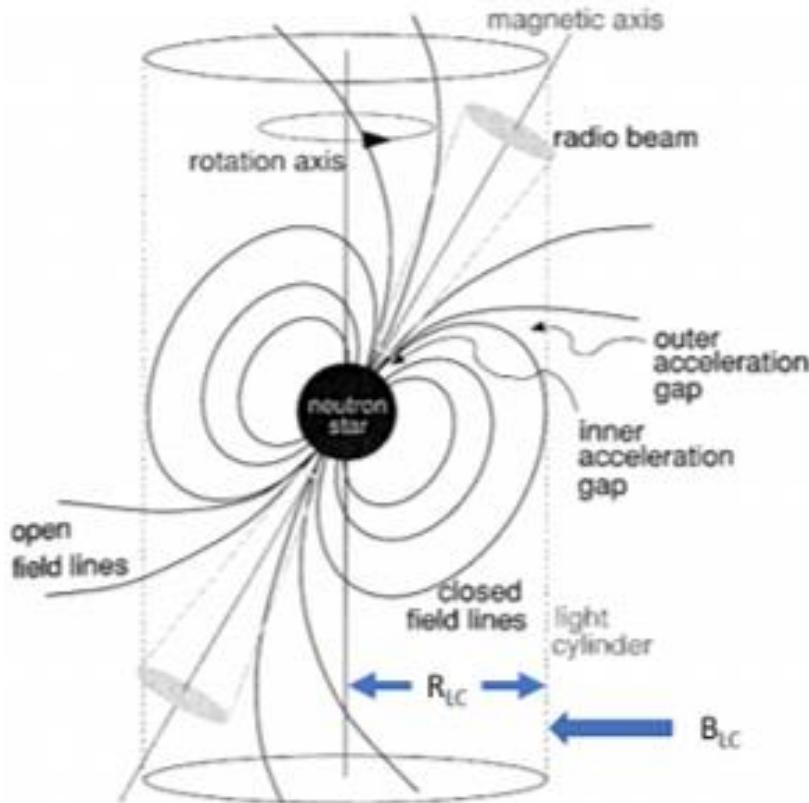


Deep Space Exploration Society

Science Meeting



Pulsar Data Analysis

August 24, 2020

Dr. Richard Russel

DrRichRussel@netscape.net

DSES.science

Information

- 9 ft Dish – Down because hard drive crashed
- SuperSID – Down because of hard drive crash
- Radio Jupiter – still need to get a new receiver and setup at site
- Pulsar - Waiting for new feed to be installed per schedule
 - Observing using 408 MHz feed per September schedule
 - Simultaneous HI measurements give extra data on Doppler and DM for the pulsar measurement
 - Bring SpectraCyber and powered splitter along with pulsar equipment
- Fast Radio Bursts:
 - Working on getting PRESTO to do analysis command (path problem getting PRESTO to do analysis)
 - Observe FRB 121102 located at: RA: 05h31m58s DEC: +33d08m04s
 - This is a repeating FRB.
- SARA East Conference – videos online: www.radio-astronomy.org

2020 Observation/ Feed Schedule

- August
 - Week 1-4: 1420 MHz Feed
 - Skip's Project (TBD)
 - HI Measurements – SpectraCyber
 - Pulsar Measurements
- September
 - Week 1-4 408 MHz Feed
 - Pulsar Measurements
- October
 - Week 1-3: 1296 MHz
 - Oct 10-11 Moonbounce (1296 MHz): <http://www.arrl.org/contest-calendar>
 - Week 4: 1420 MHz – Skips Project
- November
 - Week 1-3: 408 MHz – Pulsar Observations
 - Week 4: Moonbounce (1296 MHz)
 - Nov 28-29 Moonbounce (1296 MHz): <http://www.arrl.org/contest-calendar>
- December
 - Week 1-4 408 MHz Pulsar/FRB

Bob Haggart Research on Betelgeuse

Here is the URL for the info;

https://www.cnet.com/news/nasa-telescope-uncovers-cause-of-betelgeuse-star-mysterious-dimming/?UniqueId=AC53F6A8-DDD7-11EA-A373-791E3A982C1E&ftag=COS-05-10aaa0a&TheTime=2020-08-14T02%3A41%3A36&PostType=link&ServiceType=facebook_page&fbclid=IwAR09OBNa0e1itr_2MThPIsPjiXOwDK2bVAltWnLzEQtVZWMLoxHhFm0hwAs

Canadian Centre for Experimental Radio Astronomy

Citizen Science and Radio Astronomy

www.ccera.ca

The Canadian Center for Experimental Radio Astronomy is a membership association which supports education and research in radio astronomy techniques and applications targeted at smaller institutions and interested individuals. We are federally incorporated as a not-for-profit in Canada.

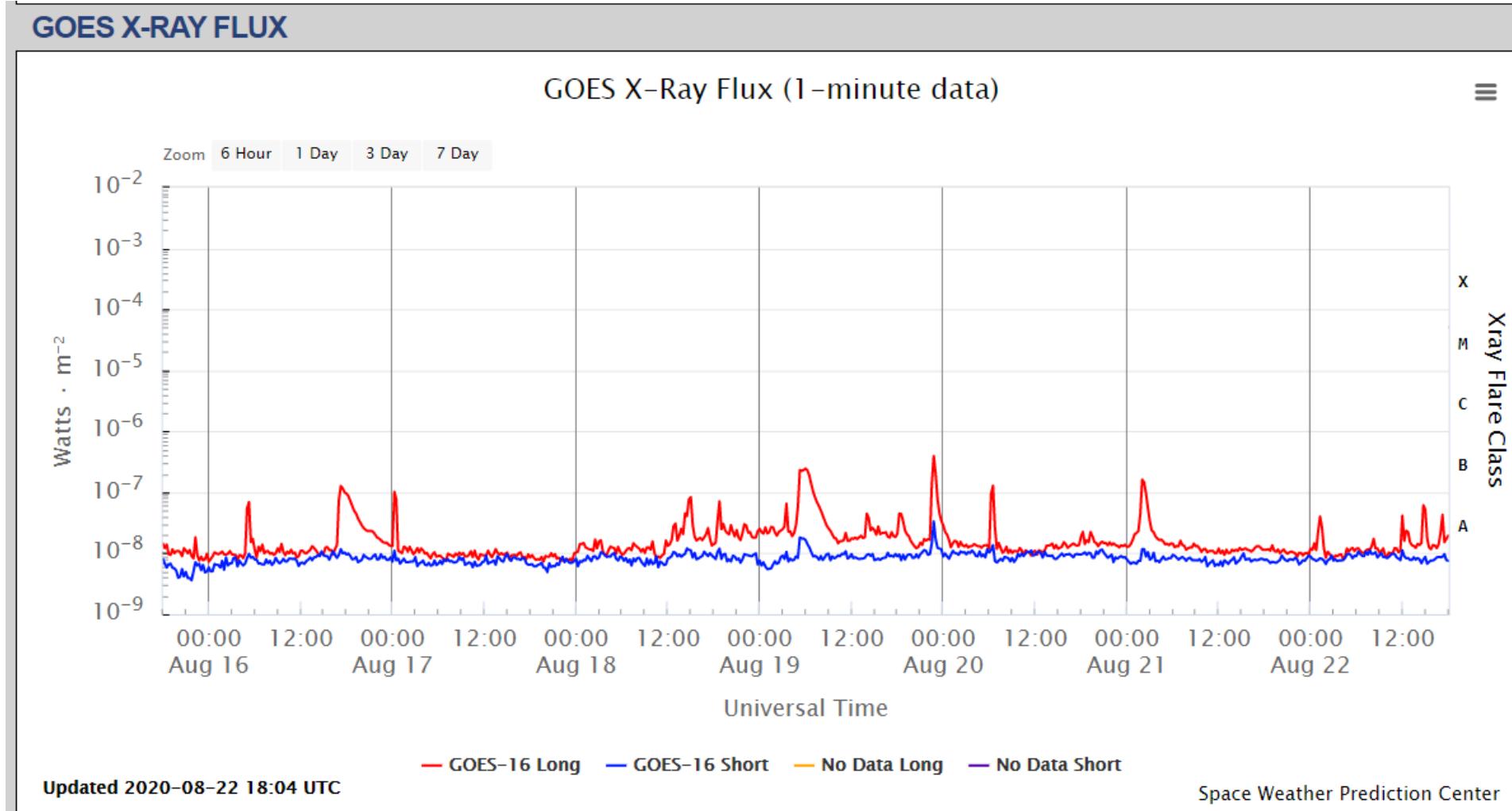
We operate an observatory and research centre near Smiths Falls, Ontario, Canada.



Marcus and Gary

NOAA Space Weather Prediction Center

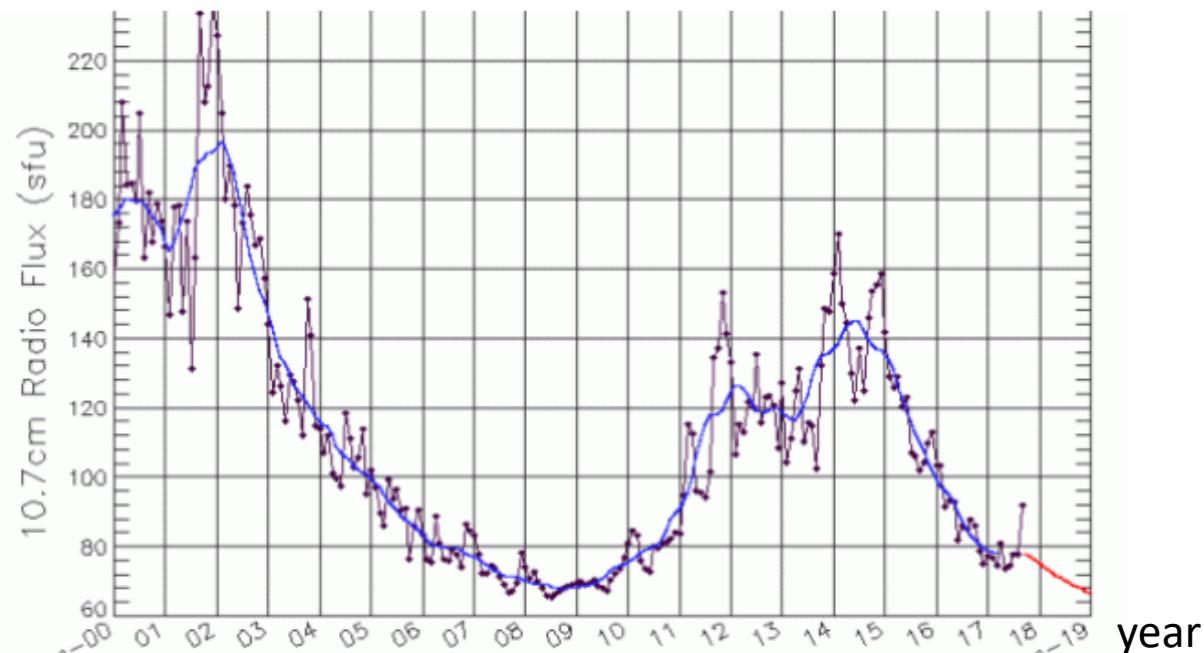
- <https://www.swpc.noaa.gov/products/goes-x-ray-flux>
- Excellent Check on SuperSID results



10.7 CM Radio Emissions

- <https://www.swpc.noaa.gov/phenomena/f107-cm-radio-emissions>

F10.7 CM RADIO EMISSIONS



F10.7 CM RADIO EMISSIONS

The solar radio flux at 10.7 cm (2800 MHz) is an excellent indicator of solar activity. Often called the F10.7 index, it is one of the longest running records of solar activity. The F10.7 radio emissions originates high in the chromosphere and low in the corona of the solar atmosphere. The F10.7 correlates well with the sunspot number as well as a number of UltraViolet (UV) and visible solar irradiance records. The F10.7 has been measured consistently in Canada since 1947, first at Ottawa, Ontario; and then at the Penticton Radio Observatory in British Columbia, Canada. Unlike many solar indices, the F10.7 radio flux can easily be measured reliably on a day-to-day basis from the Earth's surface, in all types of weather. Reported in "solar flux units", (s.f.u.), the F10.7 can vary from below 50 s.f.u., to above 300 s.f.u., over the course of a solar cycle. These F10.7 measurements are provided courtesy of the National Research Council Canada in partnership with the Natural Resources Canada. Further information about Canada's solar weather monitoring services may be found at https://www.nrc-cnrc.gc.ca/eng/solutions/advisory/solar_weather_monitoring.html.

The F10.7 Index has proven very valuable in specifying and forecasting space weather. Because it is a long record, it provides climatology of solar activity over six solar cycles. Because it comes from the chromosphere and corona of the sun, it tracks other important emissions that form in the same regions of the solar atmosphere. The Extreme UltraViolet (EUV) emissions that impact the ionosphere and modify the upper atmosphere track well with the F10.7 index. Many Ultra-Violet emissions that affect the stratosphere and ozone also correlate with the F10.7 index. And because this measurement can be made reliably and accurately from the ground in all weather conditions, it is a very robust data set with few gaps or calibration issues.

Predicted Sunspot Number

- <https://www.swpc.noaa.gov/products/predicted-sunspot-number-and-radio-flux>

Predicted Sunspot Number and Radio Flux						
Date	Sunspot Number Predicted	Sunspot Number High	Sunspot Number Low	10.7 cm Radio Flux Predicted	10.7 cm Radio Flux High	10.7 cm Radio Flux Low
2020-02	2.6	3.6	1.6	69.7	70.7	68.7
2020-03	2.7	4.7	0.7	69.8	70.8	68.8
2020-04	2.9	5.9	0	69.9	71.9	67.9
2020-05	3.2	8.2	0	69.9	72.9	67.7
2020-06	3.5	8.5	0	69.8	73.8	67.7
2020-07	3.6	9.6	0	69.6	73.6	67.7
2020-08	3.9	10.9	0	69.5	74.5	67.7
2020-09	4.5	11.5	0	69.5	78.5	67.7
2020-10	5	13	0	69.6	78.6	67.7
2020-11	5.7	14.7	0	69.8	78.8	67.7
2020-12	6.5	15.5	0	70.1	79.1	67.7
2021-01	7.2	17.2	0	70.4	79.4	67.7
2021-02	8.3	18.3	0	70.9	79.9	67.7
2021-03	9.6	19.6	0	71.4	80.4	67.7
2021-04	11.1	21.1	1.1	72	81	67.7
2021-05	12.7	22.7	2.7	72.7	81.7	67.7
2021-06	14.4	24.4	4.4	73.5	82.5	67.7

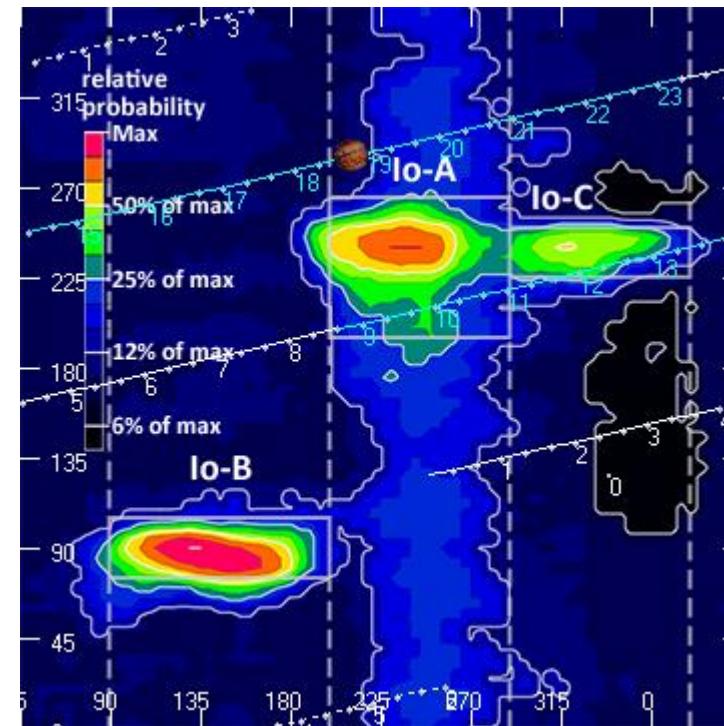
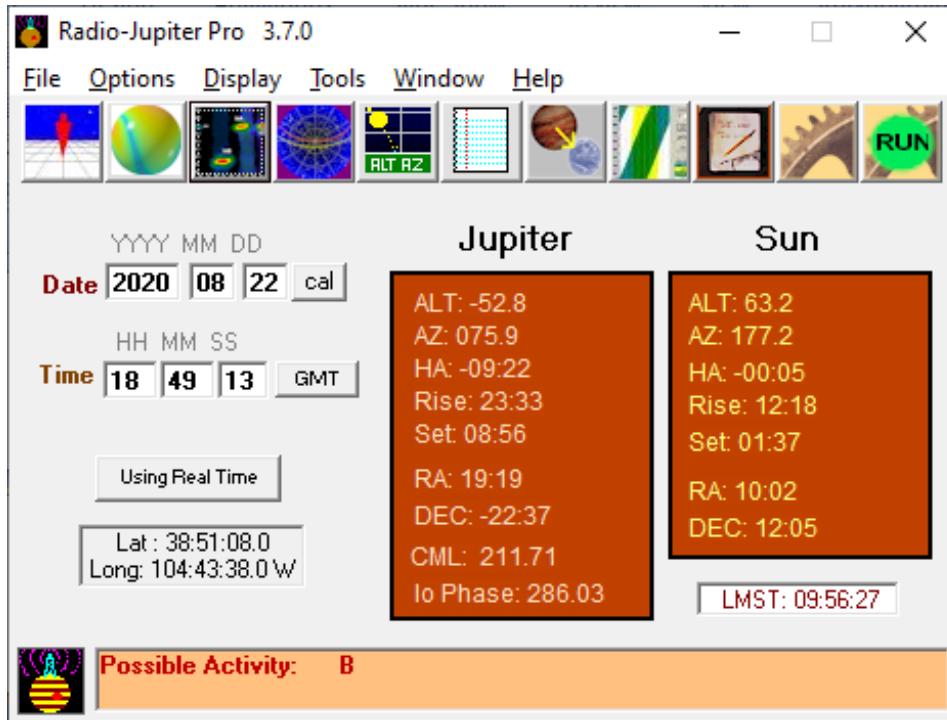
10.7 cm Radiometer

- Take sun measurements daily at same time and center of sun
- Take absolute measurement - 10.7 cm (2800 MHz)
 - Measure background noise
 - Measure data with Dicke Switch
 - Subtract Peak sun transit signal from average background signal
- Calibrate with NOAA measurements for 10.7 cm SOLAR FLUX UNITS (SFU)
- Calibrate with NOAA measurements to convert 10.7 cm flux to sunspot number

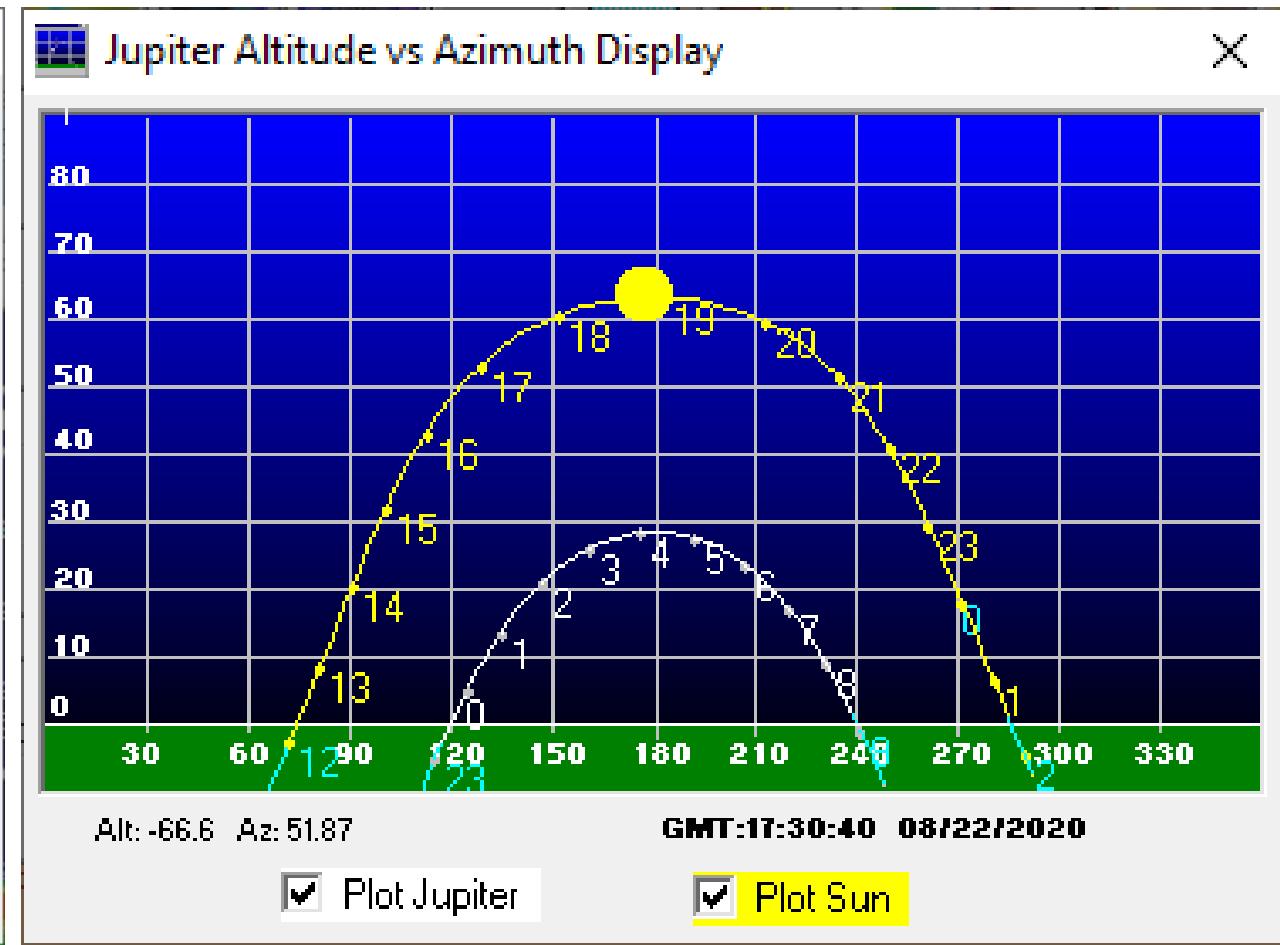
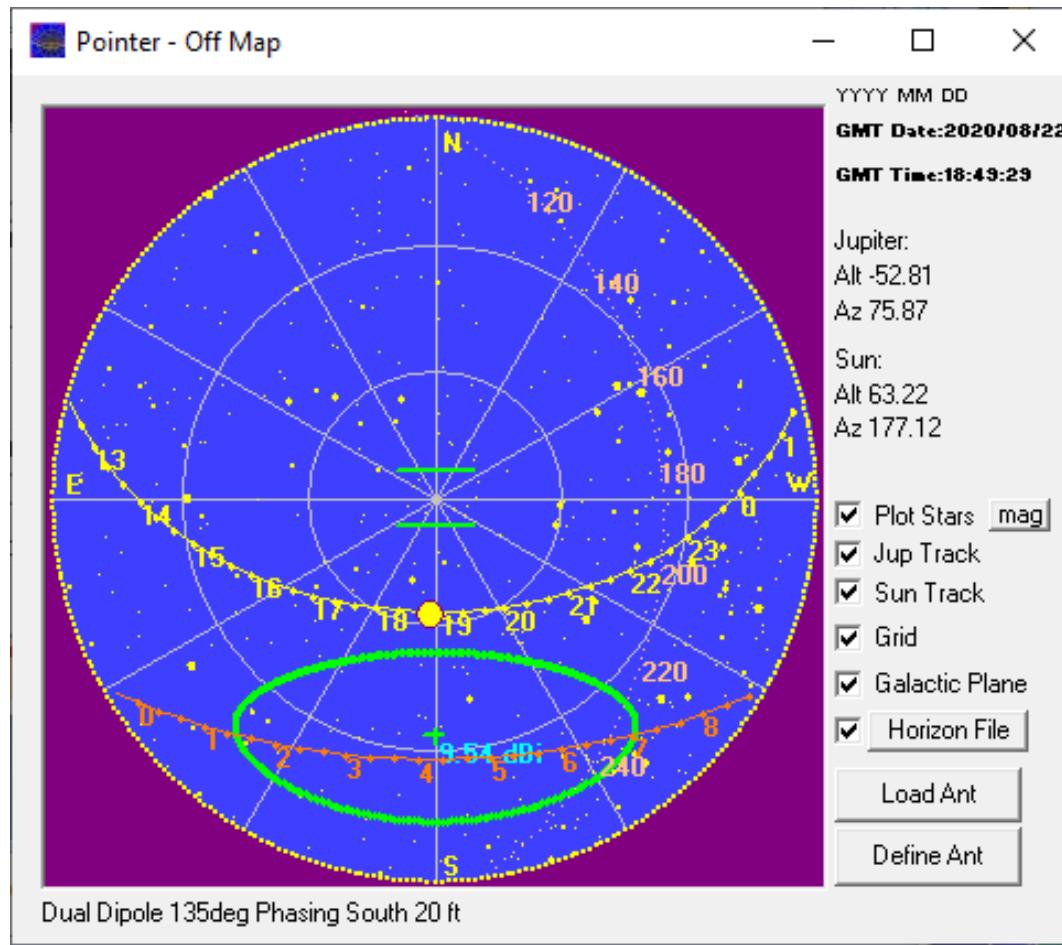
Radio Jupiter Pro

(Available at: <http://radiosky.com/>)

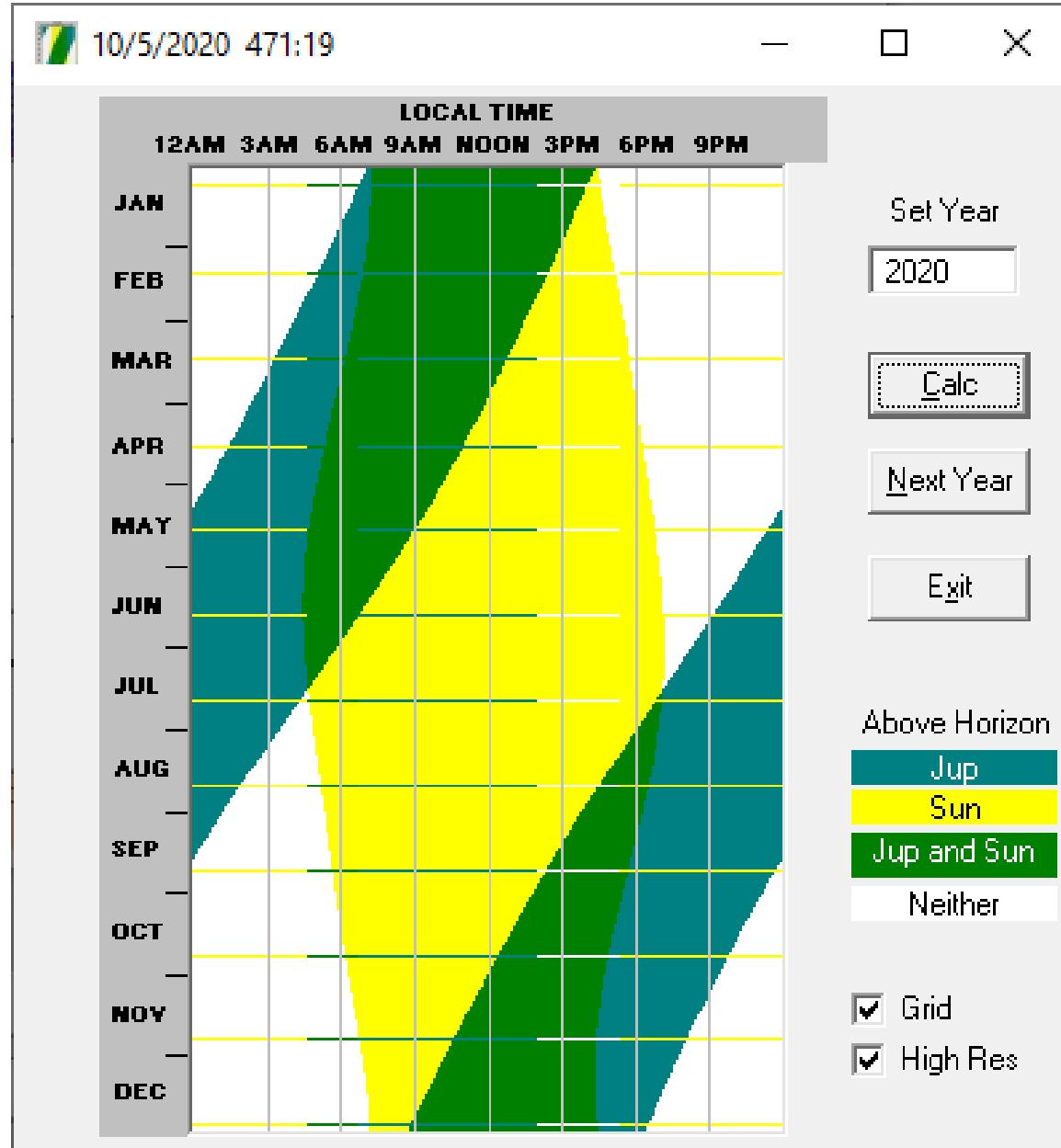
Main Screen and Prediction Chart



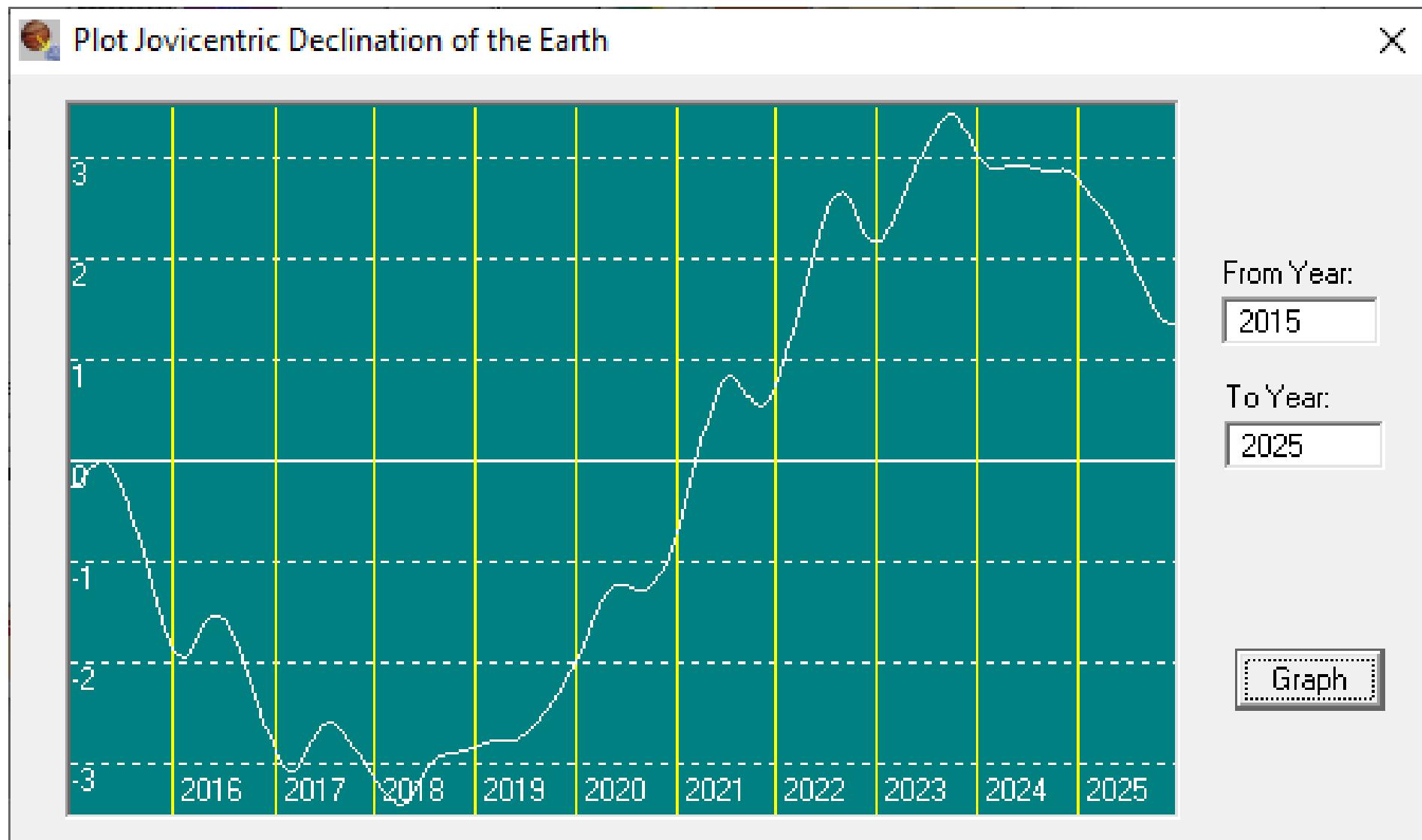
Jupiter / Sun Positions



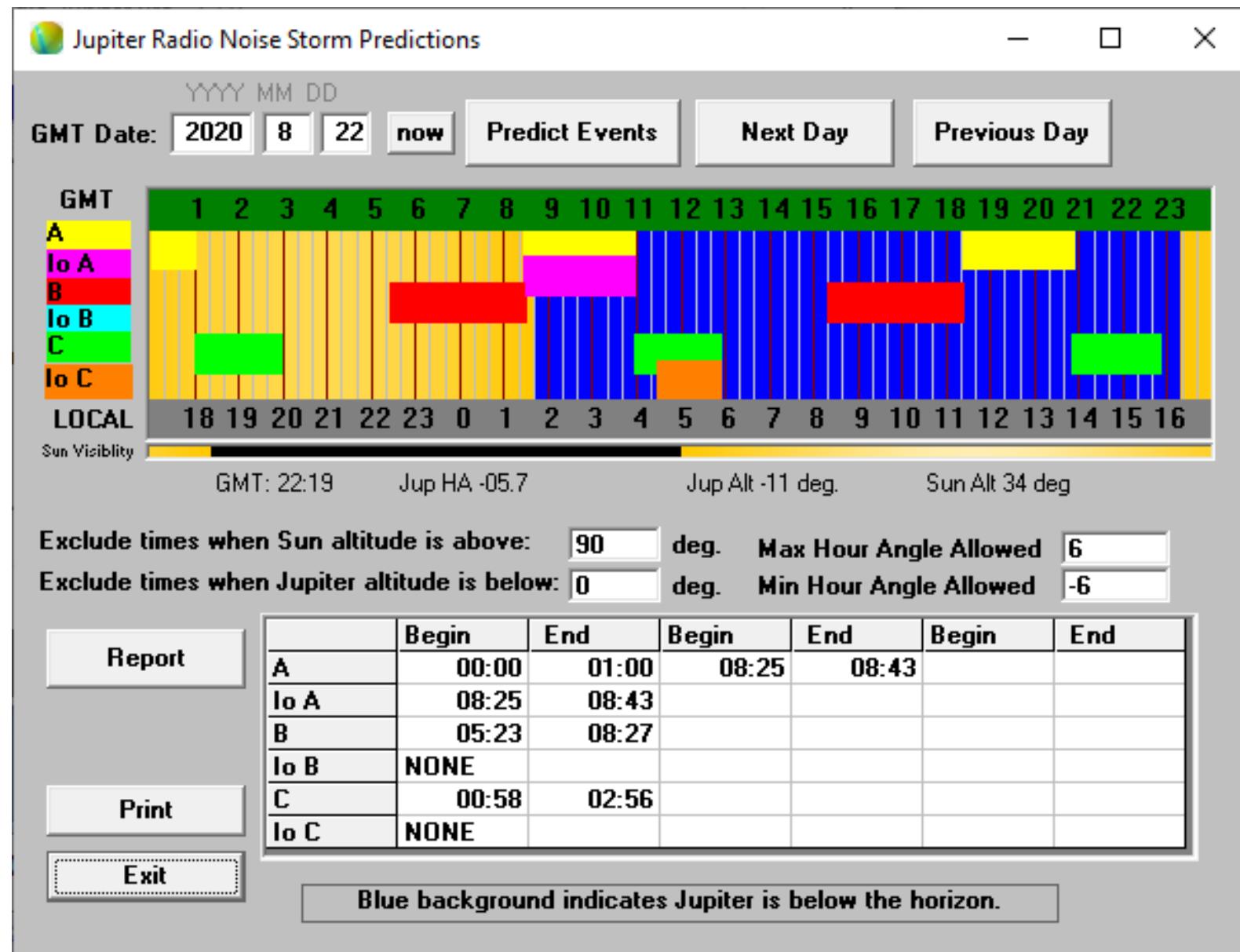
Jupiter/ Sun Overlap Plot



Jupiter Declination Over Time

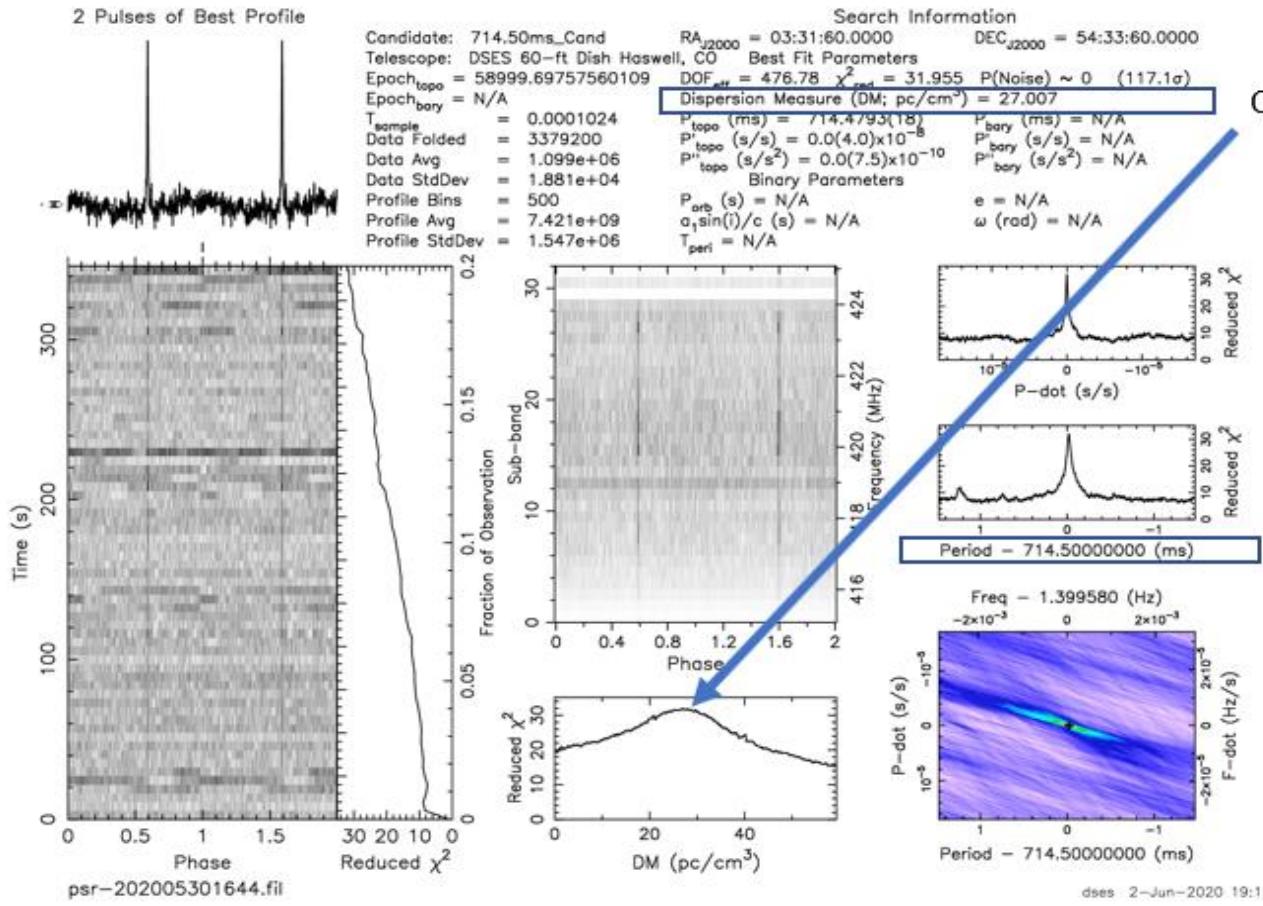


Jupiter Storm Predictions



Science Training

Pulsar Data Analysis and Equations



Observed DM

Observed spin period

Pulsar Formulas

Period: This value was both measured and provided by the ATNF database.

P-dot (\dot{P}): derivative of the spin period (ATNF)

$$\text{Frequency } (v) \quad v = \frac{1}{P} \quad (1)$$

$$\text{f-dot} \quad \dot{v} = \frac{\dot{P}}{P^2} \quad (2)$$

$$\text{f-dot dot} \quad \ddot{v} = \frac{2\dot{P}^2}{P^3} - \frac{\ddot{P}}{P^2} \quad (3)$$

The ATNF database does not have \ddot{P} so it is derived from equation 3 as:

$$\text{P dot dot} \quad \ddot{P} = \frac{2\dot{P}^2}{p} - \ddot{v}p^2 \quad (4)$$

Spin Down Luminosity:

$$\dot{E} = 4\pi^2 I \dot{P} P^{-3} \cong 3.95 \times 10^{31} \text{ erg s}^{-1} \left(\frac{\dot{P}}{10^{-15}} \right) \left(\frac{P}{s} \right)^{-3} \quad (5)$$

Source: Lorimer, D. and Kramer, M. *Handbook of Pulsar Astronomy*. s.l. : Cambridge University Press, 2004.

Pulsar Formulas

Assumption: 1.4 M_{sun} , neutron star with radius 10 km and moment of inertia $I=10^{45}$ g cm $\underline{\underline{2}}$.

Breaking Index (n): $n = 2 - \frac{P\ddot{P}}{\dot{P}^2}$ (6)

Characteristic Age: $\tau_c = \frac{P}{2\dot{P}}$ (7)

Surface Magnetic Field Strength: $B_S = 3.2 \times 10^{19} G \sqrt{P\dot{P}}$ (8)

Goldreich-Julian model of the pulsar magnetosphere plasma density at the polar cap:

$$\eta_{GJ} = \frac{\Omega B_S}{2\pi c e} \cong 7 \times 10^{10} \text{ cm}^{-3} \left(\frac{P}{s}\right)^{-1/2} \left(\frac{\dot{P}}{10^{-15}}\right)^{1/2} \quad (9)$$

Polar Cap Radius: $R^P = \sqrt{\frac{2\pi R^3}{cP}} \cong 150 m \left(\frac{P}{s}\right)^{-1/2}$ (10)

The potential drop between the magnetic pole and the polar cap

Pulsar Formulas

The potential drop between the magnetic pole and the polar cap

$$\Delta\Psi = \frac{B_S \Omega^2 R^3}{2c^2} \cong 2 \times 10^{13} V \left(\frac{P}{s}\right)^{-3/2} \left(\frac{\dot{P}}{10^{-15}}\right)^{1/2} \quad (11)$$

Light Cylinder Radius: $R_{LC} = \frac{c}{\Omega} = \frac{cP}{2\pi} \cong 4.77 \times 10^4 km \left(\frac{P}{s}\right)$ (12)

Corresponding dipole magnetic field: $B_{LC} = B_S \left(\frac{\Omega R}{c}\right)^3 \cong 9.2 G \left(\frac{P}{s}\right)^{-5/2} \left(\frac{\dot{P}}{10^{-15}}\right)^{1/2}$ (13)

B0329+54 Observation

The presto output of B0329+54 is shown in figure 2. The measured spin period was: 714.50 ms. and the DM was: 27.007 pc cm^{-3} . The ATNF values were: period = 714.5197 ms. and the DM = 26.7641 pc cm^{-3} .

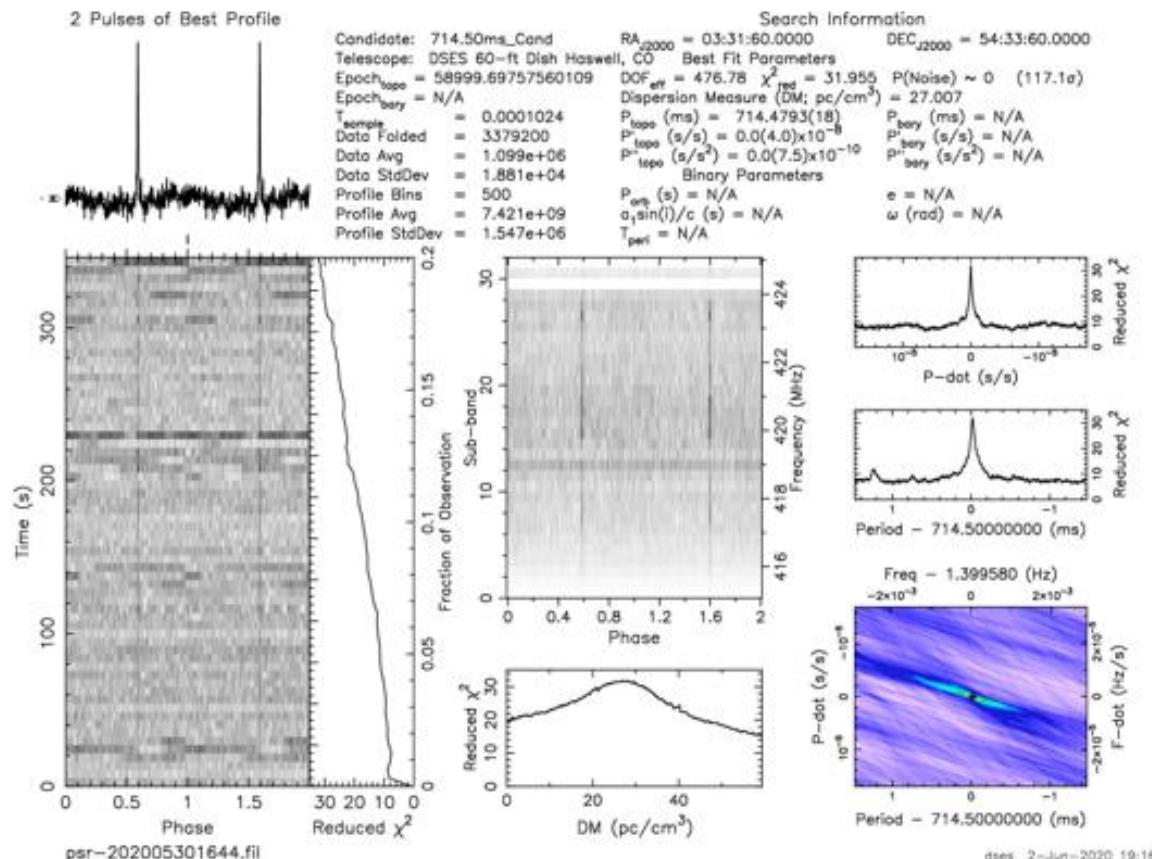
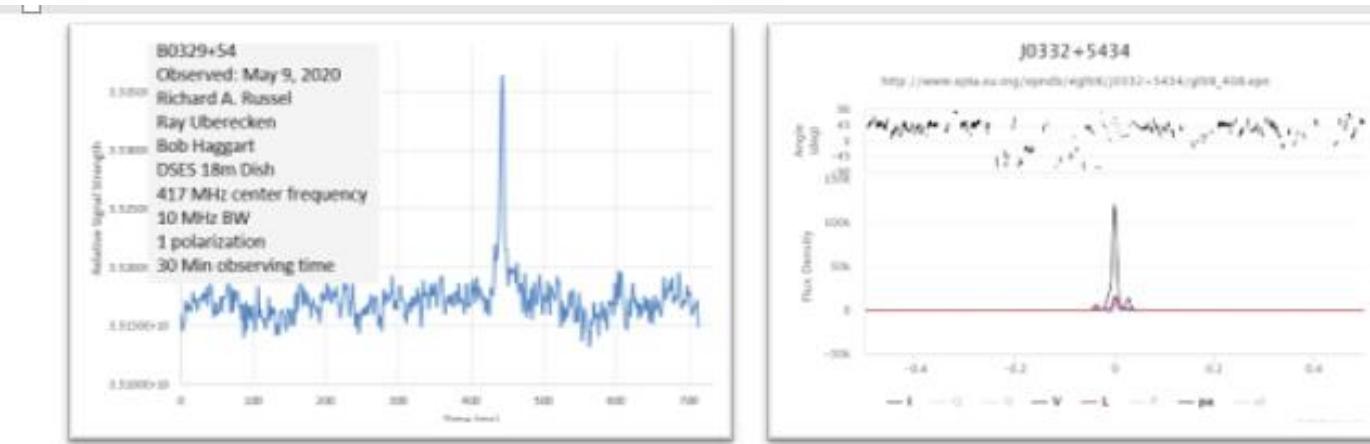


Figure 2: PRESTO Output of B0329+54

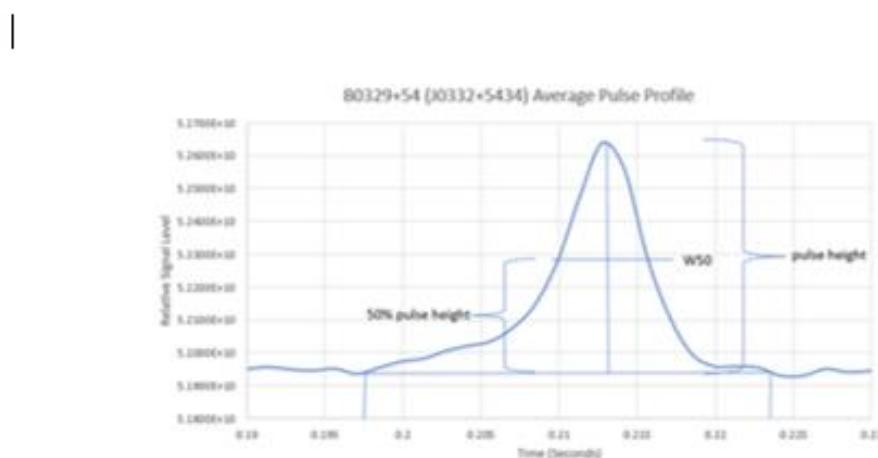
B0329+54 Analysis



<http://www.epta.eu.org/epndb/>

Figure 3: B0329+54 Plot of One Spin Period next to the EPN database observation

The pulse width W(50) can be determined by measuring the width of the pulse at 50% of the pulse height compared to the average noise level. (figure 4)

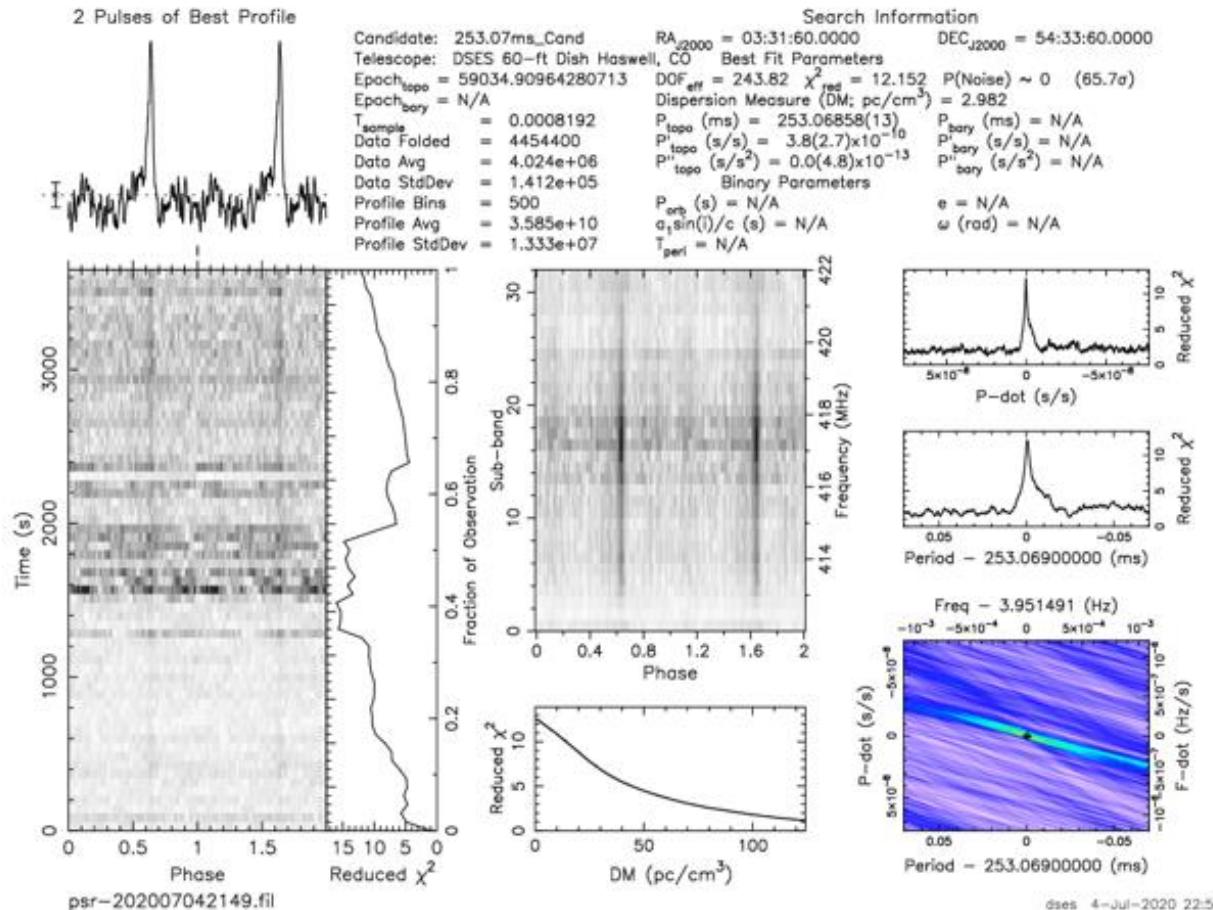


**W(50) is 50% of pulse height
Expected value for B0329+54 is 6.6 ms
Value measured is approx. 6.0 ms**

Figure 4: Pulse Width W(50) for B0329+54

B0950+08 Observation

The spin period of B0950+08 was measured to be: 253.06858 ms the DM was measured to be: 2.982 pc cm^{-3} . (figure 5). This is compared to the ATNF values of: period =252.58 ms. and DM =2.96393 pc cm^{-3} .



B0950+08 Analysis

The raw data output for one spin period is plotted in figure 6 along with the EPN (3) database observation.

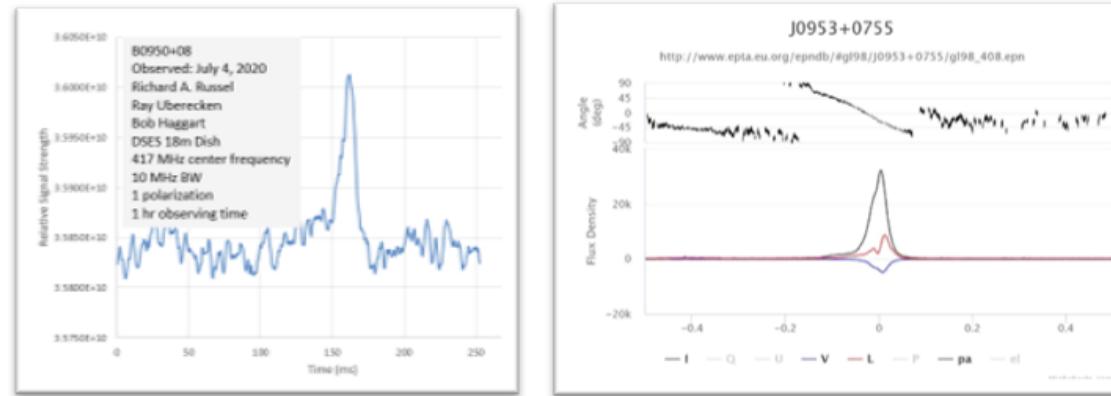


Figure 6: B0950+08 Raw Data Plot of One Spin Period and the EPN database observation

The W(50) value was measured to be 11 ms vs. the ATNF (2) database value of 9.1 ms. (figure 7)

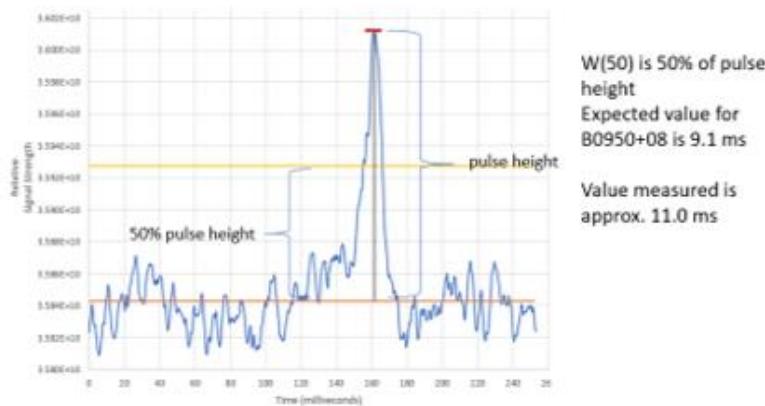


Figure 7: B0950+08 W(50) Plot

B1133+16 Observation

The spin period of B1133+16 was measured to be: 1187.954 ms and the DM was measured to be: 4.86 pc cm⁻³. (figure 8) The ATNF values were: period = 1187.913 ms. and the DM = 4.8407.

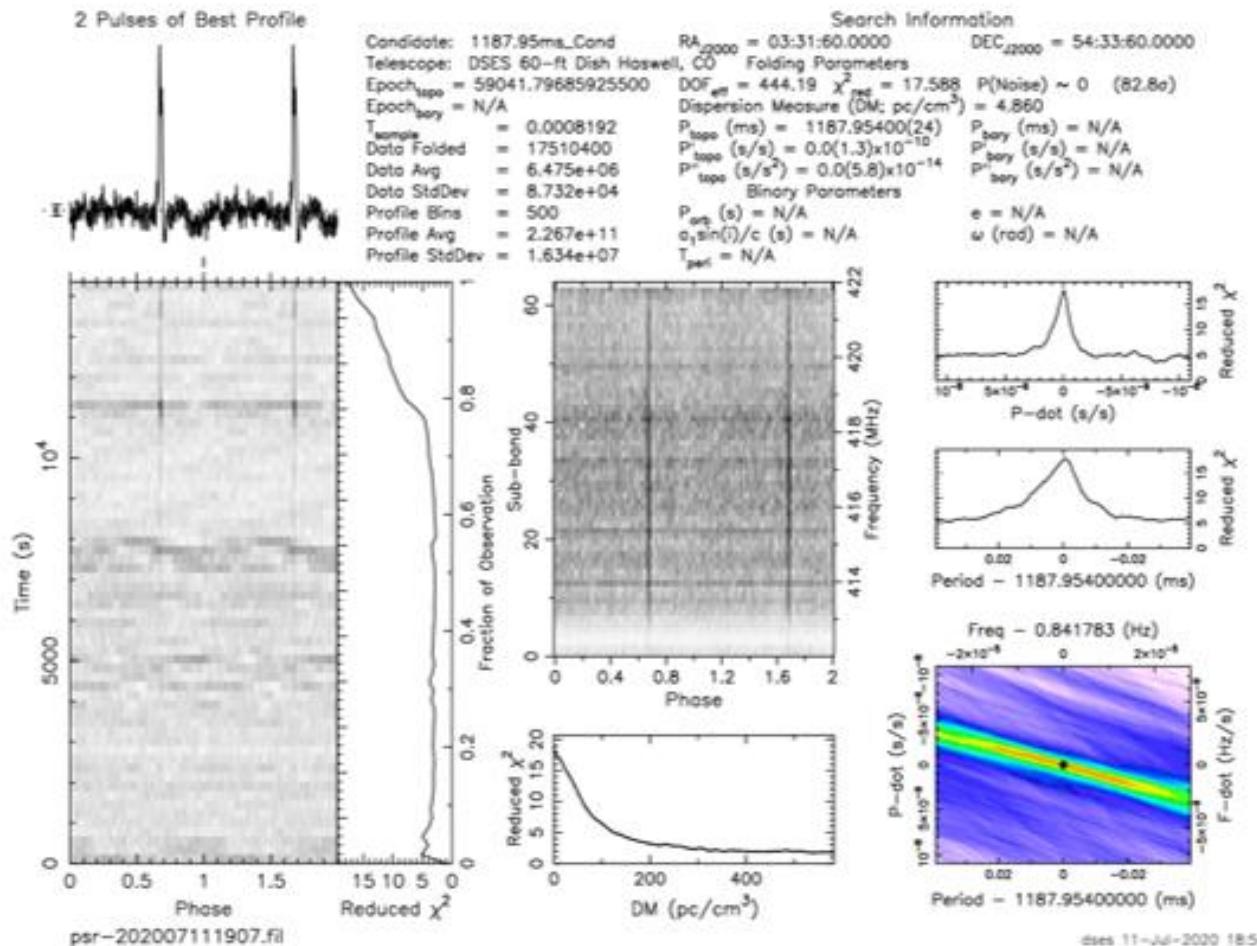


Figure 8: B1133+16 PRESTO Output

B1133+16 Analysis

The raw data plot for one spin period of B1133+16 is shown in figure 9 along with the EPN (3) database observation.

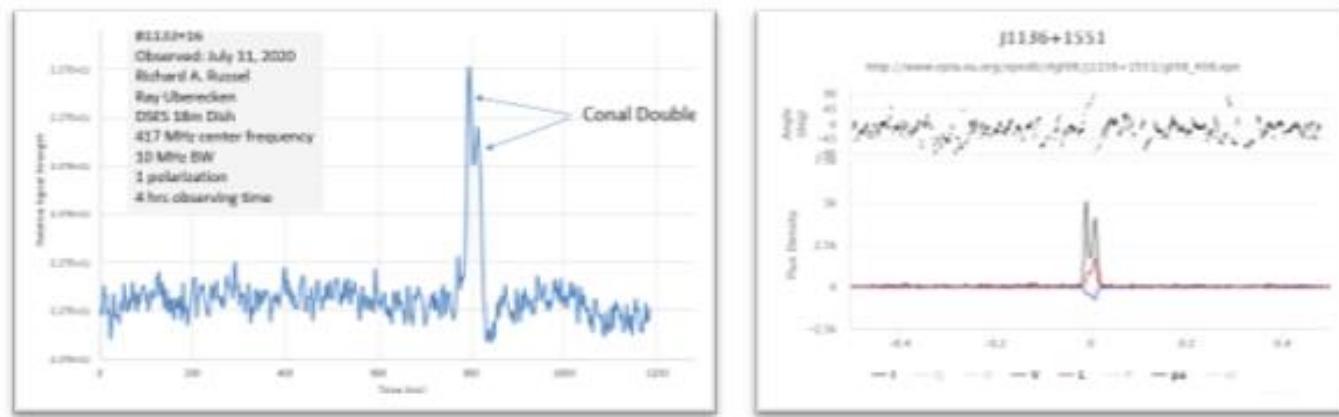


Figure 9: B1133+16 Raw Data Plot of One Spin Period with the EPN (3) database observation

The derivation of W(50) is shown in figure 10. Note that the measured value of 27 ms. is significantly larger than the ATNF database value of 5.9 ms.

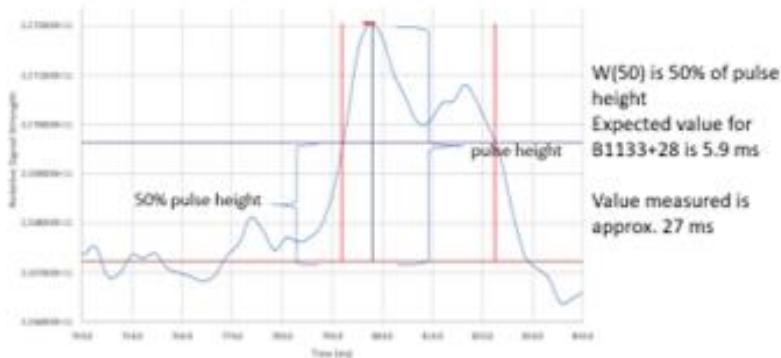


Figure 10: B1133+16 Raw Data W(50) Measurement

2nd Pulse Analysis

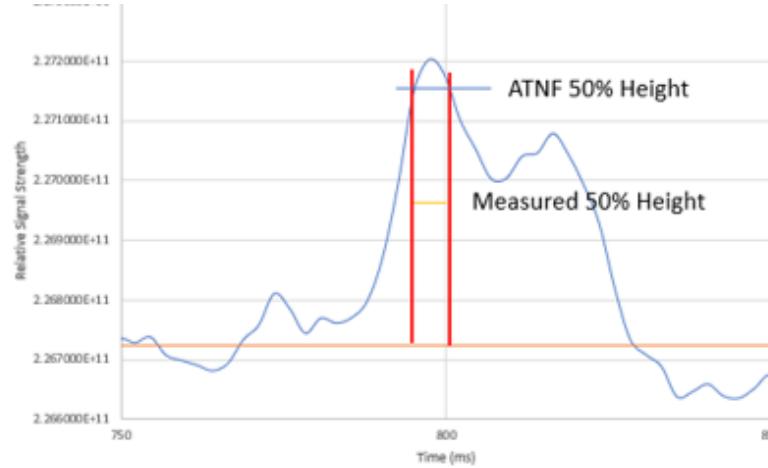


Figure 11: Measured vs ATNF 50% height

The W(50) of the second pulse was measured to be 16 ms. (figure 12).

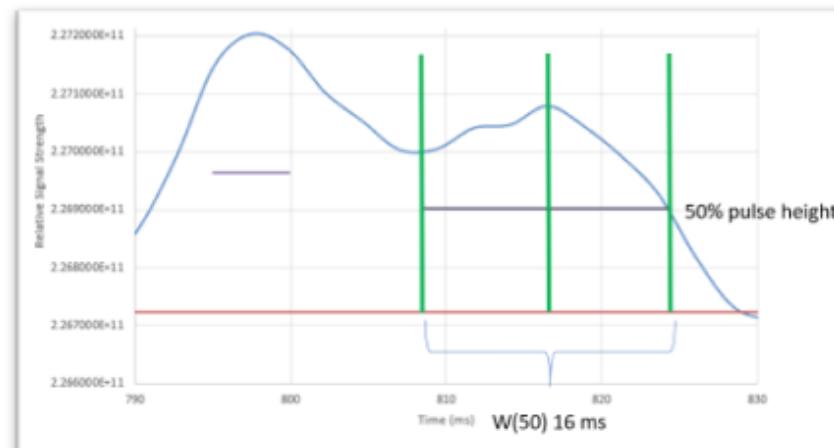
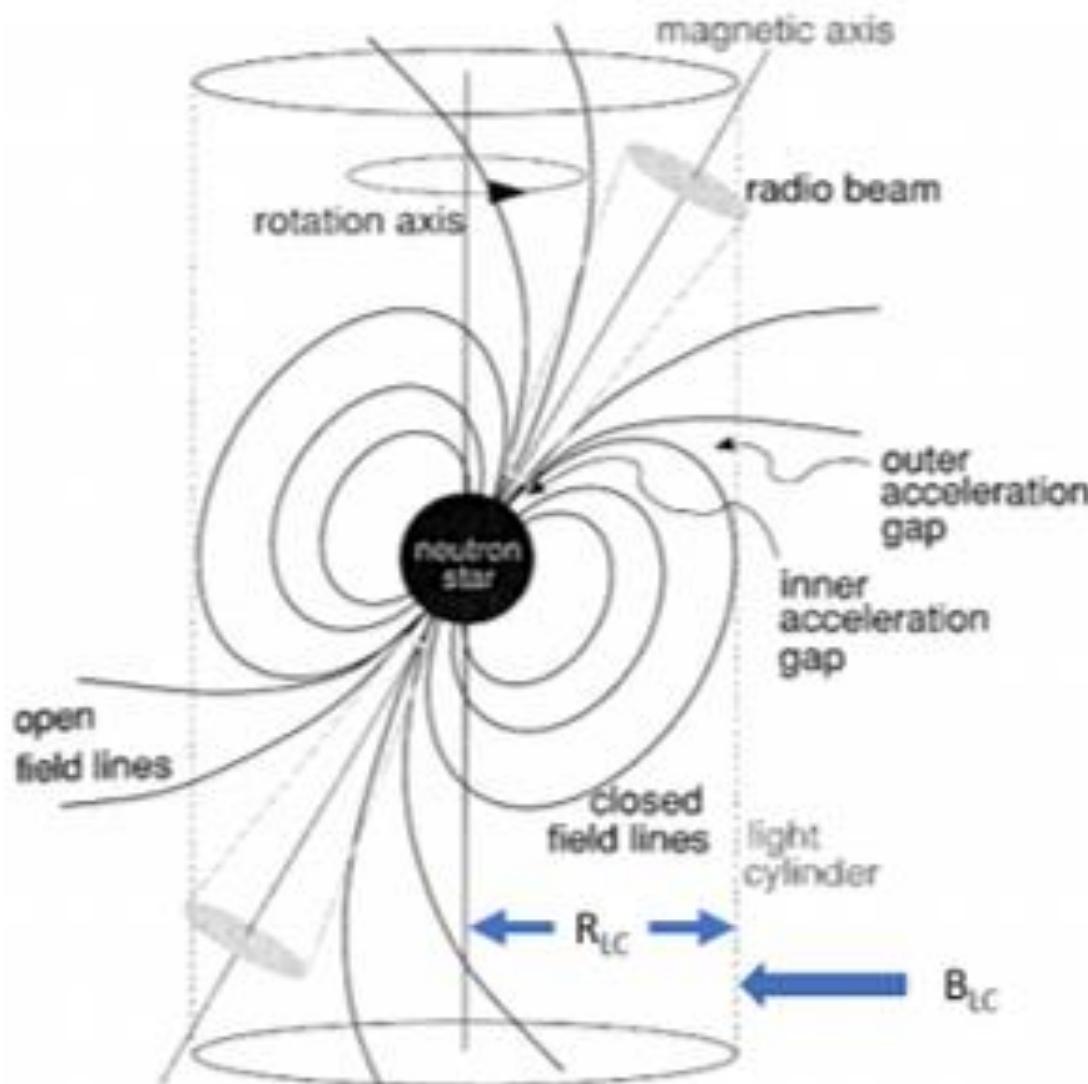


Figure 12: Second Pulse Measured W(50)

Pulsar Geometry



Source: Lorimer, D. and Kramer, M. *Handbook of Pulsar Astronomy*. s.l. : Cambridge University Press, 2004.

Calculated Parameters

Parameter	B0329+54	B0950+08	B1133+16	Units	Equation
P	0.7145197	0.25258	1.187913066	seconds	ATNF
P-dot	2.05E-15	2.30E-16	3.73E-15	seconds/second	ATNF
P-dot-dot	-2.59E-28	4.85E-28	-1.20E-27	seconds/seconds ²	
Dispersion Measure (DM)	26.7641	2.9693	4.8407	pc/cm ³	ATNF
Pulse Width 50% (W(50))	6.6	8.9	5.9	ms	ATNF
f	1.40	3.96	0.84	hz	1
f- dot	4.01E-15	3.60E-15	2.65E-15	s ⁻²	2
f- dot-dot	5.30E-28	-7.60E-27	8.70E-28	s ⁻³	ATNF
E _{dot} (Spin down luminosity)	2.22E+32	5.60E+32	8.80E+31	ergs/second	4
n (braking index)	-4.41E+01	2.34E+03	-1.03E+02		5
age (Myears)	5.53	17.46	5.04	Myears	6
Surface Magnetic Field Strength	1.22E+12	2.44E+11	2.13E+12	Gauss	7
η GJ Goldreich- Julien plasma density	3.75E+03	2.11E+03	3.92E+03	cm ⁻³	8
R _p (polar cap radius)	126.8	75.5	163.5	meters	9
$\Delta\psi$ (potential drop between magnetic pole and polar cap)	1.50E+06	2.38E+06	9.44E+05	V	10
RLC (light cylinder)	3.41E+04	1.21E+04	5.67E+04	km	11
BLC (Light cylinder dipole magnetic field)	9.65E-07	4.33E-06	3.66E-07	Gauss	12

Figure 14: Calculated Parameters

Summary

- Formulas for the parameters of a pulsar are shown in the HPA. The amateur radio astronomer has the capability of deriving important pulsar science using these formulas.
- This has been an excellent exercise in using radio astronomy observations to derive science. This exercise can be used by professionals and college students alike to characterize pulsars.

Questions?