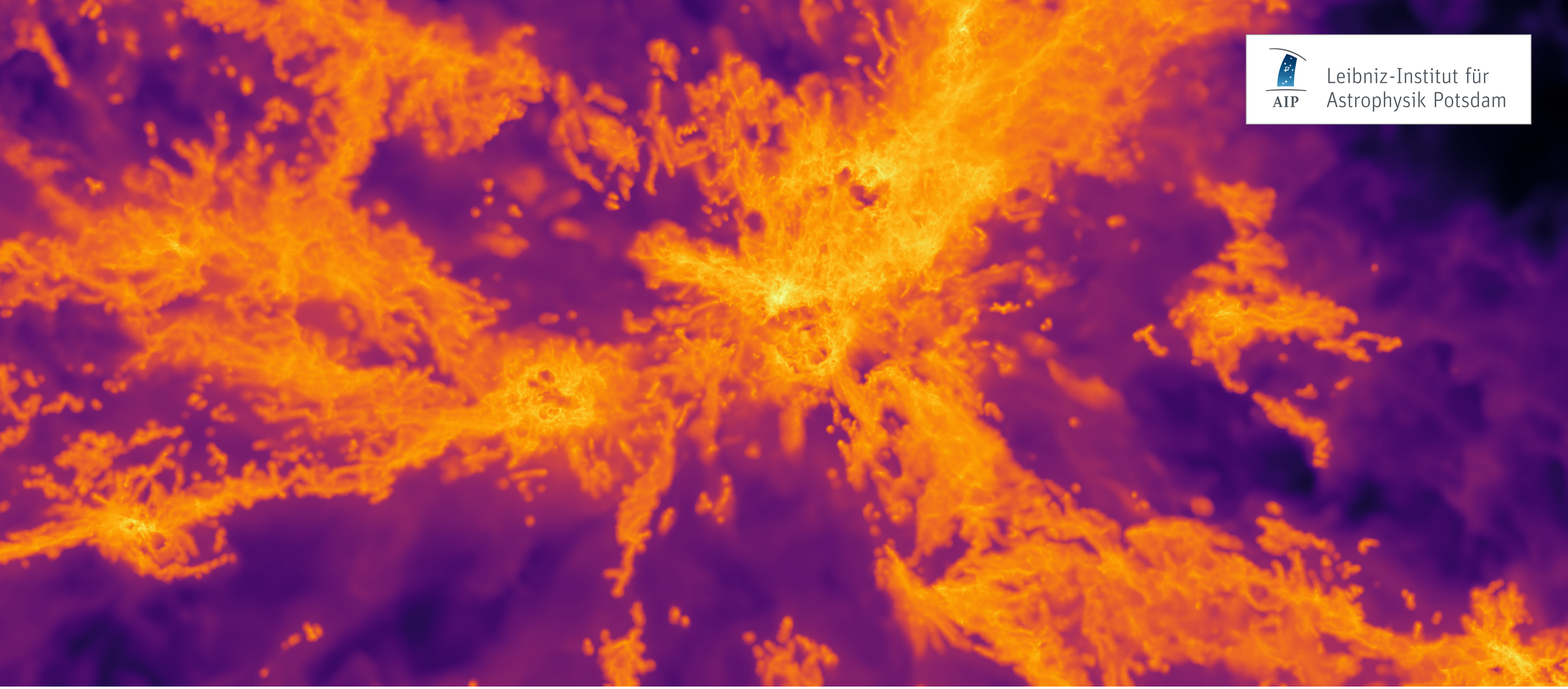


Leibniz-Institut für Astrophysik Potsdam

Illuminating High-Redshift Galaxy Formation

Cosmological Radiation-Hydrodynamical Simulations with AREPO-RT

Ewald Puchwein (AIP)

team: Rahul Kannan, Aaron Smith, Enrico Garaldi, Josh Borrow, Laura Keating, Mark Vogelsberger et al.

Motivation

- Go beyond THESAN by getting **higher resolution** and an ISM model that **“resolves” hot and cold phases**

- Perform **zoom-in radiation-hydrodynamics simulations** of 14 objects (~10^8-10^{13} $M_\odot$ at z=3) to study:

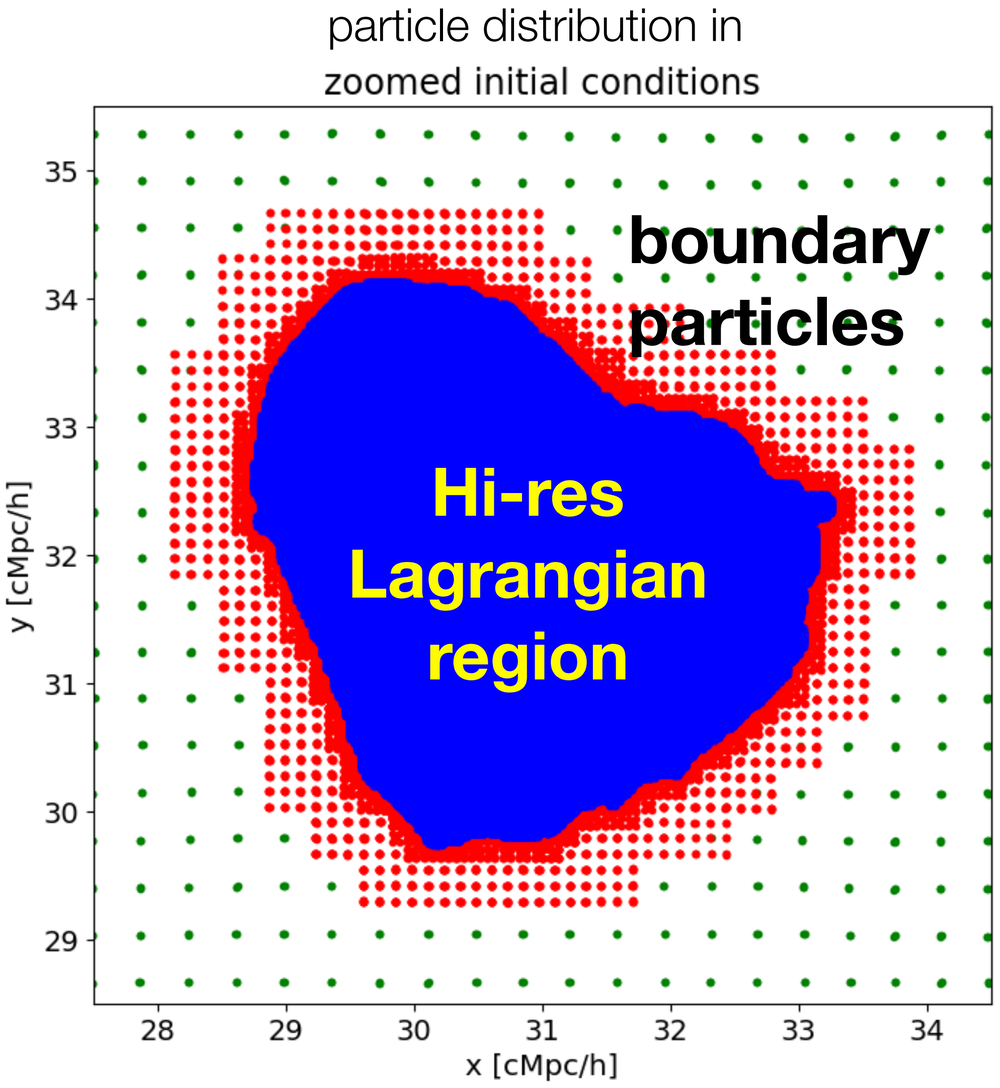
  - high-redshift galaxy formation

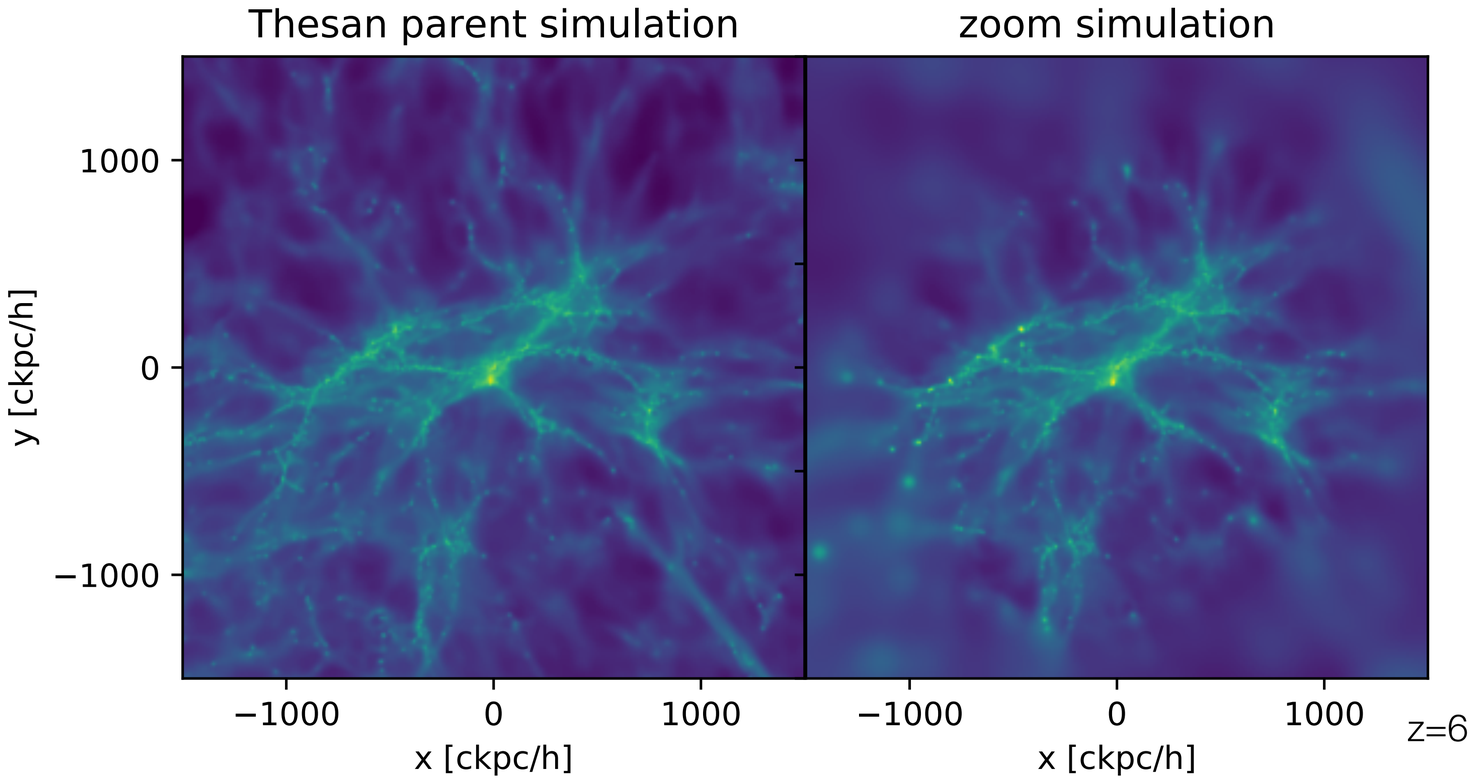
  - Lyman continuum escape -> driving reionization

  - observational tracers: Lyman-α & H-α emission, metal line emission/absorption

  - molecular hydrogen and dust formation

Our new zoomed-initial conditions code

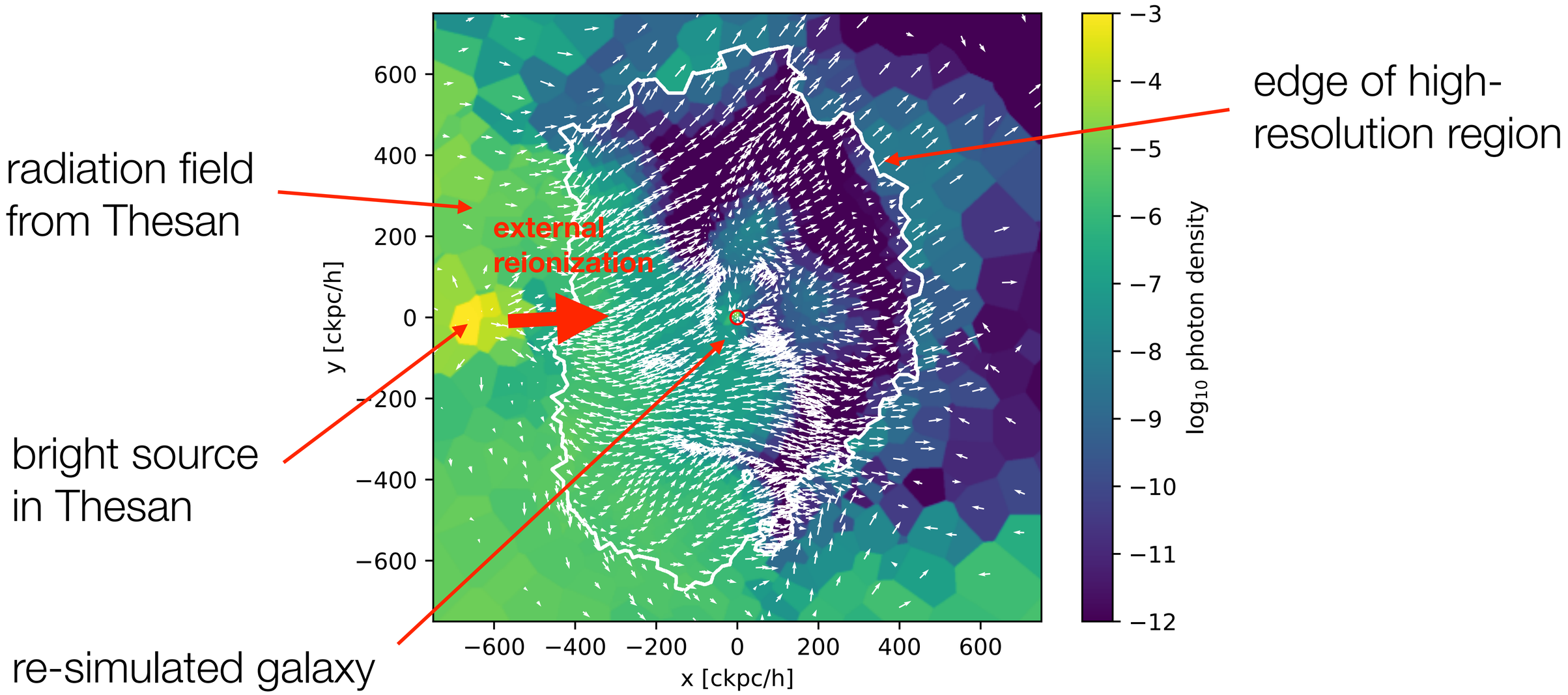




Puchwein et al., in prep.; **public release planned**

compatible with N-GenIC/Gadget-4 (e.g., TNG, MTNG, Thesan), easy to modify (Python/C++/OpenMP mix)

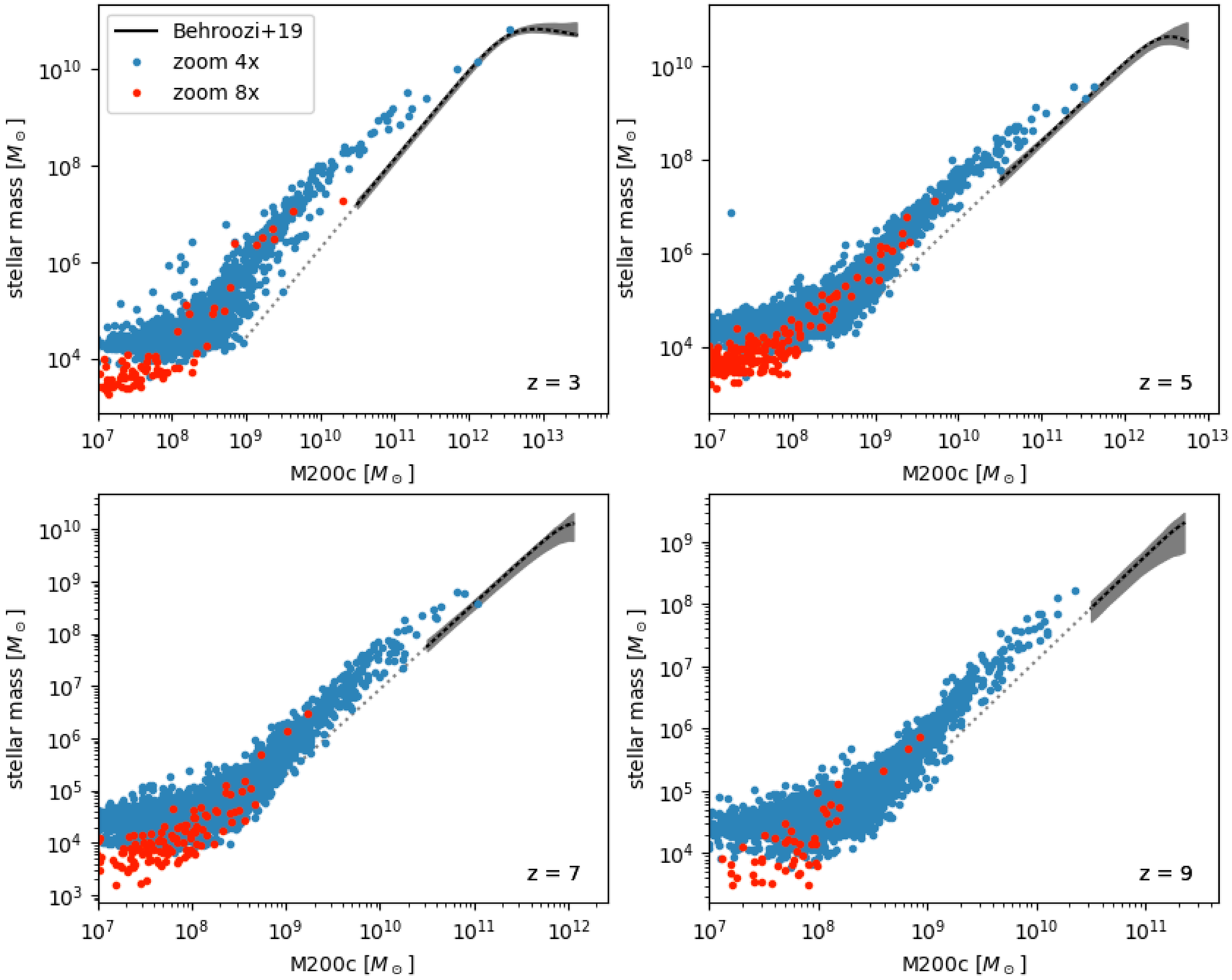
Allowing external reionization in the zoom simulations



Our updated galaxy formation model

- **Based on the SMUGGLE model** (Marinacci+19; low-temperature cooling -> cold/hot phase, local supernovae and wind feedback around star particles)
- **Coupled to multi-frequency radiation hydrodynamics** (Kannan+20)
- Jeans criterion for star formation (typically at $n \gtrsim 10^2$ cm-3)
- Additional early stellar feedback in part of the runs (momentum injection around star particles in first 5 Myr)
- model H_2 and dust

The stellar mass-halo mass relation

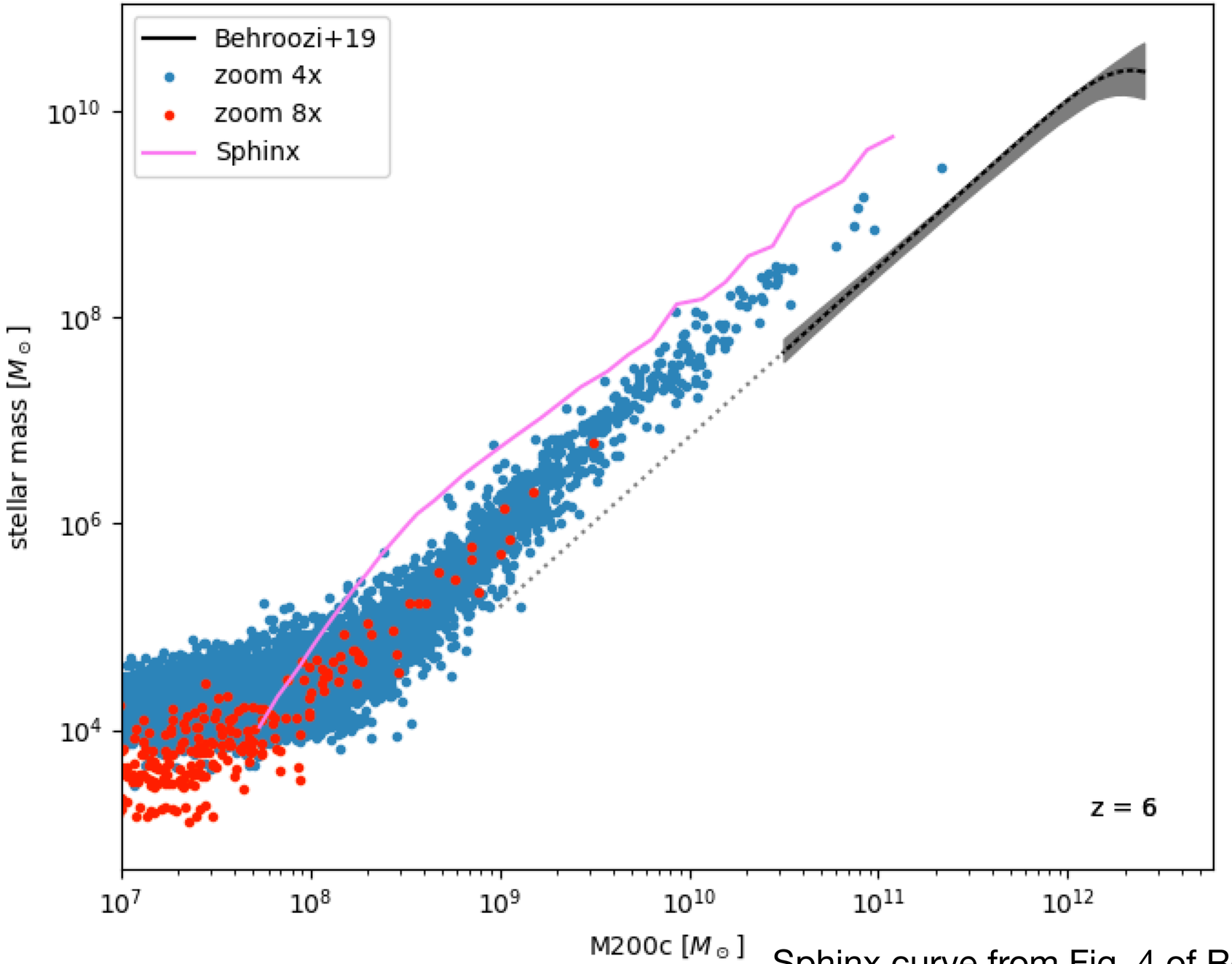


zoom 4x: m_{gas} ~ 8x10^3 $M_\odot$

zoom 8x: m_{gas} ~ 10^3 $M_\odot$

planned - zoom 16x: m_{gas} ~ 10^2 $M_\odot$

The stellar mass-halo mass relation at z=6



Sphinx curve from Fig. 4 of Rosdahl+22

Lyman-alpha & H-alpha emission

simulated in post-processing with the Monte Carlo-RT code COLT

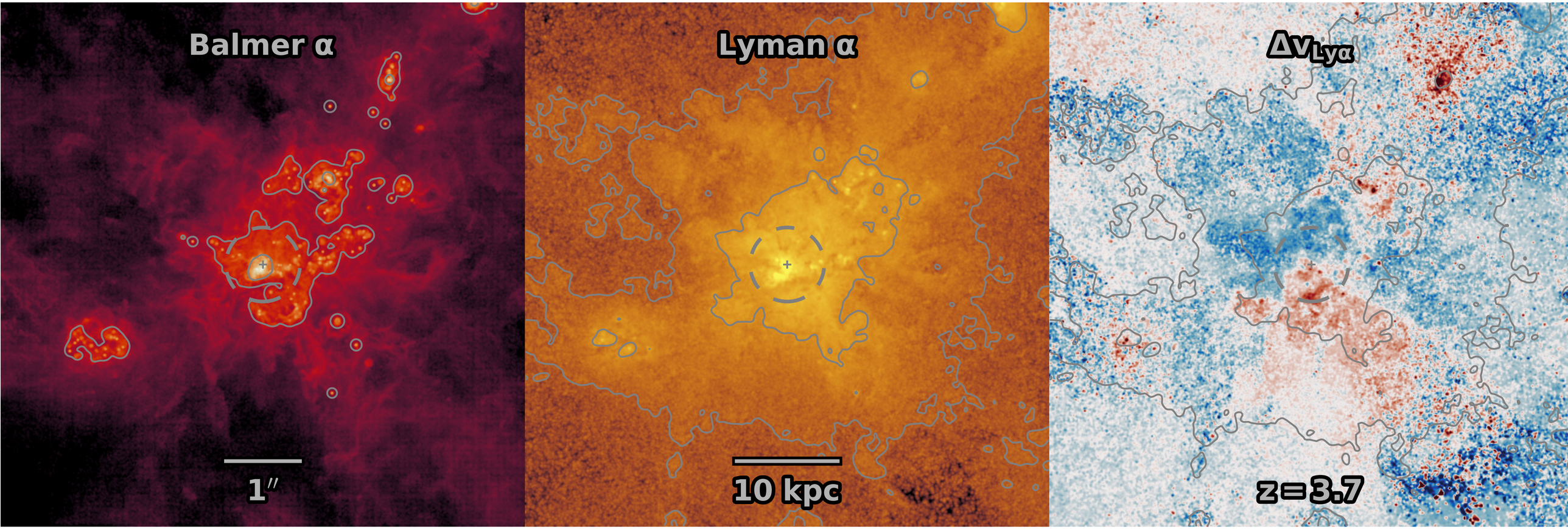
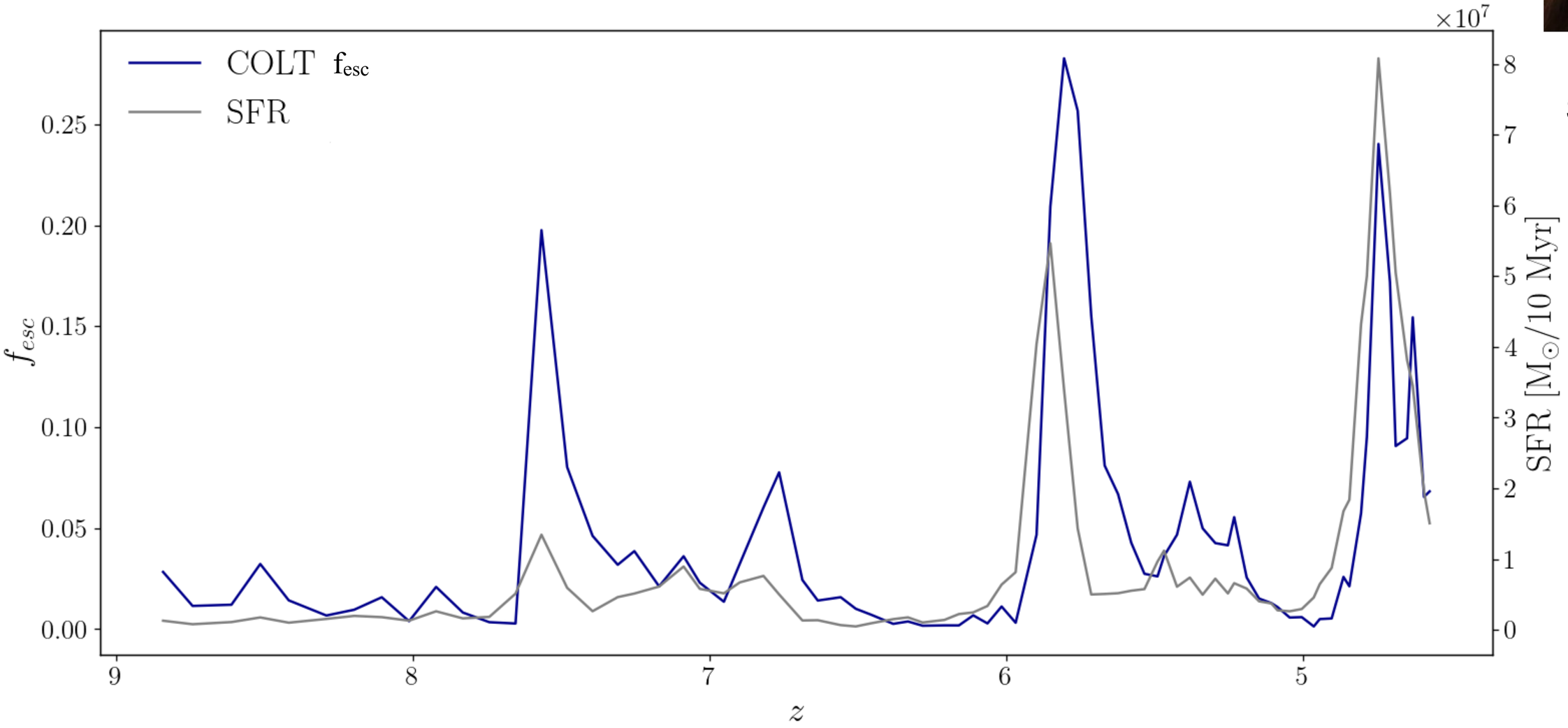


image by Aaron Smith

Time evolution of escape fraction - for a single galaxy

Nele Stachlys (AIP)



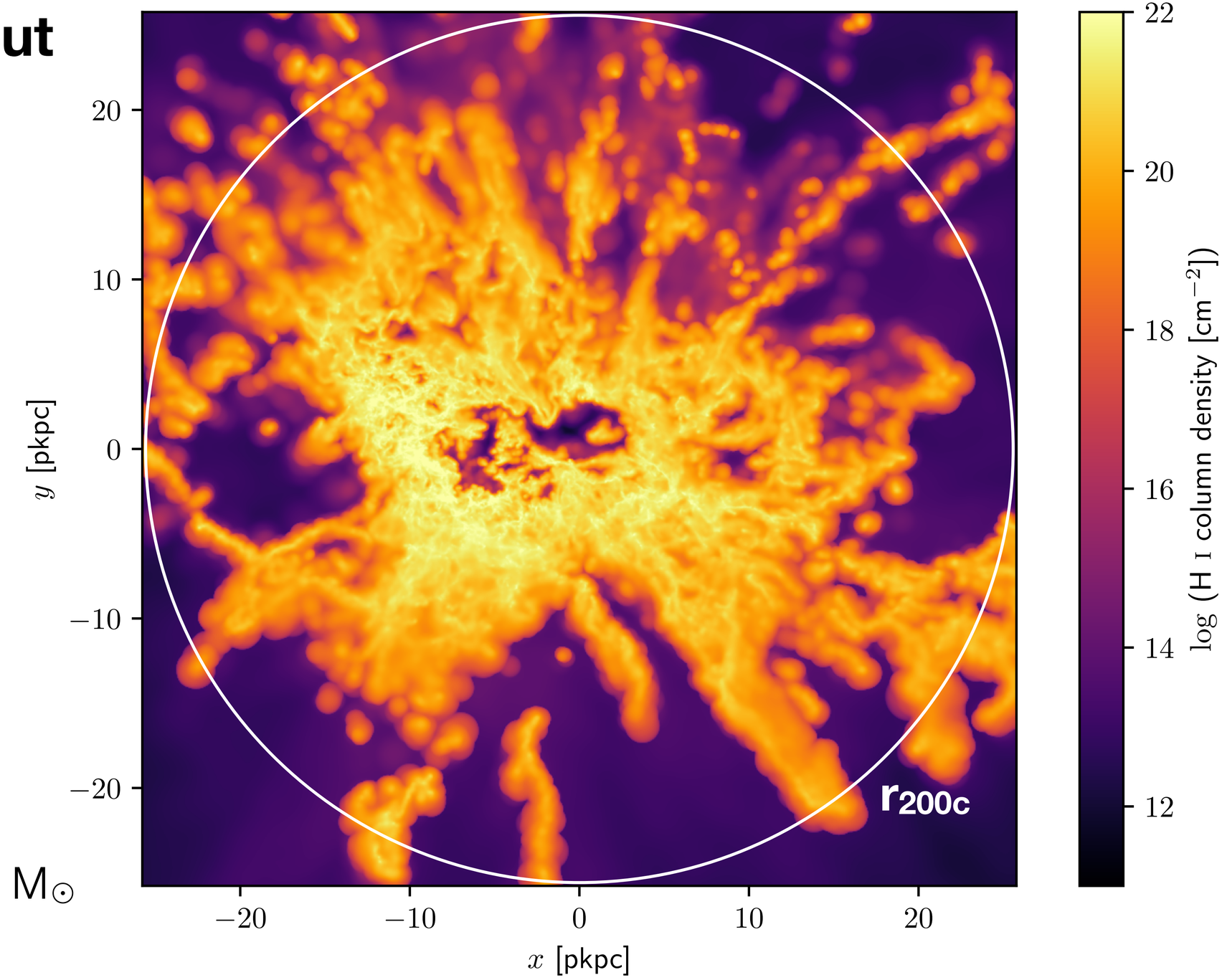
Feedback breaking out

neutral hydrogen column density

thin projection

$M_{200c} = 2 \times 10^{11}\, M_\odot$

$z = 6.15$



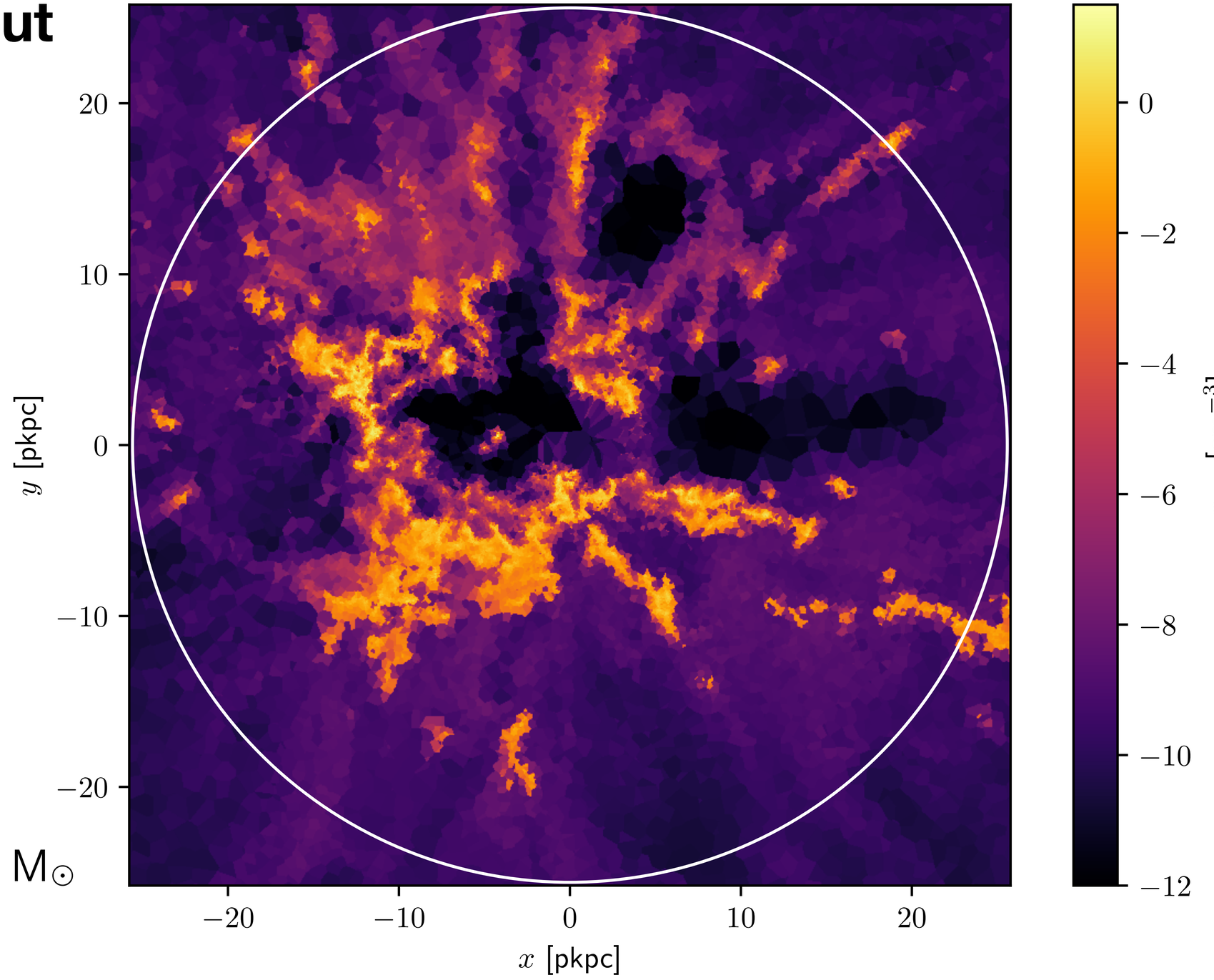
Feedback breaking out

neutral hydrogen
(3D) density

slice

$M_{200c} = 2 \times 10^{11}\, M_\odot$

$z = 6.15$



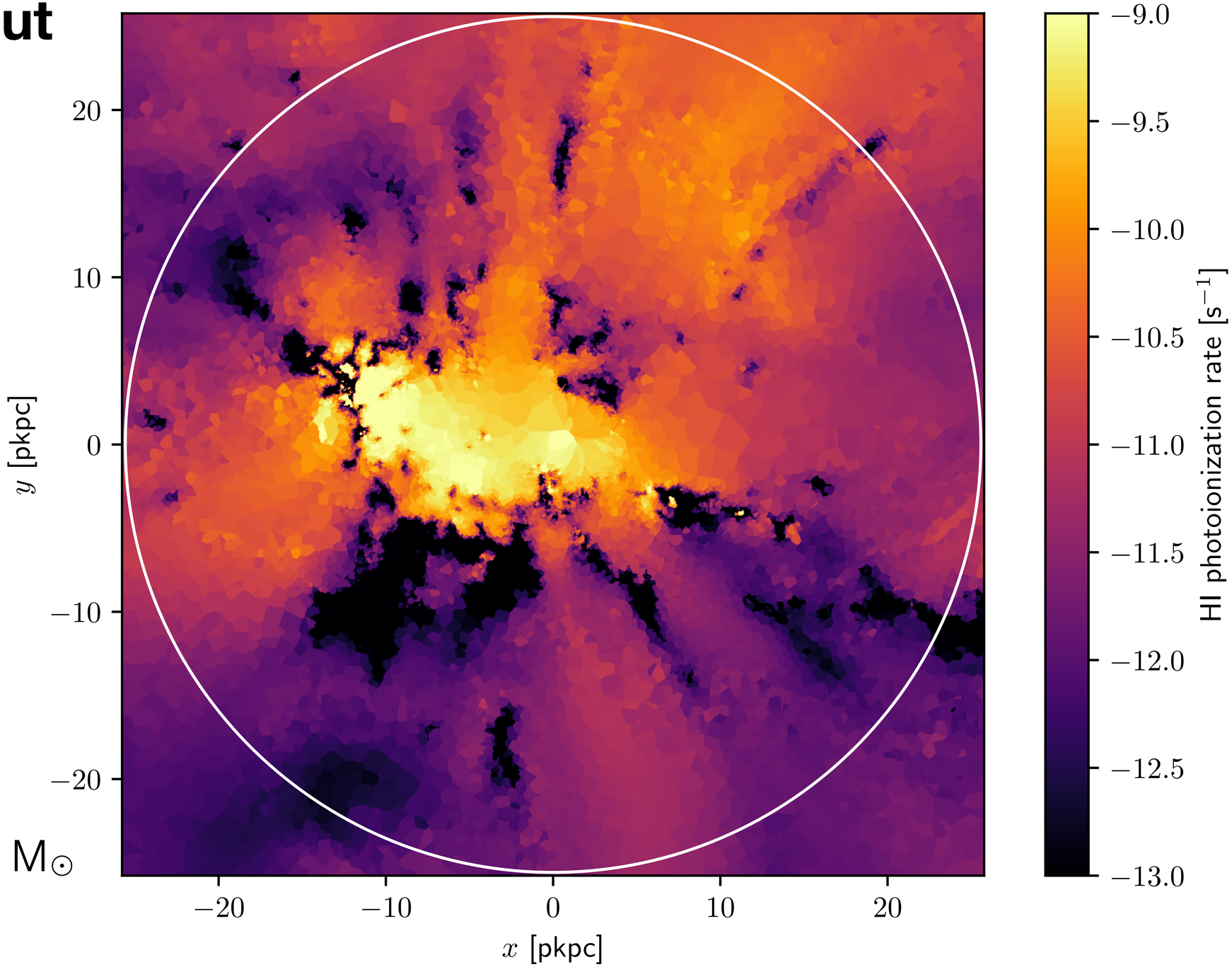
Feedback breaking out

radiation field
($\mathbf{\Gamma}_{\mathrm{HI}}$)

slice

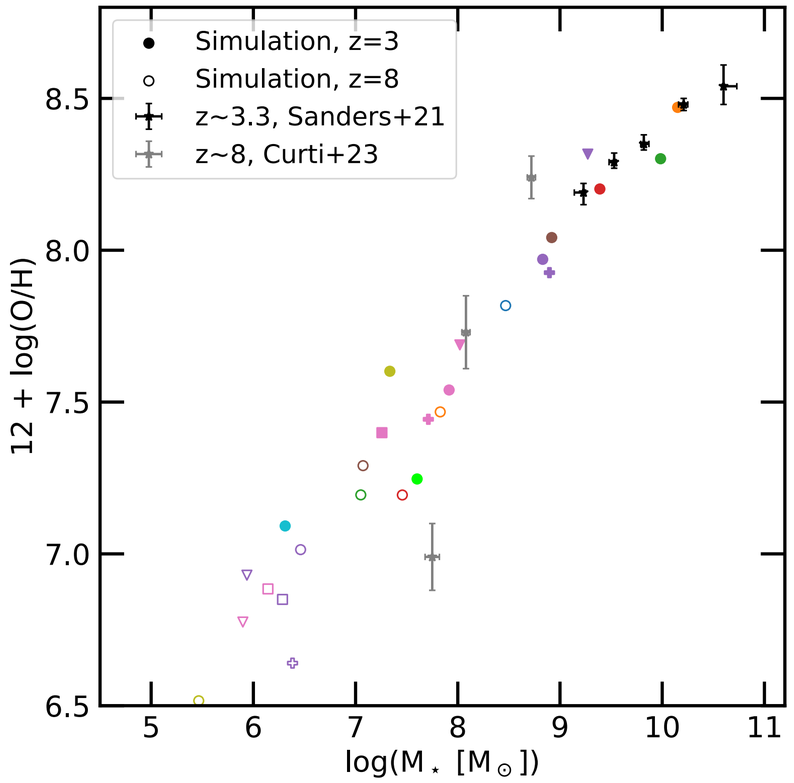
$M_{200c} = 2 \times 10^{11}\, M_\odot$

$z = 6.15$

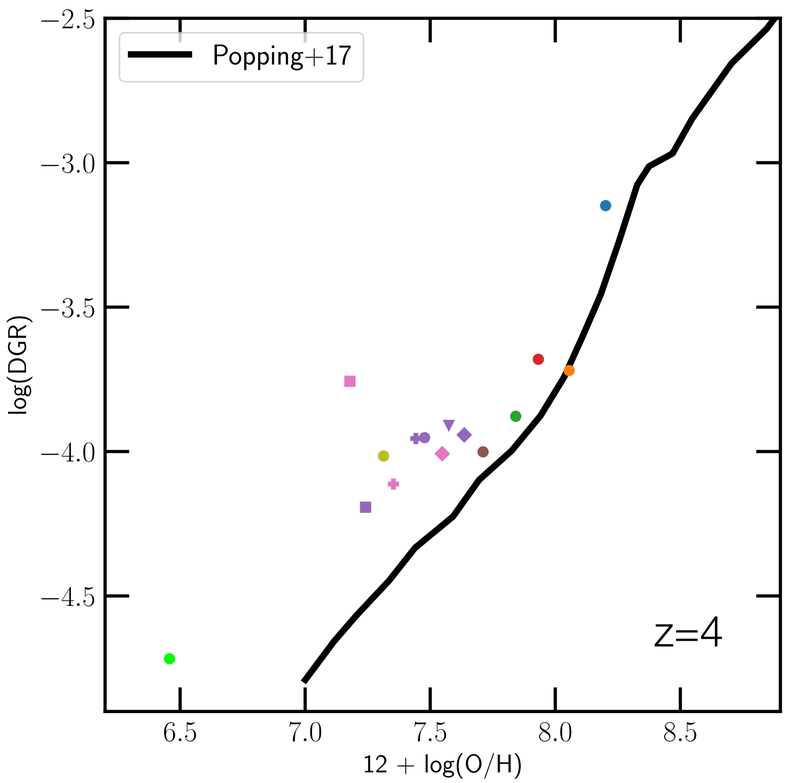


Metals and Dust

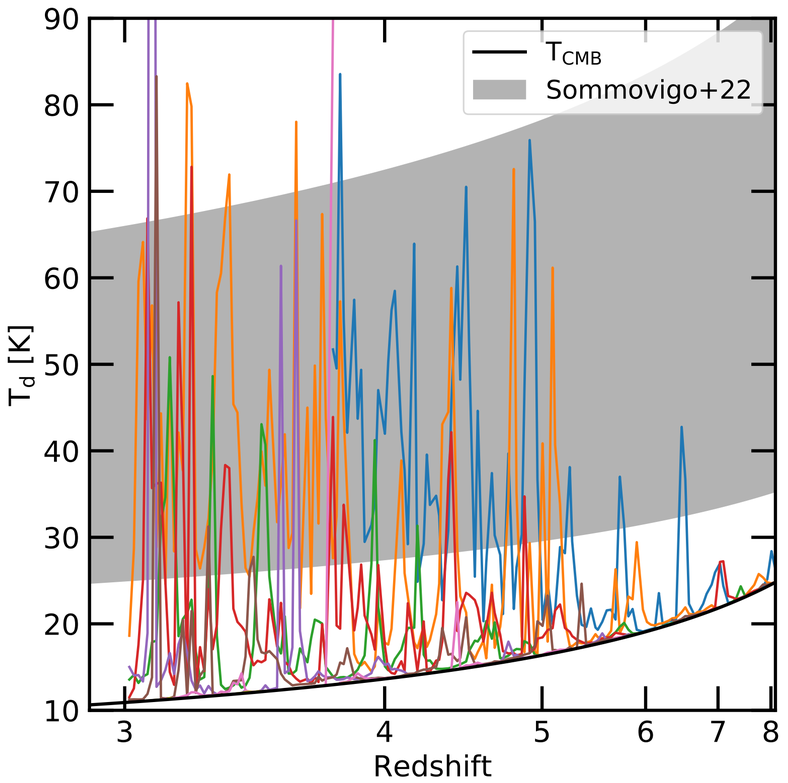
stellar mass-gas metallicity



dust to gas ratio



dust temperature



Summary

- **New Zoomed-Initial Conditions code** (compatible with N-GenIC/Gadget-4 -> TNG, MTNG, Thesan; arbitrarily shaped high-resolution regions; easy to modify; ***public release planned***)

- **New set of zoom simulations of Thesan objects with more detailed physics** (RHD, low-temperature cooling, cold/hot phases, local feedback, dust modelling)

- **preliminary results**: reasonable stellar mass-halo mass relations; bursty LyC escape (e.g. when feedback clears channels); metallicities, dust-to-gas ratios and dust temperatures in broad agreement with data **-> *stay tuned for more!***

video by Josh Borrow