Probing Cosmological Models Through the Era of First Galaxies

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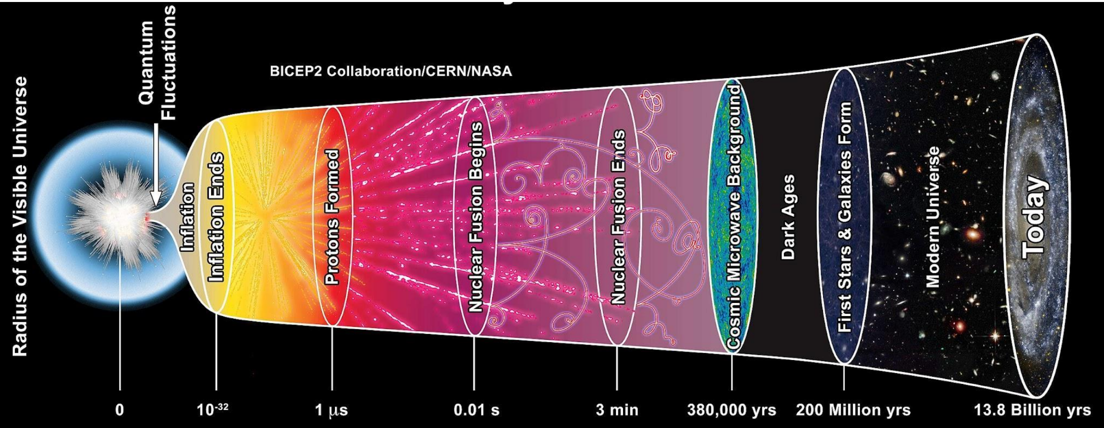
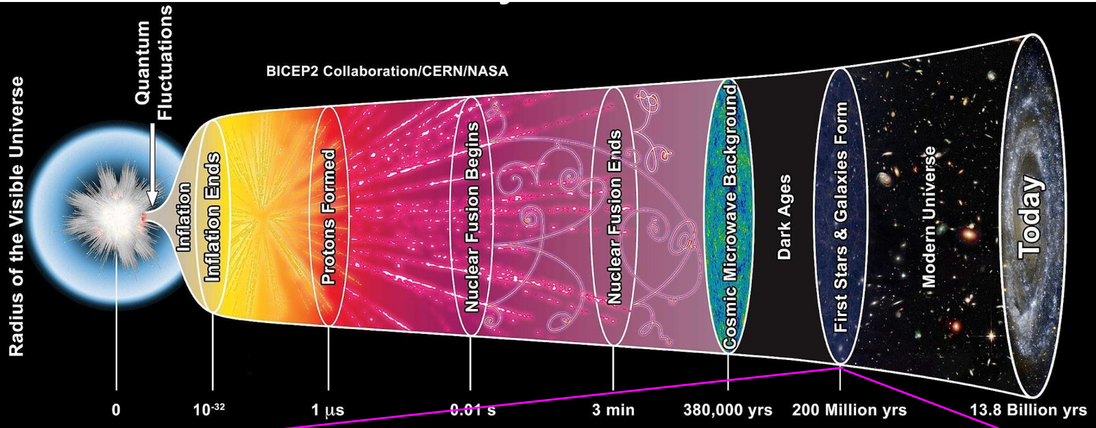
NORDITA

23 Oct 2023

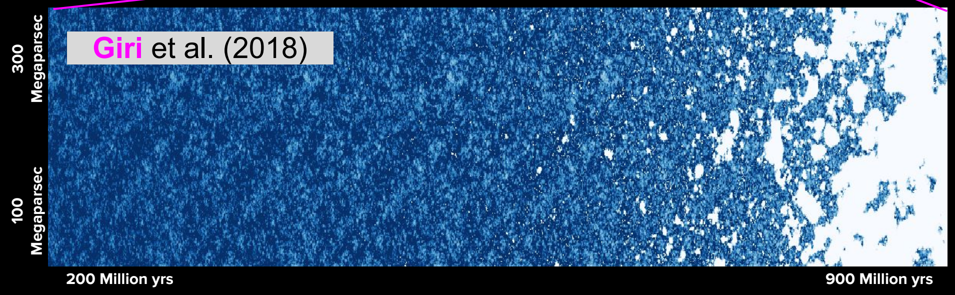
History of our Universe



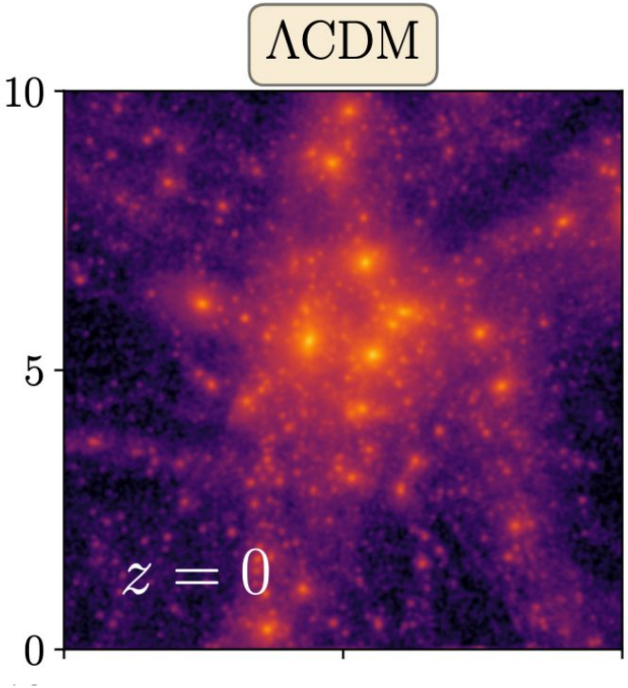
History of our Universe

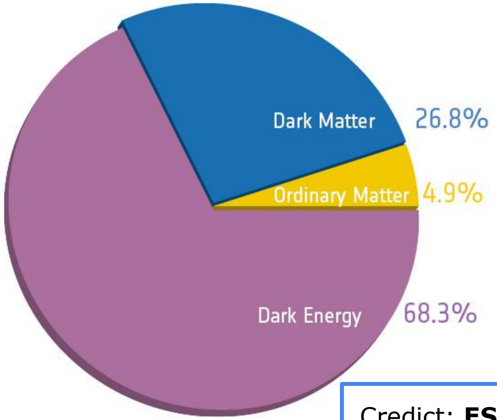


Intergalactic neutral hydrogen gas

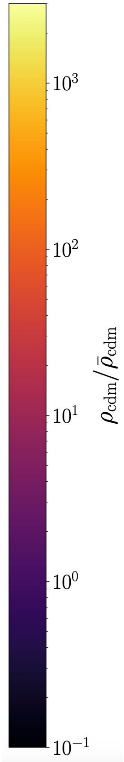


Cosmic structure formation



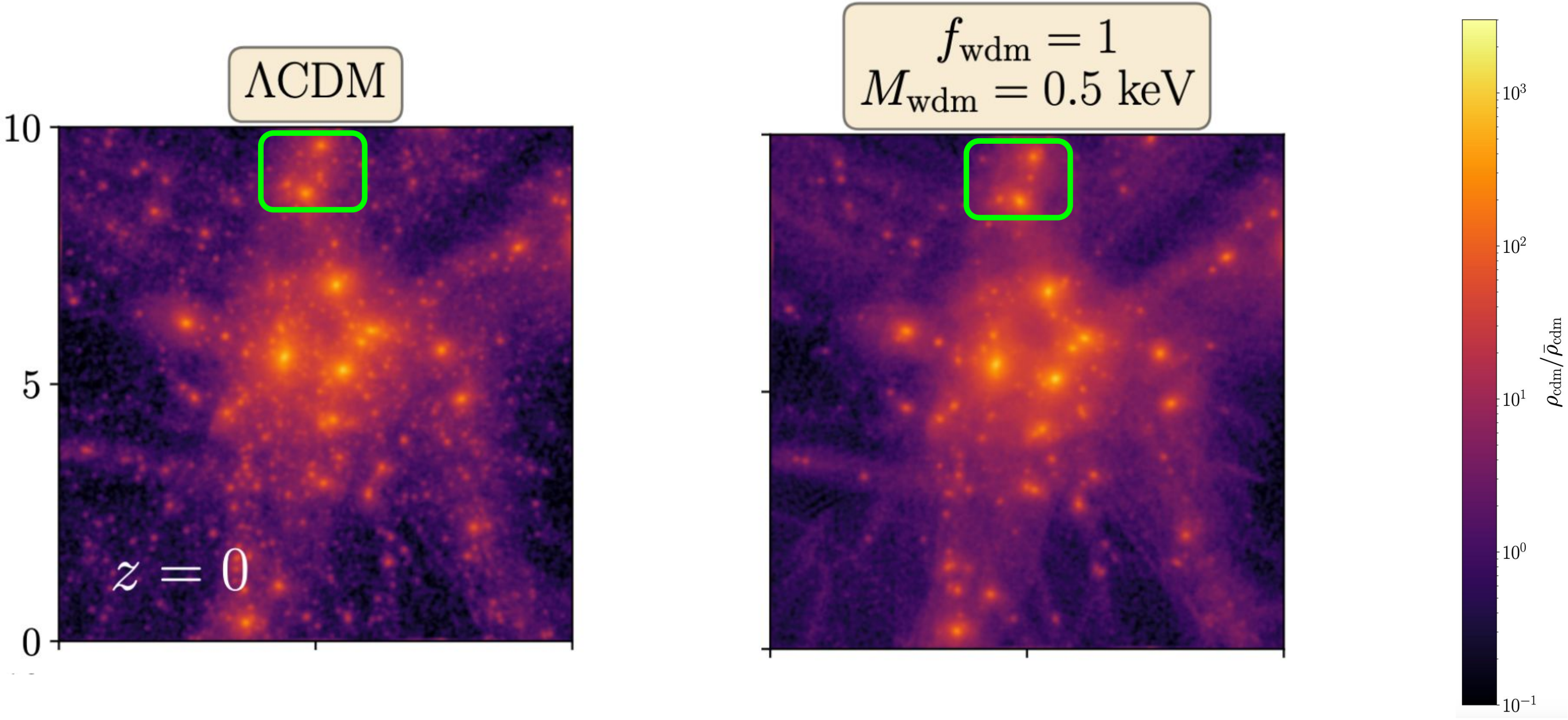


Credict: **ESA**



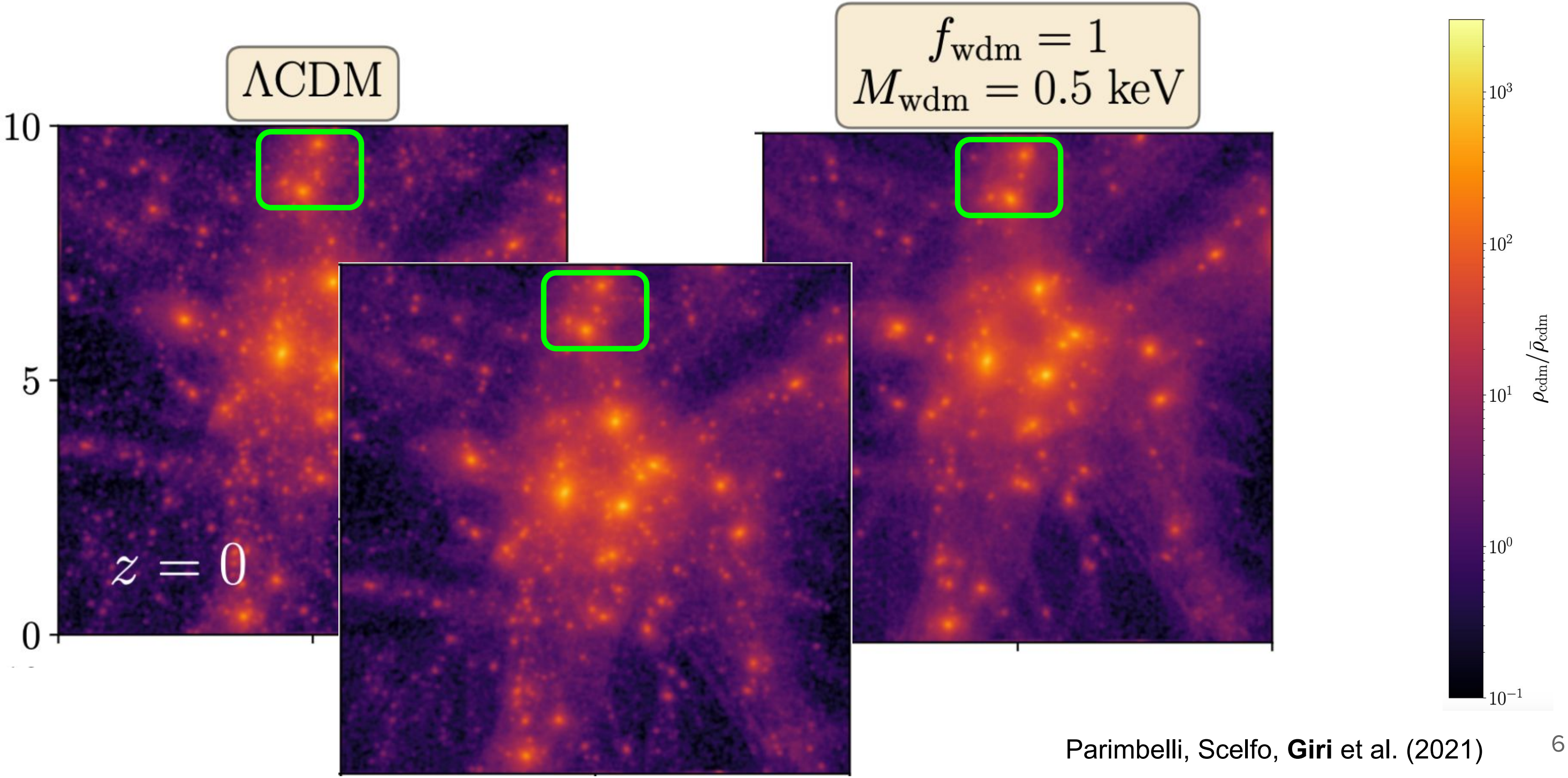
Parimbelli, Scelfo, **Giri** et al. (2021)

Non-standard dark matter models



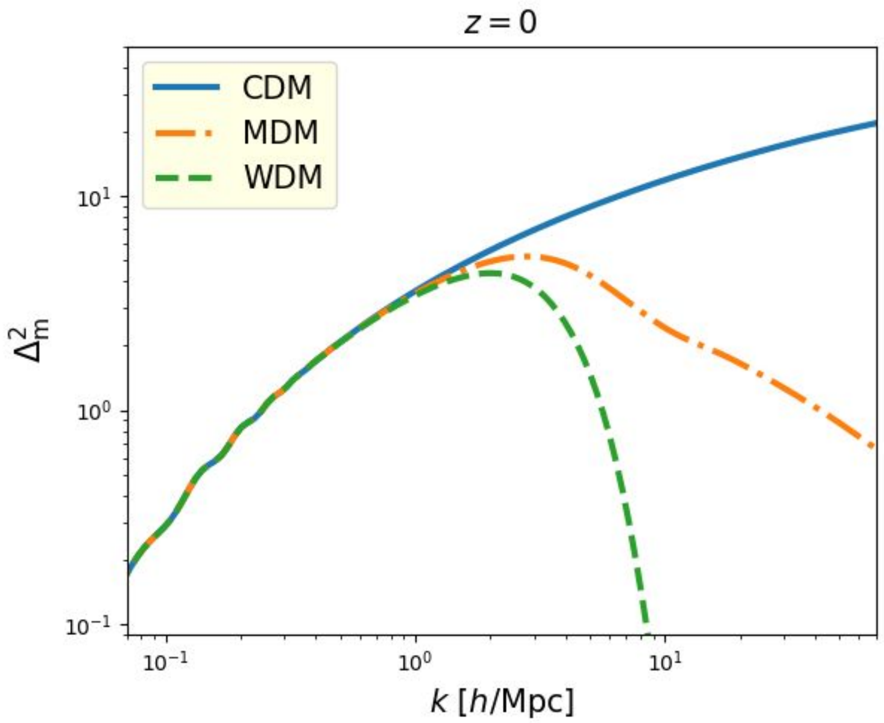
Parimbelli, Scelfo, **Giri** et al. (2021)

Mixture of cold and warm dark matter particles



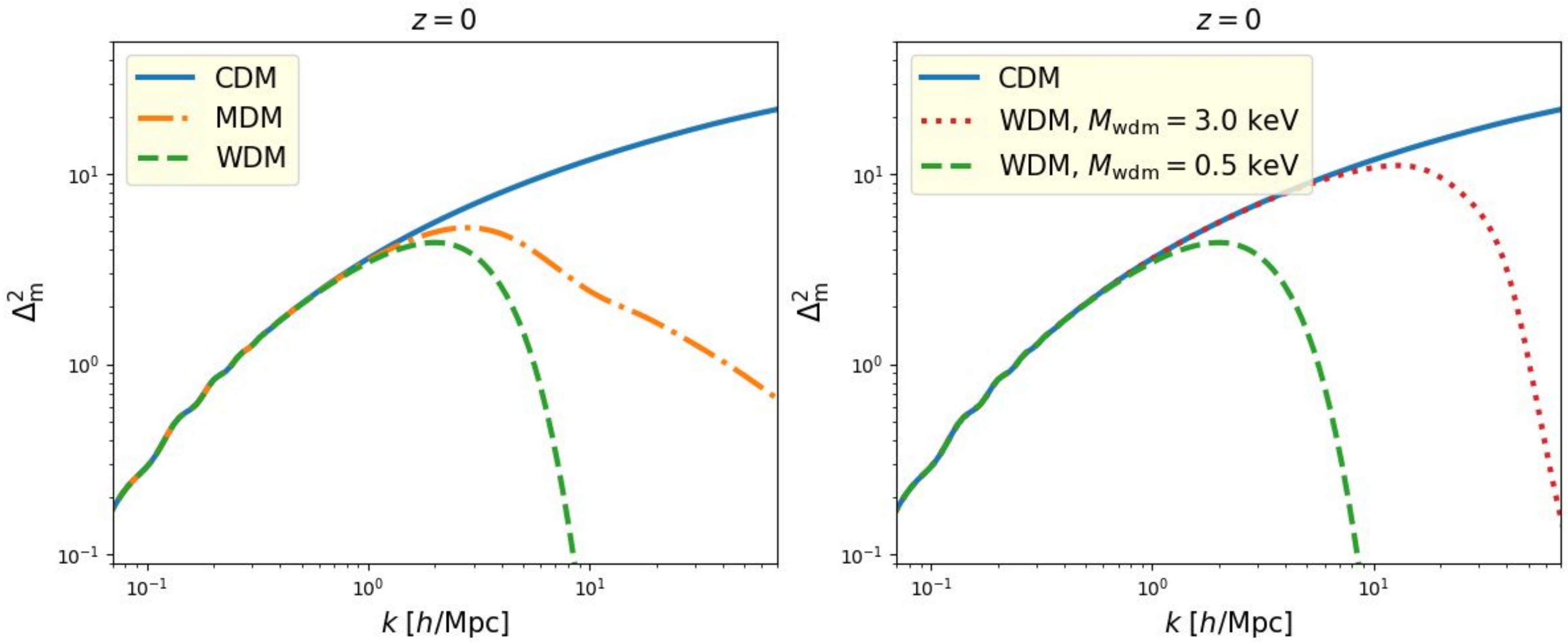
Parimbelli, Scelfo, **Giri** et al. (2021)

Matter power spectrum



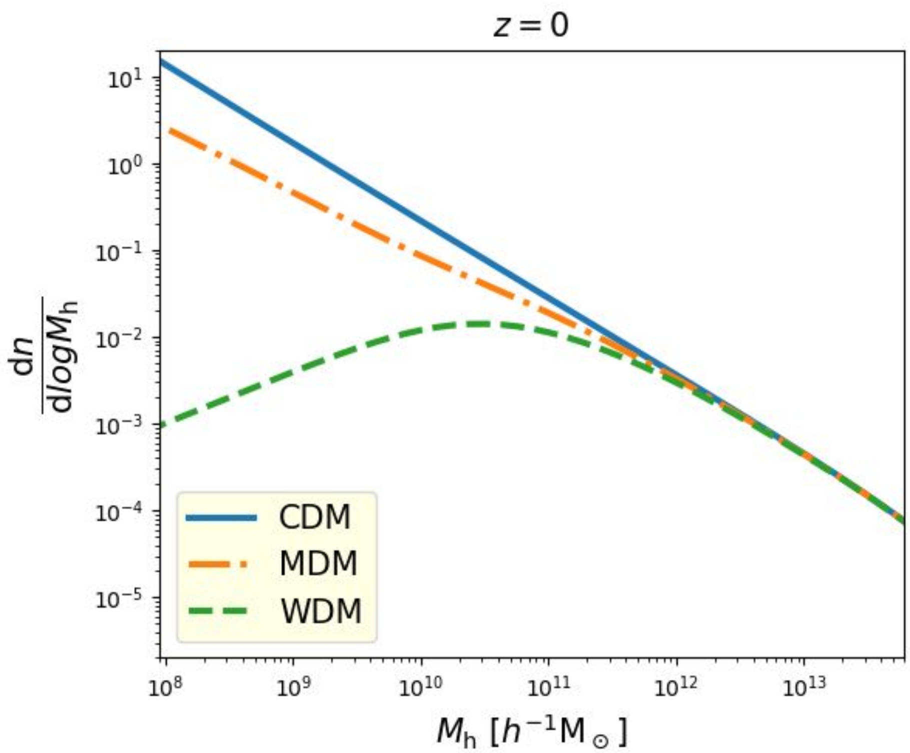
Giri & Schneider (2022)

Dark matter mass decides the suppression scale



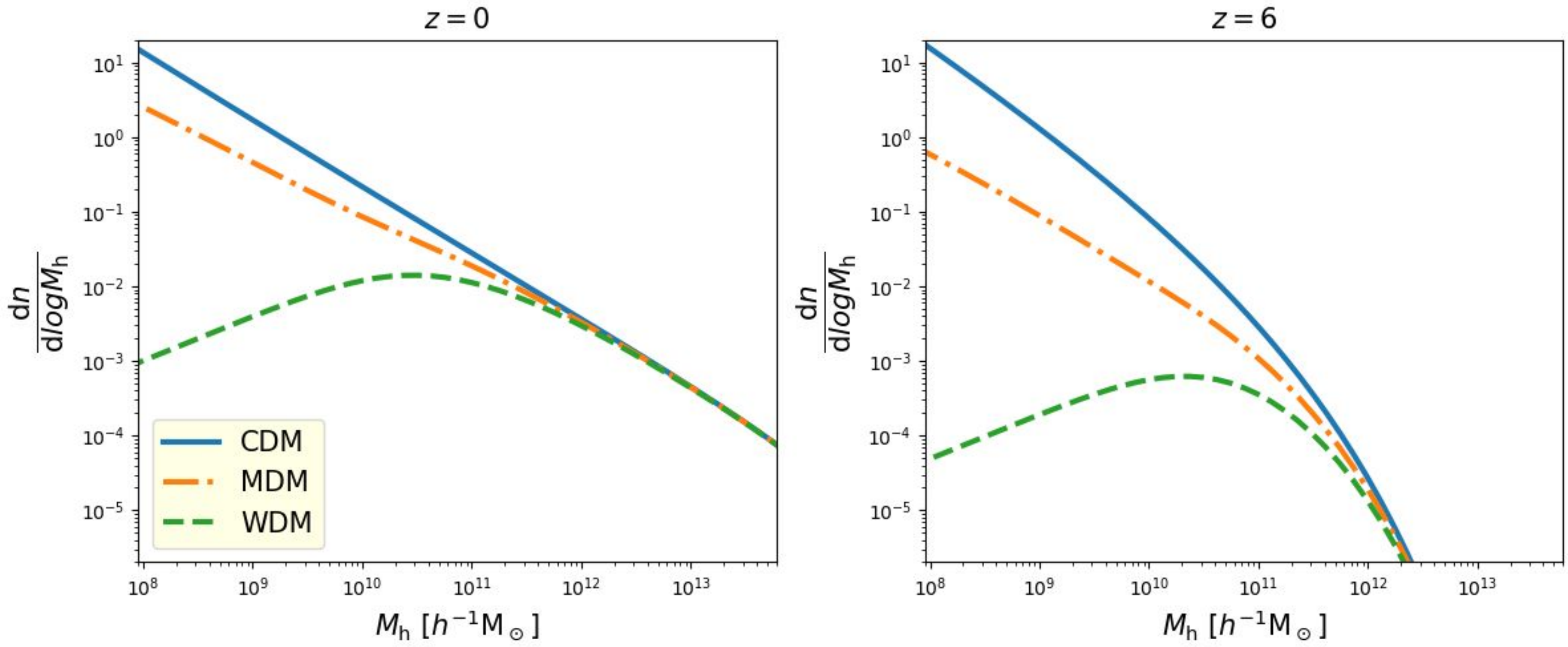
Giri & Schneider (2022)

Halo Mass Function



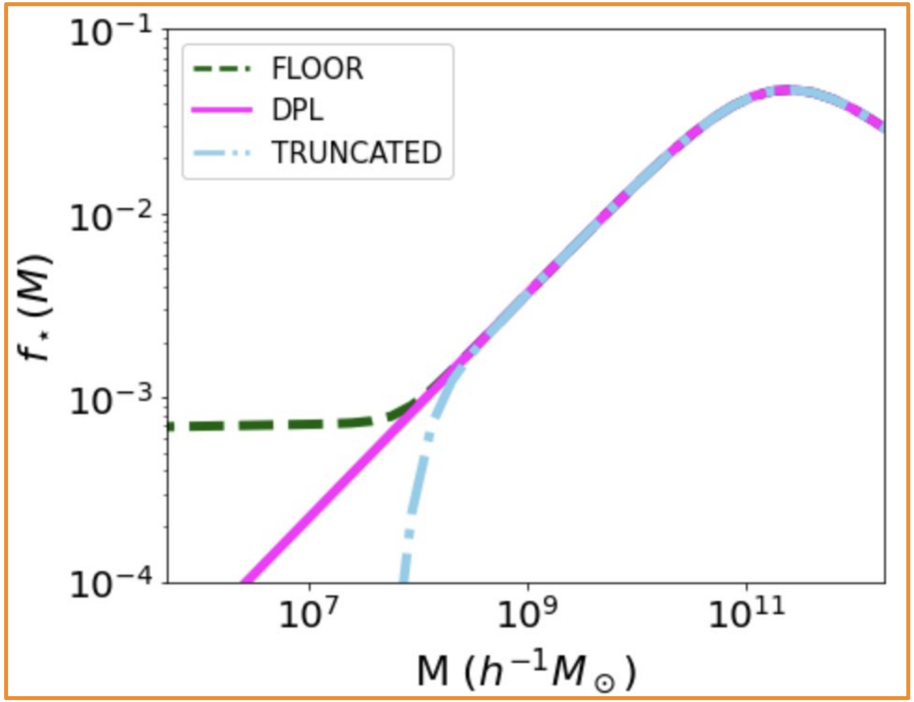
Giri & Schneider (2022)

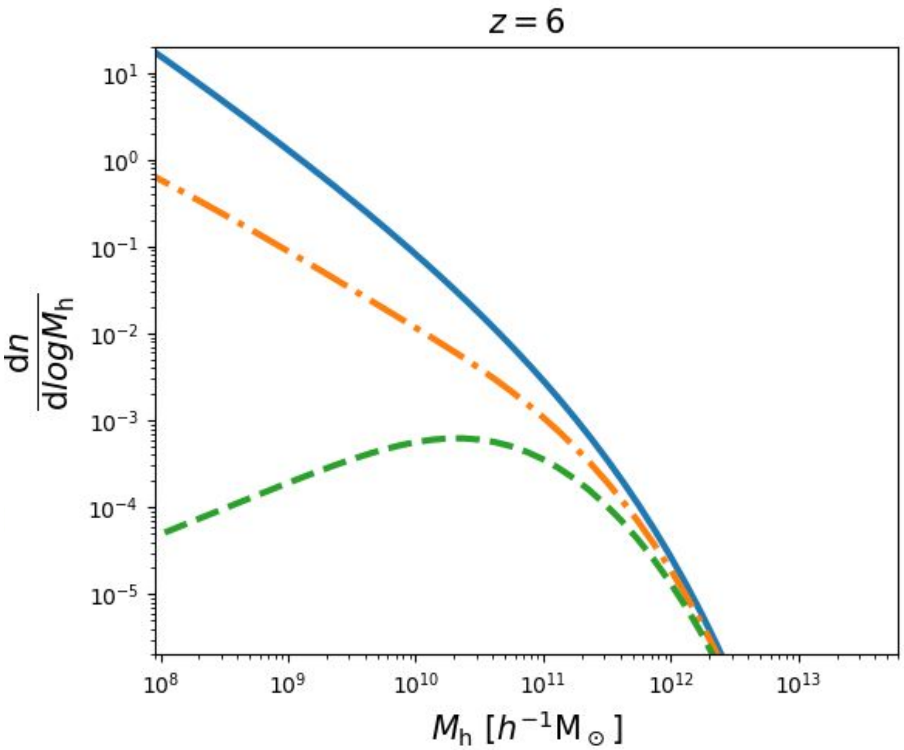
Differences are more distinct at high redshift



Giri & Schneider (2022)

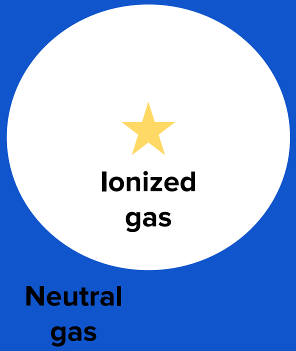
Stellar-to-halo relation consistent with UVLFs





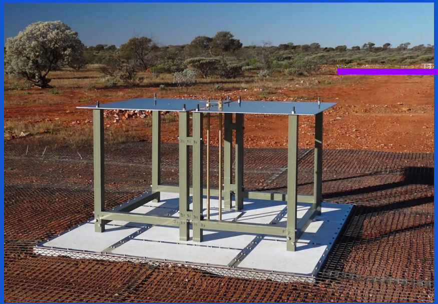
Giri & Schneider (2022)

Epoch of reionization

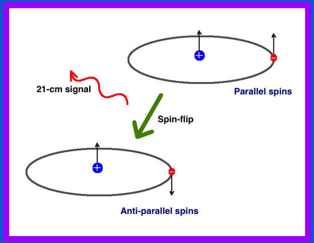


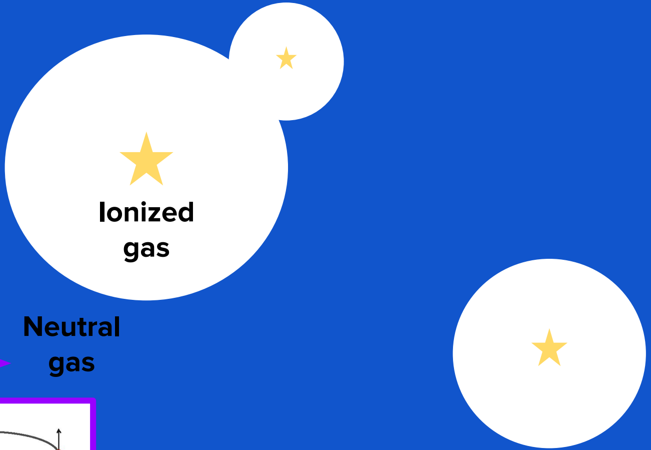
Observing the impact of Early Galaxies

Square Kilometre Array (SKA)

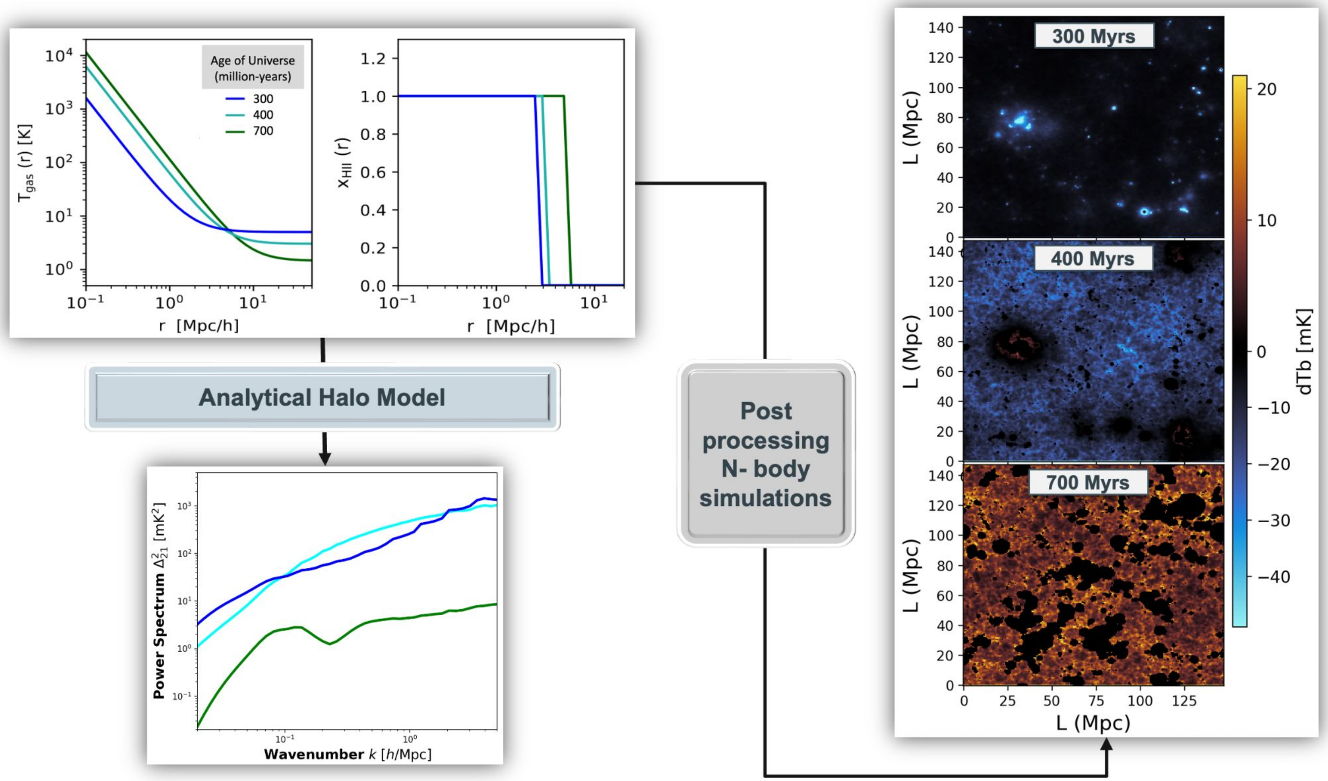


Experiment to Detect the Global EoR Signature (EDGES)



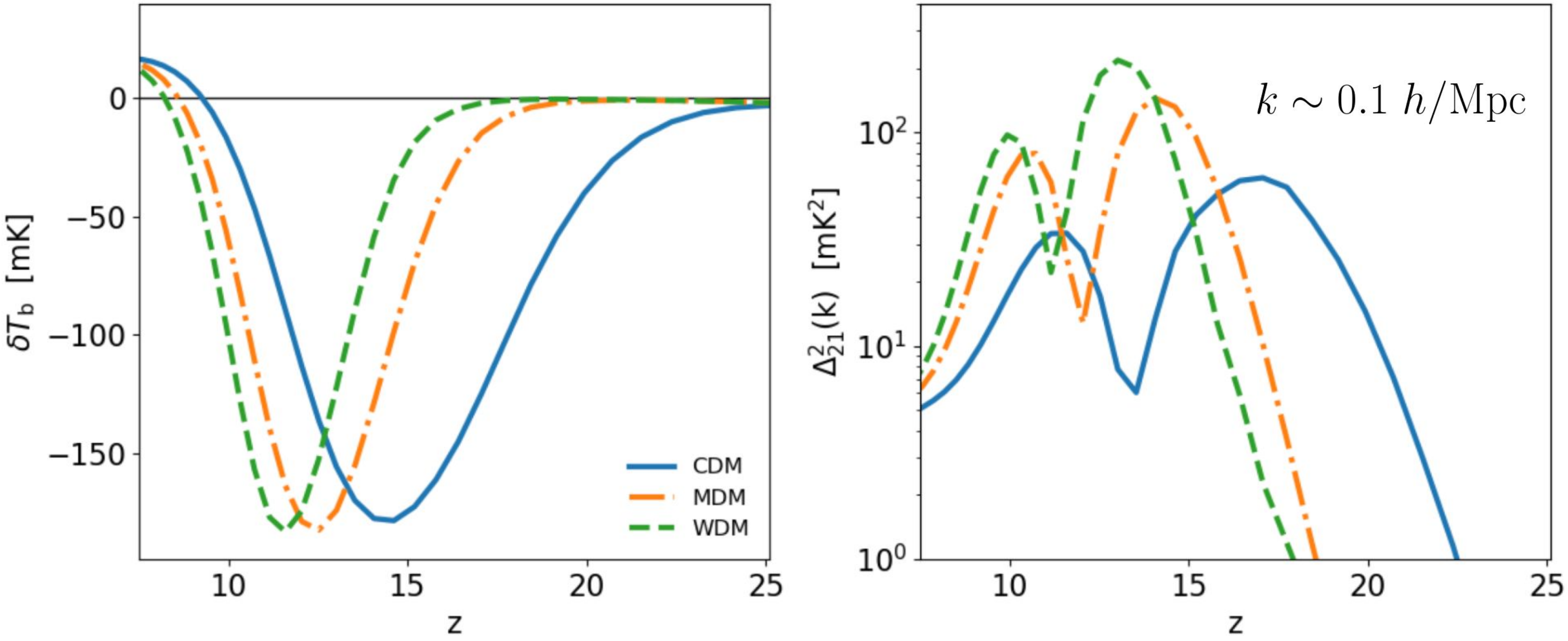


Bubbles during Epoch Of Reionization Numerical-simulator (BEORN) framework



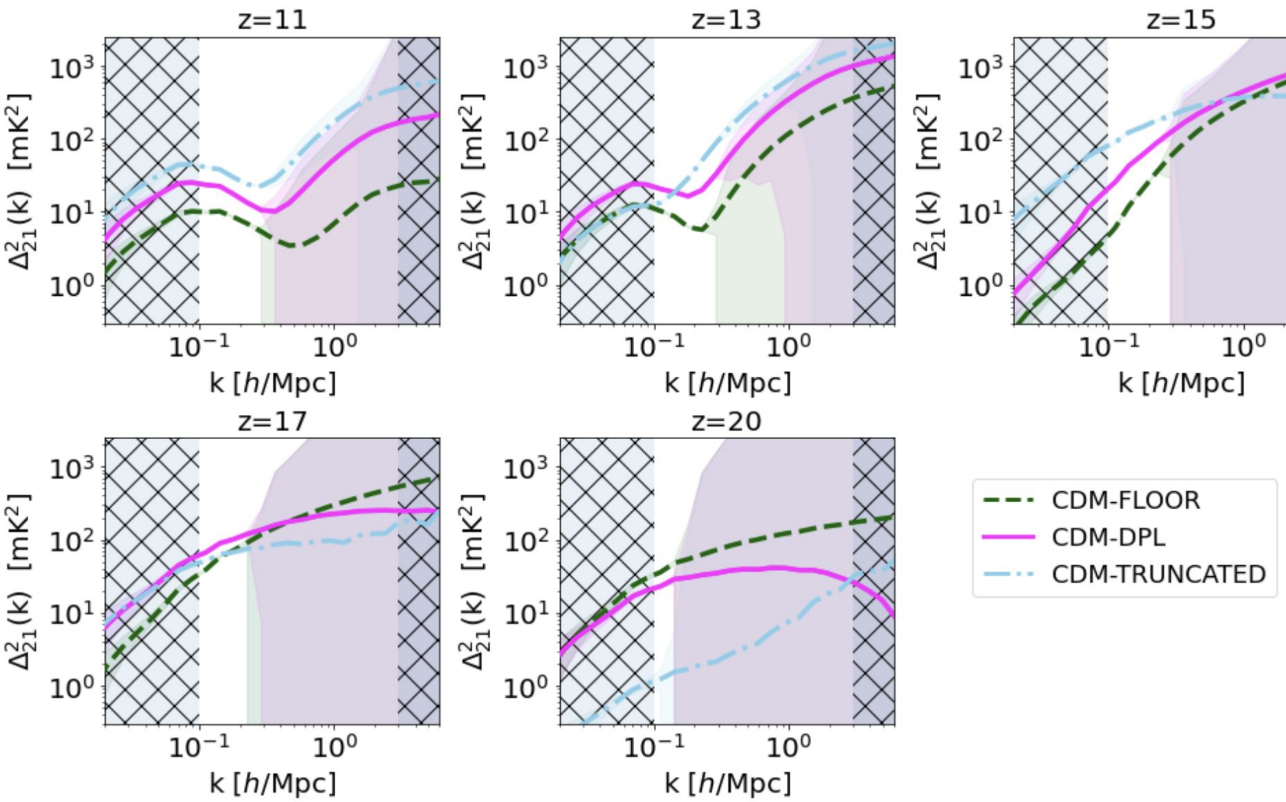
Schaeffer, **Giri** & Schneider (2023)

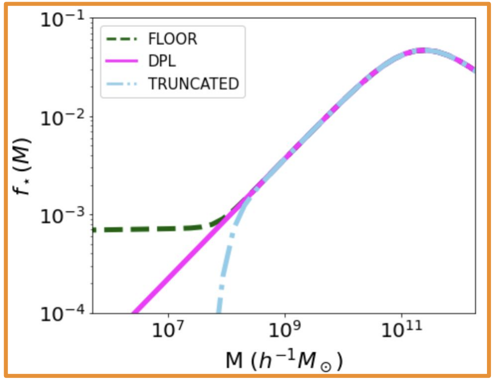
Global 21-cm signal & Power Spectrum



Giri & Schneider (2022)

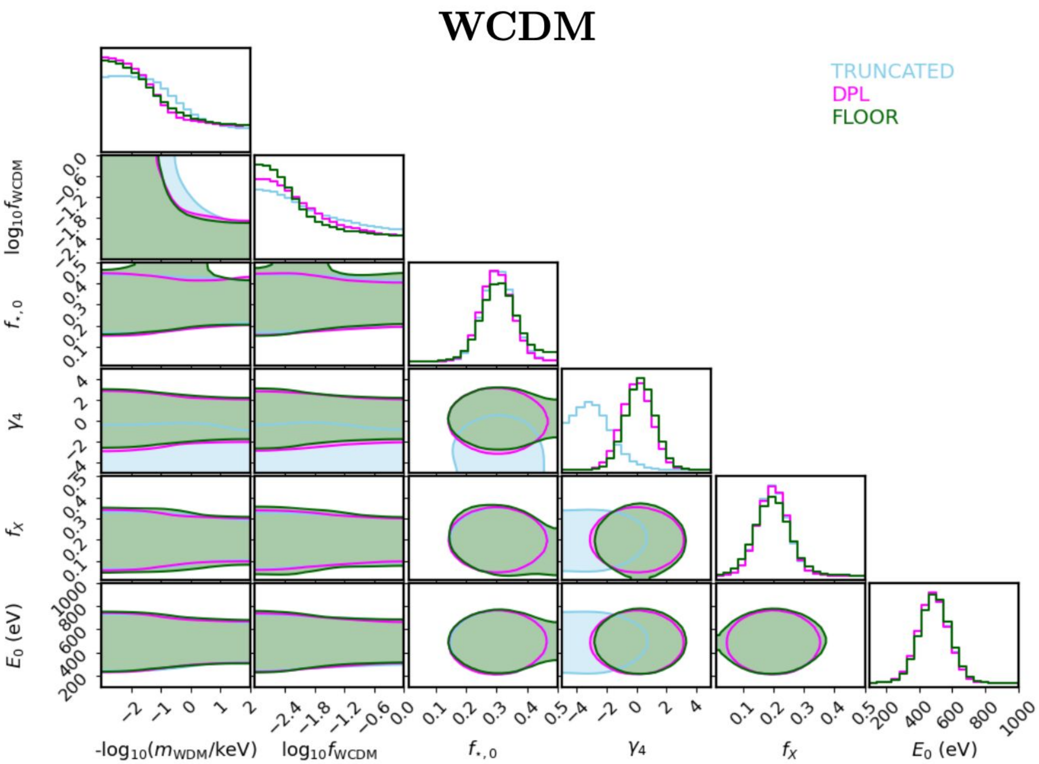
Expected SKA Power Spectra





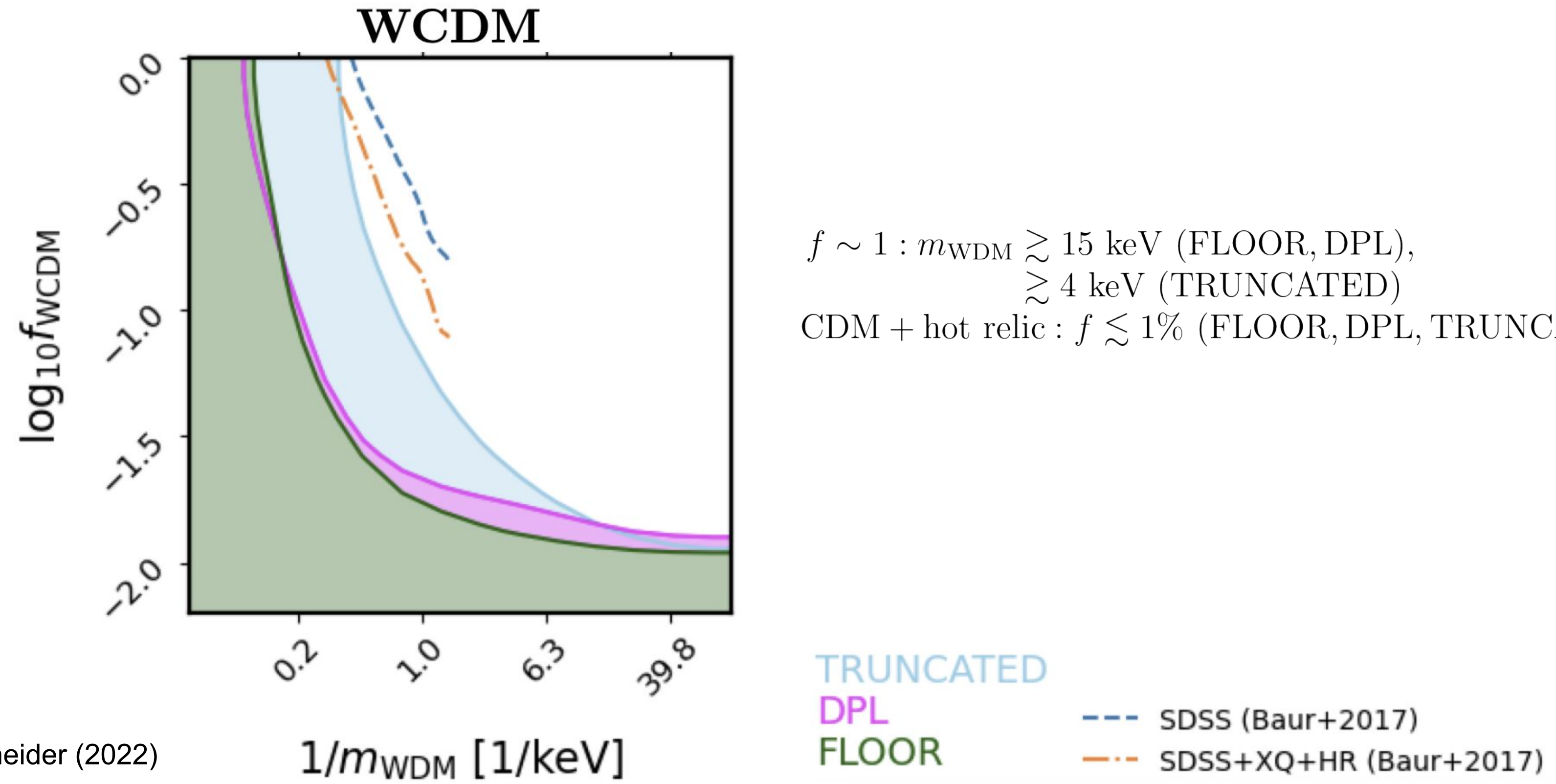
Giri & Schneider (2022)

Forecast study with SKA Power Spectra



Giri & Schneider (2022)

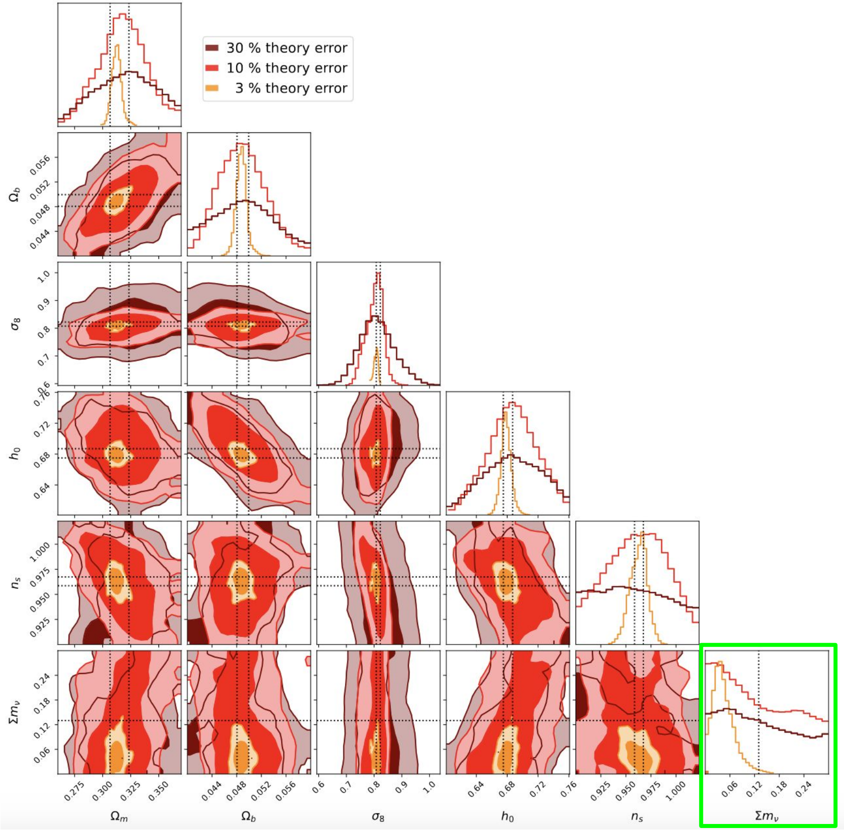
Constraints on warm+cold dark matter (WCDM)



$$f \sim 1 : m_{\rm WDM} \gtrsim 15 \text{ keV (FLOOR, DPL)},$$
$$\gtrsim 4 \text{ keV (TRUNCATED)}$$
$$\text{CDM + hot relic} : f \lesssim 1\% \text{ (FLOOR, DPL, TRUNCATED)}$$

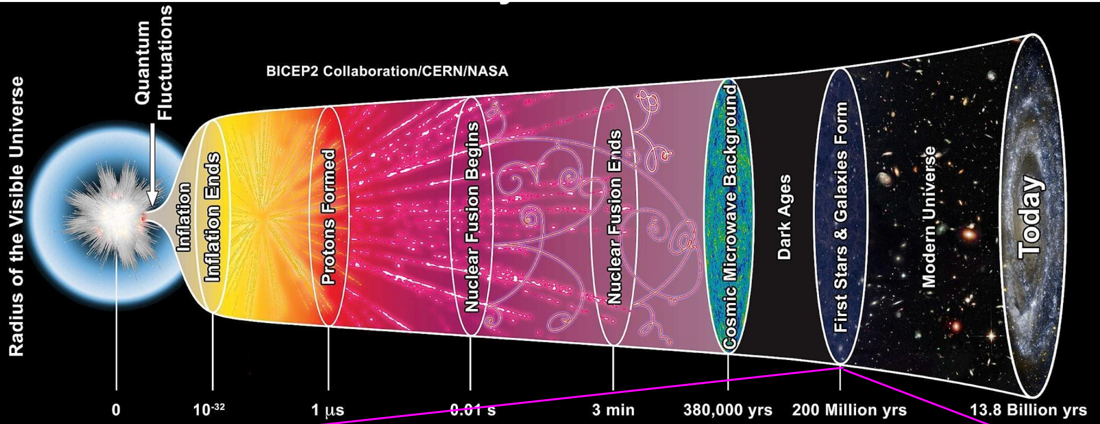
Giri & Schneider (2022)

Can we constrain the CDM cosmology?

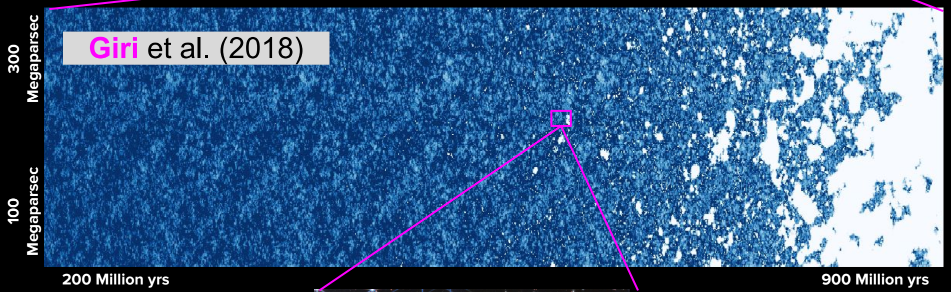


Schneider, Schaeffer, **Giri** (2023)

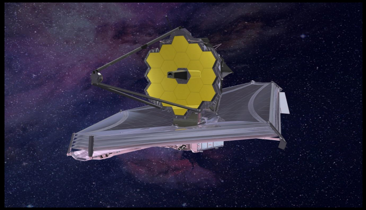
History of our Universe



Intergalactic neutral hydrogen gas

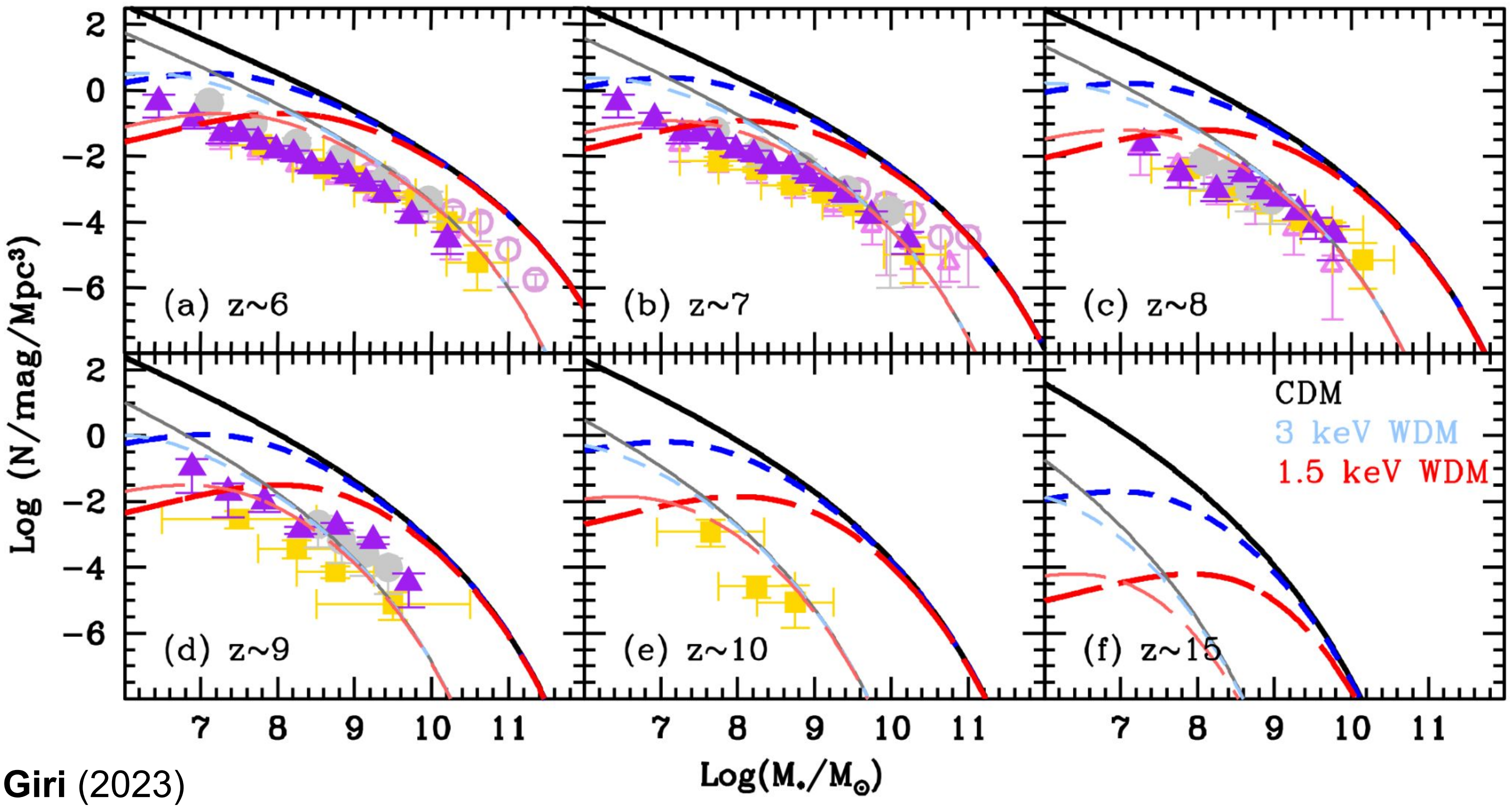


First generation of galaxies



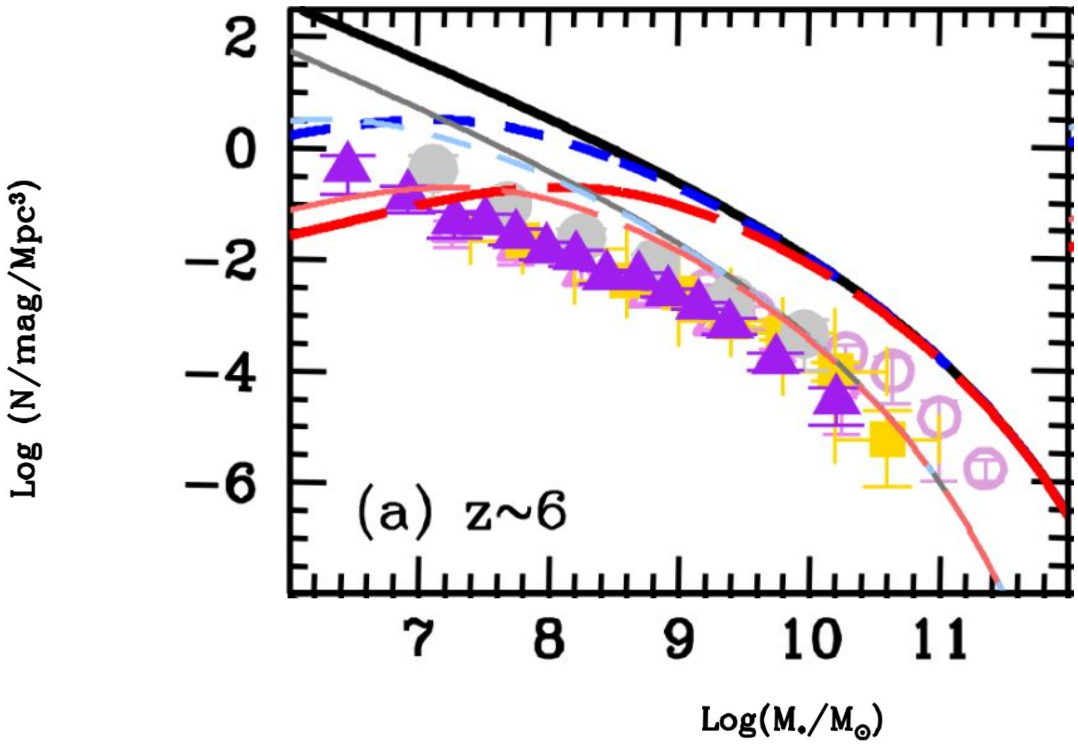
James Webb Space Telescope (JWST)

Testing WDM with JWST



Dayal & **Giri** (2023)

Stellar Mass Function at Redshift 6

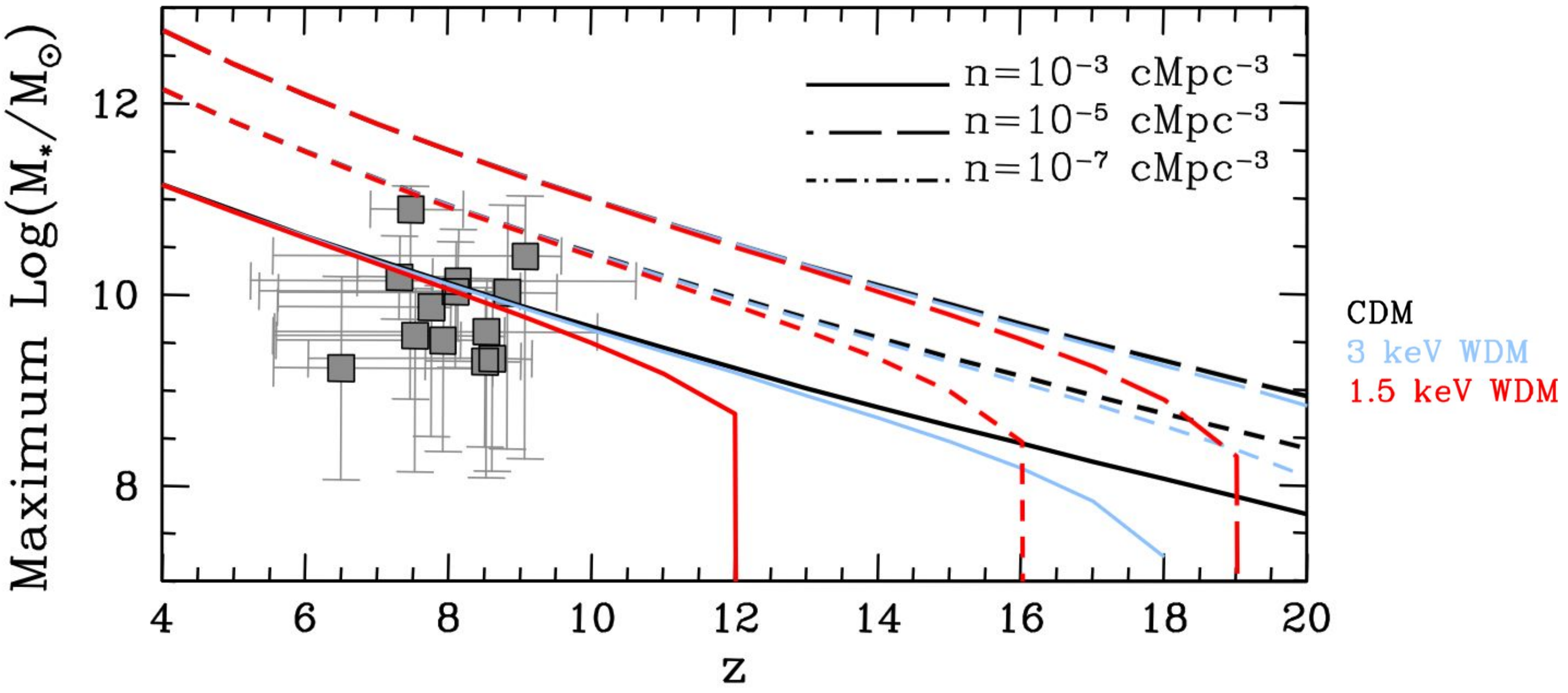


$$M_\star = \frac{\Omega_b}{\Omega_m} \varepsilon M_{\mathrm{halo}}$$

CDM
3 keV WDM
1.5 keV WDM

Maximum stellar mass allowed

$$n(> M_\star) = \frac{\Omega_b}{\Omega_m}\varepsilon \int_{M_{\rm halo}}^{M_{\rm max}} dM \frac{dn}{dM}$$

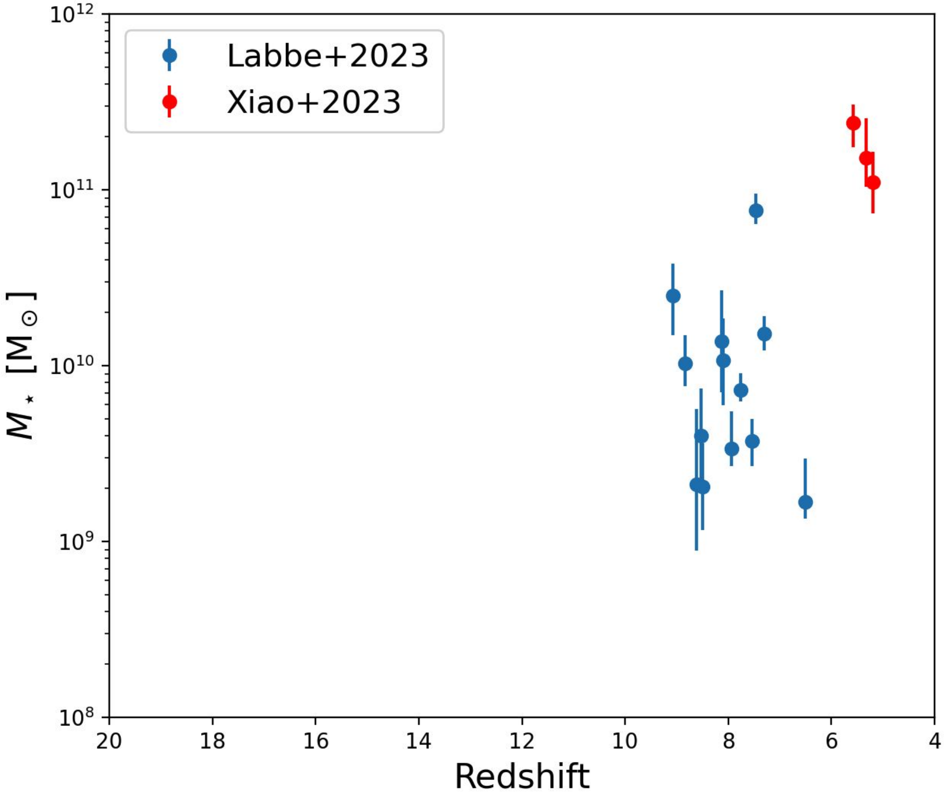


Summary

- Non-cold dark matter models show **greater distinctions in earlier times**
- **Cosmic reionization is delayed** due to formation of less number of small mass light sources in non-cold dark matter scenarios
- Reionization epoch observations can **improve upon the constraints on the dark matter models**

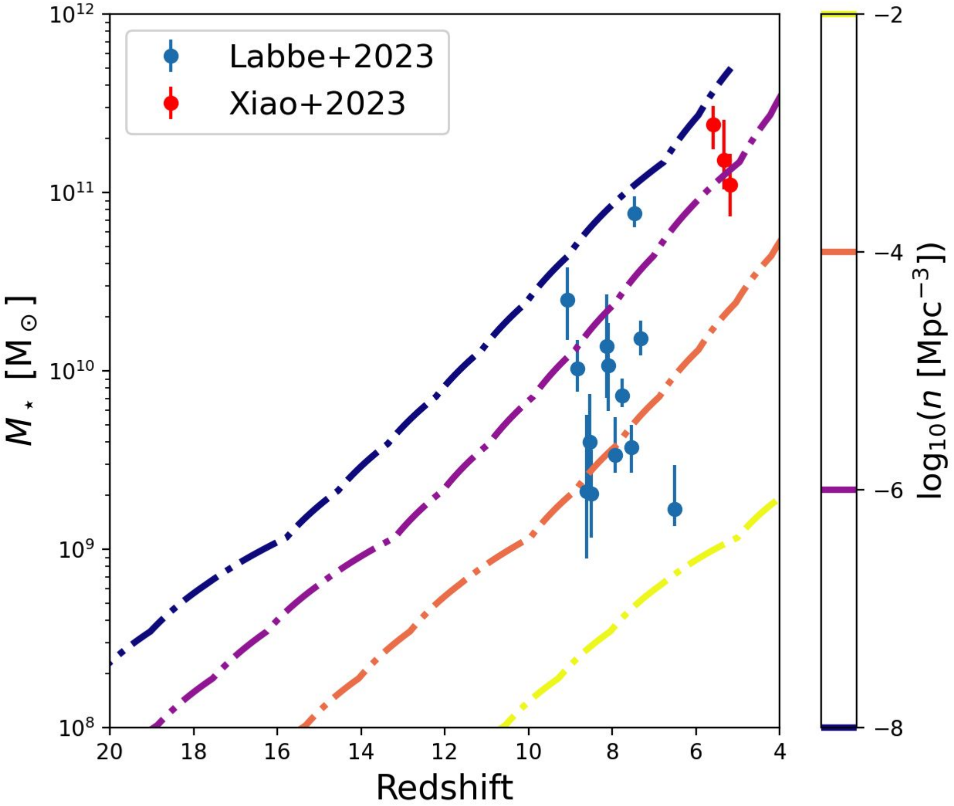
Back-up slides

Massive Early Galaxies



$$M_\star = \frac{\Omega_b}{\Omega_m} \varepsilon M_{\rm halo}$$

Cumulative number density of galaxies

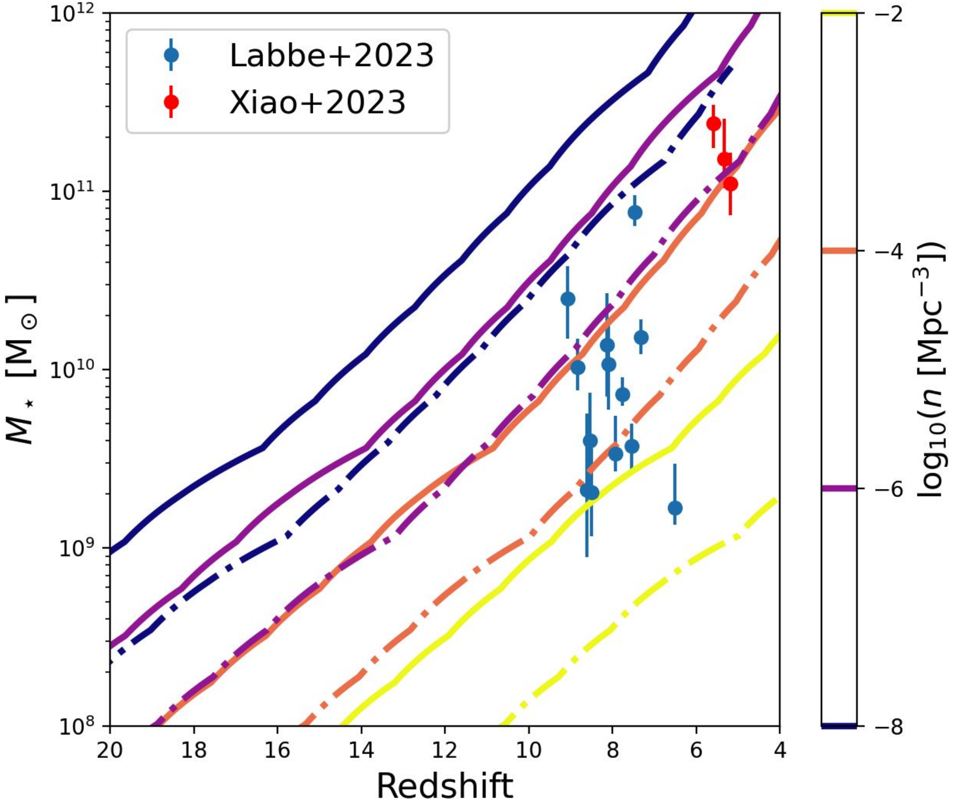


$$M_\star = \frac{\Omega_b}{\Omega_m} \varepsilon M_{\rm halo}$$

$$n(>M_\star) = \frac{\Omega_b}{\Omega_m} \varepsilon \int_{M_{\rm halo}}^{M_{\rm max}} dM \frac{dn}{dM}$$

Analysis similar to **Boylan-Kolchin (2023)**

Increasing star formation efficiency

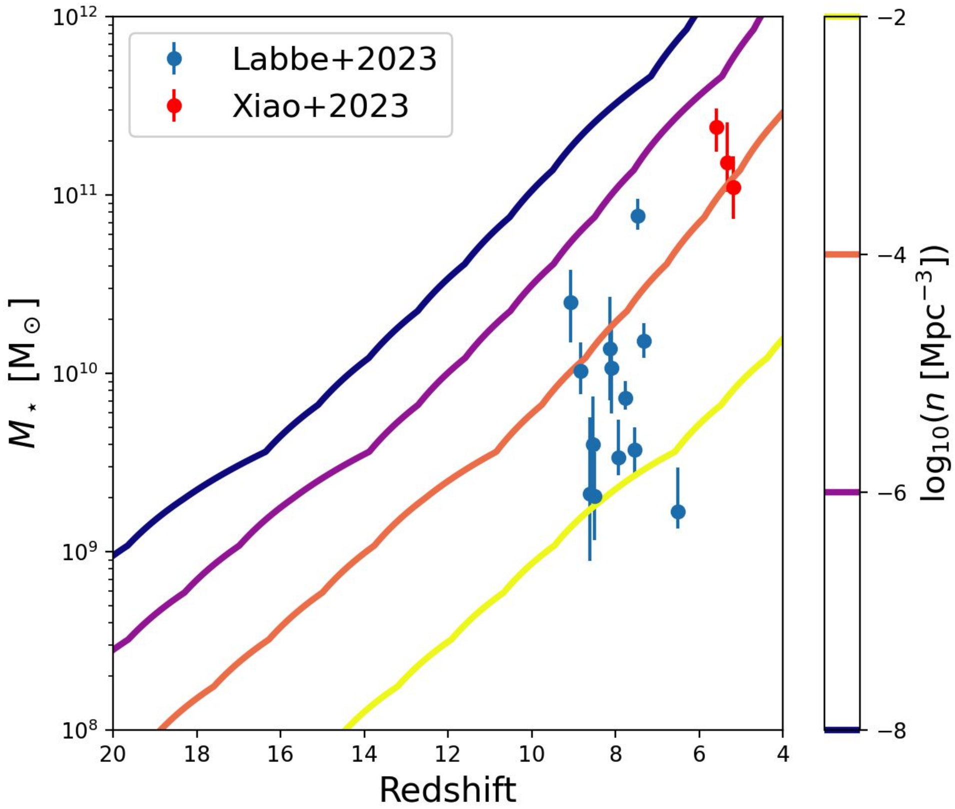


$$M_\star = \frac{\Omega_b}{\Omega_m} \varepsilon M_{\text{halo}}$$

$$n(> M_\star) = \frac{\Omega_b}{\Omega_m} \varepsilon \int_{M_{\text{halo}}}^{M_{\max}} dM \frac{dn}{dM}$$

Analysis similar to **Boylan-Kolchin (2023)**

Massive Early Galaxies with spectroscopic data

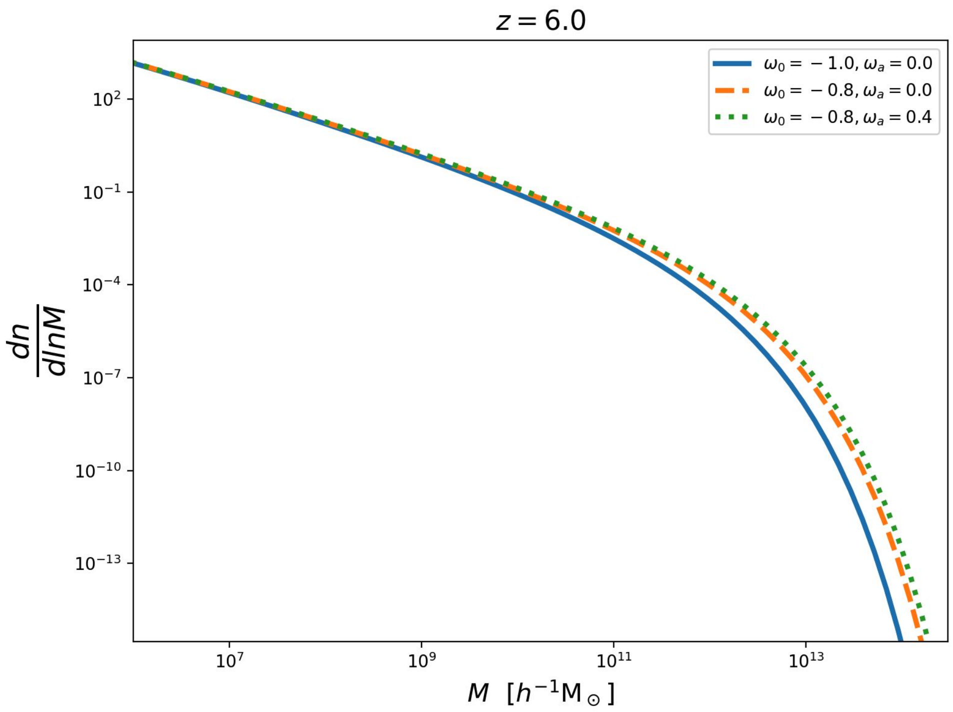


$$M_\star = \frac{\Omega_b}{\Omega_m} \varepsilon M_{\mathrm{halo}}$$

$$n(> M_\star) = \frac{\Omega_b}{\Omega_m} \varepsilon \int_{M_{\mathrm{halo}}}^{M_{\mathrm{max}}} dM \frac{dn}{dM}$$

Analysis similar to **Boylan-Kolchin (2023)**

Dynamic Dark Energy - HMF

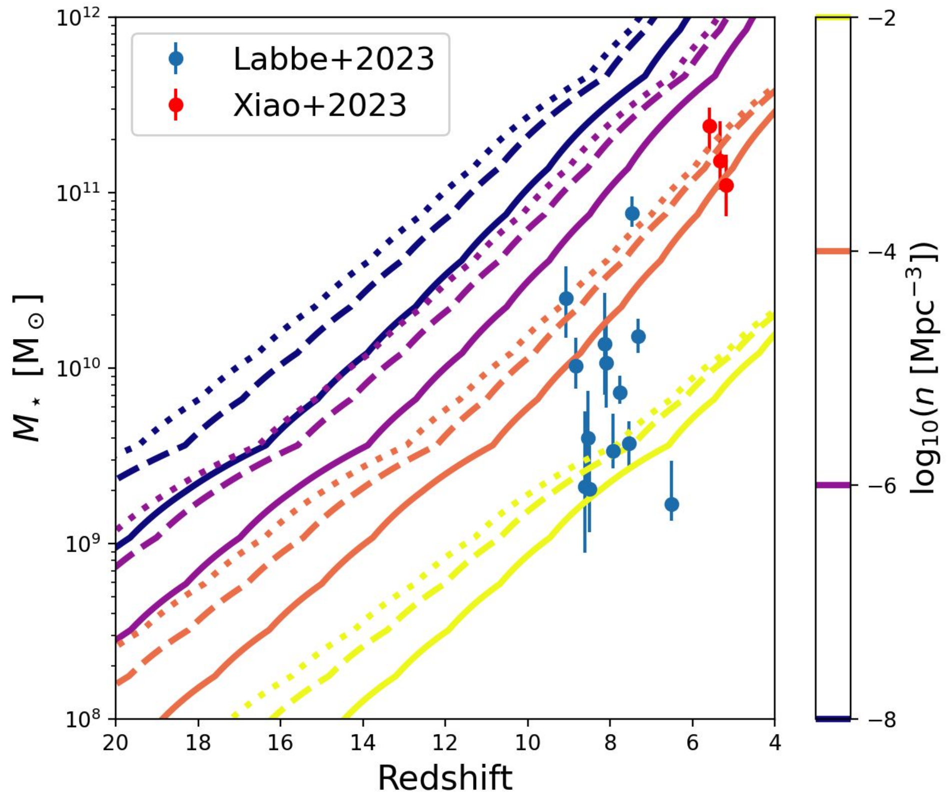


CPL

$$\left(\frac{H(z)}{H(0)}\right)^2 = \Omega_\gamma(1+z)^4 + \Omega_m(1+z)^3 + \Omega_\Lambda(1+z)^{3(1+\omega_0+\omega_a)} \exp\left(\frac{-3\omega_a z}{1+z}\right)$$

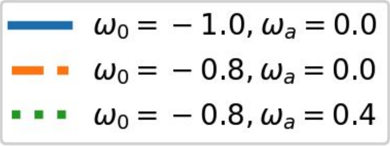
Preliminary Work with **Suhail Dhawan**

Dynamic Dark Energy



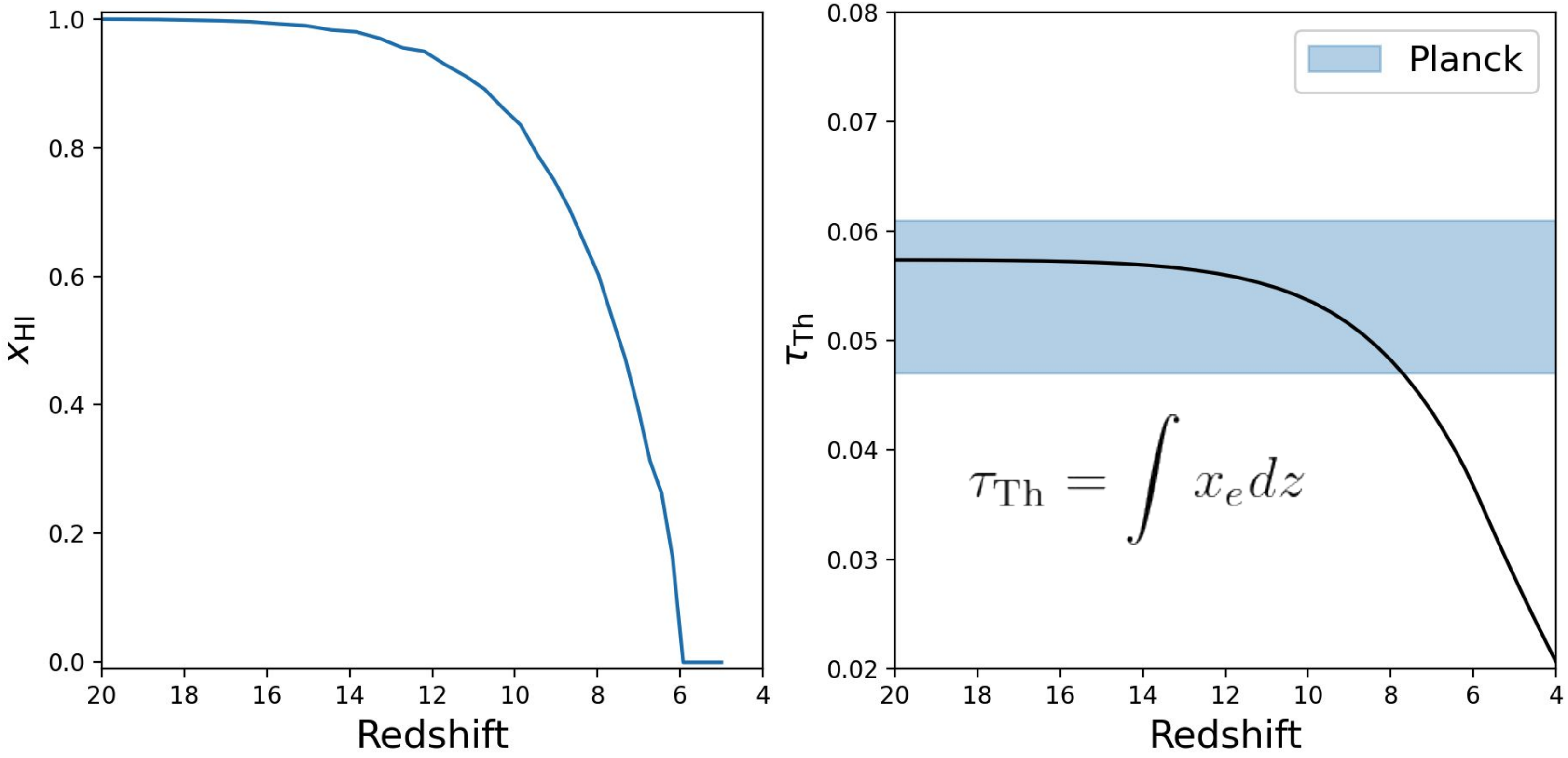
CPL

$$\left(\frac{H(z)}{H(0)}\right)^2 = \Omega_\gamma(1+z)^4 + \Omega_m(1+z)^3 + \Omega_\Lambda(1+z)^{3(1+\omega_0+\omega_a)} \exp\left(\frac{-3\omega_a z}{1+z}\right)$$

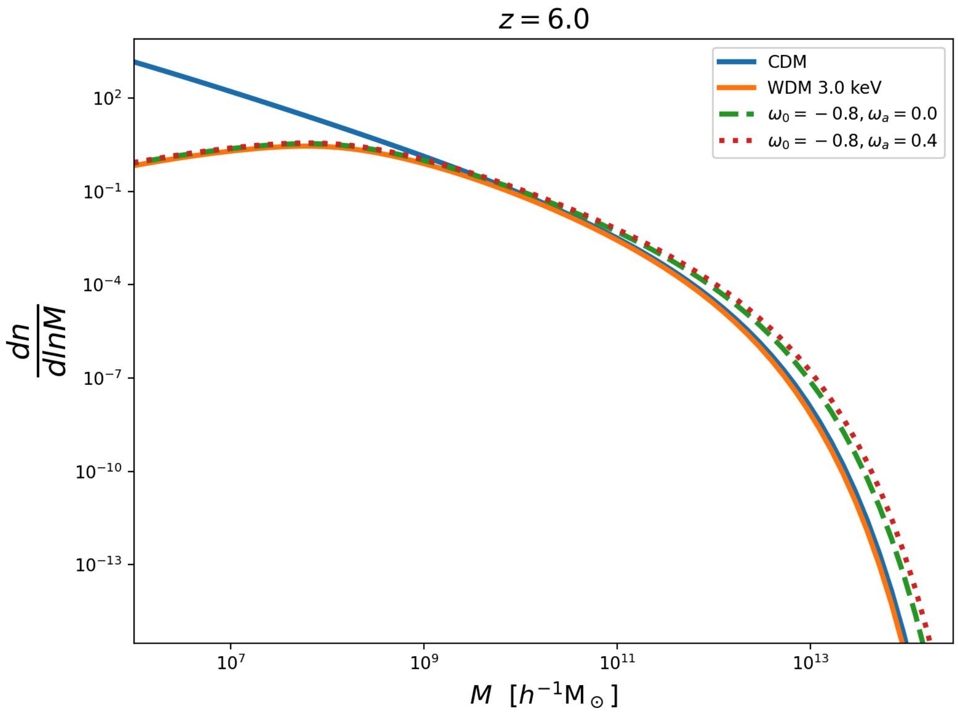


Preliminary Work with **Suhail Dhawan**

Implications on cosmic reionization



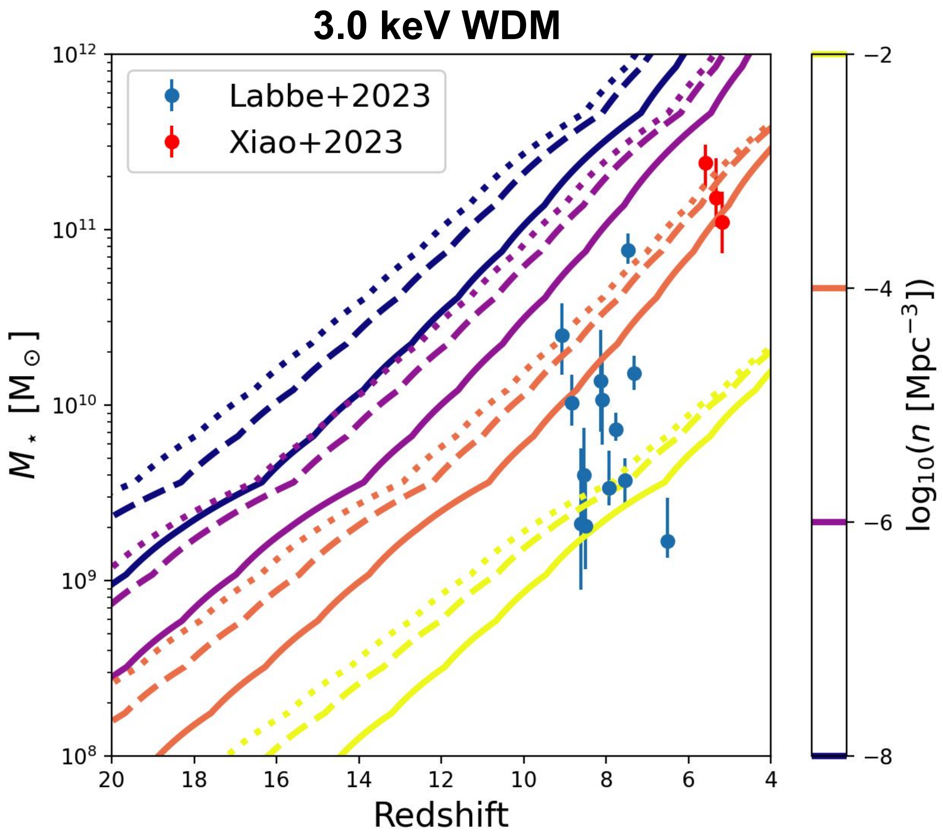
Dynamic Dark Energy & non-Cold Dark Matter



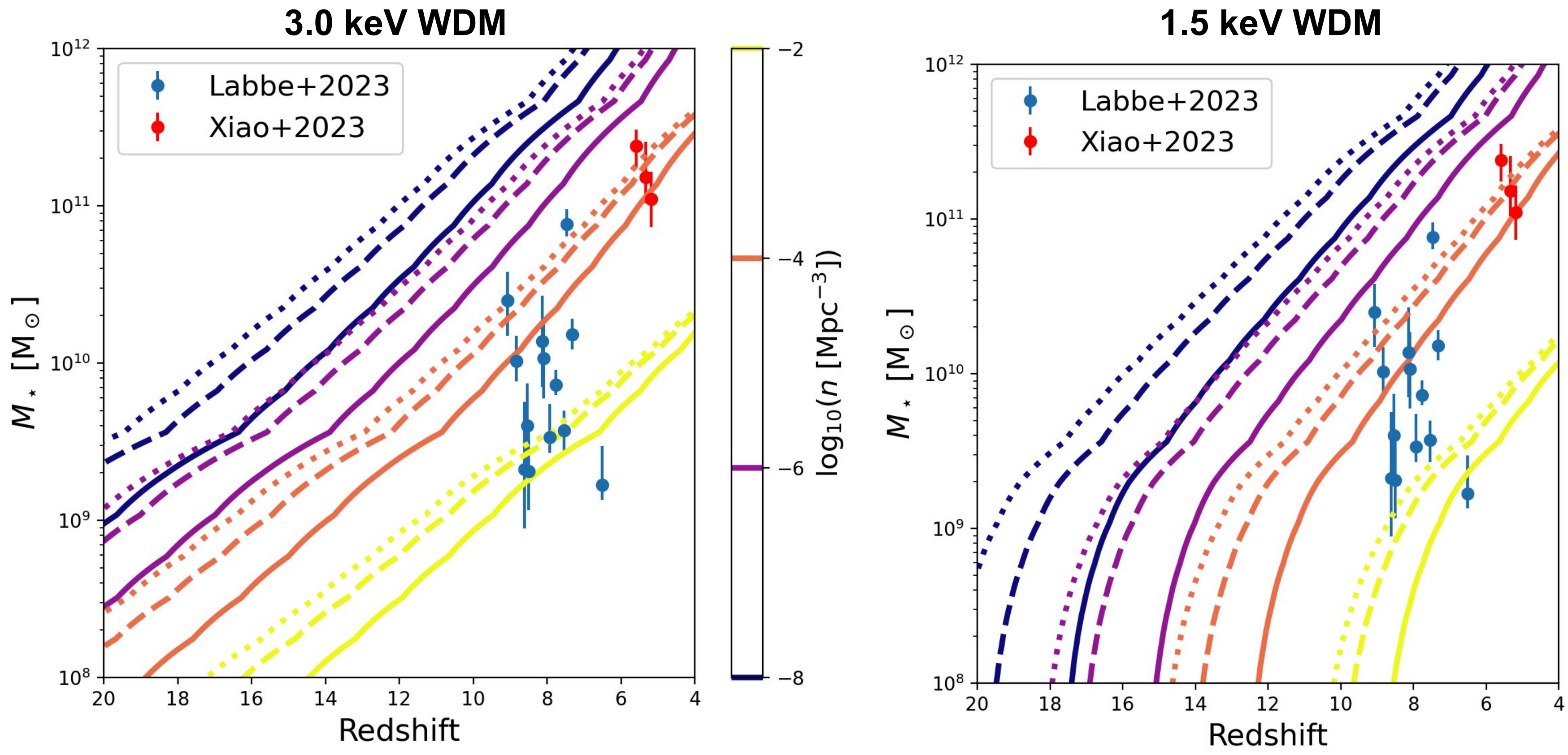
CPL

$$\left(\frac{H(z)}{H(0)}\right)^2 = \Omega_\gamma(1+z)^4 + \Omega_m(1+z)^3 + \Omega_\Lambda(1+z)^{3(1+\omega_0+\omega_a)} \exp\left(\frac{-3\omega_a z}{1+z}\right)$$

Dynamic Dark Energy & non-Cold Dark Matter



Dynamic Dark Energy & non-Cold Dark Matter



Summary

- Future SKA observations are capable of improving the constraints on non-Cold Dark Matter models
- JWST suggests that either
  - **structure formation began earlier**, or
  - **galaxy formation was very efficient at early times**
- **Dynamic Dark Energy with non-Cold Dark Matter** is a plausible explanation for early structure formation