Image: TNG Collaboration

Using the metal content of galaxies to inform stellar feedback modeling

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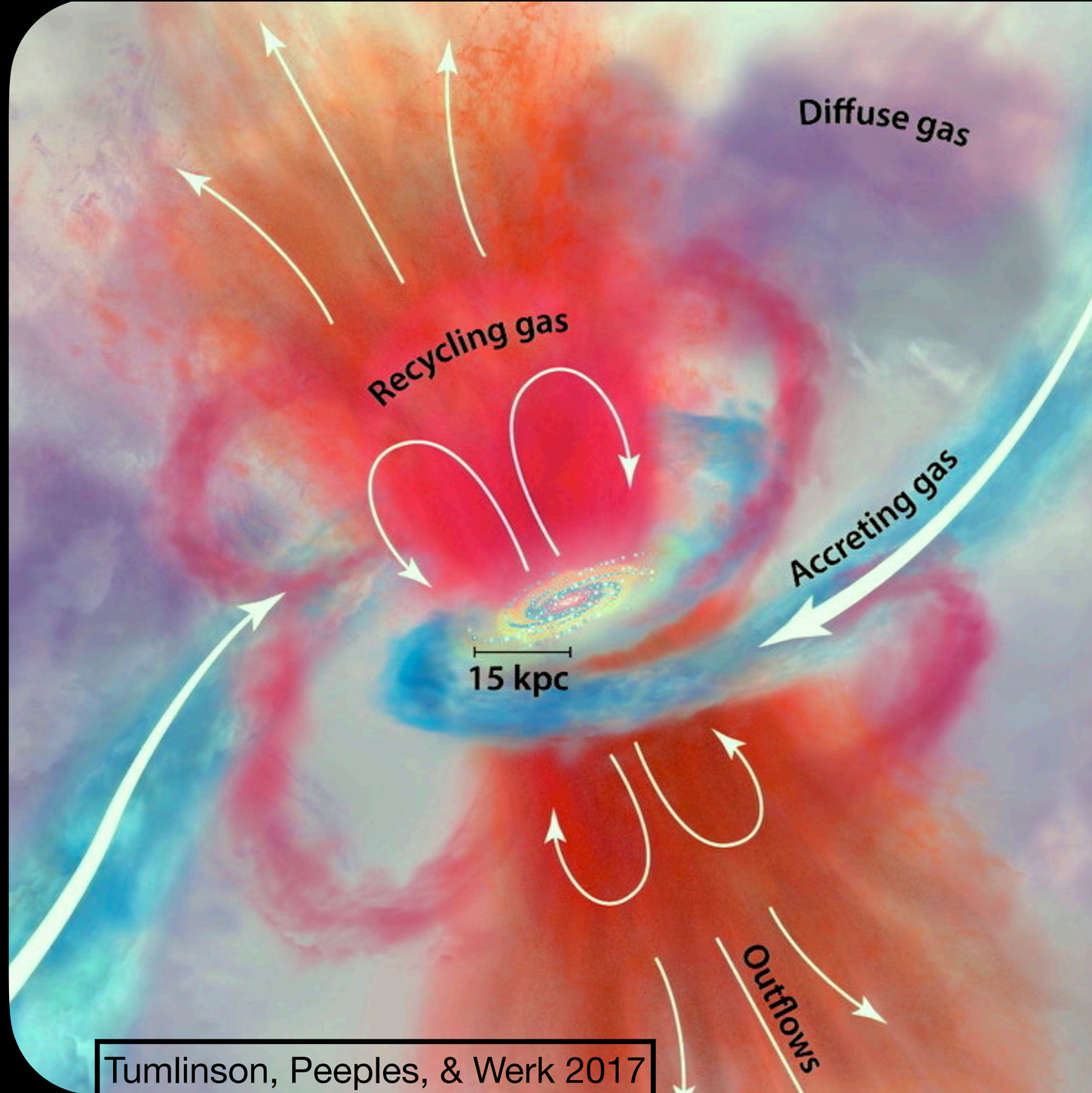
Baryon Cycle

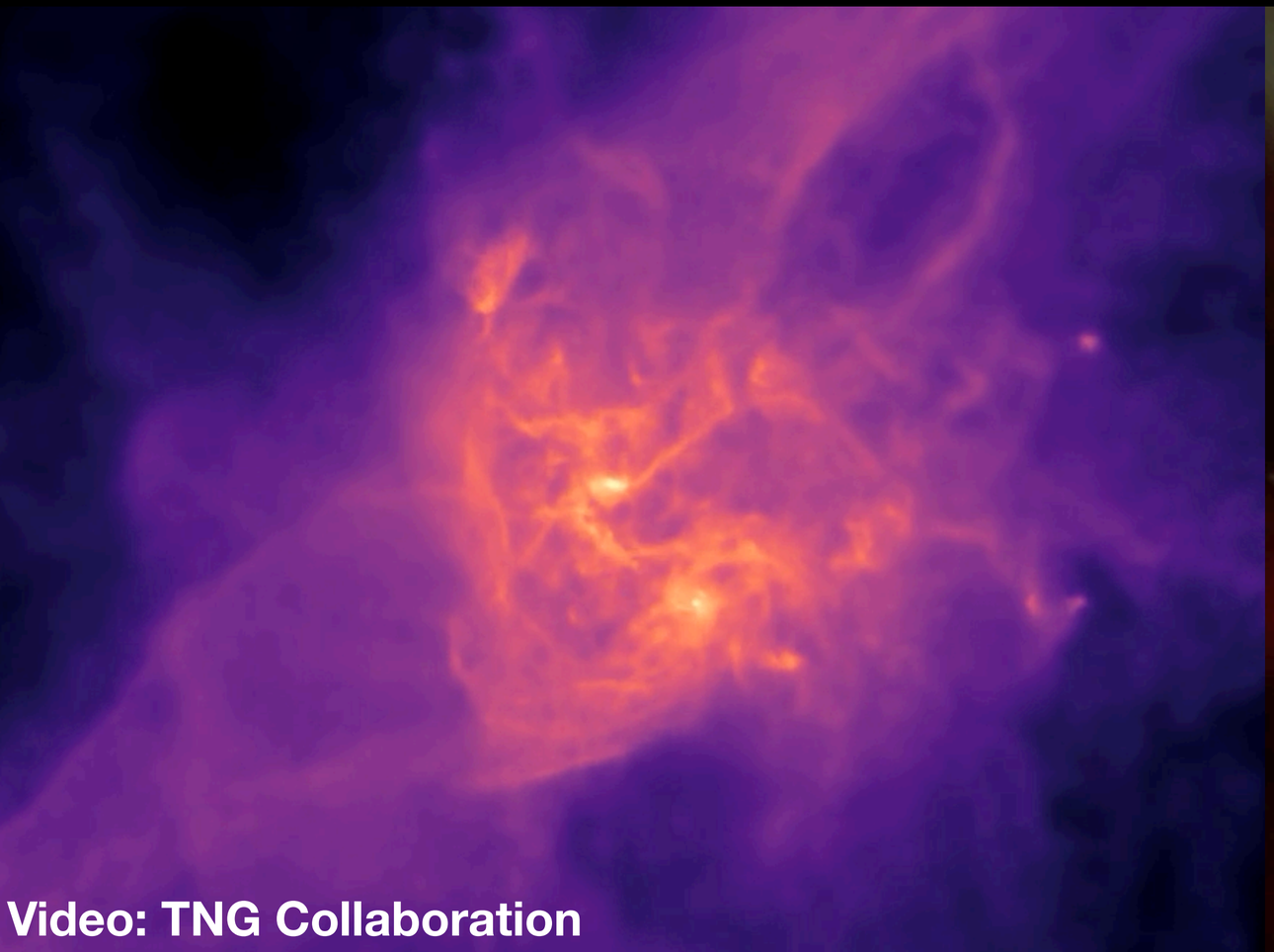
Complete set of interactions within a galaxy and with the environment



Modeling the baryon cycle in simulations

Case Study: Stellar Feedback

Gentle Feedback



Video: TNG Collaboration

Bursty Feedback

Video: FIRE Collaboration

Are there observable ways to distinguish the two?

1. Metallicity gradients
2. Interplay of stellar and gas-phase metallicities

Are there observable ways to distinguish the two?

1. Metallicity gradients: Hemler+21 and Garcia+23
2. Interplay of stellar and gas-phase metallicities

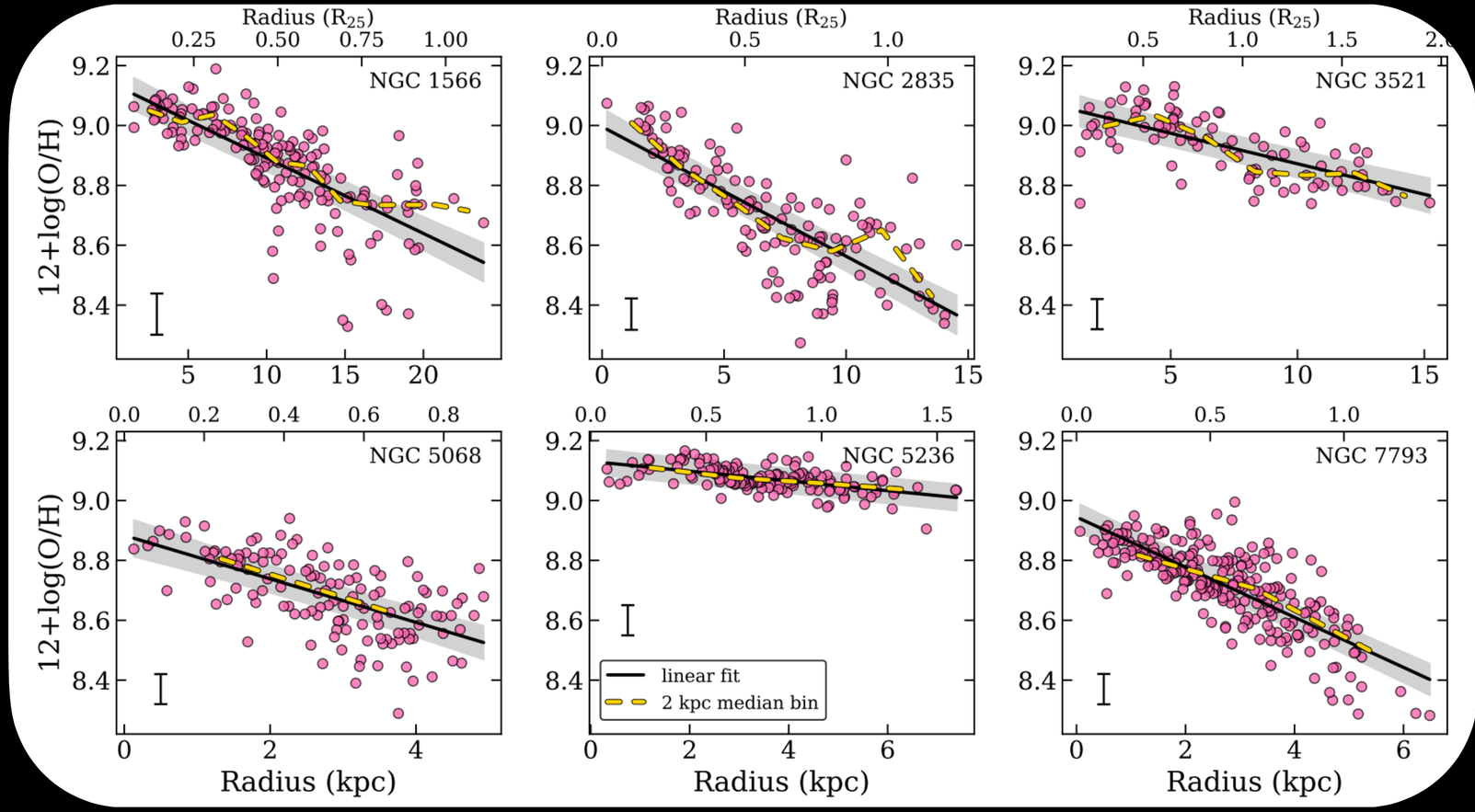
Gas-phase Metallicity Gradients

Observations

Predominately negative gradients at low redshift

Higher redshifts (z~0.6-3)

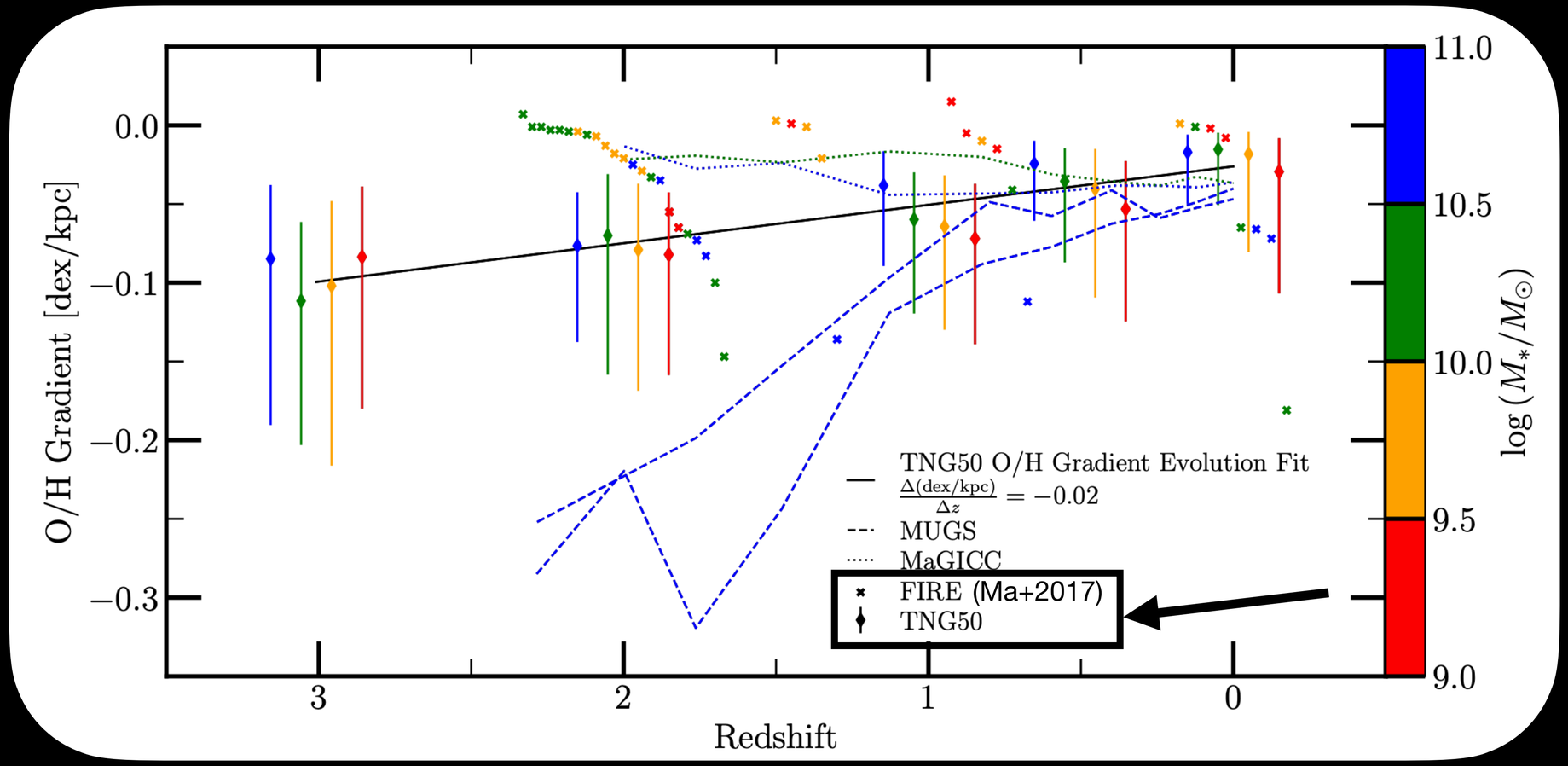
- Wide variety of gradients



Grasha+2022

Gas-phase Metallicity Gradients

Simulations



Hemler+2021

What we learn about feedback modes

Gentle Feedback

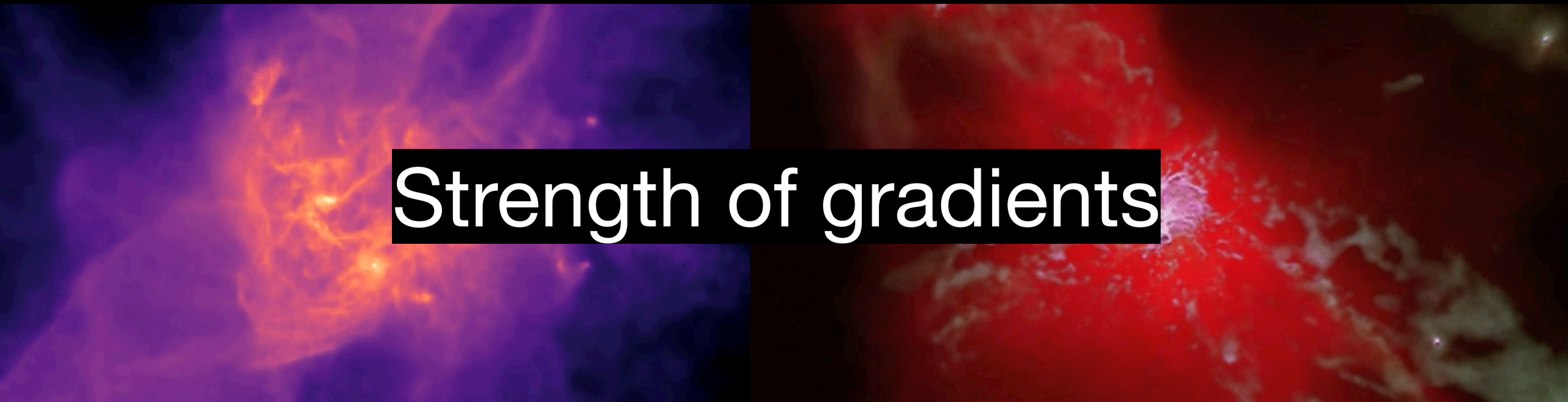
No mechanism to catastrophically destroy gradients

Mixing takes a while

Bursty Feedback

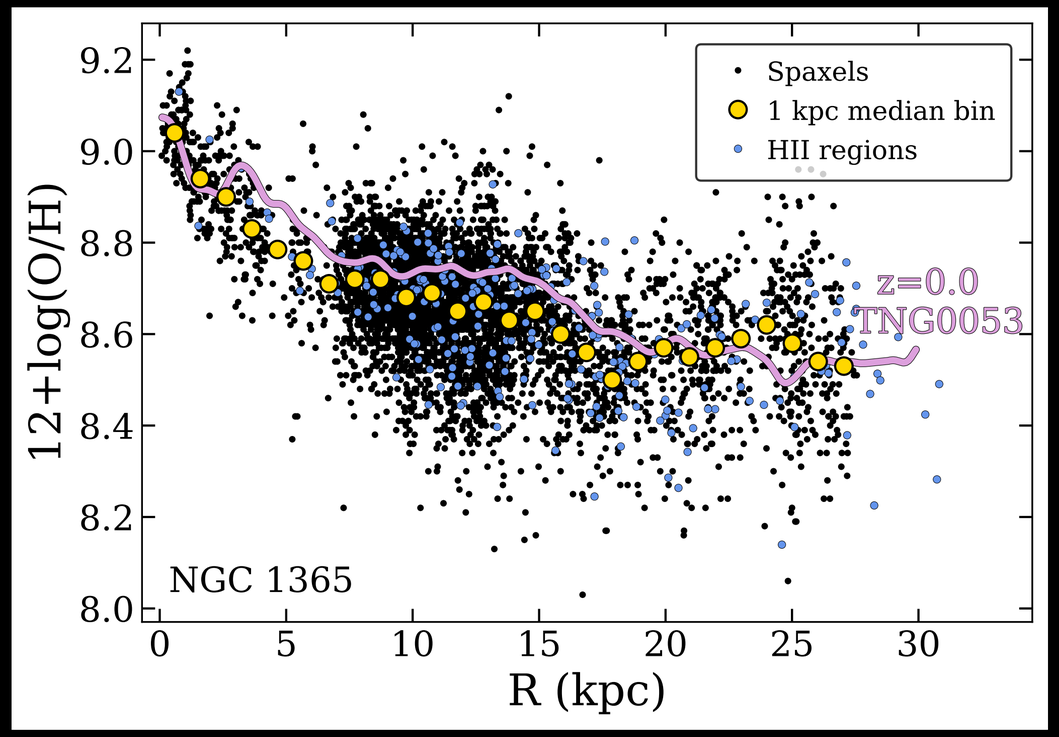
Washes out metallicity gradients very quickly

Allows re-growth of the gradients

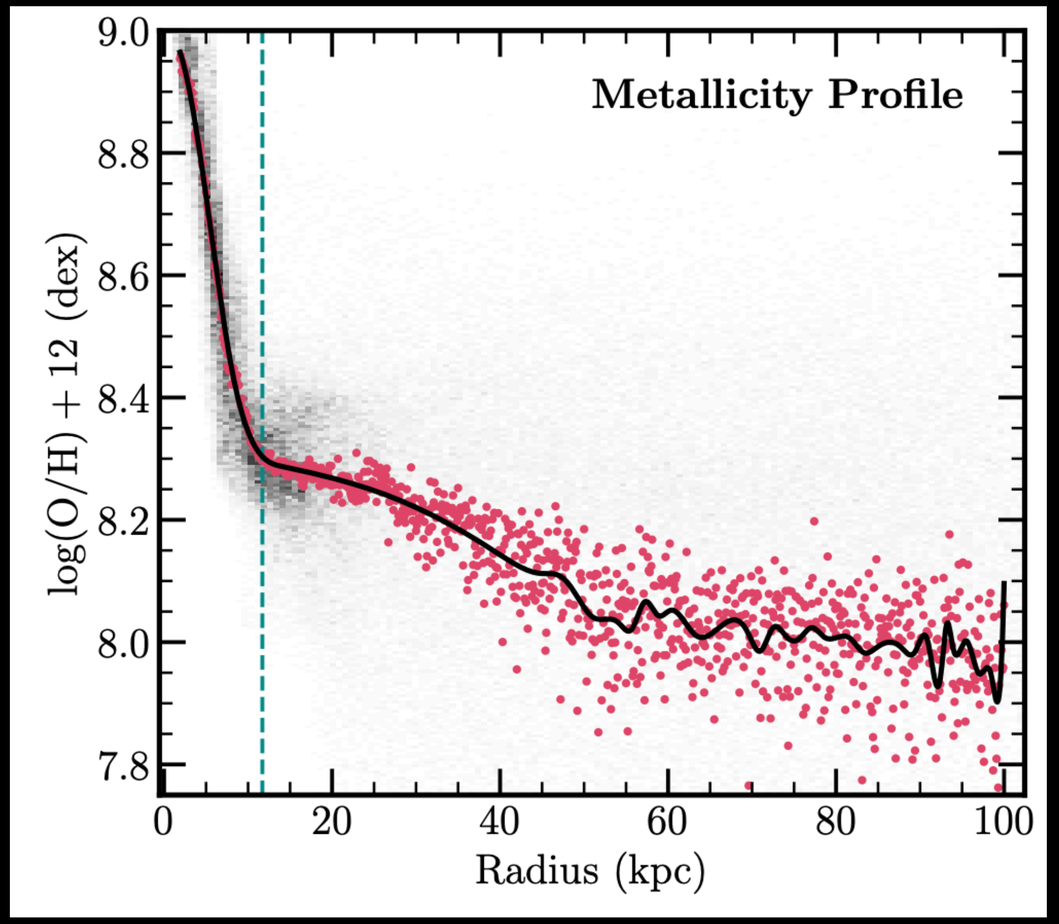


Extended metallicity profiles

Profile flattening

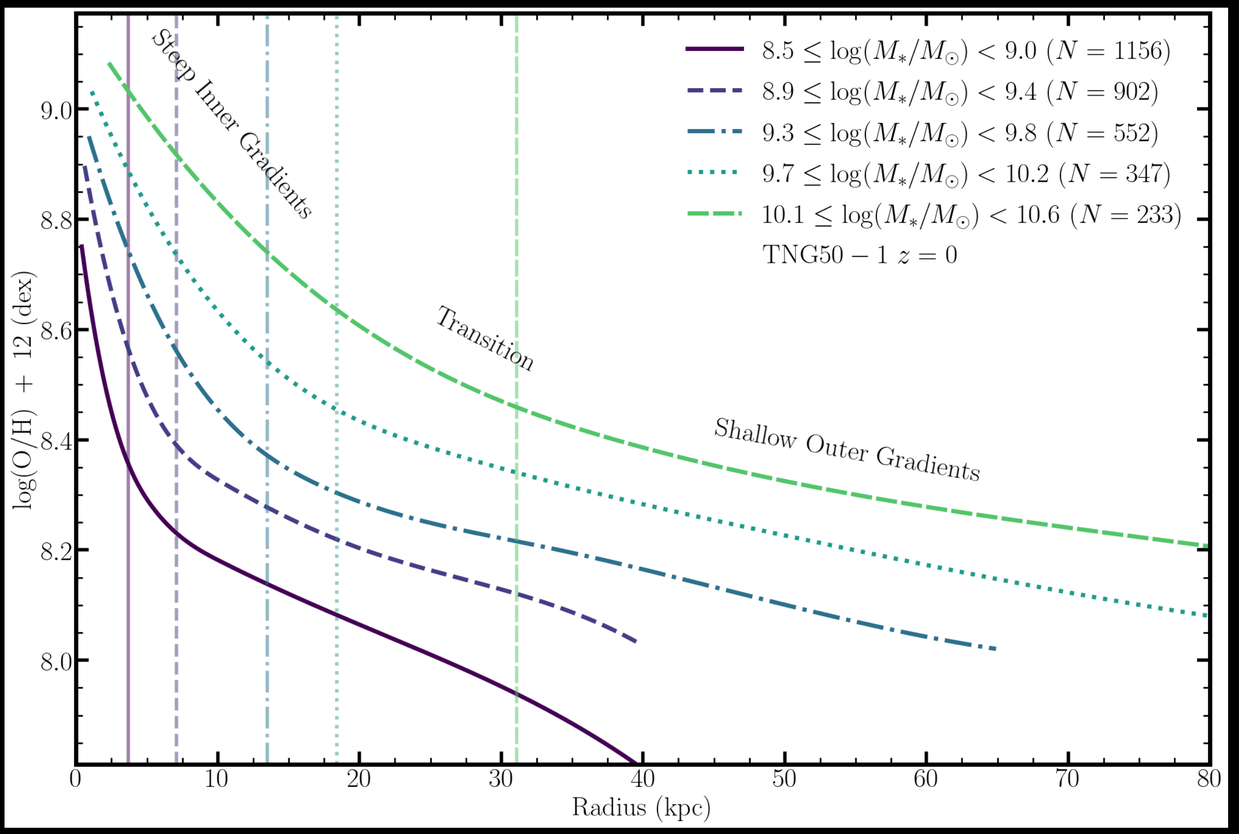


Kewley+(In Prep)



Garcia+2023

Where do metallicity profiles “break”?

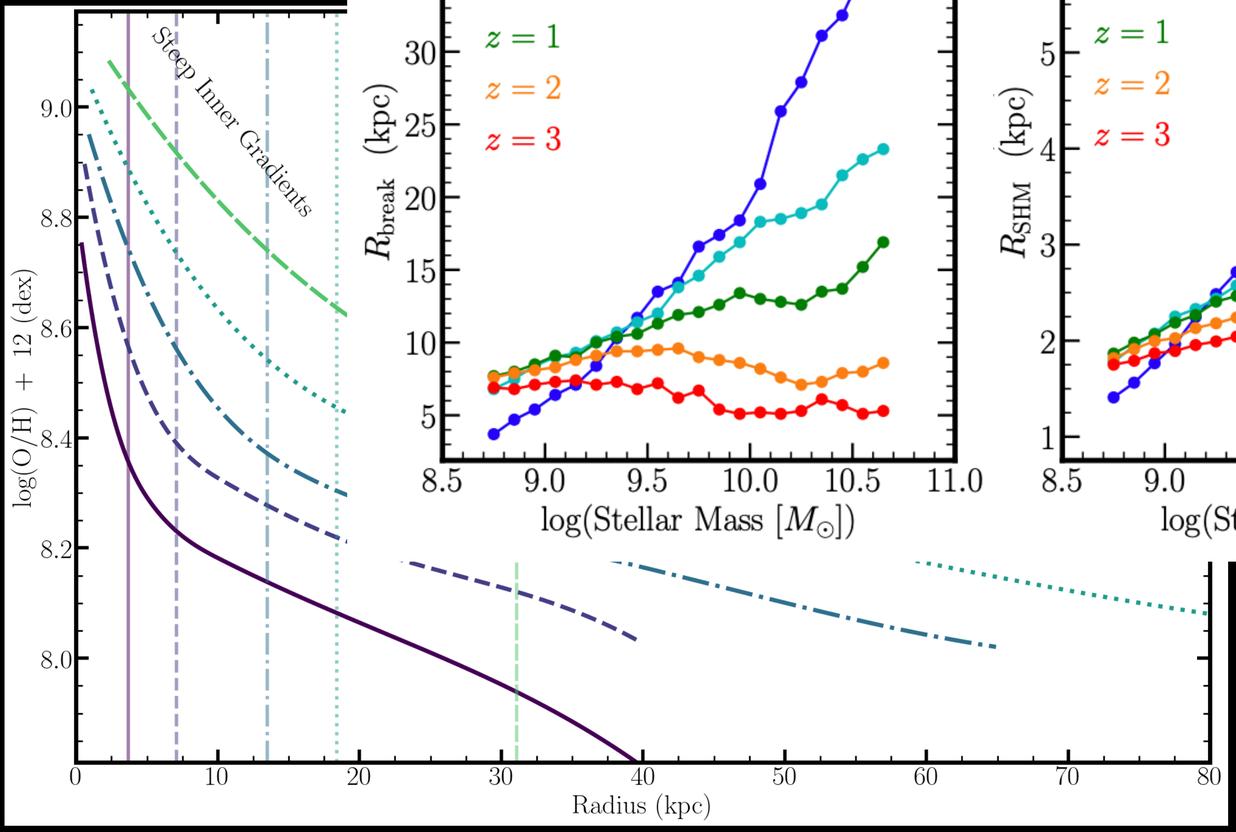


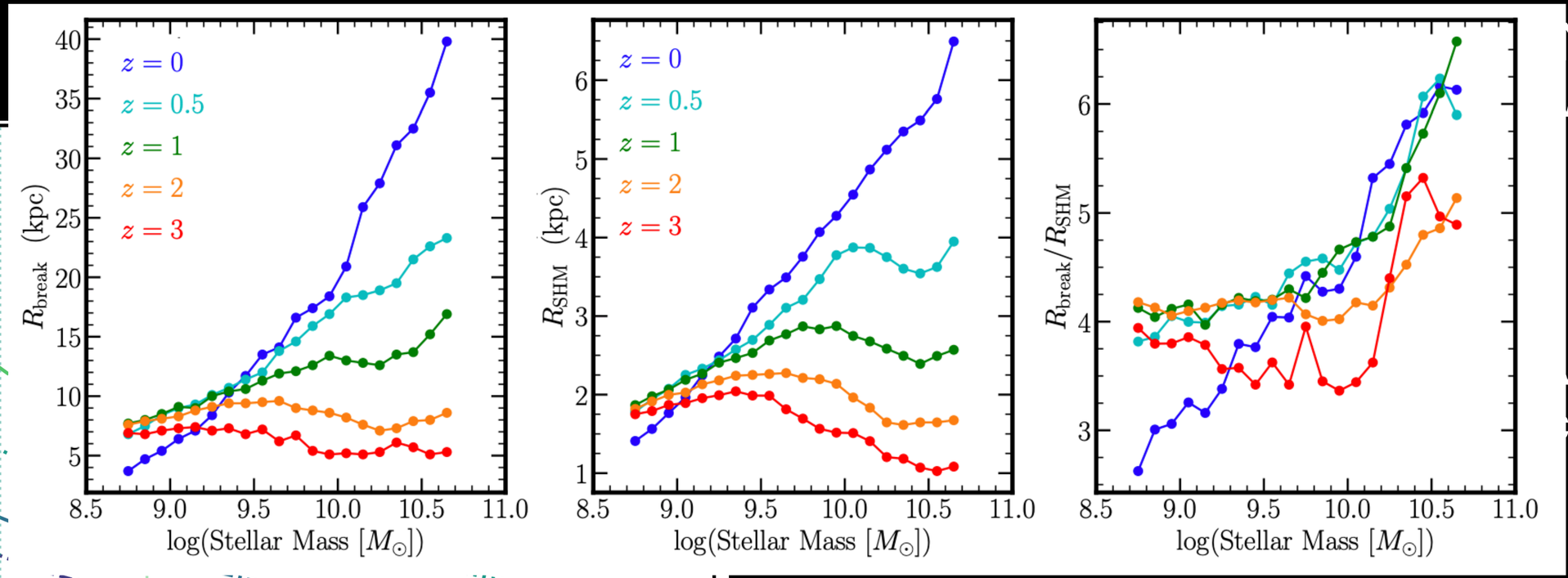
Garcia+2023

Stack star-forming galaxies in TNG50 by mass and fit metallicity profiles with a spline

Define break radius location as where the gradient has decreased by a factor of 3.5 (with some size scaling)

Where do metallicity profiles “break”?





NG50 by
with a

where the
tor of 3.5

When normalized by galaxy size, only a weak trend with mass, across cosmic time

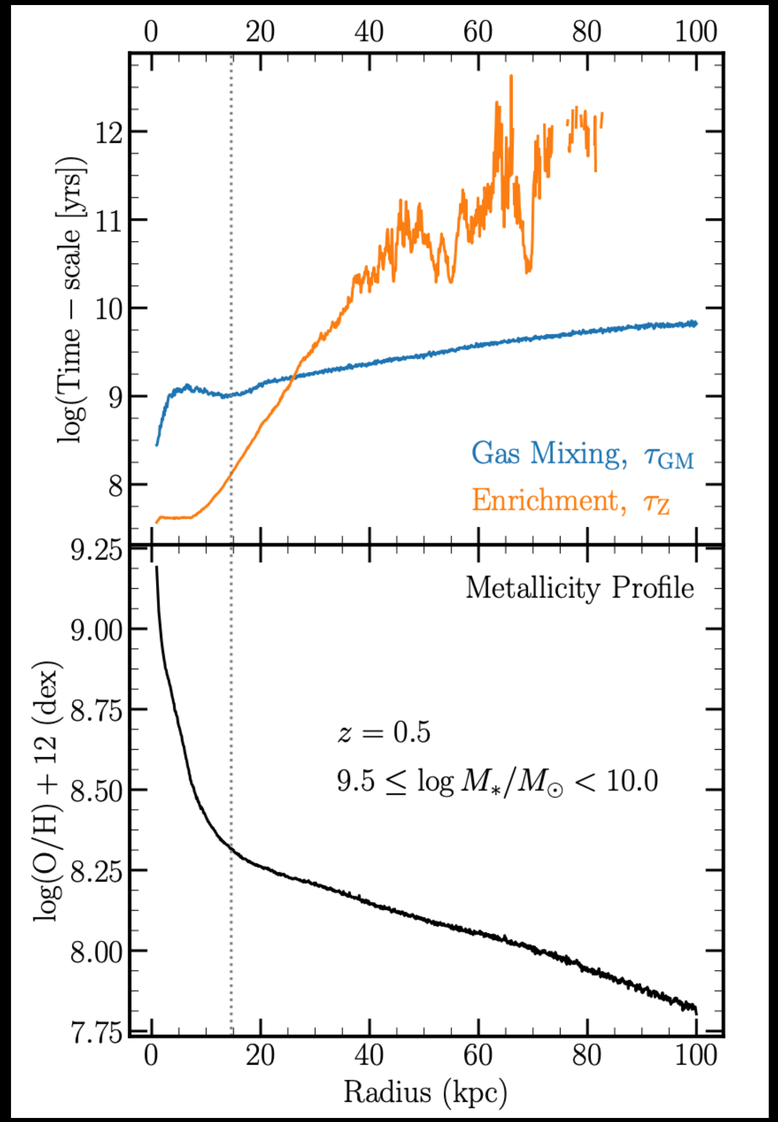
Garcia+2023

Why do metallicity profiles “break”?

What sets a gradient?

Ratio of timescales ~1/10 at location of the break

Location of the break radius determined by the competition of gas mixing and enrichment within the disk



Garcia+2023

Implications for feedback modeling

Gentle Feedback

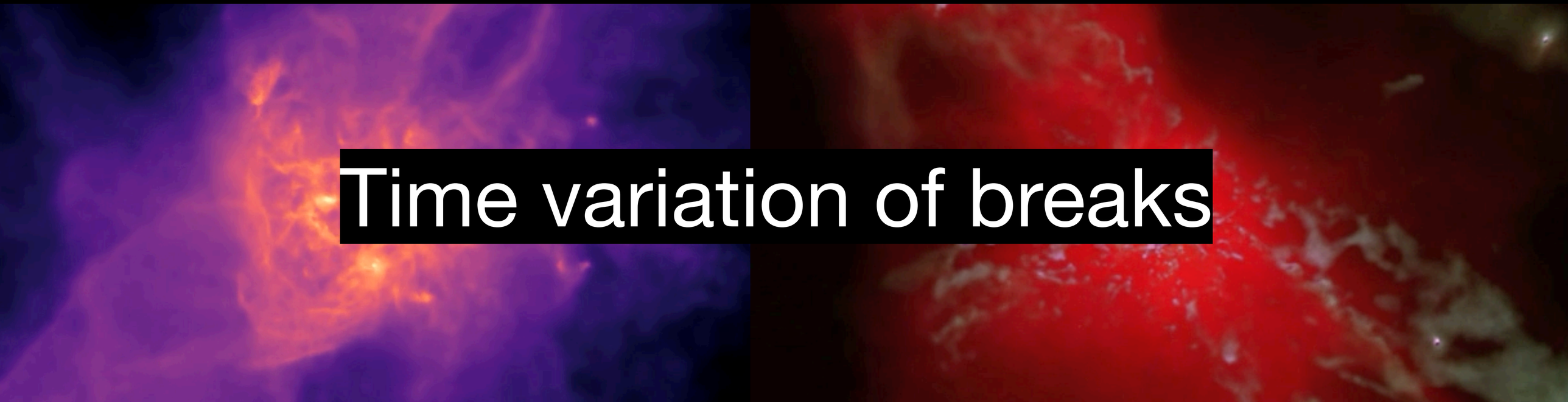
Mixing takes a long time

Changes take a while

Bursty Feedback

Bursts destroy gradients… but!

Very soon after system back to “normal”



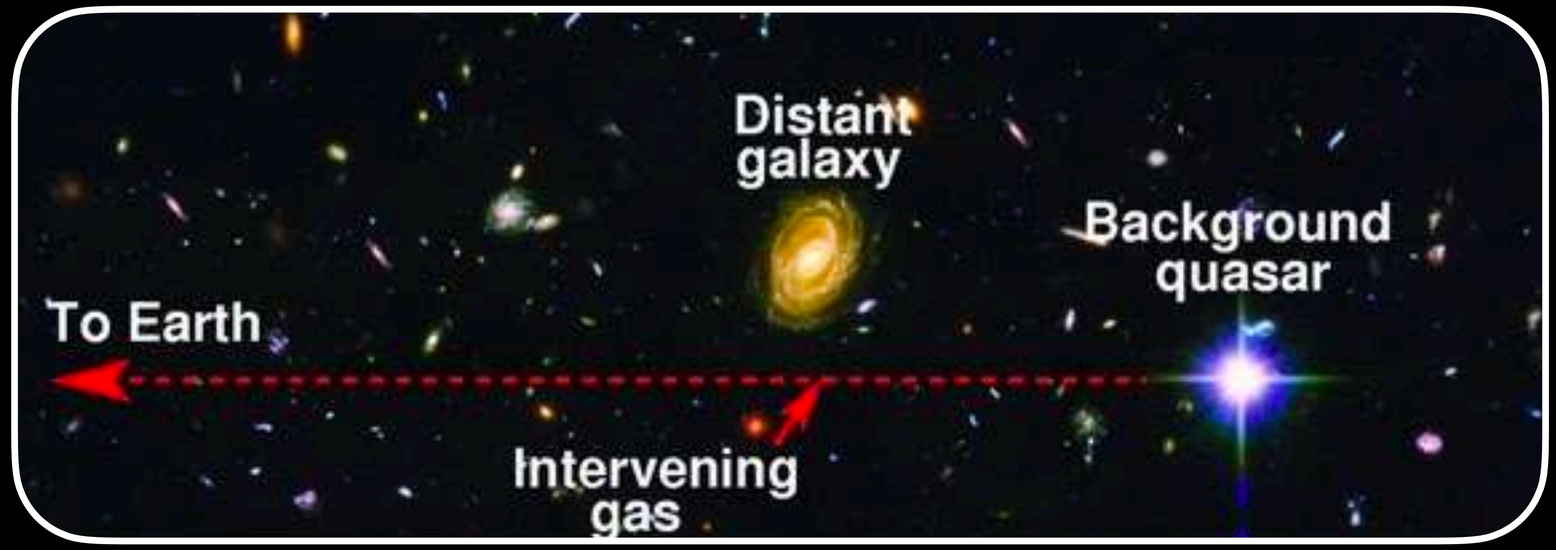
Time variation of breaks

How could we observe extended profiles?

Nearby galaxies

Background quasar absorption — with galaxy stacks

Kewley+(In Prep)



ASTRO3D - Slaven-Blair

Metallicity Gradients

Summary

Both the strength and physical extent of metallicity gradients are sensitive to the adopted physics within simulations

High spatial resolution surveys of local galaxies & high redshift observations with, e.g., JWST should provide some discriminatory power in the near-term future

Are there observable ways to distinguish the two feedback models?

1. Metallicity gradients
2. Interplay of stellar and gas-phase metallicities

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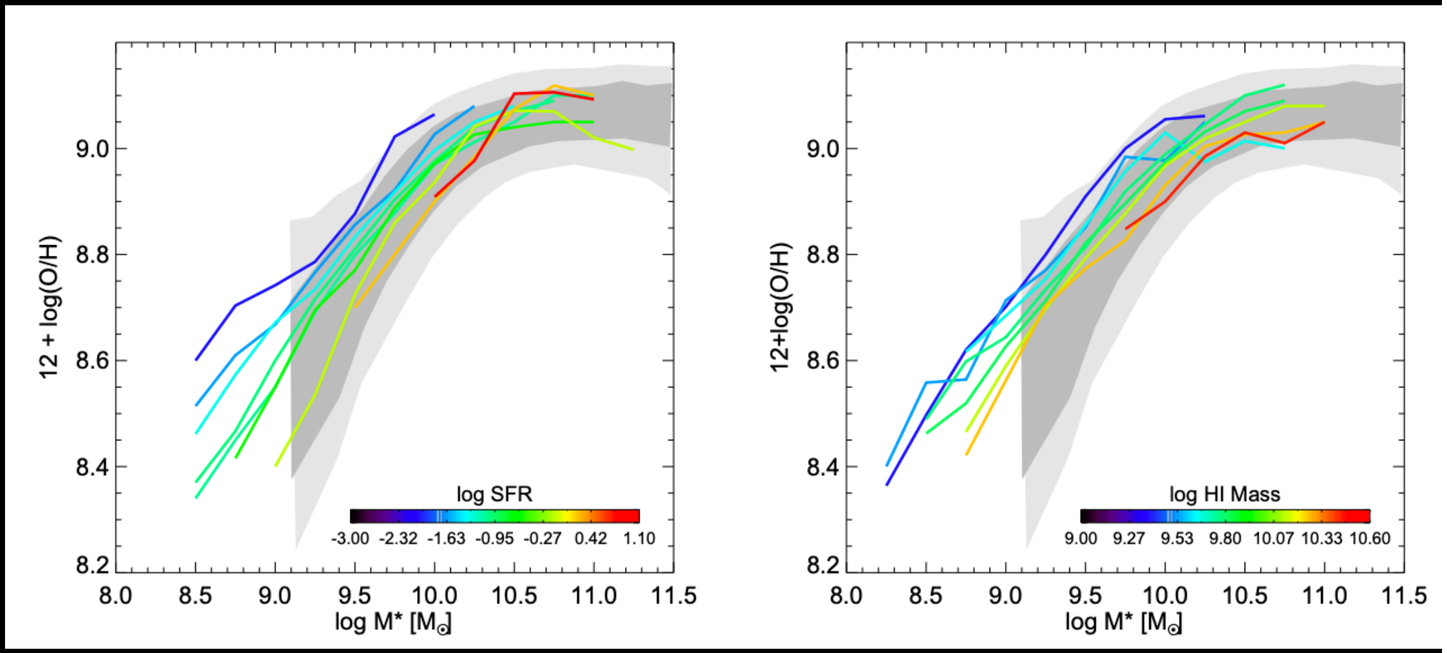
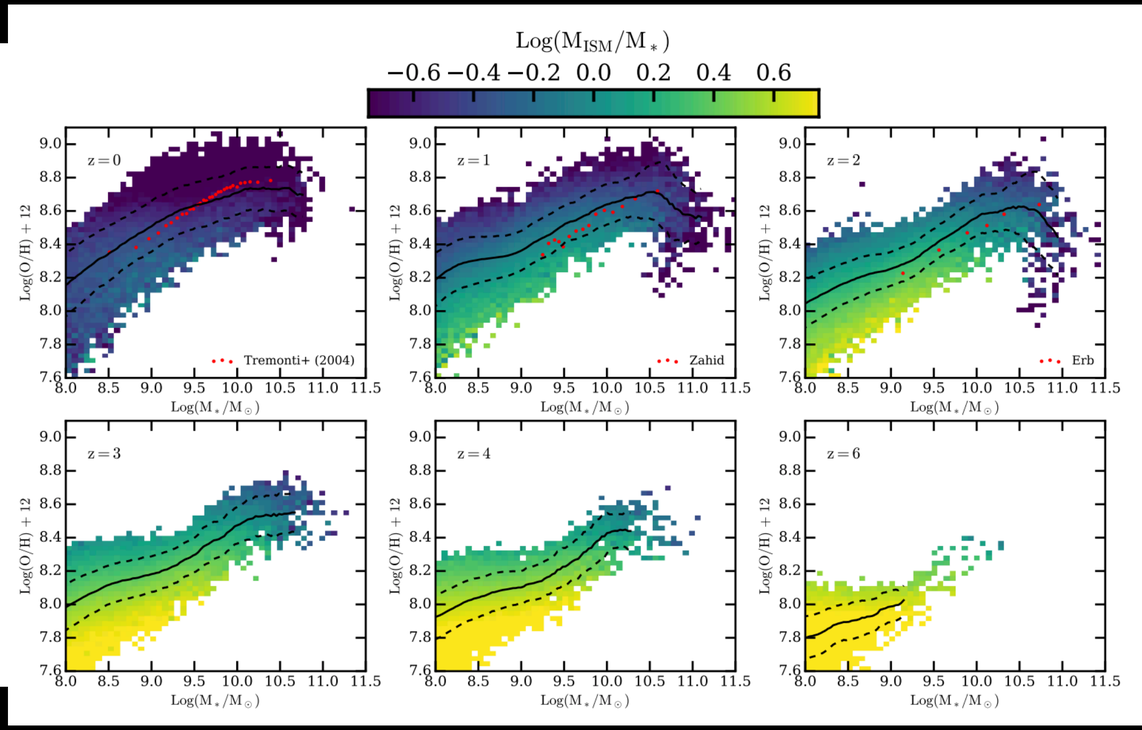
Mass-Metallicity Relation

Correlated scatter with Gas-phase metals

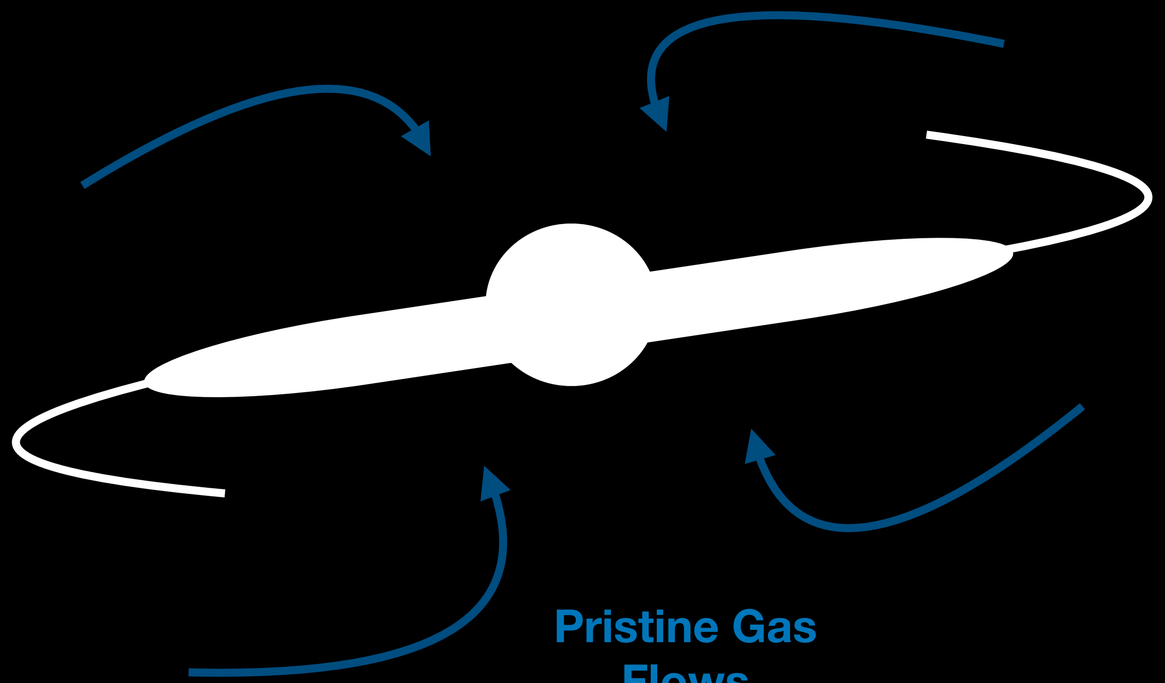


Bothwell+2013



Torrey+2019

Physics behind correlated scatter



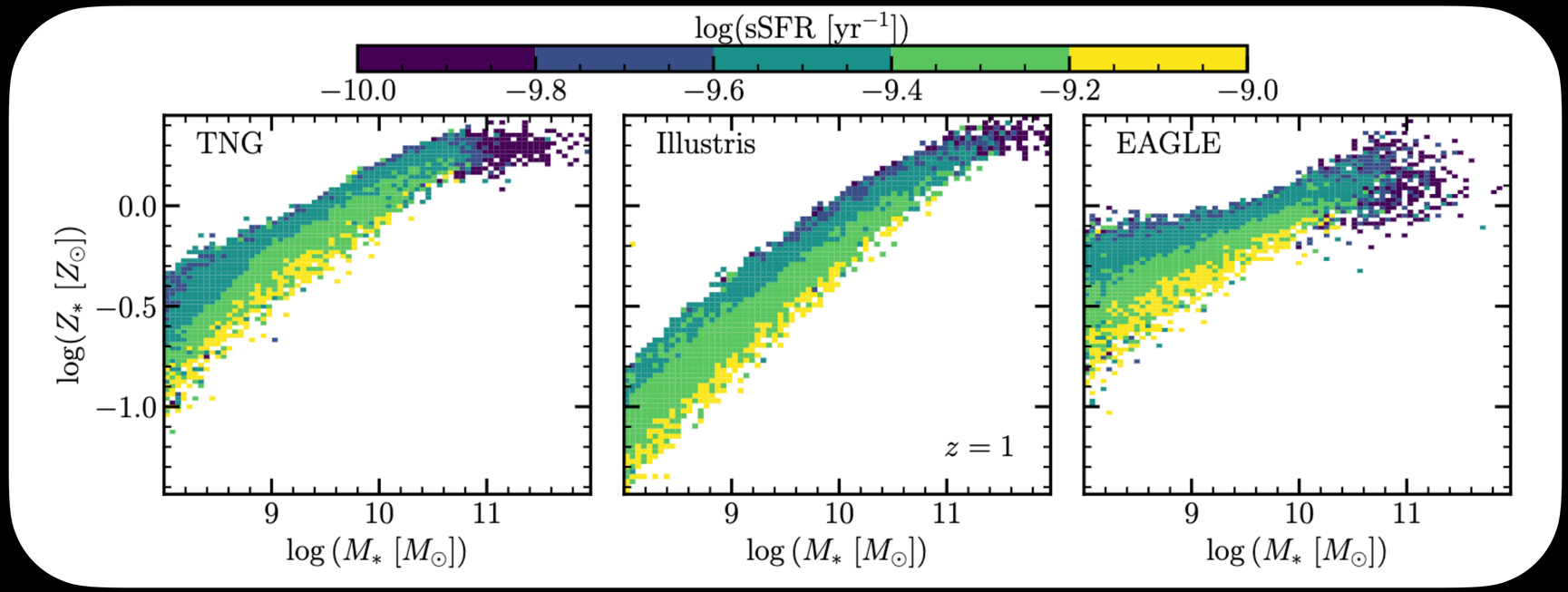
Pristine gas increases the richness of the galaxy

- Decreases the metallicity
- SFR increases! (Ellison+2008)

Stellar metallicities are not *directly* impacted by gas accretion!

On global scales

“And yet it moves!”



Garcia+(In Prep)

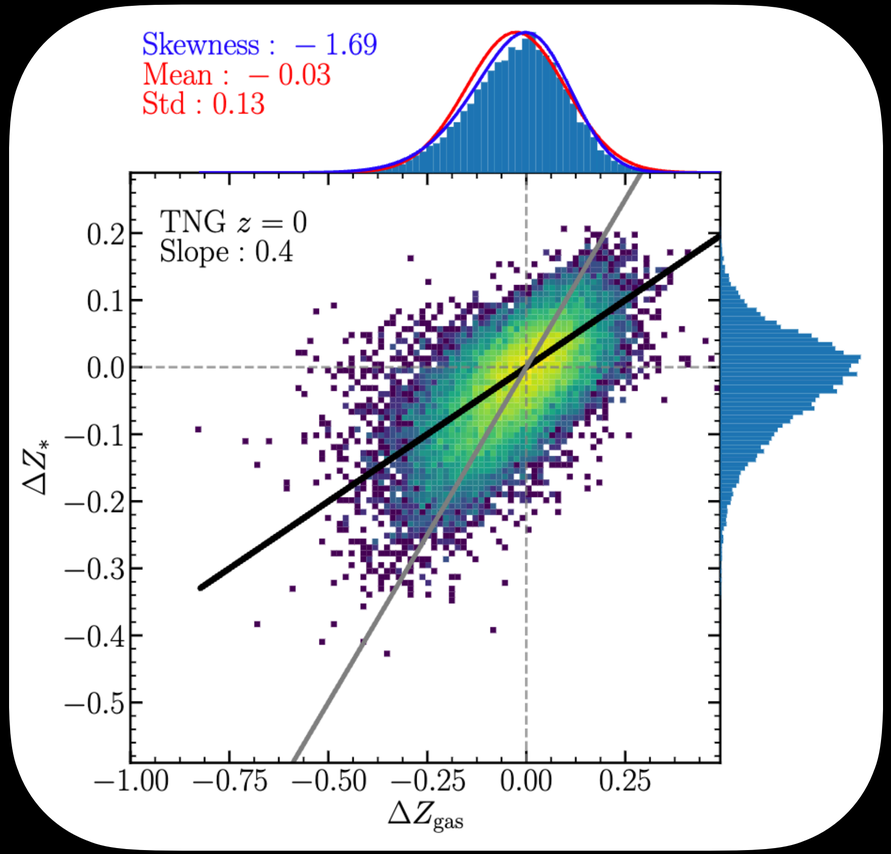
In gentle feedback models we find evidence for an analogous residual correlation with stellar metallicities

Where does this residual correlation originate?

Though not *directly* influenced, stars will feel the effects of gas accretion over time

A galaxy's offset from both the stellar MZR and gas-phase MZR are correlated

The more tightly correlated stellar and gas-phase metals are: the steeper the relationship



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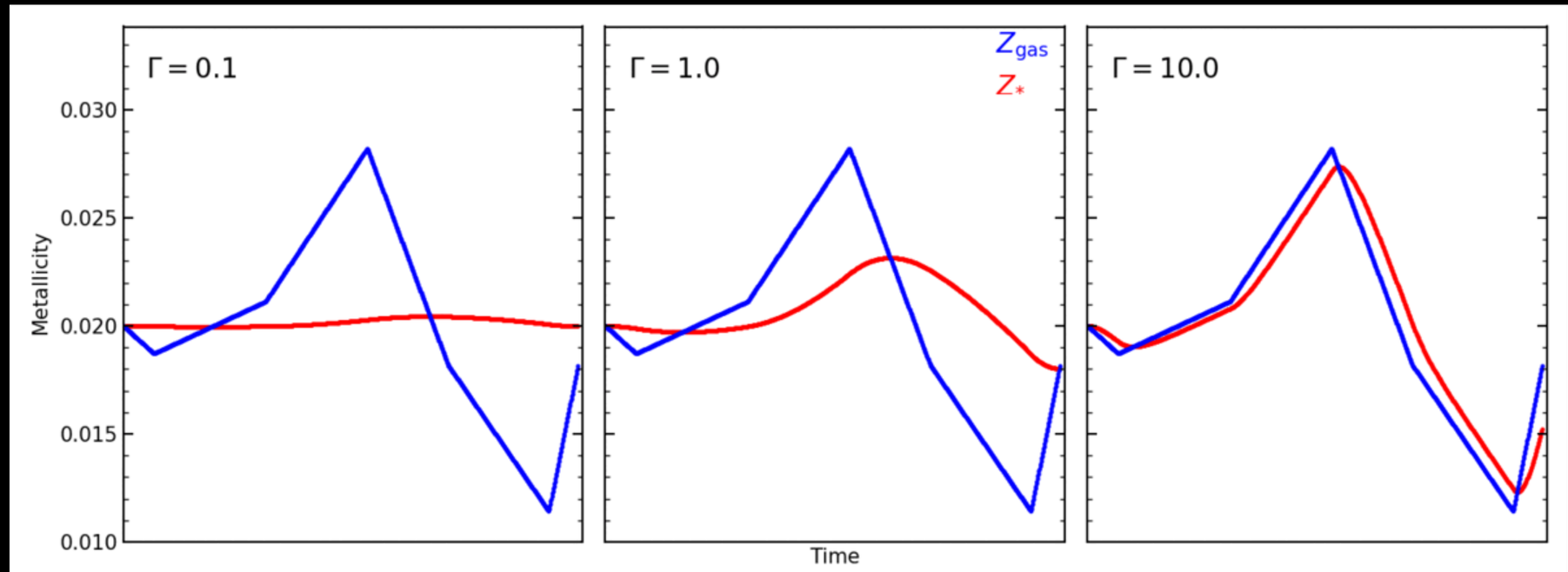
Tightness of correlation

More timescales!

Coherence timescale -> timescale on which gas-phase metals change

Star formation timescale -> timescale on which gas makes new stars (i.e., stars can catch up to gas)

$$\Gamma = \frac{\tau_C}{\tau_{\rm SF}}$$



BUT! This (likely) depends on the model

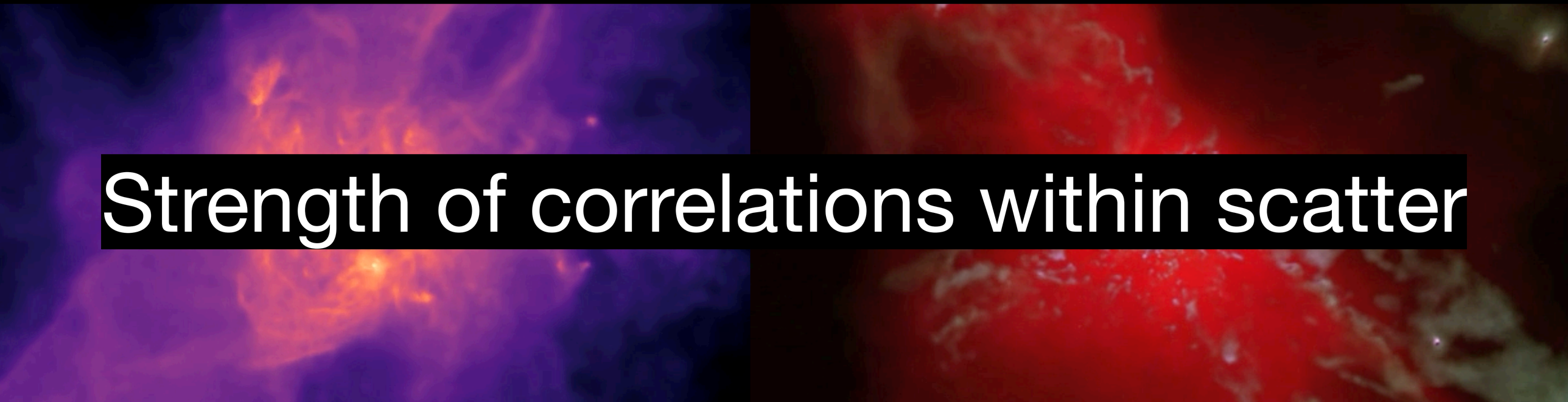
Gentle Feedback

Implicitly assumed

Allow system to respond

Bursty Feedback

Bursts likely interrupt/stop this process!



Strength of correlations within scatter

Are there observable ways to distinguish between feedback models?

Potentially

Strength of metallicity gradients

Time variation of spatial extent (break) of gradients

Correlations within scatter within stellar mass-stellar metallicity relation