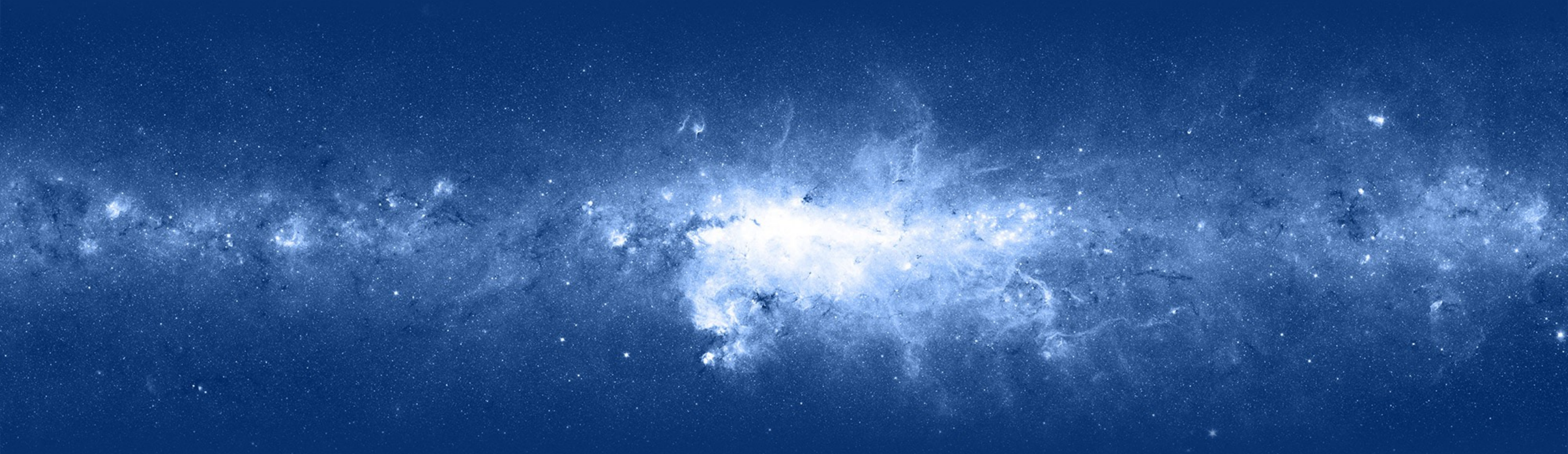


ASTR 670: Interstellar medium and gas dynamics

Prof. Benedikt Diemer



Chapter 4 • Neutral atomic gas

Gas phases (in the Milky Way)

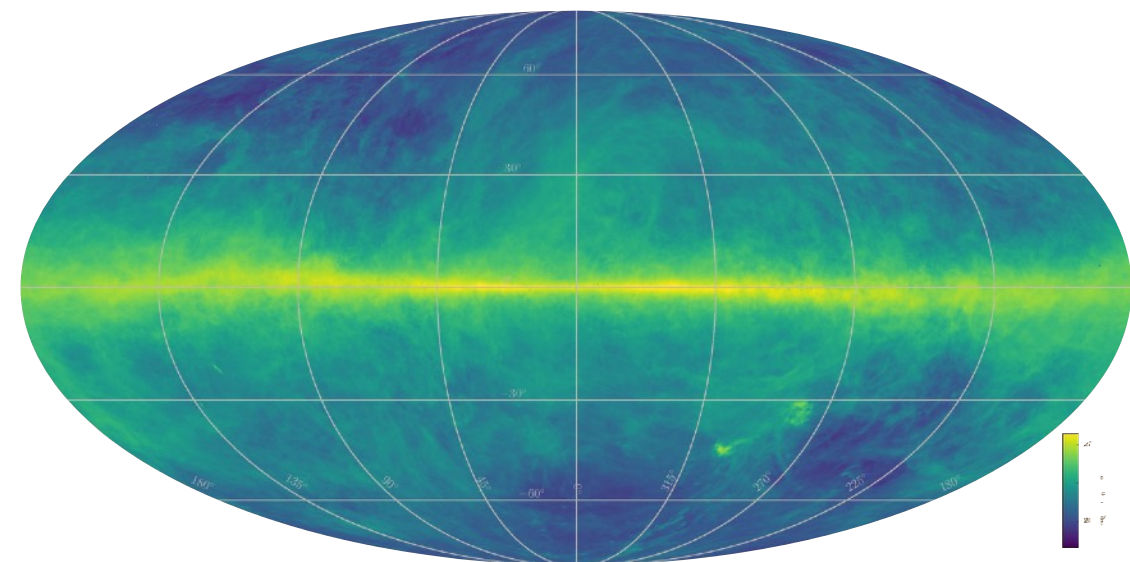
Phase		T (K)	n _H (cm ⁻³)	f _V -	P/k _B (K/cm ³)	Comments
H II 23%	Hot ionized medium (HIM)	10 ^{5.7}	0.004	0.5	4400	Collisionally ionized, shock-heated by supernovae and stellar winds
	H II regions	10000	0.1-10 ⁴	0.01	varies	Photo-ionized nebulae around stars; density and pressure vary across these bubbles
	Warm ionized medium (WIM)	8000	0.2	0.1	4400	Diffuse photo-ionized gas, large scatter in temperature and density
H I 60%	Warm neutral medium (WNM)	8000	0.5	0.4	4400	About 60% of HI by mass; in pressure equilibrium with CNM
	Cool neutral medium (CNM)	100	40	0.01	4400	Significant fraction of the mass despite small volume filling fraction
H ₂ 17%	Diffuse molecular gas	50	150	0.001	4400	Self-shielded against dissociation, but not dense enough to form stars
	Molecular clouds	10-50	10 ³ -10 ⁶	0.0001	>10000	The site of star formation; more or less gravitationally bound

Radio & The 21cm line

- **Jansky 1932:**
 - Discovery of radio emission from the Milky Way
- **van de Hulst 1944:**
 - Prediction of 21cm line: 1.42 GHz radiation due to hyperfine spin-flip transition in atomic hydrogen (HI)
 - Allows us to detect HI
- **Ewen/Purcell & Muller/Oort 1951:**
 - Detection of 21cm radiation from the MW
- **1950s/60s:**
 - First 21cm maps of the MW
 - The bulk of the ISM mass is in atomic H!

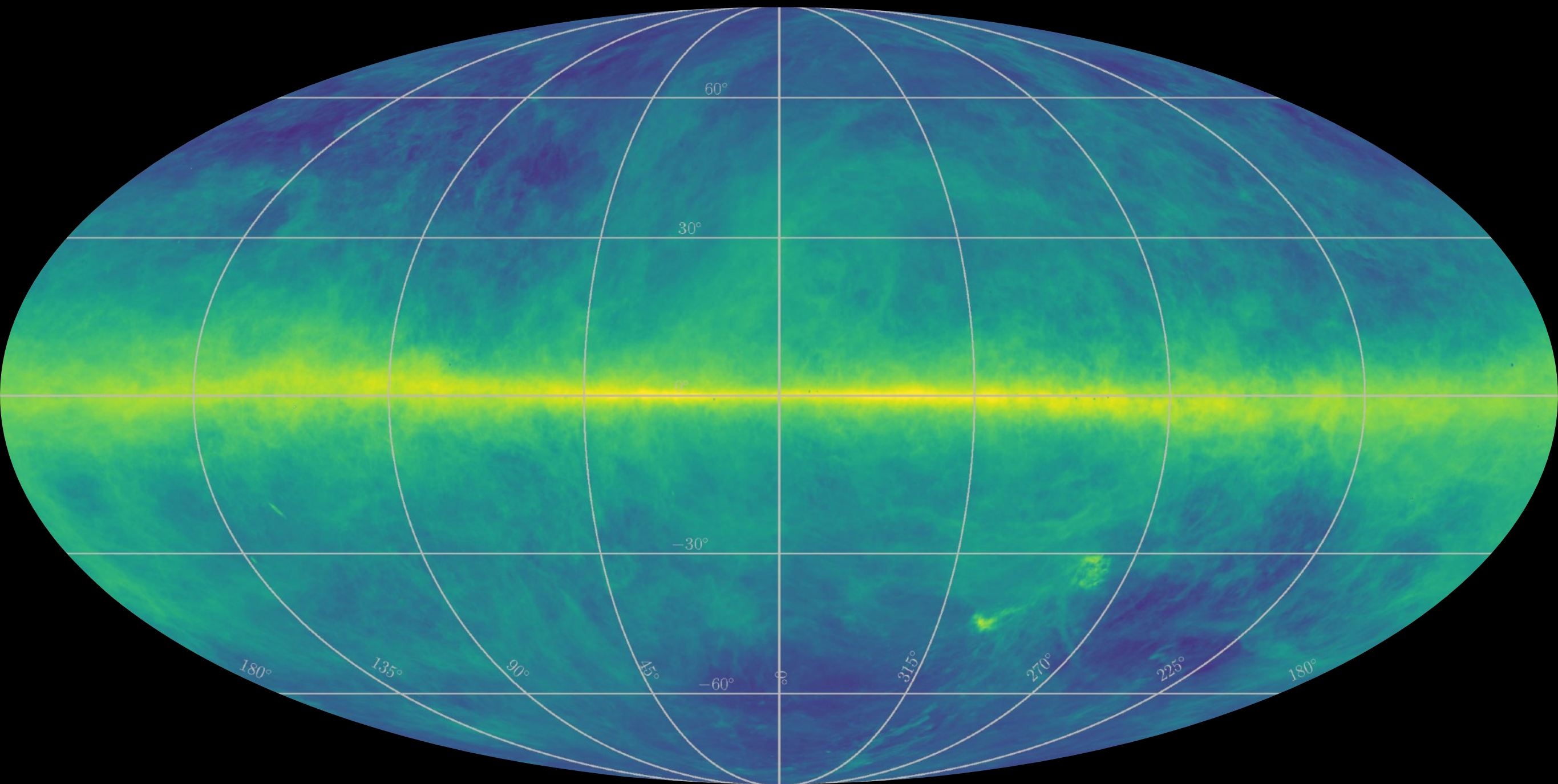


Ewen & Purcell's horn

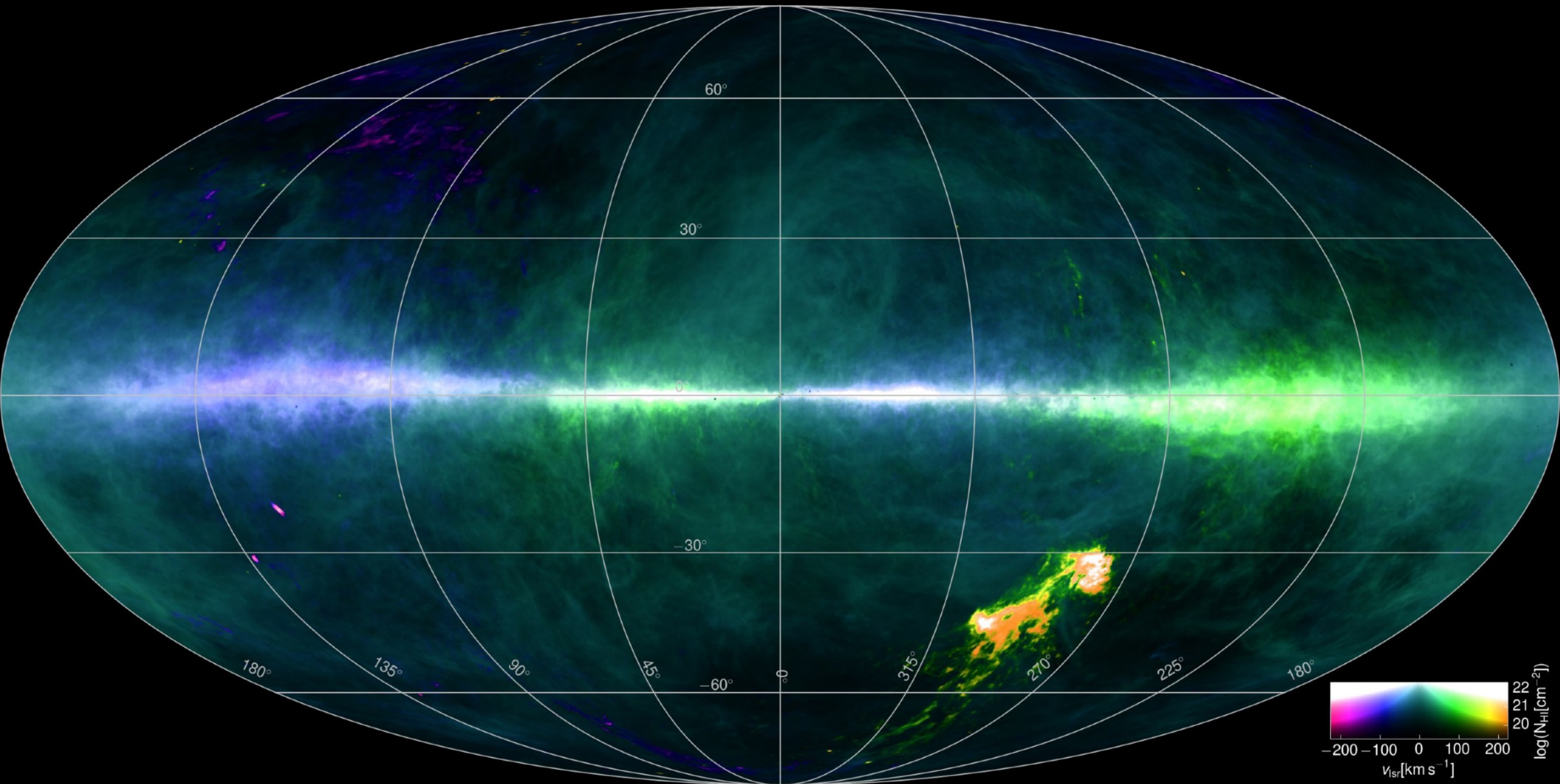


HI all-sky map

HI (21cm)

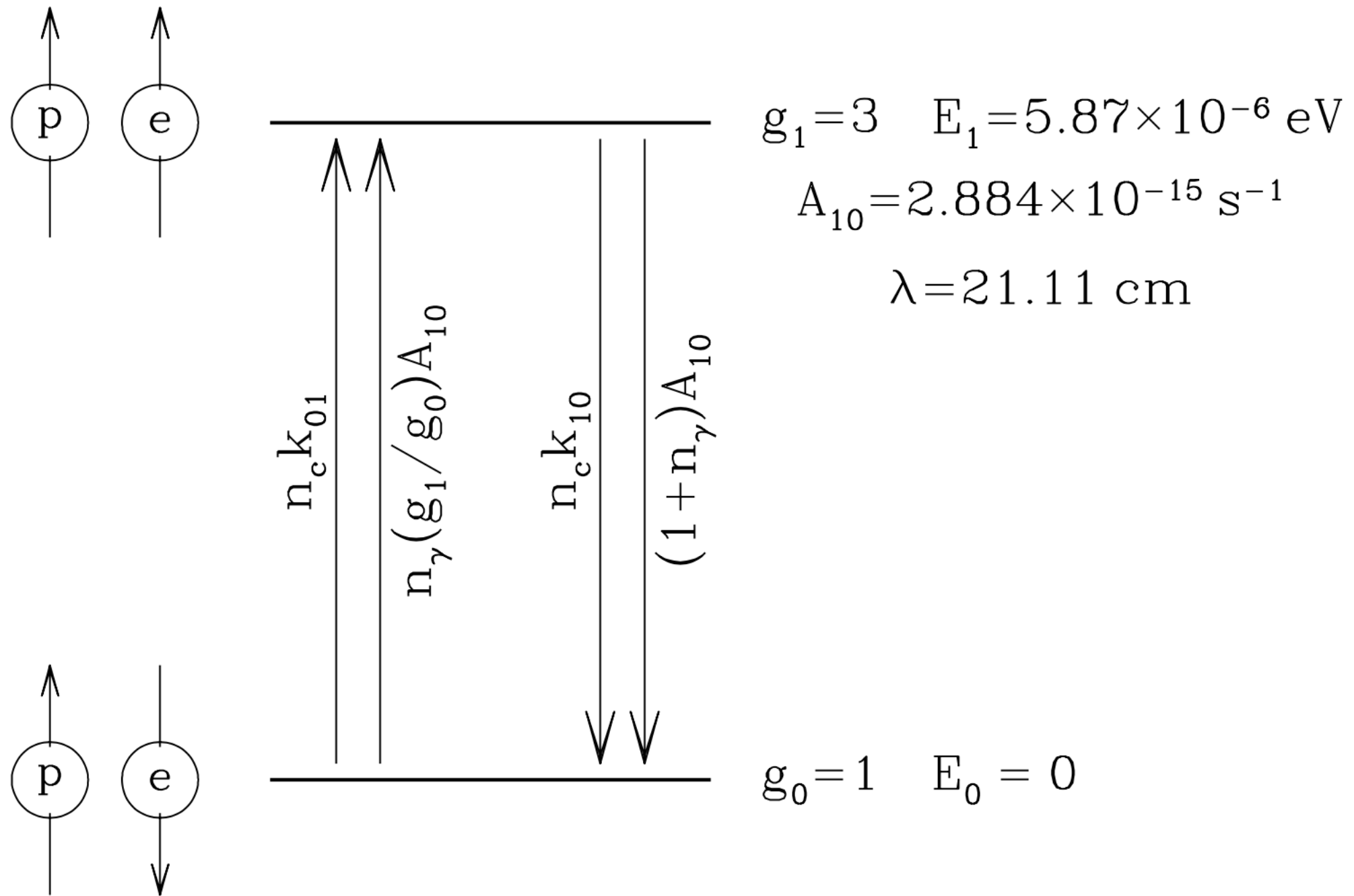


HI (21cm)

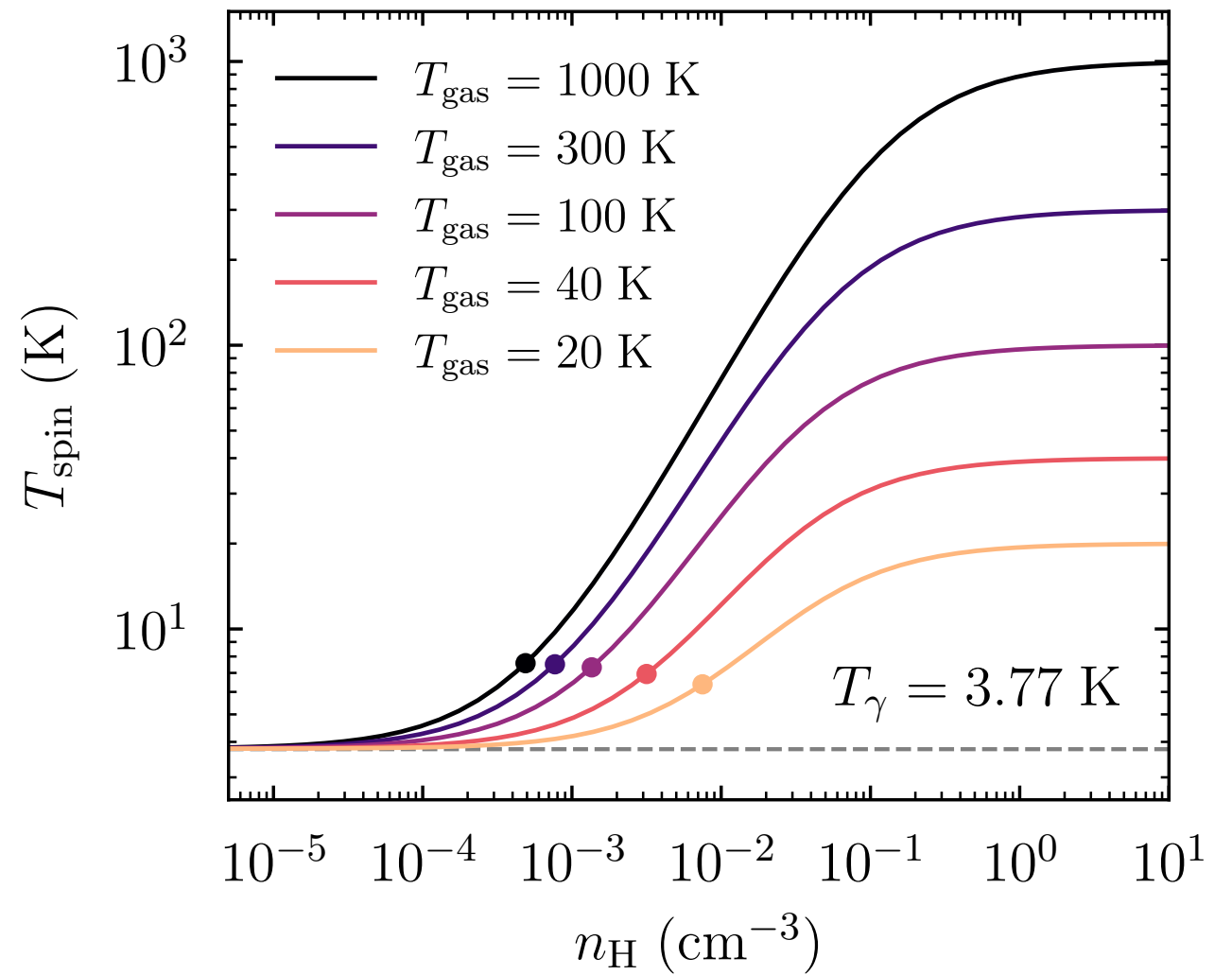
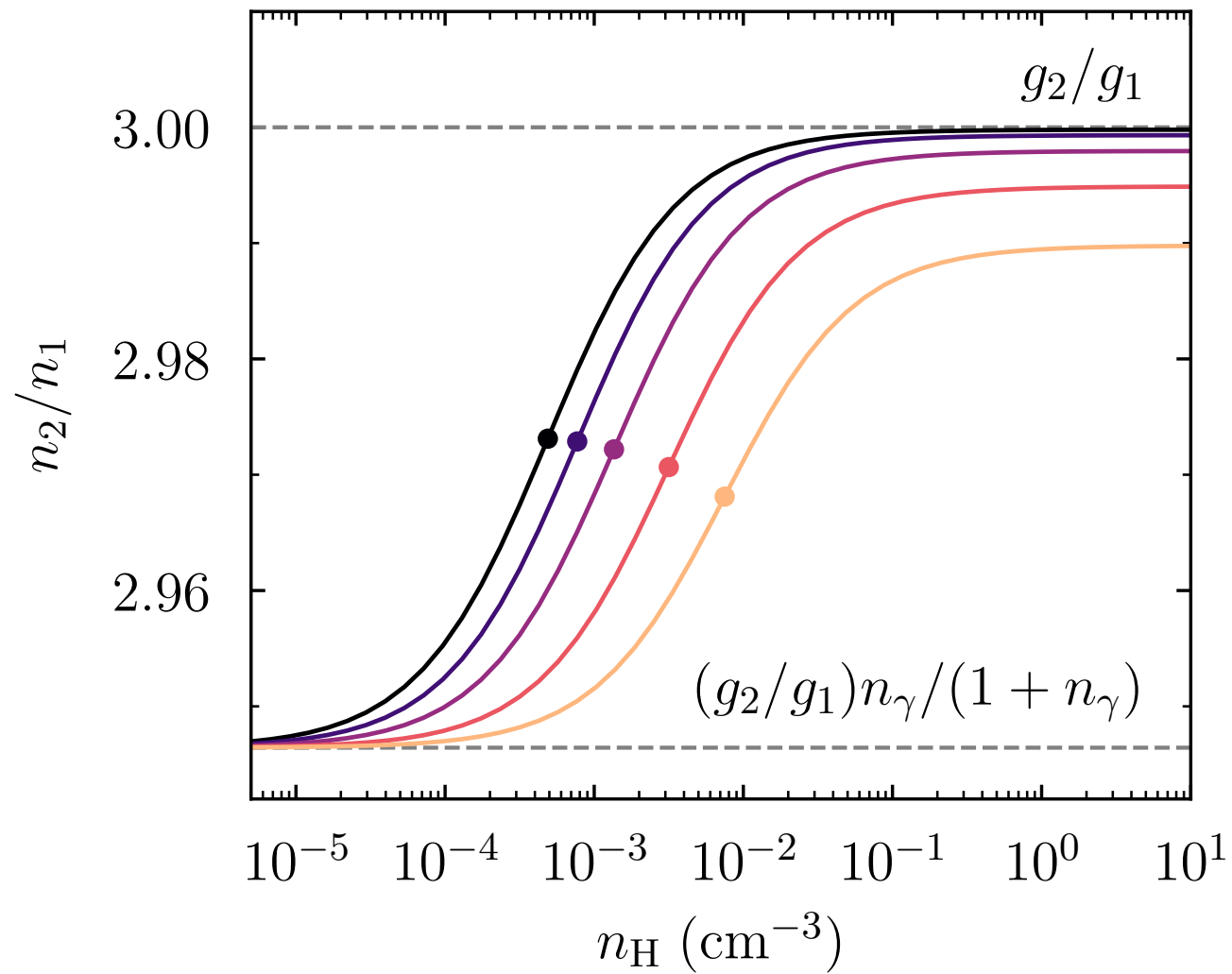


§4.1 • Hyperfine splitting of hydrogen and the 21cm line

Hyperfine splitting of 1s level of H atom

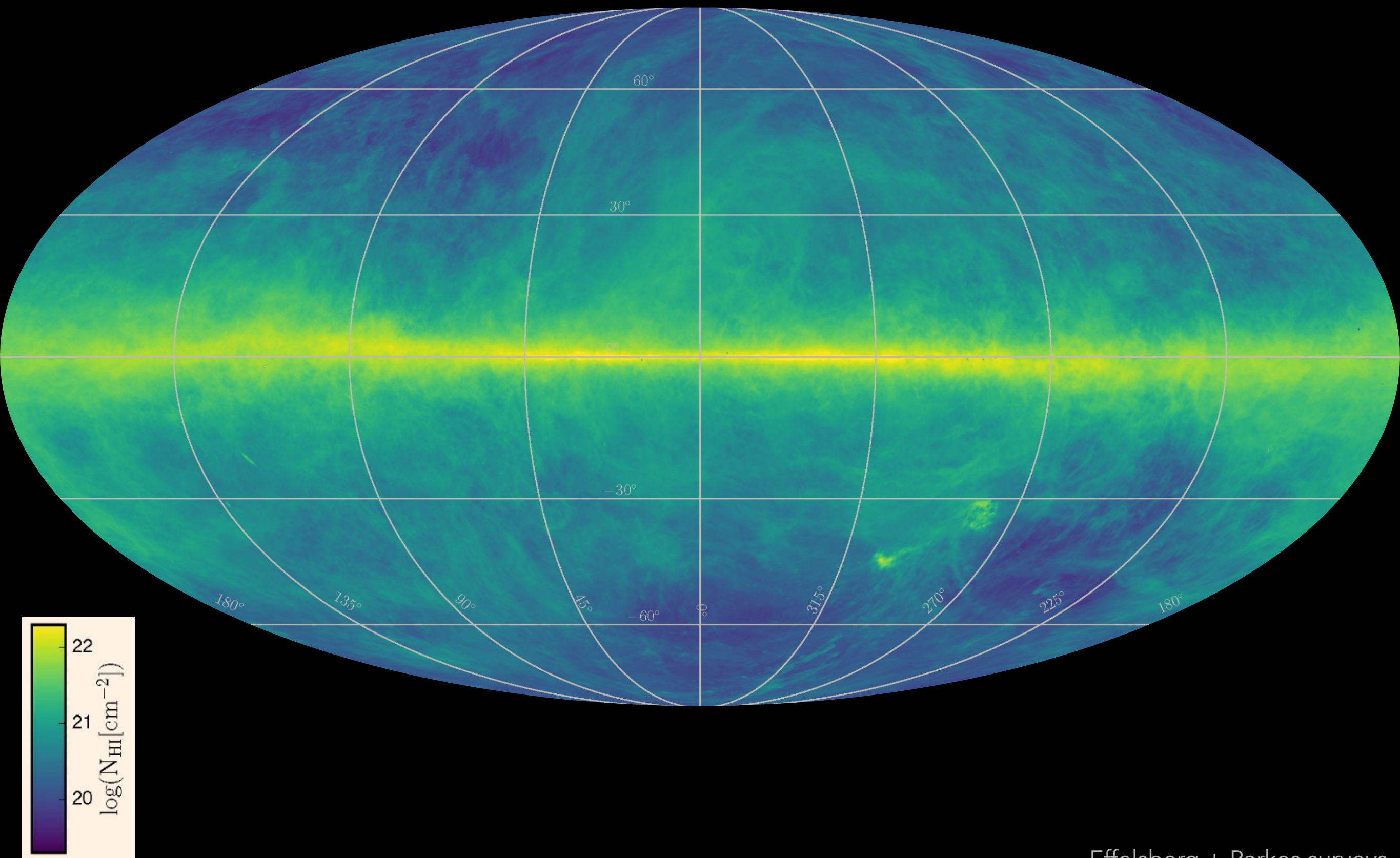


Level populations and spin temperature



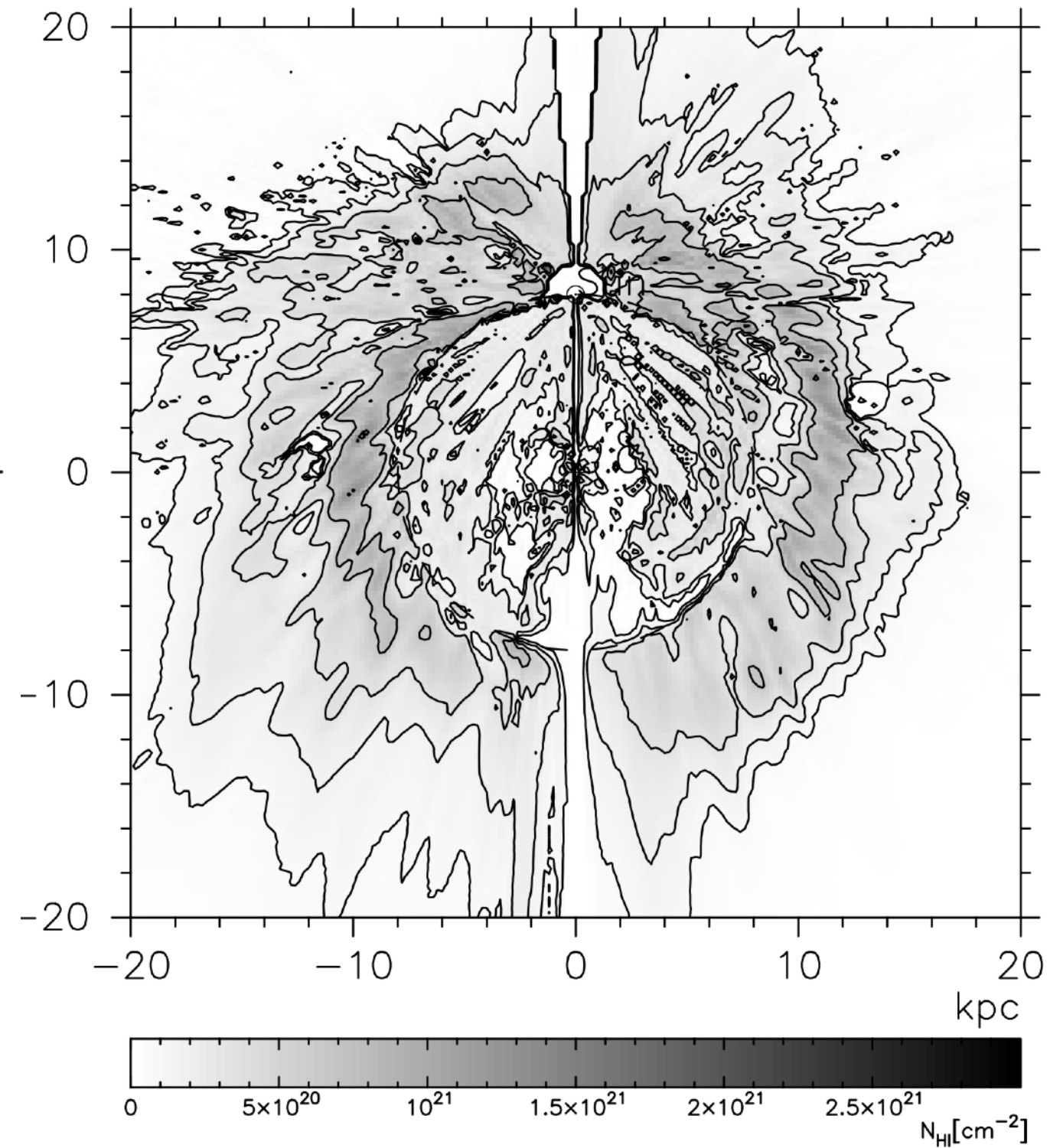
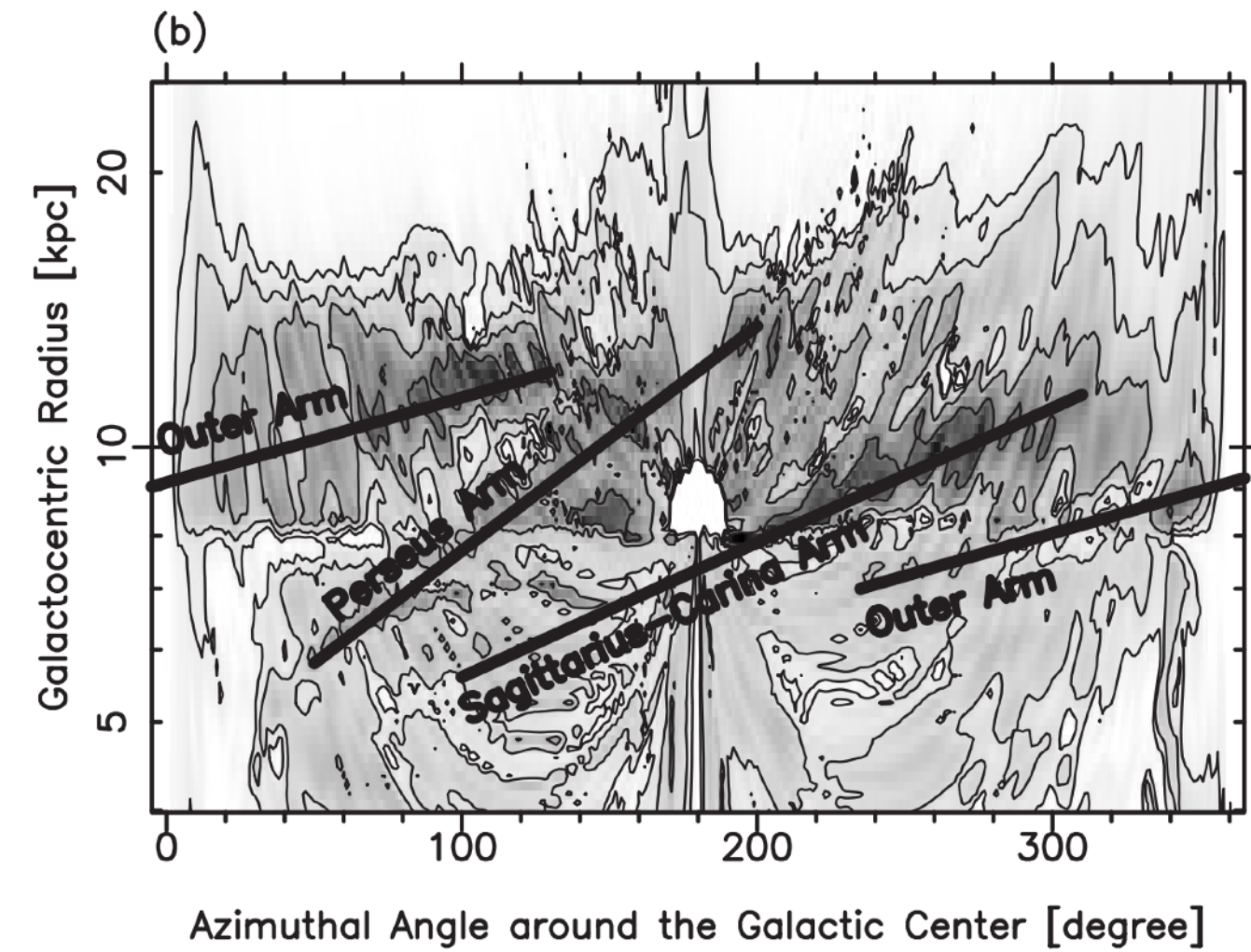
§4.2 • Emission and absorption in HI gas

HI (21cm)

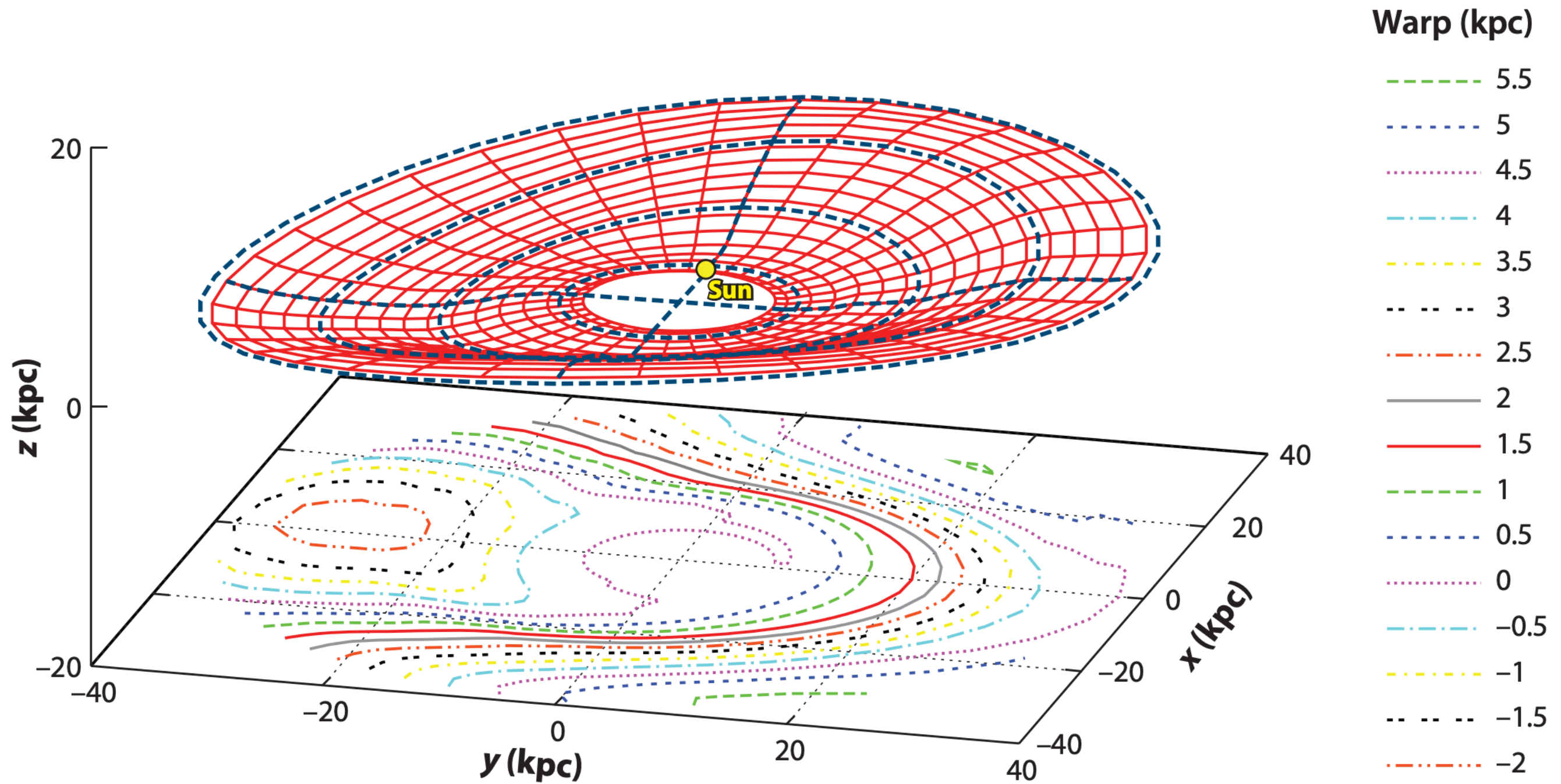


HI in the Milky Way

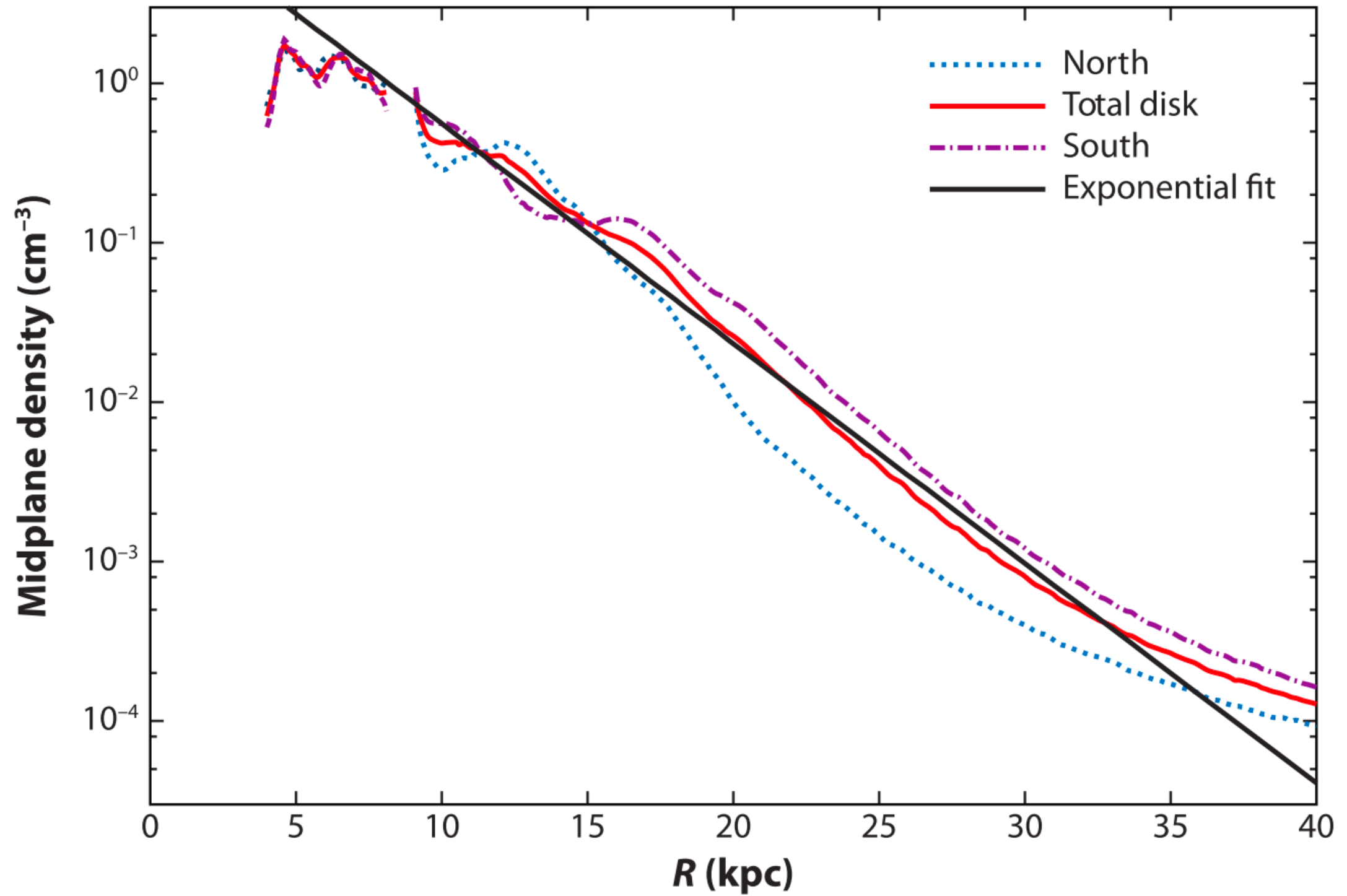
HI in the Milky Way



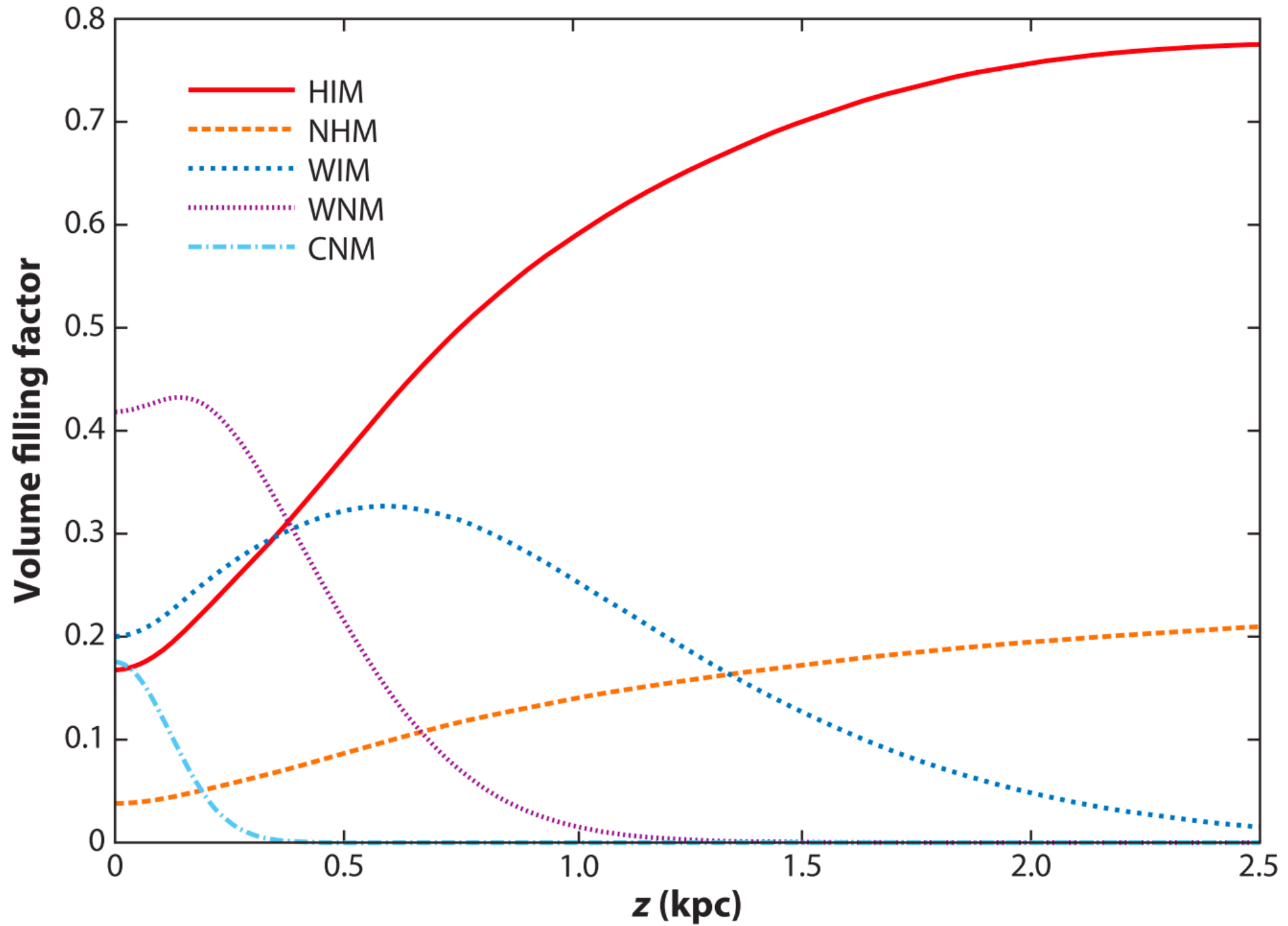
HI in the Milky Way



HI in the Milky Way



HI in the Milky Way

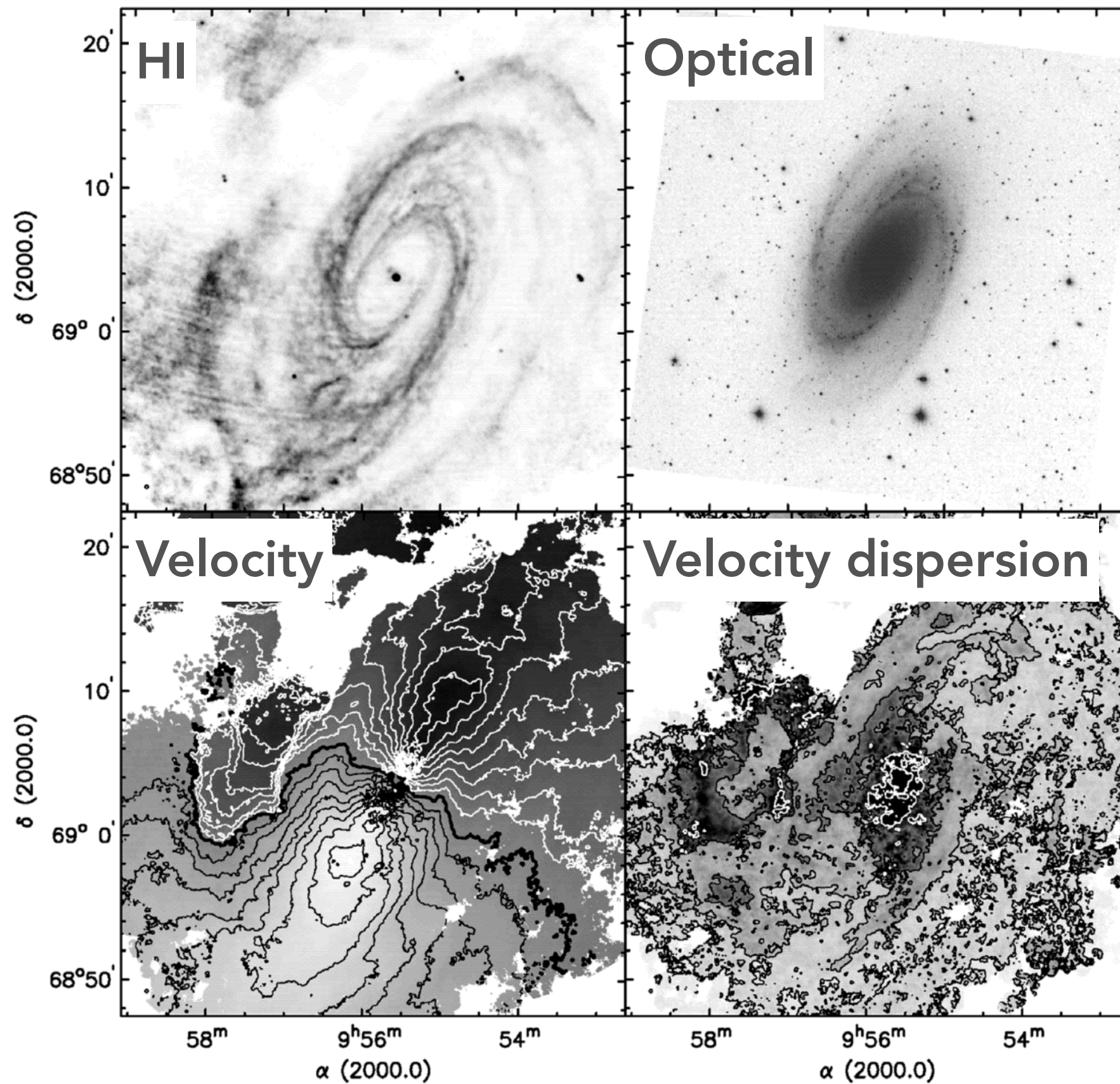


Extragalactic HI

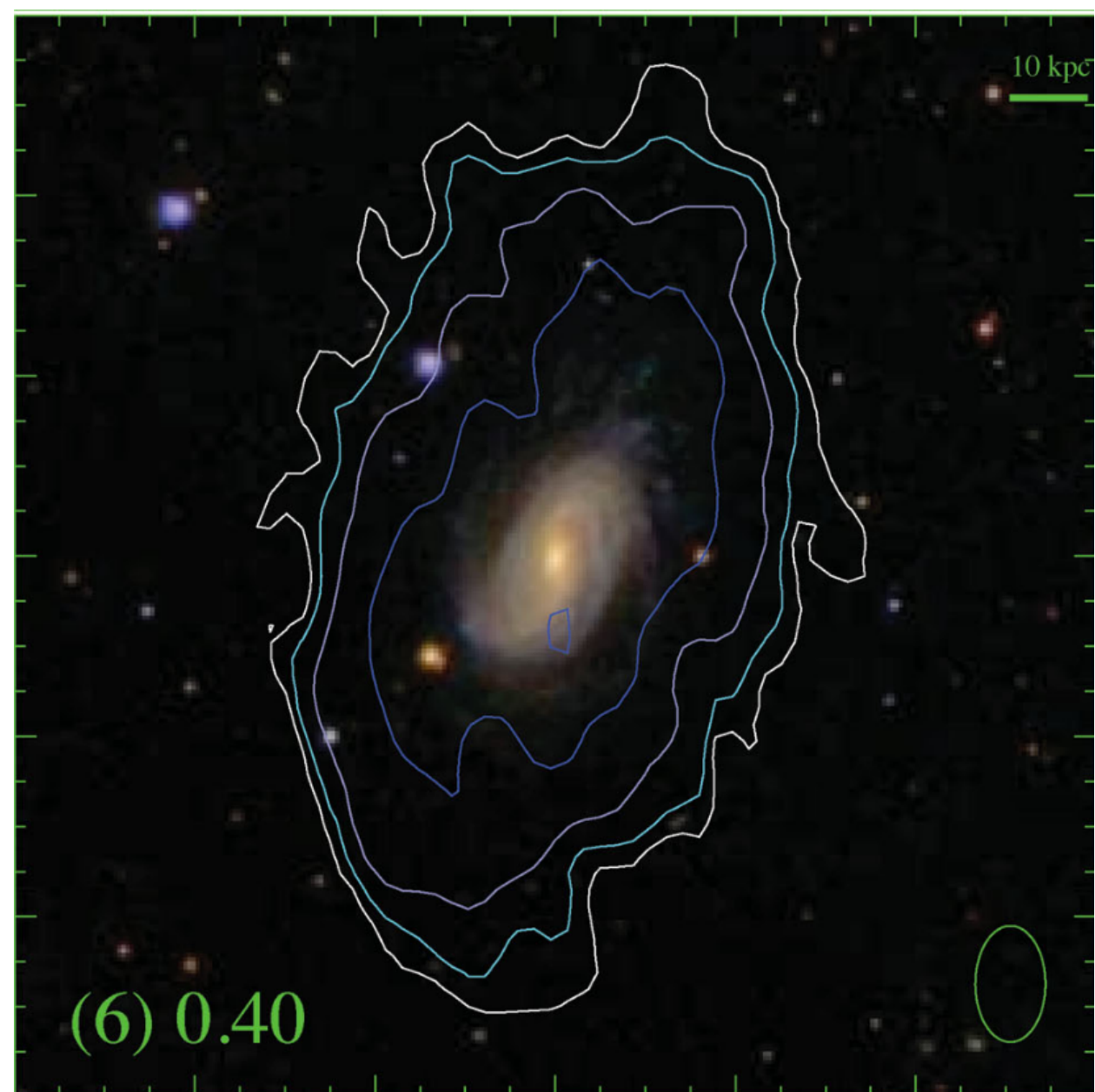
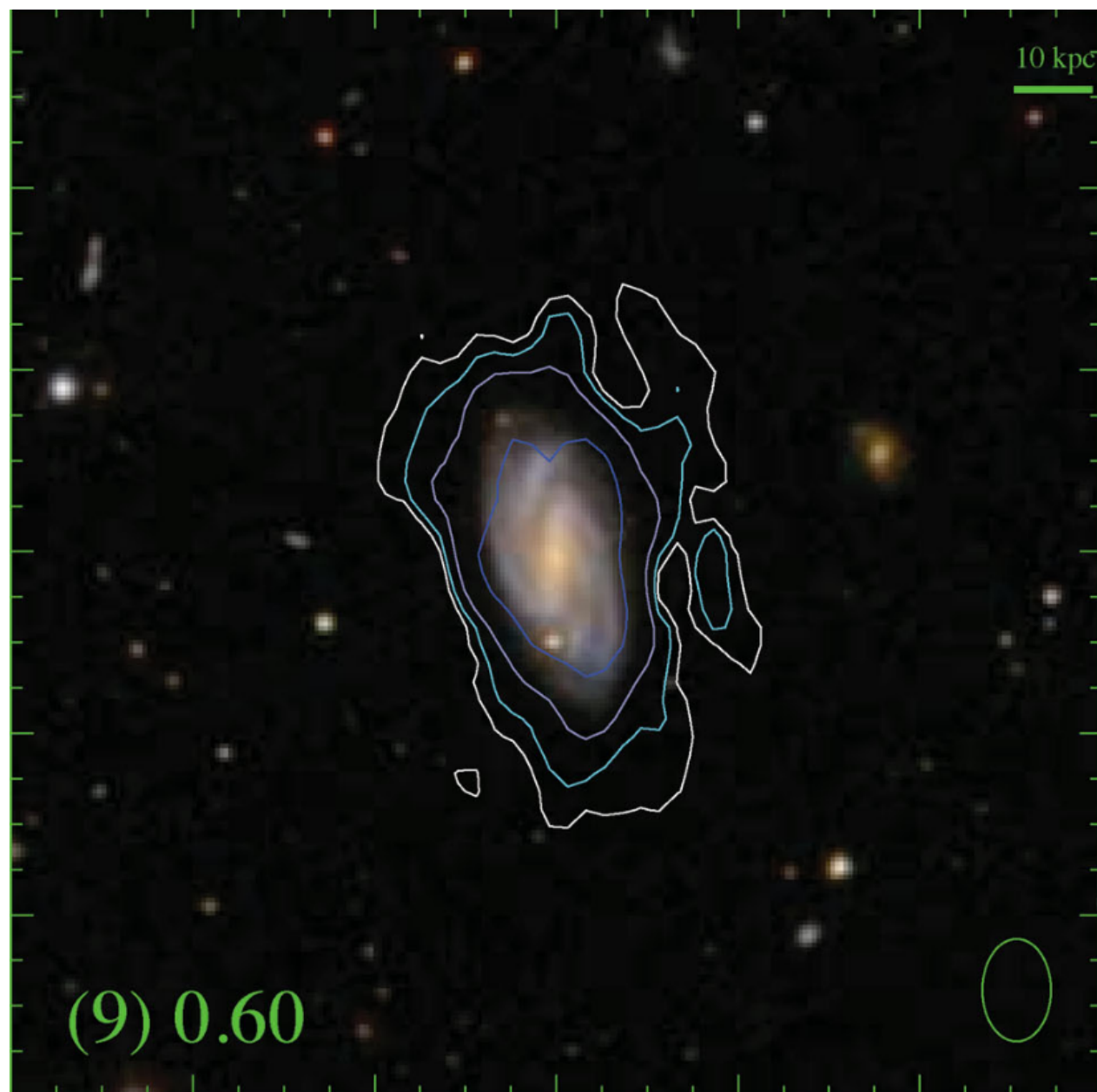


Very Large Array (VLA)

Resolved HI observations



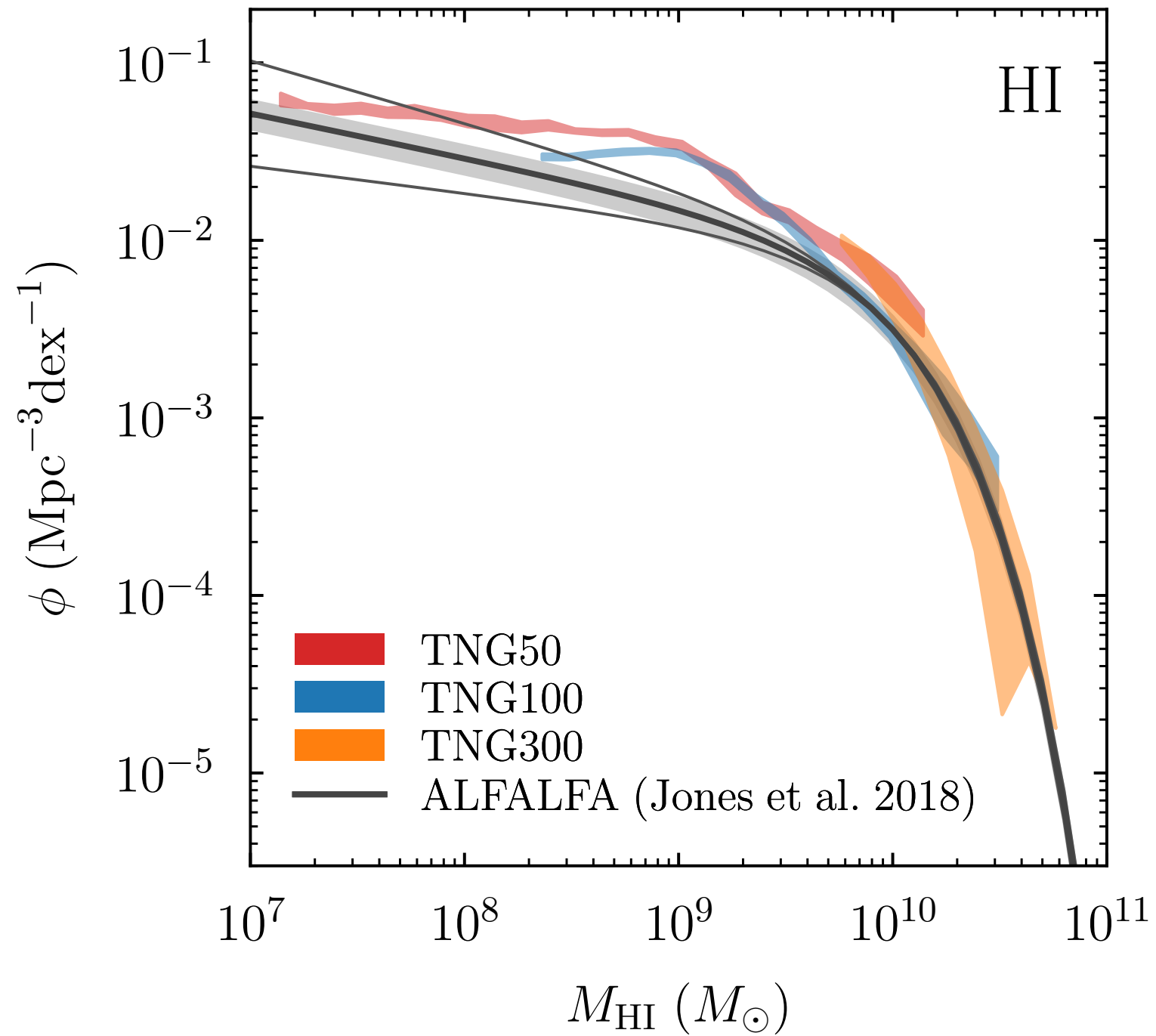
HI disks



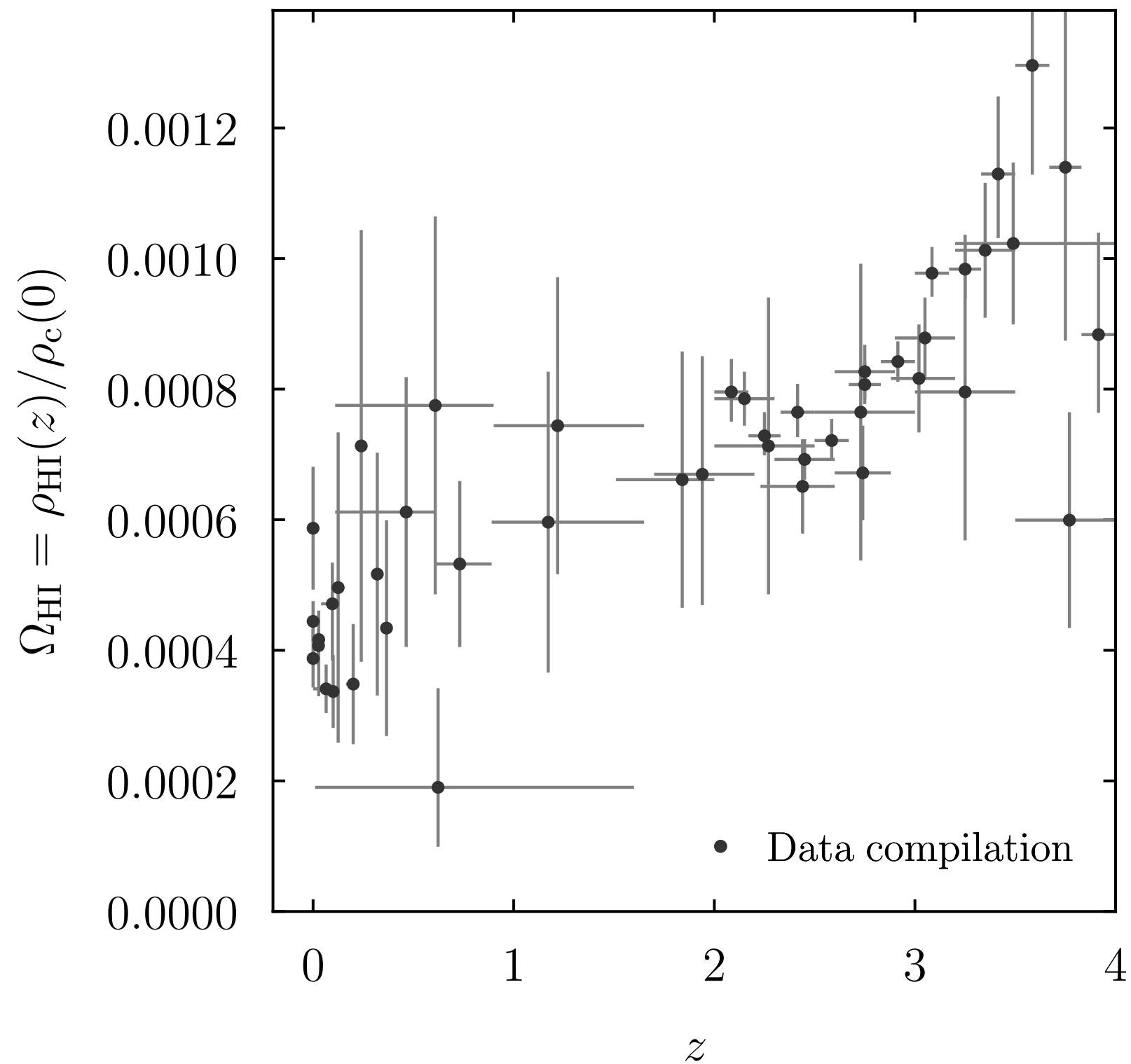


Arecibo Telescope

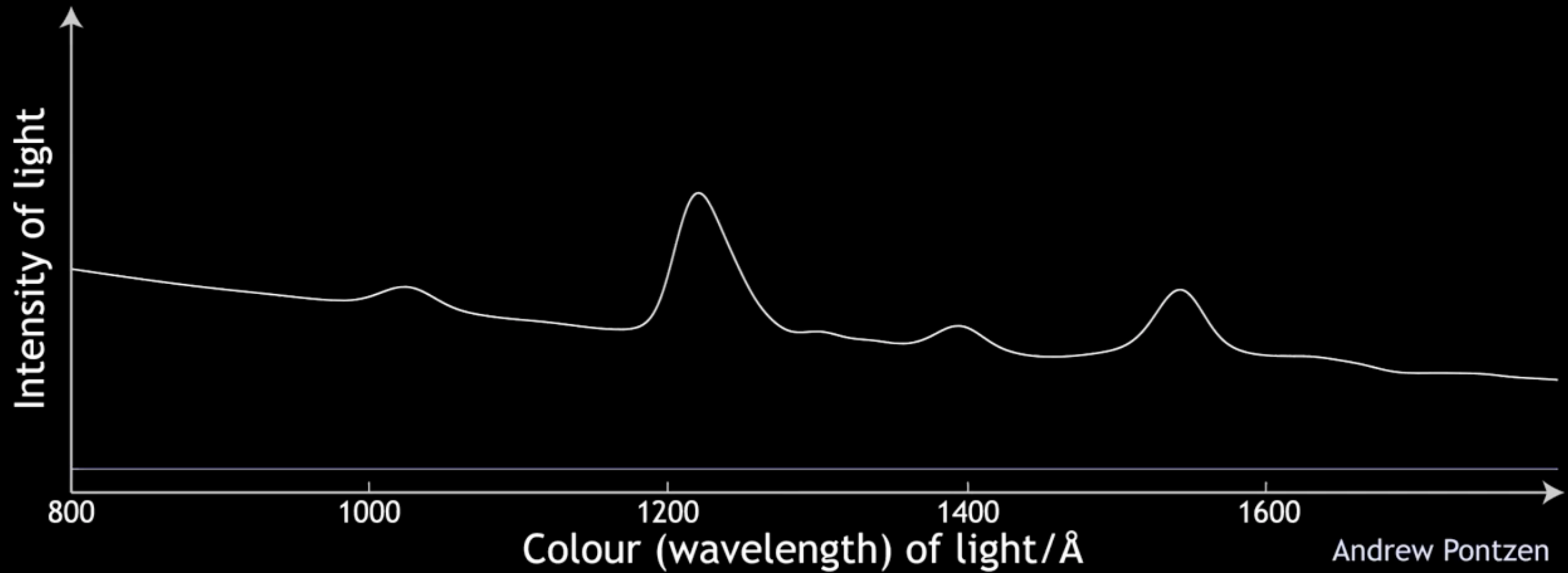
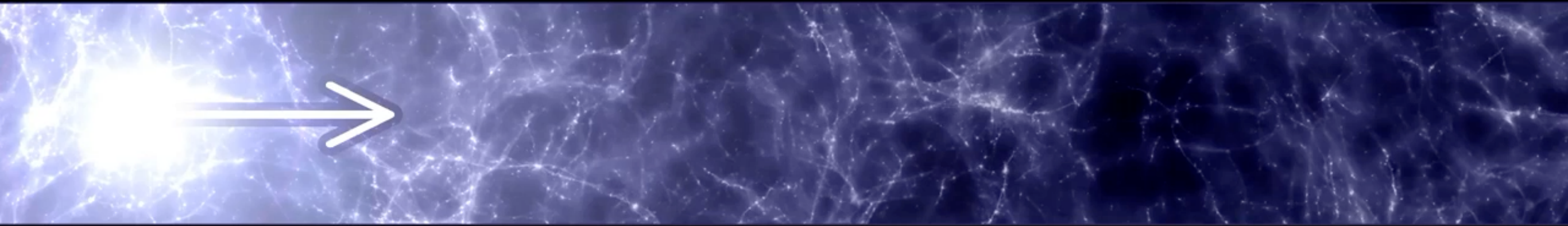
ALFALFA Survey



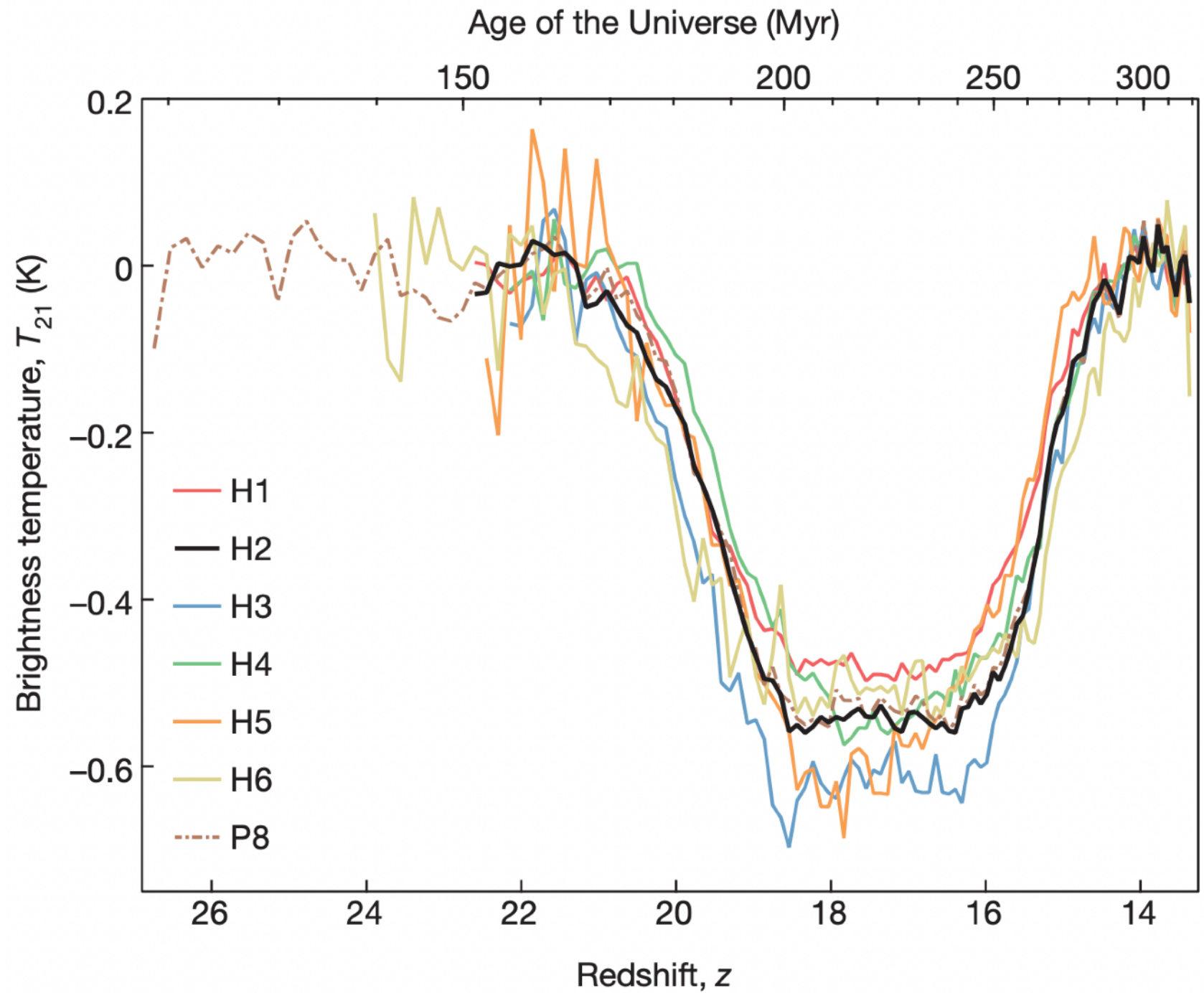
Total abundance of HI in the Universe



Lyman-alpha forest



Global 21cm signal



$$T_{21}(z) \approx 0.023 \text{ K} \times x_{\text{HI}}(z) \left[\left(\frac{0.15}{\Omega_{\text{m}}} \right) \left(\frac{1+z}{10} \right) \right]^{\frac{1}{2}} \left(\frac{\Omega_{\text{b}} h}{0.02} \right) \left[1 - \frac{T_{\text{R}}(z)}{T_{\text{S}}(z)} \right]$$

Reading

Draine

- §8.1-2
- §17.1-3
- §29.1-2