Amateur Radio Astronomy

Dr. Cran Lucas

Shreveport-Bossier Astronomical Society

& Shreveport Amateur Radio Association

KG5NMF

Outline

- Radio Astronomy Basics
- Radio Astronomy History
- Radio Astronomy Telescopes
- Amateur Radio Astronomy

Radio Astronomy Basics

Radio Astronomy Reveals the Hidden Universe-I

- We see the world around us, because our eyes detect visible light.
- Objects on Earth and in space also emit other types of electromagnetic radiation (EM) that cannot be seen by the human eye, such as radio waves.
- Radio astronomy is the **study of celestial objects that give off radio waves**.
- With radio astronomy, we study astronomical phenomena that are often invisible or hidden in other portions of the electromagnetic spectrum.

Radio Astronomy Reveals the Hidden Universe-II

- With radio telescopes, we watch:
  - Stars turn on, shine, and die.
  - We watch planets form from the dust and ice of solar nebula.
  - We clock the spin of our Galaxy and thousands of other galaxies.
  - We see the echo of the Big Bang and the Universe's very first stars and galaxies.
  - And we spot the chemical precursors of DNA and other organic molecules floating in space.

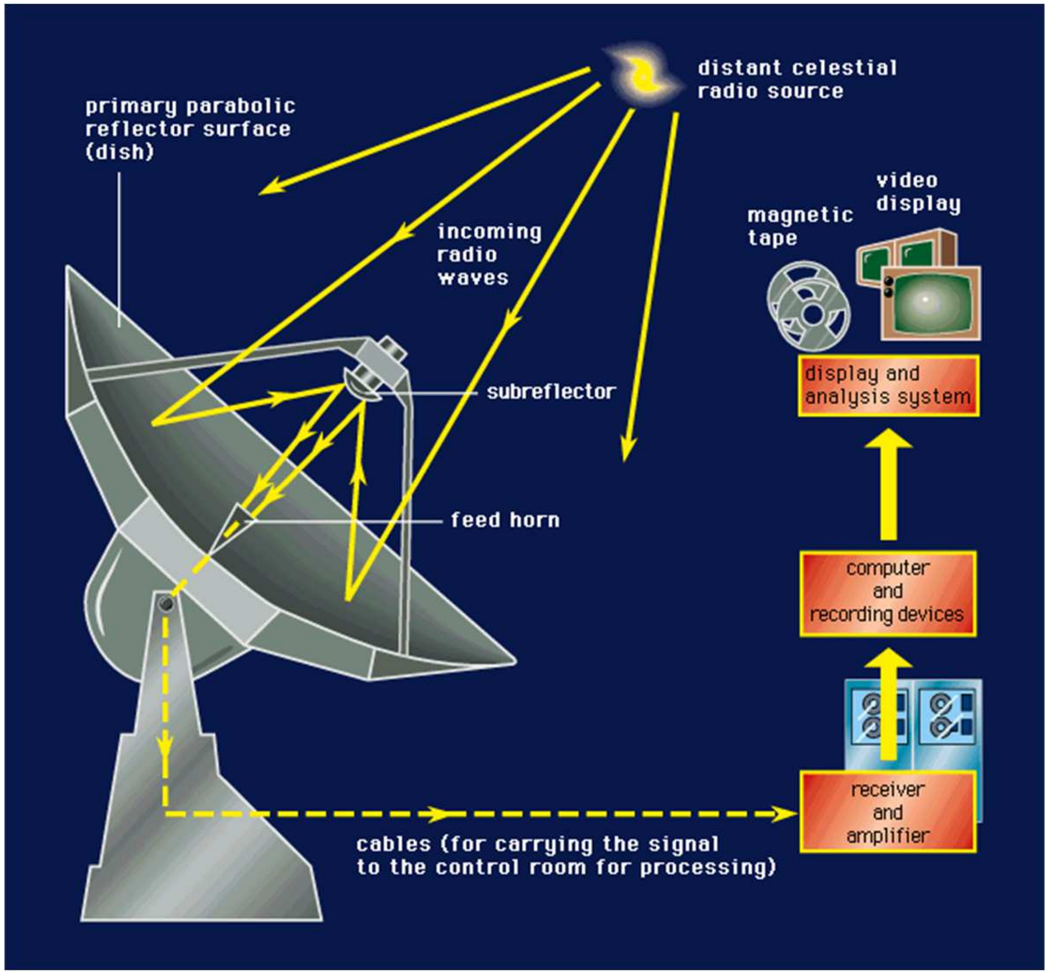
Radio Astronomy Reveals the Hidden Universe-III

- Since radio waves penetrate dust, we use radio astronomy techniques to study regions that cannot be seen in visible light, such as:
  - The dust-shrouded, center of our Galaxy, the Milky Way.
  - Radio waves also allow us to trace the **location, density, and motion** of the **hydrogen gas** that constitutes three-fourths of the ordinary matter in the Universe.

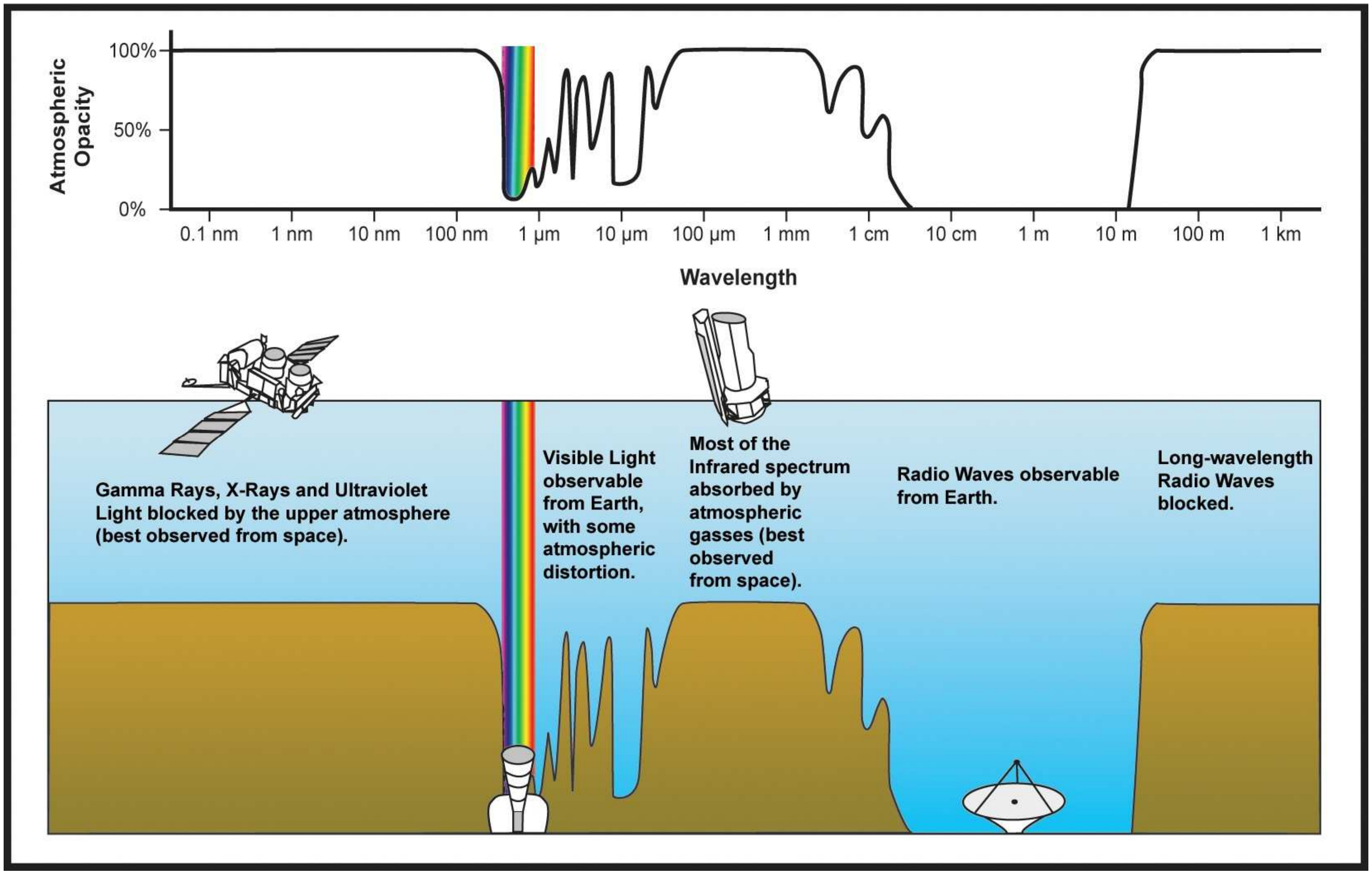
Radio Astronomy Basics-I

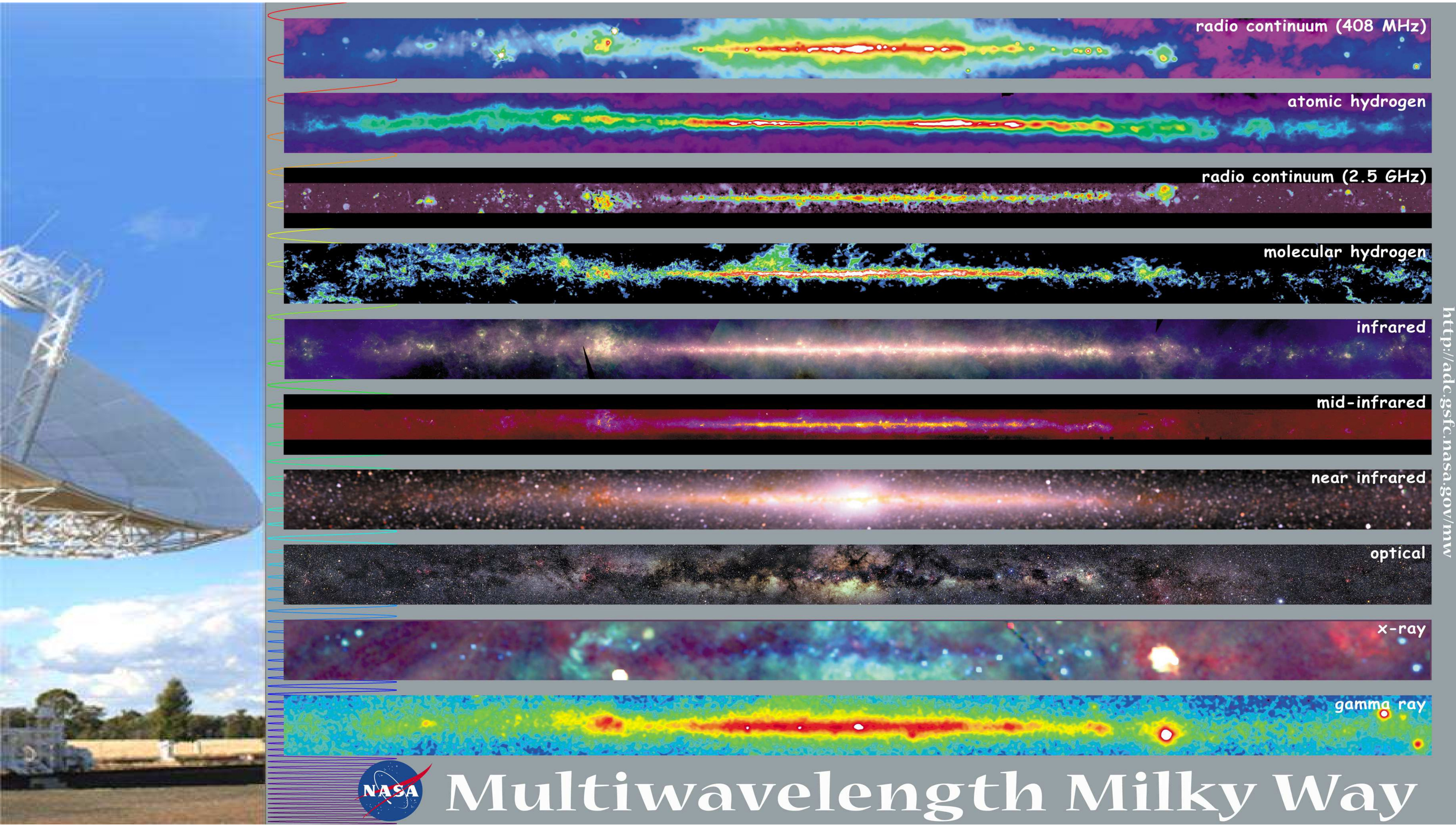
- RF waves that can penetrate Earth's atmosphere range from wavelengths of a few millimeters to nearly 100m.
- These wavelengths have no discernable effect on the human eye or photographic plates, they do induce a very weak electric current in a conductor such as an antenna.
- Most radio telescope antennas are parabolic reflectors that can be pointed toward any part of the sky.
- They gather up the radiation and reflect it to a central focus, where the radiation is concentrated.
- The weak current at the focus can then be amplified by a radio receiver so it is strong enough to measure and record.

Radio Astronomy Basics-II

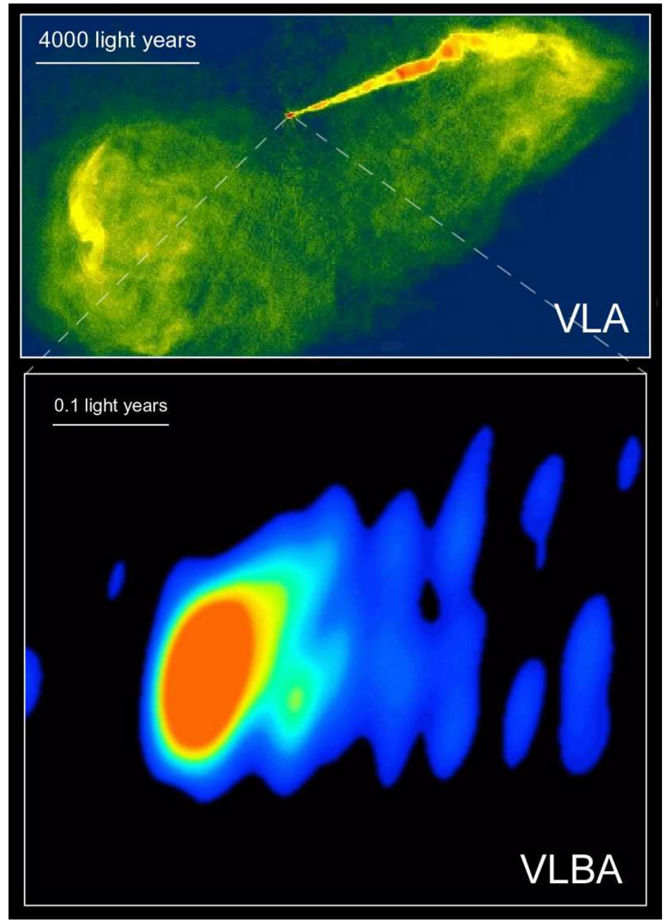


Atmospheric Opacity to Radiation




radio continuum (408 MHz)
atomic hydrogen
radio continuum (2.5 GHz)
molecular hydrogen
infrared
mid-infrared
near infrared
optical
x-ray
gamma ray
NASA
Multiwavelength Milky Way
http://adc.gsfc.nasa.gov/mw

Optical vs. Radio Images



An **optical** image of the galaxy M87 (**HST**), a radio image of same galaxy using **Interferometry** (**VLA**), and an image of the center section (**VLBA**). The jet of particles is suspected to be powered by a black hole in the center of the galaxy.

Visible (white) vs. Radio (blue)

Whirlpool Galaxy (M51)

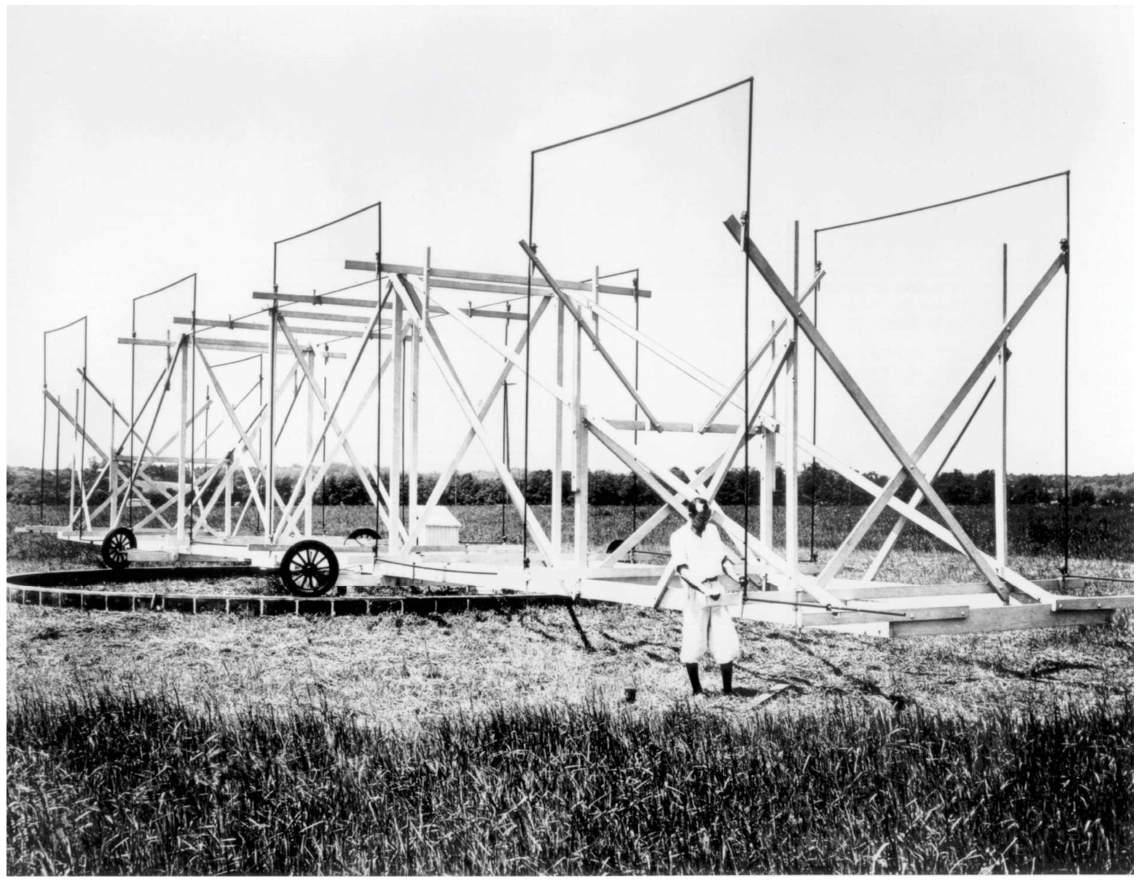
Radio Astronomy History

Karl Jansky's Early Work-I

- It was the decade of 1930s and the Bell Telephone Company was having trouble with the functioning of their transatlantic service, due to static of some sort. The company asked the physicist **Karl Jansky (1905-1950)** to find the source of such interference.

- In order to track and identify the source of static, Jansky built a big rotating antenna, given the name of **"Jansky's merry-go-round"**.

Karl Jansky and the First Radio Telescope



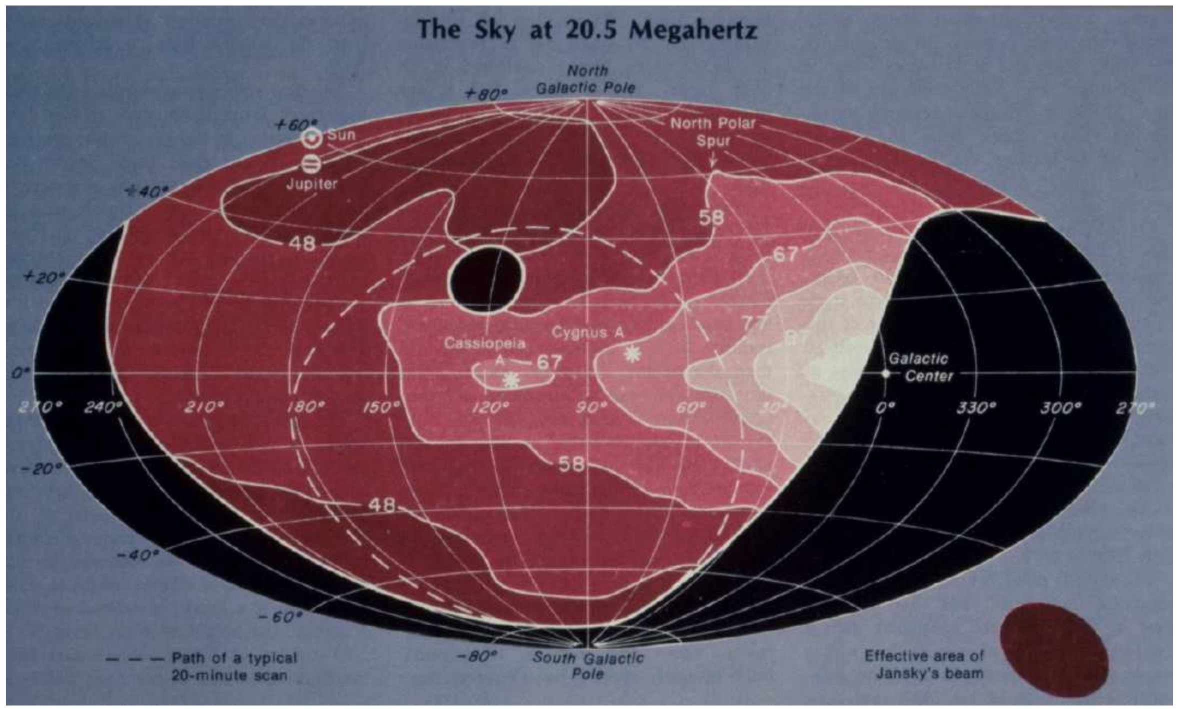
Karl Jansky's Early Work-II

- The antenna was designed to receive radio waves at a **frequency of 20.5MHz**, and with its rotation ability it was able to locate the direction of any radio signal.
- After several months of studying such static, Jansky was able to classify it into **three different types**.
- The source of the first two originated from **nearby and distant thunderstorms**.

Karl Jansky's Early Work-III

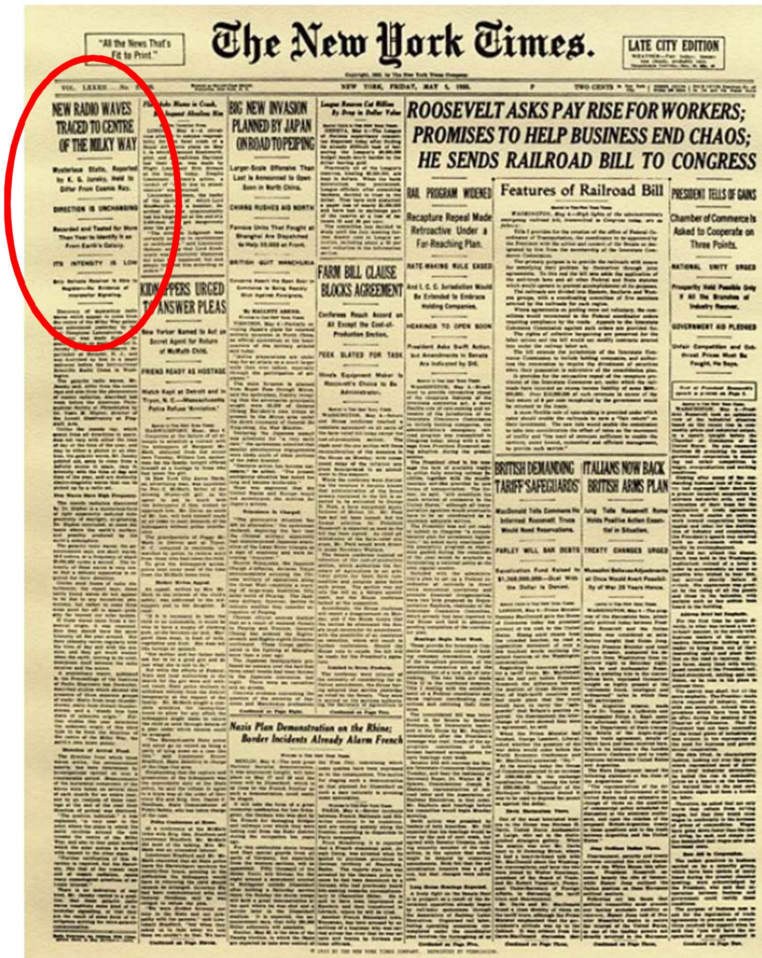
- There was a third source of static that was somehow different. He realized that there was a pattern characterizing these signals similar to the known location of the Sun.
- After more accurate measurements, **(the signals repeated every 23 hours and 56 seconds),** Jansky concluded that the **radiation came from** the constellation Sagittarius (direction of the **core** of the **Milky Way Galaxy**.)
- Discovery was fundamental to radio astronomy.

Jansky’s All Sky Map at 20.5MHz



Jansky's Discovery

Jansky's discovery attracted major public attention, including front page of NY Times May 5, 1933.



"All the News That's Fit to Print."

The New York Times.

LATE CITY EDITION

NEW RADIO WAVES TRACED TO CENTRE OF THE MILKY WAY

BIG NEW INVASION PLANNED BY JAPAN ON ROAD TO PEIPING

ROOSEVELT ASKS PAY RISE FOR WORKERS; PROMISES TO HELP BUSINESS END CHAOS; HE SENDS RAILROAD BILL TO CONGRESS

RAIL PROGRAM WIDENED

Recapture Repeal Made Retroactive Under a Far-Reaching Plan.

Features of Railroad Bill

PRESIDENT TELLS OF GAINS

Chamber of Commerce Is Asked to Cooperate on Three Points.

FARM BILL CLAUSE BLOCKS AGREEMENT

KIDNAPPERS URGED TO ANSWER PLEAS

BRITISH DEMANDING TARIFF SAFEGUARDS

ITALIANS NOW BACK BRITISH ARMS PLAN

Nazis Plan Demonstration on the Rhine; Border Incidents Already Alarm French

Grote Reber & His Telescope (1937)

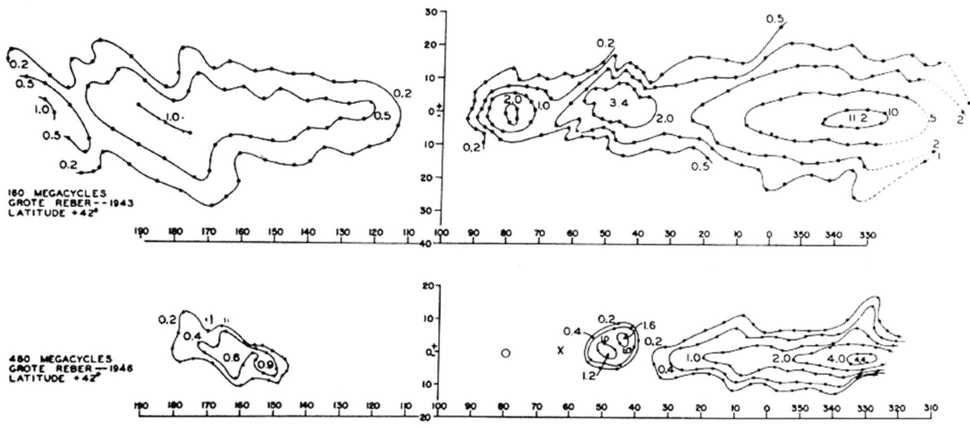
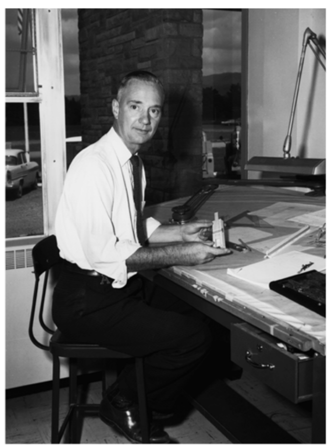
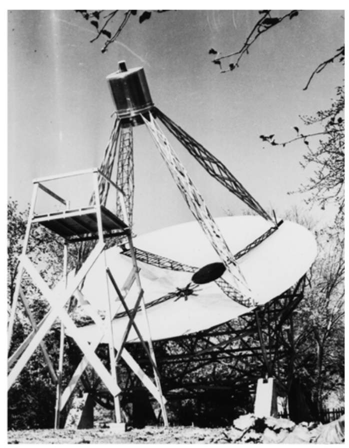


FIG. 7—Contours of constant intensity at 160 MHz and 480 MHz, taken at Wheaton, Illinois.





Grote Reber. Cosmic Static. *Proc. IRE*, **28**, 68, 1940.

Grote Reber. Cosmic Static. *Astrophys. J.*, **91**, 621, 1940.

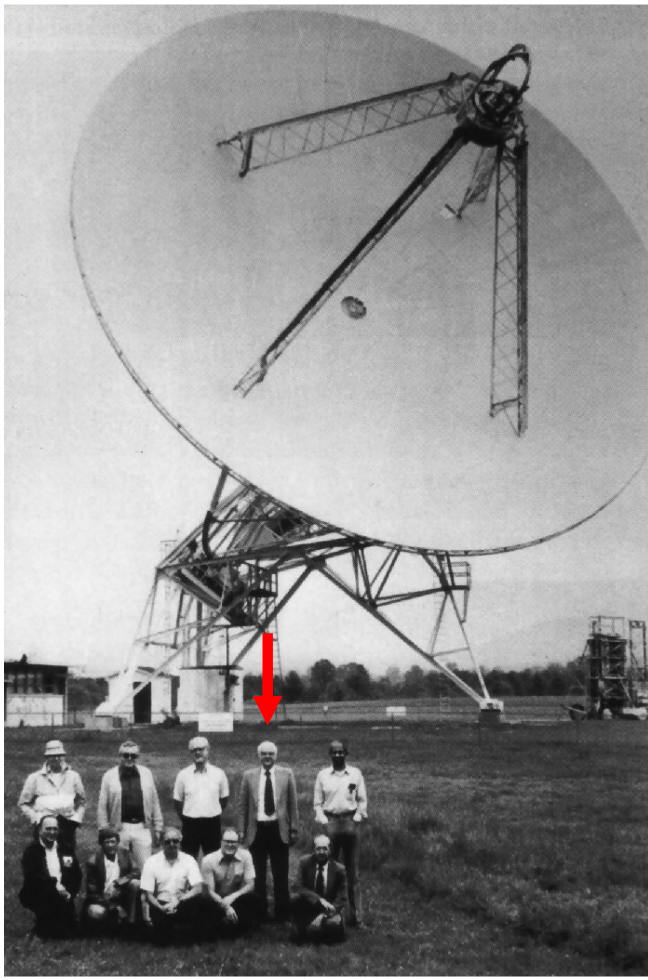
Grote Reber. Cosmic Static. *Proc. IRE*, **30**, 367, 1942.

Grote Reber. Cosmic Static. *Astrophys. J.*, **100**, 1944.

Project Ozma (1960)

- Organized by Frank Drake.
- First search for extraterrestrial radio signals.
- Targeted two stars:
  - Tau Ceti
  - Epsilon Eridani

Project Ozma



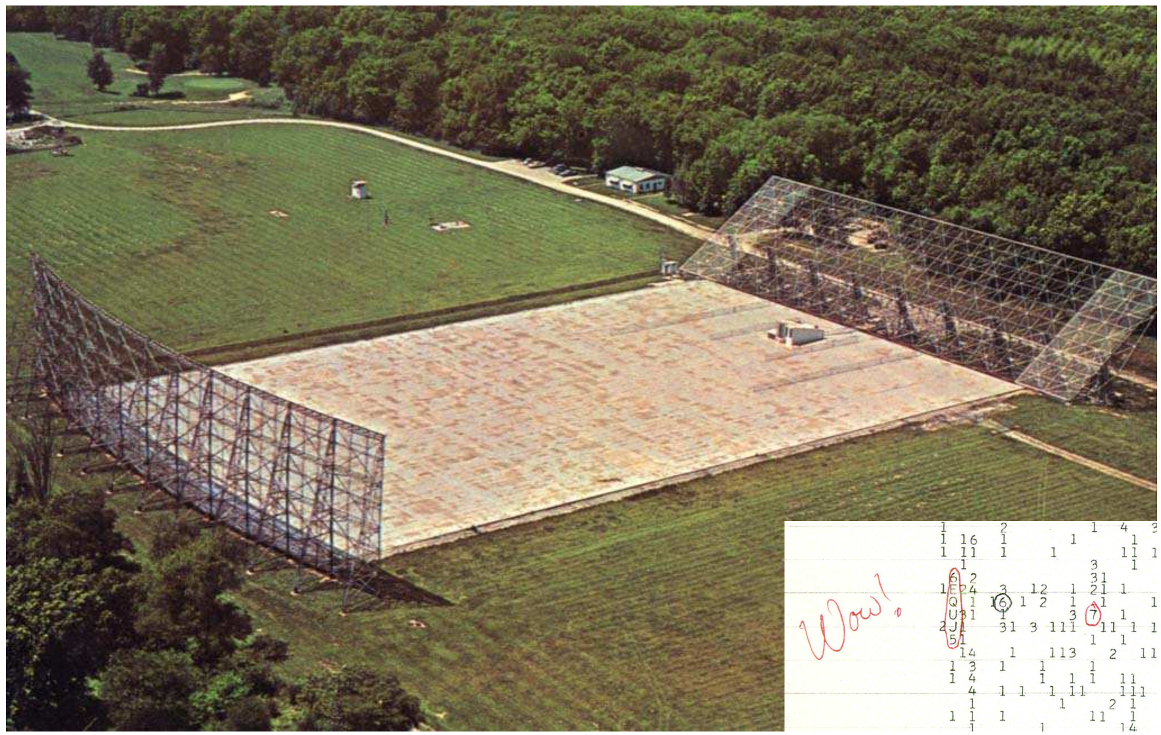
The Beginning of
Search for Extraterrestrial
Intelligence (SETI)

What Temperature is Venus?

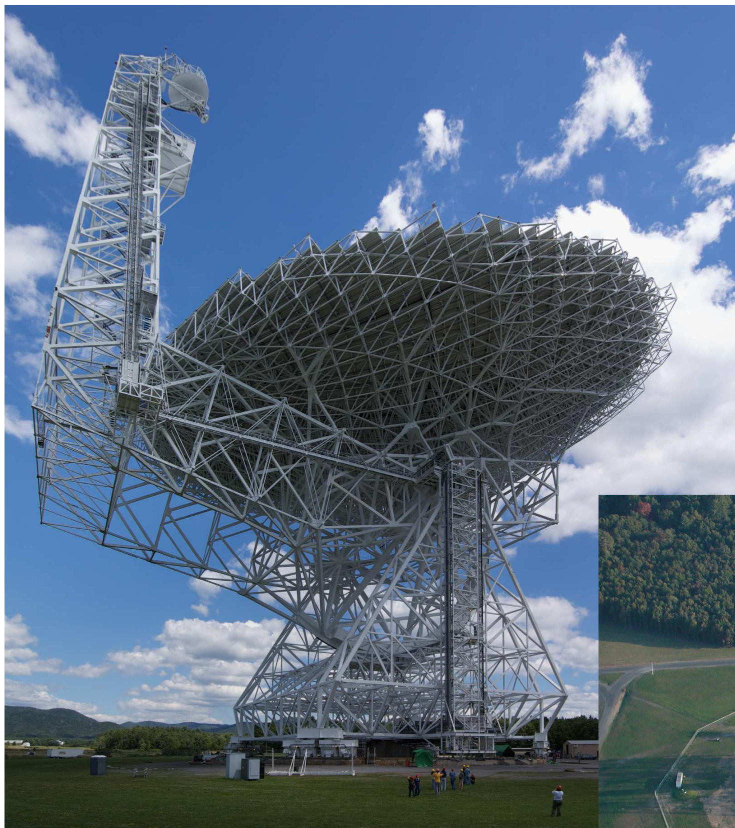
- Venus has thick cloud layers that reflect light very well.
- At **infrared wavelengths** these **clouds** are opaque and the temperature measured at these wavelengths is only about **225K or -55 degrees F**.
- However measurements at **radio wavelengths** imply a **surface temperature of about 700 K or 800 degrees F**.
- High temperature due to thick CO_2 atmosphere and **“runaway” greenhouse** effect.

Radio Astronomy Telescopes

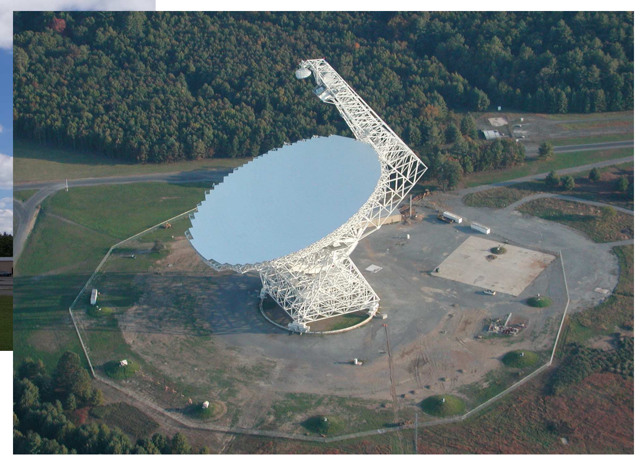
Ohio State University Radio Telescope: 1960s-1970s



Green Bank Telescope (GBT) in West Virginia



100 m Diameter



Arecibo (P.R.) Radio Telescope

300 m Diameter

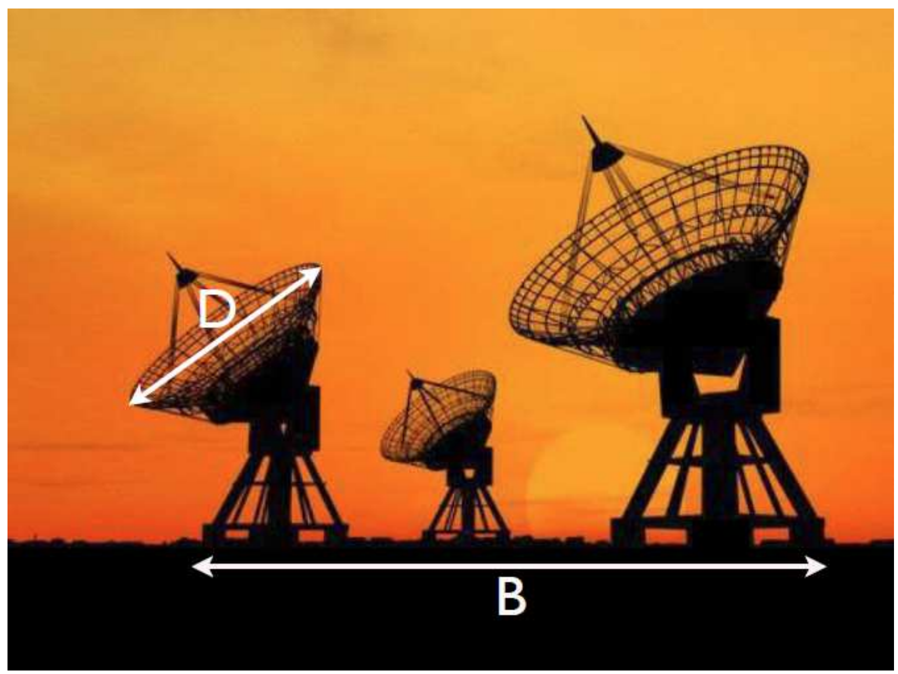
VLA-Very Long Array

25 m Diameter

VLBA-Very Long Base Array

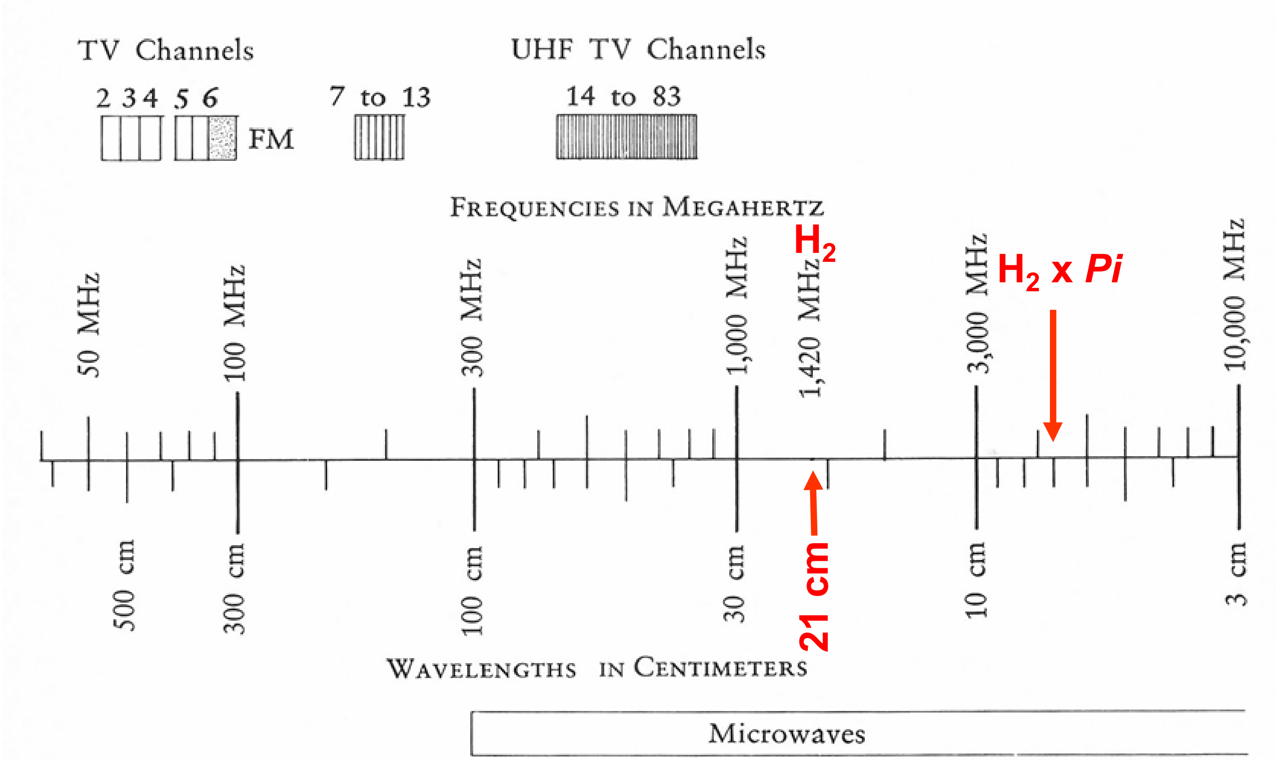
Interferometers

- For a **<u>single dish</u>** the **<u>resolution is λ/D</u>**, where D is the diameter of the telescope.
- But for an **<u>interferometer array</u>** the **<u>resolution is λ/B</u>**, where B is the maximum baseline.

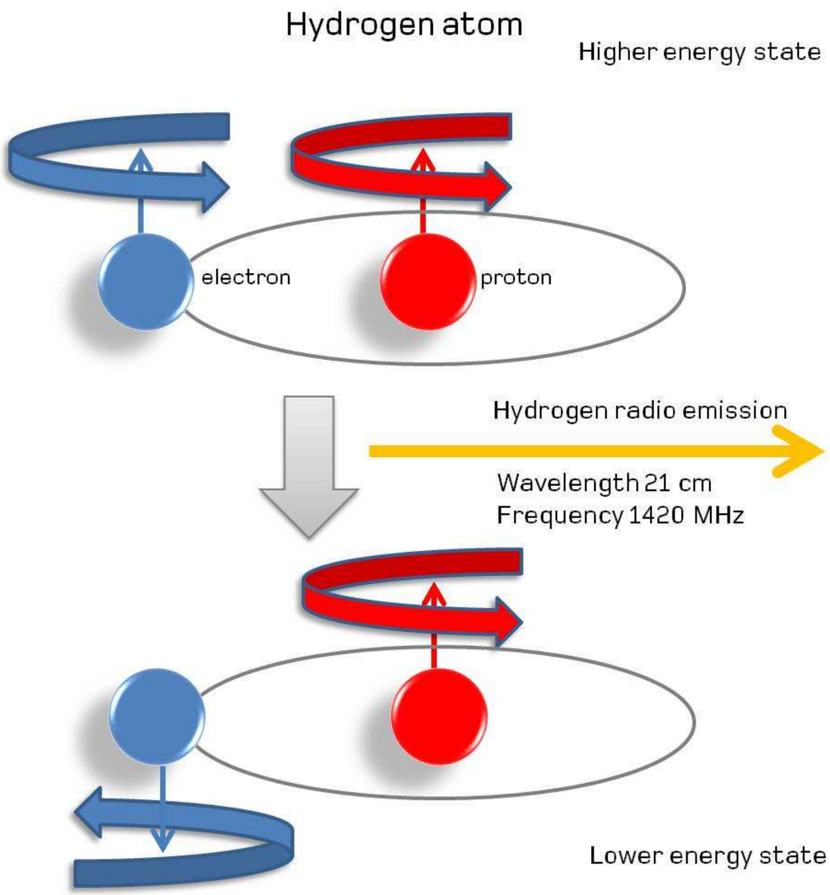


CHIME Digital Telescope (Prototype)

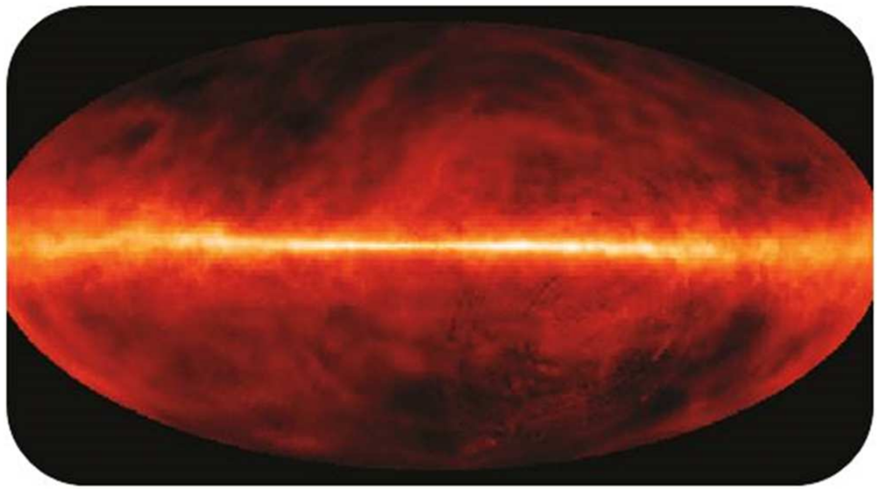
Radio Wave Frequencies

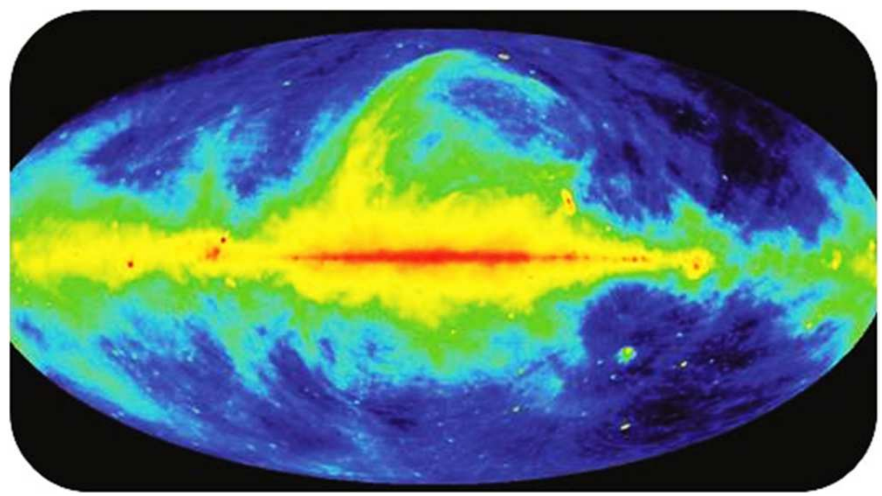


21 cm/1420 MHz Neutral Hydrogen Line

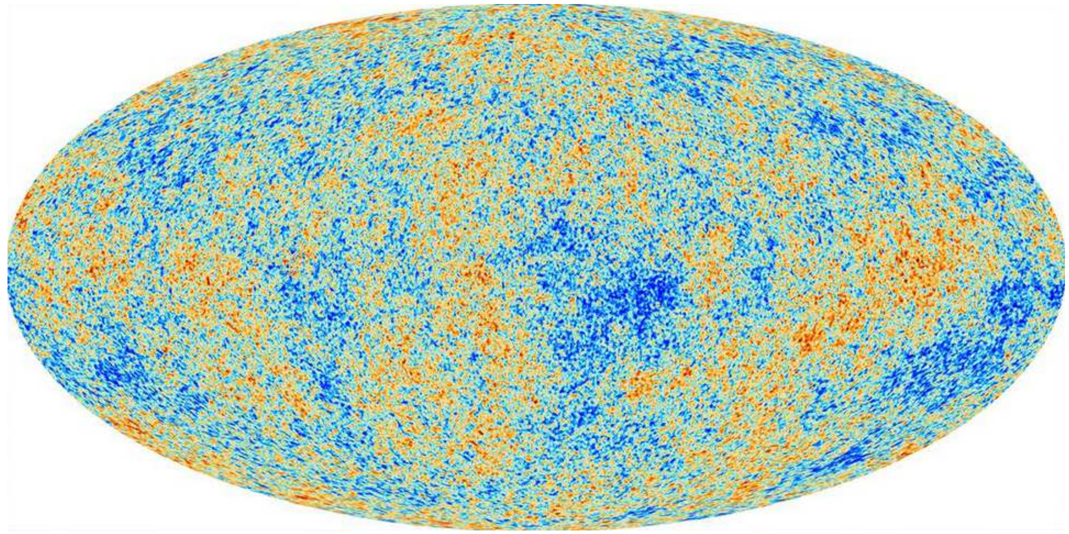


1420 MHz vs. 408 MHz

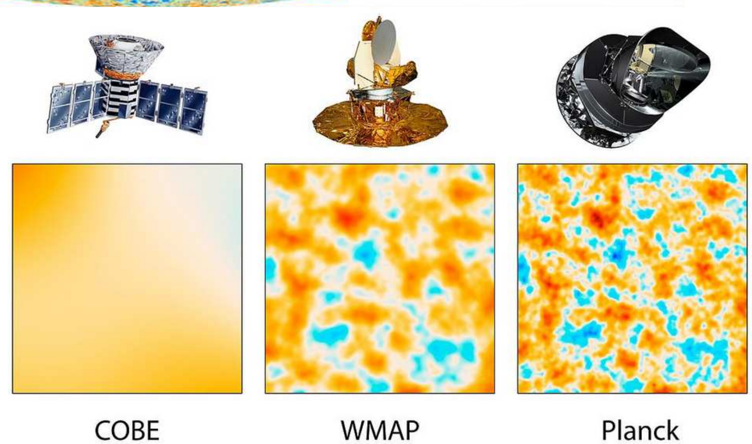




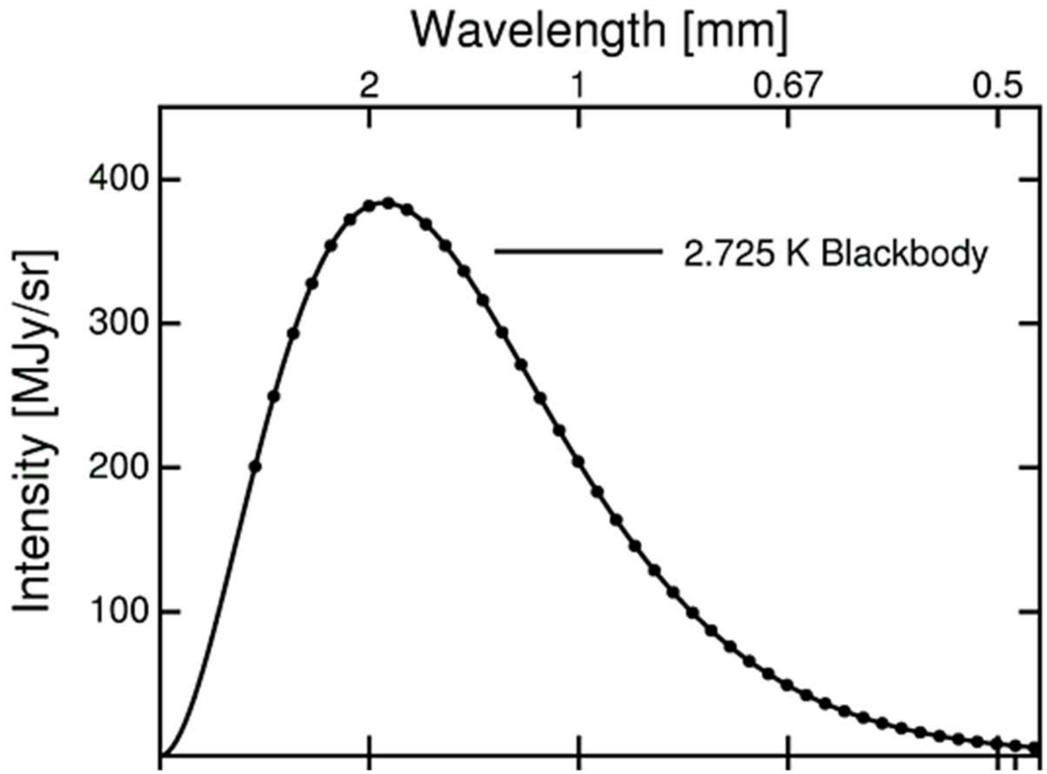
Microwave View of the Sky



Cosmic
Microwave
Background



CMB Spectra



Wavelength [mm]
2
1
0.67
0.5
400
300
200
100
Intensity [MJy/sr]
2.725 K Blackbody

Amateur Radio Astronomy

Another SARA!

SOCIETY OF AMATEUR RADIO ASTRONOMERS

www.radio-astronomy.org

Radio Astronomy Amateurs

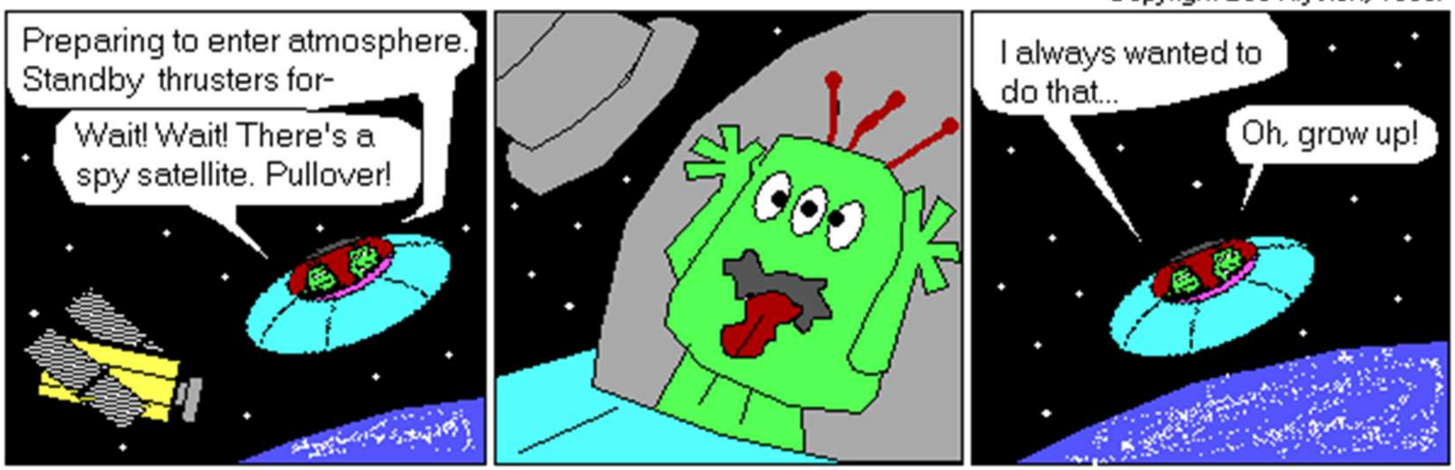
What can I do with a small radiotelescope?

1. Study Jupiter's noise storms.
2. Record solar flares and predict geomagnetic activity.
3. Detect a pulsar (rotating neutron star) using DSP (digital signal processing).
4. Detect stronger radio sources.
5. Look for HEPs (high energy pulses) from the galactic center.
6. Search for radio correlations to gamma ray bursts.
7. Study ionospheric scintillation and refraction.
8. Detect meteors invisible to the eye.
9. Develop a long base line interferometer.
10. Learn radio technology.
11. Learn astronomy.

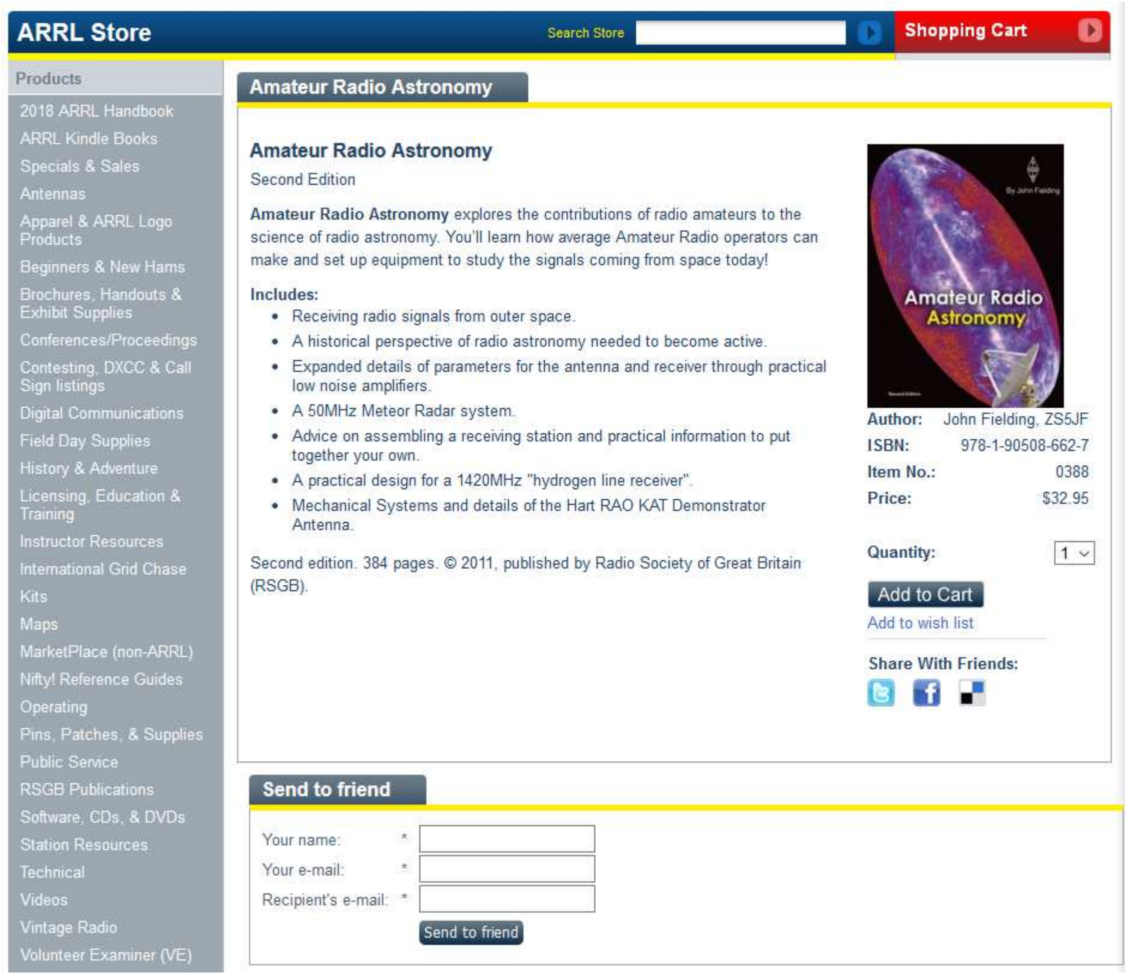
What can I do with a small radiotelescope?

12. Find ET

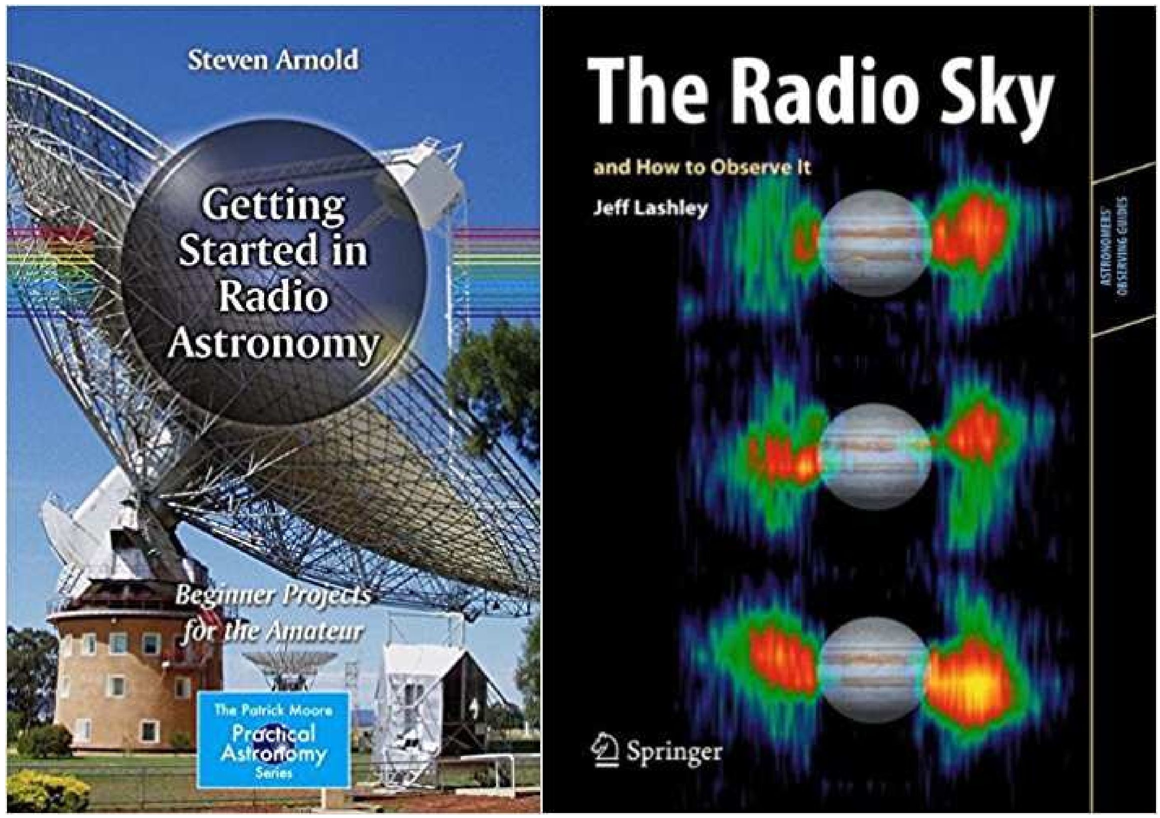
LGM


Preparing to enter atmosphere. Standby thrusters for-
Wait! Wait! There's a spy satellite. Pullover!
I always wanted to do that...
Oh, grow up!

Radio Astronomy Book



Additional Books on Amazon



Build a Homebrew Radio Telescope

Explore the basics of radio astronomy with this easy to construct telescope.

Mark Spencer, WA8SME

Figure 1 — Radio telescope system based on TV dish antenna.

There are many ham radio related activities that provide a rich opportunity to explore and learn more about the science of radio. One of those opportunities is radio astronomy.

All matter emits radio frequency (RF) energy dependent on the temperature and makeup of the matter, including the matter in space. The foundation of radio astronomy is to study the heavens by collecting and analyzing the RF energy that is emitted by bodies in space, very much as optical astronomers use light energy collected by telescopes. It sounds complicated. While professionals use very sophisticated and expensive equipment, you can, with some simple equipment and a little investment, build a radio telescope that will allow you to learn and explore the fundamentals of radio astronomy.

A Homemade Radio Telescope

In this article, I will build on an existing design of a radio telescope made from one of those ubiquitous TV dish antennas that you see around your neighborhood. The radio telescope (RT) project described here can easily be reproduced. Although this is not a fully capable RT, it can provide a wonderful learning opportunity for you, or perhaps students in your local school.

Figure 1 shows the radio telescope set up. The major components include a modified TV dish antenna mounted on a wooden support structure to allow pointing the antenna, a commercial satellite signal strength detector that displays the signal strength of signals collected by the dish on a meter and an interface that converts the signal strength into a amplitude modulated tone. The tone is fed into a computer sound card and finally a computer and software graphically displays the signal strength as a function of time.

The TV dish modifications are structural, and any available TV dish system can be used. The signal strength detector costs between $40 and $65 and is widely available from Web retailers. The interface circuit, which will be described shortly, is easily duplicated and costs approximately $20. Finally, the display software is free.

Figure 2 — Dual LNB mount. Note two coax connectors.

Figure 3 — Homemade plastic single LNB mounting bracket.

What it Can Do

The following is just a sample of what you can do with this simple RT:

- Use the sun to study and determine the beamwidth of the dish and verify the mathematic formula that is used to predict dish antenna performance.
- Measure the radiation intensity of the Sun and perhaps detect changes in solar activity.
- Measure the relative changes in the surface temperature of the moon.
- Learn about and explore a common radio astronomy collection technique called the *drift scan*.

From June 2009 QST © ARRL

http://www.mikebrownsplanets.com/2013/06/summer-project-build-radio-telescope-at.html

Summer project: Build a radio telescope at home

When we moved into our house more than 7 years ago now the old owners left their Dish Network satellite TV dish attached to the roof. A few months later we got a sternly worded letter from the Disk Network demanding that we send them the dish back. With my detailed knowledge of the intricacies of the American legal system my obvious response was: come and get it. Which would have been fine with me. But, actually, that was not even my response, my response was to throw the letter in the trash while thinking in my head "come and get it."

Seven year later the dish was still on the side of the house. Luckily it is on the side that I never really see, so I didn't worry about it, but every now and then I thought to myself: "I should at least go up and take down that eyesore." But I never did. Until now.

I occurred to me a while ago that a parabolic dish like that would make a fine radio telescope (OK, it will end up a microwave telescope, but we'll get into the details later).

I'm not a radio astronomer or an electrical engineer or a Ham radio guy or any of that stuff, so I really had no idea what I was talking about, but it seemed a fun project for Lilah and I to play around with for the summer and for both of us to learn a little bit about microwaves. The caveat, though, is that my electronic explanations might not be exactly right. And I might break things.

We started last week. Step 1: remove the dish from the roof and see what was there. I had to snip the coax cables that went into the house and then undo five big screws and then everything just came unceremoniously down. The main issue was figuring out how to hold the wrench, dish, and ladder at the same time without falling. Luckily I survived this crucial part. Lilah stayed far enough away to avoid getting a dish on her head but to be able to both take pictures of me and make fun of me each time I dropped something and had to go pick it up.

The next step was to figure out what I really had. The dish itself

The Itty Bitty Telescope (IBT): Tips for building and using a simple radio telescope

FAST Facts about the IBT:

1. This is a 12,000 MHz radio telescope.
2. It can detect frequencies in the range of 12,200 to 12,700 MHz.
3. It is not a radio telescope system that can be used for serious sky surveys.
4. It can detect the sun.
5. It can detect blackbody radiation such as 300K trees, buildings, people, when viewed against blank sky.
6. You must use it outside, or through a large window.

Parts list and options for the IBT:

1. Need the works? By an RV kit from Gorgeous Collectibles and Satellite:
   a. http://stores.ebay.com/Gorgeous-Collectibles-and-Satellite
   b. 2 9-V batteries, and two battery clips or a two-battery snap (part number 123-BS-M-4A-GR) from www.mouser.com
   c. SMALL wire nuts, electrical tape
   d. Tools: wire stripper, wrenches.

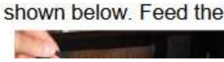
2. Have a dish and a tripod? You need:
   a. Signal meter.
   b. Power supply. The Channel Master 1004IF and cheaper signal meters require a power supply. You'll need to make one. You will need coax cable with f-connectors and items b-d above. Signal meters can be found here: http://www.a1components.com/searchn.aspx?Search=Satellite+Siganl+Meter
   and here: http://www.satpro.tv/meters.html

Putting together the dish:

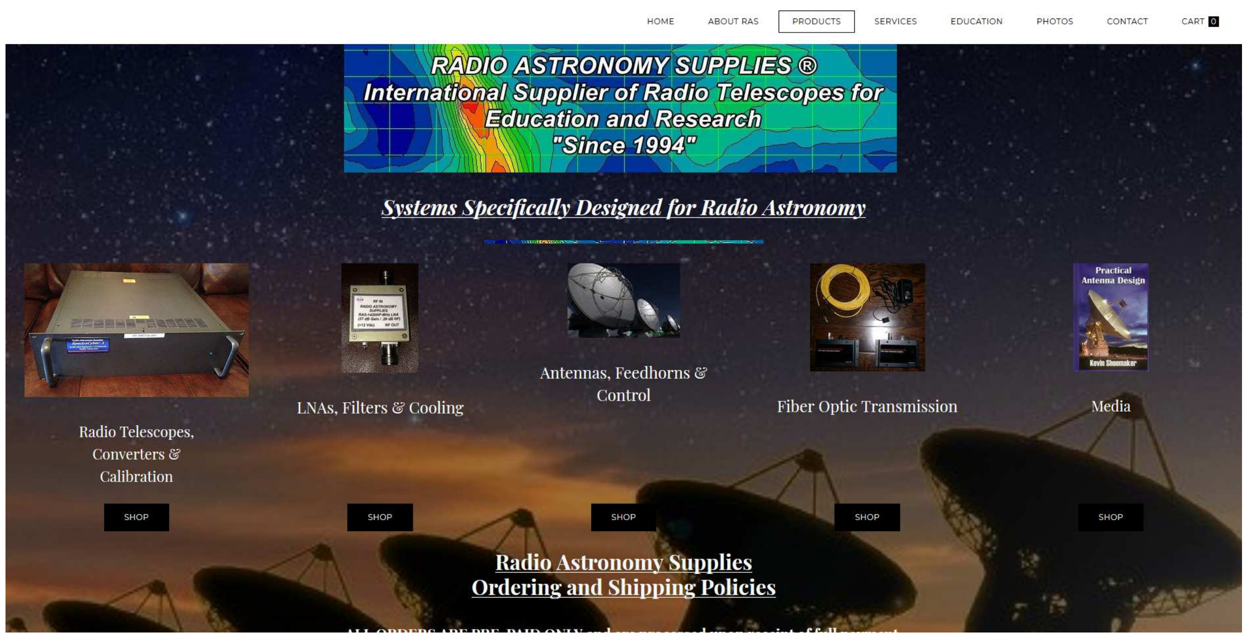
Remove the dish and its parts from the box and find the LNB arm mounting screws. Align the arm and attach with the screws making sure to keep the button screws flush with the surface of the dish as shown below.



Attach the LNB coax cable to the LNB as shown below. Feed the coax cable through the LNB arm as shown below.

Radio Astronomy Supplies



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Our SPIDER complete radio telescopes are available with different dimensions and are designed to let you really perform radio astronomy research. Every radio telescope comes with antenna, computerized mount, receiver and software.

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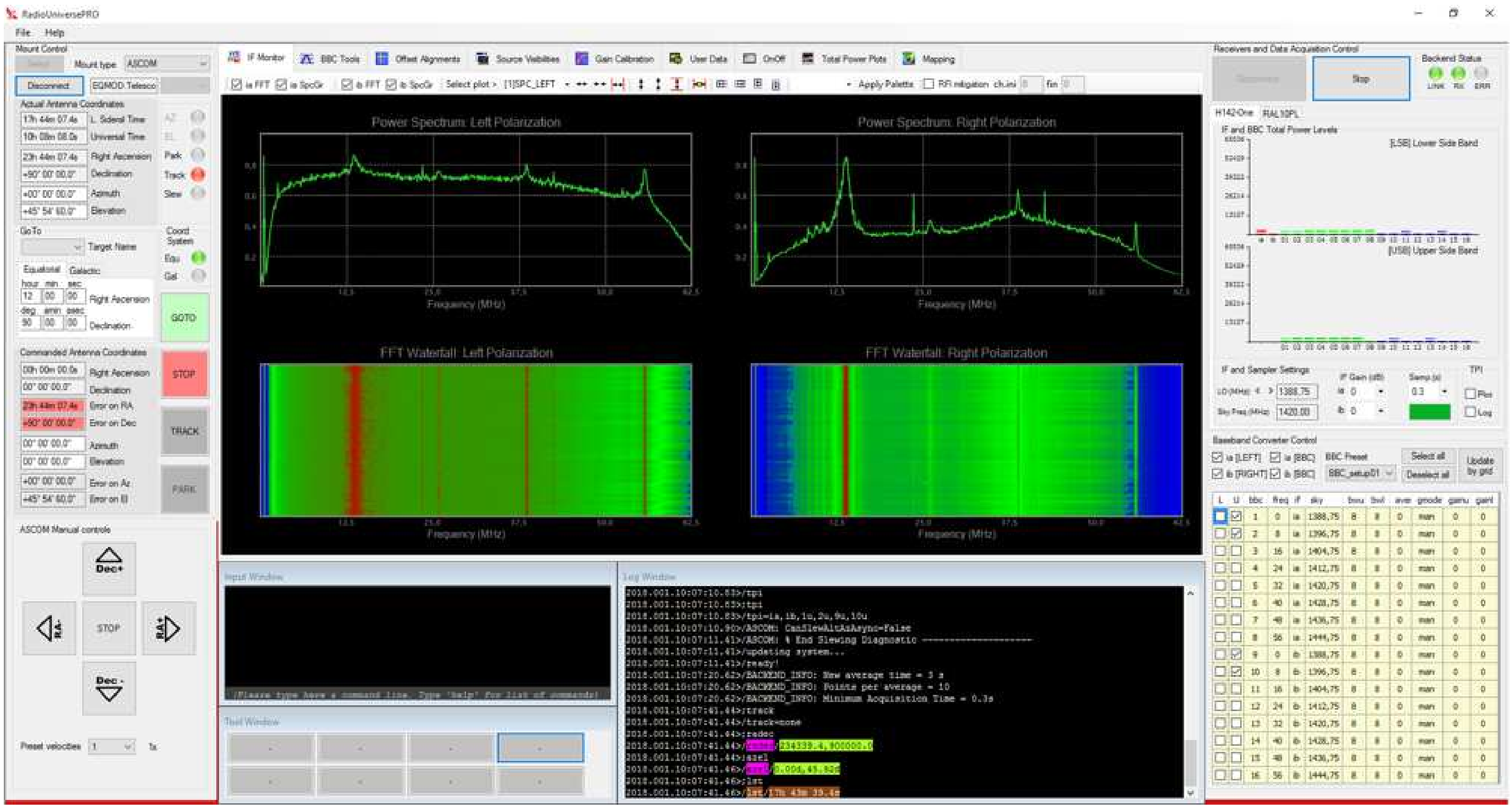
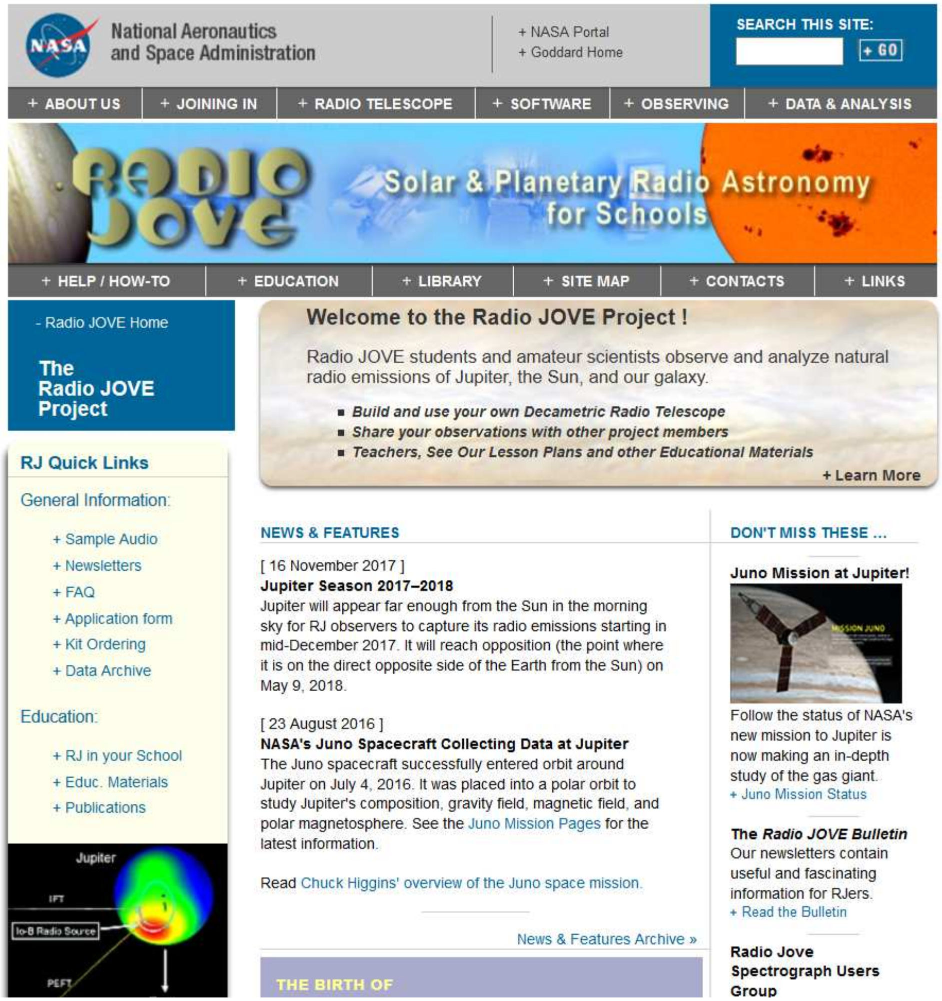
Spider230 amateur radio telescope

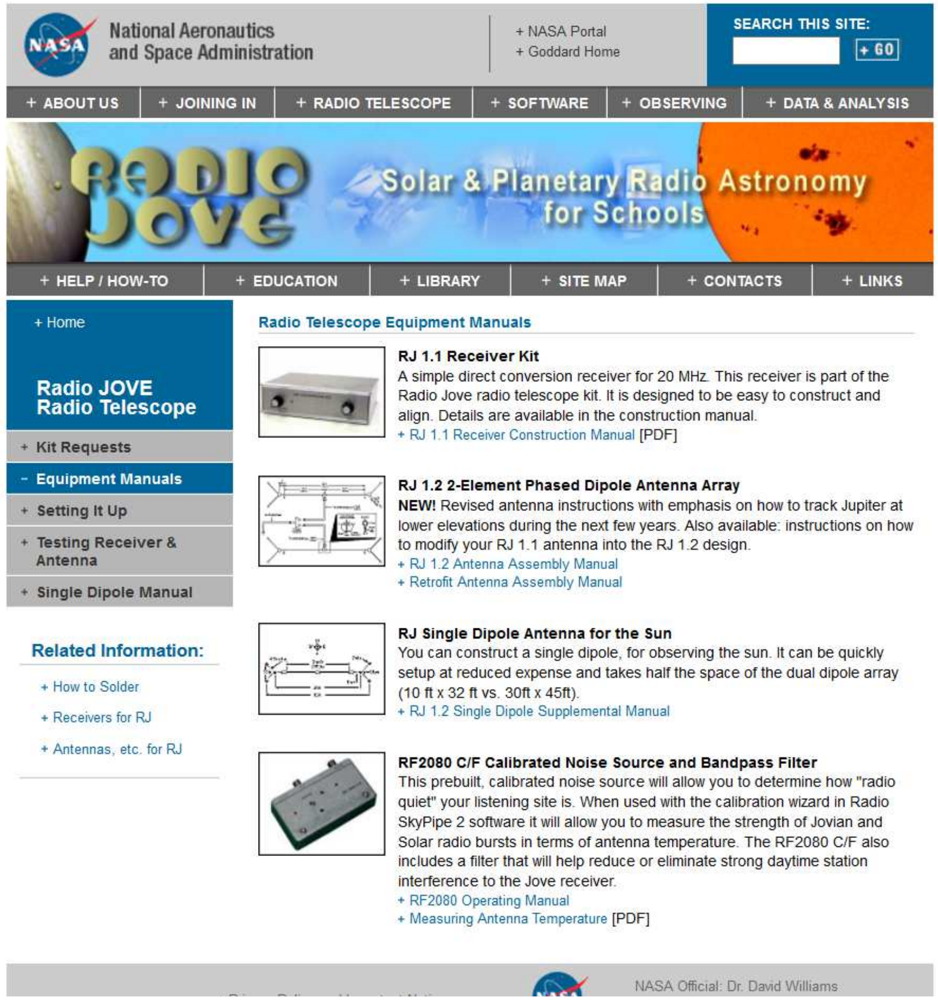
Radio Telescope Software



Radio Jove https://radiojove.gsfc.nasa.gov/



Radio Jove Equipment



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RADIO JOVE — Solar & Planetary Radio Astronomy for Schools

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Radio JOVE Radio Telescope

+ Kit Requests
- Equipment Manuals
+ Setting It Up
+ Testing Receiver & Antenna
+ Single Dipole Manual

Related Information:

+ How to Solder
+ Receivers for RJ
+ Antennas, etc. for RJ

Radio Telescope Equipment Manuals

RJ 1.1 Receiver Kit
A simple direct conversion receiver for 20 MHz. This receiver is part of the Radio Jove radio telescope kit. It is designed to be easy to construct and align. Details are available in the construction manual.
+ RJ 1.1 Receiver Construction Manual [PDF]

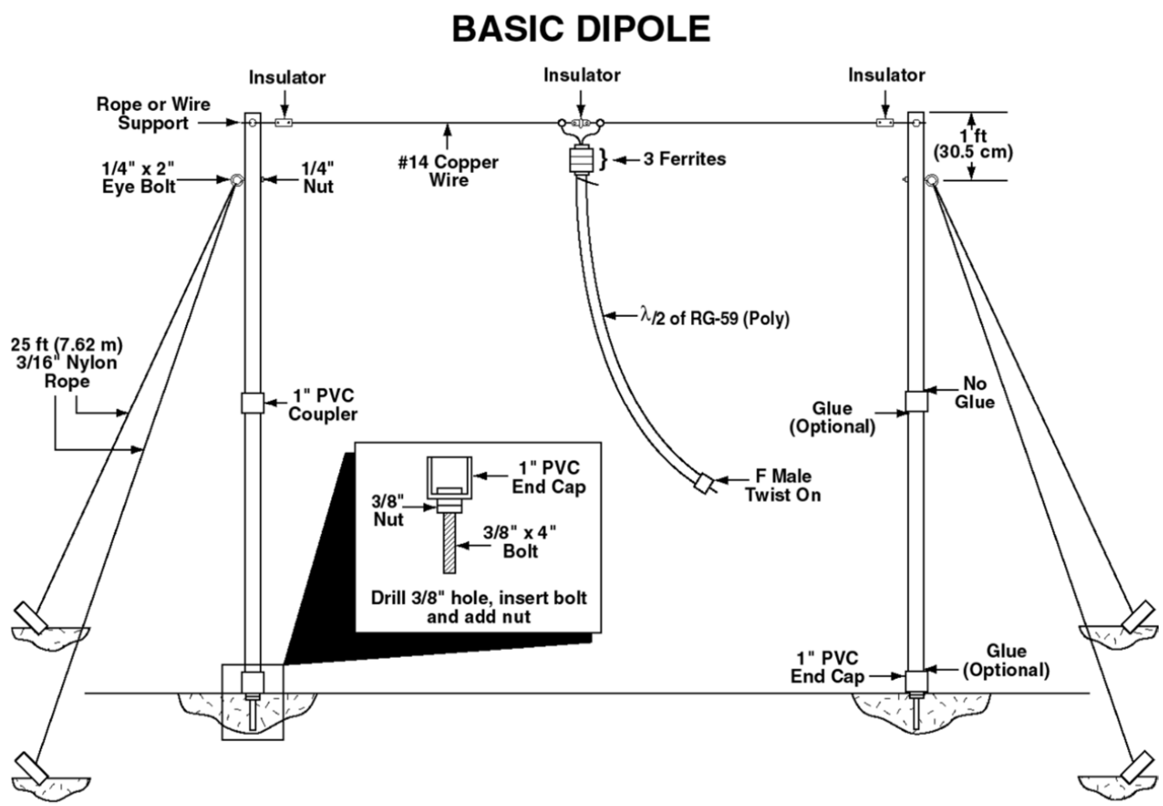
RJ 1.2 2-Element Phased Dipole Antenna Array
NEW! Revised antenna instructions with emphasis on how to track Jupiter at lower elevations during the next few years. Also available: instructions on how to modify your RJ 1.1 antenna into the RJ 1.2 design.
+ RJ 1.2 Antenna Assembly Manual
+ Retrofit Antenna Assembly Manual

RJ Single Dipole Antenna for the Sun
You can construct a single dipole, for observing the sun. It can be quickly setup at reduced expense and takes half the space of the dual dipole array (10 ft x 32 ft vs. 30ft x 45ft).
+ RJ 1.2 Single Dipole Supplemental Manual

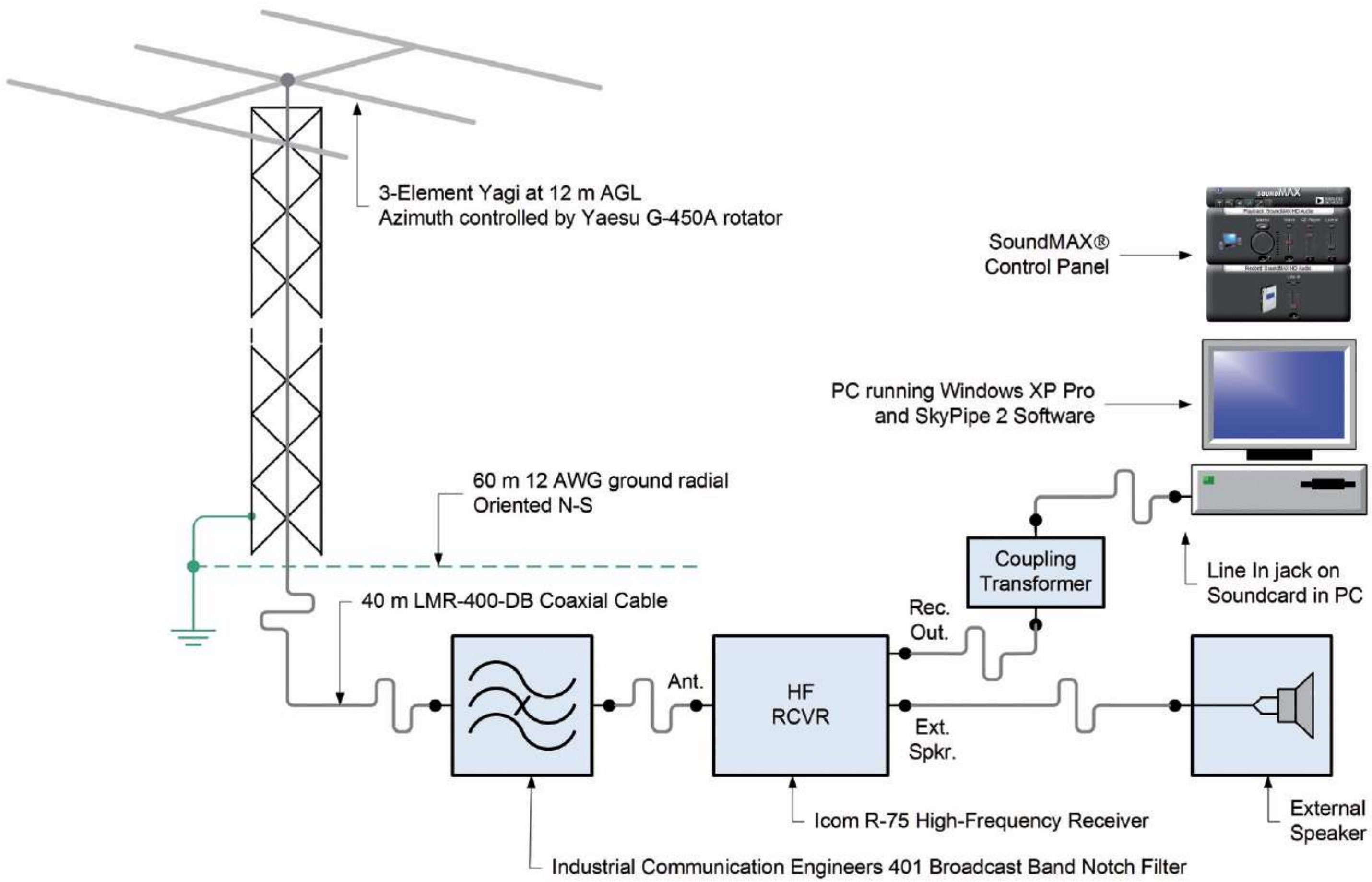
RF2080 C/F Calibrated Noise Source and Bandpass Filter
This prebuilt, calibrated noise source will allow you to determine how "radio quiet" your listening site is. When used with the calibration wizard in Radio SkyPipe 2 software it will allow you to measure the strength of Jovian and Solar radio bursts in terms of antenna temperature. The RF2080 C/F also includes a filter that will help reduce or eliminate strong daytime station interference to the Jove receiver.
+ RF2080 Operating Manual
+ Measuring Antenna Temperature [PDF]

NASA Official: Dr. David Williams

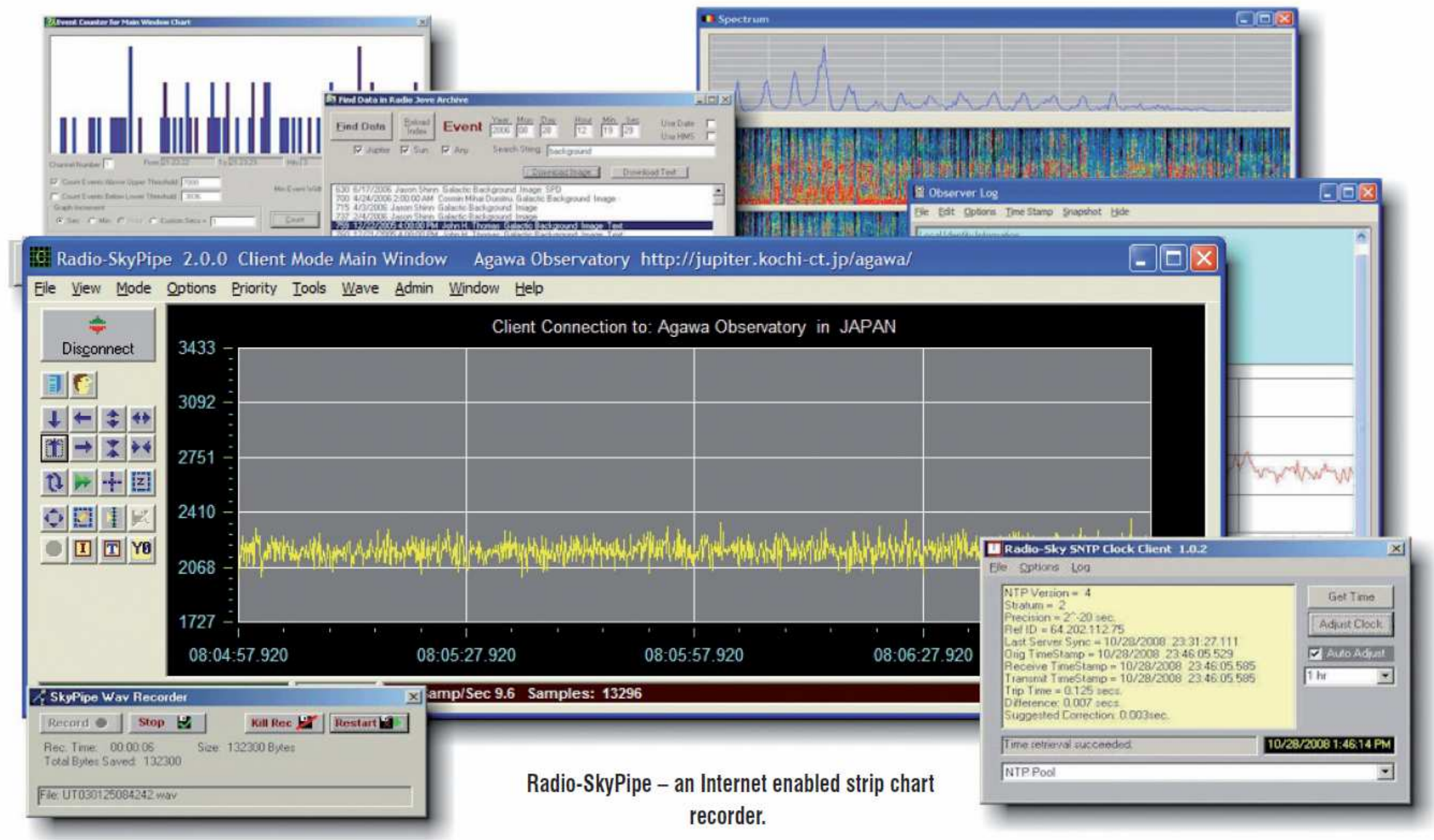
Radio Jove Antenna



Monitoring System Example

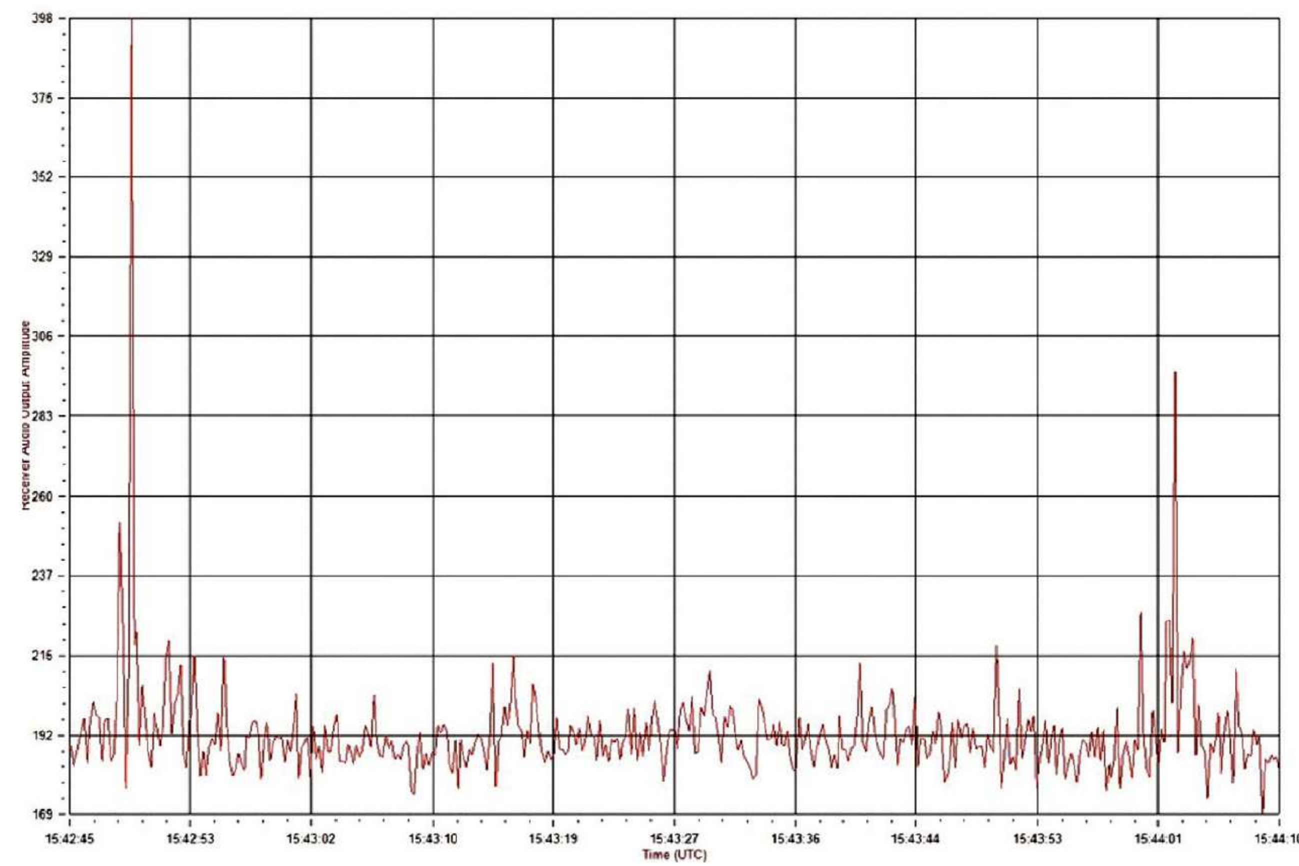


Radio SkyPipe: Internet Enabled Strip Chart Recorder



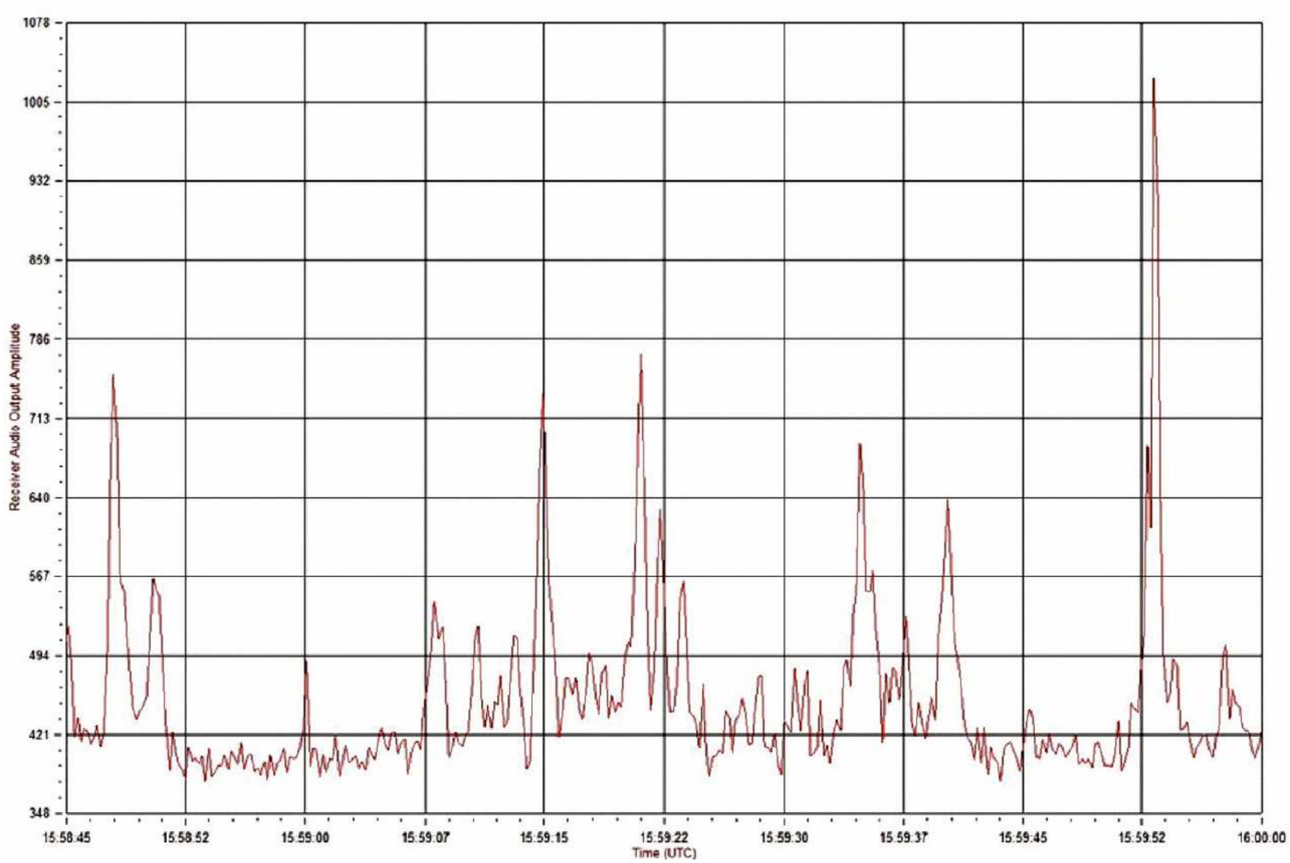
Radio-SkyPipe – an Internet enabled strip chart recorder.

Jupiter L-bursts



Jupiter L-Bursts **sound like ocean waves breaking up on a beach**. Much of the L-burst structure is formed as signals travel though the interplanetary medium from Jupiter to the Earth.

Jupiter S-bursts



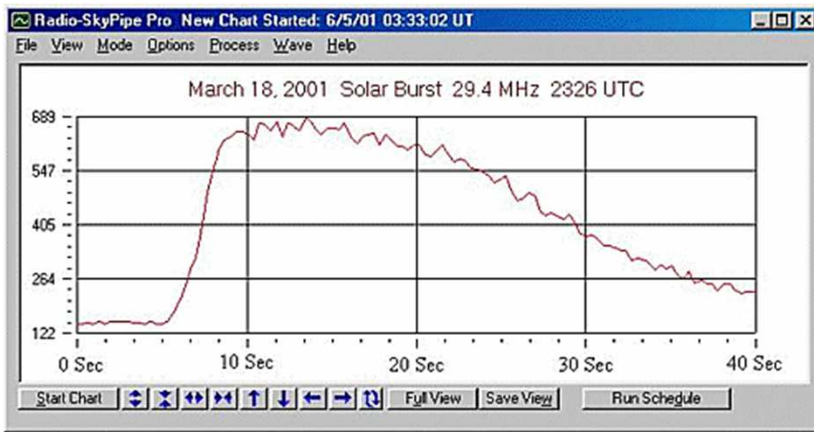
Jupiter S-Bursts **sound like a handful to pebbles thrown on a tin roof** (or popcorn being cooked). These bursts each last for a few thousandths of a second and occur at rates as high as several dozen per second.

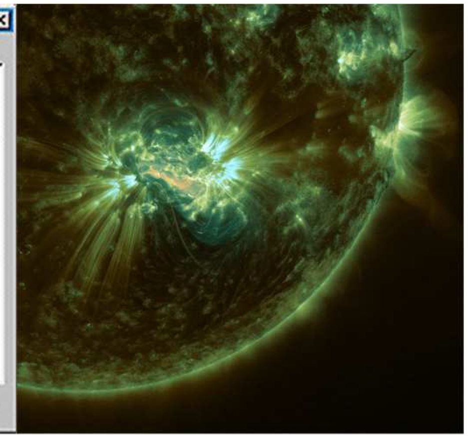
Origin of Jupiter's Emissions

- Radio storms on Jupiter come from **natural radio lasers** in the giant planet's magnetosphere.

- Electrical **currents flowing between Jupiter's upper atmosphere and the volcanic moon Io** can boost these emissions to power levels easily detected by ham radio antennas on Earth.

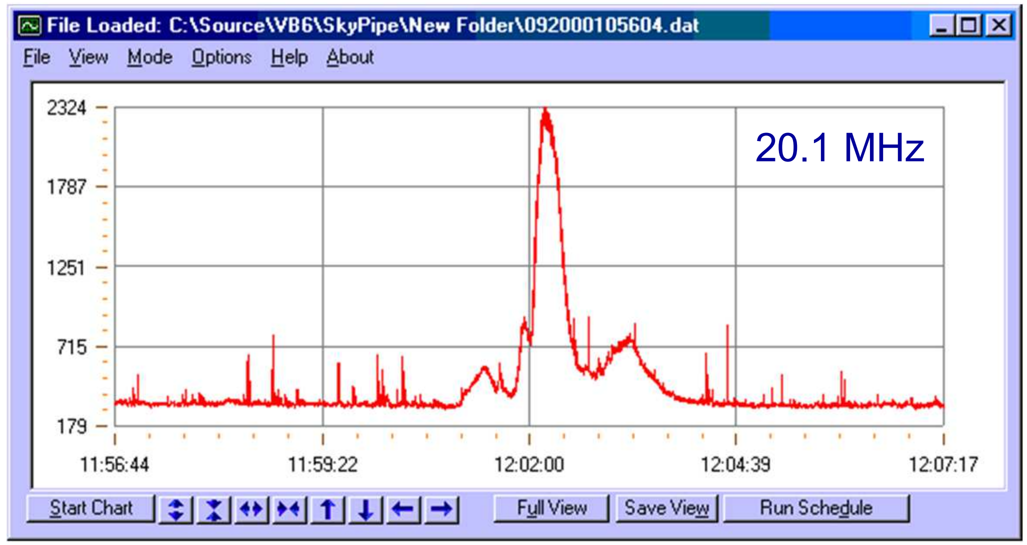
Solar Burst-I



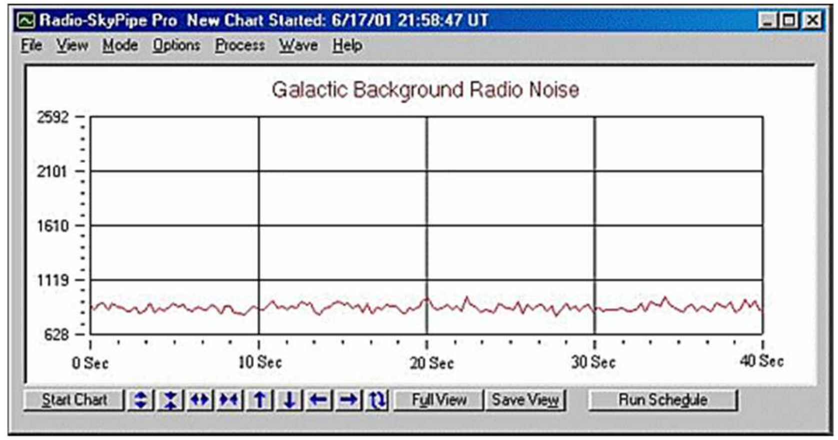


Solar Bursts received near the frequency 20 MHz often **turn on rapidly and decay slowly** -- looking somewhat like a shark fin on the strip chart record. These bursts can be quite strong and often last for tens of seconds. You will hear the weak galactic background noise for several seconds, followed by a Solar radio noise burst.

Solar Burst-II



Galactic Background



Galactic Background signals are generated by **relativistic electrons spiraling in the galactic magnetic field**.

The sound is a **quiet hiss** devoid of any interesting features like bursts or sudden changes in amplitude.

Pulsars

- Remnant of a supernova.
- Rotating neutron star.
- Radiates at visible and/or radio frequencies.

Slower (0.71 sec.) Faster (0.089 sec.)

Radio Meteor Detection-I

http://www.skyscan.ca/meteor_radio_detection.htm

How to Use Your FM Radio to Detect Meteors

Sky Scan Science Awareness Project

HOME | GRADE 6 | GRADE 9 | SCIENCE LIBRARY
NEWS | SEARCH | SITE MAP | FAQ

Home

Up

"Thank you so much for visiting our class on Friday! The kids loved it...they thought it was pretty cool to meet a "real" Astronomer! Thanks again, Janine"

Updated November 19, 2011

Get Started Meteor Showers Equipment Pick FM Station How to Observe

You can use your FM radio to detect meteors as they enter the earth's atmosphere. As the meteor burns up on entry, atmospheric gases are ionized creating conditions that will reflect line of sight radio waves over the horizon from distant radio stations where they normally won't travel. If you are tuned to an FM radio station over the horizon from your home, and you hear music or voices, a meteor has probably passed between you and the radio station. Click this link to find sample audio files.

Please note: The information on this page is written with reference to locations in Alberta, Canada due to the mandate of this site as a public education project of the Edmonton Centre of the Royal Astronomical Society of Canada and the Dept. of Physics at the University of Alberta. However, most of what you see here applies to other locations around the globe.

Here's how to get started

1. Check the Meteor Showers table for the dates of upcoming meteor showers. Pick a shower you want to observe.
2. See What You Need to make sure you have the equipment required.
3. Select an appropriate FM radio station.
4. Make your observations.
5. Look at your observations to produce data.

Meteor Showers

While meteors are constantly falling into the atmosphere, there are times each year when the number of meteors is noticeably higher. As the earth travels in its orbit around the sun, it passes through the paths of a number of comets and other space debris that also orbit the sun. These are called meteor showers.

These showers are of particular interest to both amateur optical and amateur radio astronomers because they are predictable events to plan observing sessions around. Both optical and radio astronomers count the number of meteors they detect and compare notes with others observing in different locations. This provides useful information about changes in the nature of the shower stream. Follow this link for a list of Meteor Showers.

Top

More on how meteor showers work.

Equipment

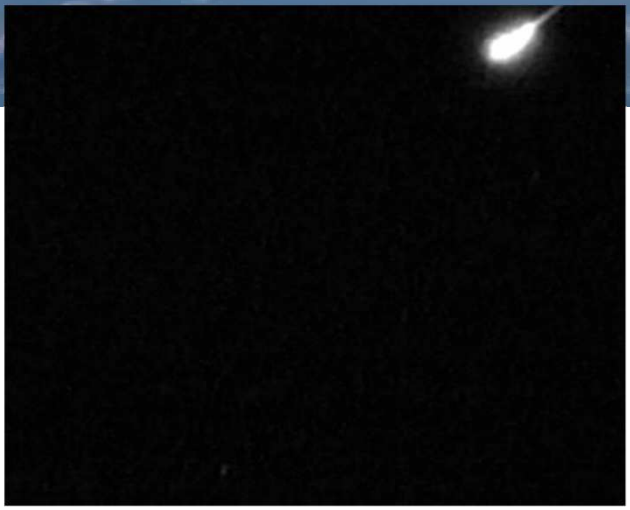
You will need a good FM radio, an antenna, a method of recording your observation (optional), and a way of showing your data. Depending on how involved you want to get, you can also add a pre-amplifier and other recording equipment.

Top

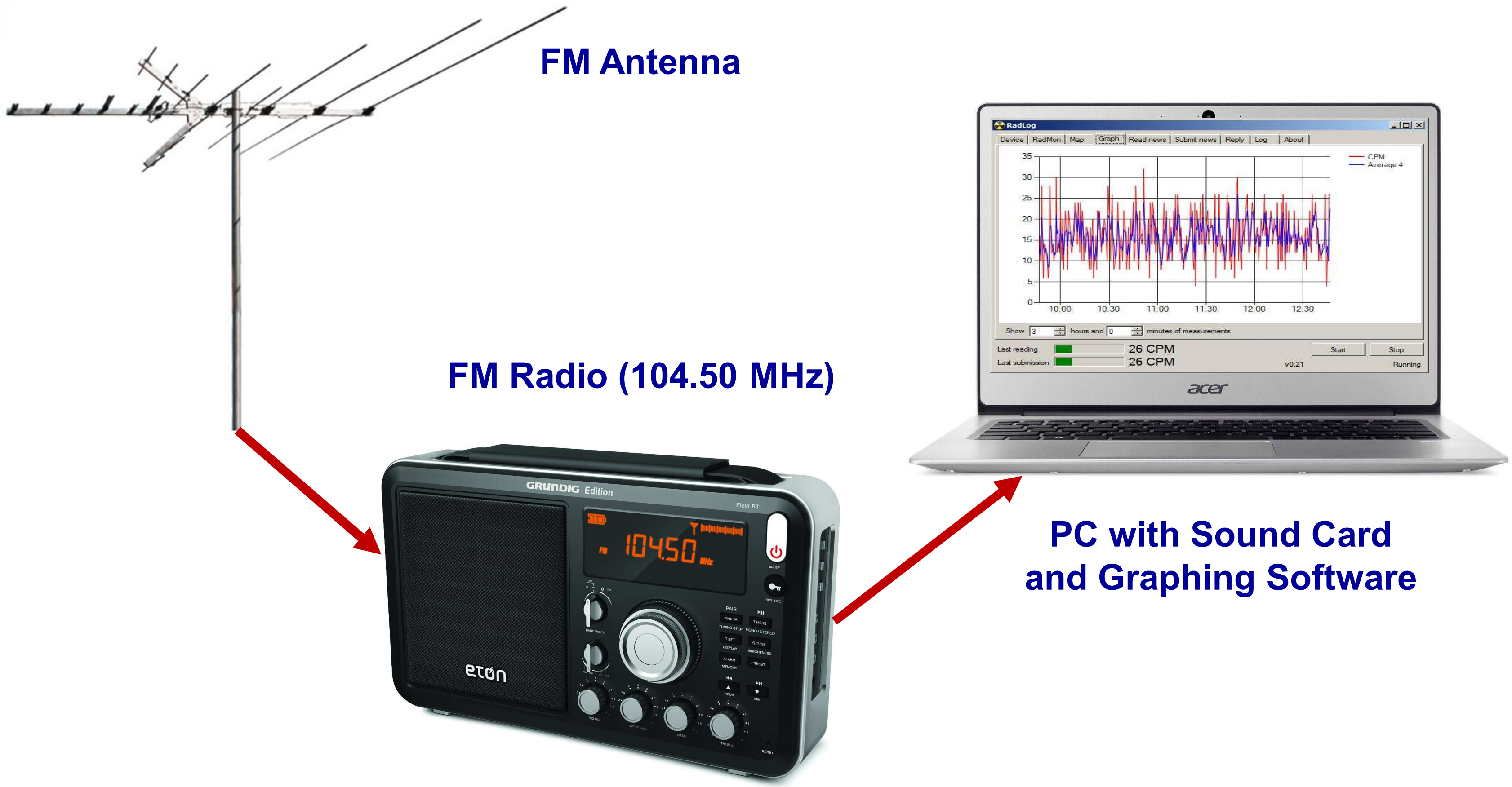
Picking an FM Radio Station

PrintKey-Pro

Radio Meteor Detection-II



Radio Meteor Detection Setup-I

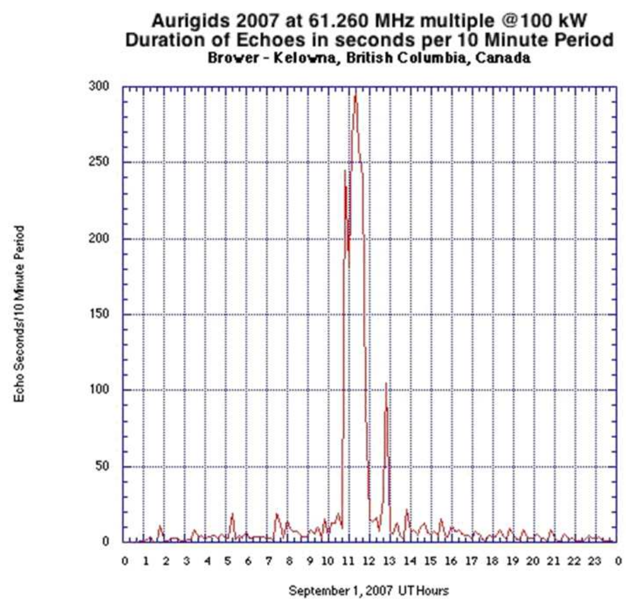


Radio Meteor Detection Setup-II

- You will need a good **FM radio, an antenna, a method of recording** your observation (optional), and a way of showing your data. Picking an FM Radio Station: Choose a radio station that does not broadcast in your area.
- For best results, you need to **choose a radio station that is about 1300 km (800 mi) away**. This distance usually gives the longest duration signal. But you can also detect signals reflected off meteors from stations between 200 km (400 mi) and 2100 km (1300 mi) possibly even closer or farther away. Take a provincial or state road map and with a compass, draw three circles one at 200 km, a second at 1300 km and a third at 2100 km.
- Look in the FM station chart for a radio station that is between the smallest and largest circles. Make sure the station transmits on a frequency different from the ones that you can receive on your FM radio at home. If you can't find a suitable station in the table, bookmark this site and go to **http://radiostation.com** to find one. Look for stations with the highest power possible. 100 Kilowatts is a good figure. Note the compass bearing from your location. This will be important for pointing your antenna in relation to meteor shower streams.
- Connect the receiver to the antenna. Connect your data logging equipment to the earphone jack of the receiver.

Radio Meteor Signals-I

- Receiver set to 61.260 MHz.
- ICOM PCR-1000 software driven receiver.
- 7 element log periodic antenna pointed south.
- Counting software: Spectrum Lab FFT and mAnalyzer program.



http://www.thornett.net/Rosliston_Archive_2009-11/html/cross_dipole_antenna.html

Cross dipole antenna

A good place to start listening for the sounds of meteors hitting the atmosphere is in the VHF and UHF bands. For example, picking up the signals of French TV stations.

A long dipole is not the best antenna for this purpose. Rather, a crossed dipole antenna would work well - these can be made easily using thick copper wire and a two inch white plastic conduit box.

Four copper rods are cut from the thick copper wire - it has to be stiff enough to stay straight without support. Aluminium can be used instead.

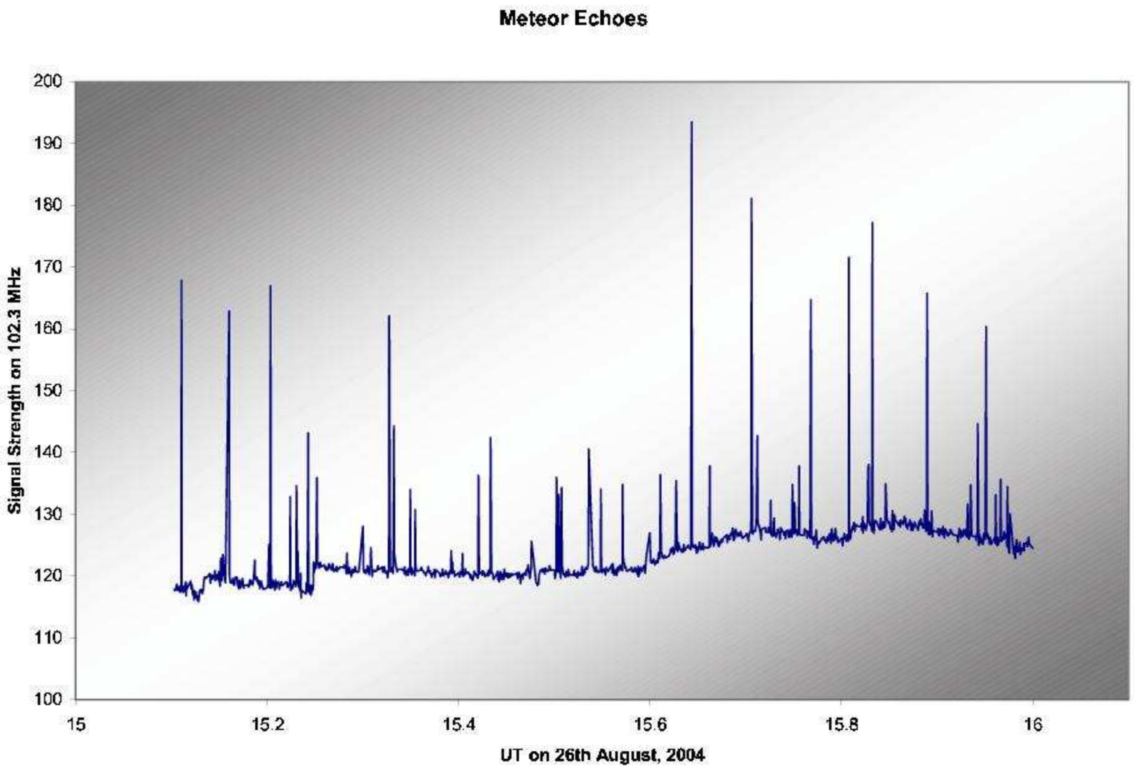
The rods are then connected to the white conduit box through the four holes at 90 degrees to each other. The holes can be filled with cork, wooden dowling or similar and drilled to a size to allow rods to be pushed through them. Another system is to wrap ends of rods in masking tape until they fit snuggly in the holes. A conduit box (see above) is recommended as this is electrically resistant. A wooden block risks becoming conductive once it gets wet at which point the antenna will not work.

The corks/dowling in the holes can be wood or cork because it does not matter if they get wet - this won't make a circuit with an adjacent rod because of the plastic inbetween.

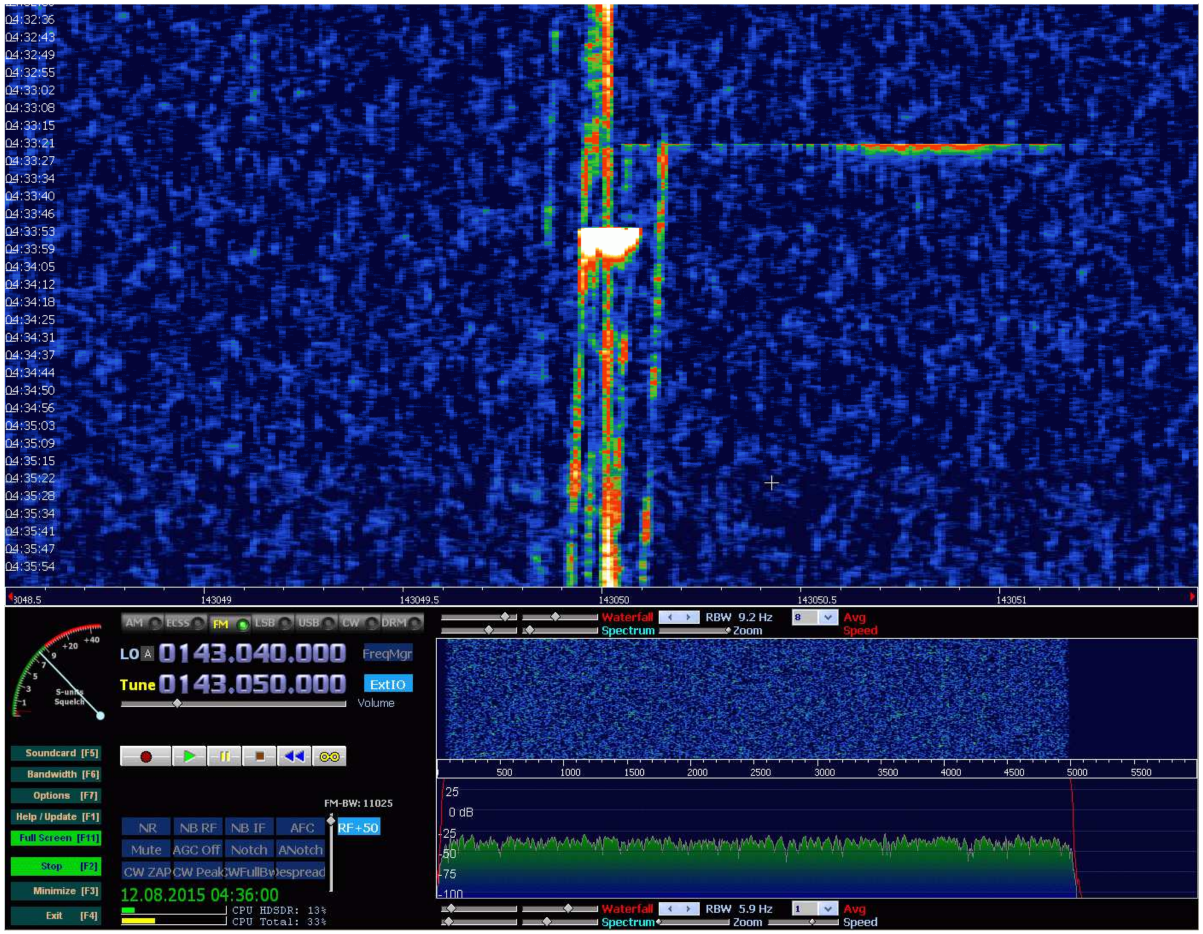
The length of the rods is determined by the frequency that we want to pick up. For UHF transmission @ 600MHz, the wires (rods) need to be 12.5cm in length - all four should be the same length

The calculations for this length = 300/600 = 0.5m. This the full wavelength. A dipole is in total 1/2 wavelength, with each element being 1/4 wavelength, so each leement is 12.5cm.

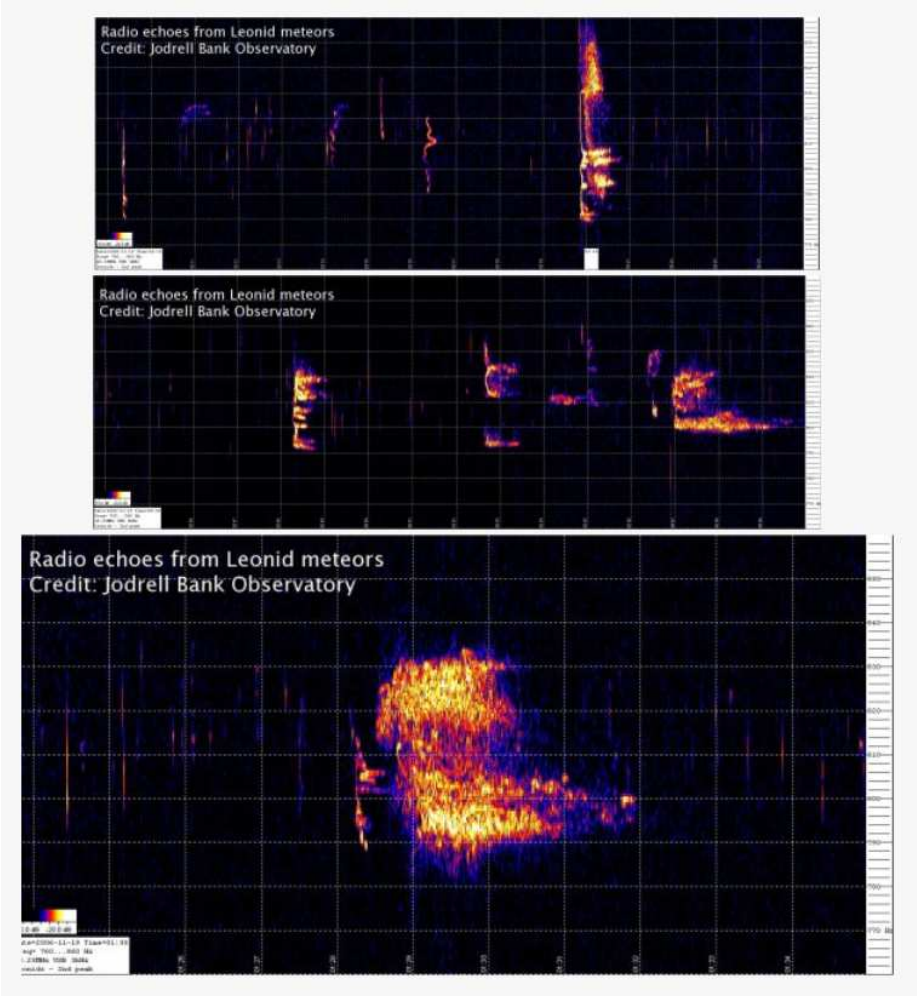
Radio Meteor Signals-II



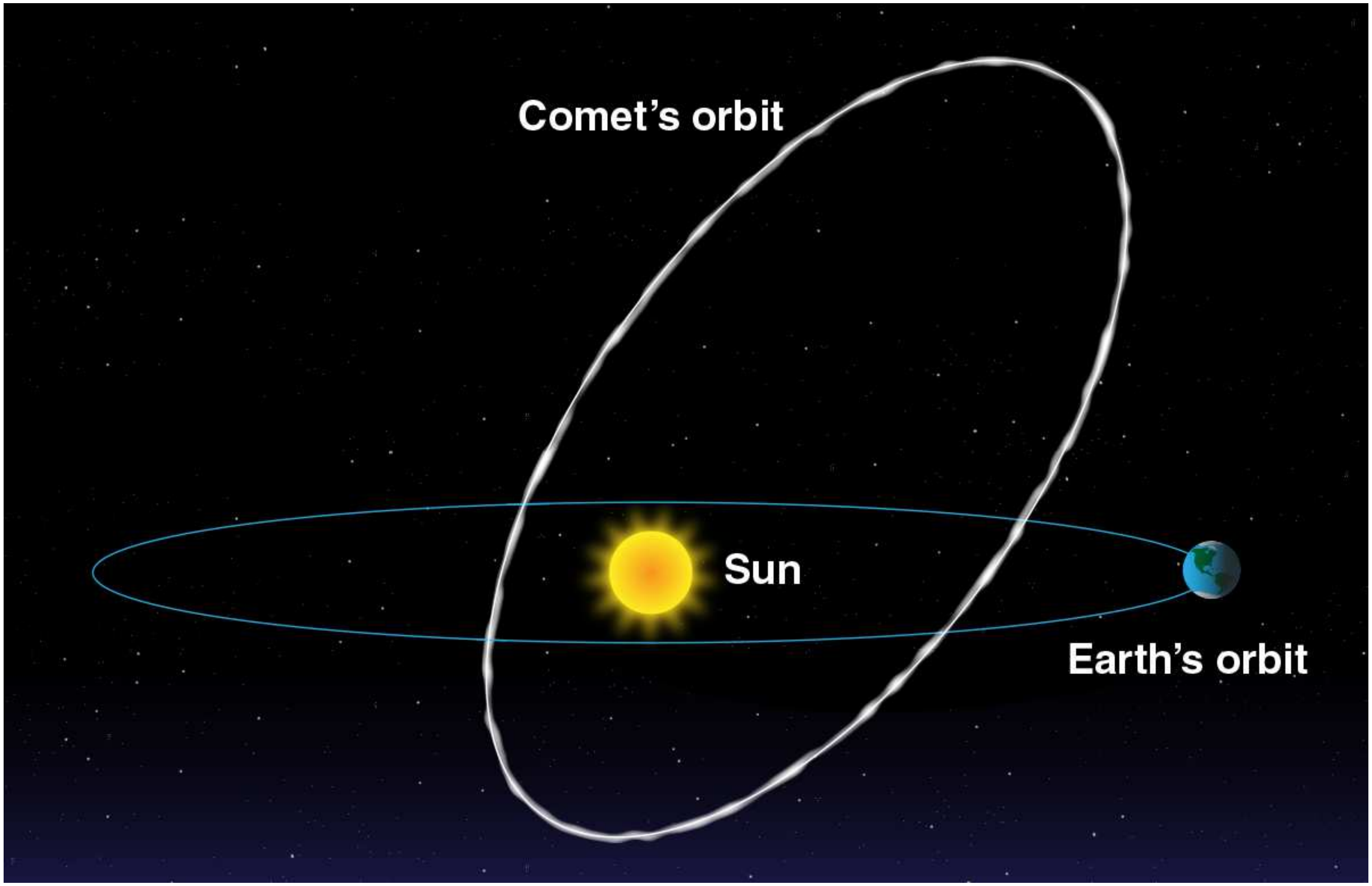
Radio Meteor Signals-III



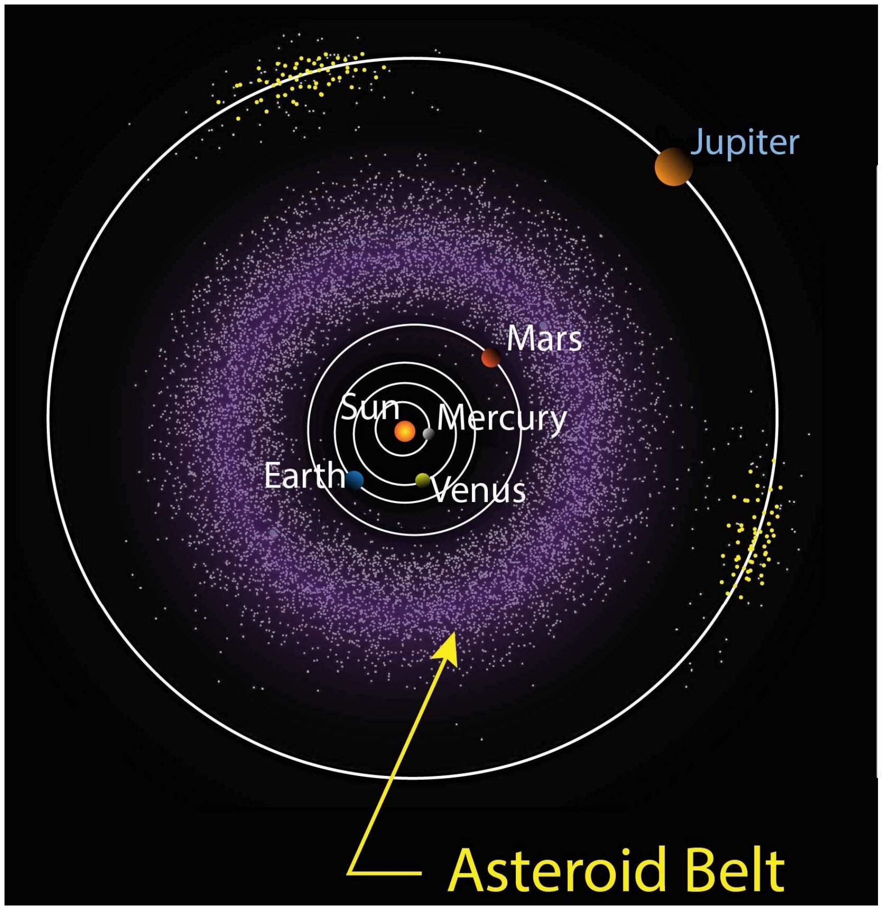
Data from Leonid Meteor Shower-Jodrell Bank Observatory, England, 2006 (Meteor Data: Hz vs. Time)

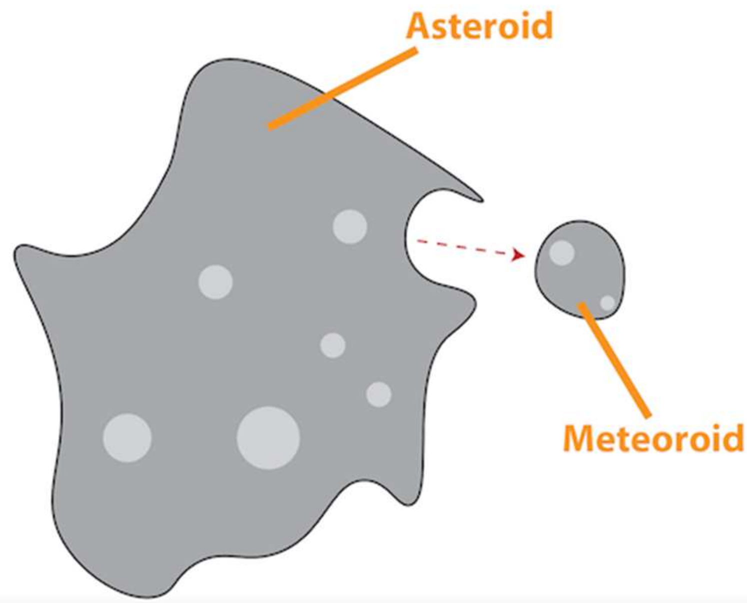


Origin of Meteors-I



Origin of Meteors-II





List of Yearly Meteor Showers

(http://www.shreveportastronomy.com/img/Yearly%20Meteor%20Showers.pdf)

Name	Dates	Peak dates	Rating
Quadrantids	1 January – 5 January	3 January	Strong
Gamma Velids	1 January – 15 January	5 January	Weak
Alpha Crucids	6 January – 28 January	15 January	Weak
Delta Cancrids	1 January – 31 January	17 January	Medium
Alpha Hydrids	5 January – 14 February	19 January	Weak
Eta Carinids	14 January – 27 January	21 January	Weak
Alpha Carinids	24 January – 9 February	30 January	Weak
Delta Velids	22 January – 21 February	5 February	Weak
Alpha Centaurids	28 January – 21 February	7 February	Medium
Omicron Centaurids	31 January – 19 February	11 February	Weak
Theta Centaurids	23 January – 12 March	21 February	Weak
February Leonids	1 February – 28 February	several	Medium
Delta Leonids	15 February – 10 March	24 February	Medium
Gamma Normids	25 February – 22 March	13 March	Medium
Virginids	1 March – 15 April	several	Medium
Delta Pavonids	11 March – 16 April	30 March	Weak
Librids	15 April – 30 April	several	Medium
Lyrids	15 April – 28 April	22 April	Strong
Pi Puppids	15 April – 28 April	23 April	Irregular
Alpha Bootids	14 April – 12 May	28 April	Weak
Mu Virginids	1 April – 12 May	29 April	Weak
Omega Capricornids	19 April – 15 May	2 May	Weak
Eta Aquariids	19 April – 28 May	6 May	Strong
Alpha Scorpiids	1 May – 31 May	16 May	Medium
Beta Corona Austrinids	23 April – 30 May	16 May	Weak
Omega Scorpiids	23 May – 15 June	2 June	Weak
Arietids	22 May – 2 July	7 June	Strong
Sagittarids	1 June – 15 July	19 June	Medium
June Lyrids[2]	10 June – 21 June	15 June	Irregular
Tau Cetids	18 June – 4 July	27 June	Weak
June Bootids	28 June – 28 June	28 June	Irregular
Tau Aquariids	19 June – 5 July	28 June	Weak
Theta Ophiuchids	4 June – 15 July	29 June	Weak
July Pegasids	7 July – 13 July	10 July	Medium
July Phoenicids	10 July – 16 July	13 July	Irregular
Alpha Cygnids	11 July – 30 July	18 July	Weak
Sigma Capricornids	15 July – 11 August	20 July	Weak
Piscis Austrinids	15 July – 10 August	28 July	Medium
Southern Delta Aquariids	12 July – 19 August	28 July	Strong
Alpha Capricornids	3 July – 15 August	30 July	Medium
Southern Iota Aquariids	25 July – 15 August	4 August	Medium
Northern Delta Aquariids	15 July – 25 August	8 August	Medium
Perseids	17 July – 24 August	12 August	Strong
Kappa Cygnids	3 August – 25 August	17 August	Medium
Northern Iota Aquariids	11 August – 31 August	20 August	Medium
Pi Eridanids	20 August – 5 September	25 August	Weak
Gamma Doradids	19 August – 6 September	28 August	Weak
Alpha Aurigids	25 August – 8 September	1 September	Medium
September Perseids	5 September – 10 October	8 September	Medium
Aries-triangulids	9 September – 16 September	12 September	Weak
Piscids	1 September – 30 September	20 September	Medium
Kappa Aquariids	8 September – 30 September	20 September	Weak
Delta Aurigids	22 September – 23 October	10 October	Medium
October Arietids	1 October – 31 October	8 October	Medium
Giacobinids	6 October – 10 October	8 October	Irregular
Epsilon Geminids	14 October – 27 October	18 October	Medium
Orionids	2 October – 7 November	21 October	Strong
Leo Minorids	21 October – 23 October	22 October	Weak
Southern Taurids	1 November – 25 November	5 November	Medium
Delta Eridanids	6 November – 29 November	10 November	Weak
Northern Taurids	1 November – 25 November	12 November	Medium
Zeta Puppids	2 November – 20 December	13 November	Weak
Leonids	14 November – 21 November	17 November	Irregular
Alpha Monocerotids	15 November – 25 November	21 November	Irregular
Chi Orionids	25 November – 31 December	2 December	Medium
Phoenicids	28 November – 9 December	6 December	Irregular
Monocerotids	27 November – 17 December	9 December	Medium
Sigma Hydrids	3 December – 15 December	12 December	Medium
Puppid-velids	2 December – 16 December	12 December	Medium
Geminids	12 December – 16 December	14 December	Strong
Coma Berenicids	12 December – 23 January	20 December	Medium
Ursids	17 December – 26 December	22 December	Strong

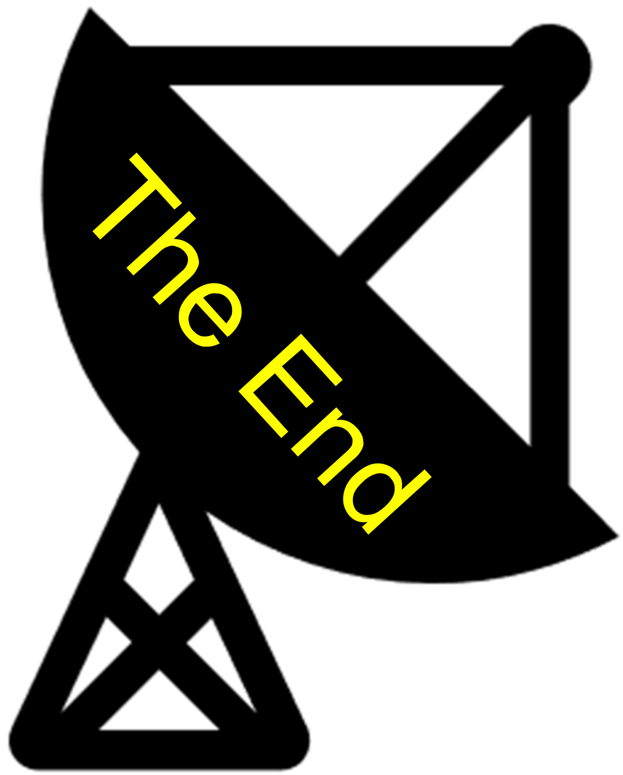
Daytime Radio Meteor Showers

Table 7. Working List of Daytime Radio Meteor Showers. According to the naming rules, the shower names should all have 'Daytime' added (it is omitted in this Table). An asterisk ('*') in the 'Max date' column indicates that source may have additional peak times, as noted in the text above. See also the details given for the Arietids (171 ARI) and the Sextantids (221 DSX) in the text part of the Calendar. Rates are expected to be low (L), medium (M) or high (H). An asterisk in the 'Rate' column shows the suggested rate may not recur in all years. (Thanks to Jean-Louis Rault and Cis Verbeeck for comments on the Table.)

Shower	Activity	Max Date	$\lambda_\odot$ 2000	Radiant α	Radiant δ	Rate
Capricornids/Sagittariids (115 DCS)	Jan 13–Feb 04	Feb 01*	312°.5	299°	−15°	M*
χ-Capricornids (114 DXC)	Jan 29–Feb 28	Feb 13*	324°.7	315°	−24°	L*
April Piscids (144 APS)	Apr 20–Apr 26	Apr 22	32°.5	9°	+11°	L
ε-Arietids (154 DEA)	Apr 24–May 27	May 09	48°.7	44°	+21°	L
May Arietids (294 DMA)	May 04–Jun 06	May 16	55°.5	37°	+18°	L
o-Cetids (293 DCE)	May 05–Jun 02	May 20	59°.3	28°	−04°	M*
Arietids (171 ARI)	May 14–Jun 24	Jun 07	76°.6	42°	+25°	H
ζ-Perseids (172 ZPE)	May 20–Jul 05	Jun 09*	78°.6	62°	+23°	H
β-Taurids (173 BTA)	Jun 05–Jul 17	Jun 28	96°.7	86°	+19°	M
γ-Leonids (203 GLE)	Aug 14–Sep 12	Aug 25	152°.2	155°	+20°	L*
Daytime Sextantids (221 DSX)	Sep 09–Oct 09	Sep 27*	184°.3	152°	0°	M*

Nighttime Meteor Showers

Name	Date of Peak	Moon
Quadrantids	Night of January 3	Just past full
Lyrids	Night of April 21/22	Sets around 2 a.m.
Eta Aquarids	Night of May 6	Rises around 2 a.m.
Perseids	Night of August 12	Just past new
Orionids	Night of October 21	Almost full
Leonids	Night of November 17	Sets around 2 a.m.
Geminids	Night of December 13	Sets in the late evening


The End

“Thanks for coming”

“Are there any questions”