Practical Training Radioastronomy

institut für astrophysik
UNIVERSITÄTSSTERNWARTE WIEN
astro.univie.ac.at

Exercises Quick Reference

Ing. Harald Chmela, BSc, MSc

harald.chmela@univie.ac.at

Image credits: ALMA (ESO/NAOJ/NRAO), C. Malin & J. Guarda

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Exercises

Note: Numbers in ( ) refer to the document „Control Software for Small Radio Telescopes”
Further Information in control_sw_for_small_radtel_v1_1.pdf on radio.univie.ac.at

Part 1: Observe the Sun

(3.4.) Measure the ground temperature, calculate the calibration factor (1P)

(3.1.) Measure the antenna beam width, calculate the dilution factor (1P)

(3.2.) Measure the aperture efficiency (1P)

(3.3.) Calculate the radio temperature of the Sun (1P)

Part 2: Observe the Milky Way Galaxy (choose one option) (6P)

(3.6.) Measuring the galactic rotation curve

or

(3.7.) Reconstruction of the spiral arm structure

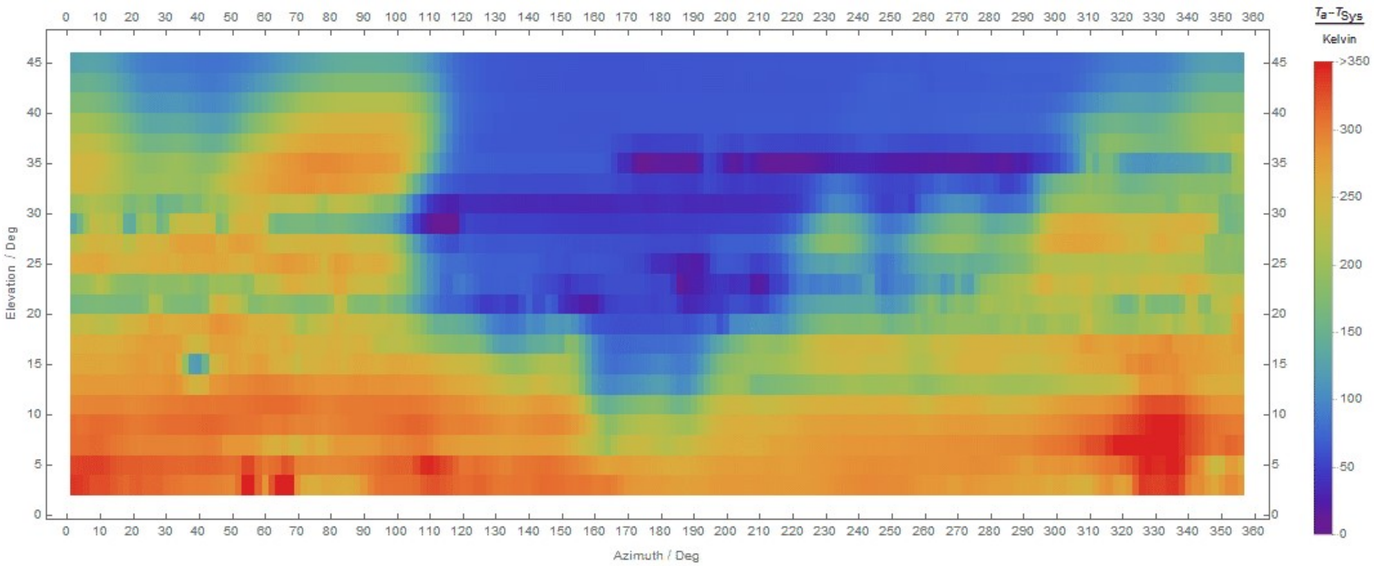
or

(3.9.1.) Observation of a faint object (CasA, M1, Moon,… ?) with different methods, **Drift scan**, cross scan, beamswitching, N-point map

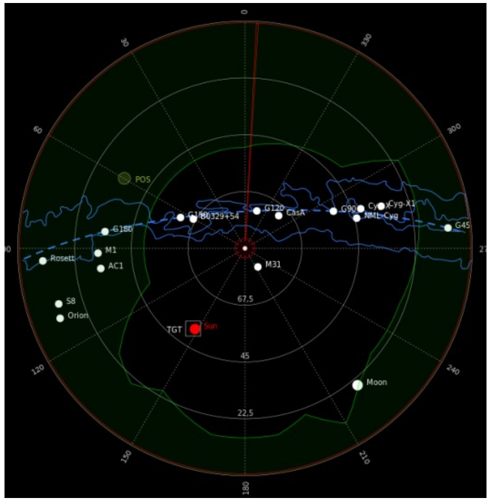
In total 10P

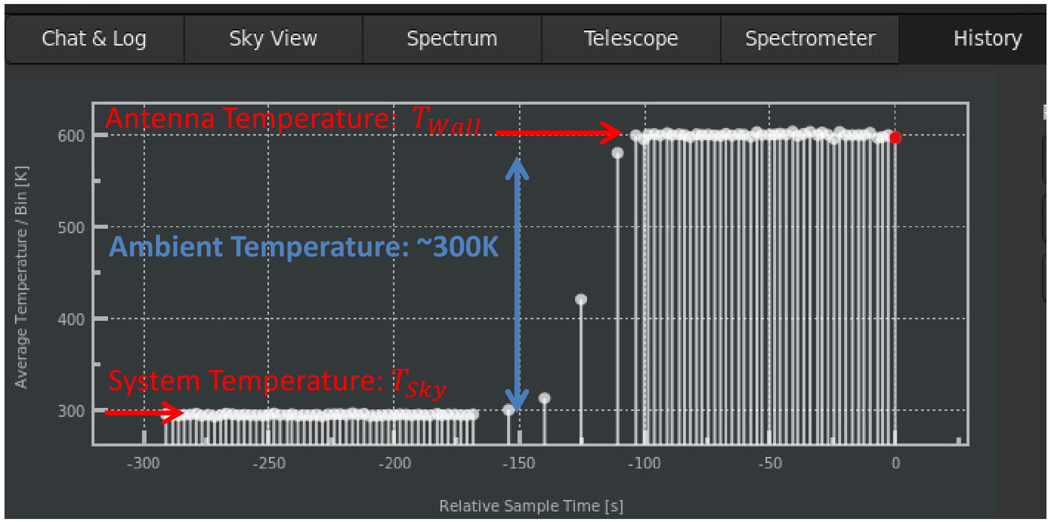
(3.4.) Ground Temperature

Continuum map at the SRT site in the frequency range 1400 MHz - 1427 MHz



Sky (black) is cold ~3K
Ground (green) is hot ~300K

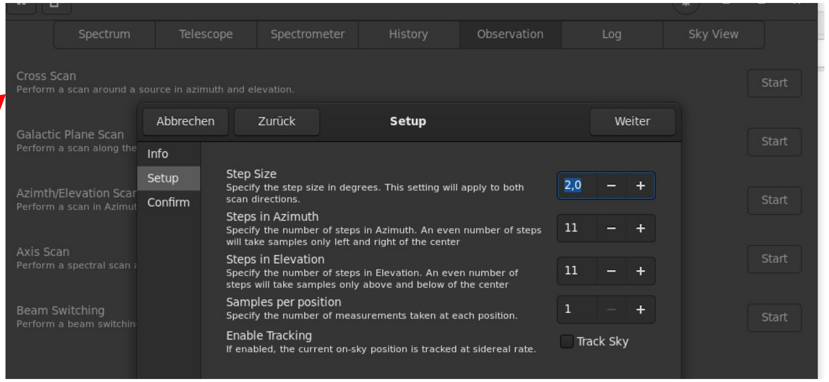


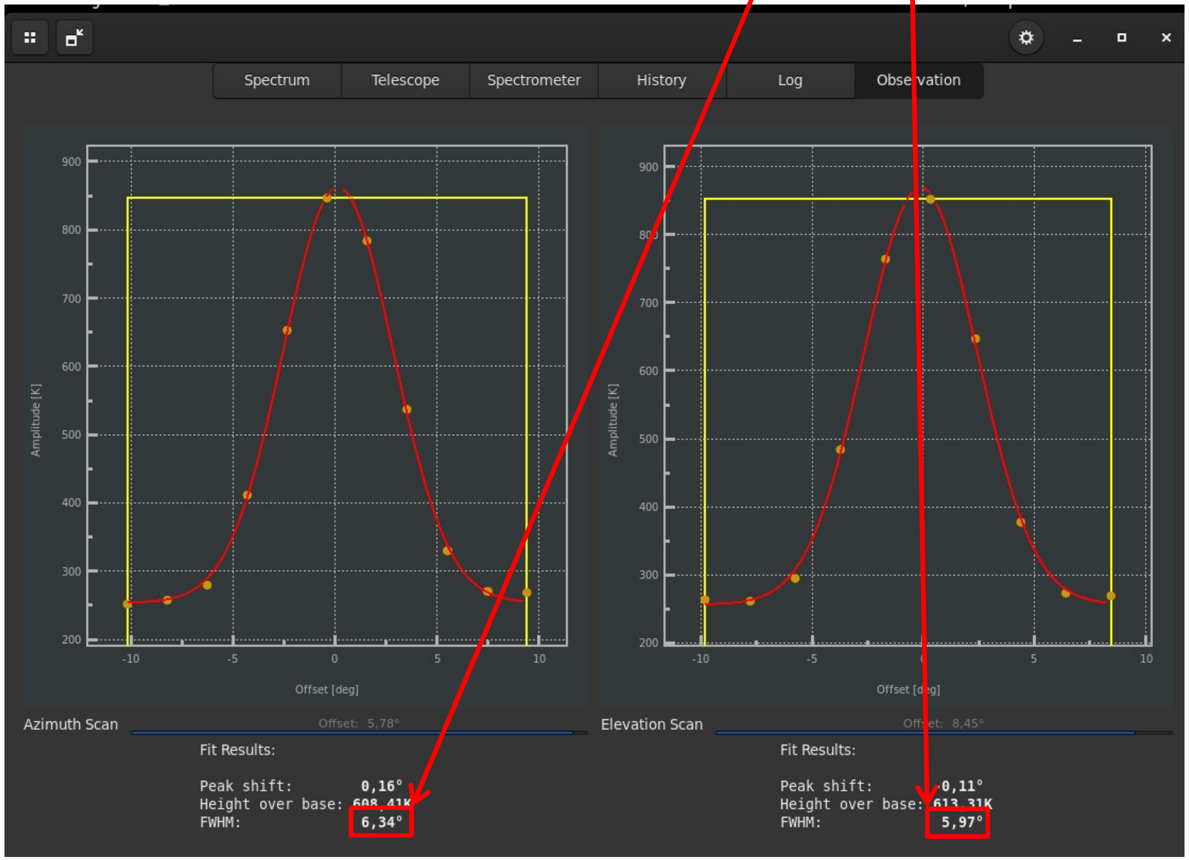


1. Point the telescope to azimuth 102° and elevation 65° into the free sky
2. Set center frequency around 1415 MHz and 0,34 MHz span
3. Check for a clean spectrum
4. Move the telescope towards the building wall at azimuth 102° and elevation 15°
5. Readout the increase in temperature in the "History" plot
6. Get the ambient temperature from www.zamg.ac.at
7. Calculate the calibration factor $= \dfrac{T_{Ambient}}{T_{Wall} - T_{Sky}}$

(3.1.) Antenna Beam Width

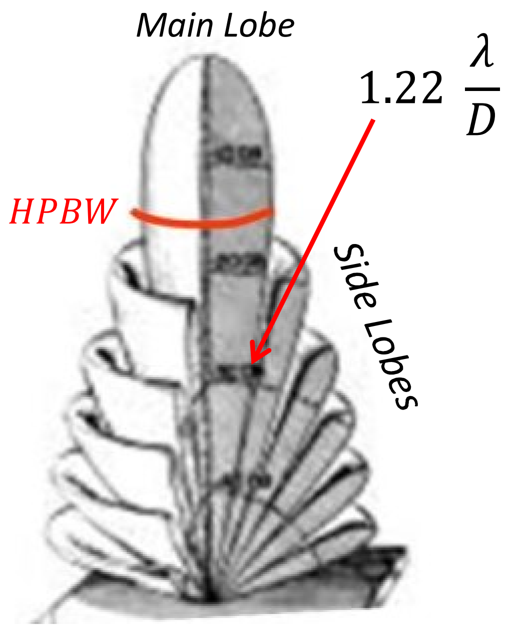
1. Point the telescope to the sun
2. Set 1415 MHz center frequency and 0,34 MHz bandwidth
3. Start the “Cross Scan” Observation with a step size of 1° and 21 points
4. Readout the beamwidth in AZ and EL





$$HPBW\,[°] \approx 1.025\,\frac{\lambda}{D}\,\frac{180°}{\pi}$$

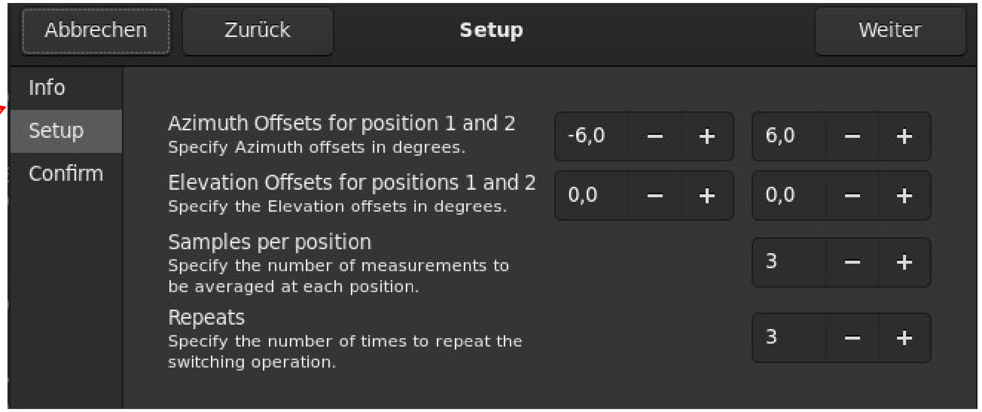
3D Beam Profile:



(3.2.) Aperture Efficiency

1. Point the telescope to the sun
2. Select 1415 MHz center frequency and 0,34 MHz bandwidth
3. Use the “Beam Switching” observation to measure ΔTa
4. Get the actual solar flux S from radio.univie.ac.at
5. Calculate η_{ap}

[Mathematica Notebook]()



Effective Aperture

The effective aperture of an antenna is given by[20]:

$$A_e = \frac{2k\Delta T_a}{S}$$

Using (5.1) one can write

$$\eta_{ap} = \frac{2k\Delta T_a}{SA_p}$$

where

k = Boltzmann's constant = $1.38 \times 10^{-23}\, JK^{-1}$

ΔT_a = measured incremental antenna temperature, K

S = source flux density, Jansky ($10^{-26}\, Wm^{-2}Hz^{-1}$)

A_p = reflector area, m^2

Link to Solar Flux Data

Actual Data at: https://radio.univie.ac.at/

Original FTP Link to 7 days data

ftp://ftp.swpc.noaa.gov/pub/lists/radio/7day_rad.txt

Note: Modern Browsers do not support FTP sites. Use an FTP Client.

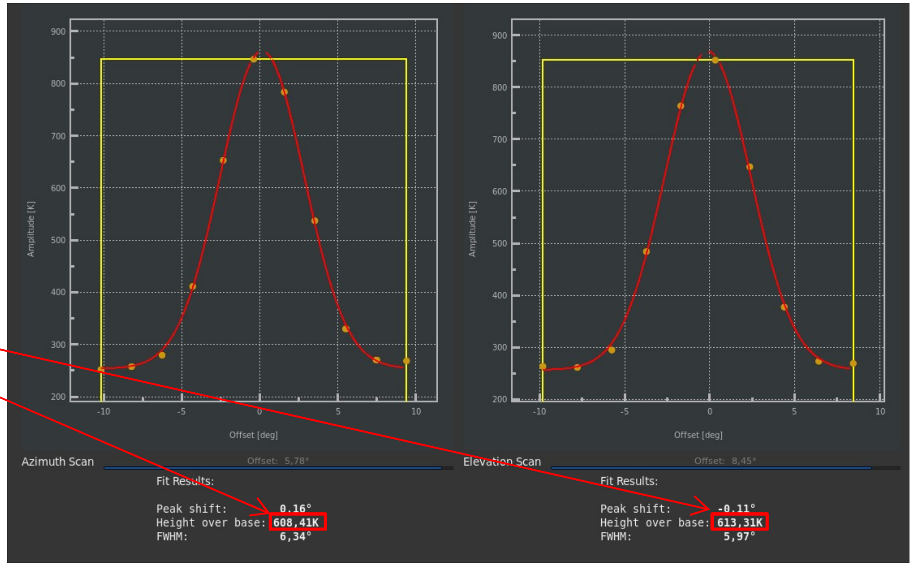
```
:Product: Solar Radio Data                 7day_rad.txt
:Issued: 1622 UTC 17 Apr 2015
#
# Prepared by the U.S. Dept. of Commerce, NOAA, Space Weather Prediction Center
# Please send comments and suggestions to SWPC.Webmaster@noaa.gov
#  Units: 10^-22 W/m^2/Hz
#  Missing Data:  -1
#
#    Daily local noon solar radio flux values - Updated once an hour
#
  Freq  Learmonth  San Vito  Sag Hill  Penticton  Penticton  Palehua  Penticton
   MHZ   0500 UTC  1200 UTC  1700 UTC   1700 UTC   2000 UTC  2300 UTC  2300 UTC

2015 Apr 17
   245        19        23        23         -1         -1        24        -1
   410        40        50        45         -1         -1        47        -1
   610        64        -1        69         -1         -1        68        -1
  1415        98       106       103         -1         -1       102        -1
  2695       146       137       149         -1         -1       136        -1
  2800        -1        -1        -1        153        150        -1       149
  4995       192       194       182         -1         -1       189        -1
  8800       294       300       288         -1         -1       308        -1
 15400       537       590       505         -1         -1       587        -1
```

Solar flux at different sites x 10^{-22} W/m²/Hz

(3.3) Sun Temperature

1. Point the telescope to the sun
2. Set 1415 MHz center frequency and 0,34 MHz bandwidth
3. Use “Cross Scan” to get ΔTa
4. Calculate T_{sun} by the beam dilution factor. Radio diameter of the sun is 0.6°.



Calculate the beam dilution, which is the ratio of the solar size to the beam width:

$$D = \frac{A_{Sun}}{A_{Beam}} = \frac{r^2_{Sun}}{r^2_{Beam}}$$

multiply the dilution factor by the mean height of the peaks to find the undiluted temperature for the solar disk:

$$T = D^{-1} T_{Peak}$$

now get T_{Sun} from:

$$T_{Sun} = \frac{T}{\eta_{ap}}$$

[Mathematica Notebook]

Sun´s Radio Frequency Temperature

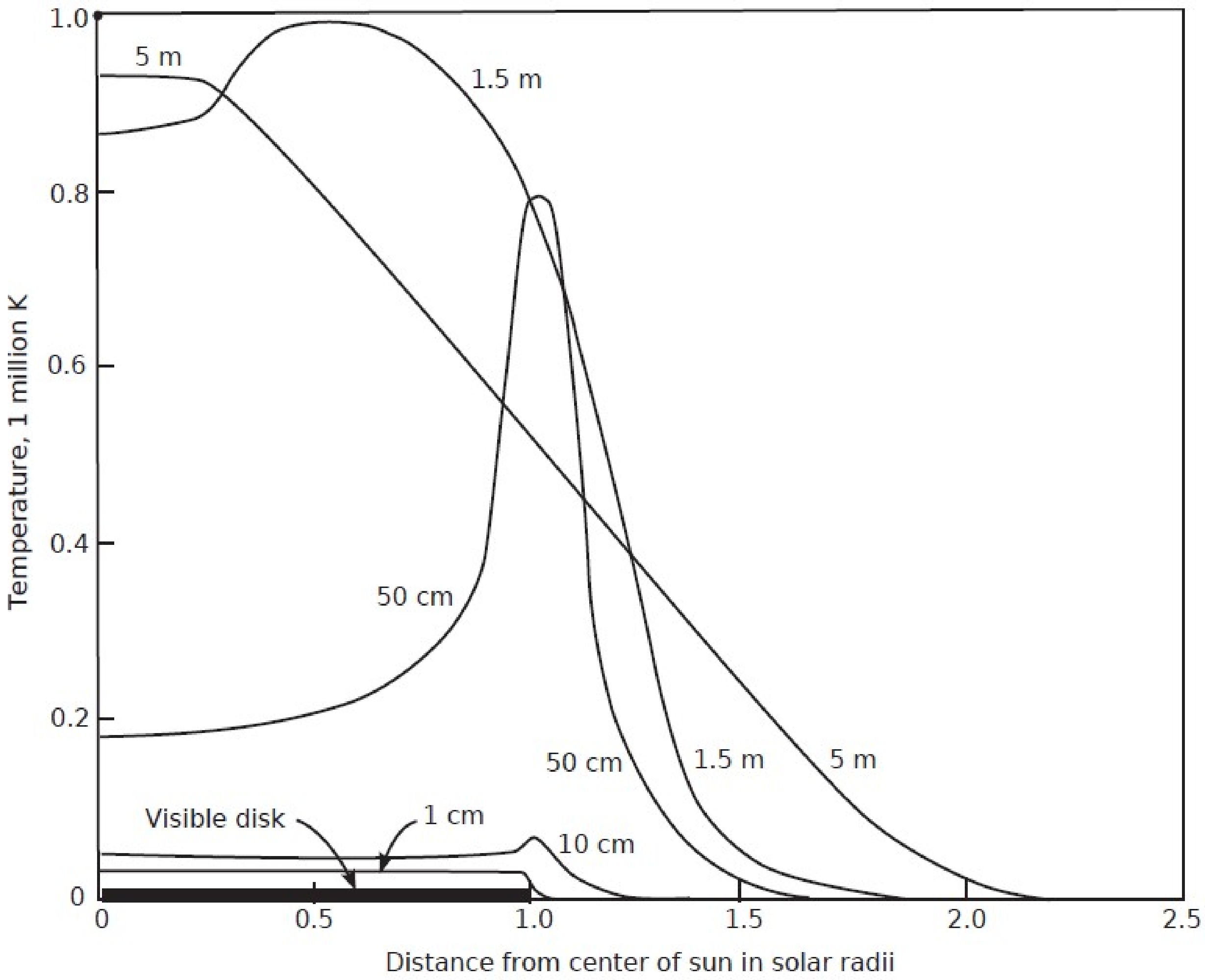
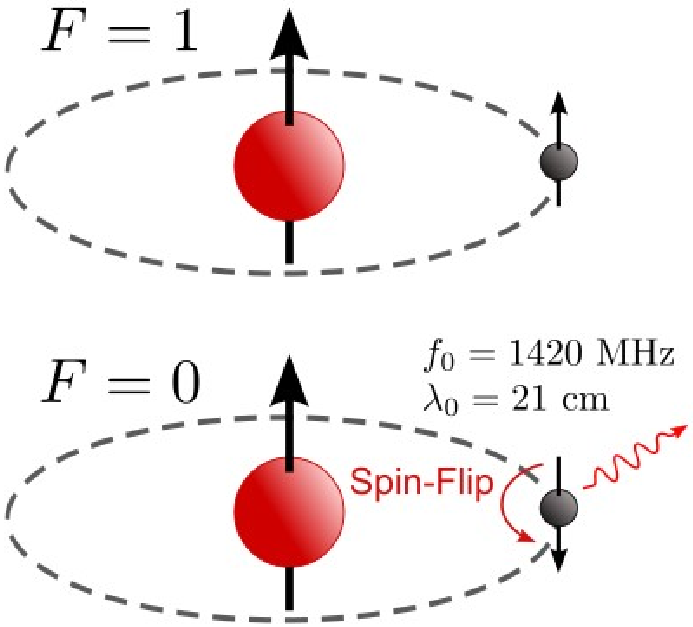
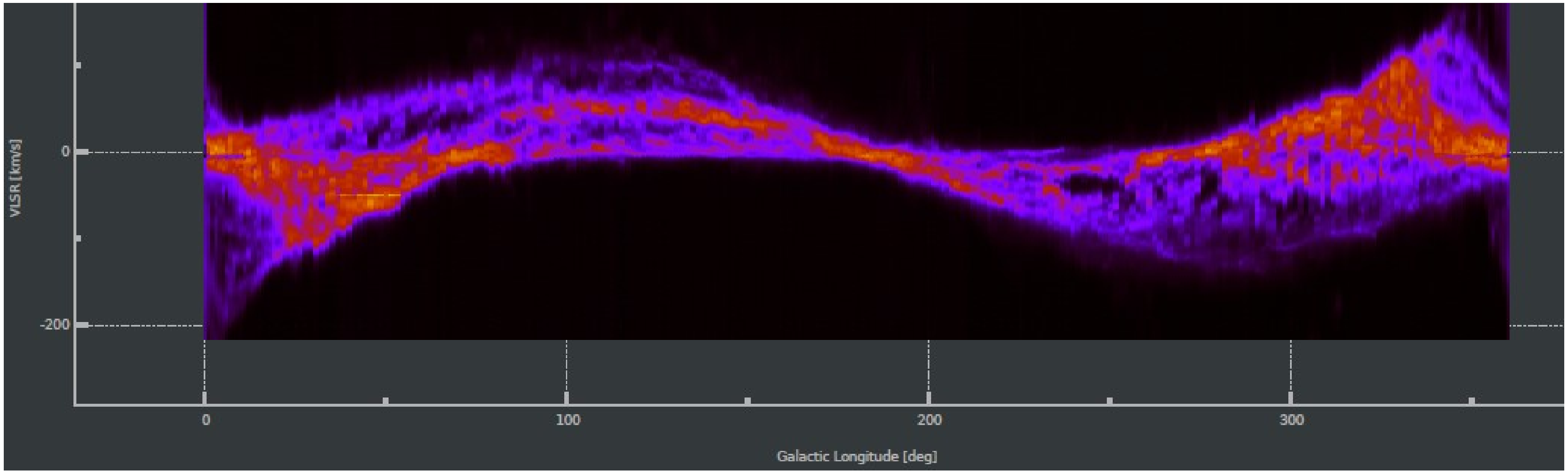


Figure 5.5.: The predicted variation of the effective temperature with distance from the centre of the solar disk at different radio frequencies. [22]

21 cm Line of the Hydrogen Atom

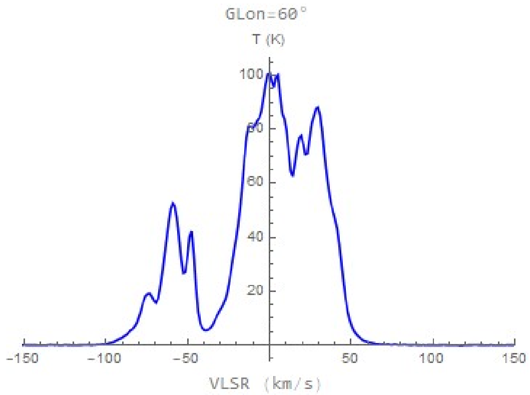


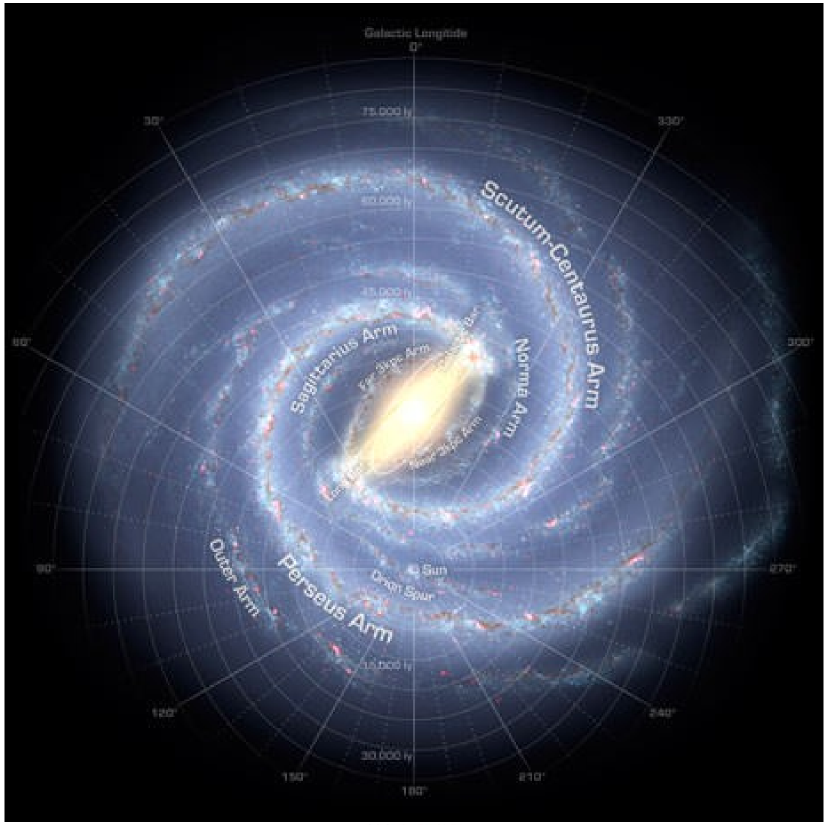
- The H atom is not ionized
- The H atom is not bound in a H2 molecule
- The parallel alignment of the magnetic moments has a higher energy content
- The spin transition has a very long lifetime around 10 million years therefore it is called a “forbidden” transition
- This can be used to study the movement of hydrogen in the Mikly Way Galaxy by the Doppler shift

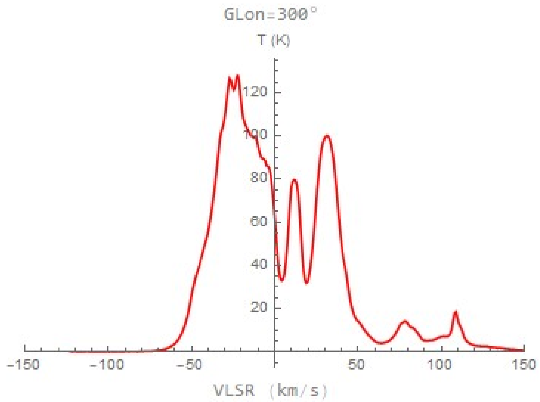


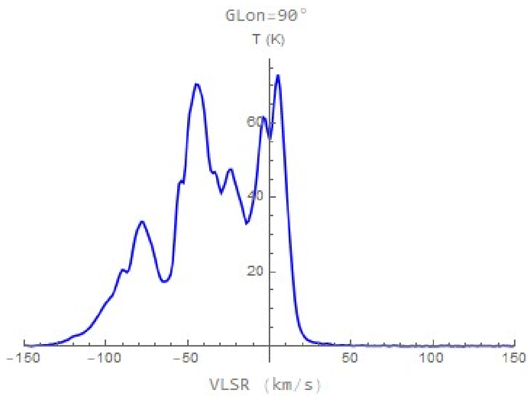
Galactic Rotation Profile [N-Body Simulation]

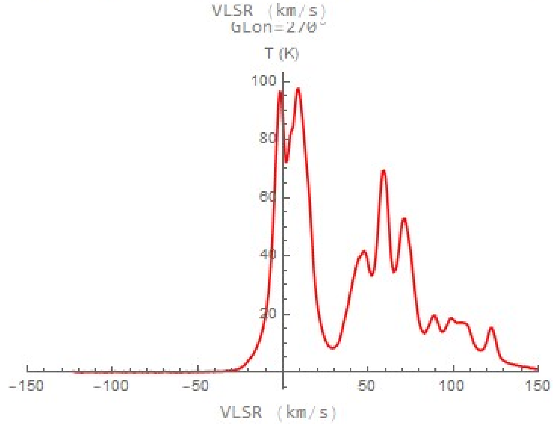
HI Survey Data Server: [www.astro.uni-bonn.de/hisurvey/AllSky_profiles]

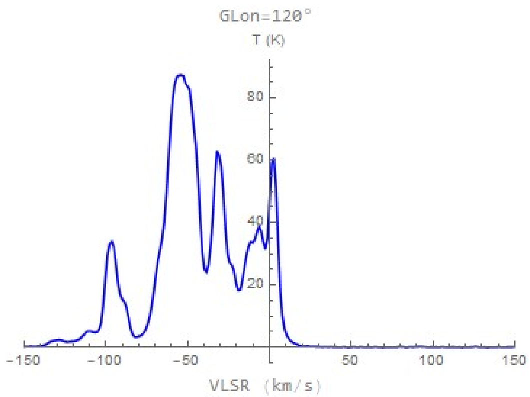


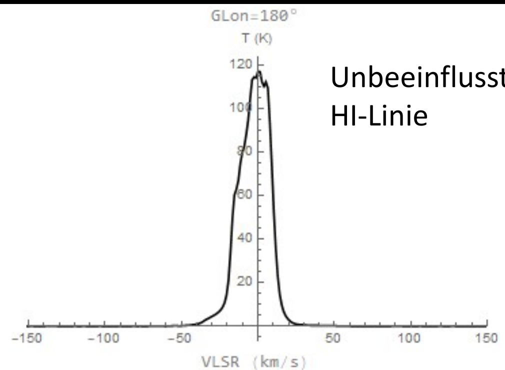




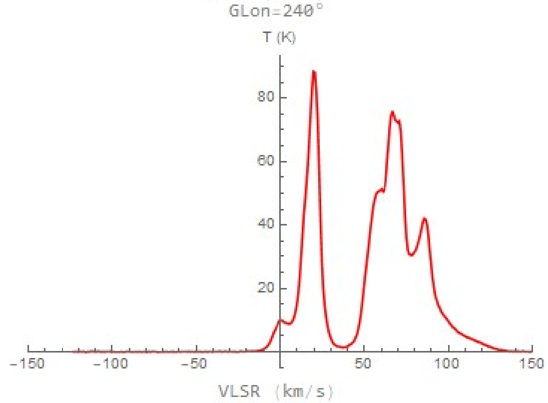






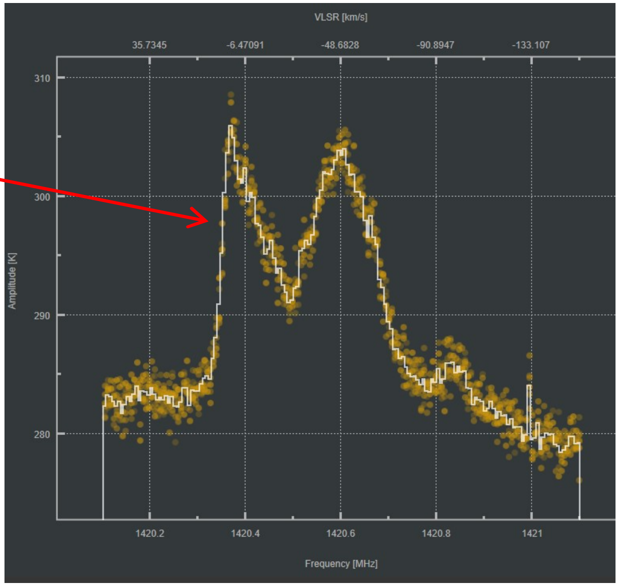


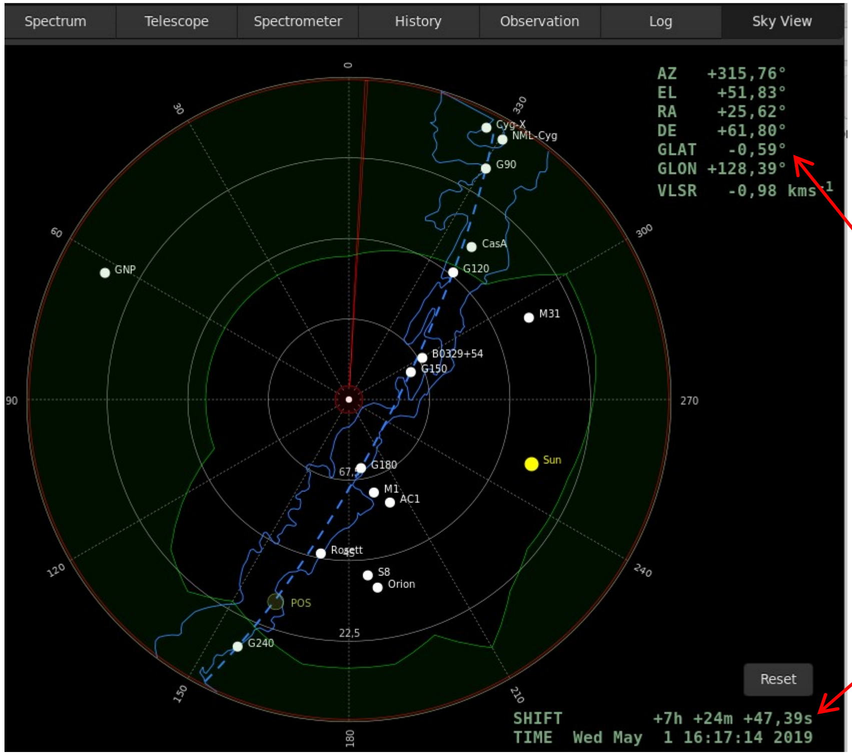
Unbeeinflusste
HI-Linie



Observing the Galactic Plane

1. Switch to galactic coordinates
2. Move the telescope into the galactic plane GLAT=0°
3. Set spectrometer input mode to VLSR
4. Set center to 0 km/s, span around 300 km/s
5. Check if the HI-Line is visible in the spectrum



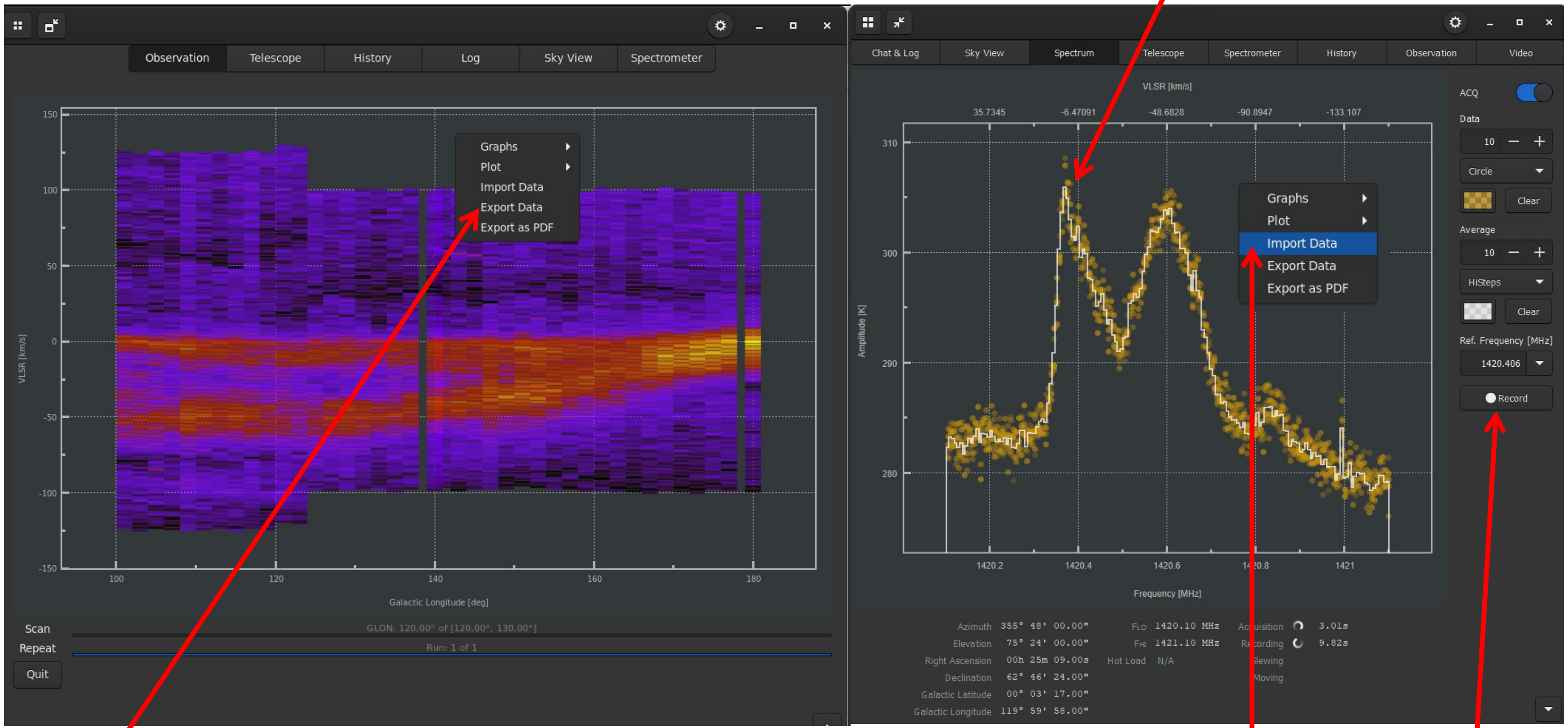


Use the cursor to readout visible coordinate range

Use right click drag to look forward in time and plan your observation to cover the whole galactic plane

(3.5.) Recording Data

1. Check if the hydrogen line around 1420,4 MHz is visible in the spectrum
2. Open observation „Galactic Plane Scan“
3. Set visible galactic coordinates and start the observation



- Data can be saved by right click in the plot and „Export Data“
- The file can be opened in spectrum window by right click and „Import Data“
- By clicking “Record” all data from the telescope during the plane scan can be saved.

(3.7.) Spiral Arm Structure

Oort's Law:

$$v_r = A \cdot R \cdot sin(2\,l)$$

$$A = 14{,}82 \pm 0{,}84 \frac{km}{s\ kpc}$$

v_r = Radial Velocity

R = Distance to galactic Center

l = Galactic Longitude

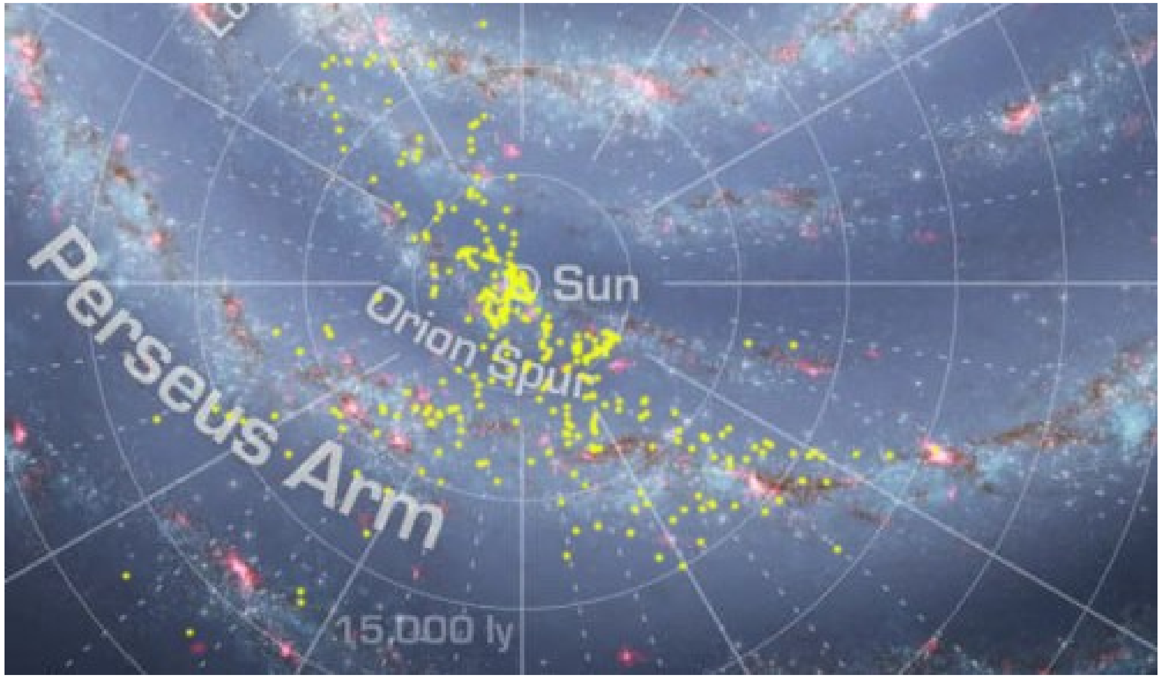
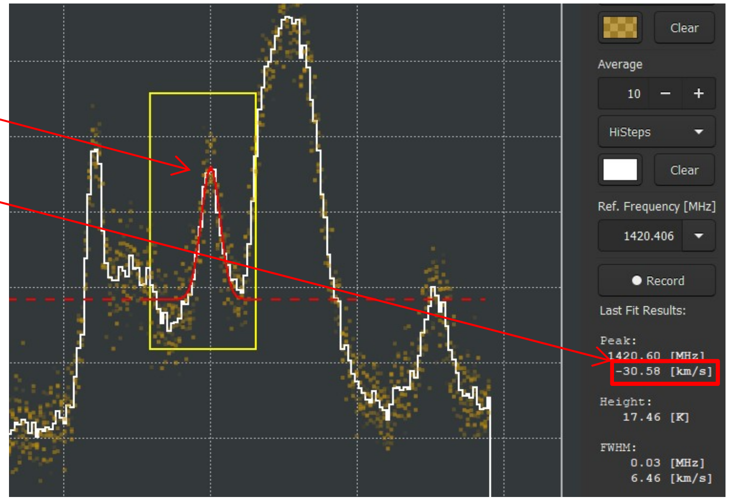


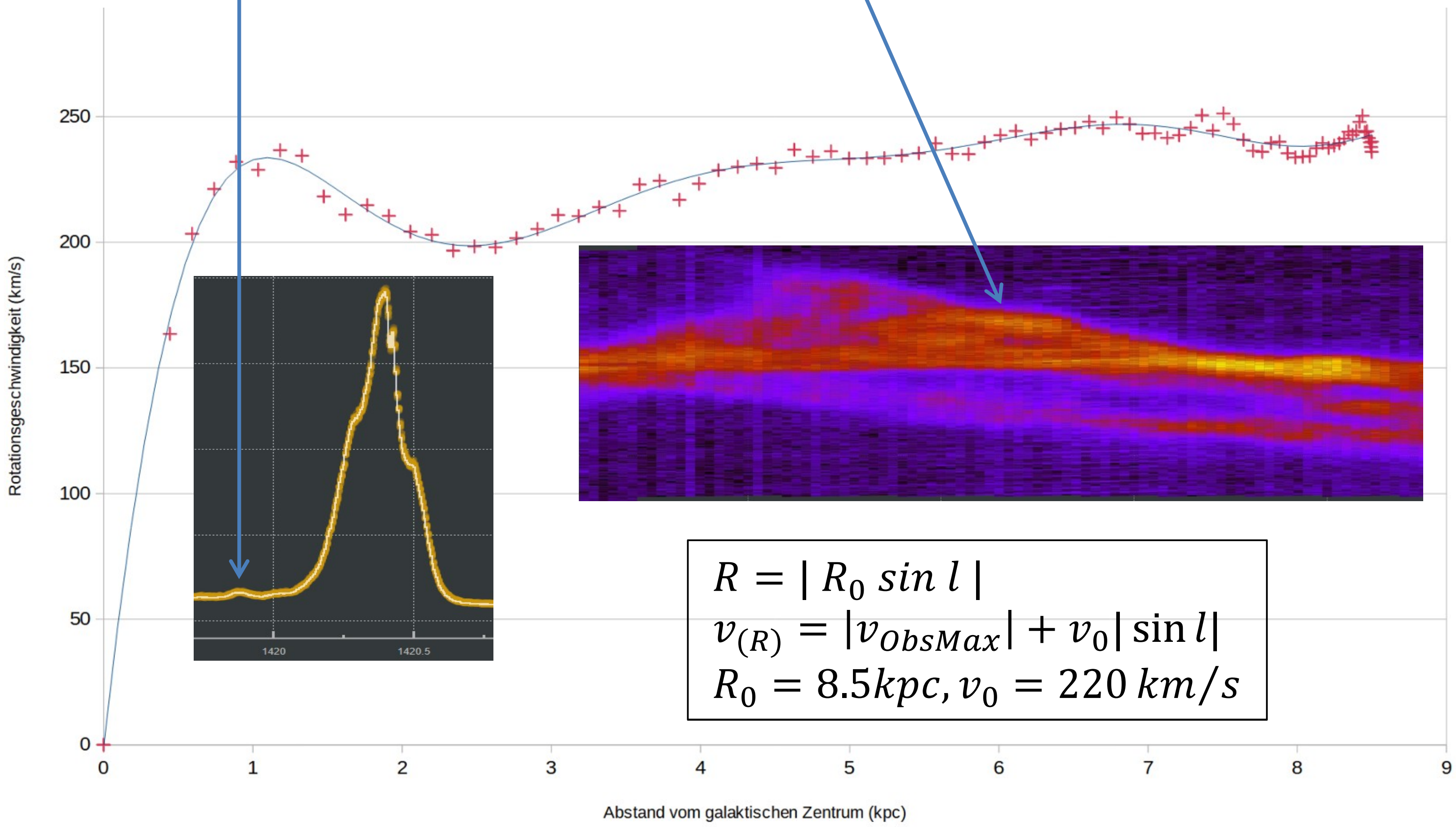
Image Credit: L. Mittermeyer, 2024

1. Point into the galactic Plane
2. Fit a Gauss to every spectral peak
3. Write down v_r for each peak
4. Calculate R using Oort's Law
5. Polar plot R and l
6. Change galactic longitude l and repeat cover the whole galactic plane



(3.6) Galactic Rotation Curve

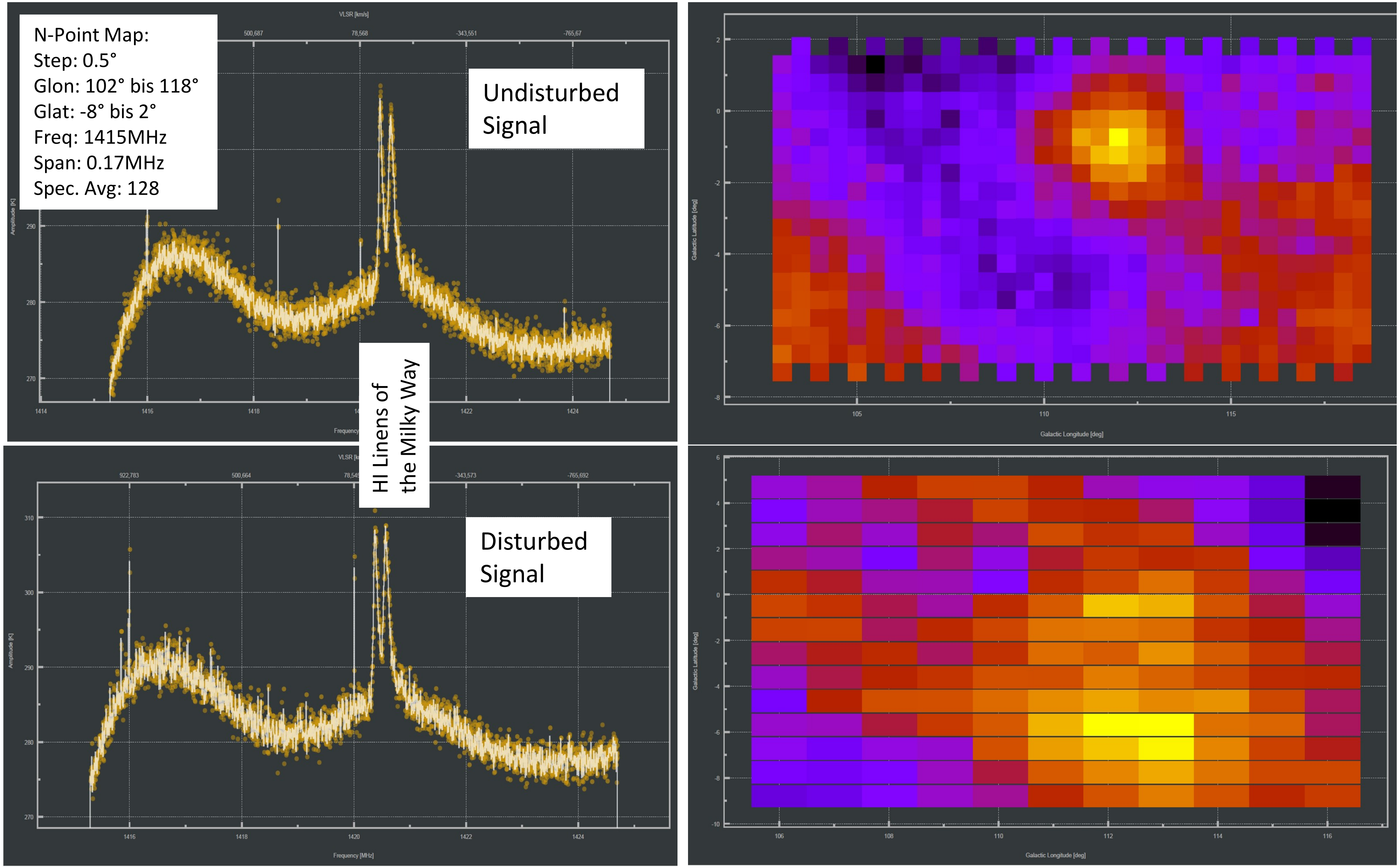
- Record data as in (3.7), but only between galactic longitudes 0° and 90°, towards the galactic center
- Find the most redshifted (highest positive velocity v_{ObsMax}) peak in each spectrum
- Plotting $v_{(R)}$ over R leads to the galactic rotation profile
- Be aware of very small peaks near the galactic center, take always the smallest, or use the cursor readout in the VLSR Profile to find the blue envelope.



$$R = |\, R_0 \sin l \,|$$
$$v_{(R)} = |v_{ObsMax}| + v_0 |\sin l|$$
$$R_0 = 8.5 kpc, v_0 = 220\ km/s$$

Observing faint Objects

Cassiopeia A or other from paper: Important Celestial Radio Sources



(3.9.1.) Drift Scan Observations

Best for faint objects because ground radiation doesn't change.

1. Point the telescope 1h in advance to the object using the sky view time offset.
2. Switch off the tracking.
3. Record data for 2h using the record button in the sky view.
4. Repeat this with small pointing offsets to the object (1° steps) for several times.
5. Use the Python Script for evaluation.
6. Be prepared for electromagnetic interference, it is better to observe at night.