The escape fraction from high-redshift dwarf galaxies

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Outline

Introduction

Modelling high-redshift dwarf galaxies

Results

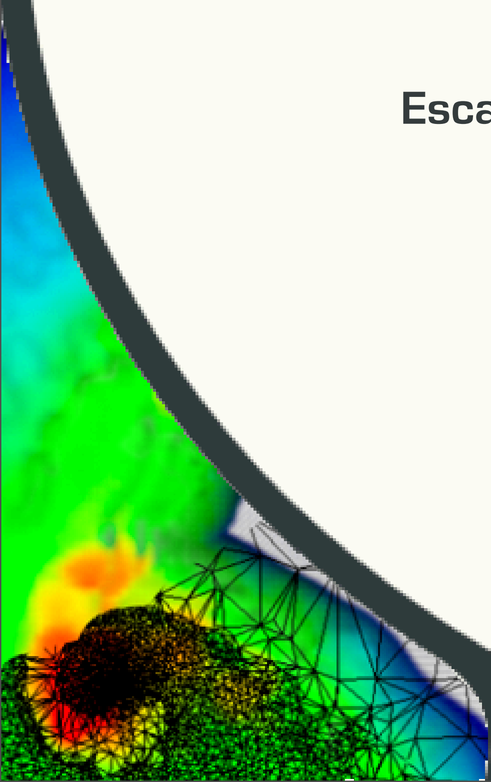
Summary

Stars are believed to be the main source of ionising photons during reionisation

Contribution of stars depends on:

- Star formation rate
- Fraction of photons that escape the host galaxy

Escape fraction is a key input parameter in reionisation simulations



Observations

Observations of escape fractions:

Milky Way: ~6%

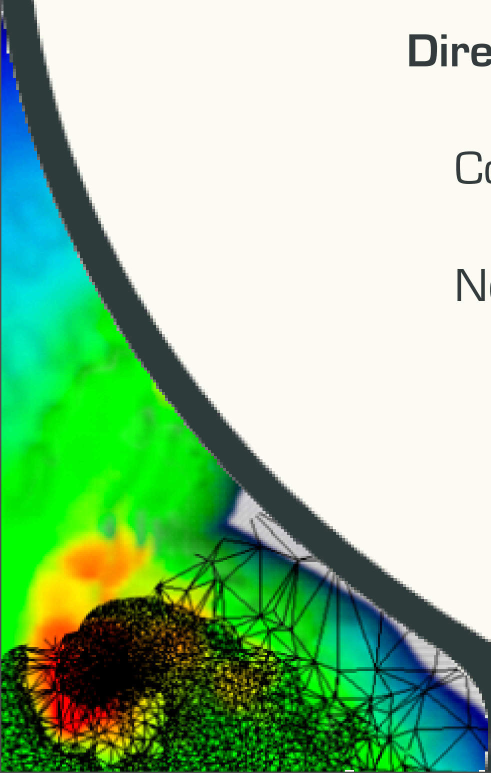
Local starbursts: < 3 - 10 %

Higher redshifts: increasing towards ~10%

Direct measurements complicated

Compare flux at Lyman limit to frequency at which intrinsic luminosity is inferred

Need model description of star formation history

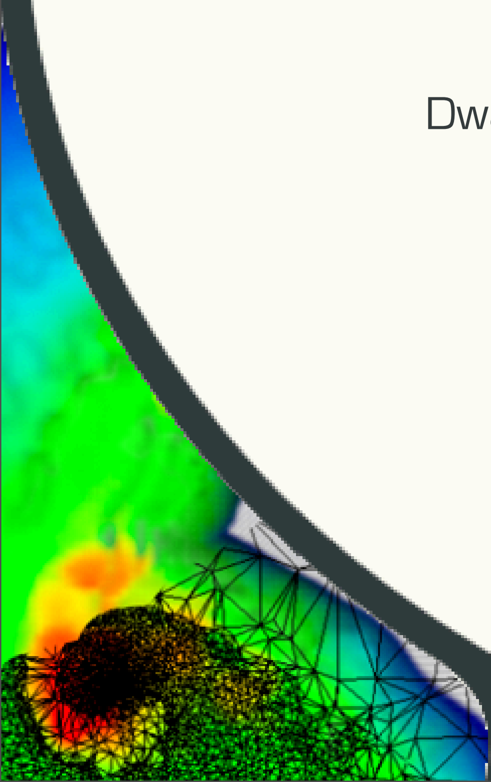


Modelling of escape fractions:

Dwarf starbursts: < 10% (Fujita et al. 2003)

Young galaxies at z ~ 3: 1 - 10 % (Razoumov & Sommer-Larsen 2006;2007)
1 - 3 % (Gnedin et al. 2008)

Dwarf galaxies at z ~ 8 - 10: 40 - ~90 % (Wise & Cen 2009)
(Razoumov & Sommer-Larsen 2010)



Modelling of escape fractions from high-redshift dwarf galaxies:

Most of ionising radiation at $z = 6$-10 is predicted to come from dwarf galaxies

Our models use a code that accurately reproduces the properties of local dwarfs

N-body/SPH code follows dark matter, gas and star particles

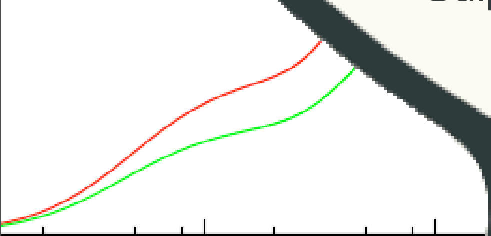
Supernova and stellar wind feedback taken into account using pressure particles

Model for 2-phase ISM similar to Wolfire et al. (2003)

Metal cooling, UV-heating and cosmic ray ionisation

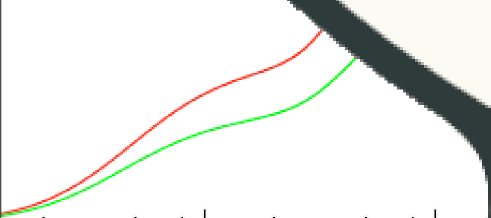
Star formation according to Jeans mass criterion

Salpeter IMF



Initial conditions

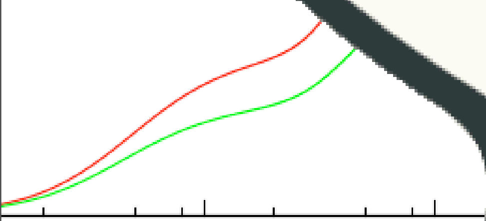
- Dark halo with NFW profile
- Baryon fraction: 0.041
- Disk of stars and disk of gas
- Isolated galaxy



Models

Different models to do parameter study of

mass	$M = 10^8 - 10^{10} M_\odot$
spin parameter	$\lambda = \dfrac{L\|E\|^{1/2}}{G M_{vir}^{5/2}} = 0.025 - 0.1$
gas fraction	$f_{gas} = 0.2 - 0.8$



Radiative Transfer

Radiative transfer in post-processing

Ionising radiation no effect on gas

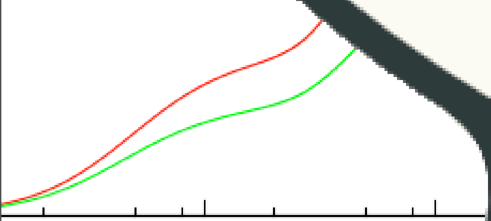
Radiative transfer algorithms:

SPHRay (Altay, Croft & Pelupessy 2008)

Ray-tracer for SPH

SimpleX2 (Paardekooper, Kruip & Icke A&A submitted, arXiv:0912.4273)

Radiative transfer on unstructured grid



Radiative Transfer

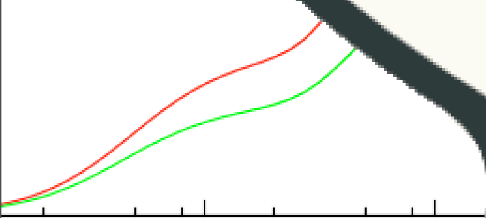
SPHRay

Calculate escape fraction using most massive sources without dust

SimpleX

Study effects of:

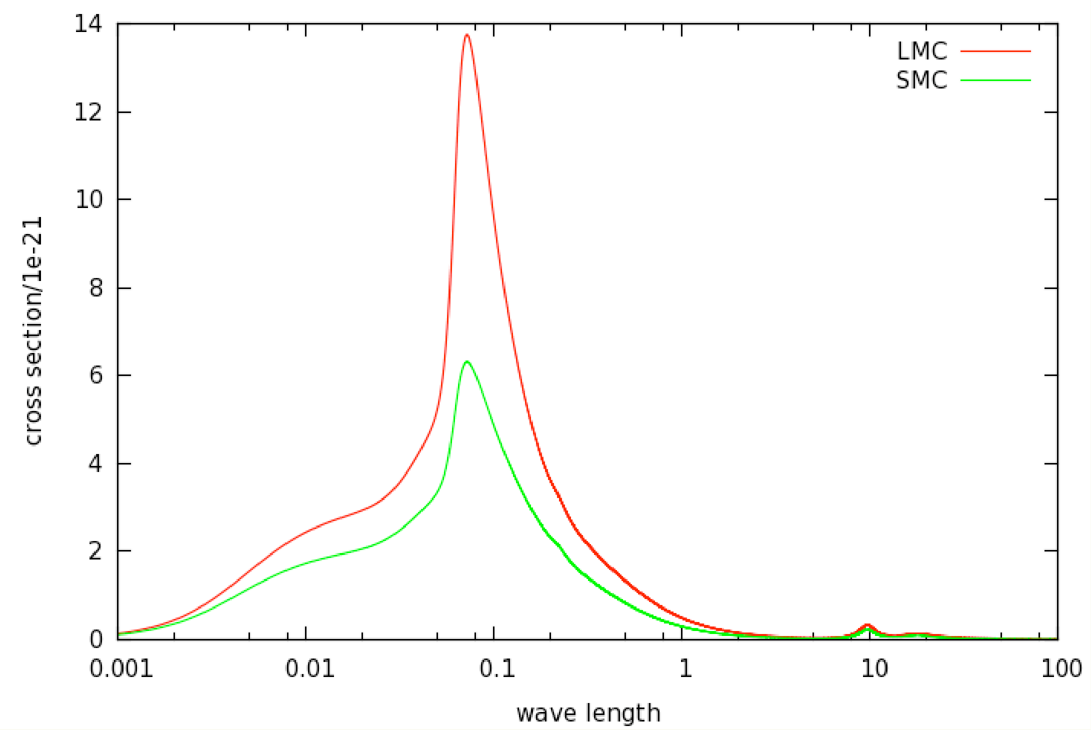
- Number of sources
- Dust



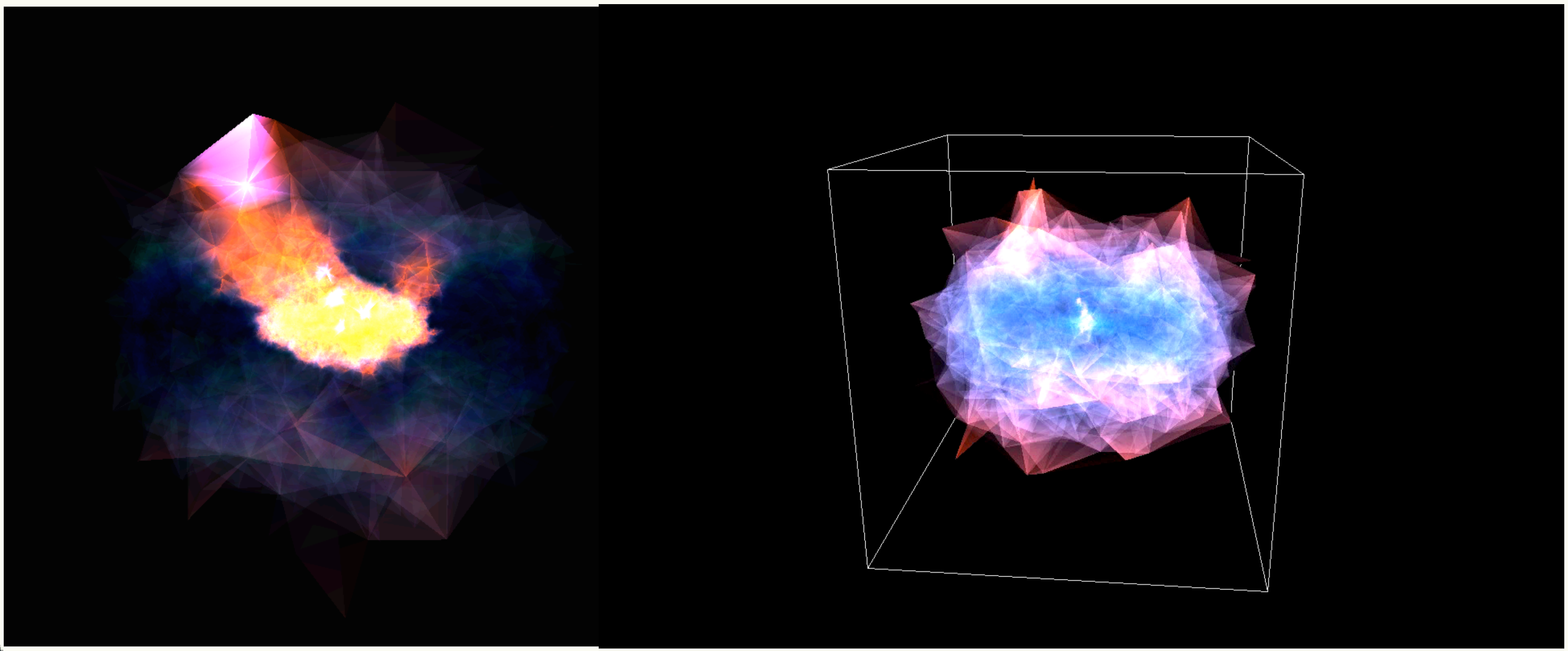
Dust model similar to Gnedin et al. (2008)

Express dust cross section as effective cross section per hydrogen atom

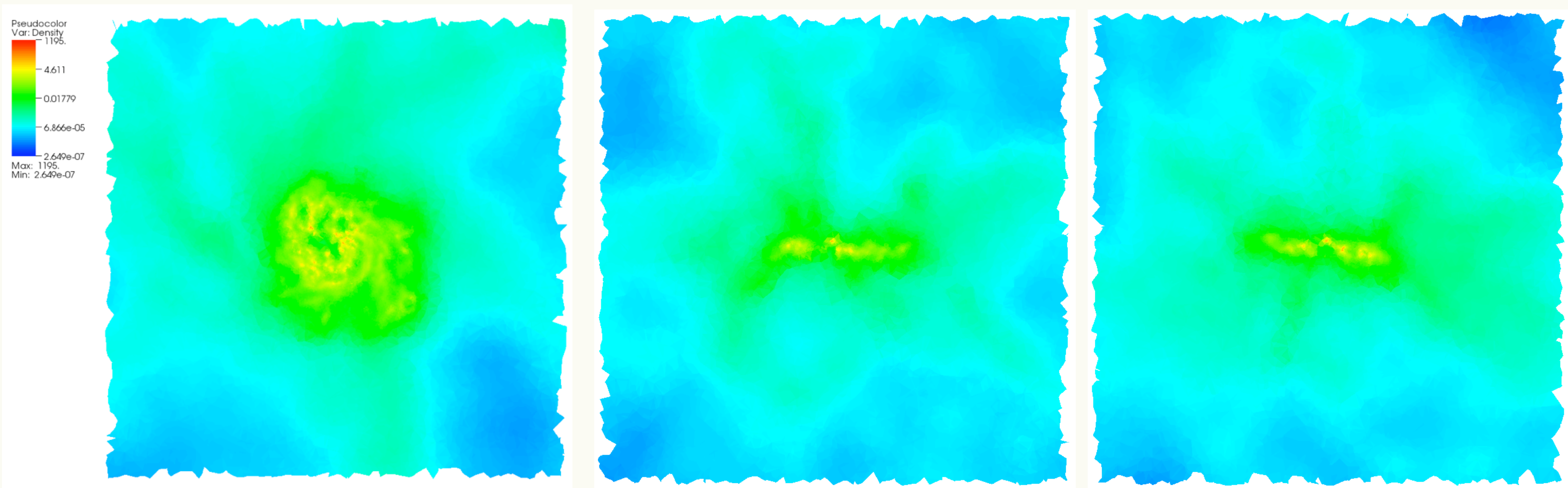
Use fit to the observed extinction curves of SMC and LMC



Radiation primarily escapes through holes blown by supernovae



Density profile of individual galaxy



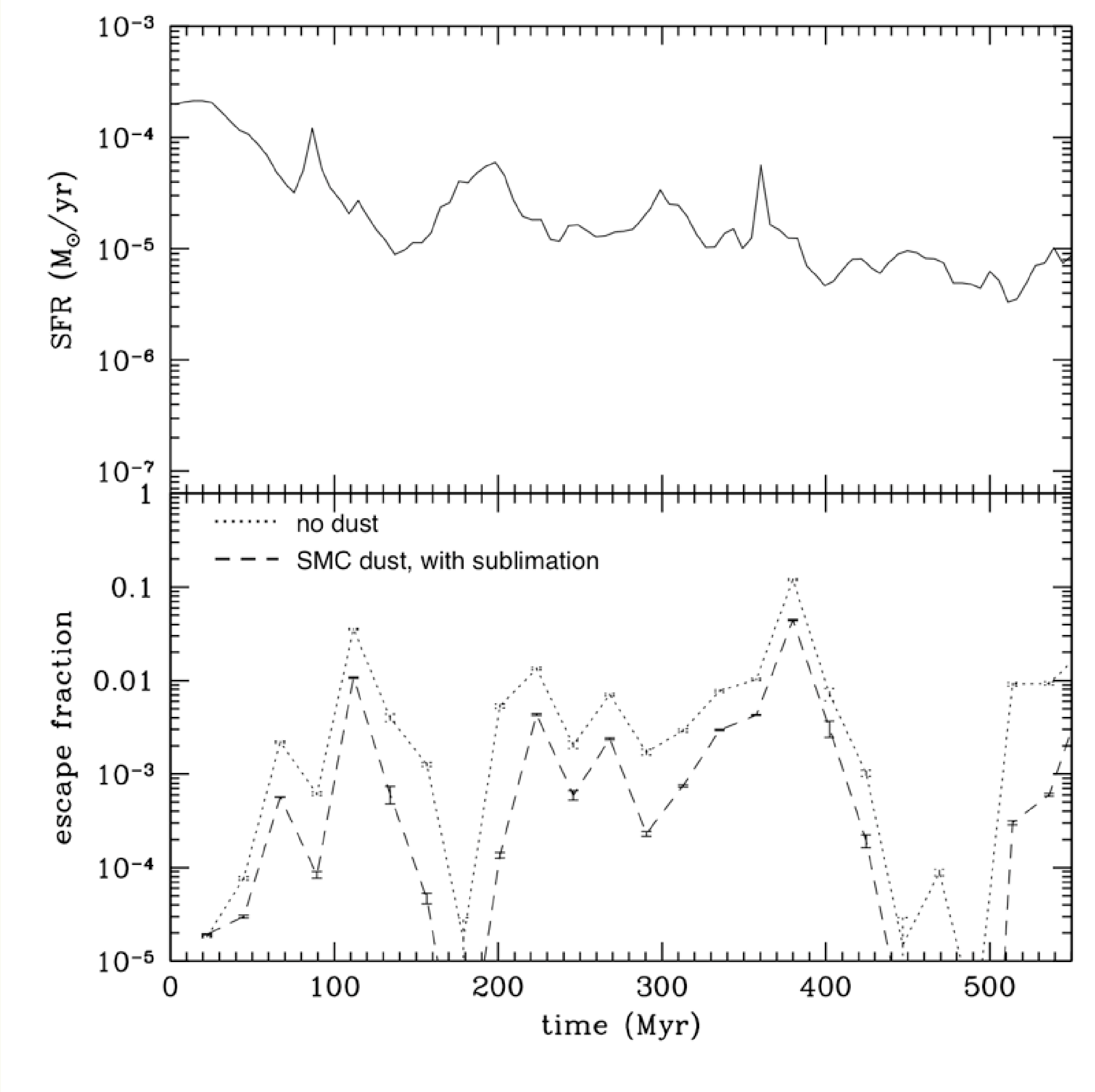
xy xz yz

$$M = 10^9 M_\odot$$

$$\lambda = 0.05$$

$$f_{gas} = 0.5$$

Escape fraction of individual galaxy

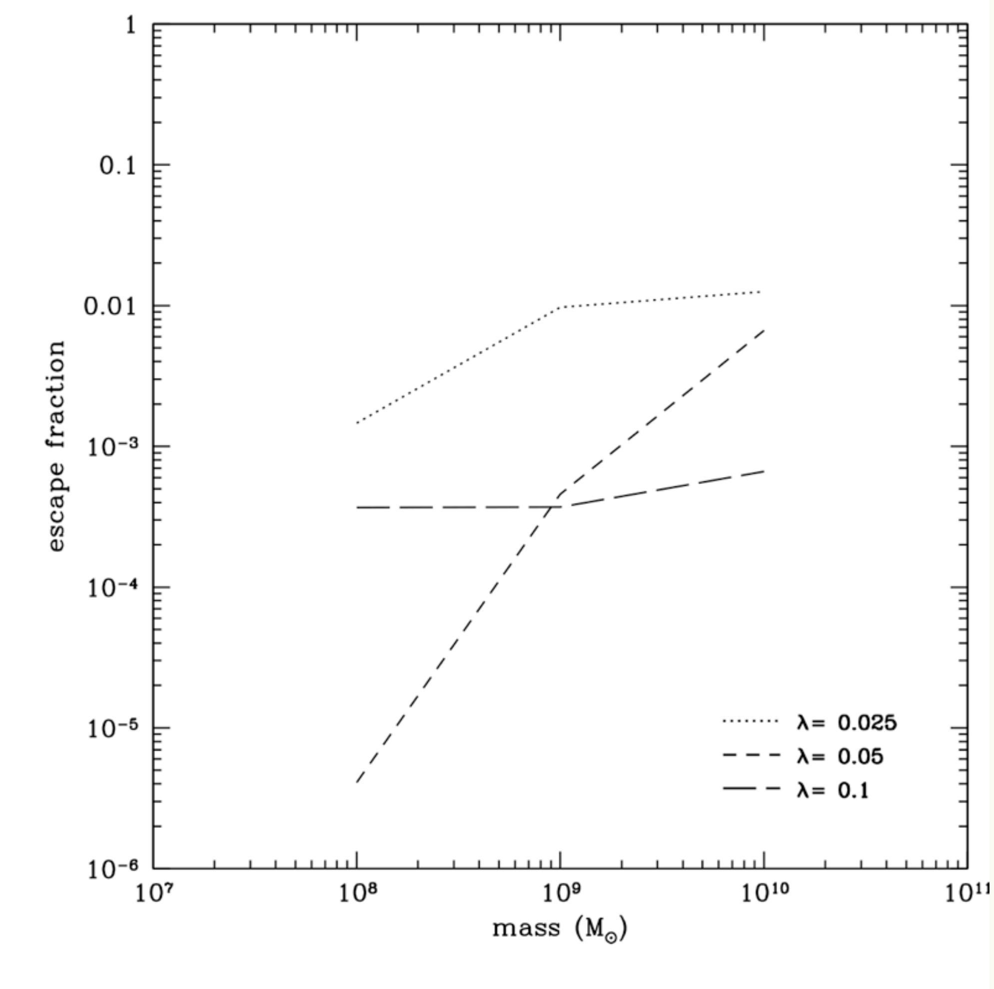


$M = 10^9 M_\odot$

$\lambda = 0.05$

$f_{gas} = 0.5$

Average escape fraction for different spin parameters



Low spin

↓

High SFR

↓

High UV escape

Escape fractions are significantly lower than previously found for high-z dwarfs

Comparable to what was found for young galaxies at z ~ 3

Possible causes are

- Initial conditions (disk vs. sphere)
- No external inflow of gas
- Supernova feedback
- Initial mass function (Salpeter vs. top-heavy)
- Coupling of radiation and gas

We find escape fractions from high-redshift dwarf galaxies < 10%

Radiation escapes through holes blown by supernovae

→ Escape highly inhomogeneous

Spin parameter has not a big impact, initial gas fraction is more important

Escape fractions lower than previous work due to lower SFR and less SN feedback