Circumgalactic Medium Overview

methods of studying it and building a theoretical framework

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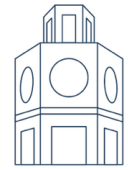
26.04.2021

Special Thanks

This work is largely motivated by
Fundamentals of Gaseous Halos
(Jan 11 - Mar 5)

Program webpage:
`www.kitp.ucsb.edu/activities/halo21`
YouTube channel:
`www.youtube.com/channel/UCuhlCSTp0KUB-_q0qlde75g`



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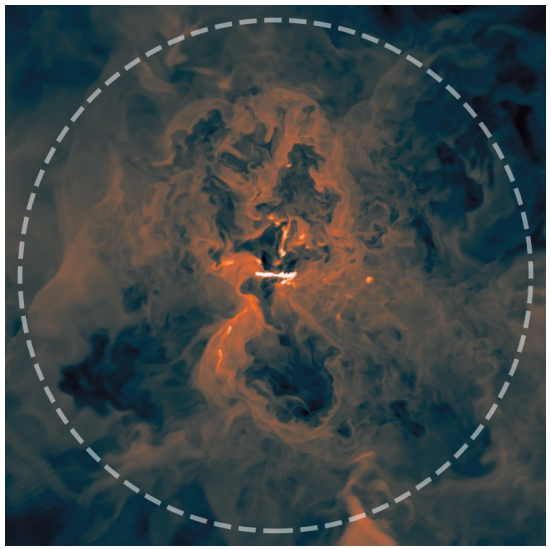


Content

1. Definition and difference
2. Multiphase nature
3. Gas flow
4. Observations

Figure: NASA, ESA, J. DePasquale and E. Wheatley (STScI) and Z. Levay

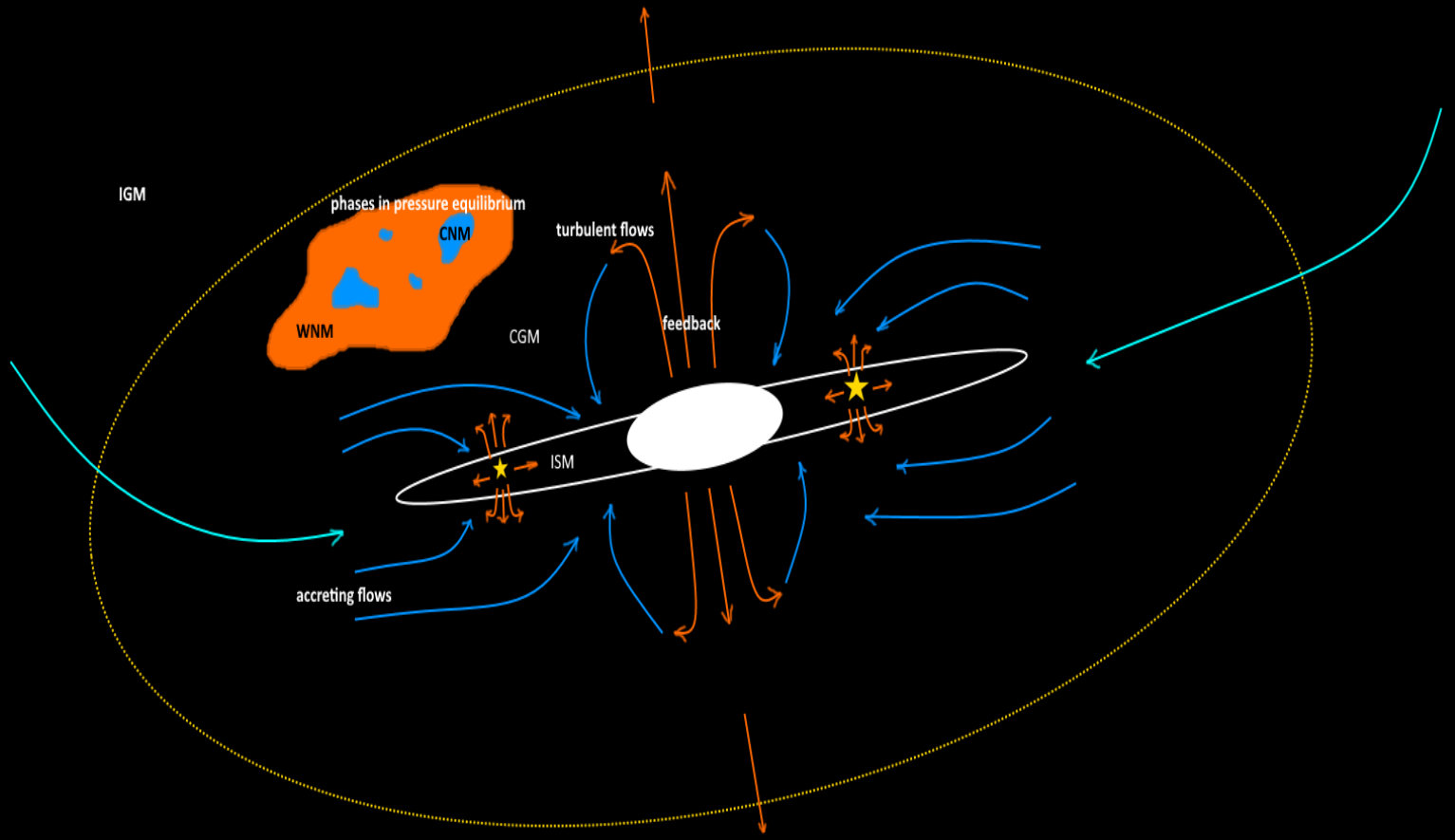
What's a CGM?

Circumgalactic medium (halo) – ionized gas that surrounds a galaxy, between ISM and inside virial radius.
Mainly consists of:

- Feedback flows
- Accreting flows
- Multiphase clouds

CGM is created by accretion of IGM and by internal processes: active galactic nuclei outflows, supernovae winds.

Figure: NASA, ESA and the Hubble Heritage Team (STScI/AURA)


IGM
phases in pressure equilibrium
CNM
WNM
turbulent flows
feedback
CGM
ISM
accreting flows

Comparison with ISM

Similarities:

- hot volume-filling phase and dense cold phase
- cold-warm phases coexist at thermal or pressure balance
- both have compressible and scale-dependent anisotropic turbulence

Differences:

CGM	ICM
warm gas $> 10^6$ K	WNM $> 10^4$ K
cool gas $< 10^4$ K	CNM $< 10^2$ K
no start formation	frequent start formation
$\frac{t_{cool}}{t_{freefall}} \approx 10$	$\frac{t_{cool}}{t_{freefall}} = 1$
WG n $< 10^{-3}$ cm^{-3}	WNM n $< 10^{-1}$ cm^{-3}
CG n $> 10^{-1}$ cm^{-3}	CNM n $> 10^0$ cm^{-3}

Different turbulence sources

CGM metallicities are lower than the galaxy ISM metallicities

Comparison with IGM

Similarities:
temperature distribution

Differences:

CGM	IGM
Higher in metallicity	Mostly ionized hydrogen?
$n \approx 10^{-3}$ cm^{-3}	$n \approx 10^{-6}$ cm^{-3}
multi-phase, multi-layer	homogeneous?

Different heating sources

Multiphase nature

Greatly determined by the temperature of the halo regions.
Depends on all kinds of time scales ratio with gas cooling time ($t_{cc}, t_{ff}, t_{comp}, t_{rps}$).

Each phase cloud can be described by:

- Number density
- Metallicity
- Temperature
- Turbulent parameter
- Relative size

Multiphase nature

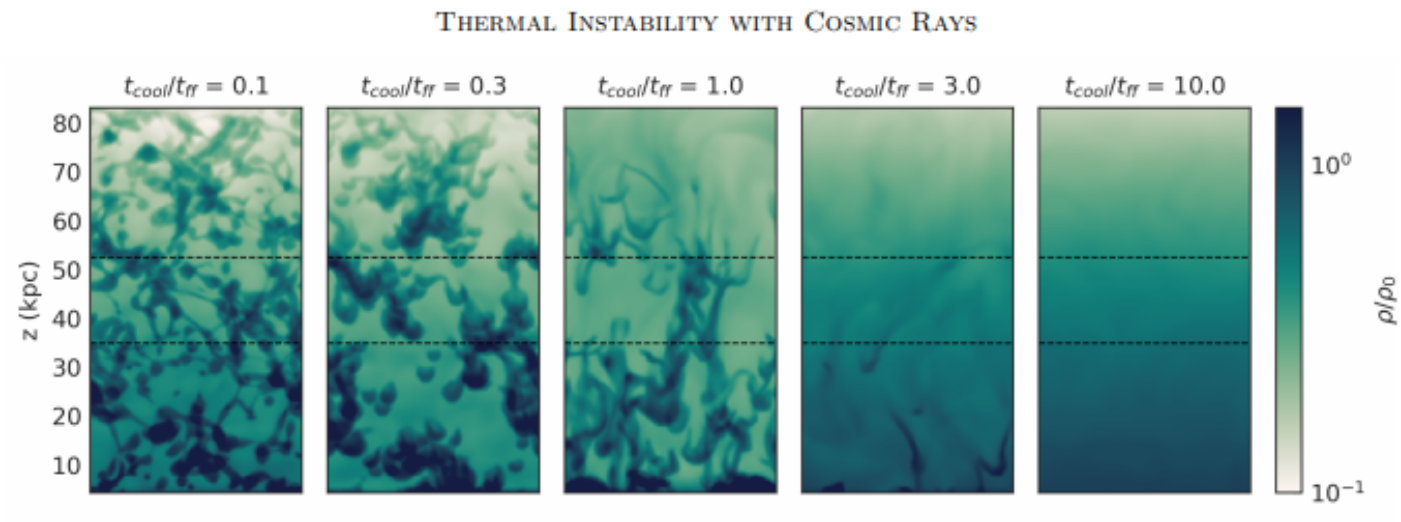


Figure: Projections of the gas density for different initial values of t_{cool}/t_{ff}

(Iryna S. Butsky et al 2020 ApJ 903 77)
`https://www.irynabutsky.me/movies`

Multiphase nature

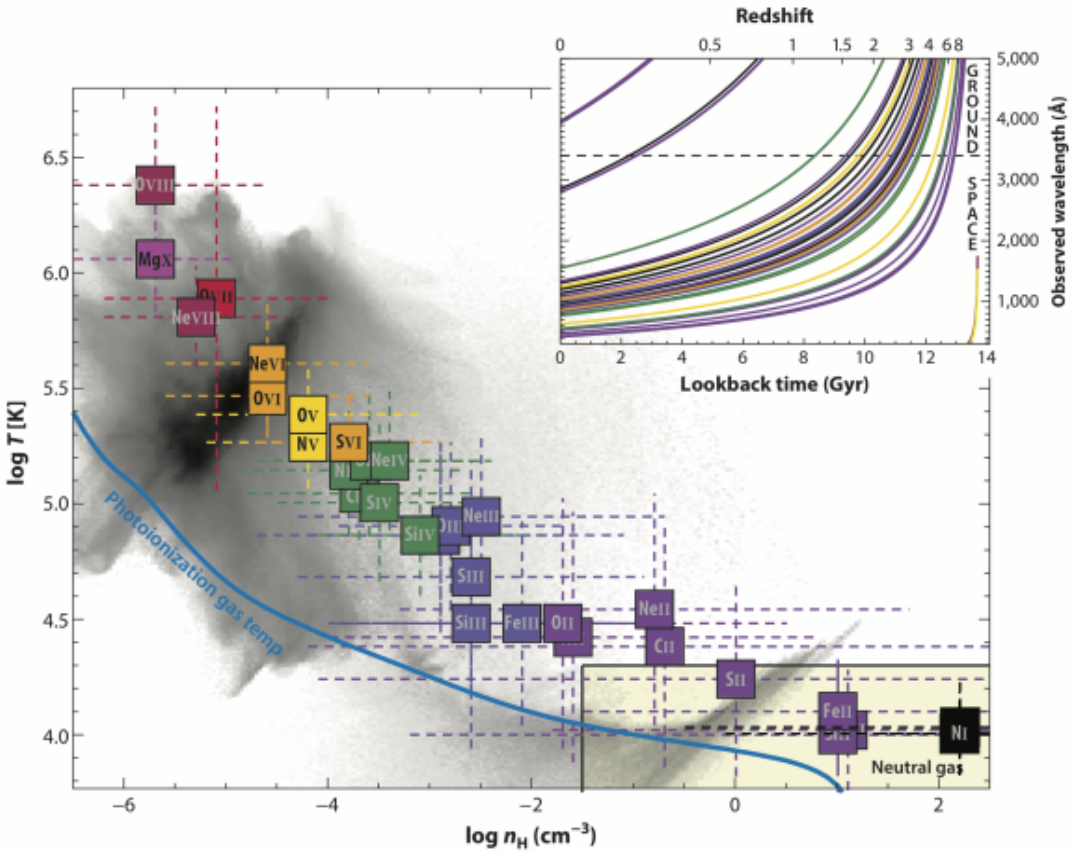
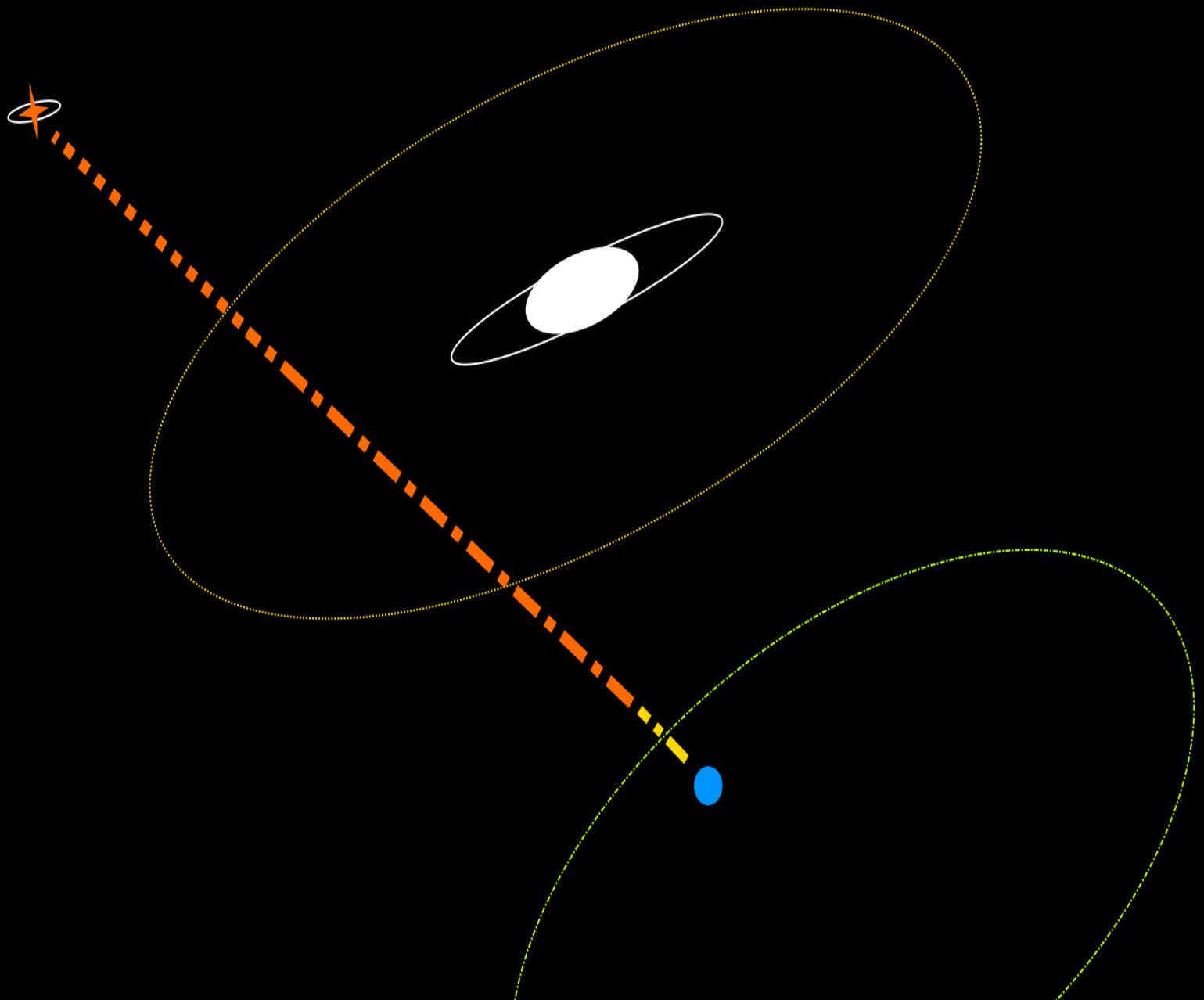


Figure: Metal absorption lines (ions) of the CGM from Mg I to O VIII having $19 < \lambda_{rest} < 6000\text{Å}$ shown on a phase (T-n_H) diagram within R_{vir} of the z = 0 EAGLE simulation shown in Figure 2.

Jason Tumlinson, Molly S. Peeples, Jessica K. Werk Annual Review of Astronomy and Astrophysics 2017 Vol. 55:389-432



Observations

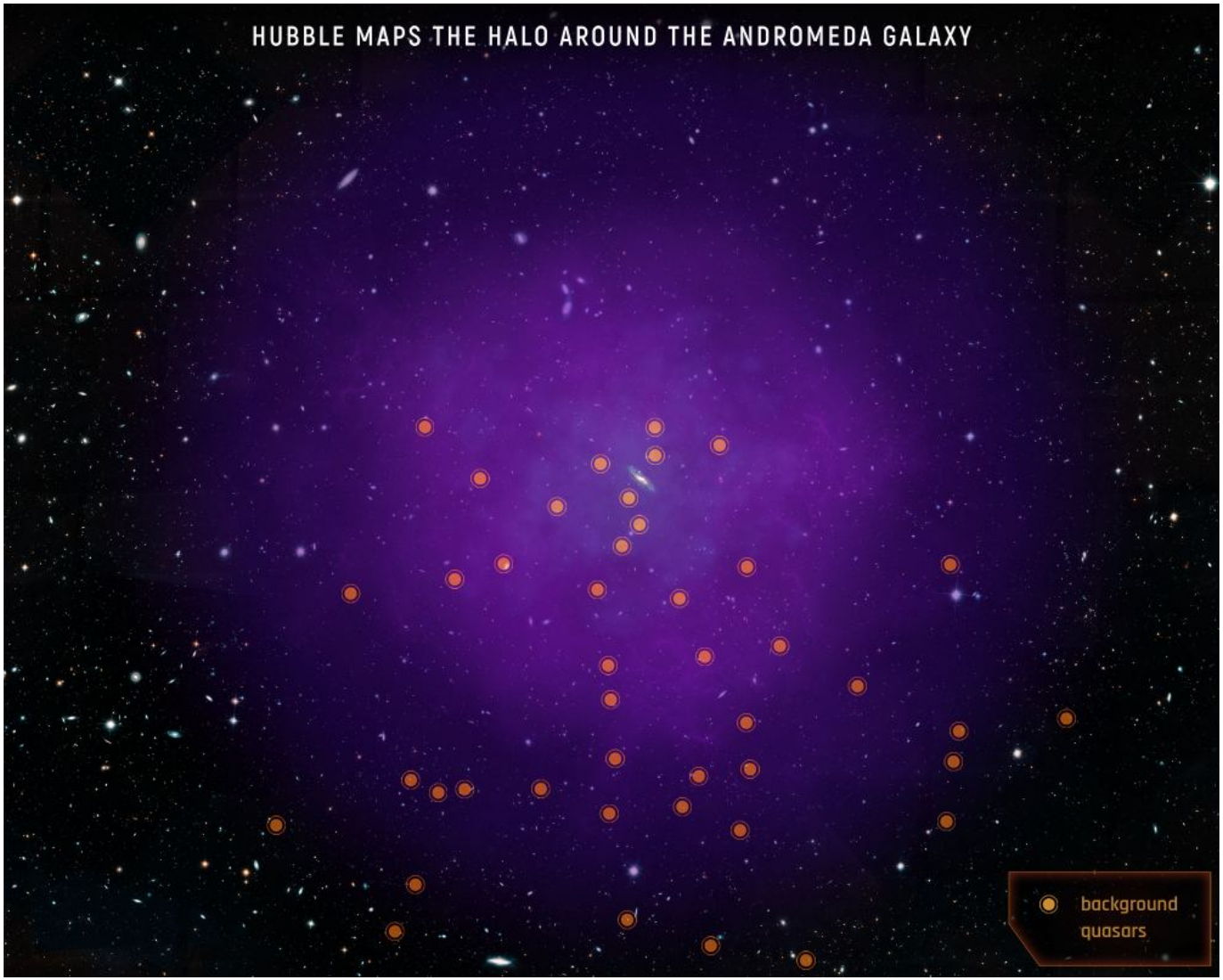
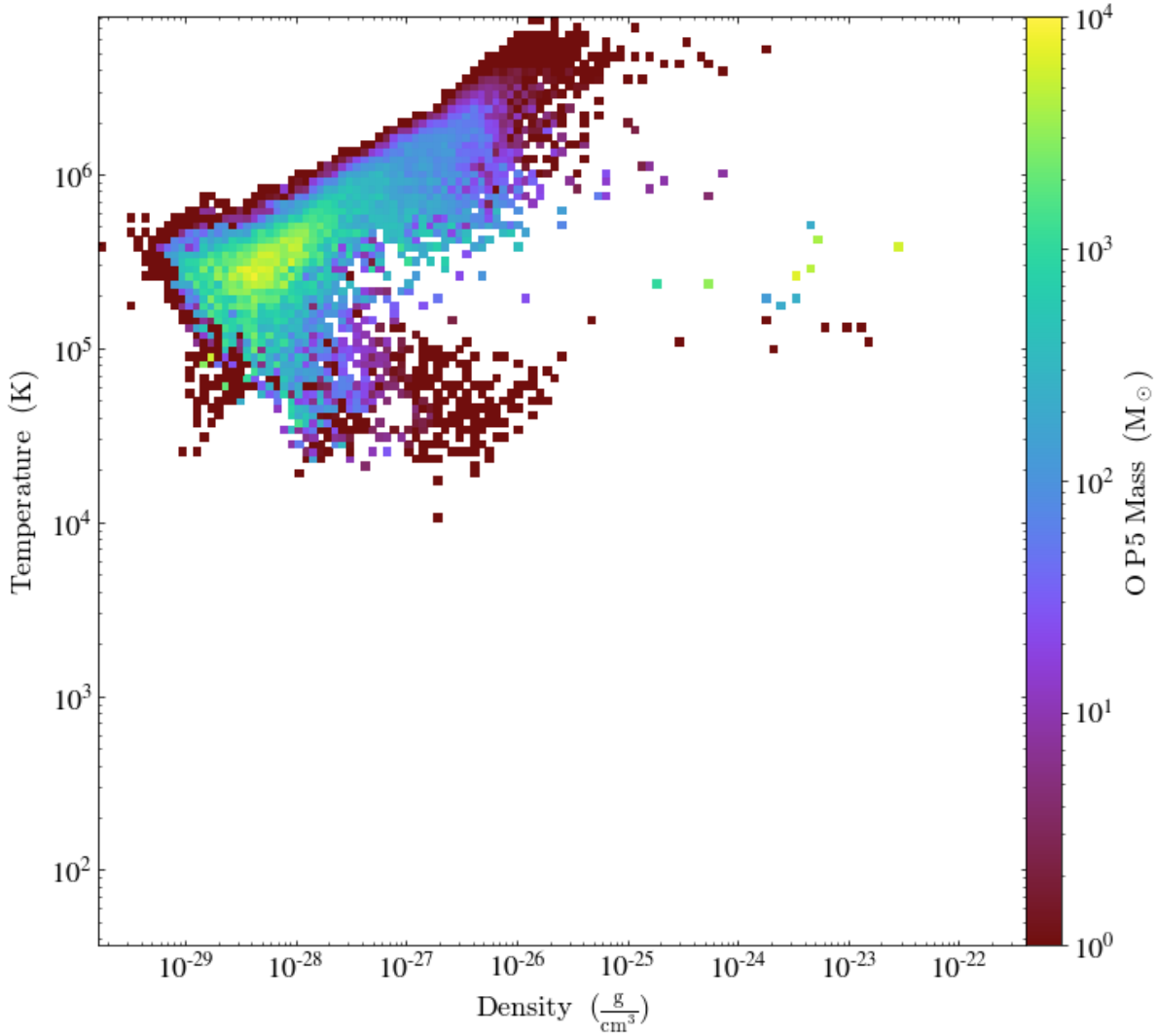
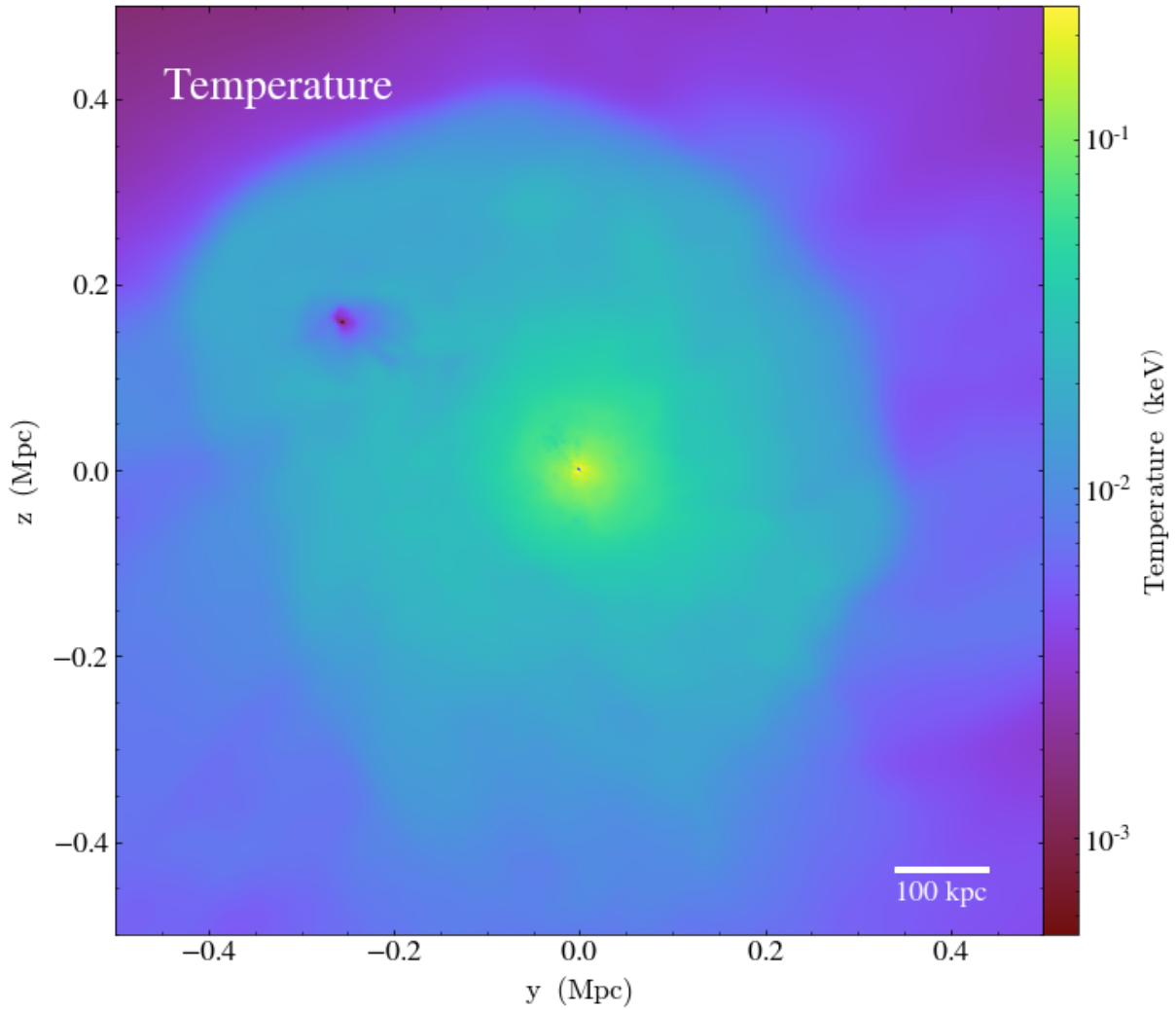


Figure: NASA, ESA, and E. Wheatley (STScI)

Simulations!



Simulations!



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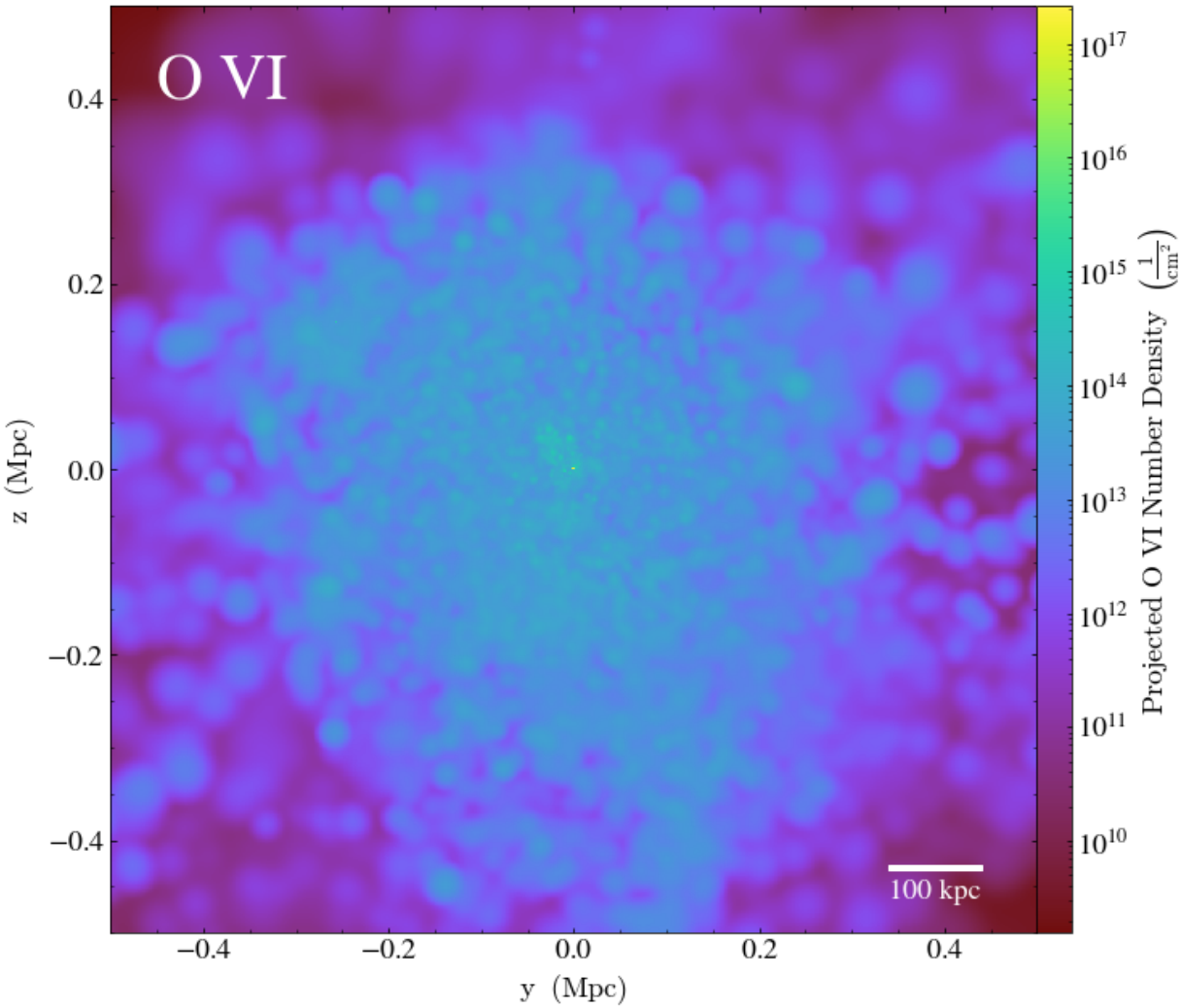
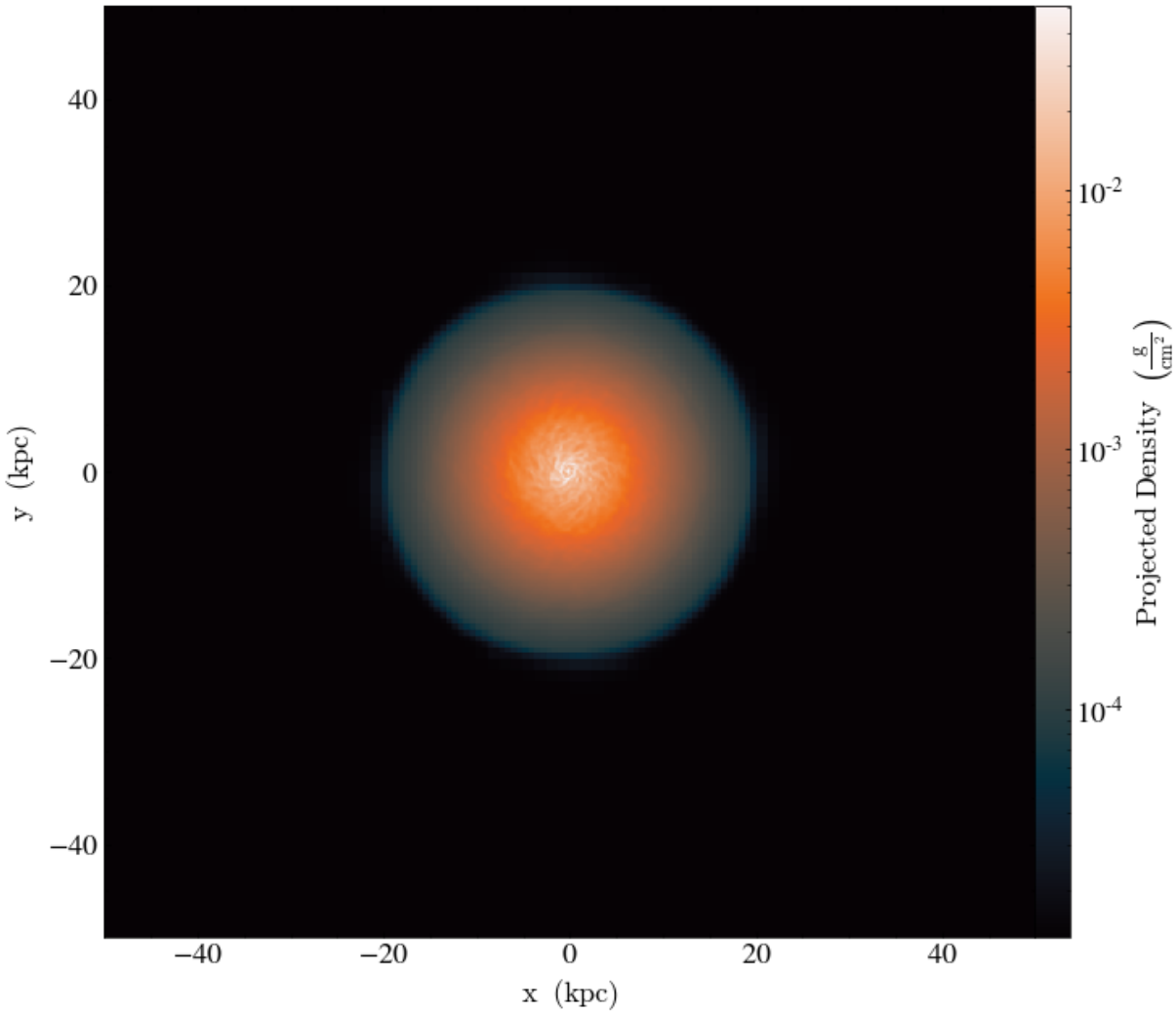


Simulations!



Frame Title

YT-project:
`https://yt-project.org/`
Trident:
`http://trident-project.org/`