EARLY CHEMICAL ENRICHMENT AND FORMATION OF THE SMALLEST DWARF GALAXIES

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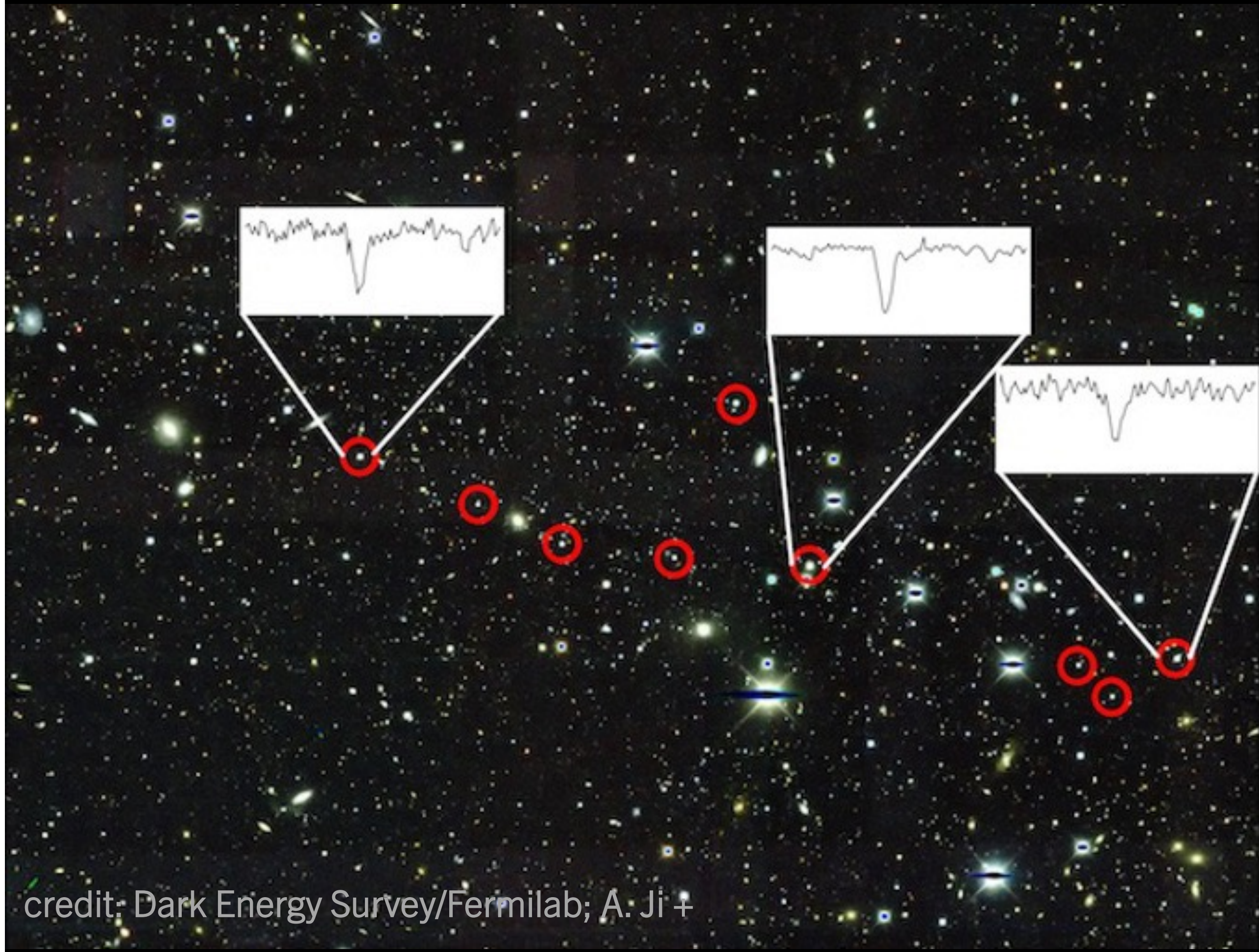
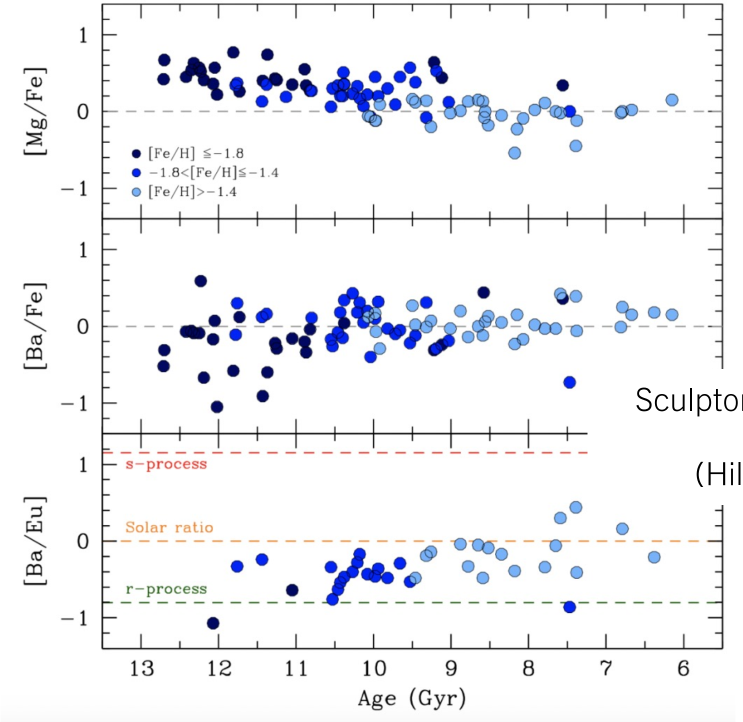
RELICS OF THE FIRST GALAXIES

dozens of small, faint dwarf galaxies around us today are leftover remnants from the era of the first galaxies

Reticulum II, a tiny dwarf galaxy orbiting the Milky Way



Stellar chemical abundances of old stars in these galaxies contain information about early galaxy formation and chemical enrichment



Sculptor age-abundance relations
(Hill et al. 2019)

stellar chemical abundances are a promising method to identify and study stars from ancient dwarf galaxies

(e.g., Brauer et al. 2019, 2022, Ji et al. 2019)

but current simulations can’t explain the scatter and star-by-star distributions of observed chemical abundances

-> we need simulations with more detailed stellar chemical abundances

AEOS SIMULATIONS

Aeos, one of the horses that pulls the Sun god across the sky

- Detailed treatment of stellar yields and metal mixing with 20 metal tracer fields
- Stellar feedback & metal enrichment from individual stars
- Focus on the smallest early galaxies that survive to present day

AEOS SIMULATIONS

Running with modified version of Enzo

(Bryan et al., 2014; Brummel-Smith et al., 2019)

Fiducial cosmological simulation:

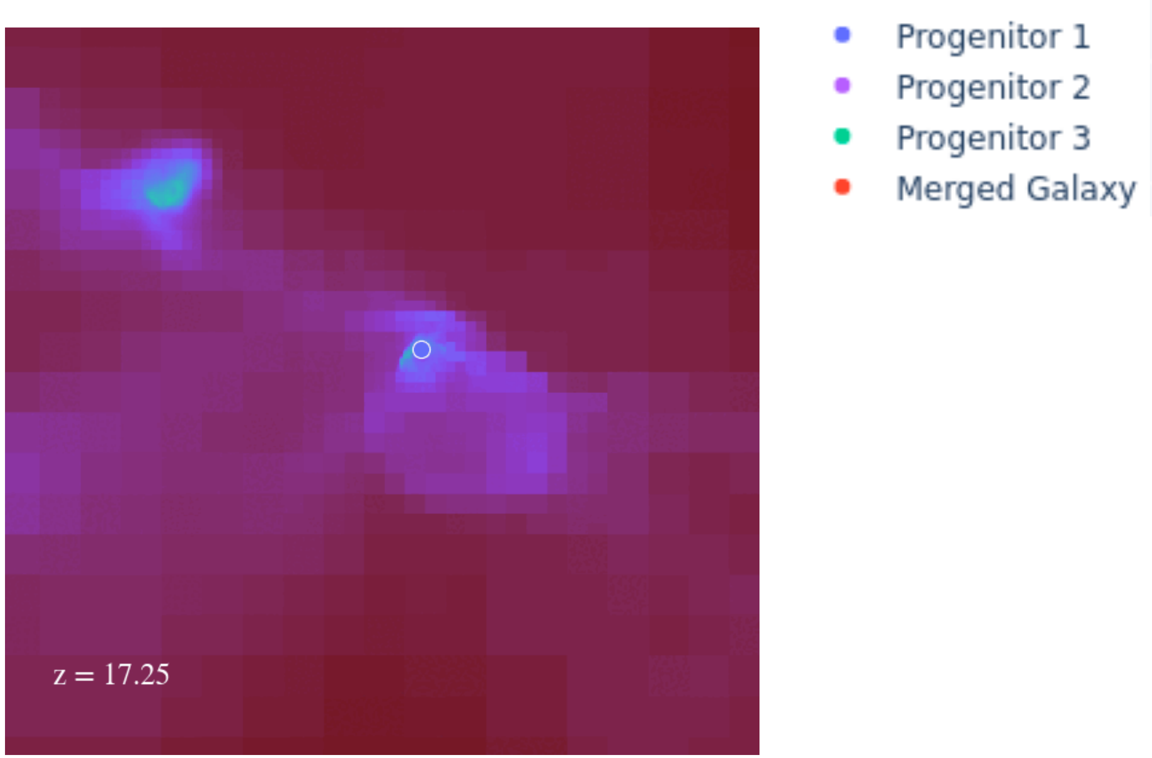
1 Mpc box,
gas resolution up to 1 pc,
individual particle for every star >2 $M_\odot$,
Pop III stars & enrichment,
redshift = 130 to 14
(zooms will run to redshift 6),
~200 star forming halos

Tracing 10 Metals:

C (CCSNe, AGB winds), N (AGB winds), O (CCSNe), Na (CCSNe), Mg (CCSNe), Ca (CCSNe), Mn (Type Ia), Fe (CCSNe, Type Ia), Sr (AGB winds), & Ba (AGB winds)
+ additional metal tracer fields including an r-process field

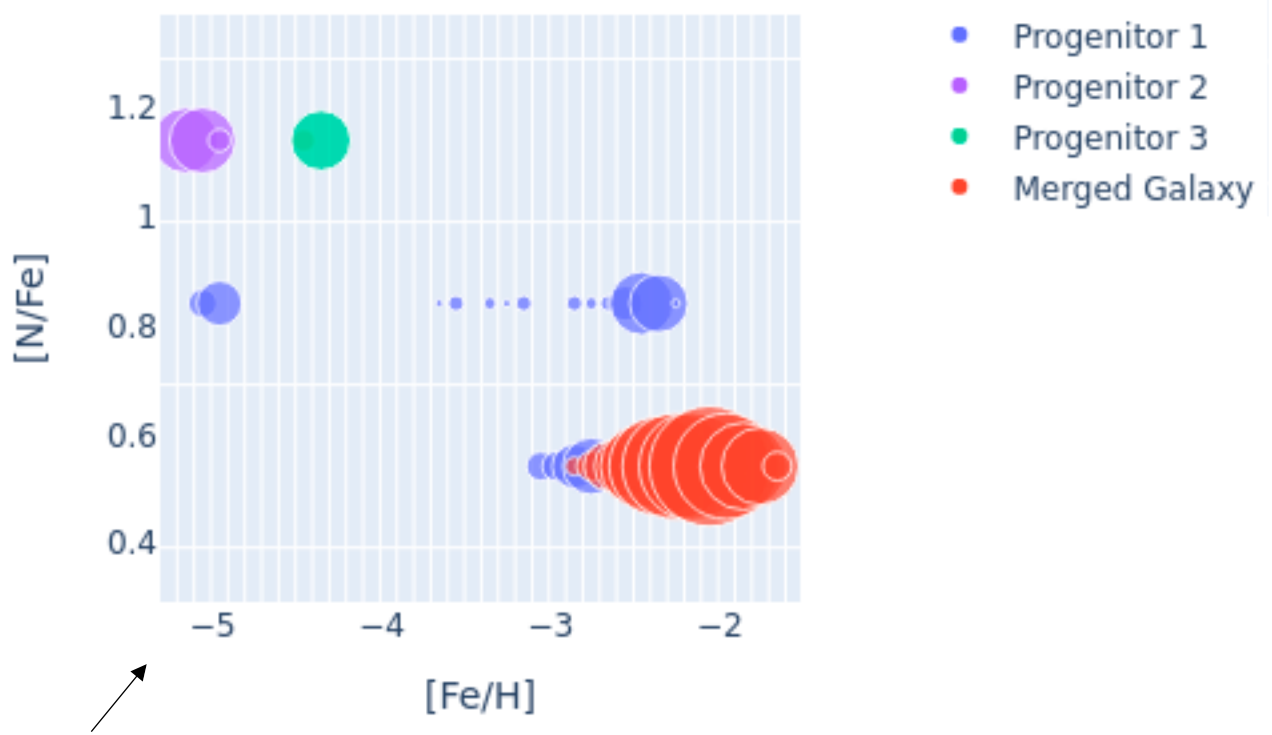
20 total metal fields for each star particle and gas cell

The chemical abundances of the stars in the simulation trace their origins



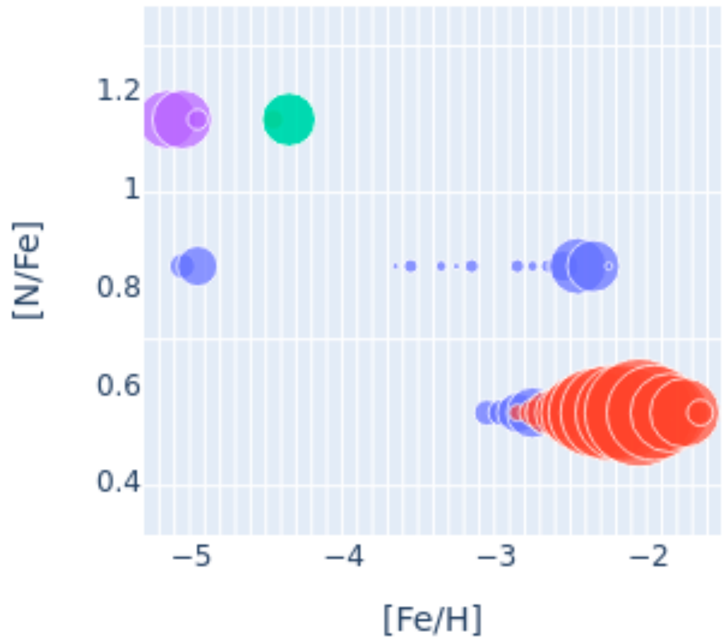
gas projection showing a merger of three systems at z~15

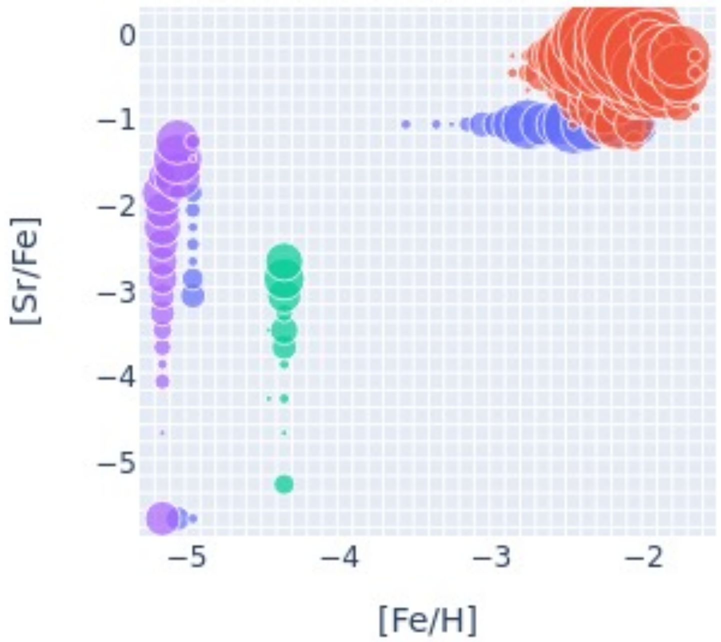
The chemical abundances of the stars in the simulation trace their origins

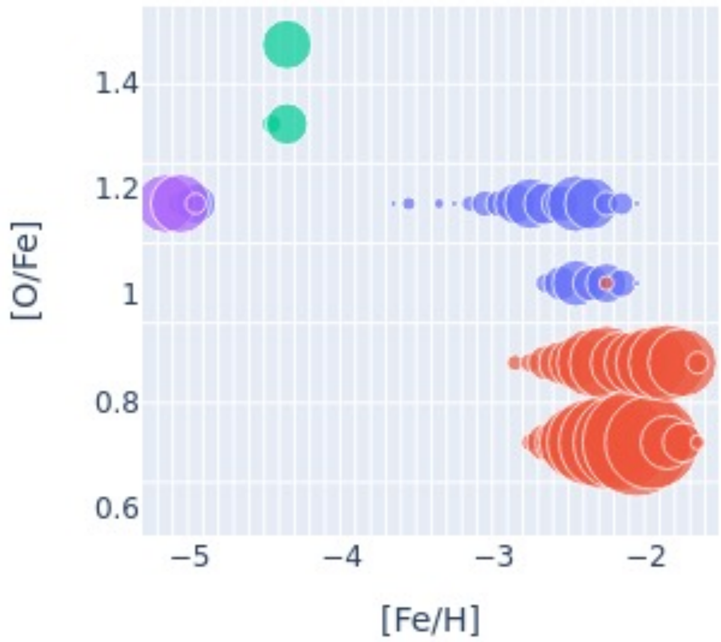


(binned according to expected observational uncertainties)

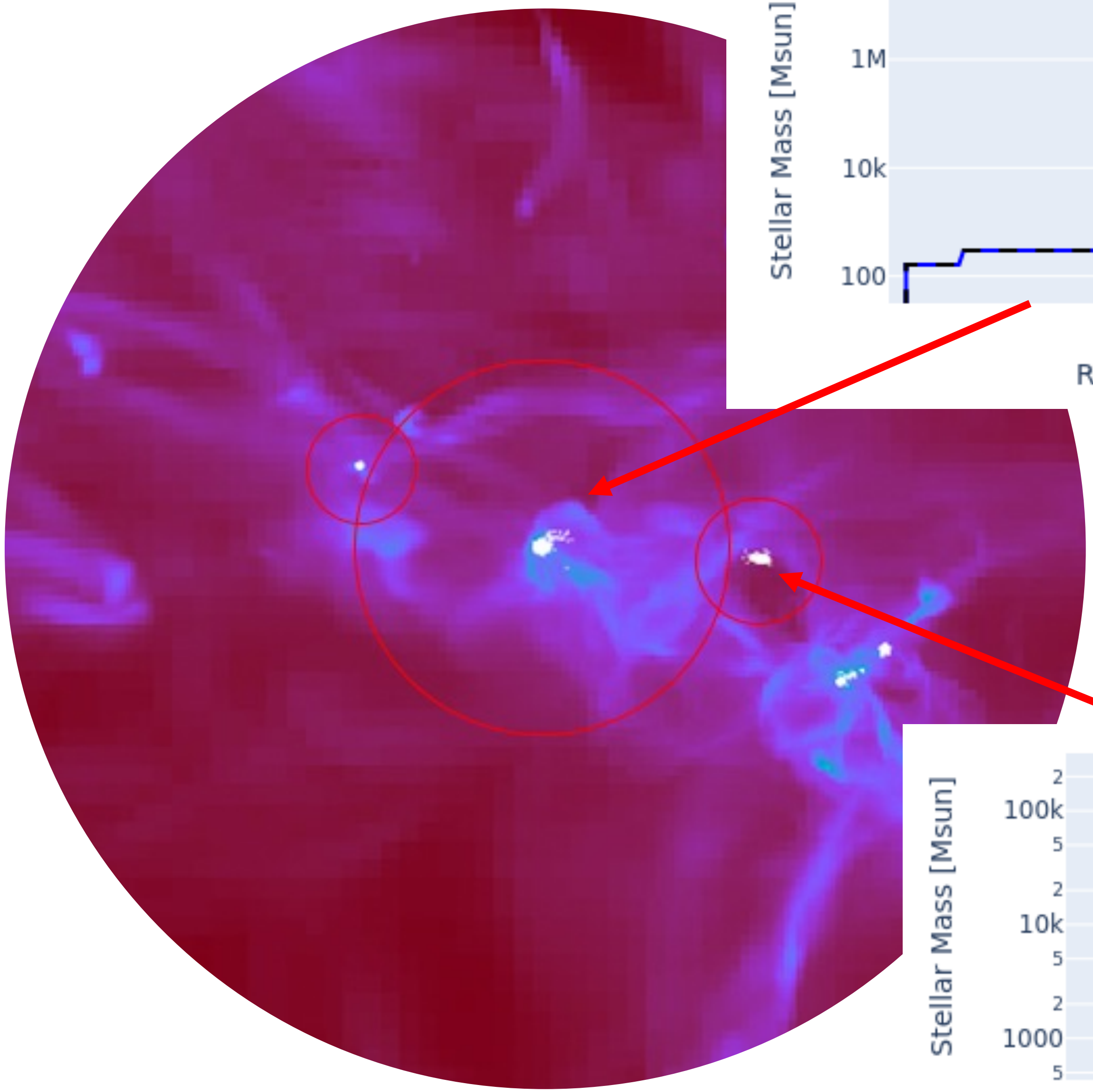
The chemical abundances of the stars in the simulation trace their origins

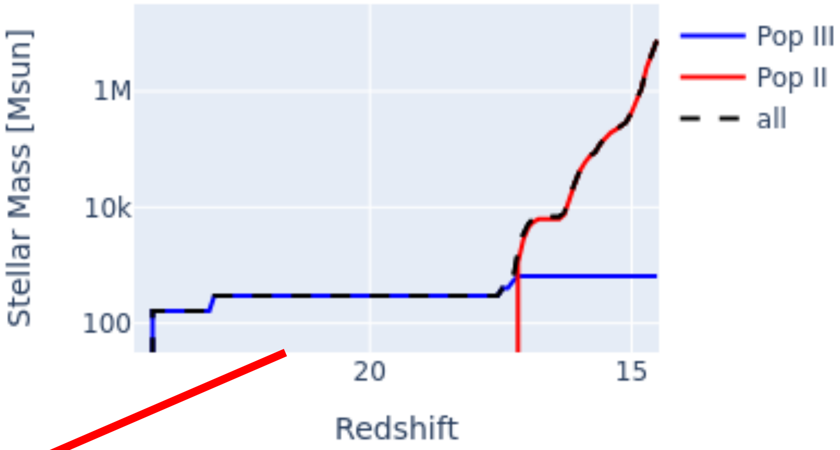




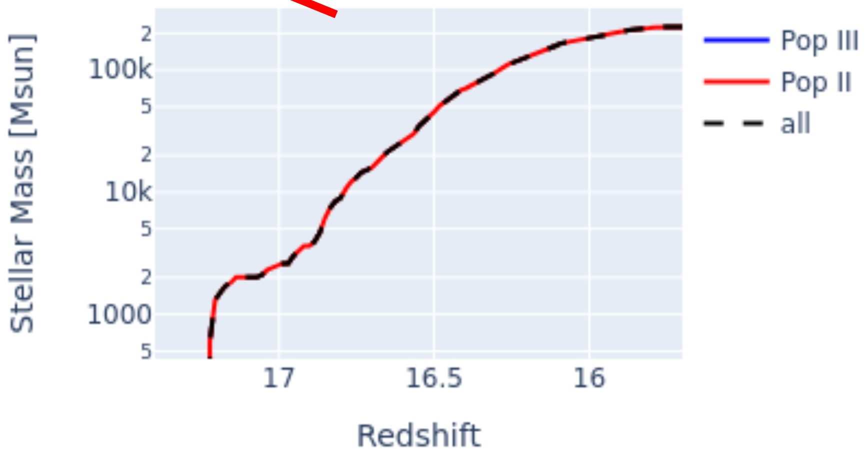


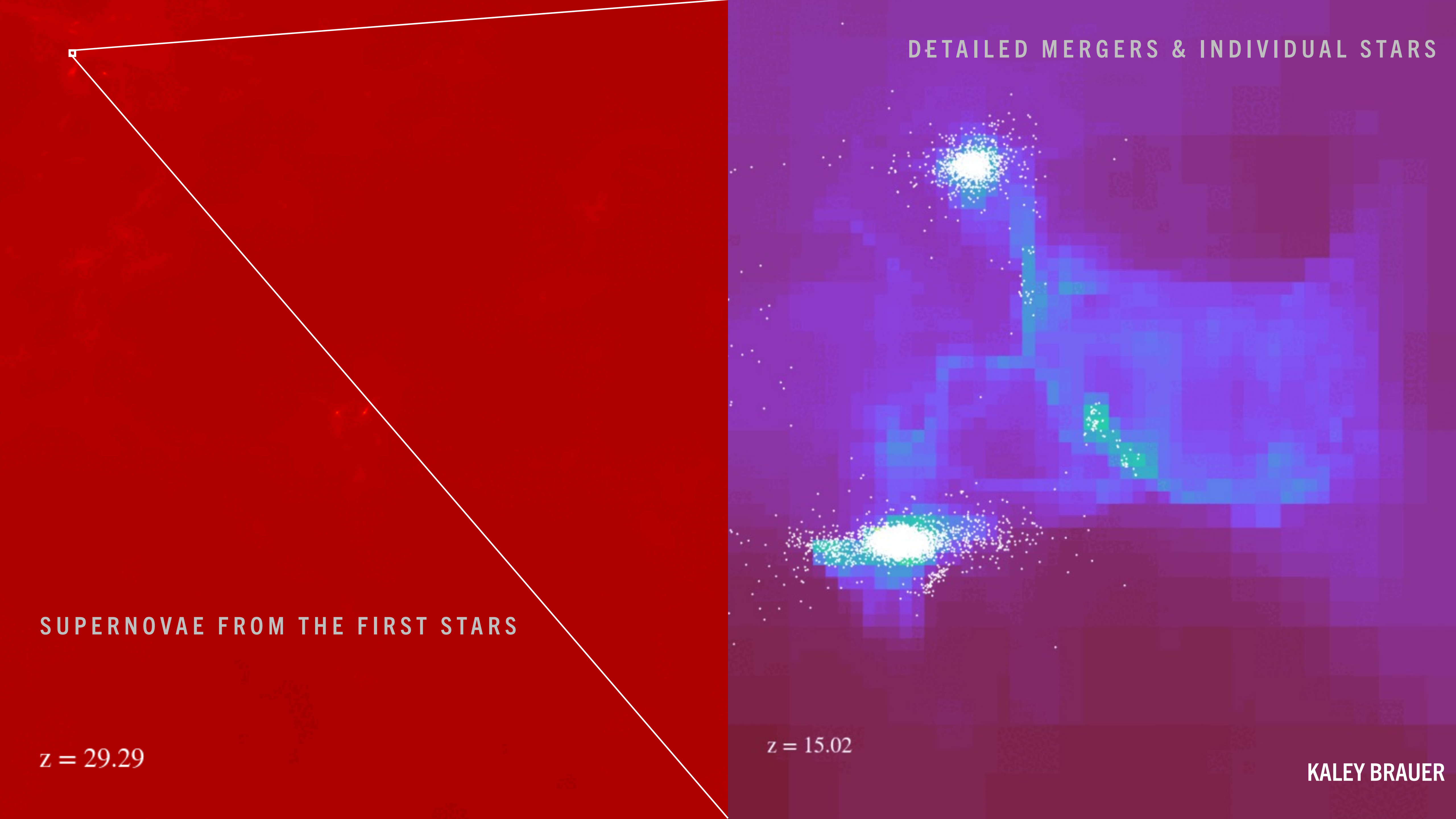
ternal enrichment





Two halos near a larger, more evolved halo were externally enriched in metals and began their star formation with Pop II




SUPERNOVAE FROM THE FIRST STARS
z = 29.29
DETAILED MERGERS & INDIVIDUAL STARS
z = 15.02
KALEY BRAUER

CONCLUSIONS

- Motivated by understanding the chemical abundances in ultra-faint dwarfs, we are developing star-by-star early dwarf galaxy cosmological simulations – the Aeos simulations
- Tracing 10 metals + 10 additional metal tracer fields; Pop III enrichment; metal mixing
- Current box is only early Universe (redshift 14), suite of zooms running until reionization (redshift 6)
- Seeing how chemical abundances trace the origins of stars, seeing external enrichment, and more!

Next immediate plans for the Aeos simulations:

- run zooms on ultra-faint dwarf galaxies (EDGE initial conditions & compare results?)
- quantify how much scatter is from galaxy formation processes vs. stochastic yields
- quantify metal mixing in ISM at high redshift - smoothing lengths/times for different metals from different sources
- identify signatures associated with stars that formed from Pop III enrichment