Gyeongju, Korea (Oct 2024)

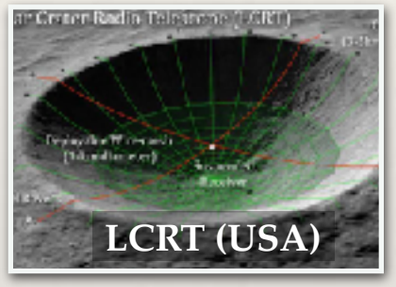
Constraining Dark Matter Properties with the 21cm Signal from the Cosmic Dark Ages

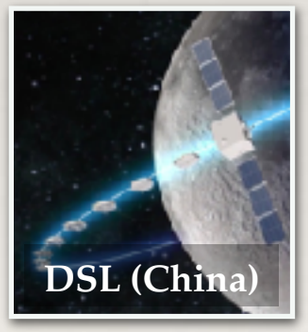
Hyunbae Park
(The University of Tsukuba)

in collaboration with Rennan Barkana, Naoki Yoshida and so on

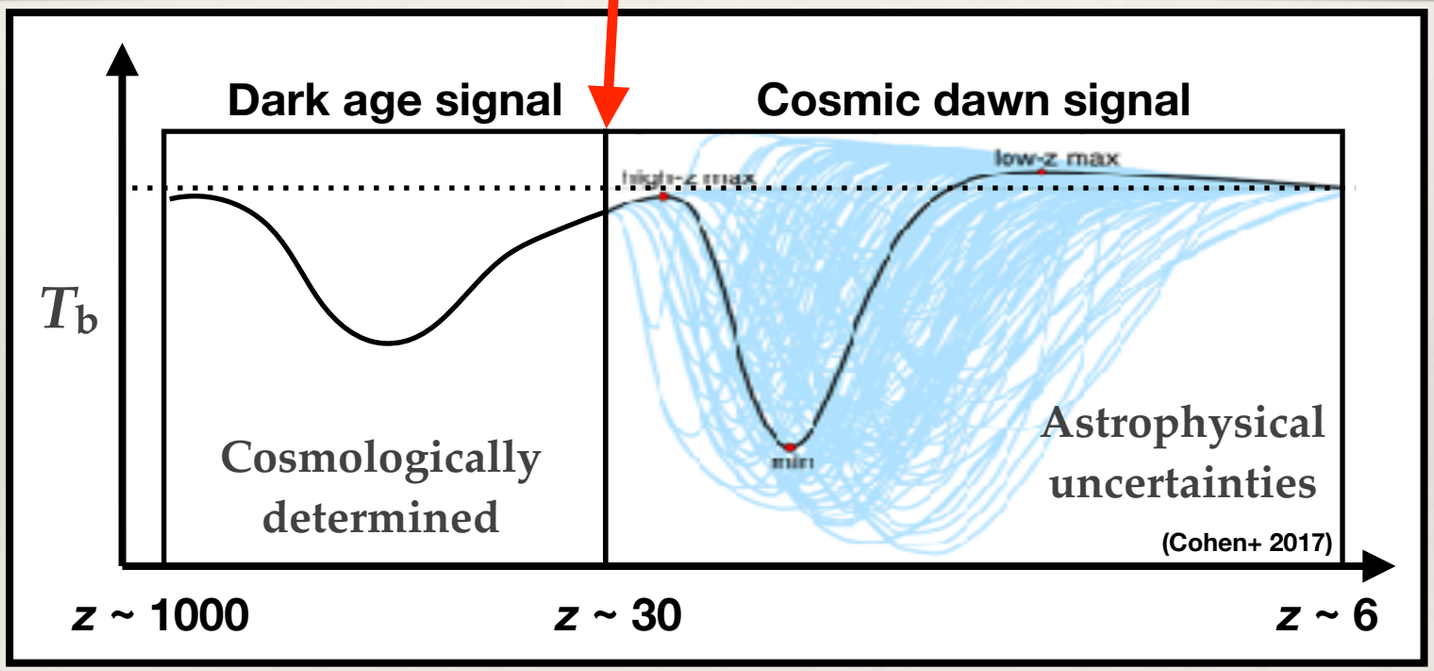
21cm Signal from the Early Universe















comes from primordial fluctuations on pristine gas.

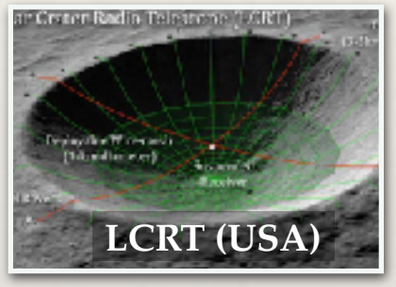
Useful for constraining cosmology and properties of matter. (e.g., Mondal+ 2020)

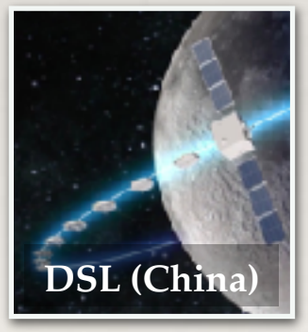
is subject to first star/blackhole formation and feedback.

Useful for constraining the First stars and blackholes,

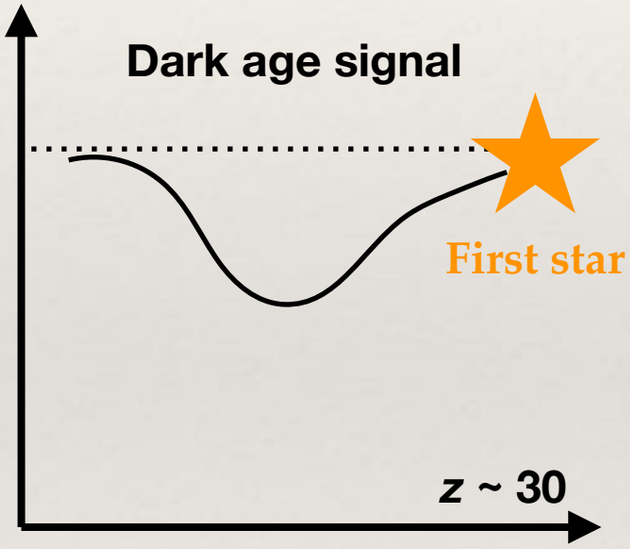
The Dark Age Signal and Structure Formation

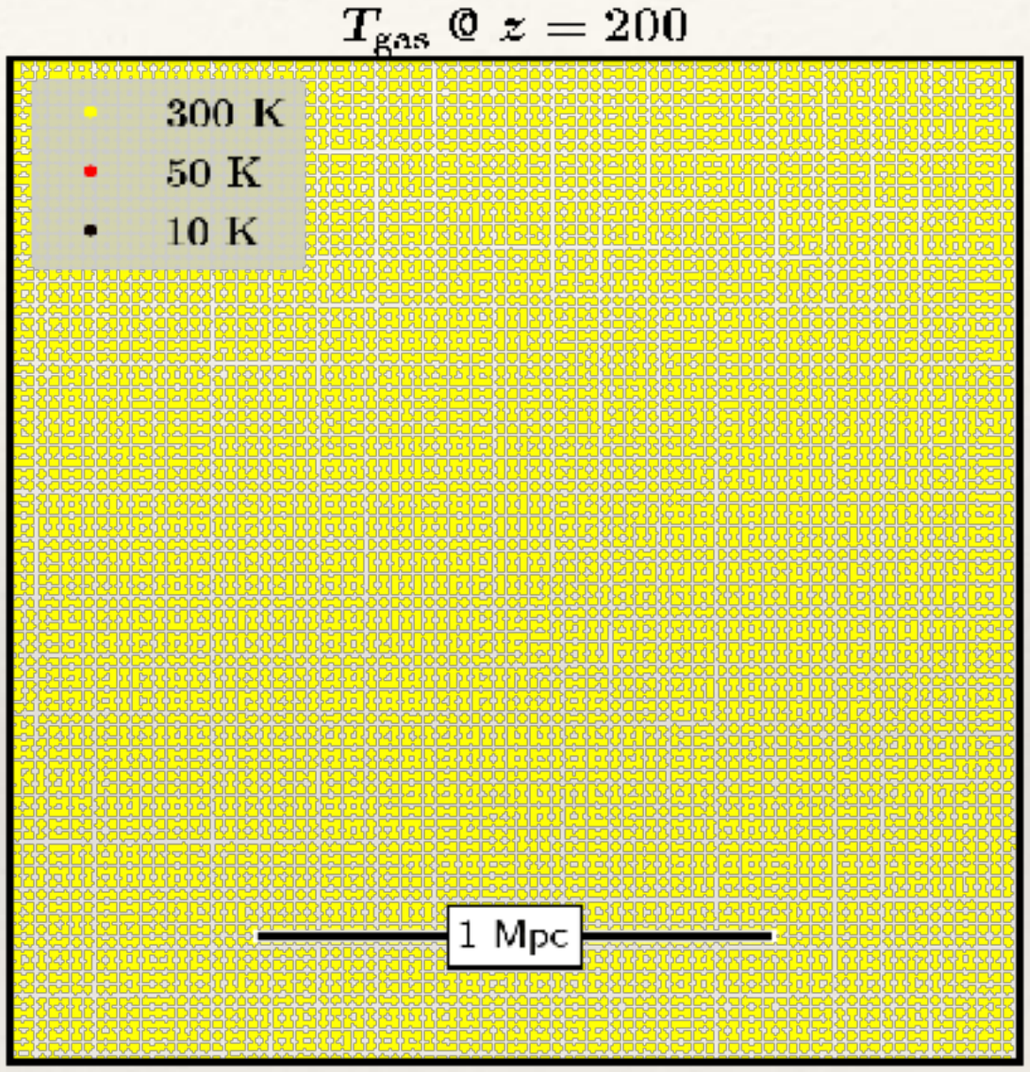








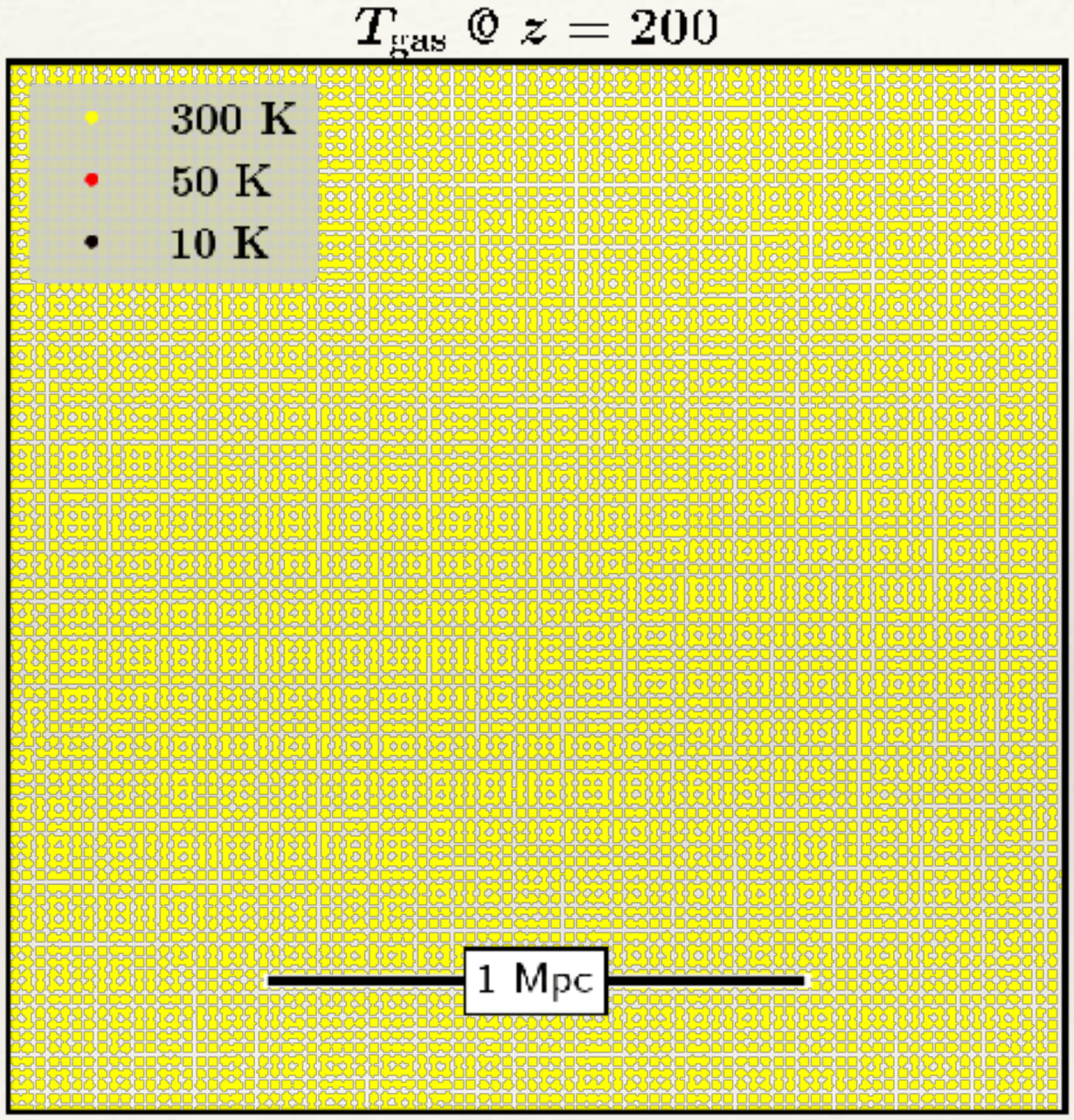




We often calculate the signal for the cosmic mean density, but nonlinear structures develop during the cosmic dark ages.

(see also Ali-haioud+ 2013 & Ahn+ 2008)

Gas Temperature w. Structure Formation



Code: GADGET-2
Resolution: 512^3 ptls
Volume: [3 Mpc]^3

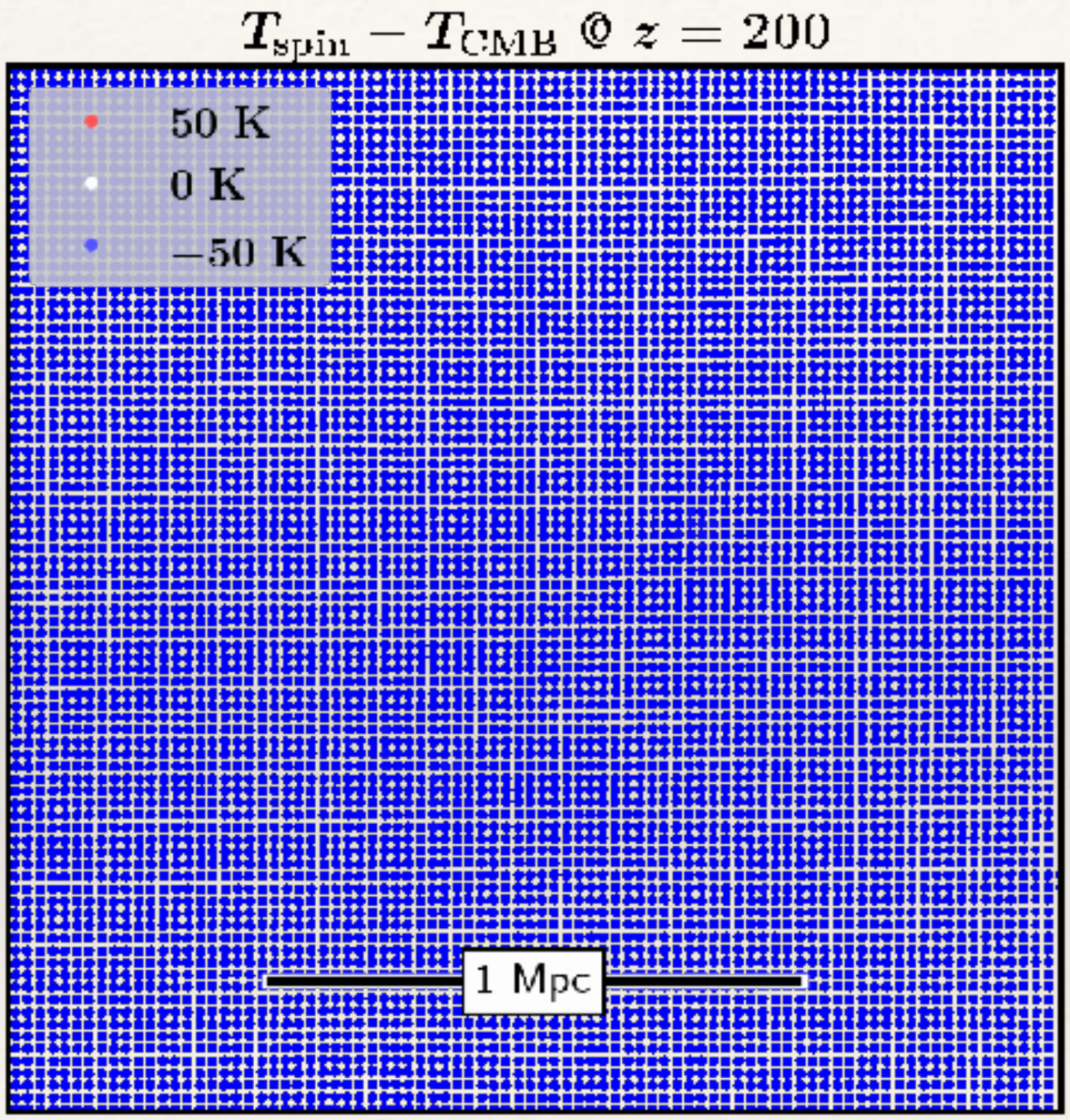
<u>Chemical processes included</u>
Compton heating
H/He recombination

<u>Physics included</u>
Baryon-dark matter streaming
Non-zero overdenstiy
Warm dark matter
(no star formation)

Gas heated by adiabatic compression in overdense structures

Relevant works: Ahn+ 2008 & Ali-Haïmoud+ 2013

Spin Temperature w. Structure Formation



$T_{\rm spin}$ - $T_{\rm CMB}$ sources the 21cm signal:

$$T_{\rm b} \propto (T_{\rm spin} - T_{\rm CMB})$$

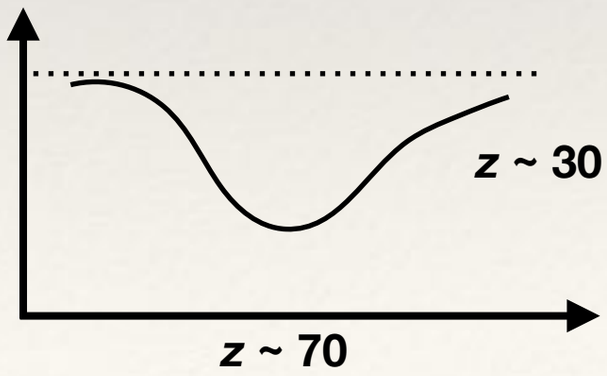
$T_{\rm spin}$ is driven by collisional coupling btw $T_{\rm gas}$ and $T_{\rm spin}$:

$$T_{\rm spin}^{-1} = \frac{T_{\rm CMB}^{-1} + x_c T_{\rm gas}^{-1}}{1 + x_c}$$

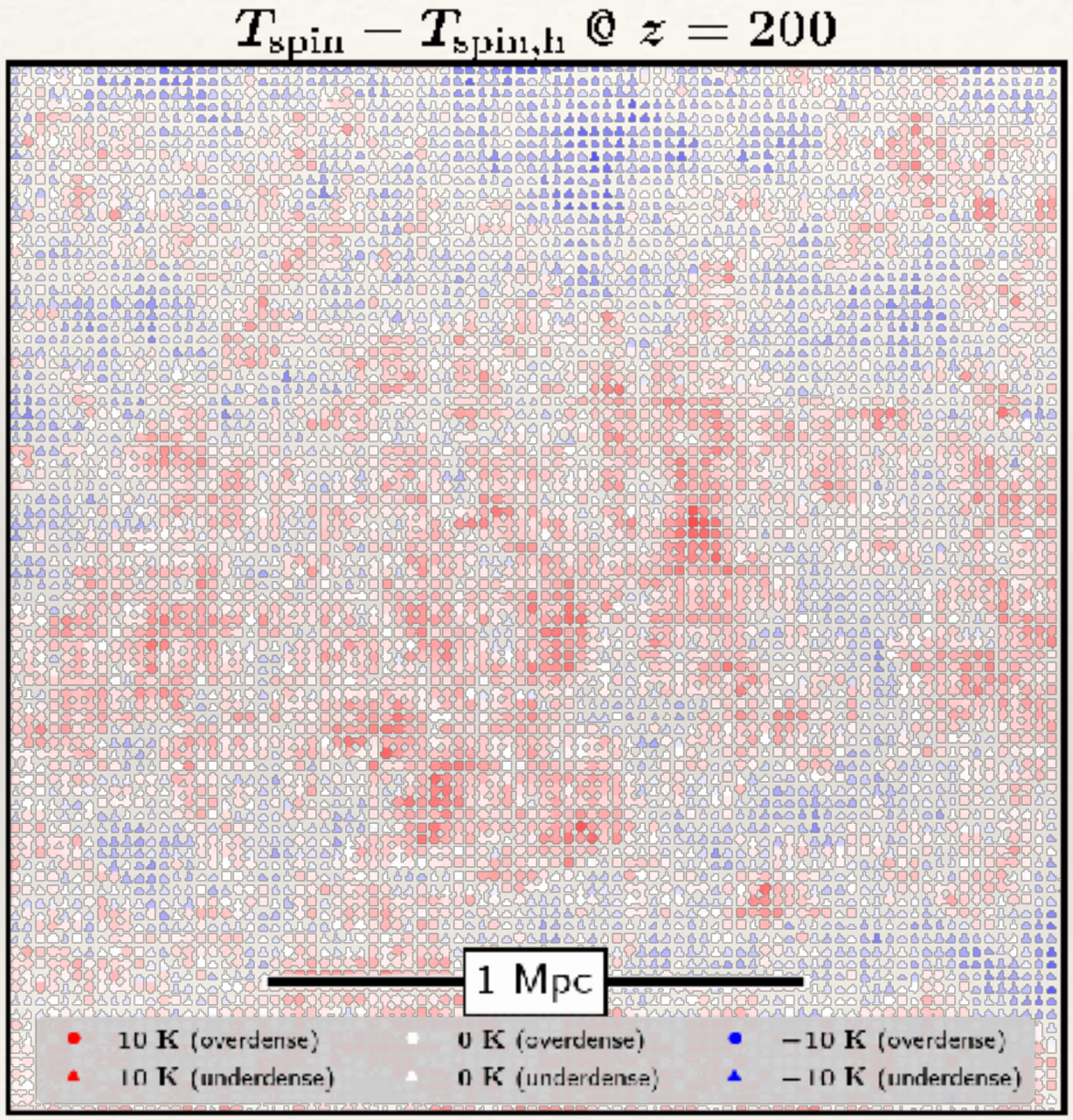
The coupling depends strongly on density:

$$x_c \propto \kappa(T_{\rm gas})\rho \propto \rho^{1.5-3}$$

Strong negative signal at z ~ 100, weakening toward low-z.



Impact of Structure Formation on $T_{\rm spin}$



At $z > 65$,

positive $\Delta T_{\rm spin}$ at overdensities (●)

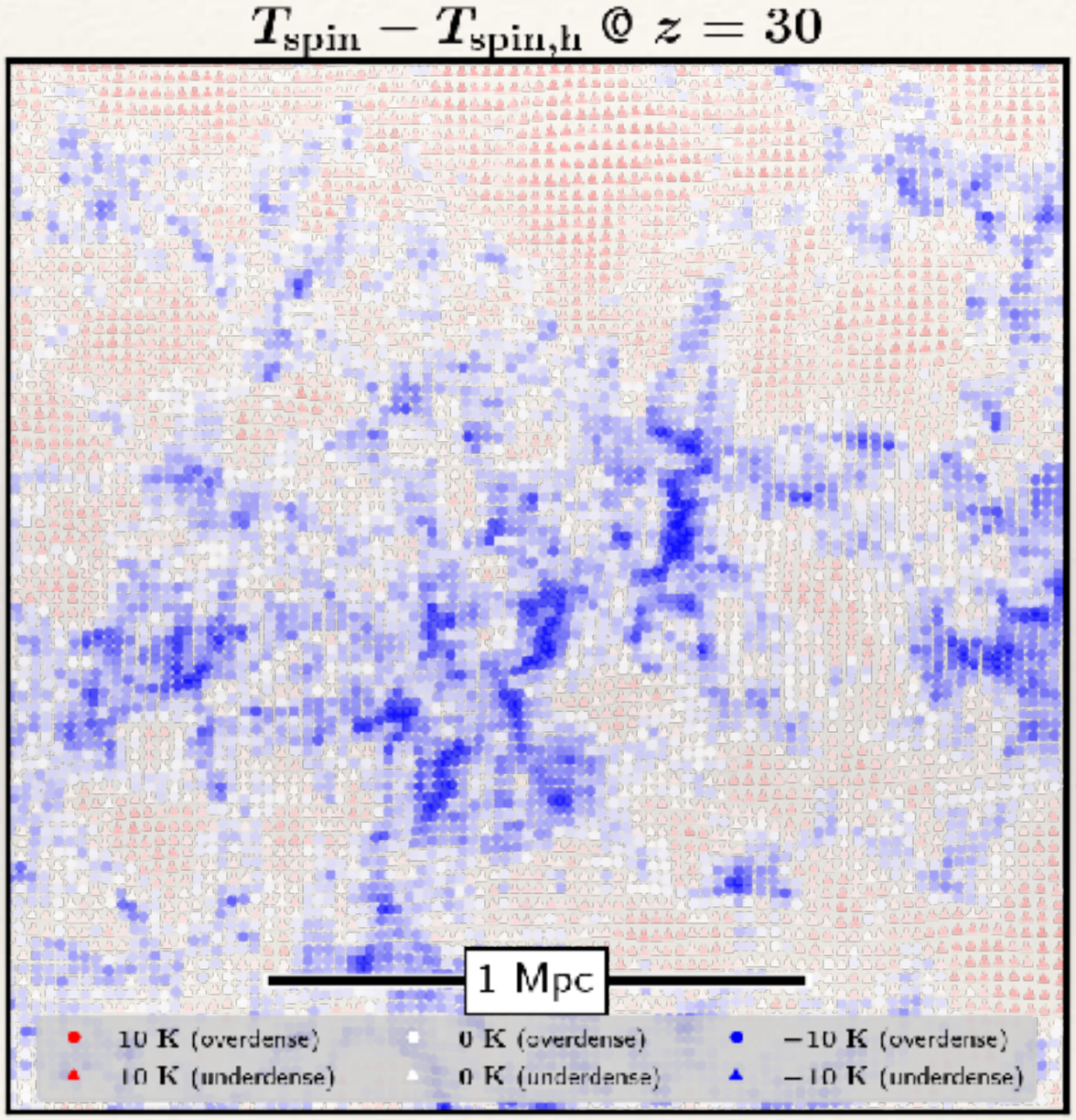
negative $\Delta T_{\rm spin}$ at underdensities (▲)

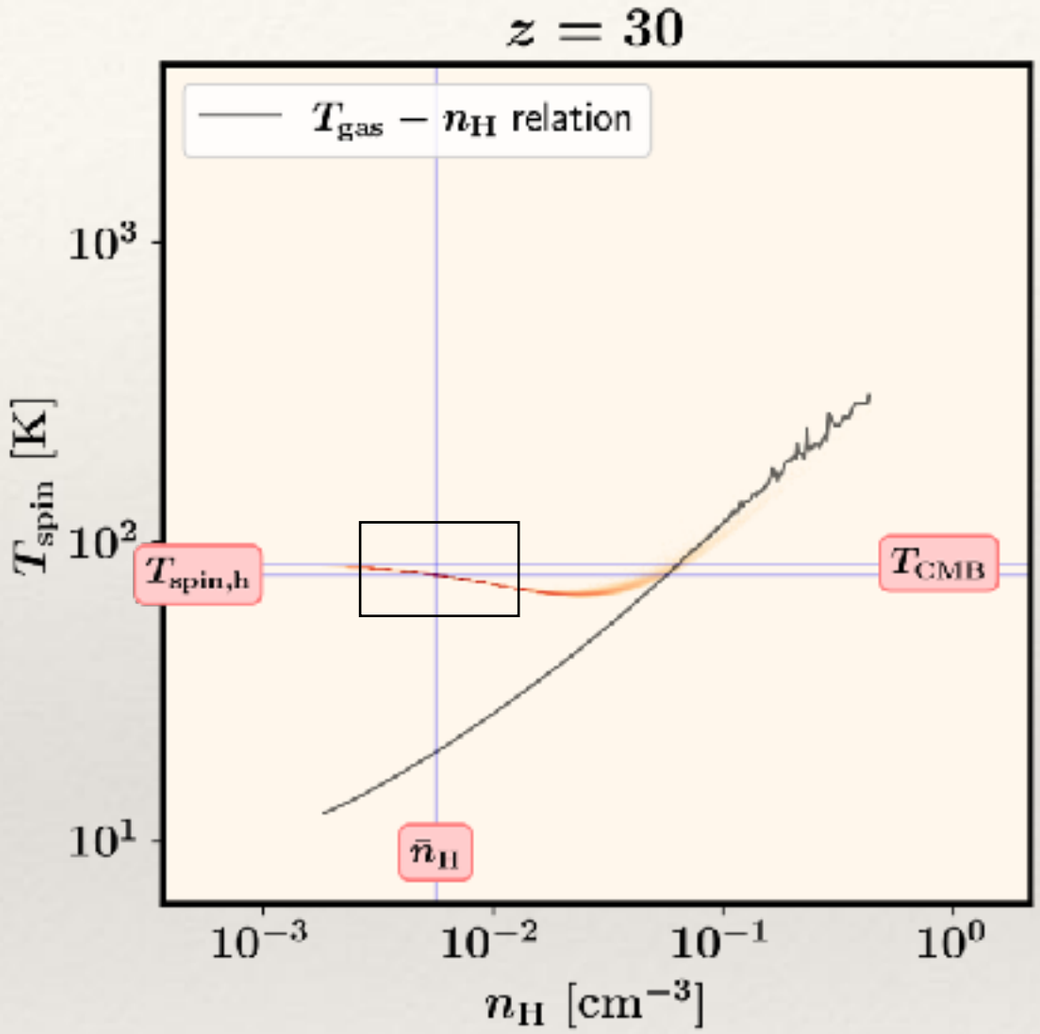
At $z < 65$,

negative $\Delta T_{\rm spin}$ at overdensities (●)

positive $\Delta T_{\rm spin}$ at underdensities (▲)

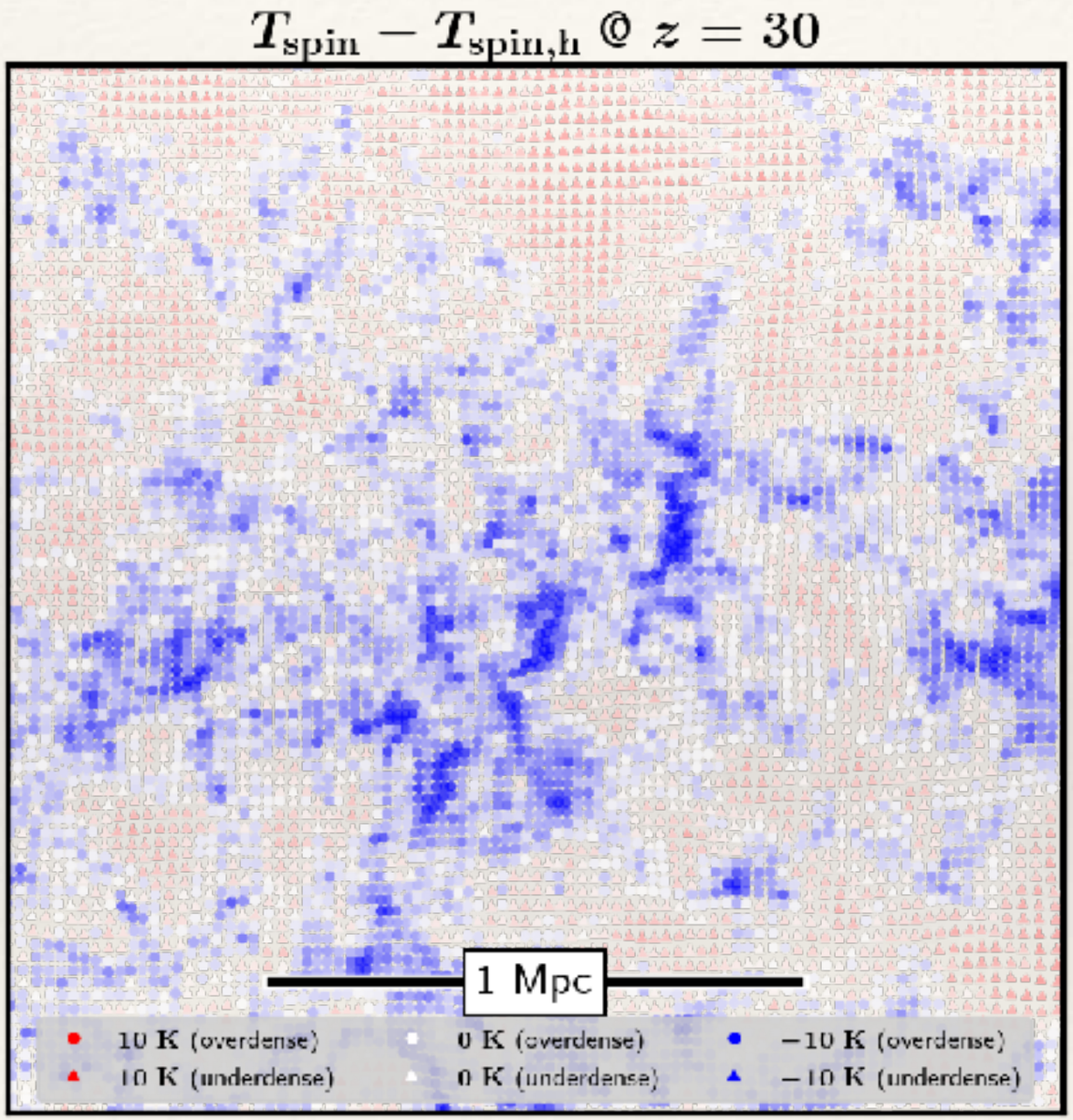
$\Delta T_{\rm spin}$ at $z = 30$

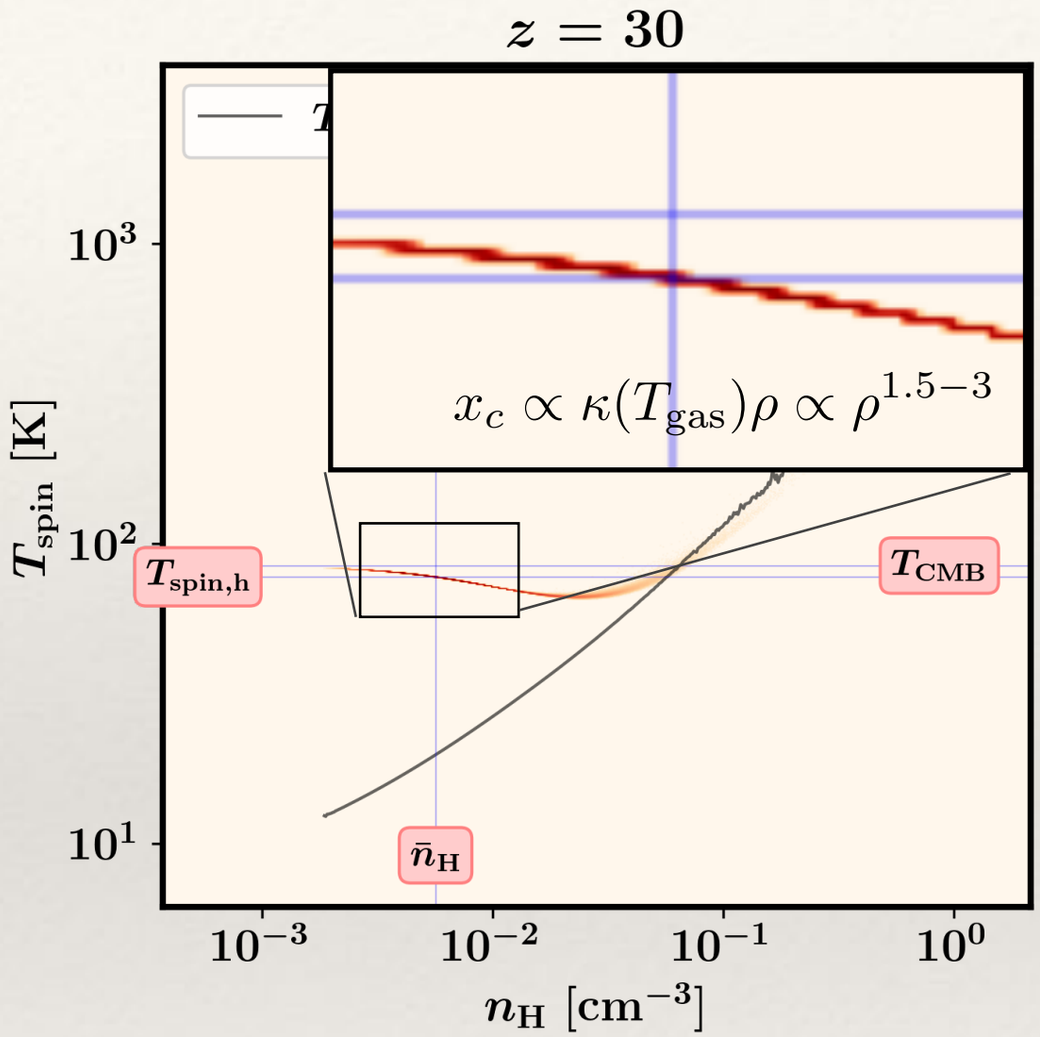




- $T_{\rm spin}$ **more decoupled from** $T_{\rm gas}$**.**
- $T_{\rm spin}$**. lowered by stronger coupling in over densities.**

$\Delta T_{\rm spin}$ at $z = 30$





- $T_{\rm spin}$ more decoupled from $T_{\rm gas}$.
- $T_{\rm spin}$. lowered by stronger coupling in over densities.
- Stronger signal from overdensities giving net negative signal