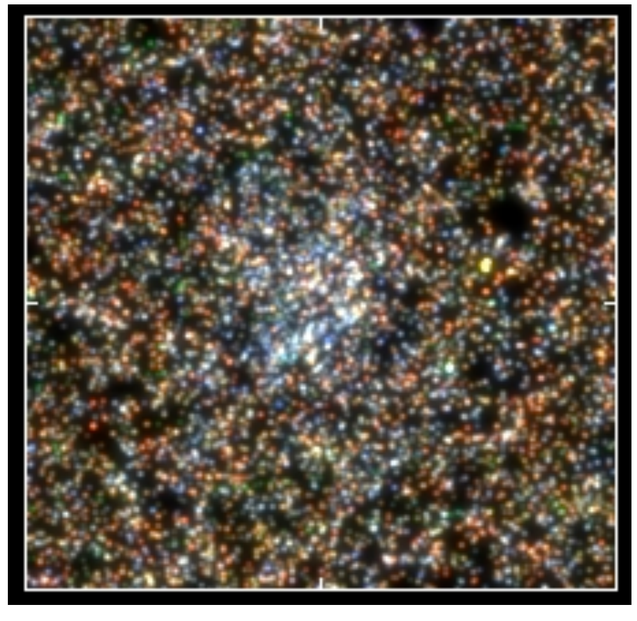
Reionization at galaxy scale

- Impact of radiation field structure on the MW satellites
- Simulations of a MW progenitor using CLUES simulations

P. Ocvirk, D. Aubert
Observatoire astronomique de Strasbourg

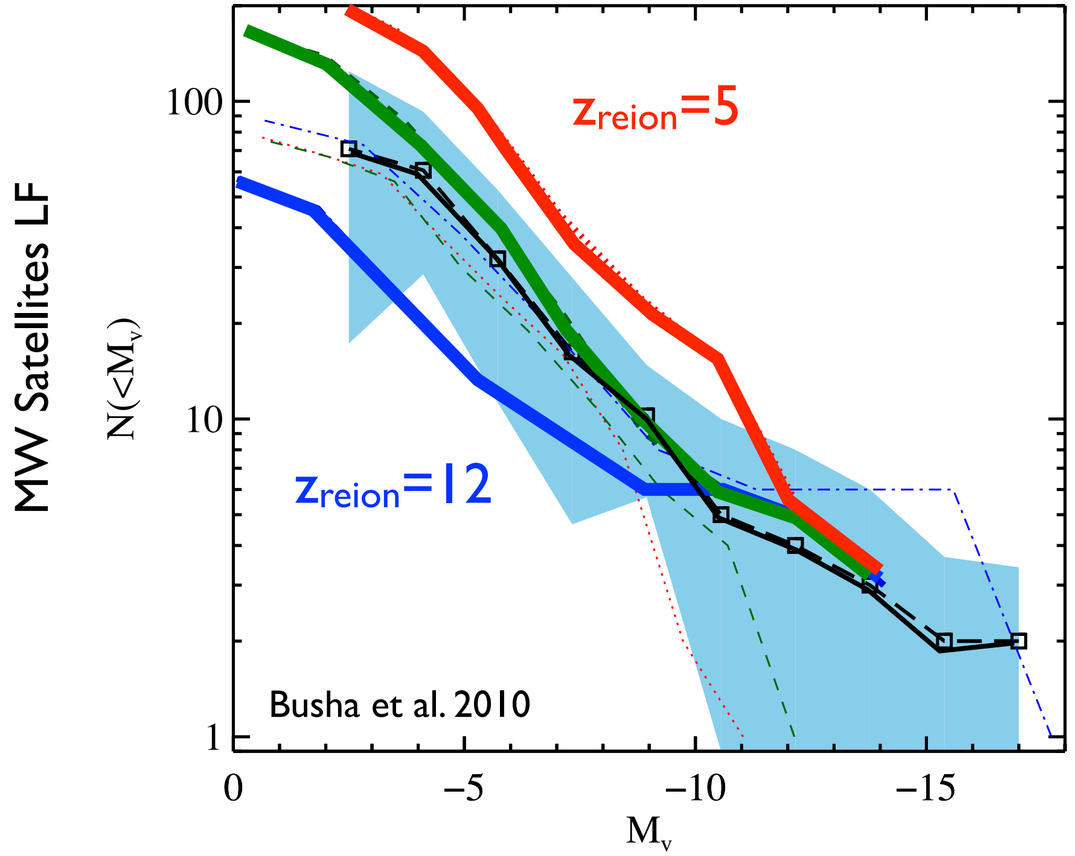
Reionization & the Milky Way

- UV background
- => gas photo-evaporation
- => SF suppression of low-mass galaxies
- => satellite galaxies, ultra-faint dwarfs →

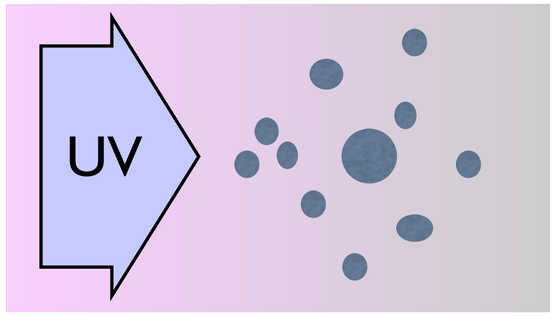


Bootes
D = 60 kpc
r_h = 220 pc
M_v = -5.8 mag

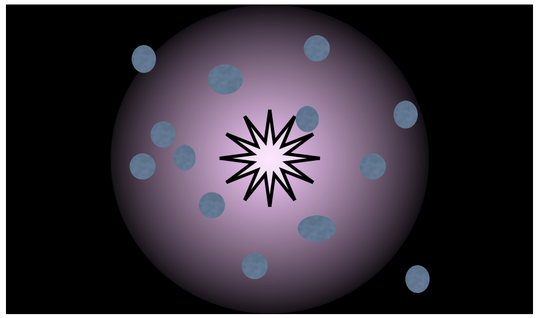
Courtesy V. Belokurov and SDSS collaboration



Impact of local structure of UV field at reionization on MW satellite pop



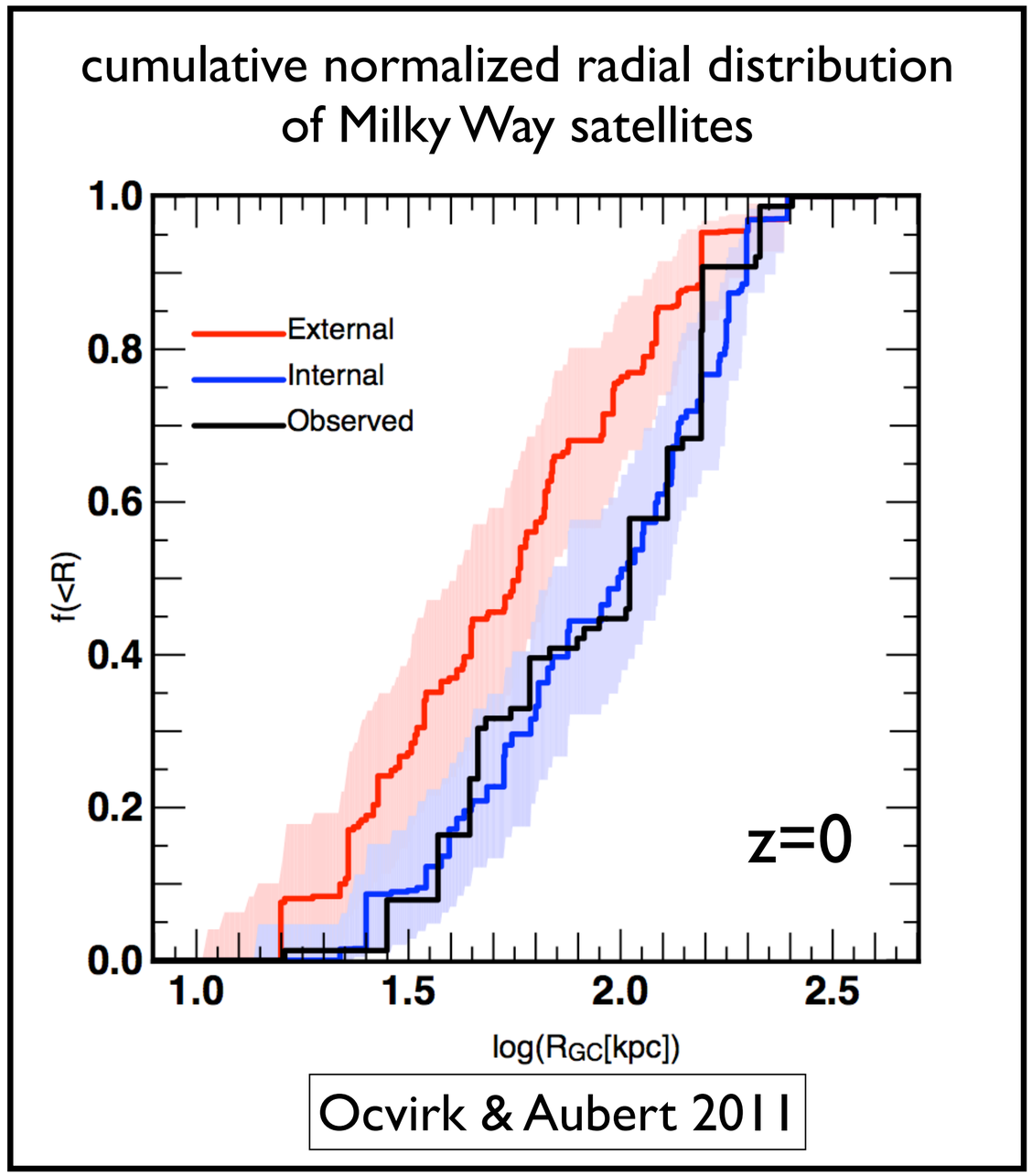
External, uniform BG



Internal, inside-out

- SAM based on Via Lactea II
- photo-evaporation recipes from Iliev et al. 2006
- => Signature of reionisation geometry survives down to z=0

- Simplification: unique central UV source -_-



PICON

PICON: Photo-**I**onization of **CON**strained simulations of the local group

Radiative post-processing of high-res hydro simulation of local group formation

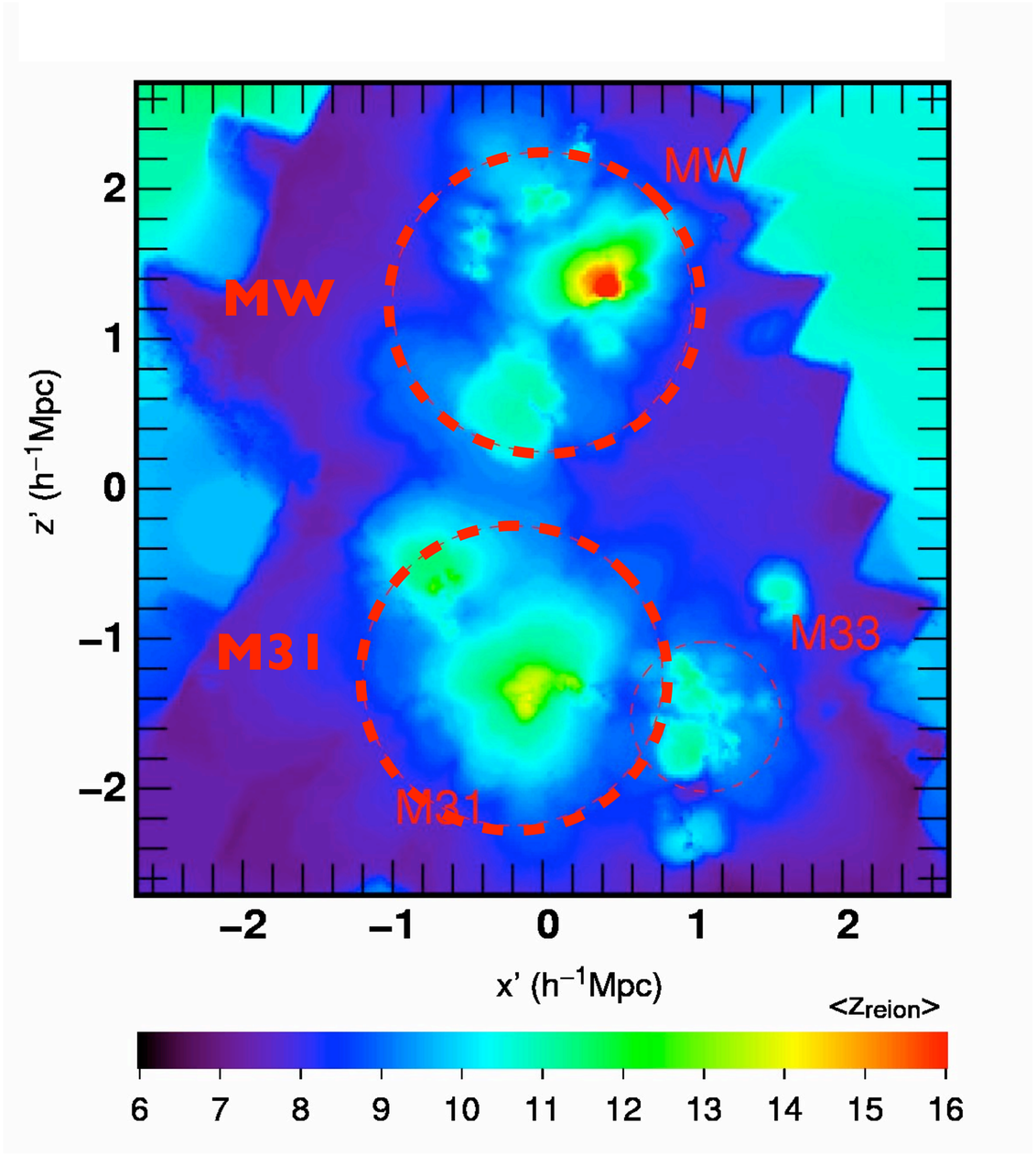
HYDRO SIMULATION

- CLUES
- **zoom** simu seed 186592
- Gottloeber et al. 2010
- GADGET 2, WMAP3 (no live RT)
- produces realistic MW+M31+M33
- $M_{part}=2.10^5\ M_\odot$ (in HR region)

RADIATIVE TRANSFER

- post processing
- ATON (Aubert & Teyssier 2008)
- grid-based method
- multi-GPU: CUDATON
- Stellar sources T=50000 K, $f_{esc}=0.2$
- H only chemistry
- ~20 h^{-1} kpc resolution, 512^3, 11 $^{h-1}$Mpc box

Local group reionization map



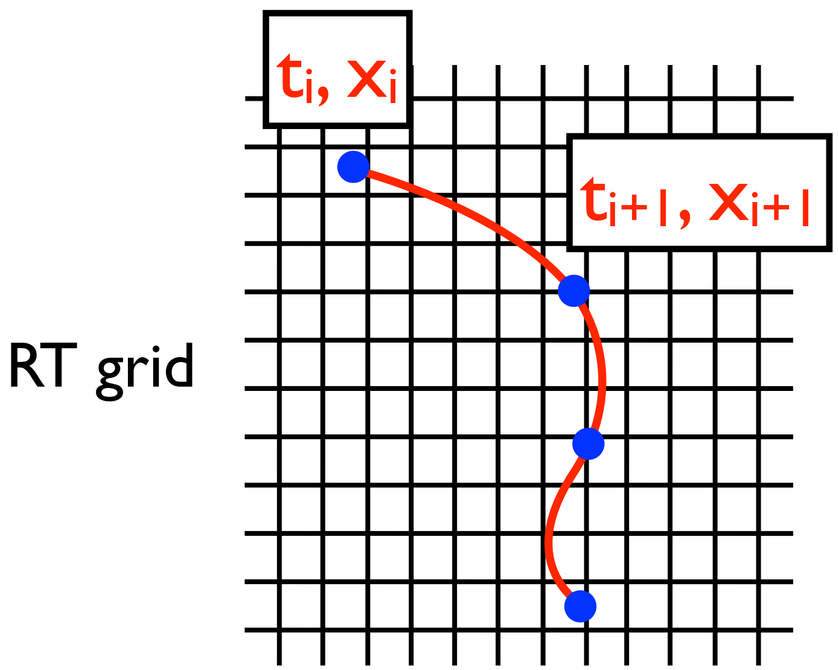
- Slice through MW-M31-M33 plane 200kpc thickness
- ~20 h^{-1} kpc resolution
- 2-4 major patches
- patches more or less structured
- each galaxy reionizes in isolation
- Effect of > 12.7 Gyr dynamical evolution?

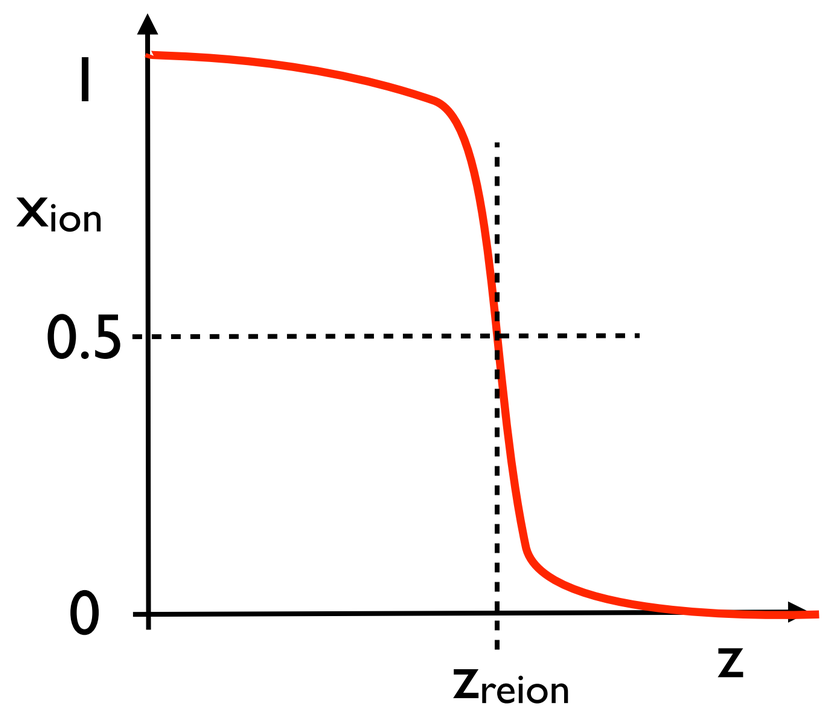
Ocvirk et al. 2012, in prep.

A new tool: Lagrangian reionization maps

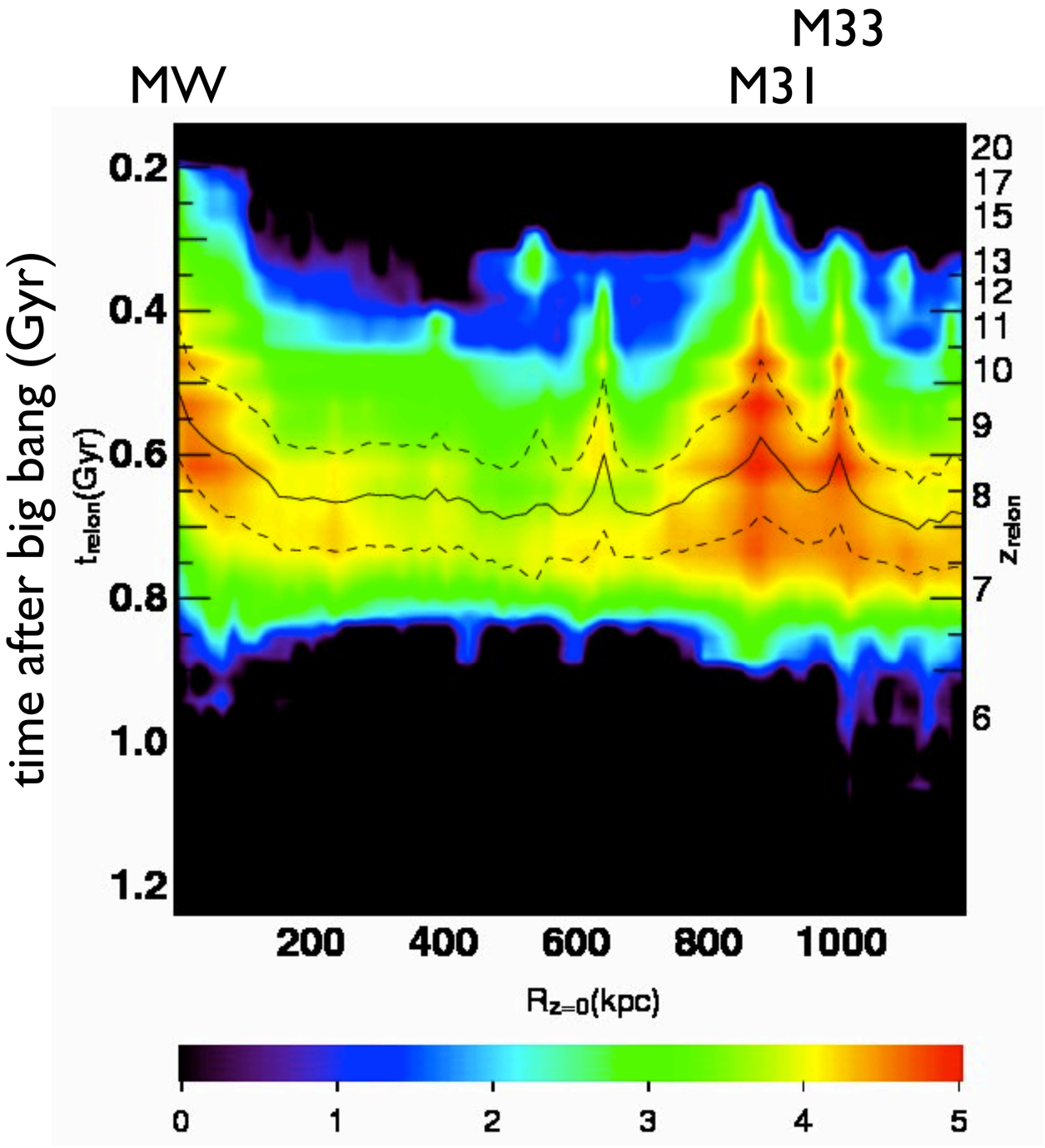
Reionization as seen by DM particles

- Follow DM particles, in every RT snapshot $x_{ion}^{particle} = x_{ion}^{cell}$
- => DM particles reionization history
- => Particle reionization redshift $x_{ion}(z < z_{reion}) > 0.5$



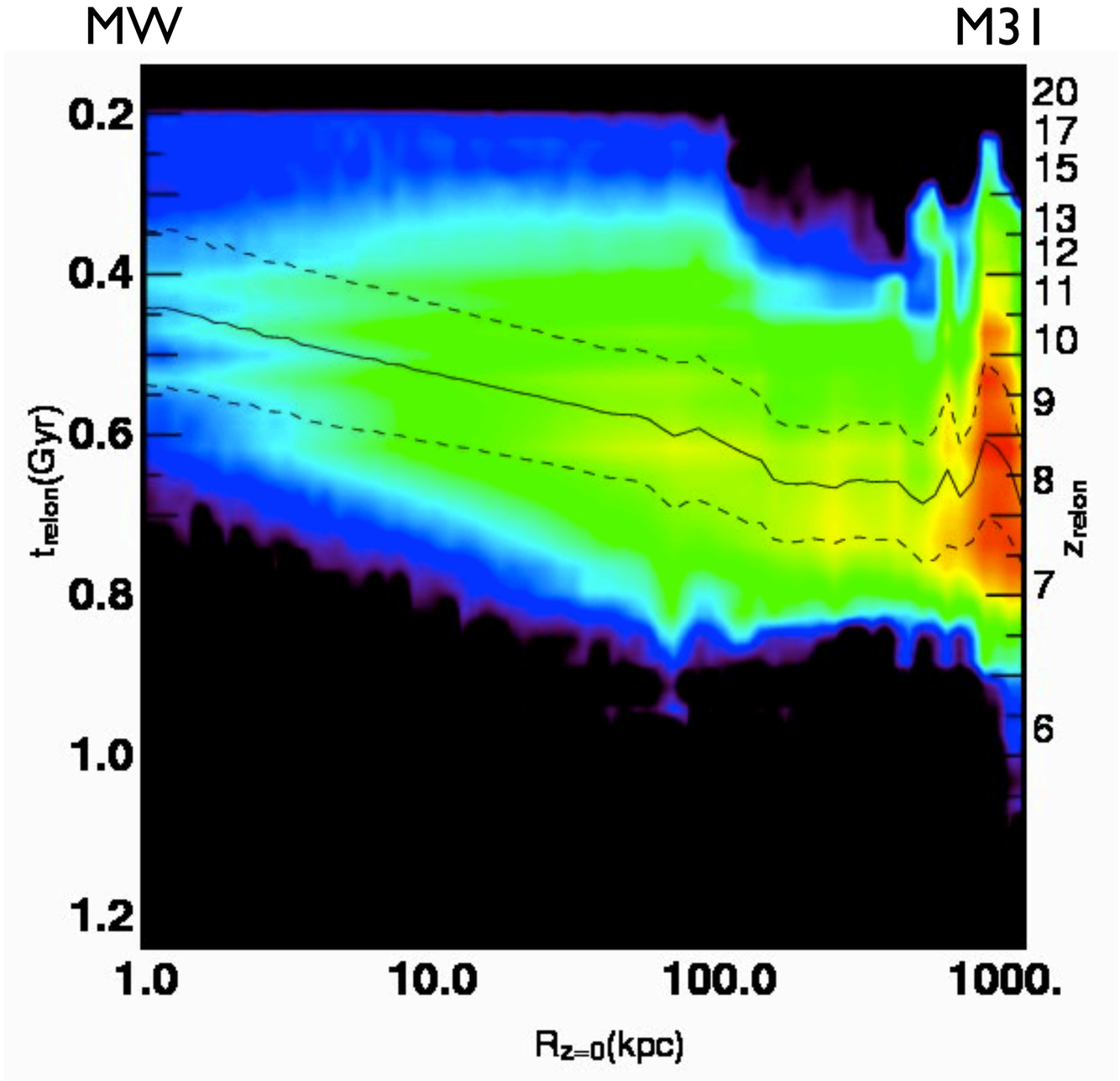


z_{reion} vs z=0 position



- Large spread in z_{reion}
- $<z_{reion}>$ increases near massive structures (M31,M33,MW)
- Floor at ~ z_{reion} = 8, R > 200 kpc
- No influence from M31 over MW during reionization ?

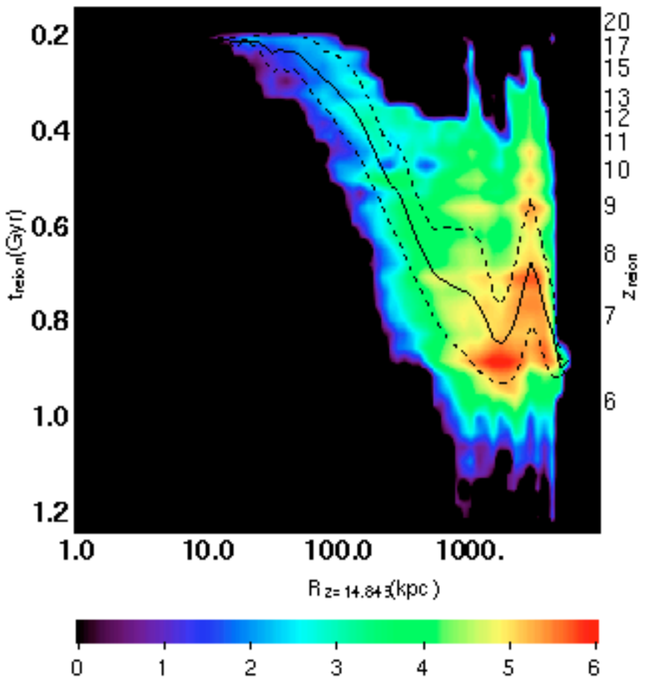
z_{reion} gradient in MW halo at z=0



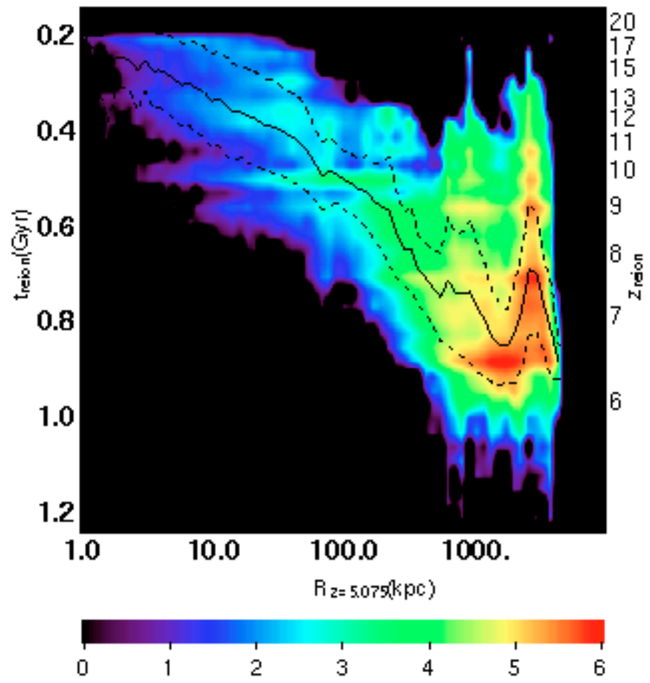
- stratification in z_{reion}
- SPH stars: $\Delta t_{reion} \sim 200$ Myr
- steady decline in z_{reion} inside-out
- (SAM model: $\Delta t_{reion} \sim 350$ Myr)

Temporal evolution of z_{rei} gradient

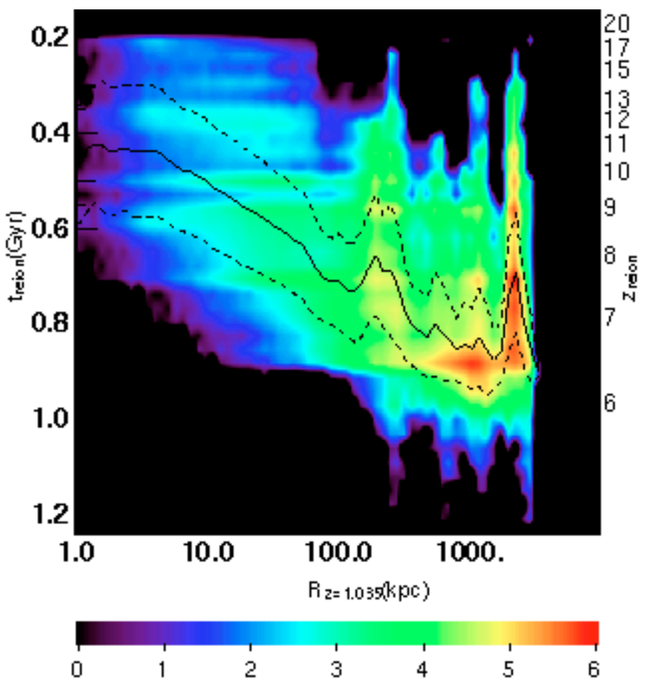
z=15



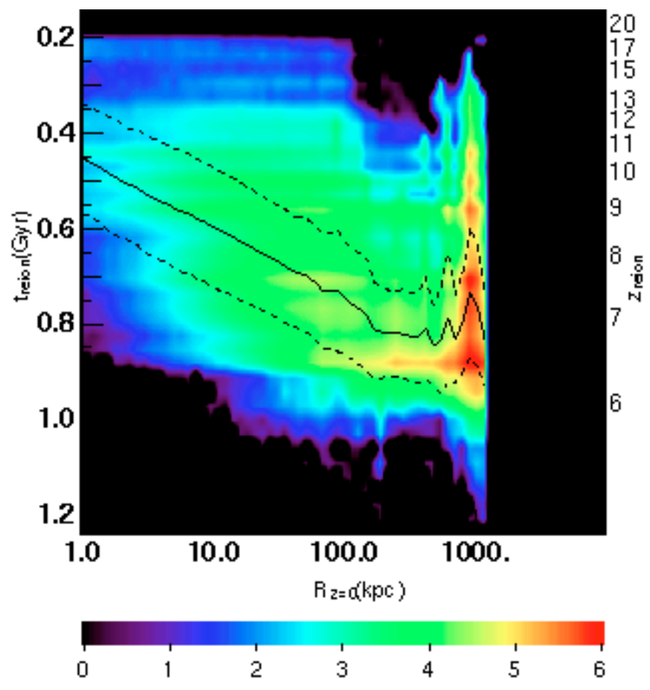
z=5



z=1



z=0



origin = MW, SAM sources

- Well defined structure at high z
- (despite source multiplicity)
- flattens out with time
- but survives
- (despite >10 Gyr of dynamical evolution)

Ocvirk et al. 2012, in prep.

Discussion: Implications

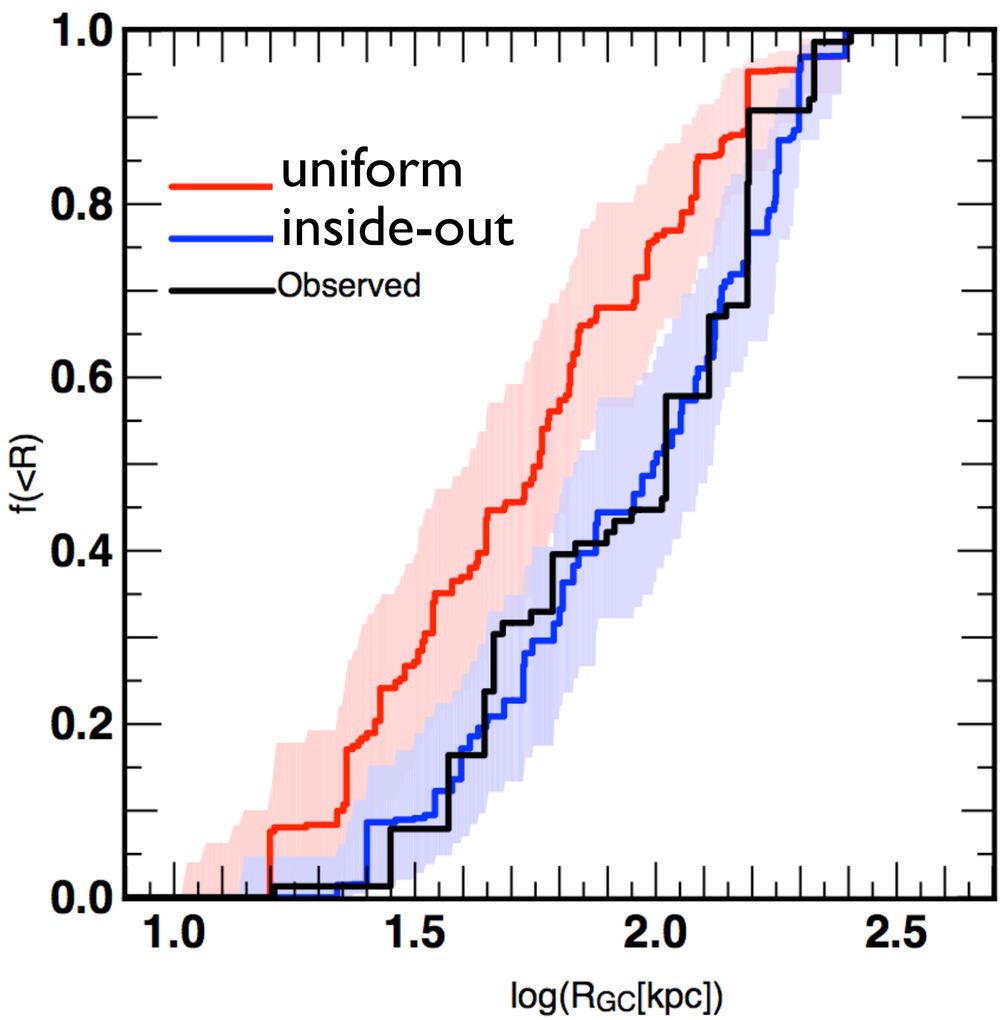
Satellite pop SAMs assume UNIFORM z_{rei}

- Koposov et al. 2008: z_{rei} = 8 - 11
- Maccio et al. 2009: z_{rei} = 7.5 - 11
- Busha et al. 2010: z_{rei} = 6 - 11

- We find strongly **non-uniform** z_{rei}
  - $\langle z_{rei} \rangle$ (R<10 kpc) >10
  - $\langle z_{rei} \rangle$ (R>100 kpc) ~7

- Therefore uniform z_{rei} is:
  - wrong in internal reionization scenario
  - ok in external reionization, but how likely?

cumulative normalized radial distribution of MW satellites



(distance to galactic center)

Ocvirk & Aubert 2011

Summary: tools/products projects suggestions

- **SAM satellites pop** with various reionization scenarios
  - run on CLUES HR sims? Push to higher res?
  - extend to stellar halo / streams <= NEED halo tracks for ALL haloes (including disrupted)
- **RT postprocessing with ATON**
  - multi-GPU => fast (very large boxes (up to 2048^3) or explore source parameter space)
- data: Detailed reionization history (x_{ion} for zoom simu with seed 186592 => LAE studies of MW progenitor?

Tools in development: coupled hydro-RT

- **RAMSES-ATON** (T. Stranex, R. Teyssier, D. Aubert)
  - hybrid:
    - RAMSES (Teyssier): gravity+hydro => CPU
    - ATON (Aubert & Teyssier): RT => GPU (CUDATON, speedup x80)
  - advantage: c=1
  - drawback: fixed grid (also hydro)!!! (at the moment...)
- **Run on Curie-hybrid** (PO)**:**
  - CLUES full box ICs: 64 Mpc, 1024^3, 128 nodes, 256 GPUs
  - z=1 in ~ 3 days
- runs ok but bad SFH because of fixed grid.
- => need AMR
- => QUARTZ (D. Aubert): coupled, hybrid, AMR, from scratch