

Detecting Galactic HI line using the 4-m SRT

1 Goal of the experiment

The goal of the experiment is to detect the galactic HI line emission and to understand the physics behind it. In this experiment, we will observe the emission from neutral hydrogen (HI) present in our Galaxy, Milky Way. This emission occurs at 21 cm (1420 MHz) and arises due to the transition between the hyperfine split ground state of the hydrogen atom. The experiment involves positioning the telescope at a given point along the Galactic plane and taking the spectrum towards the pointed direction. A shift in the line from its rest frequency is expected. The observed shift may either be redshift or blue shift and will depend on the position of the observed source on the Galactic plane. The spectrum thus obtained can then be analyzed to measure the line strength, width and position.

2 Brain Teasers

1. What is the distance of the sun from the centre of our galaxy? How are the plane of the galaxy, plane of the solar system and plane of the revolution of the earth and the axis of rotation of the earth linked with one another? Estimate maximum speed of the earth due to all these motions. How much Doppler shift will these motion be responsible for (if an observer decides to receive a signal from a stationary source outside our galaxy)?

Ans.:

2. Our galaxy - Milky way, forms a bright band in the sky visible on a dark night. Find out how the galaxy lies in the sky at the time of the experiment and draw it approximately in the space provided below by showing directions. Indicate whether the Galactic center, which is believed to harbour a supermassive black hole, is visible at the time of the experiment.

Ans.:

3. Three strong radio sources are CRAB, CASA and CYGA. Which constellations harbour these? Indicate below the names of the constellations and whether these sources are visible at the time of experiment. If yes, find the area of sky where these will be located.

Ans.:

4. Indicate the approximate time of rise and set in IST today when the sources with following RA and Dec can be observed using our 4-m telescope at NCRA East Campus.

RA	Dec	Time (IST)
01h 30m	+33 deg 20 min	
05h 31m	+21 deg 10' min	
04h 37m	-56 deg 01 min	
17h 10m	-30 deg 23 min	
21h 05m	+40 deg 21 min	

Table 1: List of sources

3 Procedure for the experiment

Before starting with the experiment, initialization of the telescope has to be done. For this purpose please refer to the document titled "Initialization of the 4-m Telescope System". The experiment involves observations of a few selected points along the Galactic plane with 0 degree Galactic latitude. The list of some standard strong radio sources is given below. The Table-2 gives coordinates of 4 of the IAU calibrators (i.e., their brightness temperature (T_b) is accurately known - Williams, 1973) and can be used for the HI detection experiment as well as for determining the system temperature (T_{sys}). The sources given in Table-3 are the points on the galactic plane and can be used for mapping the Galactic HI emission.

Source	T_b (K)	RA	DEC
S9	85±6	17h 52m 05s	-34 deg 25 min 42 sec
S8	72±5	05h 47m 21s	-01 deg 40 min 18 sec
S7	100±7	02h 06m 13s	+60 deg 32 min 52 sec
S6	51±4	15h 31m 34s	-02 deg 25 min 09 sec

Table 2: Coordinates of HI bright IAU calibrators sources, in J2000 Epoch

The source position is given in the Equatorial Coordinate System (RA,DEC) of 1950 epoch. Precess the coordinates to the epoch of your observation and convert it to Horizontal coordinates to get the position of the source at a given time. The telescope can be pointed to these sources by rotating it in both axes.

The procedure for the experiment is given below:

1. Please read the document titled "Initialization and operation of 4-m telescope" and familiarize yourself with the instructions given there.

Source name	Galactic longitude (deg)	RA	Dec
P01	0.0	17h 42m 26s	-28 ⁰ 55' 00"
P02	30.0	18h 43m 28s	-02 ⁰ 39' 46"
P03	45.0	19h 11m 20s	+10 ⁰ 38' 13"
P04	60.0	19h 41m 47s	+23 ⁰ 46' 10"
P05	75.0	20h 19m 02s	+36 ⁰ 26' 45"
P06	90.0	21h 10m 18s	+48 ⁰ 07' 24"
P07	105.0	22h 28m 06s	+57 ⁰ 36' 13"
P08	120.0	00h 23m 01s	+62 ⁰ 26' 55"
P09	135.0	02h 28m 10s	+60 ⁰ 16' 29"
P10	150.0	04h 00m 39s	+52 ⁰ 17' 01"
P11	165.0	05h 00m 42s	+41 ⁰ 16' 57"
P12	180.0	05h 42m 26s	+28 ⁰ 55' 00"
P13	195.0	06h 14m 58s	+15 ⁰ 55' 24"
P14	210.0	06h 43m 28s	+02 ⁰ 39' 47"
P15	240.0	07h 41m 47s	-23 ⁰ 46' 10"
P16	270.0	09h 10m 18s	-48 ⁰ 07' 24"
P17	300.0	12h 23m 01s	-62 ⁰ 26' 55"
P18	330.0	16h 00m 39s	-52 ⁰ 17' 00"

Table 3: Source coordinates along the Galactic plane in 1950 Epoch

Mode	Spectral
Integration time	1 sec
IF BW KHz	15 KHz
Target Name	File Name

Table 4: Spectral mode selection steps

Parameter	Values
IF Gain	18
Spectral Gain	10
Spectral Offset	1.4
Upper limit	+2000
Lower limit	-2000
Time/step	0.2
Source name	Name

Table 5: Settings for spectral mode

In particular, read the "PRECAUTIONS" carefully and please follow these diligently.

2. Rotate the antenna using GUI on receiver system.
3. Stop the rotation once you reach the position for your observation.
4. The settings of the receiver for this experiment are as follows click and browse the setting for H1 line in spectral mode "Settings-Mode-Spectral"
5. Change the settings for spectral mode as given in table – 5. To change settings click Options – click "online", where filename should be HIbatchn (n=1/2/3/4/5/6 . . . depending on the batch).
6. Find out the Al/Az for the source you have selected at the time of observation.
7. Rotate the antenna and point it towards the source and start scan by clicking on the scan icon in the receiving computer.
8. Check the spectrum. One should see the strong H1 line on the screen.
9. If the line is not visible, check if you have followed the procedure correctly and entered the offsets.
10. If the line is visible, then record the data by putting autosave on. Check that the data are being recorded to the right filenames. Save 2,3 scans for each source.
11. Repeat the procedure for each of the source in Table 3. Record the data in a separate file. Fill the file names in the observation log.
12. Bring the telescope to home position after doing the observations.

4 Observation Log

1. Source, Data file name :
2. Source, Data file name :
3. Source, Data file name :
4. Source, Data file name :
5. Source, Data file name :

5 Analysis Procedures :

1. Copy the data file from the PC where you recorded data to the pc where MATLAB is installed (Equivalently you can analyze the data in OCTAVE or GNUPLOT).
2. Save the data file as a text file with a name such as "p1h" or "p2h" etc.
3. Click on MATLAB icon.
4. Remove the first line and copy /export the data to the MATLAB editor in the first row
5. Give some name to the folder in the work space e.g. p1 etc.
6. write the following command in command window for plotting the data

>> (your file name) e.g p' — this command will convert your data from column to row

Create an x array as

```
>> for i = 1:400 x(i) = 0.211*(i-201)*4 end
```

Create a y array as

```
for i = 1:400 y(i) = filename(i) end
```

and to plot use,

```
>> plot(x,y)
```

7. The line can be modeled as a set of Gaussians, where the height, width and position of Gaussian provides information about the strength, width and velocity of HI line. Follow the procedure to fit a set of Gaussians as in the analysis procedure for pointing offsets experiment.

Analysis with GNUPLOT:

1. To analyze with GNUPLOT one has to generate x axis with the Doppler shift formula which is as follows:

$$\pm V = (\pm \Delta \gamma * c) / \gamma$$

Where, V is the velocity of approach or recession “

c is the speed of light

$\Delta \gamma$ is the frequency shift

γ is the rest frequency for (H1 = 1420.4 MHz)

2. X - axis can be generated as follows:

```
>> seq -422 2.11 422 > 'outputfilename'
```

Where -422 corresponds to the least of the bandwidth

+422 corresponds to maximum of the bandwidth

2.11 defines the interval between each points

3. Y – axis is the output file from the receiver 'p1'.

4. Merge the two files together with the help of paste command

>> paste 'outputfilename' 'p1' > 'Newfilename'

5. Plot the graph with the gnuplot as follows:

>> gnuplot

6. gnuplot> plot 'Newfilename' w l

7. Now you can see the plot. One can fit the observation with the best model.

8. To fit Gaussian refer to analysis procedure of the previous document titled 'Determination of pointing offsets of 4-m telescope'.

9. Fit it with Gaussian and note down the fit parameters.

6 Log

1. Source :

a. Baseline fit parameters	:		
b. No of Gaussians required	:		
c. Position of Gaussians	:	±	km/s
d. FWHM of Gaussians	:	±	km/s
e. Peak of Gaussians	:	±	km/s
c. Position of Gaussians	:	±	km/s
d. FWHM of Gaussians	:	±	km/s
e. Peak of Gaussians	:	±	km/s
c. Position of Gaussians	:	±	km/s
d. FWHM of Gaussians	:	±	km/s
e. Peak of Gaussians	:	±	km/s
f. Residual Chisq	:		

2. Source :

a. Baseline fit parameters	:		
b. No of Gaussians required	:		
c. Position of Gaussians	:	±	km/s
d. FWHM of Gaussians	:	±	km/s
e. Peak of Gaussians	:	±	km/s
f. Residual Chisq	:		

3. Source :

a. Baseline fit parameters	:		
b. No of Gaussians required	:		
c. Position of Gaussians	:	±	km/s
d. FWHM of Gaussians	:	±	km/s
e. Peak of Gaussians	:	±	km/s
f. Residual Chisq	:		

4. Source :

- a. Baseline fit parameters :
- b. No of Gaussians required :
- c. Position of Gaussians : \pm km/s
- d. FWHM of Gaussians : \pm km/s
- e. Peak of Gaussians : \pm km/s
- f. Residual Chisq :

5. Source :

- a. Baseline fit parameters :
- b. No of Gaussians required :
- c. Position of Gaussians : \pm km/s
- d. FWHM of Gaussians : \pm km/s
- e. Peak of Gaussians : \pm km/s
- f. Residual Chisq :

7 Results and Discussion

Calculate the Doppler velocity from the spectrum of the sources observed. Discuss the nature of the spectrum and its features. Comment on the velocity calculated and the location of these sources on the galactic plane. Discuss the factors responsible for the Doppler shift of your spectrum. Give the sources of error and explain the results.