What is causing the drop in the cosmic star formation rate density below z=2?

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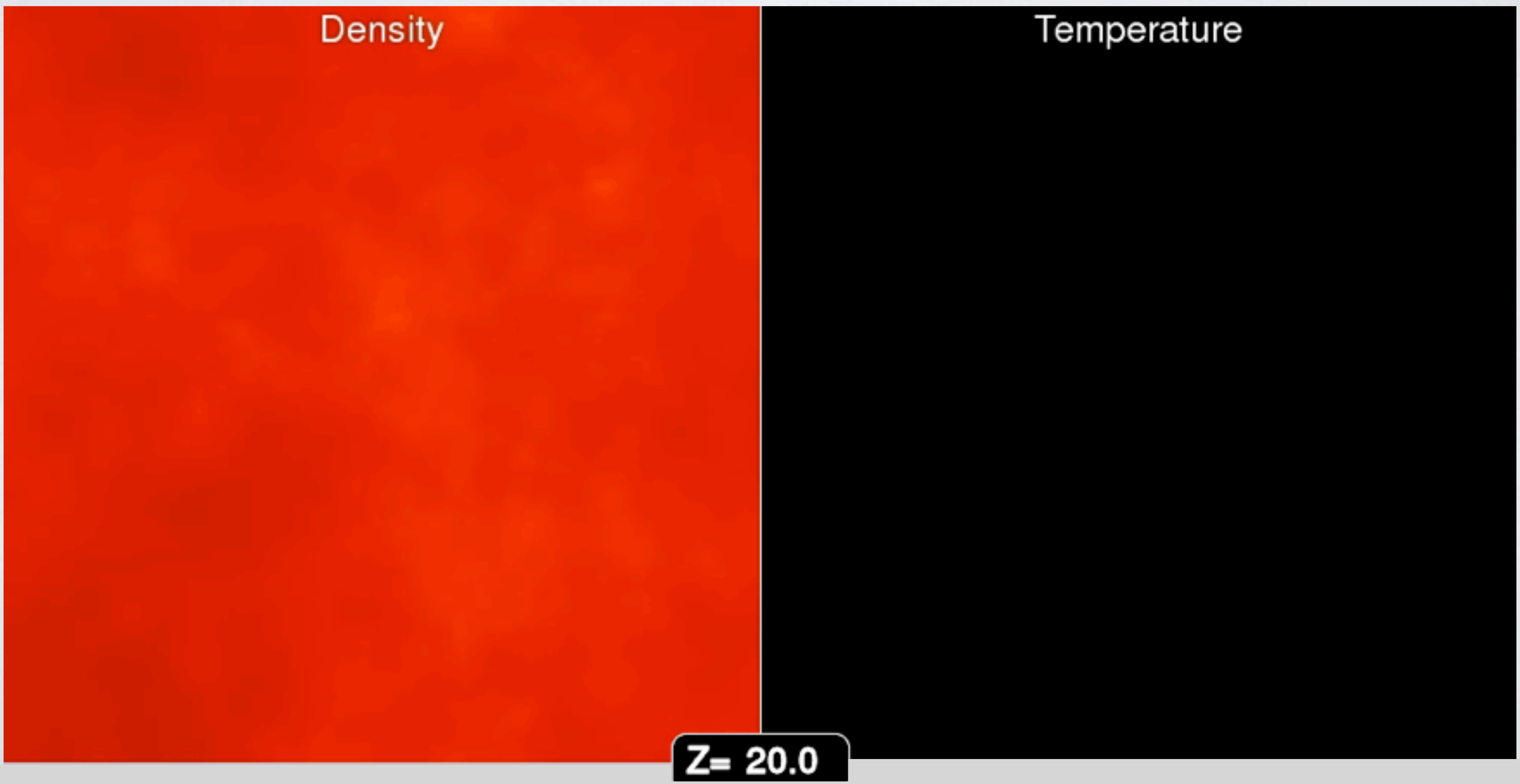
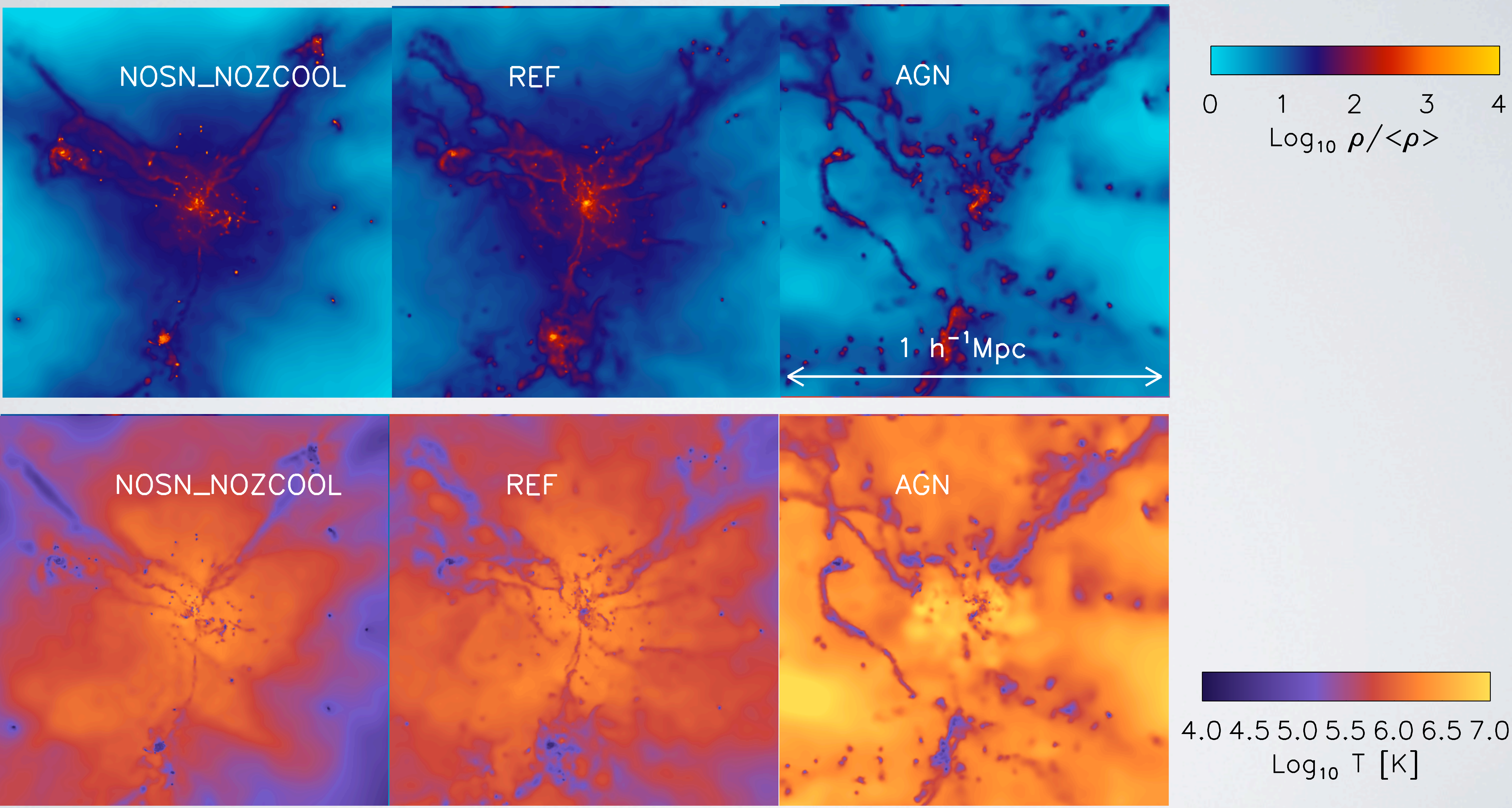
INTRODUCTION

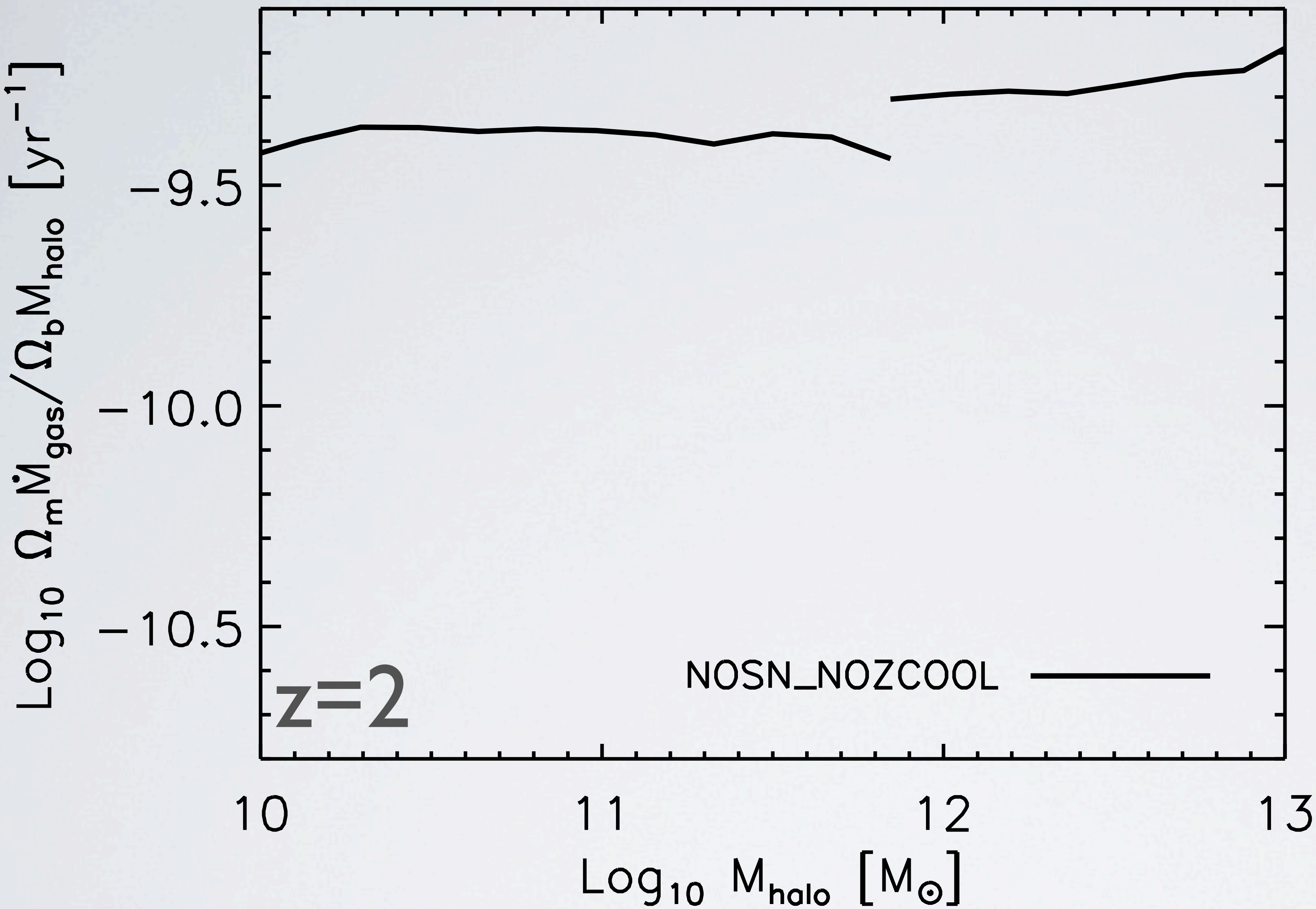
- Part of the OWLS project.
- We study how gas accretes from the IGM onto haloes and from haloes onto galaxies to fuel star formation and how this is affected by cooling and feedback.



DIFFERENT SIMULATIONS



FUELING HALOES

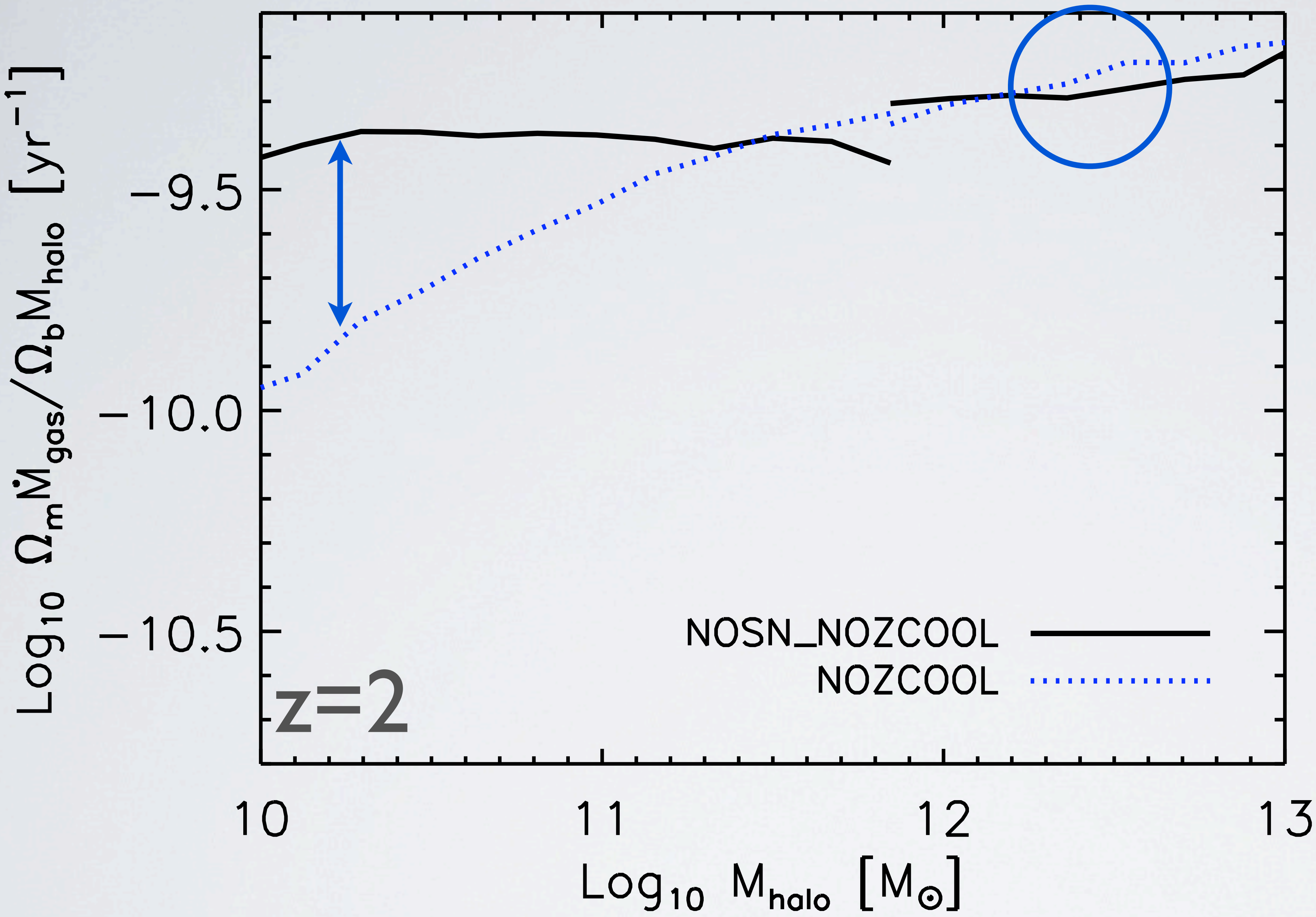


Specific accretion rate = $\frac{\text{accretion rate}}{\text{halo mass}}$

van de Voort et al. 2011a

- The dark matter accretion rate scales (almost) linearly with halo mass.
- Without feedback, the gas accretion rate onto haloes also increases (almost) linearly with halo mass.

FUELING HALOES

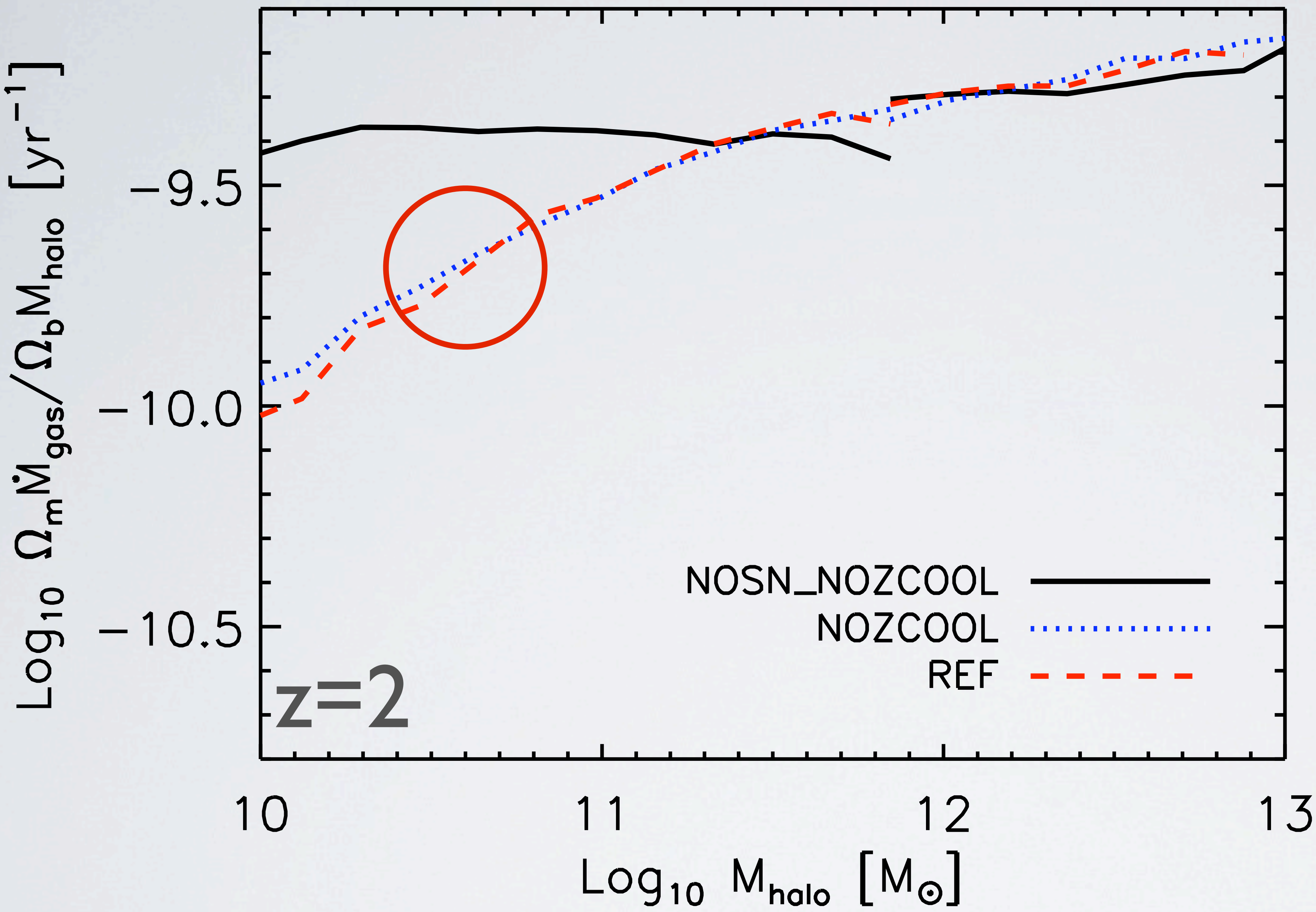


Specific accretion rate = $\frac{\text{accretion rate}}{\text{halo mass}}$

van de Voort et al. 2011a

- Supernova feedback reduces the halo accretion rate onto low-mass haloes (factor 2-3), because gas outside the halo is also affected and prevented from accreting.

FUELING HALOES



Specific accretion rate = $\frac{\text{accretion rate}}{\text{halo mass}}$

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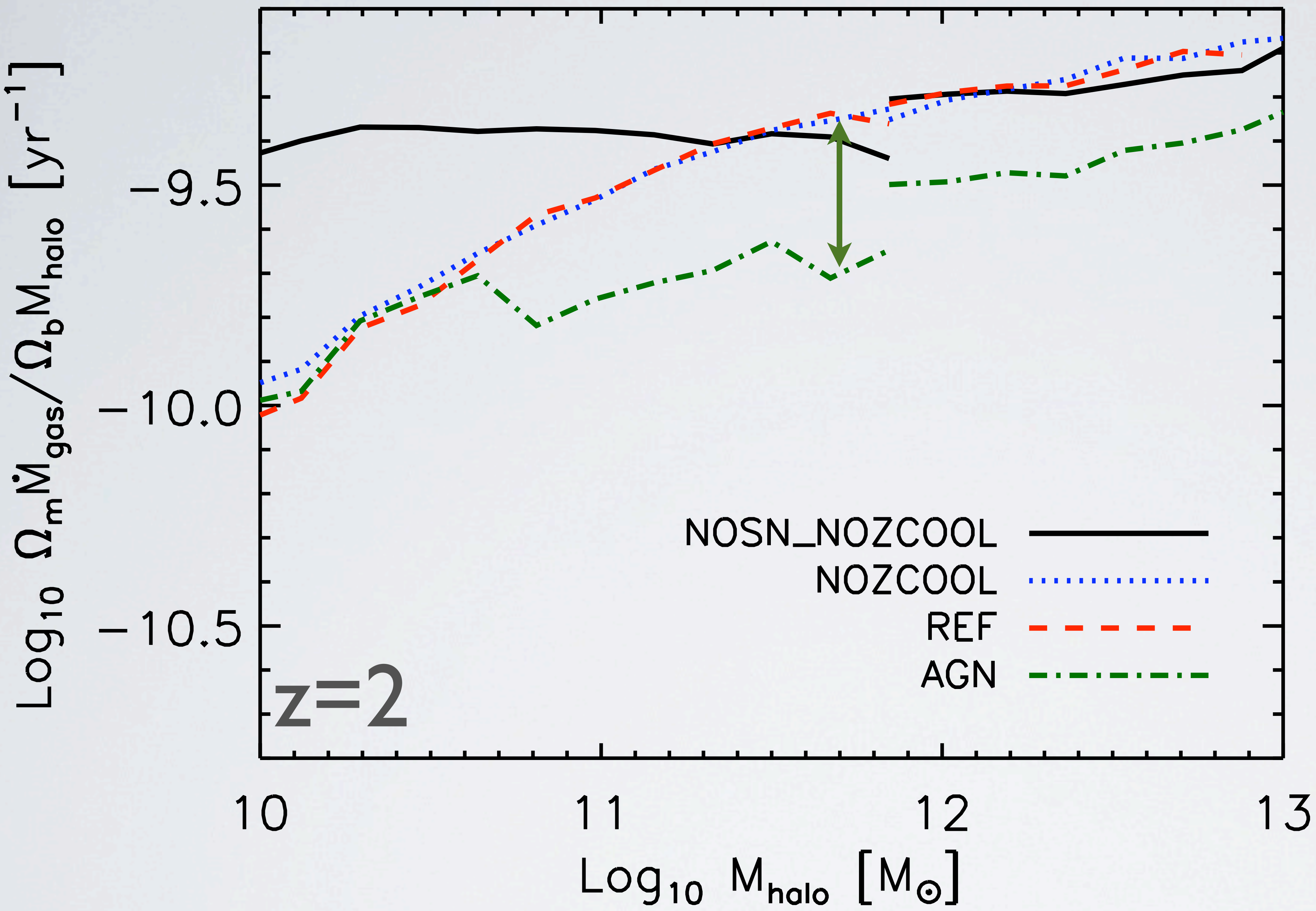
- More cooling does not change the halo fueling rate.

FUELING HALOES

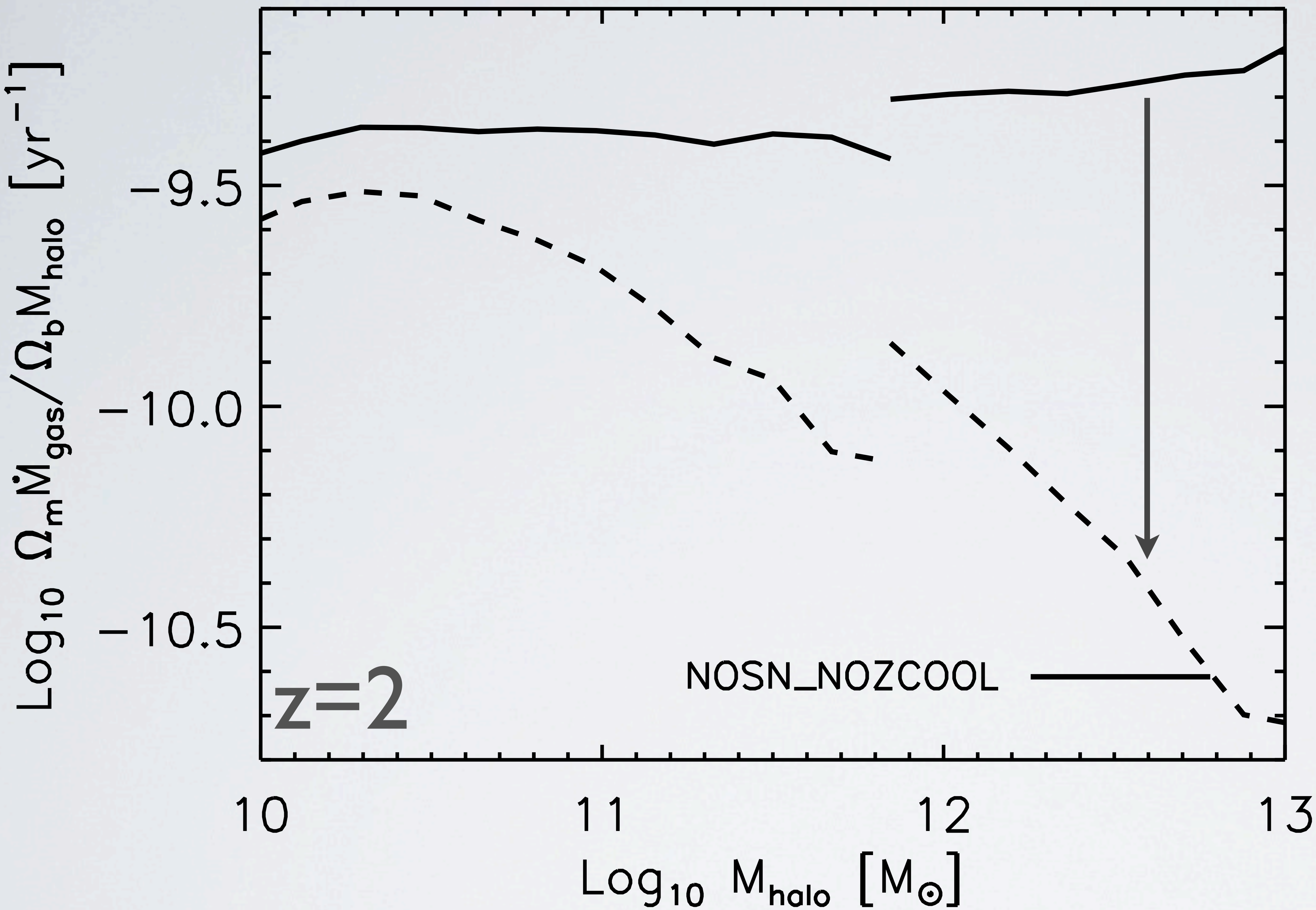


Specific accretion rate = $\frac{\text{accretion rate}}{\text{halo mass}}$

van de Voort et al. 2011a

- AGN feedback reduces the halo accretion rate onto high-mass haloes (factor 2-3), because gas outside the halo is also affected.

FUELING HALOES & GALAXIES



Specific accretion rate = $\frac{\text{accretion rate}}{\text{halo mass}}$

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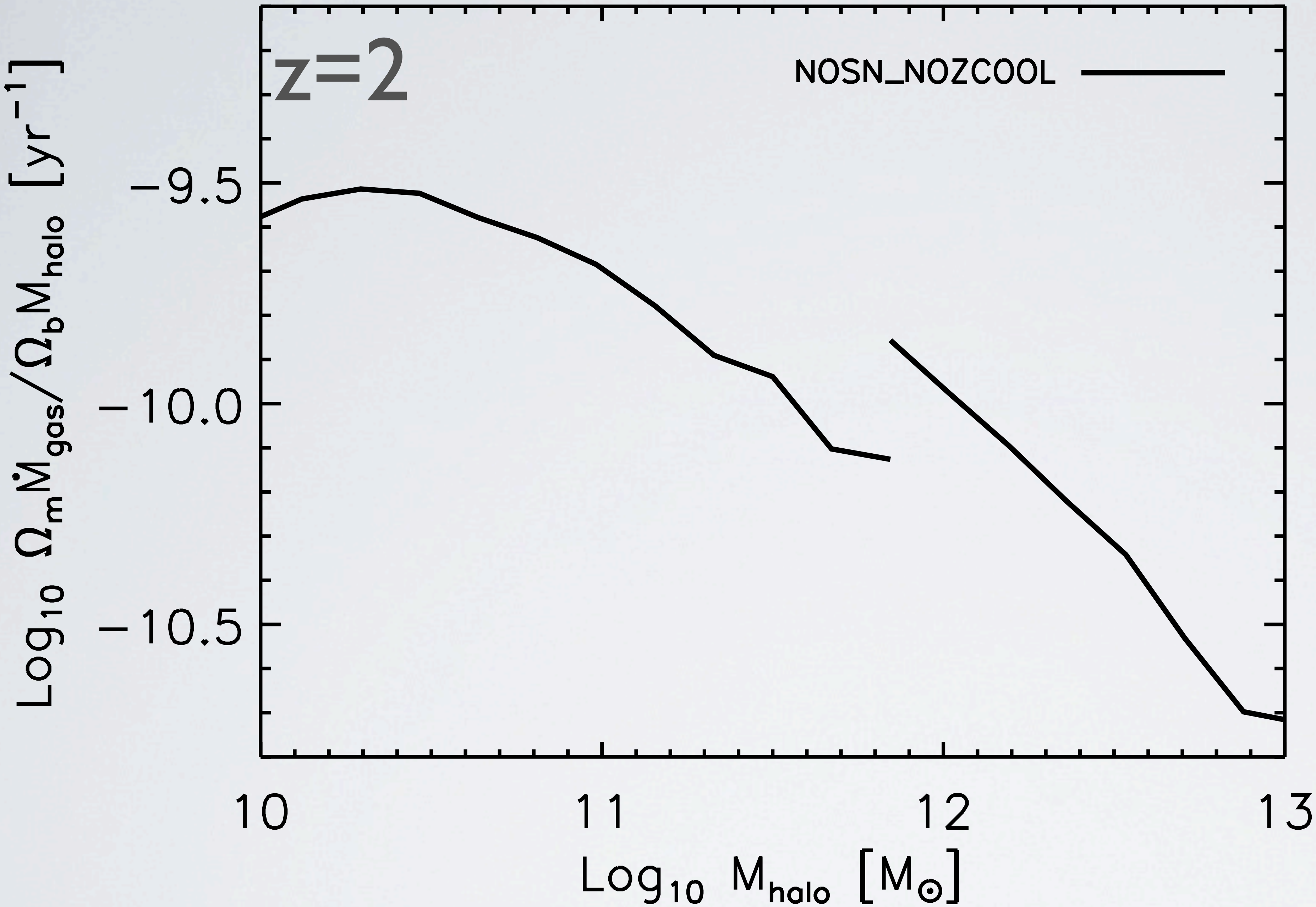
- The galaxy accretion rate is always lower than the halo accretion rate.

FUELING GALAXIES



Specific accretion rate = $\frac{\text{accretion rate}}{\text{halo mass}}$

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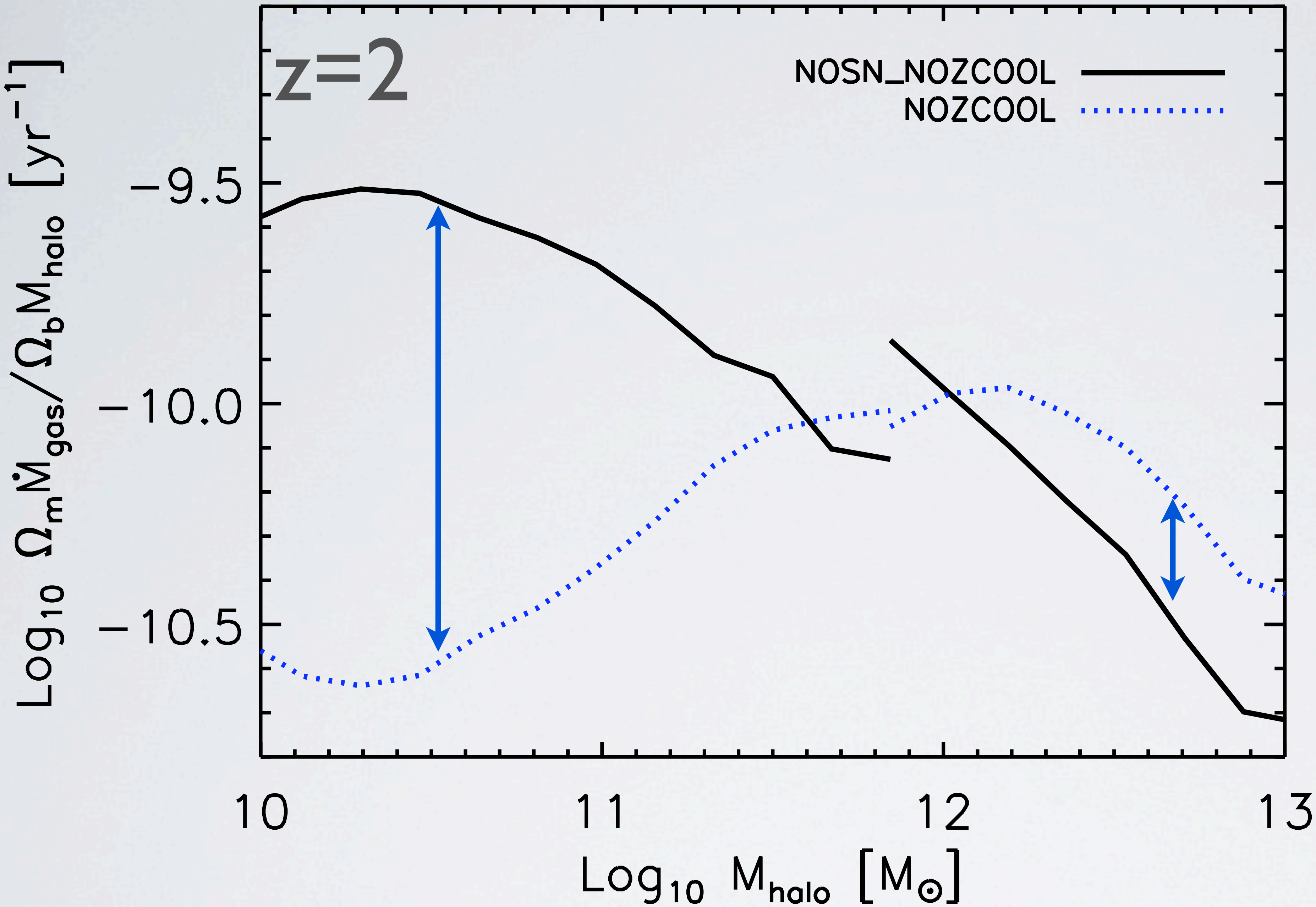
- Without feedback, the galaxy accretion rate increases less steeply than linearly with halo mass.
- Without feedback, the specific galaxy accretion rate peaks around 10^{10} M_{sun}.

FUELING GALAXIES

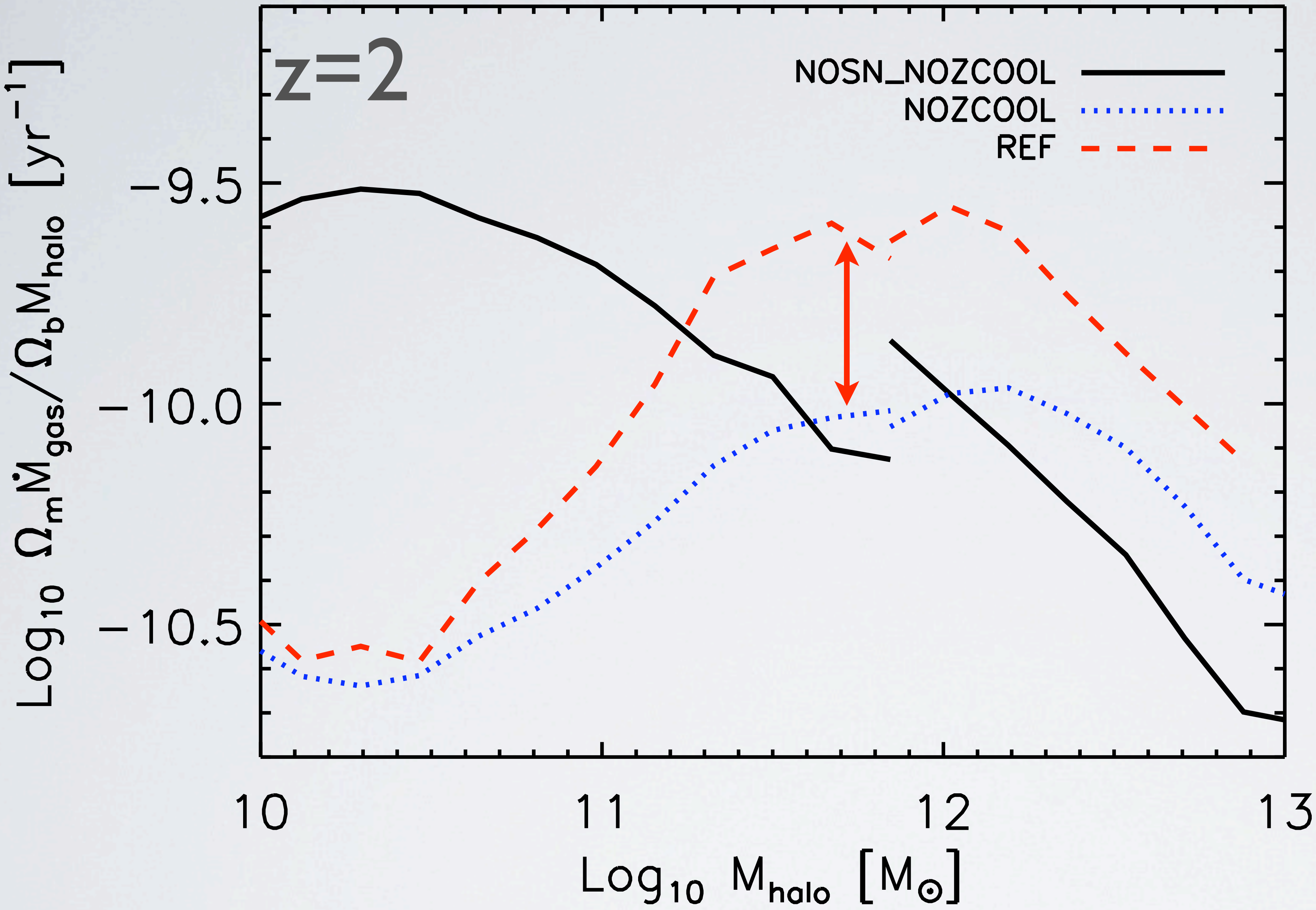


Specific accretion rate = $\dfrac{\text{accretion rate}}{\text{halo mass}}$

van de Voort et al. 2011a

- Supernova feedback reduces the galaxy accretion rate onto low-mass haloes strongly (order of magnitude).
- Increase for high-mass haloes, because more gas is left.

FUELING GALAXIES



Specific accretion rate = $\frac{\text{accretion rate}}{\text{halo mass}}$

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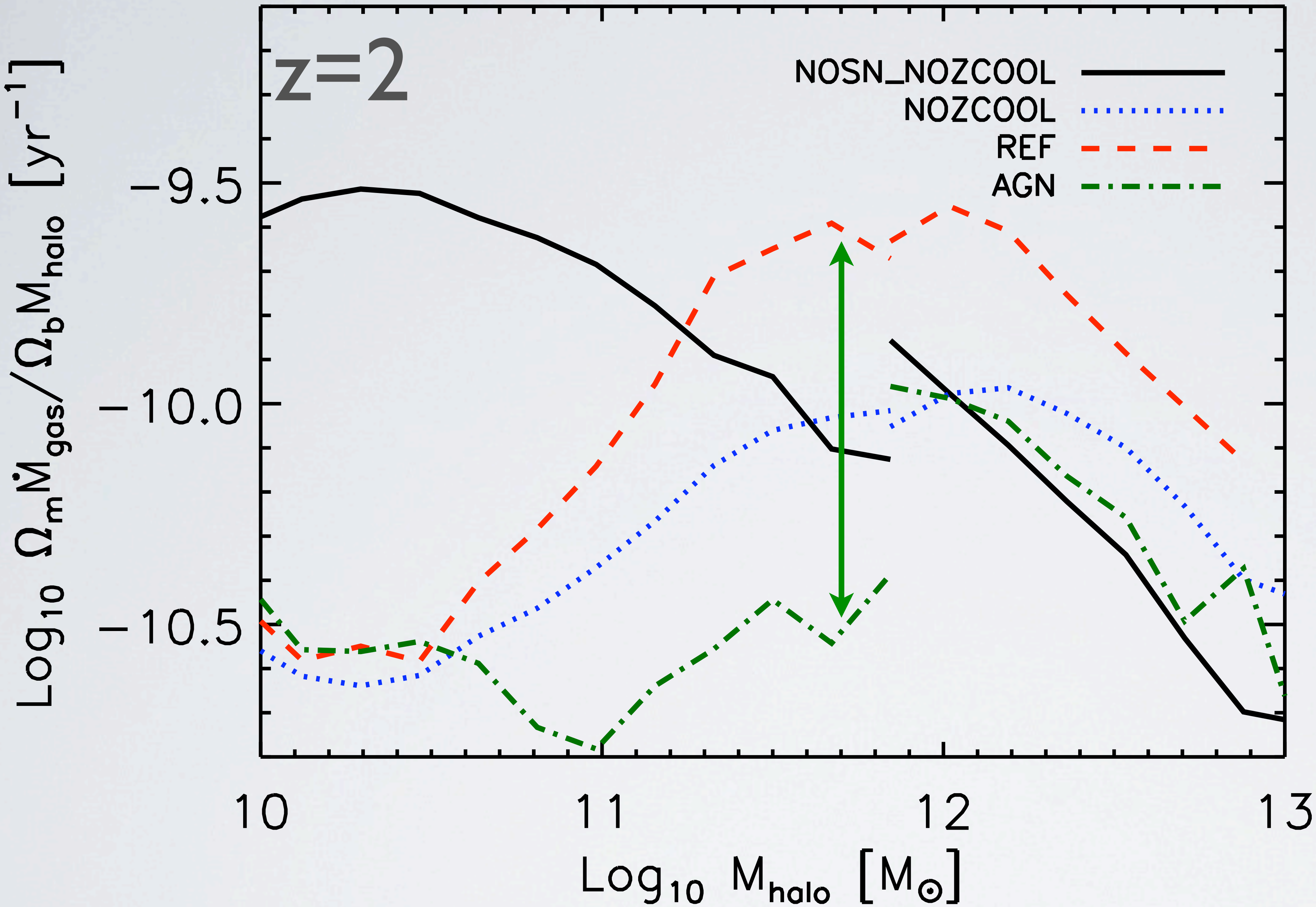
- More cooling enhances the galaxy fueling rate.

FUELING GALAXIES

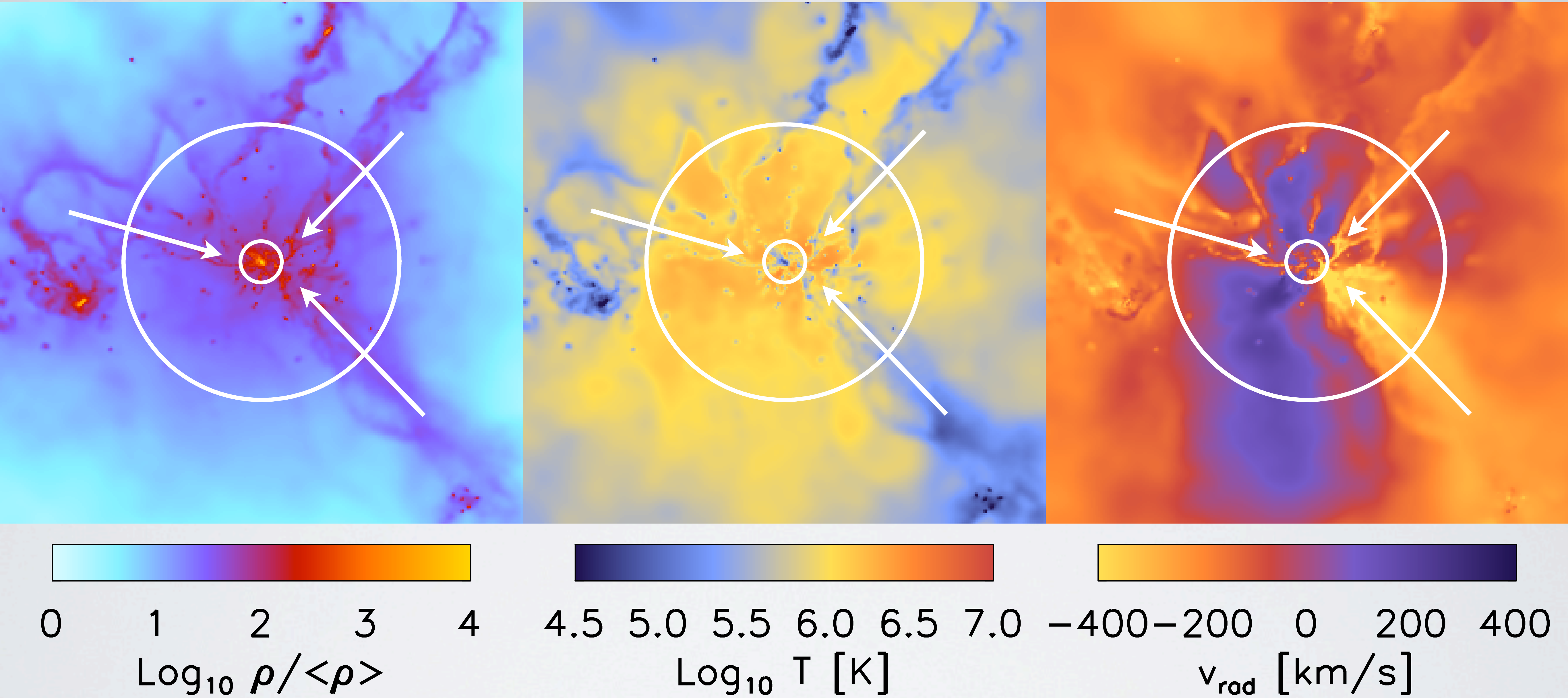


Specific accretion rate = $\frac{\text{accretion rate}}{\text{halo mass}}$

van de Voort et al. 2011a

- AGN feedback reduces the galaxy accretion rate onto high-mass haloes strongly (order of magnitude).
- With feedback, the specific galaxy accretion rate peaks around 10^{12} M_{sun}.

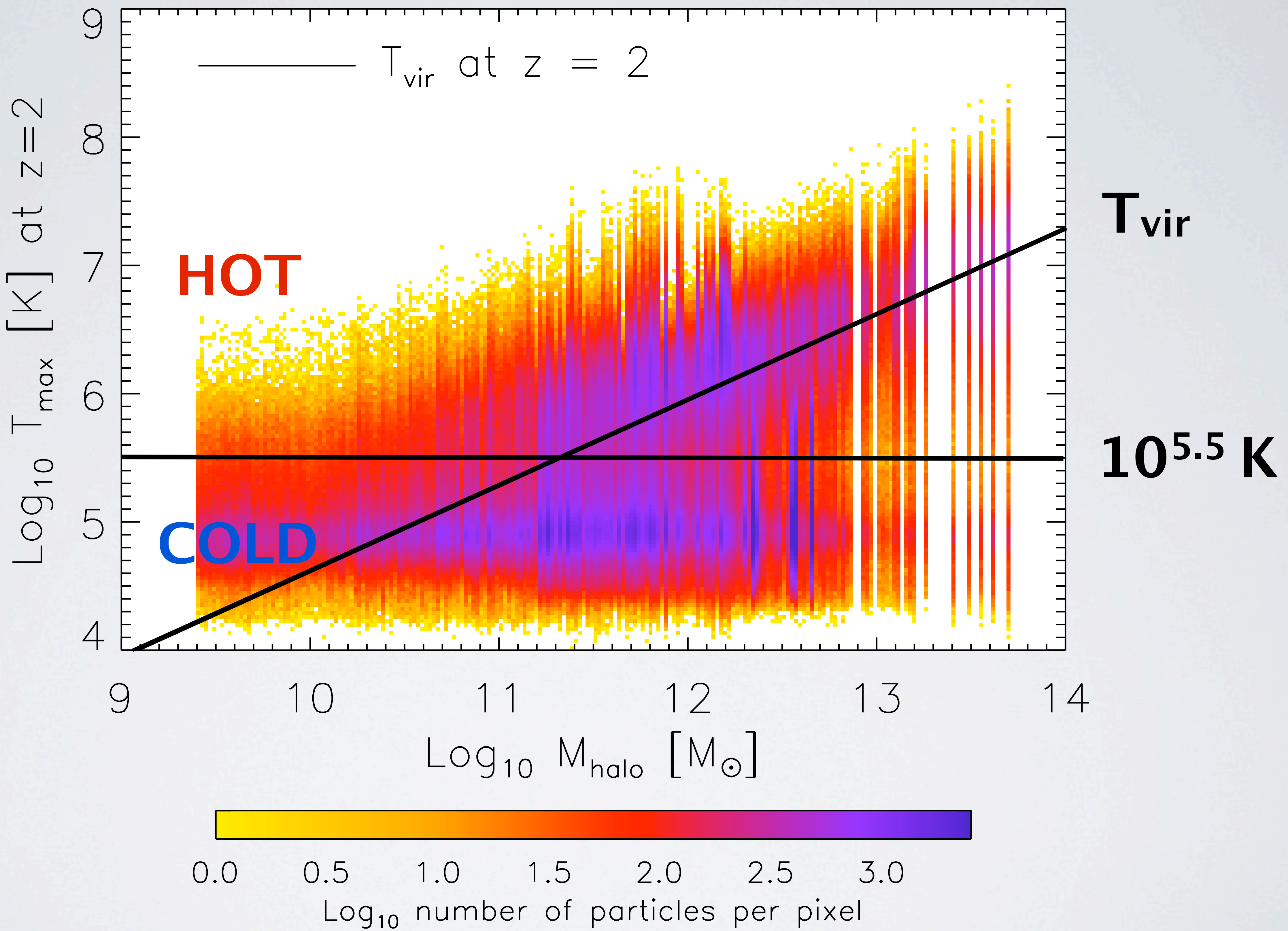
10^{12} M_{SUN} HALO AT Z=2



- Diffuse gas shock heats at the virial radius to the virial temperature, whereas dense filaments stay colder.
- Inflow happens preferentially along cold streams.

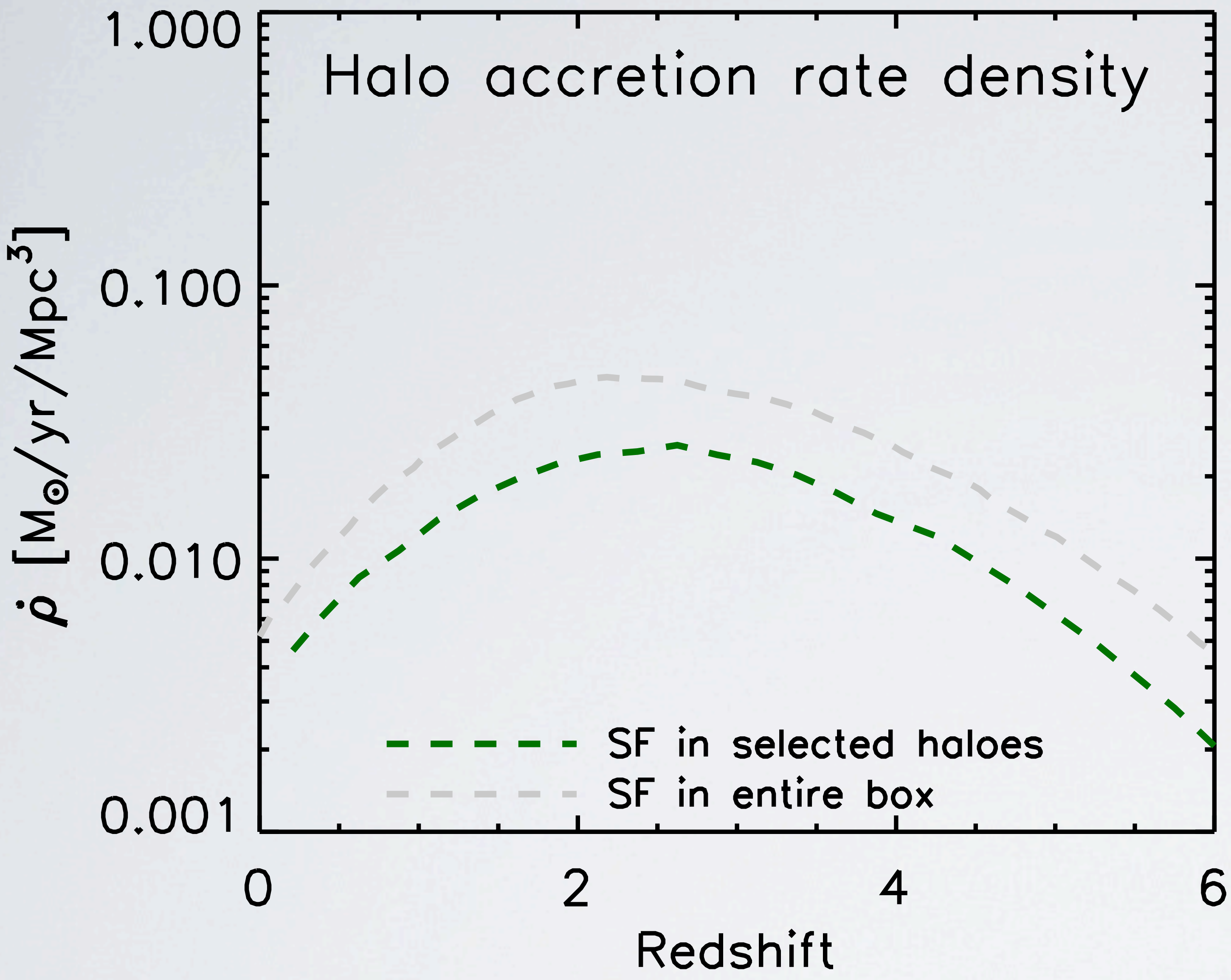
Birnboim & Dekel 2003, Keres et al. 2005, Dekel & Birnboim 2006, Ocvirk et al 2008, Brooks et al. 2009, Dekel et al. 2009, Keres et al. 2009, van de Voort et al. 2011, Powell et al. 2011, Faucher-Giguère et al. 2011

HOT AND COLD GAS



- This is the maximum PAST temperature.

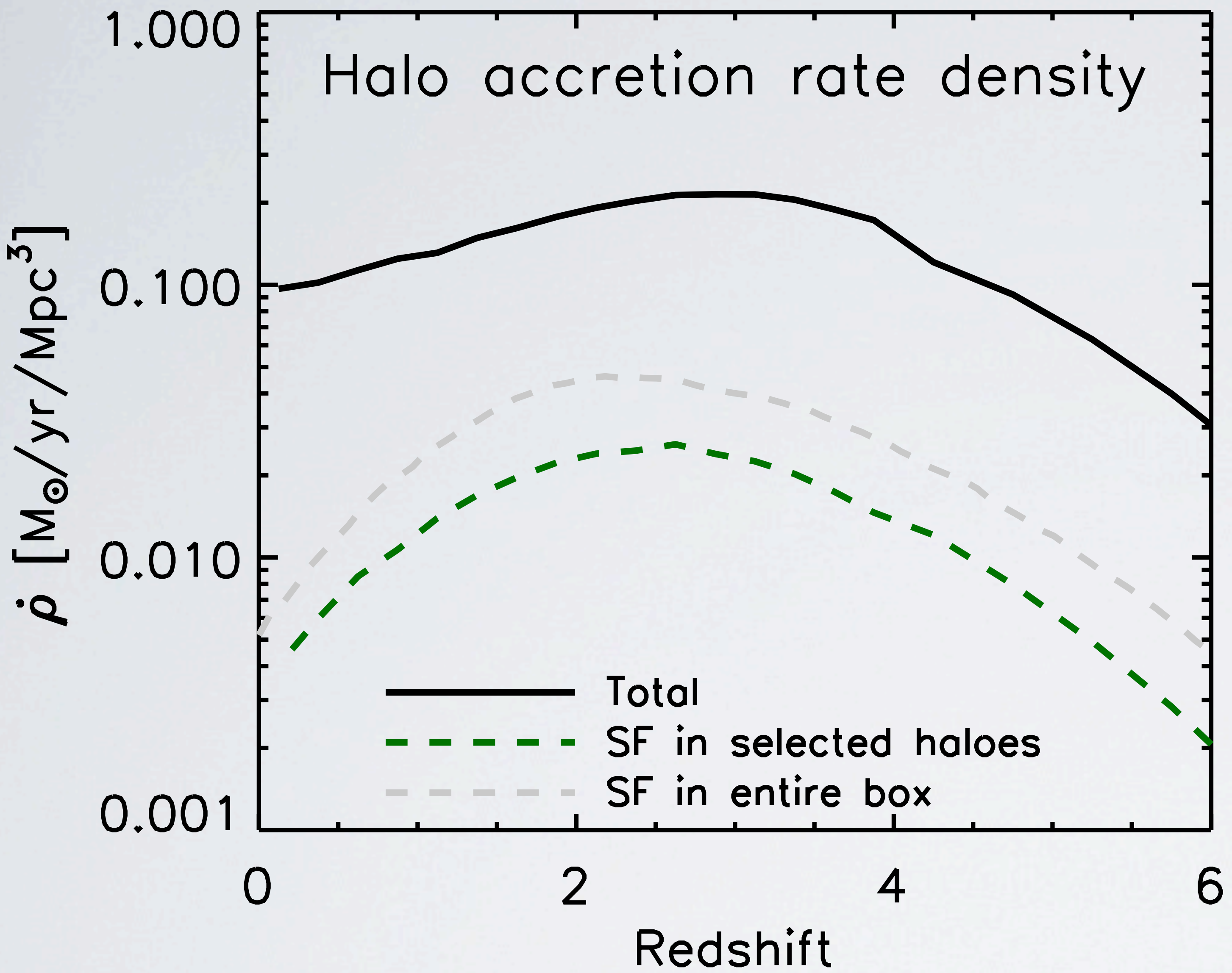
GLOBAL GAS ACCRETION



van de Voort et al. 2011b

- After redshift 2 the observed cosmic SFR density drops by an order of magnitude.
- This drop is reproduced in the simulation with AGN feedback.

GLOBAL GAS ACCRETION



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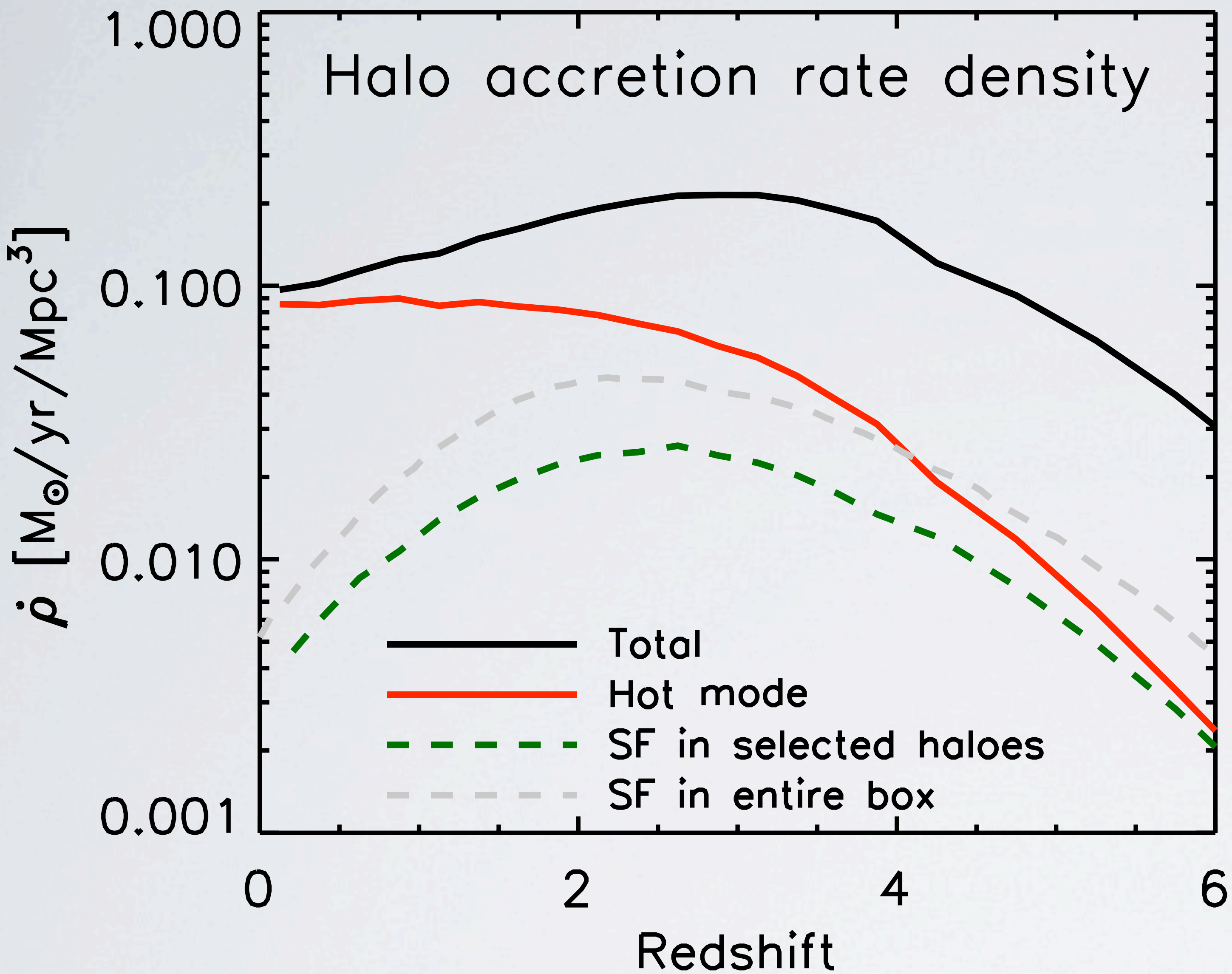
- Most gas that flows into haloes never forms stars.

GLOBAL GAS ACCRETION



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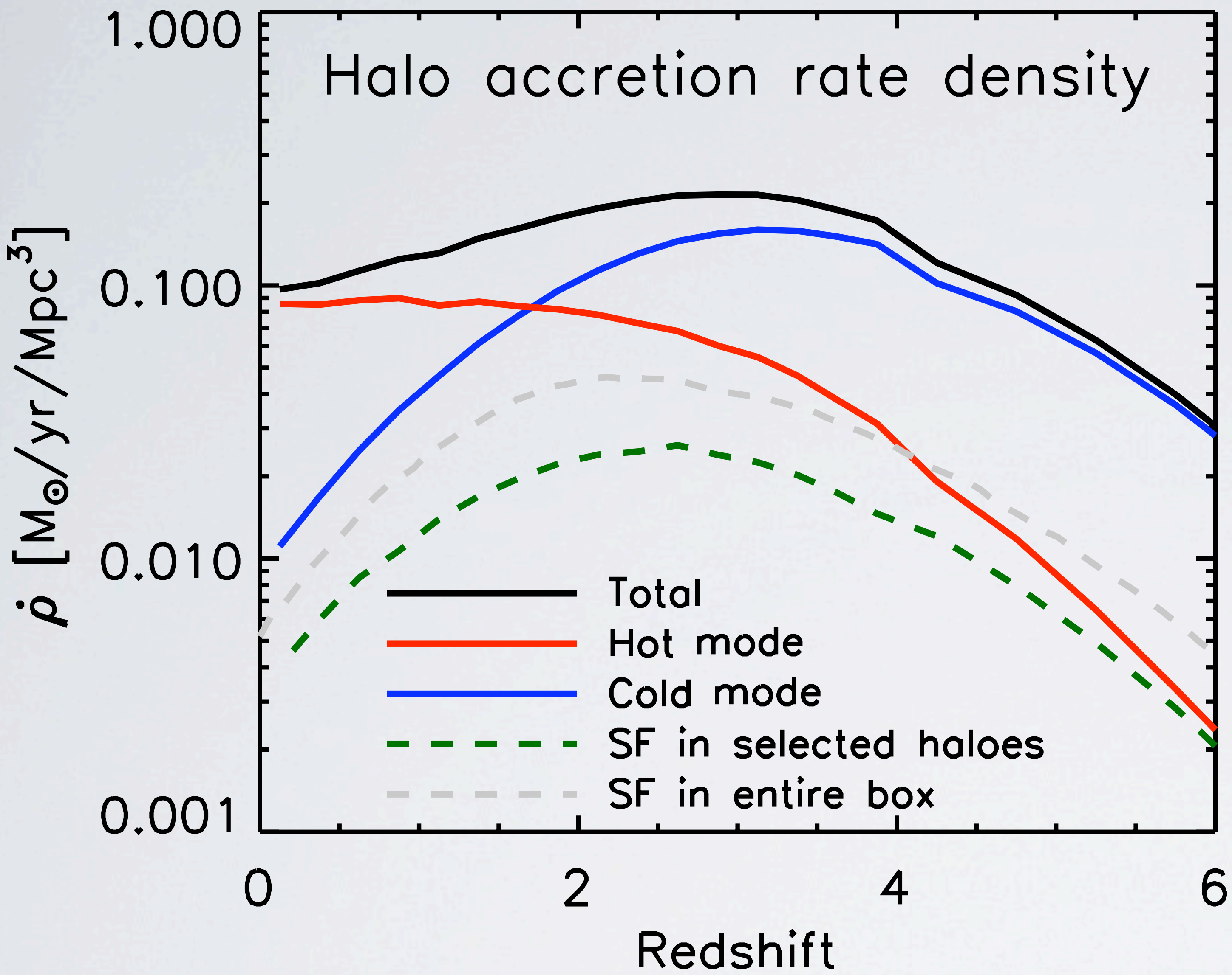
- Both hot and total halo accretion rate densities cannot explain the decreasing cosmic SFR density.

GLOBAL GAS ACCRETION



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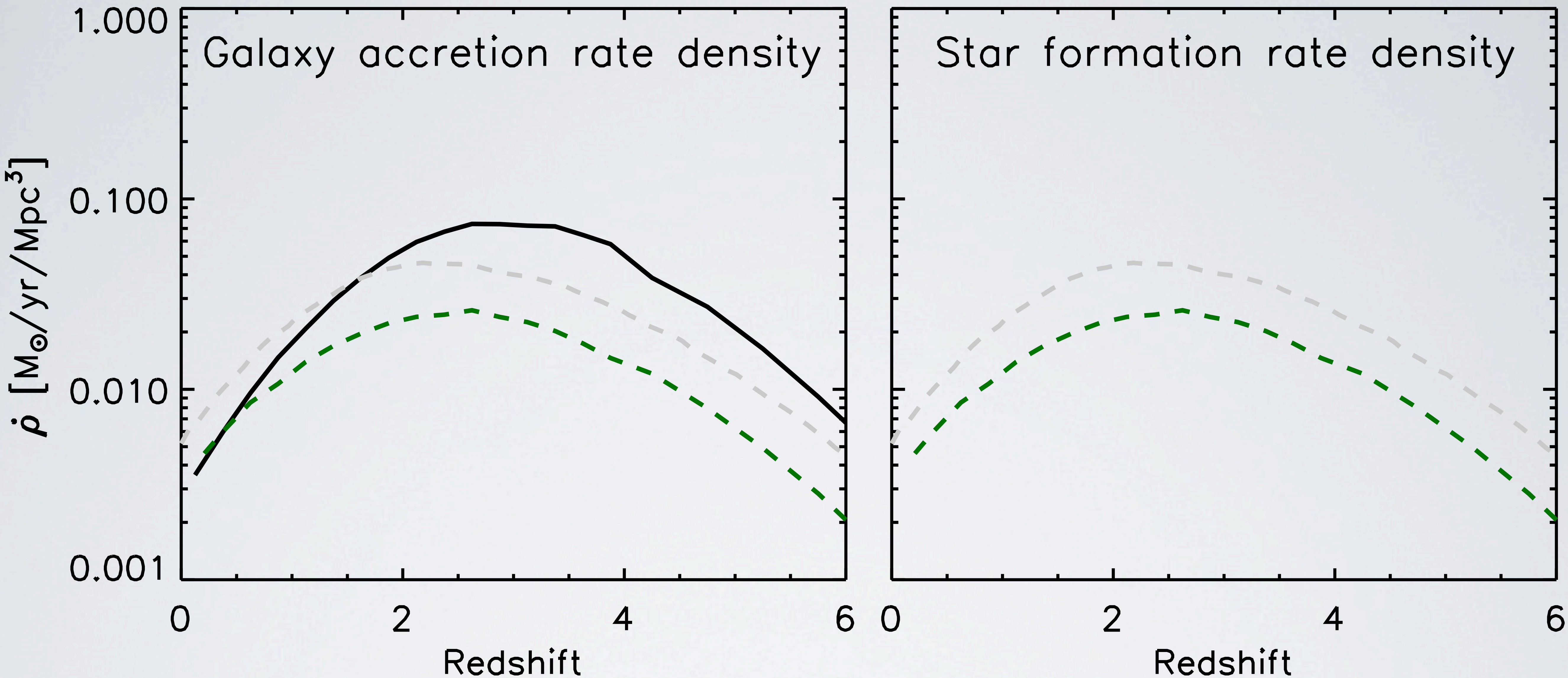
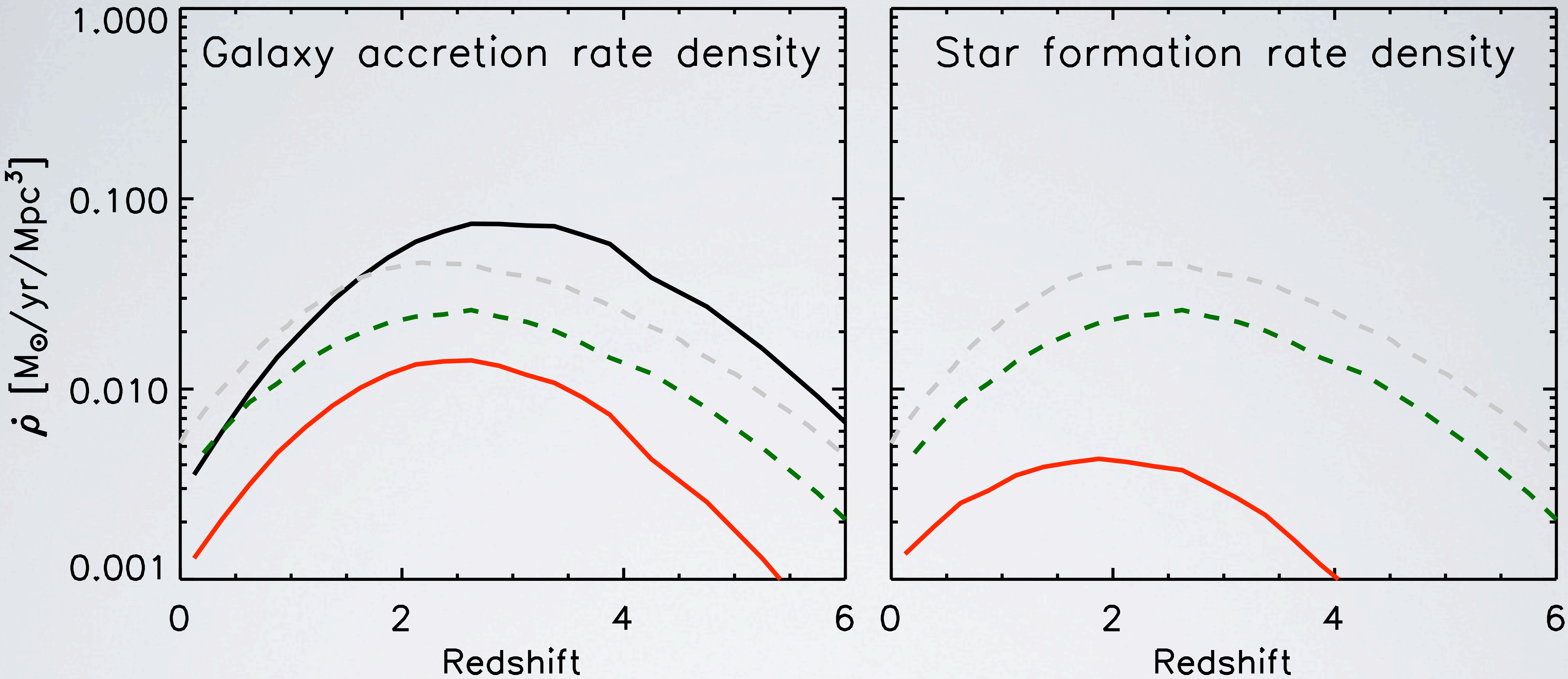
- The global cold accretion rate density declines strongly after redshift 3.
- The drop in the global SFR density is caused by the decline in the cold halo accretion rate density.

GLOBAL GAS ACCRETION



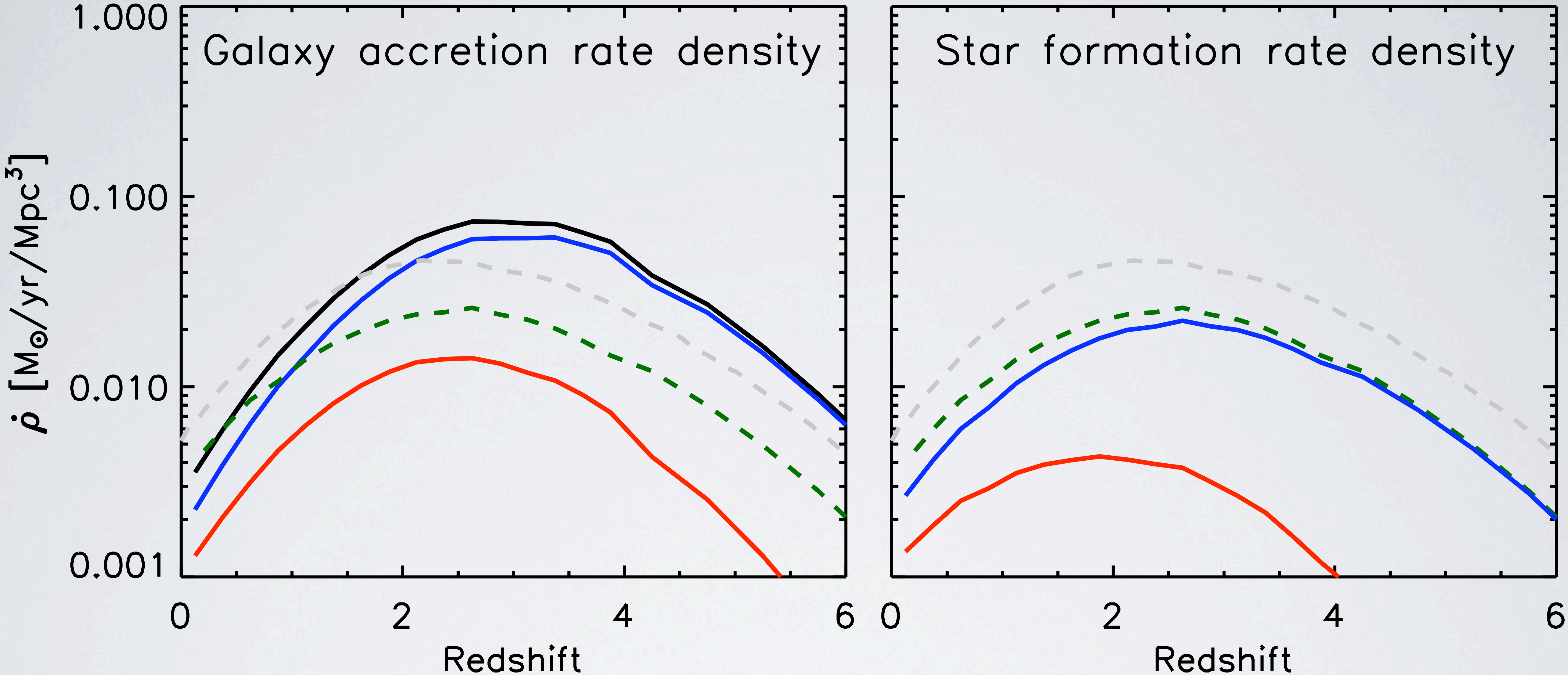
- The global galaxy accretion rate density is lower than the global halo accretion rate density.
- The resulting star formation rate density is lower because of ejection by feedback.

GLOBAL GAS ACCRETION



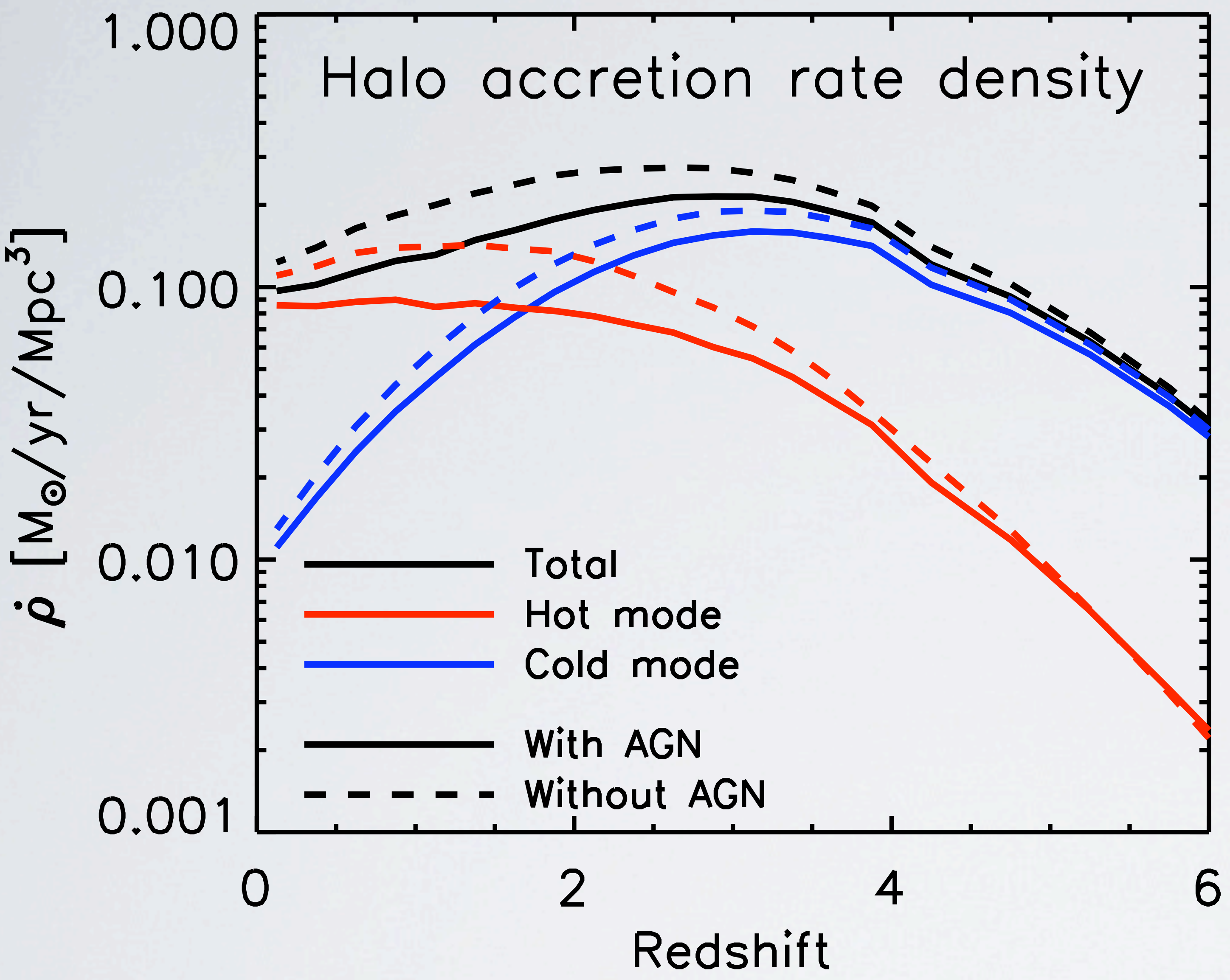
- There is not enough hot accretion onto galaxies to provide fuel for star formation.

GLOBAL GAS ACCRETION



- The drop in the global SFR density is caused by the decline in the cold galaxy accretion rate density.
- Cold mode accretion provides most of the fuel for star formation at all redshifts, if AGN feedback is included.

GLOBAL GAS ACCRETION



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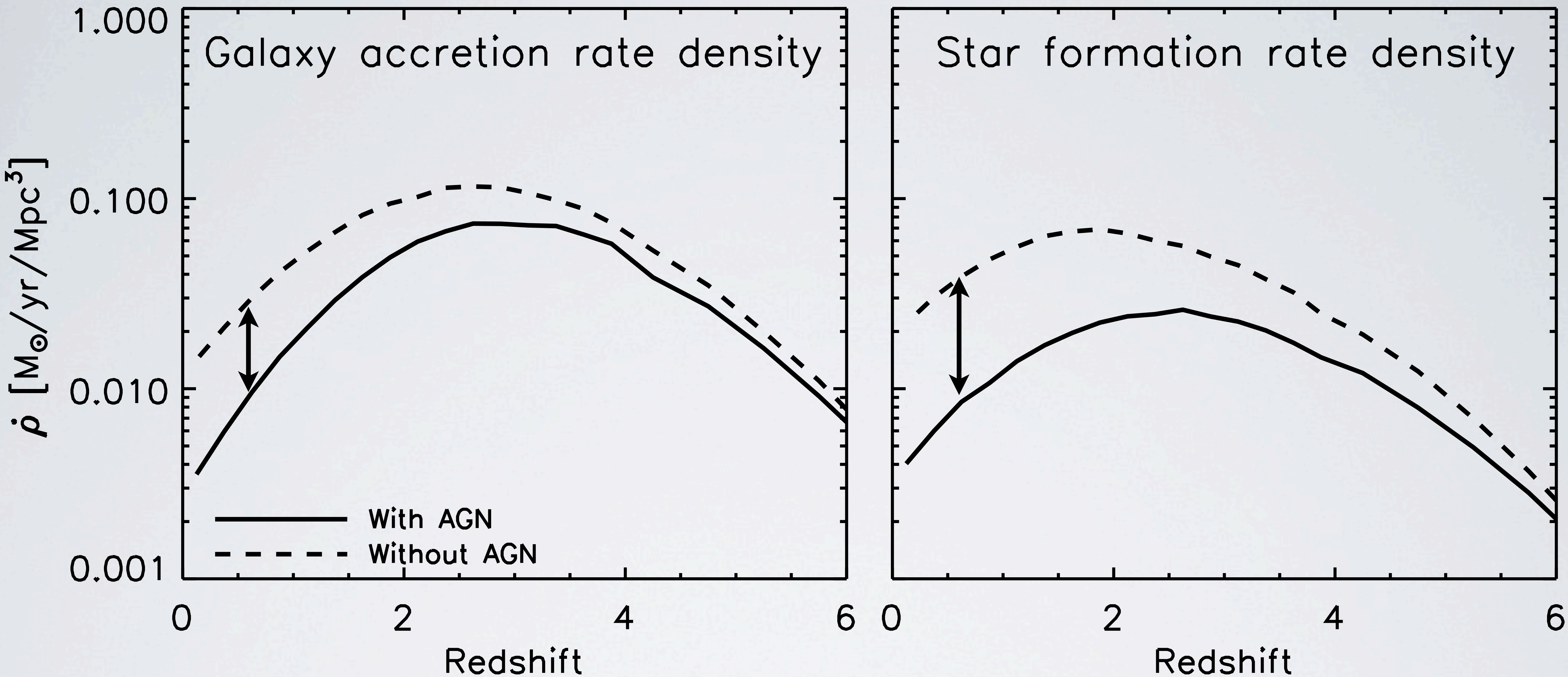
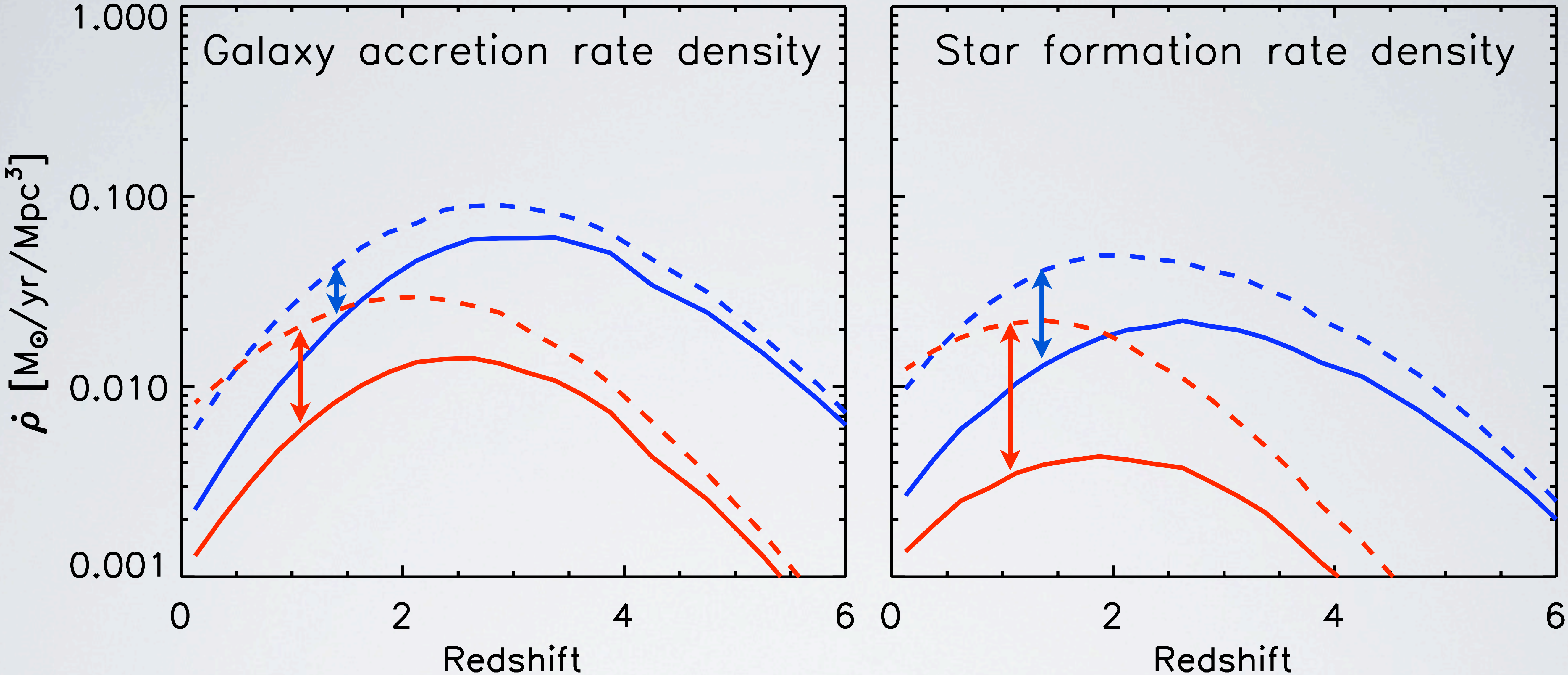
- AGN feedback suppresses halo accretion slightly.
- The suppression of hot accretion is larger than that of cold accretion.

GLOBAL GAS ACCRETION



- The effect of AGN feedback is large for both accretion onto galaxies and star formation.
- It is larger for star formation, because feedback ejects star-forming gas from galaxies.

GLOBAL GAS ACCRETION



- Hot accretion is suppressed most, up to an order of magnitude.
- Without AGN feedback, the global accretion rate density at redshift 0 would be dominated by hot accretion.

CONCLUSIONS

- Efficient feedback decreases the accretion rate onto haloes and, more so, onto galaxies.
- Cooling is not important for fuelling haloes, but it is for fuelling galaxies.
- Galaxies are fed mostly, but not only, by cold accreted gas.
- The cosmic star formation rate density is shaped by cold accretion and AGN feedback.
- We are investigate what the diffuse gas looks like in emission and absorption.