

____

11. (Optional) Your name & school:____

Thank you for your time! Your Comments Make a Difference!