Early galaxies in CDM and WDM

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Outline

Motivations

Rationale: Understand the formation of early galaxies and their link to dark-matter nature

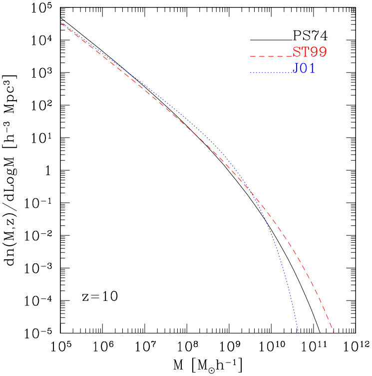
→ *What is the formation epoch of the first objects?*
→ *What is the role of early molecules and metals?*
→ *What is the role of early populations?*
→ *What are the effects of model assumptions?*
→ *...in particular of the underlying dark-matter nature?*

Requirements: Study the thermal properties of cosmic medium during cosmological evolution.

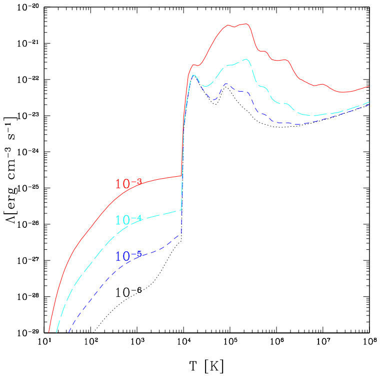
Techniques: Detailed numerical simulations

Primordial environments

Small dark-matter haloes hosting



molecular and metal cooling



H-cooling haloes: $T_{vir} \geq 10^4$ K

H_2-cooling haloes: $T_{vir} < 10^4$ K

Maio et al. (2007)

$\longrightarrow$ gas in-fall and star formation

The first "sunshine"

PopIII stars

pristine or very metal poor

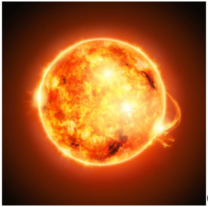
$Z < Z_{crit} (\sim 10^{-4} Z_{\odot})$

mass range: ? ? ?

explosion energies: ? ? ?

driving reionization: ? ? ?

early MBH seeds: ? ? ?



$\odot$

PopII-I stars

metal enriched

$Z > Z_{crit} (\sim 10^{-4} Z_{\odot})$

mass range: $\sim [0.1; 100]\ M_{\odot}$

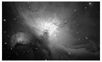
explosion energies: $\sim 10^{51}$ erg

driving reionization: No

early MBH seeds: No

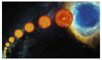
For a complete picture

$\longrightarrow$ follow gravity and hydrodynamics *coupled* to molecule formation and metal production from stellar evolution through cosmic time



molecules determine *first* gas collapsing events

metals determine *subsequent* structure formation

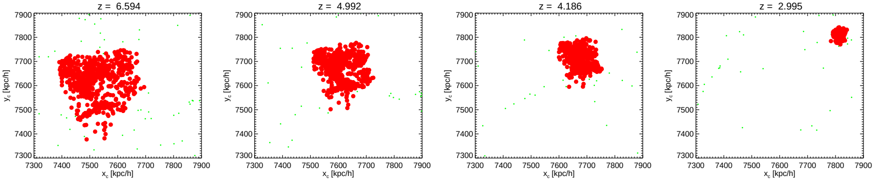


stellar evolution determines *yields*, γ and *timescales*

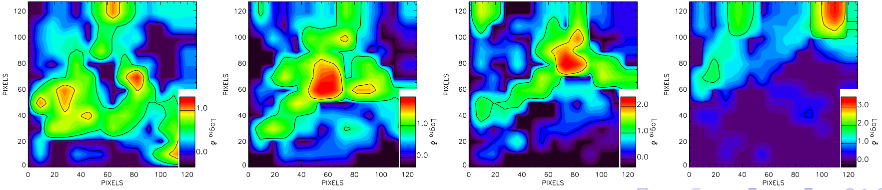
Following and implementing metal and molecule evolution in numerical codes (e.g Gadget, etc.) required

(Springel, 2001, 2005; Yoshida+, 2003; Tornatore+, 2007; Maio+, 2007, 2010, 2016, 2019; .....)

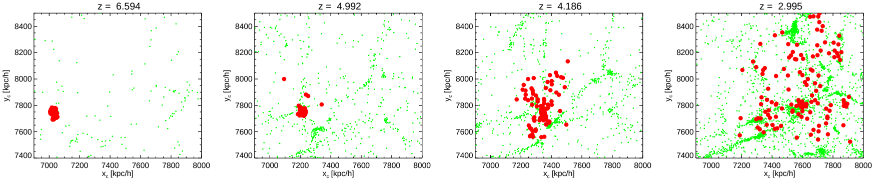
H/H_2-driven gas collapse (inflows)...



$z \simeq 6.6 \quad \longrightarrow \quad z \simeq 2.9$



... star formation and metal spreading (outflows)



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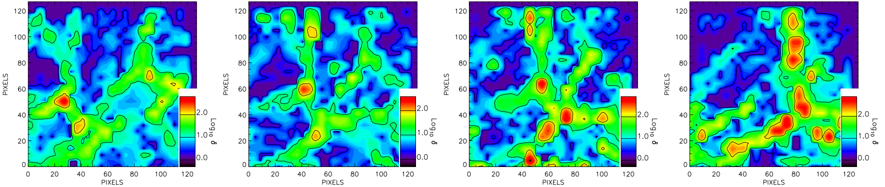


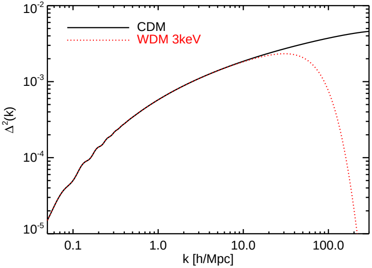
WDM and CDM

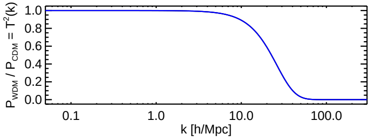
WDM particle mass:
assumed 3 keV (thermal relic)

WDM described by a sharp decrease of P(k) at large k (implications for IGM, lensing, clustering, satellite problem)

What about early epochs?

Perform *ad hoc* simulations of primordial galaxy formation
L=10Mpc/h, 2×512^3

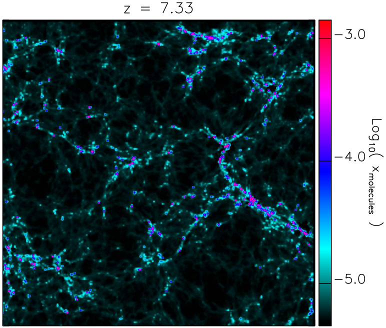


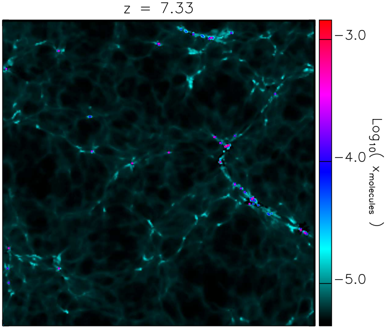


Maio & Viel (2015)

CDM and WDM star forming sites

molecular-rich star forming *knots and filaments*

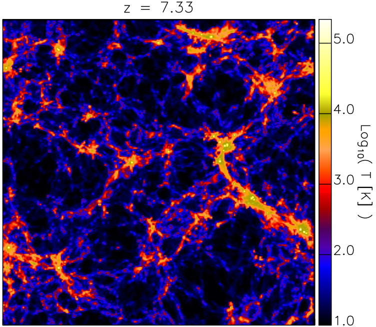




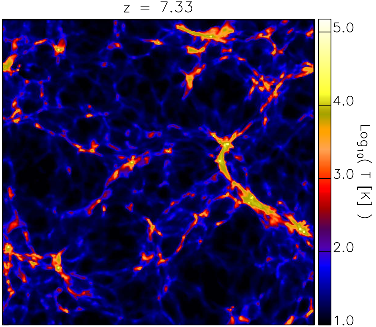
CDM **WDM**

CDM and WDM structures

star formation heated structures



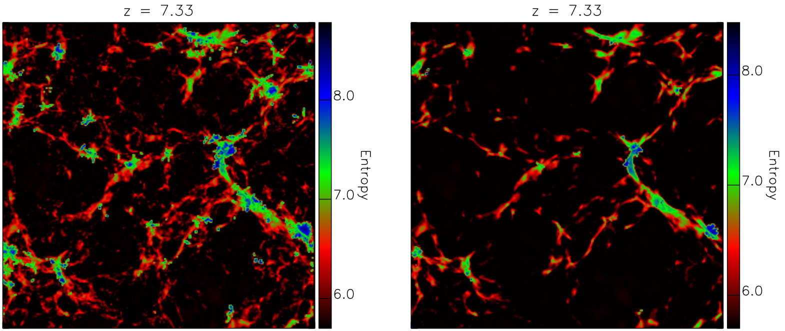
CDM



WDM

CDM and WDM gas entropy state

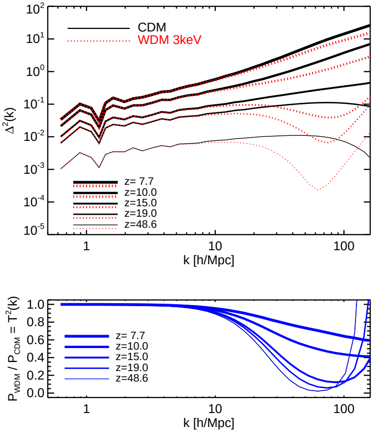
interplay between cold and hot gas phases



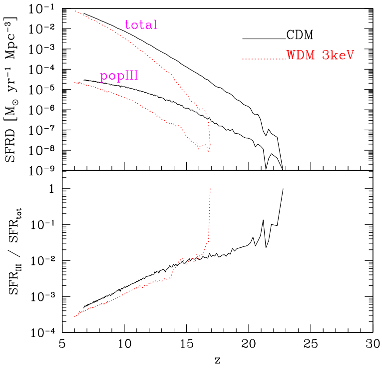
CDM **WDM**

CDM and WDM growth

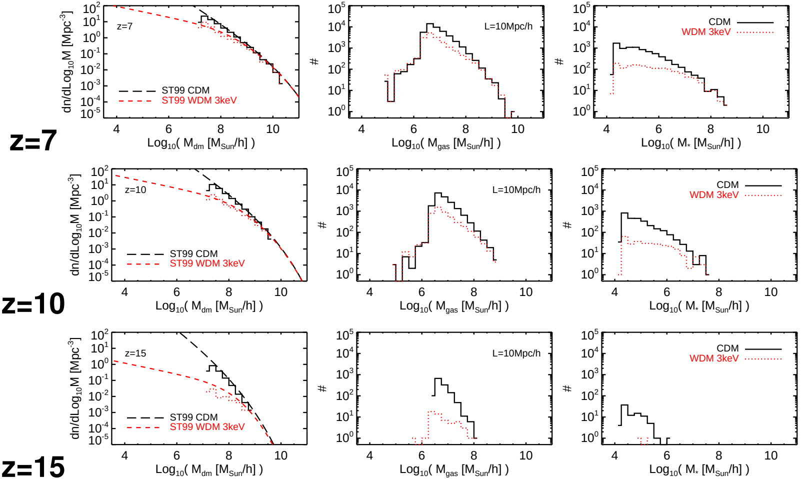
Power(k)



SFRD(z)

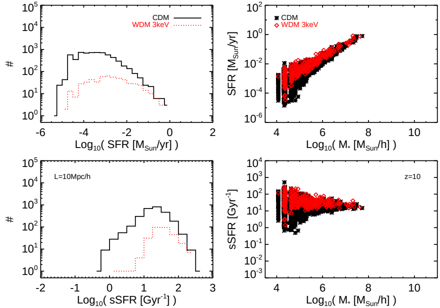


Early structures in CDM and WDM

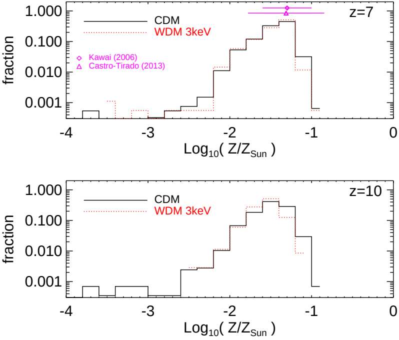


Baryonic properties in CDM and WDM

(s)SFR vs $M_\star$



z=10



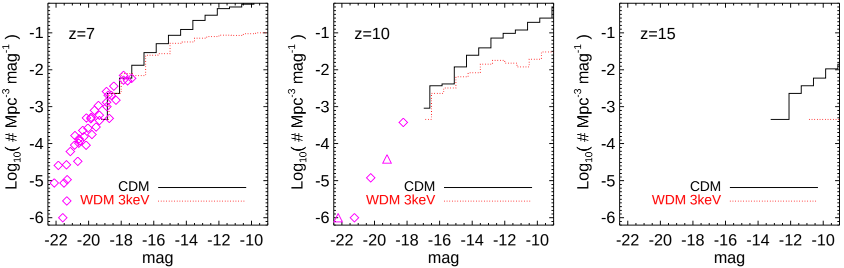
z=7

z=10

Z are little affected, but WDM objects are more bursty than CDM

– fraction of WDM star hosting haloes = 70%, 55%, 40% at redshift $z = 7, 10, 15$
– fraction of CDM star hosting haloes = 67%, 43%, 17% at redshift $z = 7, 10, 15$

UV galaxy luminosities in CDM and WDM



Departures above break magnitude $\text{mag}_\star \simeq -16\left(\frac{1+z}{10}\right)^{0.2}$

At the *faint end* WDM UV LFs are lower than CDM by up to 1 dex
sensitive instruments needed to discriminate models in the 1st Gyr

Summary...

- We have presented results from cosmological N-Body hydrodynamical chemistry simulations
- We study early galaxy populations and their interplay with the surrounding environments in CDM and WDM
  Maio & Viel, 2015; Magg et al., 2016; Villanueva et al. 2018; Ronconi et al. 2020; etc.

Conclusions...

- The high-z Universe is a promising window to explore DM nature, also in light of future instruments
- Baryon evolution of early galaxies is influenced by DM model: gas collapse, SFRs, SMDs in WDM are delayed wrt CDM and show a deficit of faint objects
- Results are not very sensitive to assumed stellar parameters (Z_{crit}, metal *yields*, IMF *slope*, wind velocity, etc.)