FIRST LIGHT: Hydrodynamical Simulations of Primeval Galaxies

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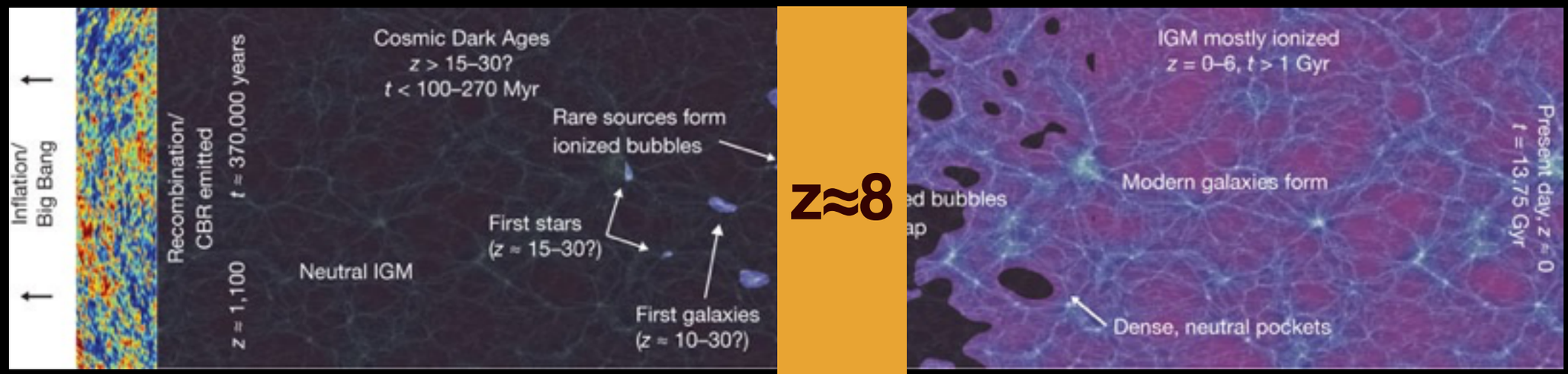
Image credit: Sindi Short

Cosmic Reionisation



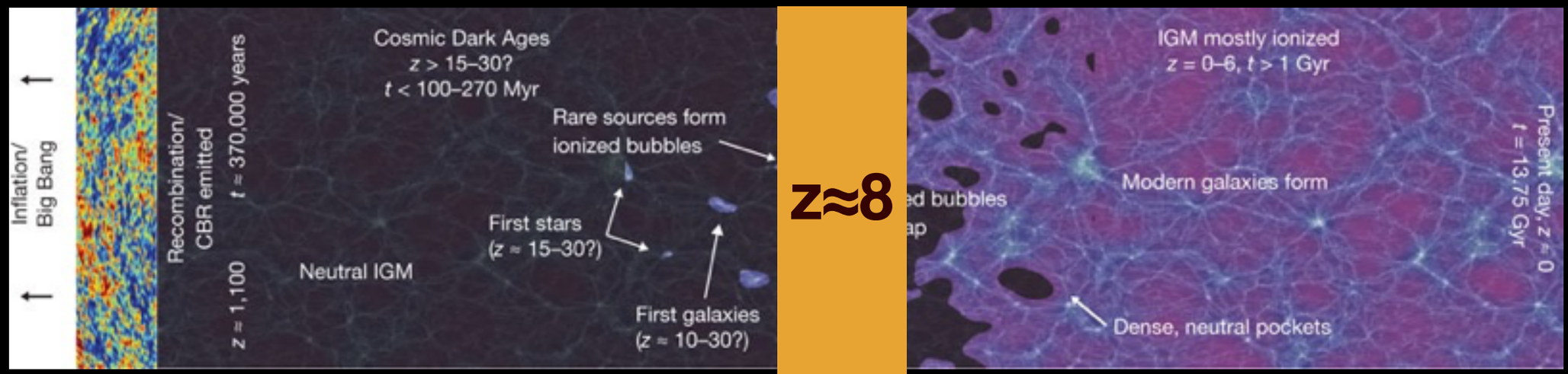
Planck 2016

Robertson et al. 2010

WHAT ARE THE PROPERTIES OF THE PRIMEVAL GALAXIES?

WHAT IS THEIR EFFECT ON THE EARLY UNIVERSE (REIONISATION)?

Cosmic Reionisation



Planck 2016 Robertson et al. 2010

Late and fast reionisation at z=7.8-8.8 ($\boldsymbol{\tau}$~0.058)

Universe was ionised at less than the 10 % level at redshifts above z ≃ 10.
Which sources drive reionisation?

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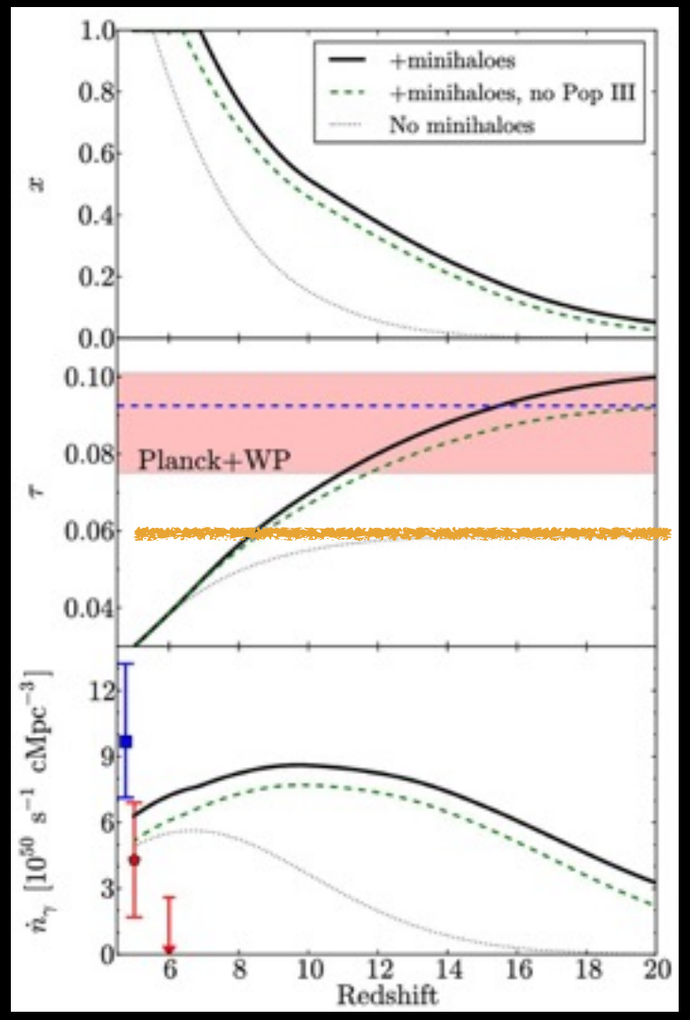
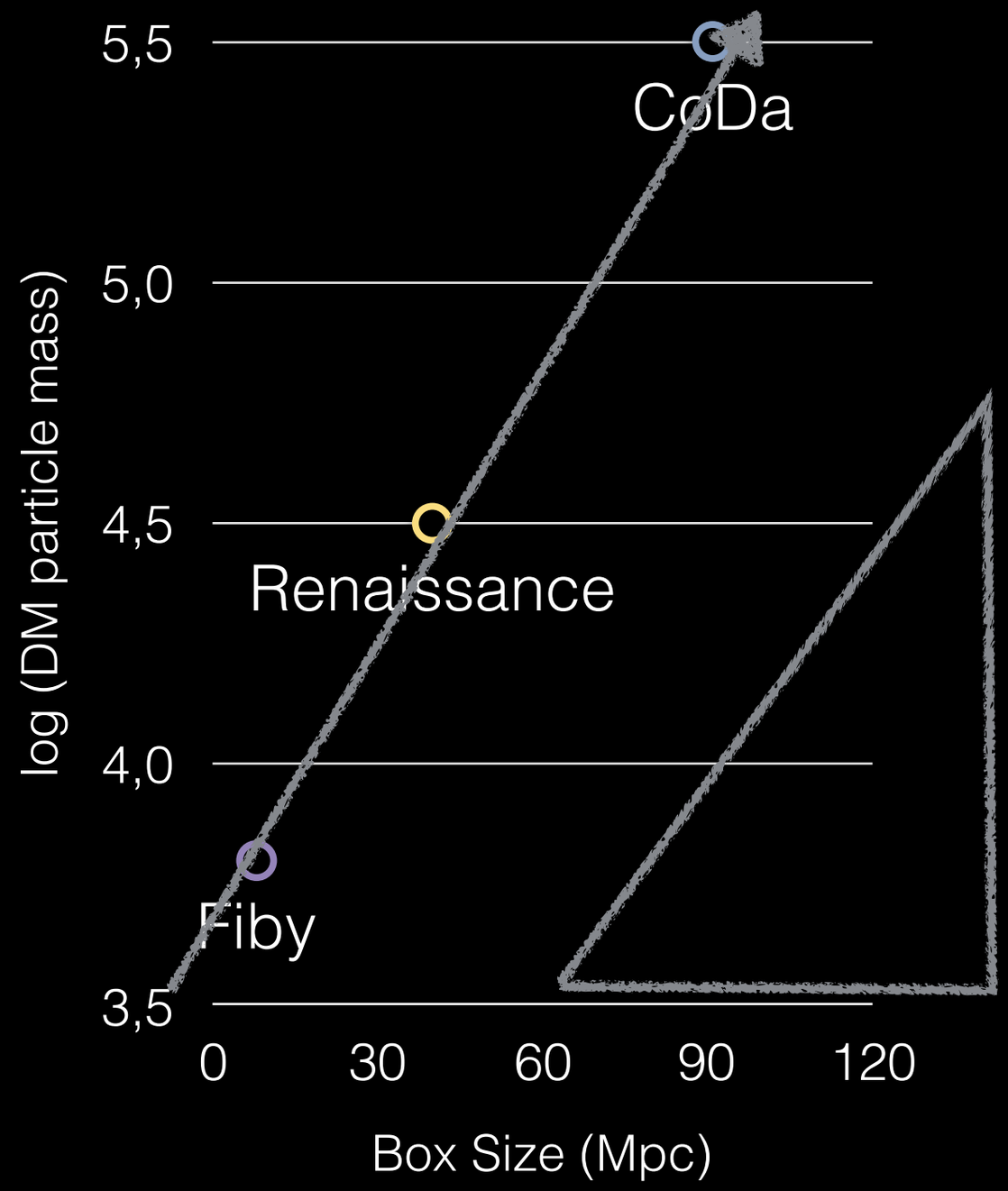
- Pop III & mini-haloes (M_H<$10^{8.25}$ $M_\odot$) do not contribute much to reionisation (M_{UV}>-13)
- Massive haloes (M_H>10^{12} $M_\odot$) are too rare at z~8
- Intermediate regime?



Wise et al. 2014

Simulations

- Simulations of galaxy formation during reionisation
- Large volumes and high resolution are needed



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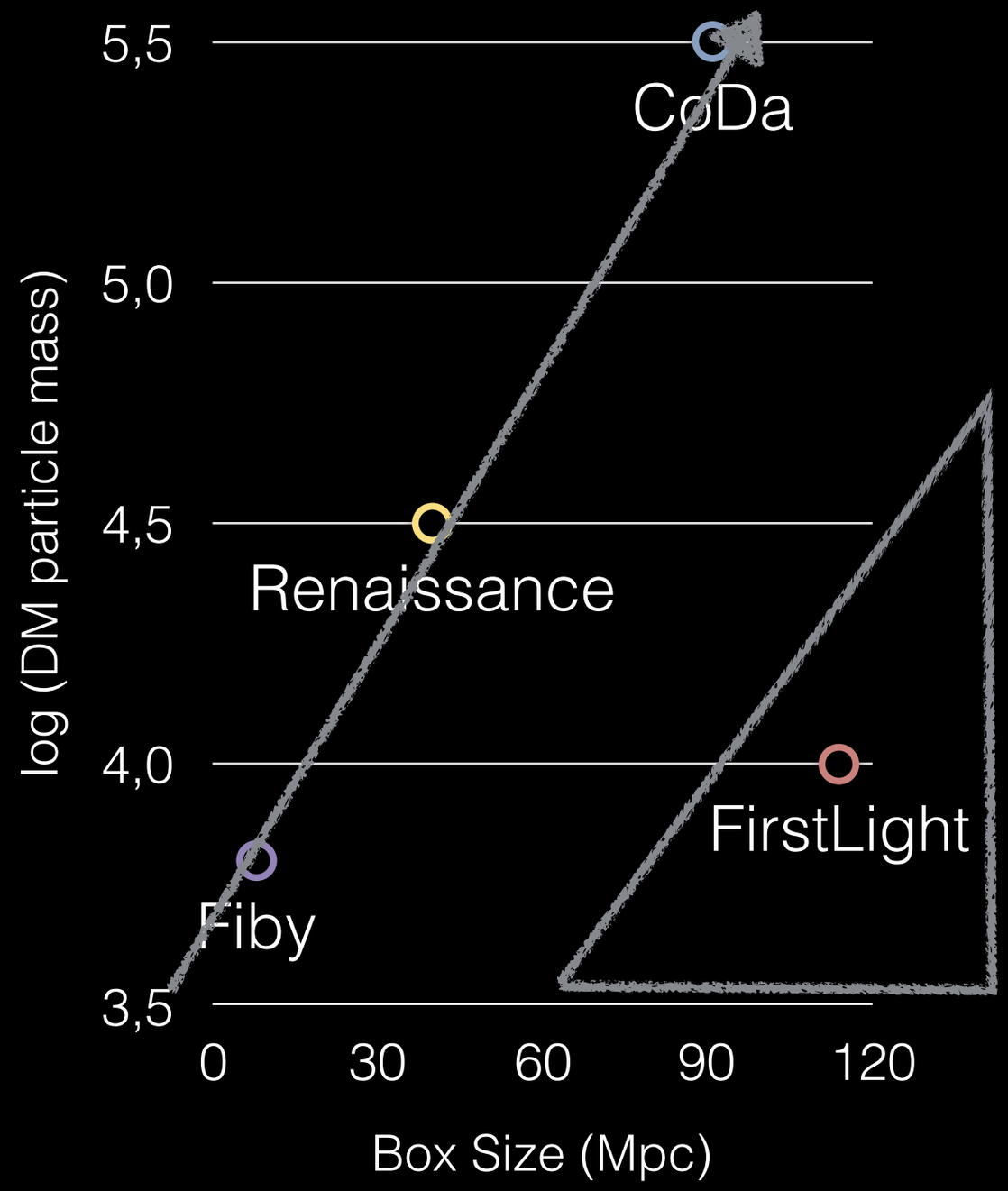
- The FirstLight Project

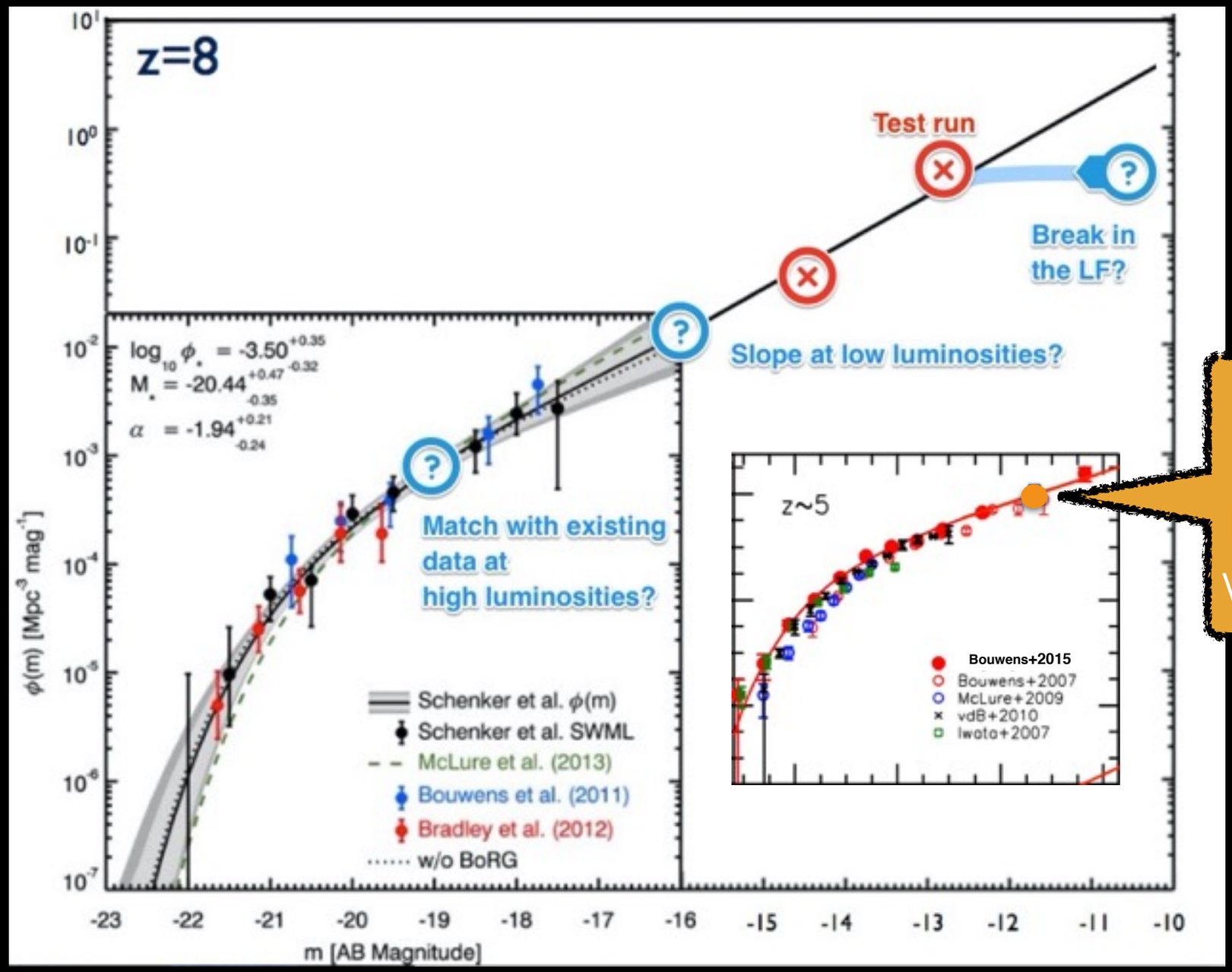


The FirstLight Project

- Order of 1000 zoom cosmological simulations of the formation of first galaxies from z=12 to z=5 in 10-80 Mpc/h boxes
- spatial resolution of 10 pc ($M_{DM}=10^4\ M_{sun}$)
- largest database of zoom simulations with this resolution

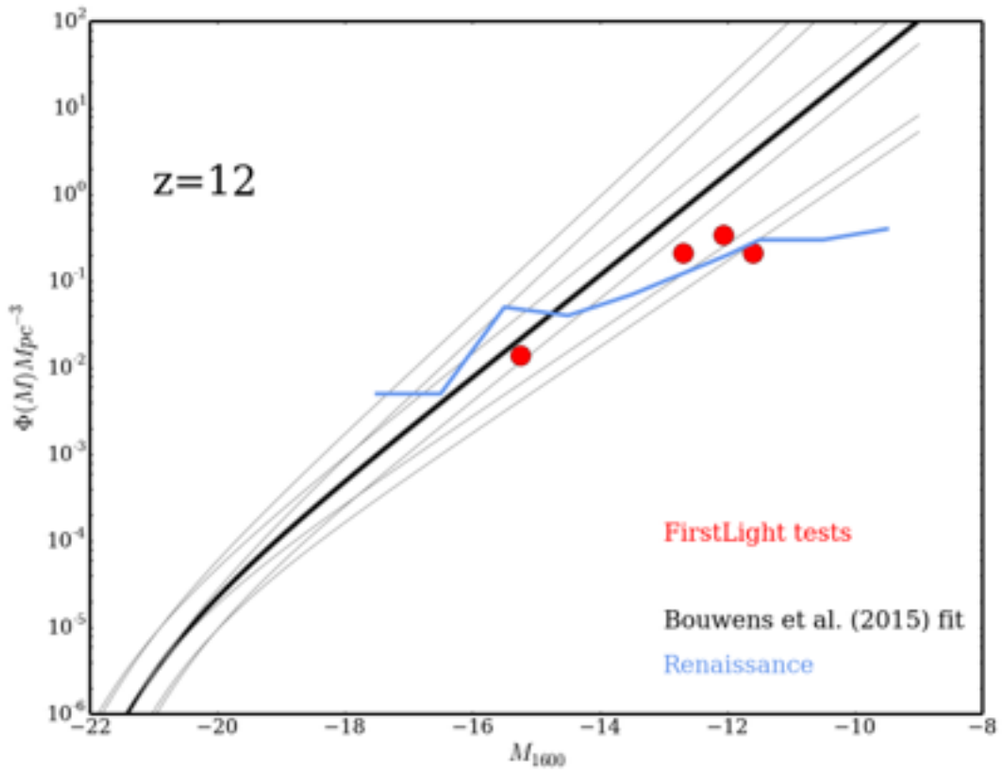
- AMR code: ART (Kravtsov et al 1997, Kravtsov 2003)
- Gas Cooling, Star Formation, Stellar Feedback (thermal) (Ceverino & Klypin 2009; Ceverino, Dekel and Bournaud 2010)
- Radiative Feedback (Ceverino et al. 2014)

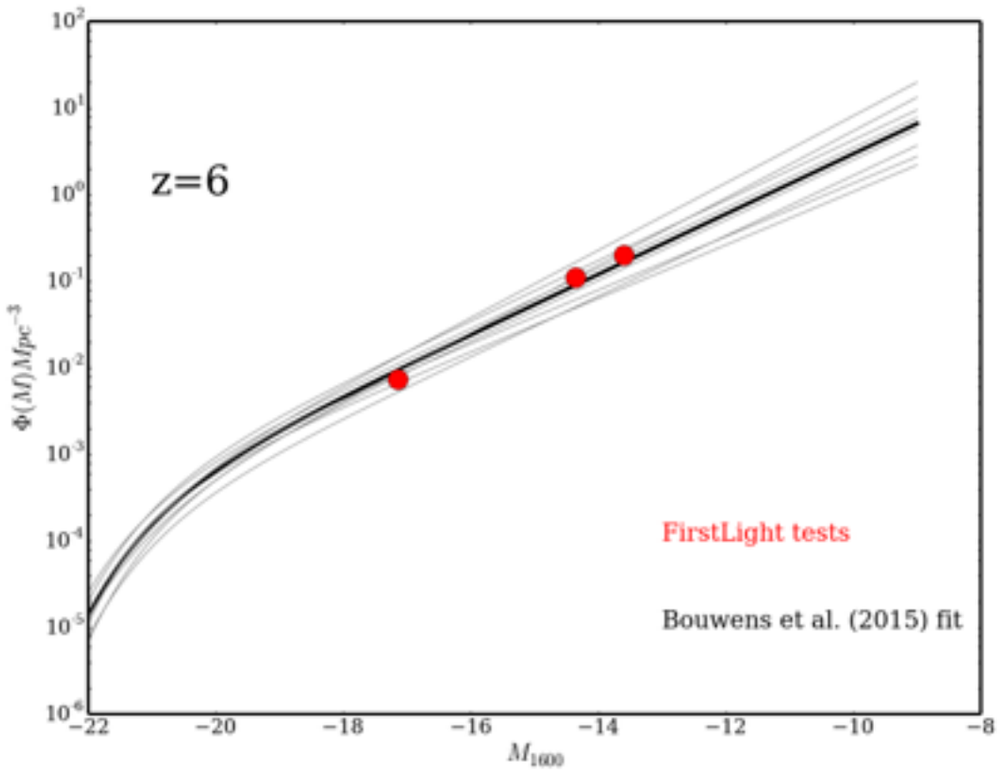
UV Luminosity Function of Primeval Galaxies



M_{UV}=-17
M_s=10^8 $M_\odot$
M_H=3 10^{10} $M_\odot$
V_{max}=100 km/s

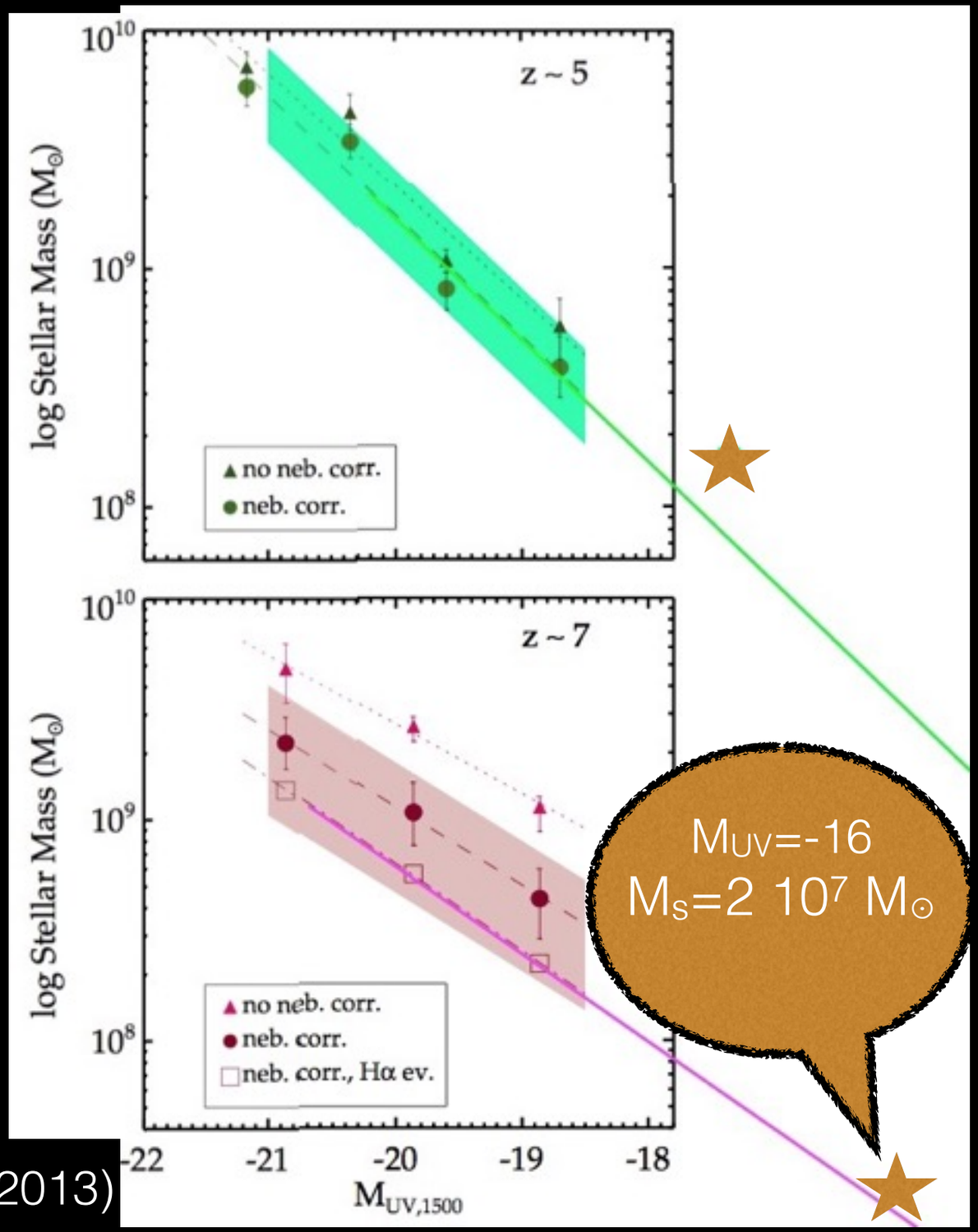
Preliminary results





Stellar Mass- UV luminosity

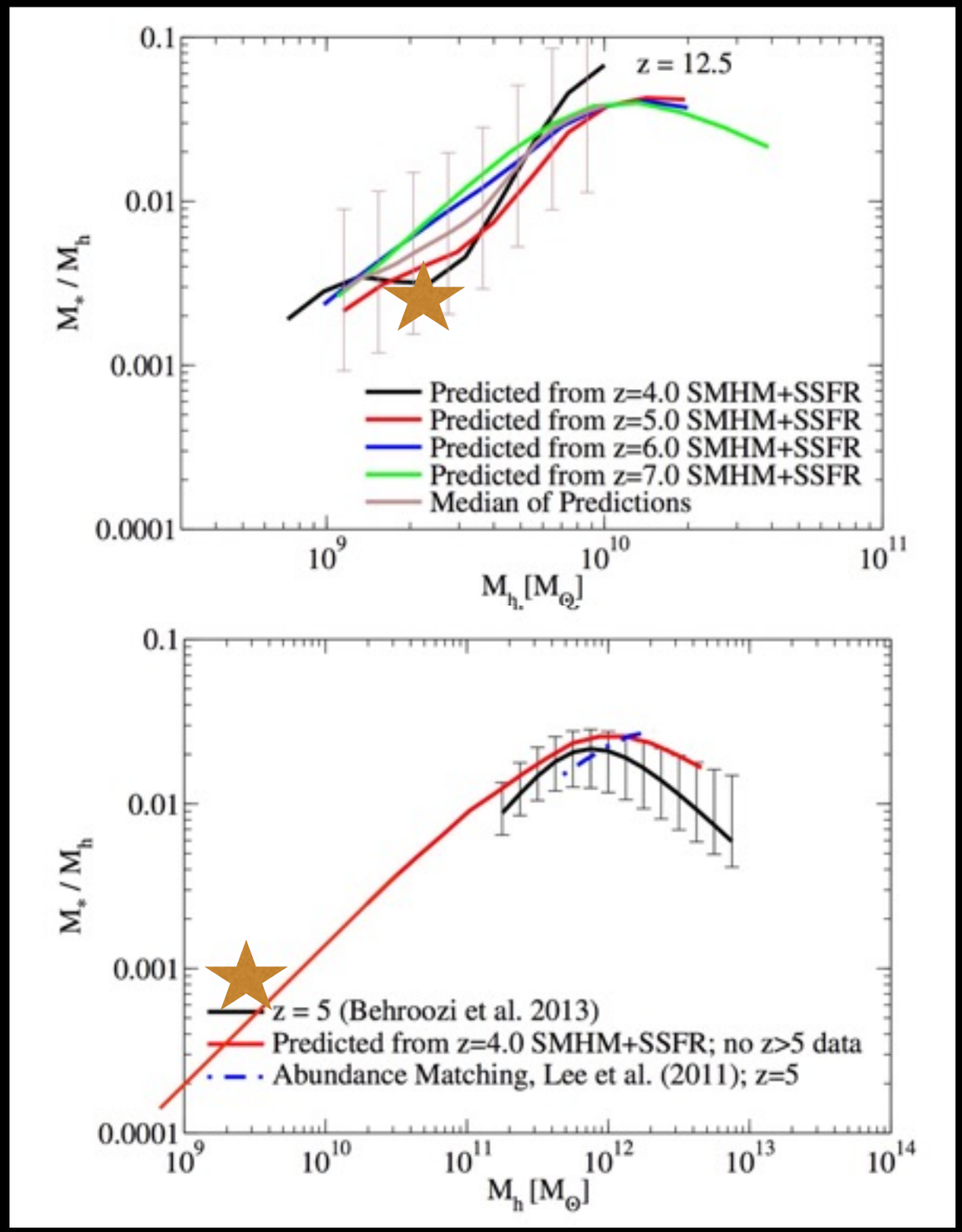
- Stellar masses in agreement with extrapolations from Stark relations, assuming evolution of the Hα line



Stark et al. (2013)

SMHM ratio

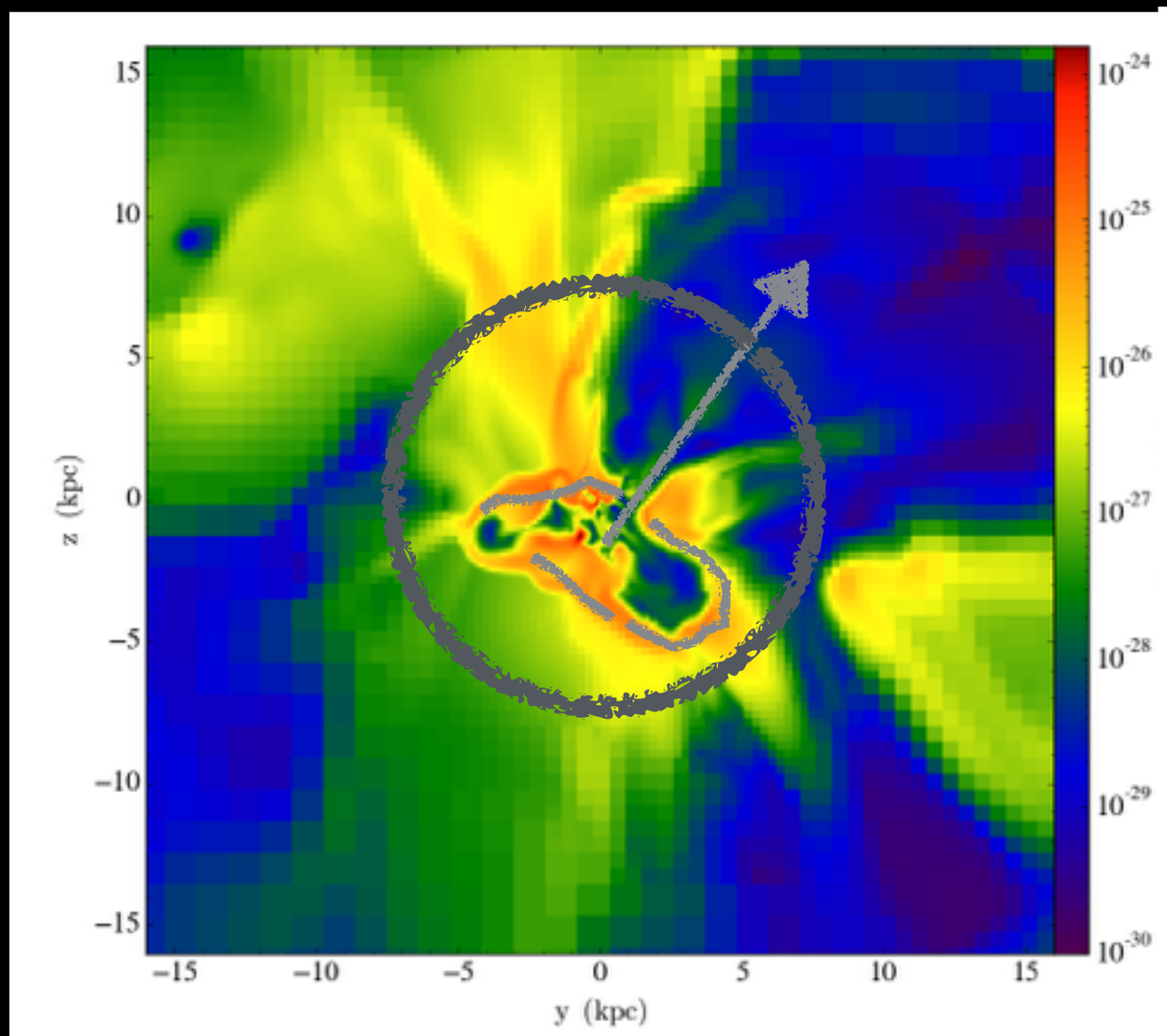
- Haloes hosting the galaxies that reionise the Universe have $M_H \geq 10^9\ M_\odot$ or V_{max}>30 km/s at z=8



Behroozi & Silk (2015)

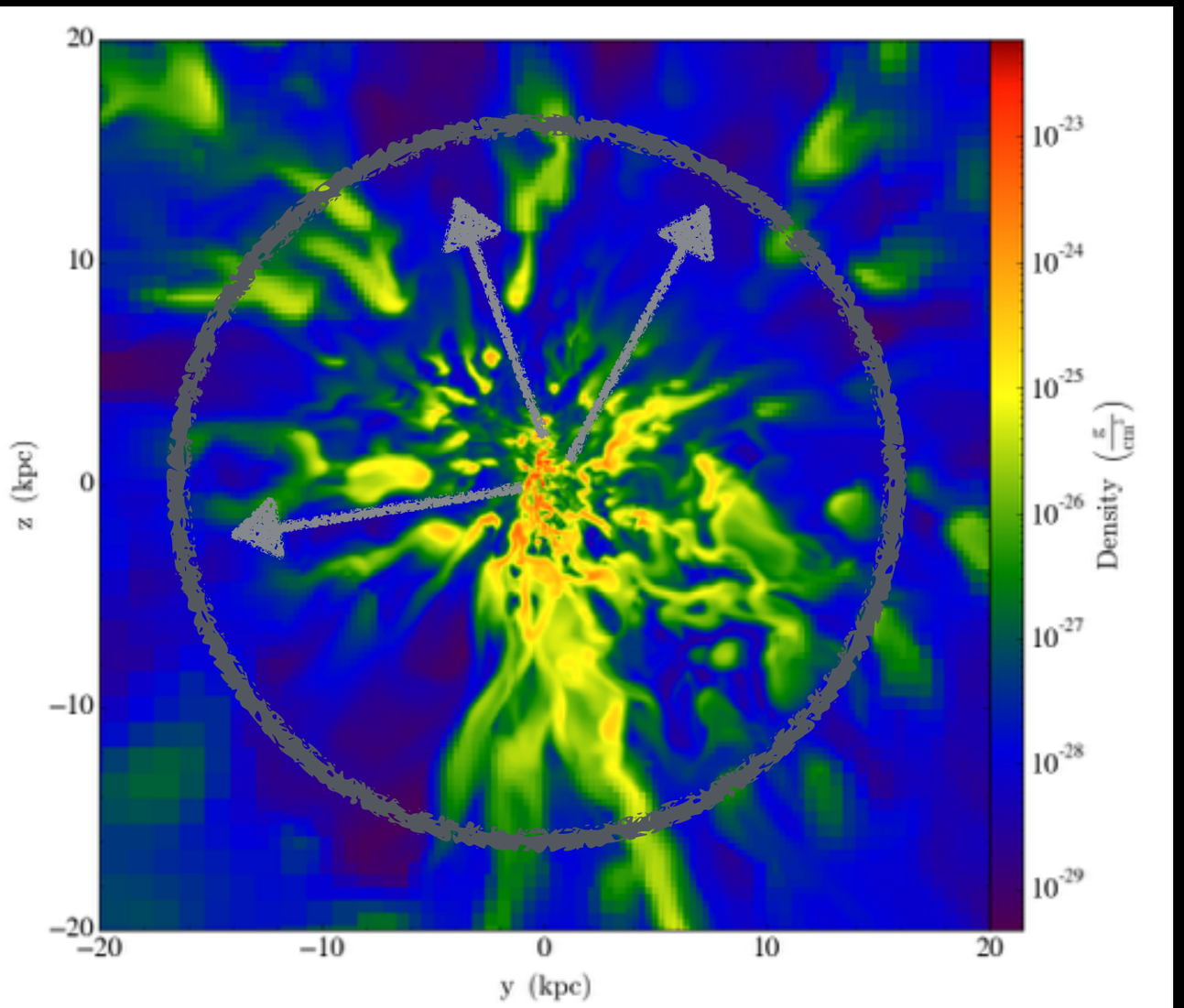
Gas Distributions at z=5

Low-mass (M_H=2 10^9 $M_\odot$, M_s=3 10^6 $M_\odot$)



Low f_{esc}, a few free channels

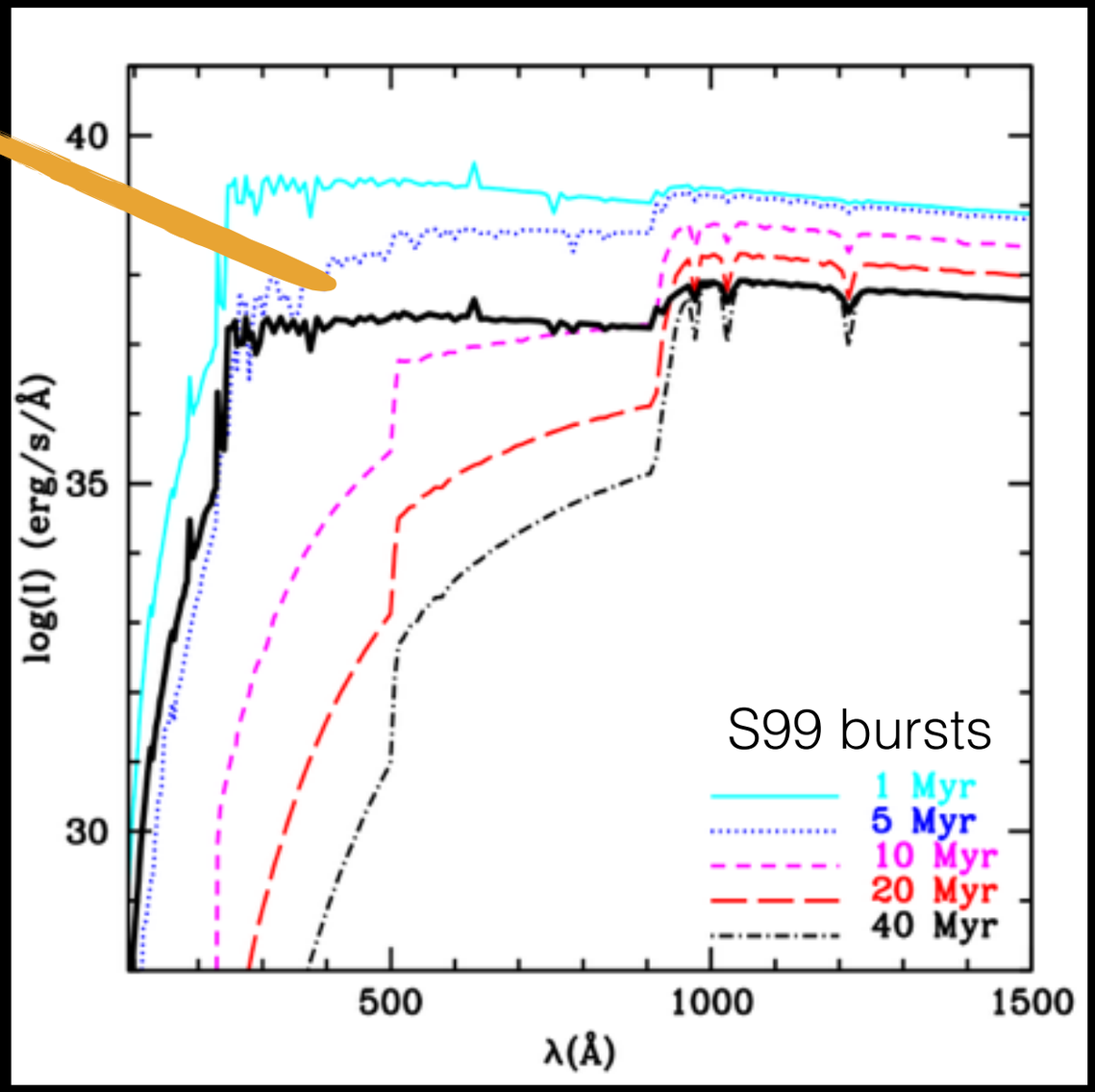
High-mass (M_H=3 10^{10} $M_\odot$, M_s= 10^8 $M_\odot$)



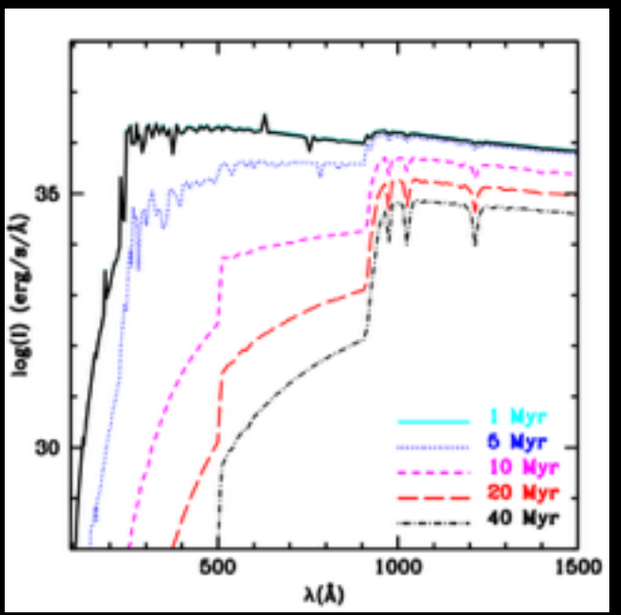
High f_{esc}, many low-density chimneys

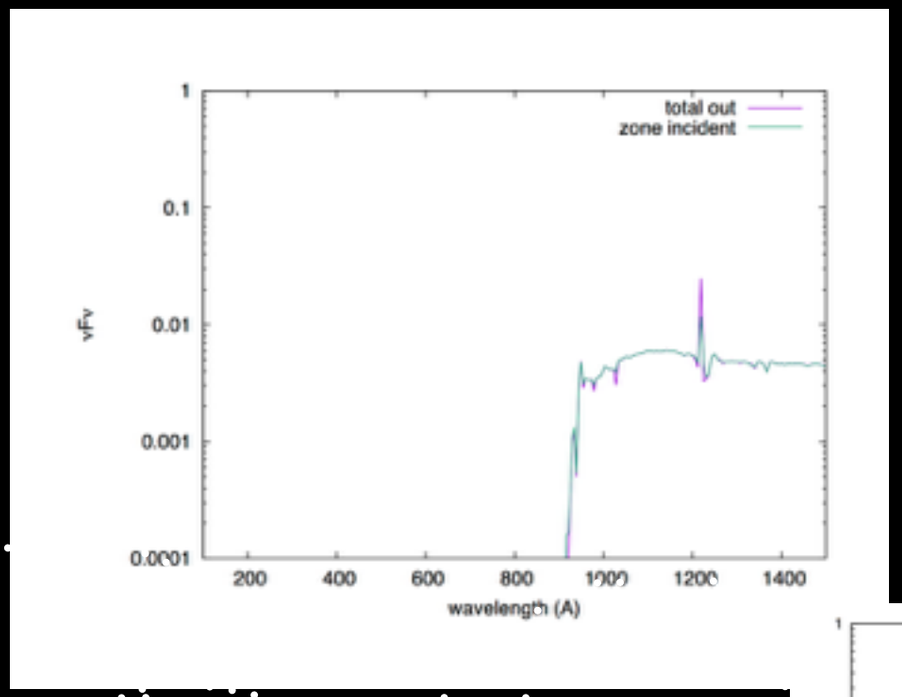
Stellar Spectrum

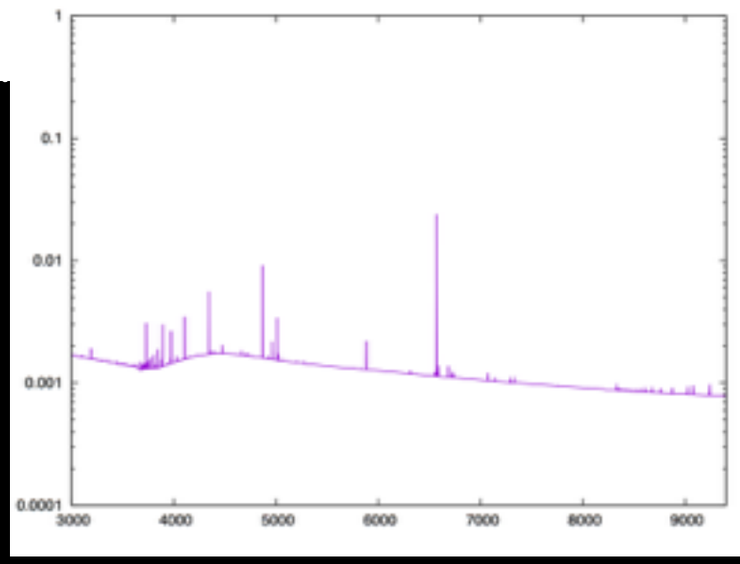
- composite stellar spectra (black) of FL05: >300 SSP
- Two basic components
- “young” population (age~100 Myr) that dominates the non-ionising region
- “extremely young” population (age~1 Myr) dominates the ionising flux



Transmitted spectrum





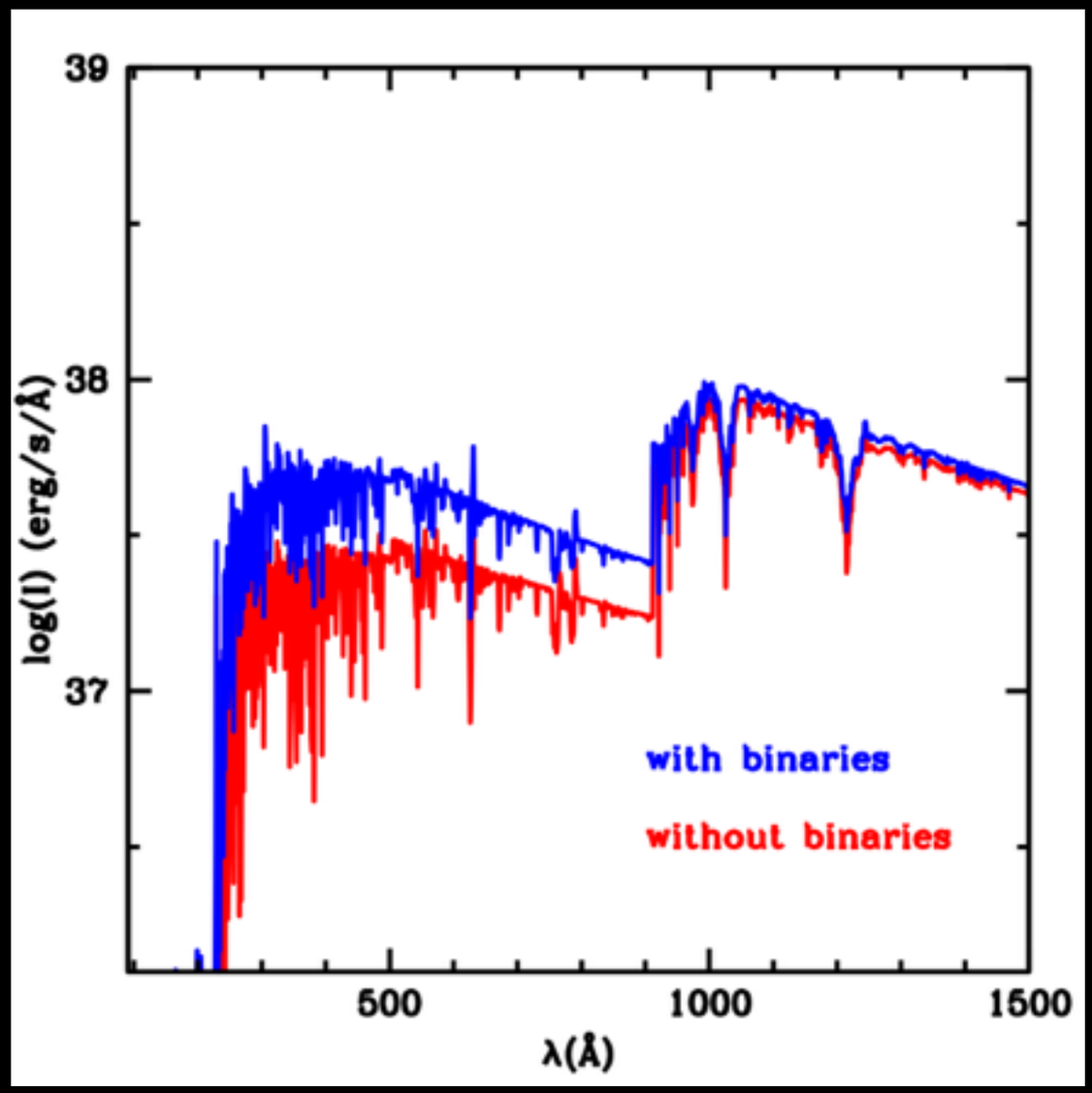


- Cloudy

Also emission lines

Investigating the effect of binaries (BPASS)

- Higher ionising flux if we include the effects of binaries



Summary

THANKS

- The FirstLight project aims to study the formation of the first galaxies that drive reionisation. Stay tuned: 1000 simulations are running…
- First results are in agreement with observed or extrapolated UV luminosity functions
- Relations between halo mass, stellar mass, SFR are consistent with current data
- Complex and multiphase gas around galaxies
- Multiple stellar populations contribute to the stellar spectrum of the galaxy