Metallicity Break Radii in Illustris TNG Galaxies

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Video Credit: TNG Collaboration

Large Scale Structure

Dark Matter only simulation

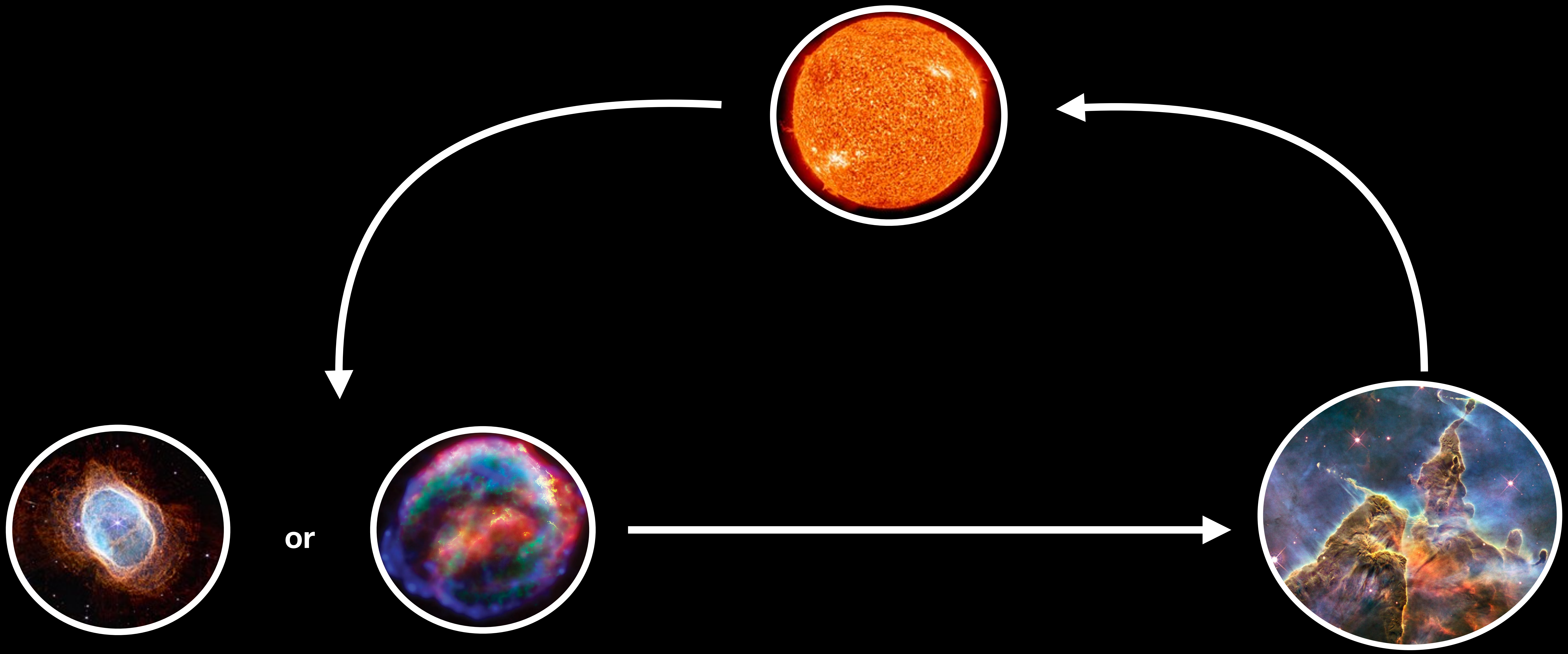
- Overproduce massive galaxies
- Baryons must be regulating galaxy mass… how?

Video Credit: TNG Collaboration

Image Credits: NASA Hubble, NASA JWST, NASA SDO

Baryons

What are they doing on small scales?



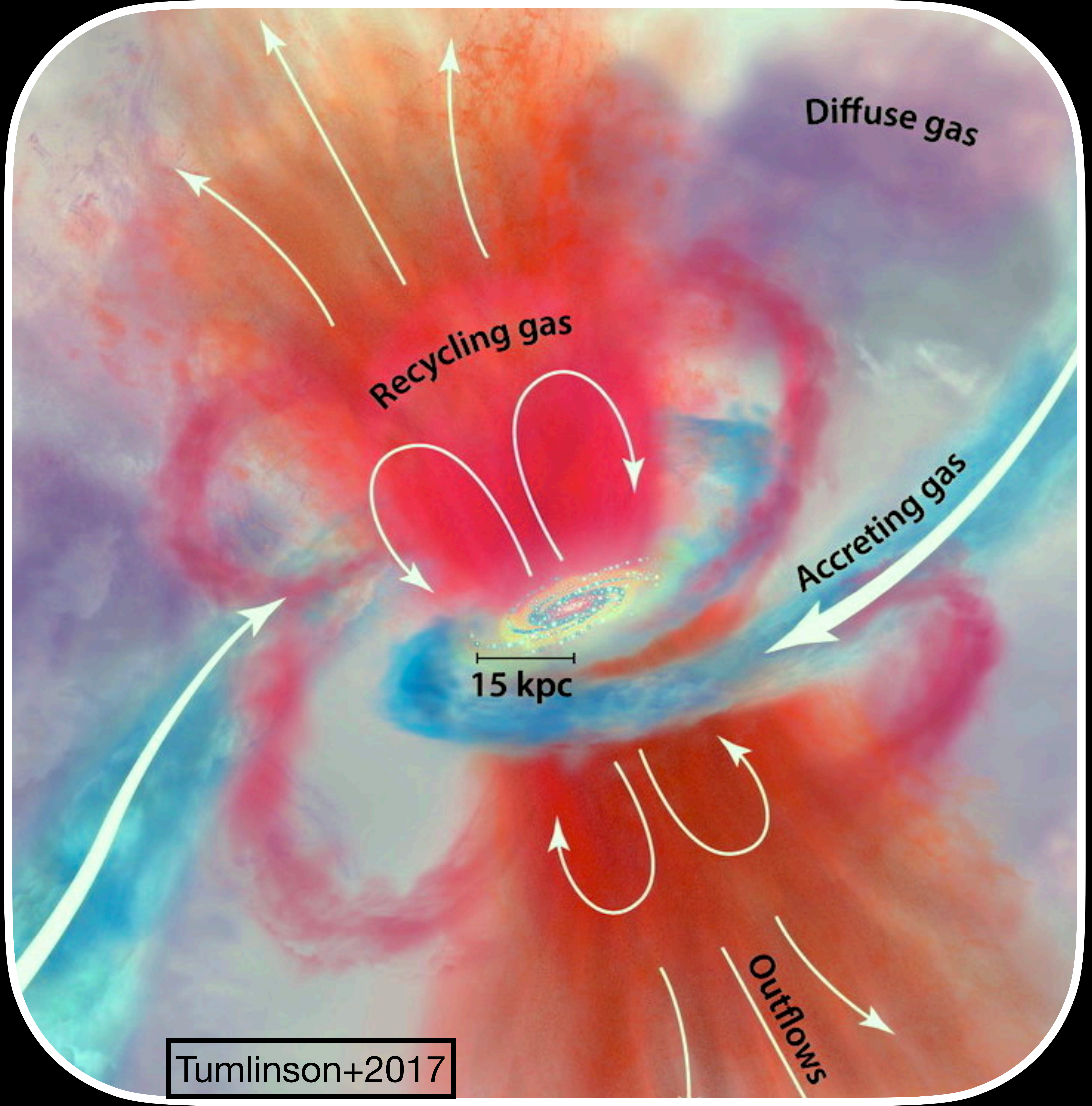
Baryon Cycle

Large Scales

- Distributing materials throughout the galaxy

- Material ejected from disk

- In-falling, metal-poor gas



Studying the baryon cycle is studying metals

What is the relationship between galaxies and their metal contents?

Stars and Gas

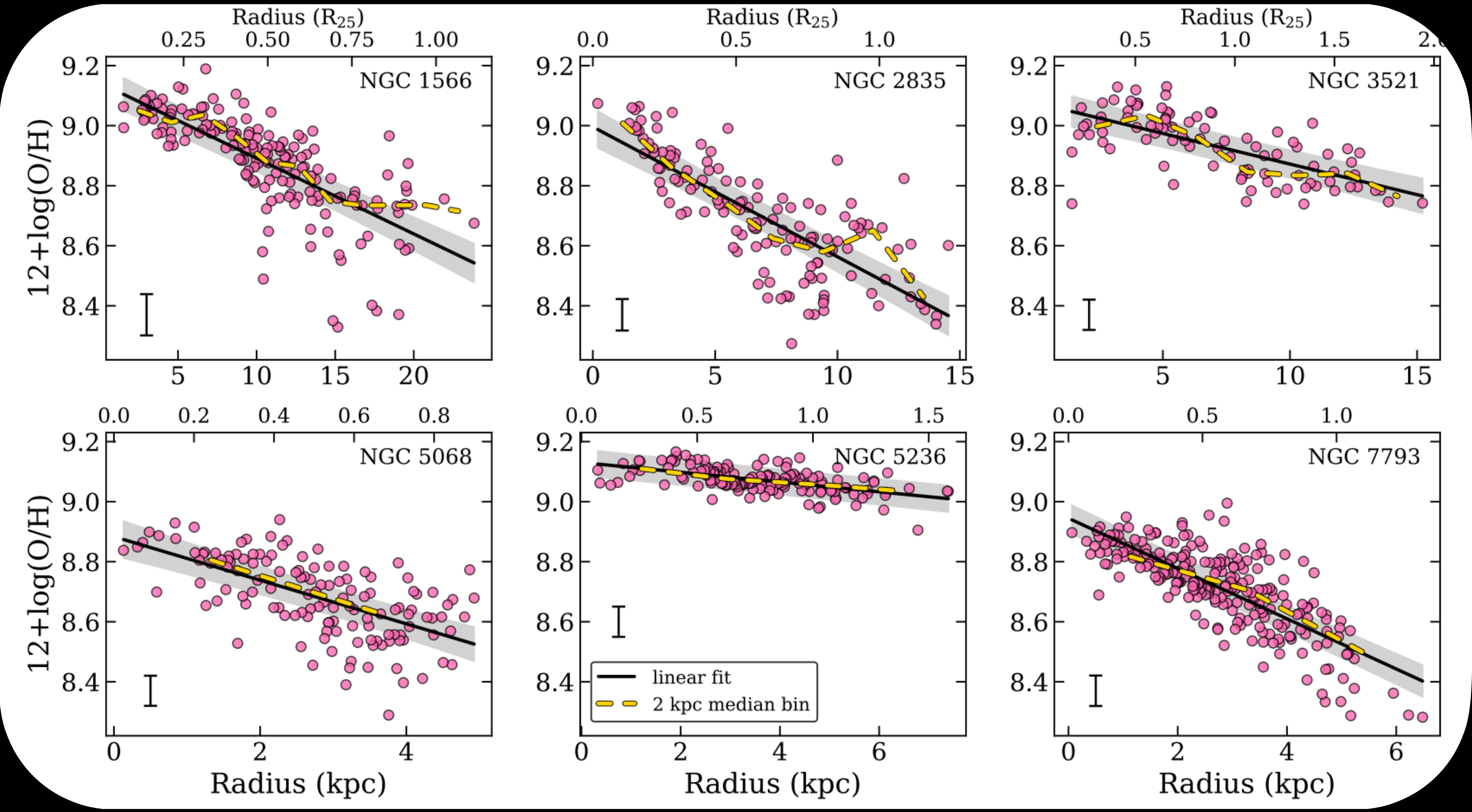
- What the cloud was made of at time of formation

- What the cloud is made of “right now”

Metallicity Profiles

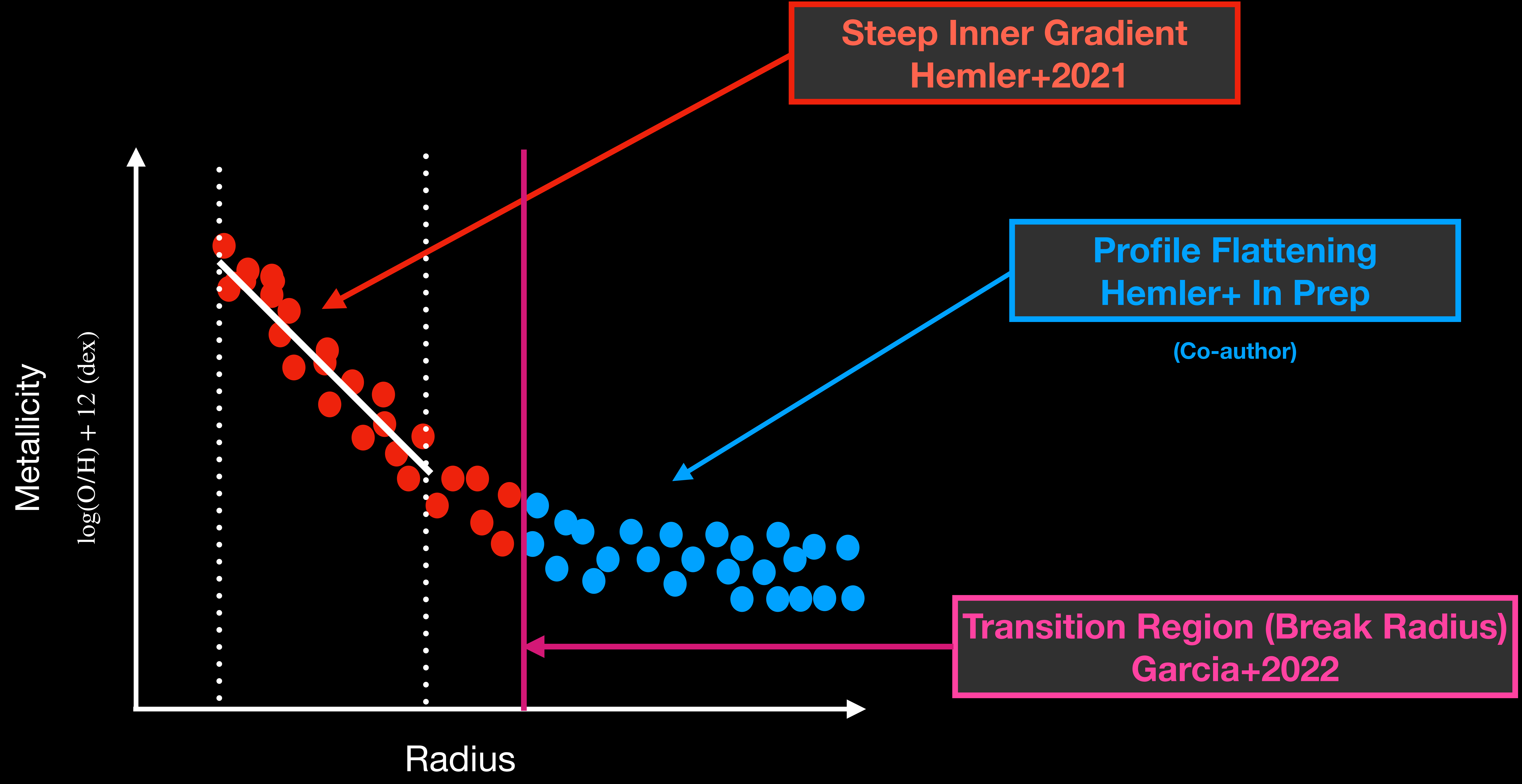
$\log(O/H) + 12$

- Predominantly negative gradients
- Inside-out galaxy growth
- Extended profiles limited by emission diagnostics
  - Dense, star-forming regions of galaxies



Grasha+2022

Our group — individual profiles in simulations



Illustris TNG

Video Credit: TNG Collaboration

What galaxies are we going to look at?

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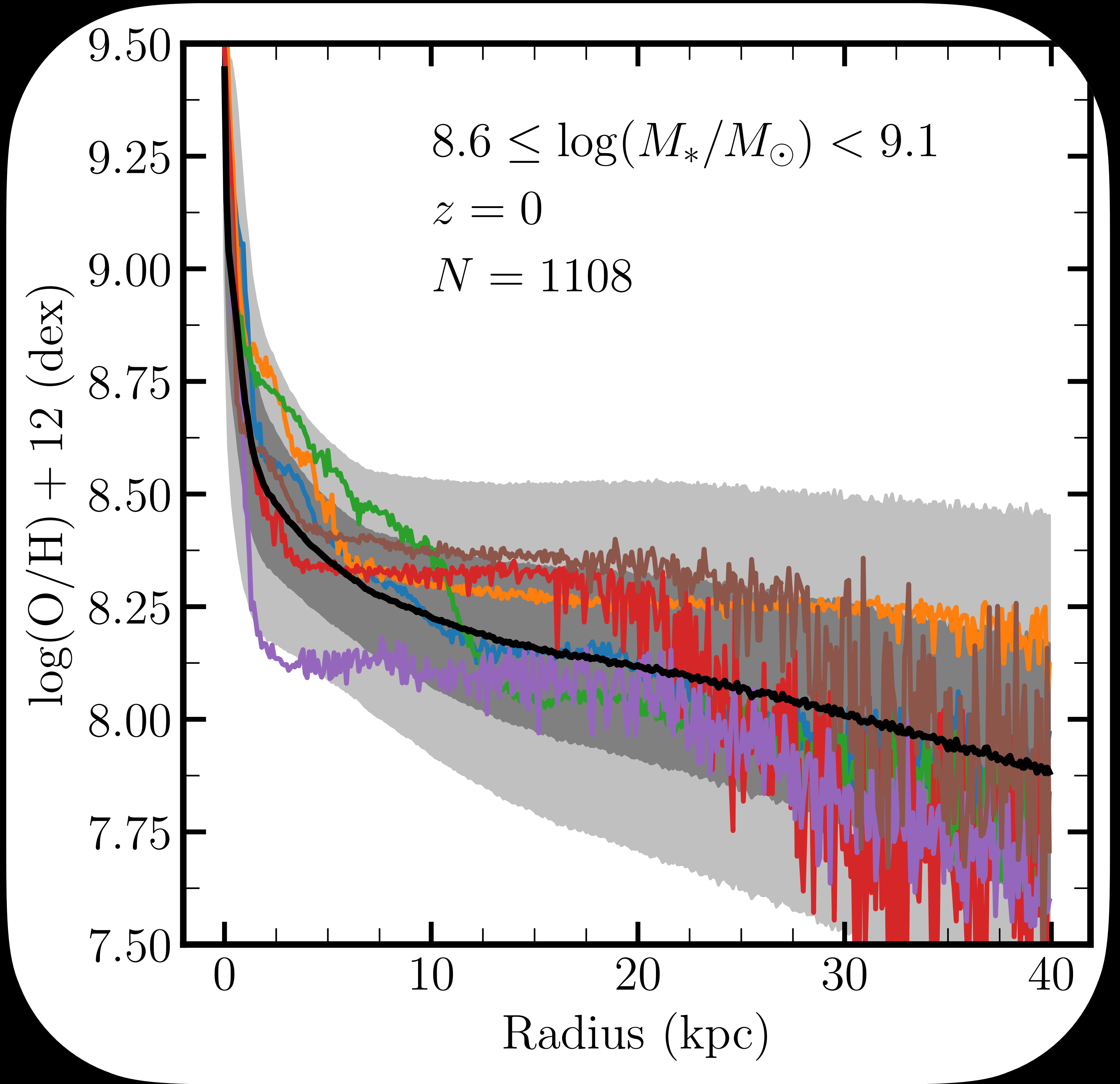
TNG50

- Star-forming galaxies, stellar mass limits of 8.5 $\leq \log M_*/M_\odot < 11.0$

$$N_{\rm galaxies} = 2{,}751 \ @ \ z = 0$$

- Rotate galaxies face-on
- Concentric shells in radial increments of 0.1 kpc

- Bin by mass — width 0.5 $\log M_*/M_\odot$
- Generate ***stacked median profiles***



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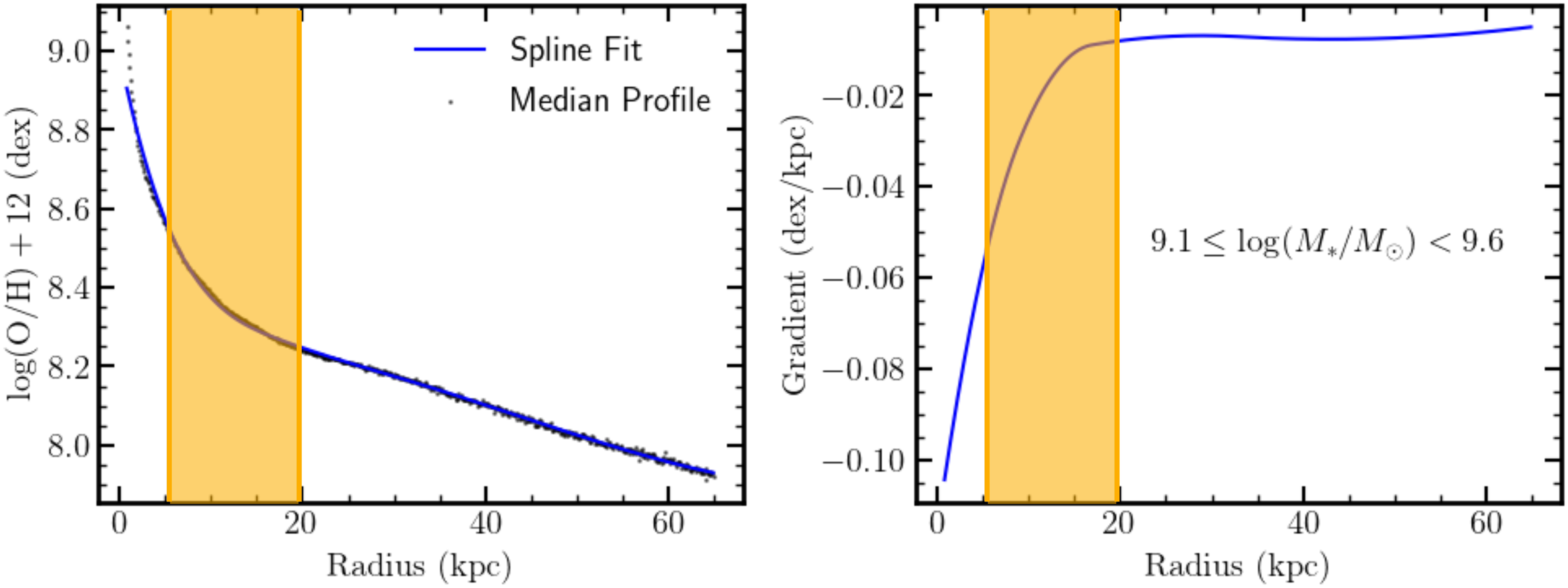
Fitting the profile



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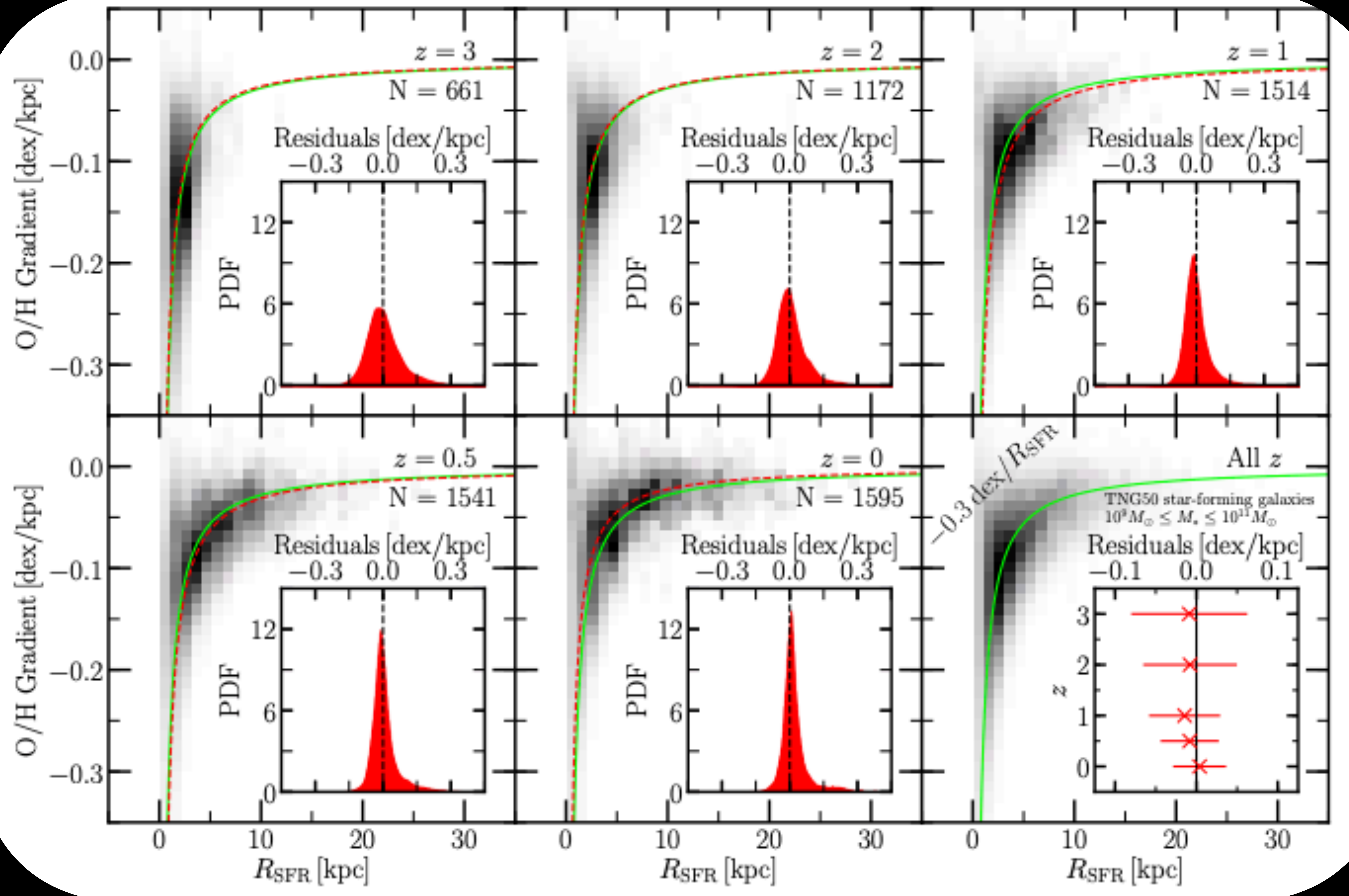
Common abundance gradient

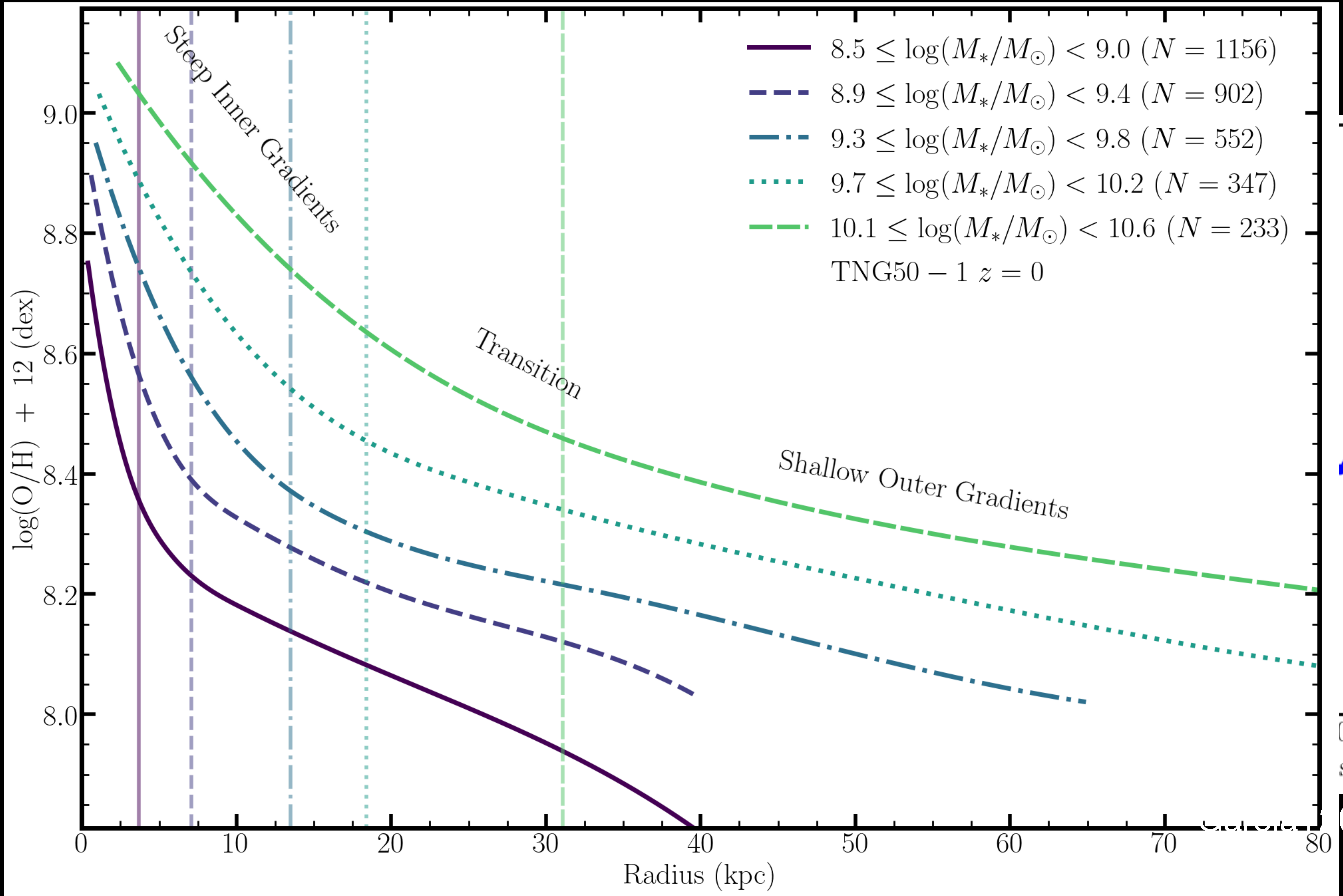


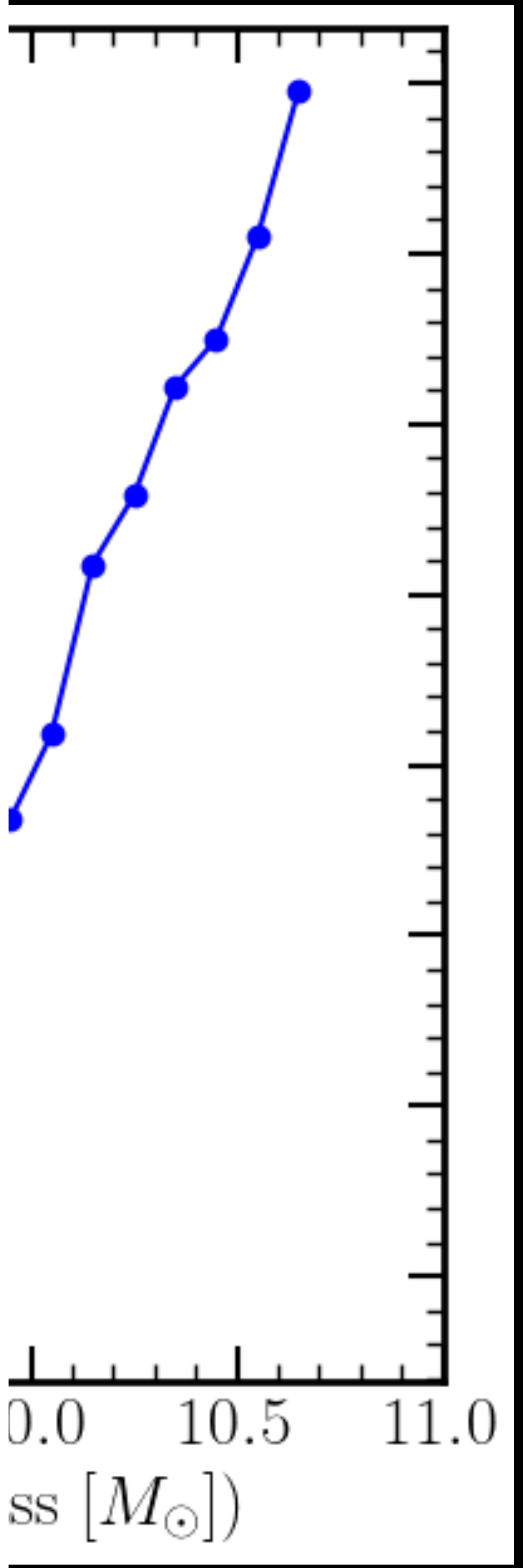
Hemler+2021

In general, gradient scales nicely with the size of the galaxy

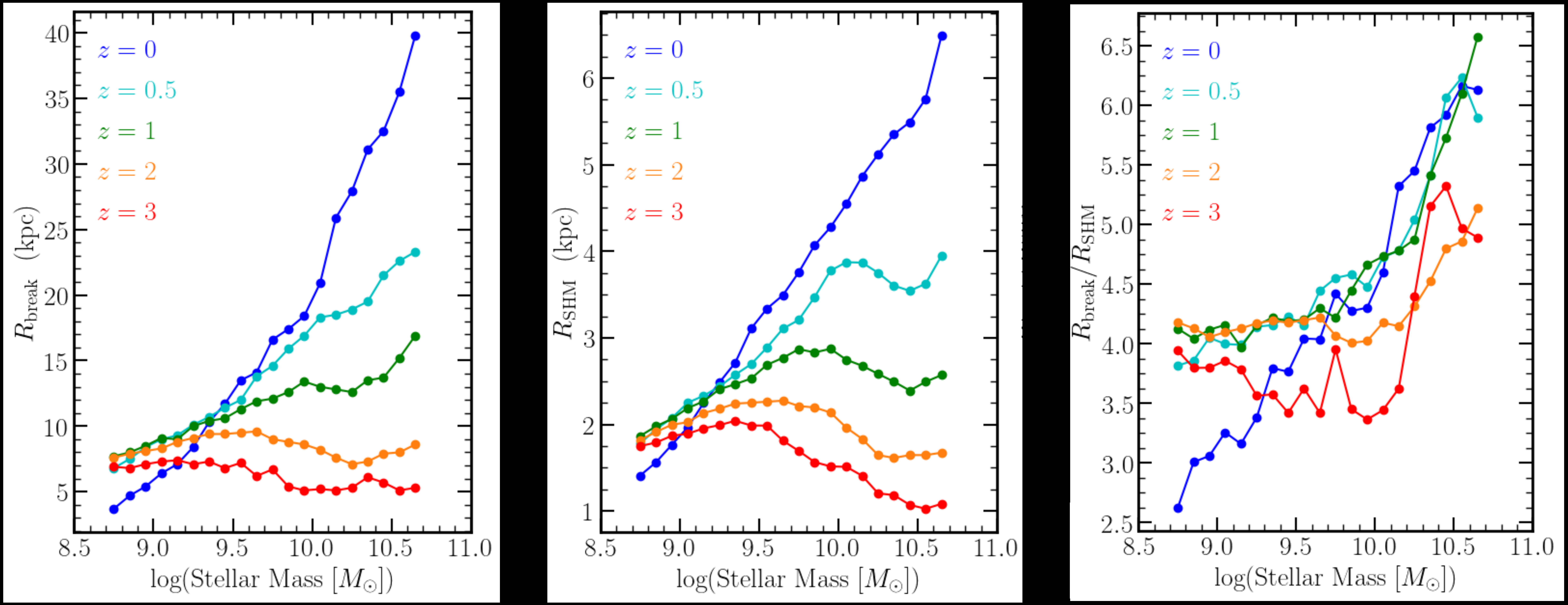
$$\alpha \propto \frac{1}{R}$$

Where the break appears physically





Redshift Evolution



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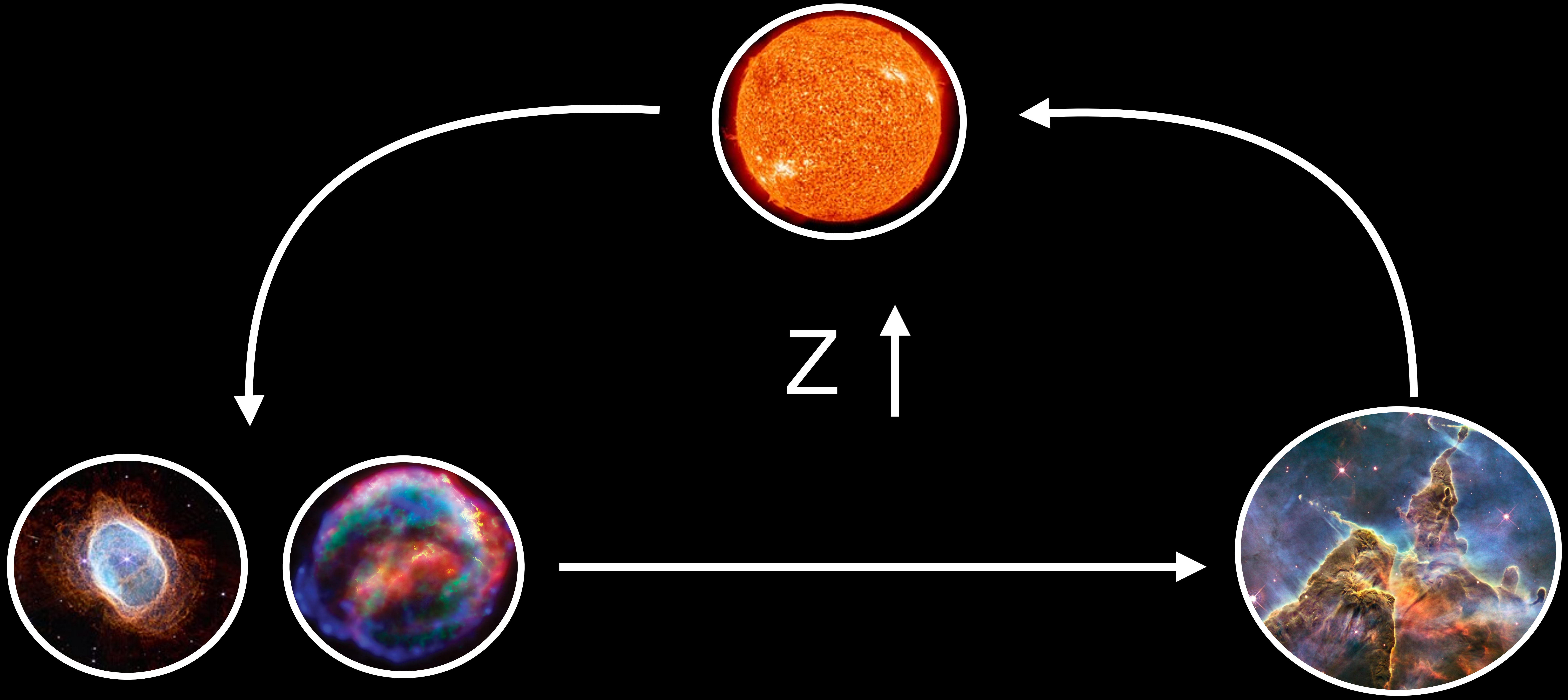
Location of Break Radius ✅

Why do profiles look the way they do?

Setting the break radius — Enrichment



Mixing — adding environment

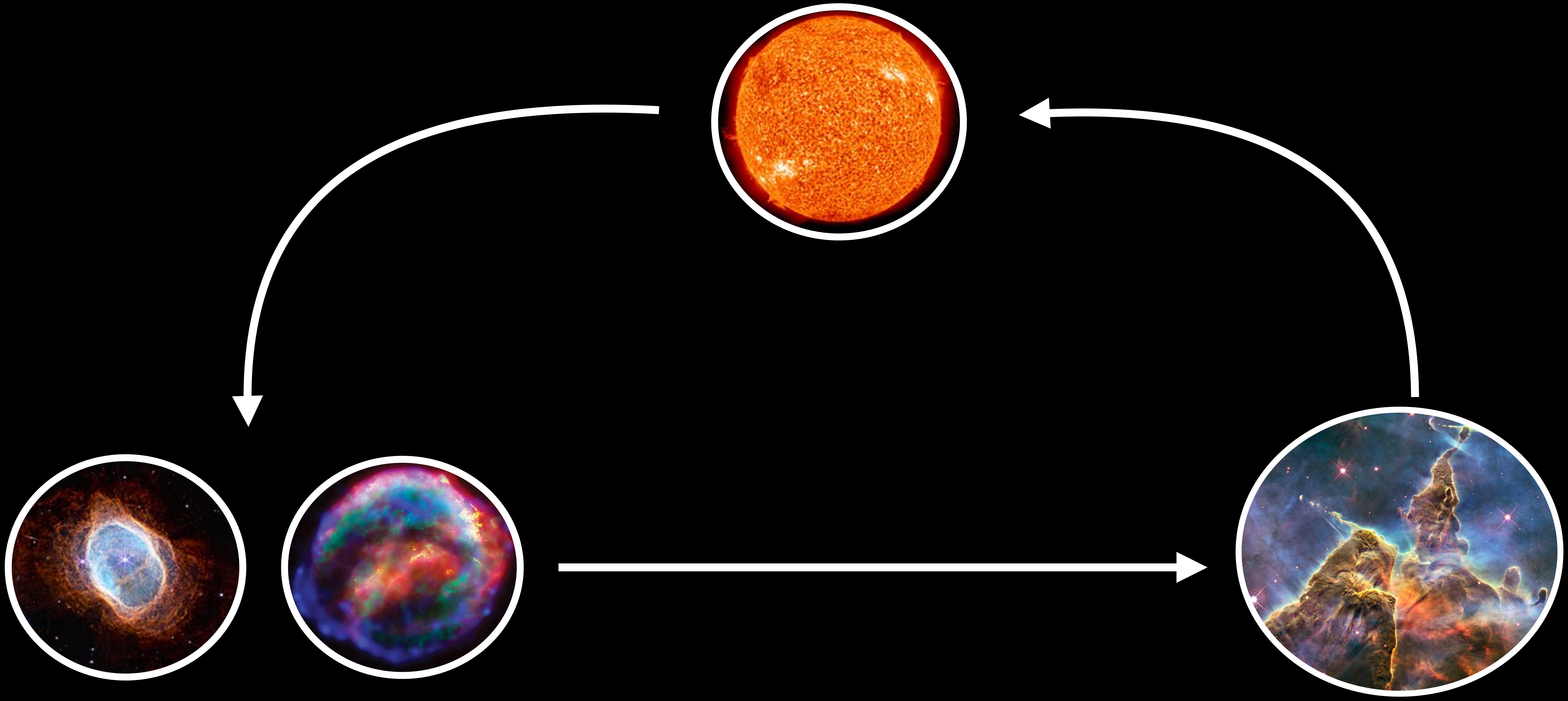



Image Credit: ESA/NASA
CGM
Enriched gas
from center of galaxy
Less enriched gas
from edges of disk
Outer Disk
Inner Disk
Galactic Bulge
CGM

Quantifying this with timescales

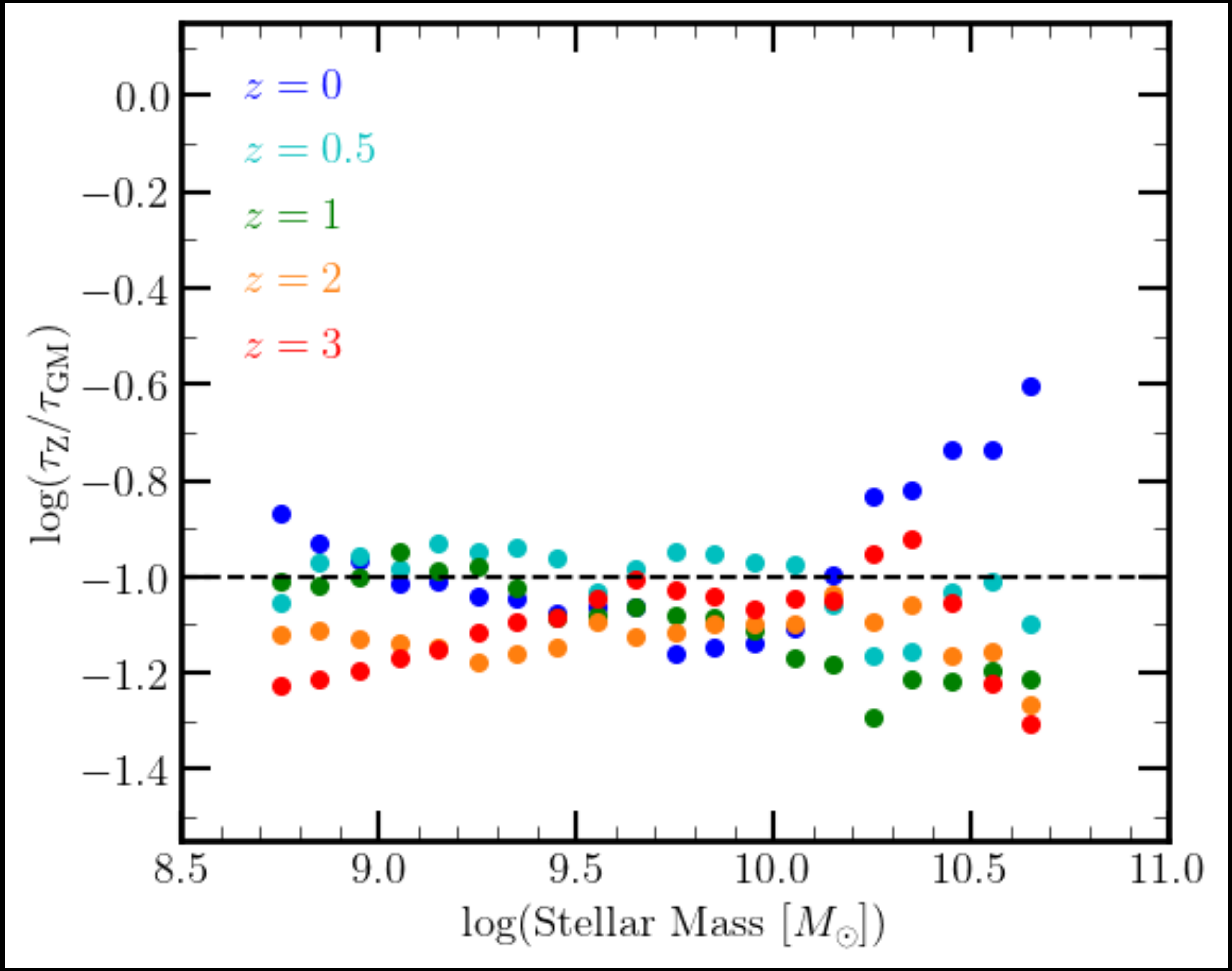
Enrichment Timescale

$$\frac{\text{Metallicity}}{\text{Change in Metallicity}}$$

Gas Mixing Timescale

$$\frac{\text{Radius}}{\text{Radial Velocity}}$$

Timescales at the break radius



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Location of Break Radius ✅

Reason for Break Radius ✅

Predictions are only as good as the model

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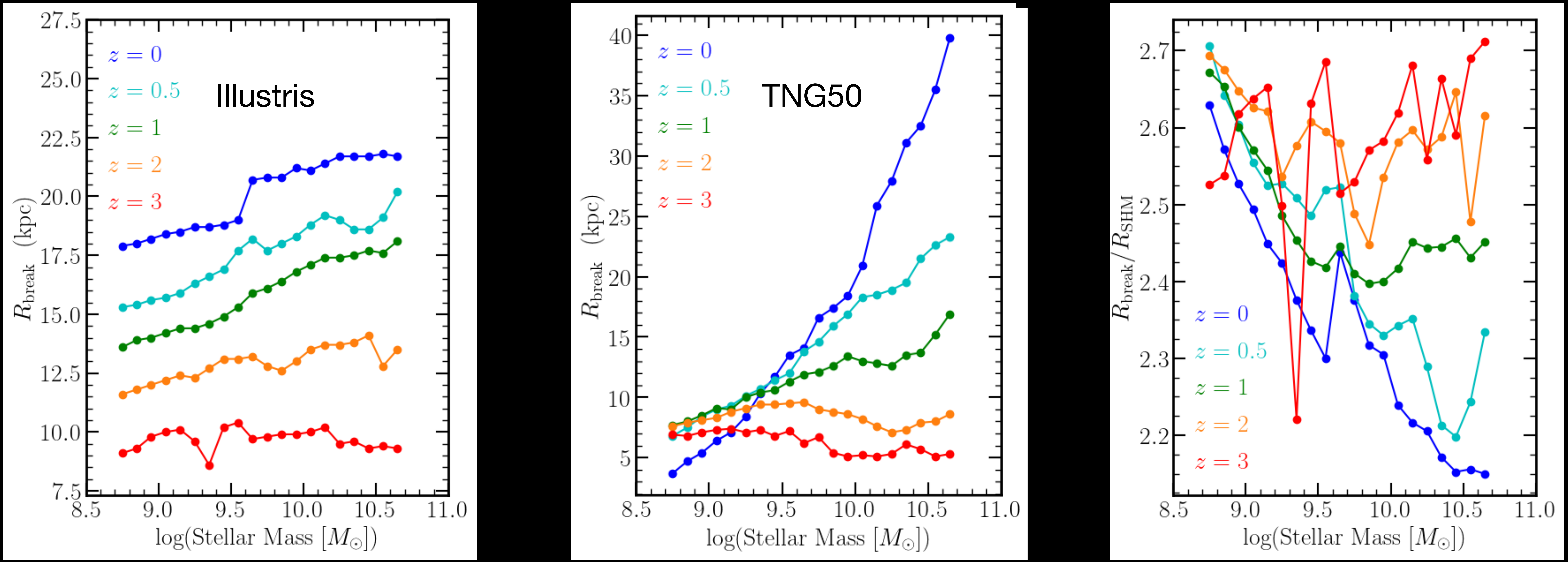
Comparisons with Illustris Original

	TNG	Illustris
Galactic Winds	Isotropic	Preferential
MHD	Yes	No
AGN	Yes (different)	Yes
CCSNe	8 Solar Masses	6 Solar Masses
Box Size	$(50\ \mathrm{Mpc})^3$	$(100\ \mathrm{Mpc})^3$
Resolution	~Same	~Same

Etc…

Comparisons in Illustris - locations



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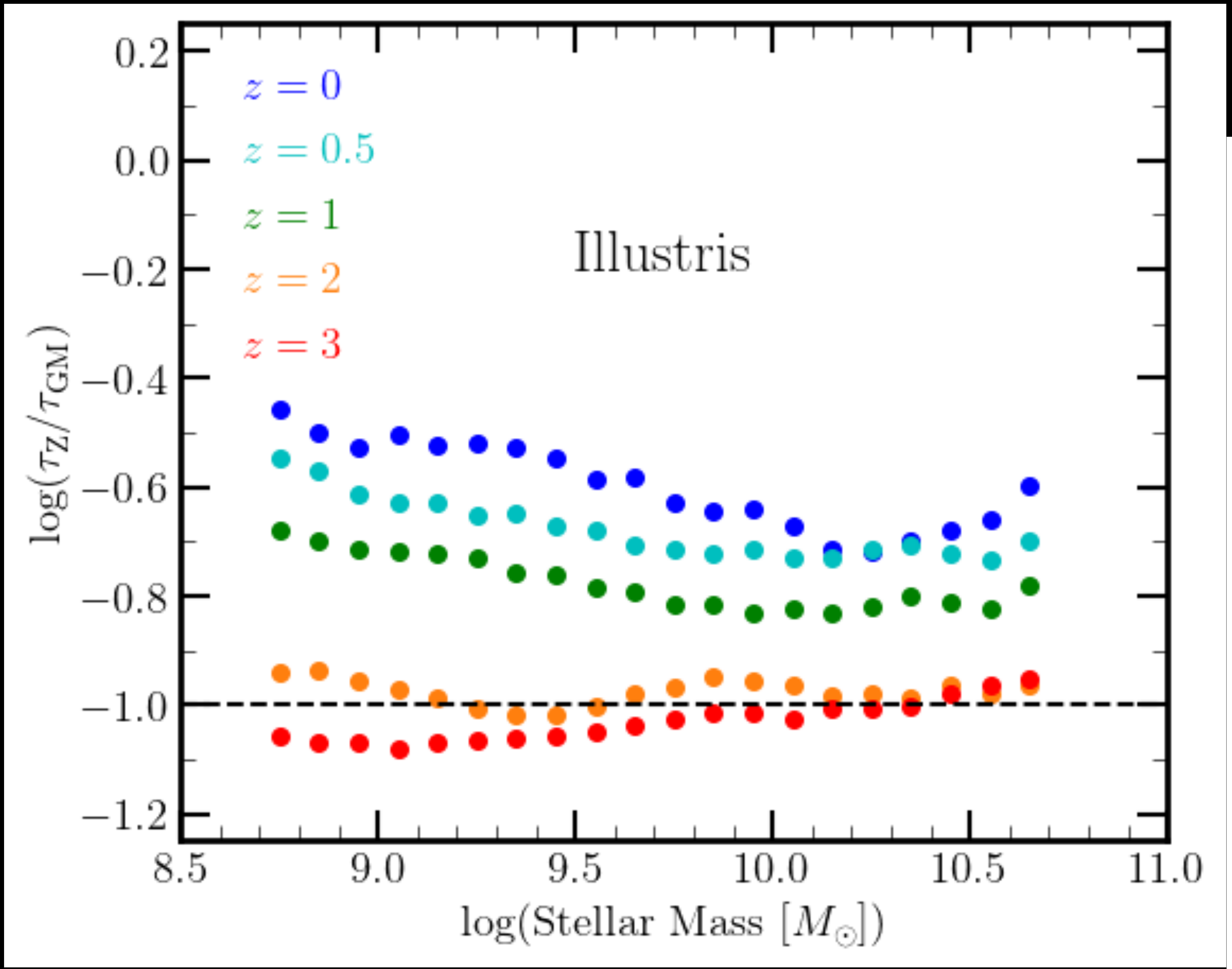
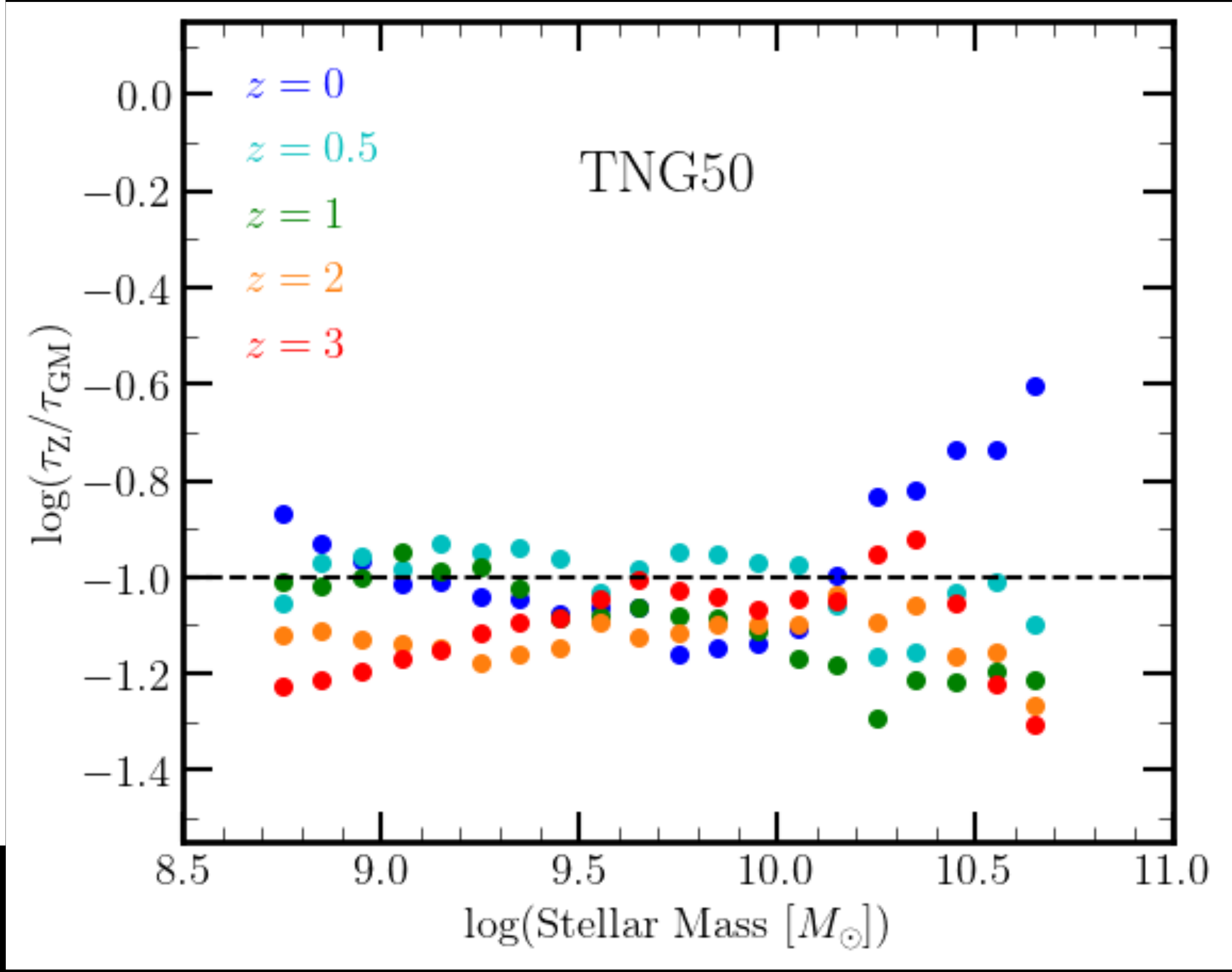
Comparisons in Illustris - timescales





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Agreement between different physical models!

😄

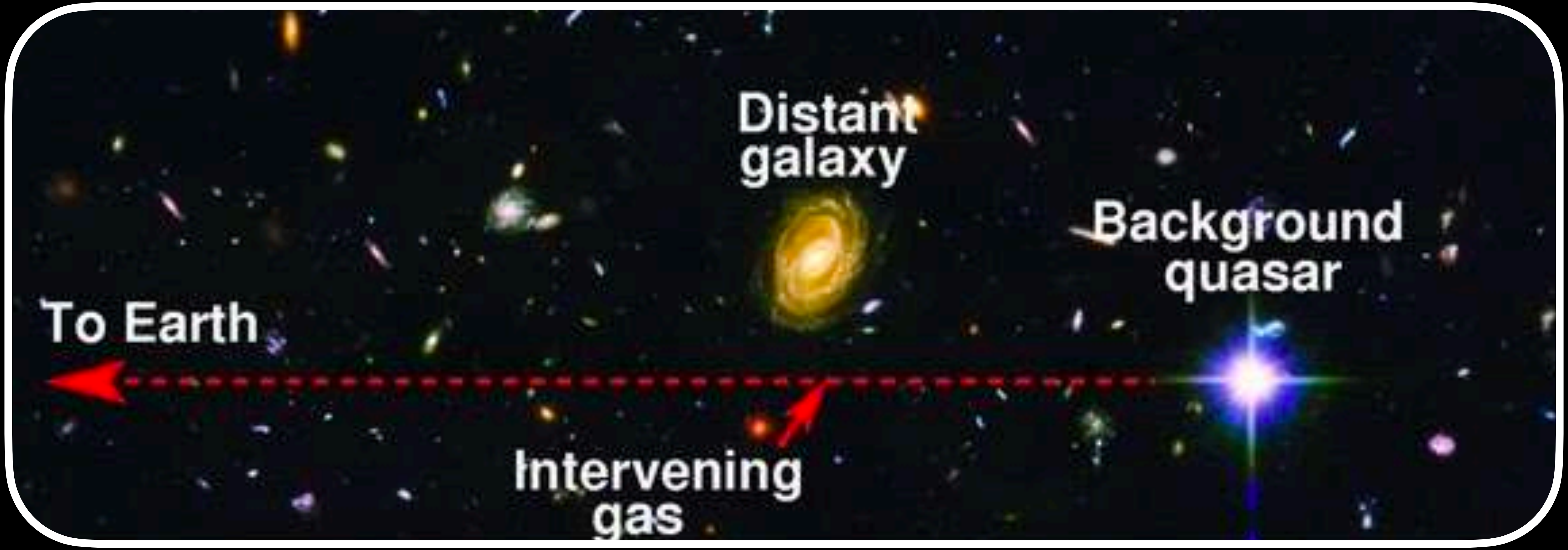
Can we do this observationally?

Potential Observational Study

- Typical metallicity diagnostics:
  - Emission lines from ionized gas

- Ionization of gas not prevalent enough to make fine resolution measurements further out in the galaxy

- Absorption diagnostics

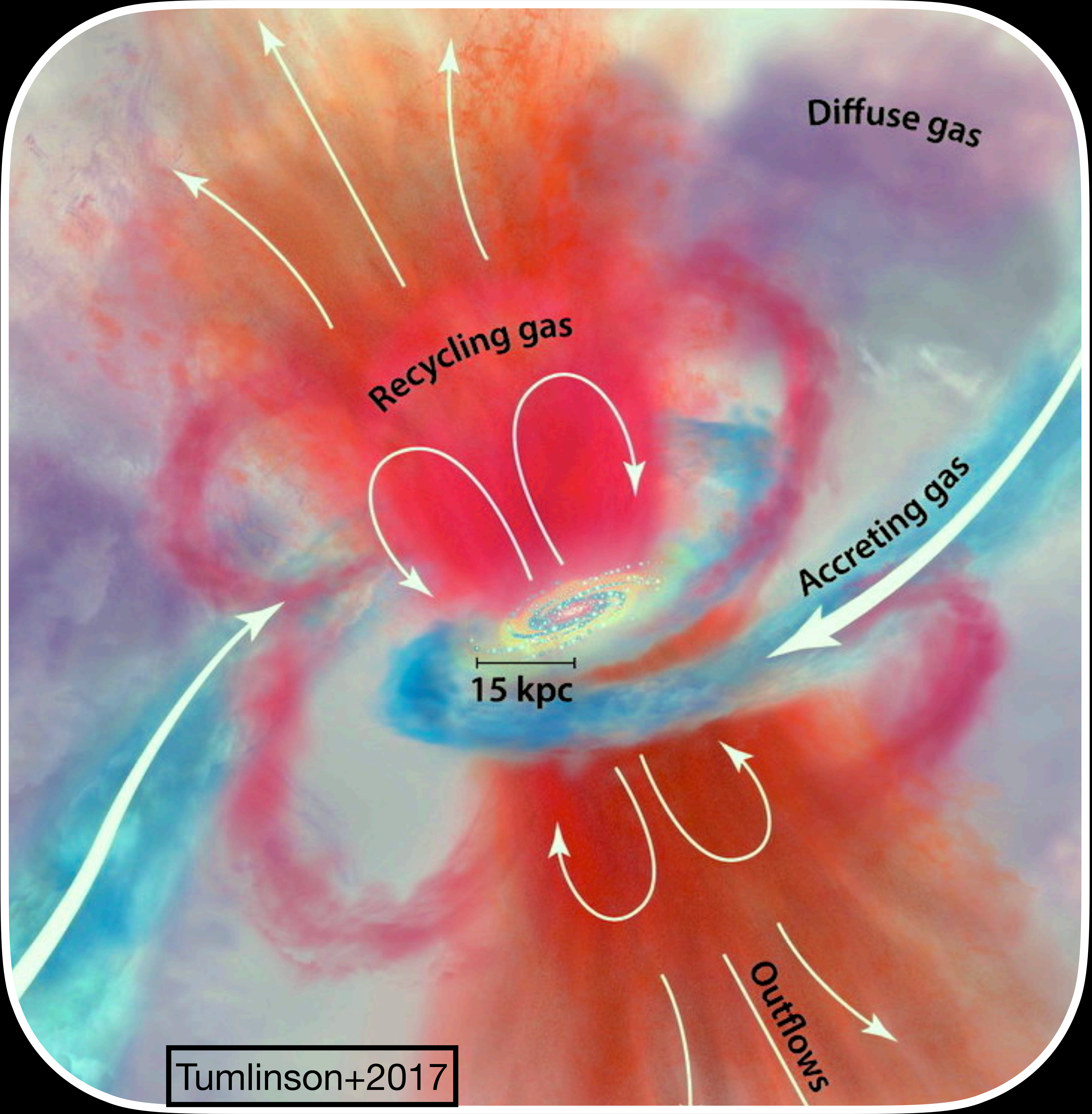


ASTRO3D - Slaven-Blair

Why is this important?

Baryon Cycle

- Inner enrichment dominated disk
- Outer mixing dominated disk
- Potential discriminator between models
  - Feedback implementations



Conclusions

- We find that at z=0, break radii are positively correlated with the stellar mass of galaxies. This correlation weakens as a function of redshift
- When normalized by size, there is weak dependence on both mass and redshift for the location of the break radius
- Metallicity profiles are set by the competition of gas mixing and enrichment
- Compared to a similar, but different, physical model, we find qualitative agreement with out results
- Break radii can provide a potential discriminator of implementations of feedback within simulations