Impact of Baryon-Dark Matter Streaming Velocity on Reionization

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Collaborators

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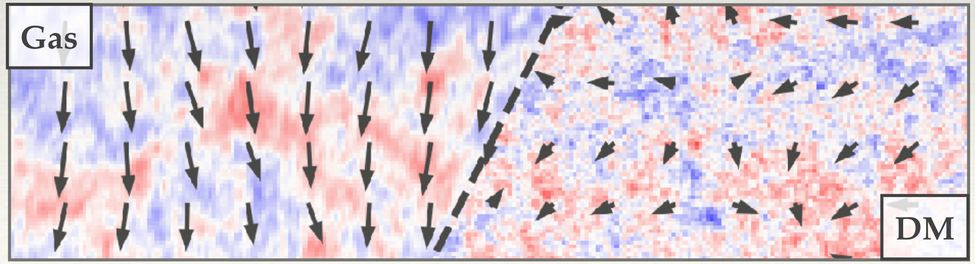
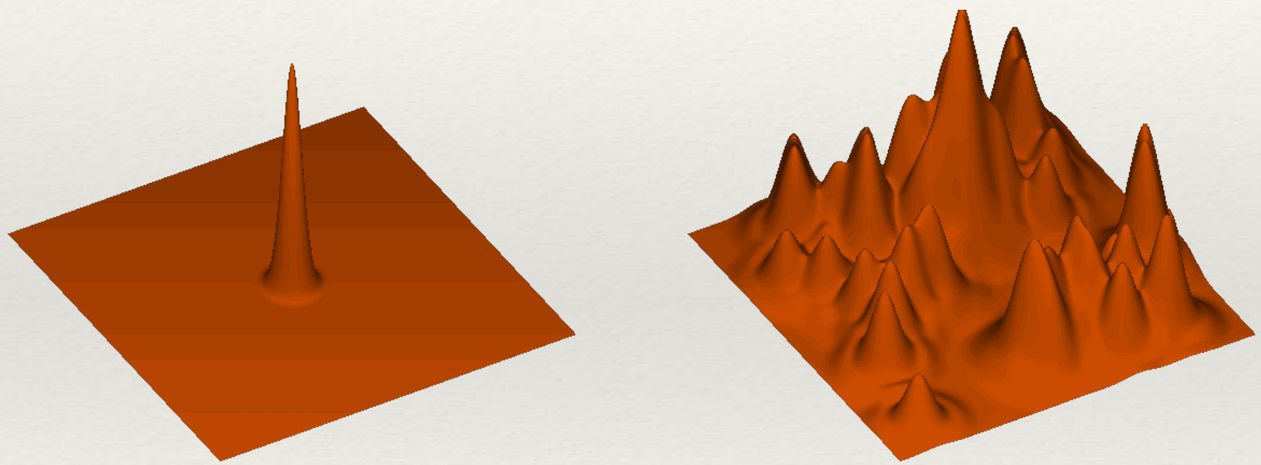


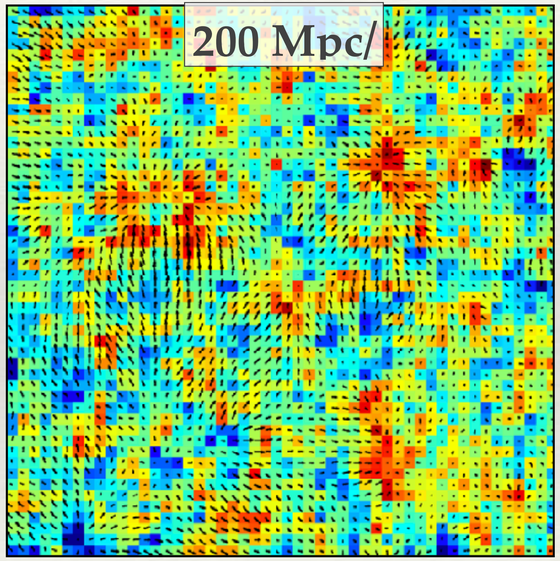
[Introduction] Baryon-Dark Matter Streaming Motion

Before $z = 1090$, …



.. pressure of photon-baryon fluid generates the Baryonic Acoustic Oscillations.
This acoustic motion = the streaming motion

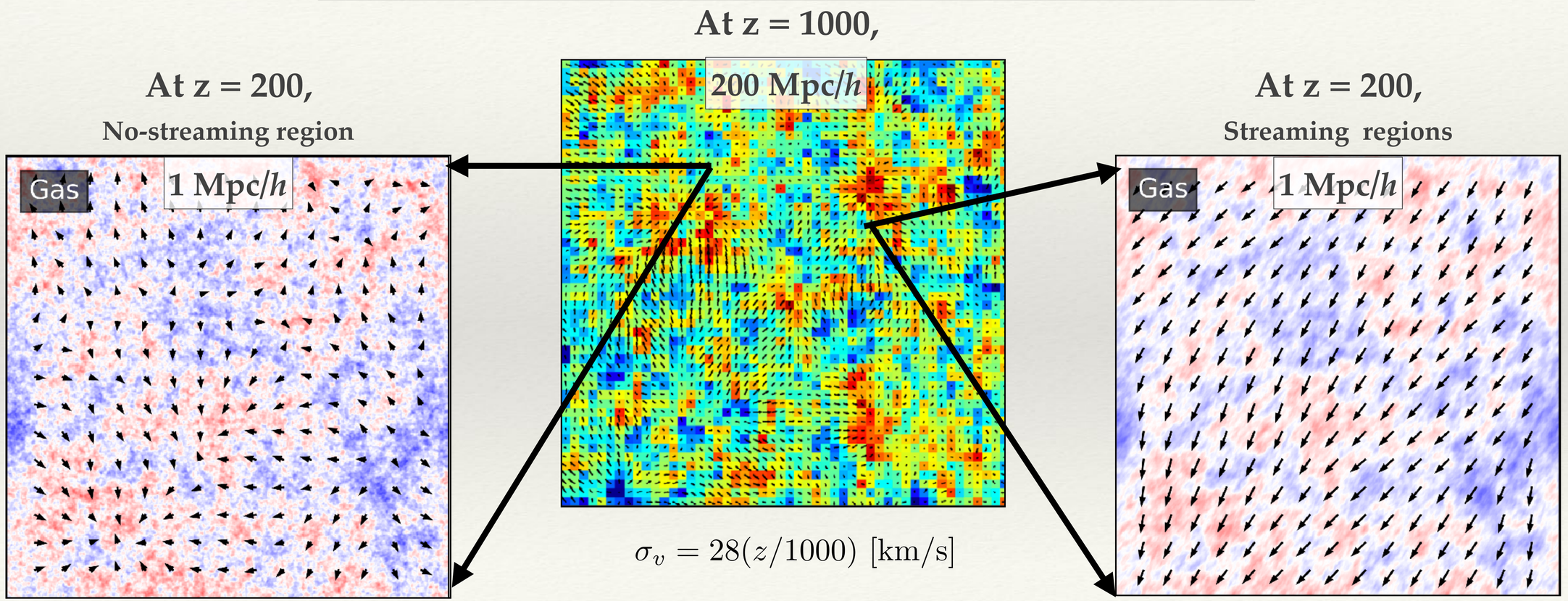
At $z = 1090$,

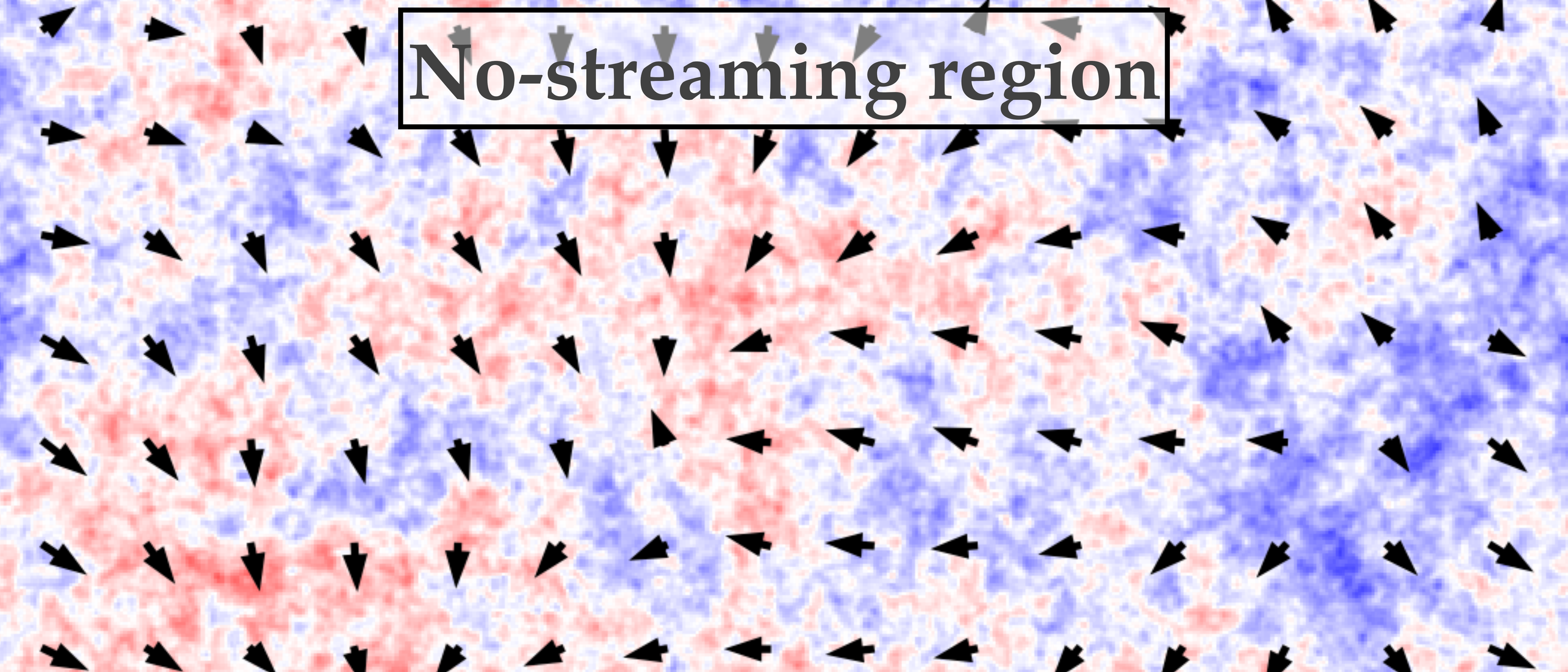


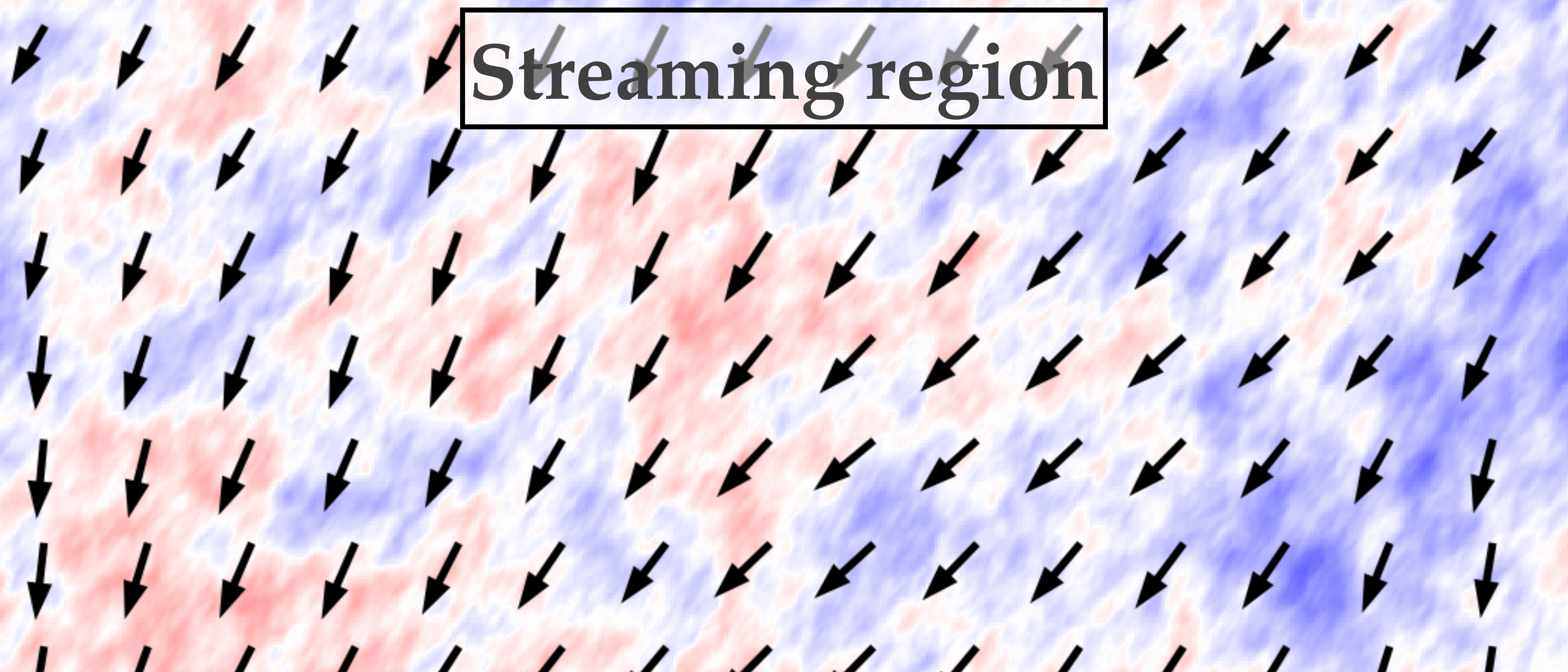
$$\sigma_v = 28(z/1000)\ [\mathrm{km/s}]$$

(Tseliakovic and Hirata 2010)

[Introduction] Baryon-Dark Matter Streaming Motion

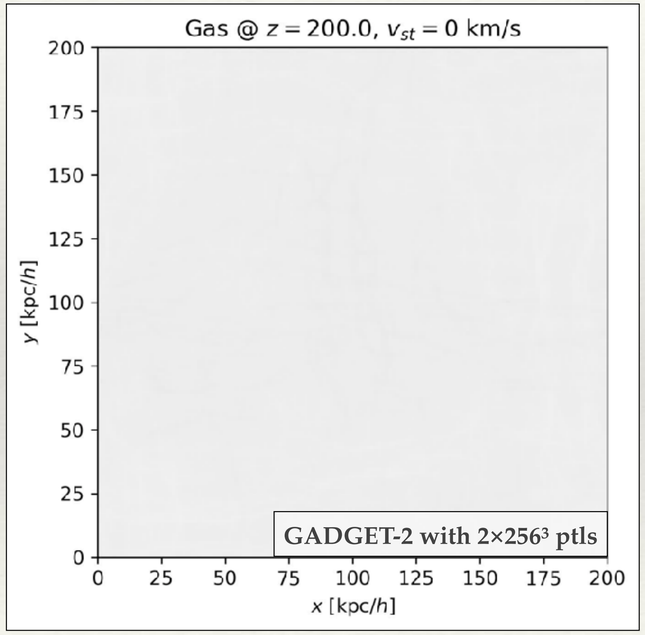



No-streaming region

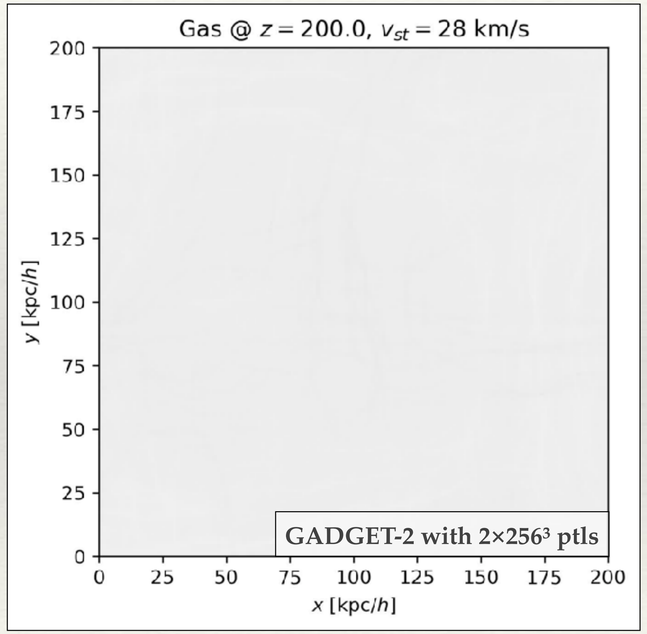

Streaming region

Structure Formation with Streaming Effect

No streaming

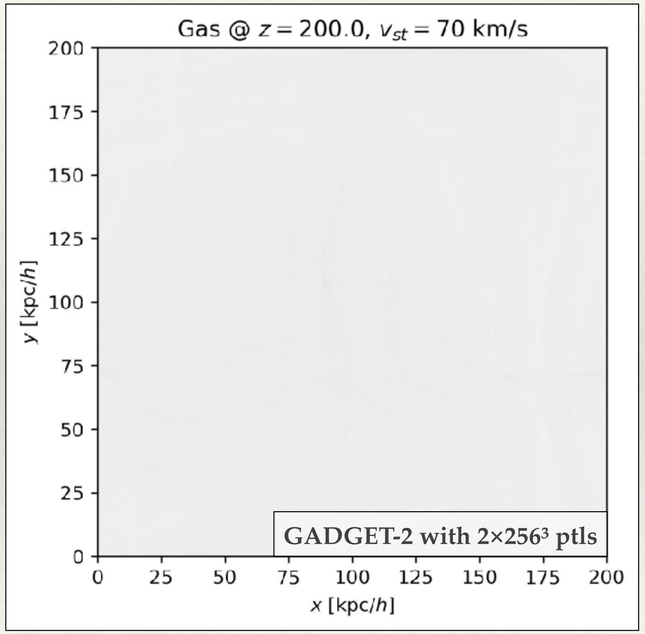


Typical streaming



$v_{cb} = \sigma_v = (z/1000)28$ km/s

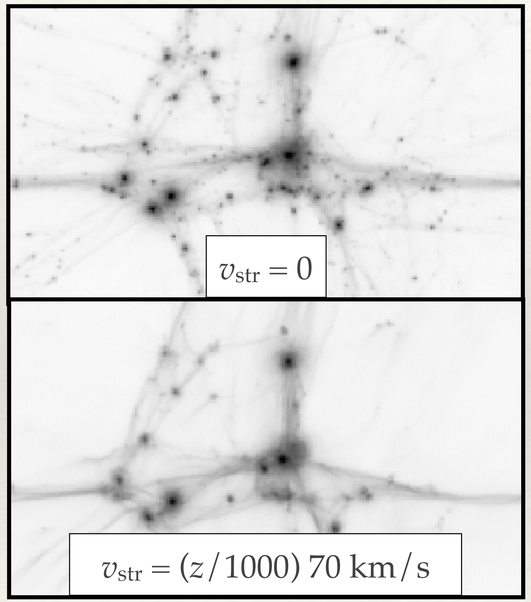
Extreme streaming



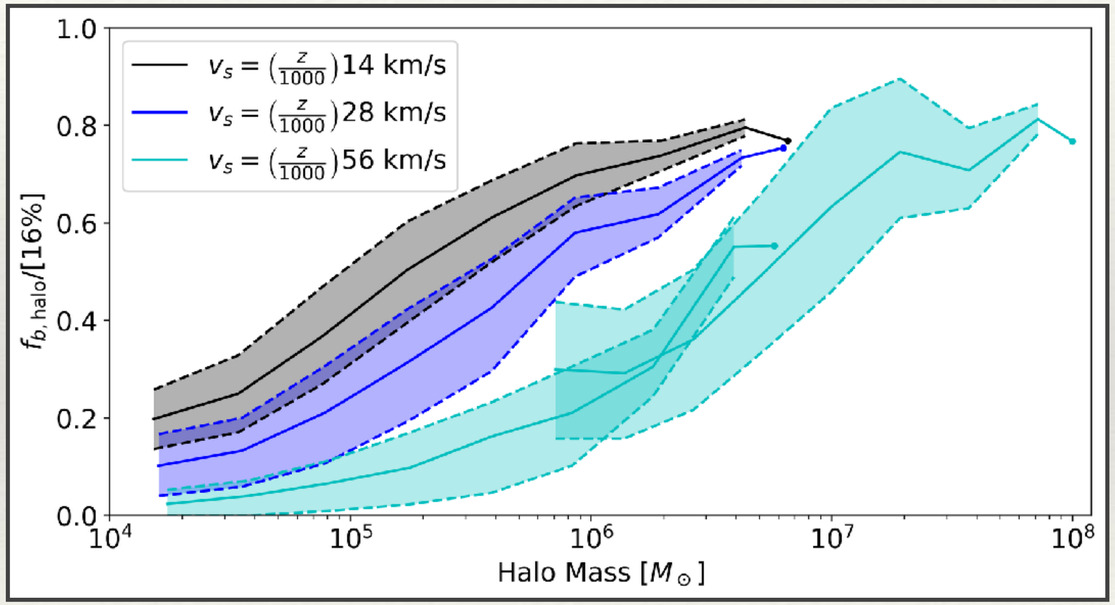
$v_{cb} = 2.5\sigma_v = (z/1000)70$ km/s

Gas Fraction in Halos

At $z = 6$,

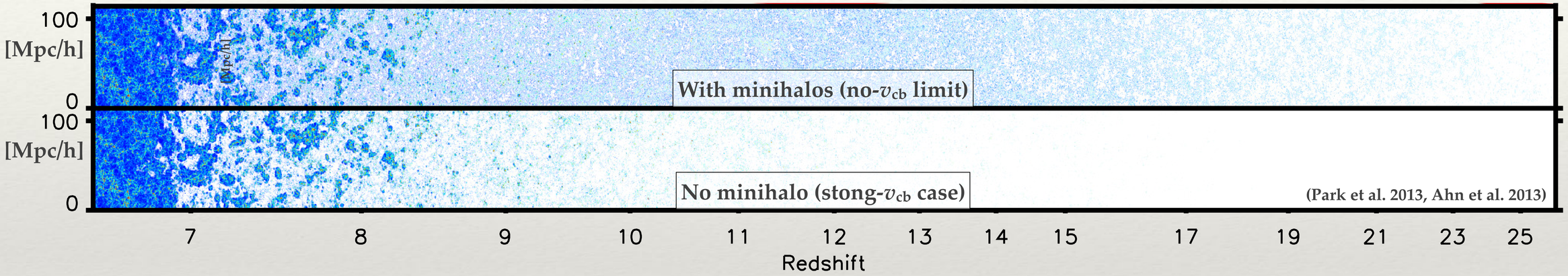


At $z = 30$,



Harder for gas to accrete into ~10^6 $M_\odot$ halos. Minimal impact on > 10^8 $M_\odot$ halos.

Delayed Beginning of Reionization

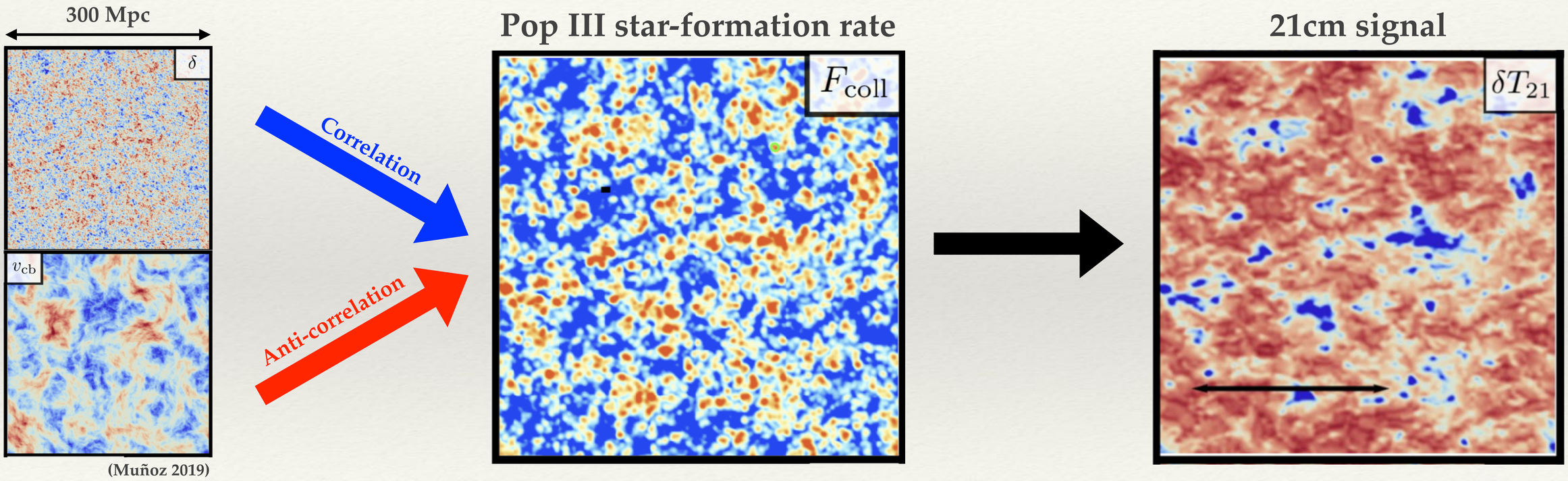


- **Early stage of reionization is driven by minihalos (~ 10^6 $M_\odot$), but late stage is driven by larger ones (> 10^8 $M_\odot$).**

→ The beginning is delayed, but the end is unaffected.

How can we observe the impact?

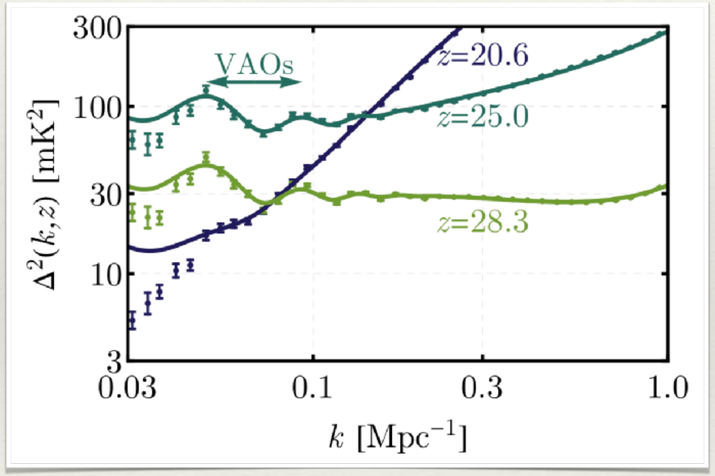
21cm Fluctuations at z≈20



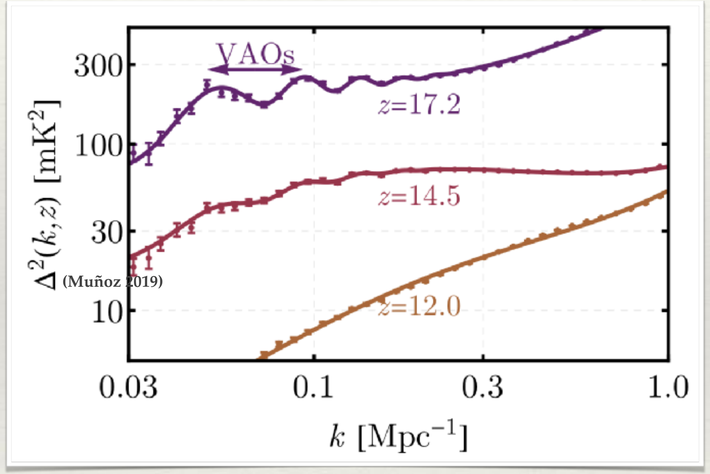
How can we observe the impact?

21cm Fluctuations at z≈20

Lya coupling signal



Heating signal



(Muñoz 2019)

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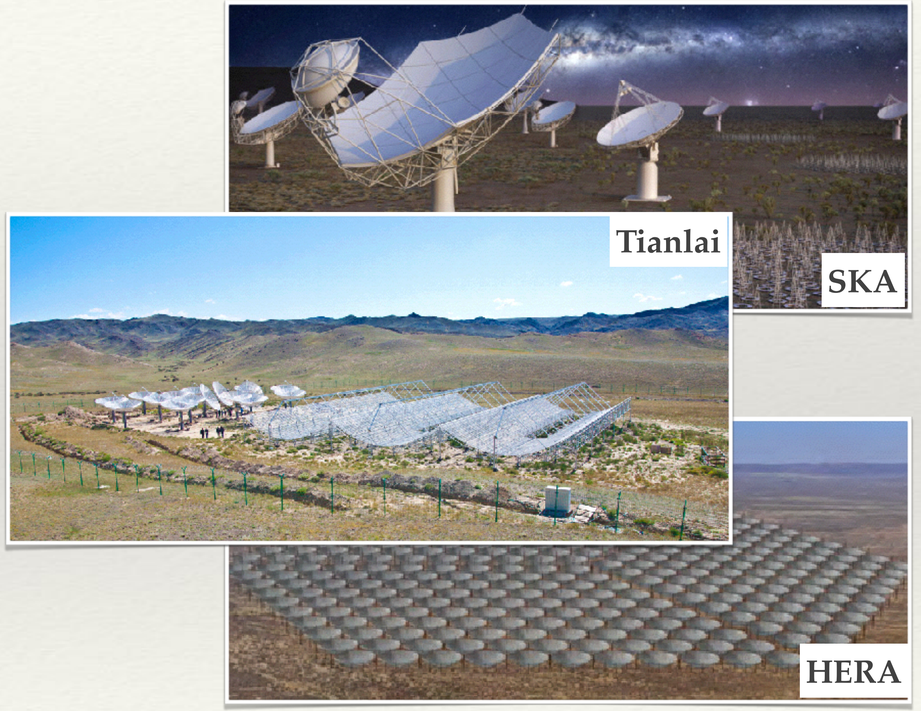
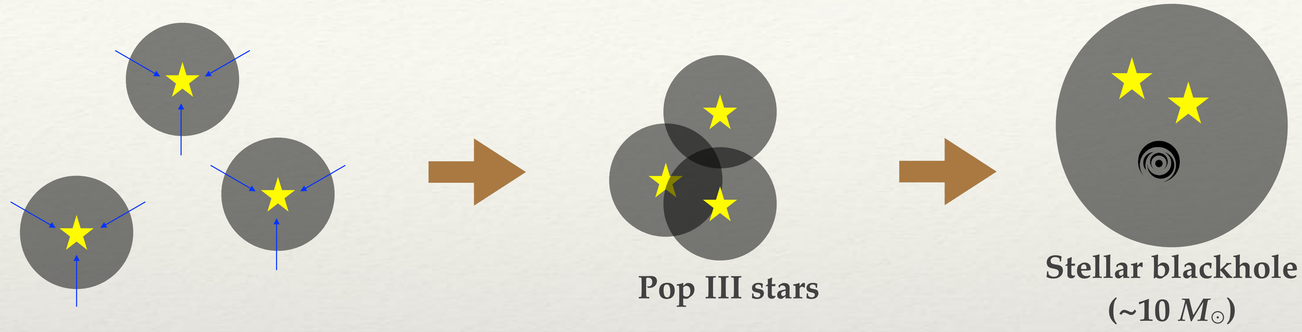


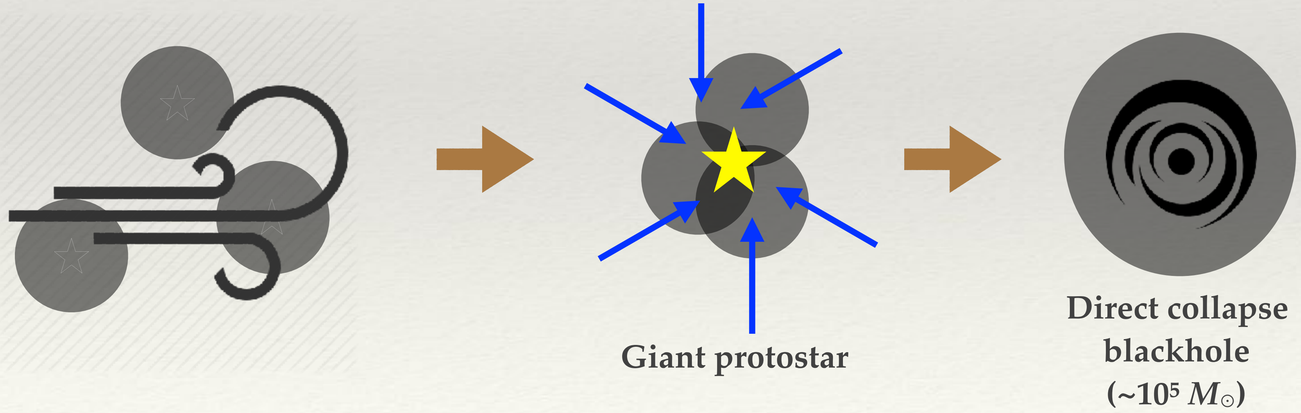
A strong BAO-like feature can be observed by Tianlai, SKA and HERA in near future.

Direct Collapse Blackhole Induced by Streaming Effect?

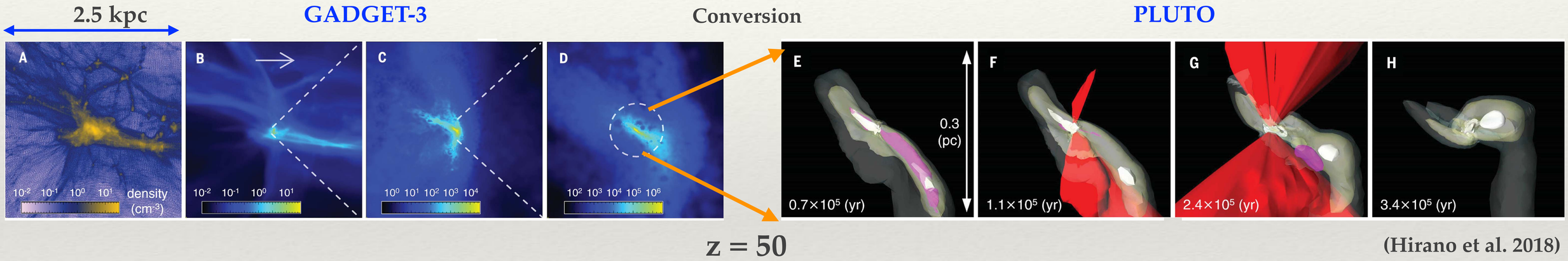
No streaming case



Streaming case



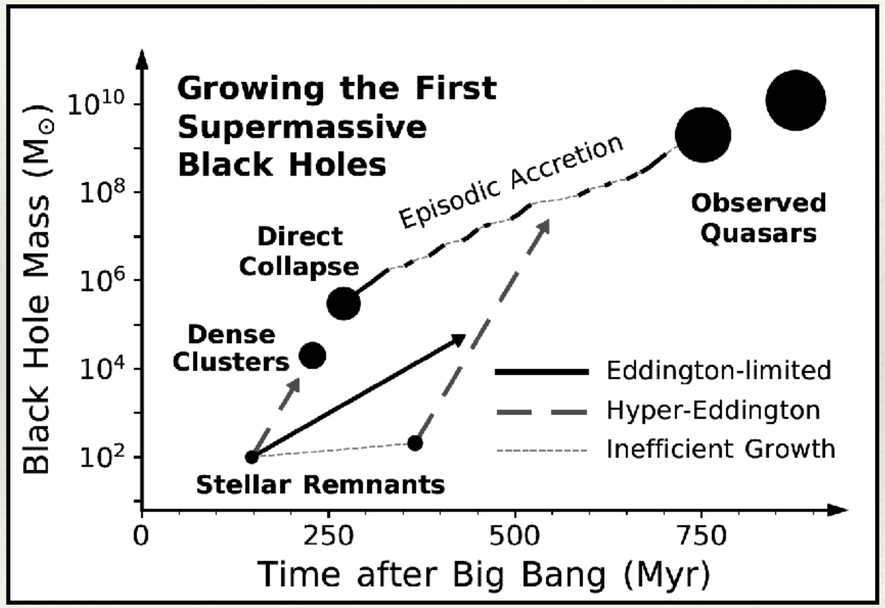
Simulations



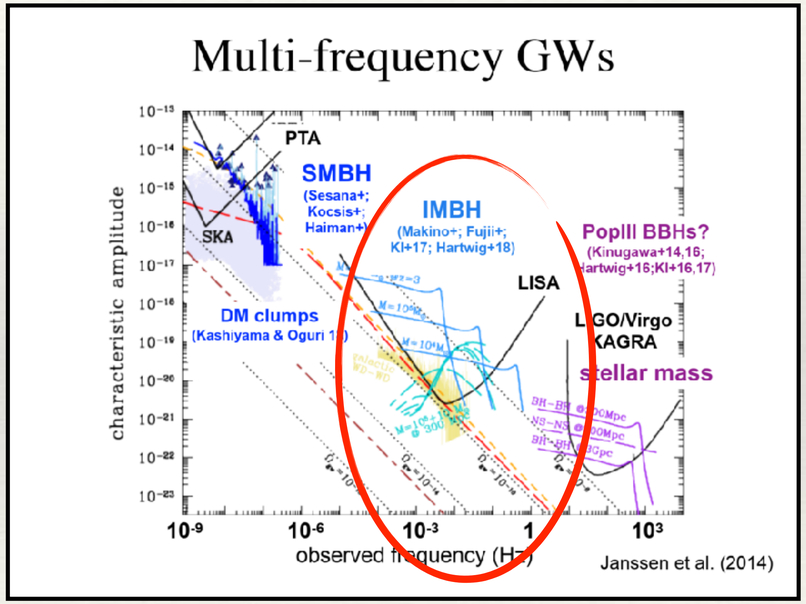
(Hirano et al. 2018)

Streaming v in overdense region makes DCBH at $z \sim 50$!

Observational Consequence



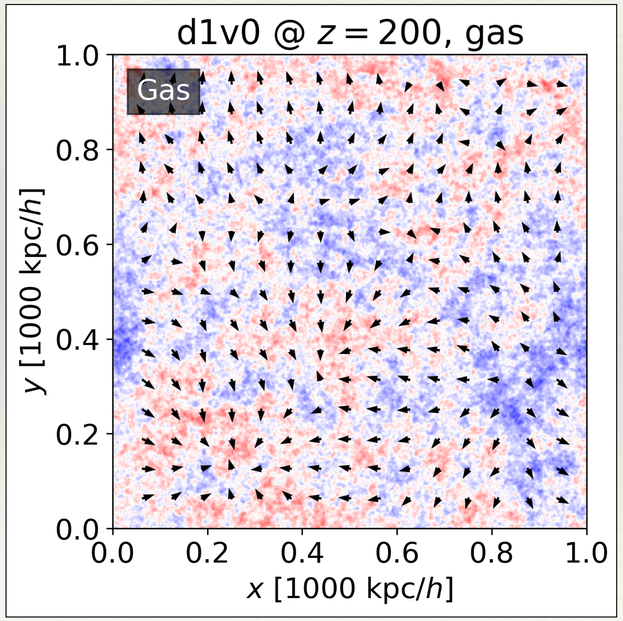
Helps explaining ~10^9 $M_\odot$ quasars at $z = 6$.



LISA can see them!

Wrong way (what most people do)

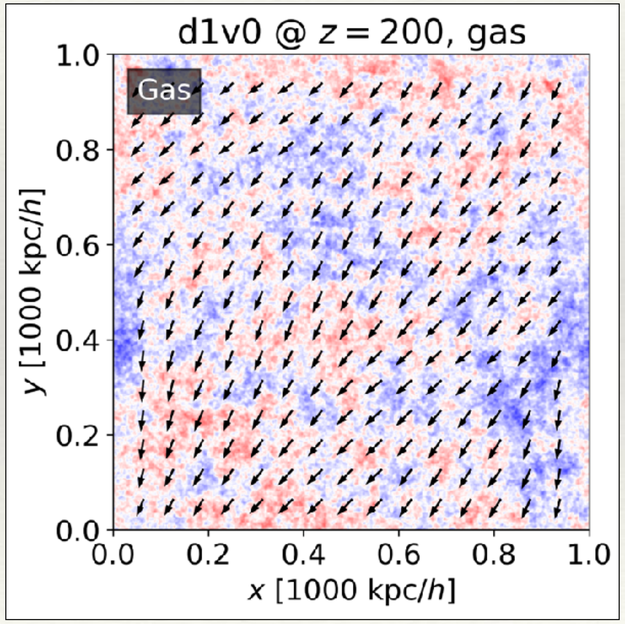
1) Solve $\frac{\partial \delta}{\delta t} = -\theta$, $\frac{\partial \theta}{\delta t} = -\frac{3H^2}{2}\Omega_m \delta - 2H\theta$ **using old IC generators.**



+

2) Add a constant velocity to gas velocity field.

=



Correct way (what should be done)

Solve

$$\frac{\partial \delta_{\rm b}}{\partial t} = -ia^{-1}\mathbf{V}_{\rm bc}\cdot\mathbf{k}\delta_{\rm b} - (1+\Delta_{\rm b})\theta_{\rm b} - \Theta_{\rm b}\delta_{\rm b},$$
$$\frac{\partial \theta_{\rm b}}{\partial t} = -ia^{-1}\mathbf{V}_{\rm bc}\cdot\mathbf{k}\theta_{\rm b} - \frac{3}{2}H^2\left(f_{\rm c}\delta_{\rm c} + f_{\rm b}\delta_{\rm b}\right) - 2H\theta_{\rm b}$$

using "BCCOMICS".

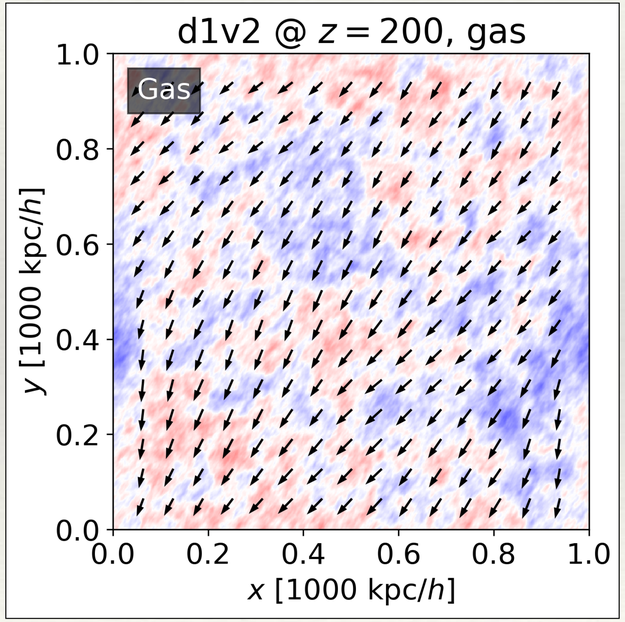
(Ahn et al. 2018)

Interested in using?
Look for it on Github!

Need help?
Contact us!

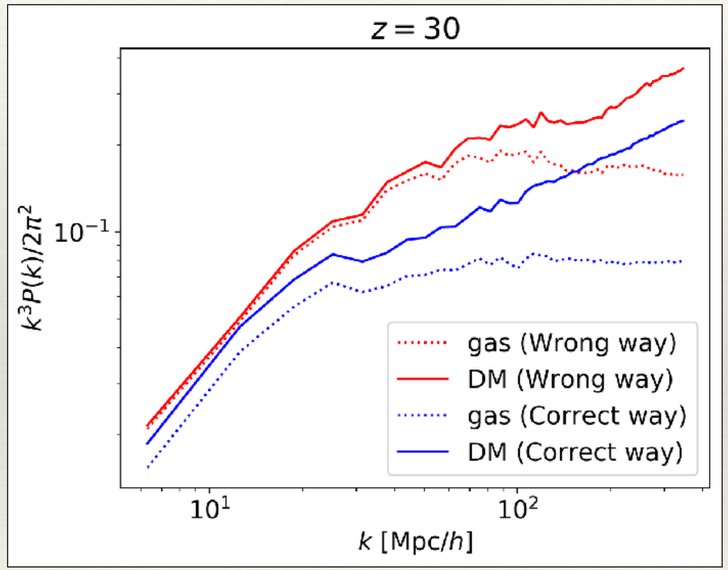
Difference

Streaming effect between z = 1000 and 200.

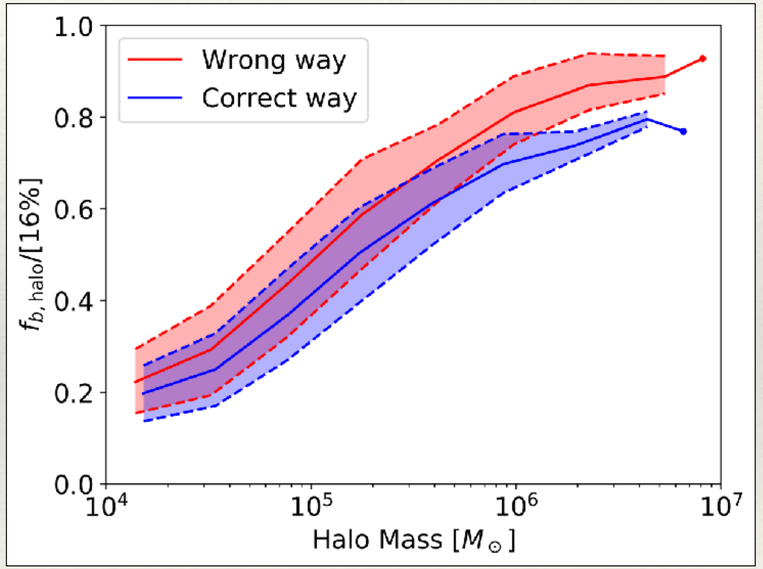


Difference at z=30

Density power spectrum



Baryon fraction in halos



Accounting for streaming motion between z = 1000 and 200 makes a significant difference at lower z's!

Summary

Baryon-dark matter streaming velocity …

- … suppresses star-formation in minihalos, but not larger halos.
- … delays the beginning of reionization, but not the end.
- … imprints a BAO signature in the 21cm power spectrum at z~20.
- … might make ~10^5 $M_\odot$ blackhole of at z ~ 50.

I am working on …

- … initial condition generator that accounts for the streaming effect. (Contact us if you need help with making IC!)
- … revisiting previous works.
- (more to present on next Monday at SJTU)