a semi-analytic model for pop III star formation

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ucla / 6.24.24

how can we use large scale observational probes to understand the properties of the first stars?

theoretical models are necessary to optimize and interpret future observations

efficient

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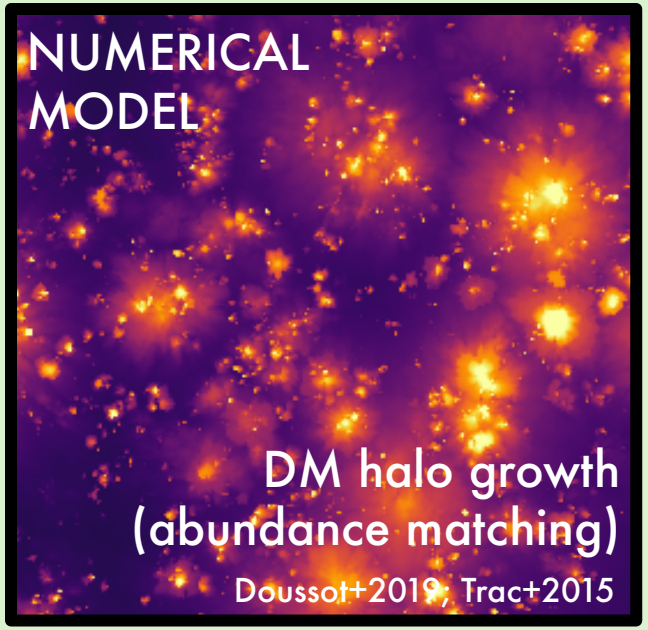
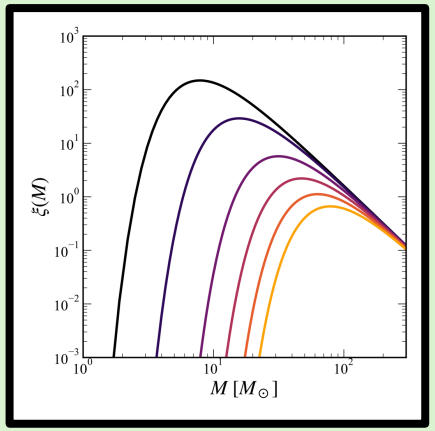
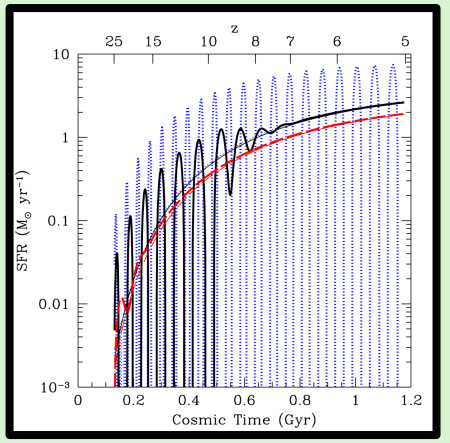


ANALYTIC MODELS



Pop III IMF



'bursty' star formation

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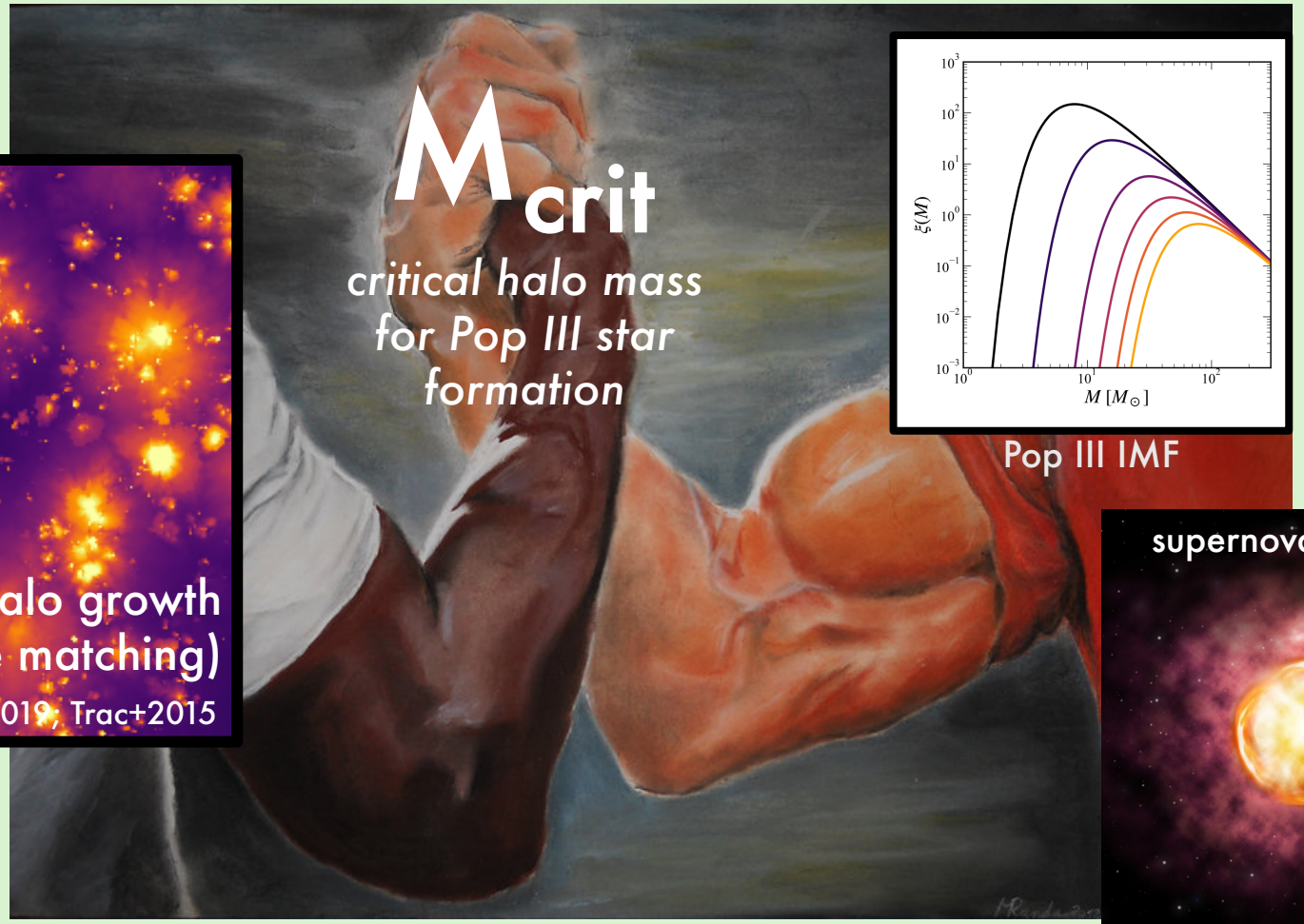
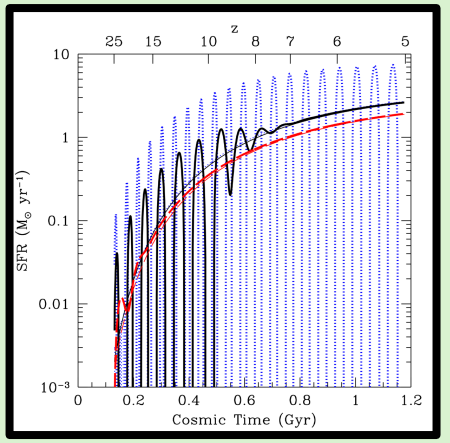


NUMERICAL MODEL

DM halo growth (abundance matching)

Doussot+2019; Trac+2015

Pop III IMF



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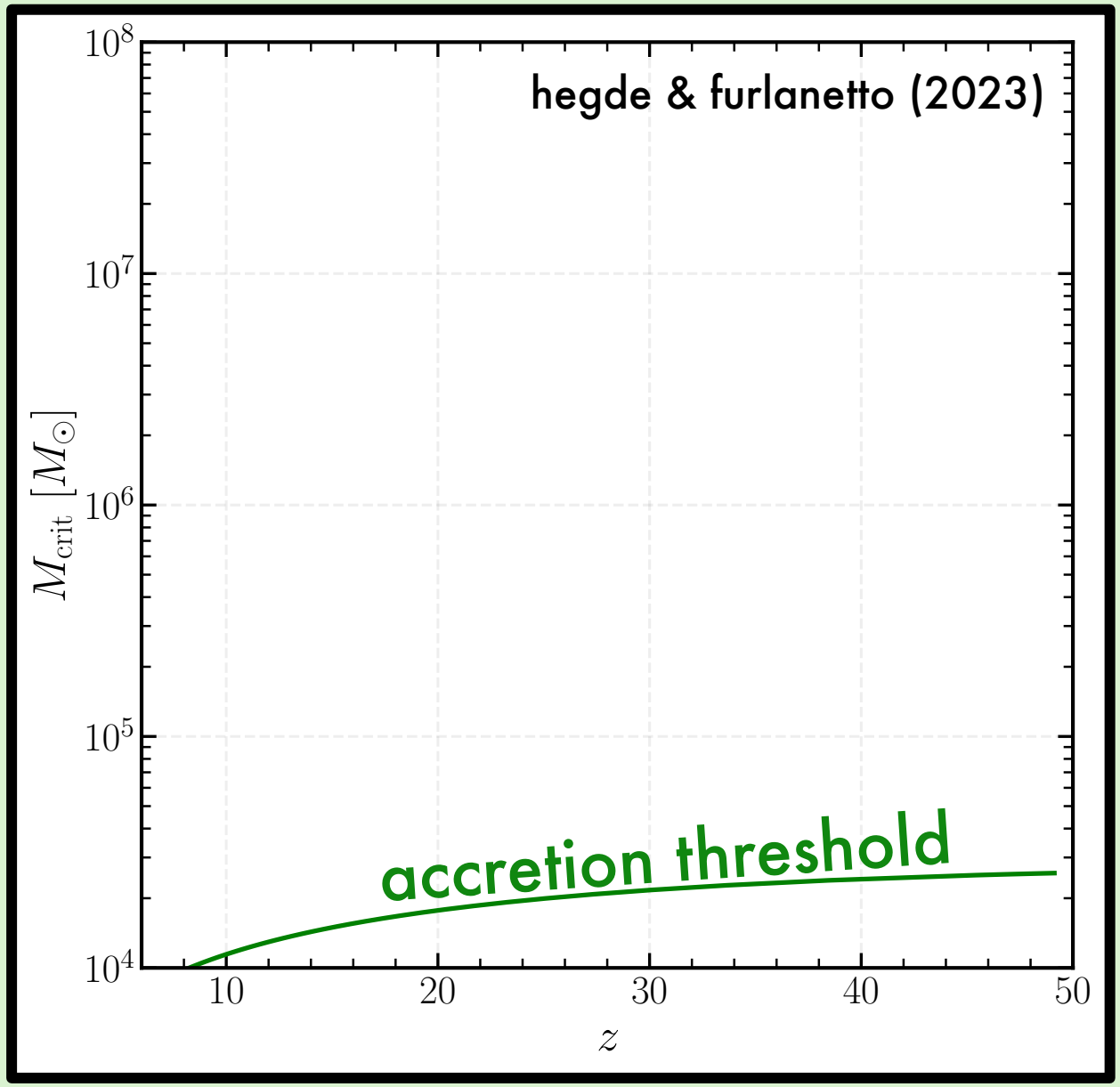
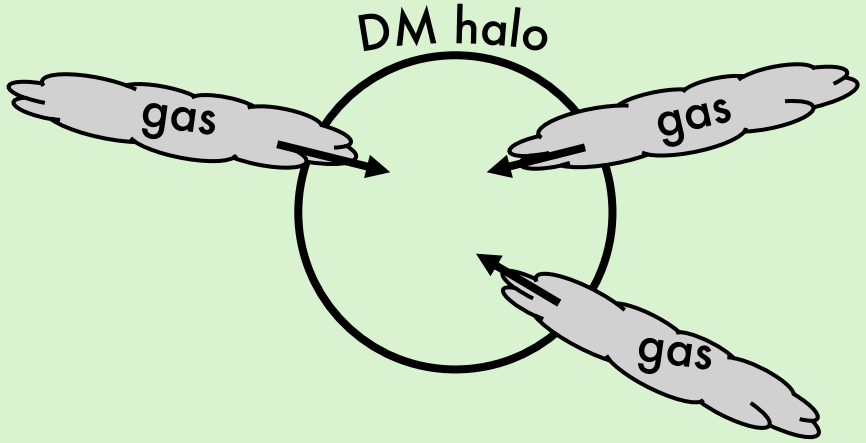
we can estimate this mass scale in a modular way

step 1: halo needs to accrete gas



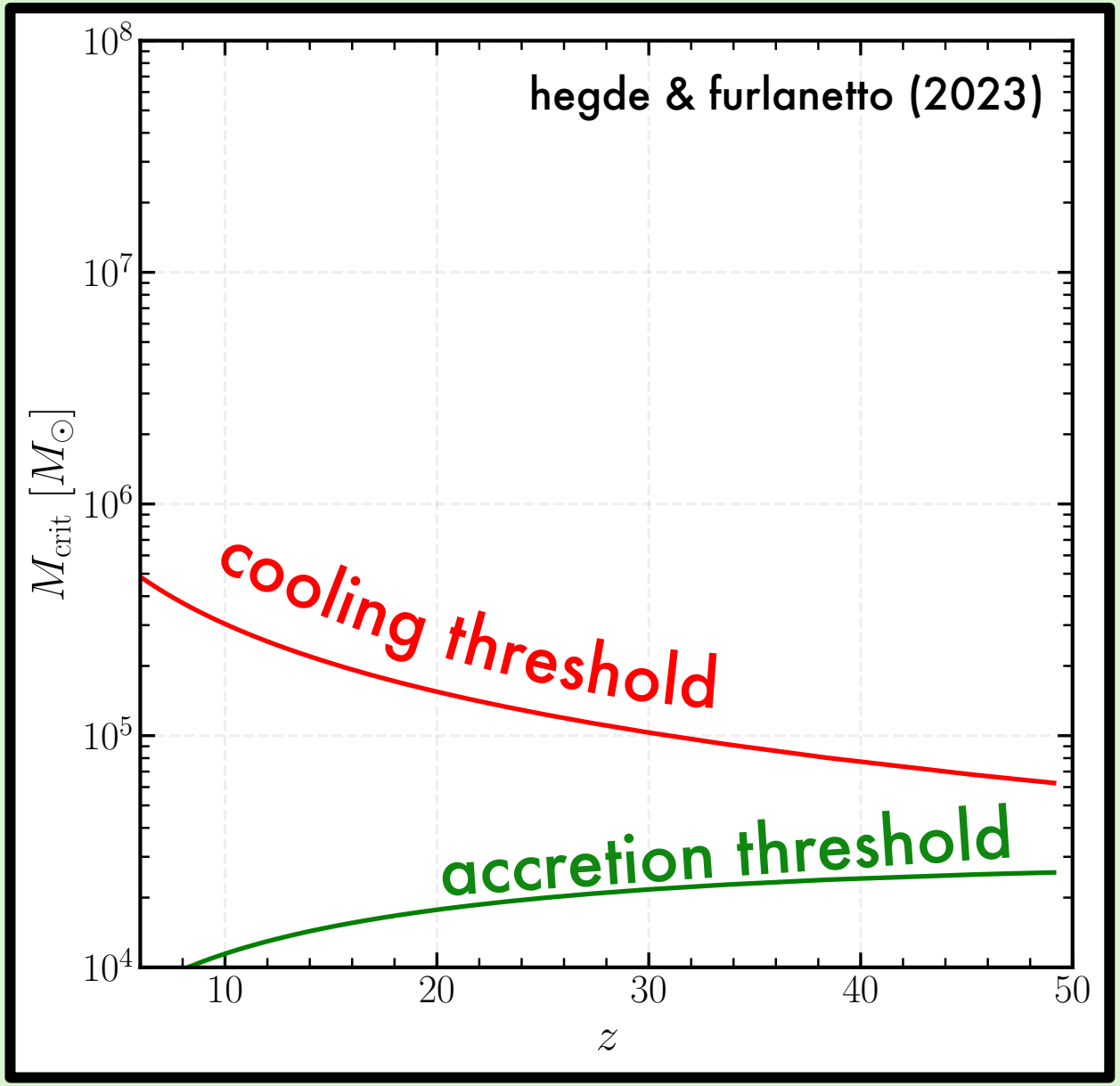


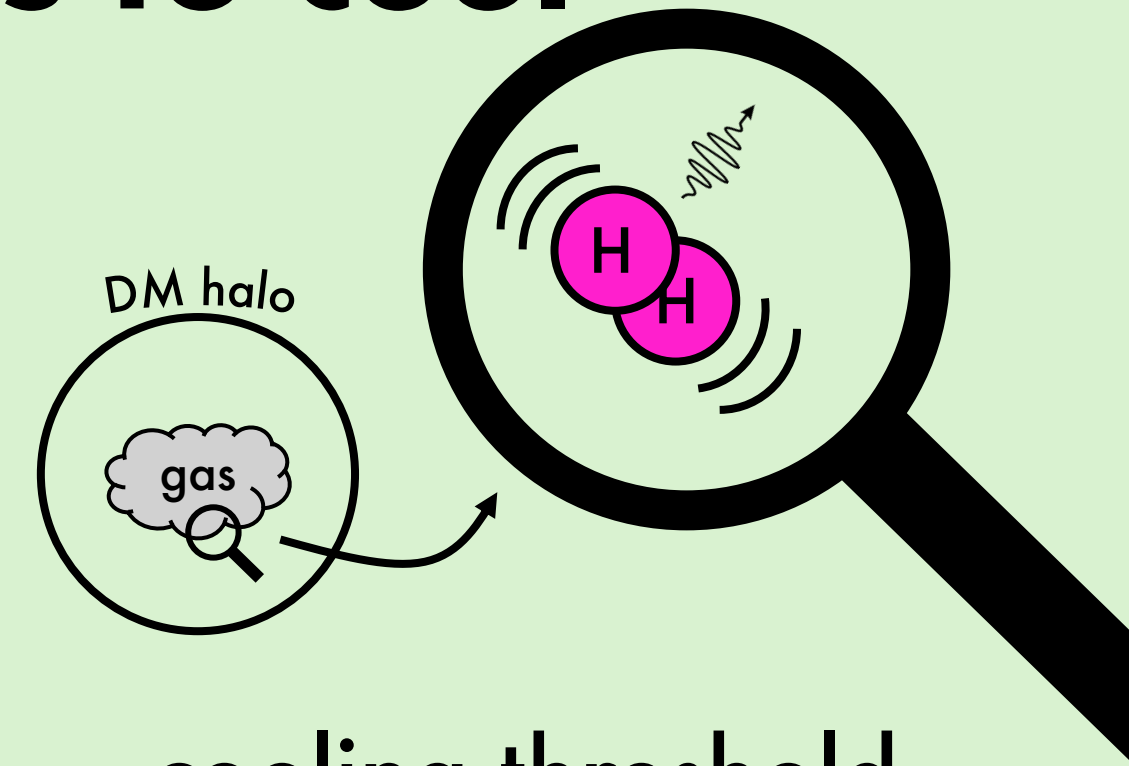
filter mass

'cosmological jeans mass'

describes the scale above which baryon density fluctuations can grow relative to the DM fluctuations

step 2: the gas needs to cool





cooling threshold

sets the halo mass necessary to reach the critical H_2 density – so that the cooling time is shorter than the free-fall time

unfortunately, there's a wrinkle...

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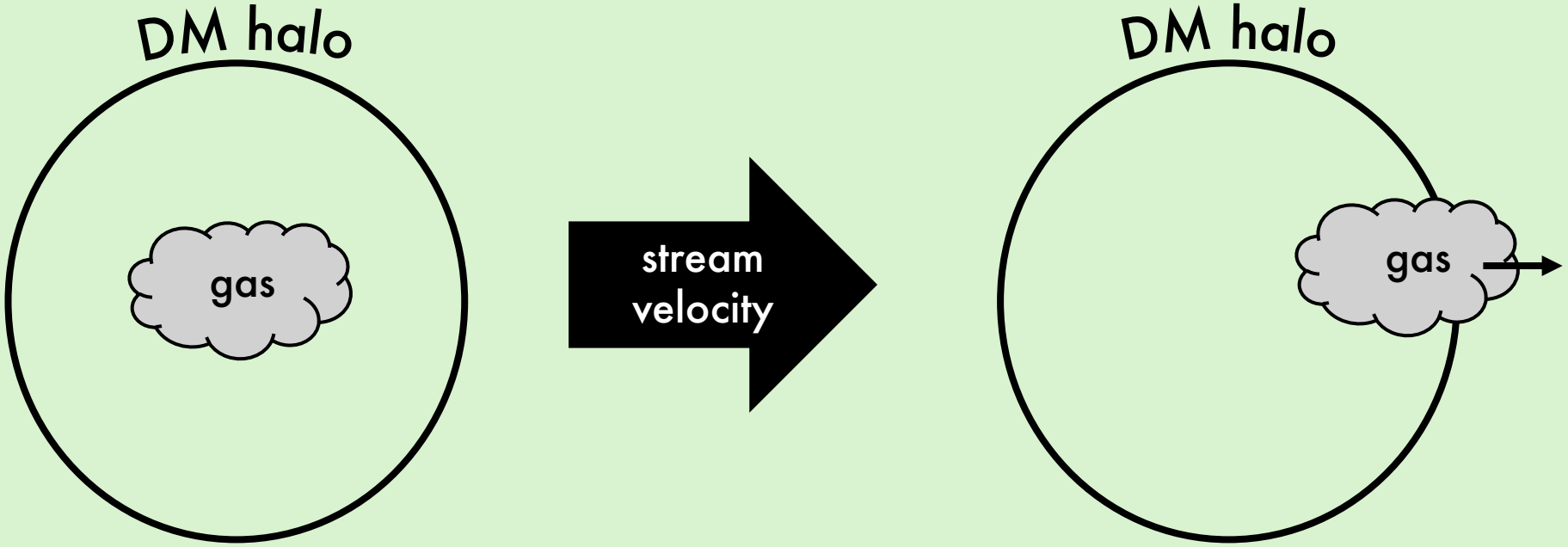
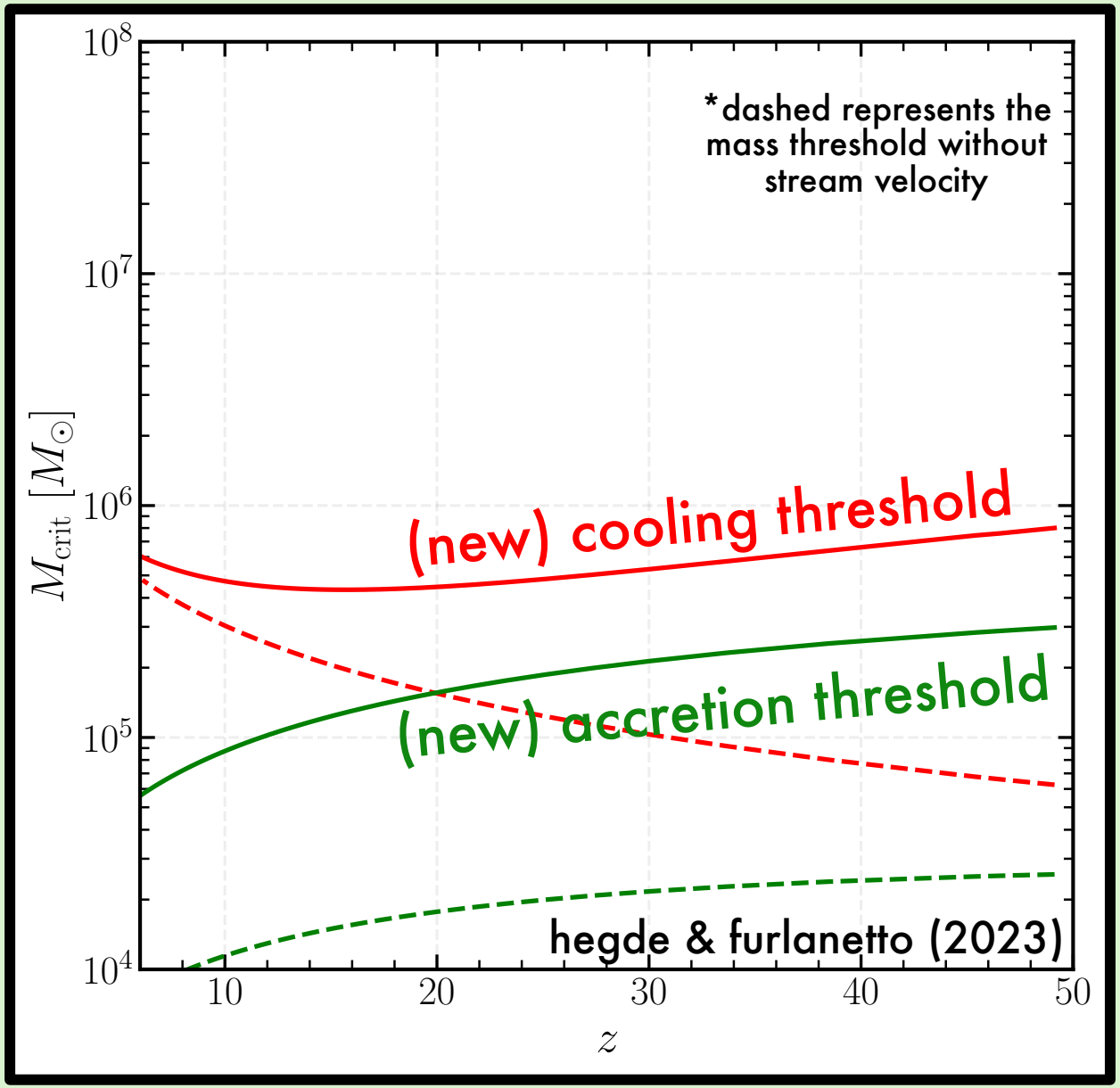
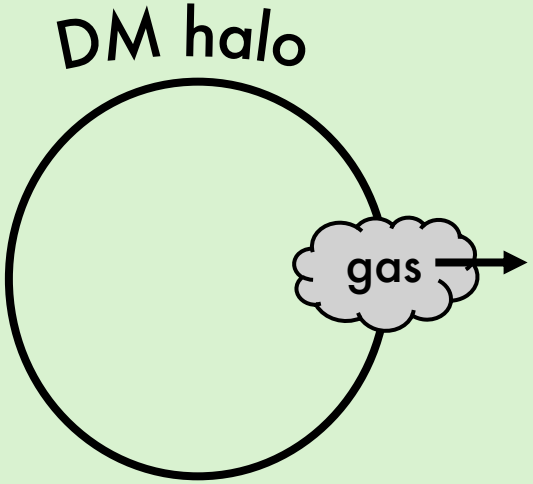


the stream velocity suppresses gas accretion onto the smallest DM halos

the stream velocity modifies these

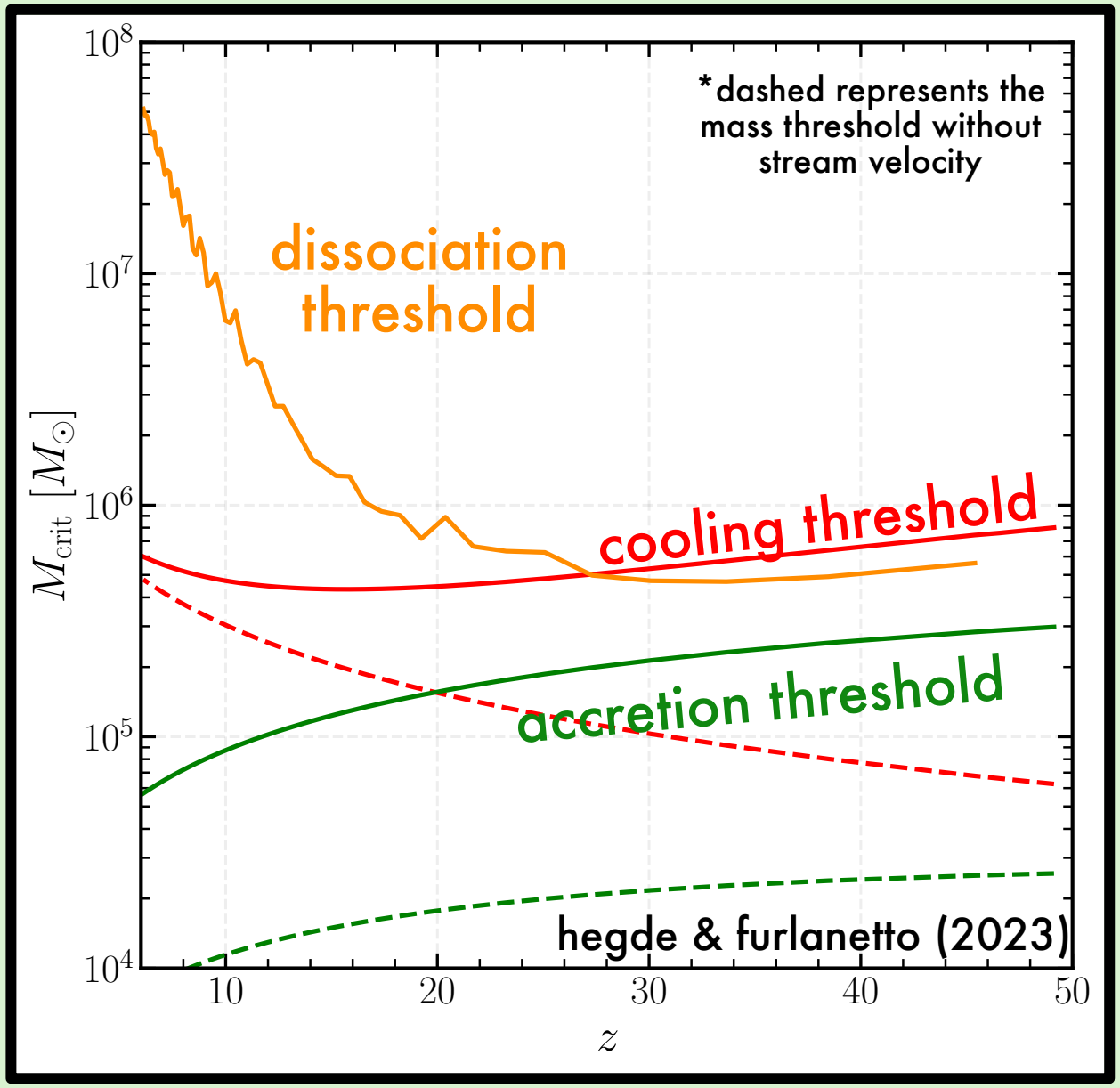


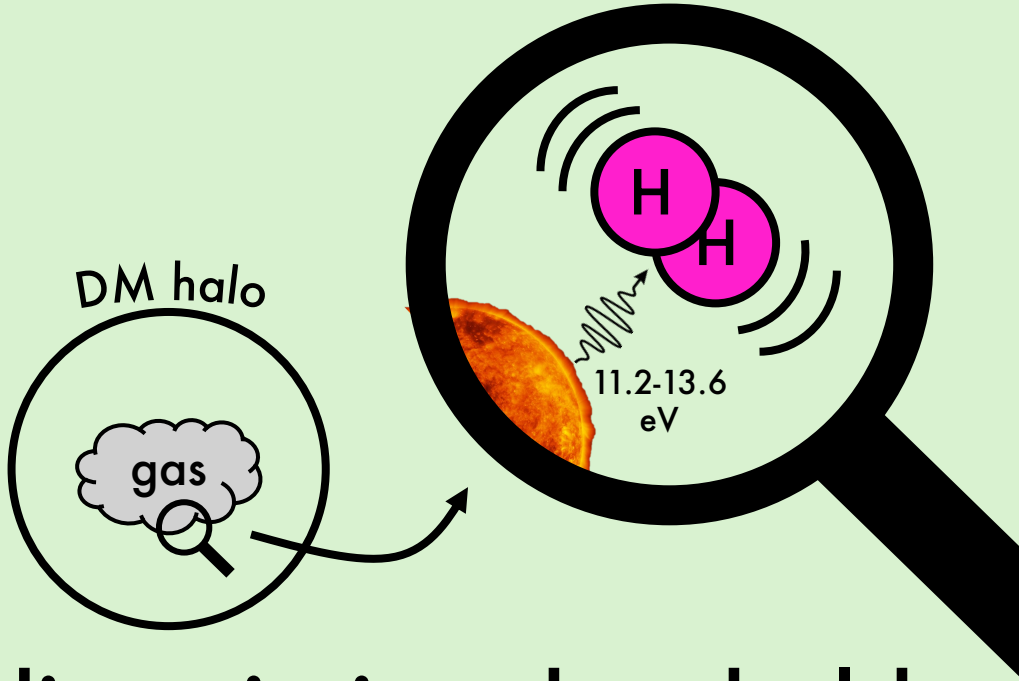


streaming threshold

the stream velocity raises the minimum mass required to build up a gas reservoir and efficiently cool

and stellar UV feedback does too

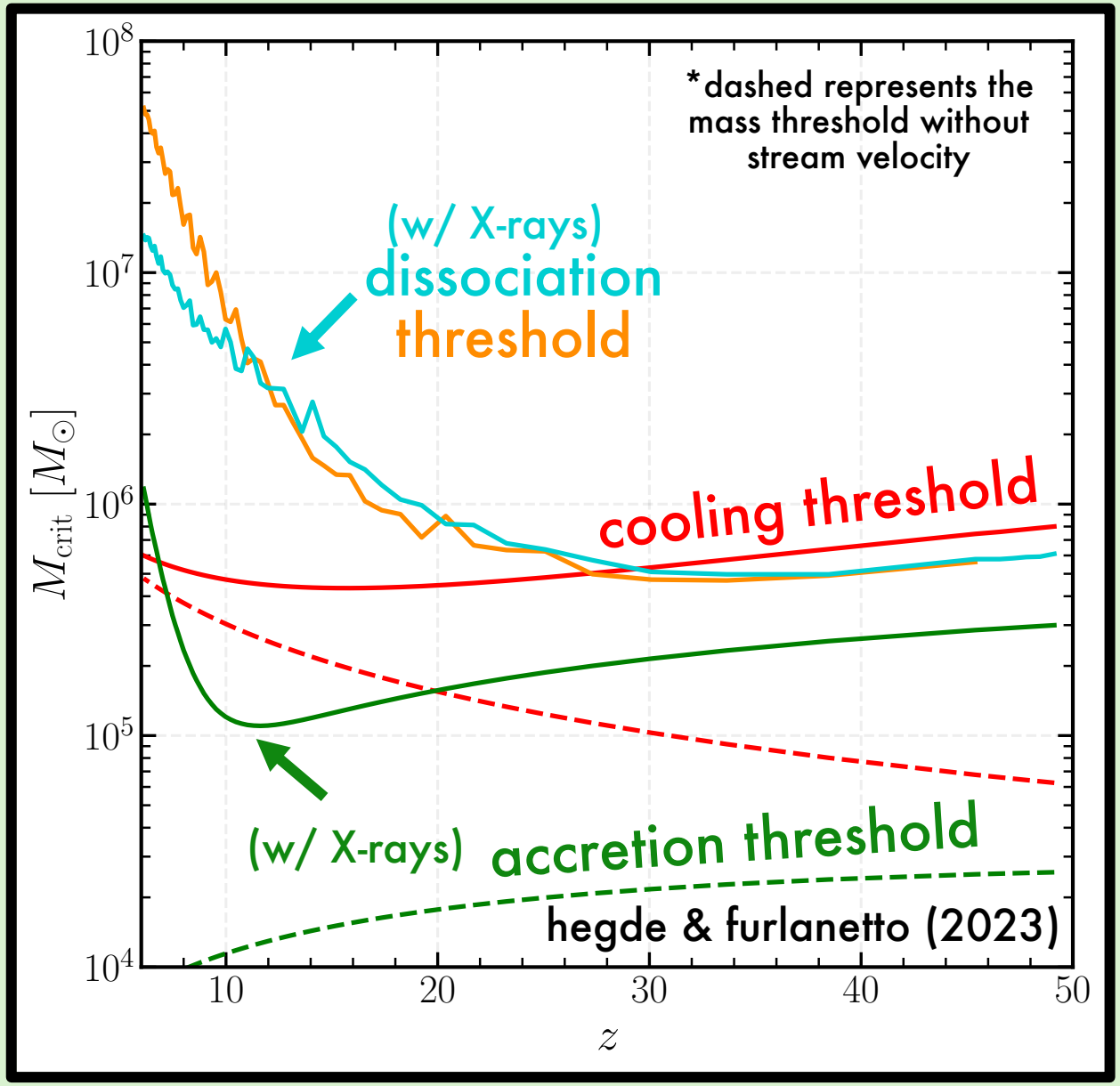


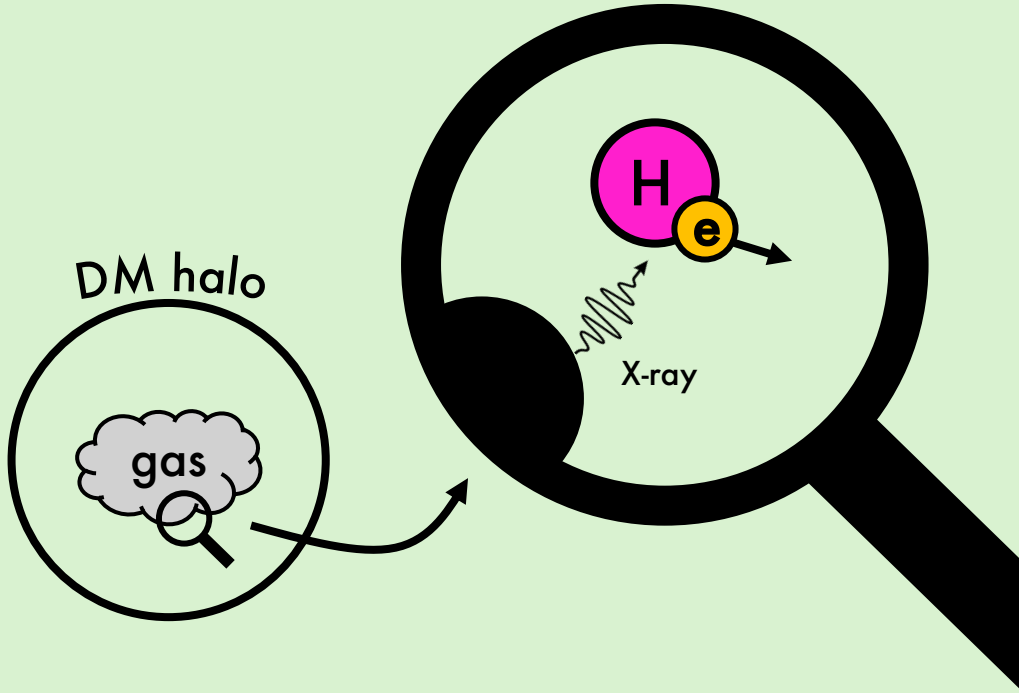


dissociation threshold

balancing the rates of H_2 formation and dissociation yields a threshold mass scale to overcome a metagalactic UV/Lyman-Werner background

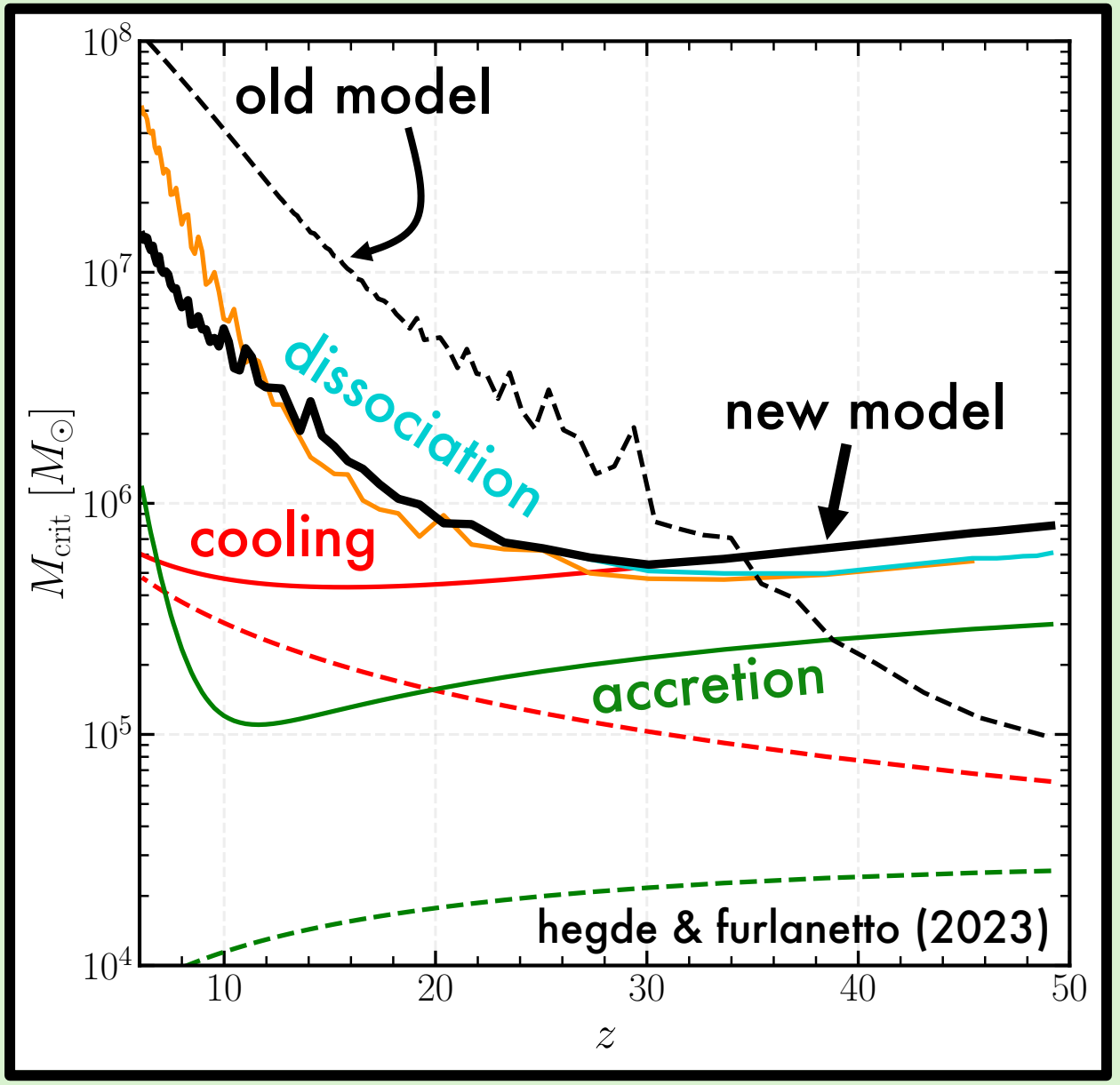
x-rays can be both good and bad





X-ray effects

as the first stars die, X-ray sources (such as high-mass X-ray binaries) will appear, ionizing and heating the IGM – these effects modify the accretion and dissociation thresholds



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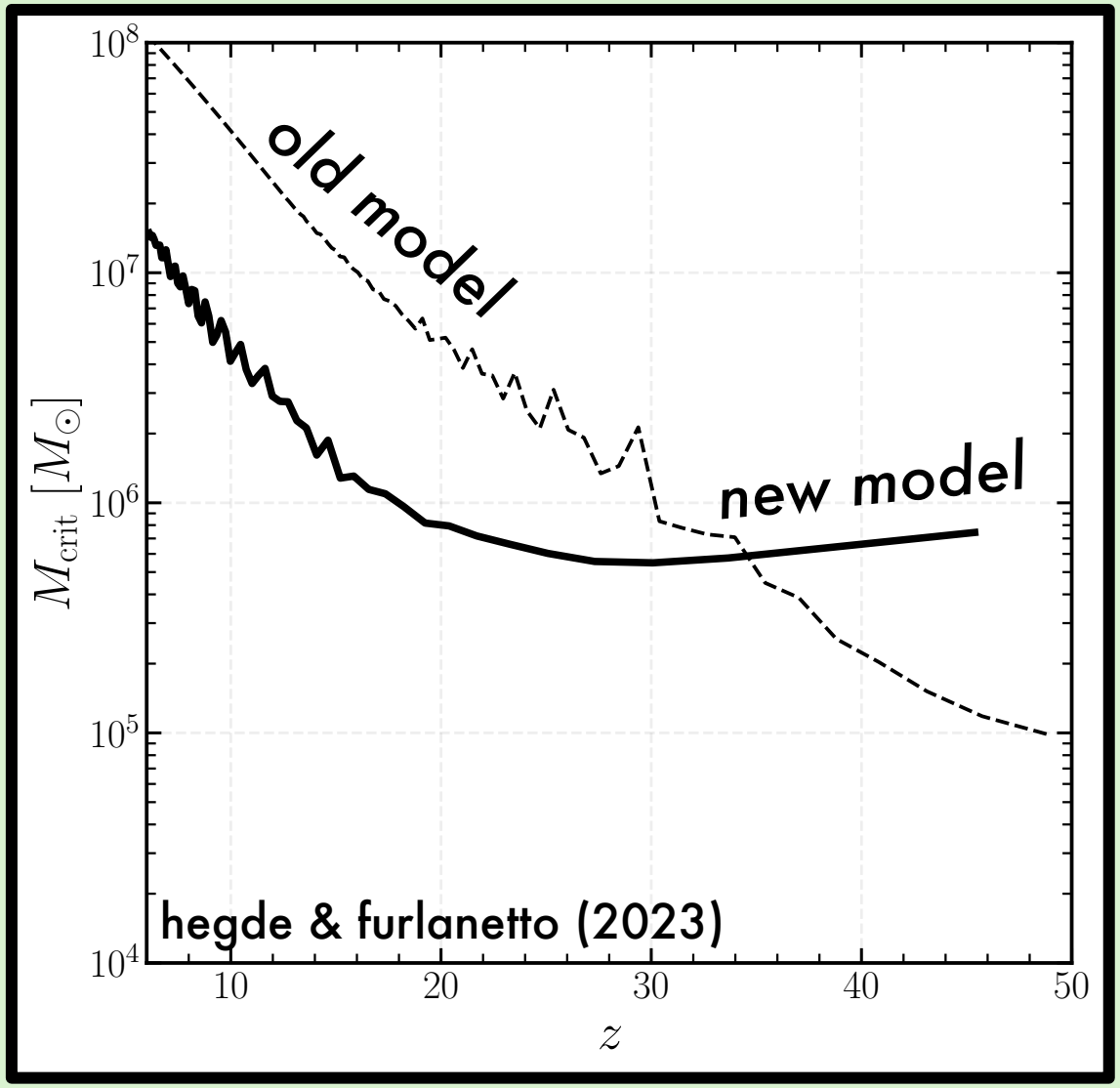
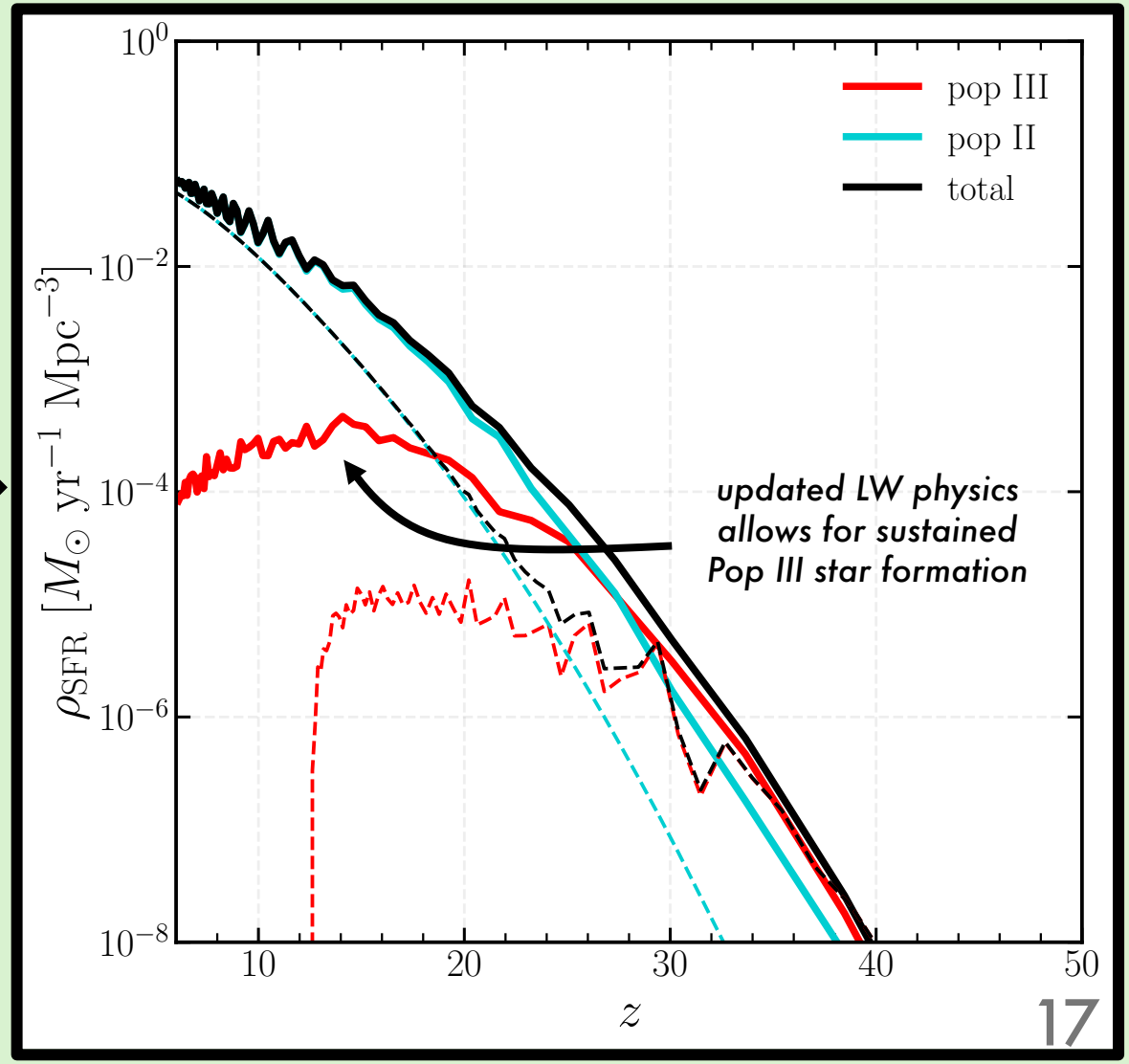
ingredients

(for our fiducial model)

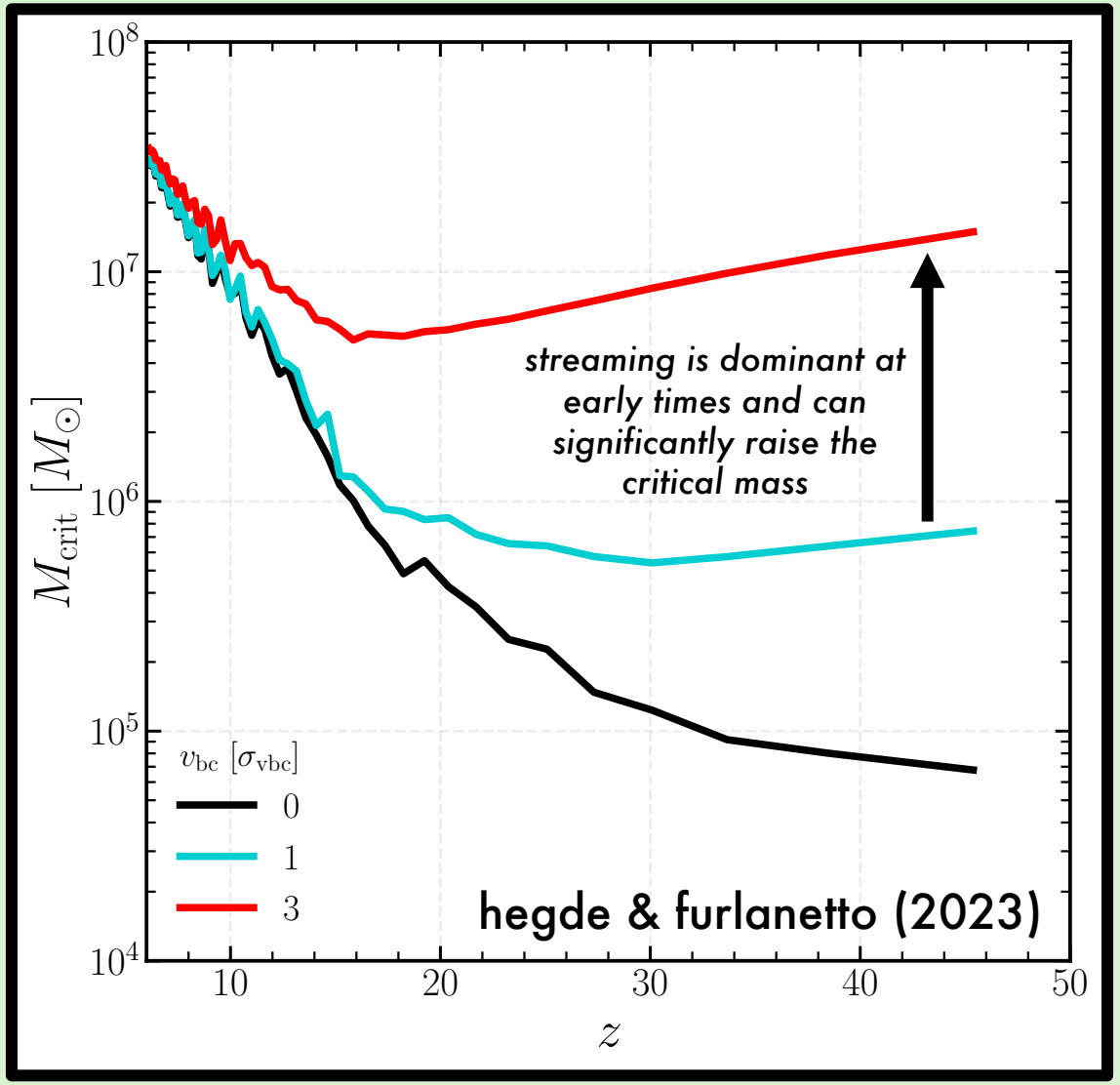
- Pop III stars
  - drawn from Chabrier IMF with M_{char} = 20 $M_\odot$
- 1σ stream velocity
- $f_X = 10$ ($L_X \propto f_X \times$ SFR)
- SN feedback
- bursty Pop II star formation
  - once halo is enriched or reaches atomic cooling threshold

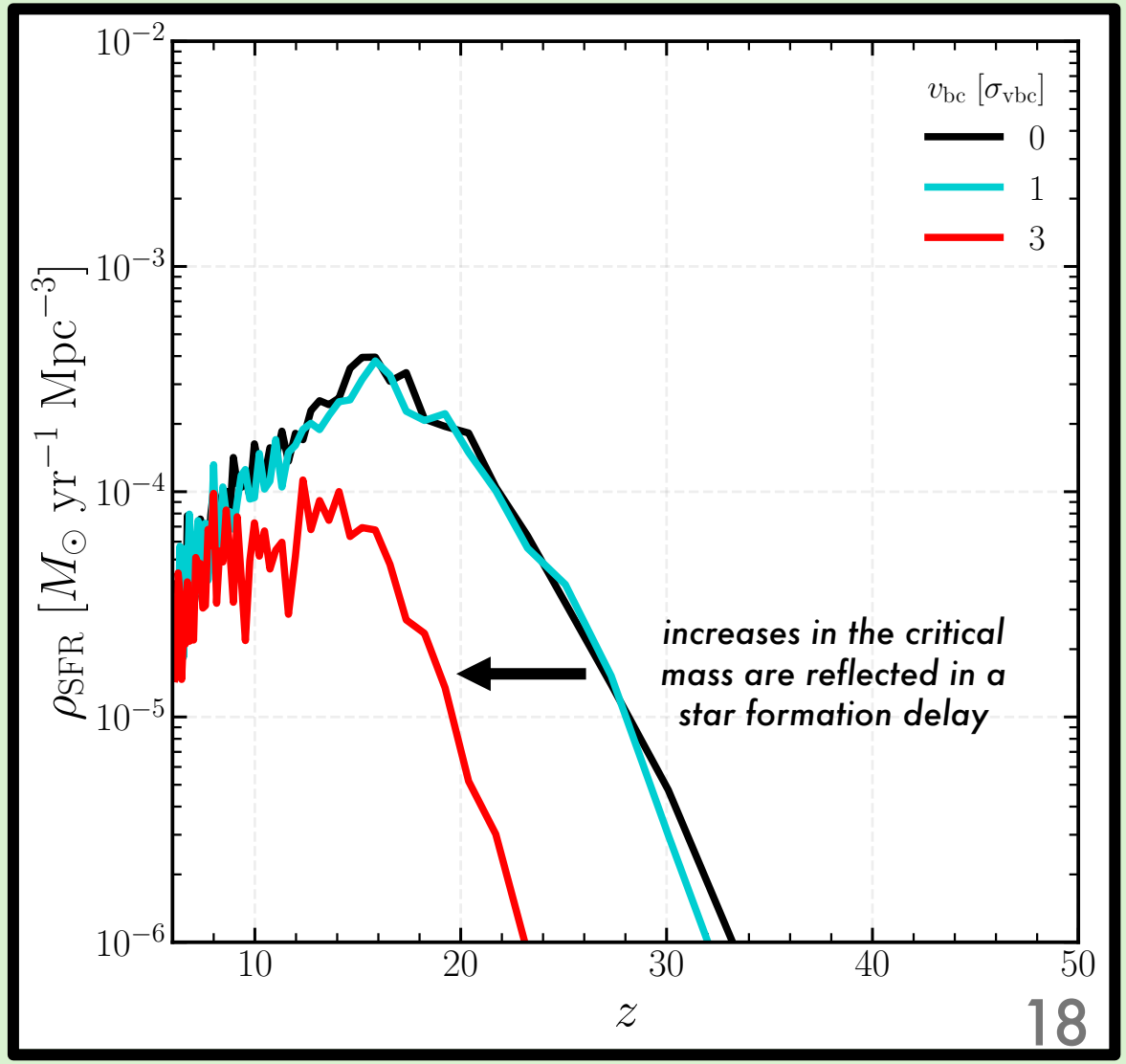
inclusion of new physics can significantly affect the global SFRD



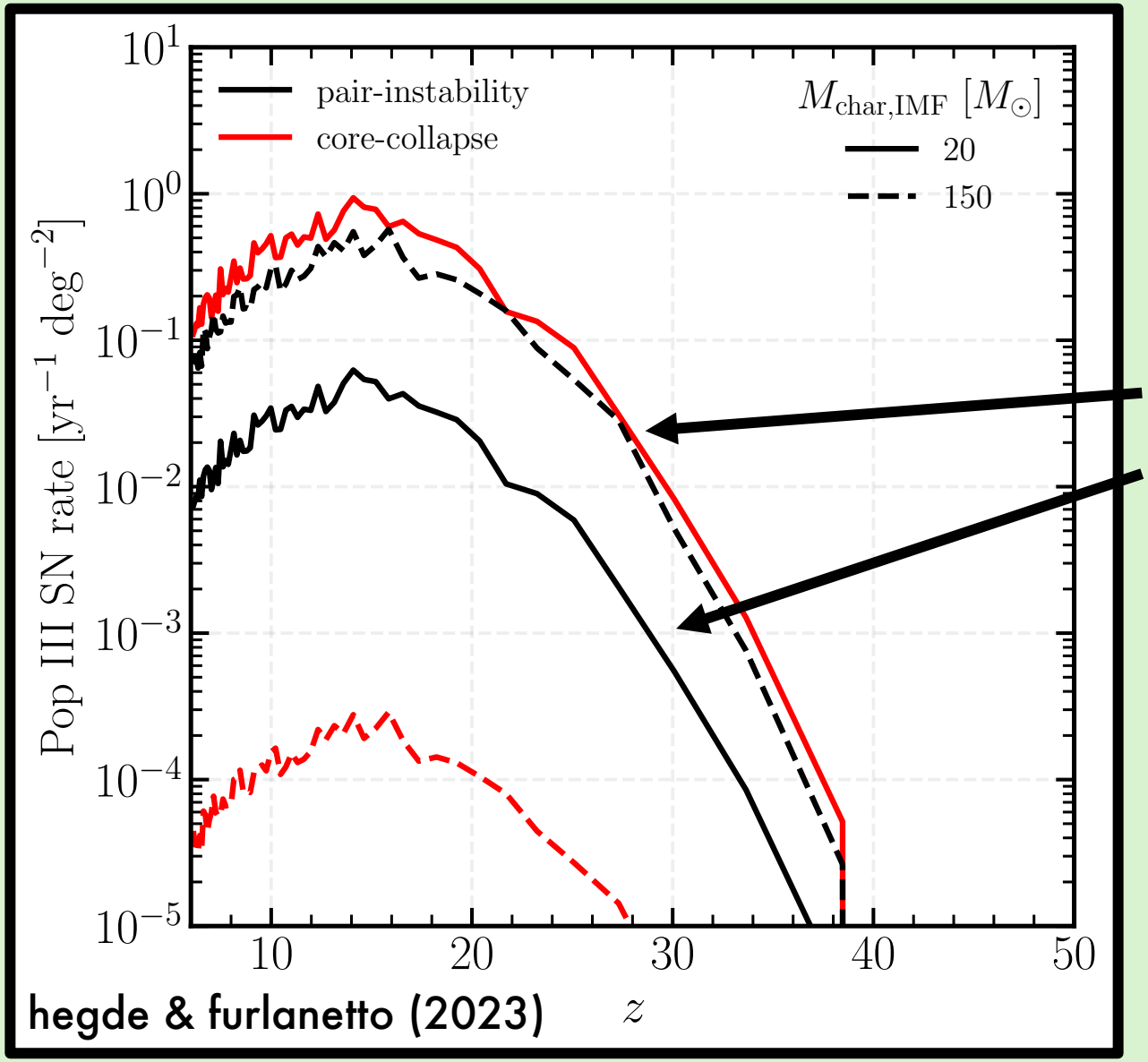


variations in the stream velocity drive changes in the SFRD

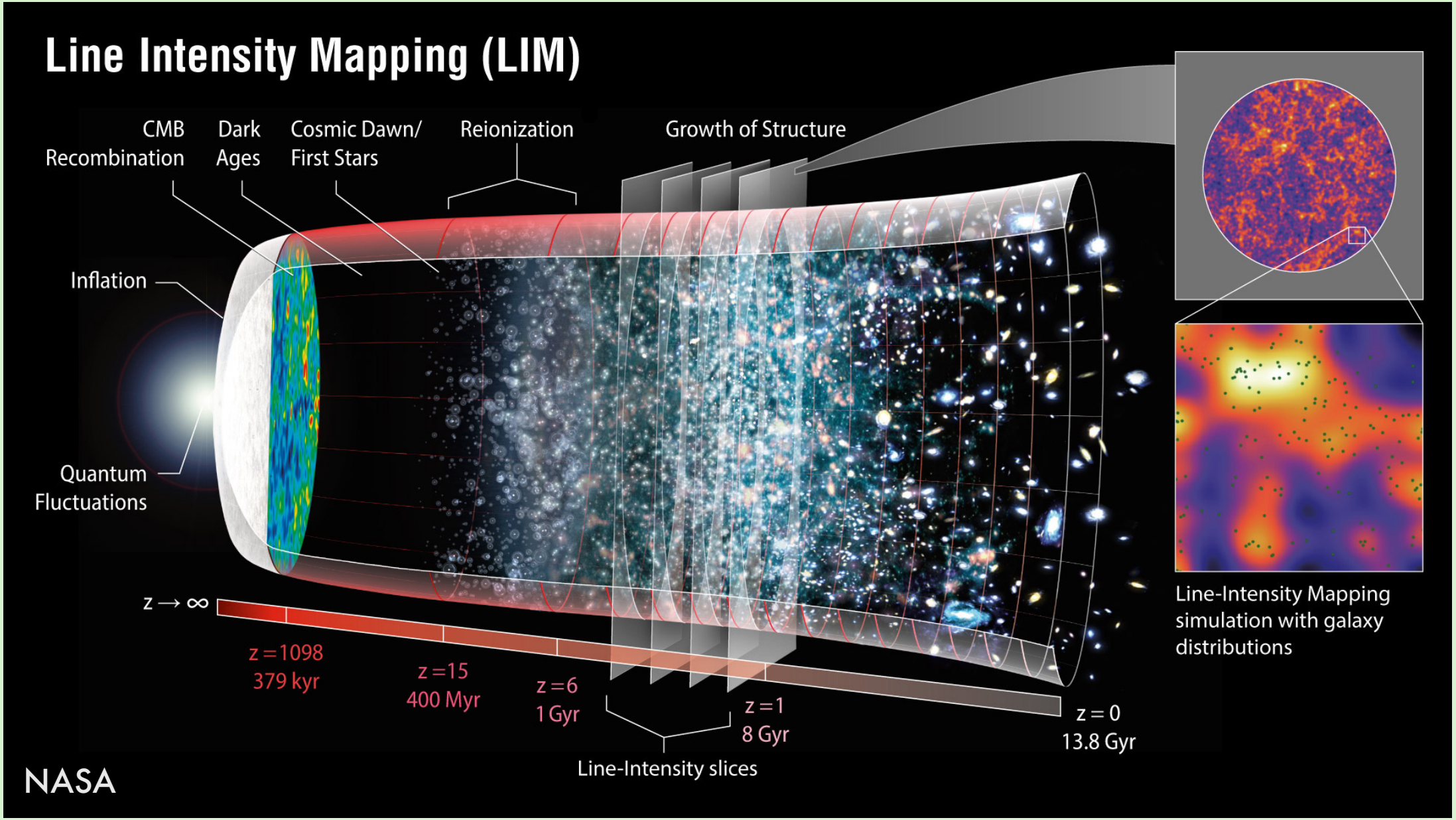




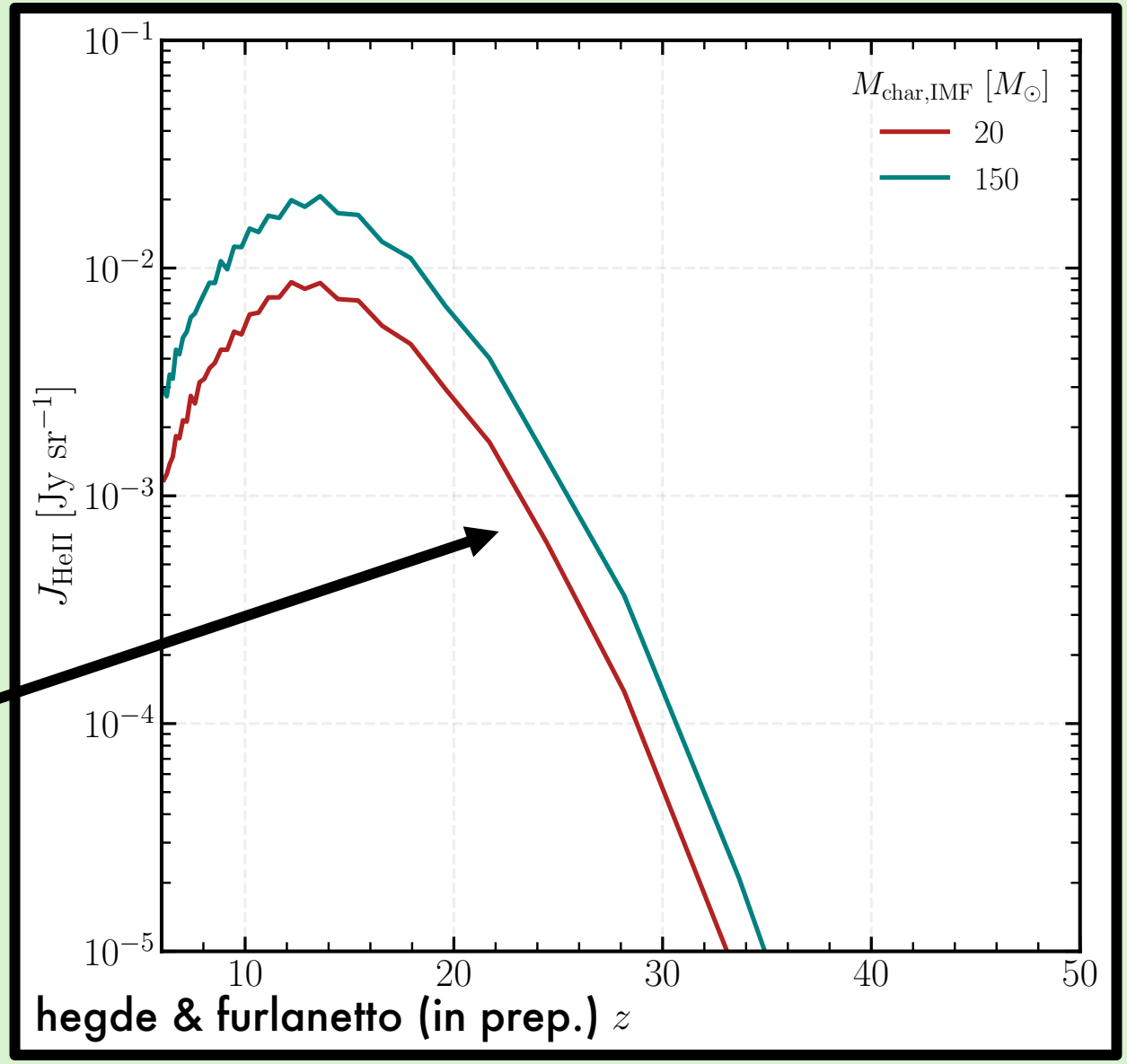
can we see any of this?



relative rates of different types of SNe are a sensitive probe of the IMF


Line Intensity Mapping (LIM)
CMB Recombination
Dark Ages
Cosmic Dawn/ First Stars
Reionization
Growth of Structure
Inflation
Quantum Fluctuations
z → ∞
z = 1098
379 kyr
z = 15
400 Myr
z = 6
1 Gyr
z = 1
8 Gyr
z = 0
13.8 Gyr
Line-Intensity slices
Line-Intensity Mapping simulation with galaxy distributions
NASA

HeII mean intensity traces the IMF and SFRD



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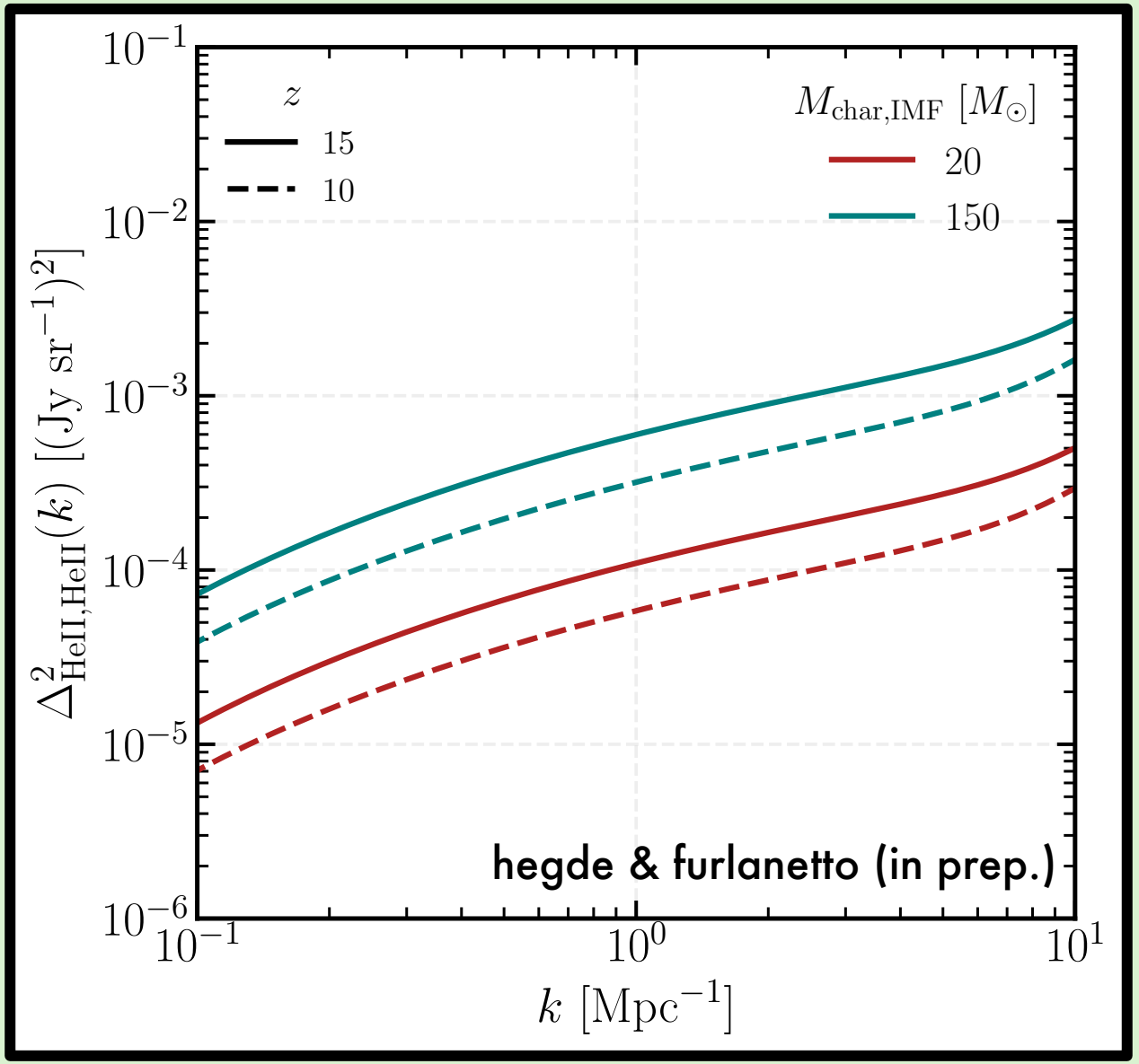

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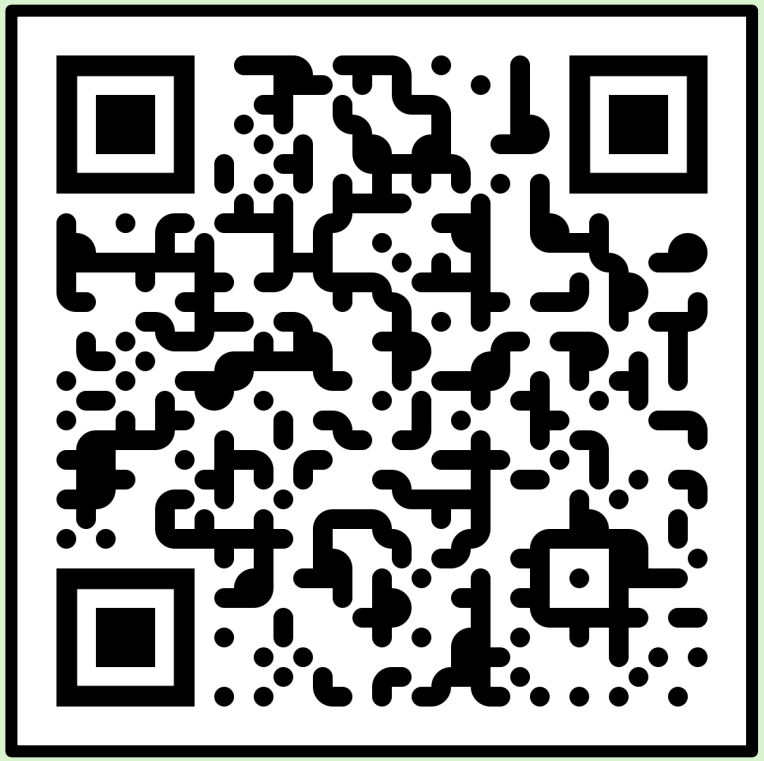

- *we have a modular calculation of the critical halo mass for star formation*
- *we can identify unique epochs associated with each process governing pop III star formation*
- *incorporating this into our SAM enables efficient observable inferences*

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