AST3003S Observational Project

Measuring the Rotational Velocity of the Galactic Plane Using HI Gas 1.4 GHz Emission

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Overview

- Telescope specifications
- Planning your observations
- Telescope operation
- Extracting the spectra
- Brightness temperature
- LSR velocity
- Calculating rotational velocity & distance
- Writing your report

The Milky Way curves over the MeerKAT telescope in South Africa. (SARAO)

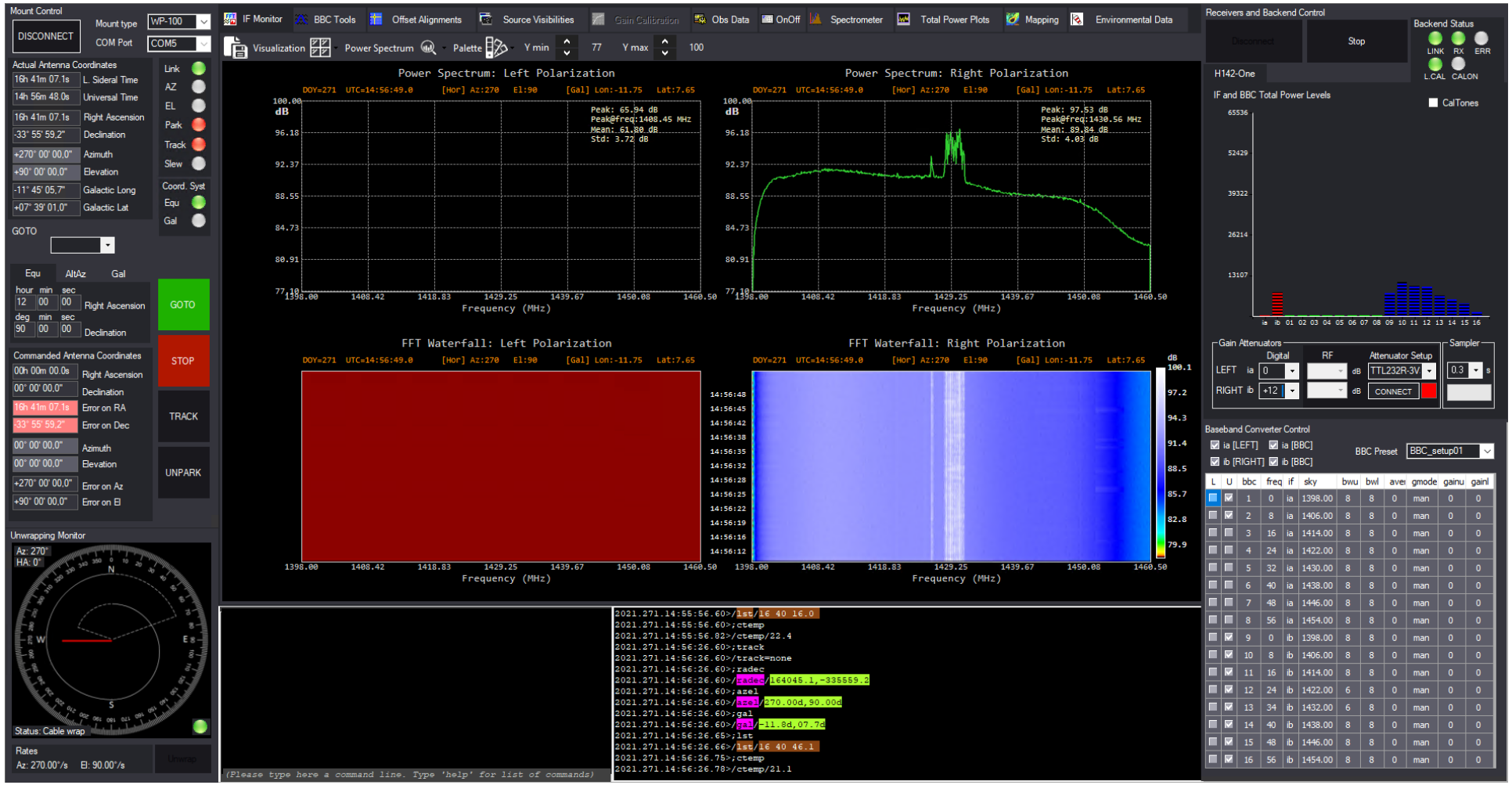
Telescope Specifications

TFTO Radio Telescope Specifications	
Diameter	3 m
Configuration	Prime Focus
Mount	Alt-azimuth
Wind stow	50 km/h
Central frequency	1428.75 MHz
Bandwidth	62.5 MHz
Spectrometer	1024 channels
Resolution	61 kHz
A/D converter	14 bit
Max slew speed	2°/s

Planning Observations

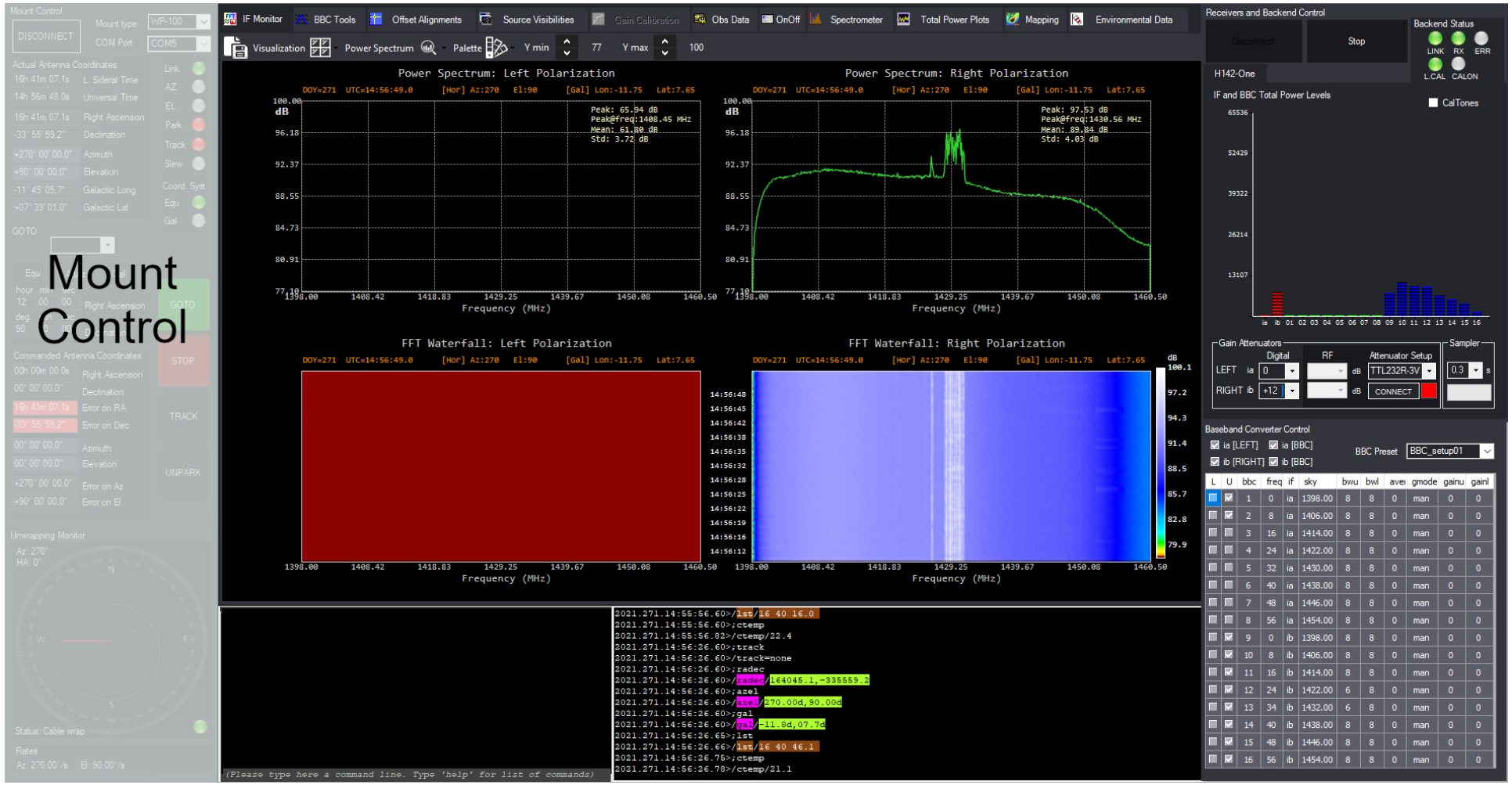
- Each group will observe 3 points along the galactic plane between 270° and 90° longitude
- Check to see what times your coordinates are visible
- Schedule your observing session
- Check weather conditions on day
- Observations done remotely from RW James

Telescope Operation



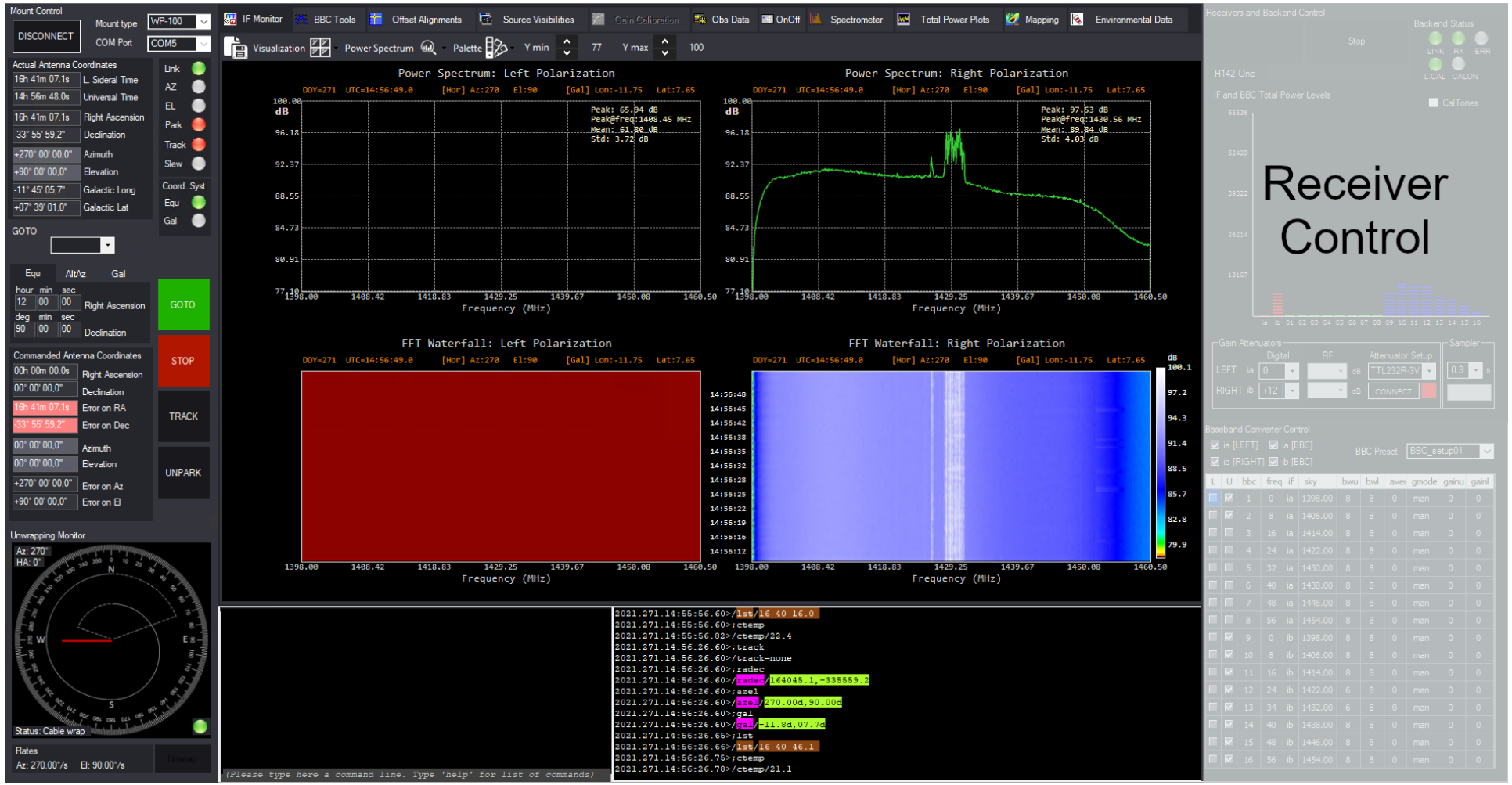
- Software UI

Telescope Operation



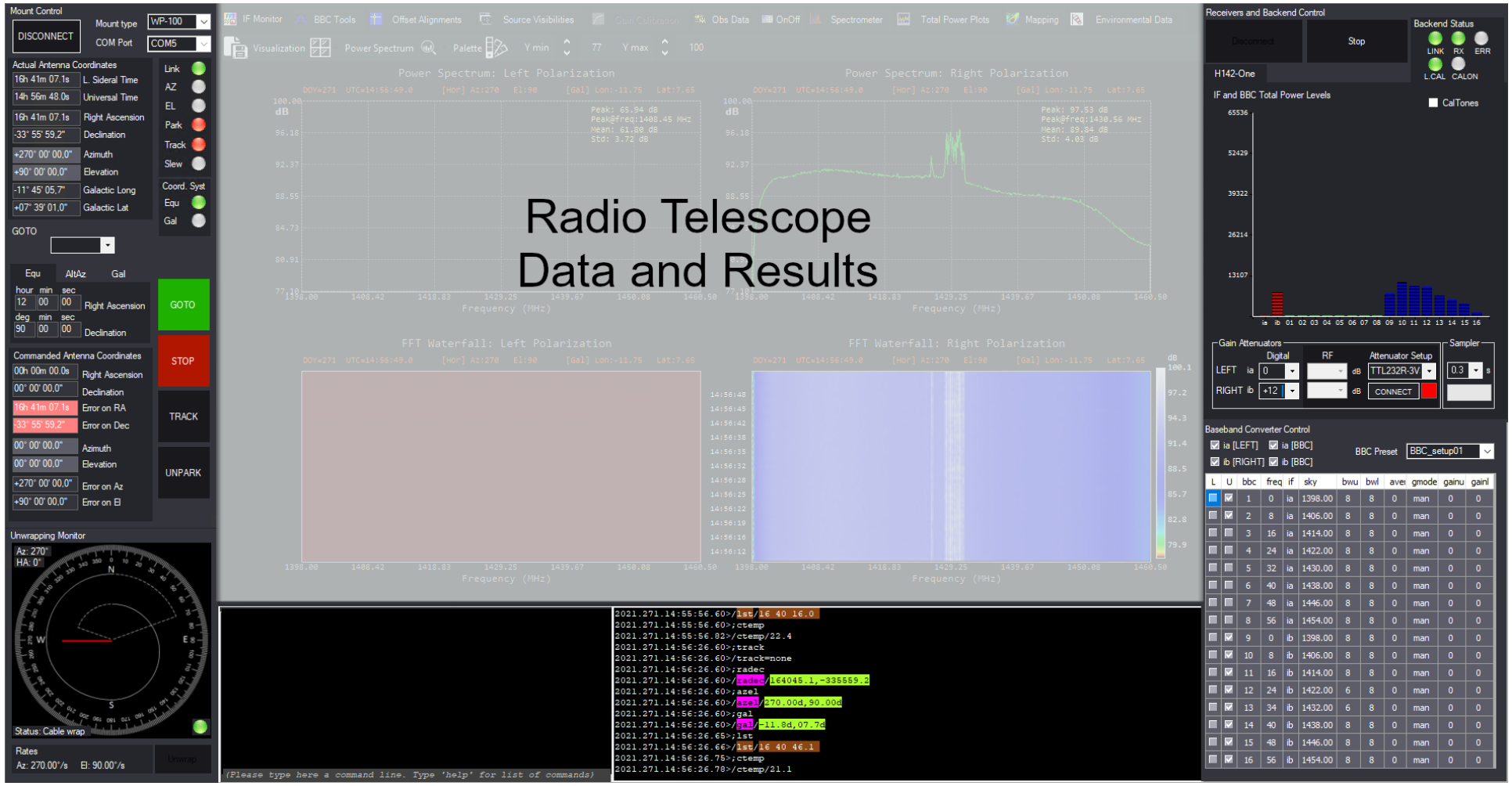
- Software UI
- Displays mount status

Telescope Operation



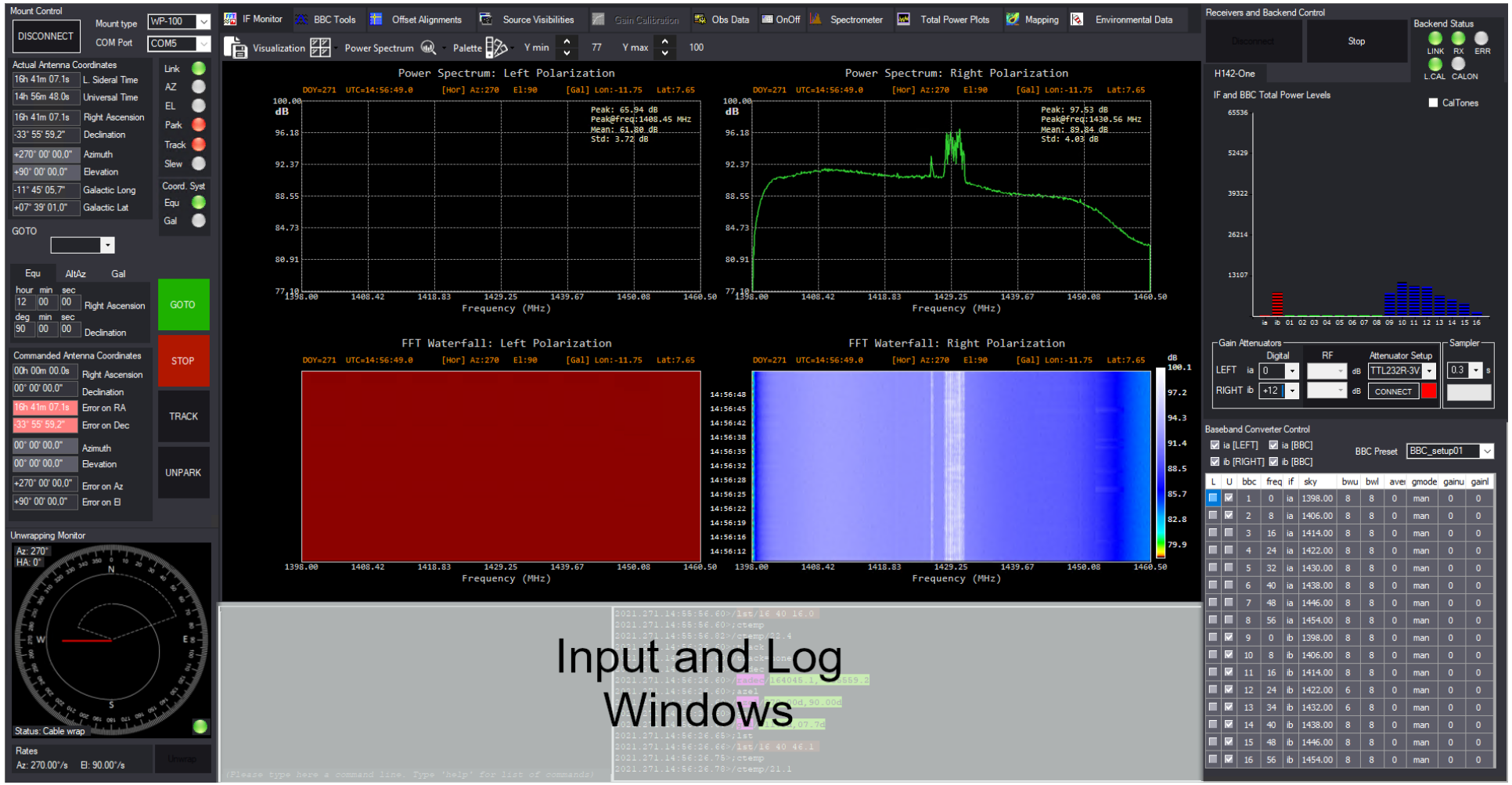
- Software UI
- Displays mount status
- Monitors power levels

Telescope Operation



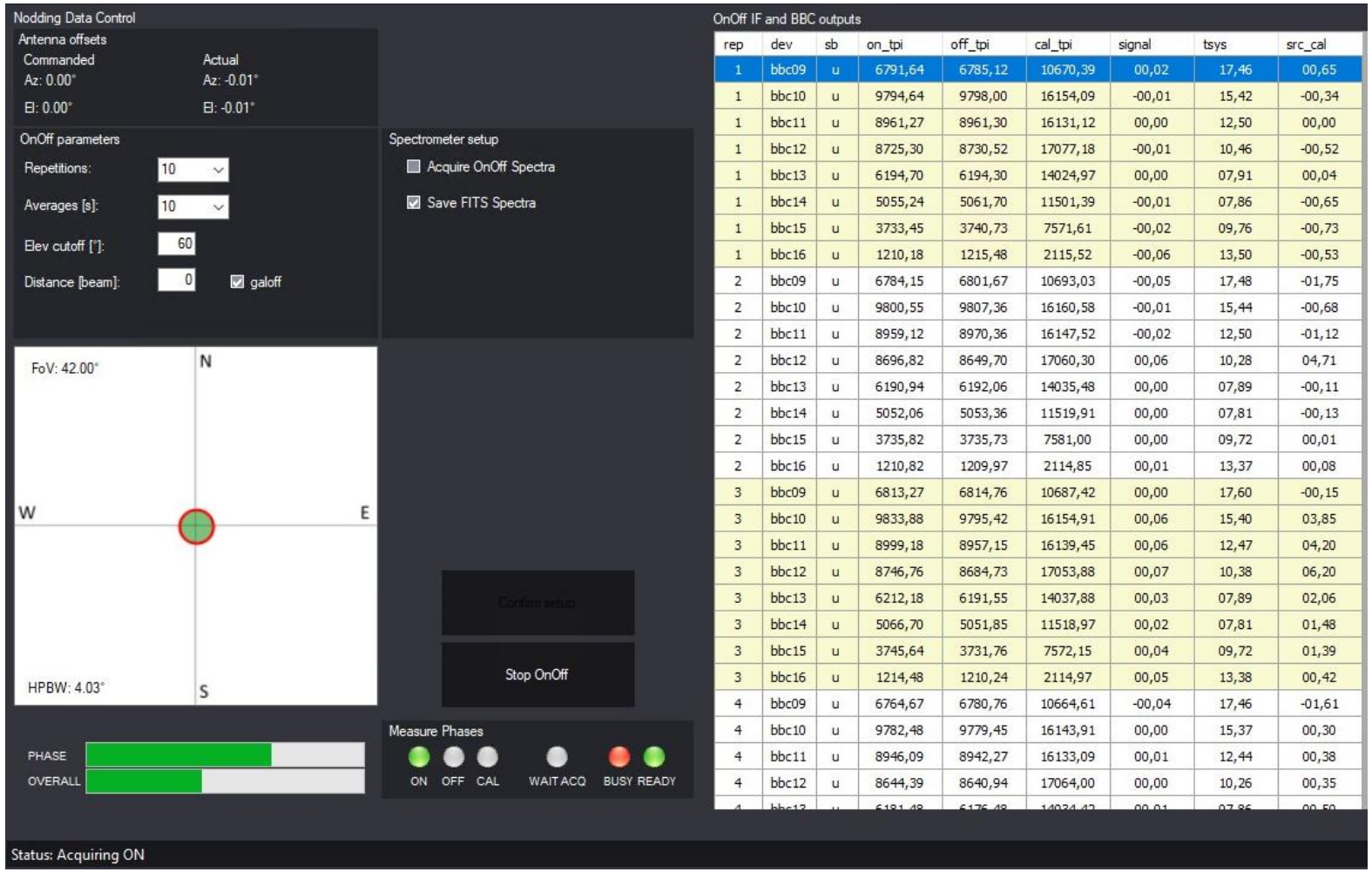
- Software UI
- Displays mount status
- Monitors power levels
- Tabs with various functions

Telescope Operation



- Software UI
- Displays mount status
- Monitors power levels
- Tabs with various functions
- Command entry and log

Telescope Operation

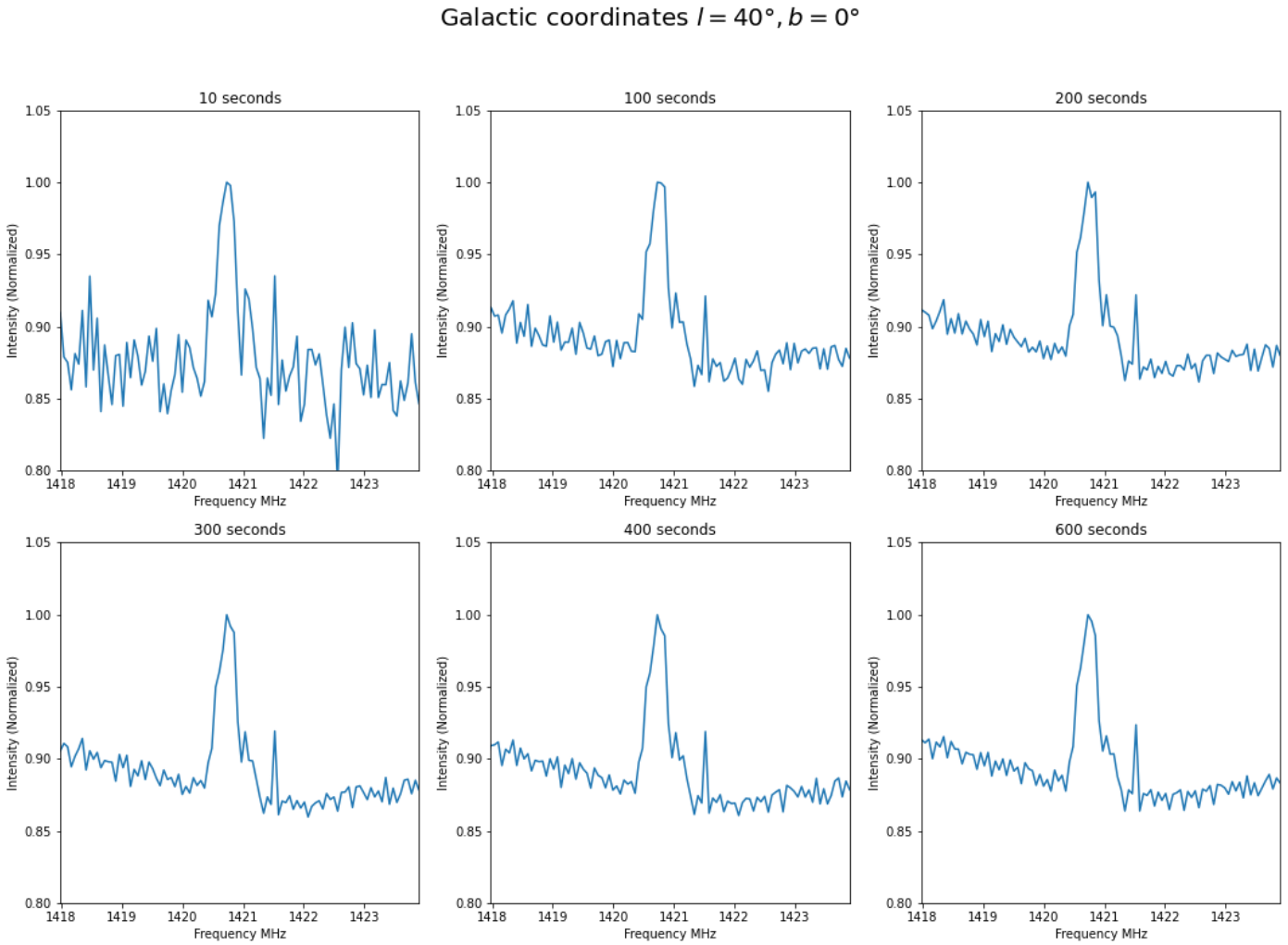


OnOff IF and BBC outputs

rep	dev	sb	on_tpi	off_tpi	cal_tpi	signal	tsys	src_cal
1	bbc09	u	6791,64	6785,12	10670,39	00,02	17,46	00,65
1	bbc10	u	9794,64	9798,00	16154,09	-00,01	15,42	-00,34
1	bbc11	u	8961,27	8961,30	16131,12	00,00	12,50	00,00
1	bbc12	u	8725,30	8730,52	17077,18	-00,01	10,46	-00,52
1	bbc13	u	6194,70	6194,30	14024,97	00,00	07,91	00,04
1	bbc14	u	5055,24	5061,70	11501,39	-00,01	07,86	-00,65
1	bbc15	u	3733,45	3740,73	7571,61	-00,02	09,76	-00,73
1	bbc16	u	1210,18	1215,48	2115,52	-00,06	13,50	-00,53
2	bbc09	u	6784,15	6801,67	10693,03	-00,05	17,48	-01,75
2	bbc10	u	9800,55	9807,36	16160,58	-00,01	15,44	-00,68
2	bbc11	u	8959,12	8970,36	16147,52	-00,02	12,50	-01,12
2	bbc12	u	8696,82	8649,70	17060,30	00,06	10,28	04,71
2	bbc13	u	6190,94	6192,06	14035,48	00,00	07,89	-00,11
2	bbc14	u	5052,06	5053,36	11519,91	00,00	07,81	-00,13
2	bbc15	u	3735,82	3735,73	7581,00	00,00	09,72	00,01
2	bbc16	u	1210,82	1209,97	2114,85	00,01	13,37	00,08
3	bbc09	u	6813,27	6814,76	10687,42	00,00	17,60	-00,15
3	bbc10	u	9833,88	9795,42	16154,91	00,06	15,40	03,85
3	bbc11	u	8999,18	8957,15	16139,45	00,06	12,47	04,20
3	bbc12	u	8746,76	8684,73	17053,88	00,07	10,38	06,20
3	bbc13	u	6212,18	6191,55	14037,88	00,03	07,89	02,06
3	bbc14	u	5066,70	5051,85	11518,97	00,02	07,81	01,48
3	bbc15	u	3745,64	3731,76	7572,15	00,04	09,72	01,39
3	bbc16	u	1214,48	1210,24	2114,97	00,05	13,38	00,42
4	bbc09	u	6764,67	6780,76	10664,61	-00,04	17,46	-01,61
4	bbc10	u	9782,48	9779,45	16143,91	00,00	15,37	00,30
4	bbc11	u	8946,09	8942,27	16133,09	00,01	12,44	00,38
4	bbc12	u	8644,39	8640,94	17064,00	00,00	10,26	00,35

- On/Off used to collect spectral data
- Parameters can be set on top left
- Zero distance will allow on and off to be used in spectra
- Monitor progress bars after starting process

Extracting the Spectra



- Take multiple acquisitions and stack to increase SNR

Extracting the Spectra

fv: Header of 20210903-183148_SPECTRUM-PROJ01-GAL_13#_01#.fits[1] in D:...

File Edit Tools Help

Search for: Find Case sensitive? No

```
MJD     =      59460.7720903703  / MJD
LST     =       18.635711423842  / LST
SITELAT =            -33.933101  / The Site Latitude
SITELONG=             18.476483  / The Site Longitude
SITEELEV=                    25  / The Site Elevation
RA      =     19.3900302918173   / RA at t=0
DEC     =     15.1469023350096   / DEC at t=0
SUNANGLE=                     0  / Angle between the sun and the target
TELAPSE =                     0  /  Time elapsed
AIRMASS =                     0  / Airmass
AUTHOR  = '                   ' / Author name
OBSERVER= '                   ' / Observer name
OBJECT  = 'gal                ' / Object observed
EQUINOX =                2000.0 / In years for the celestial coordinate system
TELESCOP= '                   ' / TELESCOPE Name
DIAMETER =                    3  / TELESCOPE diameter
FRONTEND= '                   ' / Description of frontend device
BACKEND = '                   ' / Description of backend device
BMAJ    =     4.03376144265431   / Main beam major axis size
BMIN    =     4.03376144265431   / Main beam minor axis size
OBSFREQ =              1429.25   / Observed frequency
BANDWID =                 62.5   / The bandwidth
TUNIT1  = 'd          '          / Days
```

- Take multiple acquisitions and stack to increase SNR
- Get all important information needed from FITS header

Extracting the Spectra

fv: Binary Table of 20210912-060233_SPECTRUM-PROJ01-GAL_01#_01#.fits[1] in D:/OneDrive/UCT/Work/Telescopes/Radio Data/20210912/FITS/I_297_b_-15/

File Edit Tools Help

Select / All / Invert	Gal_Long 1D deg Modify	Gal_Lat 1D deg Modify	LEFT_POL 1024K count Modify	RIGHT_POL 1024K count Modify	STATUS 4A Modify	MARKER 16A Modify
1	2.072986601615E+002	-1.441479236178E+00:	Plot	Plot	on	SPC 000
2	2.073076724812E+002	-1.441633710287E+00:	Plot	Plot	off	SPC 001
3	2.072962723984E+002	-1.441531794248E+00:	Plot	Plot	cal	SPC 002
4	2.072964274120E+002	-1.441763803679E+00:	Plot	Plot	on	SPC 003
5	2.073056305814E+002	-1.441932470252E+00:	Plot	Plot	off	SPC 004
6	2.073046538389E+002	-1.441978510431E+00:	Plot	Plot	cal	SPC 005
7	2.073057542580E+002	-1.441661321302E+00:	Plot	Plot	on	SPC 006
8	2.073048971718E+002	-1.441719105075E+00:	Plot	Plot	off	SPC 007
9	2.073041000439E+002	-1.441782748170E+00:	Plot	Plot	cal	SPC 008
10	2.073053803509E+002	-1.441483137816E+00:	Plot	Plot	on	SPC 009
11	2.073039959442E+002	-1.442126936024E+00:	Plot	Plot	off	SPC 010
12	2.073040867571E+002	-1.441639648127E+00:	Plot	Plot	cal	SPC 011
13	2.073048544026E+002	-1.441926742247E+00:	Plot	Plot	on	SPC 012
14	2.073050518680E+002	-1.441450360458E+00:	Plot	Plot	off	SPC 013
15	2.073039371880E+002	-1.442118923379E+00:	Plot	Plot	cal	SPC 014
16	2.073055868614E+002	-1.441854614762E+00:	Plot	Plot	on	SPC 015
17	2.073052798487E+002	-1.441965203799E+00:	Plot	Plot	off	SPC 016
18	2.073056916614E+002	-1.441510545716E+00:	Plot	Plot	cal	SPC 017
19	2.072966027257E+002	-1.441725007283E+00:	Plot	Plot	on	SPC 018
20	2.072964769194E+002	-1.441854173797E+00:	Plot	Plot	off	SPC 019

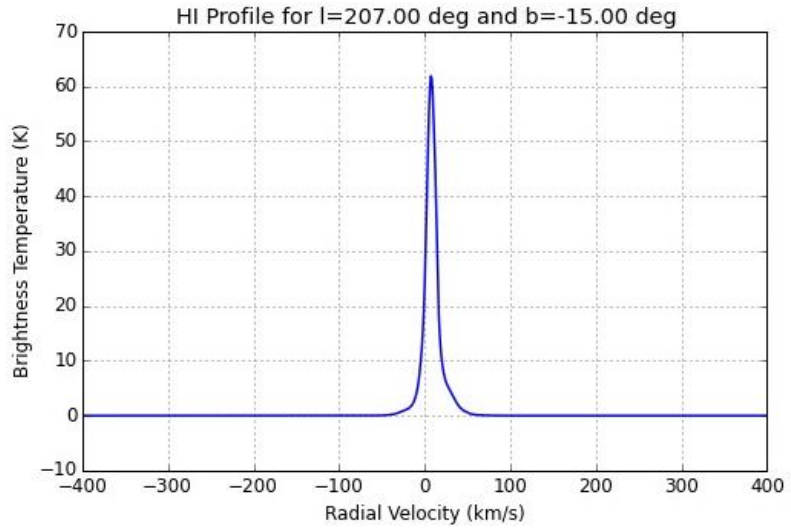
Go to: Edit cell:

- Take multiple acquisitions and stack to increase SNR
- Get all important information needed from FITS header
- Pay attention to column headers and rows
- Make use of Astropy from your JupyterHub
- Helpful commands in prac manual

Brightness Temperature

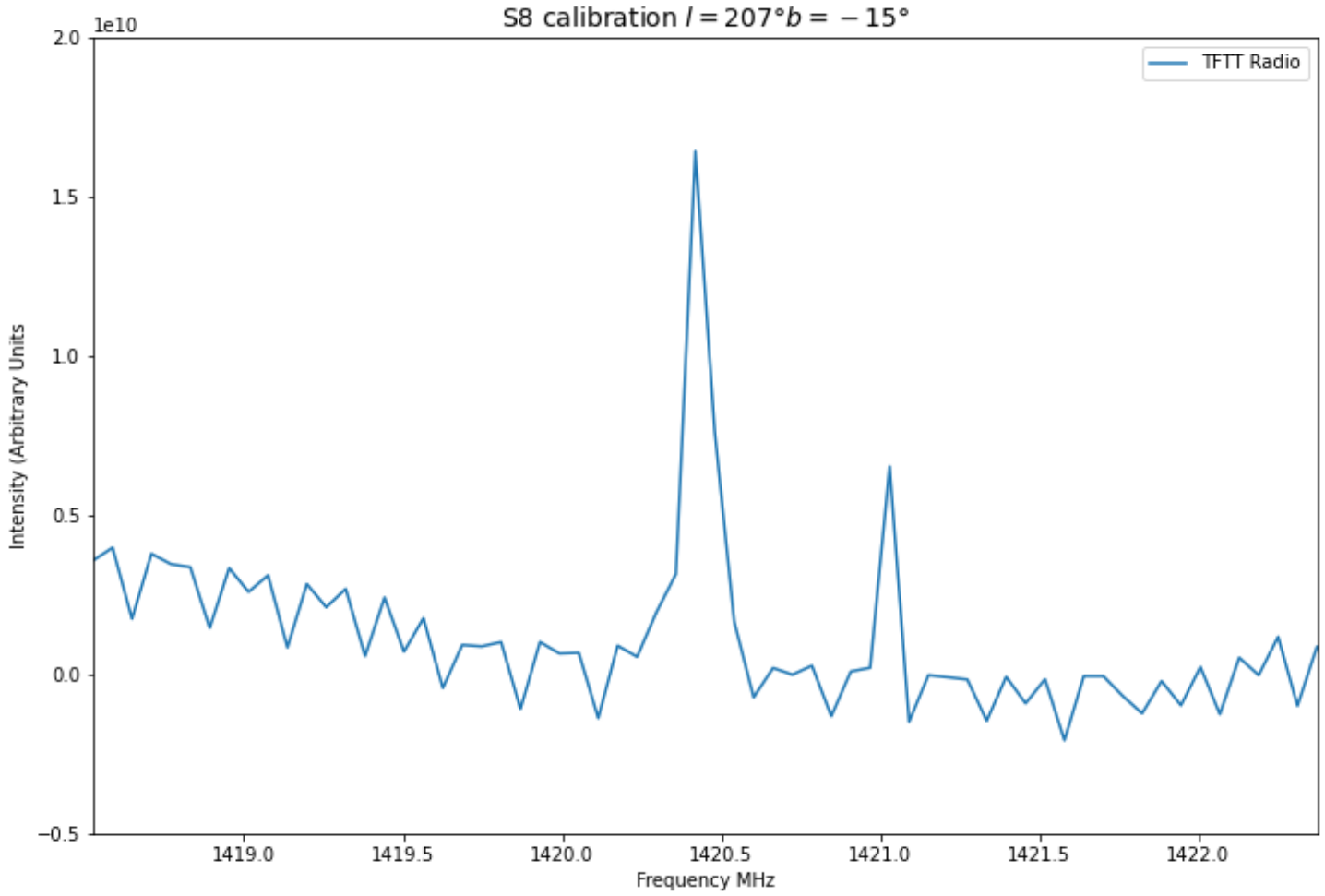
Select Position		
Coordinate system	Galactic coordinates (l, b)	
Position	RA [h m s]/ l [°]	207
	DEC [± ° ' "]/ b [°]	-15
Effective beamsize FWHM [°]		4.03
Velocity Window for display	Minimum [km/s]	-400.00
	Maximum [km/s]	400.00
Search data		

Result



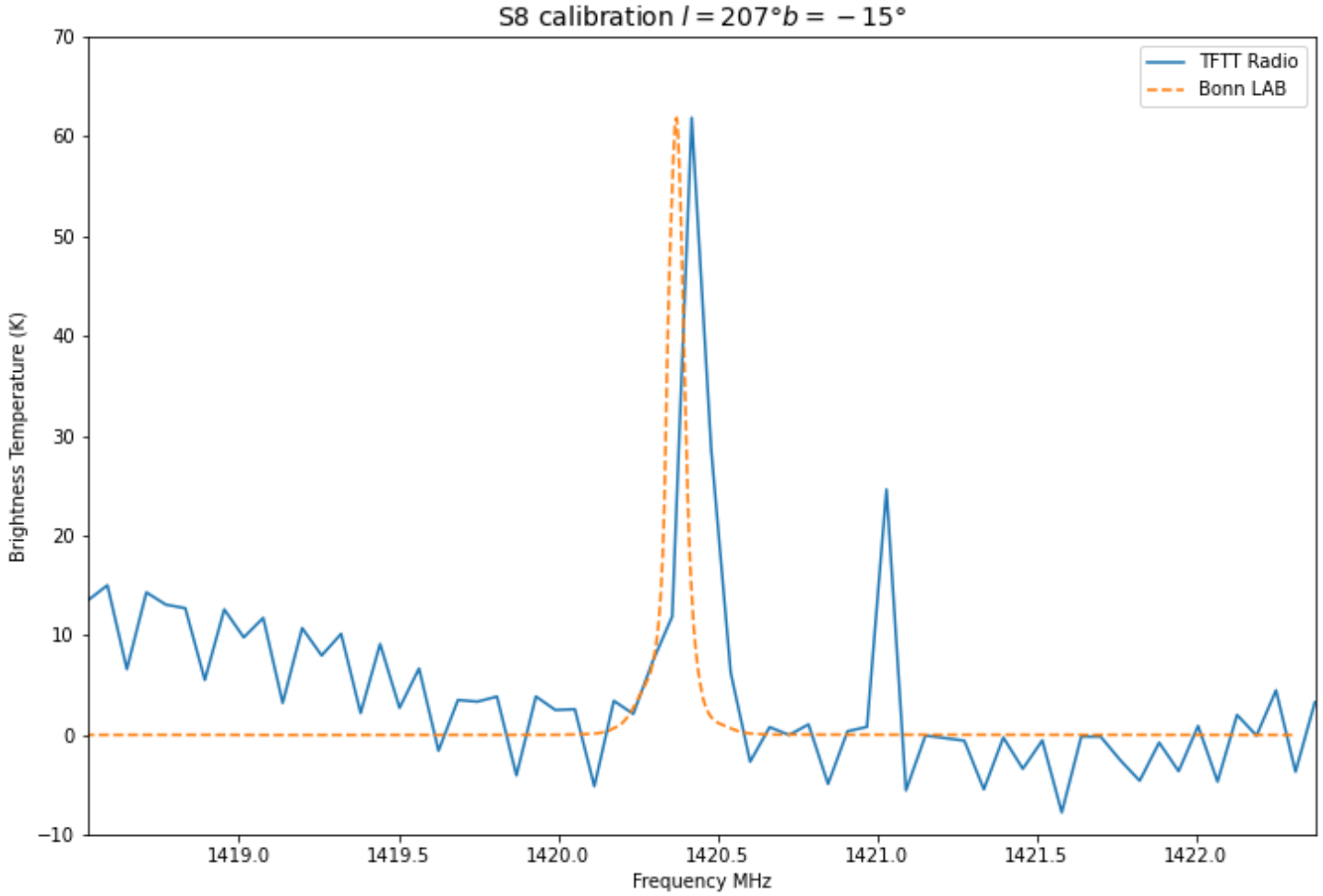
- Use IAU S8 data as source of known brightness
- Enter location into University of Bonn HI Profile Search
- Download HI profile

Brightness Temperature



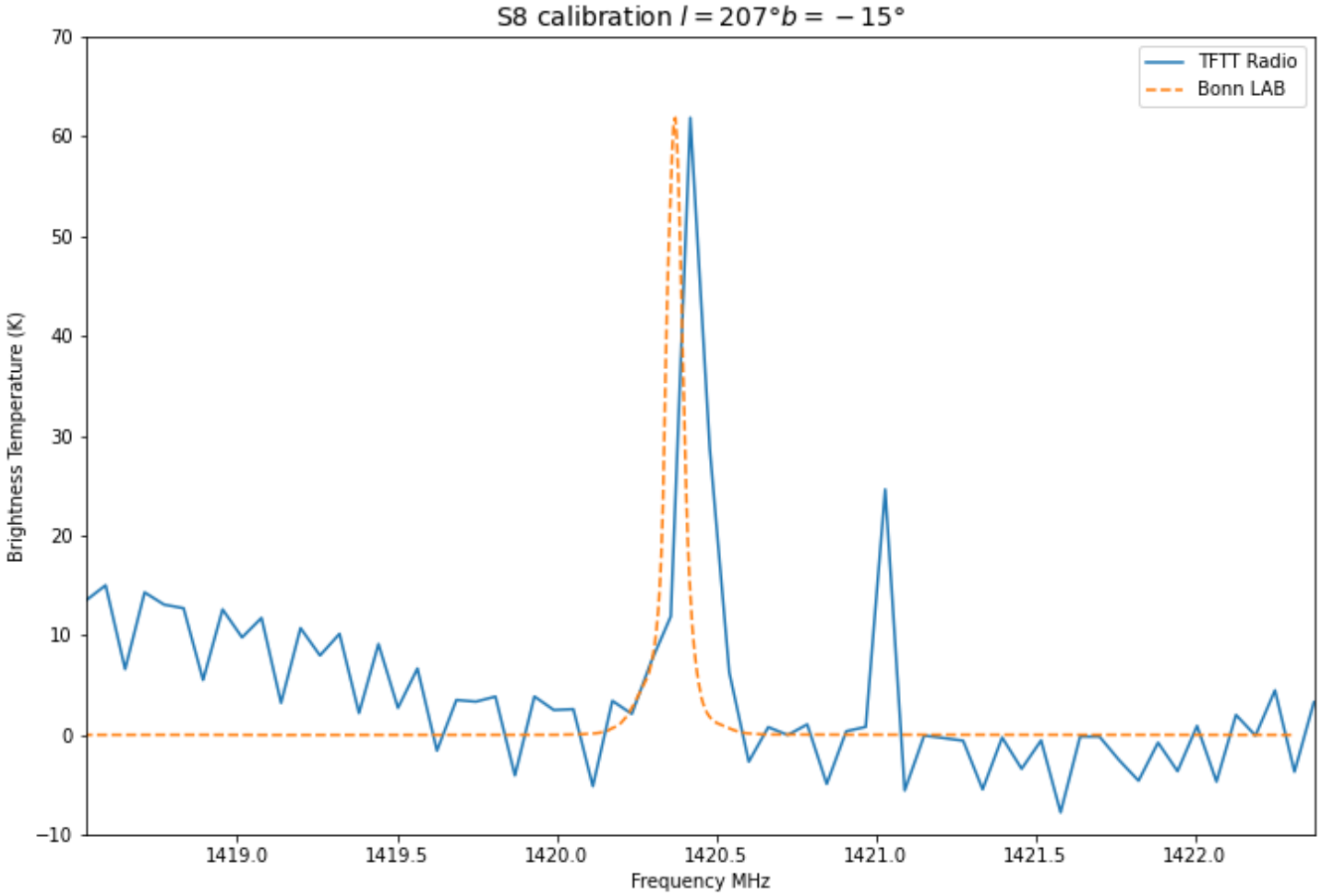
- Use IAU S8 data as source of known brightness
- Enter location into University of Bonn HI Profile Search
- Download HI profile
- Use the mean of your data around HI line to set floor

Brightness Temperature



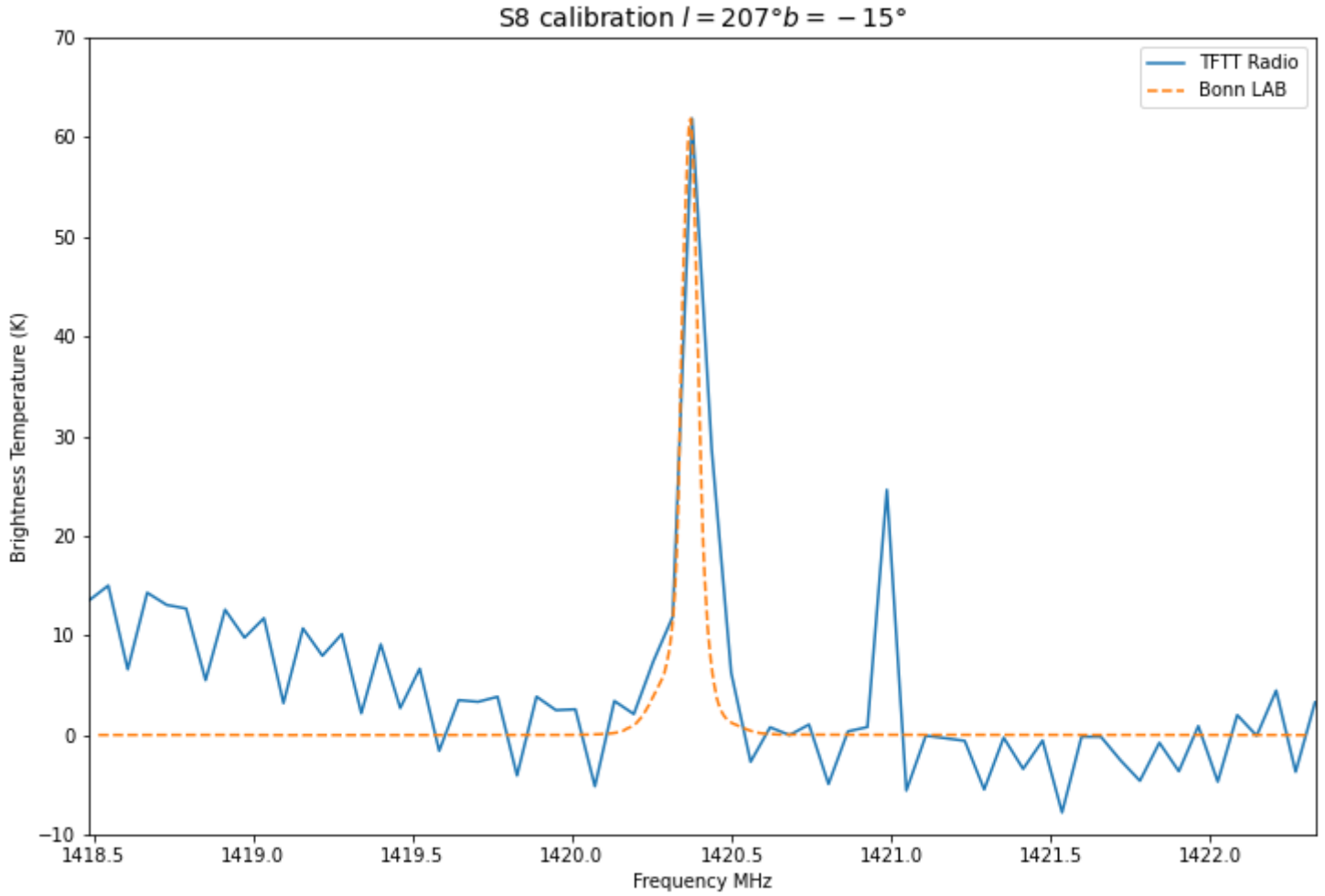
- Use IAU S8 data as source of known brightness
- Enter location into University of Bonn HI Profile Search
- Download HI profile
- Use the mean of your data around HI line to set floor
- Use Bonn profile to determine scaling factor
- Apply to all spectra

LSR Velocity



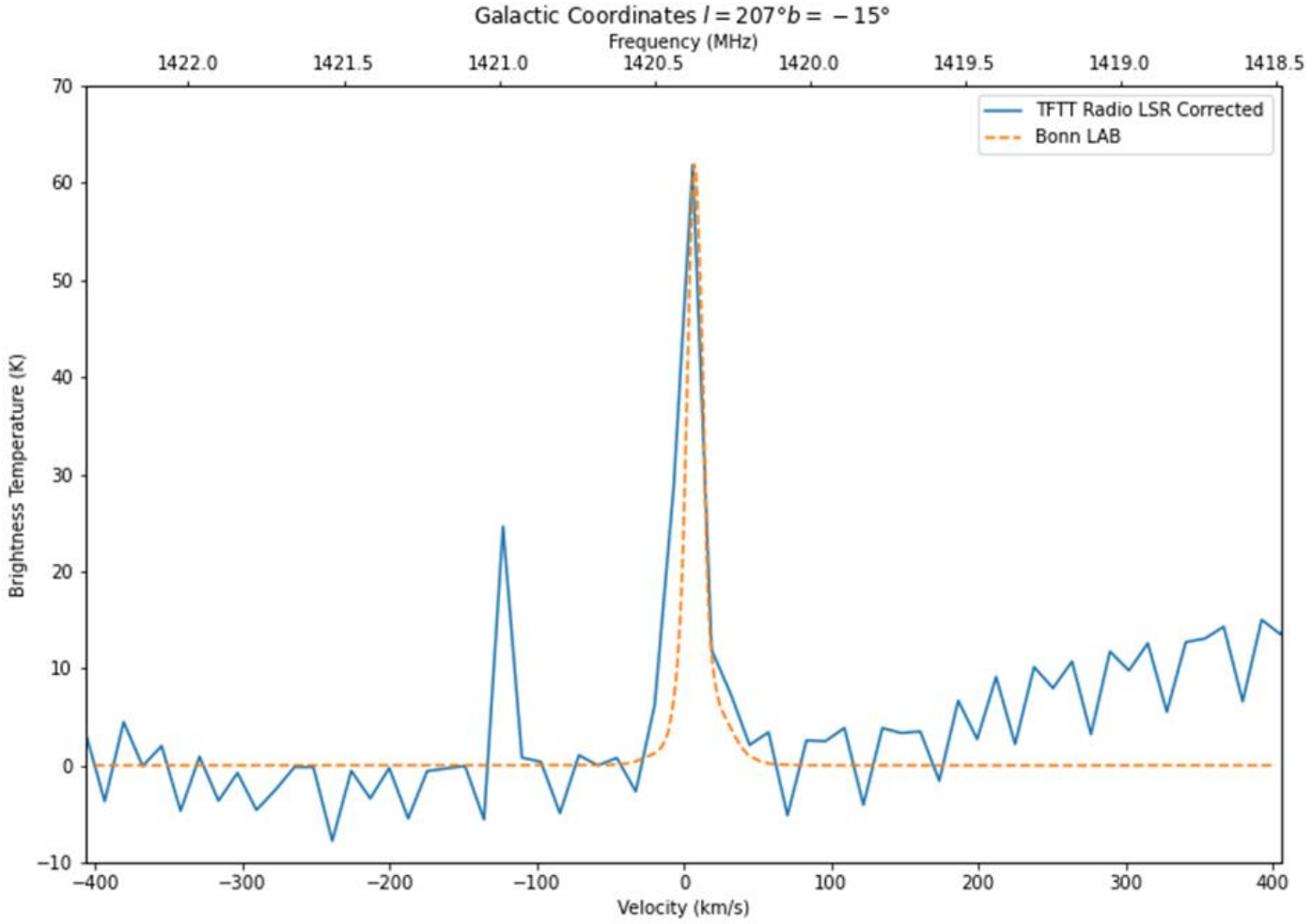
- Correct for Earth's motion in direction of coordinates
- Enter required information in Python given script

LSR Velocity



- Correct for Earth's motion in direction of coordinates
- Enter required information in Python given script
- Use observed and apparent rest frequency to correct LSRV

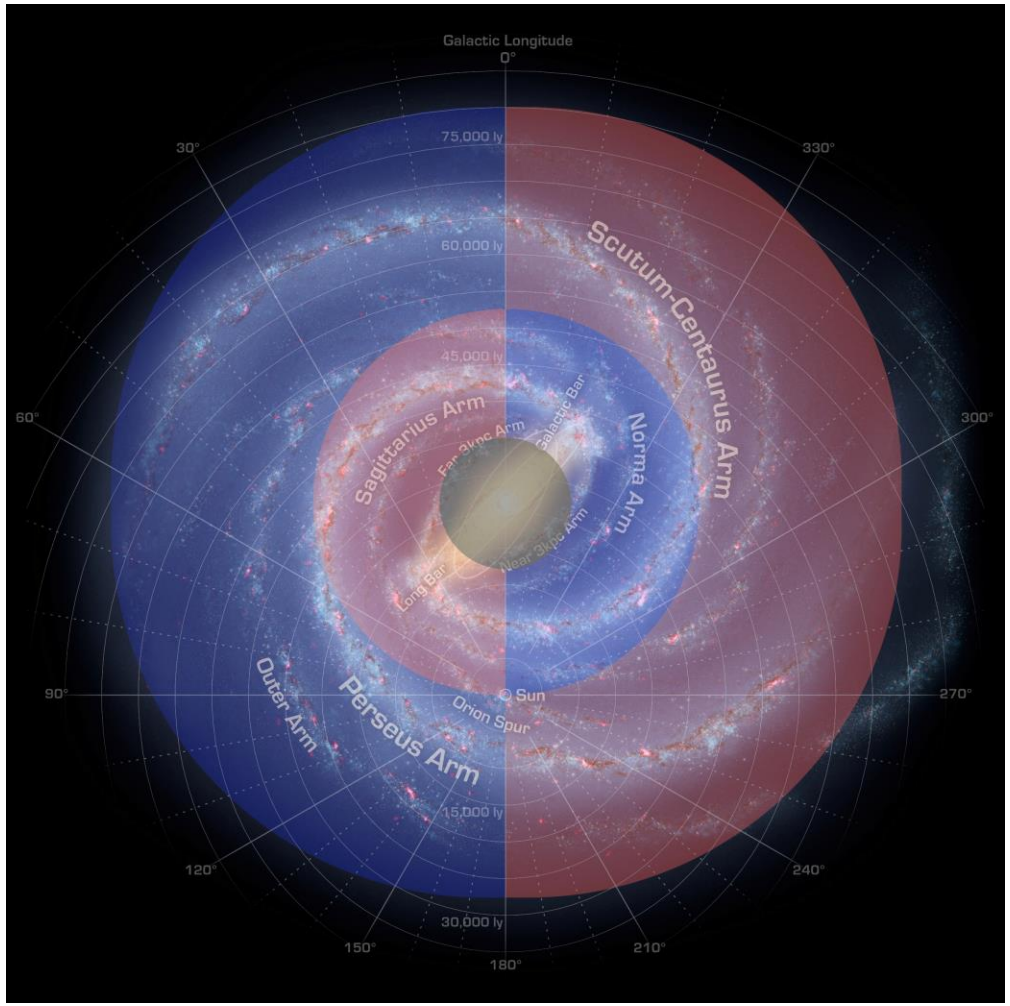
LSR Velocity



- Correct for Earth's motion in direction of coordinates
- Enter required information in Python given script
- Use observed and apparent rest frequency to correct LSRV
- Covert frequency to radial velocity scale using

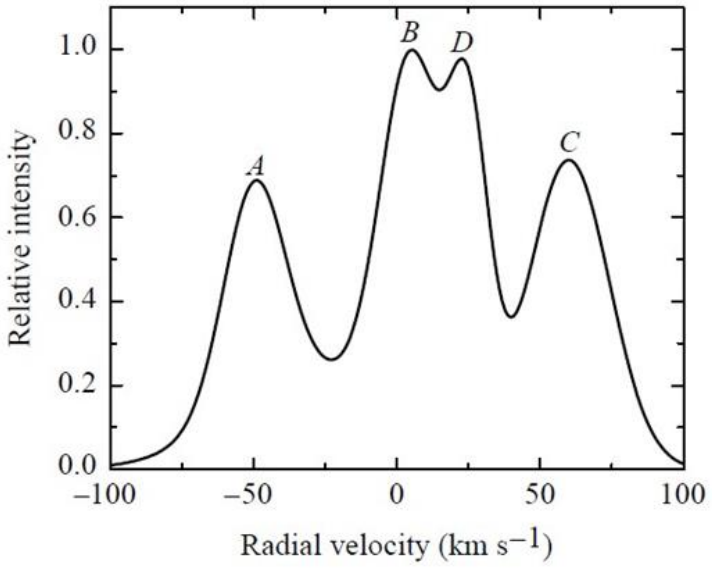
$$v = c\frac{\Delta f}{f_0}$$

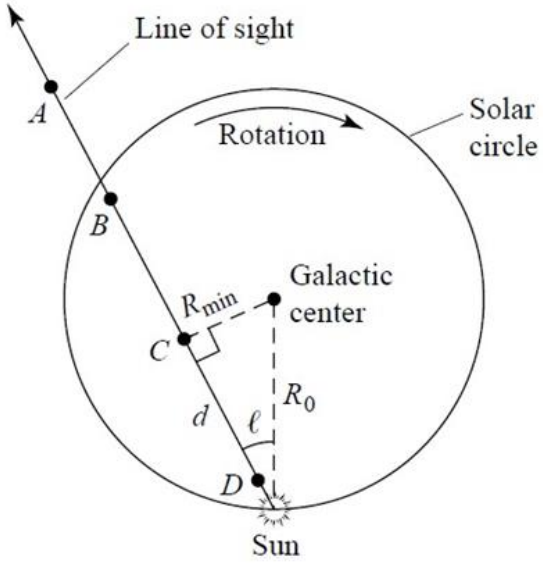
Rotational Velocity & Distance



- Rotational velocity decreases with increased distance from center
- Longitudes between 0° and 90° are redshifted within Sun's orbital radius and blueshifted between 270° and 0°

Rotational Velocity & Distance





- Rotational velocity decreases with increased distance from center
- Longitudes between 0° and 90° are redshifted within Sun's orbital radius and blueshifted between 270° and 0°
- The maximum velocity in this region point tangent to orbital circle
- Distance to point is

$$R_{min} = R_0 \sin(l)$$

Report

- Method
  - Explain your observations and every step of your practical
  - Use paragraphs and not lists
  - Avoid explaining unimportant details (*e.g. “then I clicked open”*)
- Results
  - Report all final results obtained and any calculations done
- Discussion
  - Interpret and explain your results
  - Compare your results to other findings if appropriate
- Conclusion

Report

- References
  - Reference all information from sources which are not your own (including images)
  - Use a known referencing style (e.g. Harvard)
  - Make sure references are cited within your report
- Additional comments
  - Observations are done in groups but each person must submit their own report
  - All figures and tables should be numbered and captioned
  - Plagiarism will be heavily penalized
  - Remember significant figures and errors
  - Submit in PDF form
  - If you have any questions email me (bret.yotti@uct.ac.za)