C II radiative cooling in the diffuse ISM: Lessons from the Milky Way

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Motivation

- **Star formation in DLA absorbers: N(H I) ≥ 2 x 10^{20} cm $^{-2}$**
  - main reservoir of gas at high z (Storrie-Lombardi & Wolfe 2000)
  - … and **metals** (e.g. Pettini 2004, Prochaska et al. 2003)
  - main sites of **star formation?** precursors of galaxies**?**
  - at z < 1.6, **direct** identification of about half of the sample
  - Ly-α (or Hα or rest frame UV) to SFR (Kennicutt 1998)
  - at z >1.6, arguments are **indirect** (e.g. metals from star formation)
  - **indirect star formation rate** from C II* (Wolfe et al. 2003)

Star formation rate from C II*

- [C II] 158 µm fine structure emission is a **dominant** coolant of Galactic neutral ISM (Wright et al. 1991)
- C II* λ 1335.7 (and λ 1037) arise from excited $^2P_{3/2}$ in C II
- [C II] 158 µm arises from decay of $^2P_{3/2}$ to $^2P_{1/2}$
- So, C II* observation can be used to deduce total cooling rate
- Under thermal balance, cooling rate = heating rate
- Finally, derive **star formation rate** from the implied heating rate

☆ SFR from C II* – issues

– UV radiation, cosmic ray flux (or SFR) required to maintain a given heating rate **crucially** depends on physical conditions of the gas

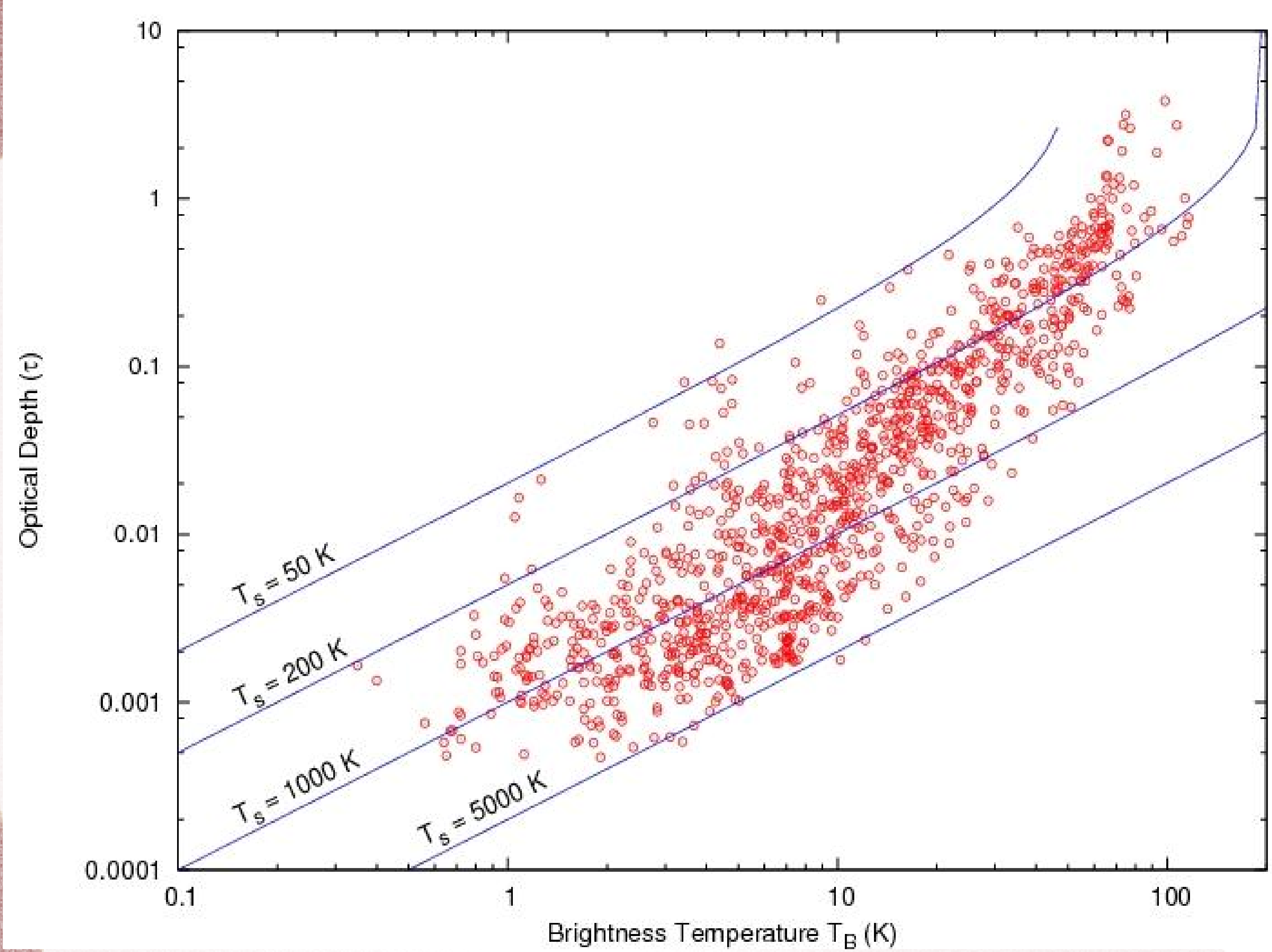
– e.g., for a sample of 45 DLAs (Wolfe et al. 2004), SFR:

$11.3 \times 10^{-3}\ M_\odot\ yr^{-1}\ kpc^{-2}$ (for CNM)

$0.21 \times 10^{-3}\ M_\odot\ yr^{-1}\ kpc^{-2}$ (for WNM)

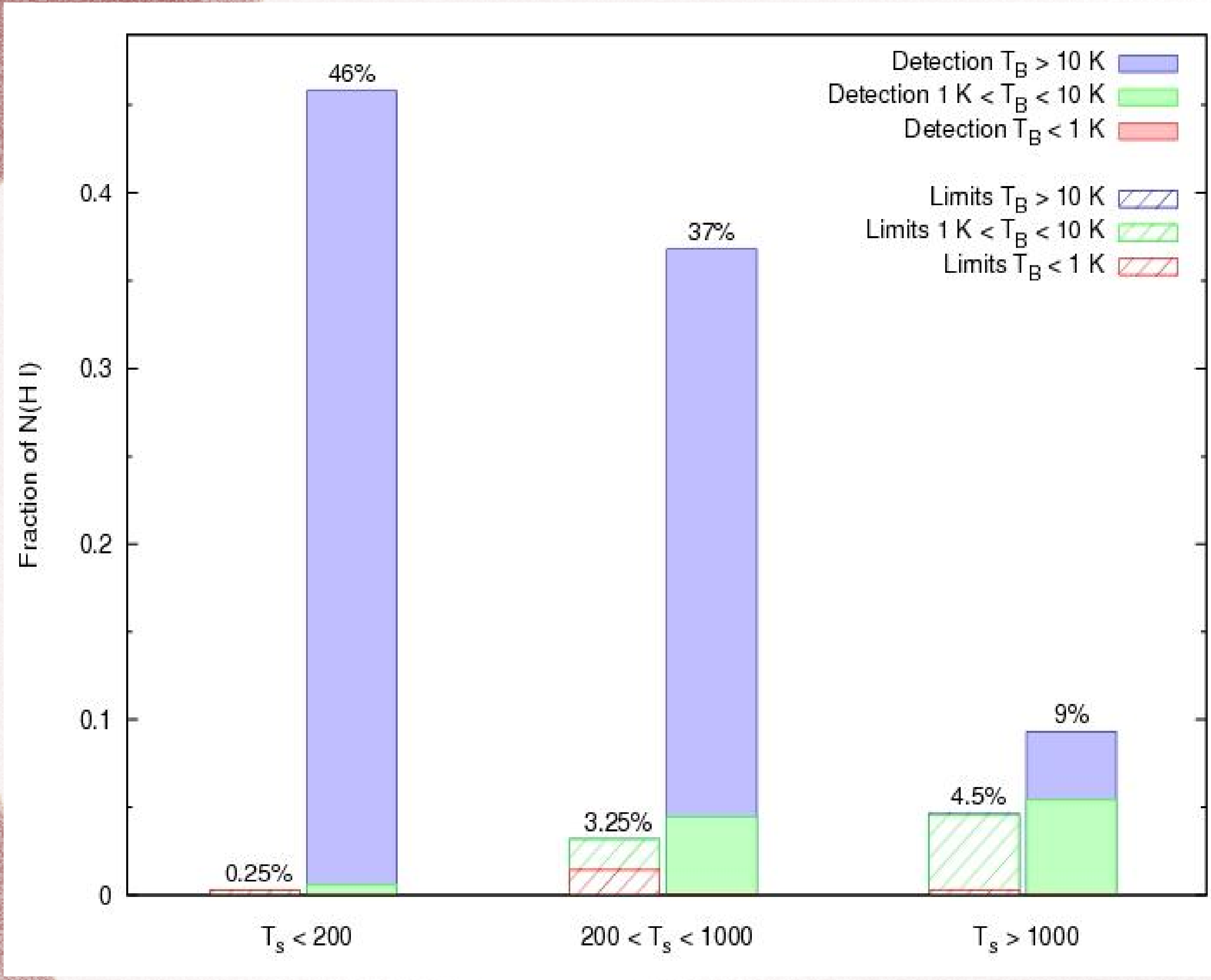
– Typical "DLA-like" high latitude **Galactic lines of sight** have very little CNM, and more WNM/WIM (e.g. Lehner et al. 2004)

$T_B - \tau - T_S$ relation (~1 km/s resolution)



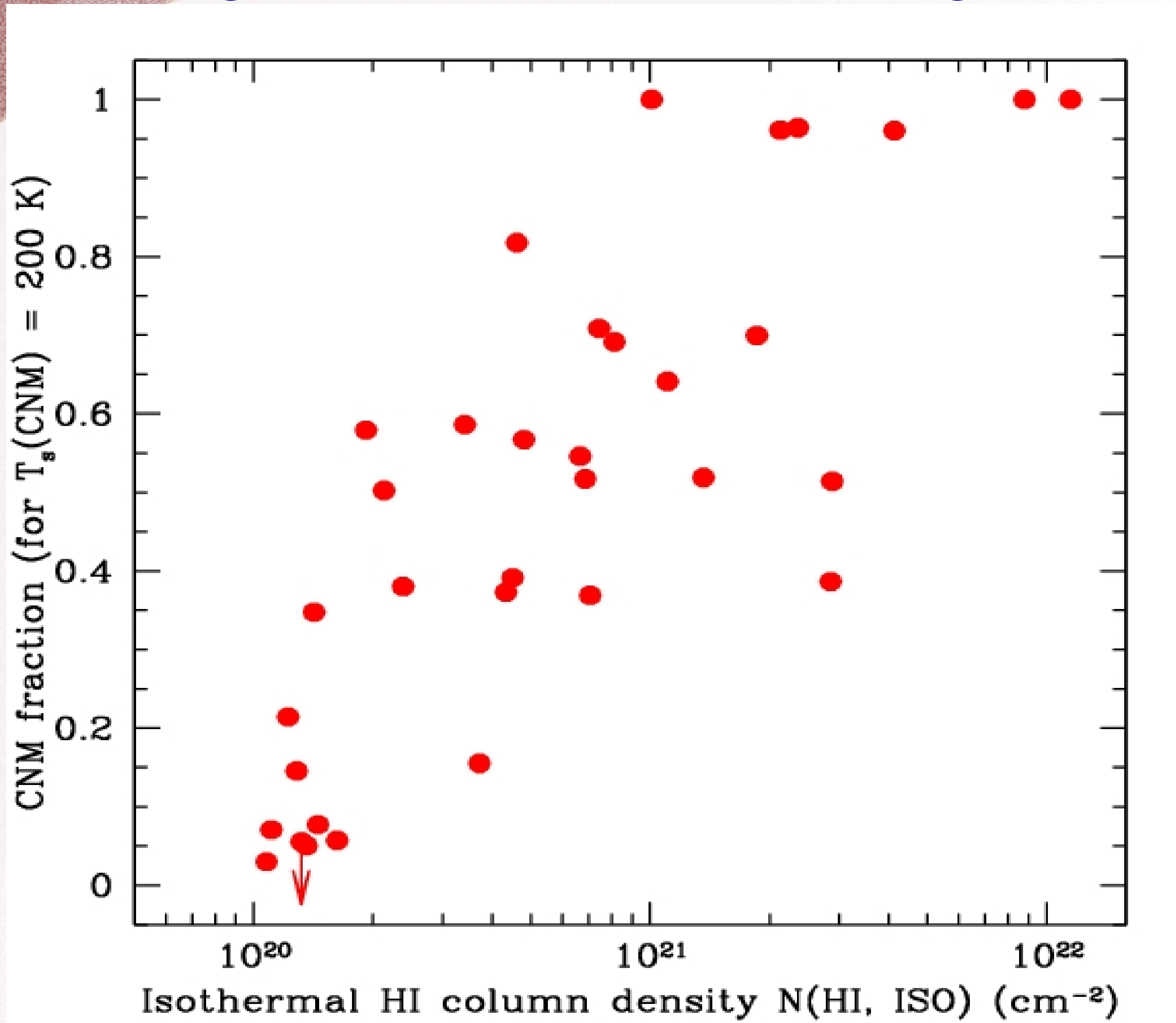
Roy, Kanekar, Braun & Chengalur (2013)

Column density distribution (~1 km/s resolution)



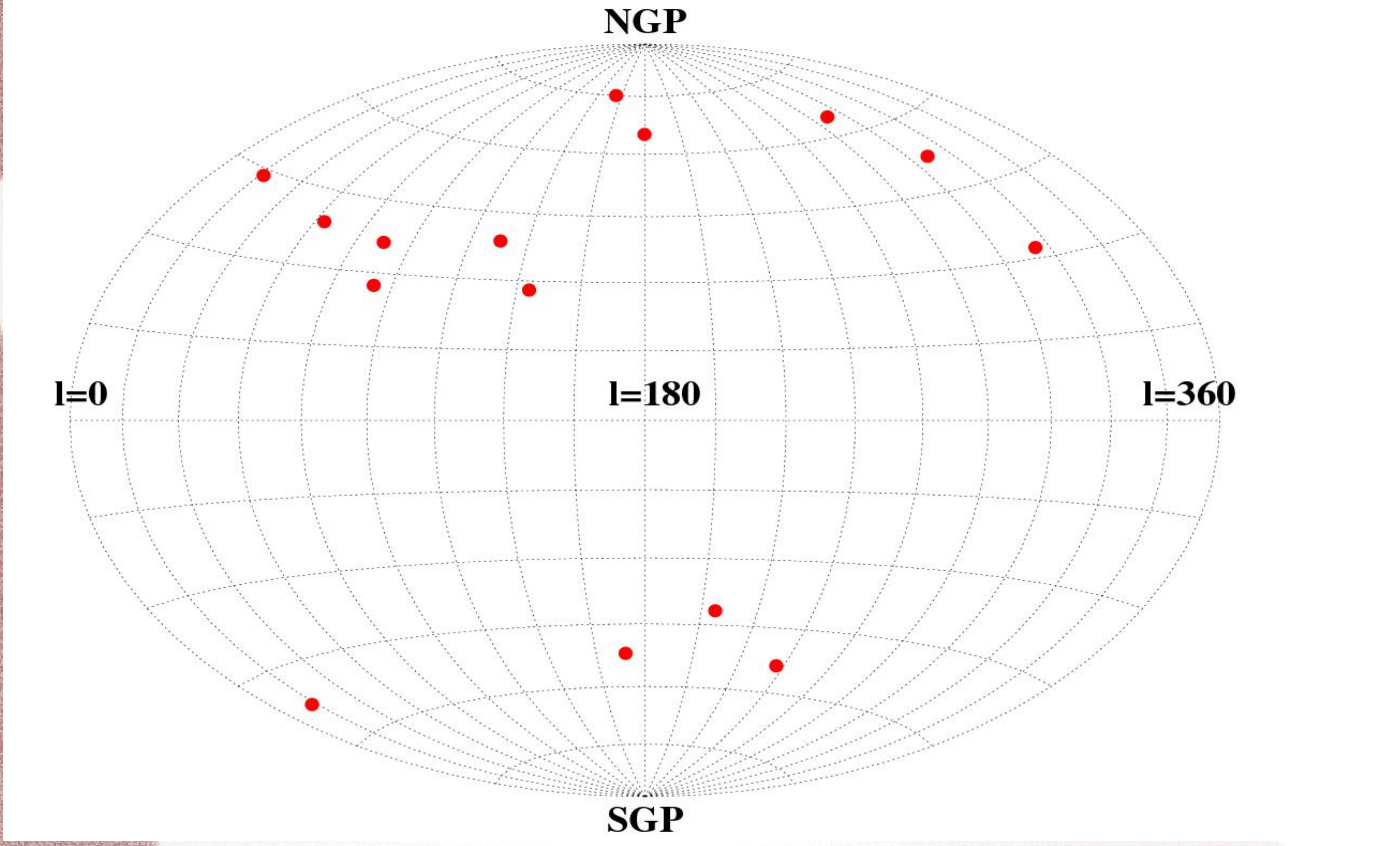
Roy, Kanekar, Braun & Chengalur (2013)

Cold gas fraction for individual lines of sight

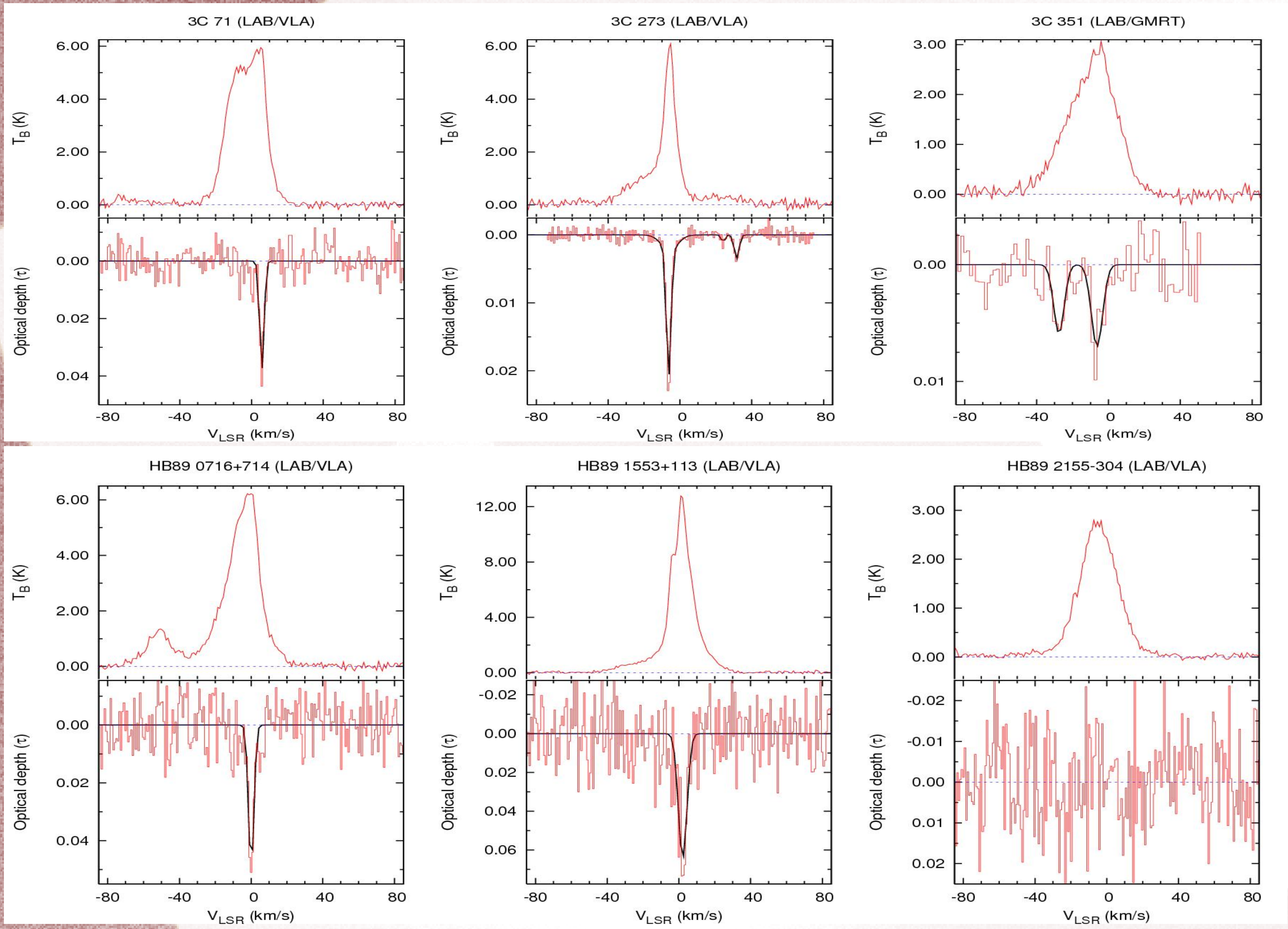


Roy, Kanekar & Chengalur (2013)

Temperature of the diffuse ISM: Sample



Temp. of the diffuse ISM: H I spectra



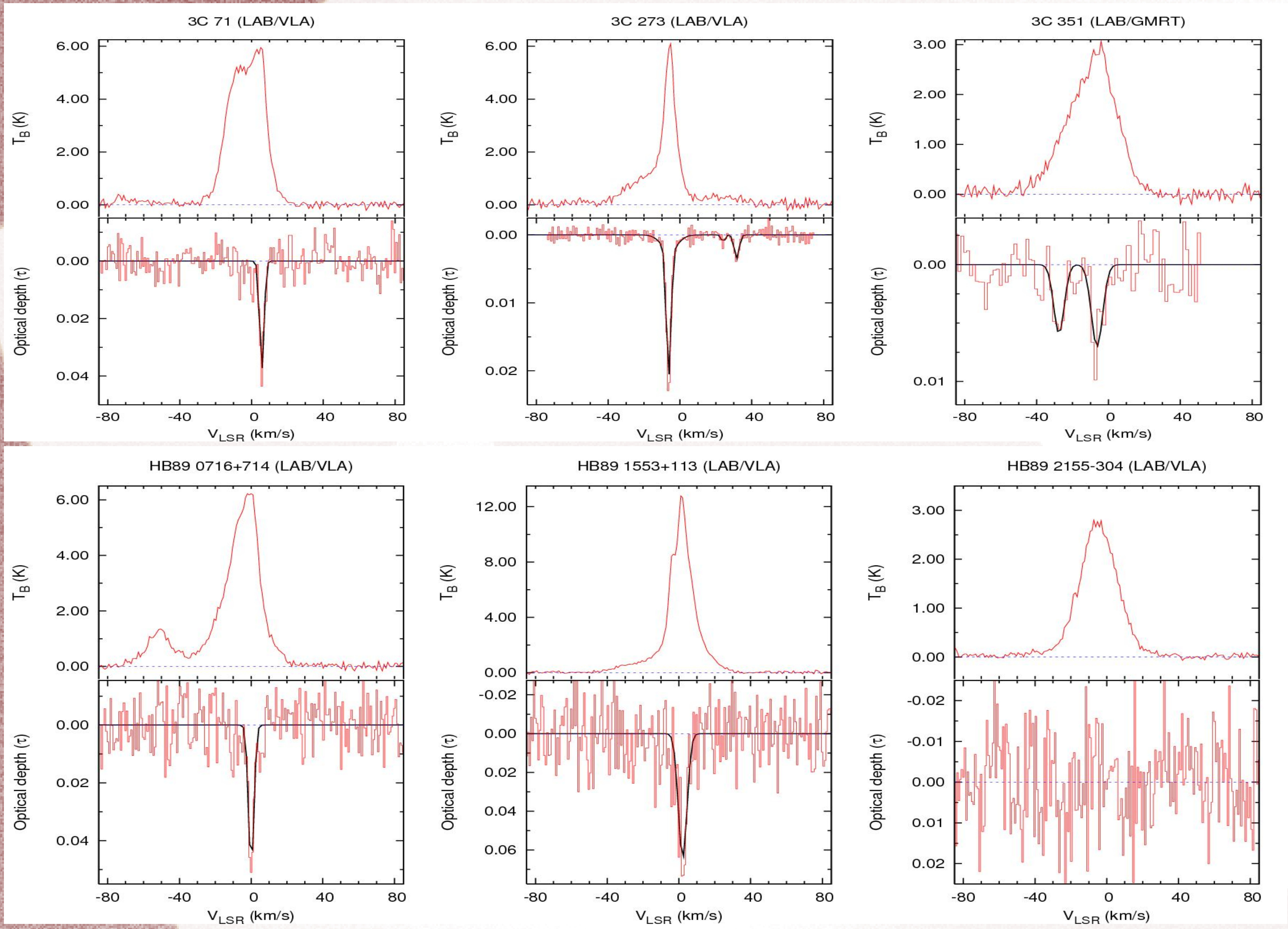
Promotional Break:

The Giant Metrewave Radio Telescope (GMRT)

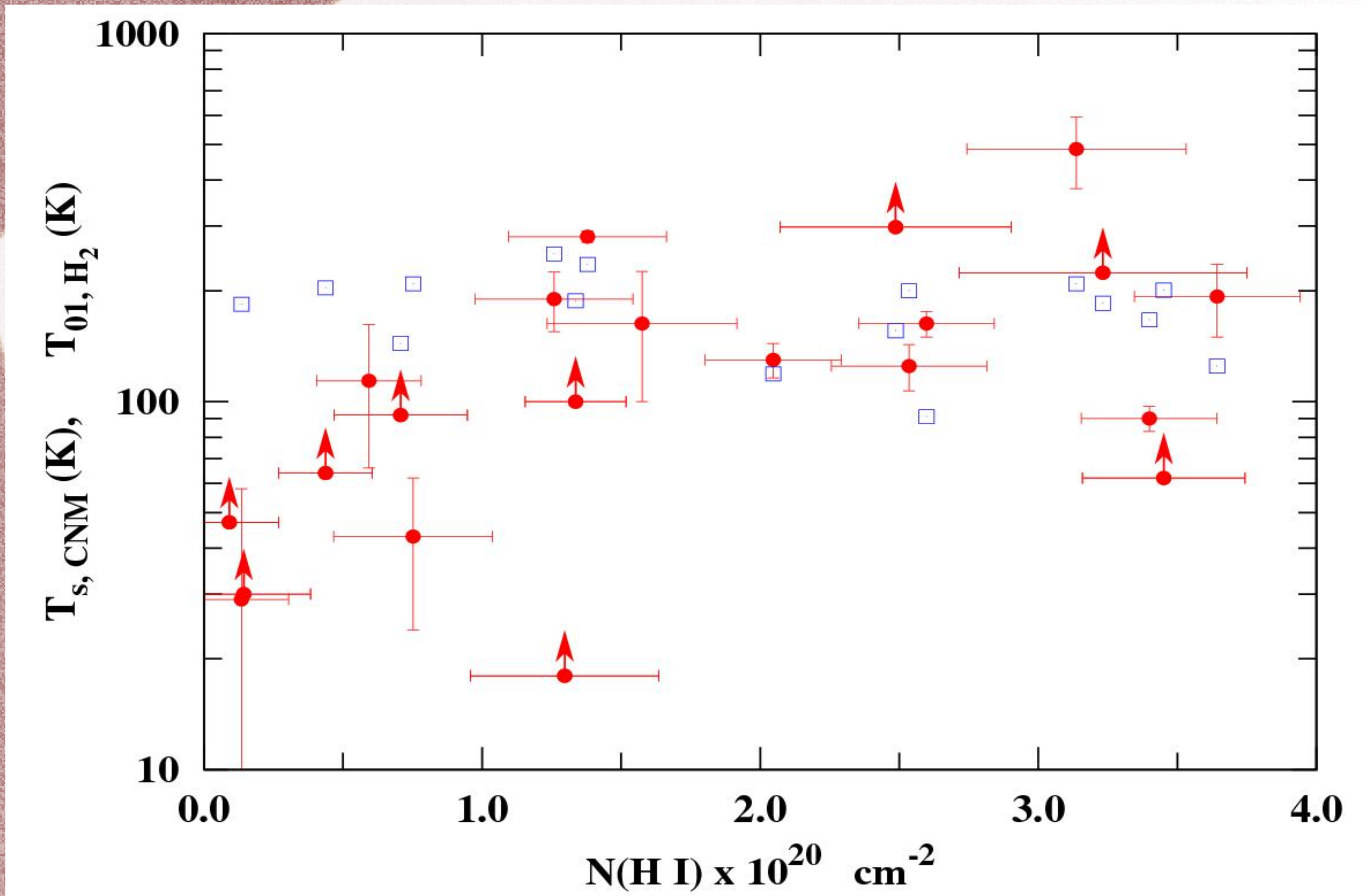
The Giant Metrewave Radio Telescope

- **Low frequency (~ 150 – 1500 MHz) radio telescope in western India (near Mumbai/Pune), operated by NCRA – TIFR**
- **Large 45 m dishes, 30 antenna, longest baseline ~ 25 km, with excellent sensitivity and continuum/spectral capabilities**
- **“Hybrid” configuration with compact “central-square”, and longer “Y-shaped” array – simultaneously sensitive to compact and extended emission structures (similar to VLA B+C config.)**
- **Currently being upgraded to increase frequency coverage and sensitivity, recognized as one of the SKA pathfinder**

Temp. of the diffuse ISM: H I spectra

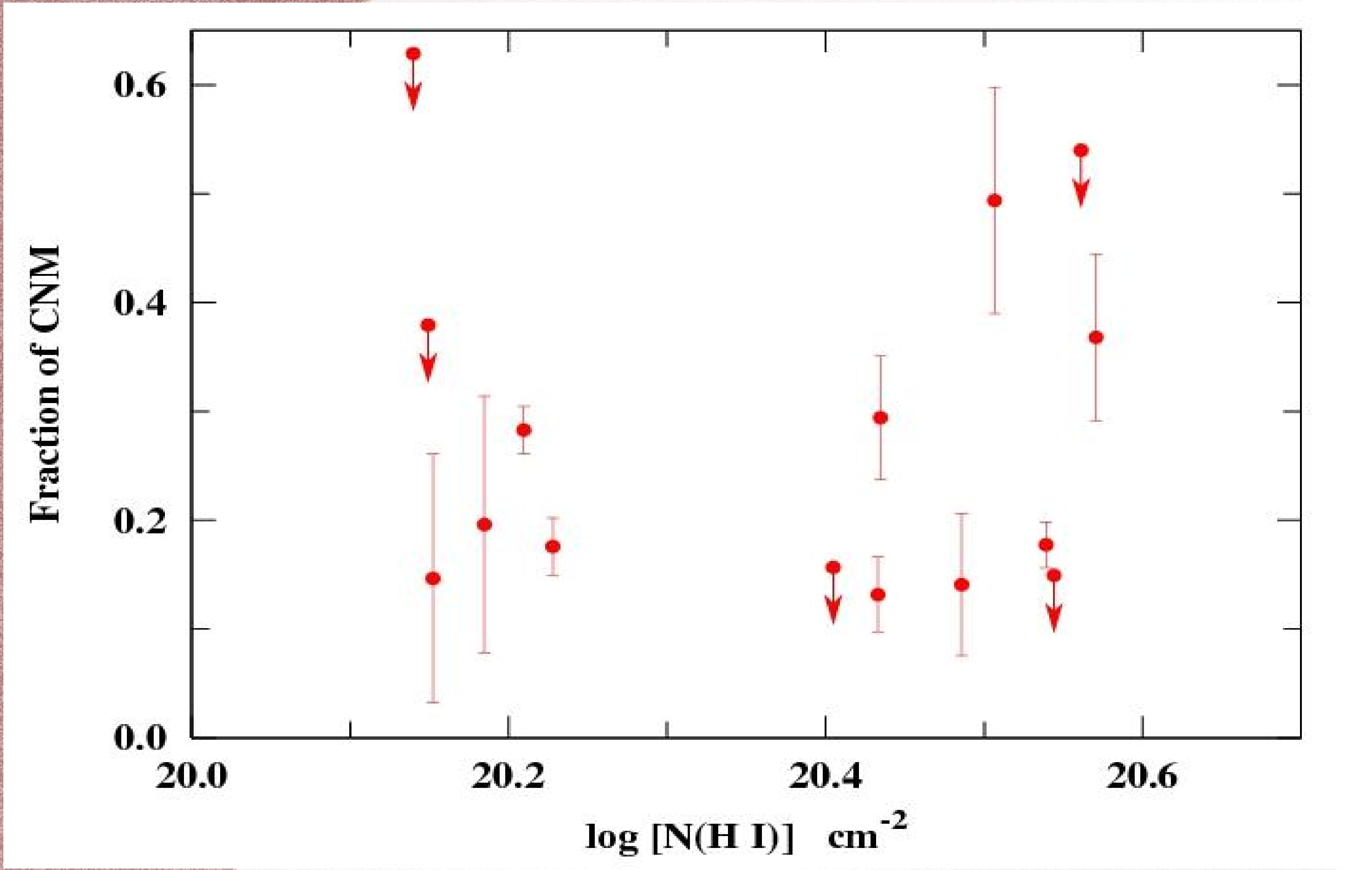


Temperature of the diffuse ISM

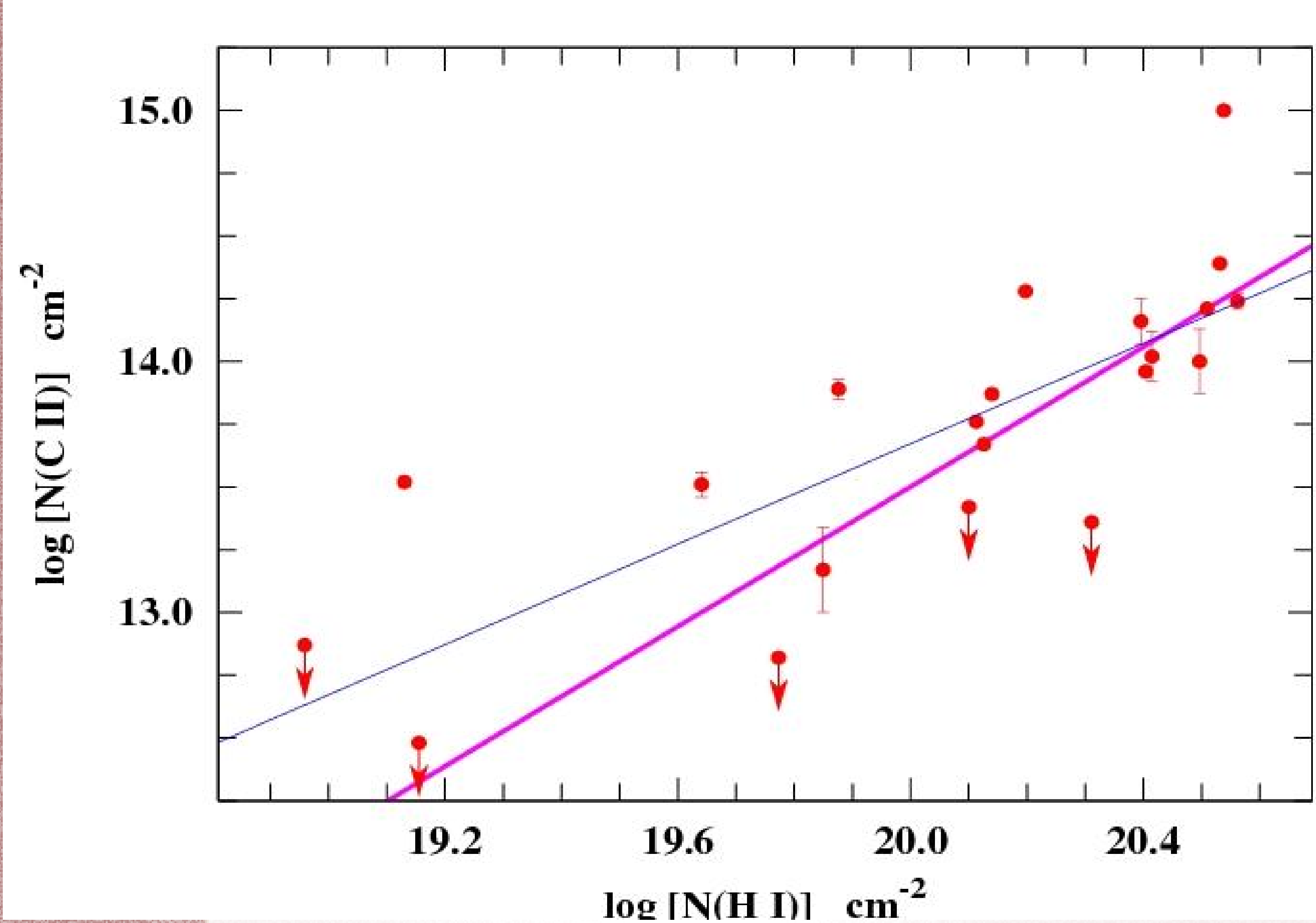


T_S from VLA/GMRT & LAB spectra; T_{01} from FUSE survey by Wakker (2006)

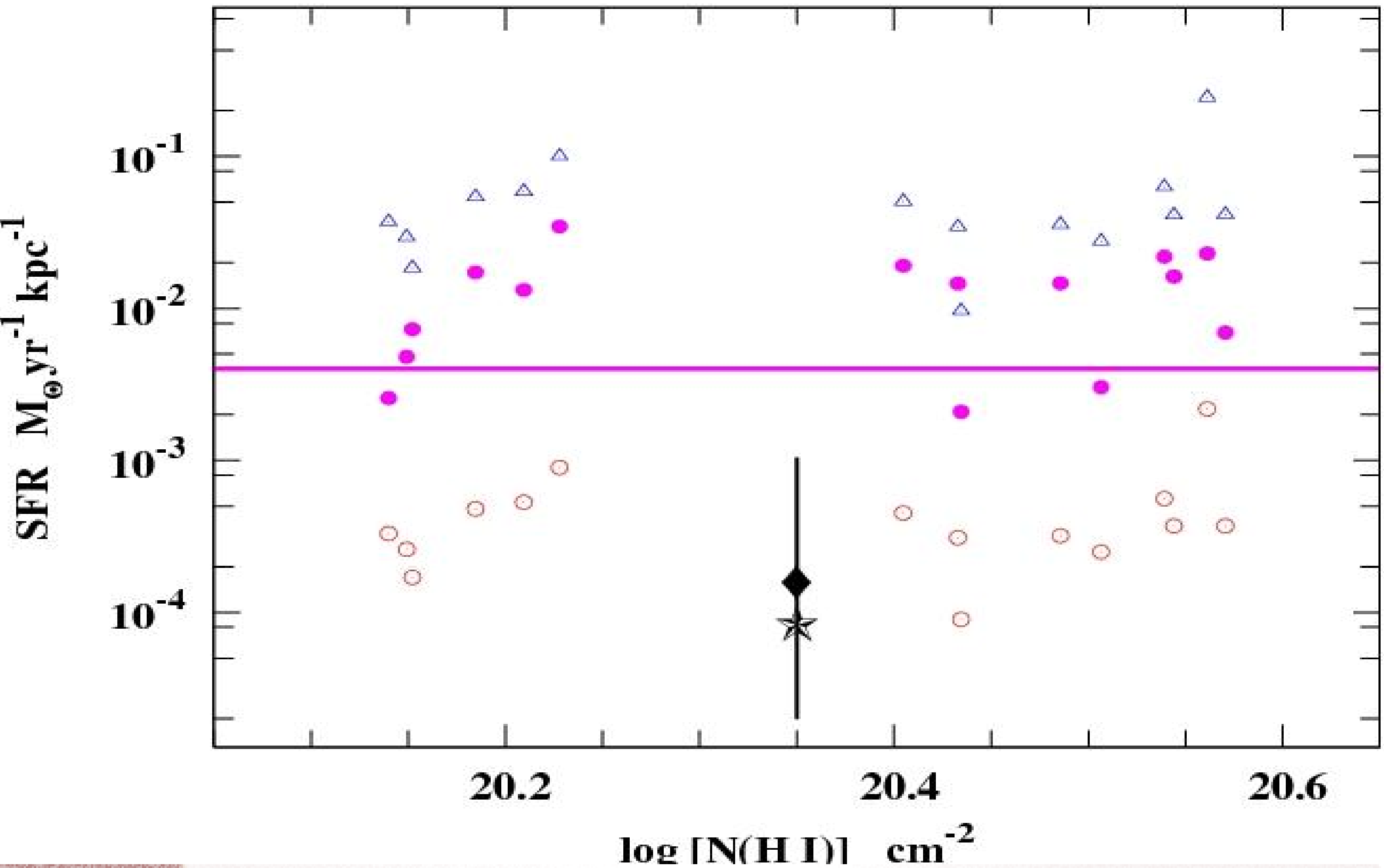
Results: CNM fraction



Results: N(C II) vs. total N(H I)



Results: Milky Way SFR



Conclusions

- Radio/UV data are used to understand if C II 158 µm transition is a good tracer of the star formation rate
- High Galactic latitude sightlines contain 10 – 50% CNM
- To estimate the SFR correctly, C II cooling in both the phases should be considered!
- These results are particularly important in the context of SFR in the Damped Lyman-alpha systems

Thank you!