শ্রীমতী সুস্মিতা চট্টোপাধ্যায়

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NCRA

PUNE

Expt: Determination of Pointing Offsets Beam Pattern Measurement of the 4-Meter telescope.

16/12/2024

Initialization of 4-m telescope at NCRA

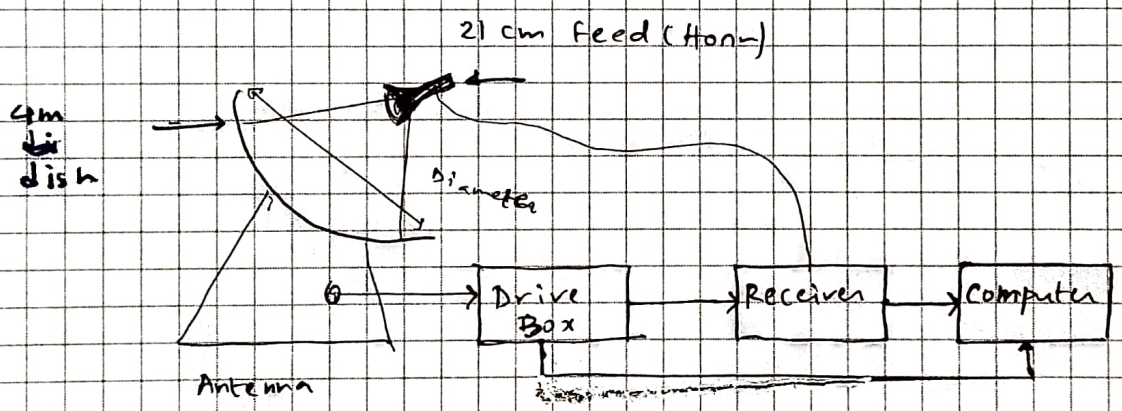
Before performing any experiment, the telescope and receiver has to be initialized.

Precaution | **Parking Post:** 140 deg Az, 50 deg Elev.

- Do NOT rotate the antenna beyond limit angles.
- Wait for 10-15 sec after clicking START scan before starting actual scans for the first time.

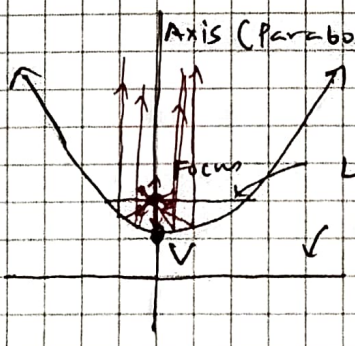
Aim:

① To find the ~~others~~ Offsets of telescope coordinates, the beam-width of the telescope, detection of Galactic HI line etc.



- θ motion control using stepper motor
- Position detection using Encoder PC/104.

∴ Parabolic → All inc. ∥r rays will merge at focus !!

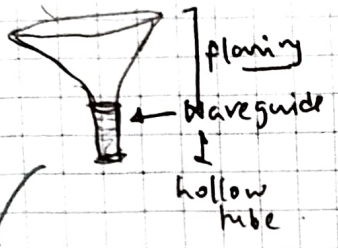


By symmetry we can also assume an isotropic point source at focus to be ~~not~~ producing beam ↓ reflecting to give ∥r beams.

Hence, all the waves reaching the aperture have the same phase

As the waves are in phase, the beam of radiation along the parabolic axis will be strong and concentrated.

Horn Feed → collects signal made by parabolic dish ~~dish~~ are collected by horn-feed antenna.



designed to minimize reflection.

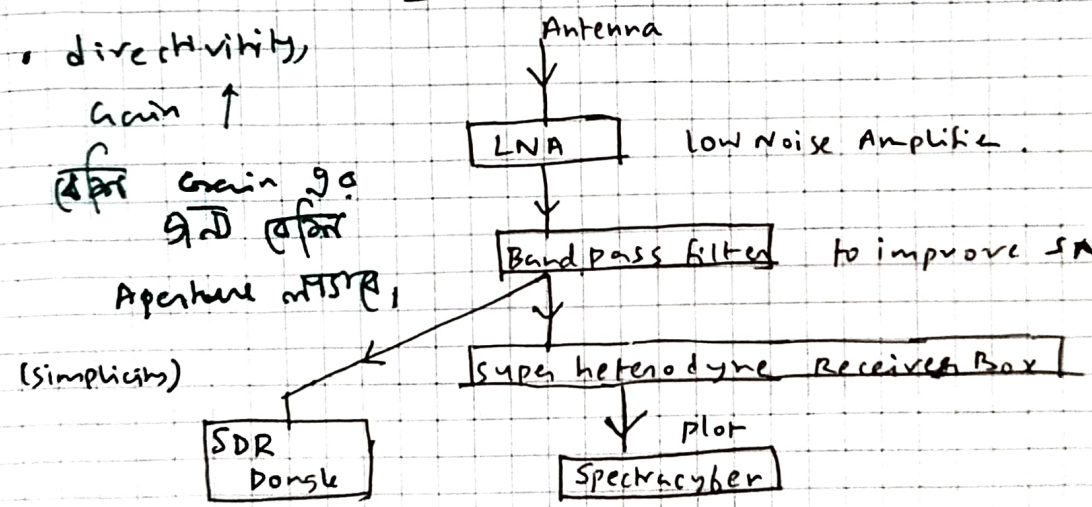
A horn antenna is an antenna that ~~consists~~ of flaring metal waveguide

↓

Radio waves ⇒ beam

Receiver

- directivity, gain ↑
- Aperture ↑



Motion Control

— Alt-Az mount

↳ DC stepper motor

↳ L298N control driver.

↳ relay and limit switches.

Position detection.

Instantaneous angular position of antenna is being detected by

↓

Position Encoder

Rotational movement

↓

Electrical signal.

Starting up.

① Start stepper motor Driver and Encoder PC/104

② Boot Receiver

③ Wait 10s to start initialization

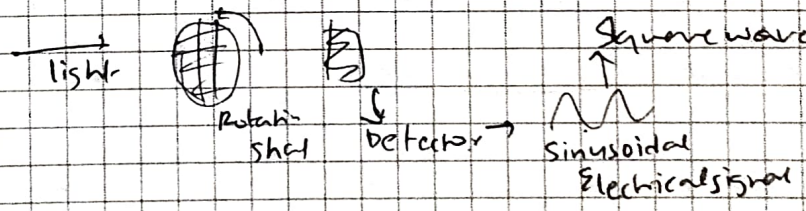
④ Take readings.

PC/104 Encoder ही? → Absolute Encoder.

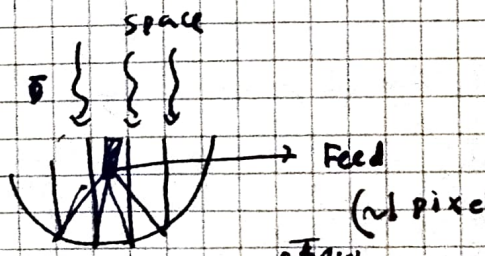
Encoders allow mounts to ensure that the telescope is pointing exactly where you want it for long periods. with extremely high degree of precision.

Encoder gives feedback abt

→ Position
→ Speed
→ Count
→ Direction



Determining of Pointing Offsets and Beam Pattern.



EM waves → Electrical signal.

But Actually NOT

these waves Are ~~not~~ focused to a point at ~~the~~ Feed, but rather form Airy DISK

A circular aperture yields an Airy Disk
↓
Bessel function.



Reflectivity at ~~Edge~~ Edges is tapered
~ to prevent unwanted 2nd ary peaks in signal.

~~Beam~~ Focused beam ⇒ Central peak (Lobe) followed by weaker side lobes

Best Modelled by weaker side lobes.

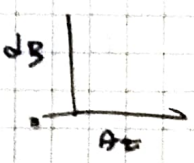
Aim

① We will determine the offsets b/w the electronic reference of the telescope and the astronomical Alt/Az coordinate system at observatory

② Using cal. offset, we scan in Alt, Az direction to calculate beam-width of 4m telescope.

① Get Exact Alt, Az post of sun.
Then Measure with telescope.

(deg) Az.	Az. Intensity	Intensity (dB).



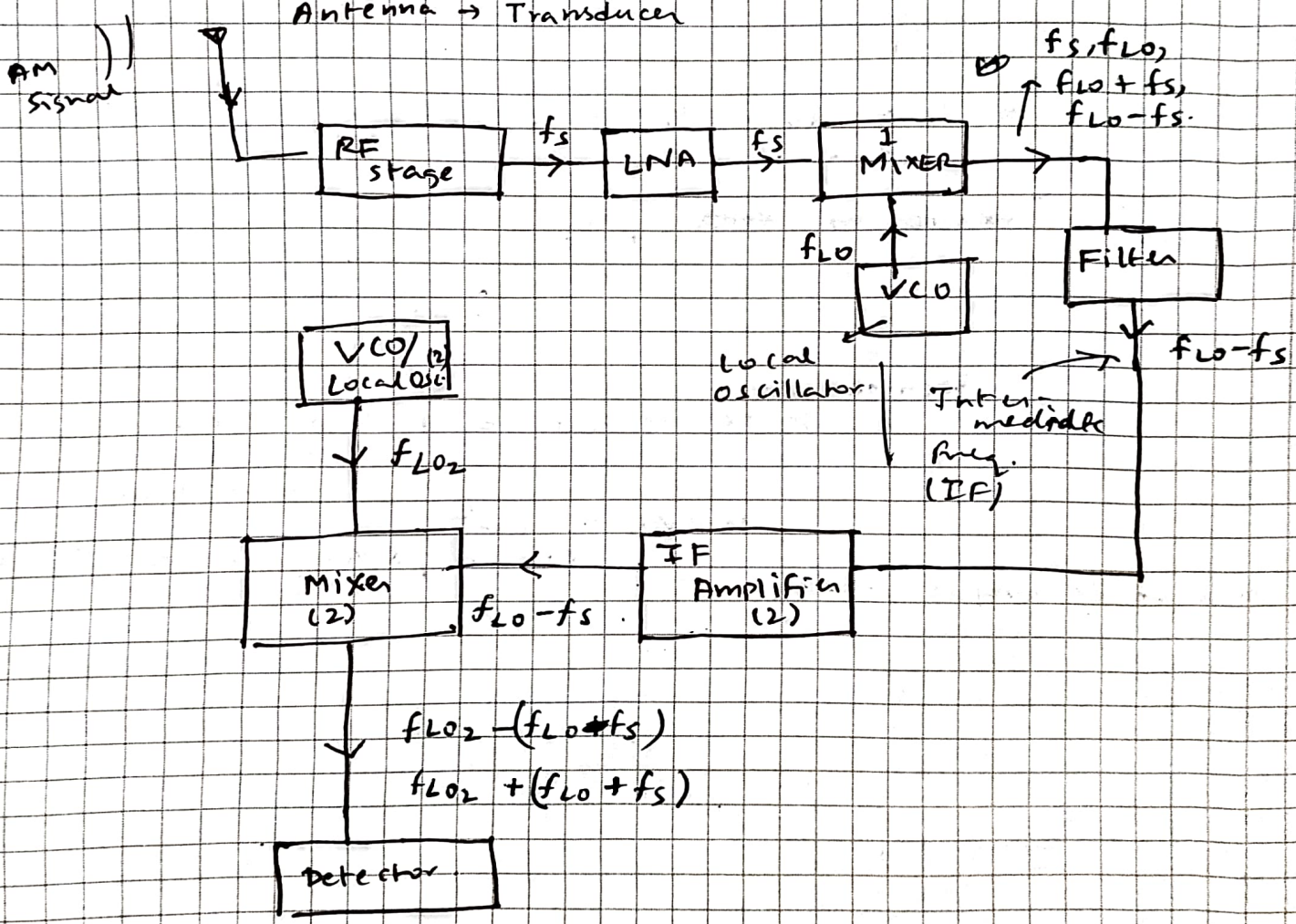
Fit data with Gaussian.

Find FWHM of gaussian → Beam width.

Resolution $\theta \sim \frac{1.22\lambda}{D}$ D = Diameter

Resolving Power = $\frac{1}{\theta}$.

Expt: Superheterodyne Receiver

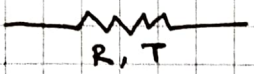


Johnson Noise Experiment

~~Team~~

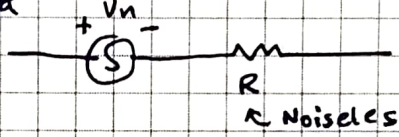
Aim: To measure Johnson Noise of a given resistor at room temperature and compare its properties with Nyquist's theory.

Introduction



How do we diff. b/w a hot circuit & "cold" circuit.

modelled as ~~volta~~



Because our source of heat ≡ power source.

III

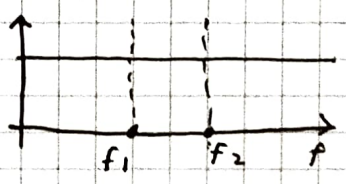
Thermal Noise

However, we can't extract power from this circuit and ~~to~~ do useful work.



~~Thermal freq.~~

Let power density is flat wrt frequency,



$$\text{Average Power} = \int_{f_1}^{f_2} S(f)\,df = S\Delta f = \frac{V_{rms}^2}{R} \quad (W)$$

↳ Ω

For thermal Noise

$S = 4K_B T$ = Constant ⇒ White Noise.

$K_B = 1.38 \times 10^{-23}$ J/K.

Now,

$P_{av} = \frac{V_{rms}^2}{R} = 4K_B T \Delta f$

$V_j \Rightarrow V_{rms} = \sqrt{4 K_B T (\Delta f) R}$ $\propto T$ ↓

Thermal Noise

$\propto R$ ↑ small and less noisy

$\propto \Delta f$ ↓ Don't allow wide freq.

For

$R = 50\Omega$

$T = 300$ K

$\Delta f = 1$ Hz

$V_{rms} = 9.1 \times 10^{-10}$ V $\simeq$ 1nV.

↳ Noise voltage!

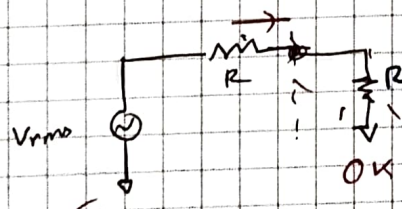
For

$R = 1$ KΩ.

$\Delta f = 20$ KHz

$T = 300$ Hz

$V_{rms} = 575.5$ nV. ← Noise level to expect at room Temp.



What's the max power the above resistor can transfer to the rest of a circuit.

Max Power

$T = 300$K

$R_L = R$

$P_{av.(R_L)} = \frac{\left(\frac{V_{rms}}{2}\right)^2}{R_L} = \frac{V_{rms}^2}{4R_L}$

$= \frac{4K_B T \Delta f R_L}{4R_L}$

$= 8.28 \times 10^{-17}$ W

This means if we had a completely sealed room, then Energy would flow from $T = 300$K side to $T = 0$K side, and energy dissipated across R_L per second $= 8.28 \times 10^{-17}$ W.

Once RL gets hot, it will again flow back, and then it will reach thermal equilibrium.

Johnson Noise = Thermal Noise = Nyquist Noise = White Noise

~ Arises due to statistical fluctuations in the movement of charge carriers due to thermal agitation.

Low Level Electronics (LLE)

total gain 60 dB

High-level Electronics (HLE).

to control bandwidth

gain ~ 10 000

- Seeing and Quantifying Johnson Noise
- ↳ see $V_j^2 = 4 K_B T (\Delta f) R$.
  - $V_j^2 \propto R$, & Δf.
  - see increase gain to maximum level and saturation level.
- see how Johnson's Noise depends on resistance. (Note temp. at each reading)
- 2nd Johnson Noise Dependence on Bandwidth.

R & Constant

(21 cm) HI line Experiment

_ IUCAA ACE

We shall be pointing the horn antenna to various galactic longitudes (l) in the galactic disk and take readings for 6 hr (τ_{int})

FOV : 16°

l = [5, 15, 25, ... 85, 115, 135]

Step 1 Find (l, Alt, Az) coordinates for a particular l at THAT TIME using stellarium.

Step 2 1st. Make the Antenna Horizontal (to point X-axis of phone's magnetometer to the horizon)

- Rotate to the Azimuth. (keeping it horizontal)!
- Gently tilt it to adjust ~~elevation~~ elevation.
- Tight the lock screws!

Take Readings

we will set

Power (arbitrary units)	Frequency (MHz)
⋮	⋮

* Do this for all l

Then take 1 reading for ground ($T = 300K$),

& other for sky ($T = 3K$) by pointing telescope away from the disk.

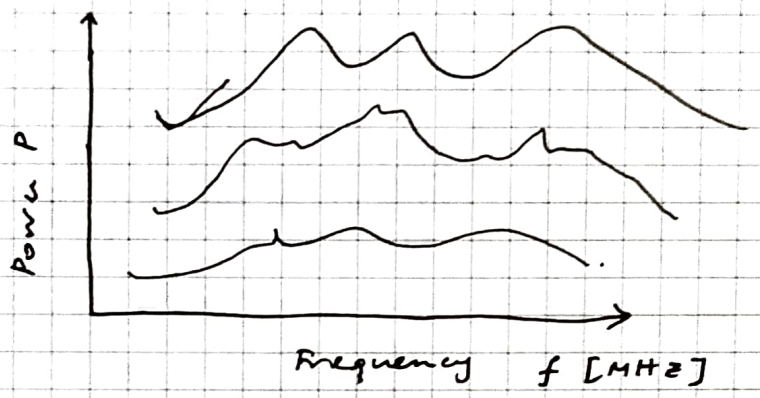
We have

$T_{source} = ?$ $\ell = (\cdot, \cdot)$ → P_{source}

$T = 5K$ sky → P_{sky}

$T = 300K$. ground → P_g .

1. Plot .



2. change y axis to Temp.

$$P_g = G(T_g + T_r)$$

$$P_{sky} = G(T_{sky} + T_r)$$

↓

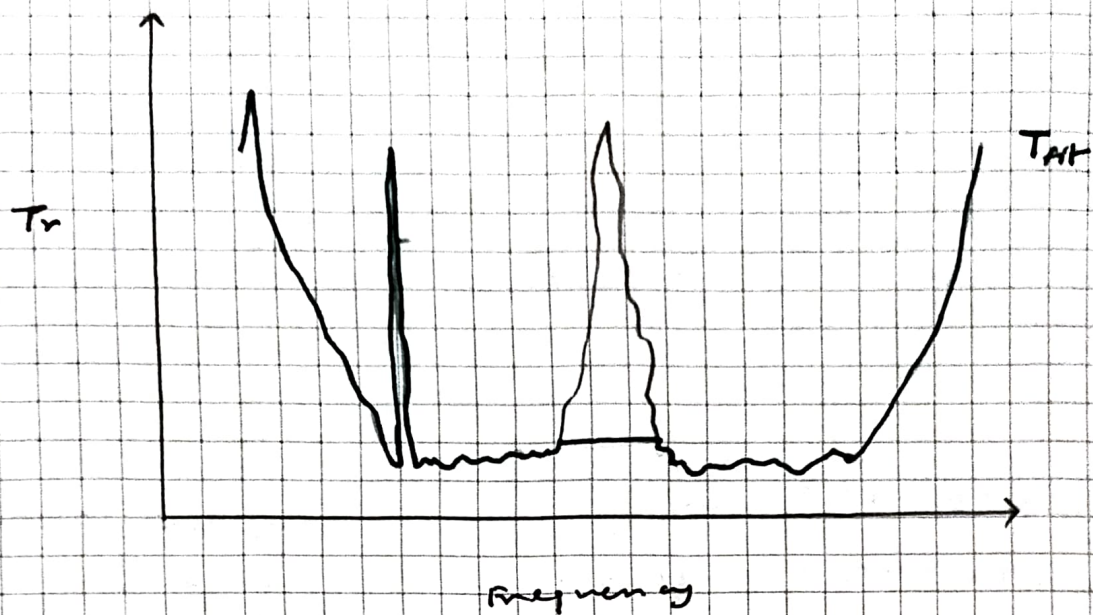
G ← proportionality constant

T_r → Temp. of receiver (Antenna)

$$T_r = \frac{T_{sky}\left(\frac{P_g}{P_{sky}}\right) - T_g}{1 - \left(\frac{P_g}{P_{sky}}\right)}$$

3. Correct T_r . → T_r has an artefact of H1 peak which is present in any direction of sky, (also in T_{source}). So,

In order to get the T_{HI}, we remove the peak by linear fitting the baseline.



4. Now Put T_{fit} in place of T_r.

Find $\underline{T_{source}}$.

$$P_g = G_n (T_g + T_{fit})$$

$$P_{source} = G_n (T_{source} + T_{fit})$$

$$\downarrow$$

$$T_{source} = \frac{T_g + T_{fit}}{\left(\frac{P_g}{P_{source}}\right)} - T_{fit}$$

5. Find Brightness Temperature.

$$T_b = T_s - \text{np.min}(T_s)$$

Lo baseline ~0 K

Where

$$B_\nu(T) = \frac{2\nu^2 k_B}{c^2} T_b$$

↓

* this is a measure of non-thermal emission. It is the equivalent temp. of a blackbody that would emit the same intensity at a particular ν.

6. Velocity Calibration

X axis

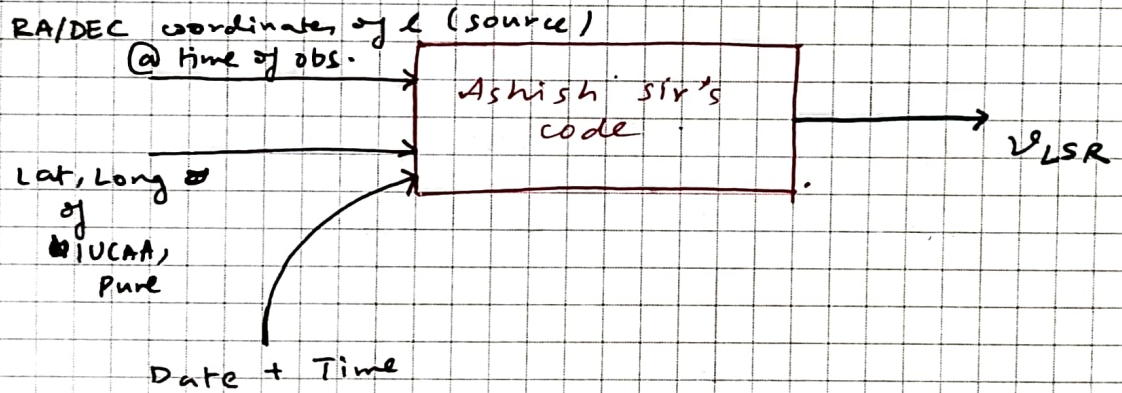
$$v_{corr} = c\left(1 - \frac{f}{f_0}\right) + v_{LSR}$$

v_{LSR} → Local standard of Rest correction.

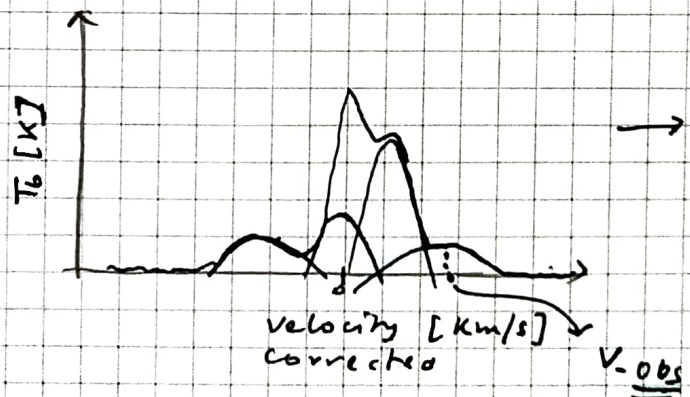
So, that our results are independent of our position on Earth / solar system.

$c = 299792.458$ km/s

$f_0 = 1420.4057$ MHz.



7. Multipeak fit, to identify the molecular cloud which has the largest +ve velocity (along LOS)



eg:- → 4 gaussians fitted.

Do this individually for all 'l' and each unique v_{LSR}.

No. of gaussians is limited by the no. of spiral arms in Milky Way!! Max 5-6 fits.

8) Using simple trigonometry.

$$v_{source} = v_{obs} + v_{sun} \cdot \sin l$$

v_{sun} = 220 Km/s
$R_\odot$ = 8.5 #Kpc

And dist. of source from galactic center,

$$R = R_\odot \sin l$$

9) Plot HI rotation curve!!

