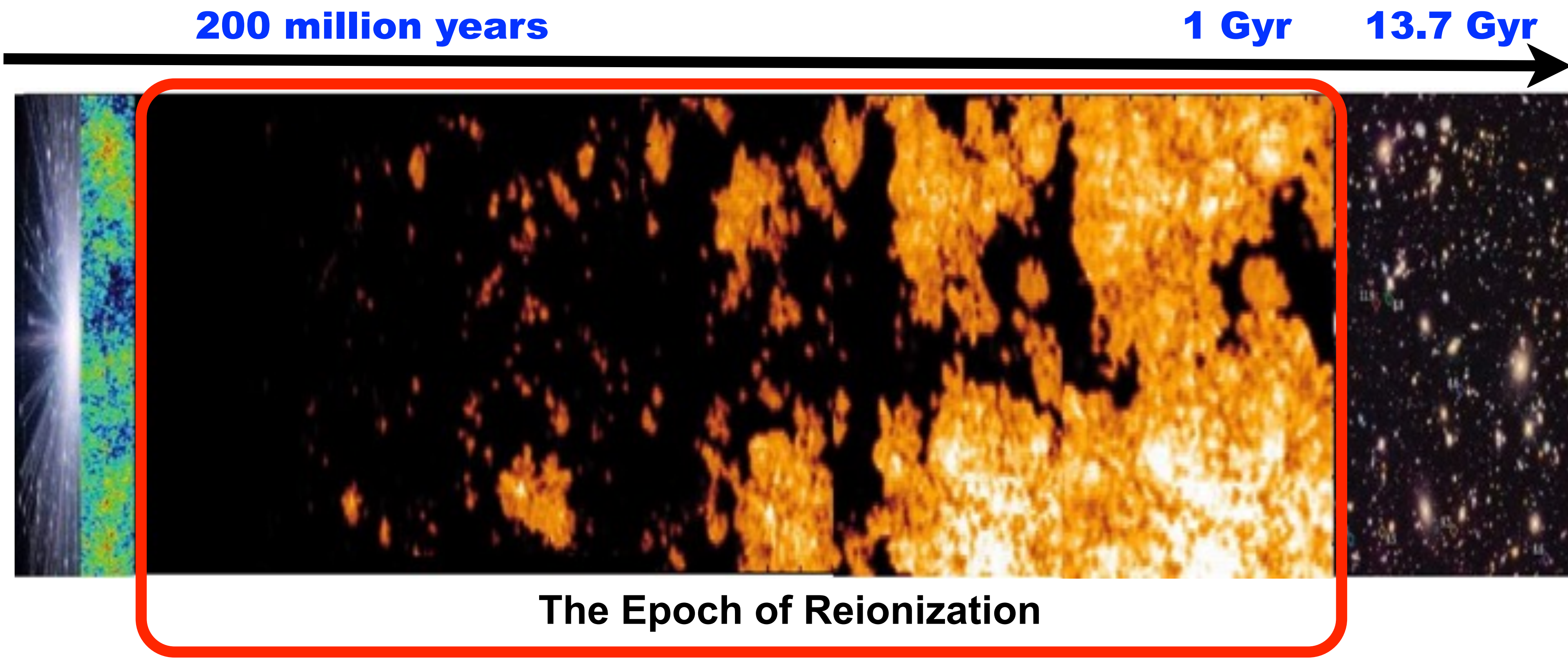
The sources of cosmic reionization

Pratika Dayal



With: Volker Bromm, Tirth Choudhury, James Dunlop, Andrea Ferrara, Anne Hutter, Andrei Mesinger & Fabio Pacucci

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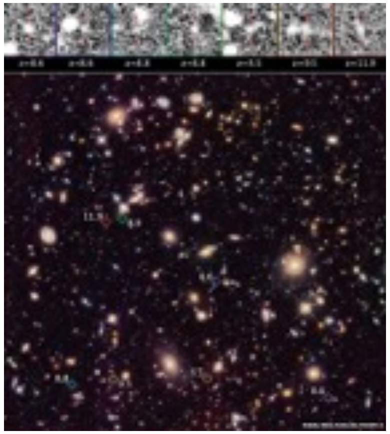
The main questions

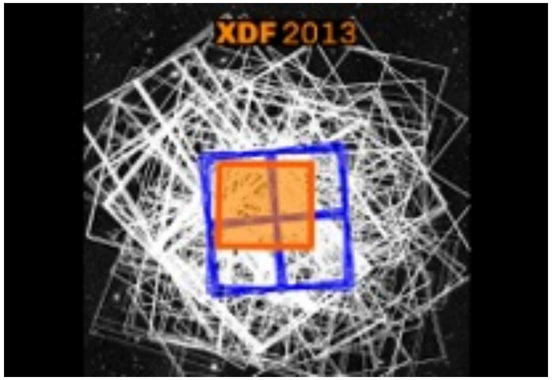
- What is the fundamental physics driving the formation of the key reionization sources?
- What constraints do early galaxies/reionization yield on the nature of Dark Matter?

Observational status of Lyman break galaxies



HUDF

z	Number of galaxies
5	3391
6	940
7	598
8	225
9	~4-6
10	~6



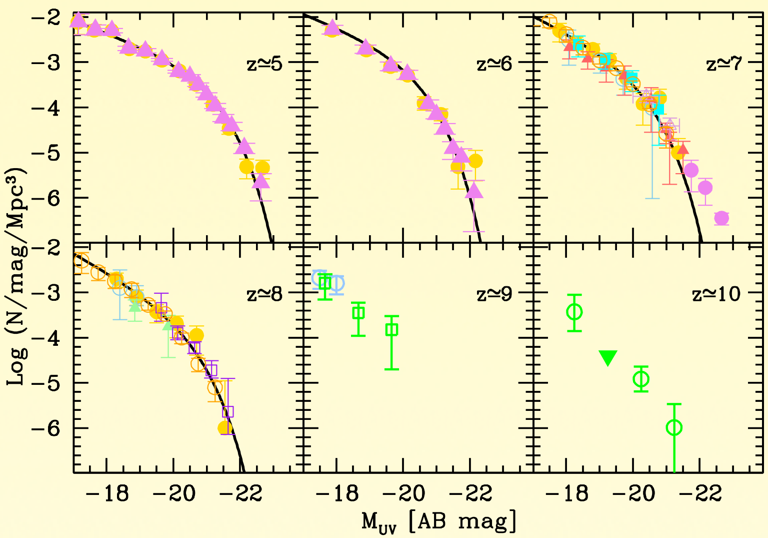
Atek+2015
Bouwens+2007, 2011, 2014
Bowler+2014, 2015
Bradley+2013
Castellano+2010, 2016
Ellis+2013
Finkelstein+2012, 2013
Livermore+2016
McLeod+2015, 2016
McLure+2009, 2013
Oesch+2010, 2014, 2016
Stanway+2010...

WFC3 BoRG SURVEY

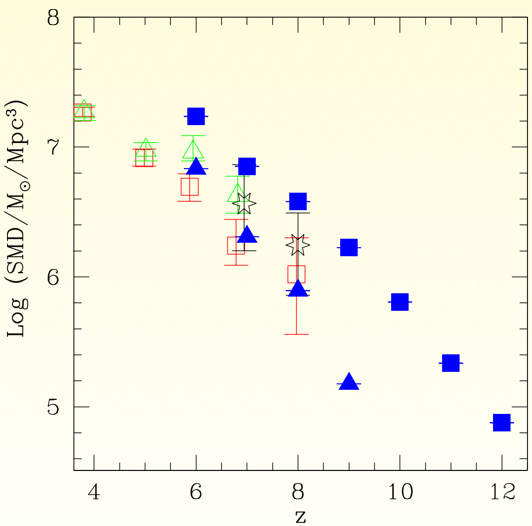
CLASH

What can we learn from all this data?

Global quantities

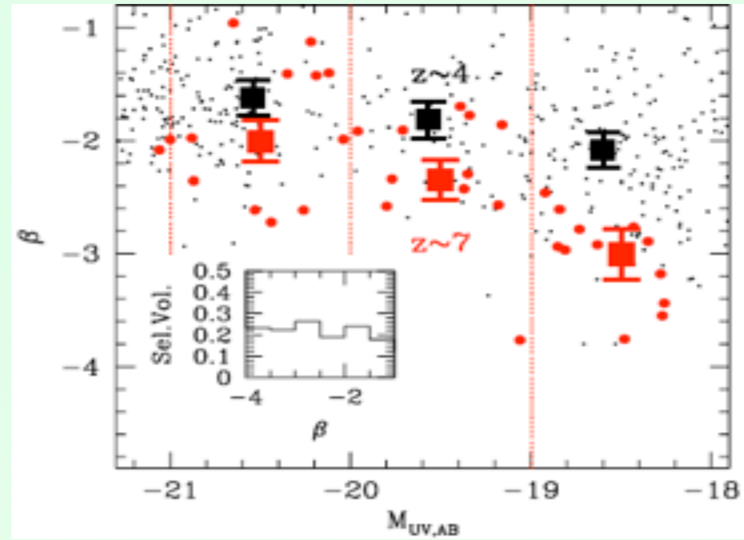


Ultraviolet luminosity functions (UV LF)

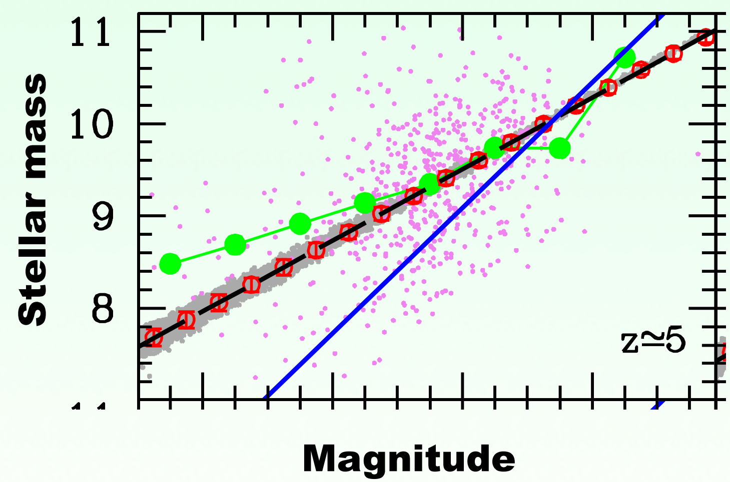


Stellar Mass Density (SMD)

Individual galaxy properties

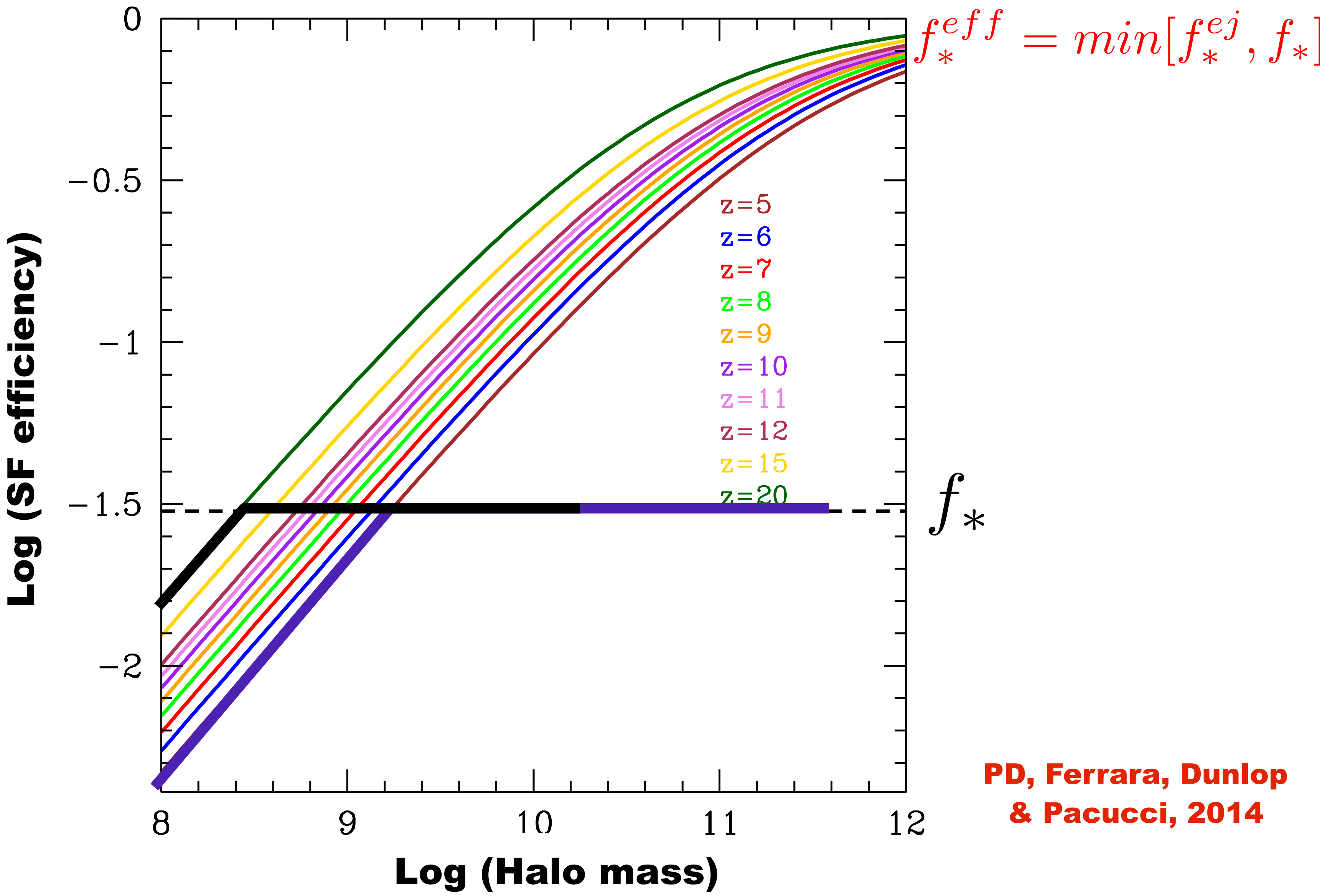


UV spectral slopes



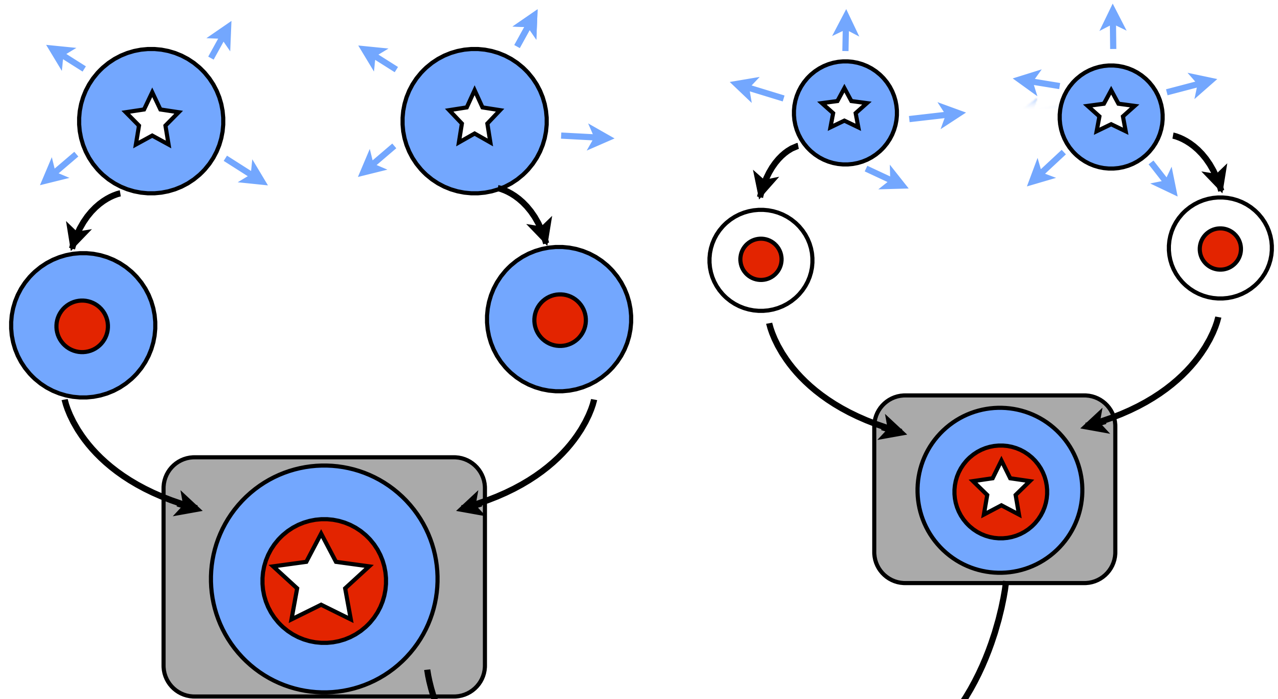
Mass-to-light ratios

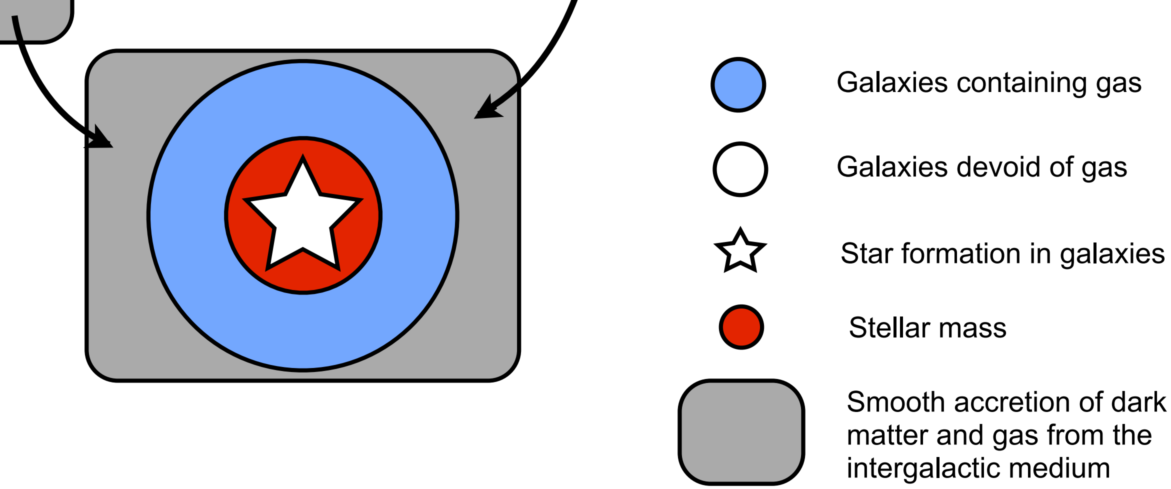
The premise: maximum star formation efficiency limited by energy required to unbind rest of the gas and quench star formation - up to a maximum threshold



PD, Ferrara, Dunlop & Pacucci, 2014

A semi-analytic model implemented with this simple idea





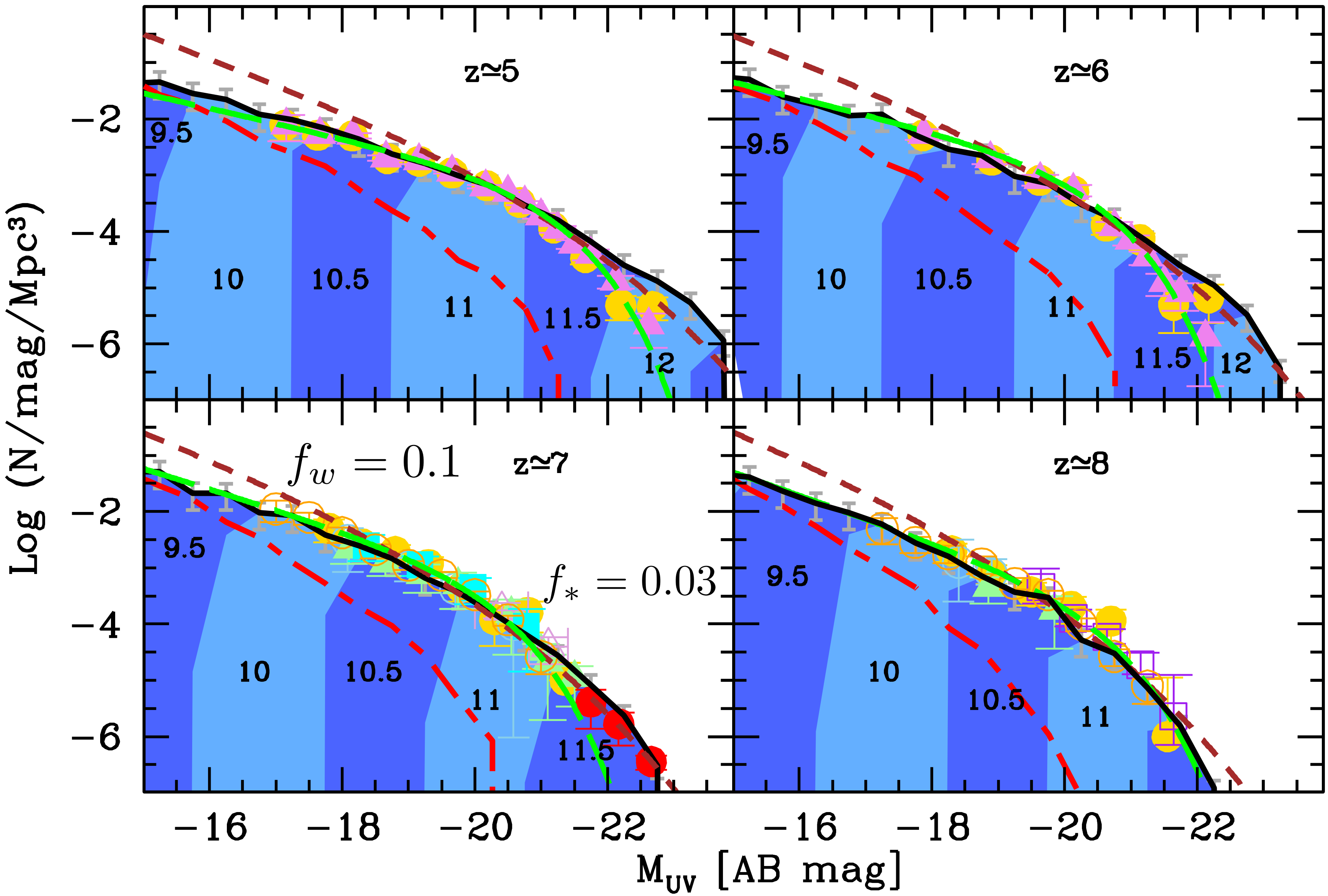
Free parameters:

f_* **1. threshold of SFE**

f_w **2. fraction of SN energy coupling to gas**

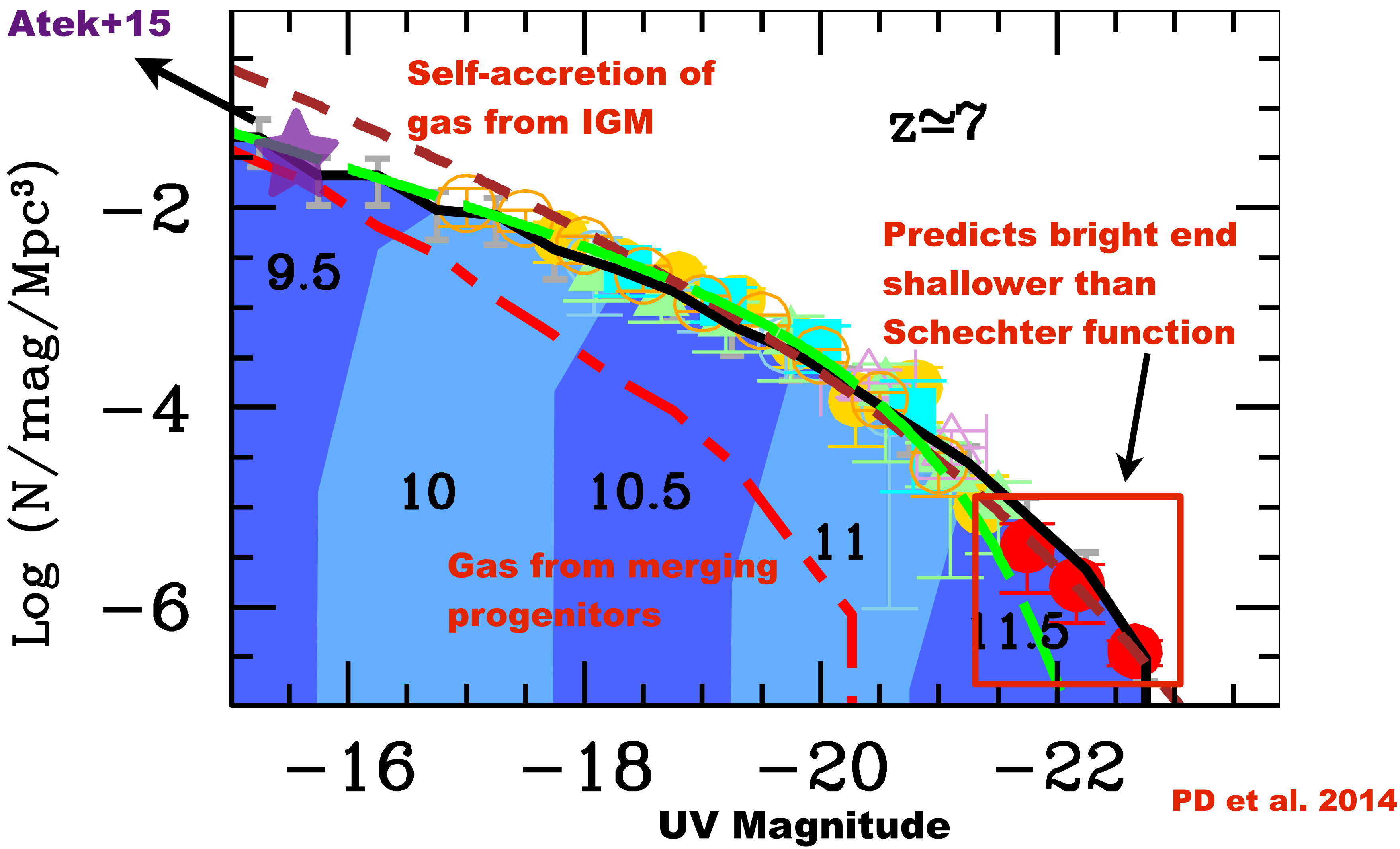
PD, Ferrara, Dunlop & Pacucci, 2014

The number counts of early LBGs (the UV LF)



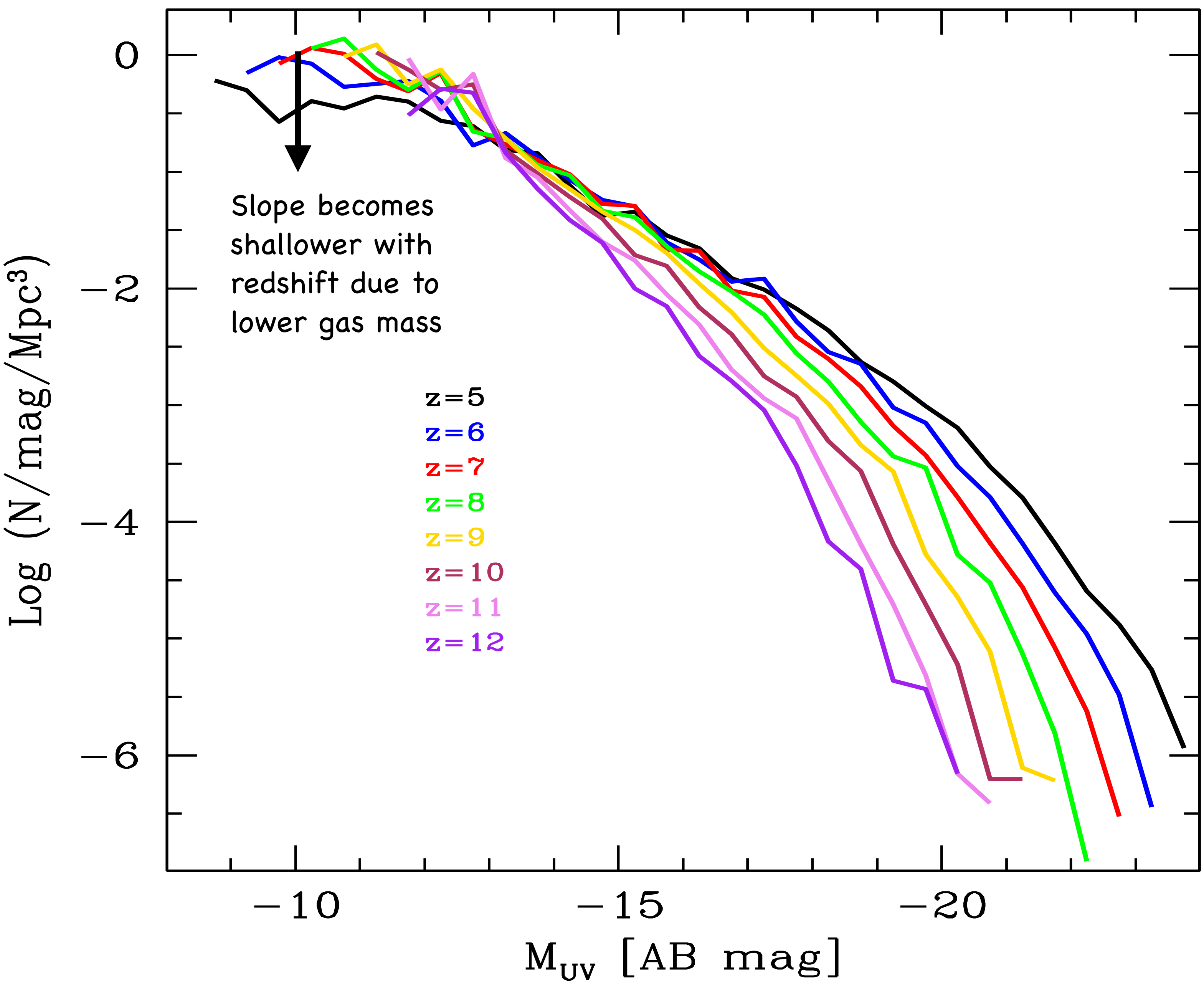
PD, Ferrara, Dunlop & Pacucci, MNRAS, 2014

The gastrophysics of early LBGs



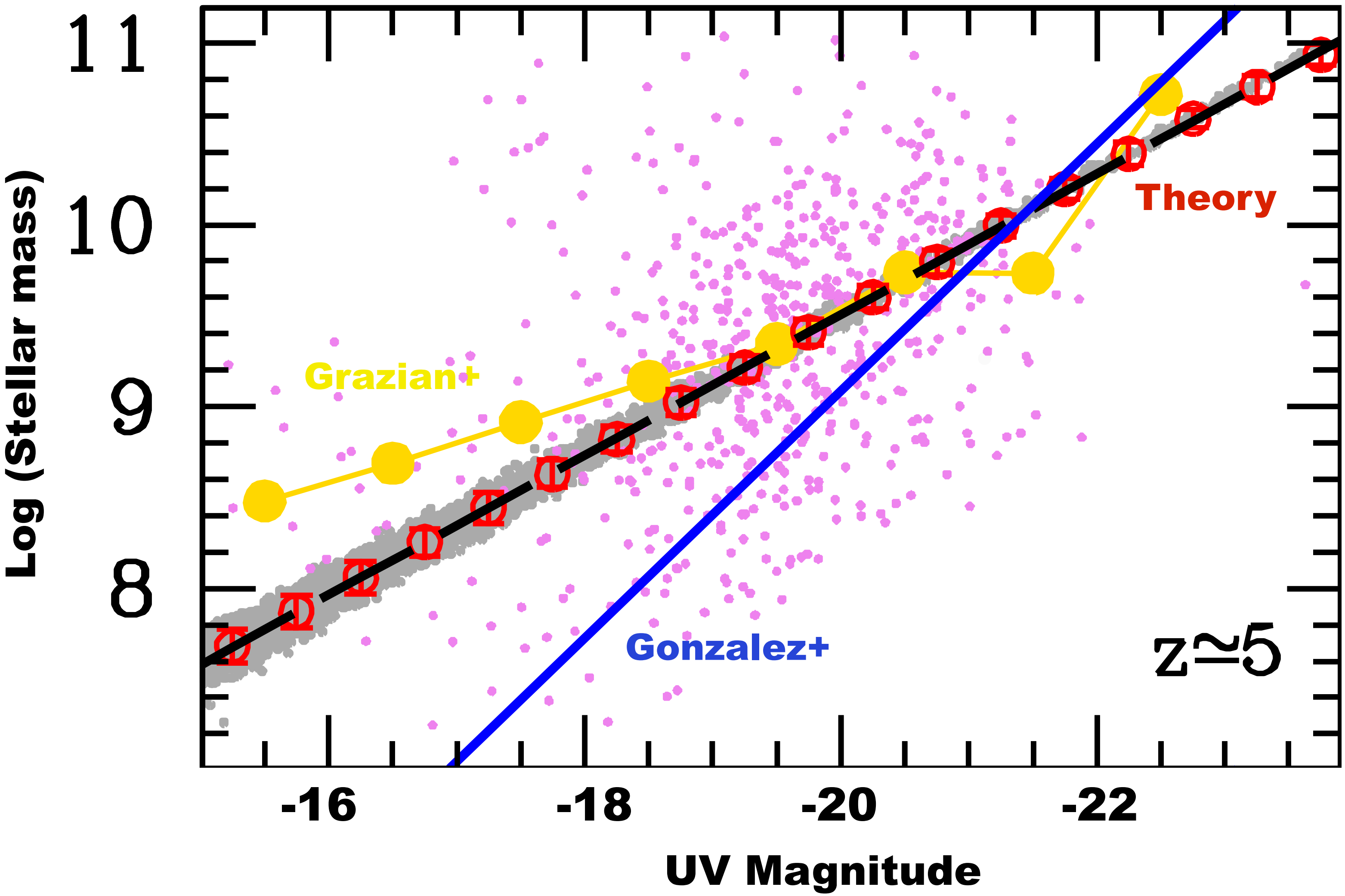
Prediction for the frontier Fields and JWST: $\alpha = -1.75 \log z - 0.52$

How far down do the LFs extend?



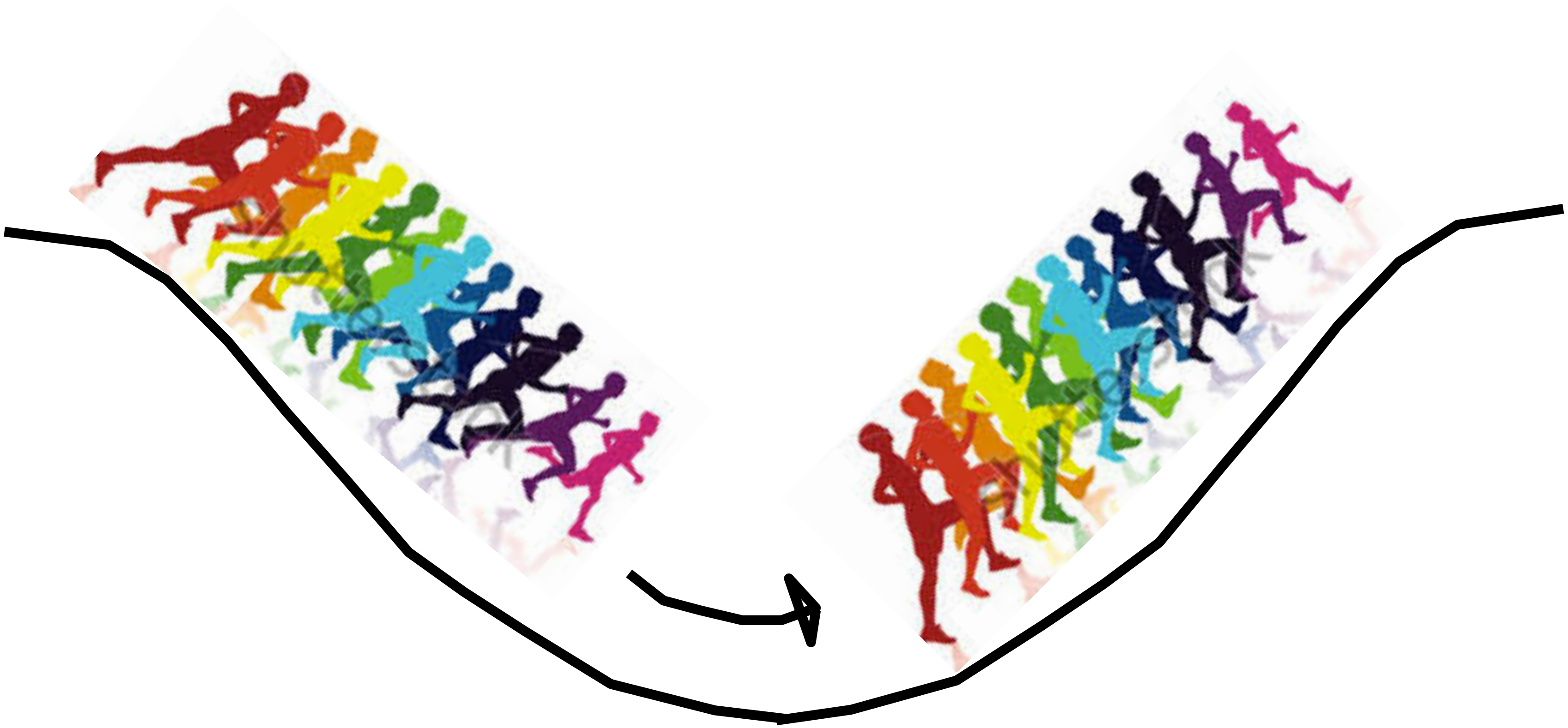
Light scales linearly with mass - but slope debated

PD, Ferrara, Dunlop & Pacucci, 2014

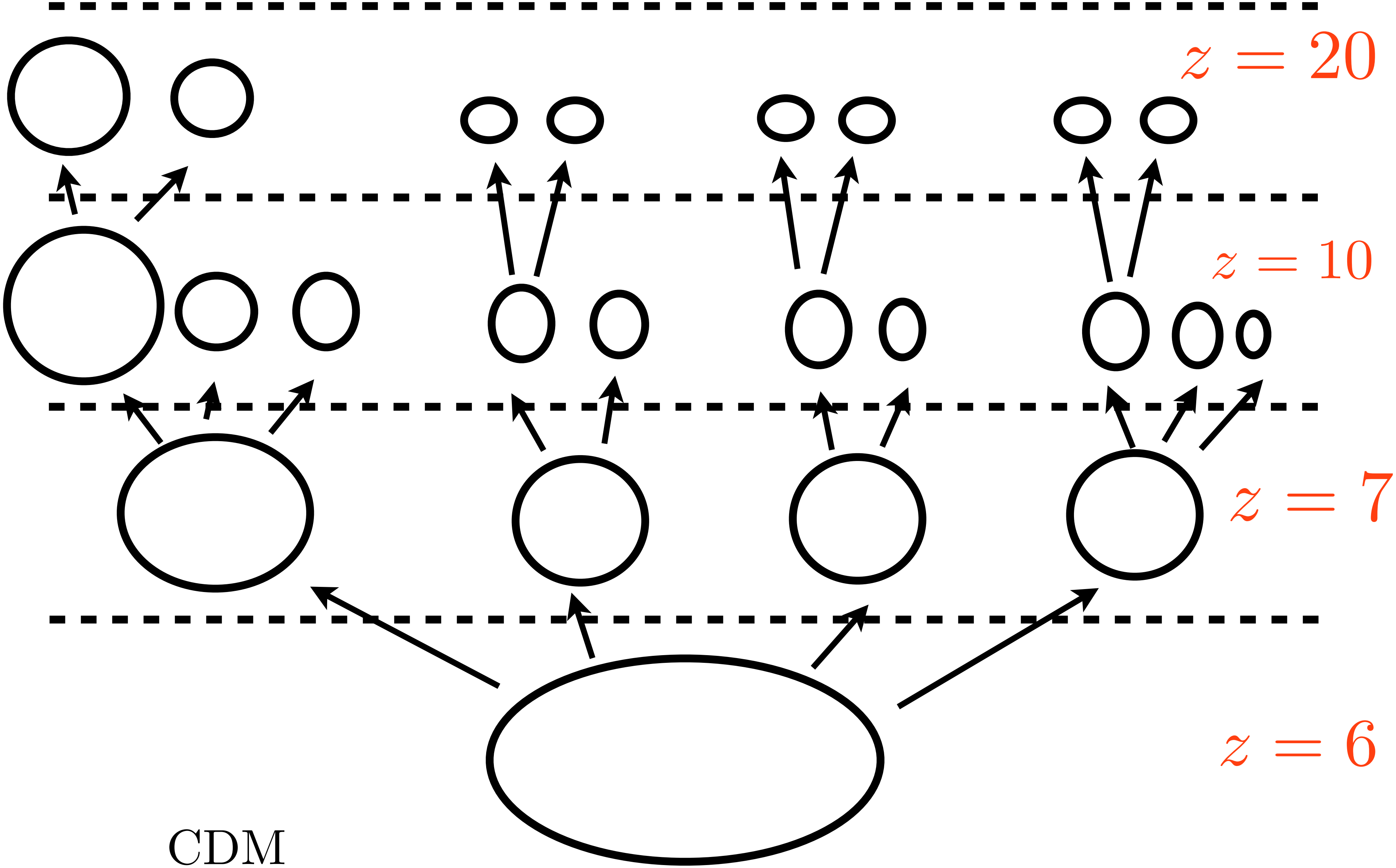


Testable prediction: $\log M_* \propto -0.38 M_{UV}$

Extending this framework to Warm Dark Matter Cosmologies

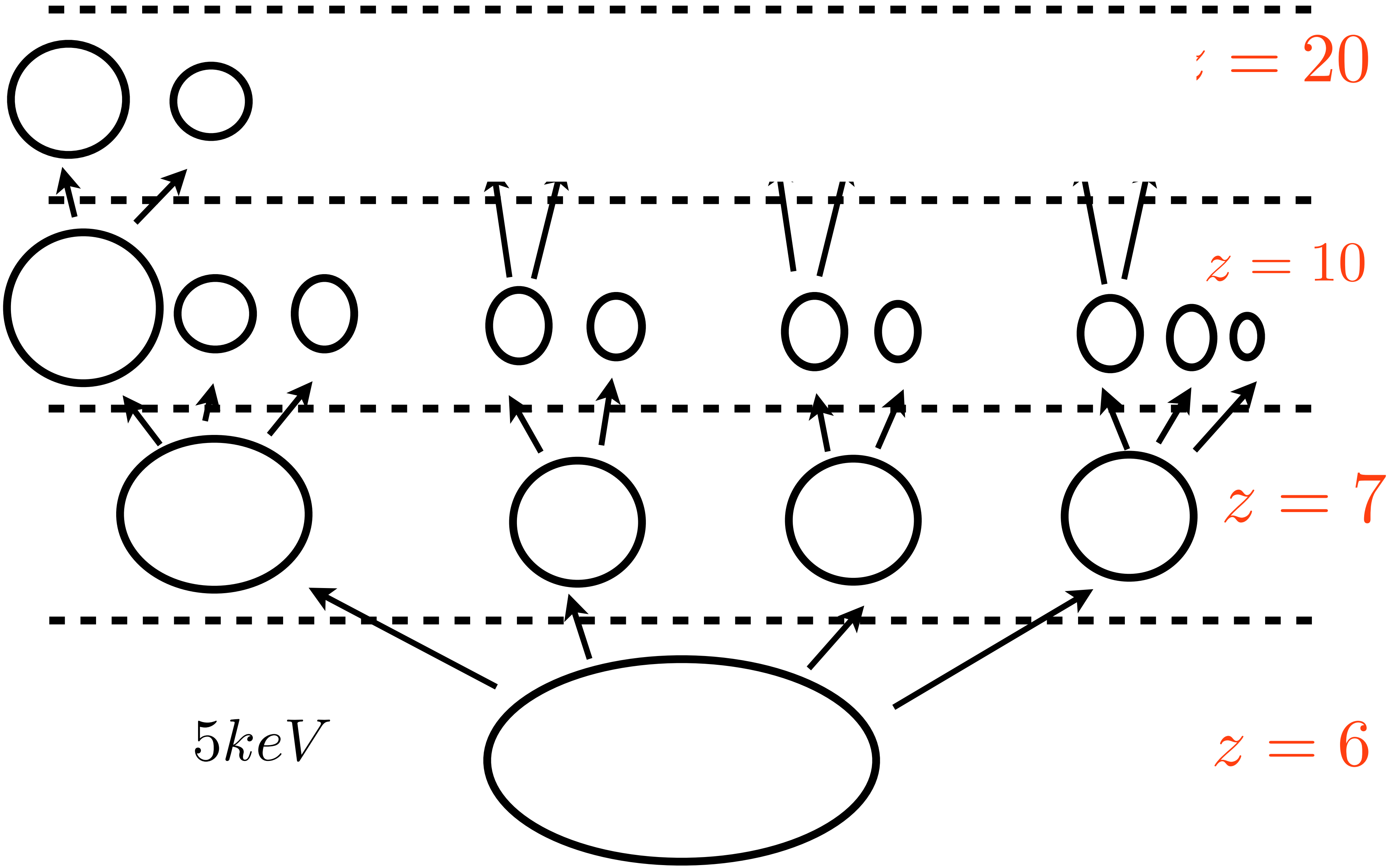


Hierarchical structure formation in CDM



Mass roughly 100 GeV

Lighter the WDM particle, more is the suppression of small scale structures



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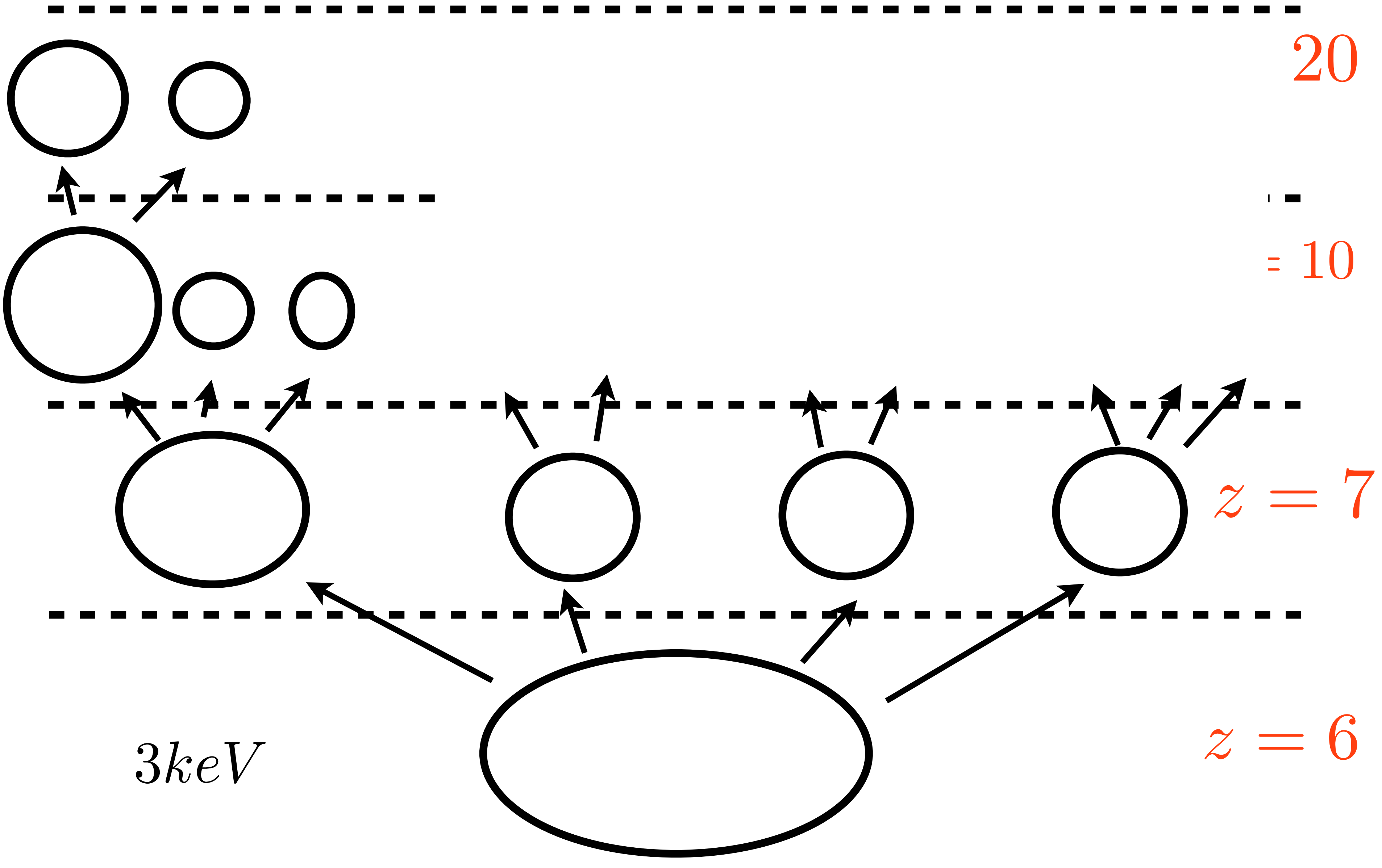

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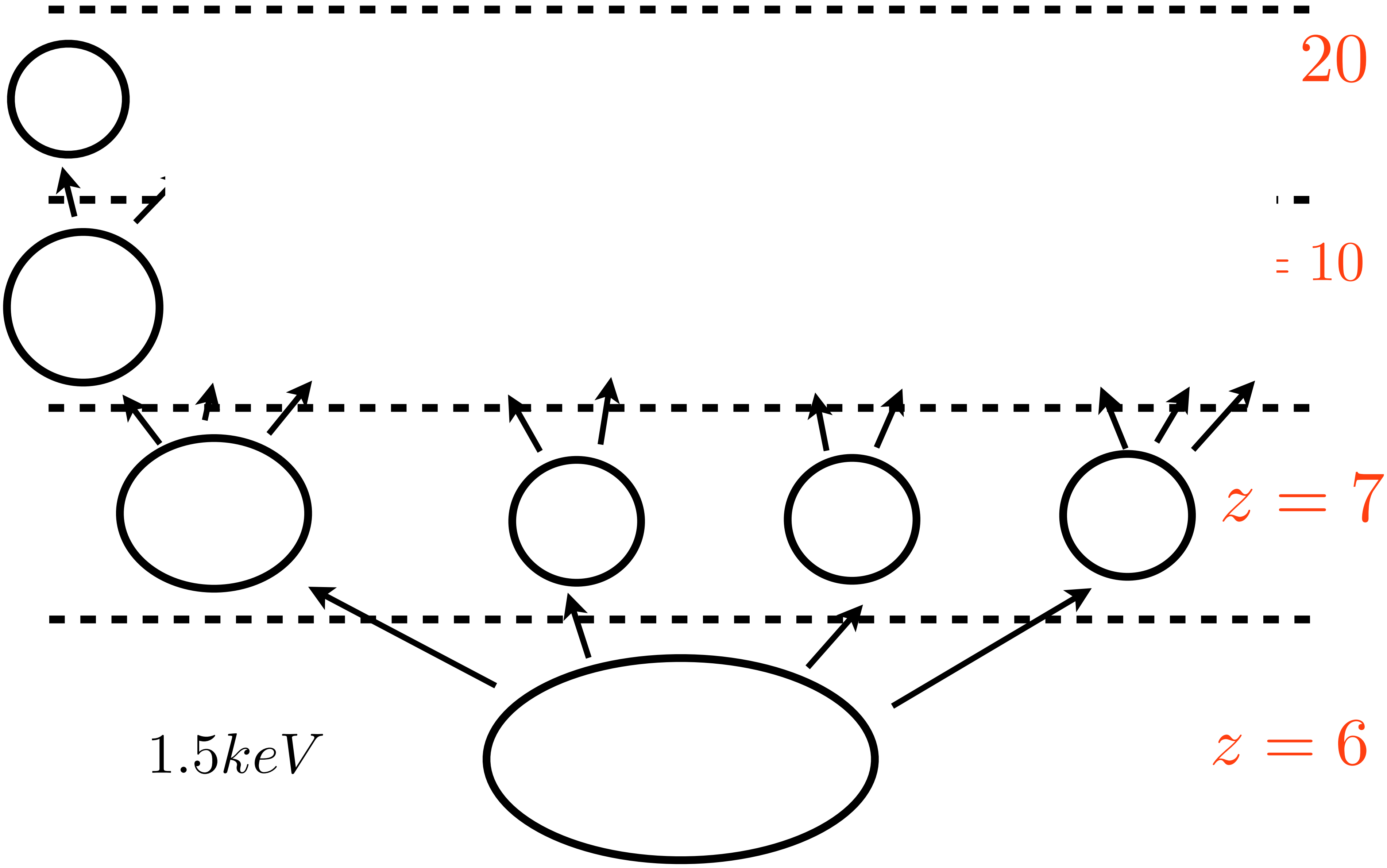
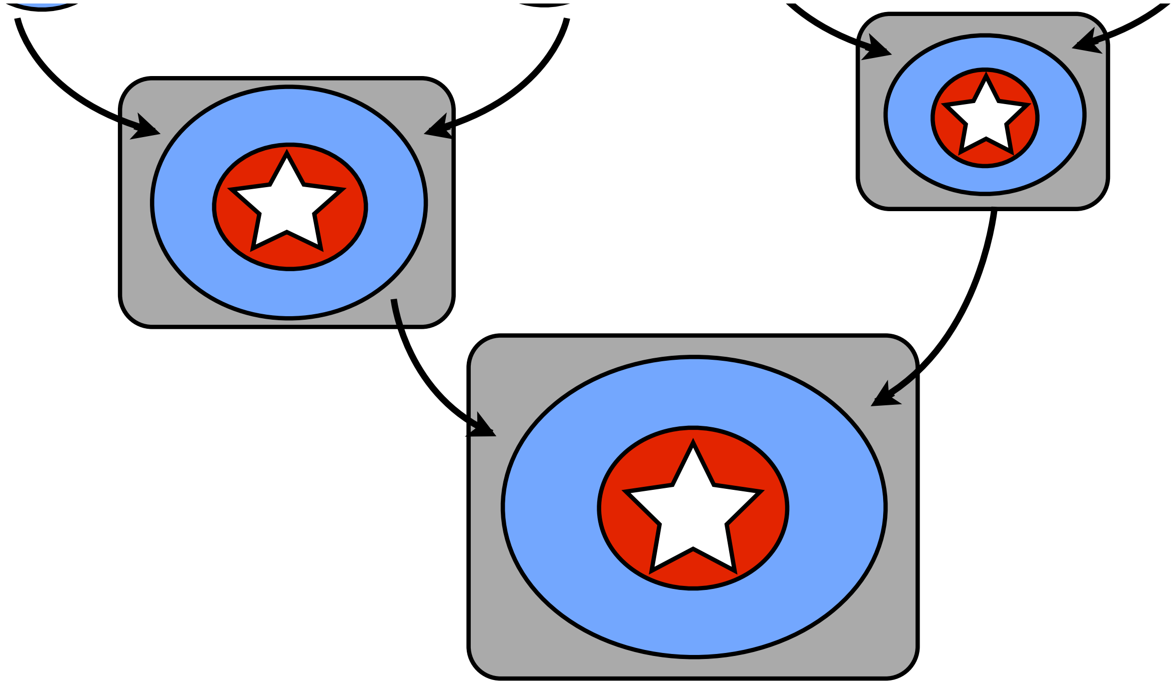
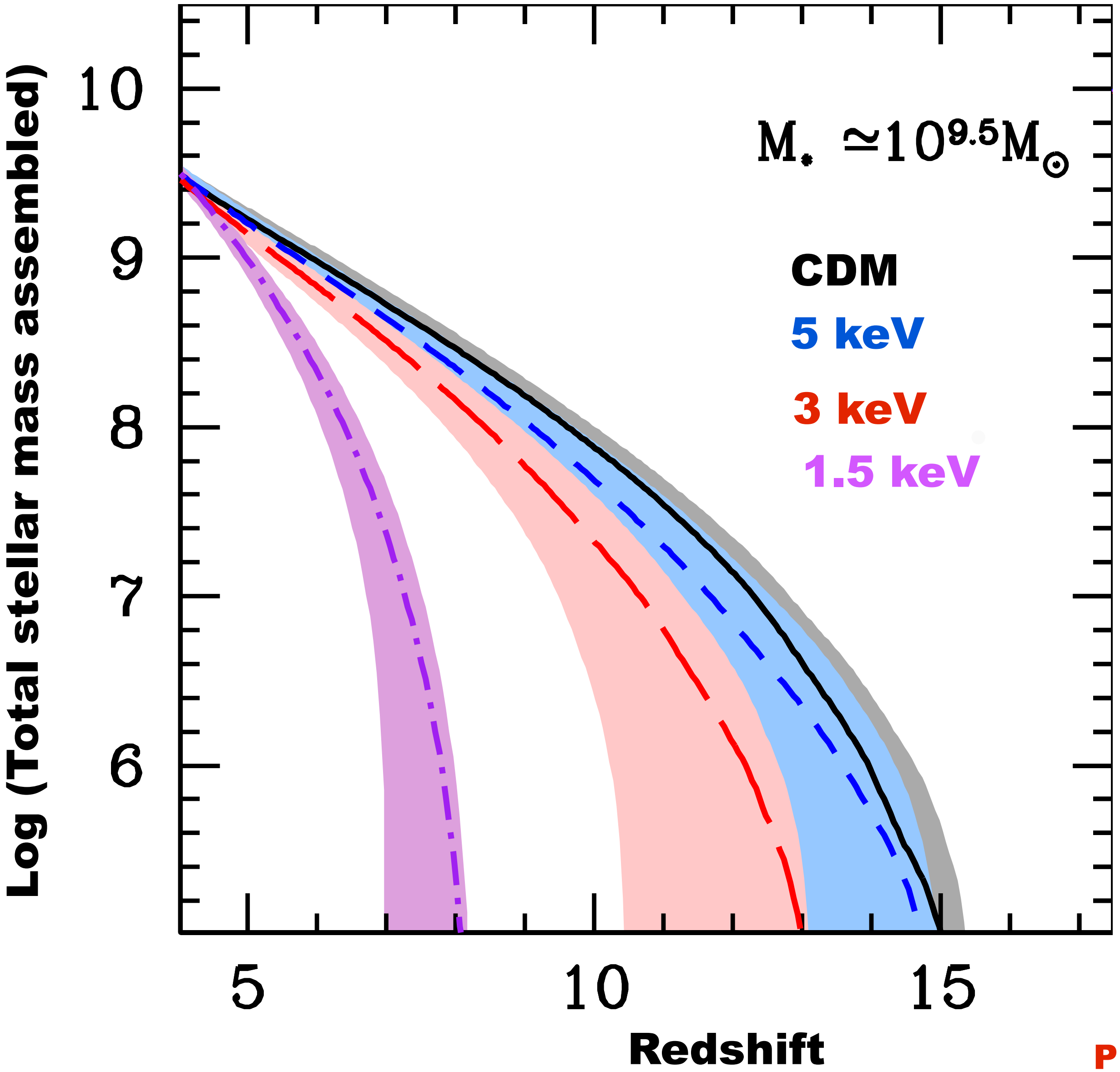


Since the merger tree starts building up later in WDM models..



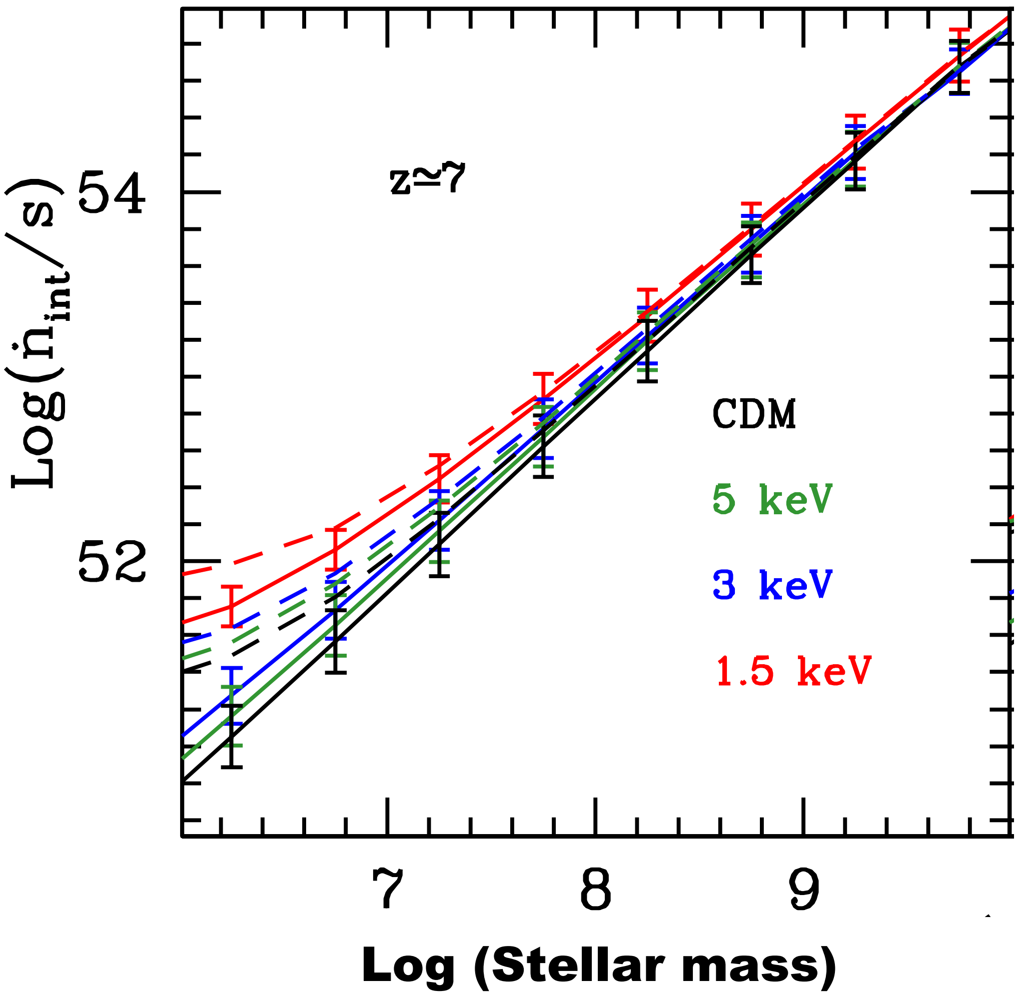
it leads to a delayed assembly of the stellar mass



Galaxies assemble faster in 1.5 keV WDM models compared to CDM. This is because they start off bigger and are less feedback limited as a consequence.

PD, Mesinger & Pacucci, 2015

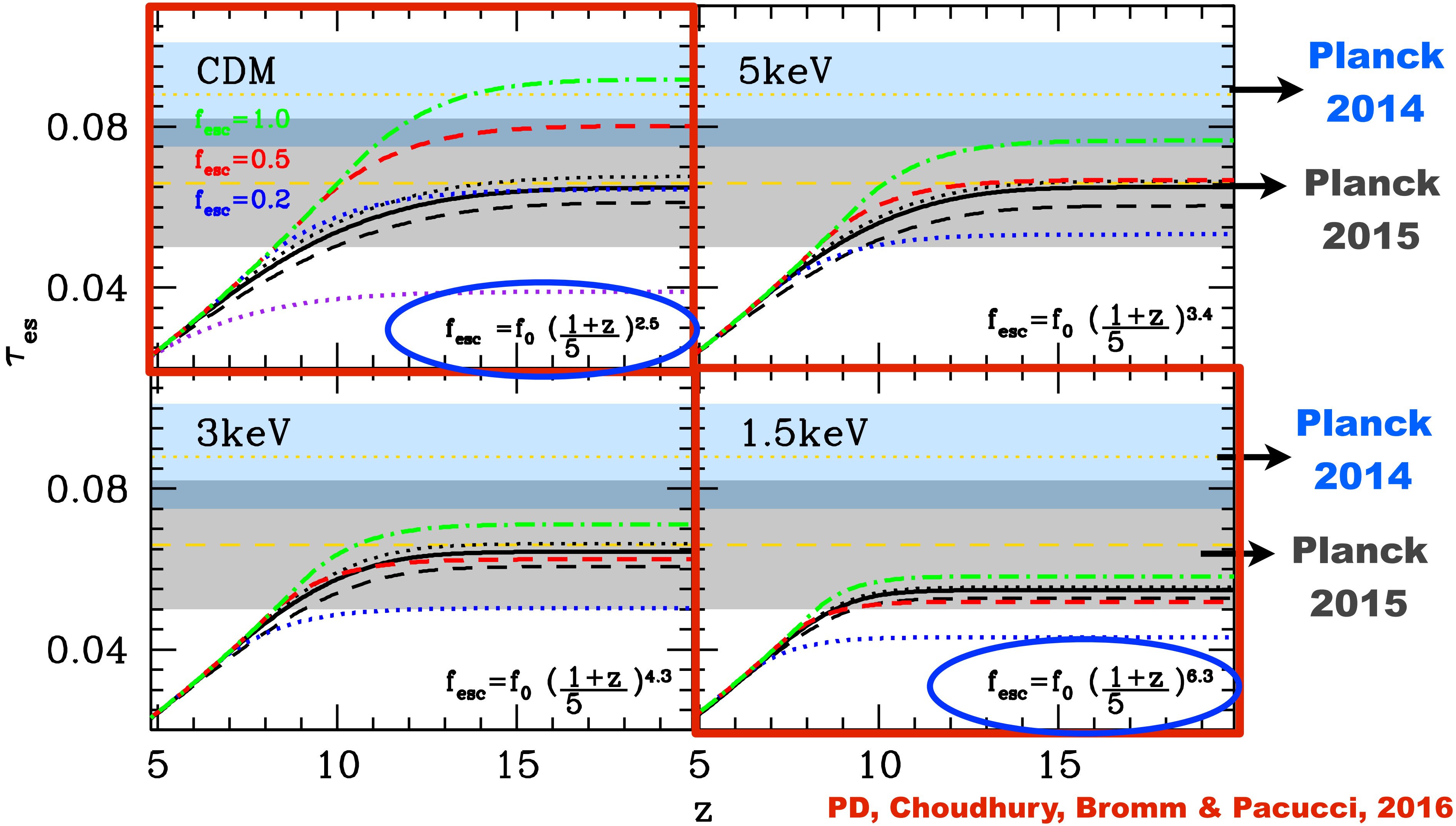
Reionization photons produced per unit mass depend on cosmology



PD, Choudhury, Bromm & Pacucci, 2016

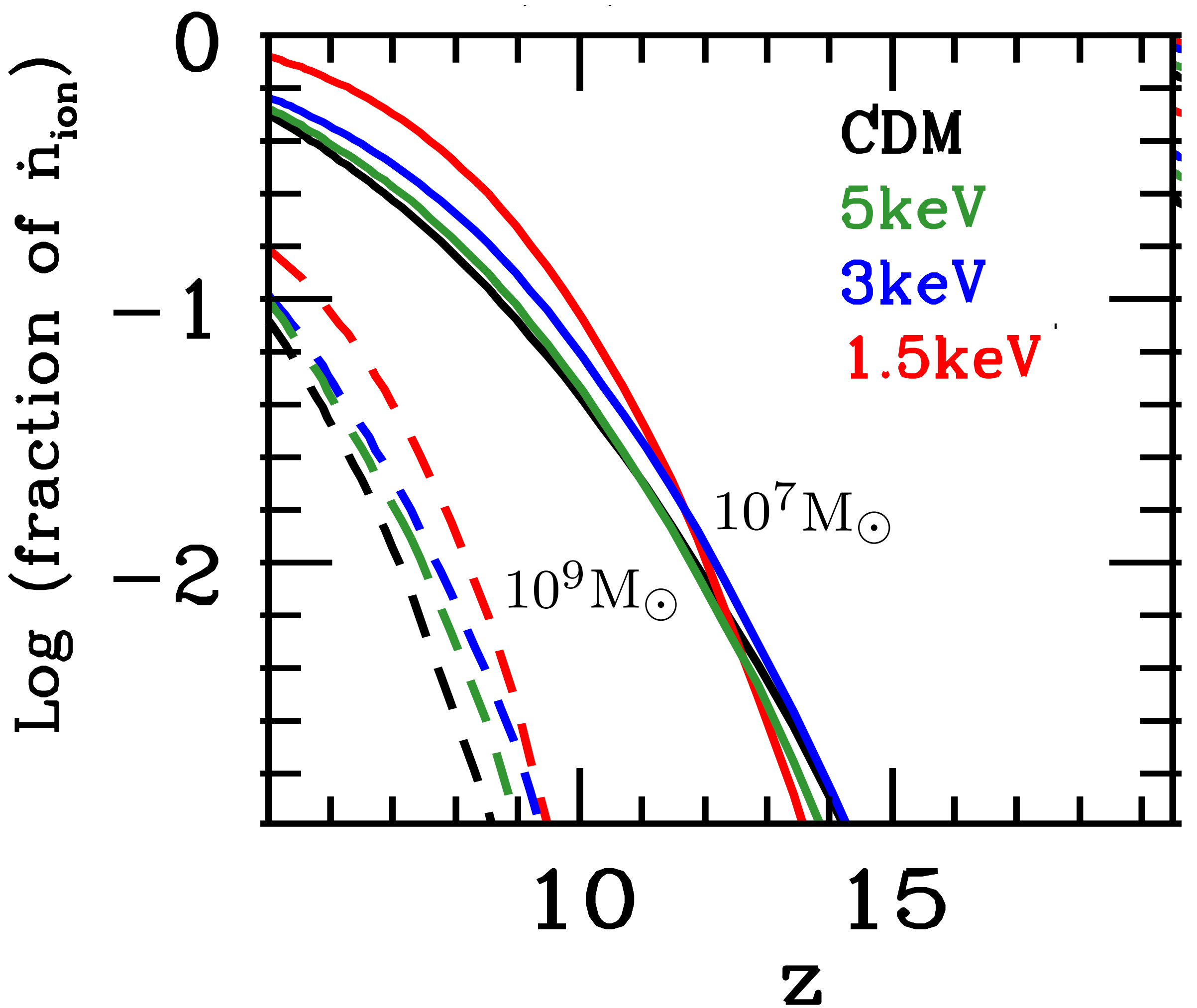
Light WDM models show higher reionization photon/M ratios (i.e. more ionizing photons per unit stellar mass) compared to CDM

Reionization constraints on WDM mass



While old Planck optical depths rules out <2 keV WDM, the newer lower measurements are consistent with such light masses.

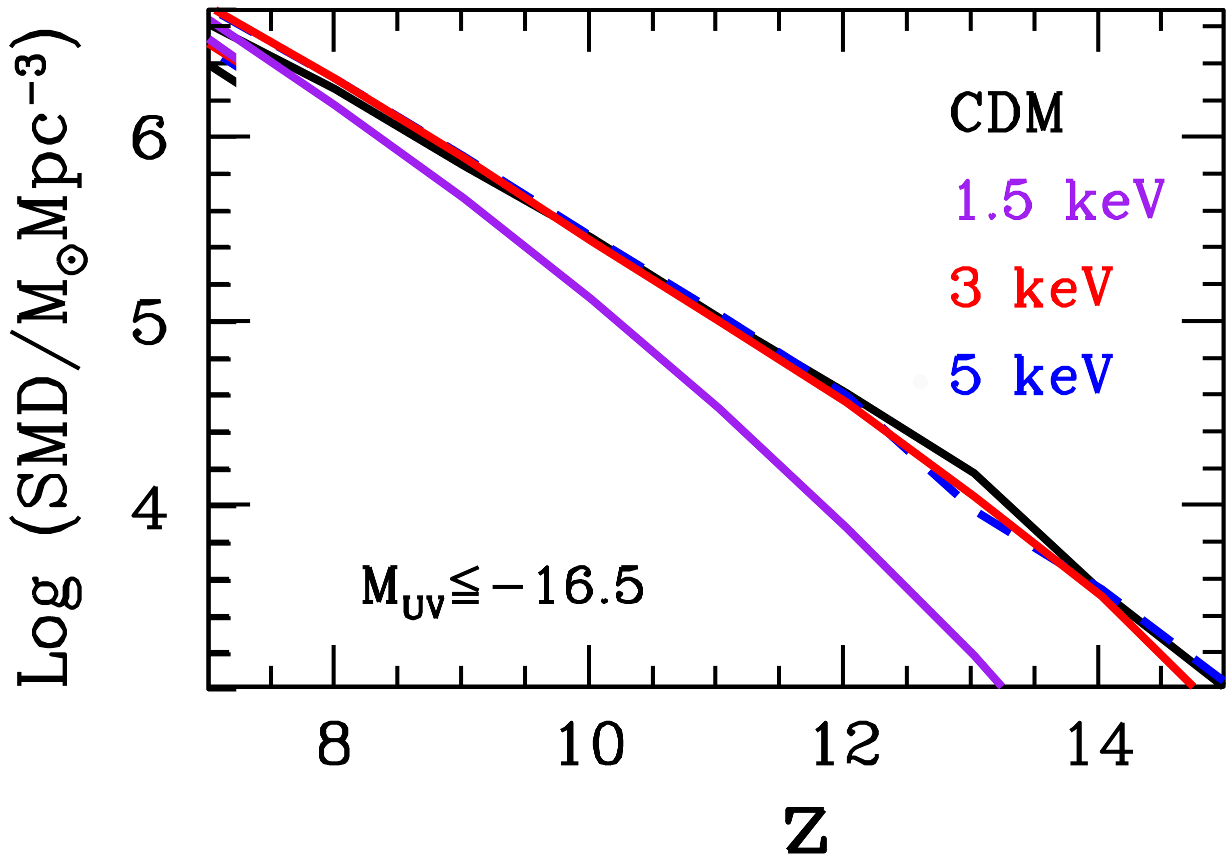
Reionization sources in different DM cosmologies



PD, Choudhury, Bromm & Pacucci, 2016

Currently detected galaxies contribute ~8% (~15%) of ionizing photons in CDM (1.5 keV WDM). Need to go as faint as 10^7 solar masses to get 50% (80%) ionizing photons in CDM (1.5 keV WDM).

Observational imprints of light WDM particles: buildup of the cosmic stellar mass density



Redshift evolution of stellar mass density with JWST-detectable galaxies can allow constraints on WDM mass of about 2keV

PD, Mesinger & Pacucci, 2015

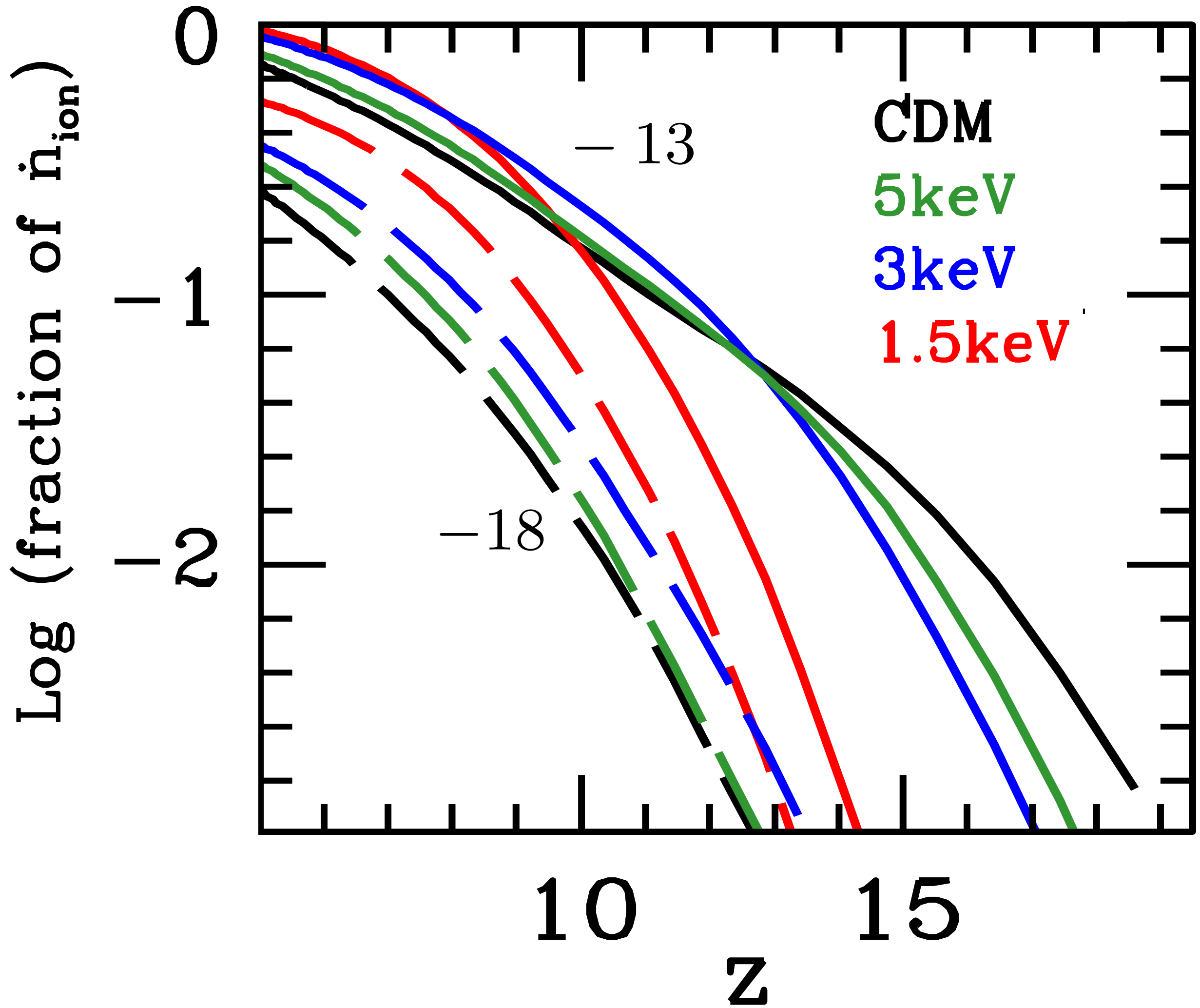
The emerging picture..

- Huge increase in high-z LBG data has led to statistically robust evolving UV LF (slope steepens with redshift), mass to light ratios (slope of -0.38) and estimates of stellar mass density (currently detected LBGs only contain 10% of total).

- Gastrophysics depends on halo mass - self accretion (mergers) build up the gas mass for low mass (high mass) galaxies.

- Implementing the same baryonic physics, we find CDM and >3 keV WDM models to be indistinguishable. But the JWST can be used as a “DM-machine” - stellar mass density buildup with time can help distinguish lower mass (~1.5 keV) WDM.

Reionization sources in different DM cosmologies



PD, Choudhury, Bromm & Pacucci, 2016

Currently detected galaxies contribute <25% (~50%) of ionizing photons in CDM (1.5 keV WDM). Need to go as faint as UV magnitude of -13 to get 65% (100%) ionizing photons in CDM (1.5 keV WDM).