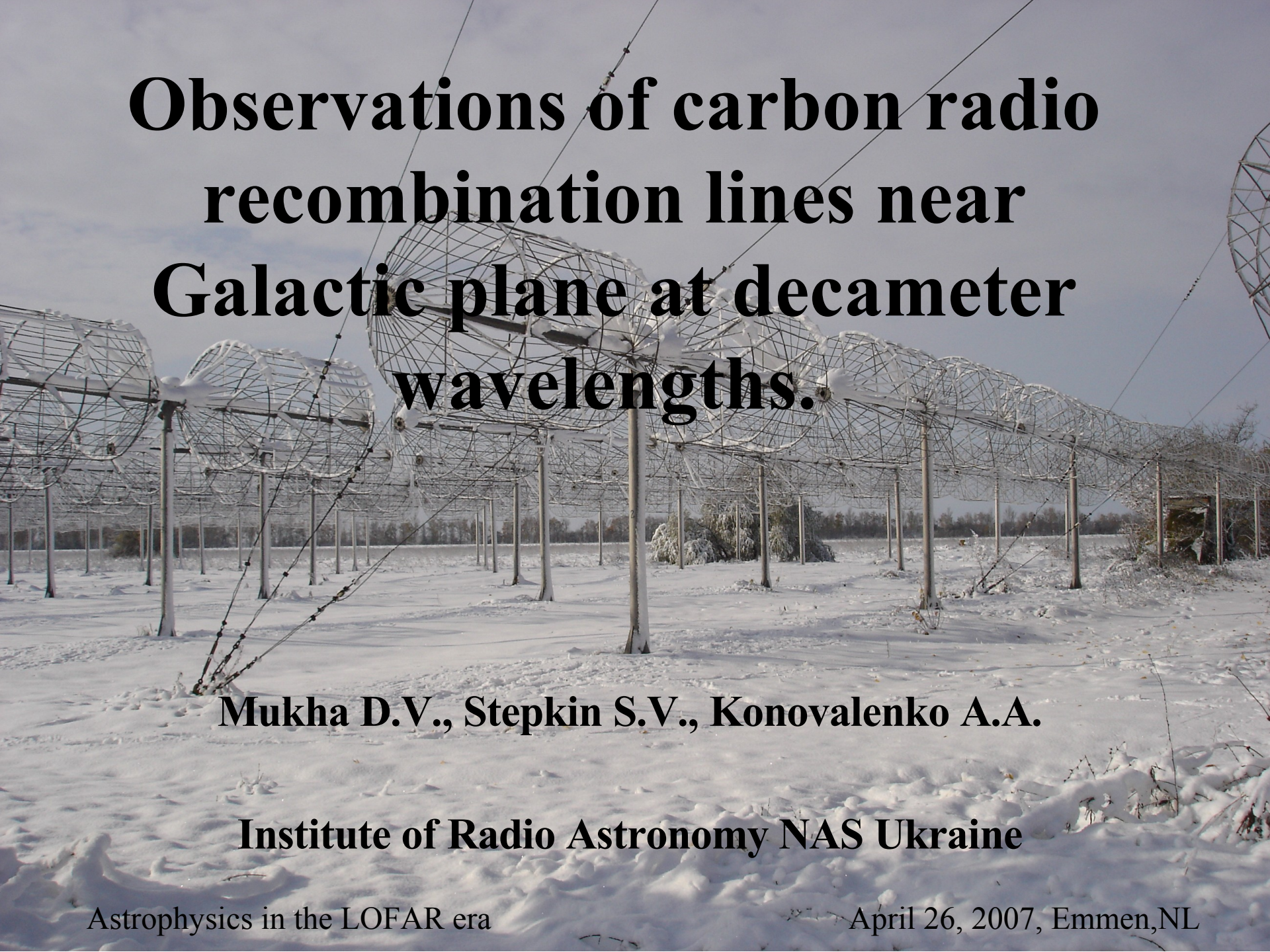
# Observations of carbon radio recombination lines near Galactic plane at decameter wavelengths.



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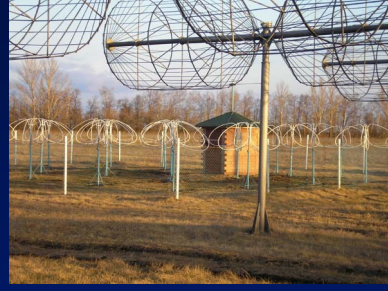
# Abstract

We present the attempt to carry out a large scale survey of the Galactic plane in carbon radio recombination lines (RRLs) at frequencies near 25-26 MHz as well as the observations against several adjacent to the Galactic plane objects (among them are 3C144, DR-21, GSH139-03-69, HB21, L1407, and S140). Space atoms producing these RRL are excited up to the levels corresponding to principal quantum numbers more than 600 and are concentrated around the Galactic plane. The features are strongly broadened mostly due to Doppler processes. The Galactic plane was scanned using West-East arm of the decameter wavelength radio telescope UTR-2 (spatial resolution was 40′x10°) in the range of galactic longitude from 30° to 180° with the step of 10°. Unexpectedly, the features were detected in all measured directions. The distribution of RRLs radial velocities was in good correspondence with the standard model of the Galactic rotation. Low frequency spectroscopy provides effective ways of diagnostic of the cold low density and partially ionized interstellar plasma, but the achievable at the moment spatial resolution limits the possibilities of mapping using this kind of spectral lines. LOFAR characteristics make this instrument very suitable for carrying out such investigations.



# Radio Reconbination Lines in the ISM

T~ 20 … 100 K

$n_e$ <0.5 $cm^{-3}$

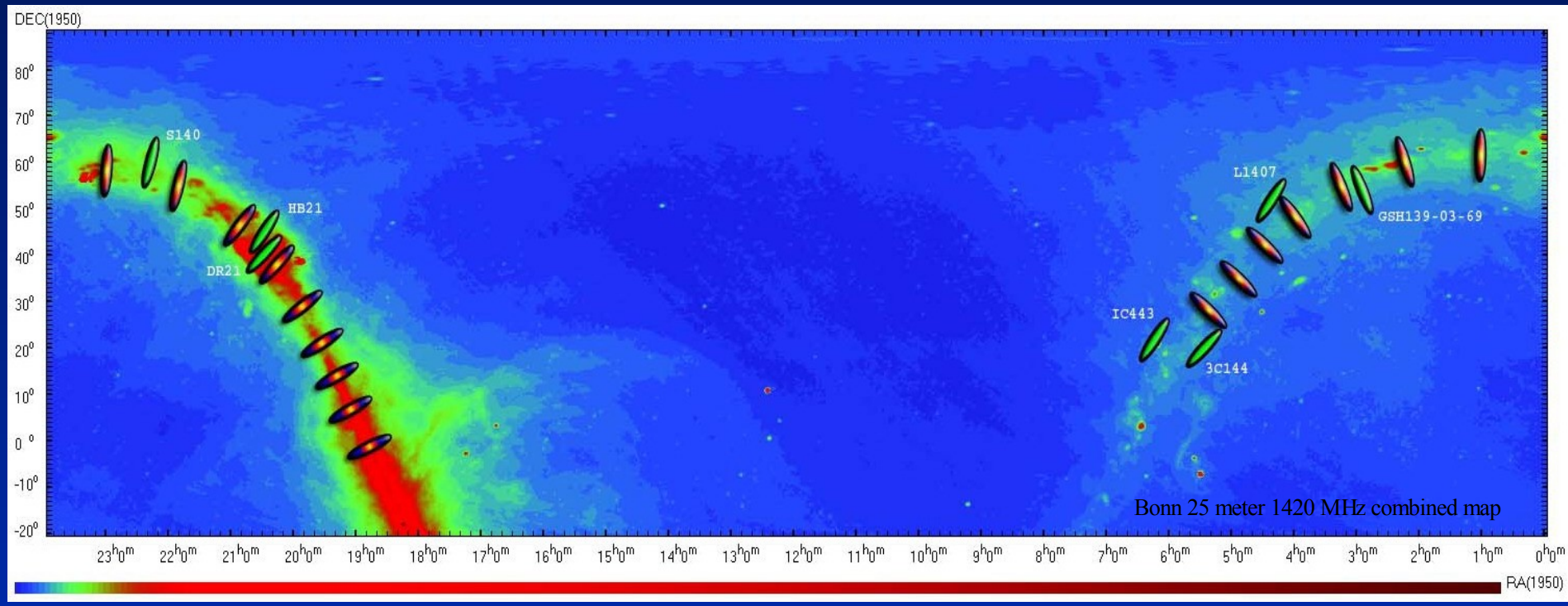
## Previews Low Frequency RRLs Observations

GEE-TEE at 34.5 MHz
Ooty at 328 MHz
} Galactic Longitude < 20 degree

## General Formula

$$\nu = R\left(1 - \frac{m}{M}\right) cZ^2 \left(\frac{1}{n^2} - \frac{1}{(n + \Delta n)^2}\right)$$

# Directions Where Carbon Radio Recombination Lines have been Observed with UTR-2




C635α – C645α lines have been detected near 25 MHz

Integration times are from 150 to 250 hour

# Scheme of Observation in the Direction of Galactic Plane

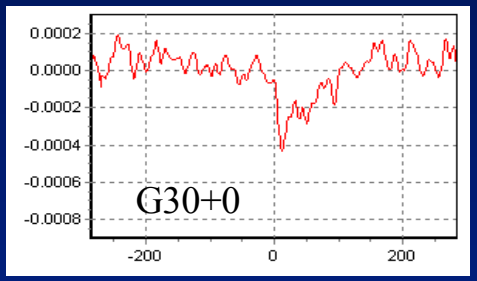
E-W arm UTR-2 → Receiver (F central 25 MHz; bandwidth 1.2 MHz) → Correlator → Computer

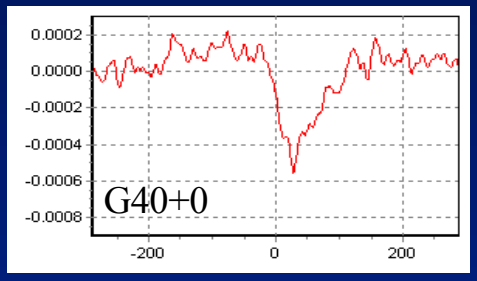
4096 channel digital autocorrelator

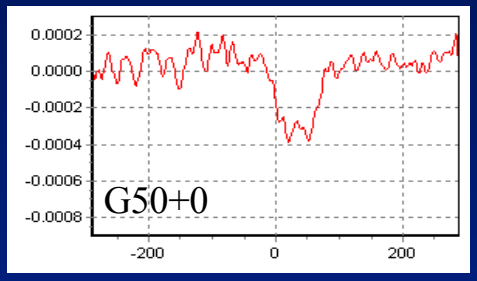
$$R(mT_0) = \sum_{i=1}^{M} \operatorname{sgn}[x(iT_0)]\operatorname{sgn}[x(iT_0 + mT_0)]$$

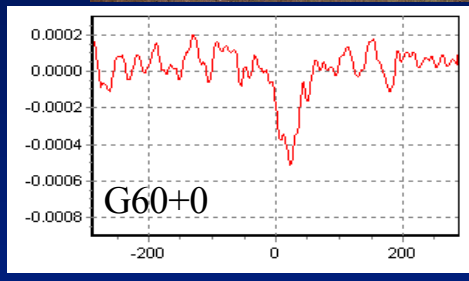
$$G(f) = \frac{TR(0)}{M} + 2T_0 \sum_{m=1}^{N} \omega(mT_0) \sin\left(\frac{\pi R(nT_0)}{2M}\right) \cos(2\pi f m T_0)$$

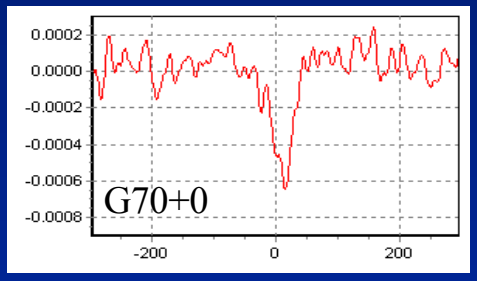
# Observation of Carbon Radio Recombination Lines in the Direction of Galactic Plane

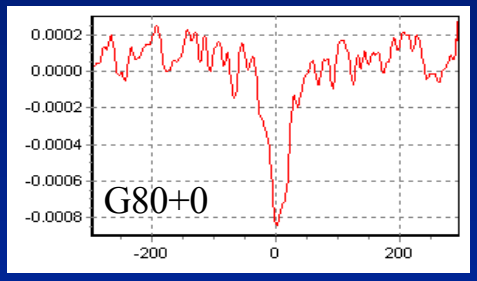


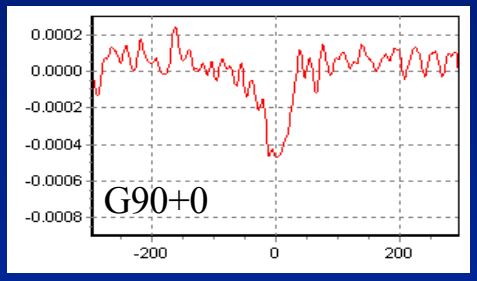



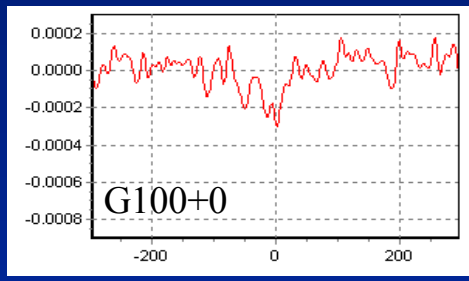



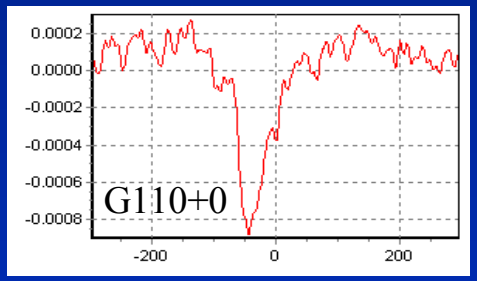



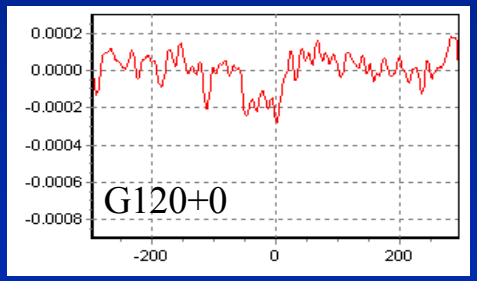



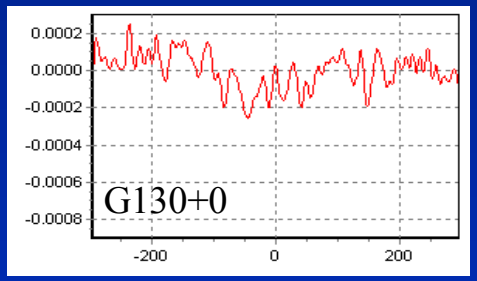



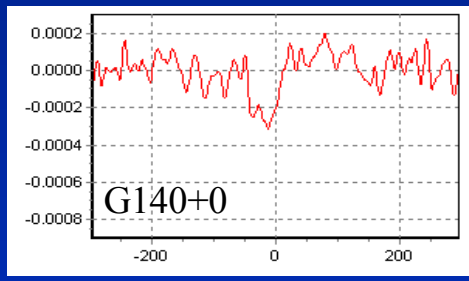



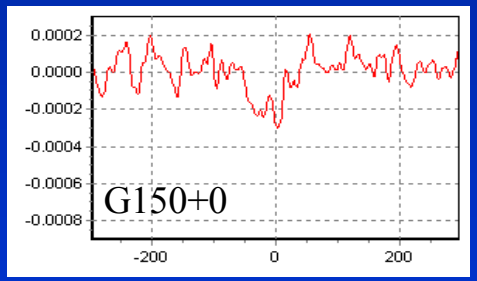



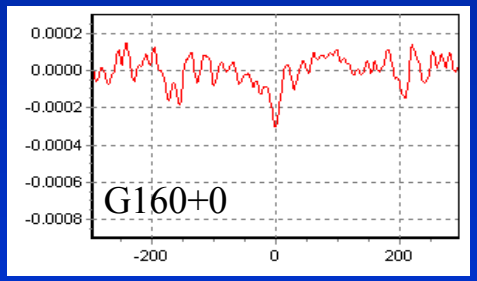



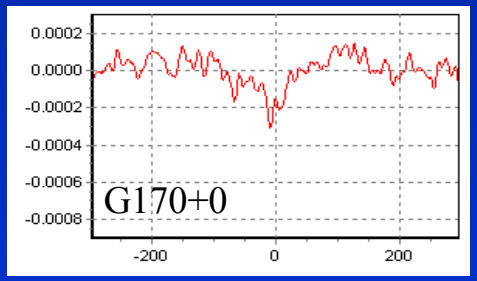



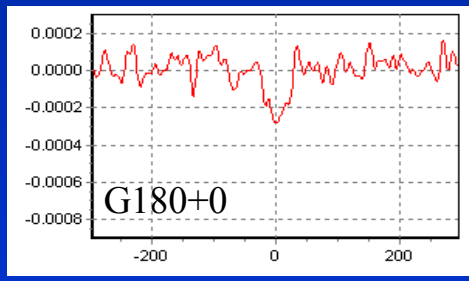



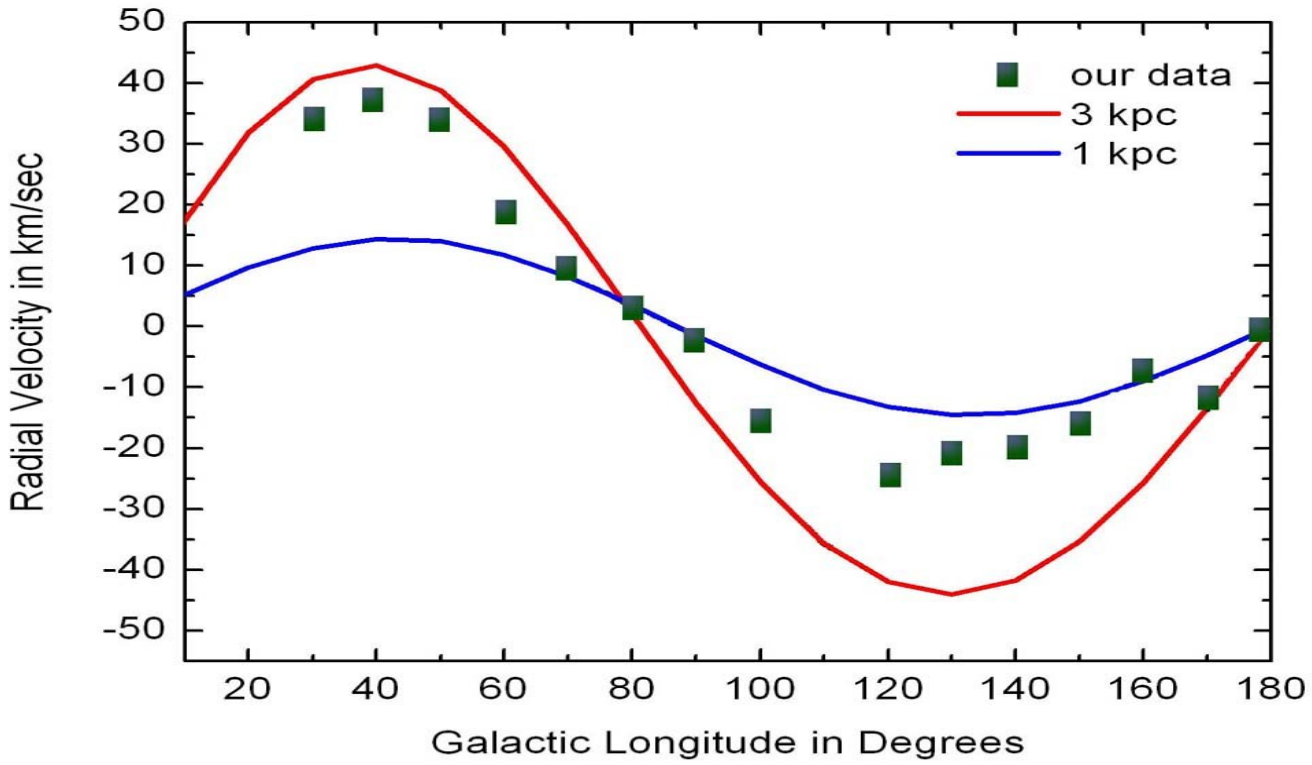



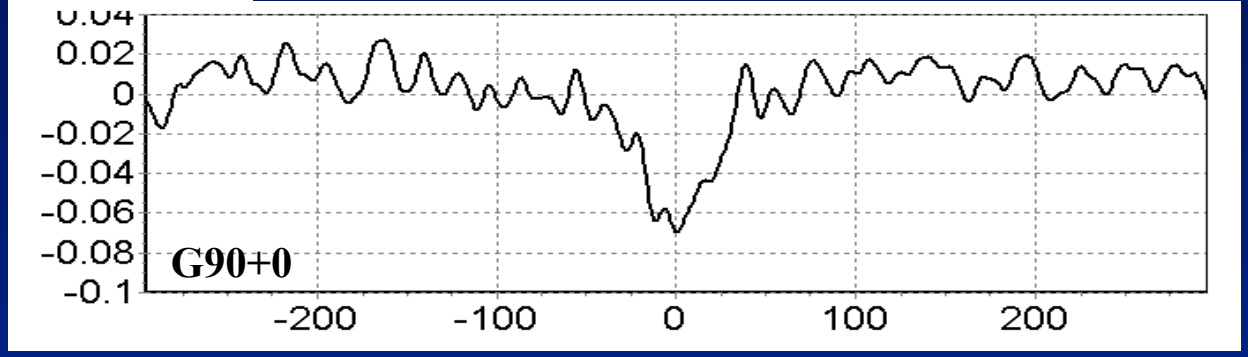



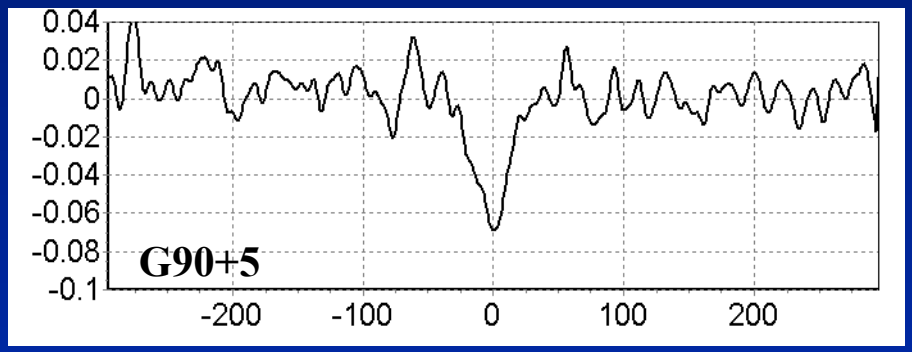
# The Longitude-Velocity Diagram of the Carbon Recombination Lines at 25 MHz

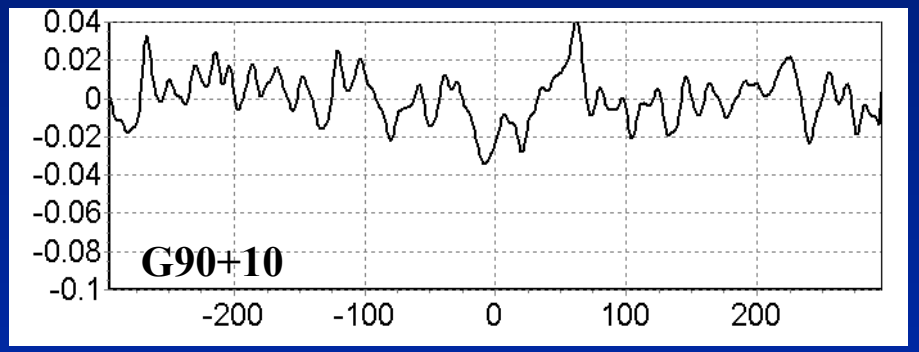


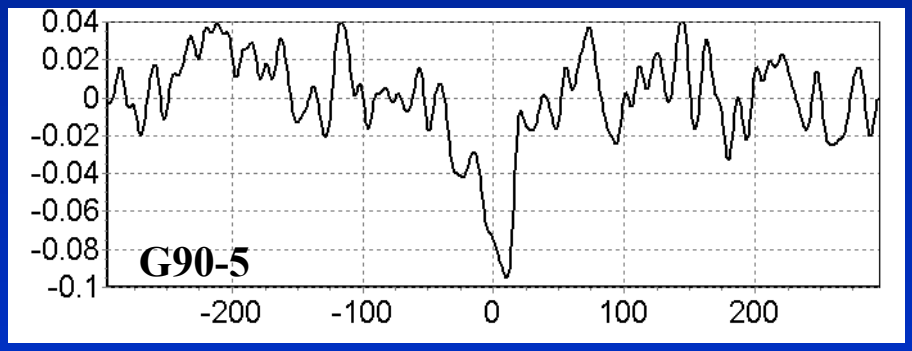
# Spectra Measured Toward Position Shifted from GP (G90+0)

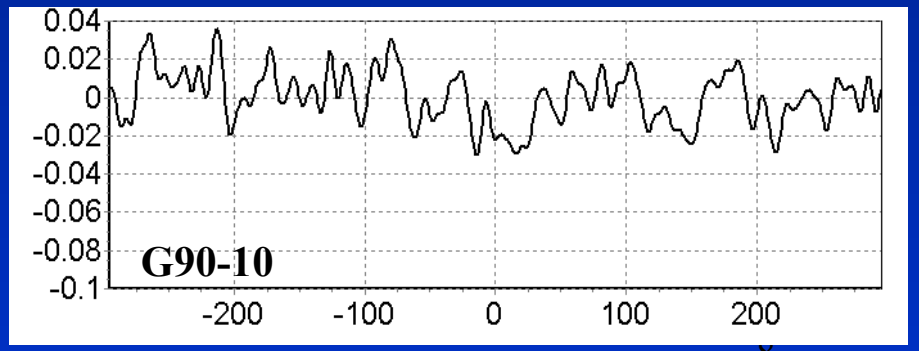
$\Delta T_L/T_C \cdot 10^{-2}$



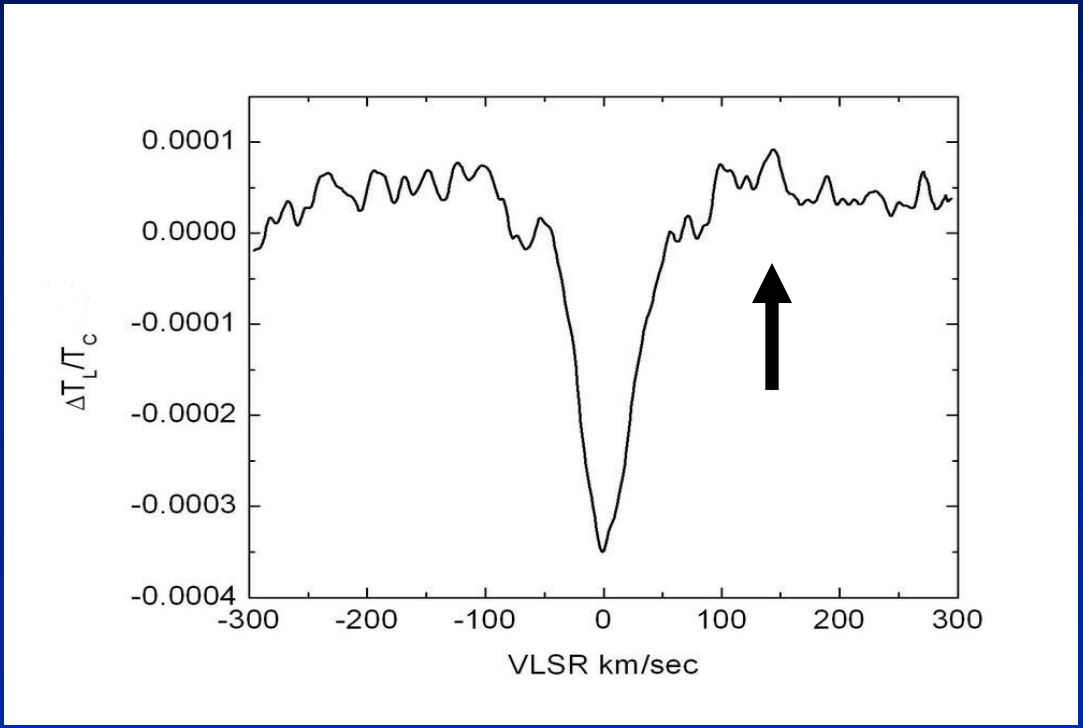




VLSR, km/sec

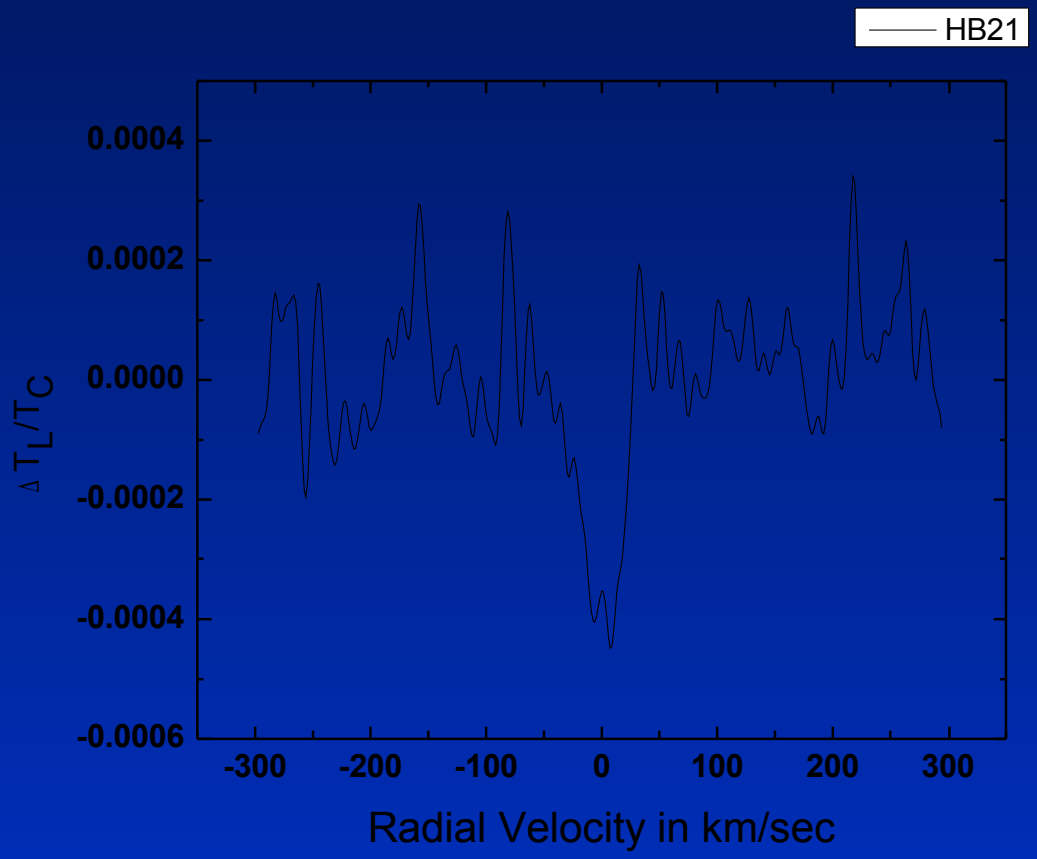
# The Integrated Spectrum of the Radio Recombination Lines along the Galactic Plane




Effective integration time is about 3000 hour.

Hydrogen recombination lines Hnα, which have to be at the distance of 150 km $s^{-1}$, have not been detected.

# HB21 Supernova Remnant



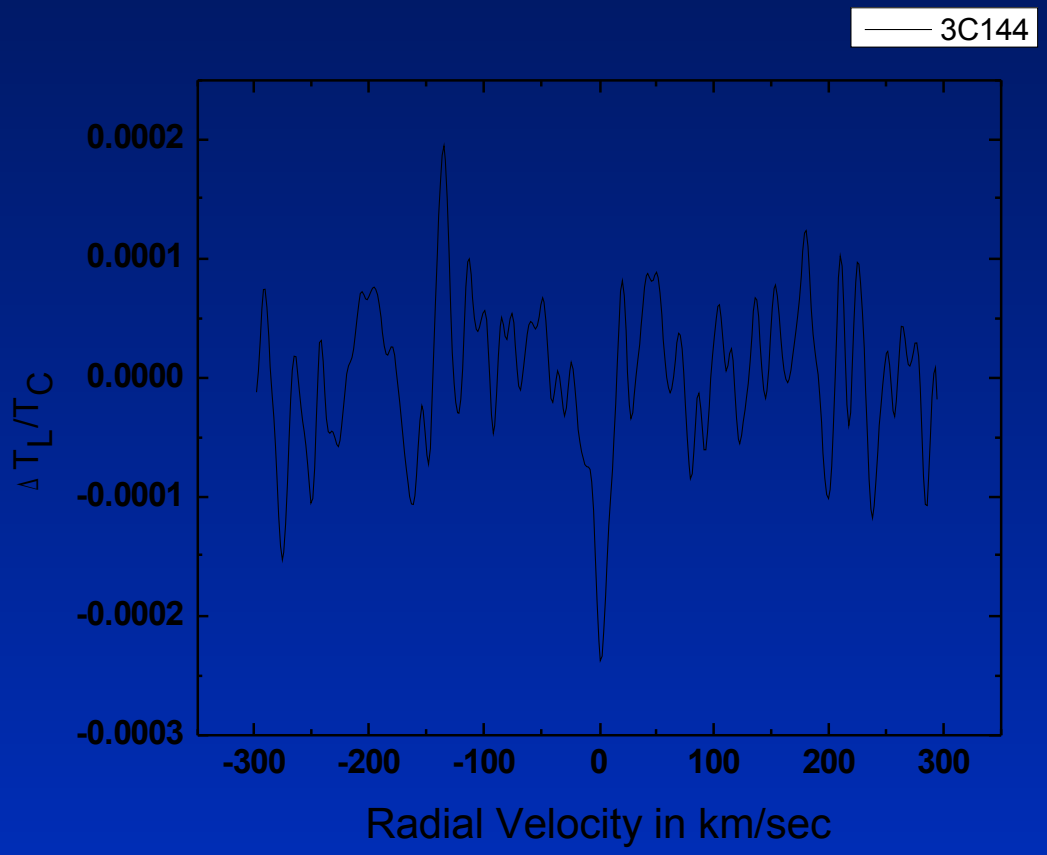

RA1950 = 20h43m30s

DEC1950 = 50g40m00s

Effective Integration Time = 92 h

C635α – C645α

# 3C144 Crab Nebula



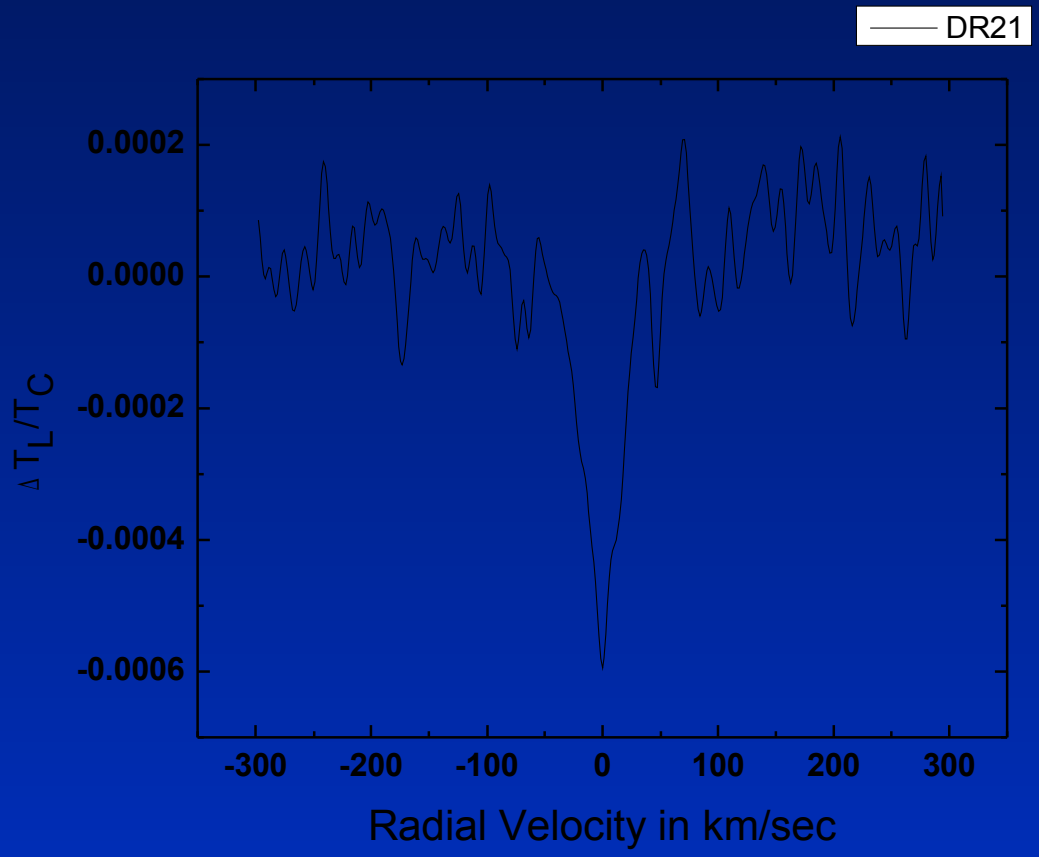

RA1950 = 05h31m30s

DEC1950 = 21g58m00s

Effective Integration Time = 195 h

C635α – C645α

# DR-21 Nebulosity



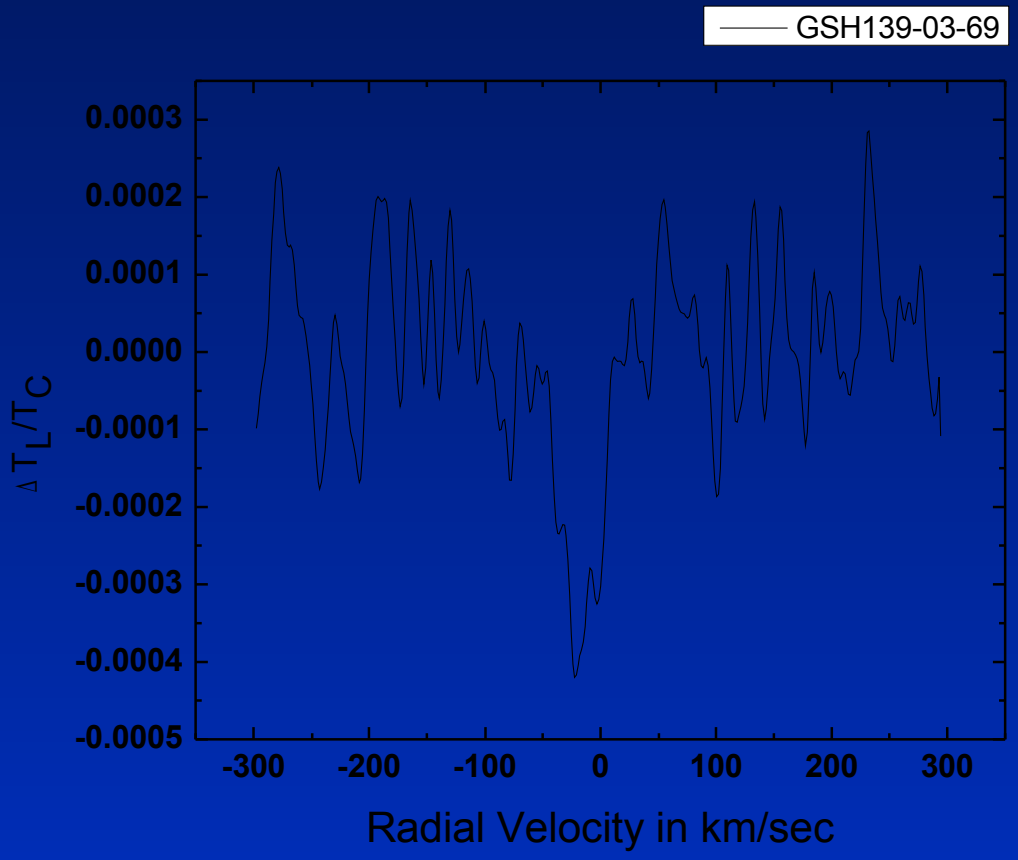

RA1950 = 20h37m13s

DEC1950 = 42g09m00s

Effective Integration Time = 99 h

C635α – C645α

# GSH139-03-69 Super Shell



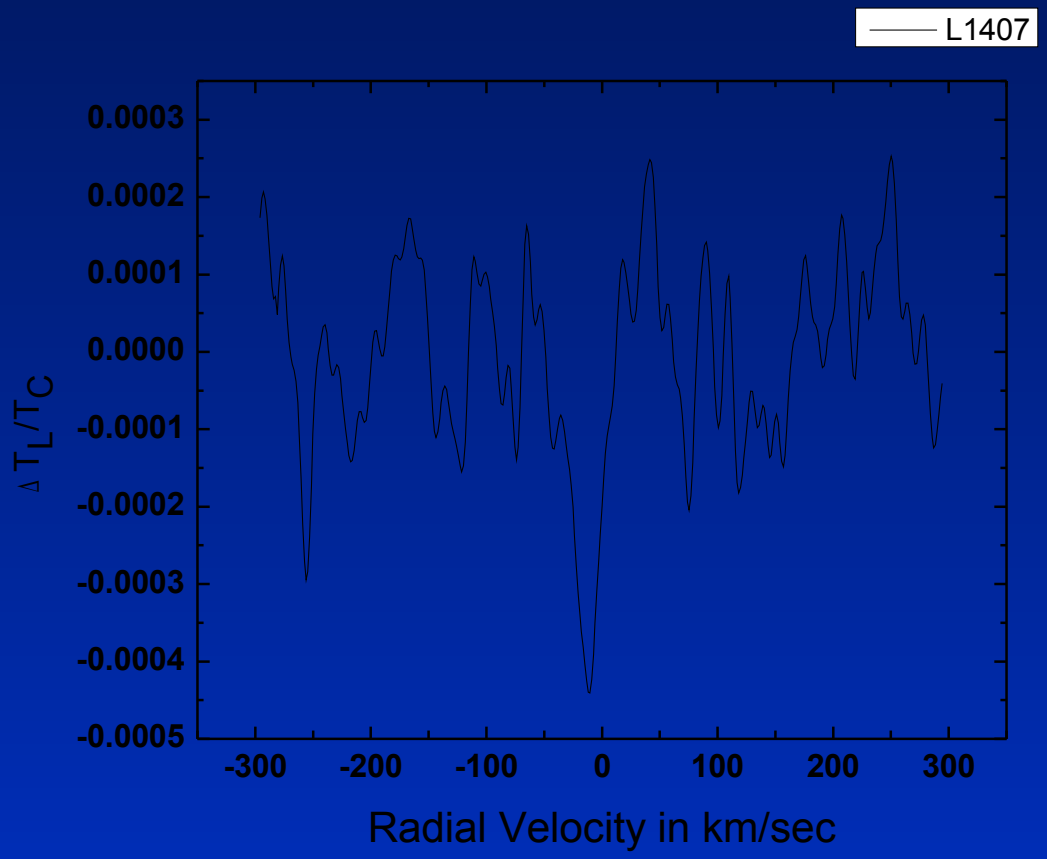

RA1950 = 02h50m00s

DEC1950 = 61g22m00s

Effective Integration Time = 115 h

C635α – C645α

# L1407 Dust Cloud



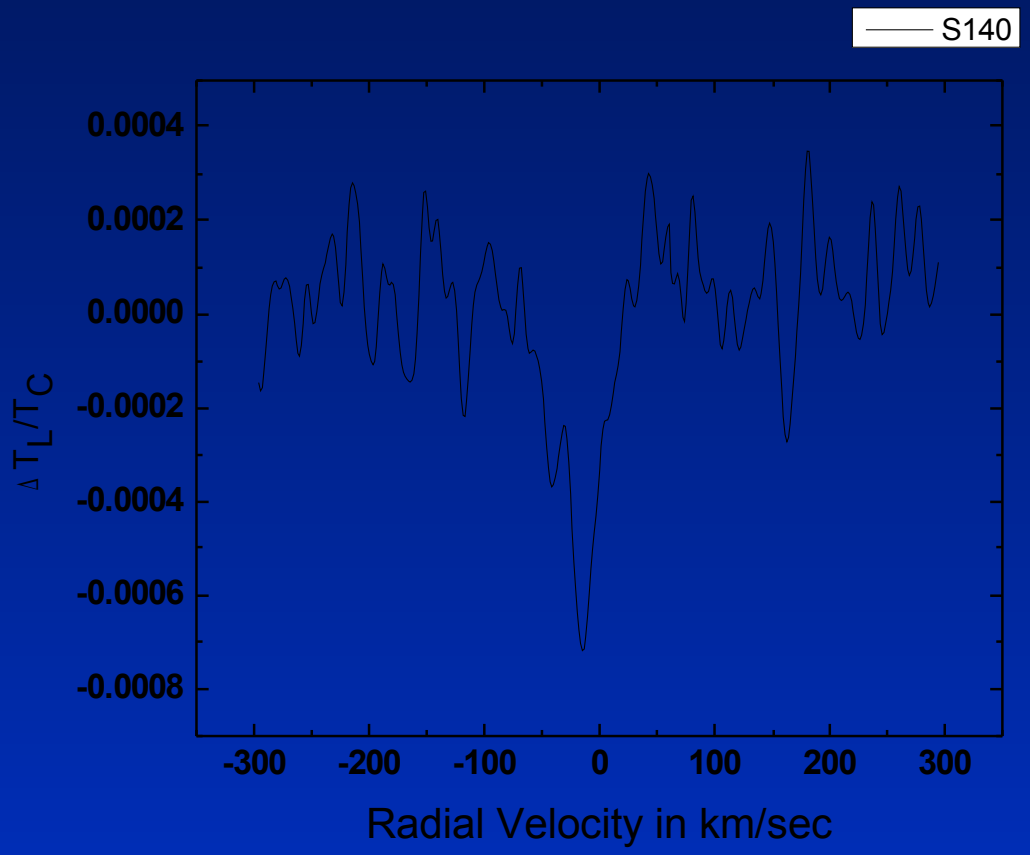

RA1950 = 04h26m30s

DEC1950 = 54g17m00s

Effective Integration Time = 172 h

C635α – C645α

# S140 Nebulosity



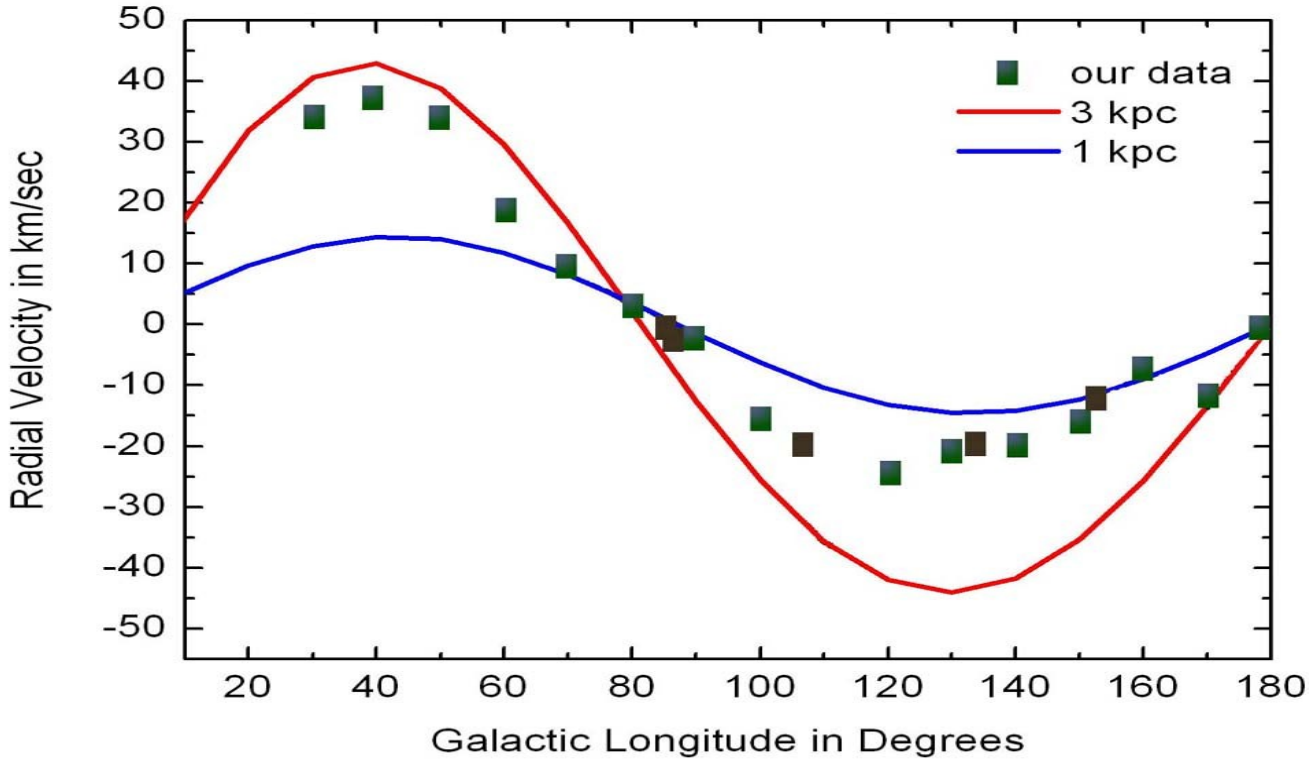

RA1950 = 22h17m36s

DEC1950 = 63g04m00s

Effective Integration Time = 108 h

C635α – C645α

# The Longitude-Velocity Diagram of the Carbon Recombination Lines at 25 MHz



# Conclusions

**Mapping of the ISM in Galactic Plane in RRLs at frequencies less than 100 MHz using existing instruments is difficult and time-consuming task. At the same time, this is effective approach to study cool, low density, and partially ionized interstellar matter. LOFAR possibilities are very suitable and promising for carrying out such investigations.**

References


2. Konovalenko, A. A., Stepkin, S.V. Radio Recombination Lines. JENAM 2003 - Radio Astronomy from Karl Jansky to Microjanski, eds. L. Gurvits, S. Frey and S. Rawlings, EAS, EDP Sciences, v. 15, 271 -295, (2005).
3. Gordon, M. A., Sorochenko, R. L. Radio Recombination Lines: Their Physics and Astronomical Application. , (Kluwer, 2002).
4. Kantharia, N.G., Anantharamaiah, K.R. Carbon Recombination Lines from the Galactic Plane at 34.5 & 328 MHz. J. Astrophys. Astr., 22, 51-80, (2001).


The End…
Thanks