It's complicated: reionization in the Local Group

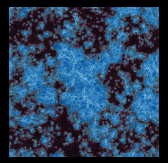
Keri Dixon, University of Sussex

with Iliev, Mellema, CLUES, and so on

Near Field Cosmology **02 April, 2016**

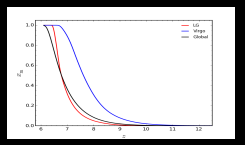
What is to come…

A brief history of reionization



Discussion of sources and simulations

Reionization histories for all

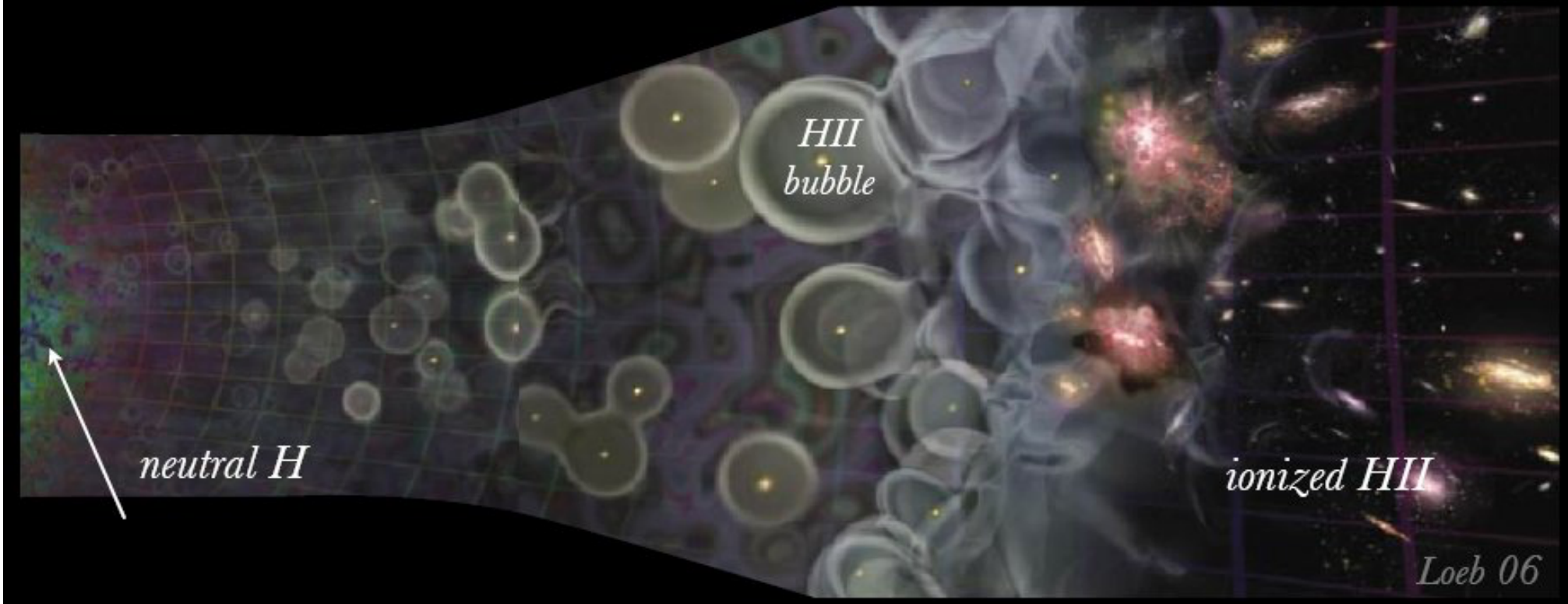


What about the UV background?

Conclusion

A brief history of reionization

The presumed process



We can't see this process directly

We do not know what the first objects are

We do not know how much energy they give off

We do not know how this is deposited into the IGM

We do not know how Xray sources will heat the IGM

We do not know how galaxies evolve

Too much neutral hydrogen in the way

Summary so far

Hydrogen ionized by z ~< 6

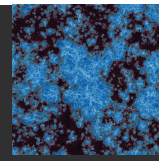
Reionization is an extended process

Reionization is inhomogeneous

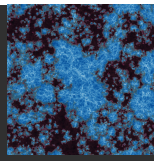
Lambda CDM is good enough for me

Make some plausible assumptions consistent with observations!

Simulations show the way



Constrained Local UniversE Simulations



64 Mpc/h

- **GADGET, 2048^3 particles**
- **Constrained ICs to produce LG, Virgo**

Questions

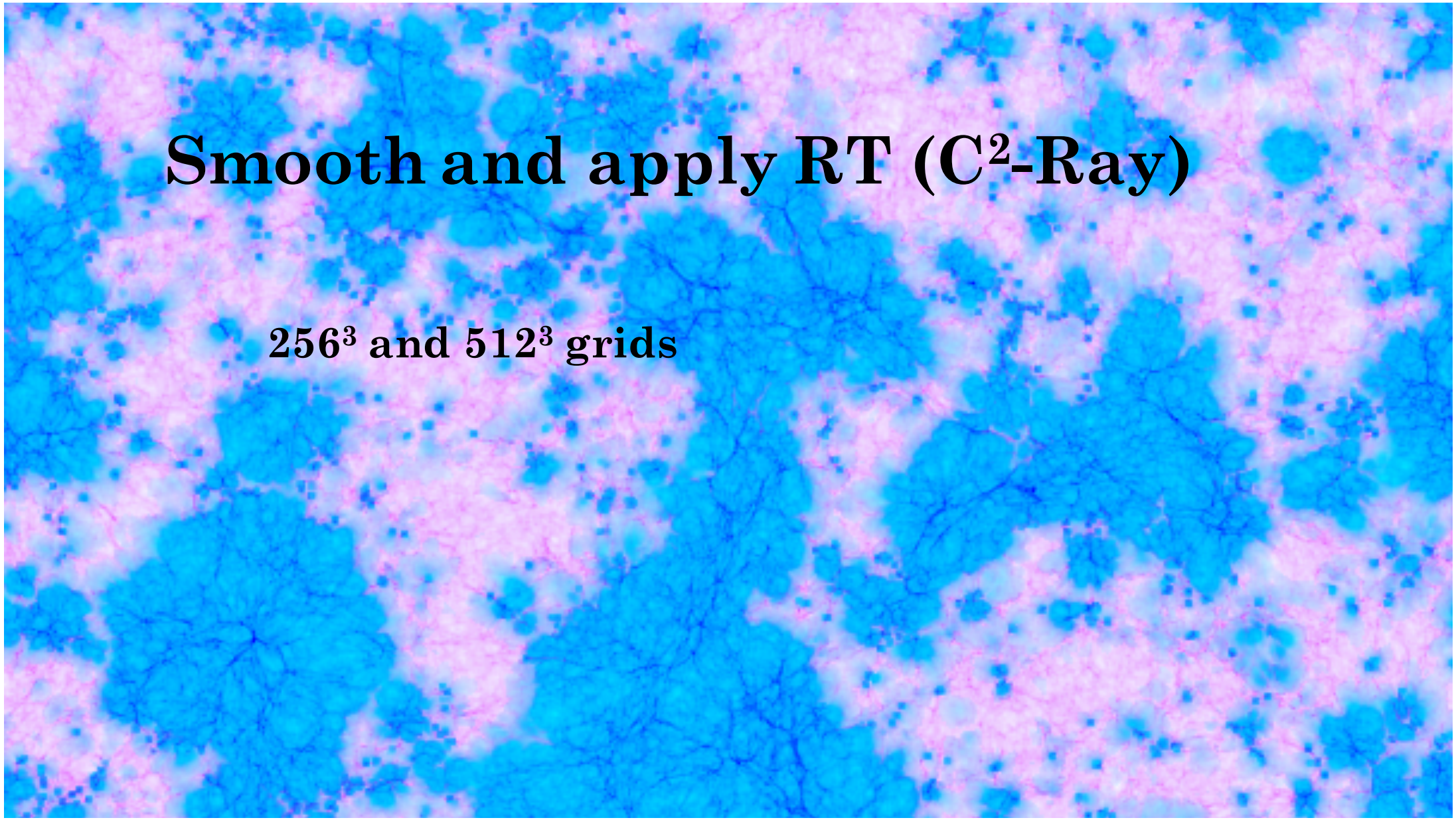
- **How does reionization affect LG?**
- **Inside out vs outside in?**
- **What happens locally compared globally?**

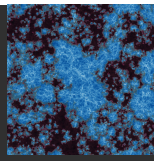
Start with dark matter

Density fields

List of halos

down to $10^8\ M_\odot$


Smooth and apply RT (C²-Ray)
256³ and 512³ grids



Very important bit…sources

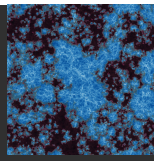
Stars and galaxies

live in dark matter halos

break into three categories:

high-M atomically cooling halos

(HMACHs > $10^9 M_\odot$)



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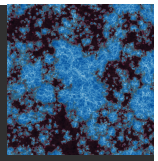
(10^8 $M_\odot$ < LMACHS < 10^9 $M_\odot$)

ignore anything below



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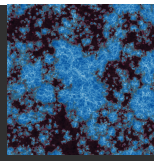
Photon production rate

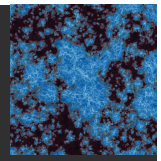
- N_γ α $f_\gamma M$, where f_γ depends on stuff

How do sources affect each other?



Ionizing UV

- **Photoheats gas in IGM to ~10^4 K**
- **Suppresses gas infall for low-mass halos**
- **Self-regulation of galaxy/star formation**



Science is hard

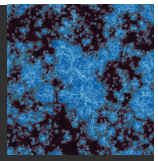
Four source models (plus or minus)

(1) only HMACHs

largest halos contribute

motivated mainly by resolution

galaxies that we know and love



(2) suppressed LMACHs

HMACHs always contribute

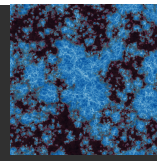
ionized region: no LMACHs

strong photoheating feedback

neutral region: higher efficiency

early stars release ionizing photons

Iliev et al (2006)



(3) partially suppressed LMACHs

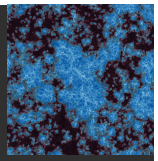
ionized region: LMACHs suppressed

some star formation survives

neutral region: higher efficiency

mimic transition from PopIII to PopII

Dixon et al. (2016)



(4) gradually suppressed LMACHs

neutral region: same efficiency

do not guess early stars

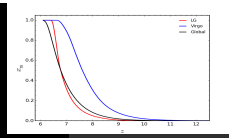
ionized region: gradual depression of f_γ

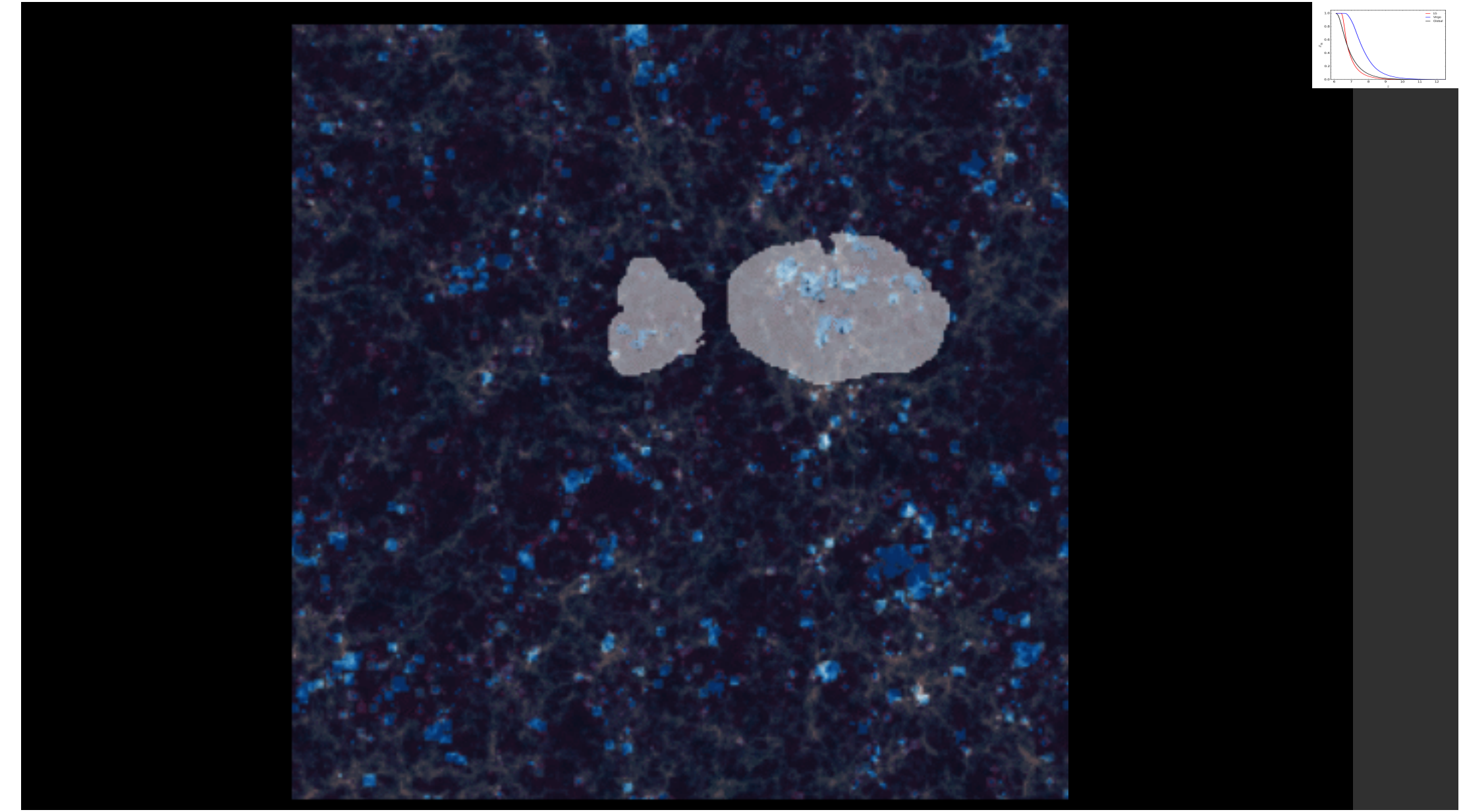
mass-dependent

motivated by galaxy sims (Wise & Cen 2009, Sullivan et al. 2016)

Dixon et al. (2016)

The Local Group: reionization thereof





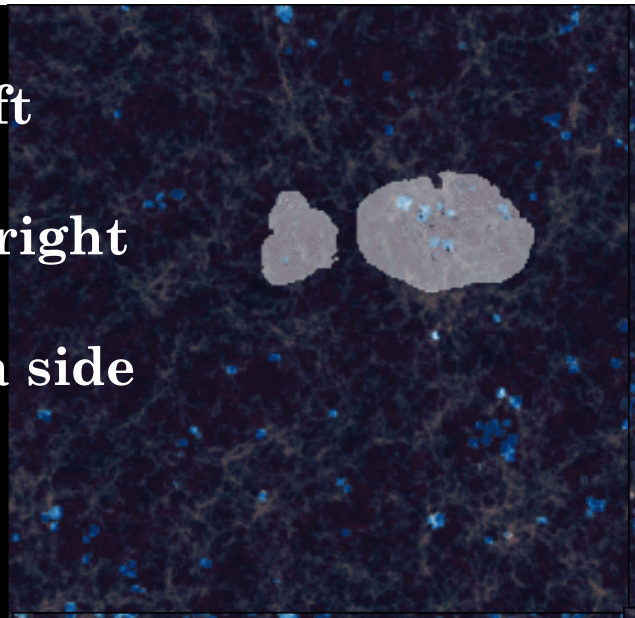
1.0
0.8
0.6
0.4
0.2
0.0
6
7
8
9
10
11
12
LO
Virgo
Orbital

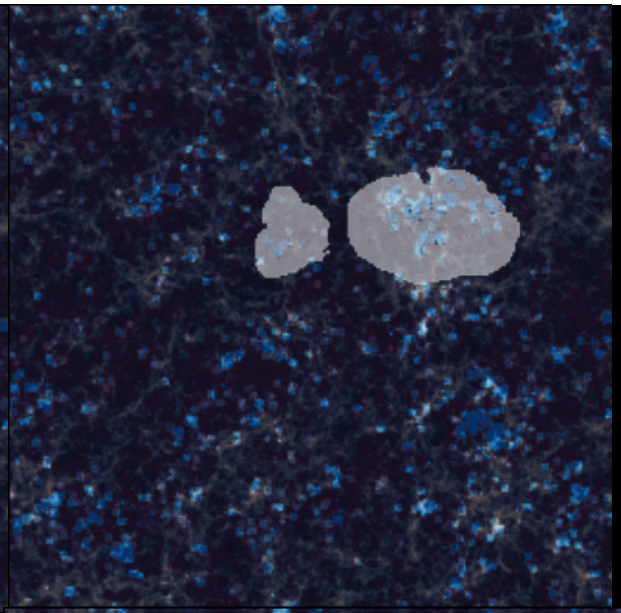
MW on the left

Virgo on the right

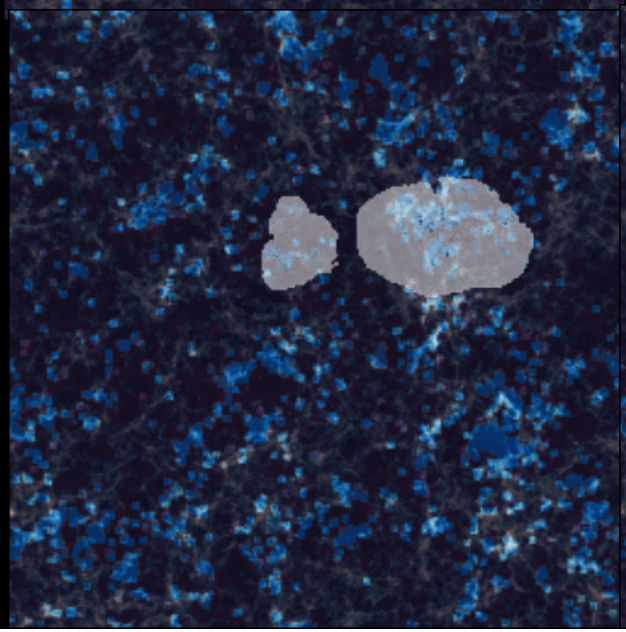
64 Mpc/h on a side

No LMACHs

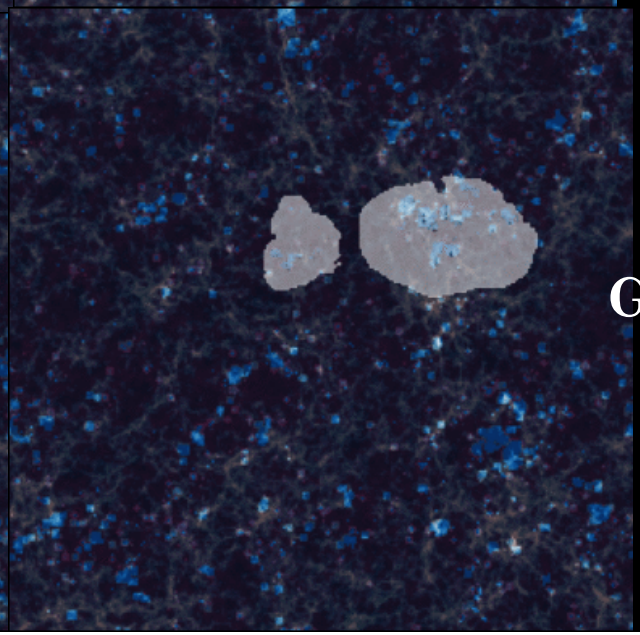




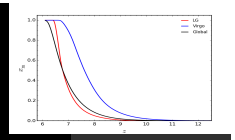
Full supp

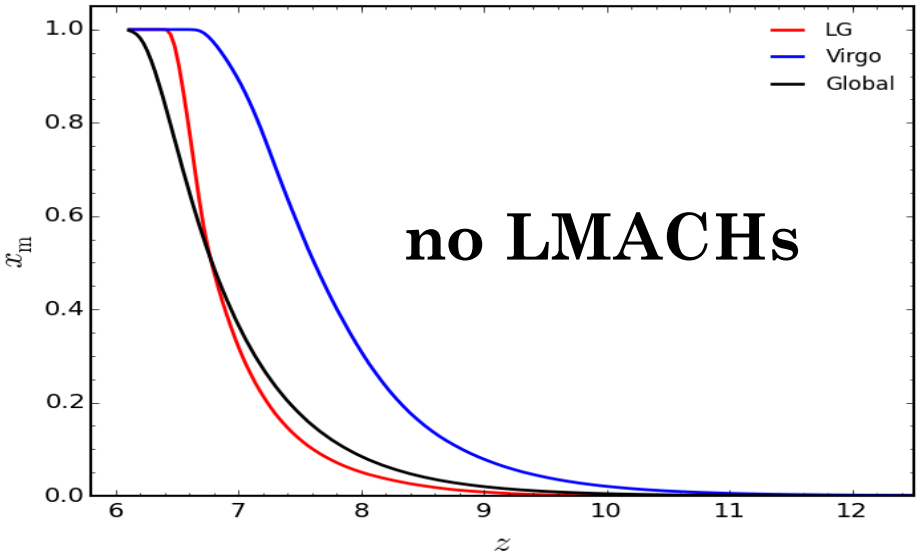


Partial supp



Gradual supp




no LMACHs
LG
Virgo
Global
$x_{\rm m}$
z
1.0
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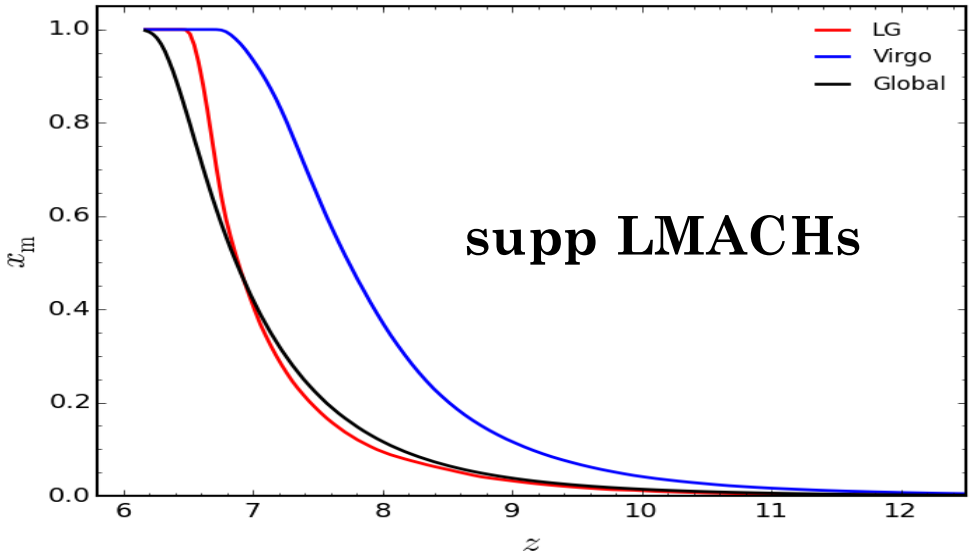
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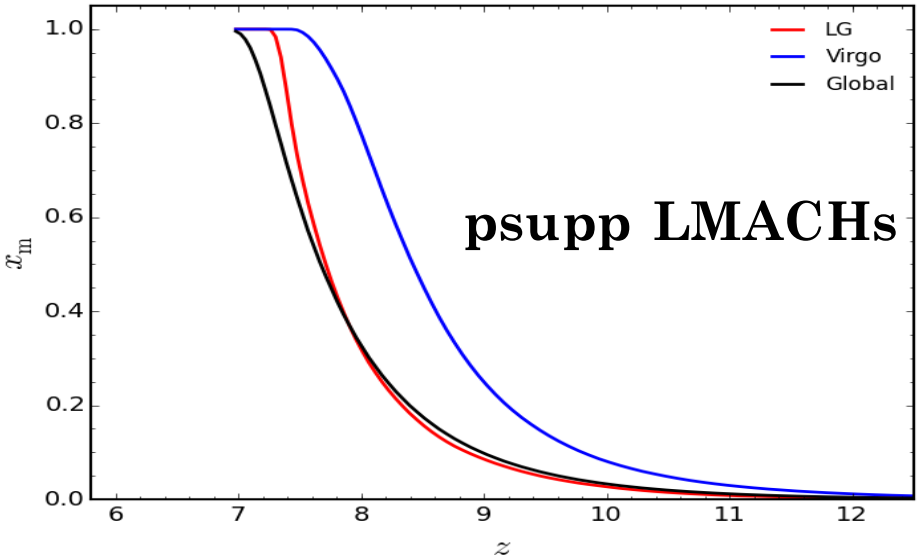
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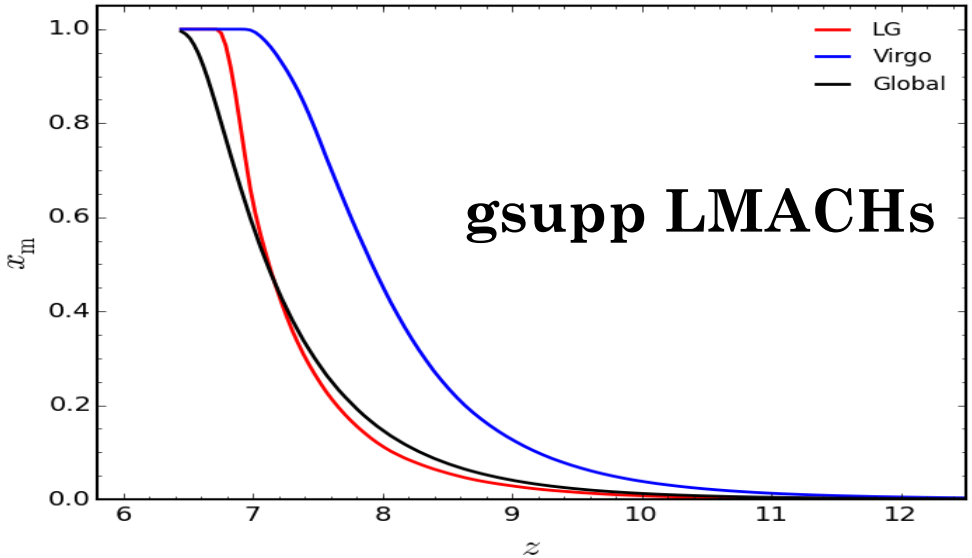
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z
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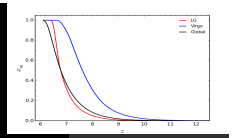
What does this mean for the Milky Way?



The material now in MW had varied history

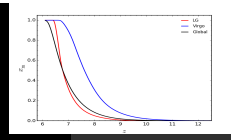
Satellites of MW could have their gas photoheated away

The local history is NOT the global history

Virgo is a major influence

Mostly inside-out and finishes outside-in

These conclusions are mildly source-dependent



What about MW satellites?

Premise:

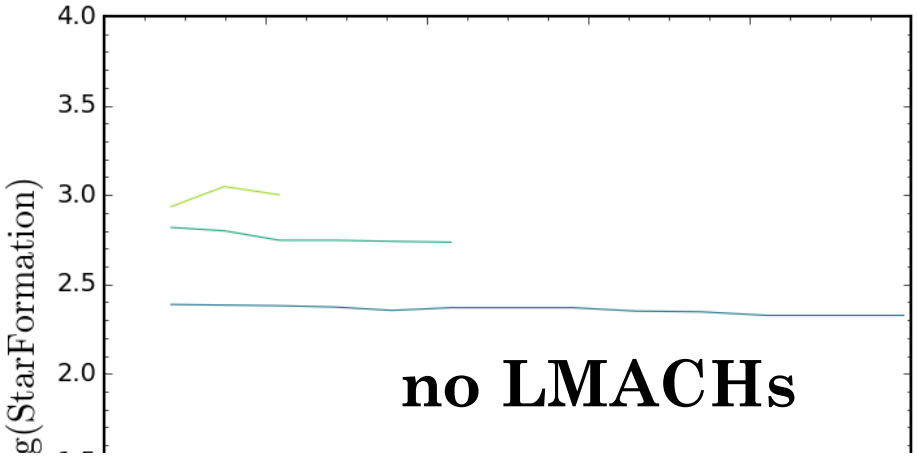
The reionization history of a satellite affects star formation

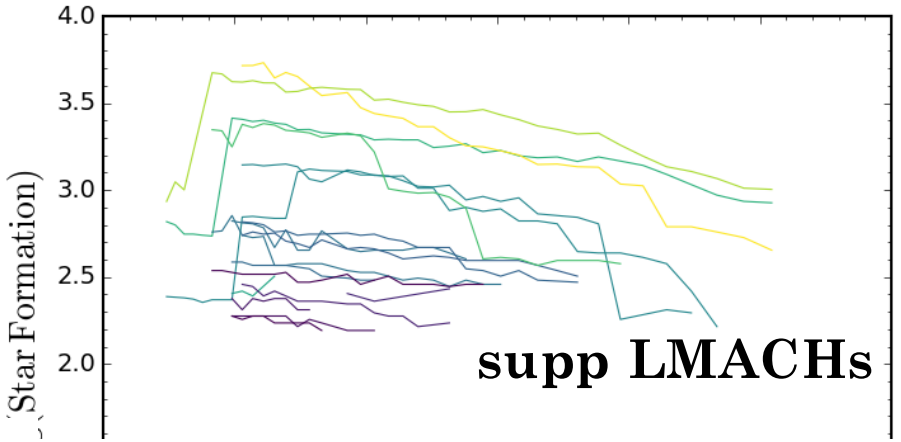
Suppression of star formation is model-dependent

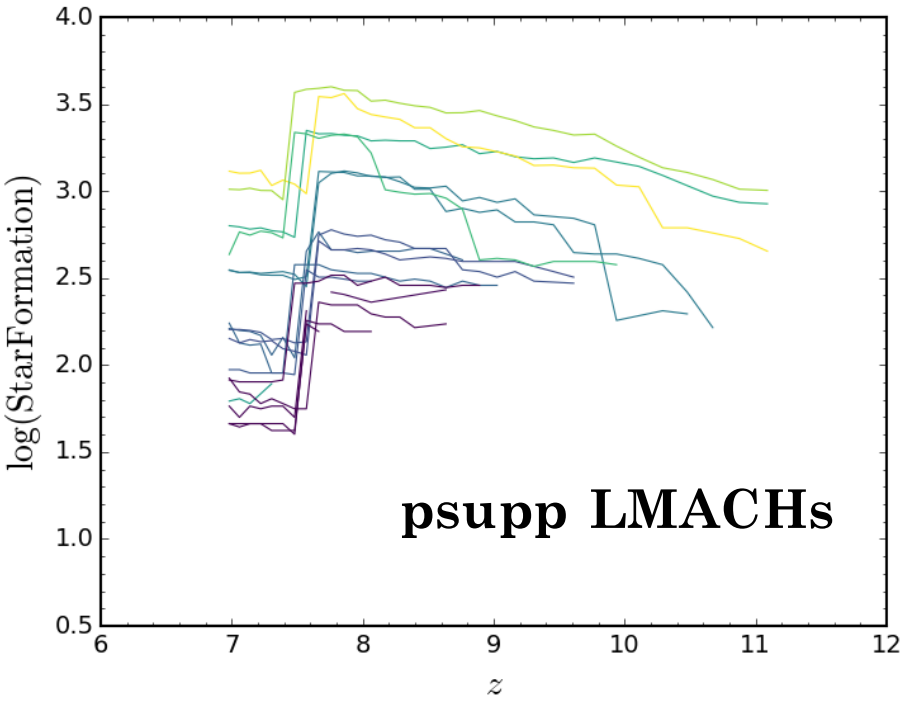
Basic results:

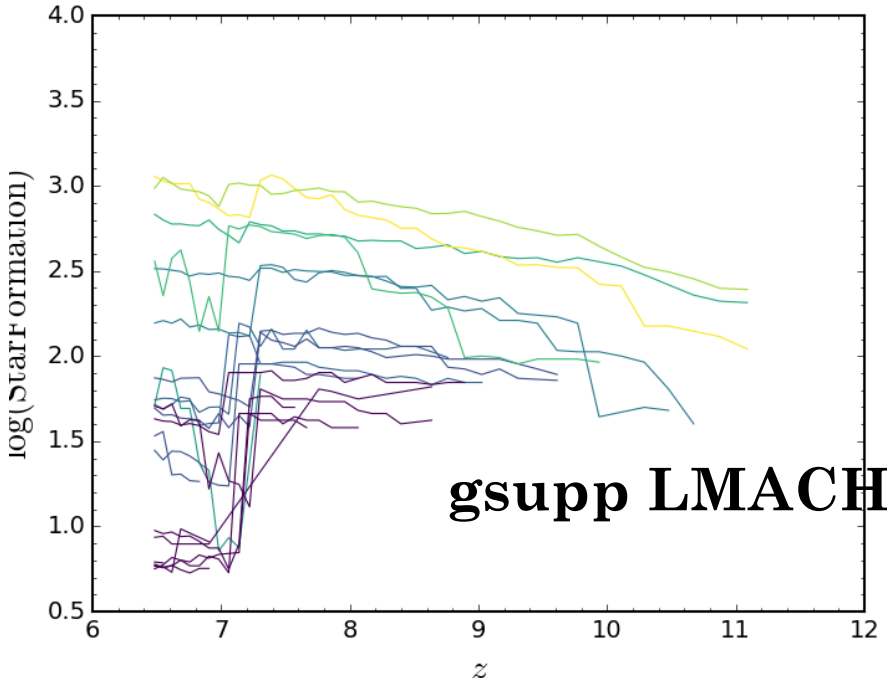
Start with ~100 satellites

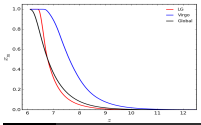
Only ~10 with star formation

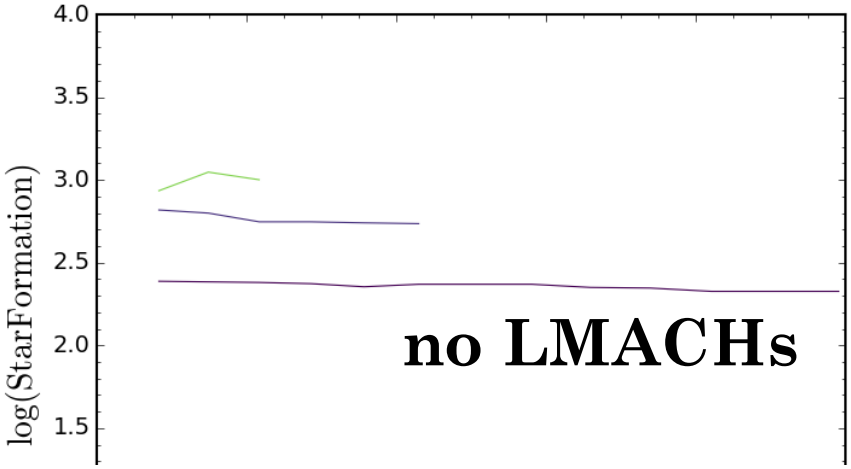

g(StarFormation)
no LMACHs


Star Formation)
supp LMACHs


log(StarFormation)
psupp LMACHs
z


log(Star Formation)
gsupp LMACHs
z

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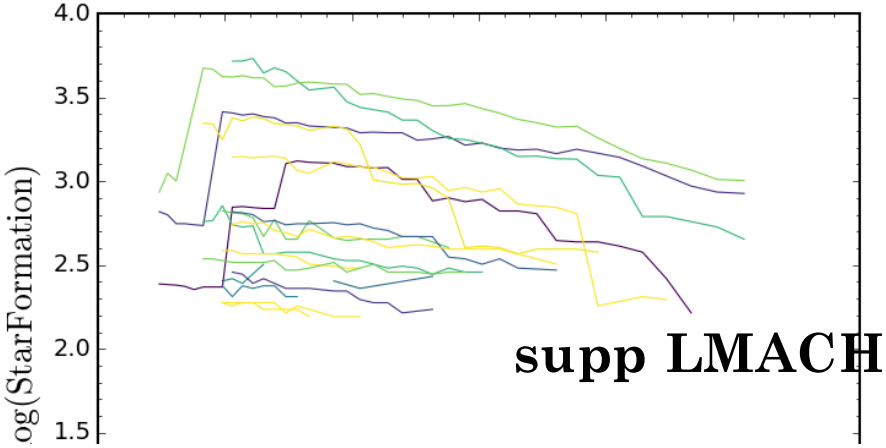
no LMACHs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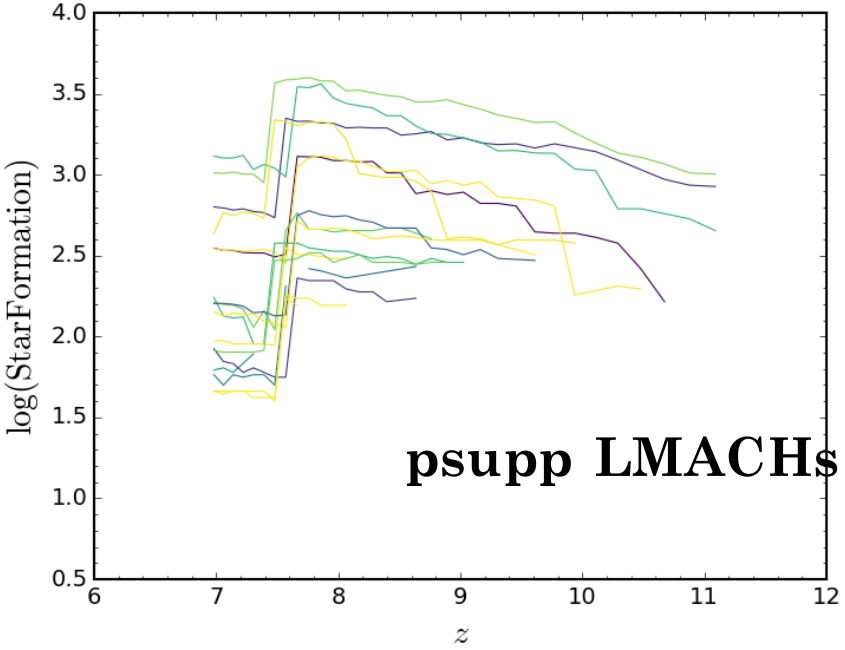
supp LMACHs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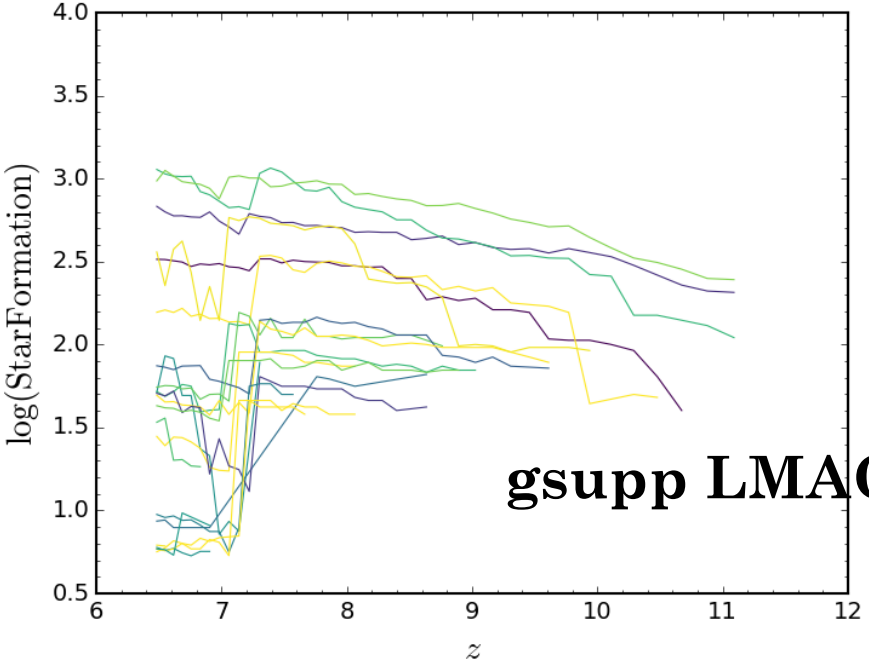
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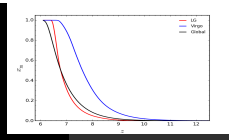
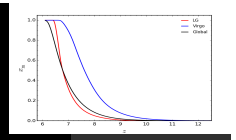
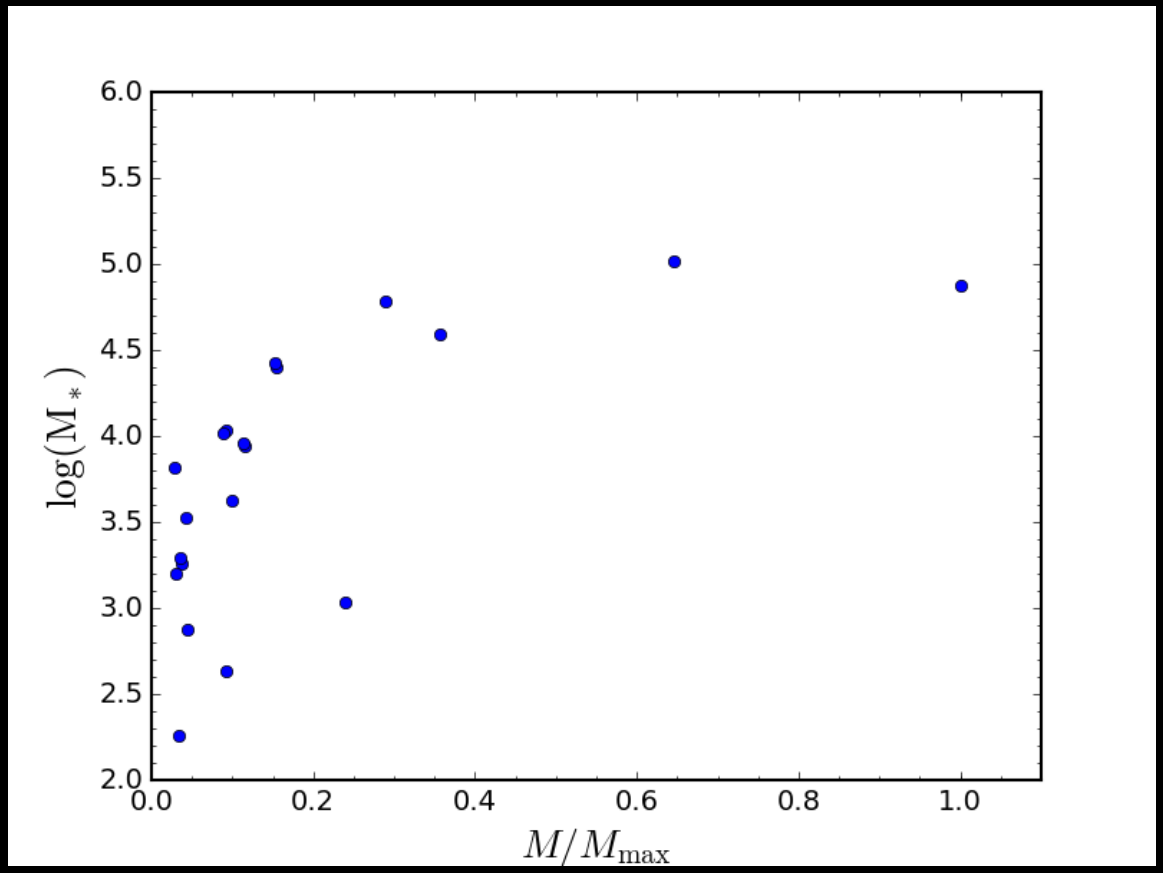
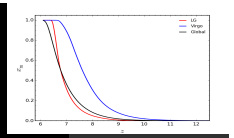




Cumulative ‘Star Formation’



It's a complicated life for the satellites of the MW



Underwent a tumultuous past

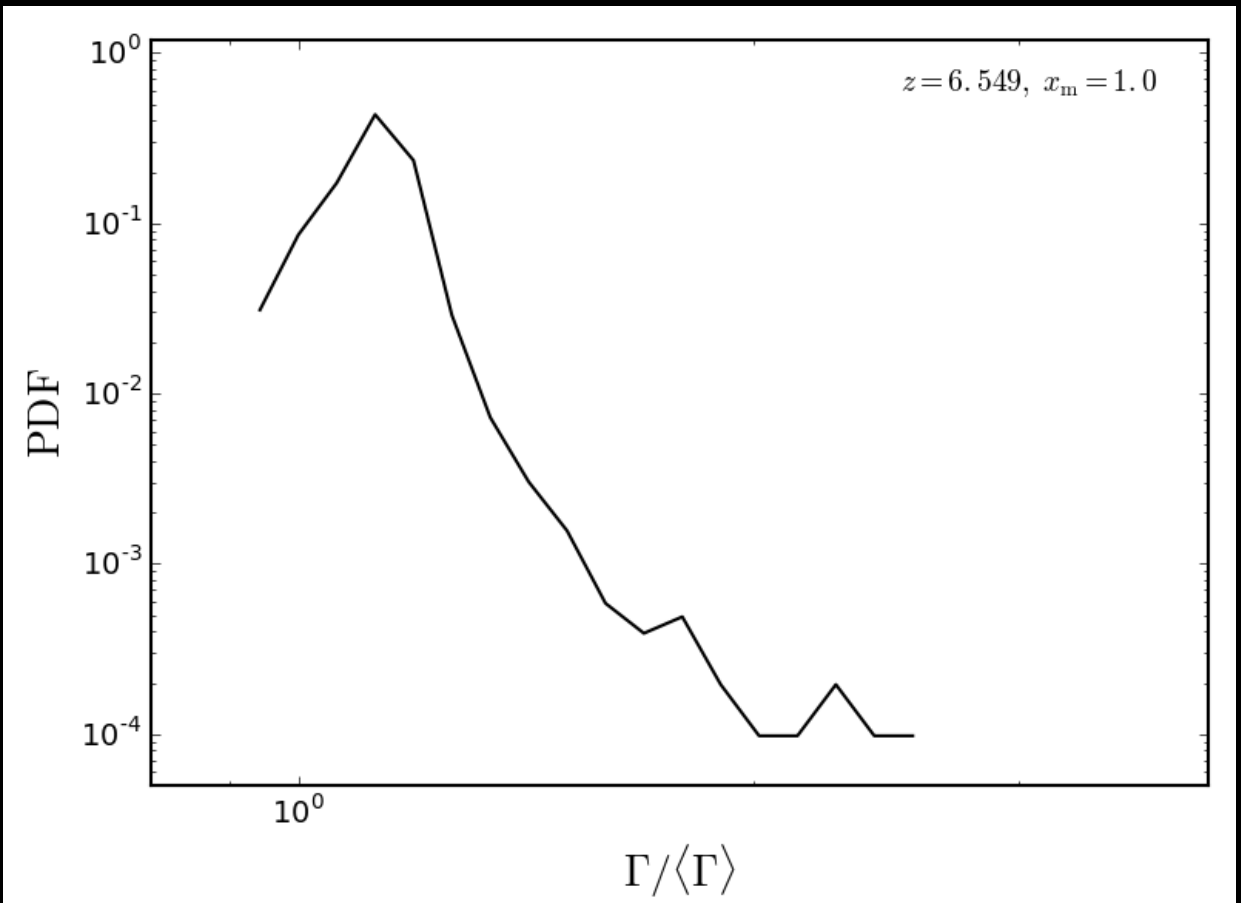
The reionization model significantly affects SF history

The final size of the satellite not only factor

Most satellites had no star formation before z ~ 6

Many more questions to investigate…

I mentioned inhomogeneous, right? (LG only)



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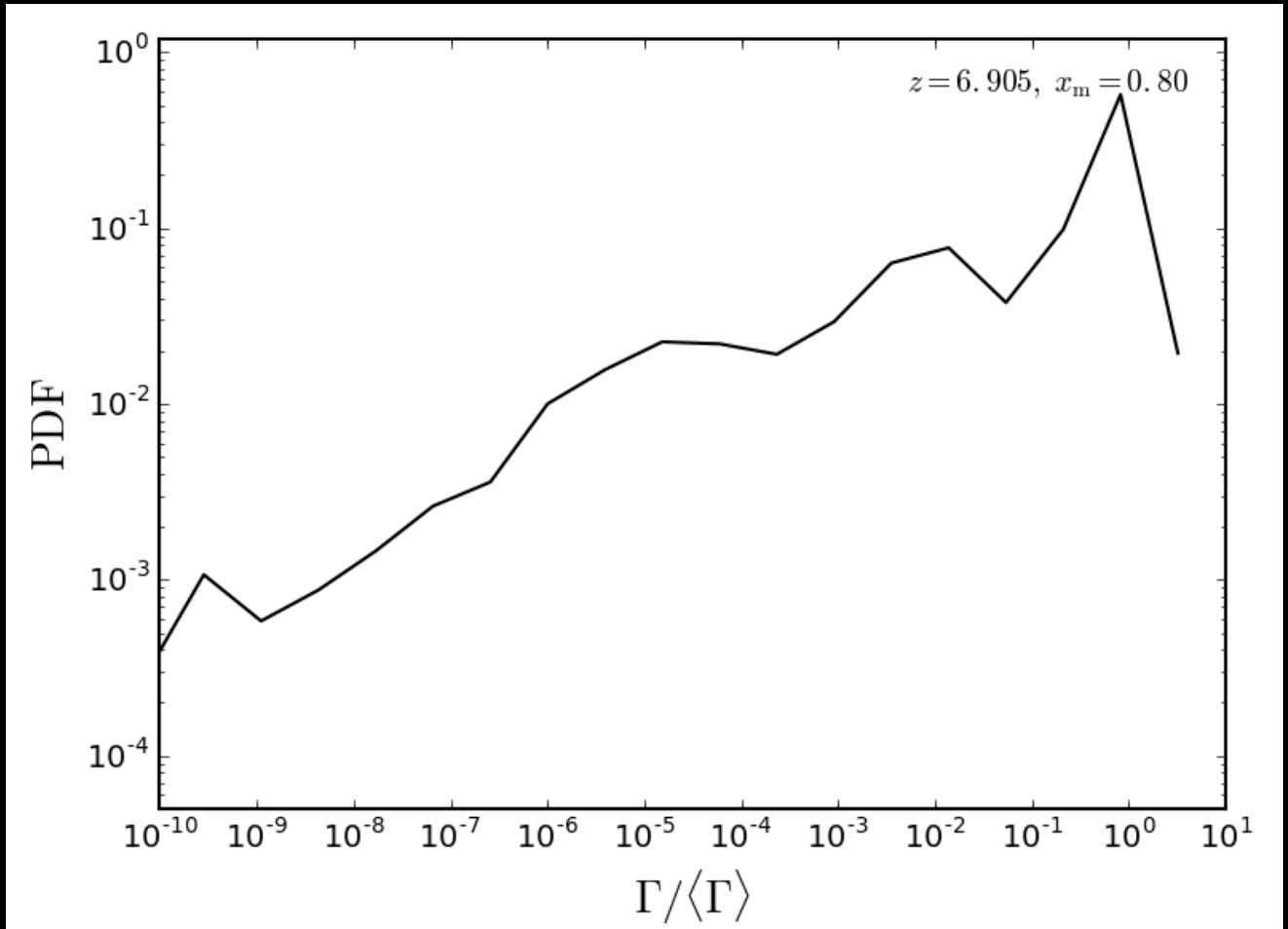

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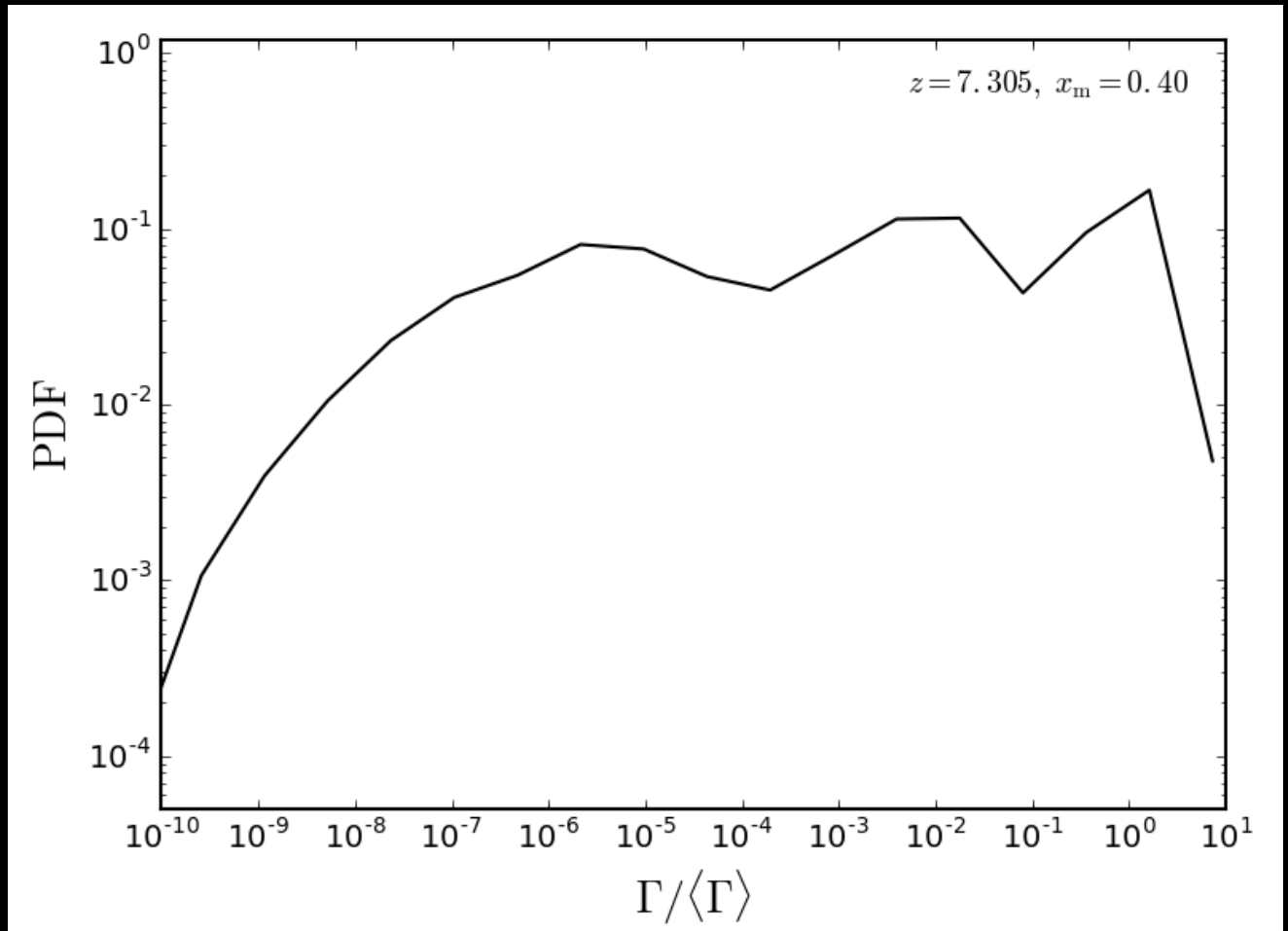


What's interesting to you?

History of cosmic reionization

- $5.5 < z_{reion} < 9$ with inhomogeneous transition in $6 < z < 7$

Sources of reionization

- Likely galaxies dominate the end (plus AGN maybe)
- Reionization impacts ongoing reionization

Large-scale simulations

- Needed for interpretation of upcoming results
- Span a range of plausible source models

The past has consequences for today

- Very inhomogeneous during a major phase transition

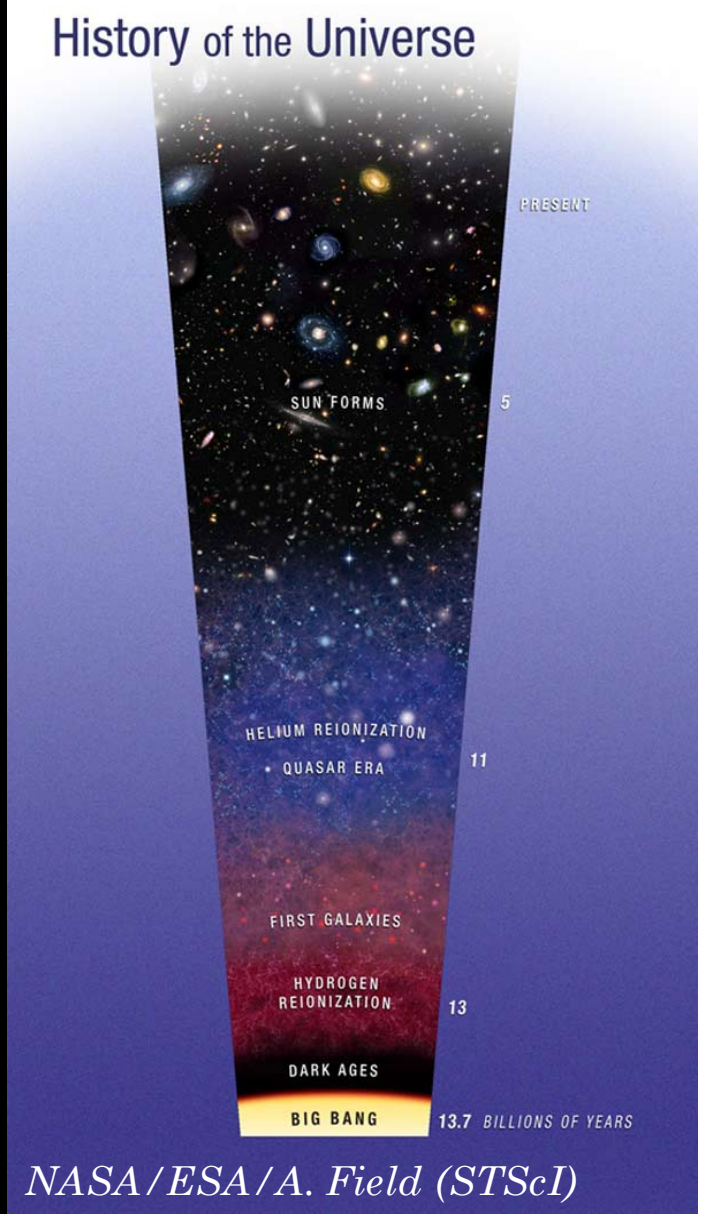
Hot then cold then hot

Big bang > inflation > recombination (probably)

Still expanding, but overdensities lead to gravitational collapse

Light > energy into IGM > change of state for hydrogen and helium

CMB surface of last scattering is the backlight



NASA/ESA/A. Field (STScI)