Amateur Radio Astronomy & Deep Space Exploration Society

W0TLM Nov. 15, 2021

Dan Layne, AD0CY

Thanks to:
Ray, AA0L
Rich, AC0UB
Bill, KC0FHN

DSES.science

Email: information(at)dses.science

Topics

- *What is DSES and what are they doing in Haswell?*
- *Can amateurs detect pulsars?*
- *Can the 60’ dish also transmit for EME?*

DSES Charter

- The Deep Space Exploration Society is a Colorado based nonprofit organization dedicated to practical astronomy, space science and radio education for students, the general public, and society members
- We own and operate a 60 ft radio telescope near Haswell, Colorado. The site is named

  “The Paul Plishner Radio Astronomy and Space Sciences Center”

Dish History

The twin 60 foot parabolic dishes near Boulder and the 60 foot dish near Haswell were originally part of a network of sites built for the National Bureau of Standards (now NIST) for tropospheric scatter propagation studies for the US Air Force from 1958 to 1974

Antenna Specifications

Frequencies: 400 Mhz to 2 Ghz

Diameter: 60 feet

Antenna Gain: 42.5 dbi at 1 Ghz

Beam Width: 2.6 degree at 400 Mhz
0.8 degree at 1.2 Ghz

Noise Temperature: 1-2db at 400 Mhz total system

Noise Figure: 0.8db at 400 Mhz w/20db LNA

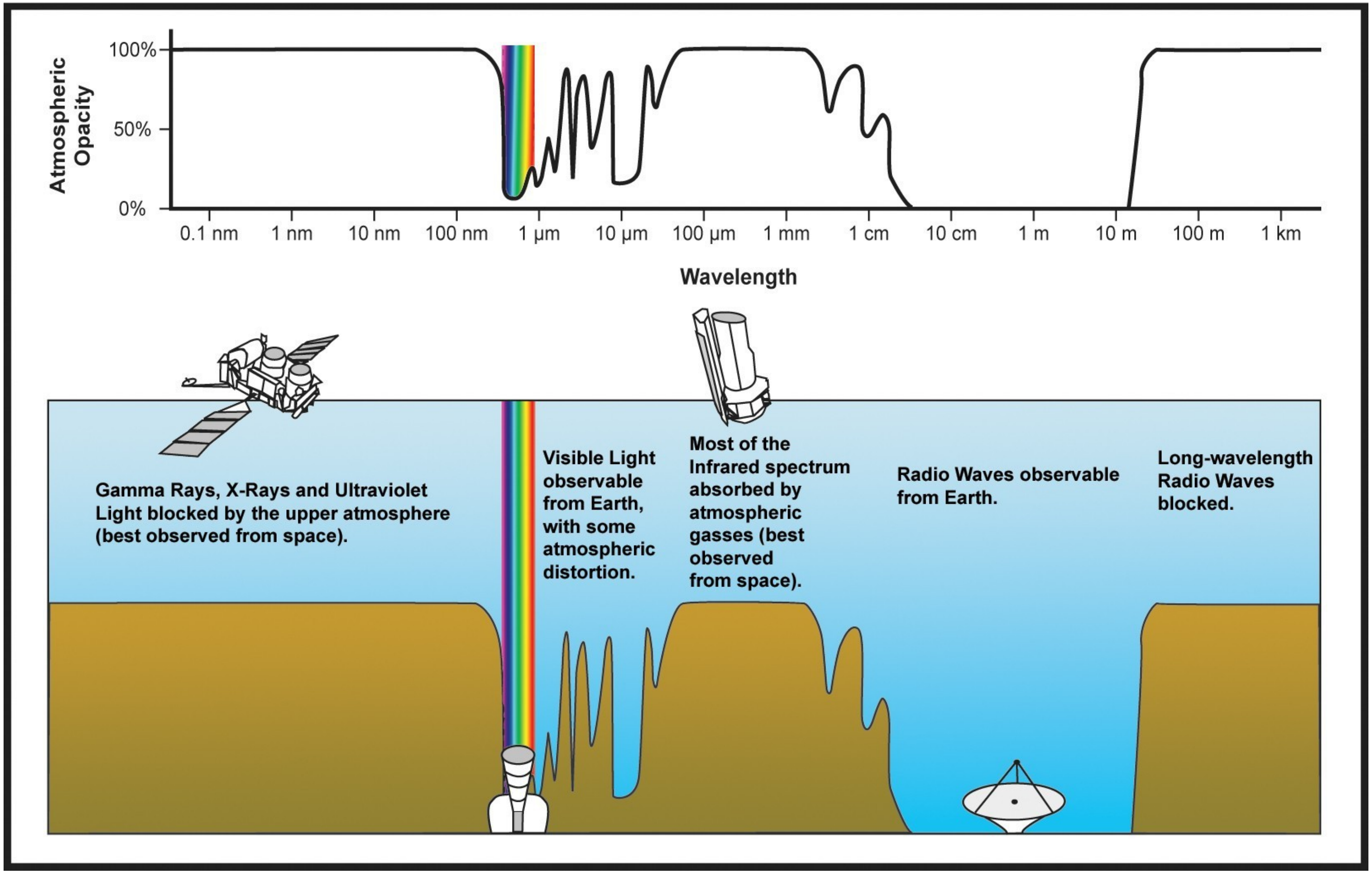
Coverage: Full Hemisphere

Slew Rate Max Az/El: 40/40 deg/min

DSES History as an Organization

- DSES was originally formed in 1991 in Boulder to restore the twin 60 ft dishes at T22 site on Table Mountain. They had good success
- Access to the Table Mountain Field Site was closed to amateurs after 9/11
- Meanwhile, the Haswell site was dormant from 1974 to 2009. Paul Plishner, a radar contractor, had purchased the site at government auction, but never used it. He eventually donated it to DSES
- The Boulder group moved a comm trailer and equipment to Haswell, and commenced facility restoration and upgrades
- As membership slowly transitioned from Boulder to Colo. Springs, upgrades continued, including digital dish control, electricity, internet, feed horns, etc.
- The facility is now operational, thanks to countless volunteer hours

Atmospheric Window for Radio Astronomy



The atmosphere is transparent to frequencies from
5 MHz to 30+ GHz

Radio waves are much longer than optical waves. So radio telescopes must be much larger than optical telescopes

Several frequency segments are protected for radio astronomy

Goal: minimize RFI; maximize SNR

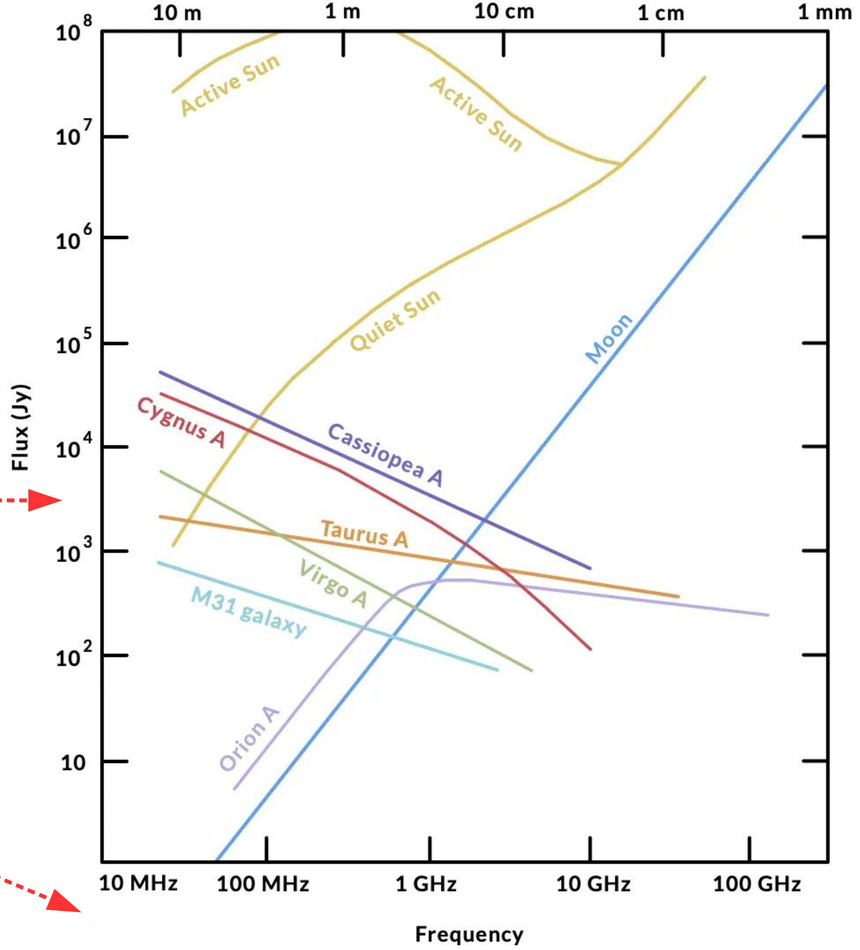
Radio Signals from Space are Weak

Flux density is a measure of signal strength. Units are Jansky (Jy)

Jy = 10^{-26} watts per meter^2 per Hertz

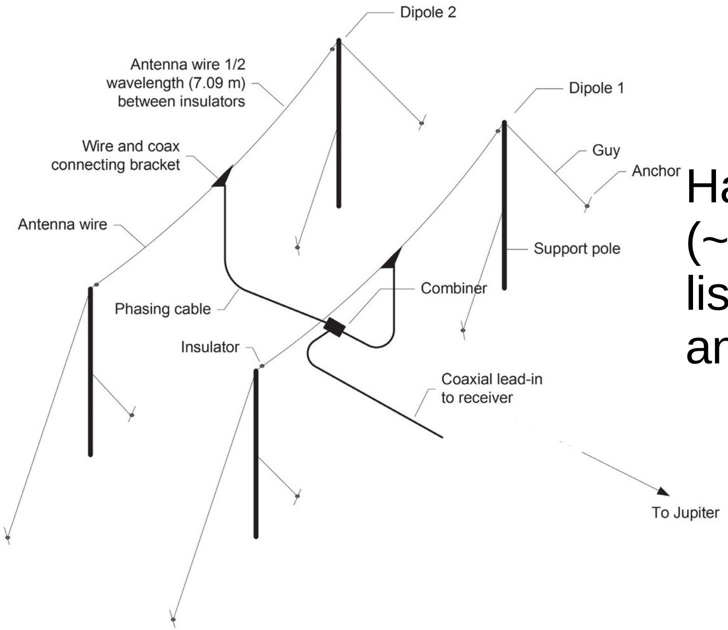
Supernova remnants in the middle

Most pulsars are in milli-Jansky range

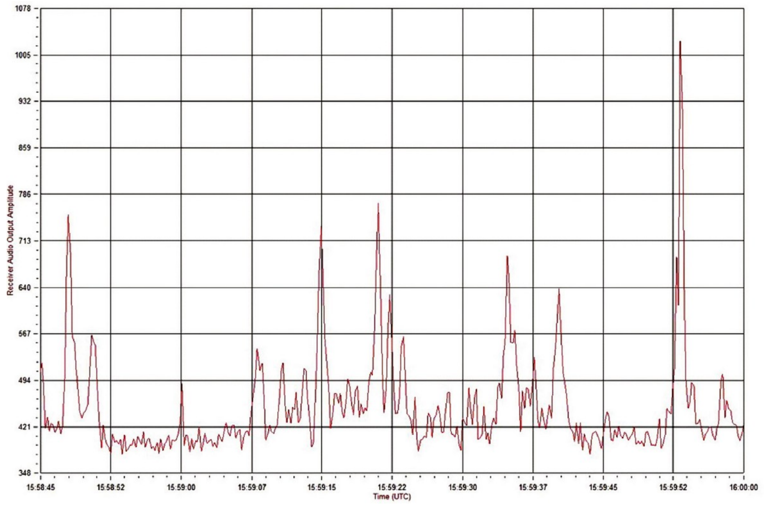


Try it at Home #1: Radio Jove

- Monitor radio storms on Jupiter
  - Strong magnetic field creates radio emissions in HF band
  - Emissions enhanced by Jovian moon Io’s orbit
  - Software tools predict likely emissions: www.radiosky.com
  - Project info: https://radiojove.gsfc.nasa.gov



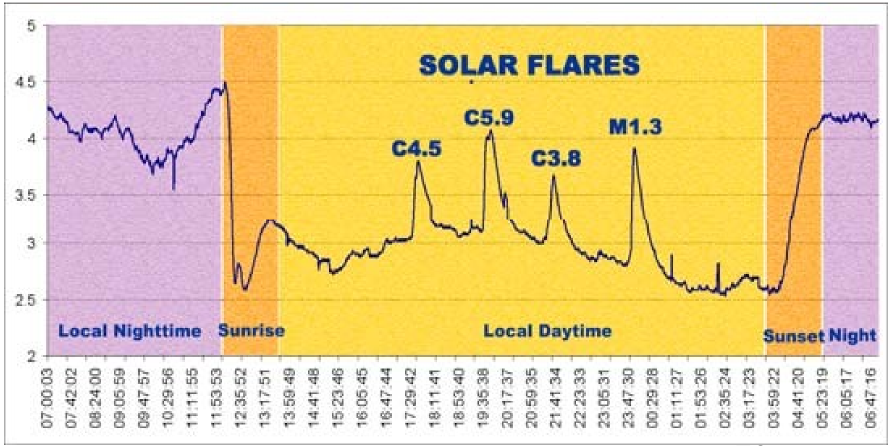
Haswell dual dipole antenna (~20.1 MHz). Visualize and listen to bursts with SDR and sound card



Try it at Home #2: Space Weather

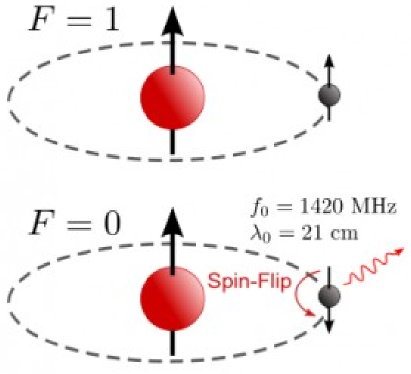
- Sudden Ionospheric Disturbance (SID) caused by solar flares
  - Monitor submarine VLF transmitters (15-25 kHz) for SIDs
  - Data goes to Stanford Solar Center http://sid.stanford.edu/database-browser/
  - SuperSID kit at SARA https://www.radio-astronomy.org/node/210

Home-made 1 m wire loop antenna on PVC frame. Can be mounted indoors.

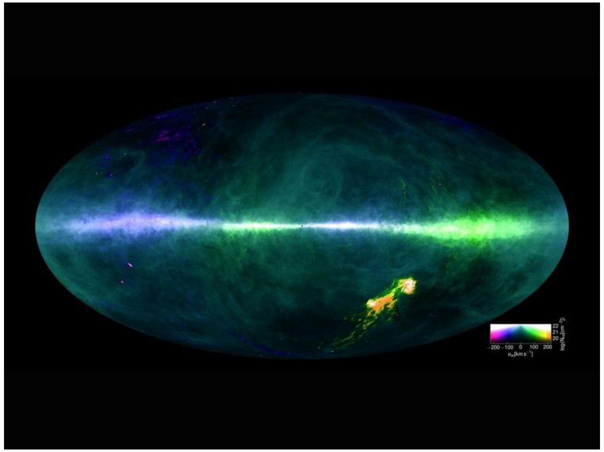


Try it at Home #3: Neutral Hydrogen

- Hydrogen is the most abundant element in the universe
  - Neutral hydrogen gas is the main component of the Interstellar Medium
  - Can observe spectral line to map bright objects and Milky Way
  - Can use a small dish or horn antenna with an SDR



Spin-flip transition produces
a 21-cm photon (1420.4 MHz)



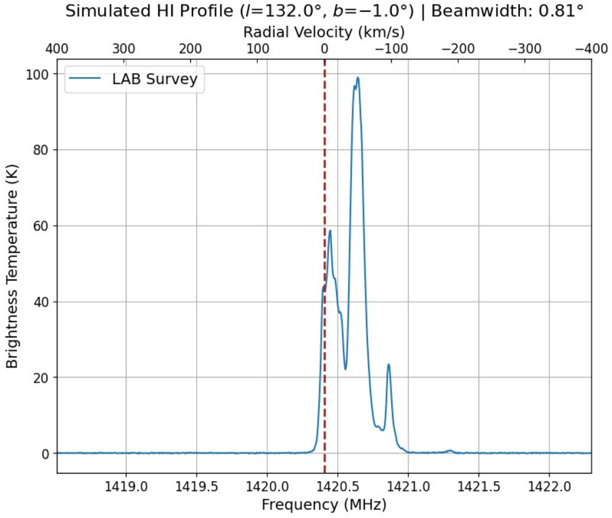
21-cm all sky map of neutral hydrogen.
The Milky Way is the bright band in center

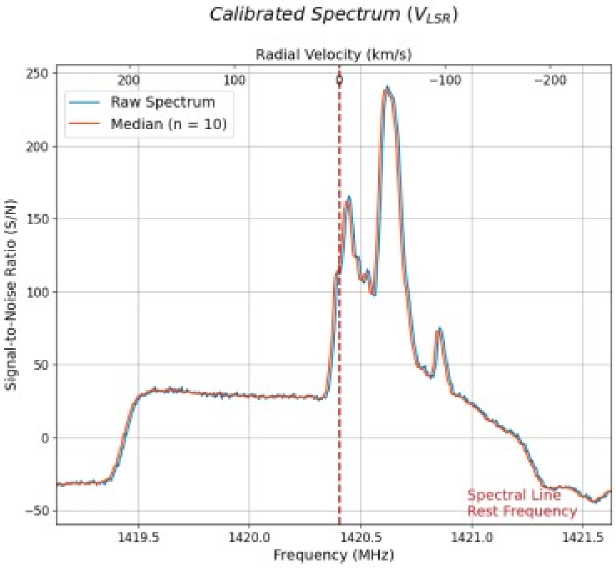
Neutral Hydrogen Observation: S7

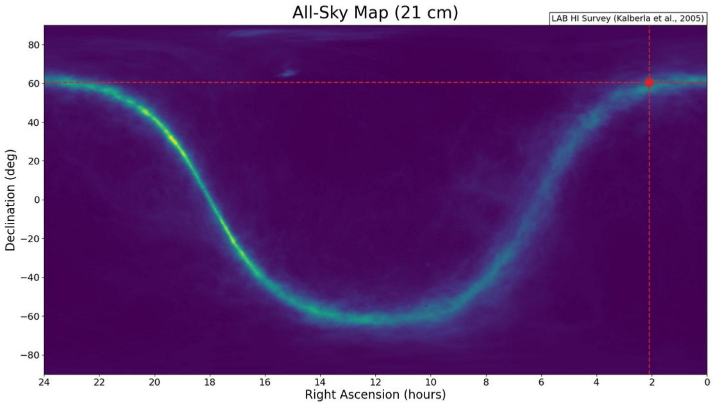
S7 is a stable, bright hydrogen emitter used for calibration. Observed Aug. 7, 2021, 161322 UTC.

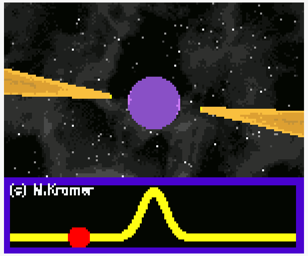
- Telescope: DSES 60’ dish, 1420 MHz feed with LNA, beamwidth = 0.81°
- Receiver: Airspy R2 + GPSDO, 2.5 MHz bandwidth, 120 seconds integration
- Laptop Software: Ubuntu 20.04, GnuRadio 3.8, Python3, astro-virgo 3.8

- Predicted profile (based on LAB HI Survey) shown on left
- Observed spectrum shown in middle (calibrated for background and Doppler shift)
- 21 cm All-Sky Map on right shows location of S7

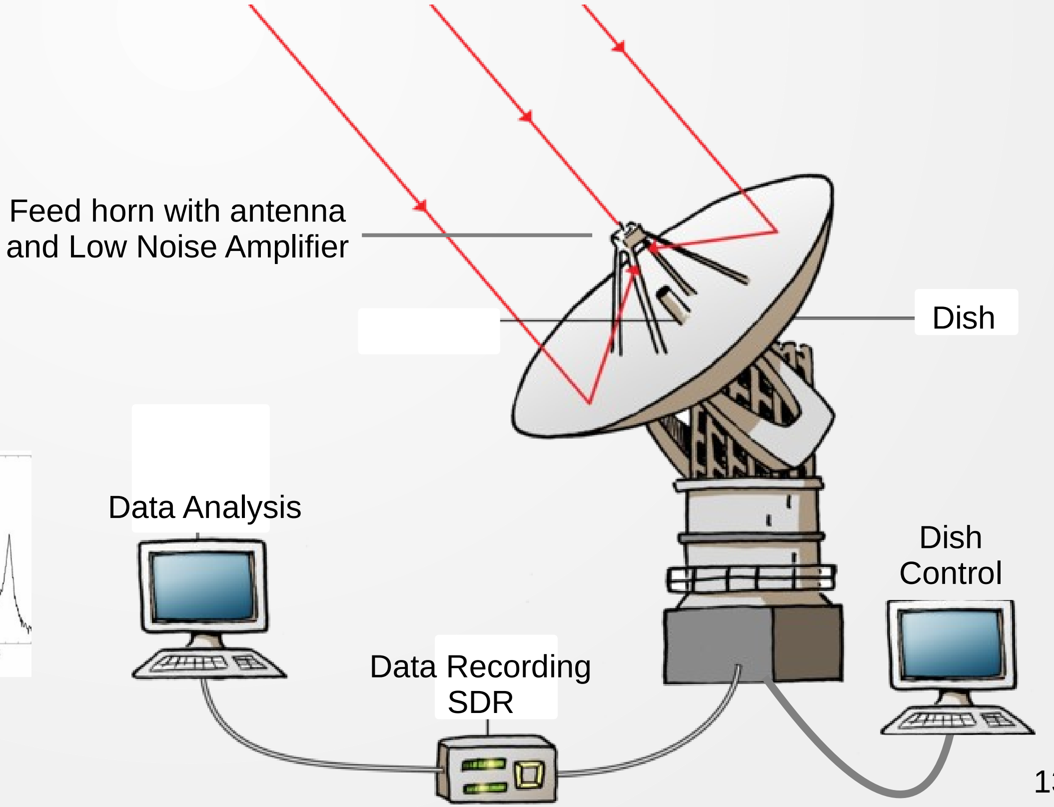


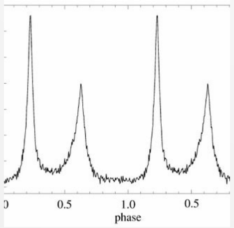




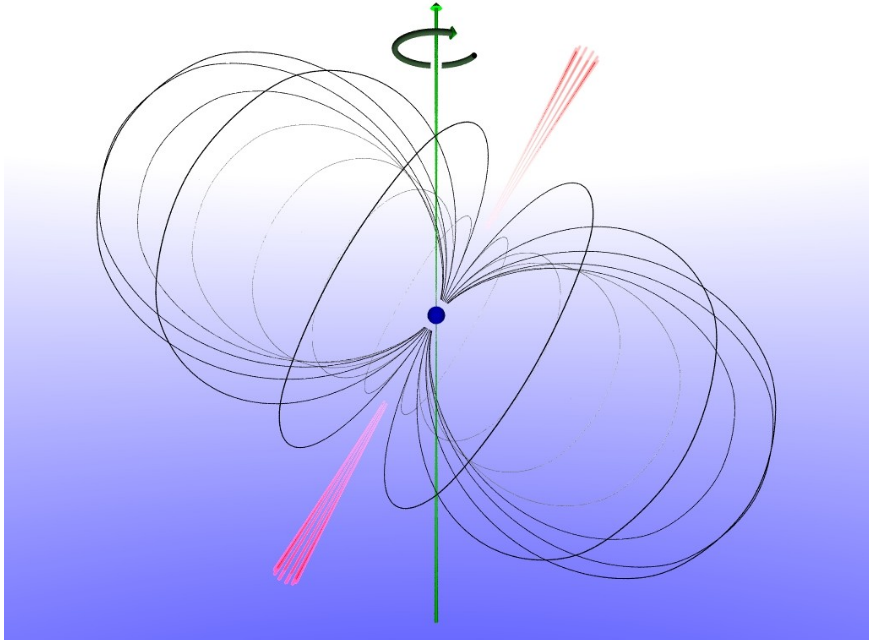


Detecting Pulsars





Basic Pulsar Properties



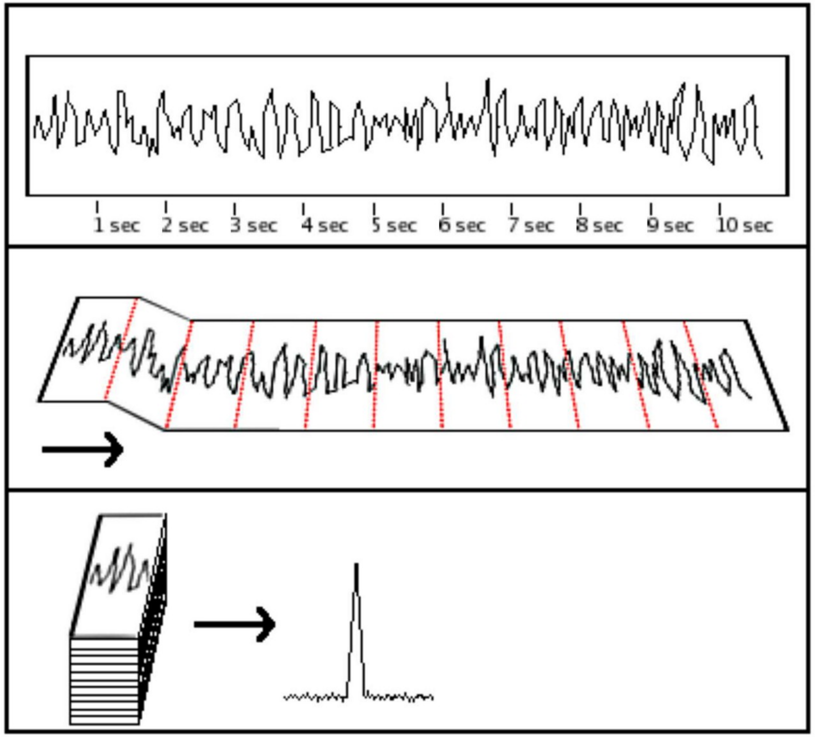
- First discovered by chance in 1967 by Jocelyn Bell, a graduate student at Cambridge
- A few thousand are now known
- Rapidly spinning, magnetized neutron star (collapsed core from supernova explosion)
- Spin periods from milliseconds to seconds. Precise clocks, but pulse features vary
- The broadband beam is emitted from the magnetosphere – details not well understood
- Higher frequencies of pulse detected slightly before lower frequencies due to pulse dispersion through the interstellar medium

Crab Nebula

- Supernova remnant, observed in 1054
- The Crab pulsar is the red star in center (very few pulsars have an identified optical counterpart)
- Period = 33 ms
- Image combines optical (Hubble) in red with X-ray (Chandra) in blue

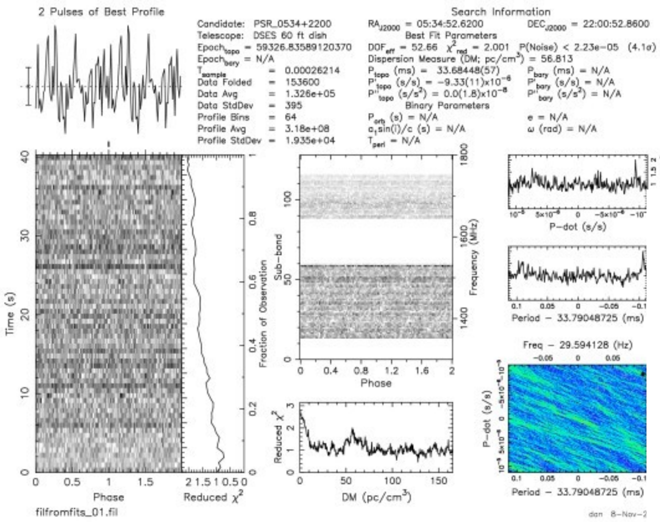
Digital Signal Processing: Folding

- Top:
  - Weak pulsar signal is lost in noise
- Middle:
  - Fold paper strip at known period
- Bottom:
  - Add up small contributions until pulse stands out (increase SNR)
- Performed in frequency domain

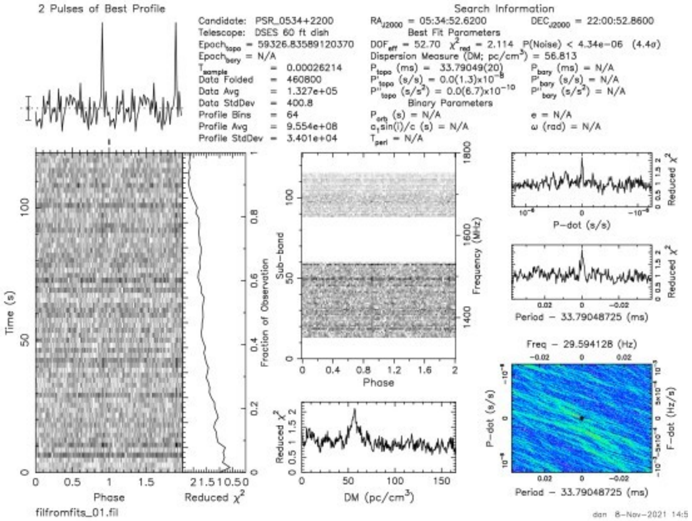


Cumulative Folding

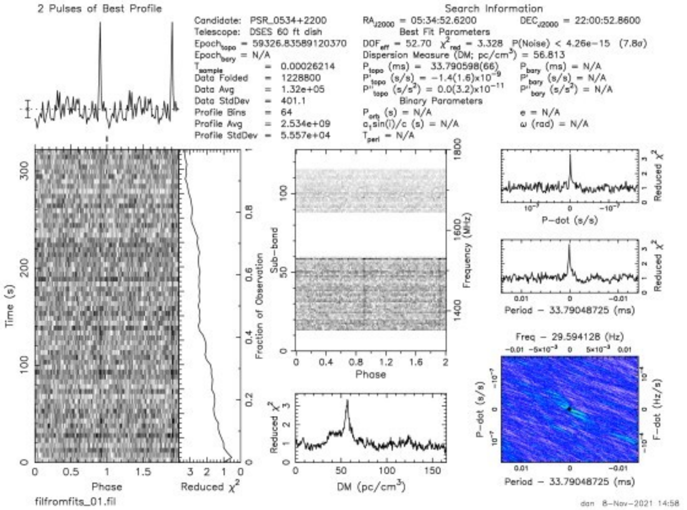
1st Iteration: Looks like noise



2nd Iteration: Pulse appears



Final Iteration: Good profile!



Amateur Pulsar Detection

- Amateurs have detected pulsars using EME equipment
  - 3 meter dish with Airspy SDR
  - Twin 23 element Yagi with RTL-SDR
  - Need to track pulsar several hours and integrate data
- Best hunting frequencies (requires different feed horns)
  - 408 MHz (70 cm); 1296 MHz (23 cm); 1420 MHz (21 cm)
- DSES has detected 15 (known) pulsars
  - 60’ dish means we don’t have to track as long as smaller dishes
  - We use hardware pulsar simulator (AA0L) to learn processing

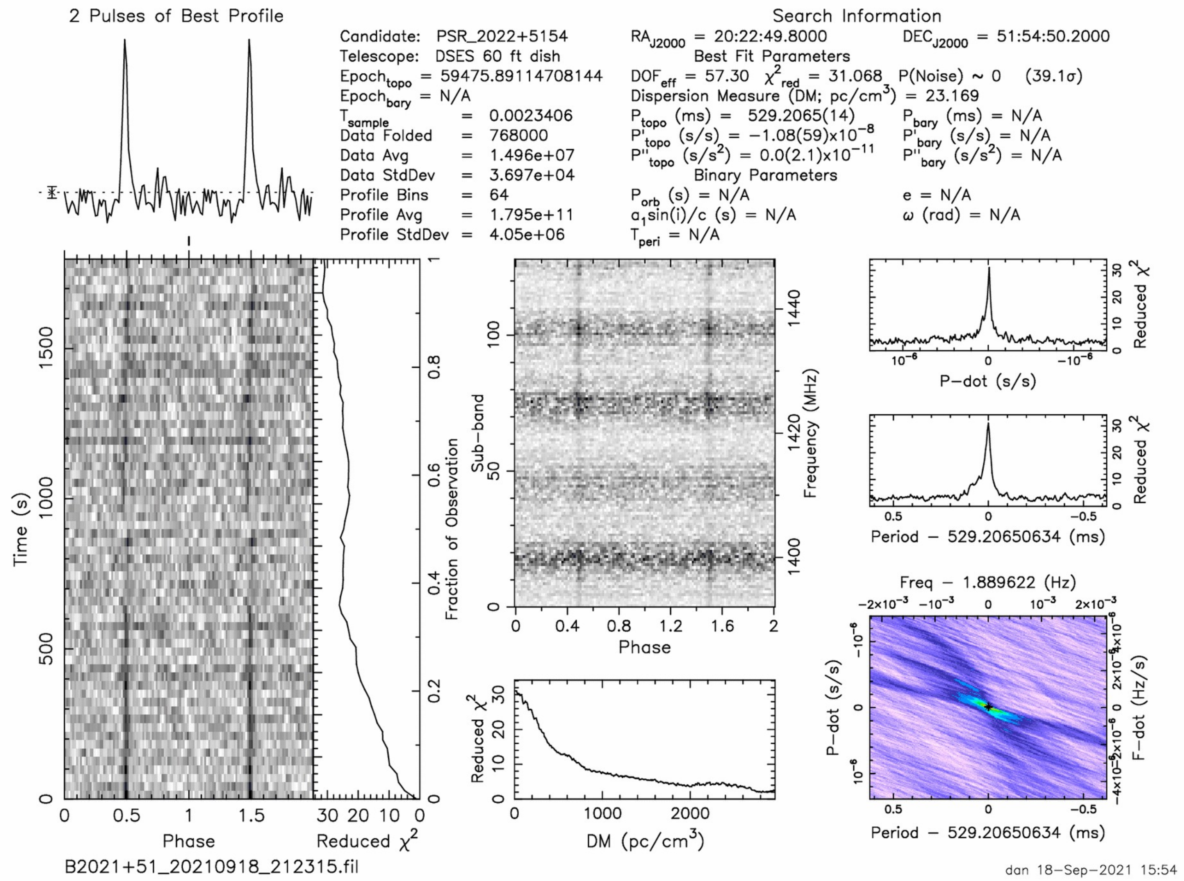
Pulsar Detection Tools

SDR: USRP B210 (56 MHz), N210 (10 MHz)

Computer: System 76, 16 core, 64 GB RAM, Ubuntu 20.04

Software Tool	Purpose
I0NAA Murmur; ATNF database	Plan observations
DSES System 1 Dish Control	Dish pointing and tracking
GnuRadio 3.8 spectrum analyzer	Calibrate gain, check RFI
GnuRadio 3.8 pulsar filterbank	Data recording (SDR)
PRESTO 4.0	Pulsar data processing
Tempo; PSRCAT (ephemeris)	Timing analysis

DSES Example: B2021+51



<u>PRESTO plot</u>

Date/Time: 20210918_212315

Run Time: 1800 seconds (30 min)

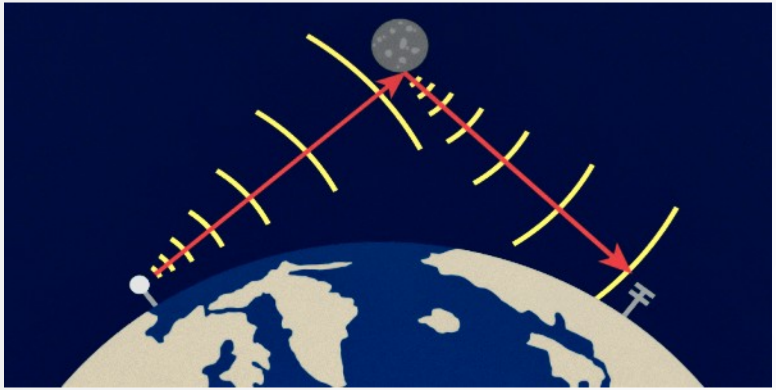
Center Frequency: 1420 MHz

Receiver: B210 at 56 MHz

Period: 529.2 ms

Distance: 5,870 light years

Flux Density: 27 mJy



EME Moonbounce & Ham Radio

Deep Space Exploration Society

K0PRT Antennas

Antennas include:

- Tri-band (10,15,20 m) Yagi on 50’ tower
- 5-band trap vertical antenna
- Dipoles for 80 and 160 meters
- 3-element Yagi for 6 meters
- VHF vertical on 50’ tower for 2 meters

- And the 60’ dish!

The ham shack is in the underground concrete bunker

K0PRT Ham Shack

In the bunker we can operate two stations at the same time

Currently using donated radios

Thanks to Gary, WA2JQZ for photos and info in this section

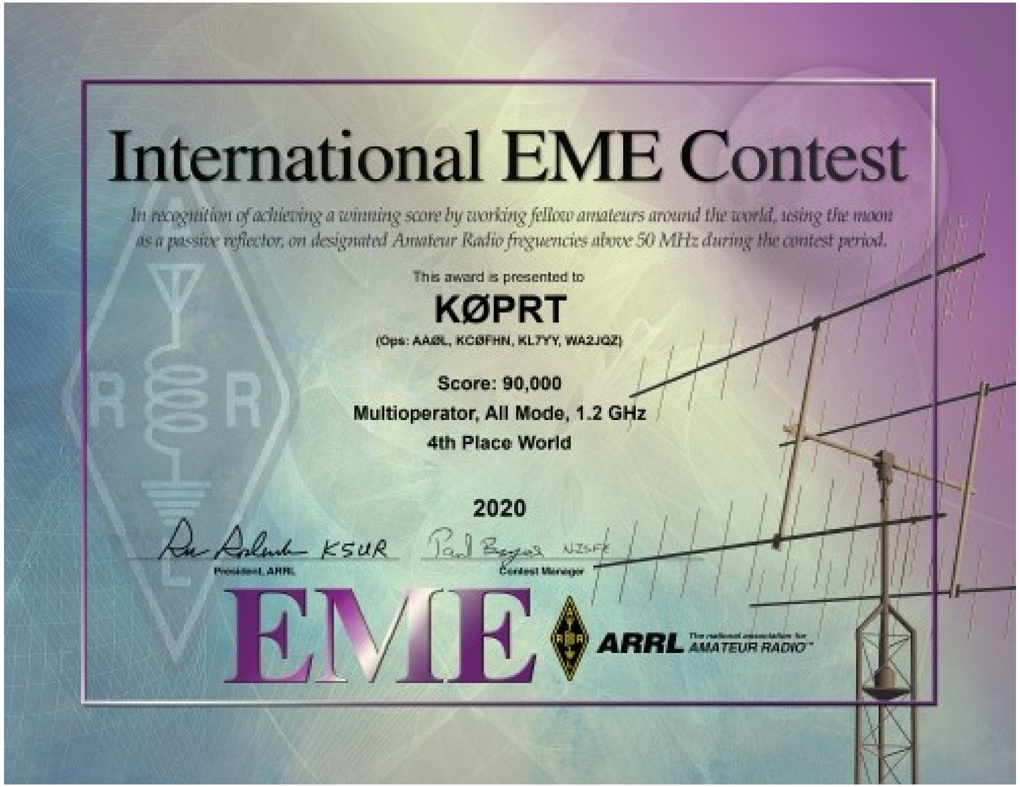
EME Moonbounce

EME with the 60’ dish is conducted from the comm trailer using an FT736. Last year the team made contacts on CW, phone and JT65C (WSJT-X)

The 1296 MHz (23 cm) feed has separate Rx/Tx dipoles. It was recently installed for the 2021 ARRL EME Contest,
Nov. 19-20, and Dec. 17-18 (full moon)

A 200 watt amplifier is installed next to the feed horn at the focal point of the 60’ parabolic dish

EME Moonbounce



4th place in 2020 for Multioperator, All Mode, 1.2 GHz

2020 was the first year DSES successfully got on the moon. The team was only on the air part of the time as they overcame several propagation challenges, including polarization, fading and Doppler shift as the earth rotates

We plan to be back on the moon this year!

Visitors and guests are always welcome

Questions?