Amateur Radio Astronomy

"Five Projects"

by

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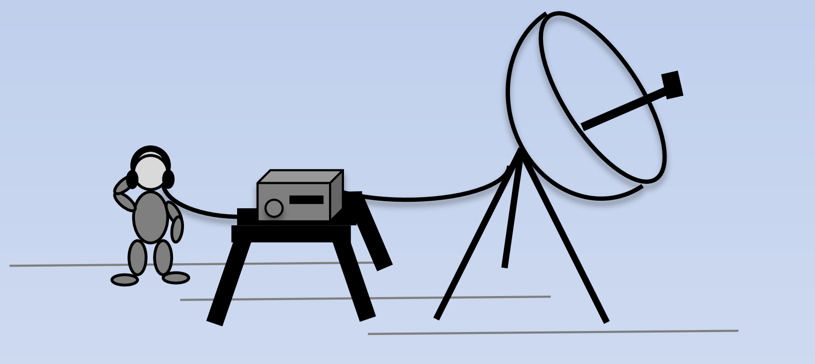


West Valley Astronomy Club
Surprise, AZ
October 2, 2019

Astronomical League

www.AstroLeague.org

www.Radio-Astronomy.org

Early Pioneers in Radio Astronomy:

1932 Karl Jansky, investigating radio interference from thunder storms, discovered a radio source “outside our solar system,” which later proved to be the center of our galaxy, the Milky Way.

1937 Grote Reber, a ham radio operator (W9GFZ), heard about Jansky’s discovery but the Great Depression left him out of work. He built a 30’ dish in his own backyard and mapped the radio sky, making him the world’s first radio astronomer!

1944 H. C. van de Hulst, a grad student working for Jan Oort, reasoned that these radio signals must be coming from hydrogen atoms in space, each of which could emit radio waves. A slight instability in the atom caused the release of a quantum of energy every 11 million years. But there are so many of these atoms in space that a “peep” from each one amounted to a continuous roar.

1963 Arno Penzias and Robert Wilson discovered an unexplainable Cosmic Microwave Background Radiation coming from every direction. If the Universe began with a Big Bang, they reasoned, it would have left such an artifact. They won a Nobel Prize in 1978.

“Five Projects”– Presentation Overview:

- #1 Observing the Sun’s Energy
- #2 Detecting a SID: Sudden Ionospheric Disturbance
- #3 Listening to Jupiter’s Radio Storms
- #4 Detecting Meteors
- #5 Detecting Galactic Radio Sources
- The RAOP Award Certificates and Pins
- Radio Frequency Imaging
- Further References
- Recap – Q&A

Radio Astronomy – Astro League's 5 Projects Overview:

Monitor the Sun, Jupiter, meteors and other galactic energy sources using homebrew, amateur grade equipment:

1 Observing the Sun's Energy

Record 3 observations of the Sun's energy, at least 24 hours apart.

2 Detecting a SID: Sudden Ionospheric Disturbance

Intense solar activity, like a solar flare, solar storm, or coronal mass ejection, can energize the ionosphere, causing changes in the reception of very low frequency (VLF) transmissions on Earth. Record 3 incidents which are at least 24 hours apart.

3 Listening to Jupiter's Radio Storms

Build a radio telescope antenna and record one L-burst (long) or S-burst (short) radio storm signal from Jupiter.

Continued on next slide…

Radio Astronomy – Astro League's 5 Projects: (continued)

4 Detecting Meteors

Meteors ionize their path through the atmosphere which can reflect signals from distant terrestrial radio stations. A high quality FM receiver can be used to detect them. (More on this later.) Include a recording of at least ten such events.

5 Detecting Galactic Radio Sources

Detect **hydrogen** in the galactic plane using a dish, multi-element Yagi, or "horn" antenna, etc. Include ten observations of at least three different objects. An object may be observed more than once, but observations must be made at least 24 hours apart. Note that hydrogen gives off radio frequency bursts at 1420 MHz (21 cm).

Submit results from <u>one</u> of these projects for Bronze level, <u>two</u> for Silver, and <u>four</u> for Gold. Results <u>must</u> include those from project #5.

Reference: *The Astronomical League website at www.astroleague.org/programs/radio-astronomy-observing-program*

Project #1 – Observing the Sun's Energy:

1. One option is to use a typical home or RV satellite TV dish antenna system.

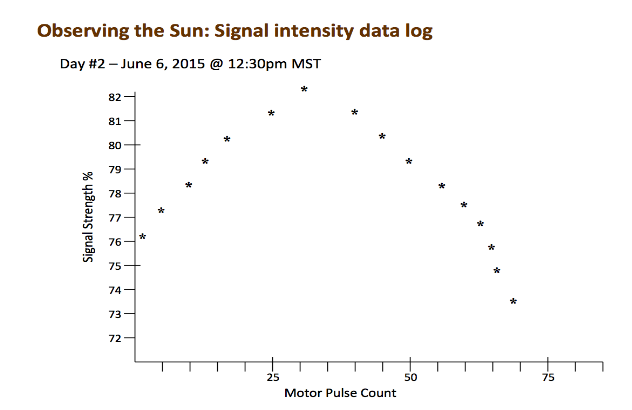
2. Attach a signal strength meter – a low cost one will do.

(Photos of your interaction with the equipment are required.)

3. Slowly *pulse* the dish across the Sun's face.

Record and plot the signal strength readings.

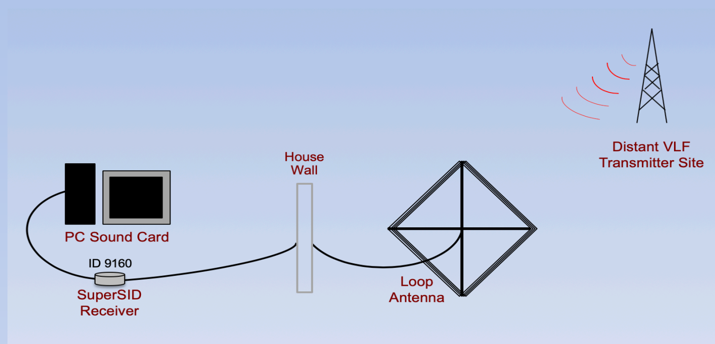
Alternatively, record the signal intensities as the Sun "drifts" across the face of your dish.



Project #2 – Sudden Ionospheric Disturbances (SIDs):

The SID Detection Project is hosted by the **Stanford Solar Center**.

Overview:



1. Start by obtaining a $120 SID monitor kit from SARA.

2. Build & mount a wire loop antenna. (Details on next slide.)

3. Configure receiver software to monitor VLF activity.

Project #2 – SID Antenna Assembly Details:

Wire for loop is included in a kit from SARA. Wooden brace was treated with four coats of “spar” polyurethane before assembly. An electrical box cover strengthens the brace and a U-bolt connects it to the mast.

Loop antenna parts ready for assembly.

Finishing nails used to hold loop of wire in place on brace.

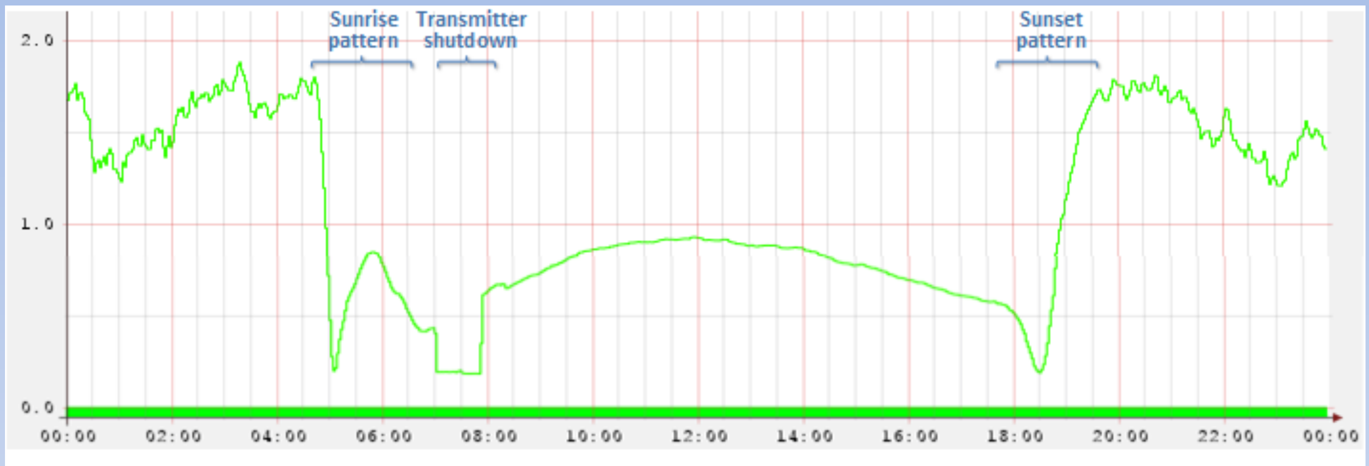
Cross member support. U-bolt for pole mount.

The wooden brace is held together by an electrical box cap and a U-bolt will hold it to the pole mount. The wire is carefully wound around the end caps of the wooden brace.

The loop antenna can be indoors, but it is more effective outdoors. It doesn’t have to be high up.

Project #2 – SID Expected Results:

Signal plot on a quiet day:

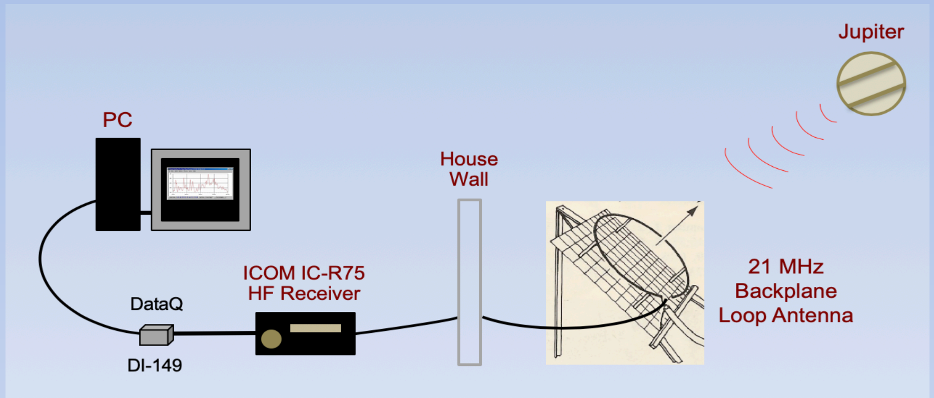


Signal plot of a day with two SID events:

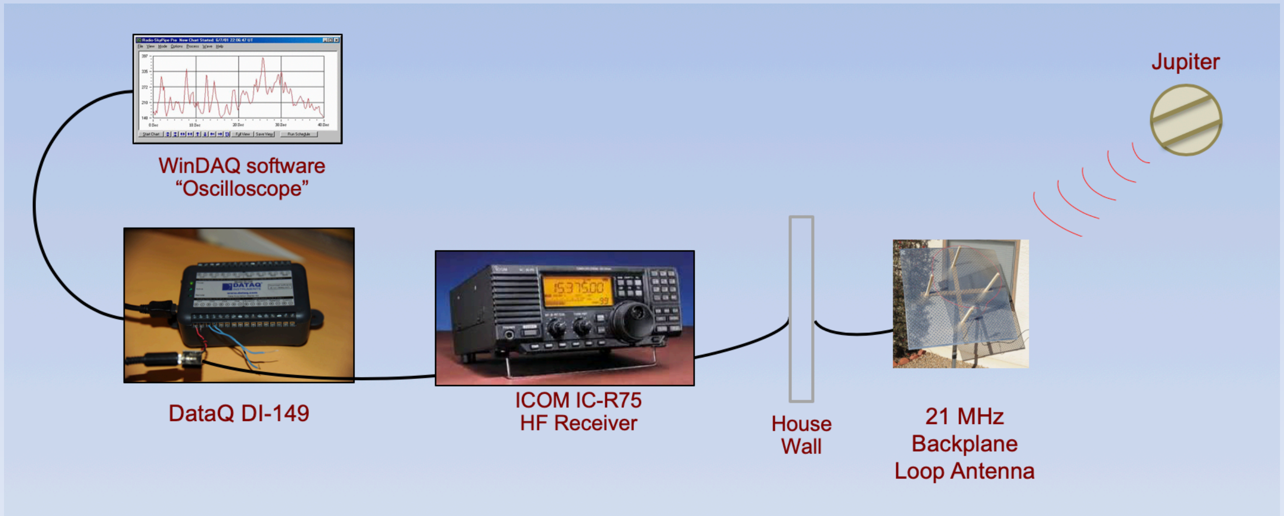
Credit: Lionel Loudet, http://sidstation.loudet.org

Project #3 – Detecting Jupiter's Radio Storms:

Jupiter detection system overview:

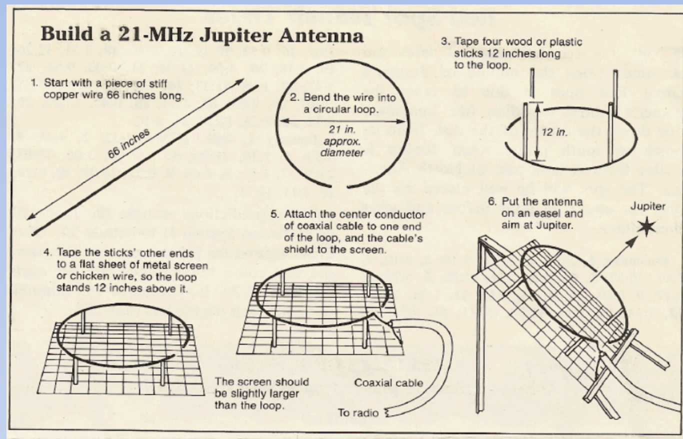


Jupiter detection system components:

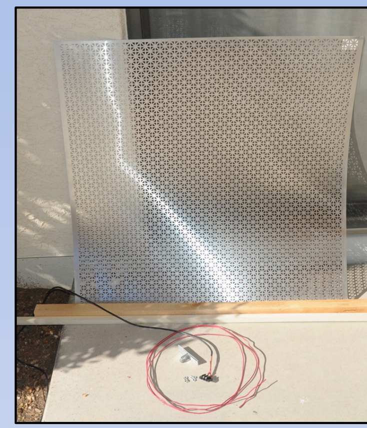


Project #3 – Jupiter Receive Antenna Assembly Details:

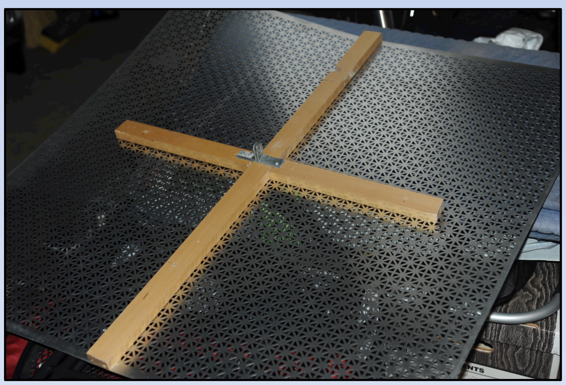
This antenna is from a design in the December 1989 issue of Sky & Tel, page 628.



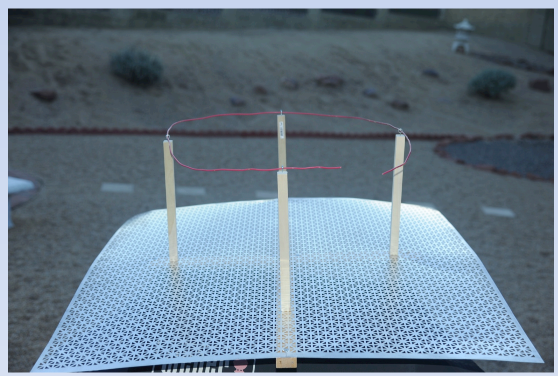
Loop Antenna Assembly Instructions



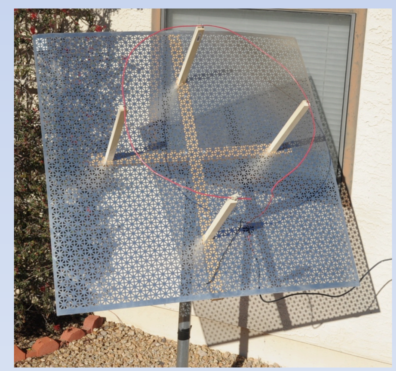
Loop Antenna Parts



Loop Antenna Back Brace



Loop Antenna Ready for Mounting



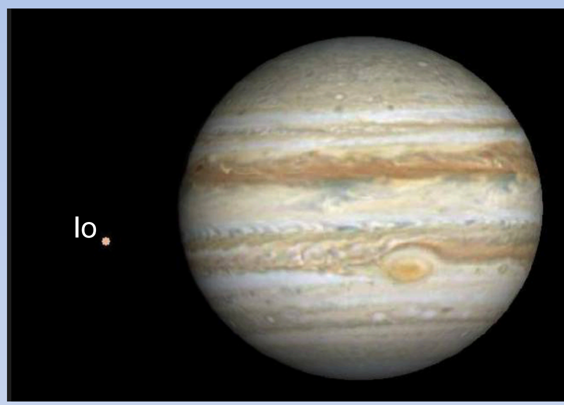
Jupiter Loop Antenna Mounted

<u>But</u>, most will tell you that it's a terrible design. (Some will say that it can't work!)

Project #3 – Predicting Jupiter’s Radio Storms:

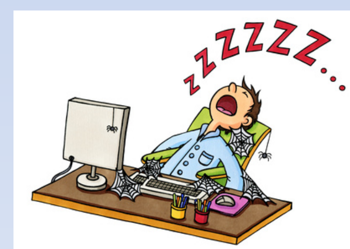
Jupiter’s three *sectors* and its moon, Io, influence reception of radio storms:

Scientists have detected three sectors, or longitudinal regions relative to the CML (Central Meridian Line), labeled A, B and C. When one of them is pointing at the Earth, the likelihood of hearing storm increases, with A being the most likely, etc. If Jupiter’s moon, **Io**, is also angled at about ninety degrees to Earth, the likelihood of hearing a storm is further increased.



Credit: http://commons.wikimedia.org

So, all we have to do is point our antenna and tune around the HF bands, somewhere between 18 and 22 MHz, and wait for an alignment, right?

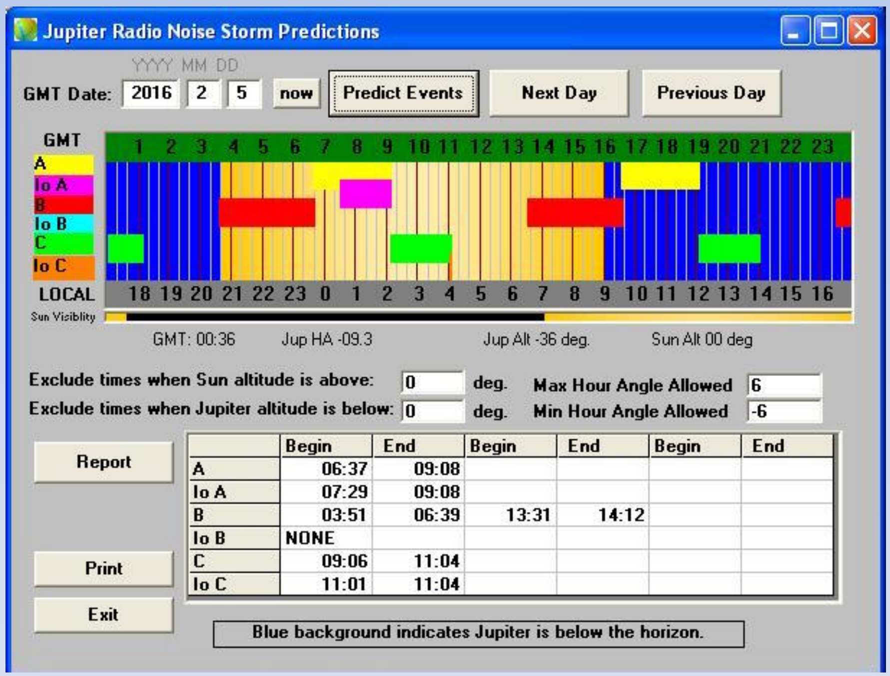


Well, no. Fortunately, there is a Jupiter radio storm prediction software package that is reasonably priced...

Project #3 – Jupiter's Radio Storm Predictor Software:

RadioSky.com offers a $20 radio storm prediction program:

Configure the software with your longitude and latitude. It will simulate Jupiter's attitude toward Earth and determine the relationship between its sectors A, B and C, and also the position of Io, one of its moons.

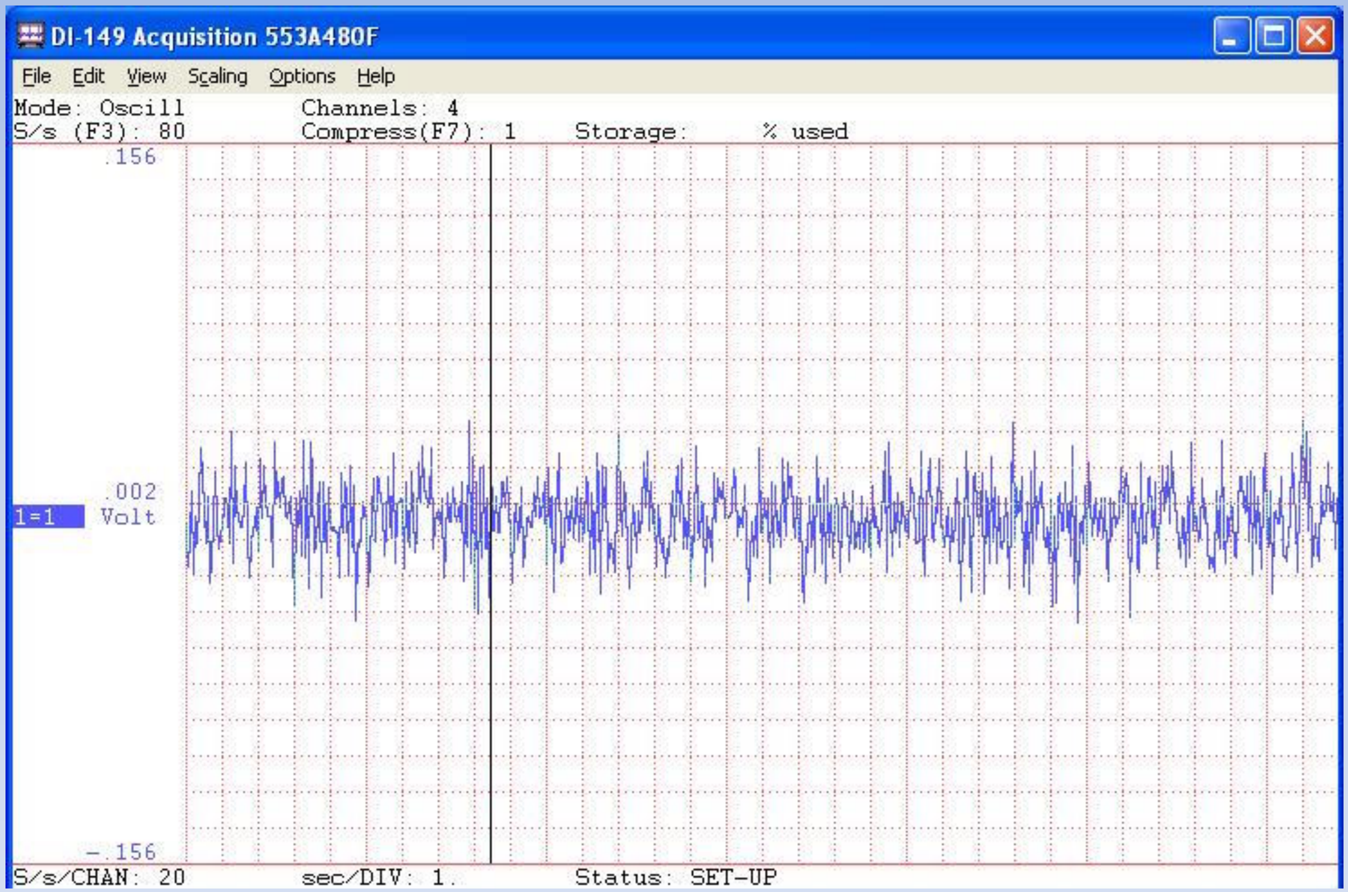


In the above screen shot, Io and sector A are in favorable position to hear a radio storm, from 12:29 AM and 2:08 AM local time on February 5, 2016.

Project #3 – Detecting Jupiter's Radio Storm Signals:

Patience, perseverance, and a little financial assistance are soon rewarded:

S-Burst

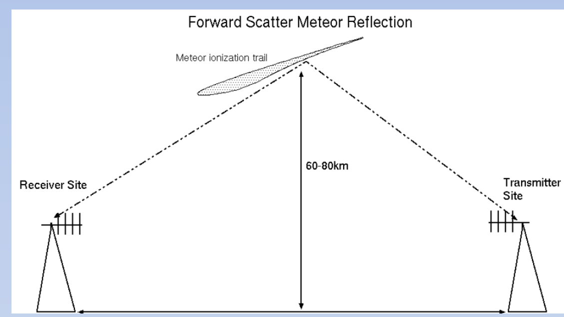


February 5, 2016
1:43am on 19.515 MHz

Long (L-Burst) signals sound like waves crashing against the shore. Short (S-Burst) signals either sound like a wood pecker, or like a plastic bag flapping in the wind.

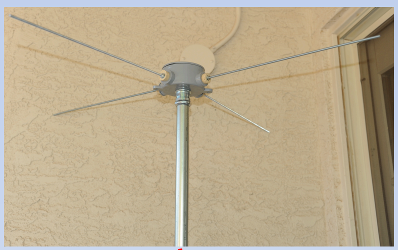
Project #4 – Detecting Meteors by Radio Reflection:

1. Tune an FM radio receiver to the frequency of a distant transmitter,
2. Build or buy an antenna that is designed for that frequency, and
3. Use monitoring hard-/software to record date and time of each audible reception.



“Forward-Scatter Meteor Detection,” M. Leech

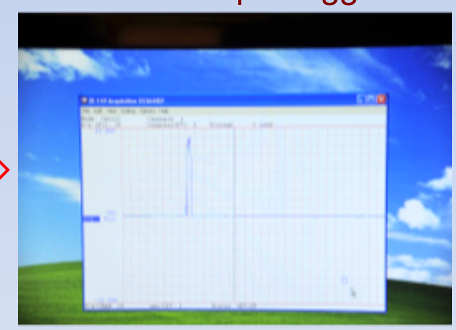
Omnidirectional Antenna



FM Receiver

DataQ DI-149

Oscilloscope Logger

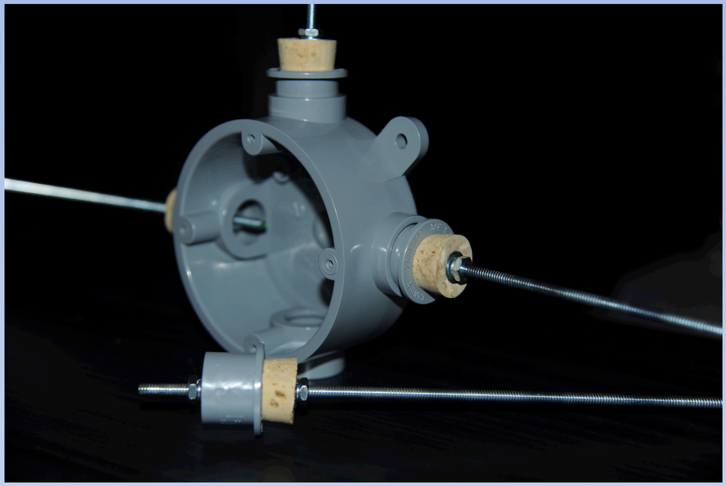


While the station is <u>too far away to be heard</u>, a meteor will form an **ionization trail**, acting like an RF *mirror*, reflecting the signal to allow a brief period of reception.

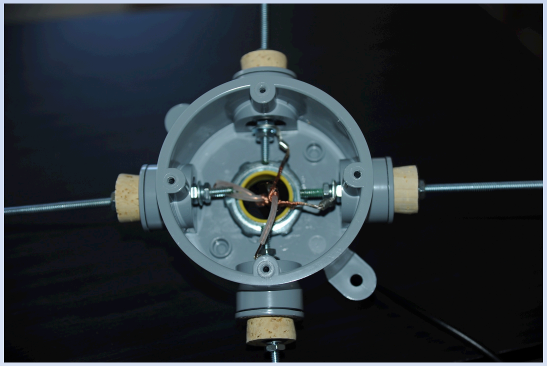
(Note that NOAA weather broadcasts from both Flagstaff and Tucson, on 162.400 MHz!)

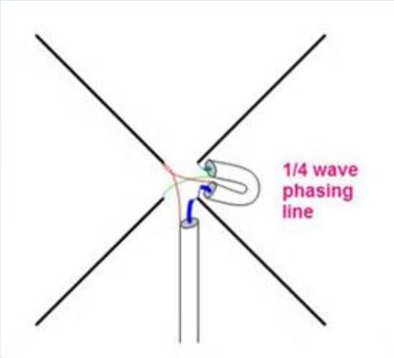
Project #4 – Meteor Detection Antenna Assembly Details:

Crossed Dipoles Antenna Parts



Crossed Dipoles Antenna PVC Enclosure





Crossed Dipoles Antenna Phase Wiring

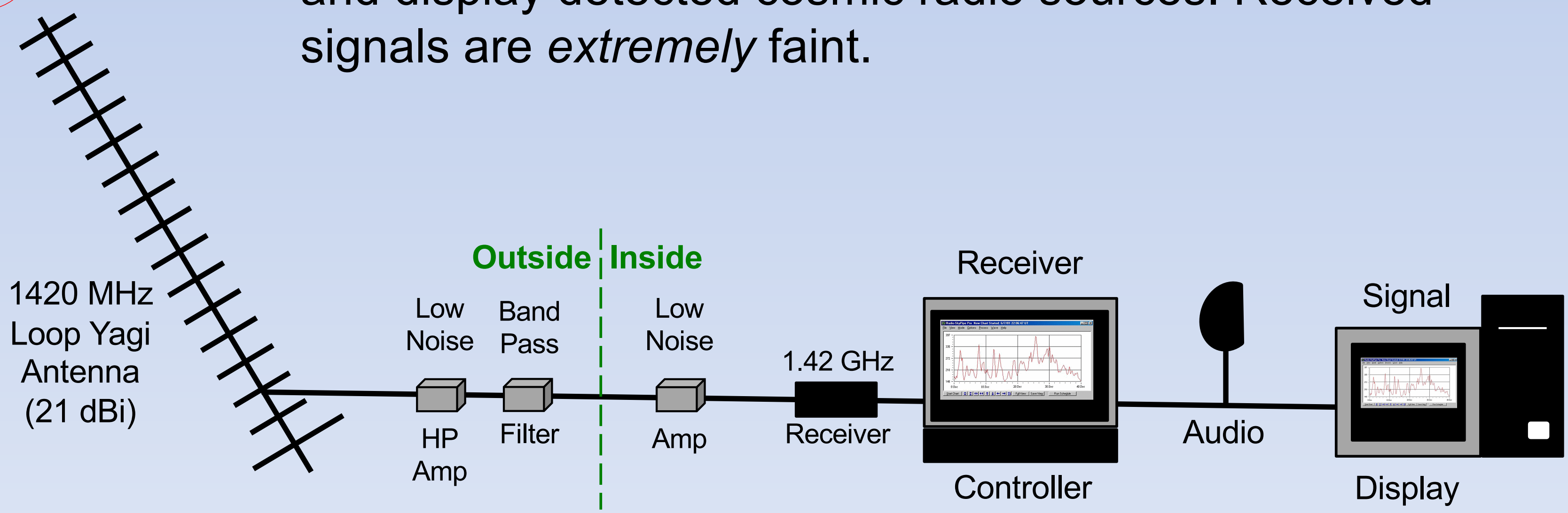
Crossed Dipoles Antenna Ready for Use

Project #5 – Hydrogen Line Receiver System Overview:

Cosmic Radio Sources

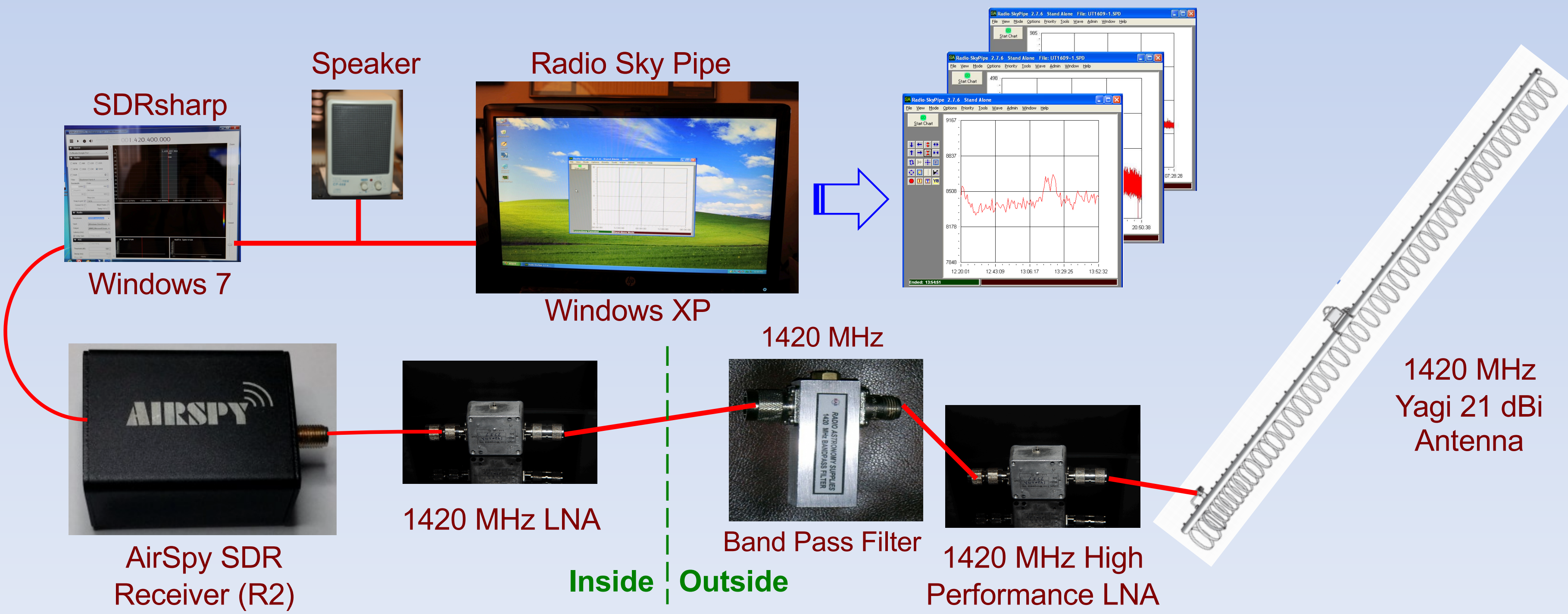
Hydrogen atoms emit radio frequency energy at 1420 MHz, a wavelength of 21 cm. Stars and certain other cosmic objects have high concentrations of hydrogen atoms, so we should be able to distinguish their radio emissions from the background of space.

The block diagram below shows the in-line system of hydrogen line components needed to capture, record, and display detected cosmic radio sources. Received signals are *extremely* faint.



Project #5 – Hydrogen Line Receiver System Components:

I built a frame to hold the commercial 1420 MHz Yagi antenna. A Low Noise Amplifier (LNA) boosts the antenna's signal, and a 1420 MHz band pass filter suppresses unwanted noise, above and below the desired frequency. An SDR (software defined radio receiver, an AirSpy R2), *detects* the 1420 MHz signal frequency as a hiss, SDR# software displays it, and Radio Sky Pipe records its strength as each Cosmic Radio Source drifts across the antenna's viewpoint.

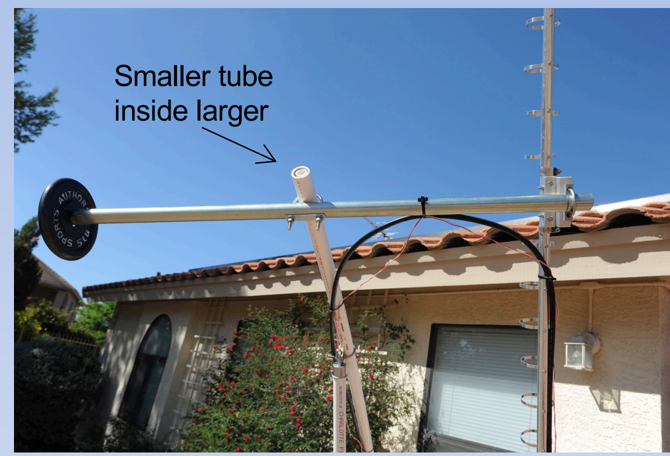


Project #5 – Hydrogen Line Antenna System Details (1 of 2):

The antenna's feed point is best kept away from metal. The thick-walled

PVC pipe, with an inner pipe in the top section, will support the antenna.

H-Line antenna
support components



The cross member provides a pivot
point, so I can adjust the elevation

Original design
built with metal
fence post rails
(slightly overkill)

Starry Night 7 software shows
The altitude of the radio source
and when it will be true south

Adjusting antenna elevation

Struts rebuilt with
PVC (Charlotte)
thick-wall tubing
sag a little but it
supports it okay

Project #5 – H-Line Antenna System Details (2 of 2):

My H-Line antenna is a 1.42 GHz loop Yagi with a 21 dBi gain. This antenna is commercially produced by Direct Systems & Engineering. The two Low Noise Amplifiers are from Down East Microwave and the Band Pass Filter is from Radio Astronomy Supply. All coax is 50 ohm Times Microwave LMR-400.

Antenna feed point detail showing the LNA and BP Filter

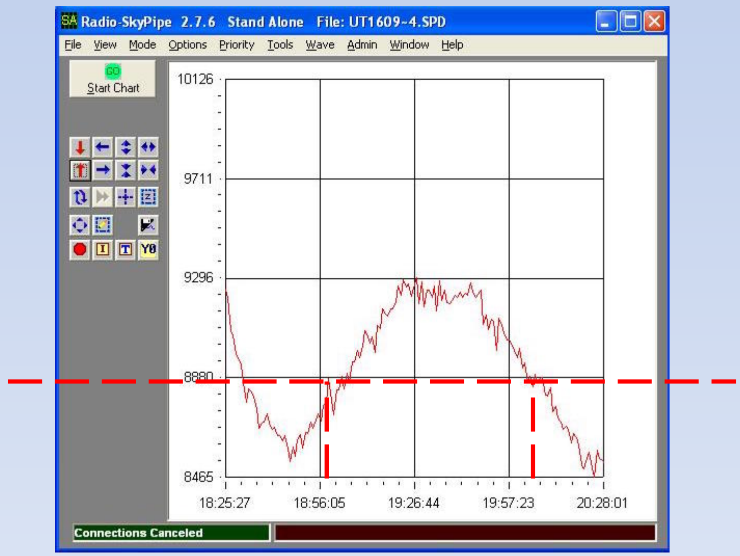
Antenna points approximately true south

Project #5 – Hydrogen Line Drift Scan Method:

In the **drift scan** method, you point your antenna to where the radio object of interest will be. As the object drifts by, the received signal strength increases to a maximum, then decreases back to the baseline.

Energy from the Sun can be used to establish the **half-power beam width** of your radio astronomy antenna system:

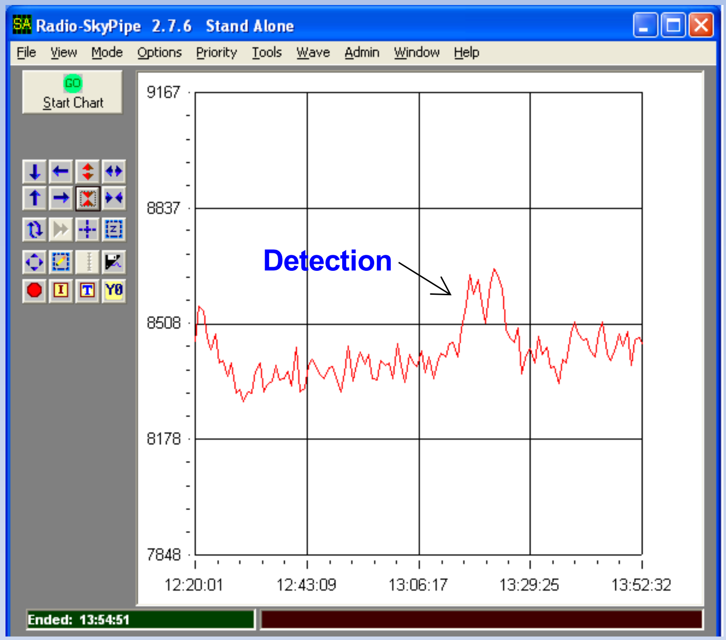
Note: The detected signal is actually ***thermal*** energy from the Sun, not radio waves from its hydrogen content.



Half-Power Beam Width (**HPBW**)
12:02pm to 1:06pm = 1 Hour+ -> **16°**

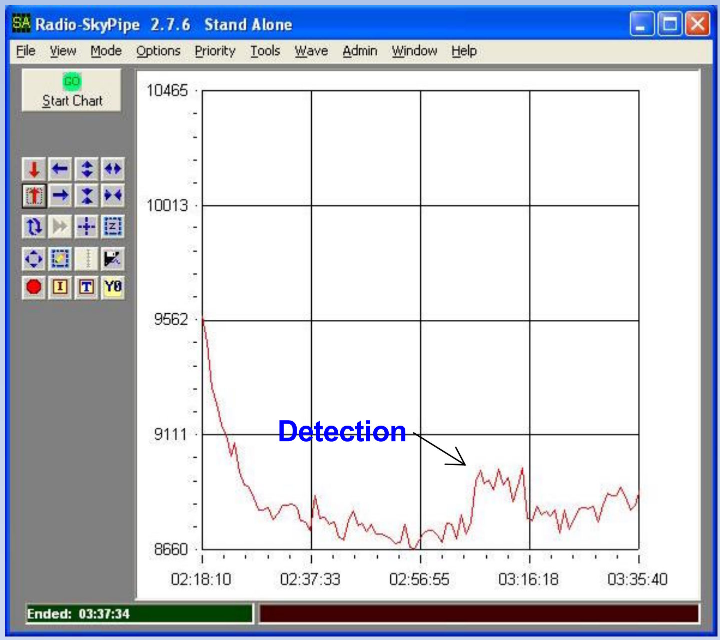
Project #5 – Hydrogen Line Drift Scan Results:

Drift scan sample results – ten such detections are required by the AL:



Taurus A (M1)

Sep 24, 2016 from 5:20am to 6:52am
Detection begins at 6:15am = 1315Z.



Cygnus A

Sep 25, 2016 from 7:18pm to 8:35pm MST
Detection begins at 8:06pm MST = 0306Z.

The Radio Astronomy Observing Program Awards:

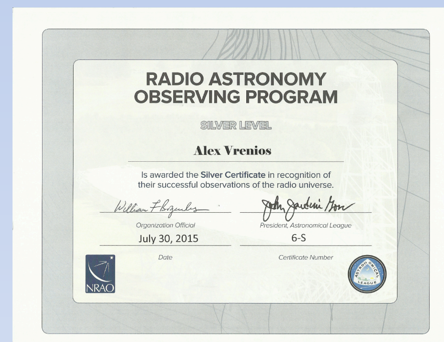
1 - Detecting Solar Radiation

Bronze

2 - Sudden Ionospheric Disturbances (SIDs)

Blah…

3 – Jovian Radio Storms



Silver

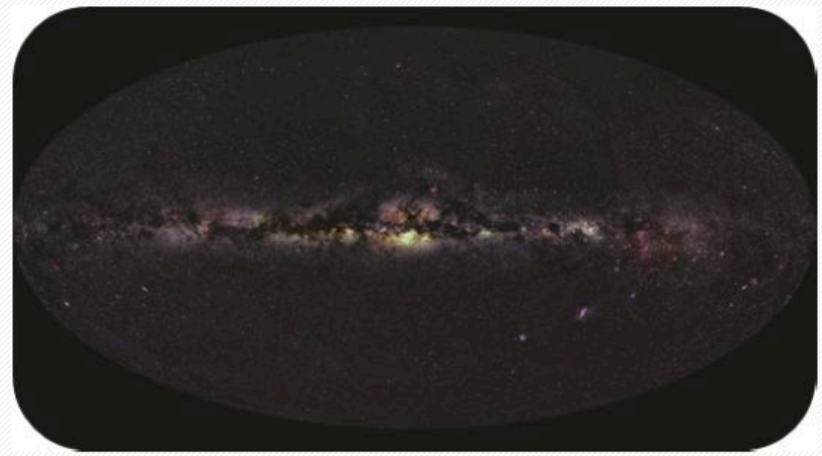
4 - Meteor Scatter Communications

5 - Galactic H-Line Radiation

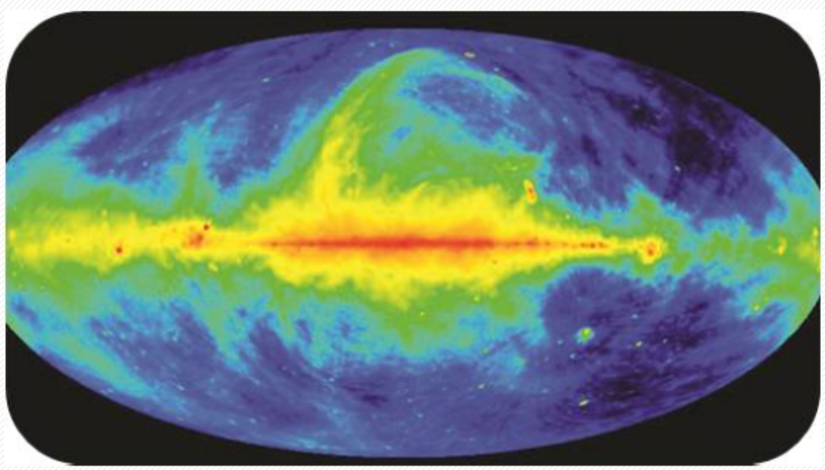
Gold!

RF Imaging – Optical vs. Radio (1 of 3):

An optical image shows the Milky Way's familiar light intensity range.



The sky seen at optical wavelengths. Credit: Axel Mellinger/NASA SkyView

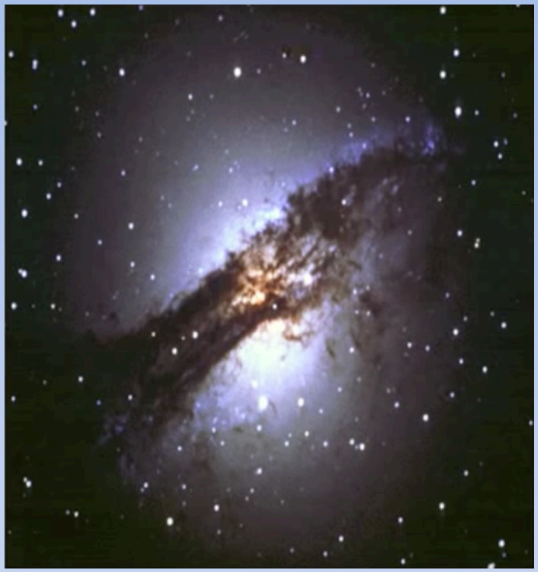


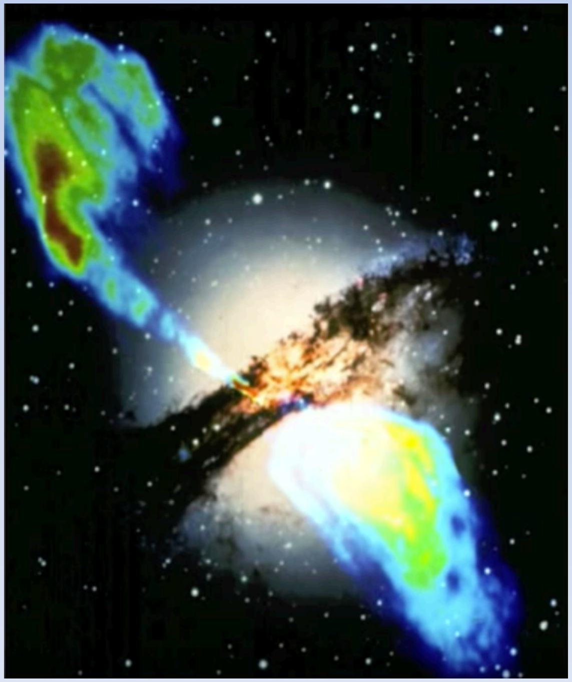
The sky seen at a radio frequency of 408 MHz. Credit: G. Haslam/MPIfR

A radio image shows the Milky Way's color-coded radio frequency intensity range. Radio wavelengths can show more detail because they "see" through dust and debris.

RF Imaging – Optical vs. Radio (2 of 3):

An optical image shows Centaurus A at optical wavelengths.



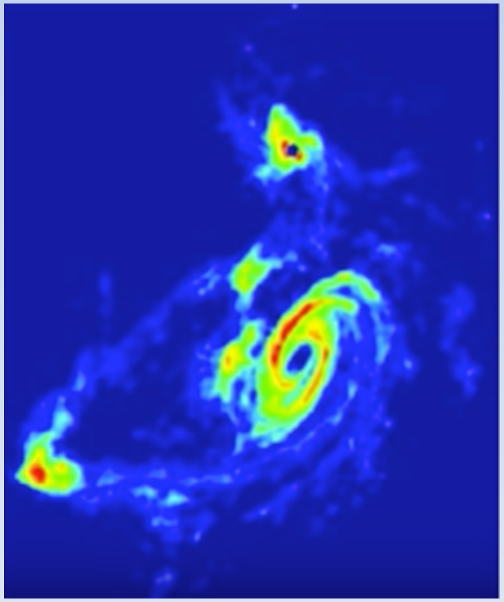


A radio image shows Centaurus A's radio frequency jets – much more information than the optical image.

"I'm a Radio Astronomer," Anna Ho, MIT

RF Imaging – Optical vs. Radio (3 of 3):

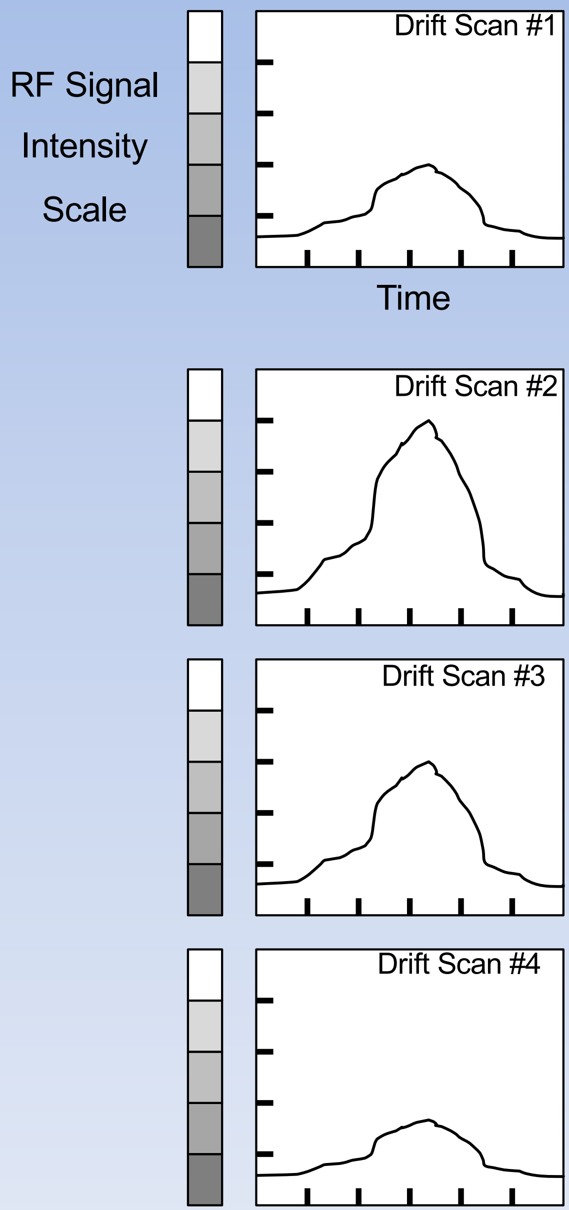
This optical image shows the M81 and M82 Group, in Ursa Major, at optical wavelengths.



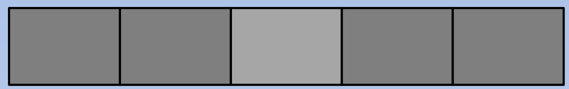
The radio image shows the M81 & M82 at hydrogen wavelengths. It correlates to the optical image, <u>but it also shows</u> how these objects are interacting.

"I'm a Radio Astronomer," Anna Ho, MIT

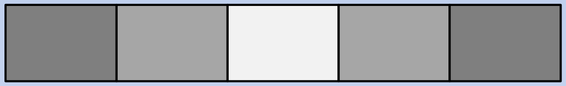
RF Imaging – How it might be done from *drift scan* data:



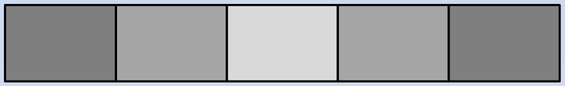
Five intensity samples effectively digitizes the signal data.



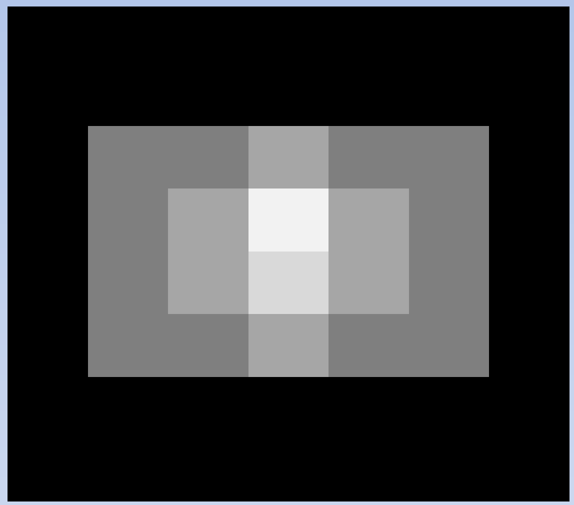
Encoded RF Signal Intensities Sampled at 5 Points in Time.



Each night the antenna is dropped down a bit.



Radio Frequency Image



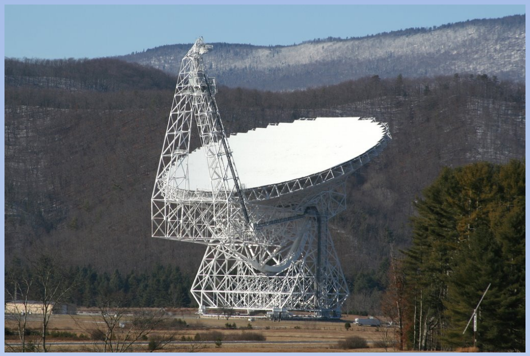
A composite image from the drift scan data at left.

A higher gain antenna means smaller pixels, which translates into greater resolution, or finer detail in an image.

We're gonna need a bigger dish…

Size Matters – Some Very Big Radio Telescopes:

Green Bank's 100 meter diameter radio telescope, the largest fully steerable, single aperture antenna is located in Green Bank, West Virginia, USA.



Credit: panoramio.com

Credit: NRAO

The Karl Jansky Very Large Array is located west of Socorro, NM, comprising twenty-seven, 25m dishes in a "Y" shape. (1973-80.)

Aricibo, Puerto Rico, is 1000 feet in diameter, built in a depression left by a karst sinkhole. Construction began in 1963.

Credit: Space.com

Size Matters – More Very Big Radio Telescopes:

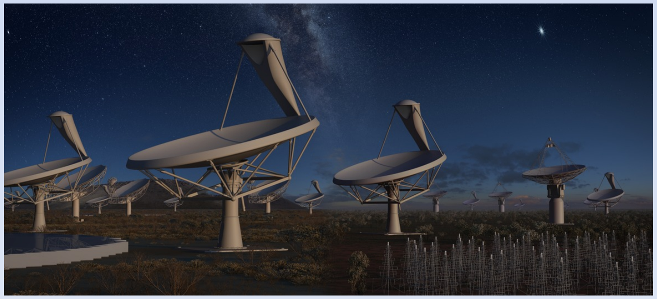
China's Five-hundred-meter Aperture Spherical Telescope (FAST), in Guizhou Province, is about twice as sensitive as the next-biggest single-dish radio telescope.

Credit Liu Xu/Xinhua, via Associated Press.

Credit: wired.co.uk

Jodrell Bank's 76.2 meter (250 ft) diameter Lovell radio telescope can be visited at the University of Manchester, at Manchester England.

The Square Kilometer Array will be the worlds largest telescope. To be co-located in Australia and South Africa. (Expected in 2020.)



Credit: SKATelescope.org

Radio Astronomy – Further Reference:

- Astronomical League: www.astroleague.org

  Promotes the science of astronomy by fostering astronomical education, providing incentives for astronomical observation and research, and by assisting communication among amateur astronomical societies.

- Society of Amateur Radio Astronomers: www.radio-astronomy.org

  An international society of dedicated enthusiasts who teach, learn, trade technical information, and do their own observations of the radio sky.

- SETI League: www.setileague.org

  An international grass-roots organization dedicated to privatizing the electromagnetic Search for Extra-Terrestrial Intelligence (SETI).

- Society for Astronomical Sciences: http://www.socastrosci.org

  Fosters interest and participation in astronomical research by backyard astronomers and encourages publication in recognized journals.

Radio Astronomy – Recap:

- **Observing the Sun's Energy**

  Detect *solar* energy from the Sun

- **Detecting a SID: Sudden Ionospheric Disturbance**

  SIDs can enhance VLF reception during the daytime

- **Listening to Jupiter's Radio Storms**

  Sophisticated software can predict Jovian radio storms

- **Detecting Meteors**

  Brief ionization from meteors can allow distant VHF and UHF reception

- **Detecting Galactic Radio Sources**

  Radio sources contain concentrated Hydrogen ions that *ping* at 1420 MHz

- **Radio Frequency Imaging**

  Amateurs can *detect* radio sources - imaging requires much higher resolution

To request a copy of these slides, email me at axv@cox.net

Questions?