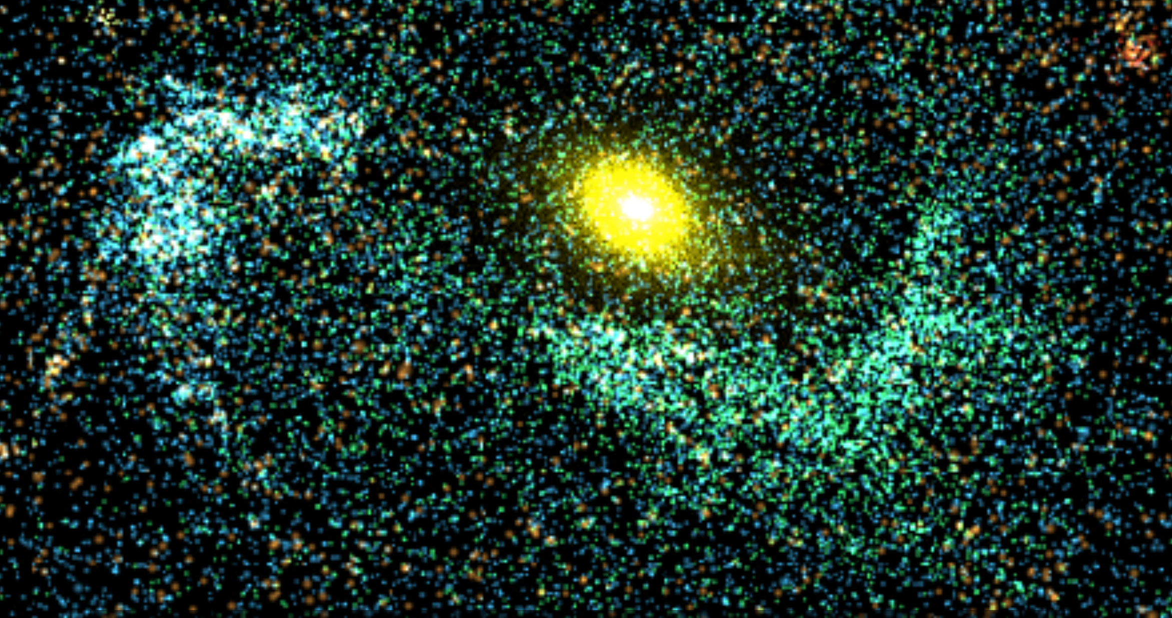
# From Observations to Origins: Disentangling Gas Flows in the CGM

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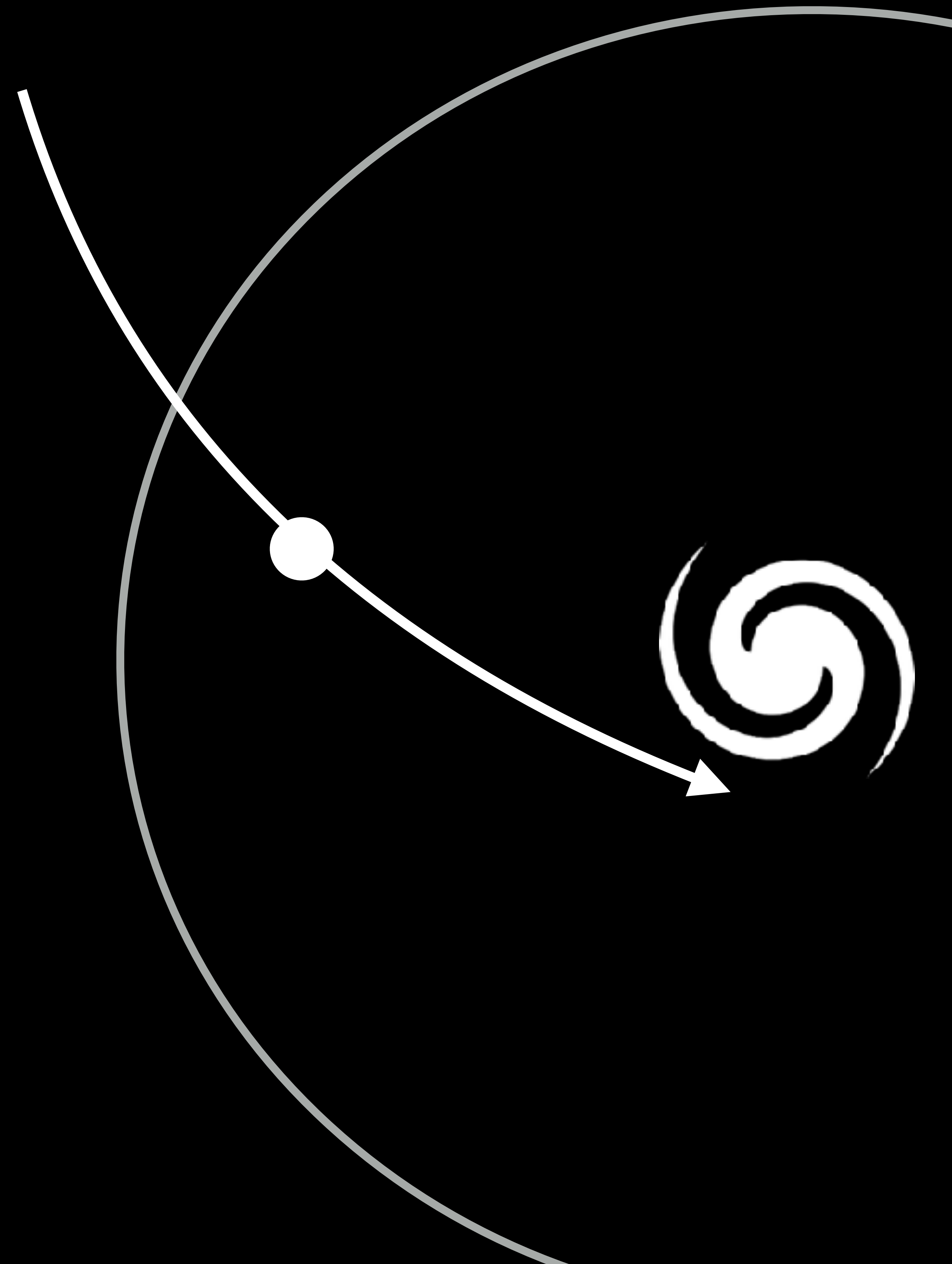
Collaborators include…
Claude-André Faucher-Giguère, Daniel Anglés-Alcázar, Jonathan Stern, and the FIRE collaboration

Northwestern University, August 3, 2018

# We employ a particle tracking analysis

- Heavily modified from Anglés-Alcázar17 to handle larger simulations and apply to more problems
- Track full history relative to all galaxies
- This is still a work in progress!



# Analysis Sample Overview

- FIRE-2: new hydro solver (MFM), better resolution ($m_p$~7000 $M_{sun}$ for MW analogs)
- ~20 zoom-in simulations
- $10^{10}$ $M_{sun}$ < $M_h$ < $10^{12}$ $M_{sun}$
- Trace the histories of $10^5$ particles in the CGM
- Focus on z=0.25 and z=2

Image Credit: Phil Hopkins

# What do our classifications really look like?

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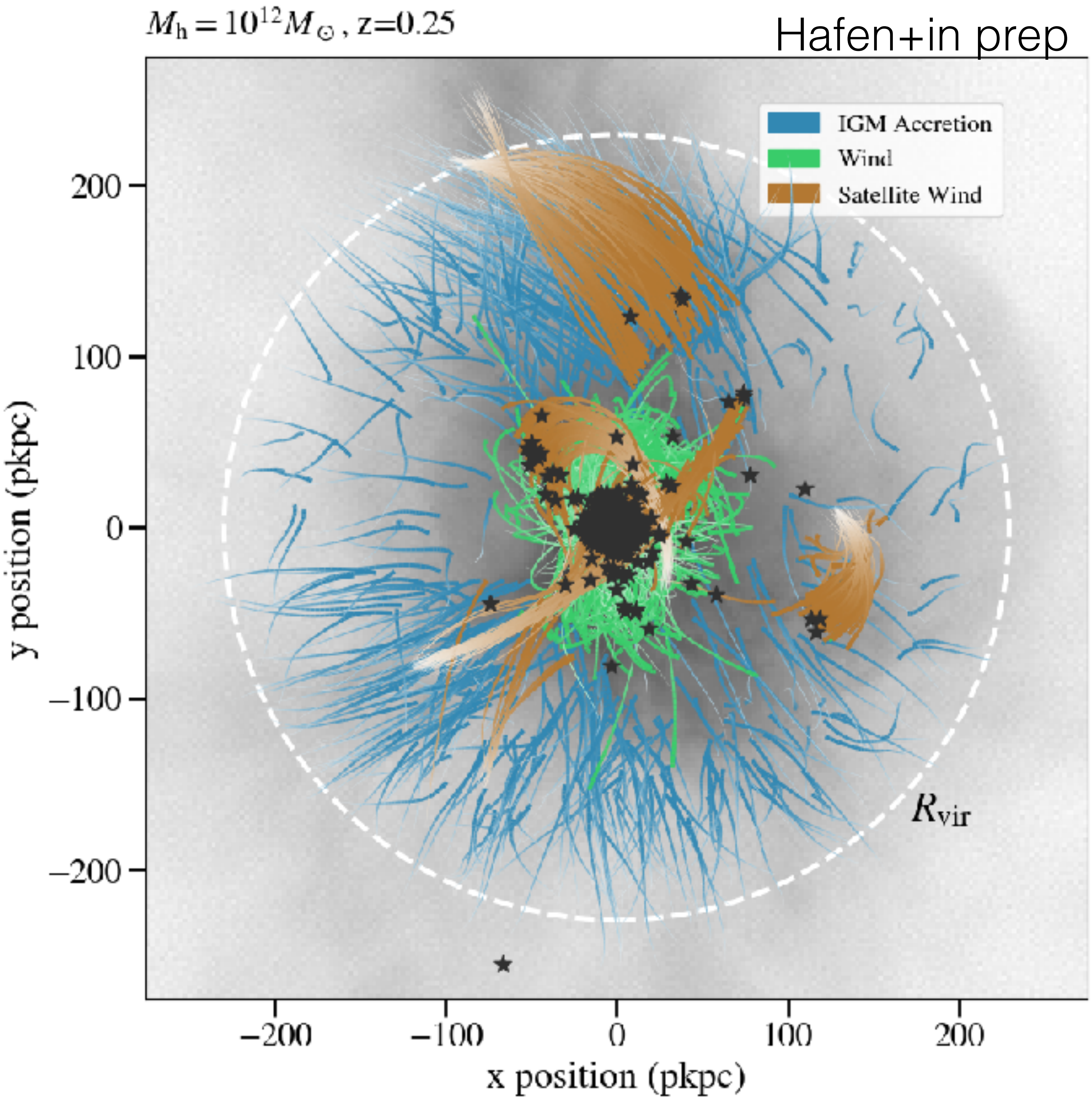


For simplicity, this only shows a sample of particles that have been in the CGM for 0.5-1 Gyr

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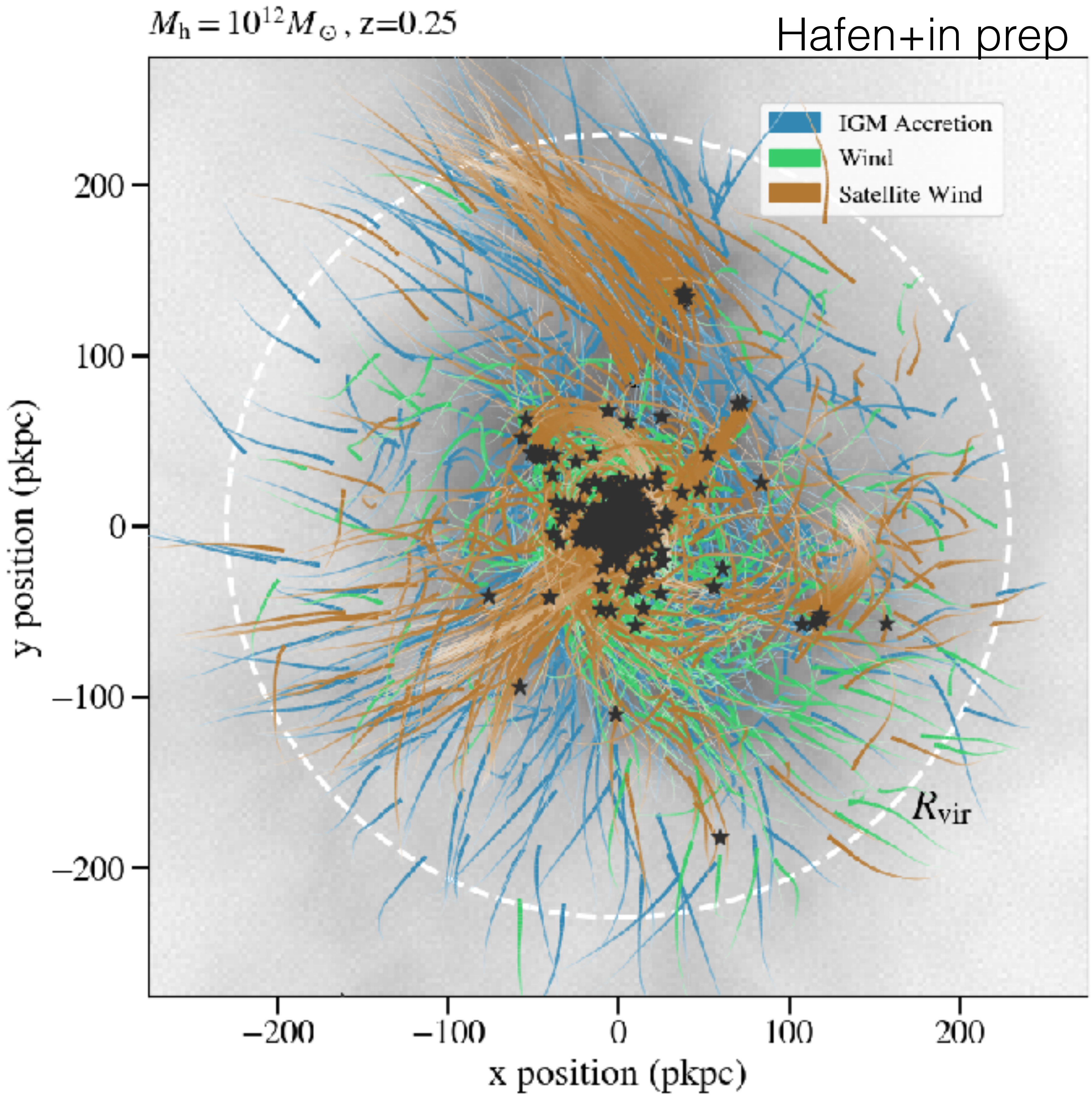
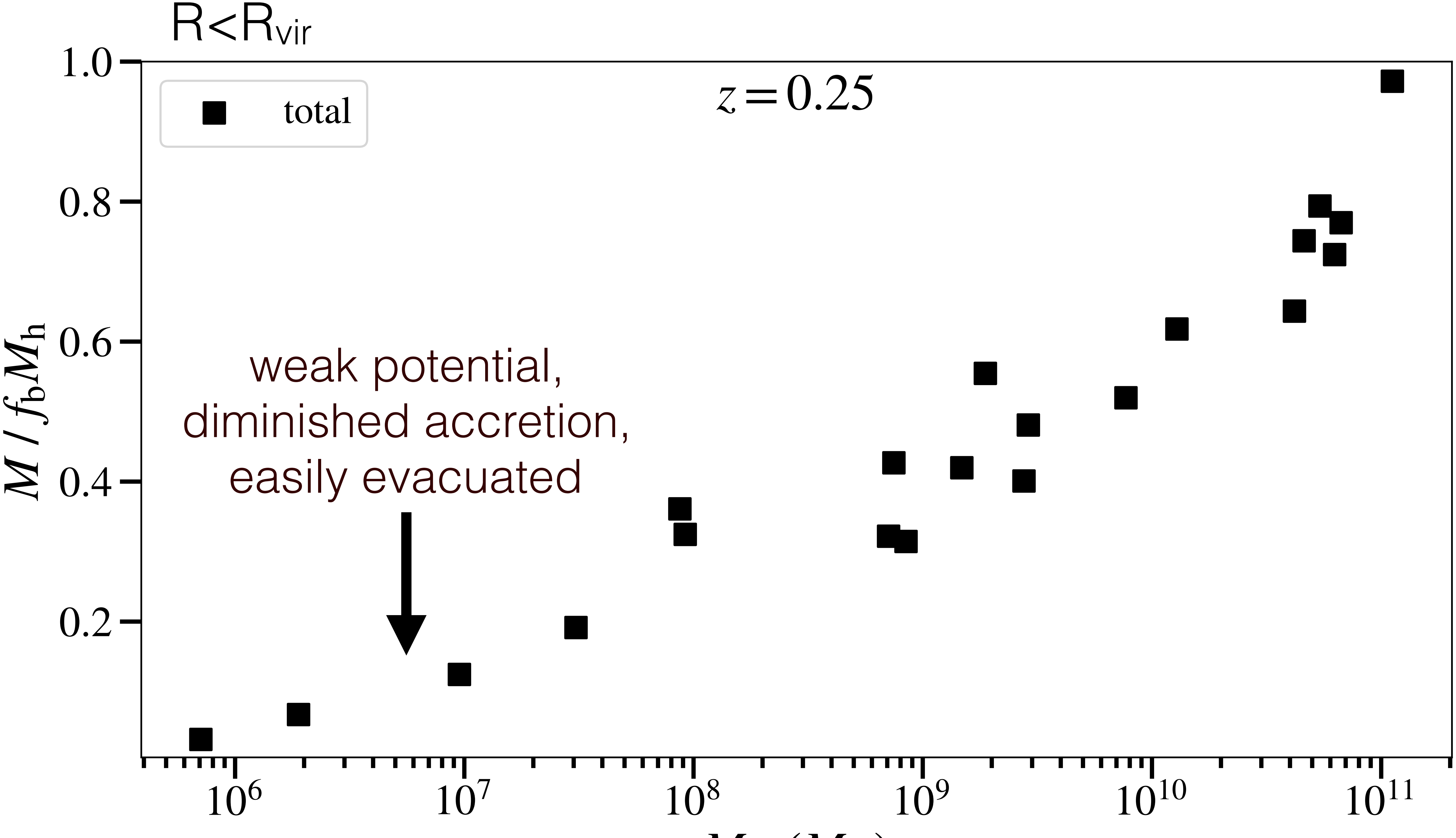



This shows trajectories for particles sampled from the CGM with no preselection

Complex trajectories suggest disentangling origins may be challenging…

# Missing baryons, but less at higher masses

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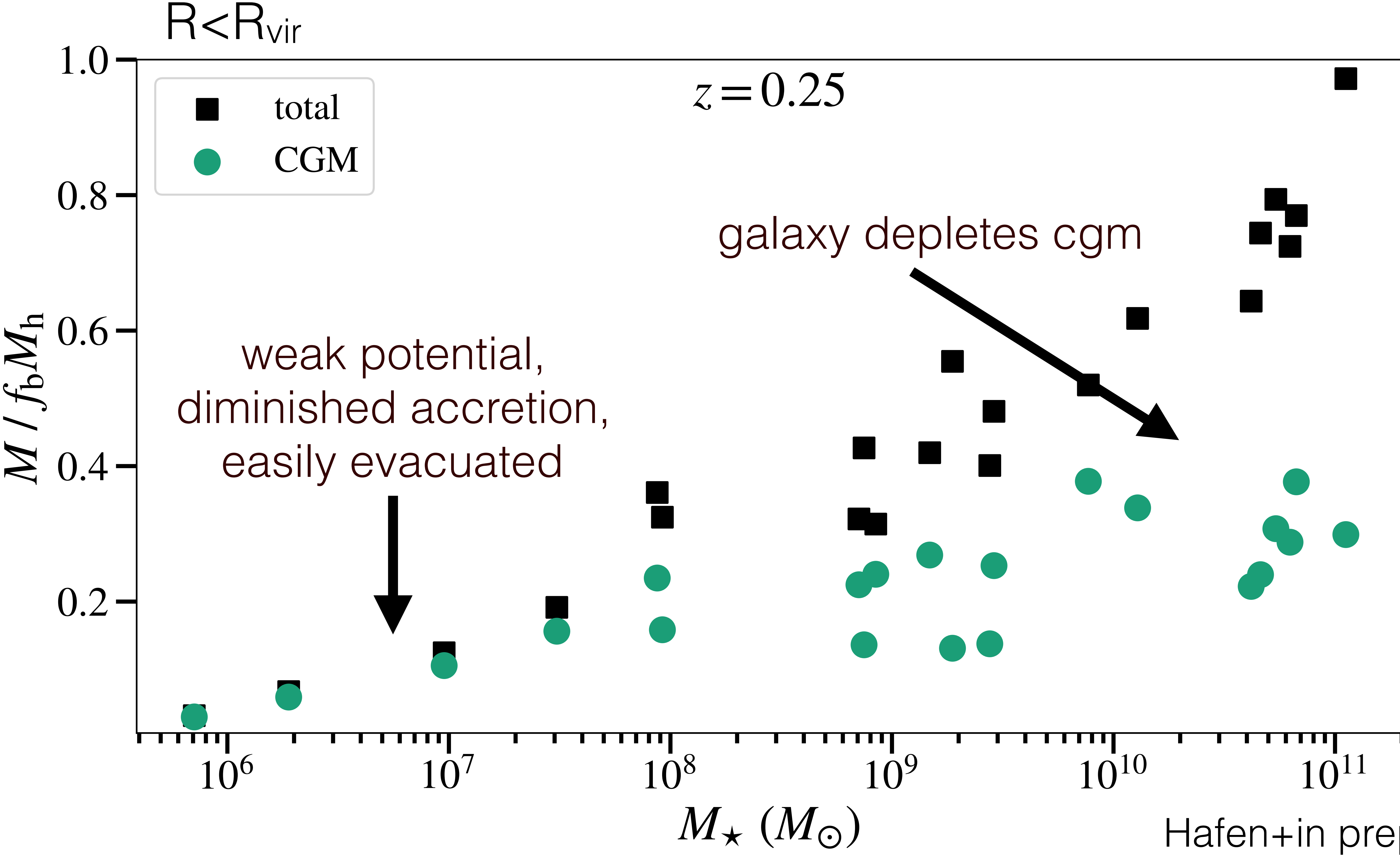


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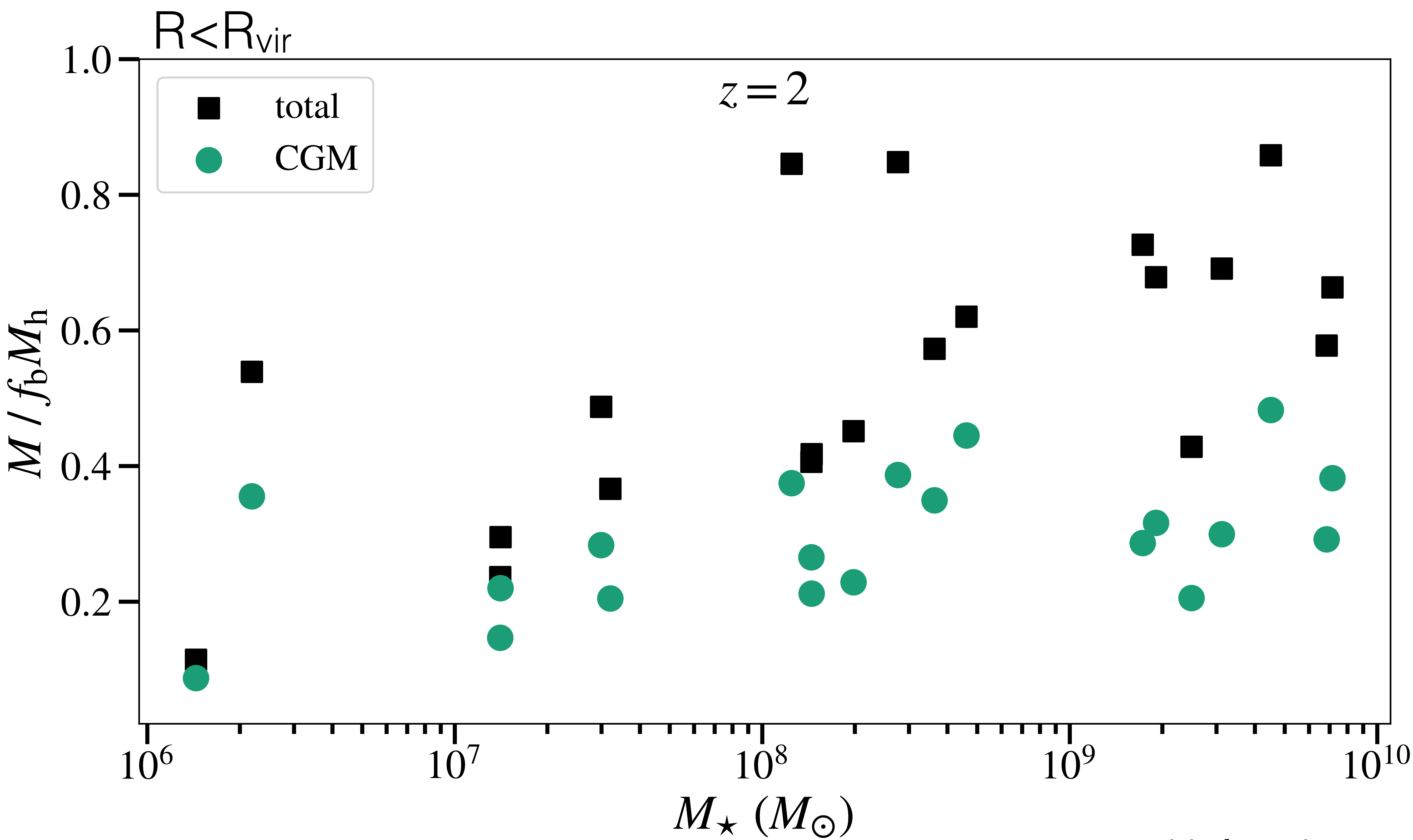


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# How do different gas flows contribute to the mass of the CGM?

IGM accretion on average >~50%

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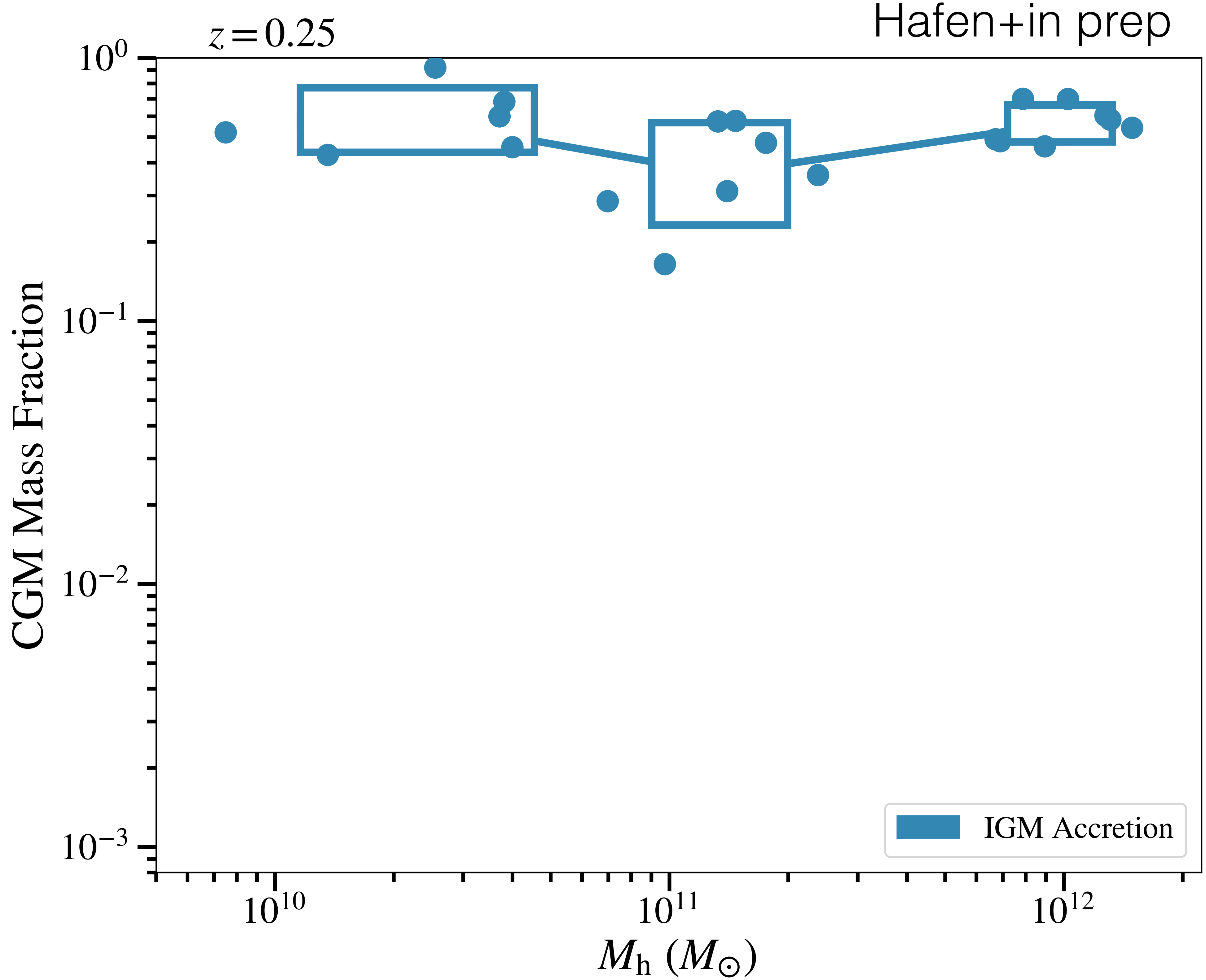

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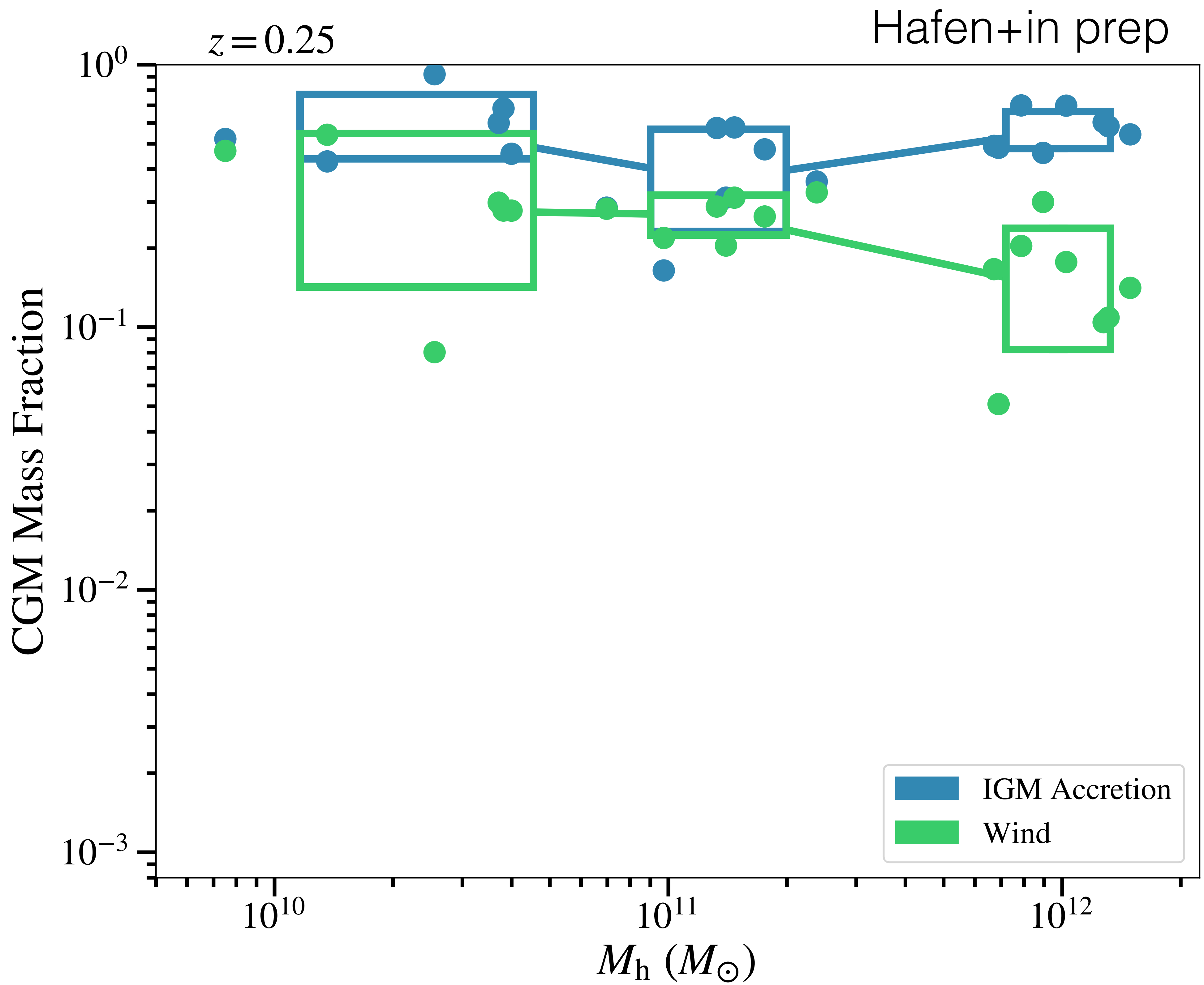
Galaxies return significant mass to the CGM via wind



# How do different gas flows contribute to the mass of the CGM?

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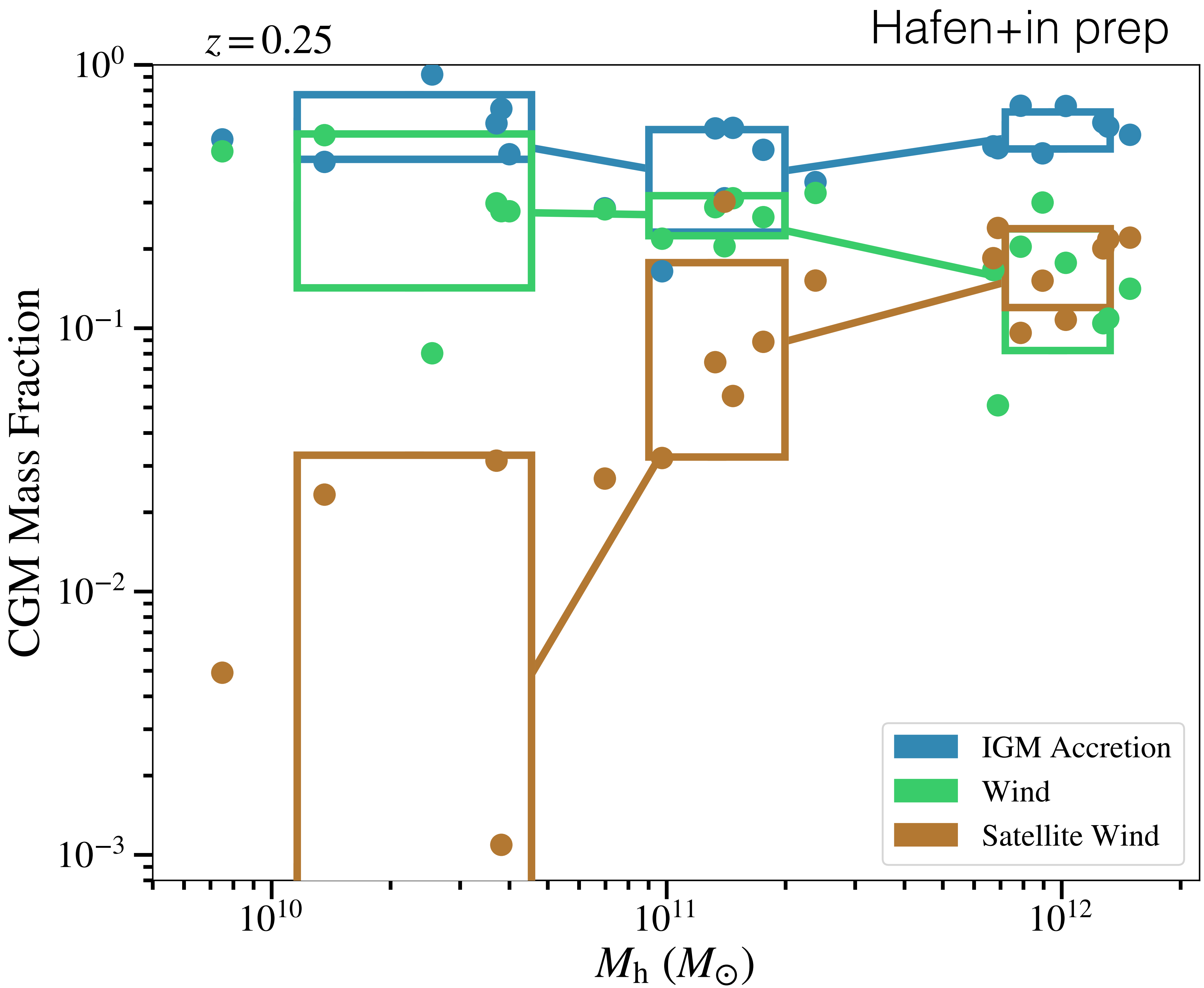
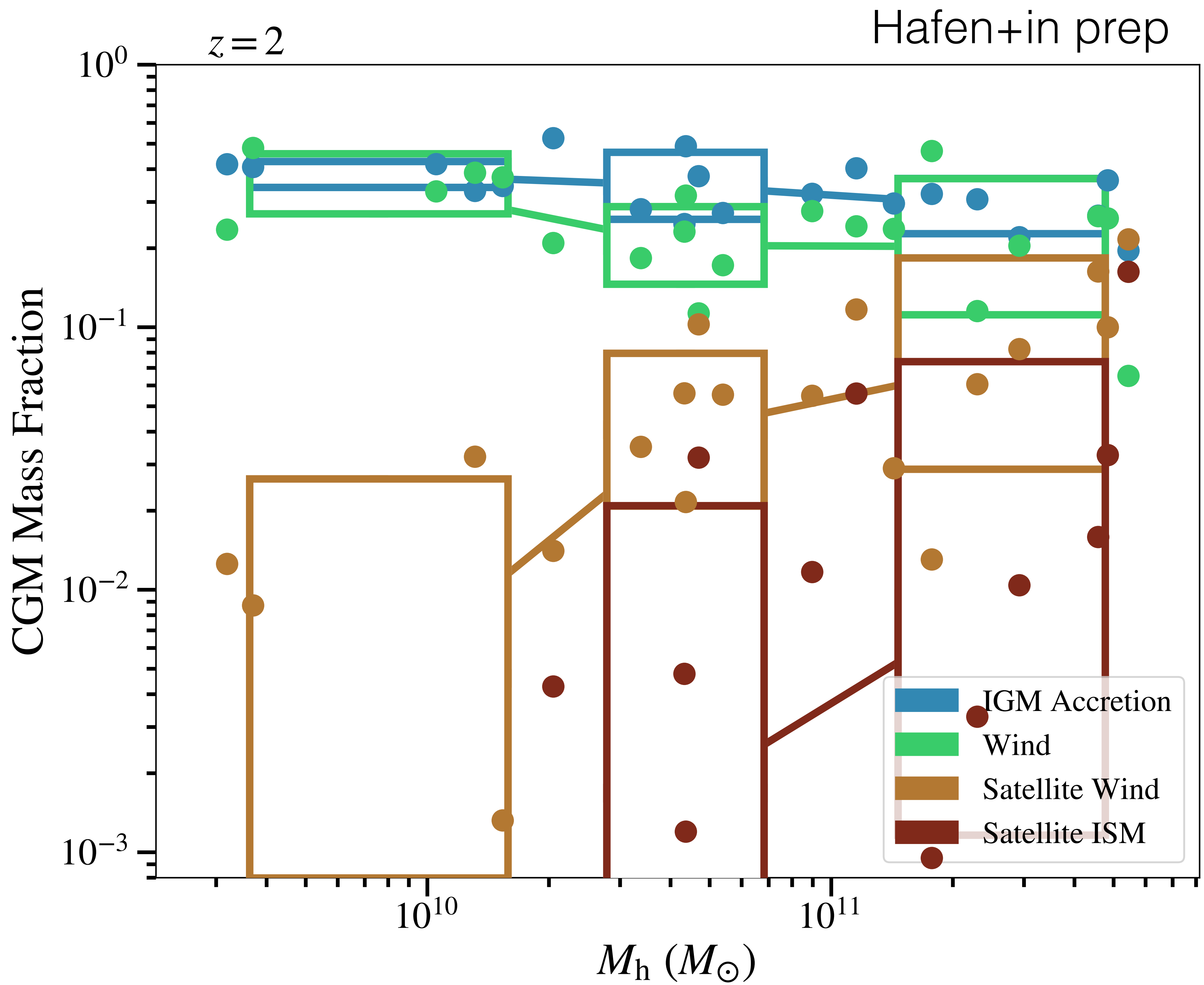
Galaxies return significant mass to the CGM via wind

Only MW mass galaxies have massive enough satellites for significant satellite wind



# Similar picture at z=2, but winds contribute more mass for MW analogs

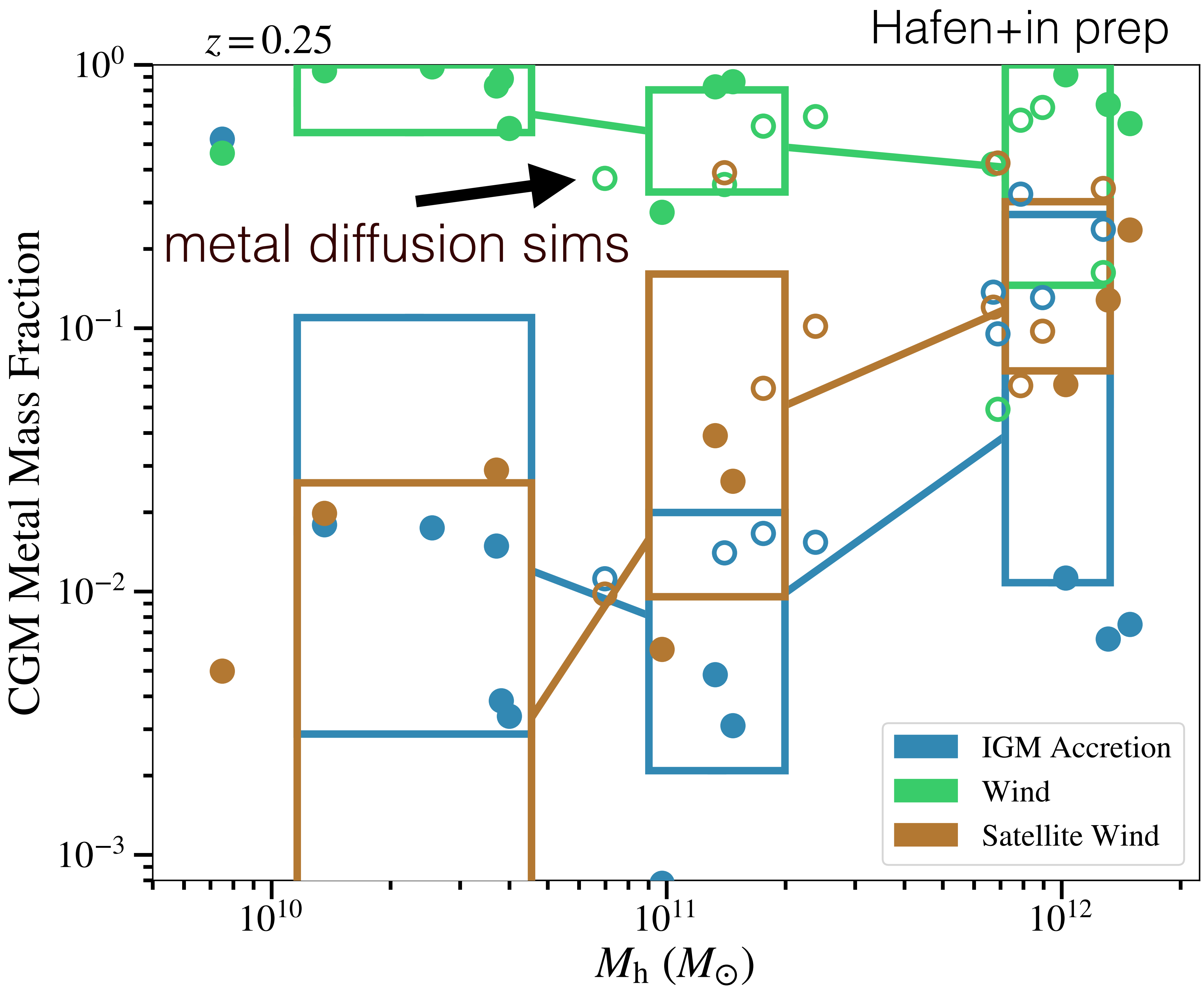
Peak of star formation -> Significant galactic winds



# Winds contribute most of the metal mass

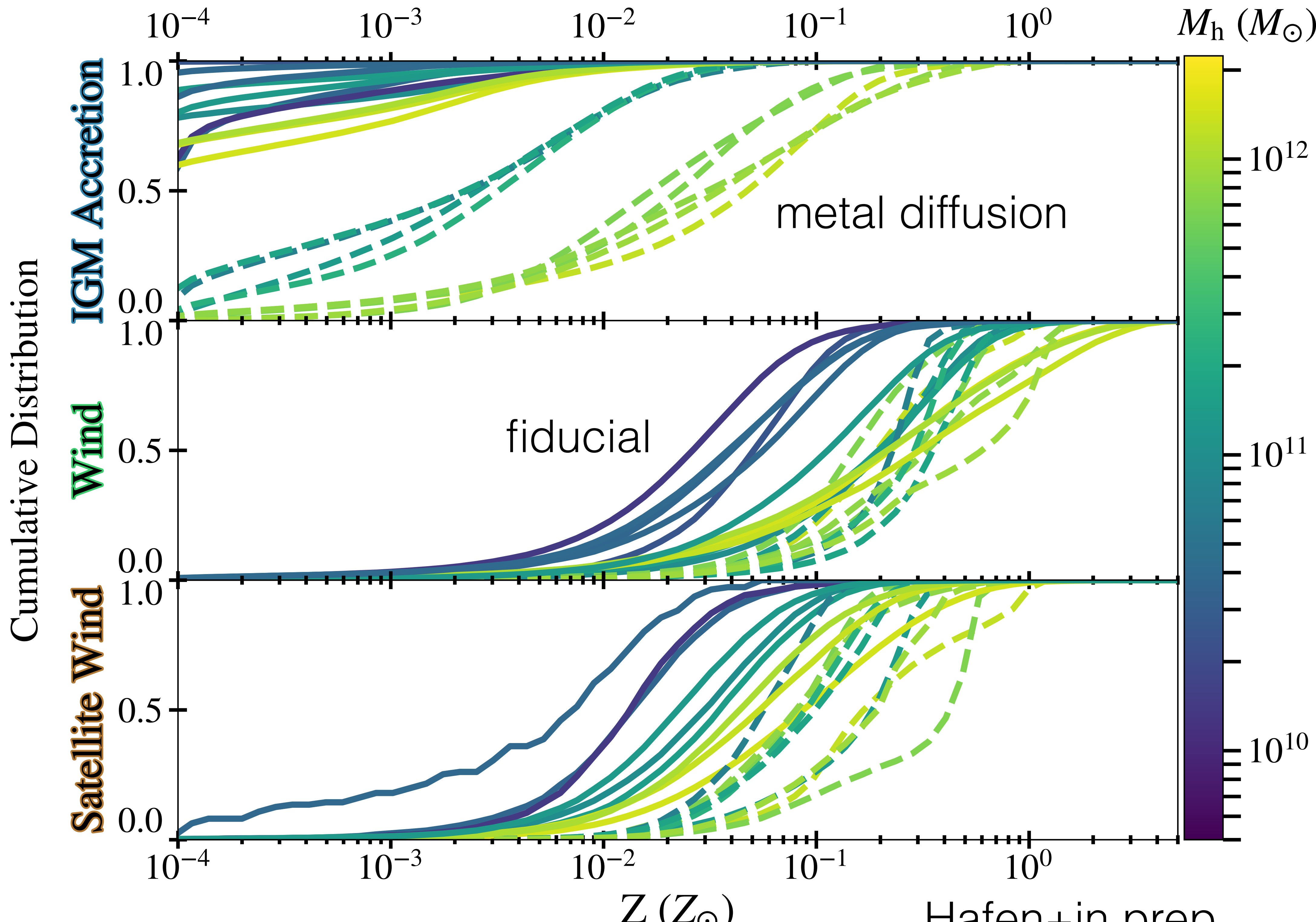
Metal diffusion complicates the picture

Satellite winds can be important!



# For a given halo mass, CGM gas flows with different origins have different metallicity distributions…

Gas in the CGM at z=0.25

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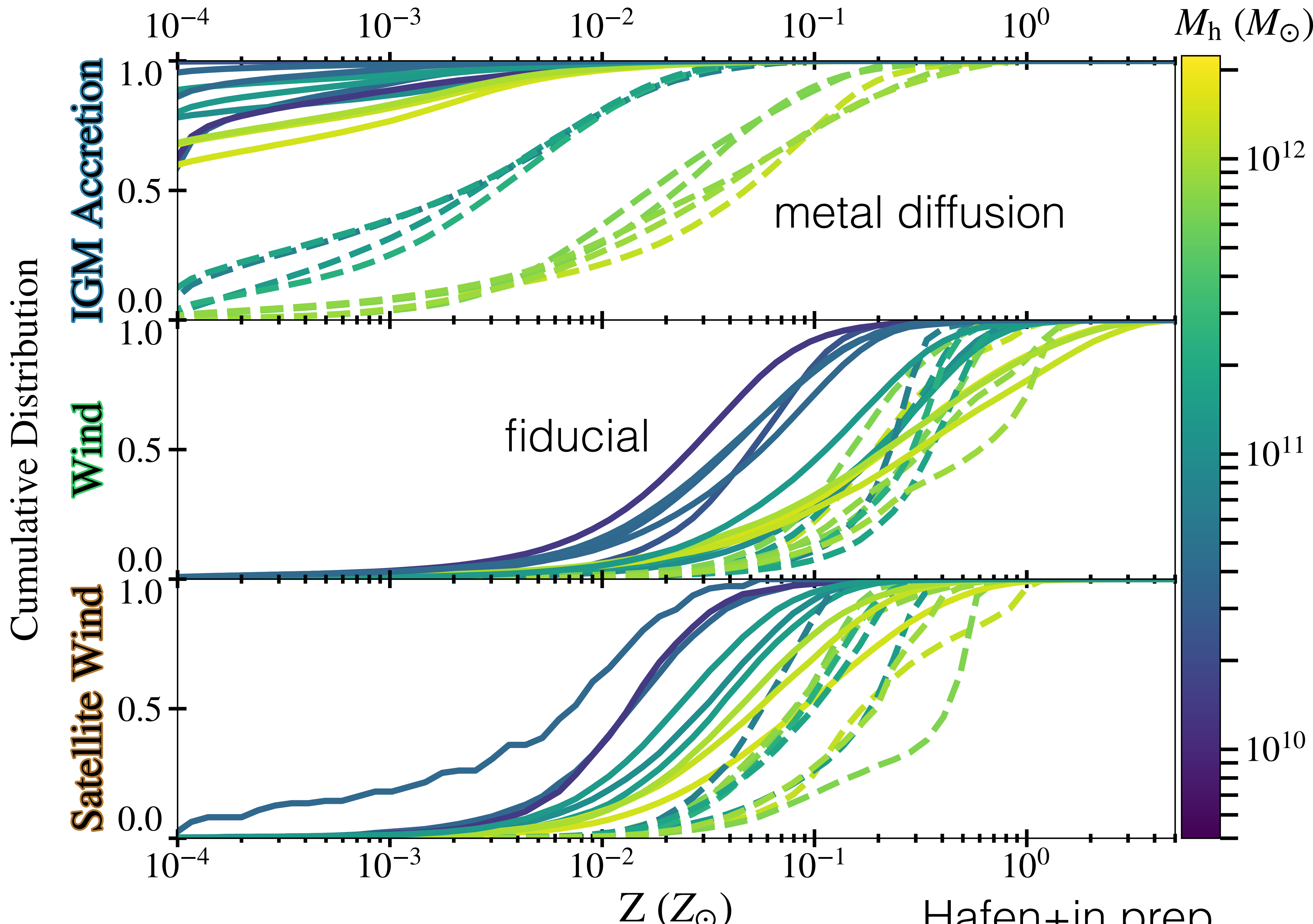
# …but different mass halos produce a spread in metallicity.

Gas in the CGM at z=0.25

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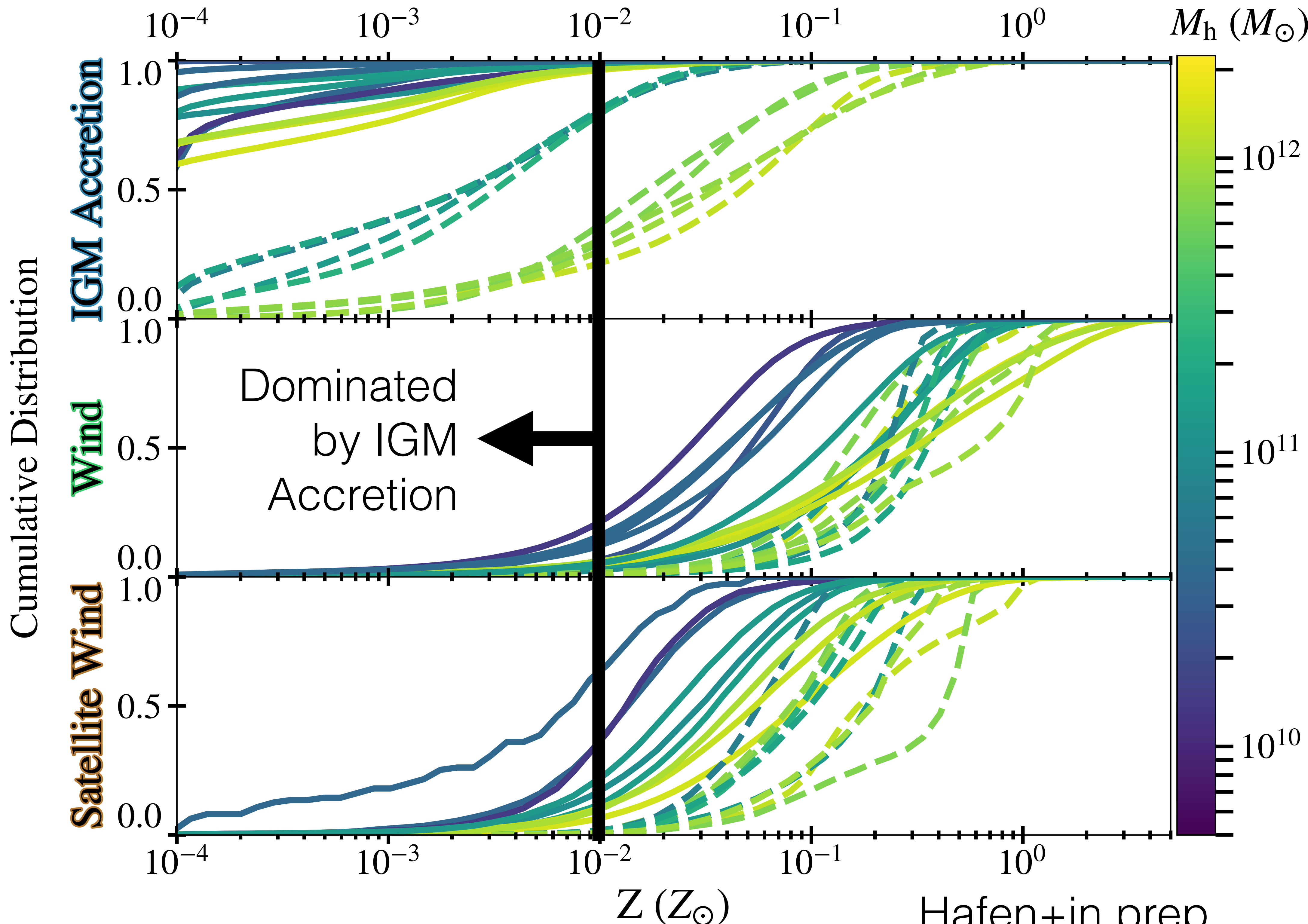
# IGM accretion may be able to be distinguished from winds at $Z \sim 10^{-2}\ Z_{sun}$

Gas in the CGM at z=0.25



# Conclusions

- Studied origin of CGM mass ($<R_{vir}$) over $M_h = 10^{10}$-$10^{12}$ $M_{sun}$ at z=0.25, 2
- Feedback / weak accretion -> halo baryon mass is a larger fraction of the cosmological baryon budget at higher halo mass
- IGM accretion is >~50% of the CGM by mass
- Strong winds from the central galaxy can contribute significant CGM mass, especially at low $M_h$ (>~30% at $M_h \sim 10^{10}$-$10^{11} M_{sun}$)
- Satellite winds can contribute up to ~20%, but only for $M_h \sim 10^{12} M_{sun}$
- Particle tracking suggests $Z \sim 10^{-2}$ $Z_{sun}$ may be useful for separating IGM accretion from winds, but further analysis is necessary

Explore for yourself!
[zhafen.github.io/Latte-CGM](zhafen.github.io/Latte-CGM)
[zhafen.github.io/time-fly](zhafen.github.io/time-fly)