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The Imprinted Typical Stellar Mass of The First Stars on The 21-cm Global Signal

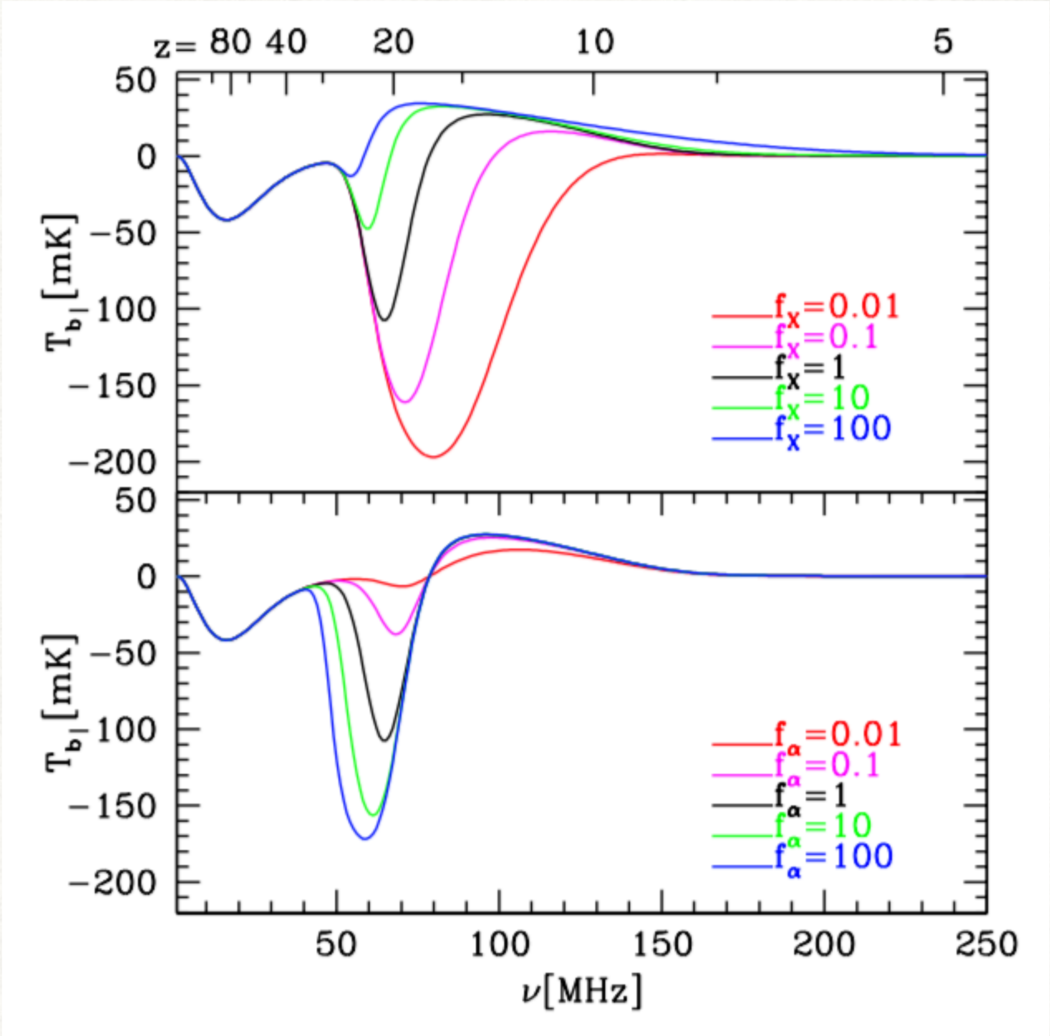
Toshiyuki Tanaka (D1)
C-lab, Nagoya univ.

Collaborators:
K. Hasegawa, H. Yajima, M. I.N. Kobayashi, N. Sugiyama

The 21-cm Global Signal

- ✓ All-sky averaged 21-cm signal
- ✓ Info. on the first stars are imprinted
- ✓ has been investigated by theoretical studies

However,
the **stellar-mass dependence**
did not be examined yet.



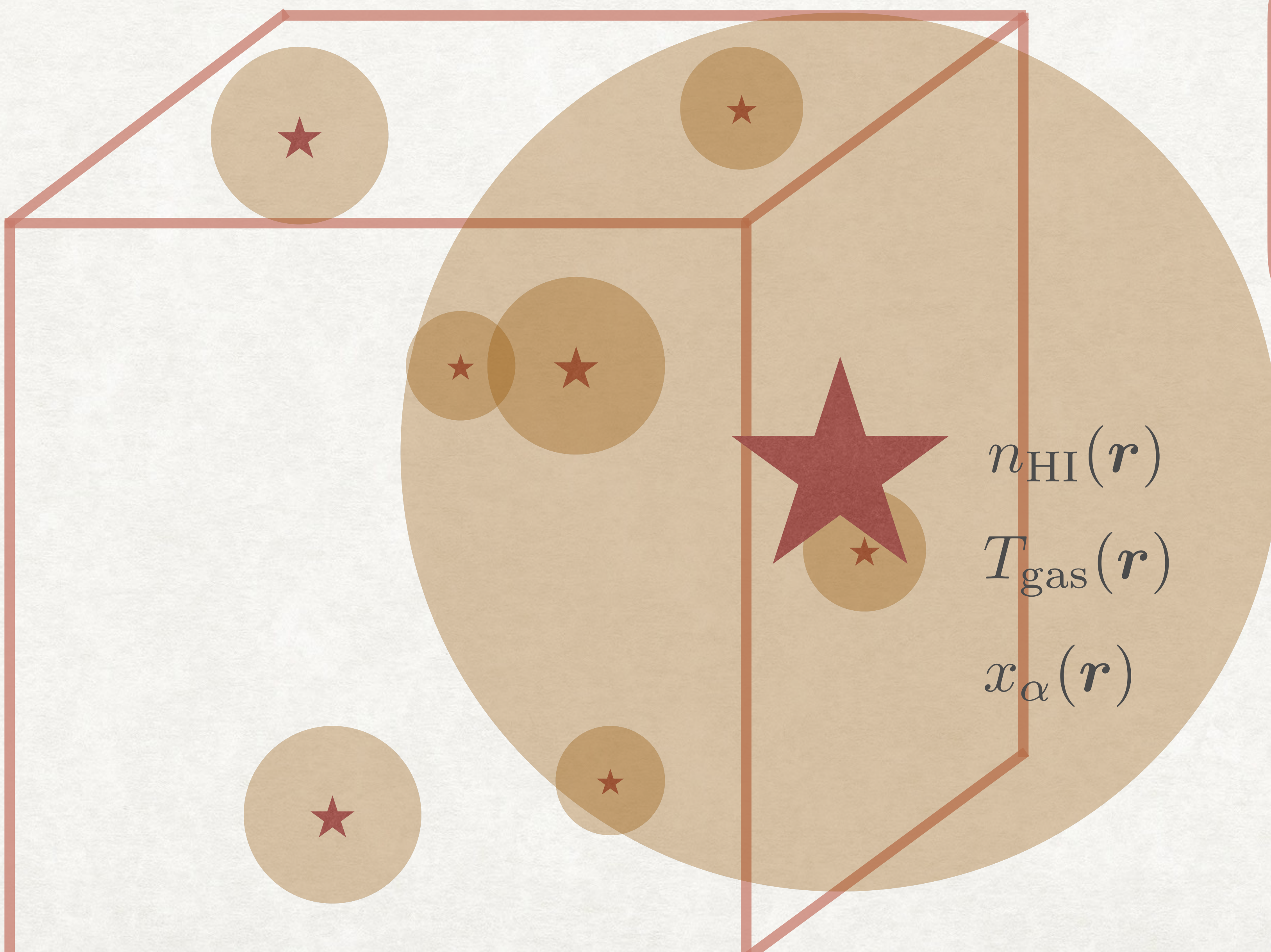
Pritchard & Loeb 2012

Purpose: Elucidation of the stellar-mass dependence of the global signal

Calculation Procedure

1. Physical values around a first star

$$\delta T_{\rm b} \approx \delta T_{\rm b}(n_{\rm HI}, T_{\rm gas}, x_\alpha) \quad \text{at given z}$$



2. Calculate 3D $\delta T_{\rm b}$ map in a calculation box.

$n_{\rm HI}(\boldsymbol{r}_{\rm box})$
$T_{\rm gas}(\boldsymbol{r}_{\rm box})$
$x_\alpha(\boldsymbol{r}_{\rm box})$

$\Downarrow$

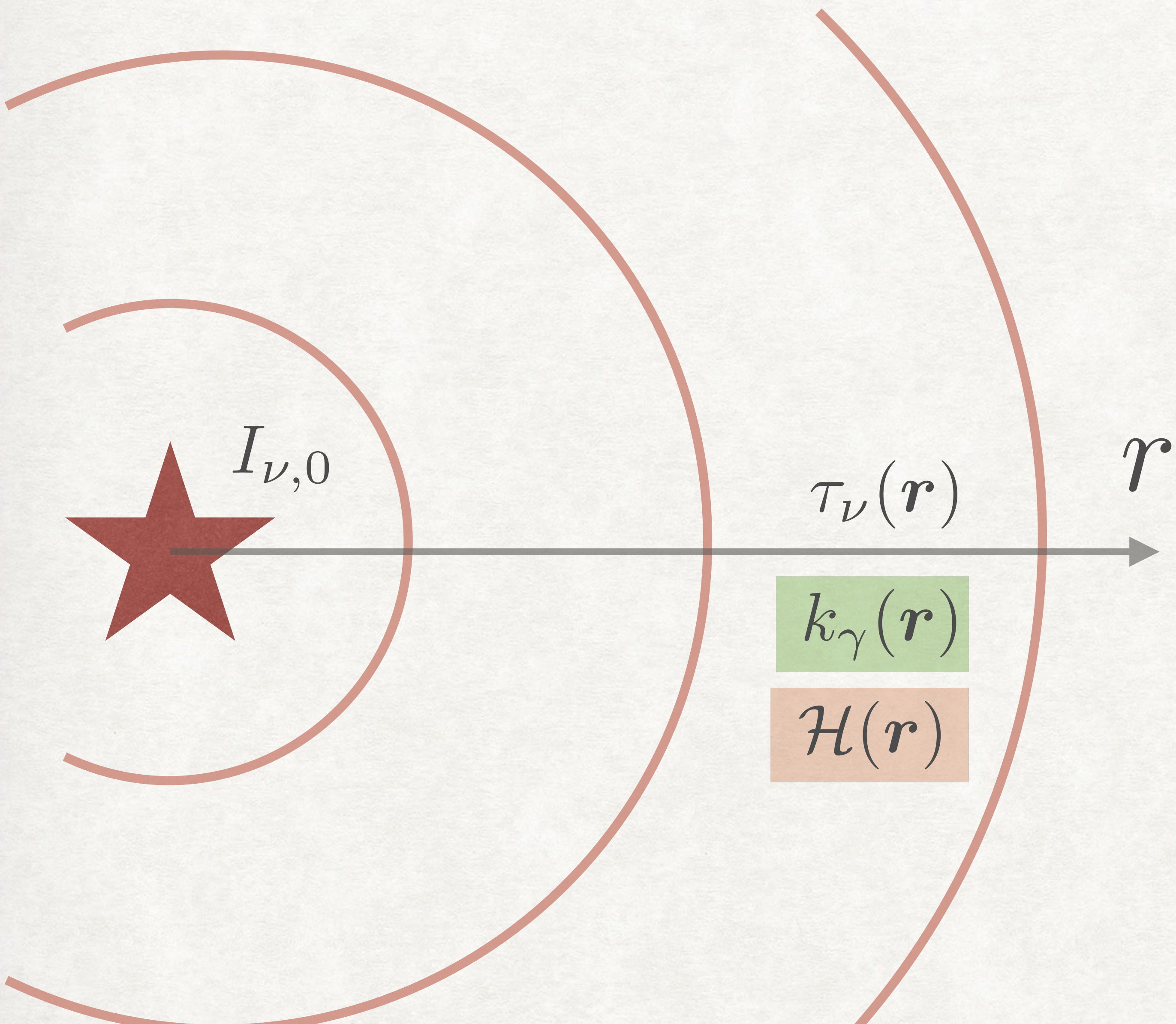
$\delta T_{\rm b}(\boldsymbol{r}_{\rm box})$

$\Downarrow$

$\delta T_{\rm b,global}$

Step1: Physical values around an individual star

✓ 1D radiative hydrodynamics simulations (spherically symmetric)



$$d\tau_\nu = \alpha_\nu dr$$

$$I_\nu = I_{\nu,0}\, e^{-\tau_\nu}$$

τ_ν : optical depth

α_ν : absorption coefficient

Creation

$$\frac{dn_{\rm HI}}{dt} = C_{\rm HI}(T_{\rm gas}, n_j) - D_{\rm HI}(T_{\rm gas}, n_j) n_{\rm HI}$$

Destruction

$$\frac{dT_{\rm gas}}{dt} = \frac{2\mu m_{\rm p}}{3k_{\rm B}\rho}\left(\frac{k_{\rm B}T_{\rm gas}}{\mu m_{\rm p}} + \mathcal{H} - \mathcal{L}\right)$$

$k_\gamma(\boldsymbol{r})$: ionization rate

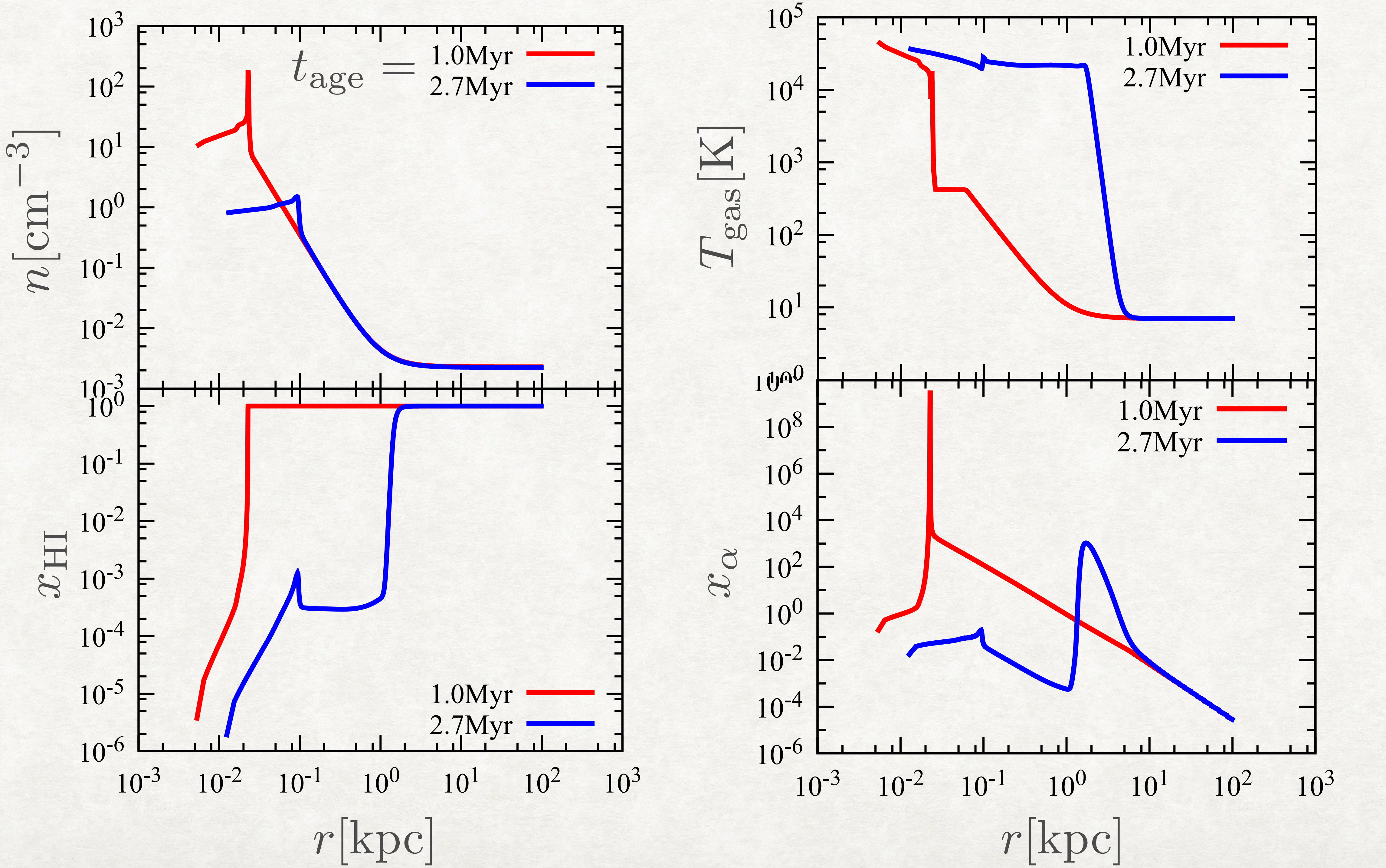
$\mathcal{H}(\boldsymbol{r})$: heating rate

species e, HI, HII, $\rm H^-$, $\rm H_2$, $\rm H_2^+$, HeI, HeII, HeIII

Gas profile in a halo is considered

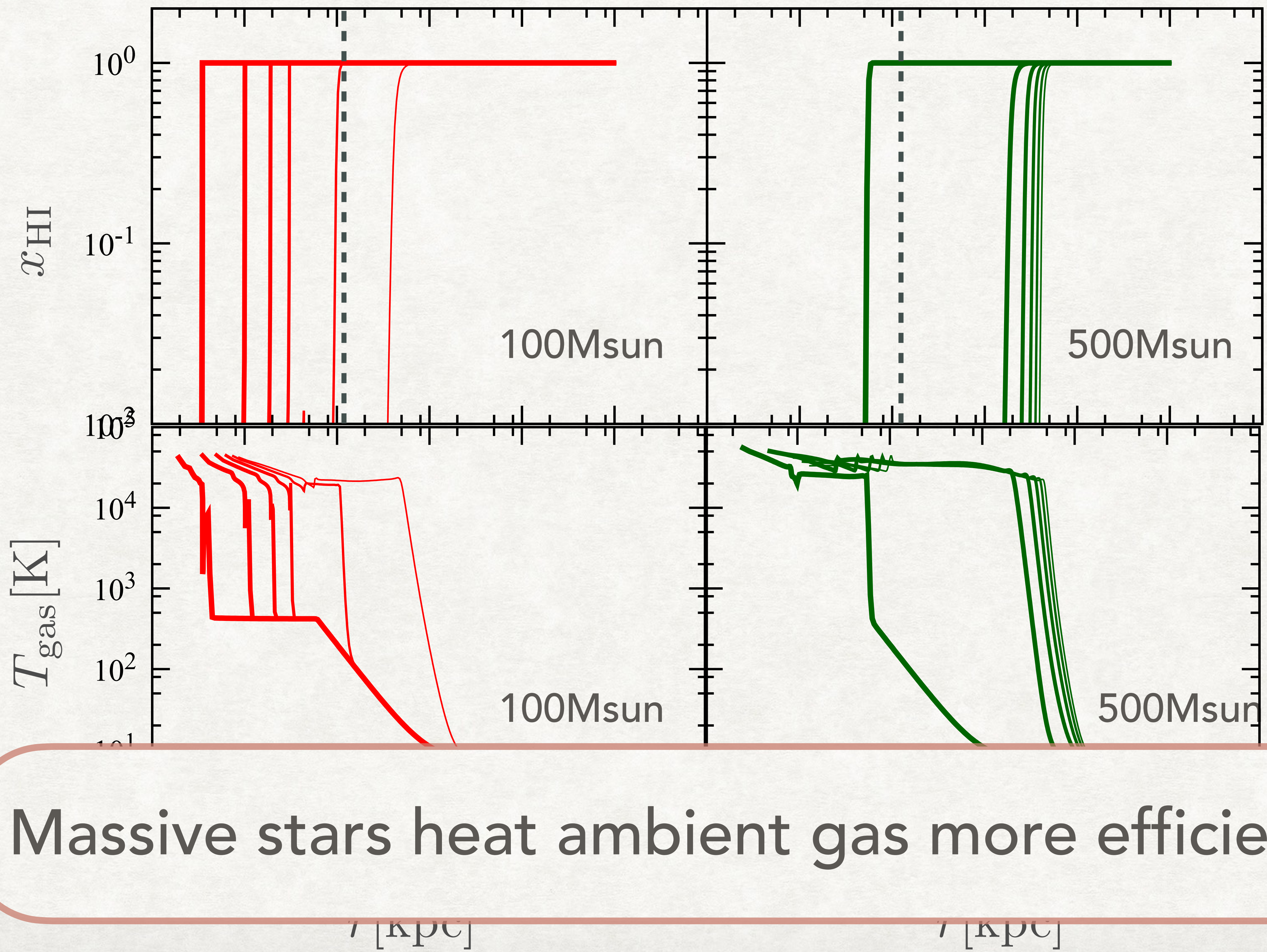
Step1: Physical values around an individual star

✓ Results $M_{\rm star} = 100 M_\odot$ $M_{\rm halo} = 8 \times 10^5 M_\odot$ $z = 20$



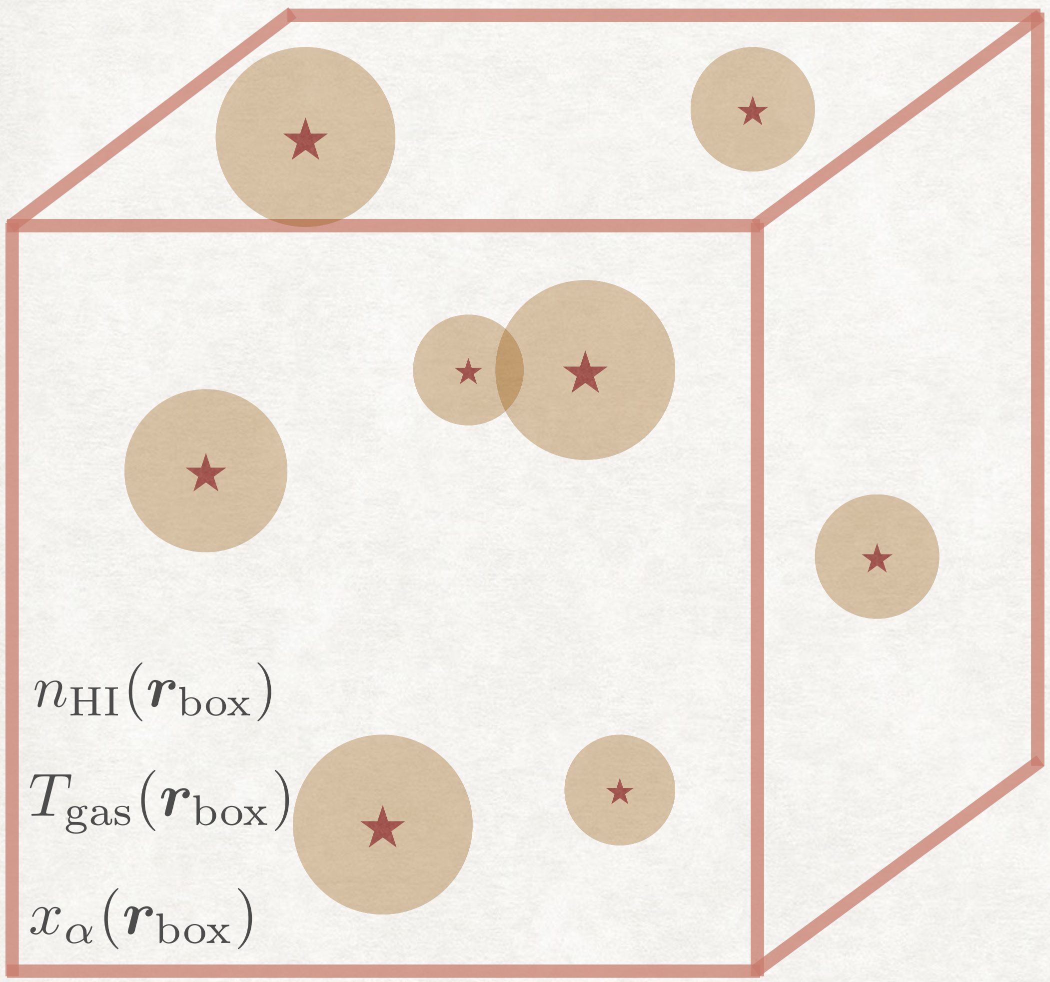
Step1: Physical values around an individual star

✓ Result $t_{\rm age} = 0.3 - 2.1[{\rm Myr}]$ $M_{\rm halo} = 8 \times 10^5 M_\odot$ $z = 20$



Massive stars heat ambient gas more efficiently

Step1: Physical values around an individual star



- ✓ Randomly distribute position of stars, stellar age, halo mass

  e.g. $T_{\rm gas}(M_{\rm star}, M_{\rm halo}, t_{\rm age}, z)$

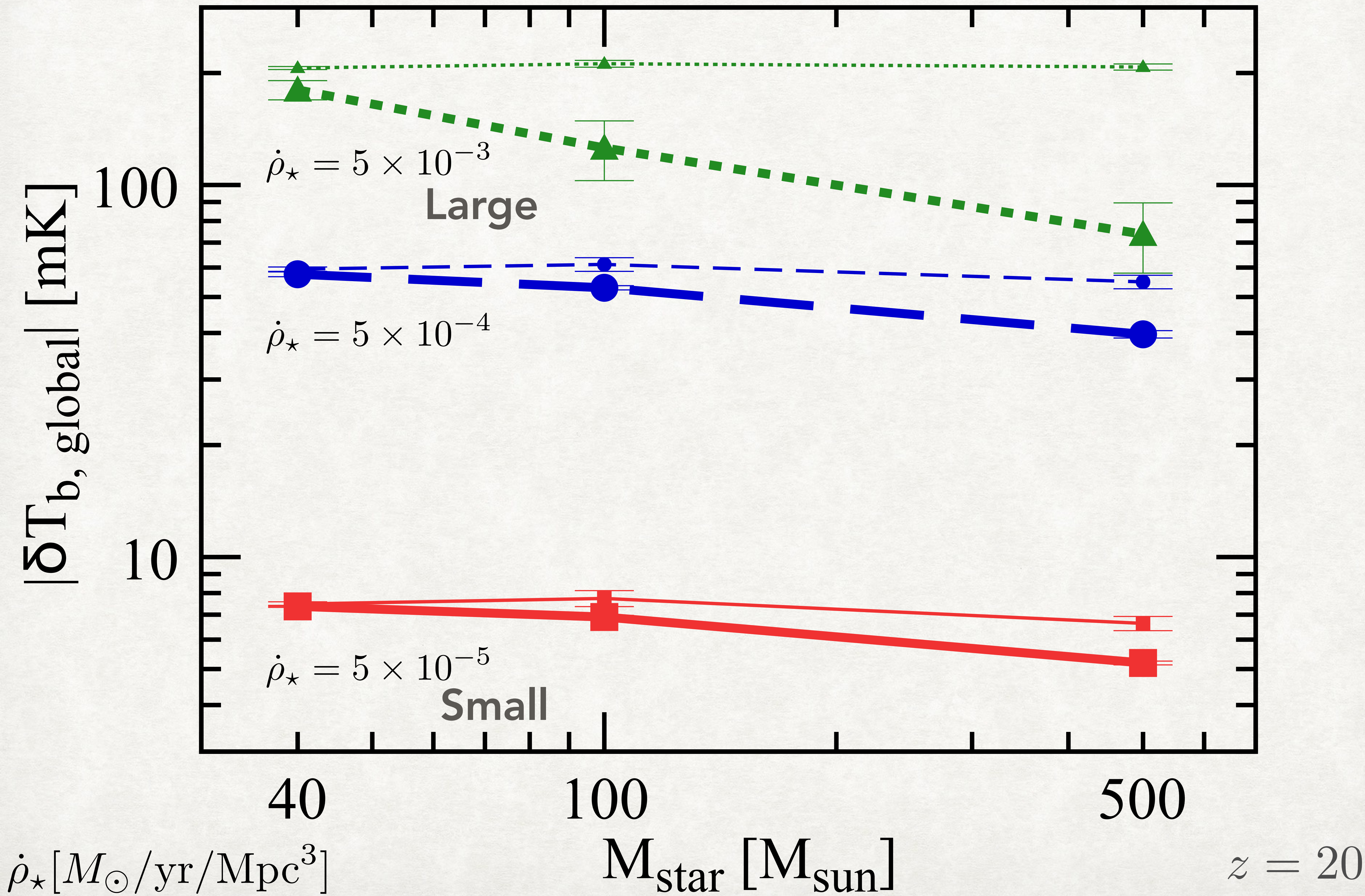
- ✓ All stars have same mass $M_{\rm star}$
- ✓ z = 20
- ✓ Number density of stars

$$n_{\rm star} = \frac{\dot{\rho}_\star t_{\rm life}}{M_{\rm star}}$$

$t_{\rm life}$: stellar lifetime

$\dot{\rho}_\star$: star formation rate density

Stellar mass dependence of the 21-cm global signal



Summary

✓ Investigate the stellar mass dependence of the 21-cm global signal

Large SFRD

$\dot{\rho}_{\star}$

Large Lya Intensity →

Strong signal

$|\delta T_{\mathrm{b,global}}|$

Massive star

M_{star}

Short stellar lifetime →

Effective gas heating

Weak signal

$|\delta T_{\mathrm{b,global}}|$

The mass function of the first stars is essential factor to understand the 21-cm global signal.

arXiv:1805.07947