Unveiling the roles of mass, environment and structure in galaxy quenching

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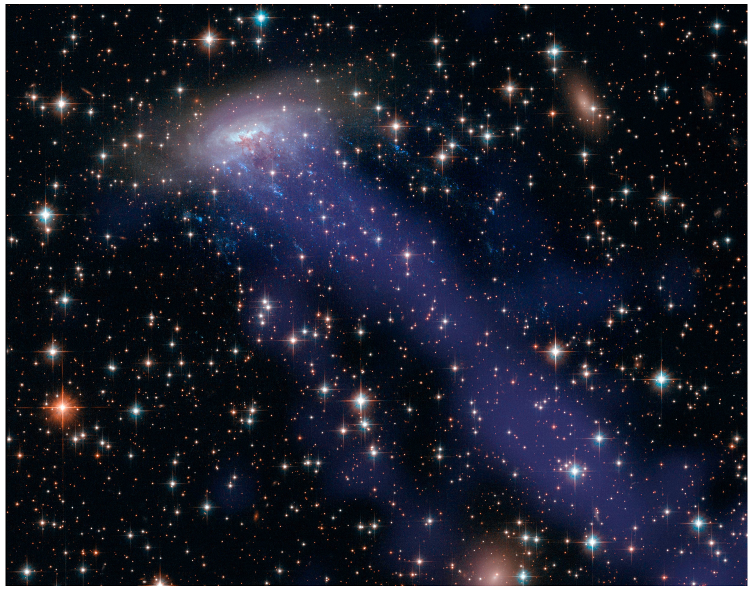
Quenching mechanisms

Mass

- Stellar feedback
- AGN feedback
- Halo quenching

Environment

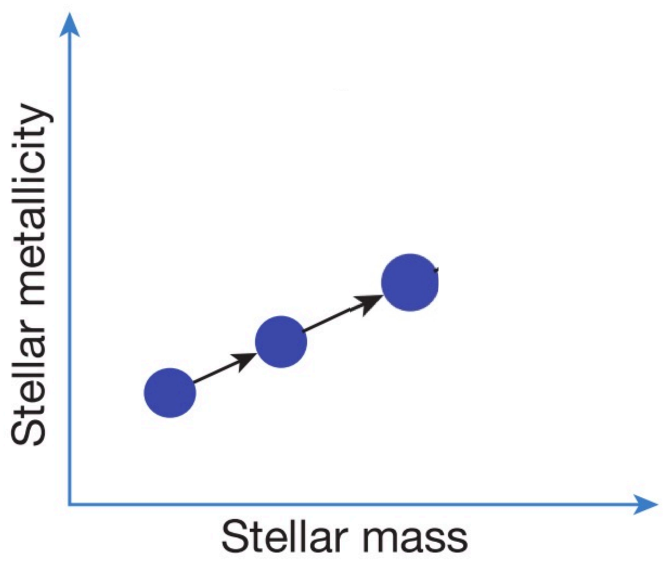
- Ram pressure stripping
- Harassment
- Strangulation

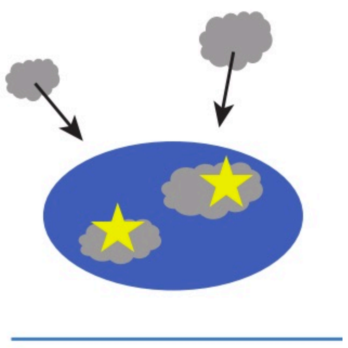


e.g. Moore+96, Keres+05, van den Bosch+08, Cicone+14, Poggianti+17

How does galaxy quenching depend on **mass**, **environment** and **redshift**?

Distinguishing between different quenching mechanisms

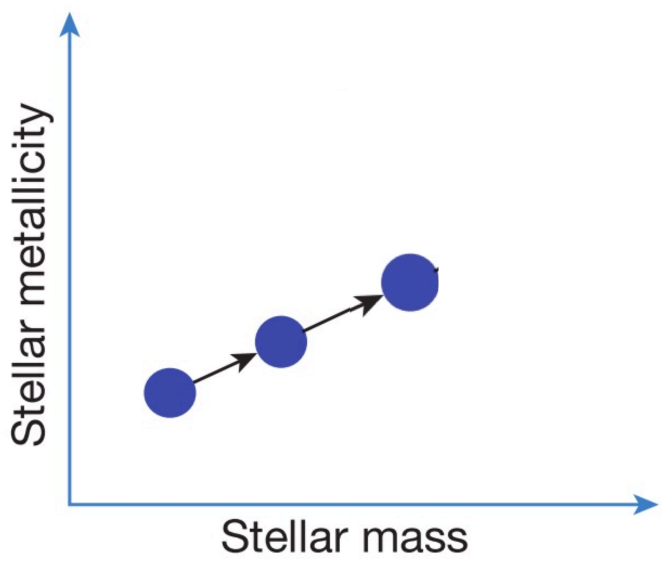


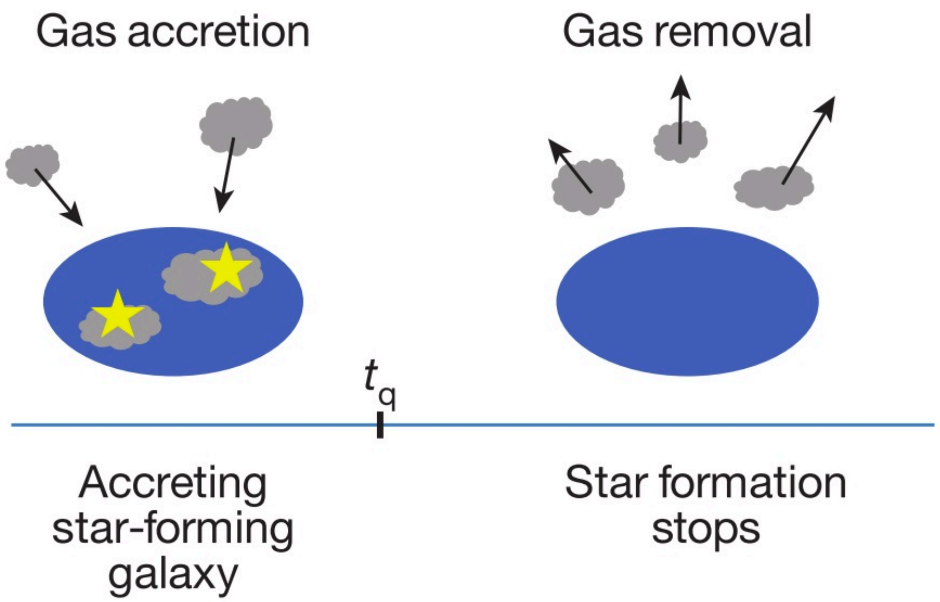


Peng+15

Distinguishing between different quenching mechanisms

Quenching by sudden gas removal





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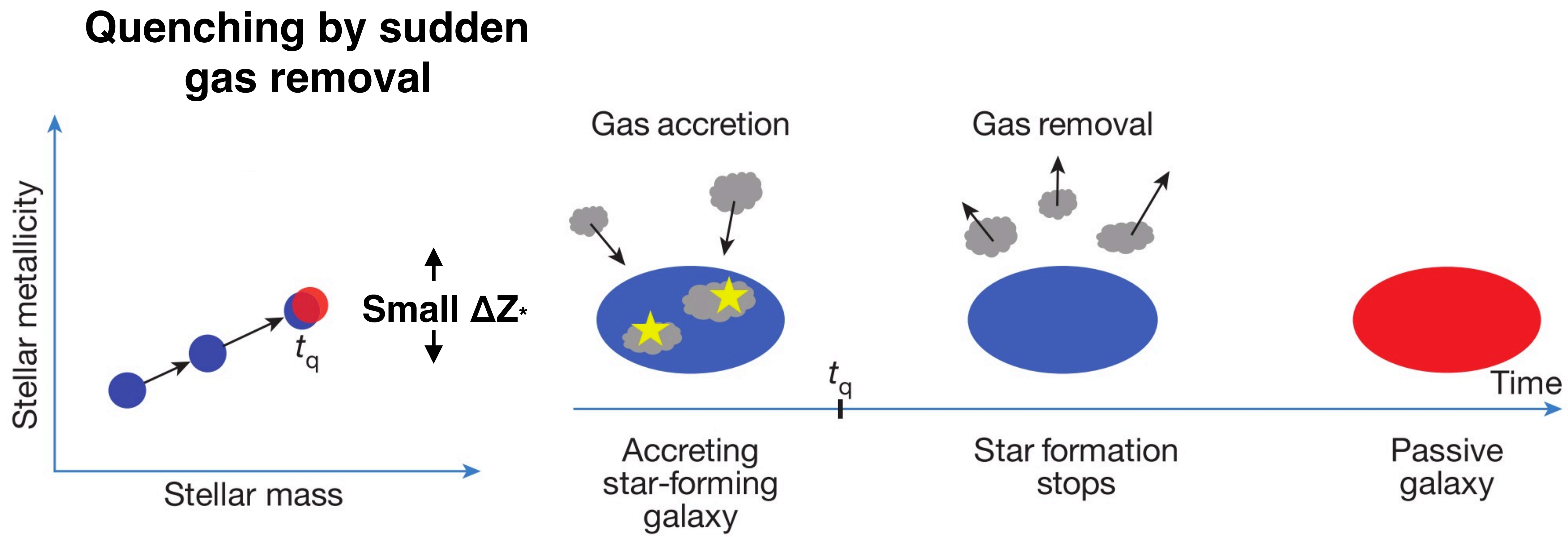

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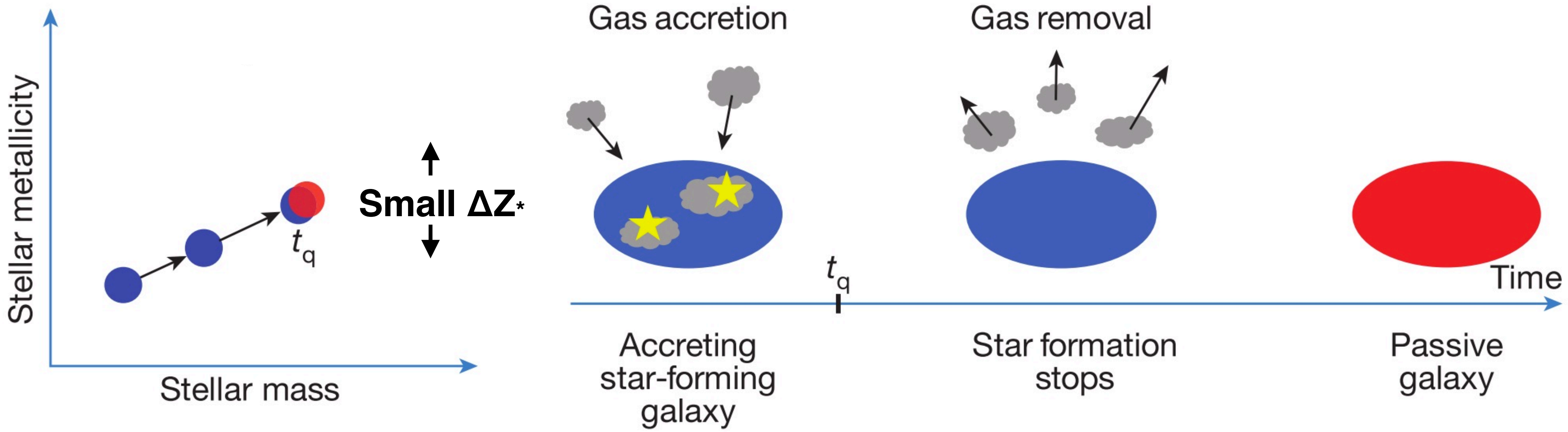
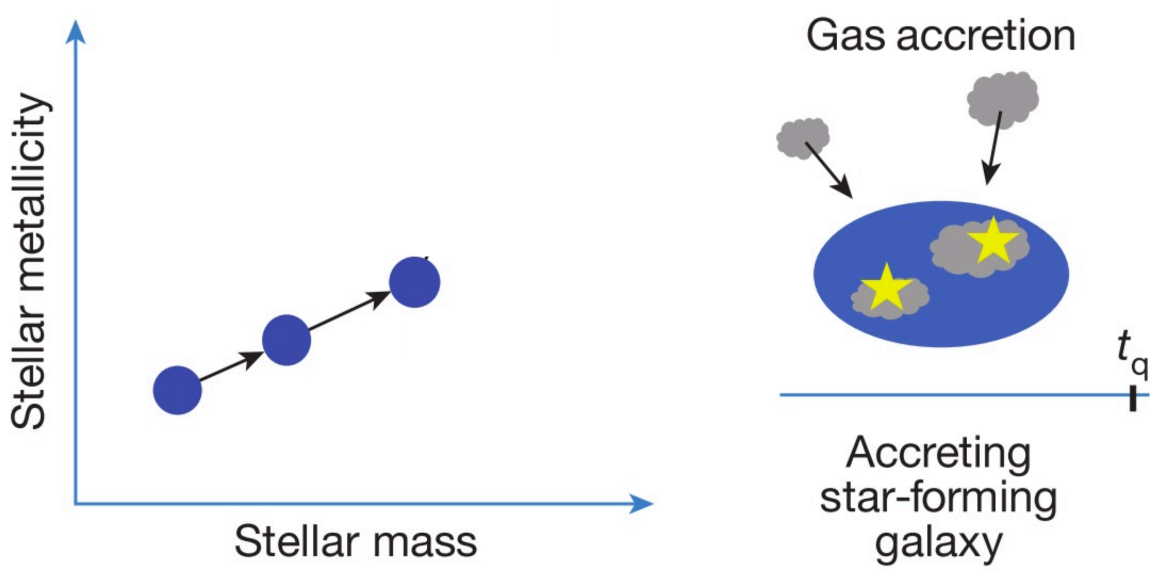


Peng+15

Quenching by starvation



Distinguishing between different quenching mechanisms

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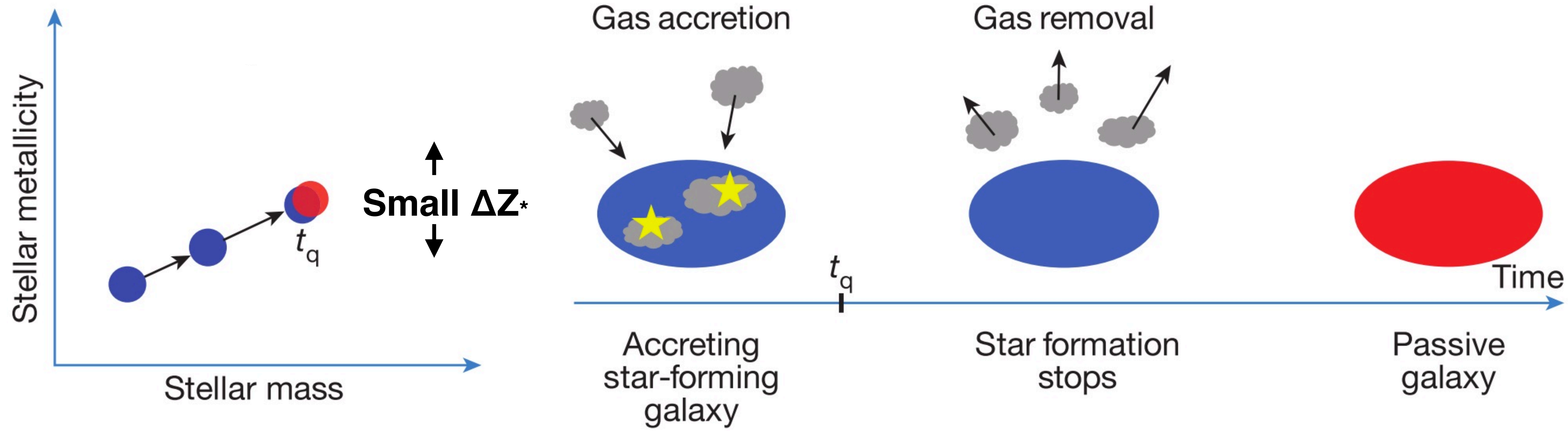

Peng+15

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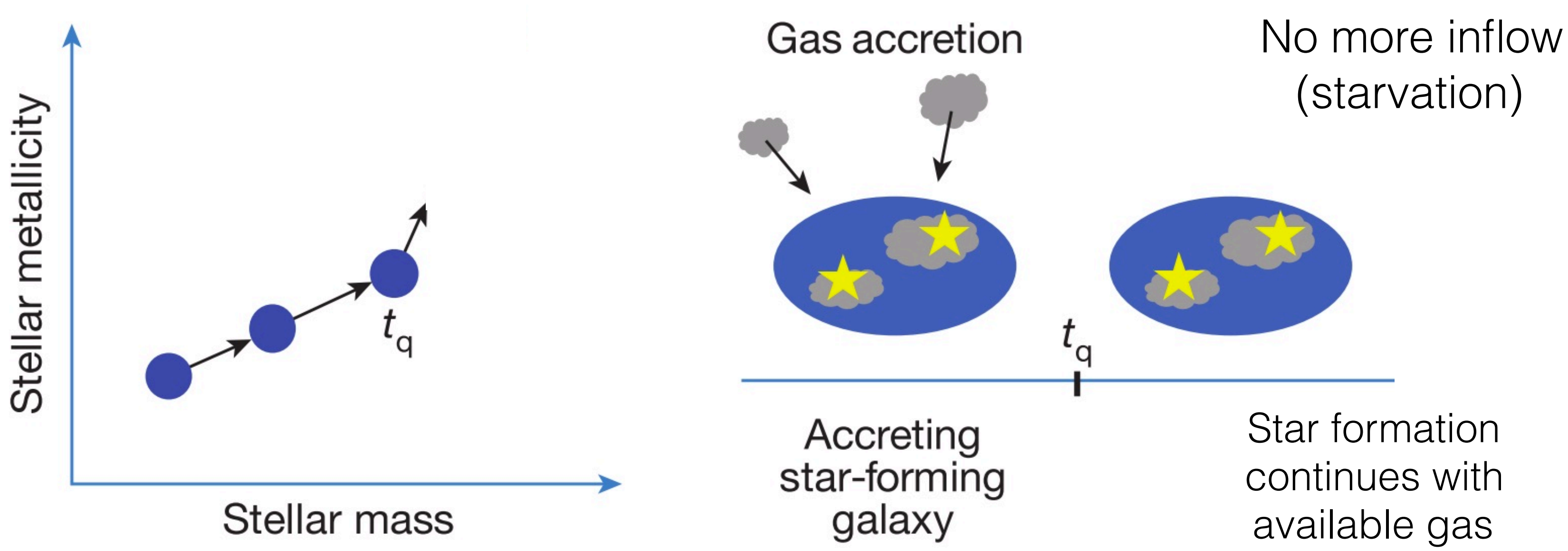

Distinguishing between different quenching mechanisms

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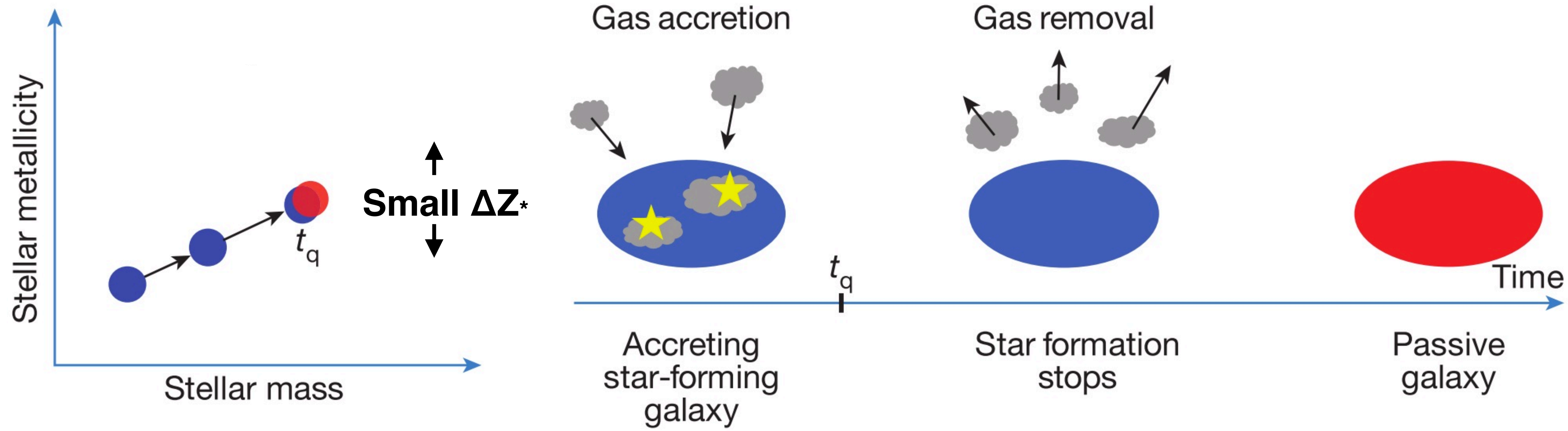

Peng+15

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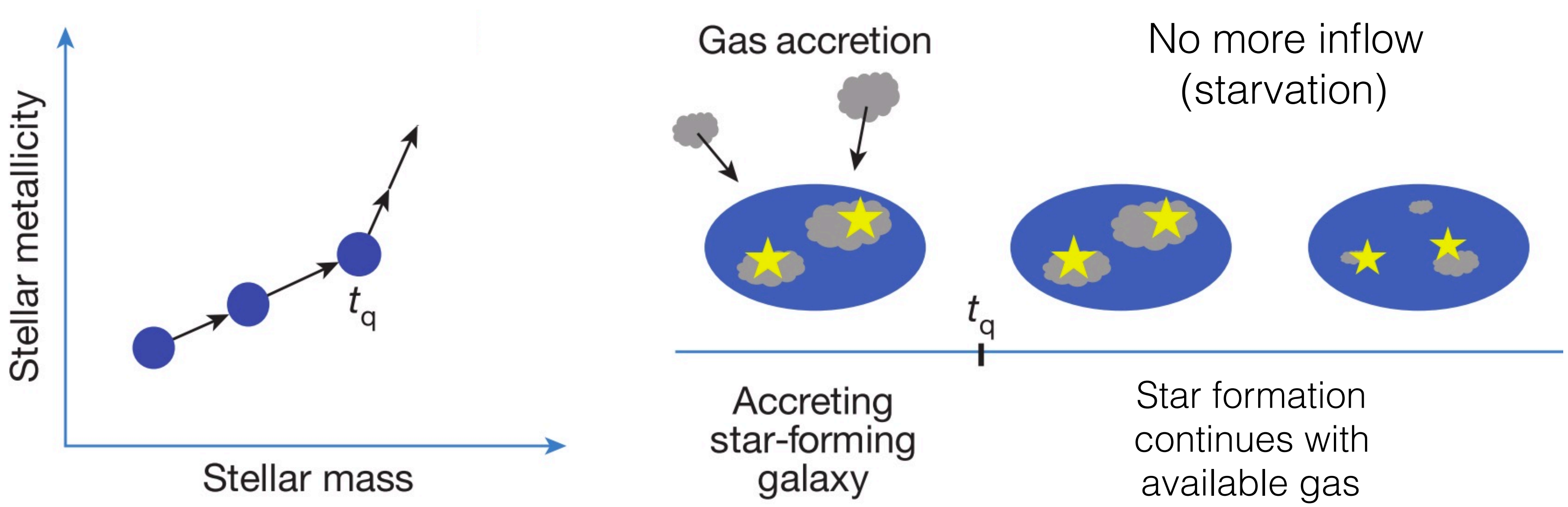

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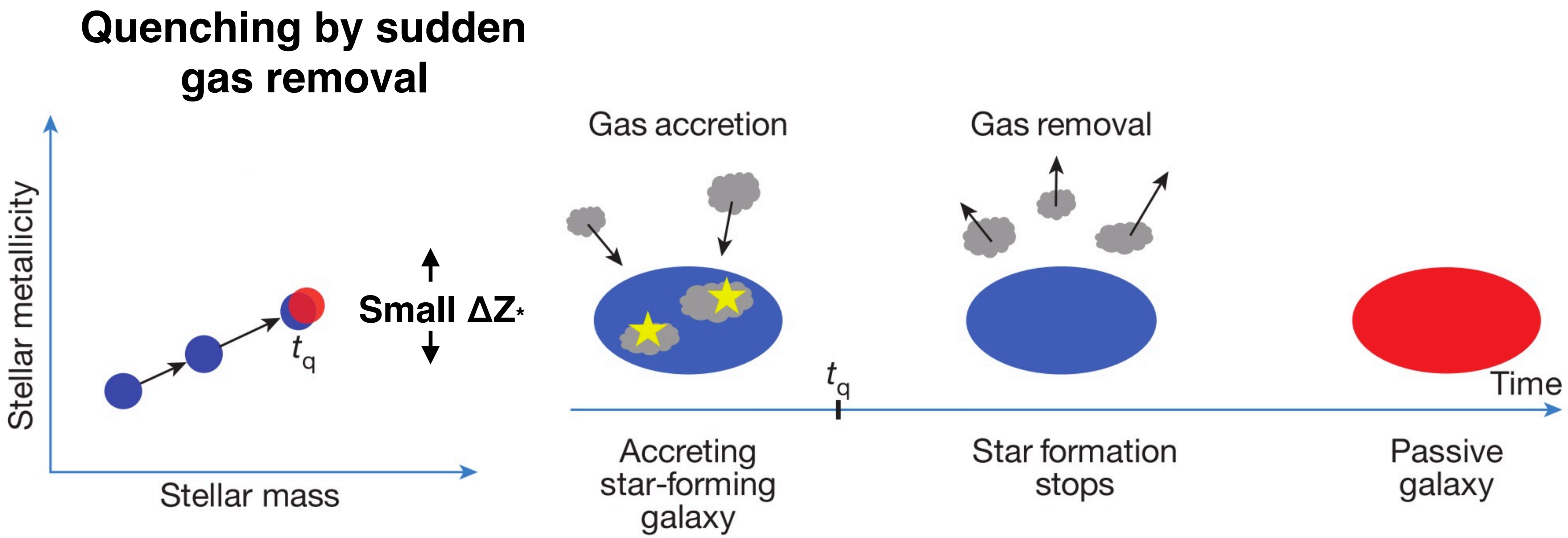

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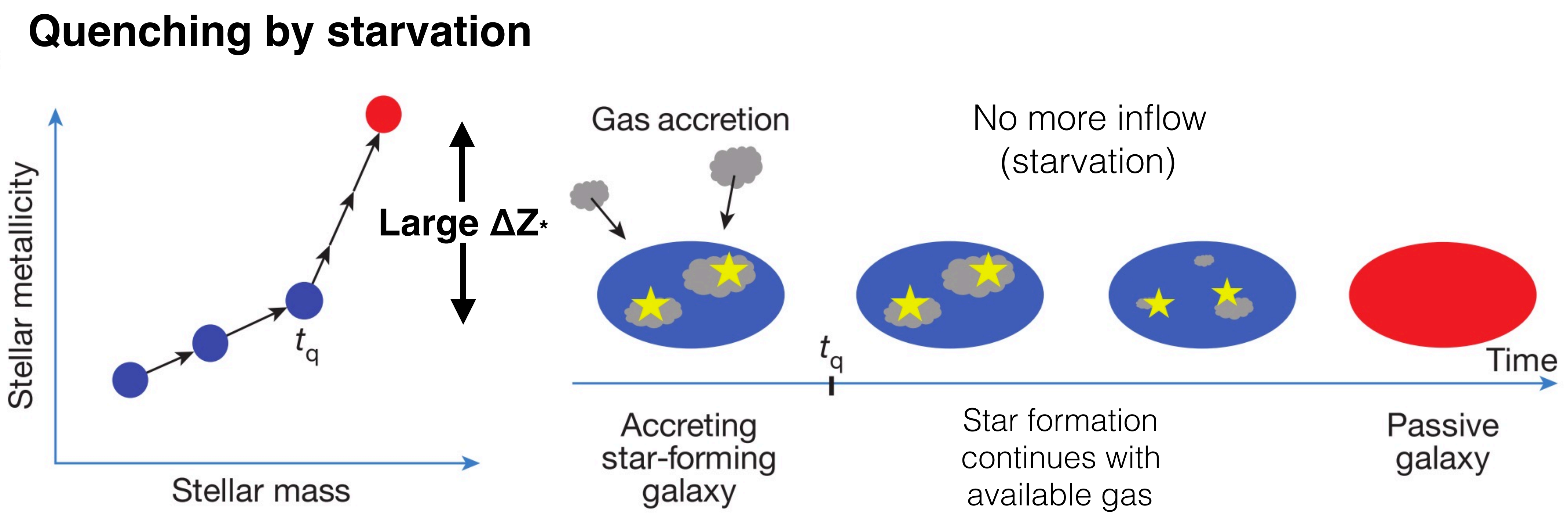

Distinguishing between different quenching mechanisms

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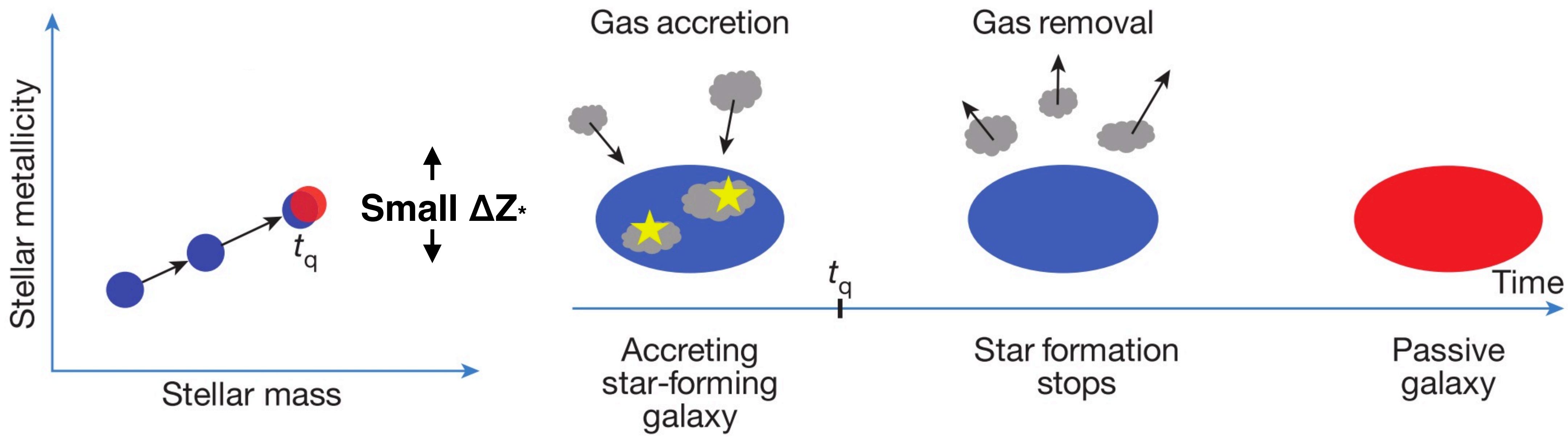

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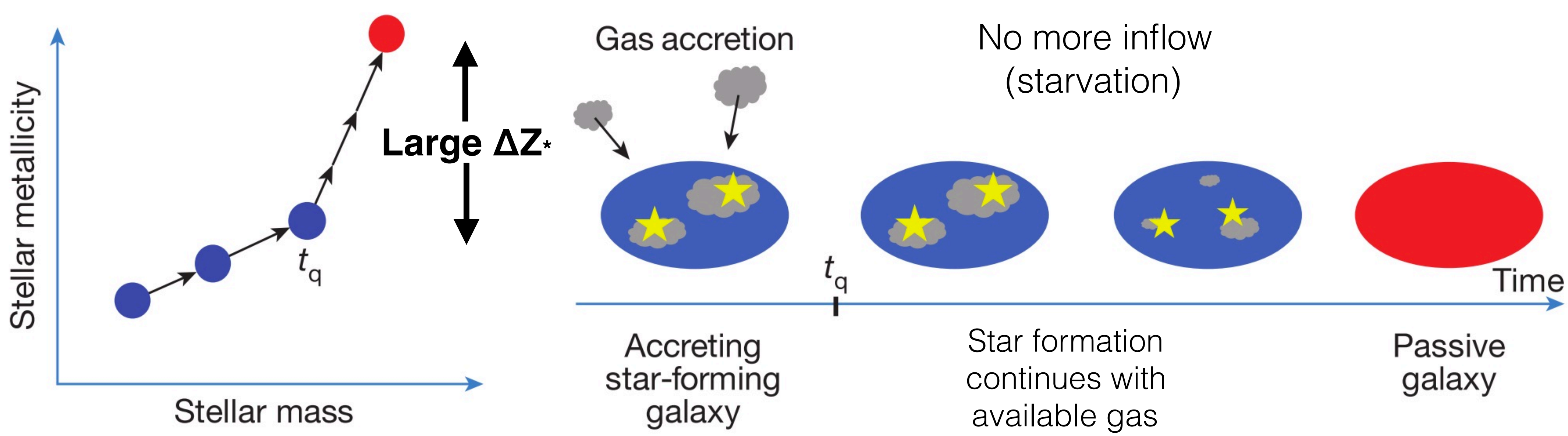
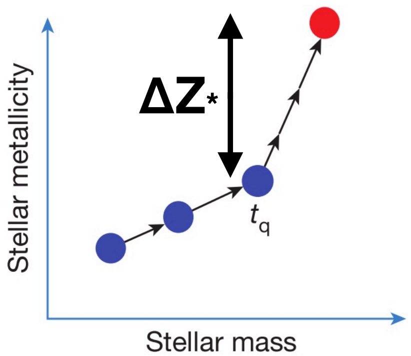
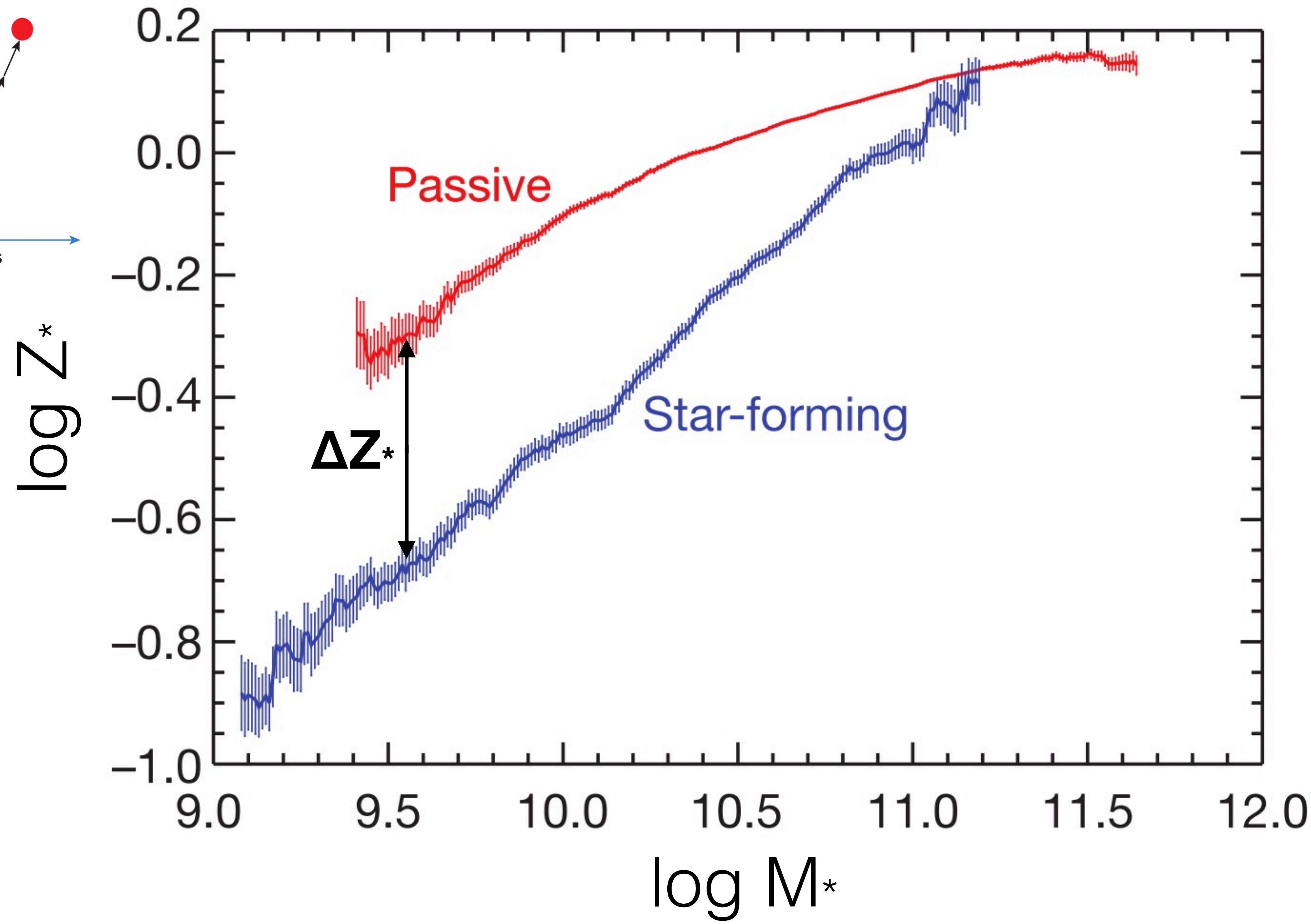


ΔZ_* during quenching depends on the **mechanism!**

Distinguishing between different quenching mechanisms





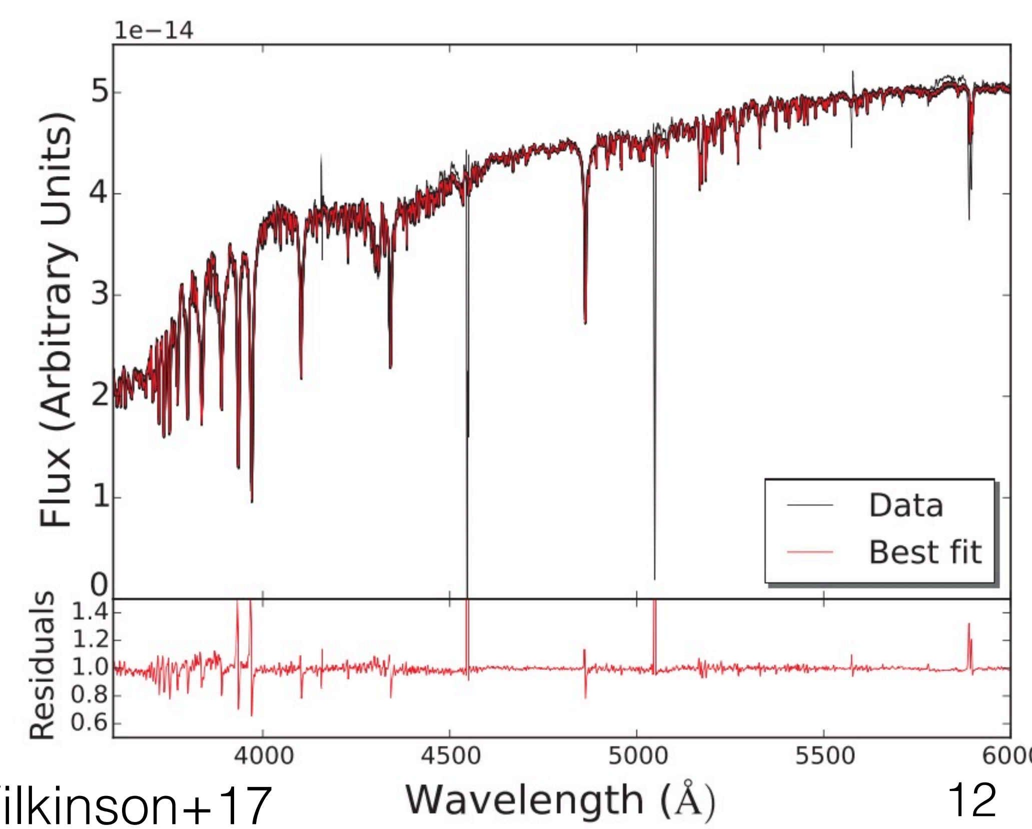
After quenching

Before quenching

ΔZ* between **star-forming** and **passive** galaxies can be used to **distinguish** between different quenching **mechanisms**

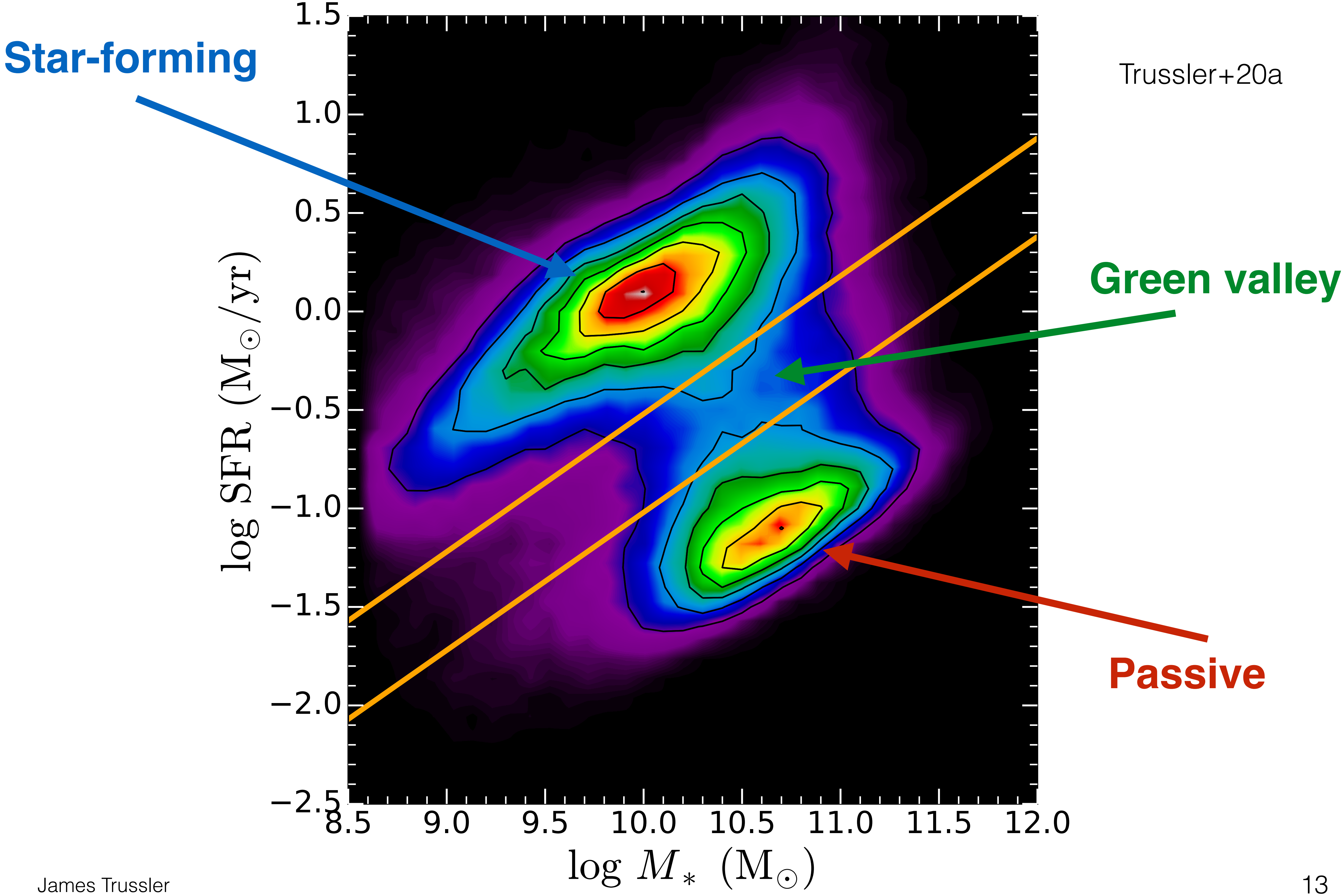
SDSS data

- SDSS DR7
  - ★ 0.02 < z < 0.085 and S/N > 20
  - ★ 80,000 galaxies after cuts
- Mass-weighted stellar metallicities from FIREFLY
- **Centrals**: most massive in group (Yang +07)
- **Satellites**: remaining galaxies in group

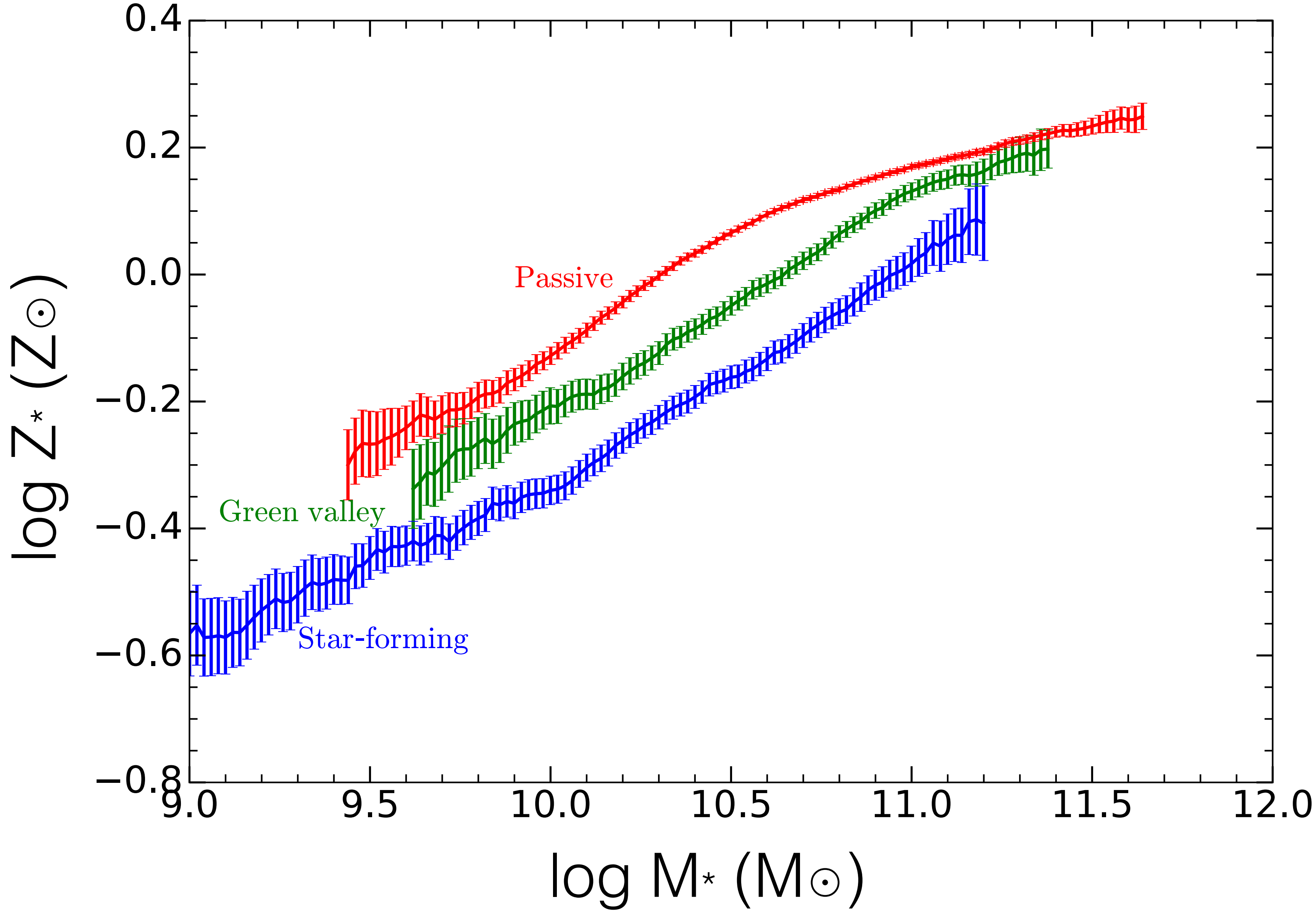


Wilkinson+17

Galaxy classification



Stellar mass–stellar metallicity relation

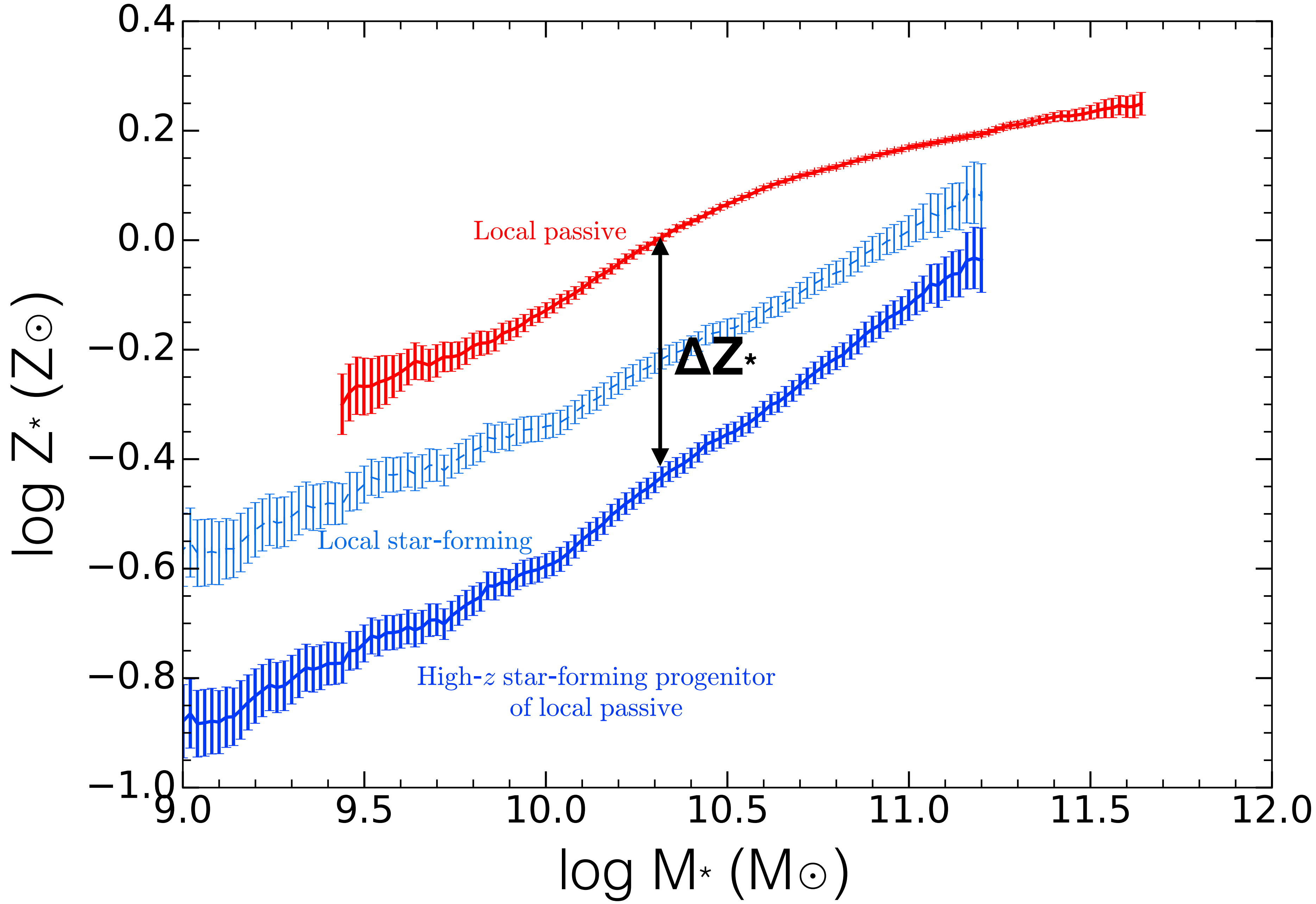


Trussler+20a

There is a significant **difference** in **stellar metallicity** between **star-forming**, **green valley** and **passive** galaxies

This is qualitatively consistent with **starvation**

Quenching at high-z

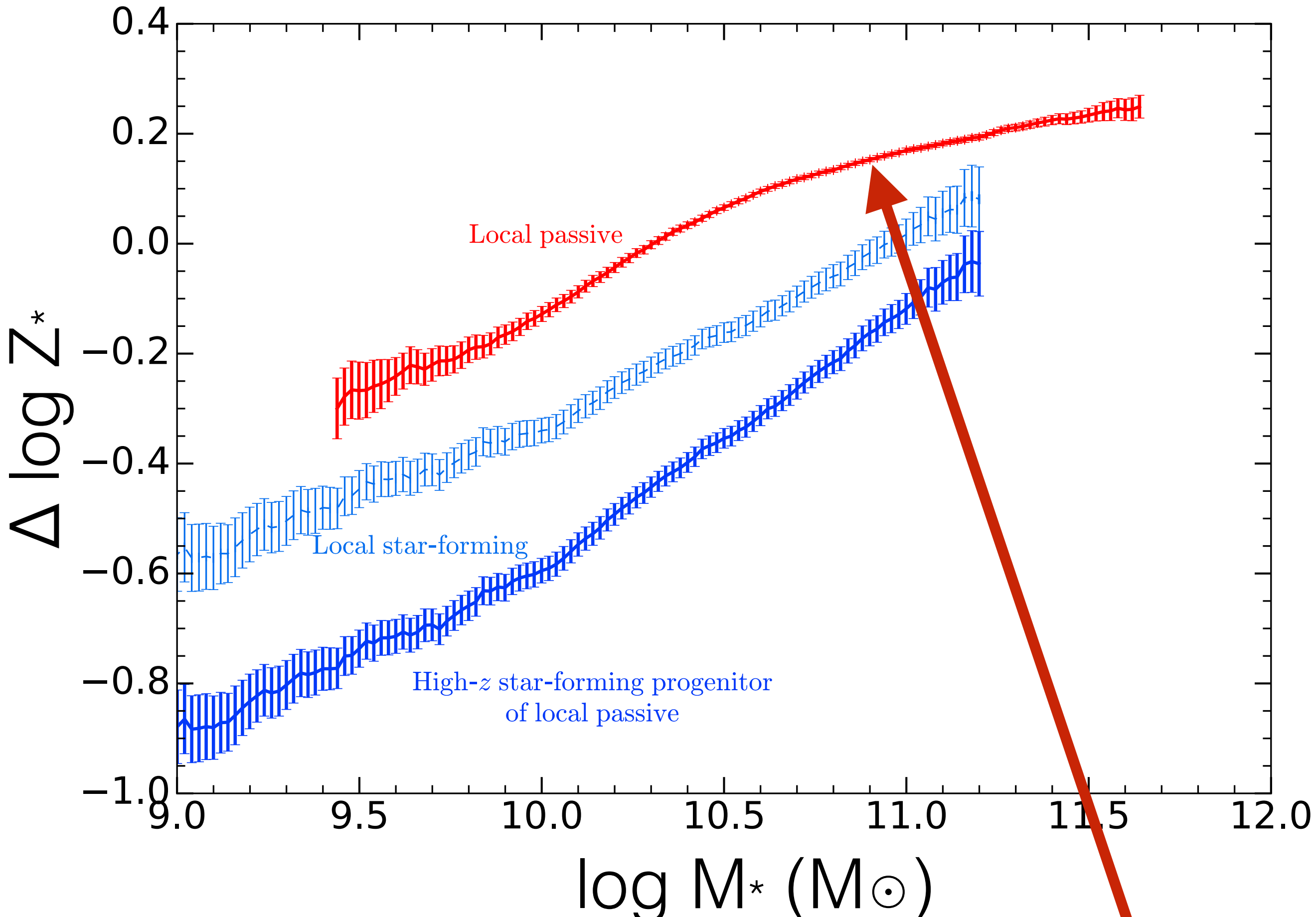


Trussler+20a

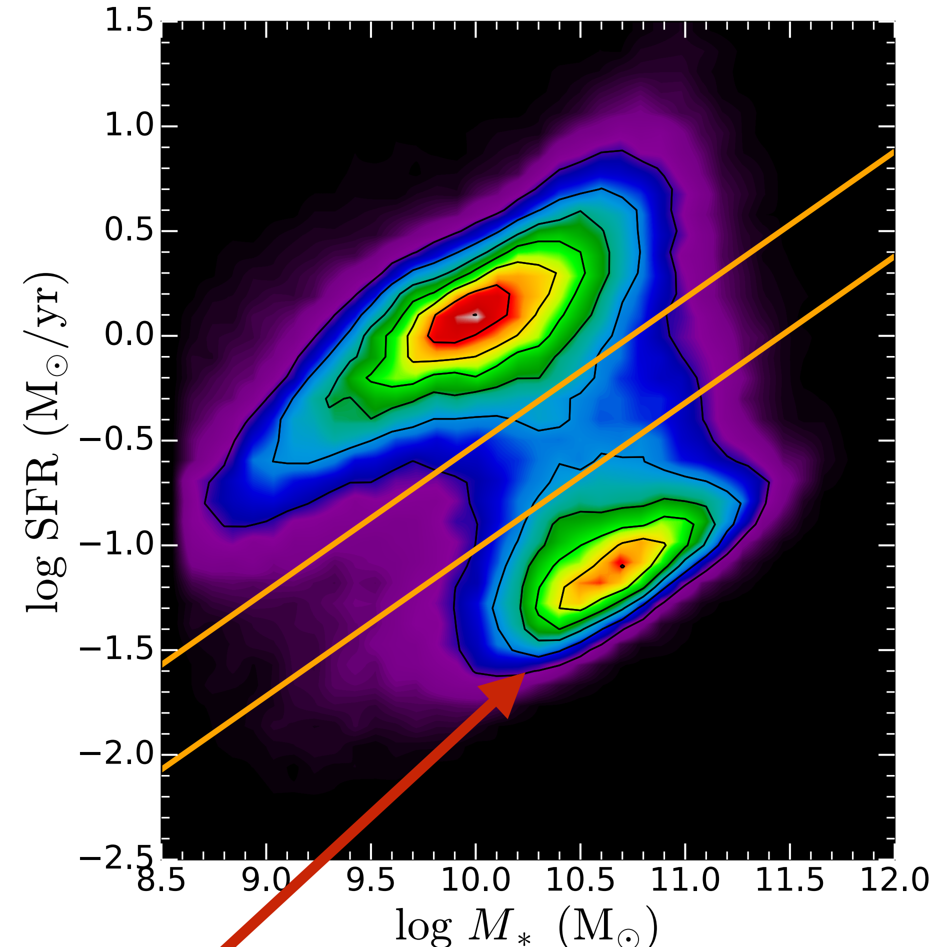
Comparing the stellar metallicity difference between **local passive** galaxies and their **star-forming progenitors** at **higher redshift**

ΔZ* larger, so even stronger evidence for **starvation**

Simultaneously matching Z_* and SFR



Trussler+20a

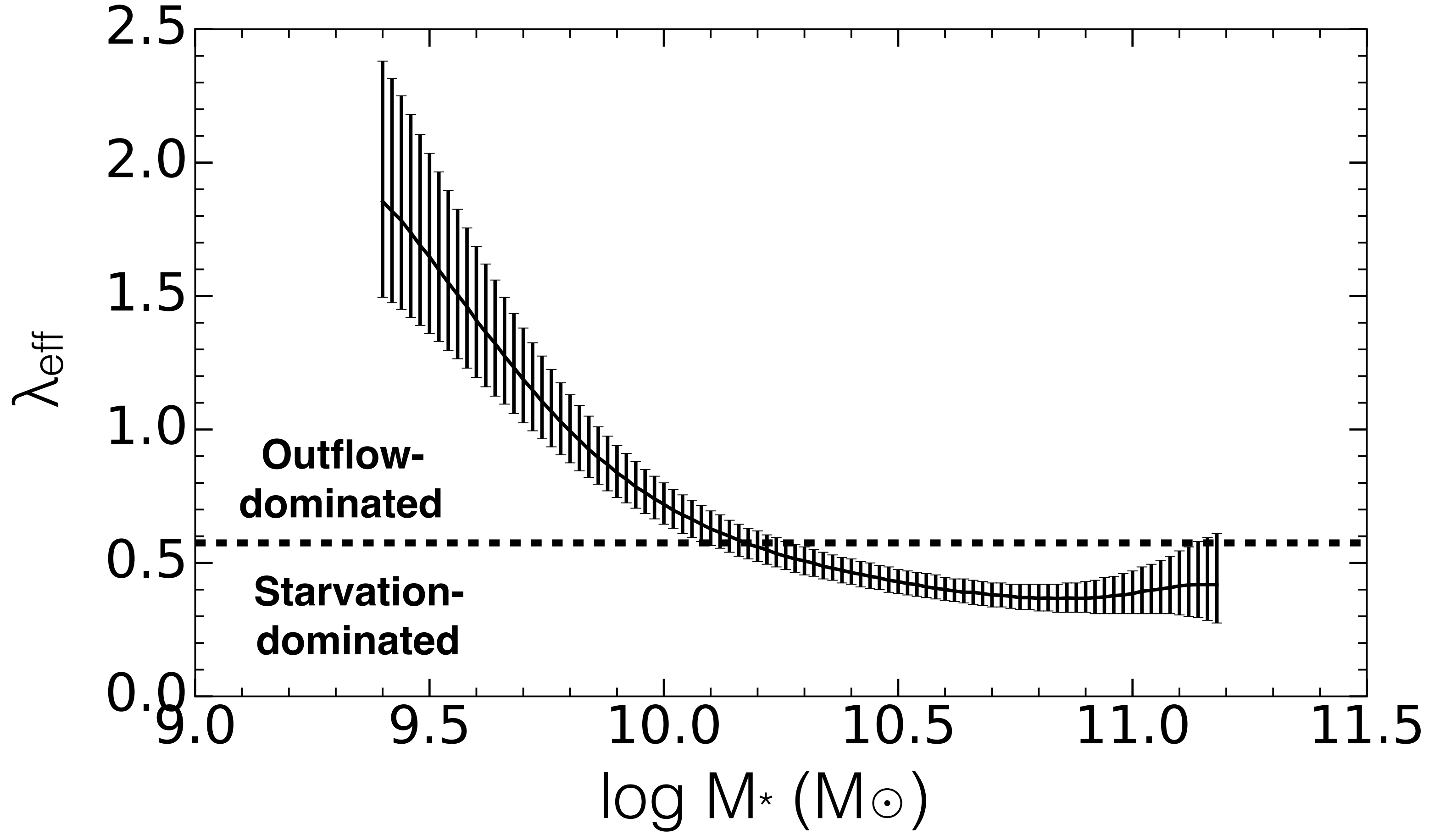


The aim here is to **simultaneously** reproduce the observed **ΔZ_*** and the **low SFR** of local **passive** galaxies

Only a **narrow range** of **λ_{eff}** values can satisfy **both** quenching criteria

Mass-loading factor λ_{eff}

Trussler+20a

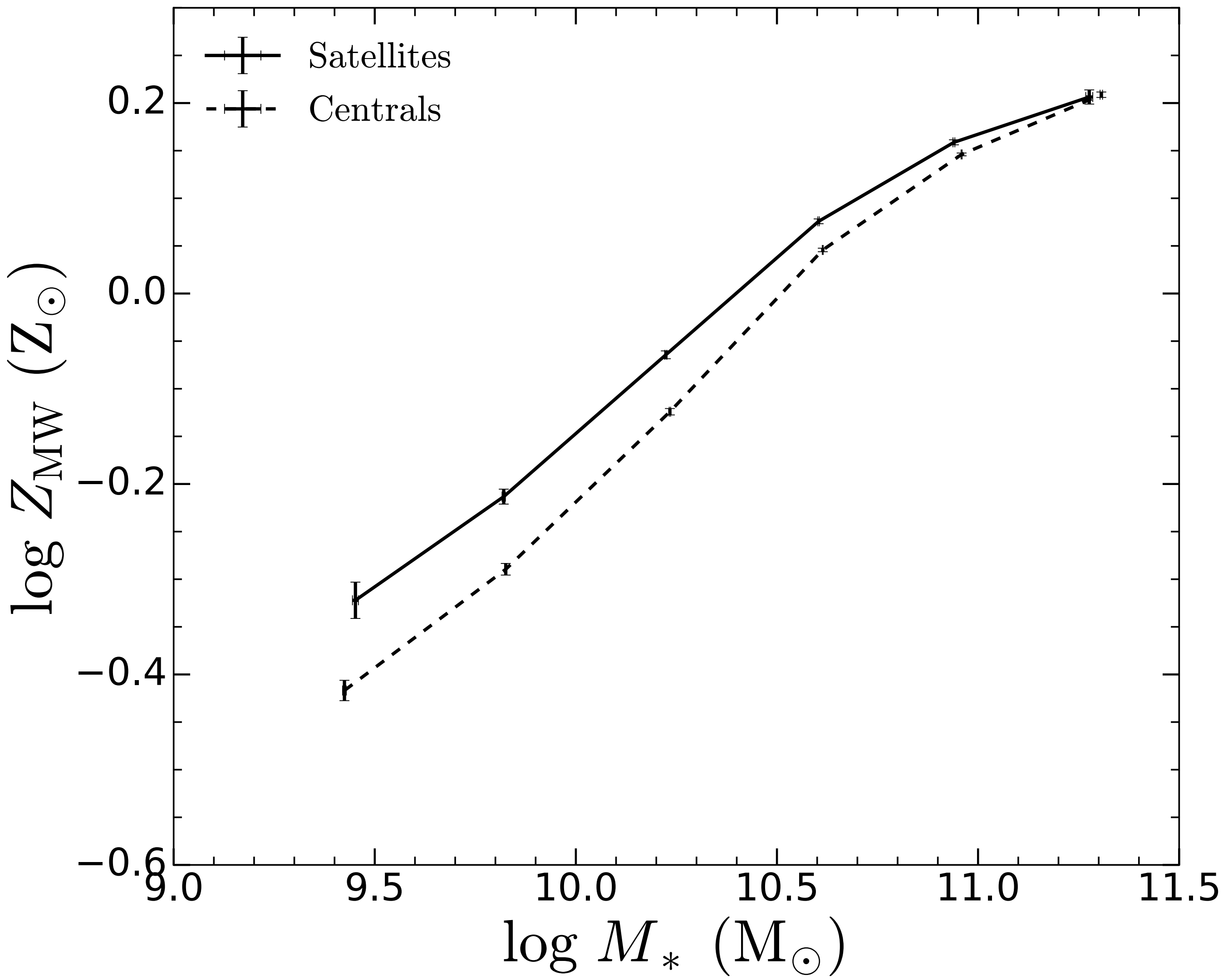


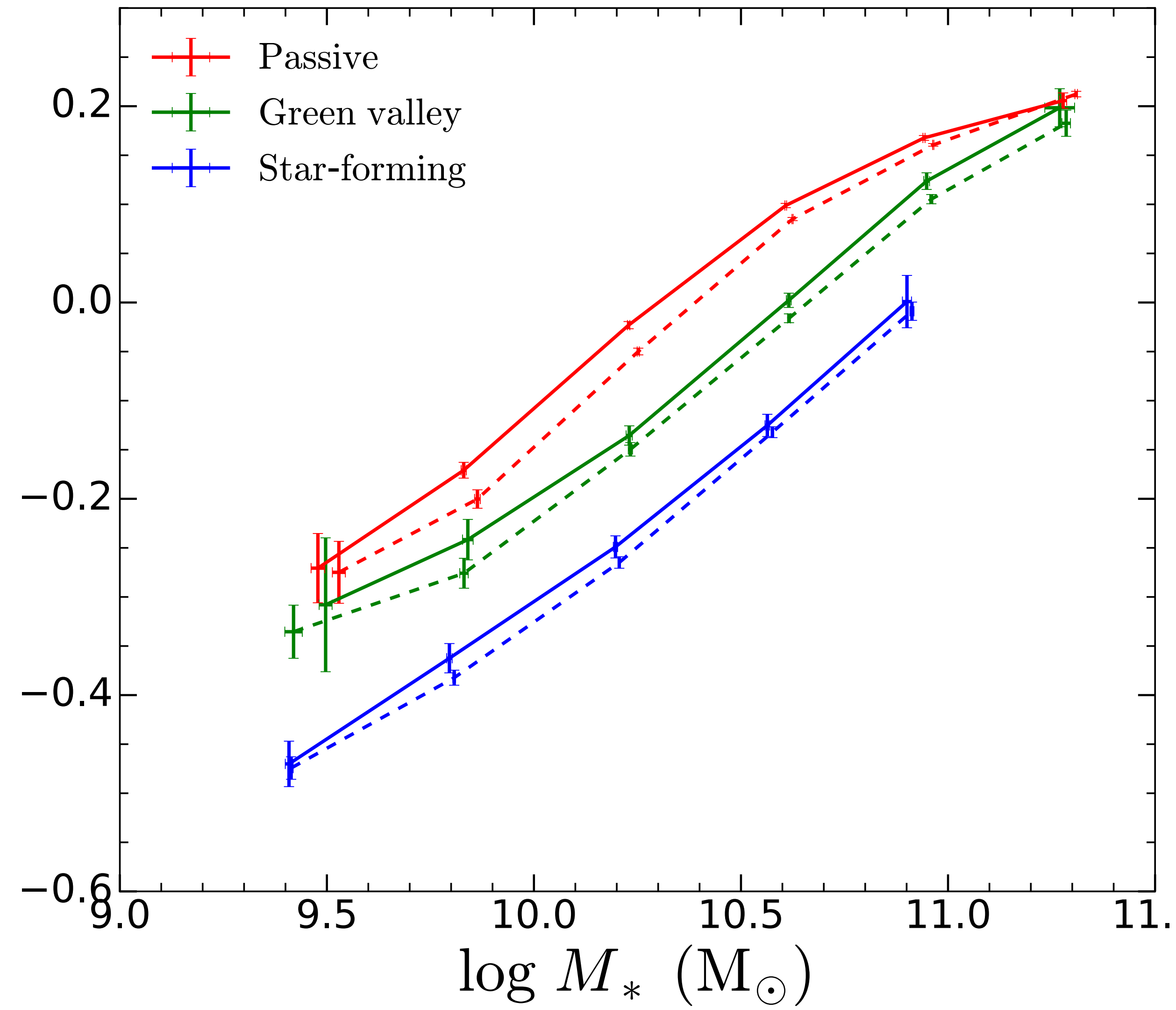
$\boldsymbol{\lambda_{eff}}$ decreases with M_*, indicating that **outflows** are of increasing importance in **low-mass** galaxies

Most of the outflowing gas **does not escape** from **massive** galaxies, and is **recycled**

Central–Satellite dichotomy

Trussler+20b



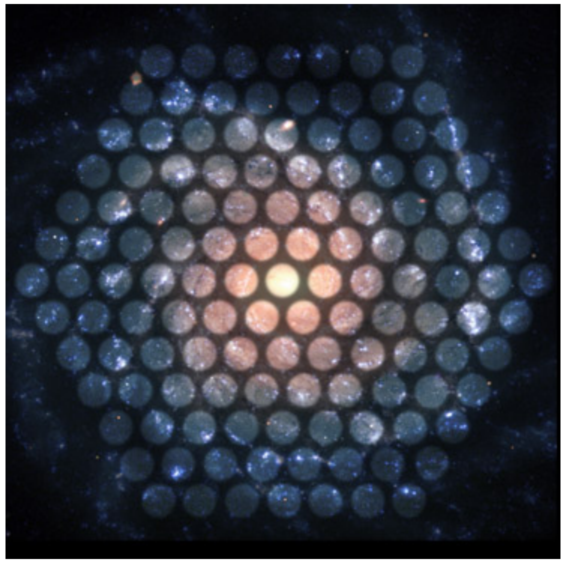


After separating, **star-forming**, **green valley** and **passive** galaxies, we find that the **true** environmental dependence is in fact much **weaker**

Satellites are only **marginally** more metal-rich than **centrals** of the same stellar mass

SDSS-IV MaNGA

- **Spatially-resolved** spectra of 10,000 galaxies



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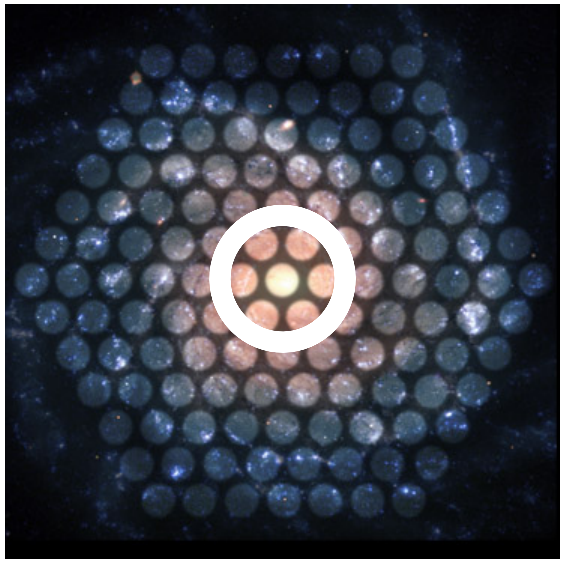

- **Spatially-resolved** spectra of 10,000 galaxies
- Divide galaxy into **annuli**

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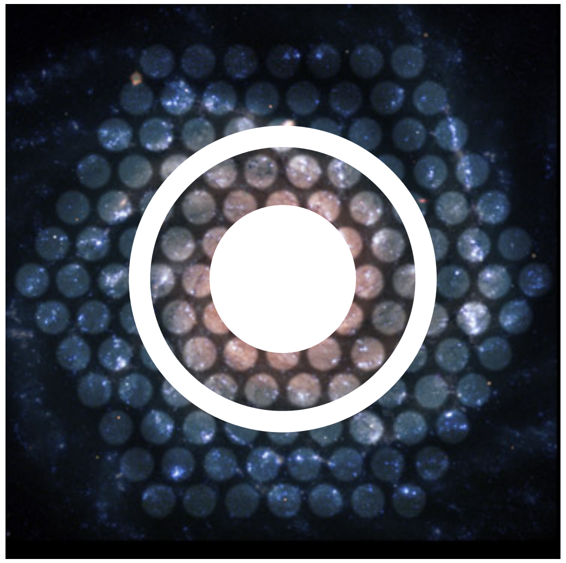

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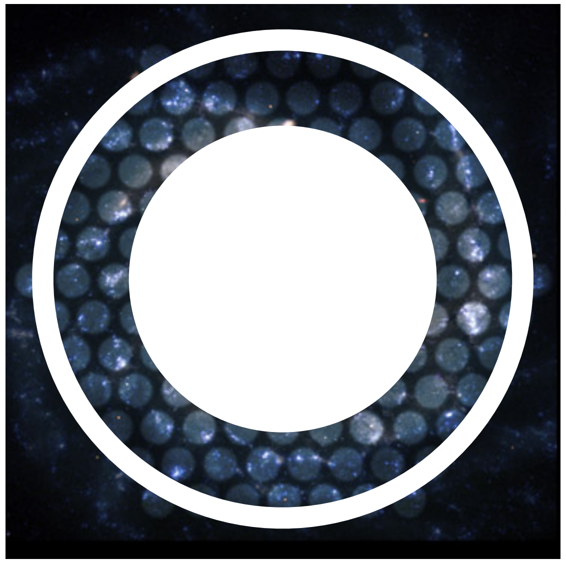
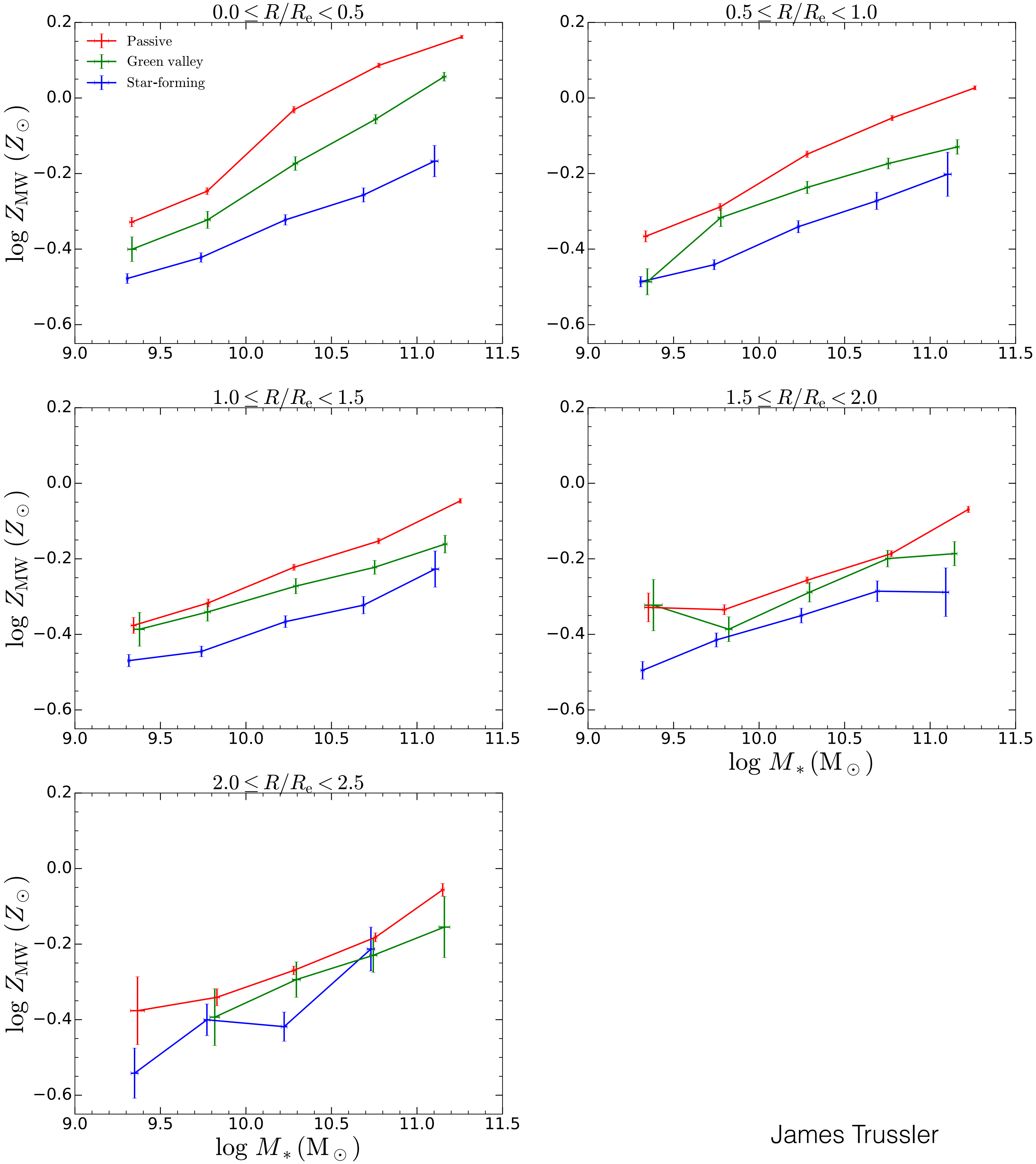


- **Spatially-resolved** spectra of 10,000 galaxies

- Divide galaxy into **annuli**

- Can investigate how **quenching** operates on a **radial basis within galaxies**

Stellar mass–stellar metallicity relation

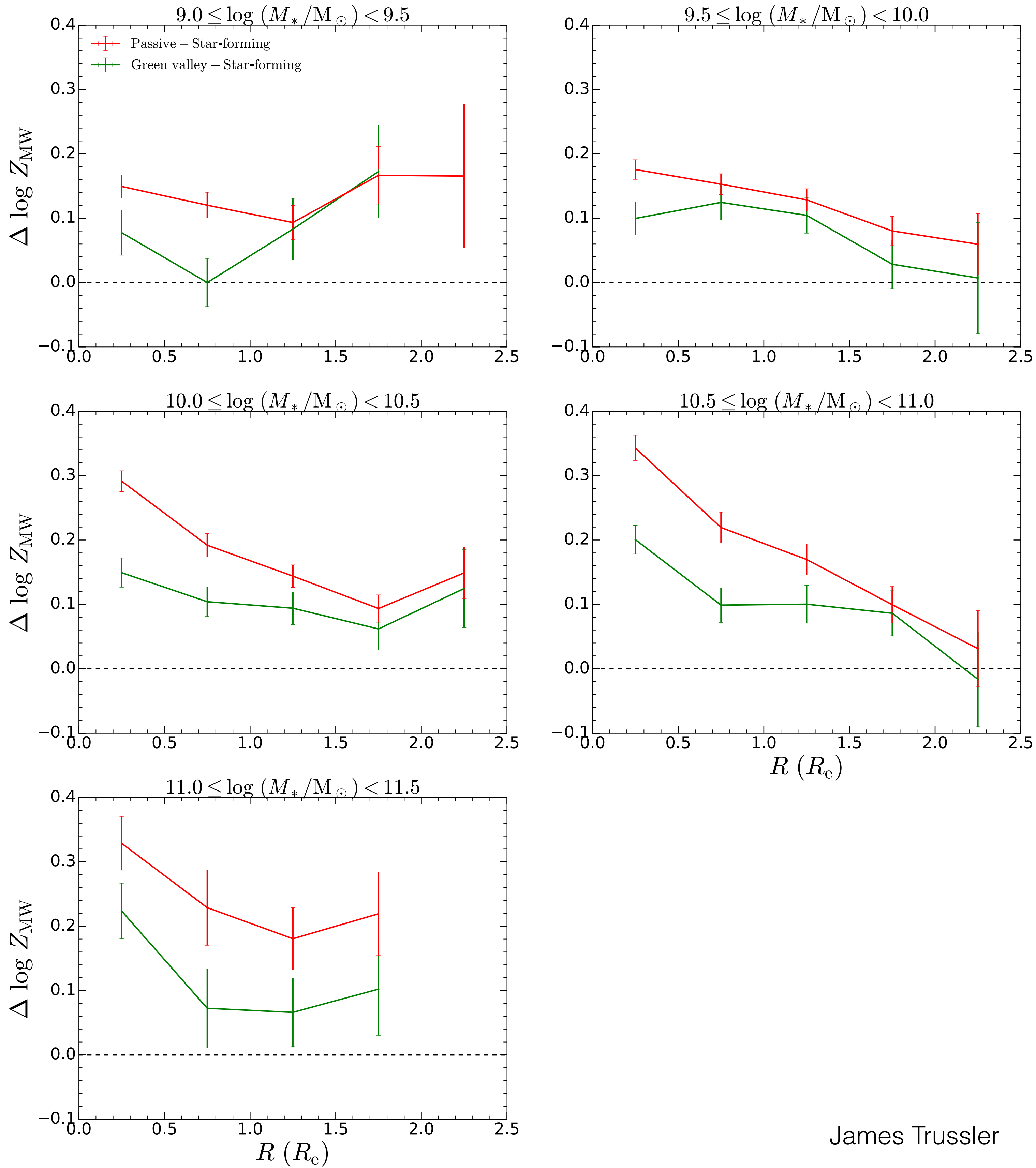


Trussler+20c

Passive galaxies are more metal-rich than **star-forming** galaxies at **all radii**

Starvation is a primary driver of quenching at **all radii**

Radial stellar metallicity difference



Trussler+20c

The stellar metallicity difference **decreases** with **increasing radial distance**

Starvation plays a prominent role in quenching the **central** regions

Starvation plays an increasingly less important role in quenching the **outskirts**

Summary

1. **Stellar metallicity**

    - The stellar metallicity differences between **star-forming**, **green valley** and **passive** galaxies can be used to **distinguish** between different quenching mechanisms

2. **Mass**

    - The **prominent stellar metallicity difference** between **local passive** galaxies and their **star-forming progenitors** indicates that for galaxies at all masses, quenching likely involved a phase of **starvation**

    - **'Effective' outflows** are, together with starvation, of **increasing importance in low-mass** galaxies

3. **Environment**

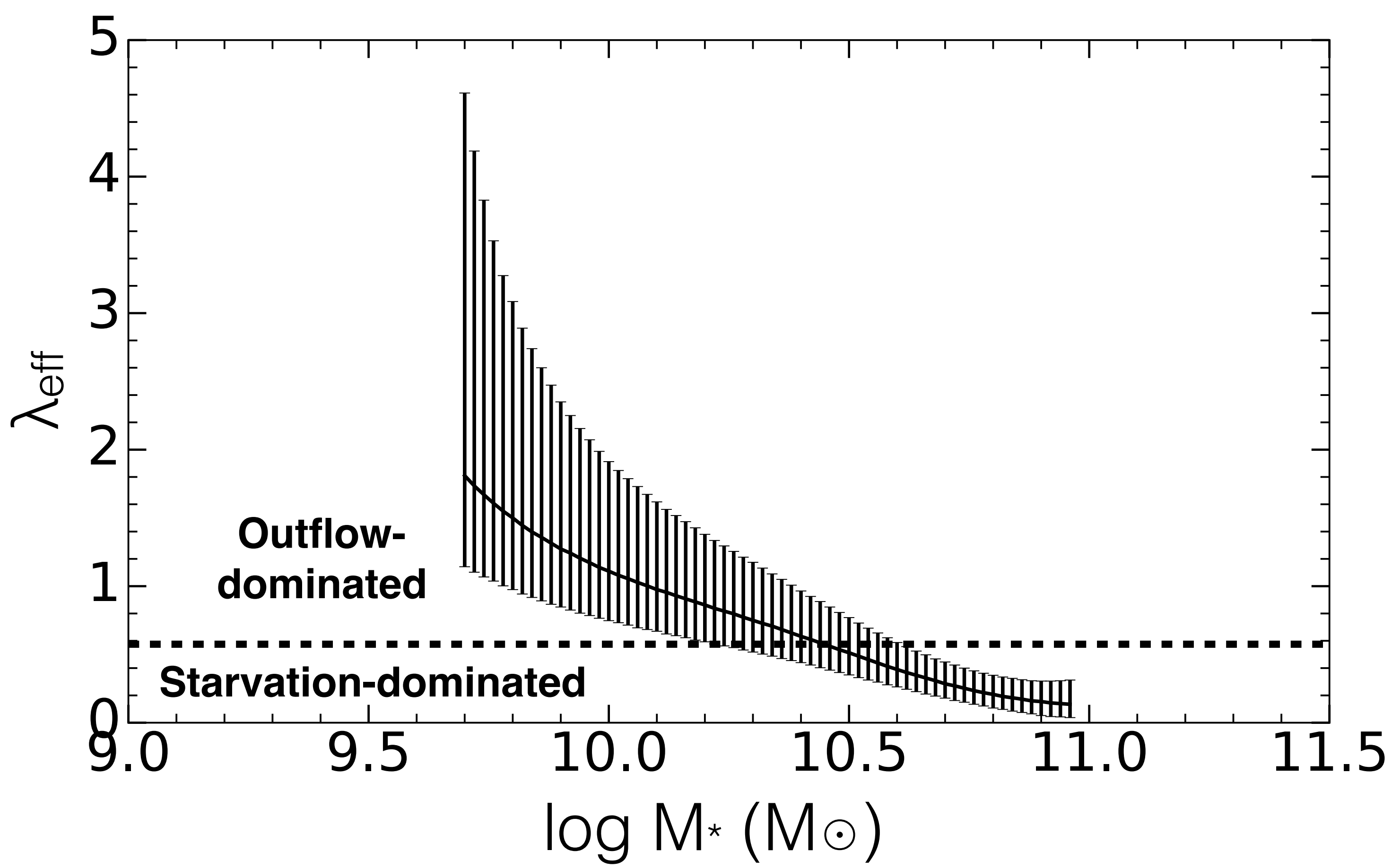
    - **Satellites** are only **marginally** more metal-rich than **centrals** of the same stellar mass

4. **Radial**

    - The stellar metallicity difference between **star-forming** and **passive** galaxies decreases with i**ncreasing radial distance`**

    - **Starvation** plays an increasingly less important role in quenching the **outskirts** of galaxies

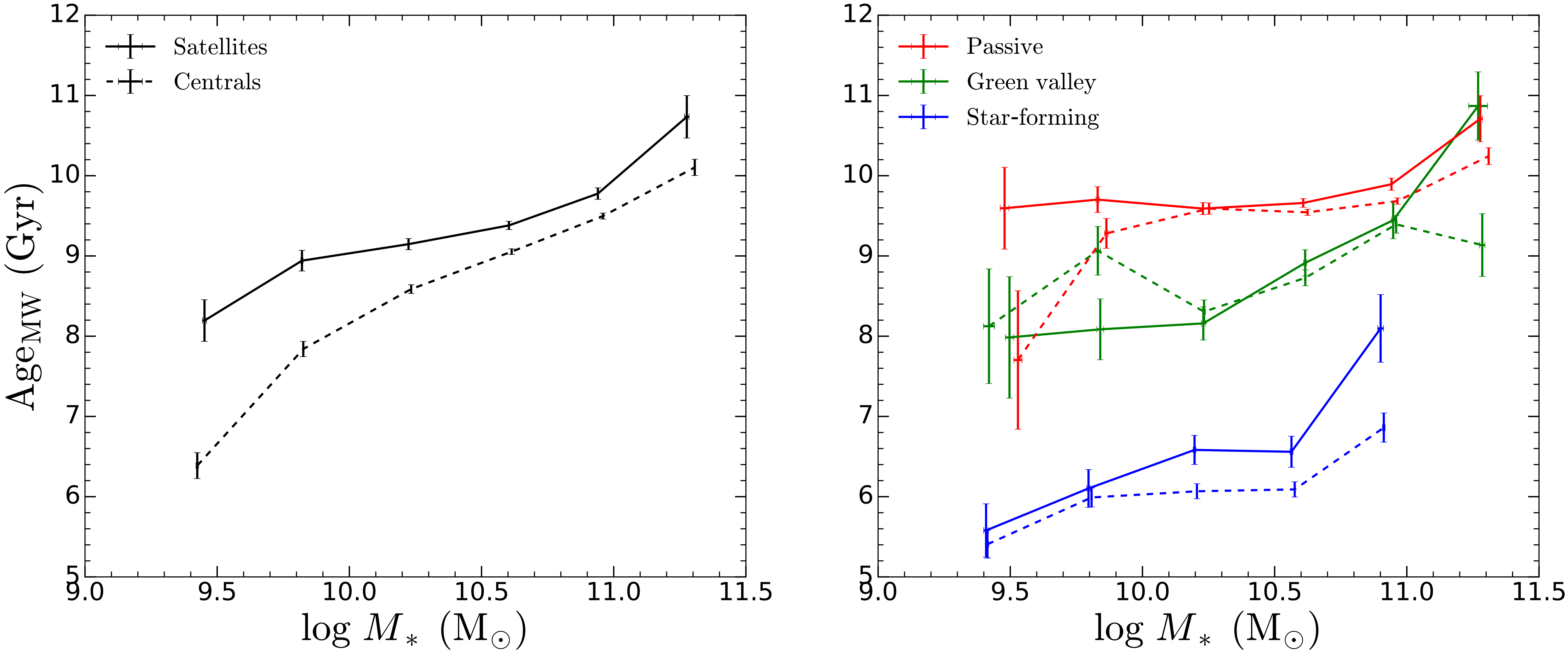
Green valley: Mass-loading factor λ_{eff}



λ_{eff} values for local **green valley** galaxies are similar to what was obtained for are similar to what was obtained for **passive** galaxies

Outflows in the local Universe are **similar** in **power and frequency** to those at higher-z

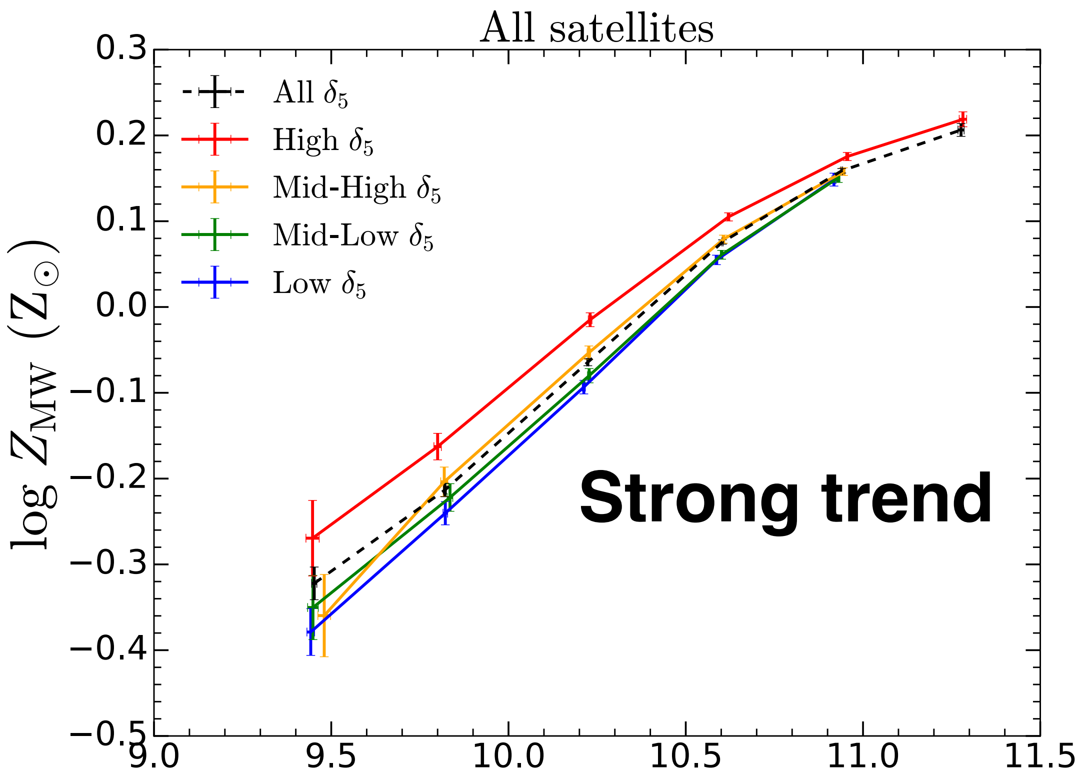
Central–satellite dichotomy: Stellar age

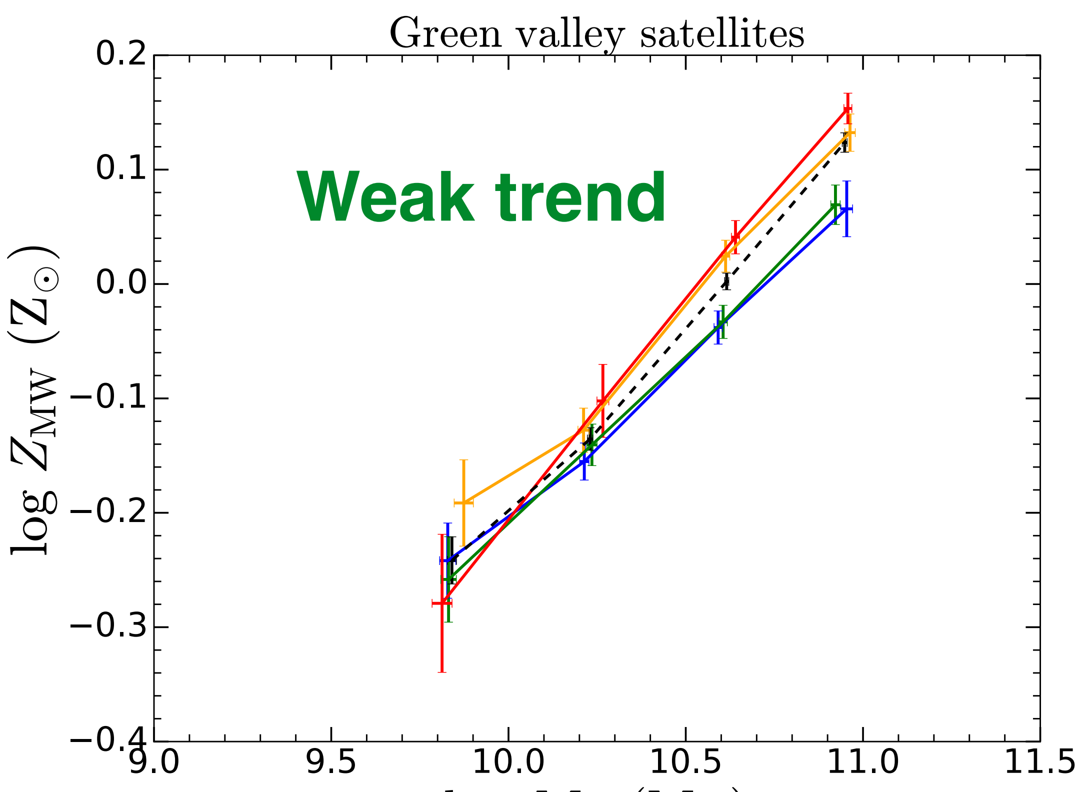


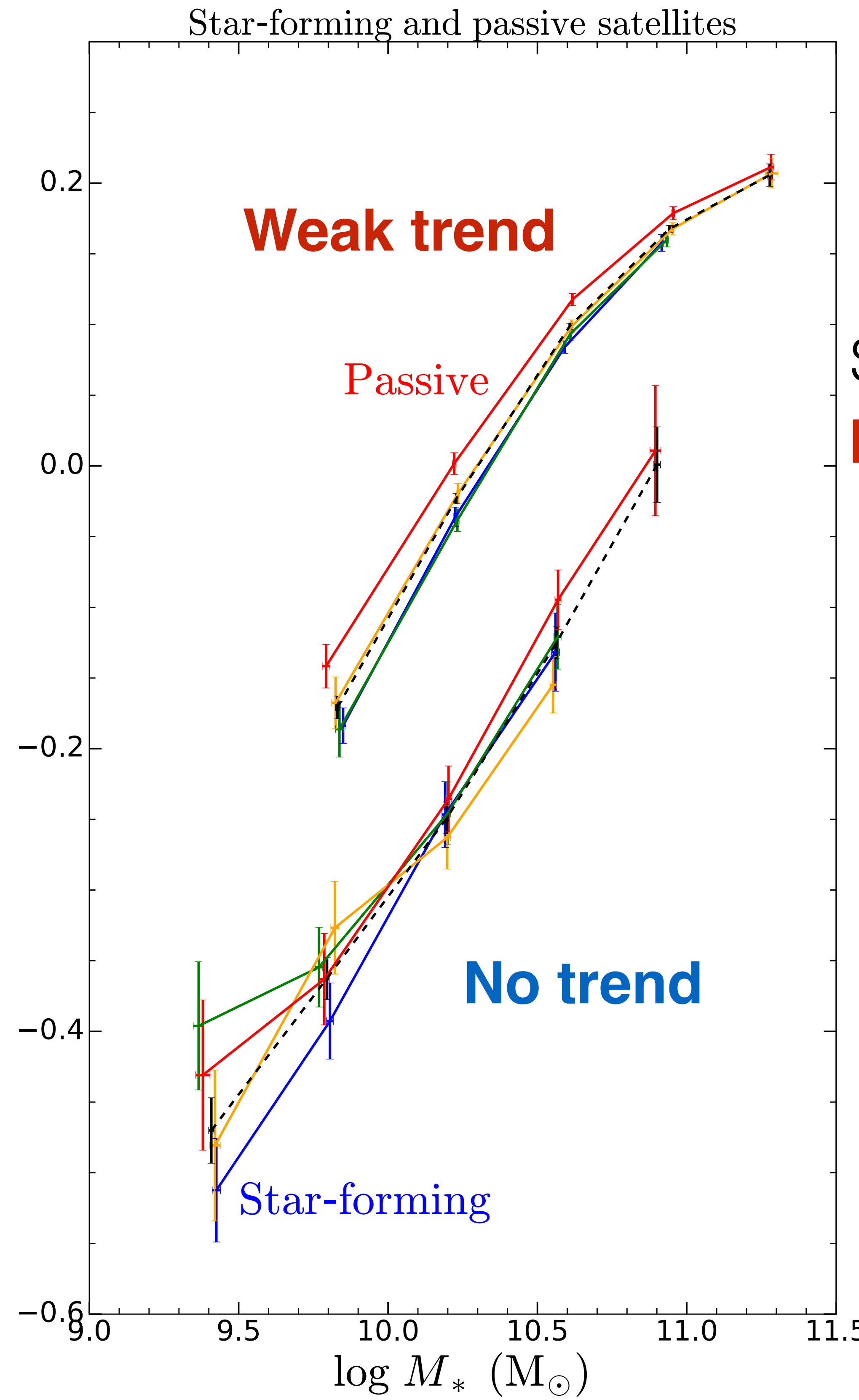
After separating, **star-forming**, **green valley** and **passive** galaxies, we find that the **true** environmental dependence is in fact much **weaker**

Satellites are only **marginally** older than **centrals** of the same stellar mass

Overdensity: Satellites



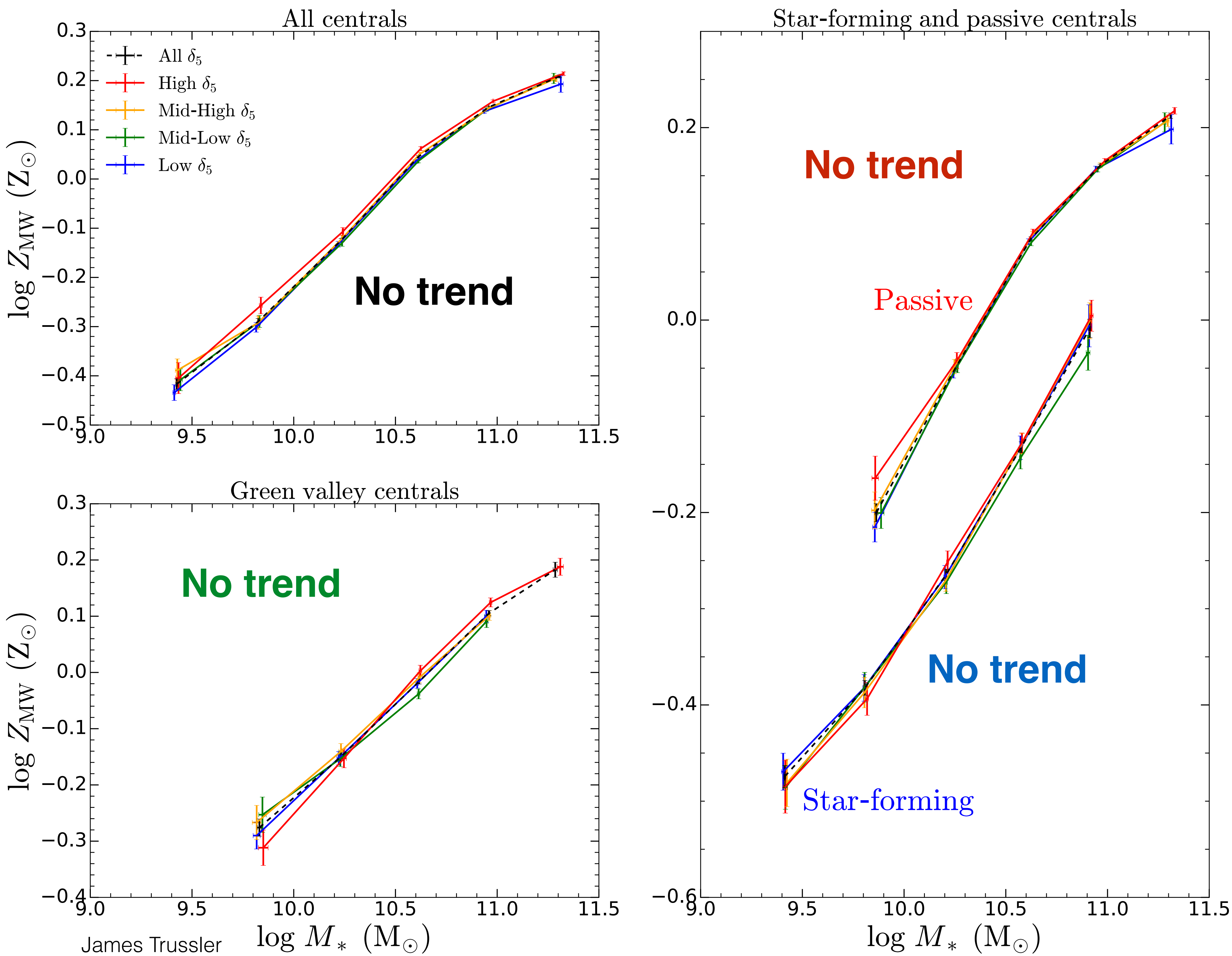




Stellar metallicity of **passive** and **green valley satellites** increase weakly with **overdensity**

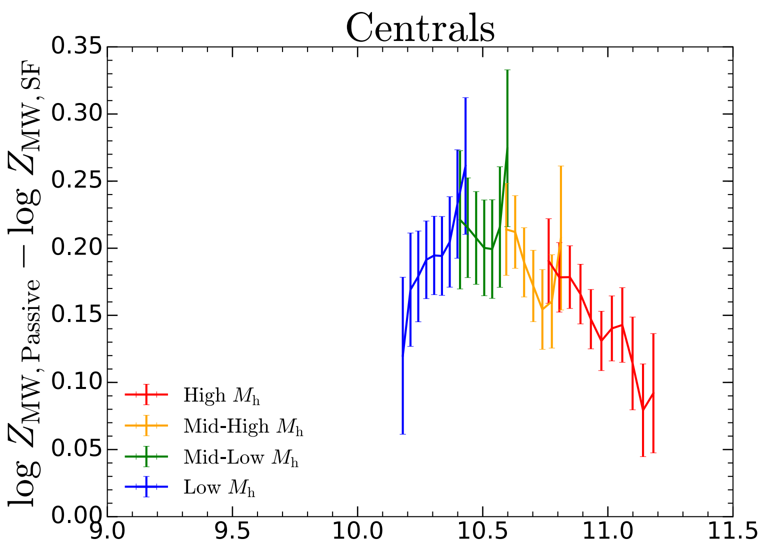
No trend for **star-forming satellites**

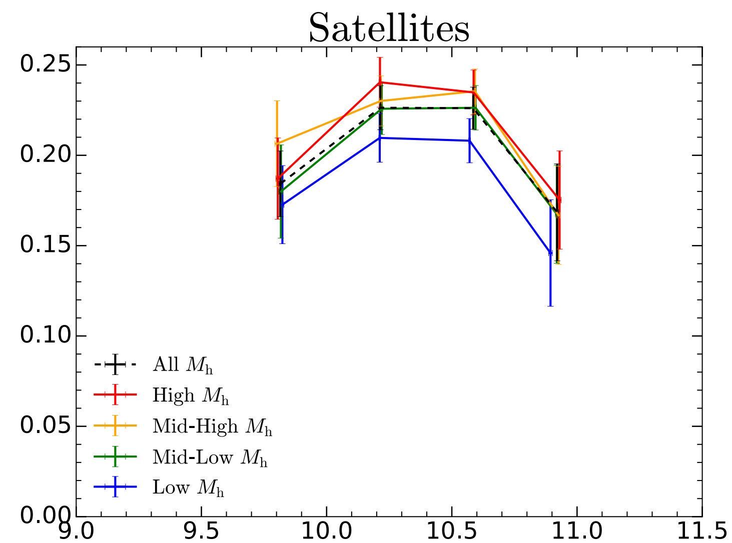
Overdensity: Centrals

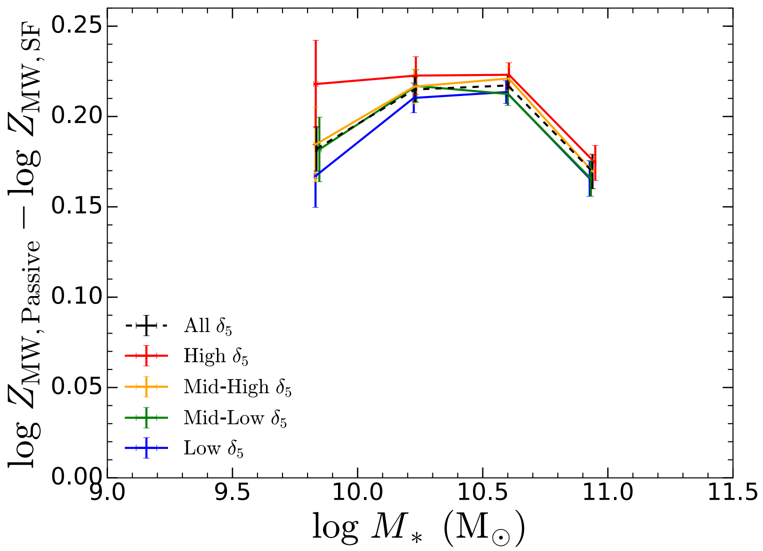


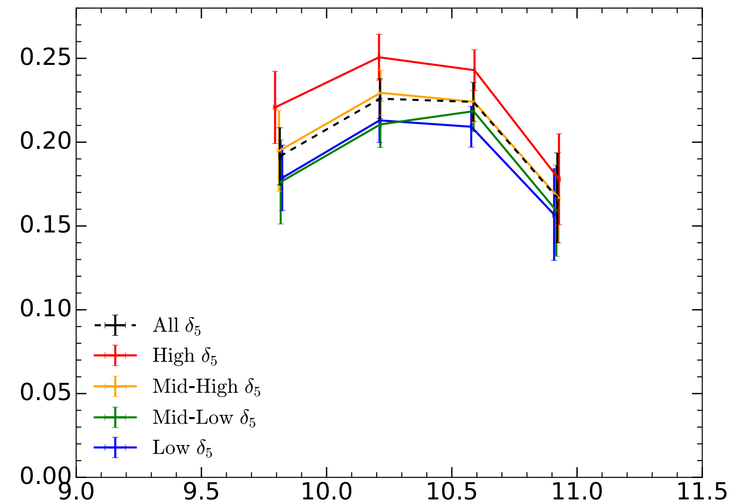
No trend for **centrals**

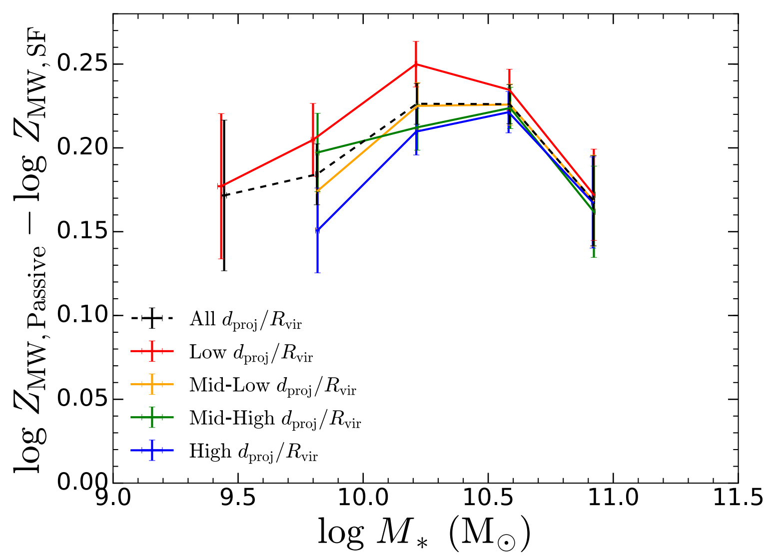
Environmental quenching











No trends for **centrals**:

Starvation is **not** driven by environmental phenomena, but primarily by **mass**-related phenomena

Stellar metallicity difference for **satellites** increases **weakly** with:

- increasing **halo mass**
- increasing **local overdensity**
- decreasing **projected distance**

Moderate environmental starvation (strangulation) contributes to the quenching of **satellites**