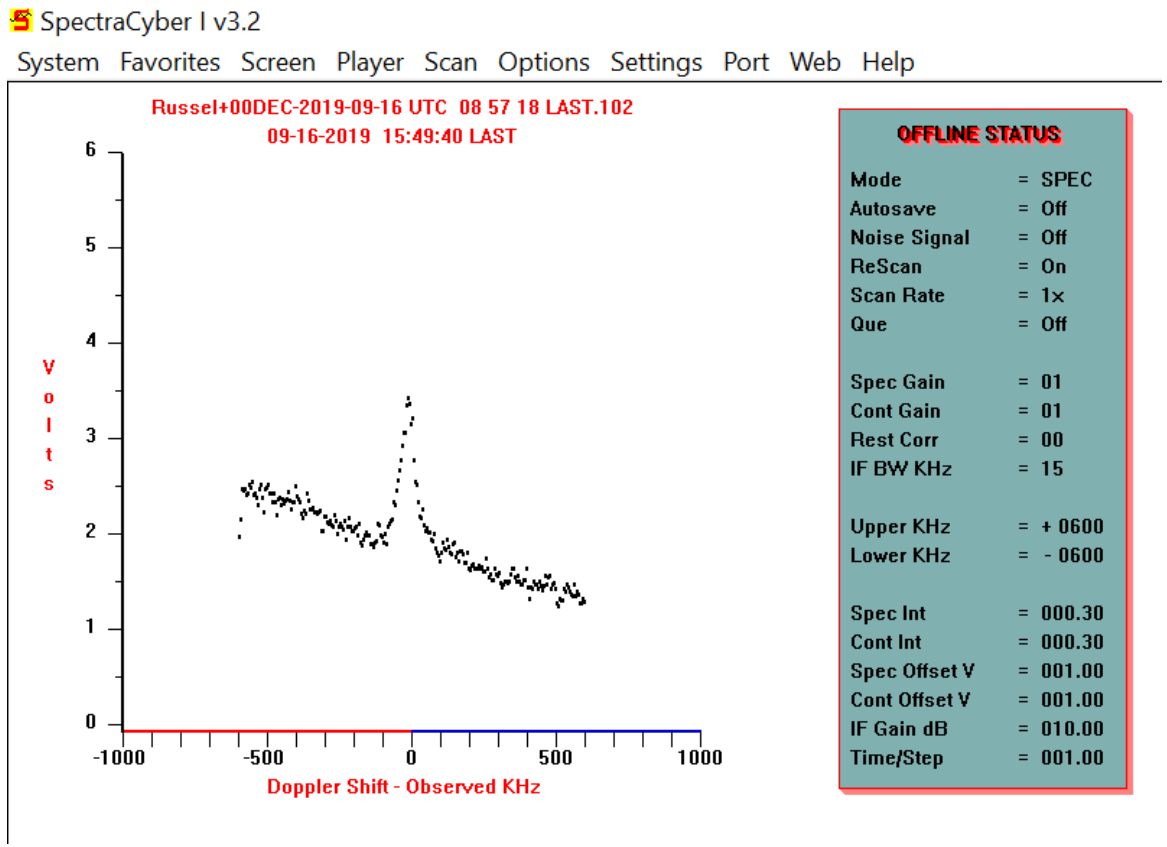
Deep Space Exploration Society
Science Meeting

HI Observations



January 25, 2021

Dr. Richard Russel

DrRichRussel@netscape.net

DSES.science

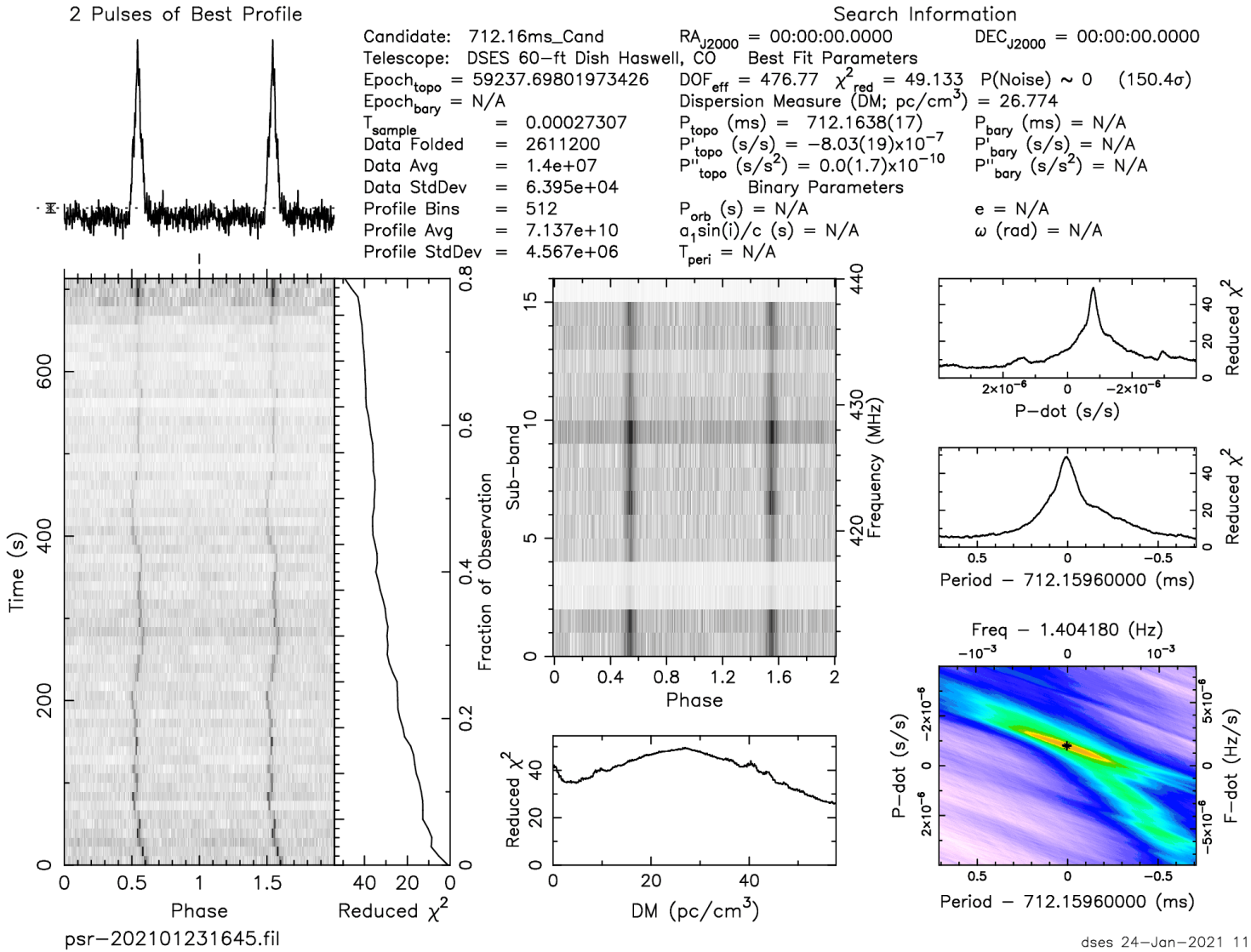
Information

- 9 ft Dish – Spectracyber running
- SuperSID – Working and porting data to Stanford
- Radio Jupiter – still need to get a new receiver and setup at site
- Pulsar – 408 MHz – Trip 1-25-21
  - Attempted 5 different pulsars only got +54
  - Issues with B210
  - Issues with pointing system

Pulsar Trip 23 Jan 2021

- Configuration
  - B210 (no frequency standard)
  - 30 MHz
  - 425 MHZ center frequency (avoided RFI)
- Attempted
  - B0329+54 – good, 15 min, 1100mJY, 30 MHz
  - B2111+46 – No, 60 min, 230 mJY, 30 MHz
  - B2020+28 – No, 180 min, 71 mJY, 30 MHz
  - B1937+21 – No, 60 min, 240 mJY, 25 MHz

B0329+54 60 ft Dish 23 Jan 2021



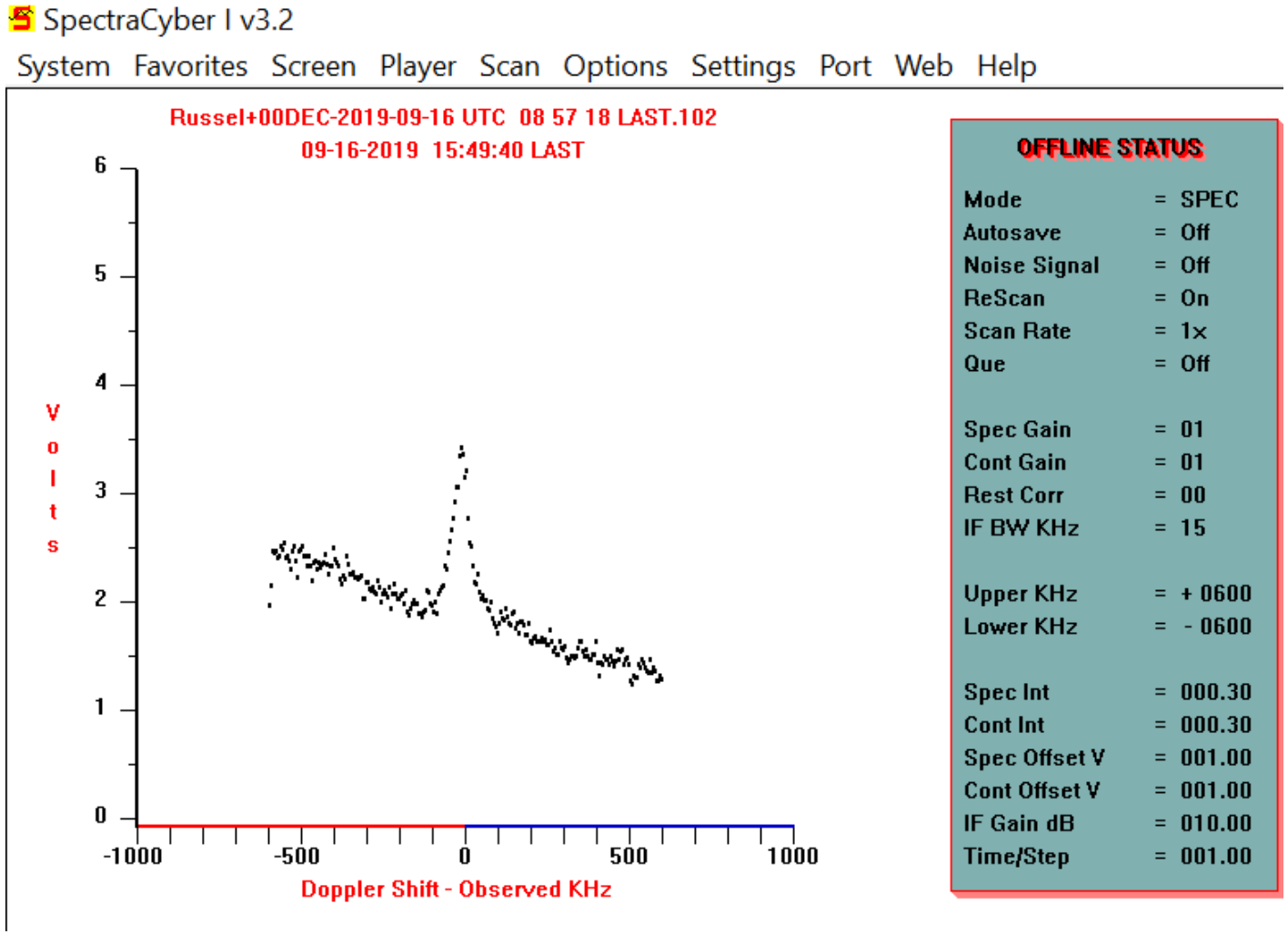
Pulsar Trip Issues/Lessons Learned

- B0329+54: Conducted a 15 min run and was able to get a good detection. The picture, looked wavy, may mean that the B210 needed to have a more stable input clock.
- After all data was taken, discovered that the cable had a 3dB attenuator.
  - Note that the B210 has a very flat signal across the bandwidth
  - This means that the gain can be increased
  - Need to verify gain above 50 in the spectrum monitor
- Bandwidth – used the max BW that the laptop could handle (30 MHz)
  - Change to 5, 10, 25, 50, or 100 MHz options only

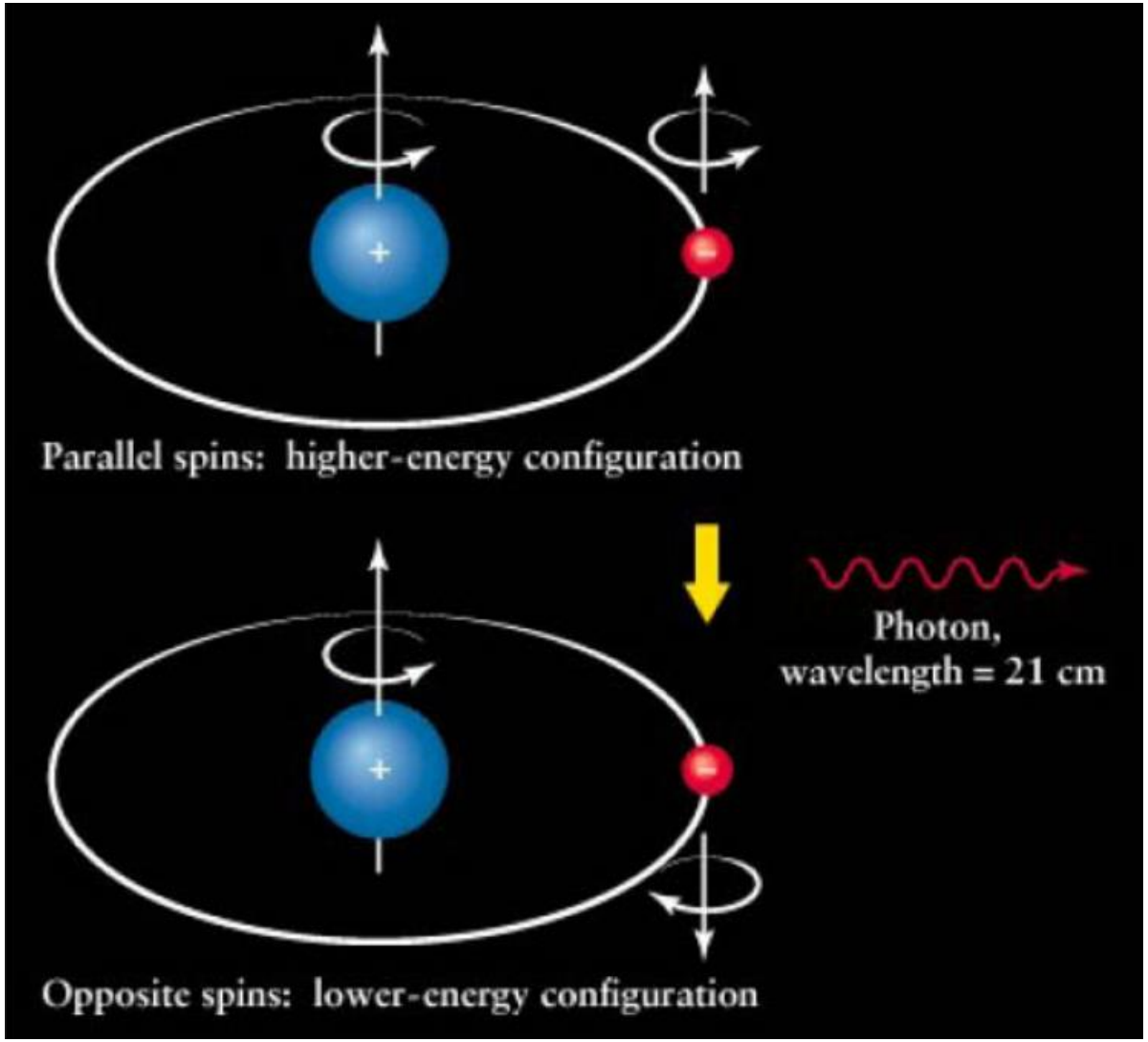
Pulsar Trip Issues/Lessons Learned

- Get better laptop
  - Need USB 3 ports
  - Need more cores
- Pointing System Issues
  - Verified good pointing with the detection of B0329+54
  - Had a power glitch (site power)
    - Laptop screen froze but antenna continued to move and went into the stops
  - Had an accidental removal of power to the ethernet switch
    - Laptop screen froze and antenna went into the stops
  - Both events were corrected by manually moving antenna while pushing override button
  - Recommended correction: Add battery backup for Rasdberry Pis and ethernet switches and hubs

HI Observations



Neutral Hydrogen



https://astronomylog.files.wordpress.com/2013/06/hyperfine.jpg

Milky Way Galaxy

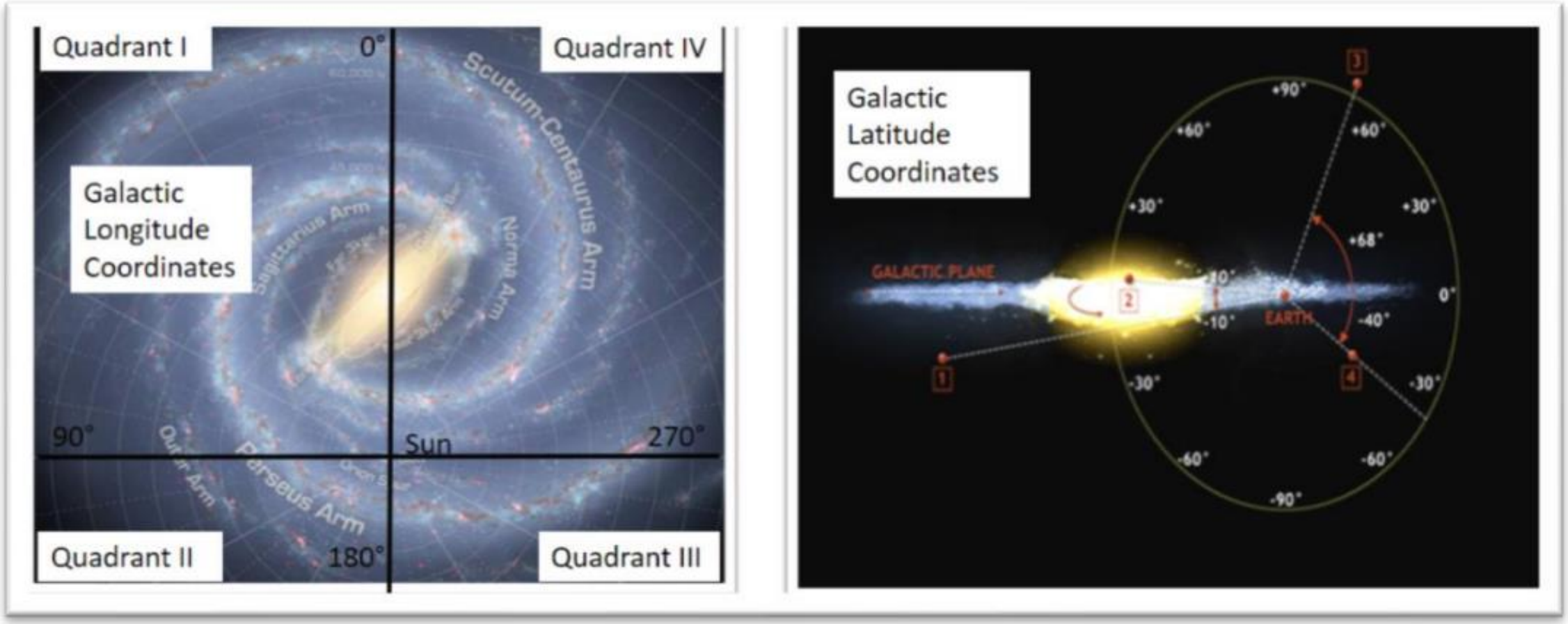
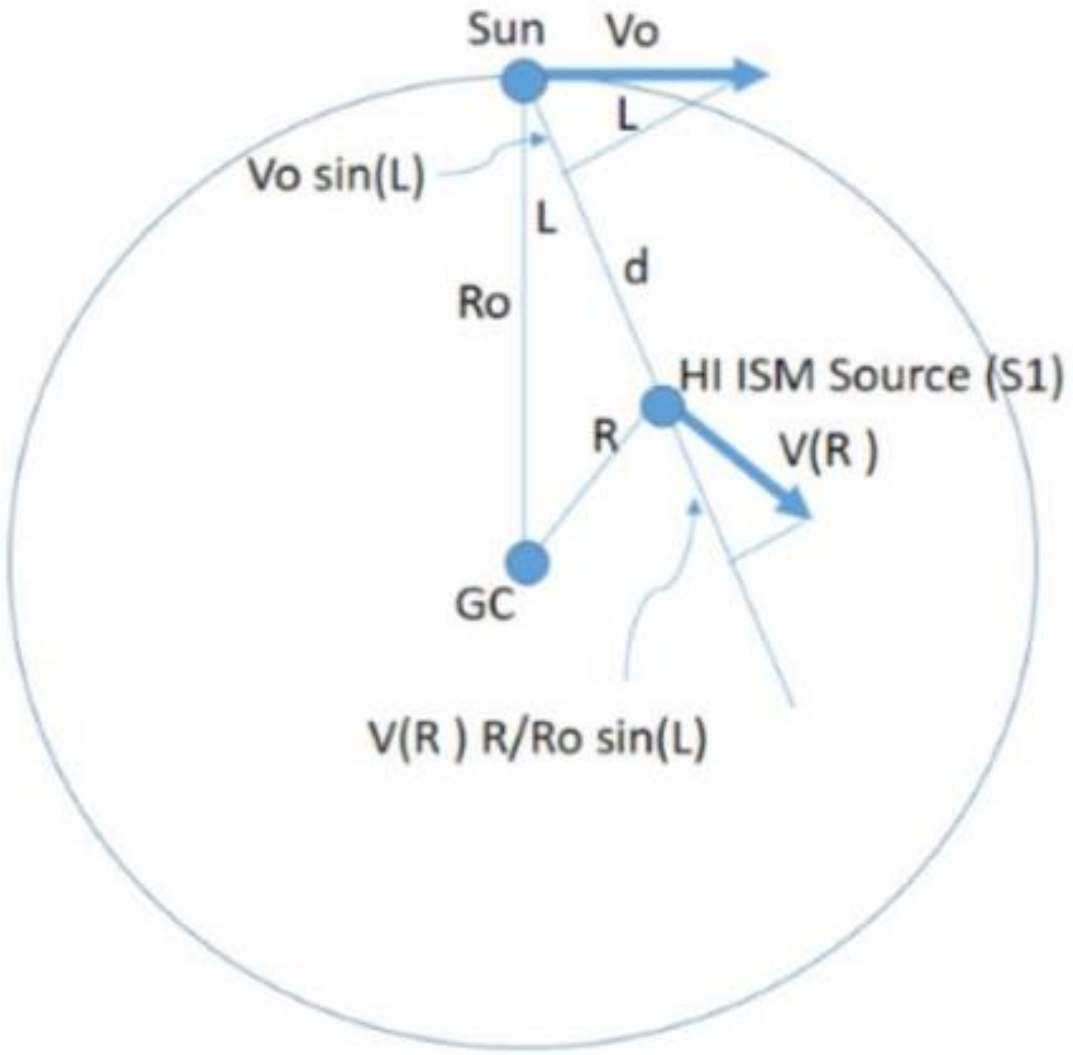


Figure 1: Milky Way Longitude and Latitude Coordinates (8), (9)

8. Charting the Milky Way From the Inside Out. [Online] 2015. https://www.nasa.gov/jpl/charting-the-milky-way-from-the-inside-out.
9. Galactic Navigation. [Online] http://chandra.si.edu/build/navigation.html.

HI Geometry



Sofue, Y. (2017). Galactic Radio Astronomy. Singapore: Springer.

Spectracyber Install at Haswell

Figure 3: Communications Trailer and Equipment Rack

Spectracyber Data Collection

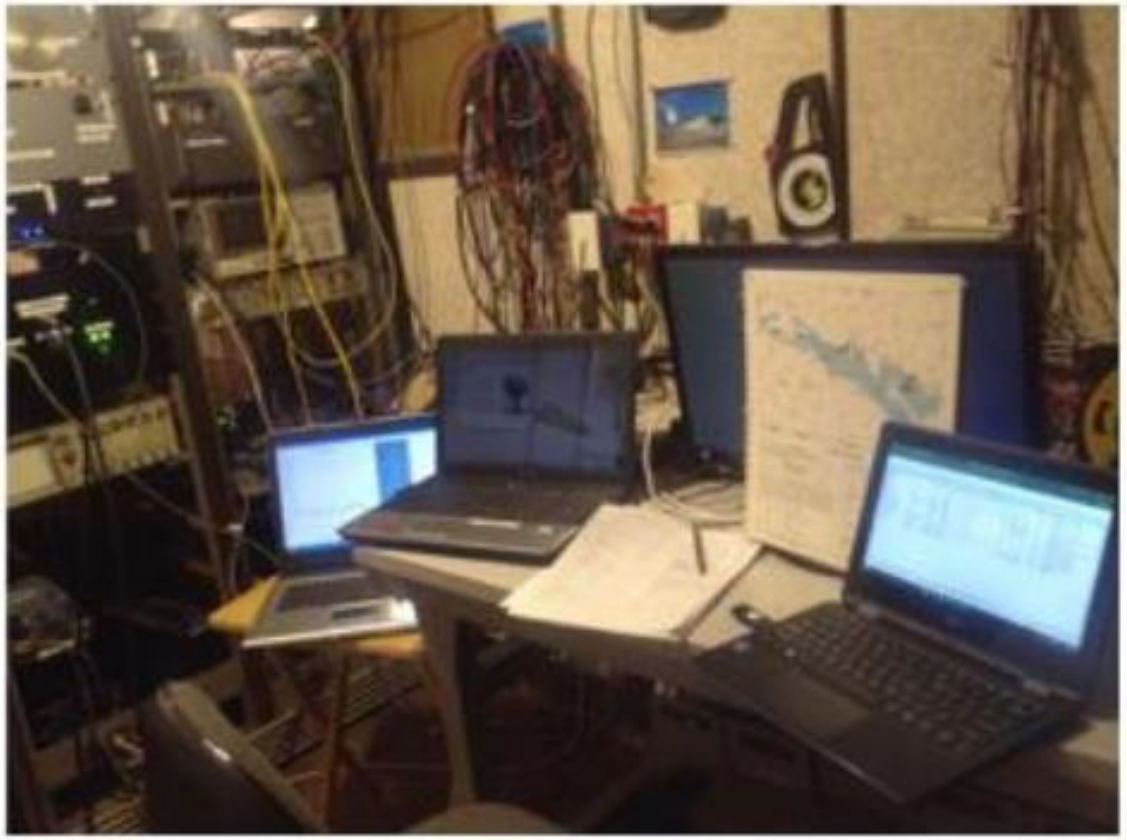
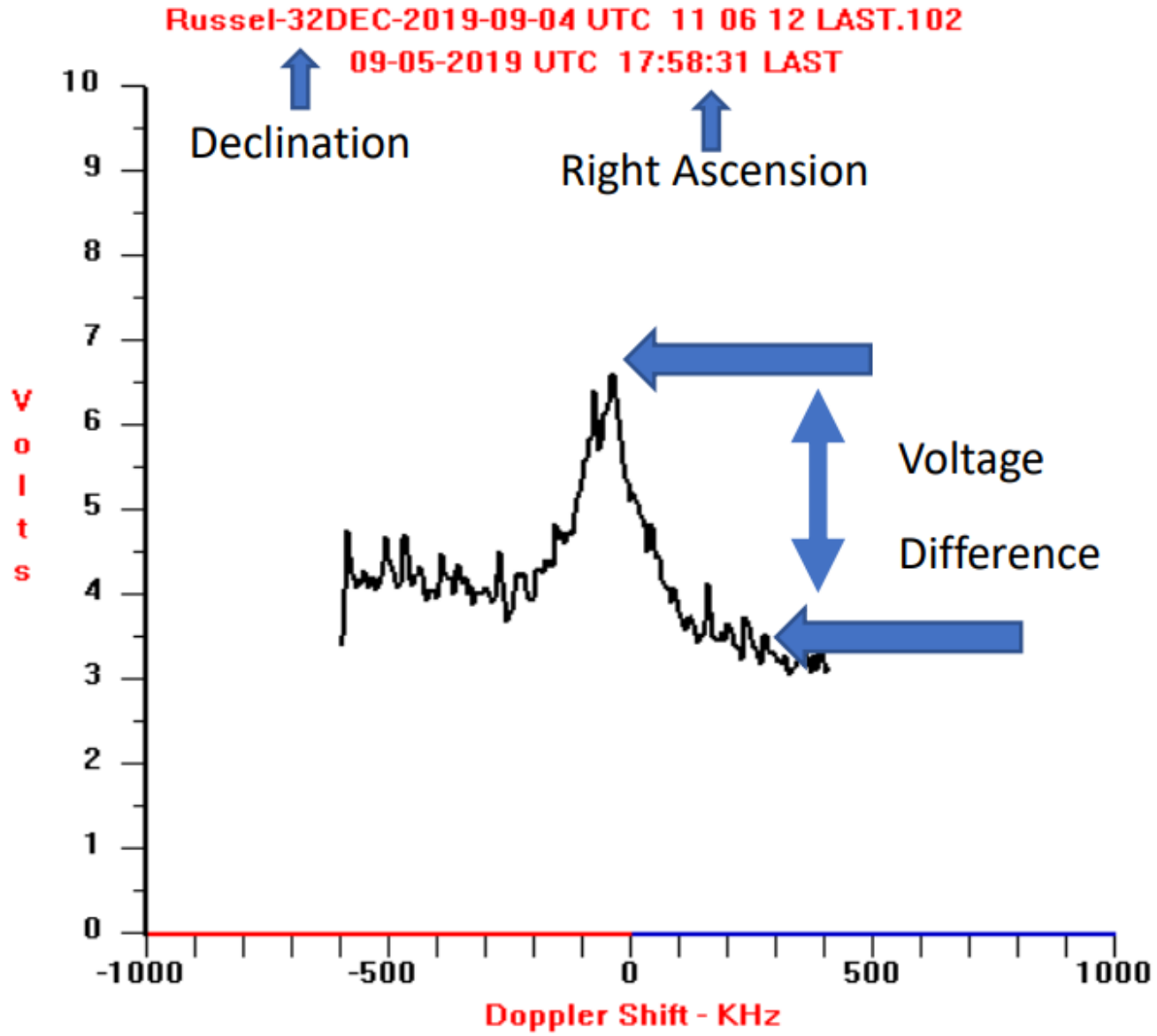


Figure 2: Observing Station for 60-foot Dish

Spectracyber Output



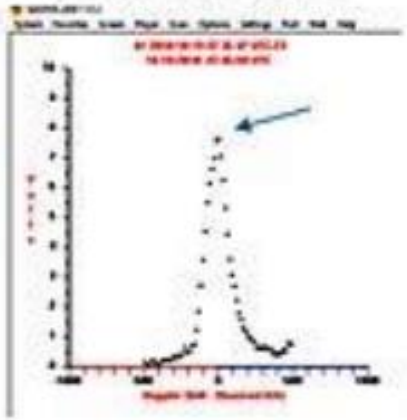
ONLINE STATUS

Mode	=	SPEC
Autosave	=	On
Noise Signal	=	Off
ReScan	=	On
Scan Rate	=	1x
Que	=	Off
Spec Gain	=	05
Cont Gain	=	01
Rest Corr	=	00
IF BW KHz	=	30
Upper KHz	=	+ 0600
Lower KHz	=	- 0600
Spec Int	=	001.00
Cont Int	=	000.30
Spec Offset V	=	002.70
Cont Offset V	=	000.00
IF Gain dB	=	025.00
Time/Step	=	001.00

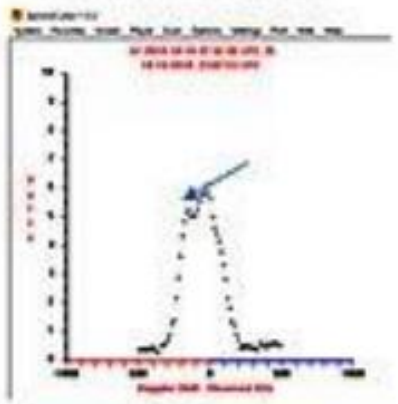
KHz = 405 Vdc = 3.145

Spectracyber Example Output
Galactic Rotation Data (10-20-18 Observations)

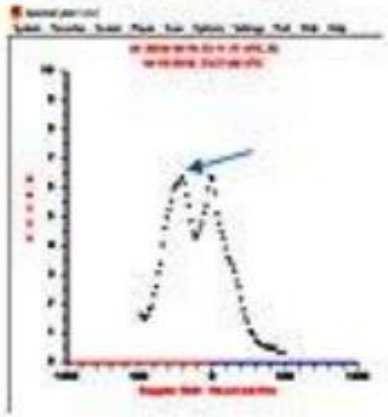
GLat 0 Glong 0



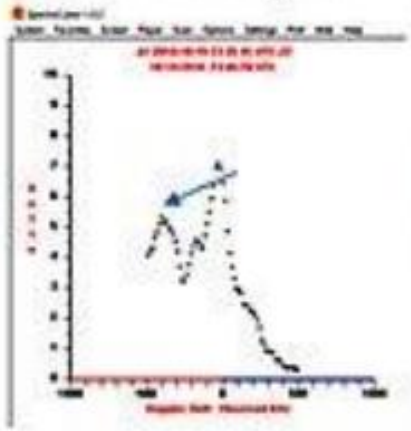
GLat 0 Glong 10



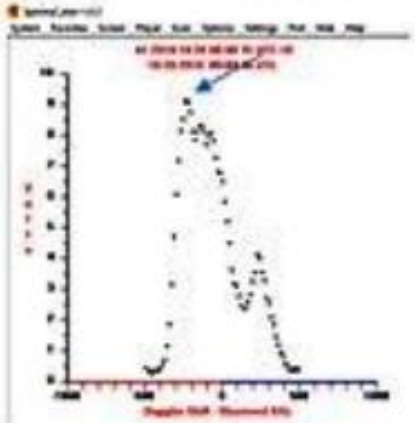
GLat 0 Glong 20



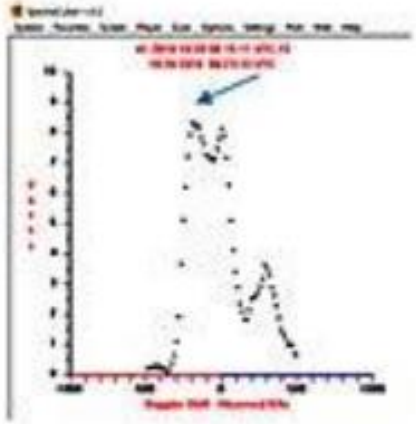
GLat 0 Glong 30



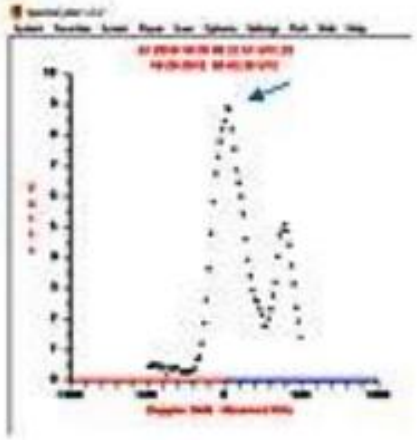
GLat 0 Glong 40



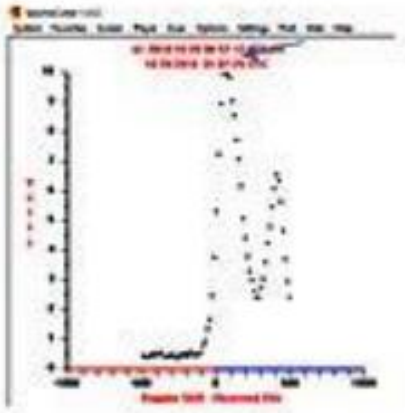
GLat 0 Glong 50



GLat 0 Glong 60

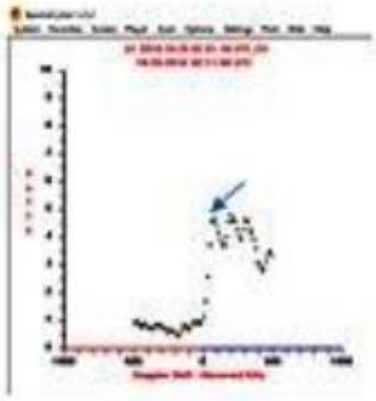


GLat 0 Glong 70



GLat 0 Glong 80

GLat 0 Glong 90



Milky Way Rotation Rates

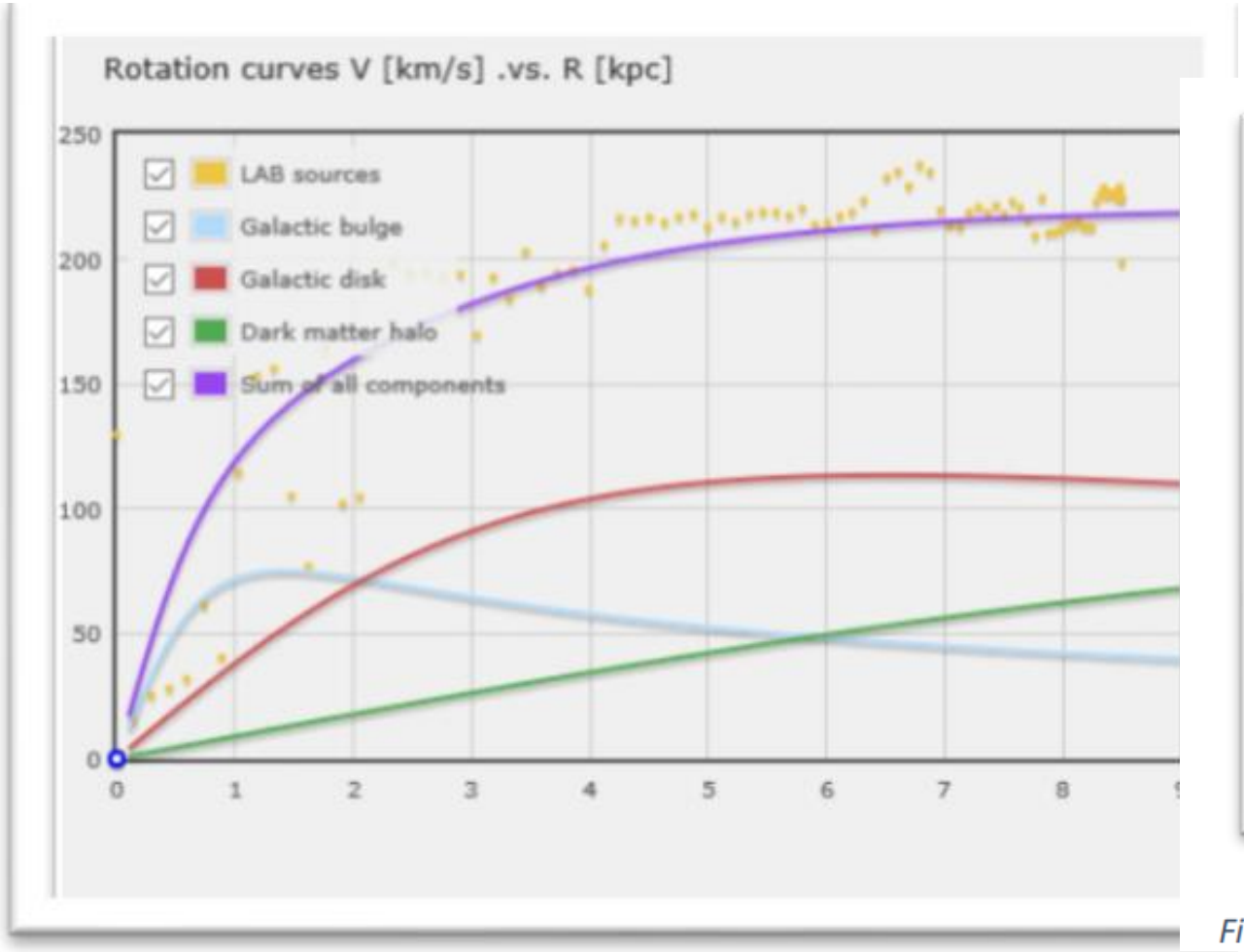


Figure 5: Baseline Galaxy Rotation Curve (10)

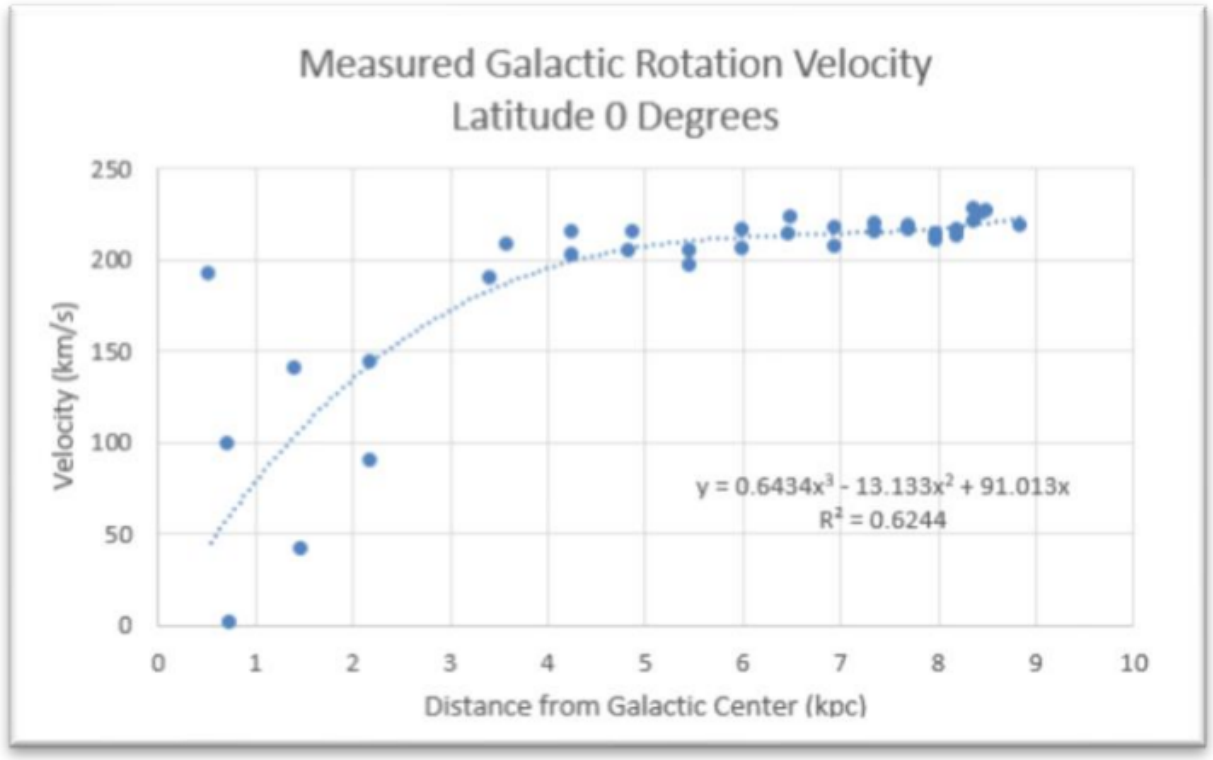


Figure 6: Rotation Rate Curve (0 Galactic Latitude)

10. Rudolph, Alexander. Understanding the Rotation of the Milky Way Using Radio Telescope Observations. [Online] http://euhou.obspm.fr/public/

Rotation Curves with Error Estimates

The plot of the results with error bars is shown in figure 5.

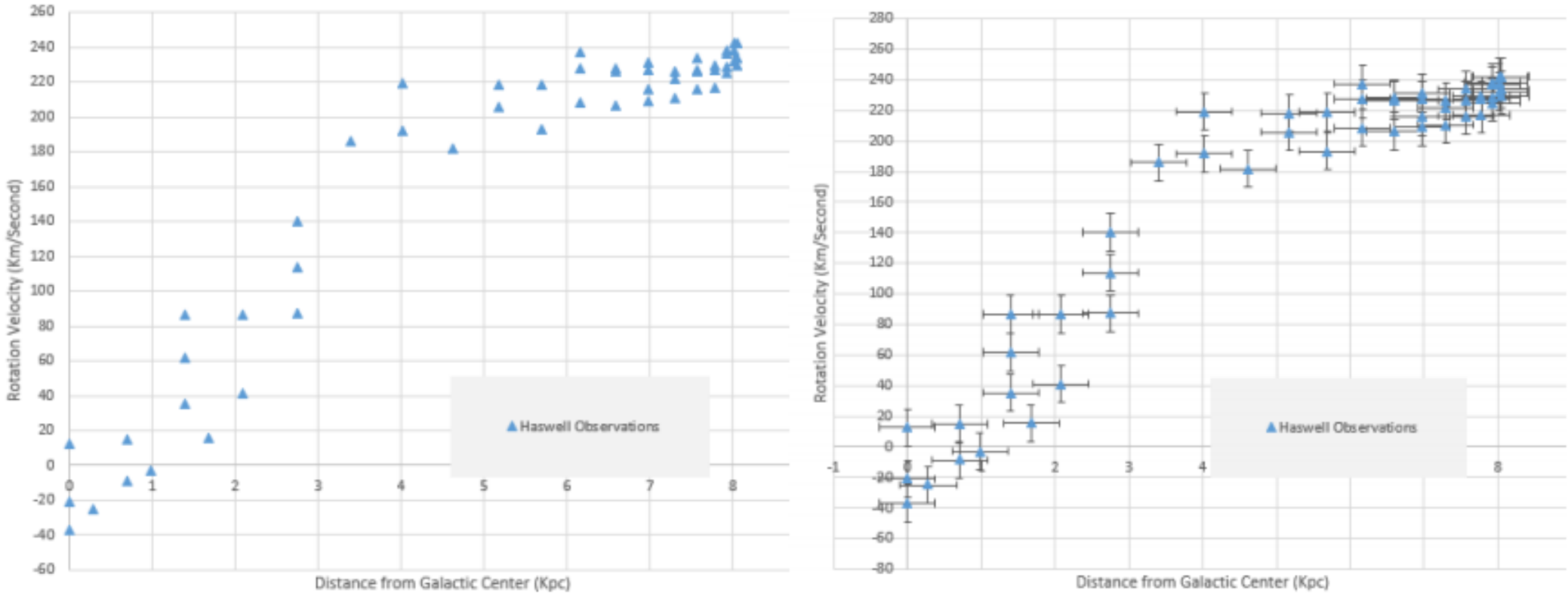


Figure 5: Galactic Rotation Plot

Calculating the Mass of the galaxy

M: Mass of galaxy (kg)
V: Velocity of the galaxy at distance R (km/second)
R: distance from galactic center (m)
G: Gravitation constant $6.67x10^{-11}m^3kg^{-1}s^{-2}$

From the measured results in table 3, the calculated velocity of the galaxy at 8.05±0.46 kpc is 243.3±16.2 km/s. Entering these values into equation 5 with the appropriate conversions:

$$M = \frac{\left(243.3\frac{km}{s}x\frac{10^3m}{km}\right)^2(8.05kpc)\left(\frac{3.09x10^{19}m}{1kpc}\right)}{(6.67x10^{-11}m^3kg^{-1}s^{-2})} = 2.21x10^{41}kg \quad (6)$$

$$M = (2.21x10^{41}kg)\left(\frac{1\,M_{Sun}}{2x10^{30}kg}\right) = 1.10x10^{11}M_{Sun} \quad (7)$$

The error range was calculated by substituting the Vo and Ro error ranges into the formulas which results in a total error range of:

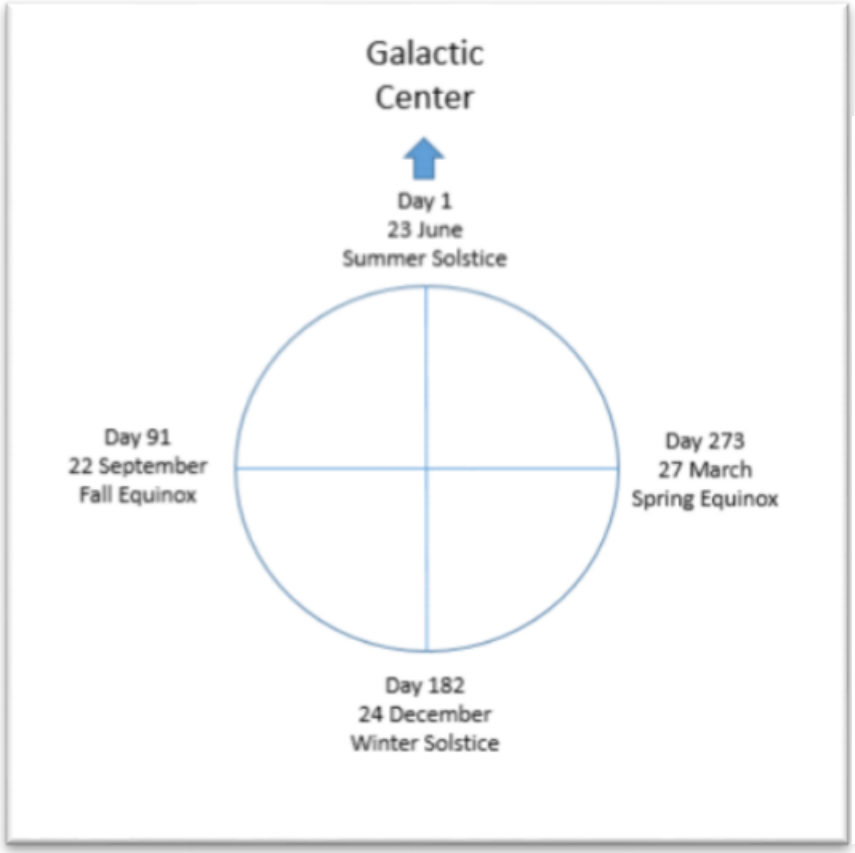
$$\mathrm{M}= 1.10x10^{11} \pm 0.22x10^{11}M_{Sun} \quad (8)$$

The estimate for the mass of the Milky Way has been estimated as (Sofue, 2017):

$$M = (1.0x10^{11})M_{Sun}\left(\frac{R}{Ro}\right) \quad (9)$$

The observed measurements, therefore, encompass the historic values of the Milky Way's mass.

Earth Position vs. Galactic Center



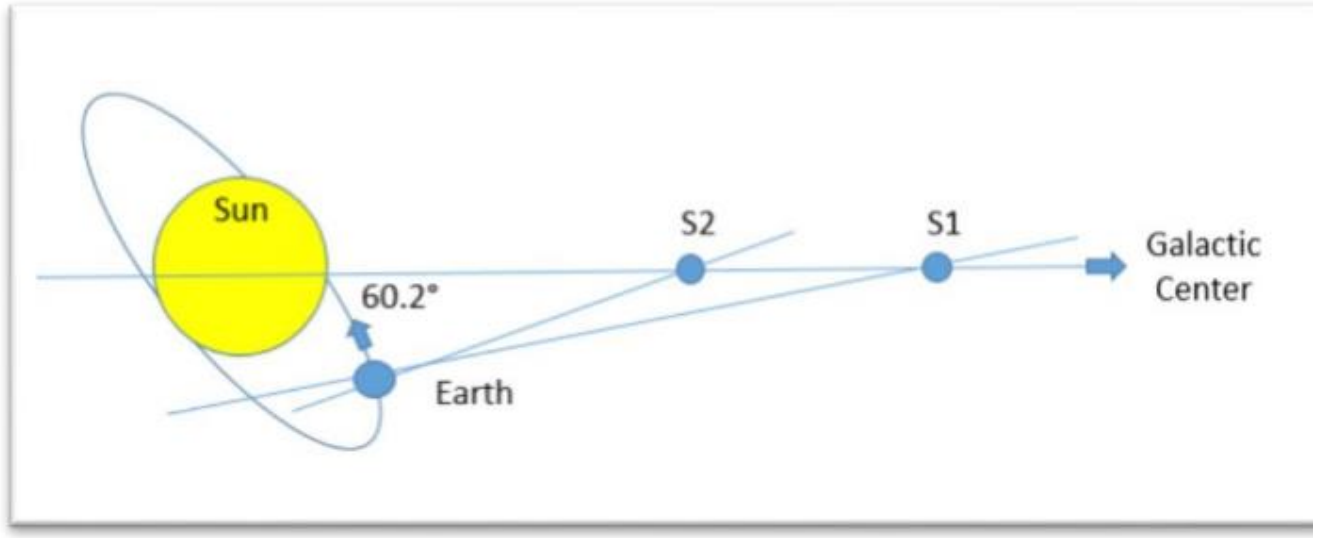
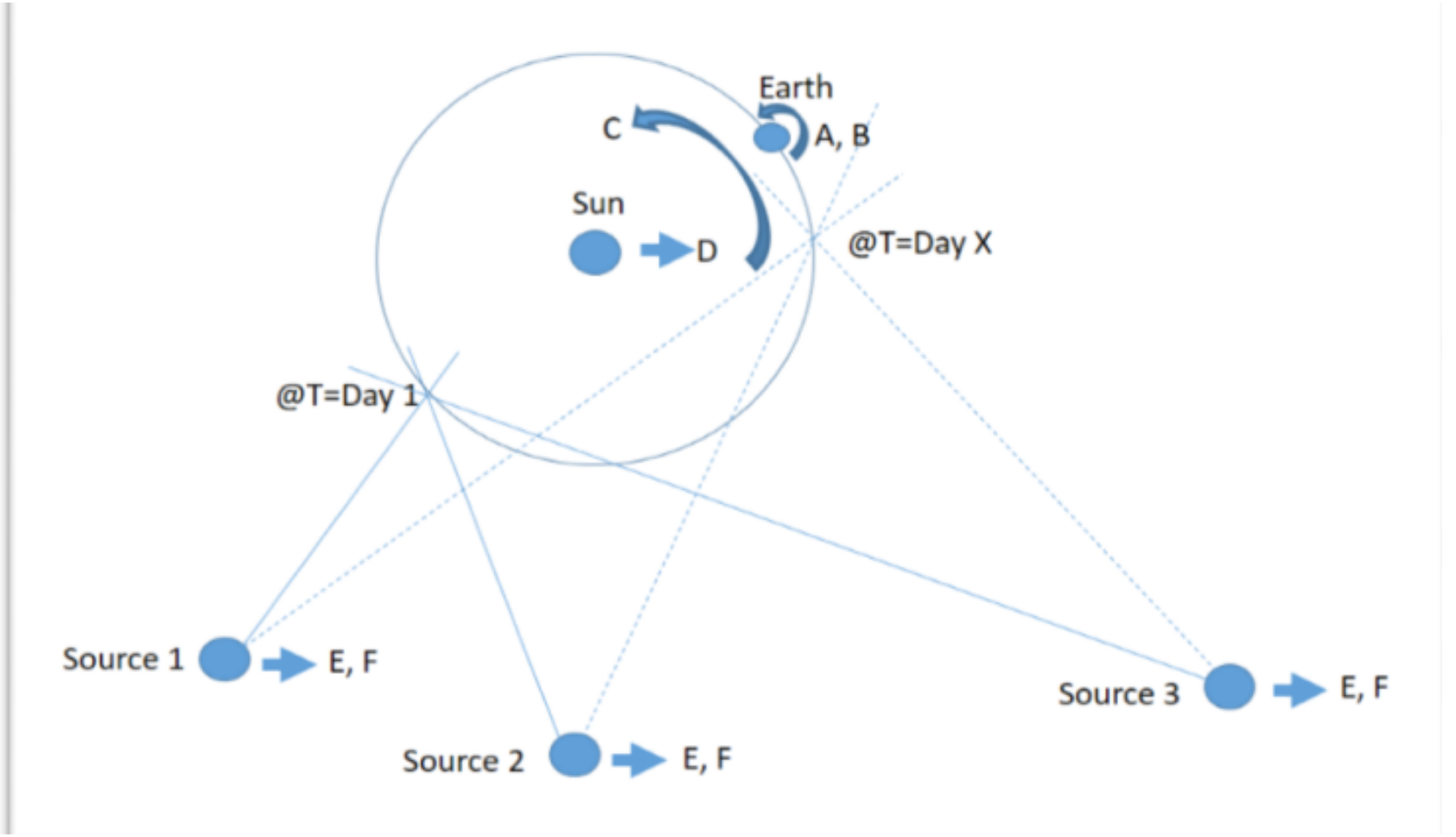


Figure 2: Sun – Galactic Center plane inclination

Figure 7: Earth's Approximate Yearly Orbital Position Relative to Galactic Center

Velocity Contribution to HI Source Measurements



Earth Orbital Position velocity Model

The maximum velocity of the Earth toward the galactic center is therefore:

$$V = 29.8\frac{km}{s}\cos(60.2°) = 14.8\ km/s$$

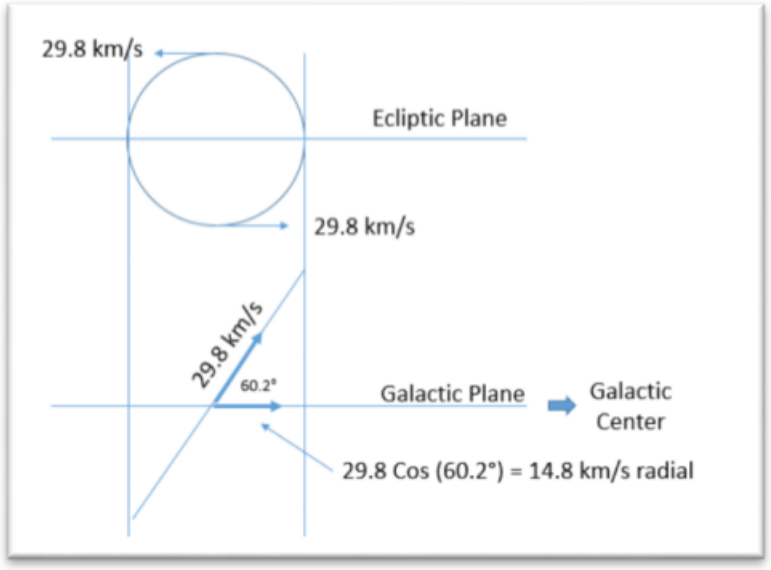


Figure 3: Radial Velocity Calculation

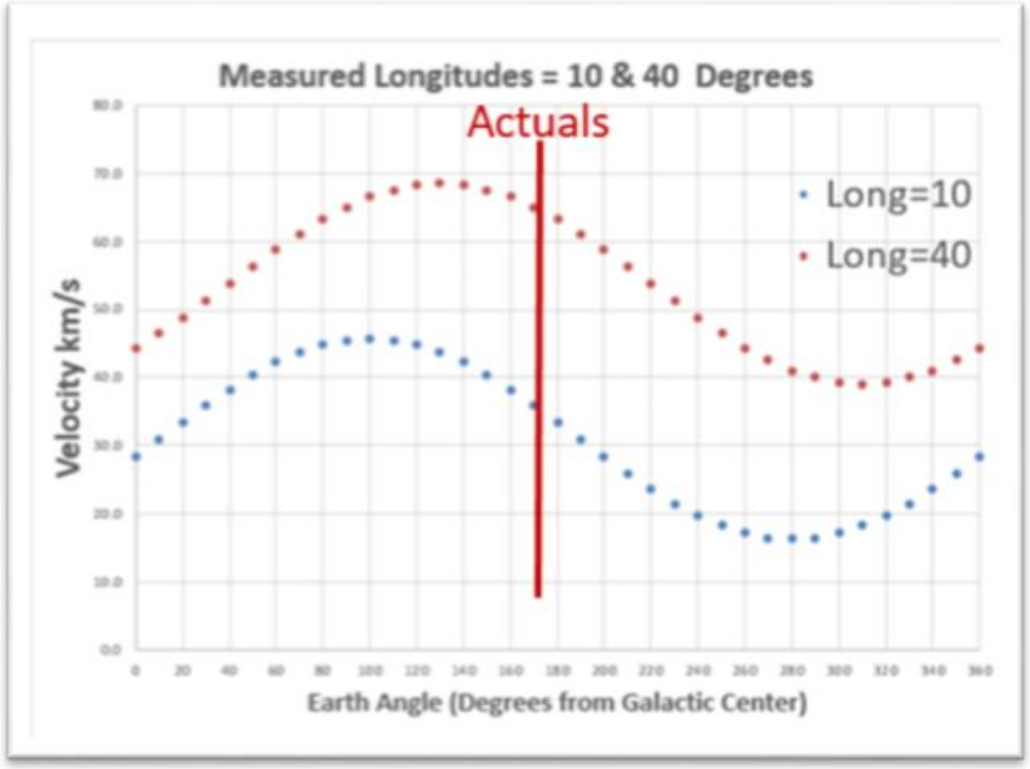
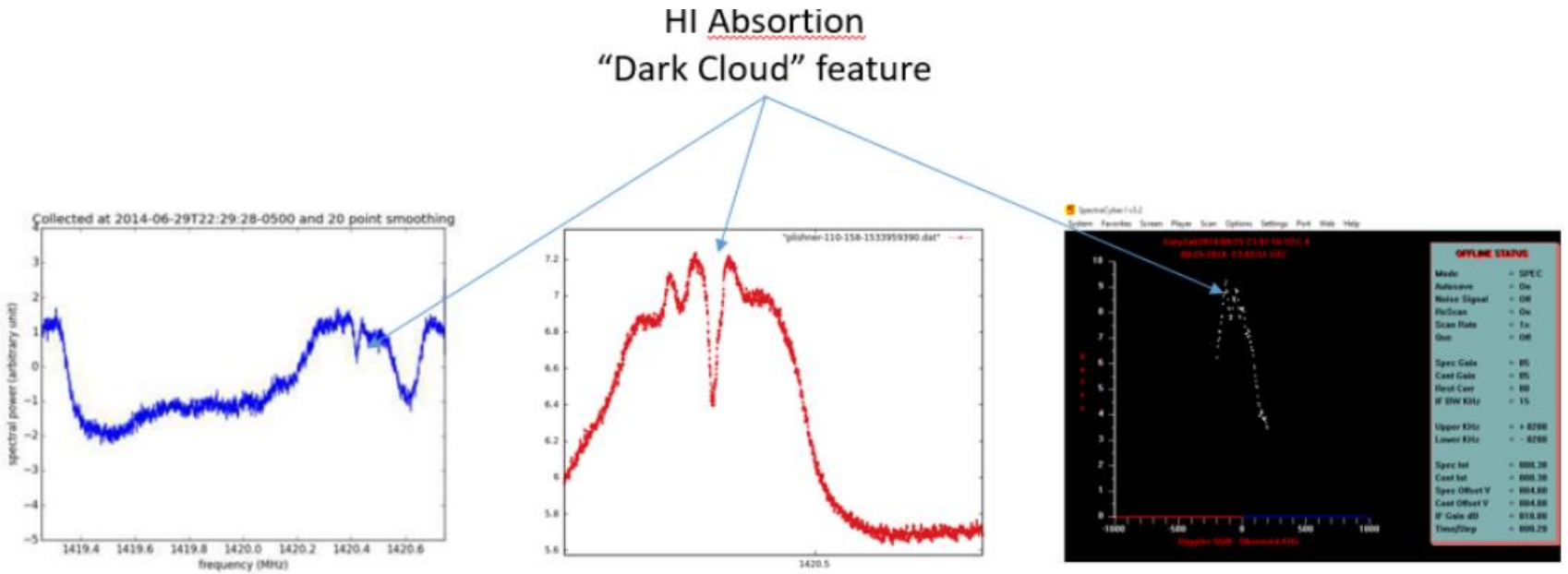


Figure 10: Predicted Vr for HI ISM Sources at galactic longitudes 10° and 40°

HI Absorption Measurements



RASDR-2 with 20m Telescope

RASDR-4 with DSES 60-foot Telescope

SpectraCyber with DSES 60-foot Telescope

Figure 6: Dark Cloud Target using the RASDR-2, RASDR-4 and SpectraCyber

9-foot Dish

Figure 1: 9- Foot dish in Colorado Springs, Colorado

9-foot dish

$$focus\ distance = \frac{D^2}{16H} \quad (1)$$

D= 9 ft x 12 in/ft = 108 in

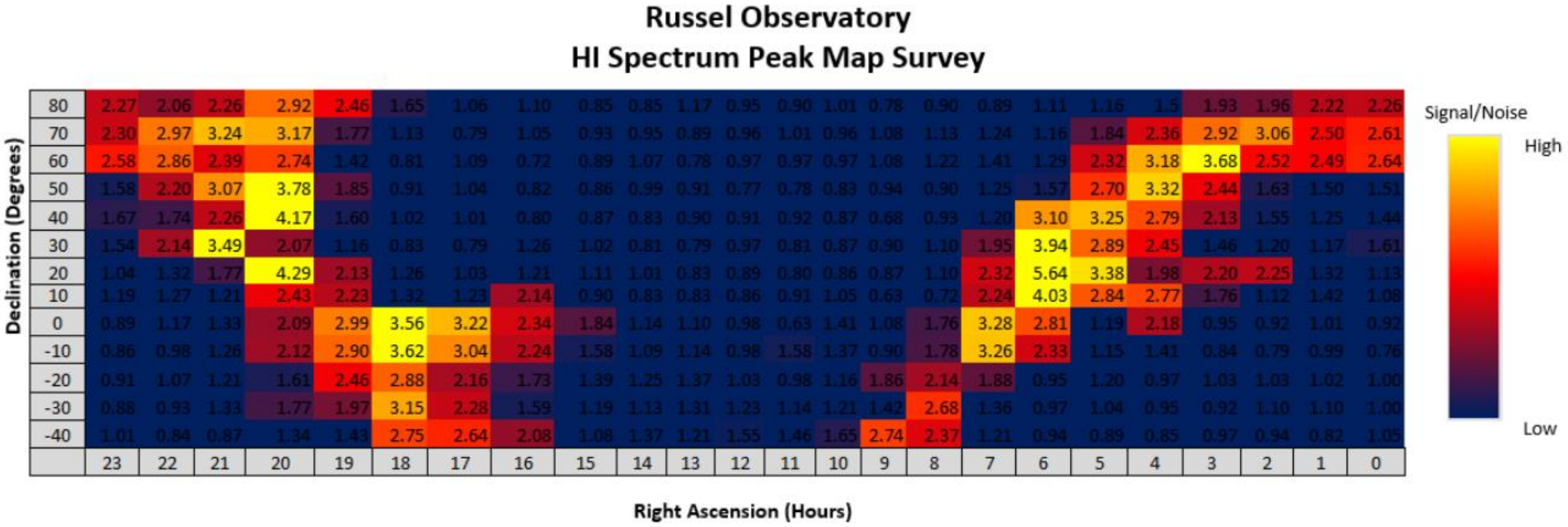
H is the depth of the dish from rim to base measured at 22 in

Focus distance = 33.1 in above center of dish

Calibrating Pointing

Figure 3: Azimuth Calibration using the Sun

Plotting the Signal Strength against RA/DEC



Plotting the Signal Strength vs Galactic LAT/LONG

Russel Observatory
HI Spectrum Peak Map Survey

	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	10	0	350	340	330	320	310	300	290	280	270	260	250	240	230	220	210	200	190	
90										0.79																												90
80							0.90																0.83								0.89				0.97		80
70			0.91				0.91				0.83			0.81				1.01		0.83				0.83				0.86									70
60	0.92		0.78		0.77	0.97	0.78	1.07	0.99		0.86	0.87		1.02		1.11					1.14			1.10			0.98				0.91				0.81		60
50	0.87	0.83		0.75	0.97	0.96	0.89	0.95	0.89		0.82		0.80	1.26		1.21		0.90	1.84			1.09		1.14			0.98			0.63		1.05		0.86	0.87		50
40	0.68	0.94	1.08		1.08	0.90	1.17	0.93	1.05	0.72	1.04		1.01	0.79			2.14	2.34		1.58			1.25	1.37		1.03		0.98	1.58		1.41			0.87		0.90	40
30	0.93	0.90	1.22		1.24	1.11	0.85	2.46	0.79	0.81	0.91	1.02			1.03	1.23			2.24		1.39	1.19	1.13		1.31	1.23	1.14		1.16	1.37		1.08	0.63			1.10	30
20	1.20	1.25	1.41	1.29	1.84	1.96	2.26	2.92	3.17	1.42	1.85	1.60	0.83	1.26	1.32		3.22		3.04	1.73	1.59	1.08	1.37		1.21	1.55	1.46		1.21	1.86	0.90			0.72	1.10		20
10		3.10	1.57	2.32	2.36	3.06	2.61	2.97	2.39	2.74	3.78		1.16	2.13		3.56	3.62		2.16	2.28	2.08							1.65	1.42			1.78	1.76		2.24	1.95	10
0	3.94	3.25	2.70	3.32	3.68	2.52	2.64	2.58	2.86	3.07	4.17	2.07	4.29		2.23	2.99		2.88	3.15	2.64								2.37	2.74	2.68	2.14		3.26	3.28		5.64	0
-10	3.38	2.89	2.79		2.44	1.63	1.50	1.51	1.58	1.74	3.49			2.43	2.09	2.90	2.46	1.97													1.36	1.88		2.81	4.03		-10
-20		1.98	2.45	2.13	1.55		1.25	1.44	1.67		2.14	1.77	1.21			2.12	1.61		1.43											1.21	0.97	0.95	2.33			2.84	-20
-30	2.77		2.20		1.20		1.17	1.61	1.54		1.32	1.27		1.33	1.26			1.77	1.34											0.94			1.20	1.15	1.19		-30
-40		1.76			2.25	1.32		1.13		1.04	1.19		1.17			1.21	1.33		0.87												0.89	1.04			1.41	2.18	-40
-50	0.95			1.12		1.42			1.08			0.89		0.98		1.07	0.93		0.84												0.85	0.95		0.97		0.84	-50
-60			0.92			1.01			0.92						0.91		0.88		1.01											0.97		0.92		1.03			-60
-70		0.79				0.99					0.76		0.86				0.88				1.05								0.94							1.03	-70
-80					1.02								1.00				1.00								0.82							1.10					-80
-90																												1.10									-90
	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	10	0	350	340	330	320	310	300	290	280	270	260	250	240	230	220	210	200	190	

Galactic Latitude

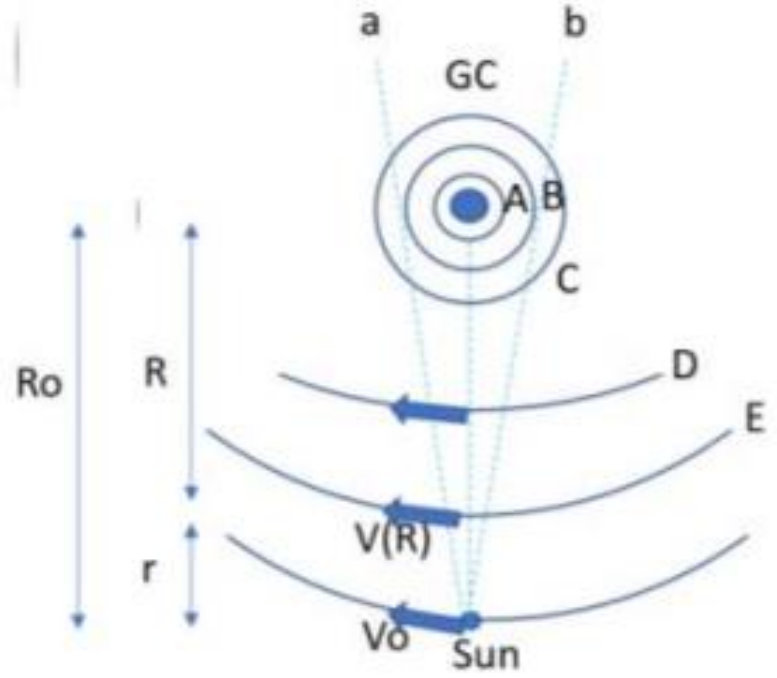
Galactic Longitude

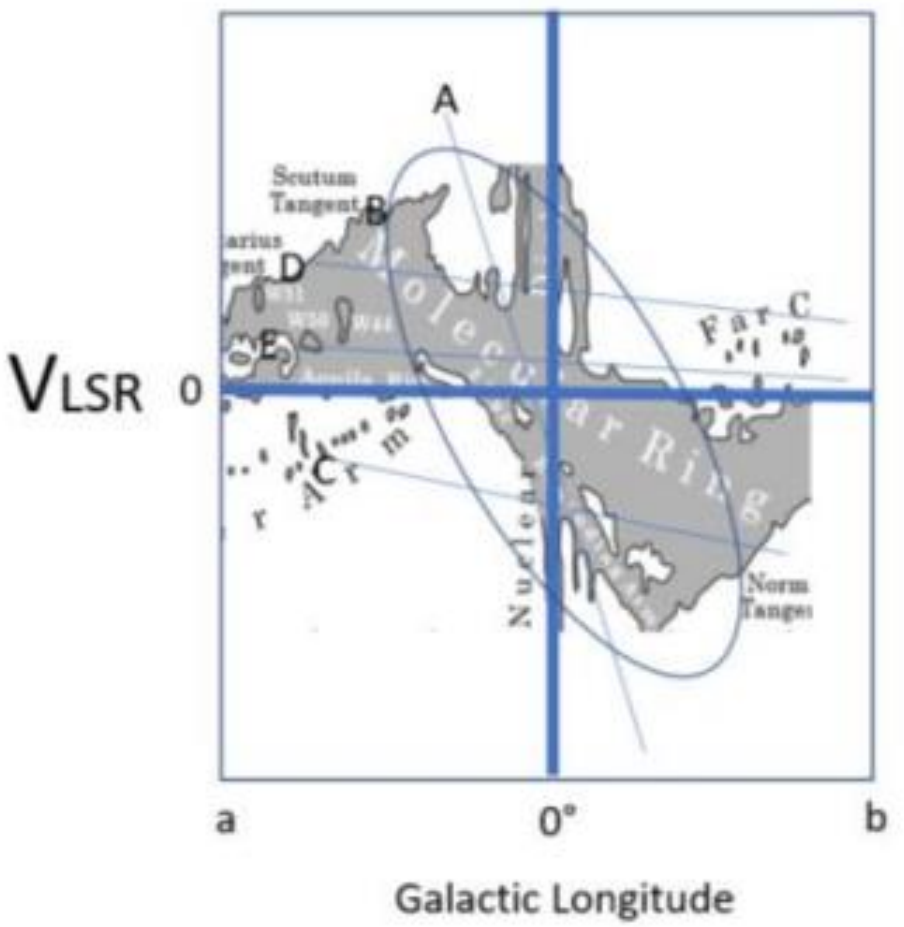
Signal/Noise

High

Low

Plotting the HI Velocity vs Galactic Longitude





dv/dL Method Geometry (1)

1. Sofue, Yoshiaki. Galactic Radio Astronomy. s.l. : Springer, 2017. ISBN 978-981-10-3444-2.

Plotting the HI Velocity vs Galactic Longitude

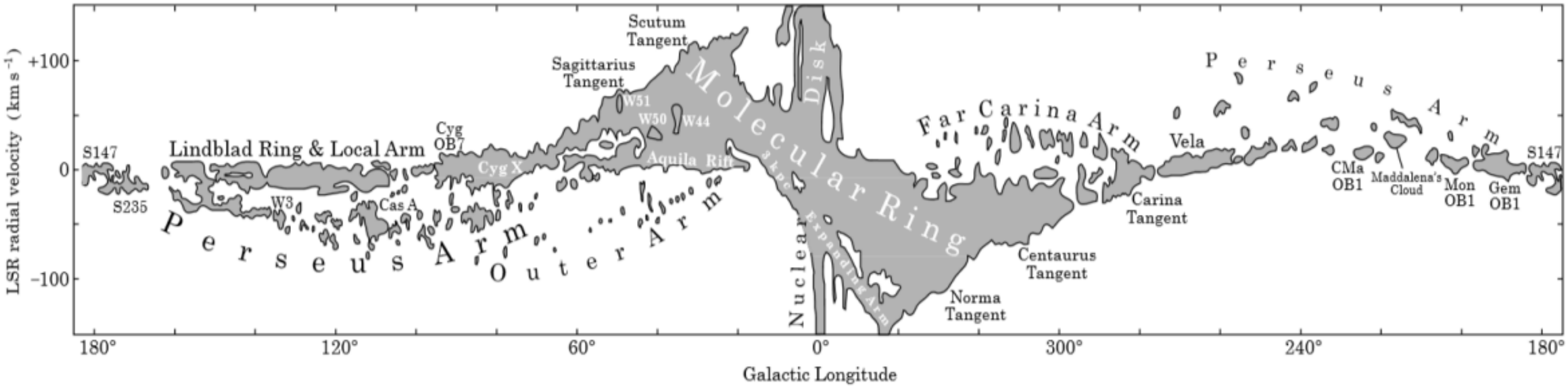


Figure 5: Velocity - Galactic Longitude map (7)

7. The Milky Way in Molecular Clouds: A New Complete CO Survey. T. M. Dame, Dap Hartmann, P. Thaddeus. s.l. : Harvard-Smithsonian Center for Astrophysics, 2000. https://arxiv.org/abs/astroph/0009217

HI Data from Haswell Plotted

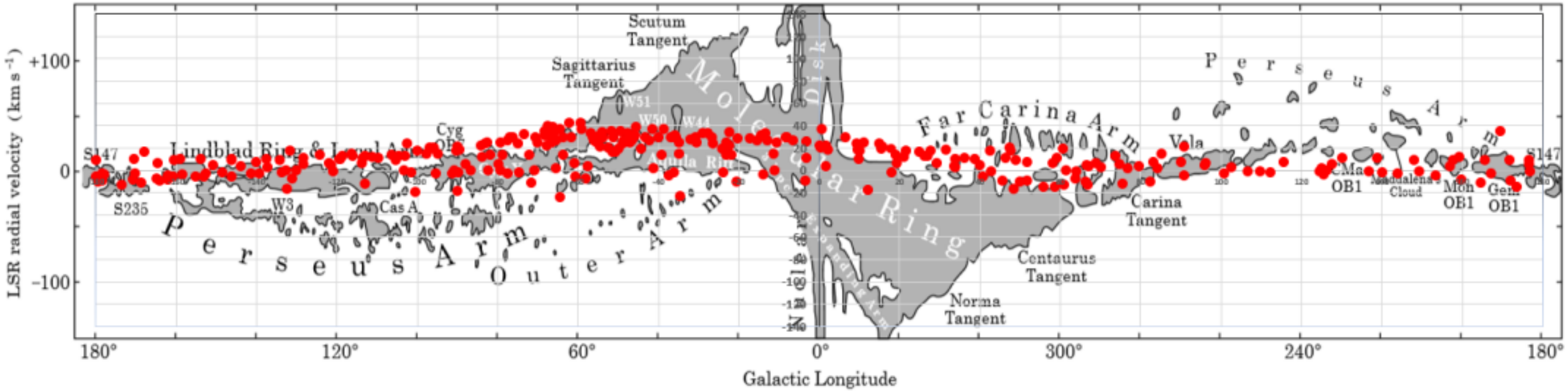


Figure 7: All HI Data plotted

Detection of Galactic Arms

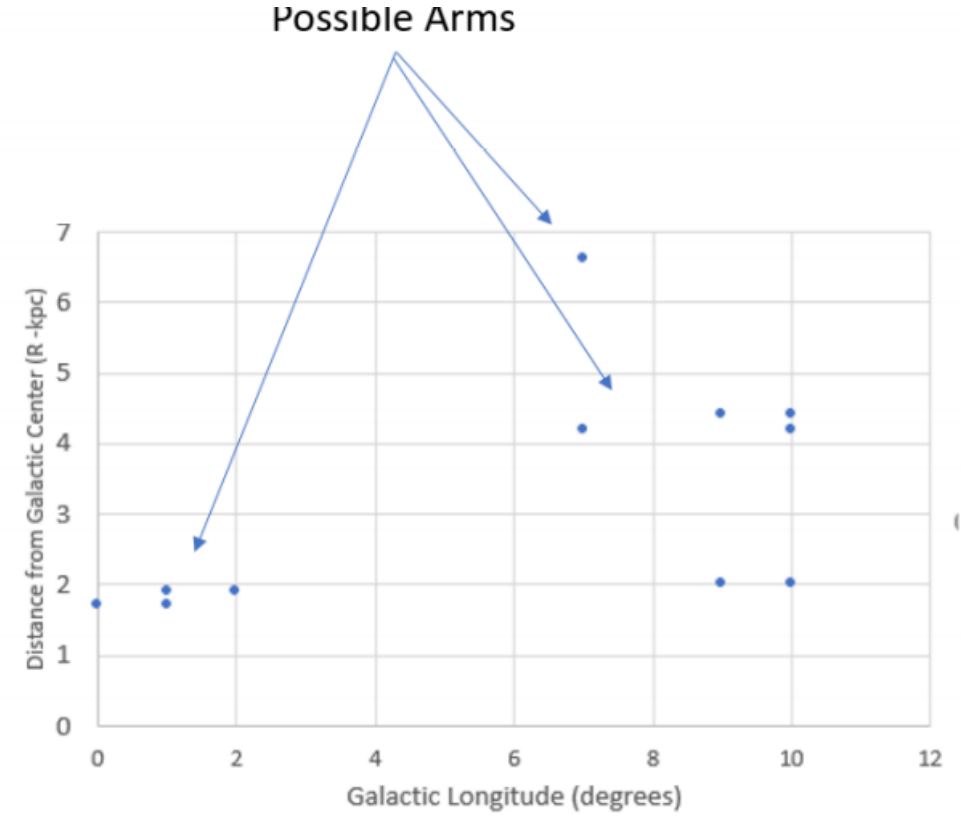
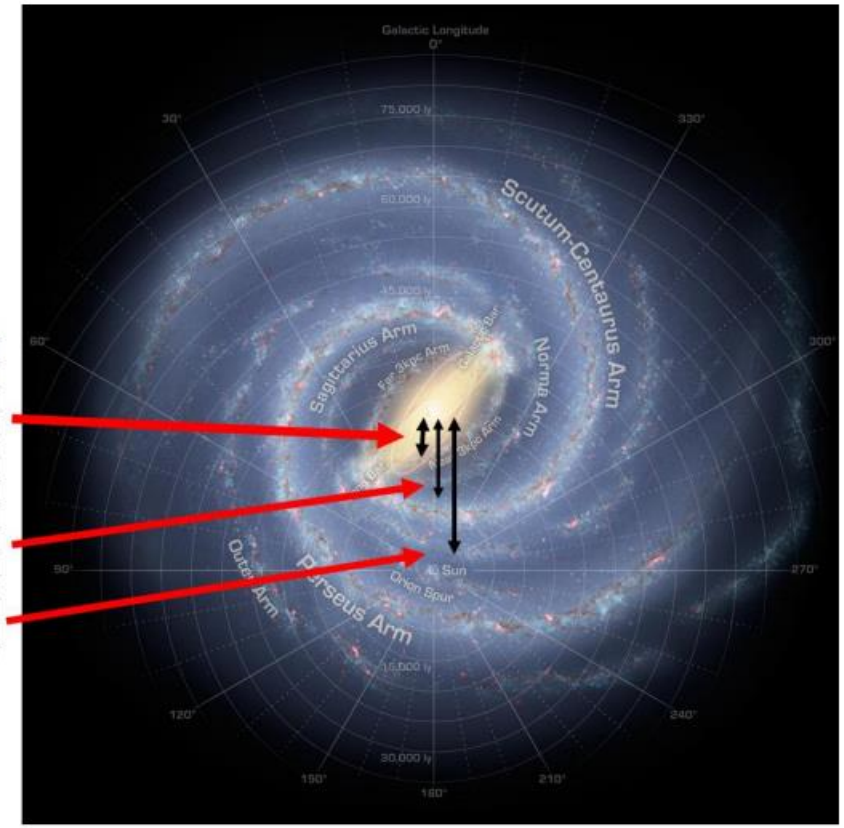


Figure 12: H1 data plotted showing distance to galactic center

HI Results
Scaled to Galaxy Map

G-Long	R (KPC)	Scale (Inches)	Galactic Arm
0	1.7	0.3	3 KPC Arm
1	1.7	0.3	3 KPC Arm
1	1.9	0.3	3 KPC Arm
2	1.9	0.3	3 KPC Arm
7	2.0	0.4	3 KPC Arm
7	2.0	0.4	3 KPC Arm
9	4.2	0.7	Norma Arm
9	4.2	0.7	Norma Arm
10	4.4	0.8	Norma Arm
10	4.4	0.8	Norma Arm
7	6.6	1.2	Sagittarius Arm
10	6.6	1.2	Sagittarius Arm



13: HI Results Plotted on NASA Galaxy Map

2020/21 Observation/ Feed Schedule

- January 2021
  - Week 1-4 408 MHz Pulsar Observations
  - (Note: the feeds can be varied based on science interests from 408/ 1296/1420 MHz)
  - 4 GHz Calibration feed
- February 2021
  - 408 MHZ Feed for pulsar observations
  - 1296 MHz if EME team wants it

Questions?