Low frequency radio recombination lines in the Galactic plane with LOFAR

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What can we learn from the low frequencies?

The lines get broadened by the presence of a radiation field and collisions with electrons.

\[ \Delta v \propto T_{rad} n^{5.8} + n_e T_e n^{\gamma_c}, \]

\[ 4.28 \leq \gamma_c \leq 5.48 \]
What can we learn from the low frequencies?

At low frequencies, the lines are in collisional equilibrium and the level population can be described as in LTE.
Electron temperature (K)

Electron density (cm$^{-3}$)

$T_{e,100} = 1100$ K

$T_{e,100} = 1600$ K

$T_{e,100} = 1900$ K
Electron density (cm\(^{-3}\))

\[ T_{e,100} = 1100 \text{ K} \]

\[ T_{e,100} = 1600 \text{ K} \]

\[ T_{e,100} = 1900 \text{ K} \]
CRRLs with an interferometer

\[ f_{\tau, d\nu} \text{ (Hz)} \]

\[ 0.0 \quad 2.5 \quad 5.0 \quad 7.5 \quad 10.0 \quad 12.5 \quad 15.0 \quad 17.5 \quad 20.0 \]

Declination (J2000)

Right Ascension (J2000)

\[ \tau \alpha d\nu \text{ (Hz)} \]

LBA

WSRT
CRRLs with an interferometer

\[
\frac{\int \tau_{\alpha}(268) d\nu}{\int \tau_{\alpha}(535) d\nu}
\]
CRRLs with an interferometer

\[ n_e \, (\text{cm}^{-3}) \]

\[ 58^\circ 46' \quad 58^\circ 48' \quad 58^\circ 50' \quad 58^\circ 52' \]

\[ 23^h \ 23^m \ 00^s \quad 15^s \quad 30^s \quad 45^s \]

\[ 58^\circ 46' \quad 58^\circ 48' \quad 58^\circ 50' \quad 58^\circ 52' \]
Bonus: hydrogen RRLs

Declination (J2000) | Right Ascension (J2000)
--- | ---
58°46′ | 23h 23m 00s 15s 30s 45s
58°48′ | 23h 23m 00s 15s 30s 45s
58°50′ | 23h 23m 00s 15s 30s 45s
58°52′ | 23h 23m 00s 15s 30s 45s

CRRL

HRRL
Doing the same on the Galactic plane
Direction independent calibration
Flux density (Jy) vs. Frequency (MHz)

Adapted from Dyer & Reynolds (1991)
Summary

- LOFAR is a unique telescope for low frequency RRL observations.

- Maps of RRLs will probe the gas properties on arcminute scales against bright sources.

- Initial tests of facet calibration on the Galactic plane show promising results.
Thanks!
Specially to the people making this possible.