Detecting Galactic HI line using 4-m SRT

1 Goal of the experiment

The final 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 splitted 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. Due to the rotation of the Galaxy, a shift in the line from its rest frequency is expected. The observed shift may either be redshift or blueshift and will depend on the position of the observed source on the Galactic plane. The spectrum thus obtained can be then analyzed to measure the line strength, width and position.

2 Brain Teaser

1. Go out on the terrace and identify different directions on the sky. If sun is visible, roughly find the direction of North pole, which is one of the reference for telescope control system. Indicate approximately the Alt-azimuth position of the telescope.
   Ans.:

2. Track the path of the Sun on the sky. How does the azimuth and altitude change through the day at NCRA campus ? How would this change if you were located +50 N at the time of the experiment? How would this change if you were located -50 N at the time of the experiment?
   Ans.:

3. Find out the RA/Dec of Sun and the constellation in which the Sun is, at the time of observation. Familiarize yourself with the equatorial coordiante system as it is visible from the telescope location. In what direction then RA/Dec increases/decreases? Where is the 0,0 RA/Dec point located in the sky?
   Ans.:

4. Three strong radio sources are CRAB, CASA and CYGA. Which constellation 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.:

5. 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 on the hemisphere of the sky visible to us in the space provided below. Indicate whether the Galactic center, which is believed to harbour a supermassive black hole, is visible at the time of the experiment.
   Ans.:

6. 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	$+33^o$ 20'	
05h 31m	$+21^o$ 10'	
04h 37m	-56^o 01'	
17h 10m	-30^o 23'	
21h 05m	$+40^o$ 21'	

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'*. Make sure that the offsets calculated from the previous experiments are correct and undisturbed. This you can check by pointing the telescope to the Sun. If the offsets are correct you will get to the peak deflection on the Sun. This check experiment can be done before the planned HI experiment. Once the initialization is done, follow the experimental procedure given below.

3.1 Experimental Procedure

Obtain the ALT/AZ coordinates of the HI source from its RA/DEC at the current time and location. Point the telescope in that direction. Follow the procedure given below.

1. Select the following settings for spectral mode.

Parameter	Value
IF Gain	25
DC Gain	10
DC offset	1.8
Time/step	0.2
Upper Limit	800
Lower limit	-800
Source name	'name'
Band width	30 kHz
Int. time	0.5 sec

2. Go to "READY - DESIGNATE mode", select the last enter block, enter the Alt and Az coordinates obtained for the HI source. Click on "GO". Wait till

the telescope reaches the source position.

3. To record the scans, click "SCAN - Auto Save - START" scan.

4. Similarly goto different HI sources mentioned and repeat the above two steps and take the spectral scans.

5. Notedown the file name and time for different sources observed, on a log sheet.

6. Copy data files on a CD (DO NOT USE PEN-DRIVES) and transfer to MATLAB PC for analysis.

7. Once the experiment is over, park the telescope as per step-9-10, mentioned in the document titled *'Initialization of the 4-m Telescope System'*.

The list of some standard strong radio sources is given below. The Table-1 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-2 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	$17h\ 52m\ 05s$	-$34^o\ 25m\ 42s$
S8	72±5	$05h\ 47m\ 21s$	-$01^o\ 40m\ 18s$
S7	100±7	$02h\ 06m\ 13s$	+$60^o\ 32m\ 52s$
S6	51±4	$15h\ 31m\ 34s$	-$02^o\ 25m\ 09s$

Table 1: Coordinates of HI bright IAU calibrators sources, in J2000 Epoch.

4 Analysis Procedure

The analysis procedure here is based on the package called as Matlab. Plot the spectrum i.e. power (arbitrary units) received verses frequency and fit a appropriate curve.

1. Copy data files on a pendrive and transfer it to the Matlab PC. Create a directory named Mydocuments/Matlab/Data/batch/date and save the files.

2. Open each file in notepad and delete the first raw (header line) and rename e.g. s8spectrum.data

Source Name	Gal Long(deg)	RA	Dec
P01	0.00	17h 42m 26s	-28d 55m 00s
P02	30.00	18h 43m 28s	-02d 39m 46s
P03	45.00	19h 11m 20s	+10d 38m 13s
P04	60.00	19h 41m 47s	+23d 46m 10s
P05	75.00	20h 19m 02s	+36d 26m 45s
P06	90.00	21h 10m 18s	+48d 07m 24s
P07	105.00	22h 28m 06s	+57d 36m 13s
P08	120.00	00h 23m 01s	+62d 26m 55s
P09	135.00	02h 28m 10s	+60d 16m 29s
P10	150.00	04h 00m 39s	+52d 17m 01s
P11	165.00	05h 00m 42s	+41d 16m 57s
P12	180.00	05h 42m 26s	+28d 55m 00s
P13	195.00	06h 14m 58s	+15d 55m 24s
P14	210.00	06h 43m 28s	+02d 39m 47s
P15	240.00	07h 41m 47s	-23d 46m 10s
P16	270.00	09h 10m 18s	-48d 07m 24s
P17	300.00	12h 23m 01s	-62d 26m 55s
P18	330.00	16h 00m 39s	-52d 17m 00s

Table 2: Source coordinates along the Galactic plane in 1950 Epoch.

3. Click on MATLAB icon and browse into the appropriate folder (Look at the top left window named 'Current directory').

4. To load data
   `>> load s8spectrum.data`.

5. The number of data points should be declared as
   `>> n=400` (n=360 for continuum mode and is 400 for spectral mode data files), you may change acording to the length of your data. Any other constant for example binw (width of a single bin), ul (upper limit) and ll (lower limit) can be declared in a similar way.

6. Generate X axis in terms of frequency (kHz) with the central frequency = 1420 MHz,
   `>> for i=1:n x(i) = (i-201)*binw; end`, here binw (bin width) and hence the x-axis is in KHz.
   or in terms of doppler velocity km/sec,
   `>> for i=1:n x(i) = 0.211*(i-201)*binw; end`, here binw (bin width) is

in KHz and hence the x-axis is in Km/sec.

7. Load Y axis
   `>> for i=1:n y(i)=s8spectrum(i); end`

8. plot data
   `plot(x,y)`

9. To fit a curve
   `>> cftool(x,y)` This will open an interactive data plot.
   Click on - `Fitting - new fit`. Select `gaussian` in Type of fit. Then select the gaussian fuction from the list below. Depending upon the source you may fit multi gaussian function of the general form: $a_1 e^{-(\frac{x-b_1}{c_1})^2}$ +... $a_n e^{-(\frac{x-b_n}{c_1})^n}$, click `Apply`.

10. Note down values of the fitting parameters $a_1, b_1 and c_1$. Parameter b_1 = Mean = peak of the gaussian.

11. Parameter $c_1 = \sqrt{2}\sigma$, where sigma (σ) is the width of the gaussian.

12. To save the plot obtained in cftool
    got to `File - print to figure - Insert x label, y label - file - save as - name.jpg - save`

5 Log sheet

Source	RA	DEC	file name	Time
1)				
2)				
3)				
4)				
5)				
6)				

6 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.

7 References

Williams, D. R. W., 1973, A & A Suppl. 8, 505 - 516.