# Stellar Metallicities and Galaxy Quenching in the SAMI Survey

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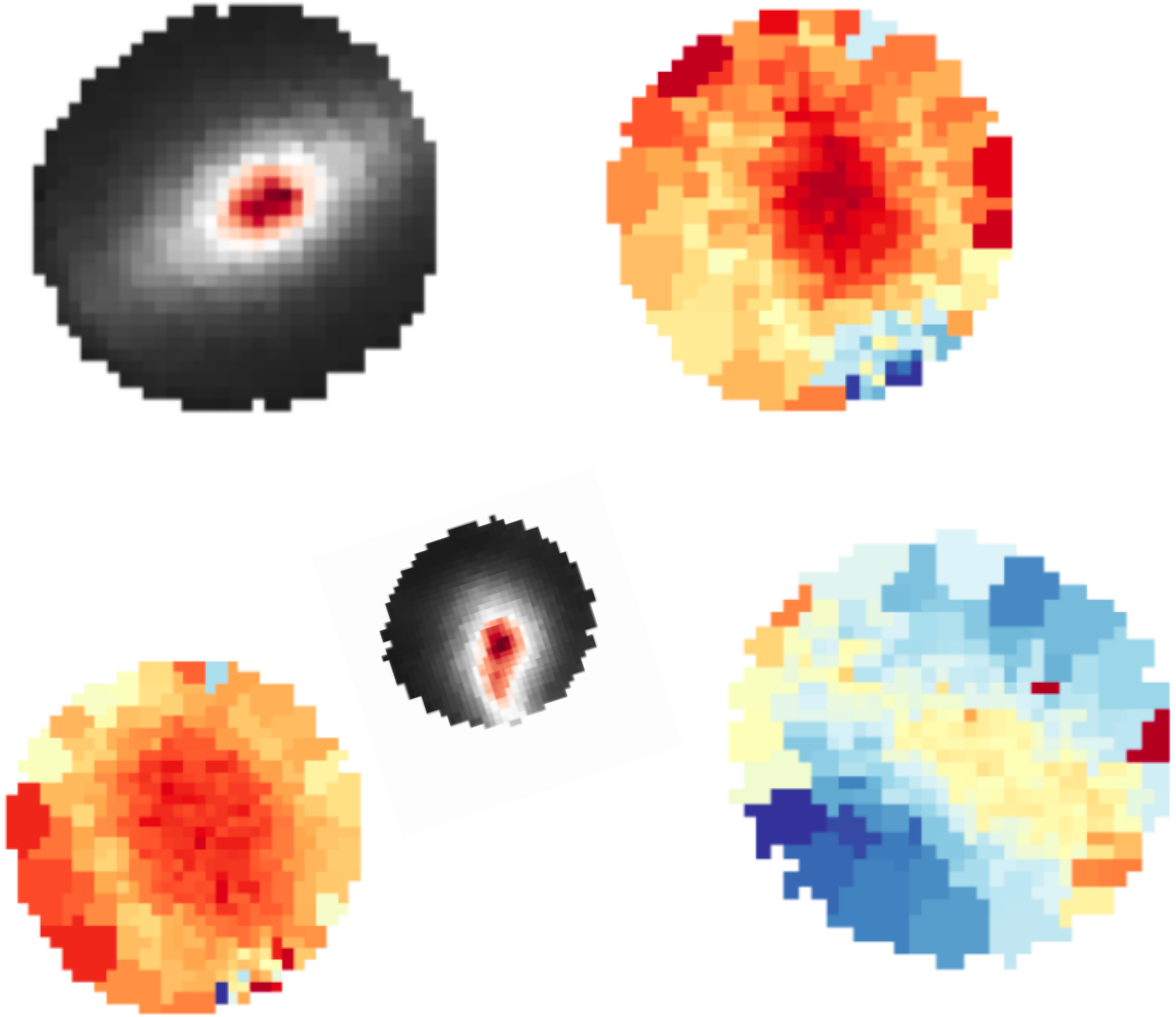
# Quick outline

- What can we learn from studying stellar populations?
- Measuring stellar metallicity
- A toy model of galaxy evolution

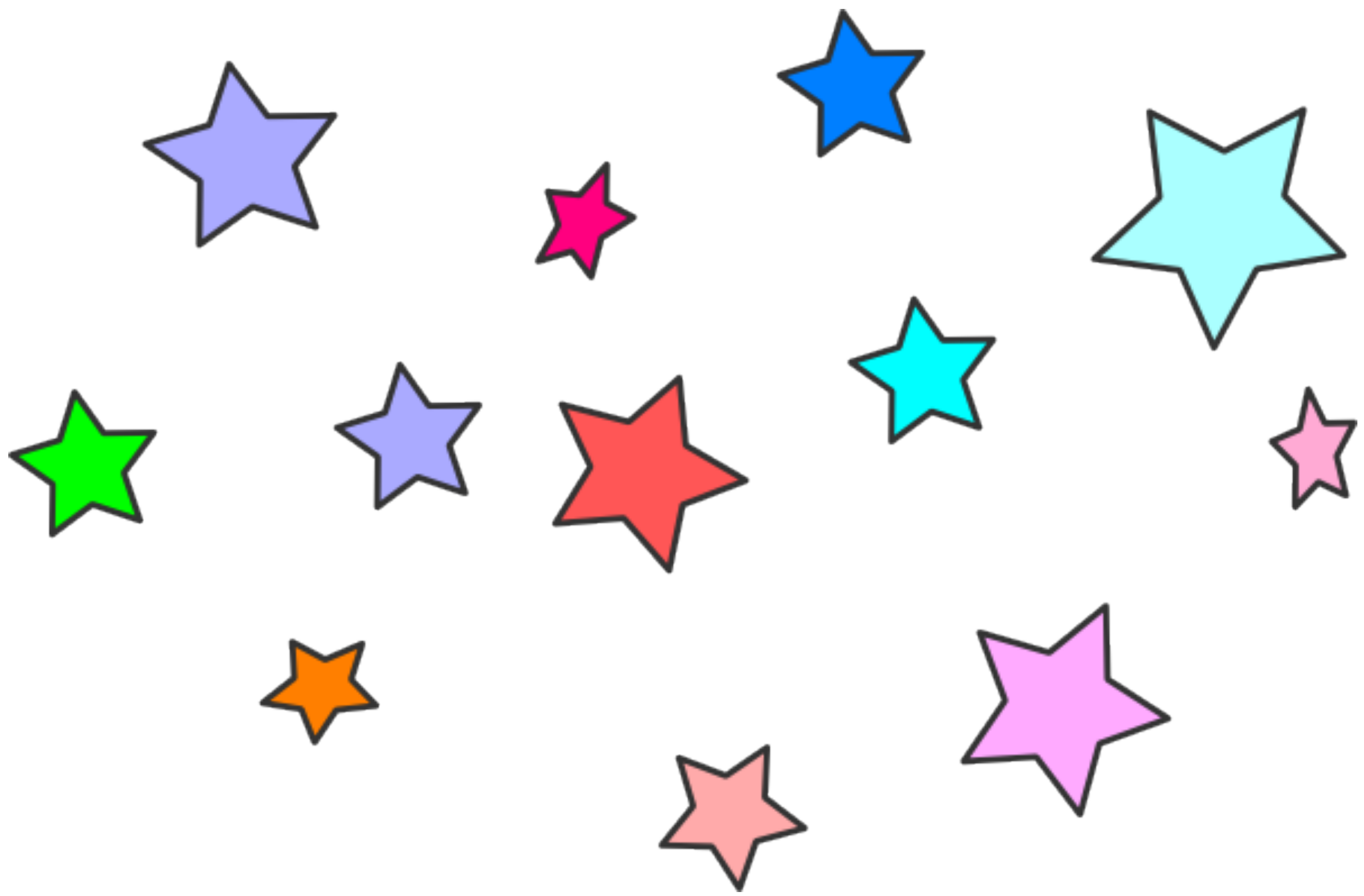


# Why are stellar populations useful?

- The present-day metallicity and age of a galaxy give us clues about its formation history.
- Peng et al. (2015) & Trussler et al. (2020) discuss the idea that metallicity relates to a galaxy's quenching **timescale**.
- Simulations show that steep metallicity **gradients** are expected from a simple "monolithic collapse" formation scenario, whilst a series of minor mergers/accretion of satellites tends to flatten gradients (e.g. Cook+2016)

# Galaxies are made of stars...

## The spectrum we observe is a linear combination of individual spectra



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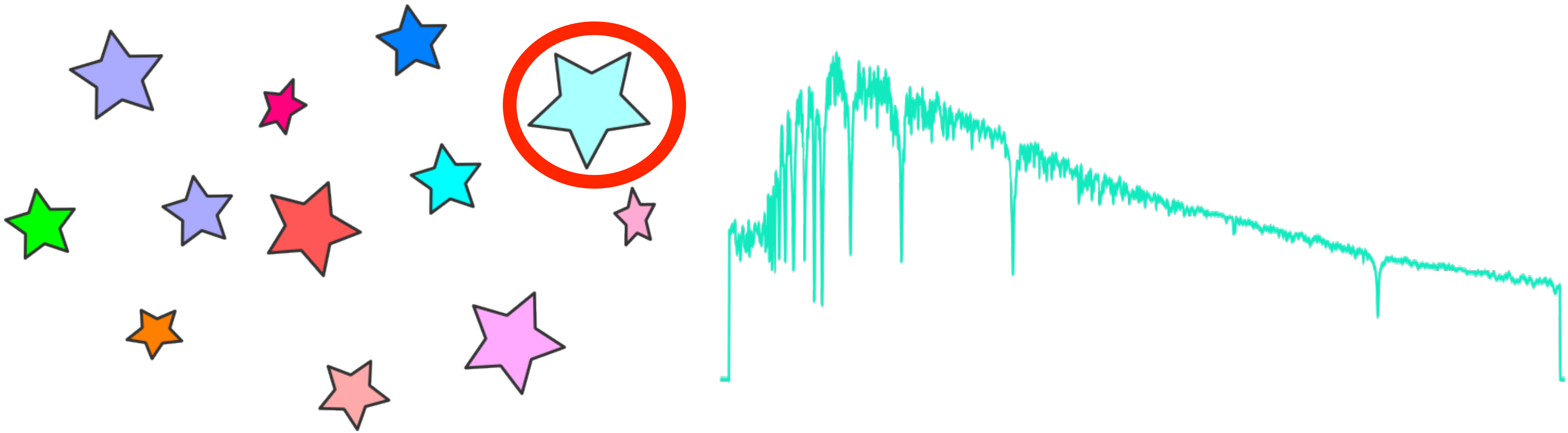

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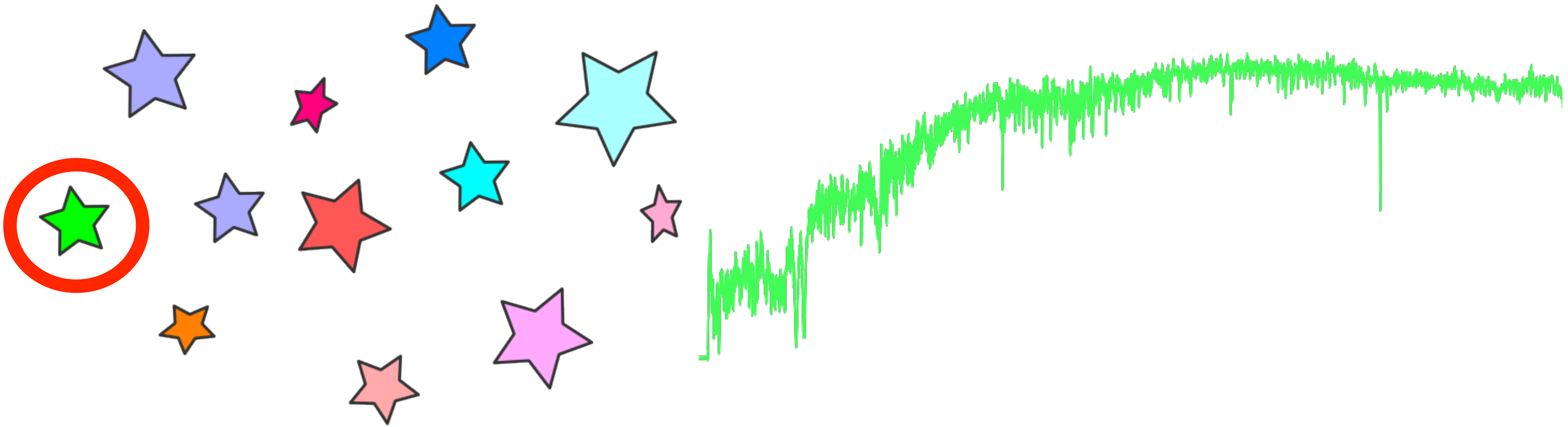

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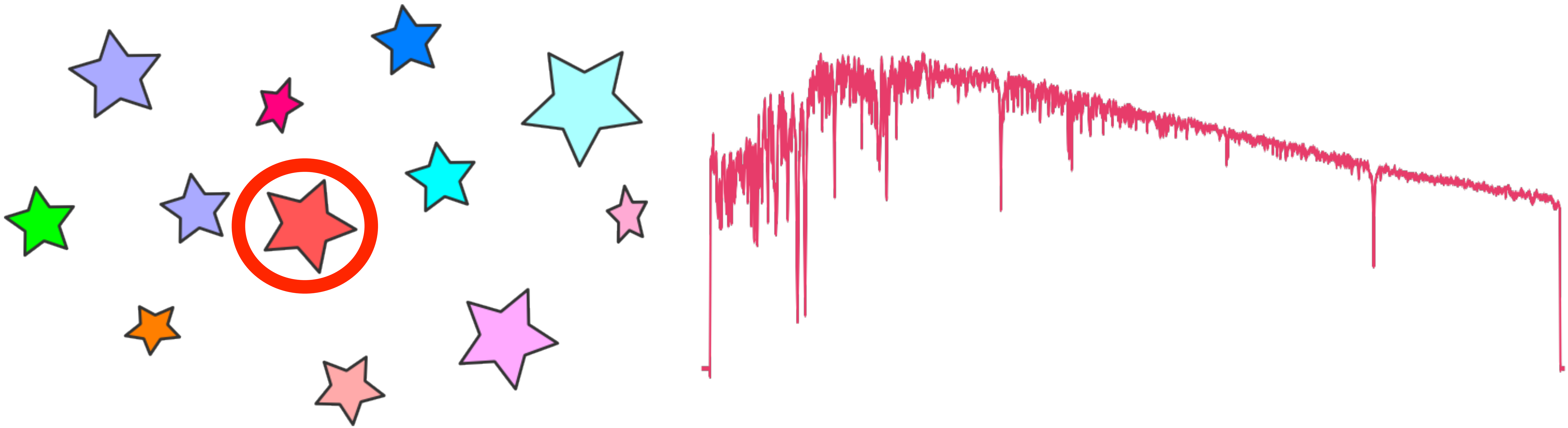

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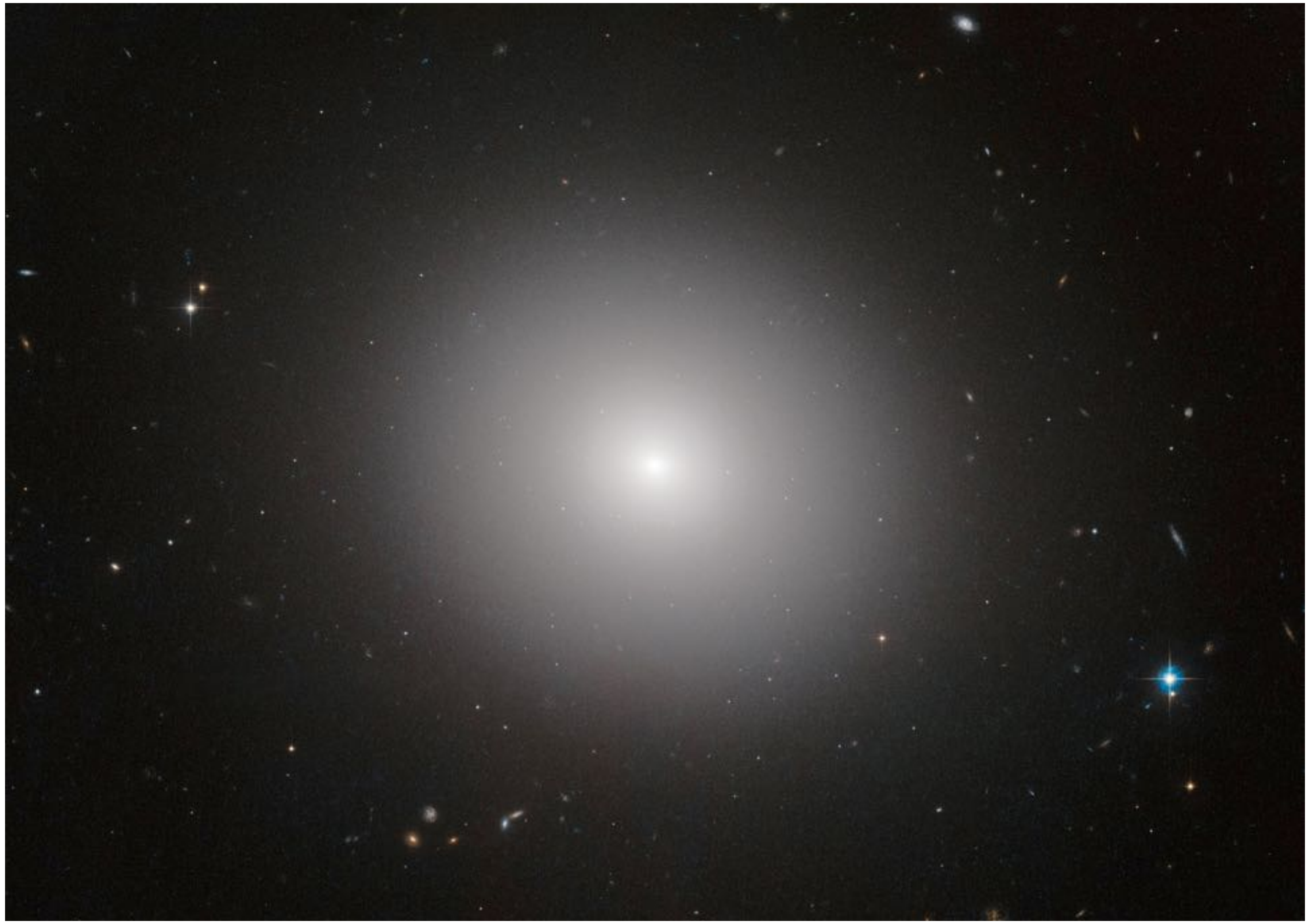

By ESA/Hubble & NASA Image acknowledgement: Judy Schmidt and J. Blakeslee (Dominion Astrophysical Observatory).

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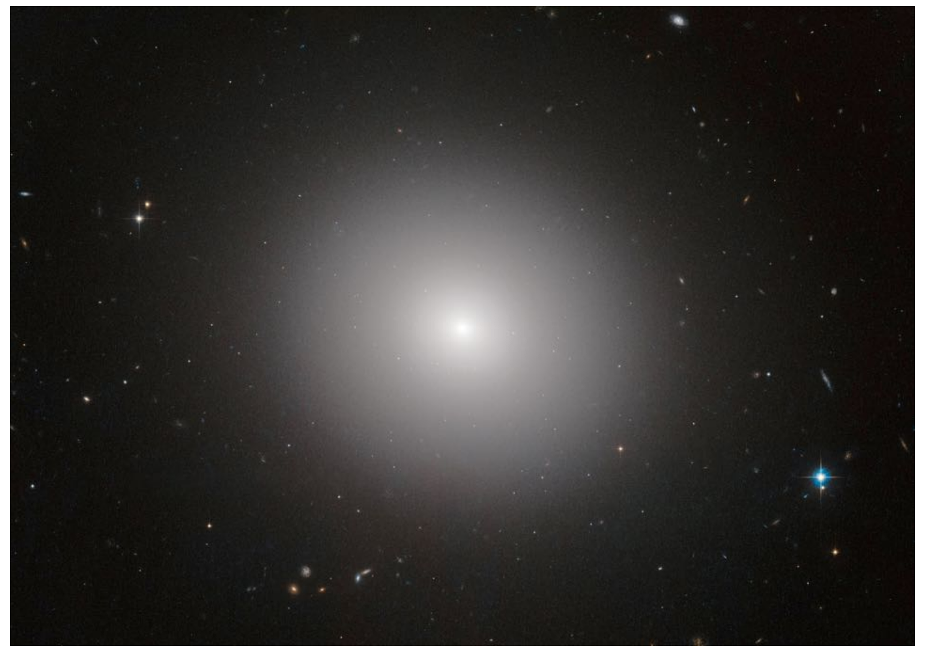

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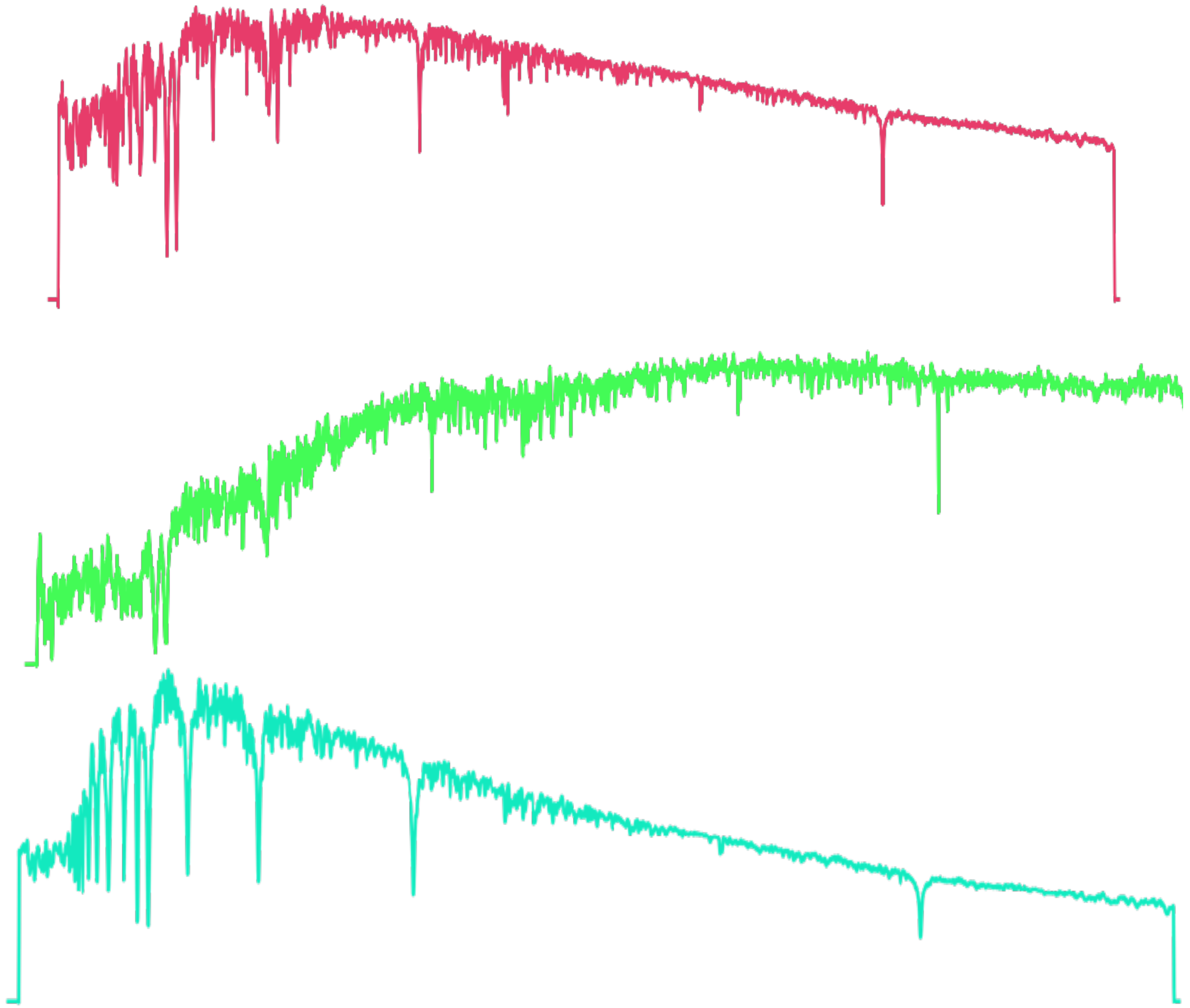

$*$ LOSVD

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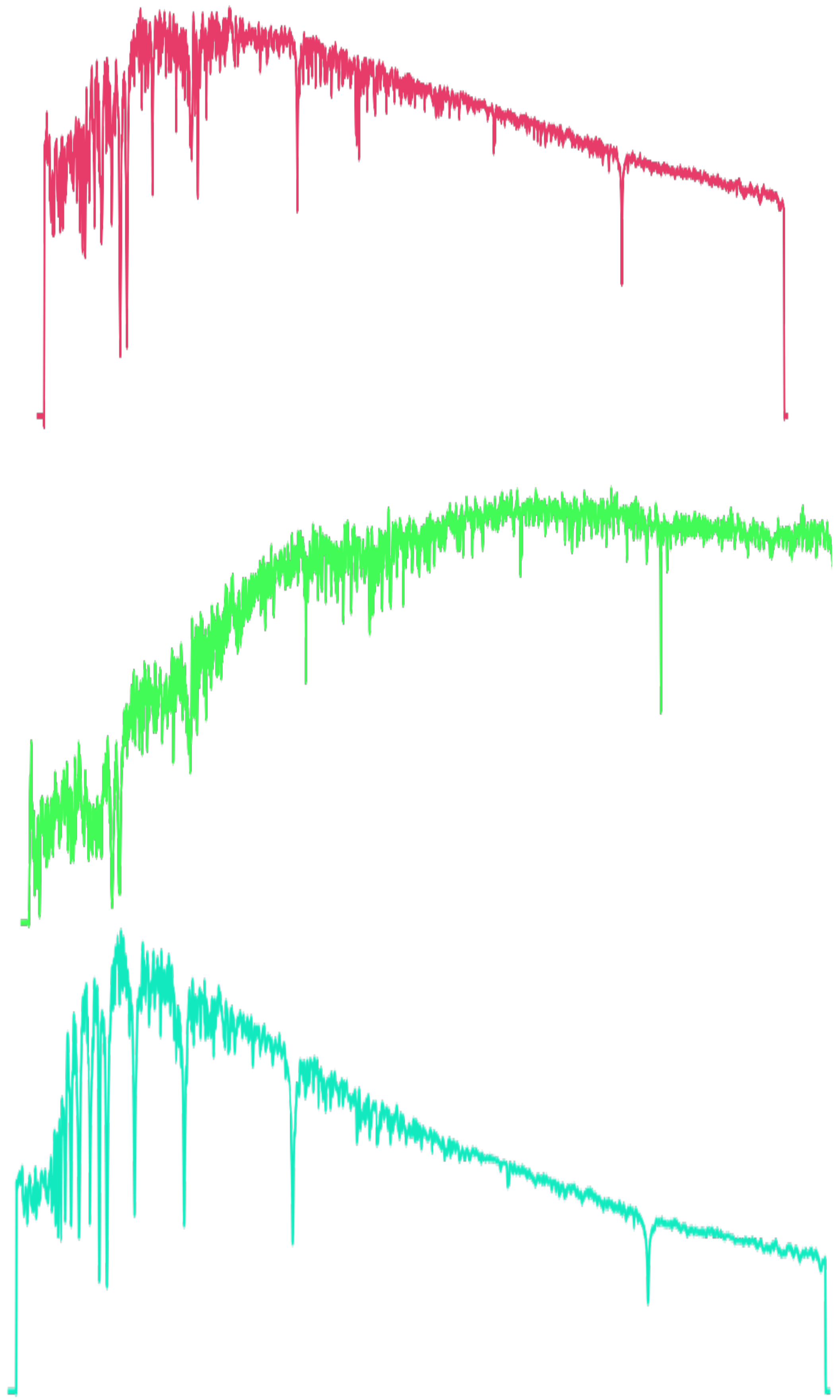

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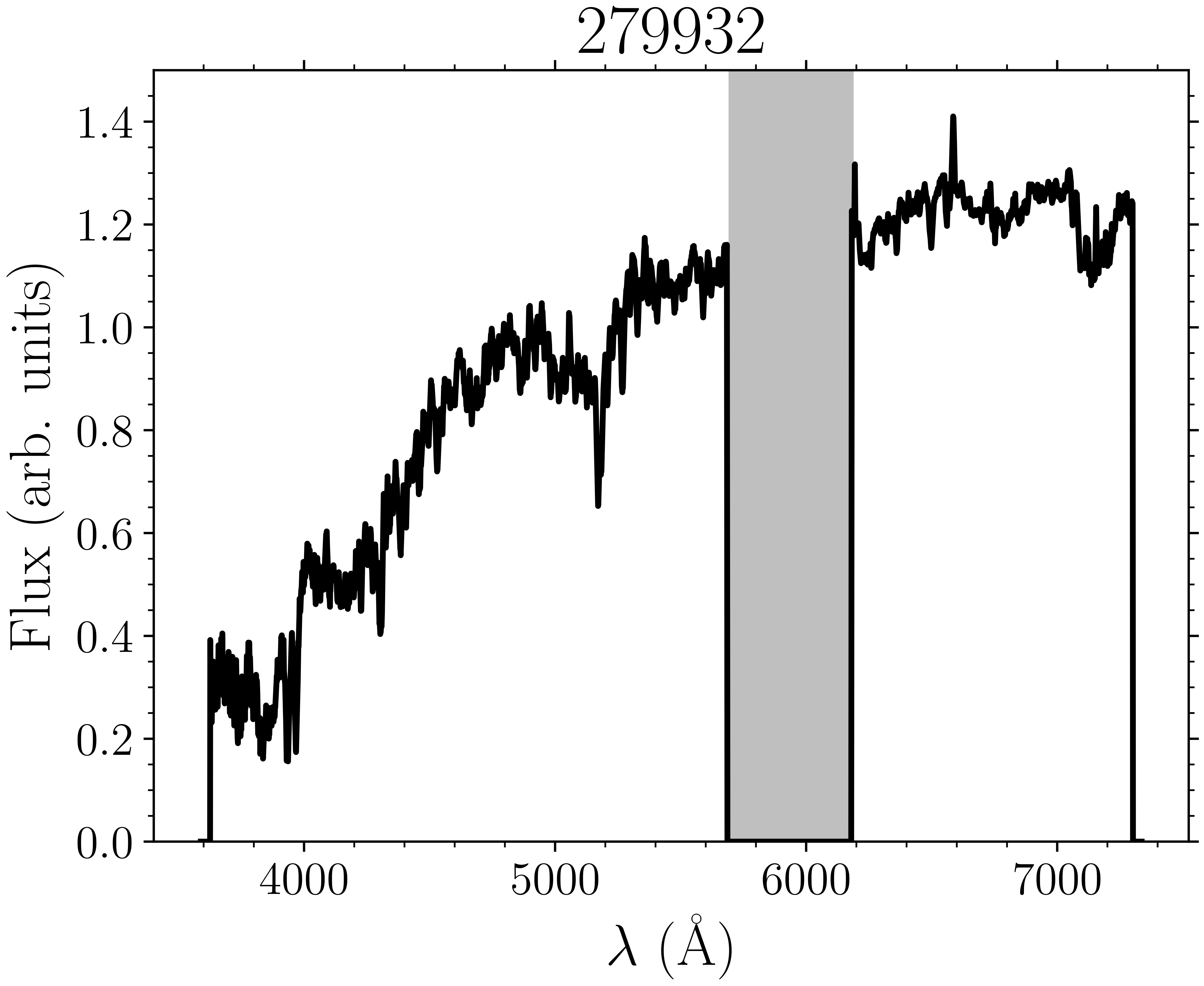
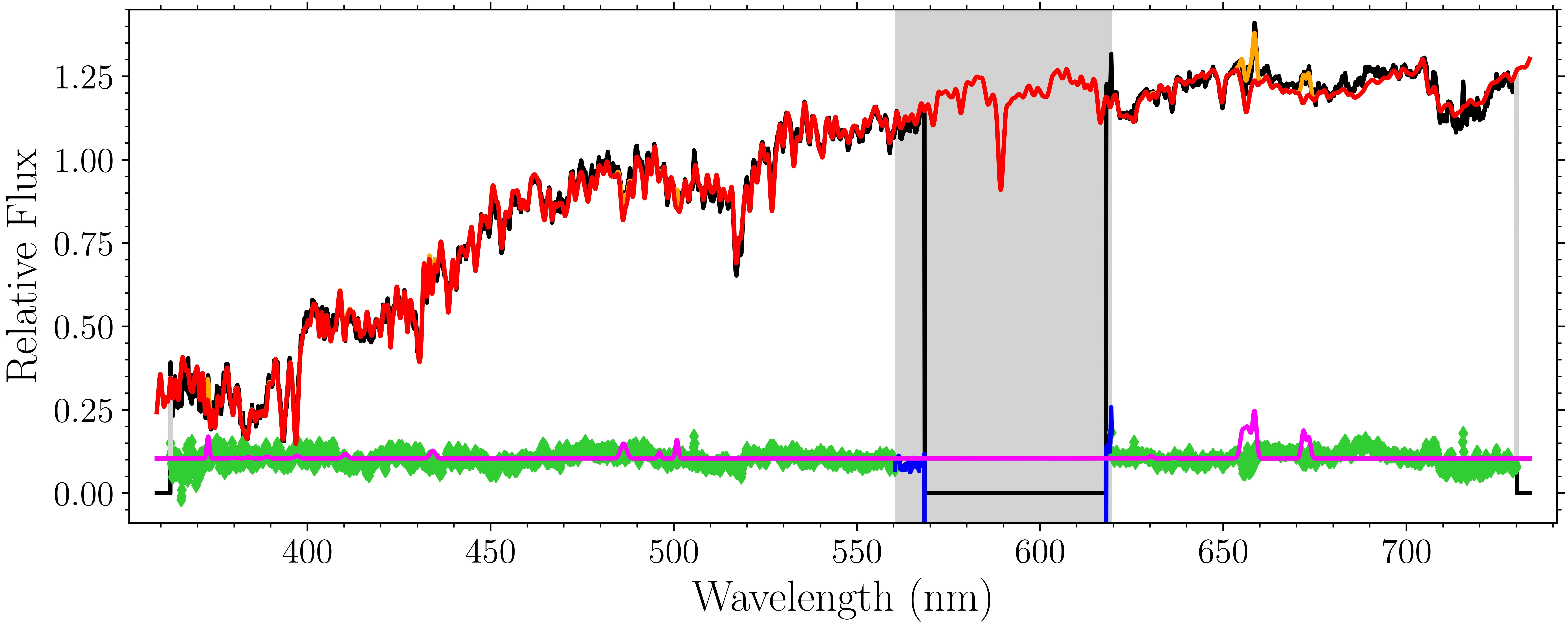


# We can reverse this process to learn about the stellar populations of galaxies



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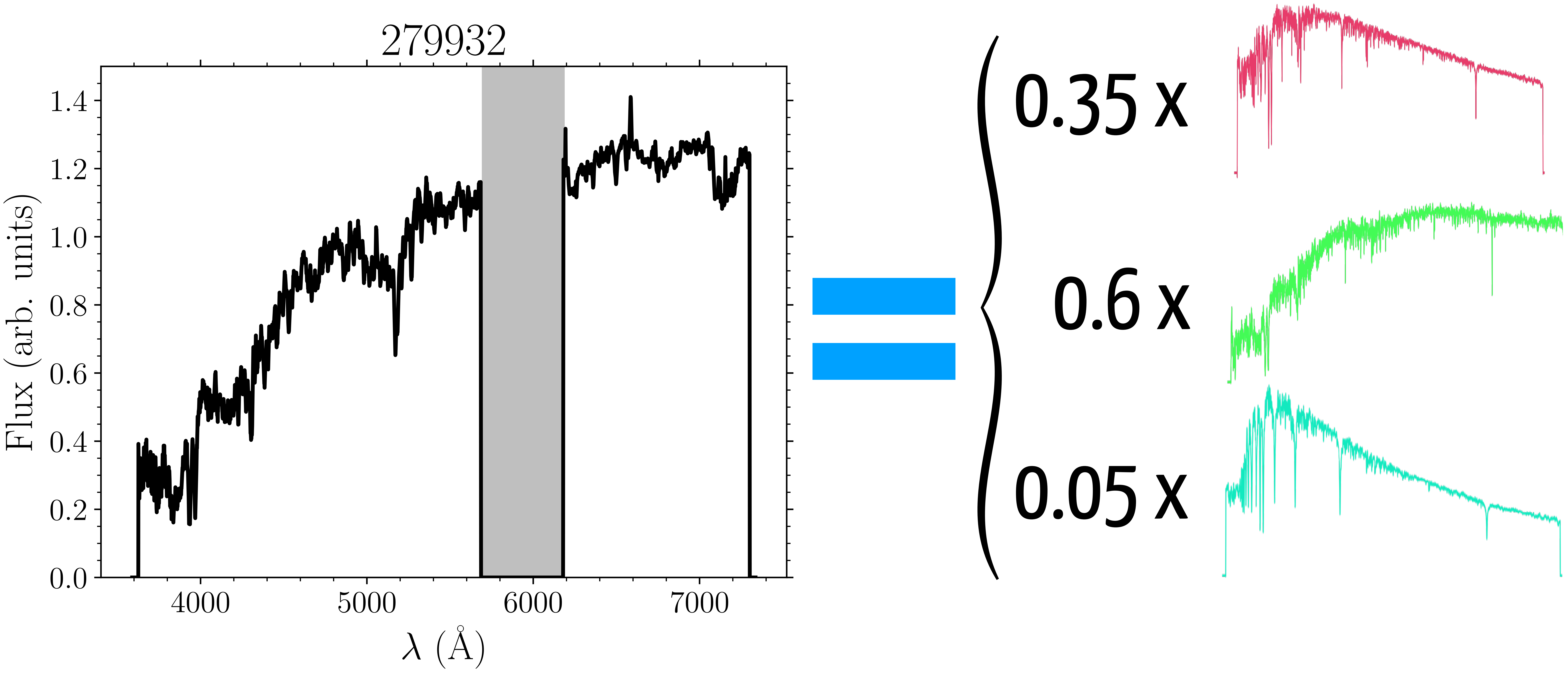


# We can reverse this process to learn about the stellar populations of galaxies

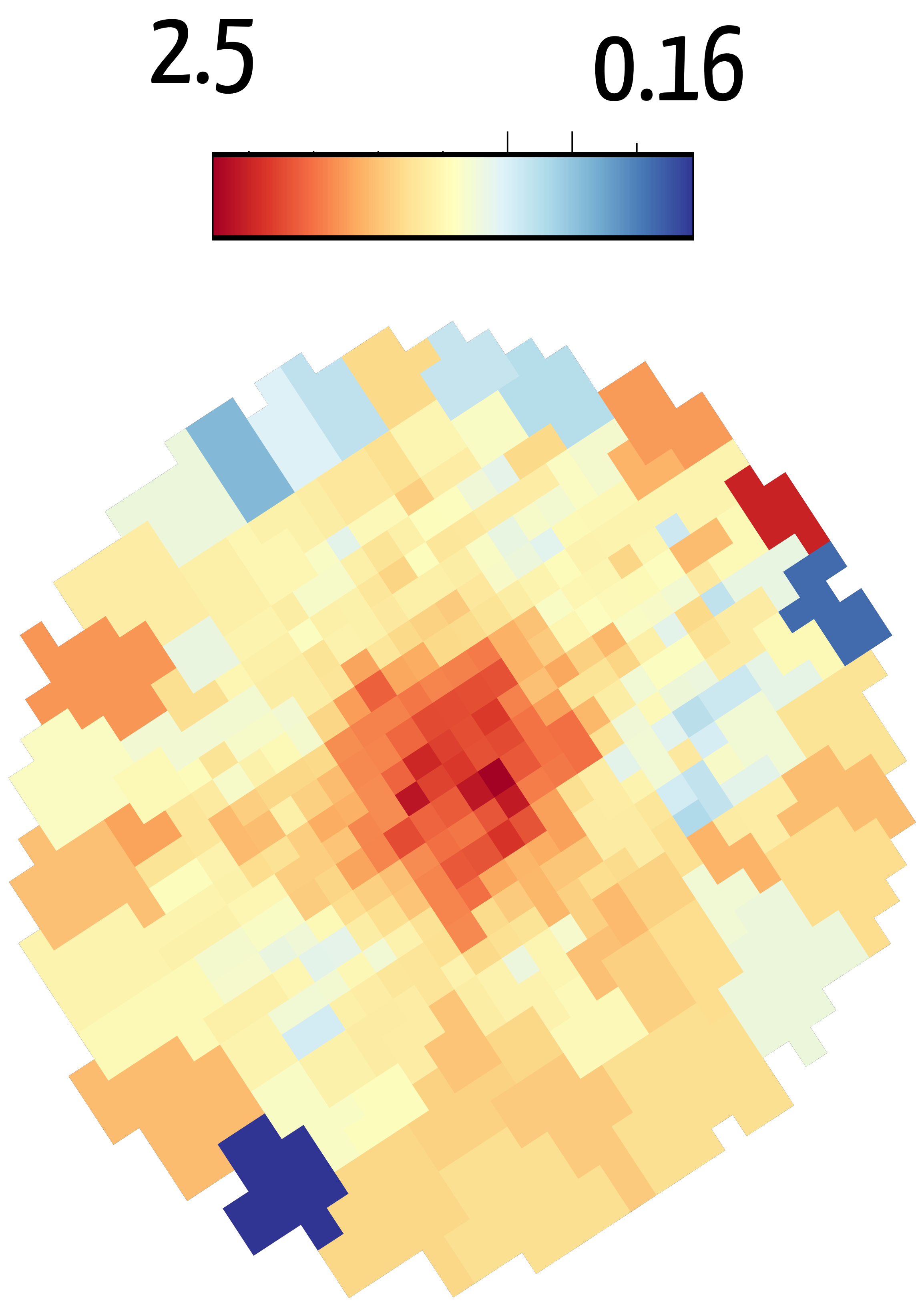
**Some things to note:**

- I don't use spectra of individual stars as my 'building blocks'. Not all combinations of stars are seen together in the Universe!
- Instead, I use spectra of 'simple stellar populations' (SSPs). SSPs are snapshots of the spectrum a collection of stars (which formed **at the same time** and with **the same chemical properties**) would have at a given time since formation.
- Specifically, the MILES library. The templates I've chosen span ages between 0.03-14 Gyrs, metallicities between -1.49 to +0.4 dex and alpha enhancements between 0.0 to +0.4 dex.
- I've fit these templates to the Voronoi-binned spectra from the SAMI survey (S/N of 20) using pPXF (Cappellari+2017). Overall, this lead to 79,160 separate fits from 1905 galaxies

# An example output...

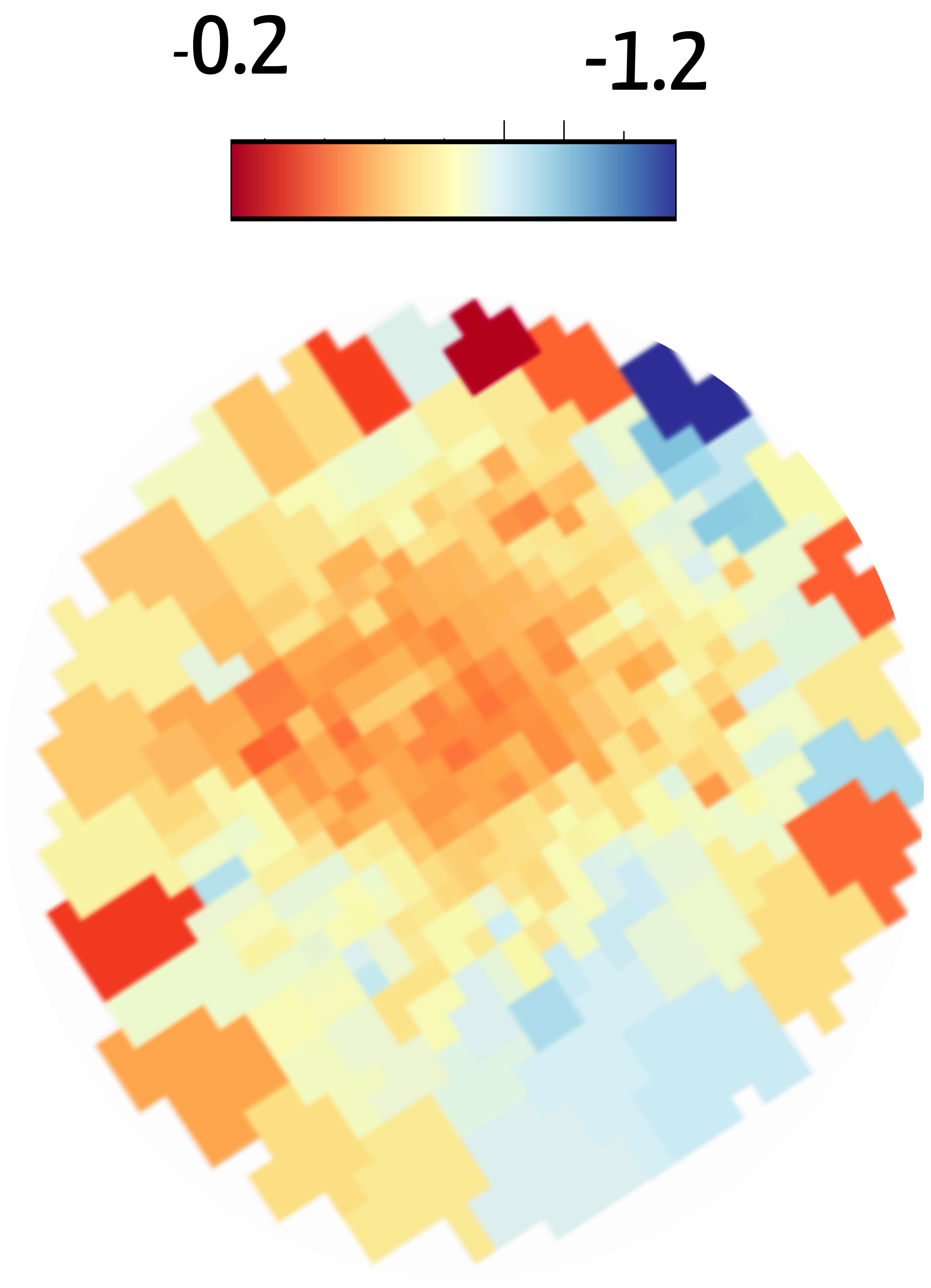
## CATID 106717

SDSS postage stamp image




Age (Gyrs)

(Light-weighted )




[Z/H]

(Light-weighted)

# Focussing on metallicity…

- I've made metallicity maps  for each galaxy in my SAMI sample. I now need to measure their metallicity gradients and their metallicities at r=0
- We have a lot of prior knowledge about the gradients and central metallicities of galaxies
- I've incorporated this prior knowledge into a bayesian "hierarchical model"
- The prior on the slope for each galaxy depends on its stellar mass, and the prior on the intercept for each galaxy depend on its stellar mass and star-formation rate
- The key thing is- we estimate the prior dependence on these quantities from the data itself. I'm not putting in any relationships by hand

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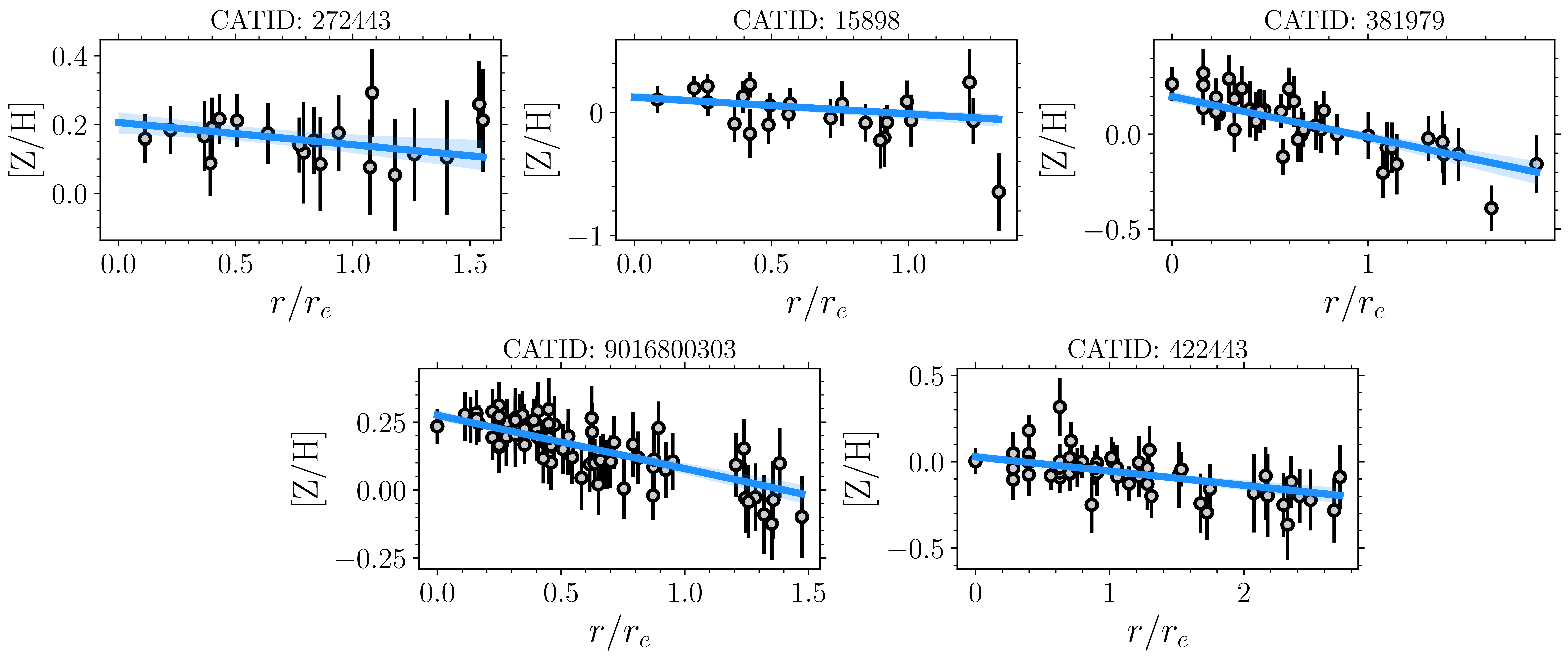
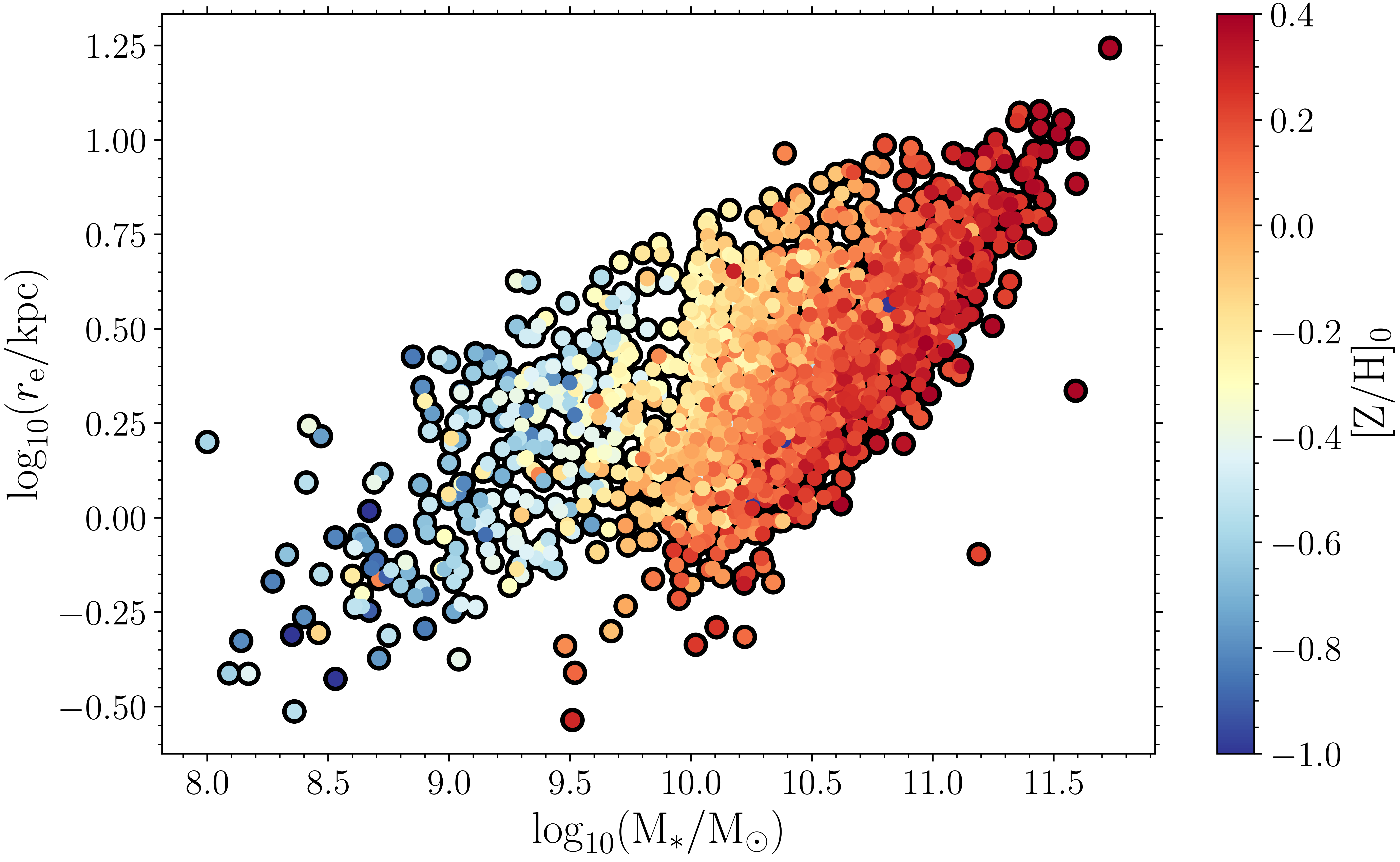
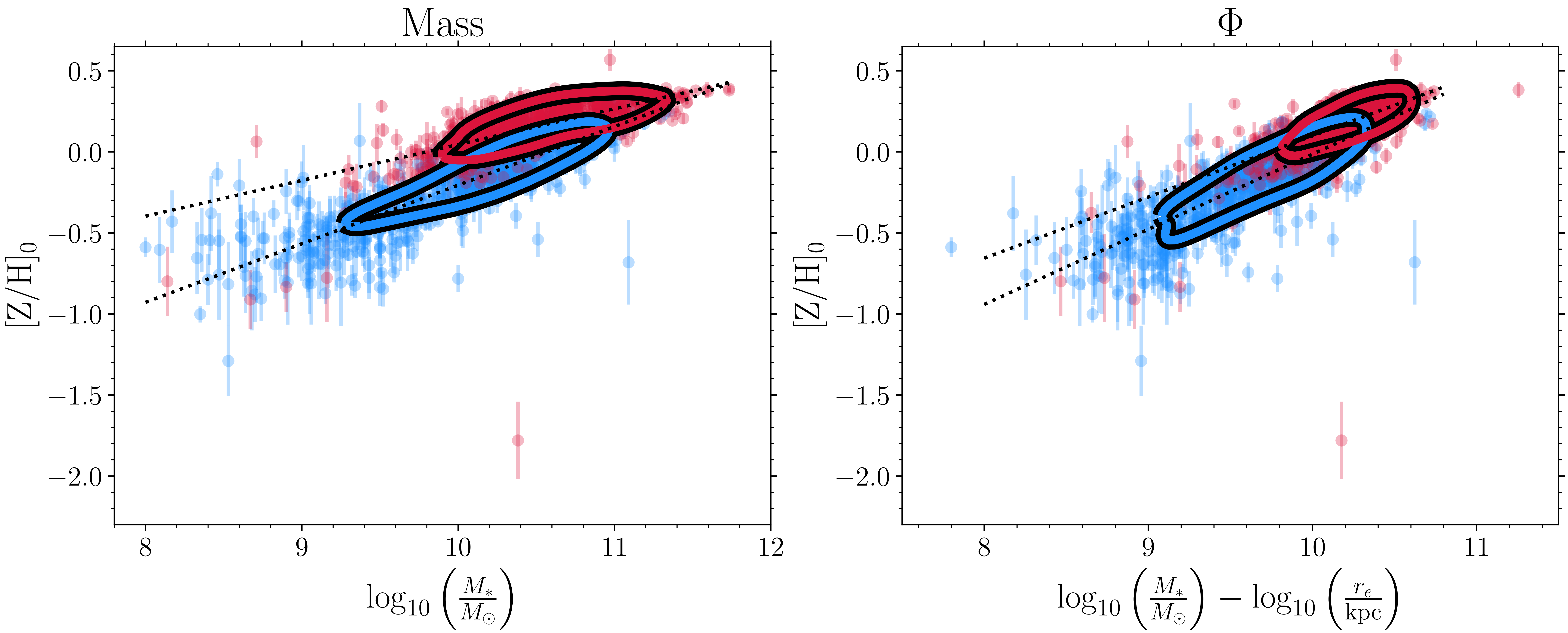


# The mass/size plane



# Mass/metallicity and potential/metallicity planes



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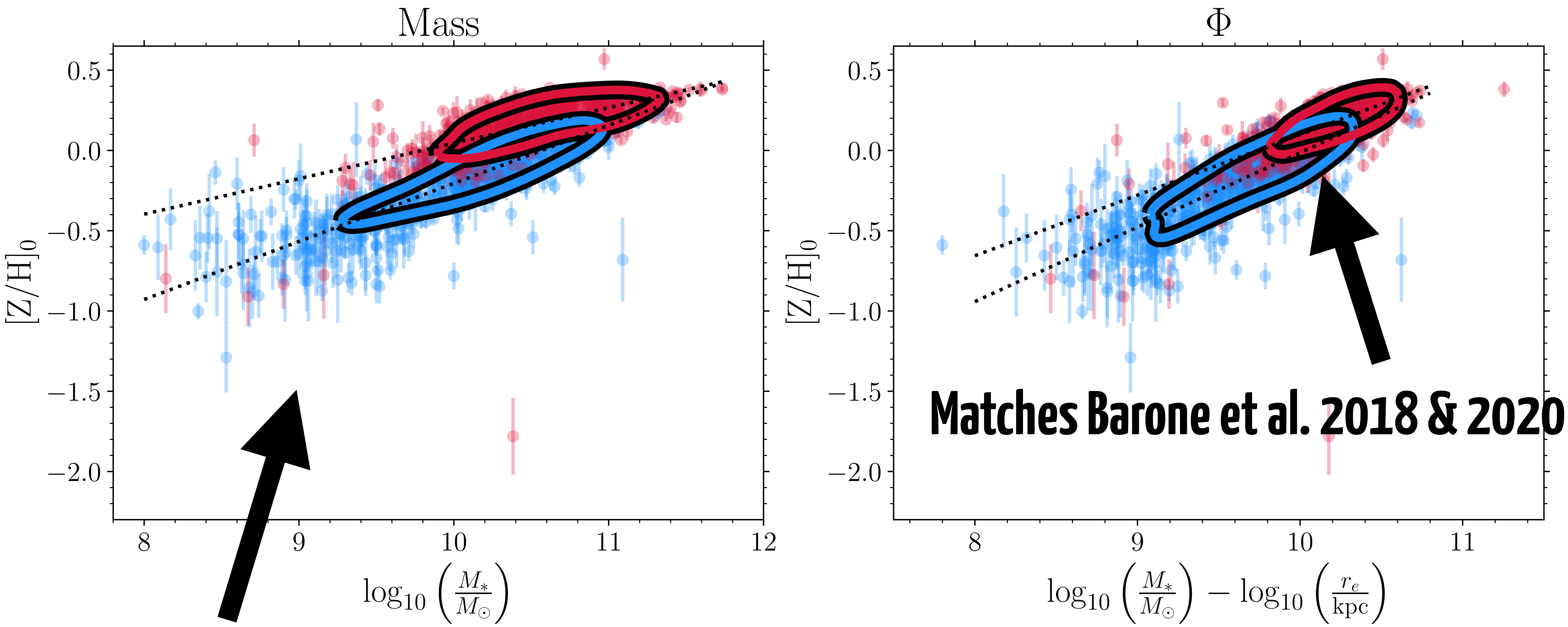
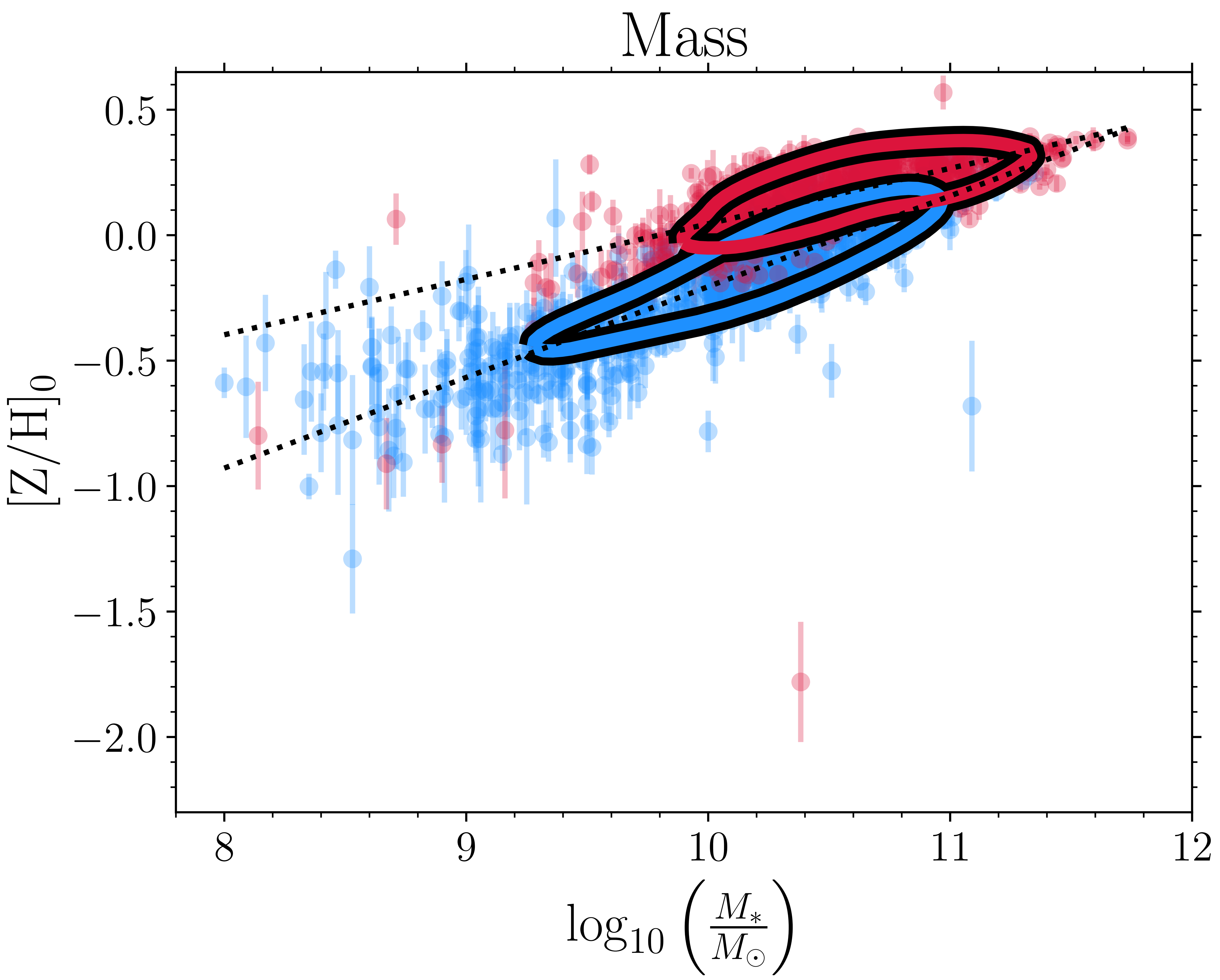



Good agreement with Trussler et al. 2020 and Peng et al. 2015

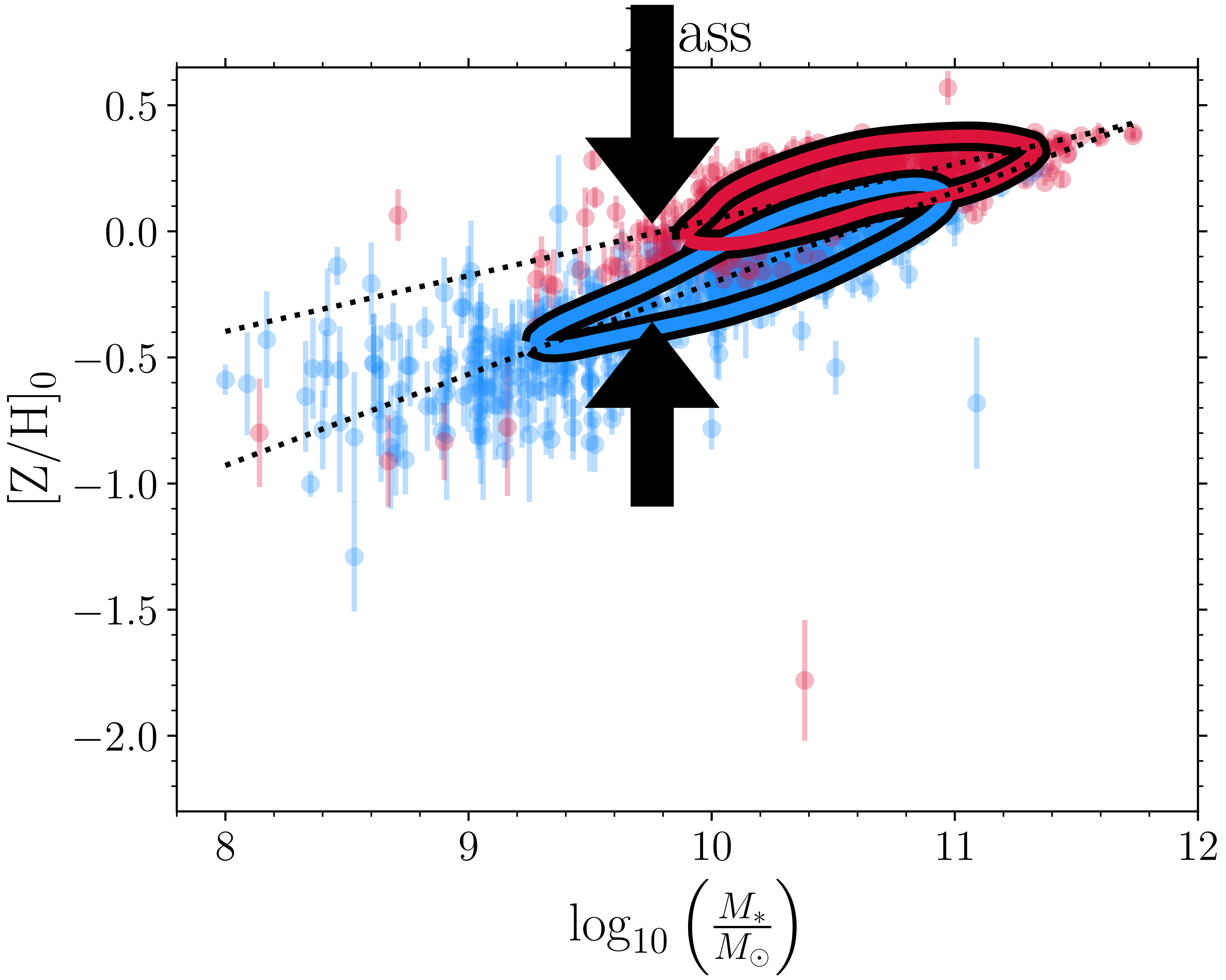
# Slow Quenching and Stellar Metallicity

- When a galaxy is forming stars, its stellar metallicity is regulated by its gas-phase metallicity (Peng & Maiolino 2014)
- Stellar evolution tends to increase a galaxy's gas-phase metallicity
- Accretion of pristine halo gas tends to decrease it



# Slow Quenching and Stellar Metallicity

- If you cut off a galaxy's supply of halo gas, its gas-phase metallicity will sharply increase and so its overall stellar metallicity will too
- Peng et al. 2015 and Trussler et al. 2020 use this idea to explain the difference in [Z/H] between quenched and star-forming galaxies



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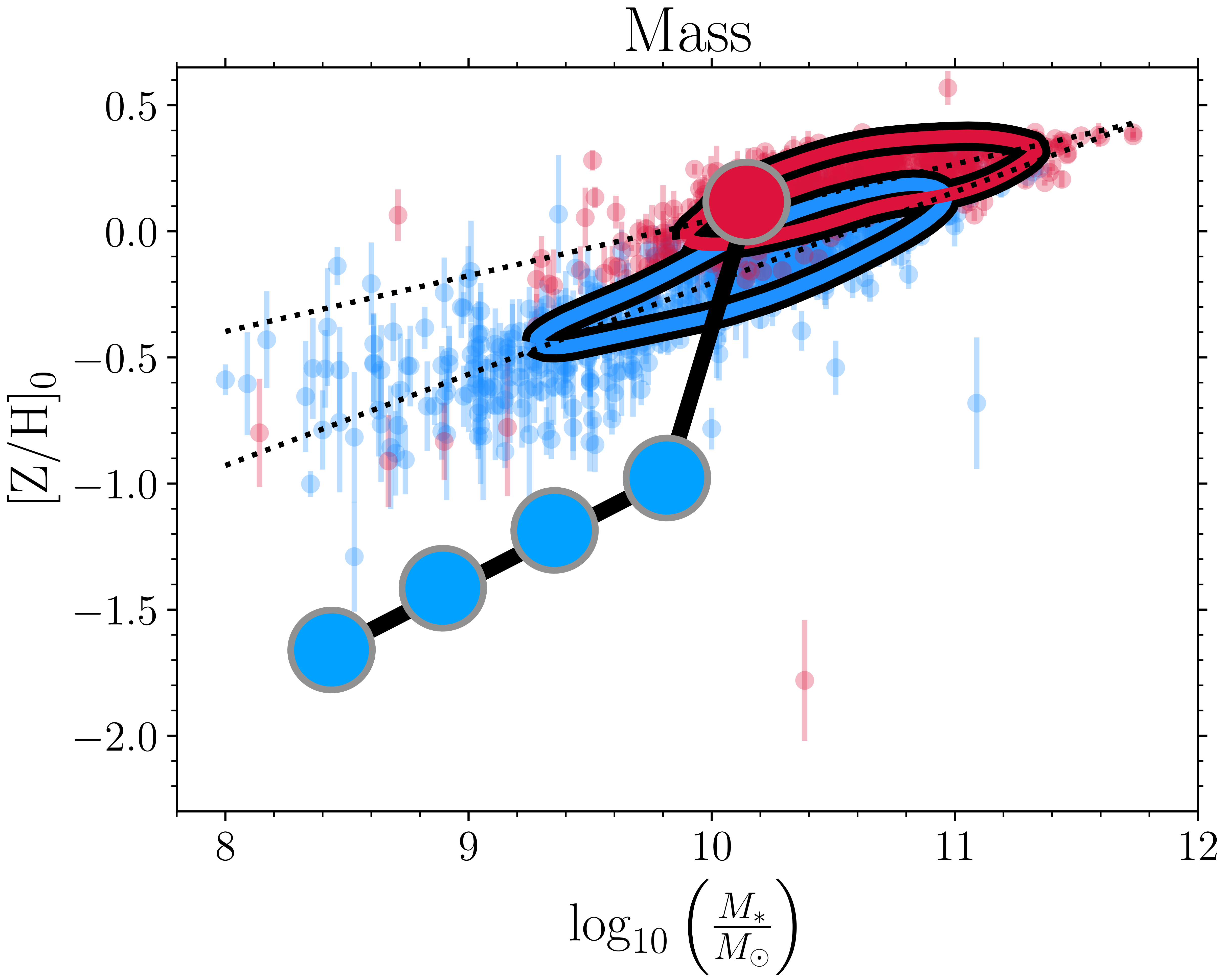


# A toy model of galaxy evolution

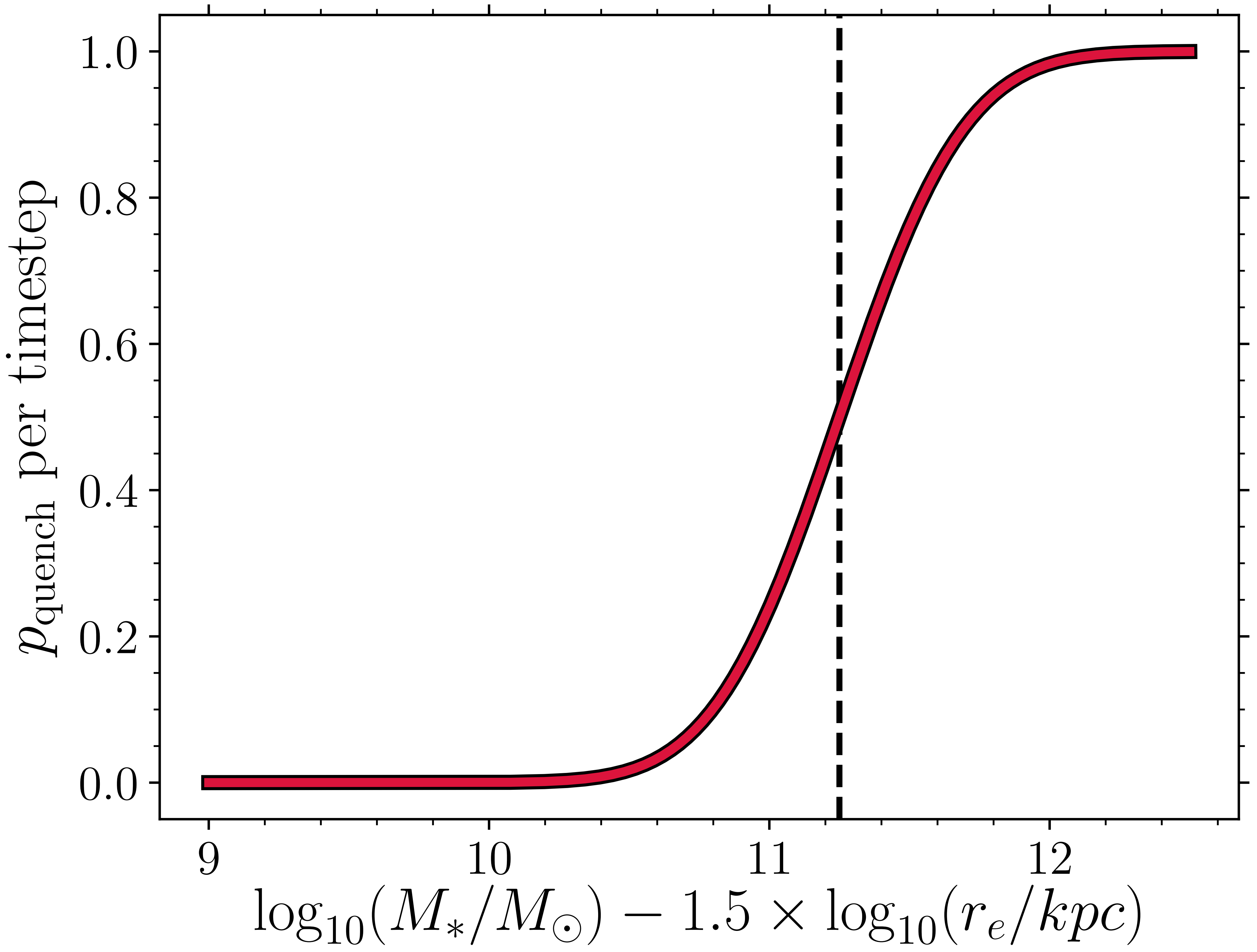
- Take a range of redshifts between (1 and 10). Give galaxies a stellar mass and a size based on observational measurements (or simple extrapolations).
- Assume that the slope of the mass/metallicity and potential/metallicity relations are the same at high redshift as they are today.
- Give galaxies a metallicity based on this

# A toy model of galaxy evolution

- Evolve galaxies forward in steps of 10Myrs.
- Star-forming galaxies form a set amount of mass each timestep which places them on the main sequence of star formation
- Assume they increase their size according to $\Delta$log(R) ~ 0.3$\Delta$log(Mstar) (e.g. van Dokkum+2015)
- Assume they increase their metallicity according to $\Delta$[Z/H] ~ 0.45$\Delta$ log(Potential) (based on my fit to the potential/metallicity plane)

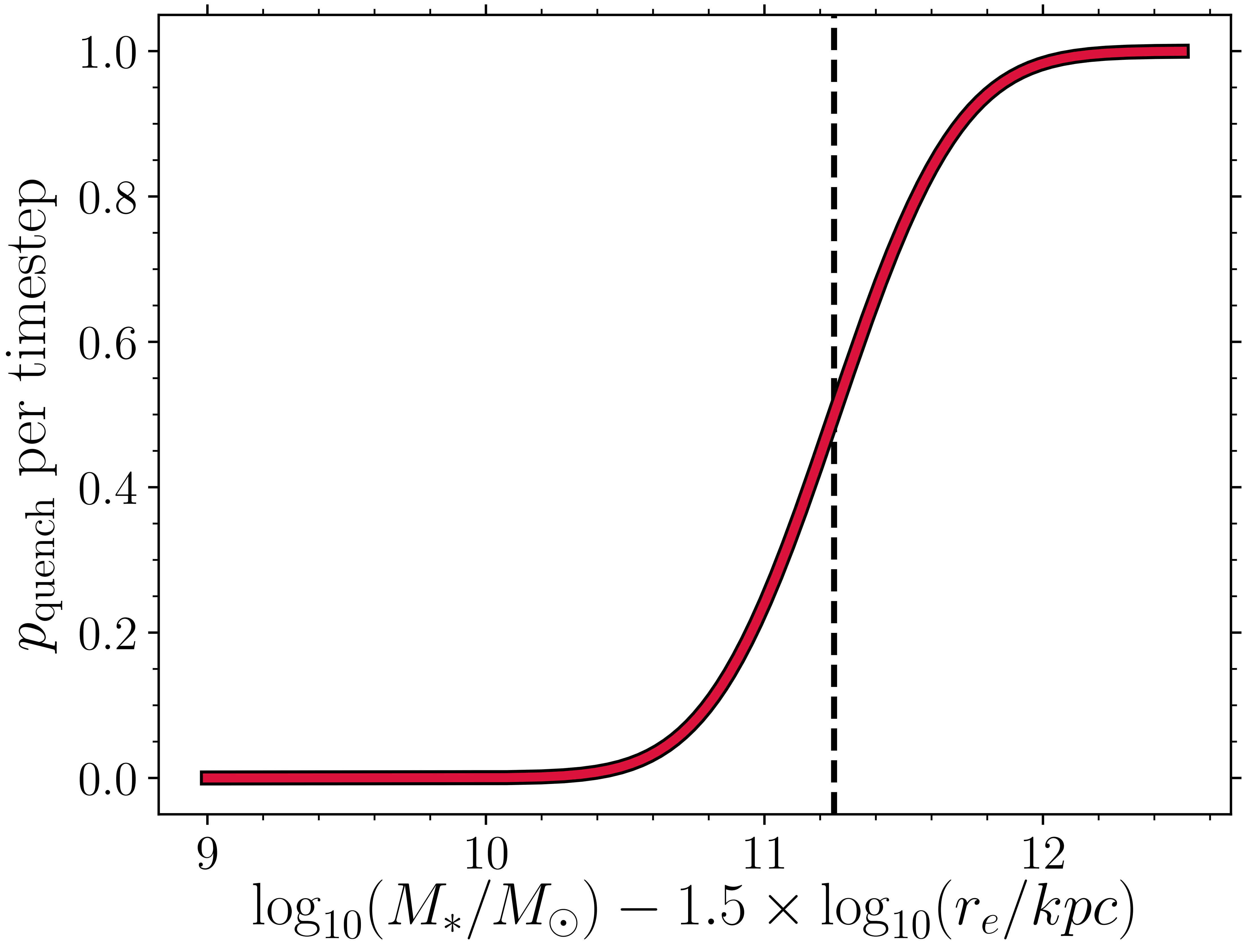
# A toy model of galaxy evolution

- Now have galaxies quench in a way which depends on their mass and size
- Once galaxies quench, they stop growing in mass, size and metallicity
- I've tried looking at quenching based on potential (m/r), and quenching based on surface mass density (m/r^2). A less obvious combination gave the best results- m/r^(3/2)



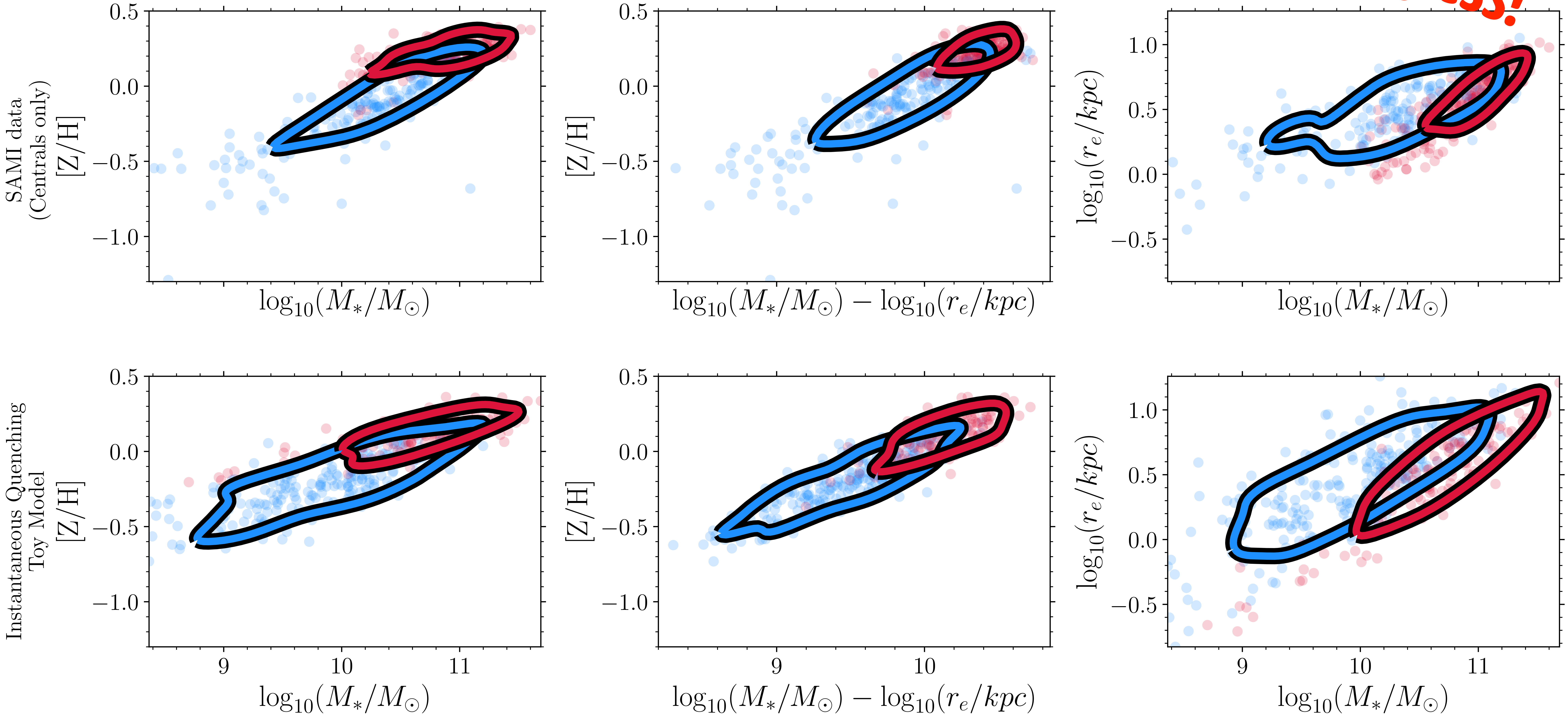
# A toy model of galaxy evolution

- Sample my galaxies to have the same mass-function as SAMI
- Add in observational uncertainties as random scatter
- Compare to the SAMI centrals, since SAMI satellites may have quenched due to environmental processes



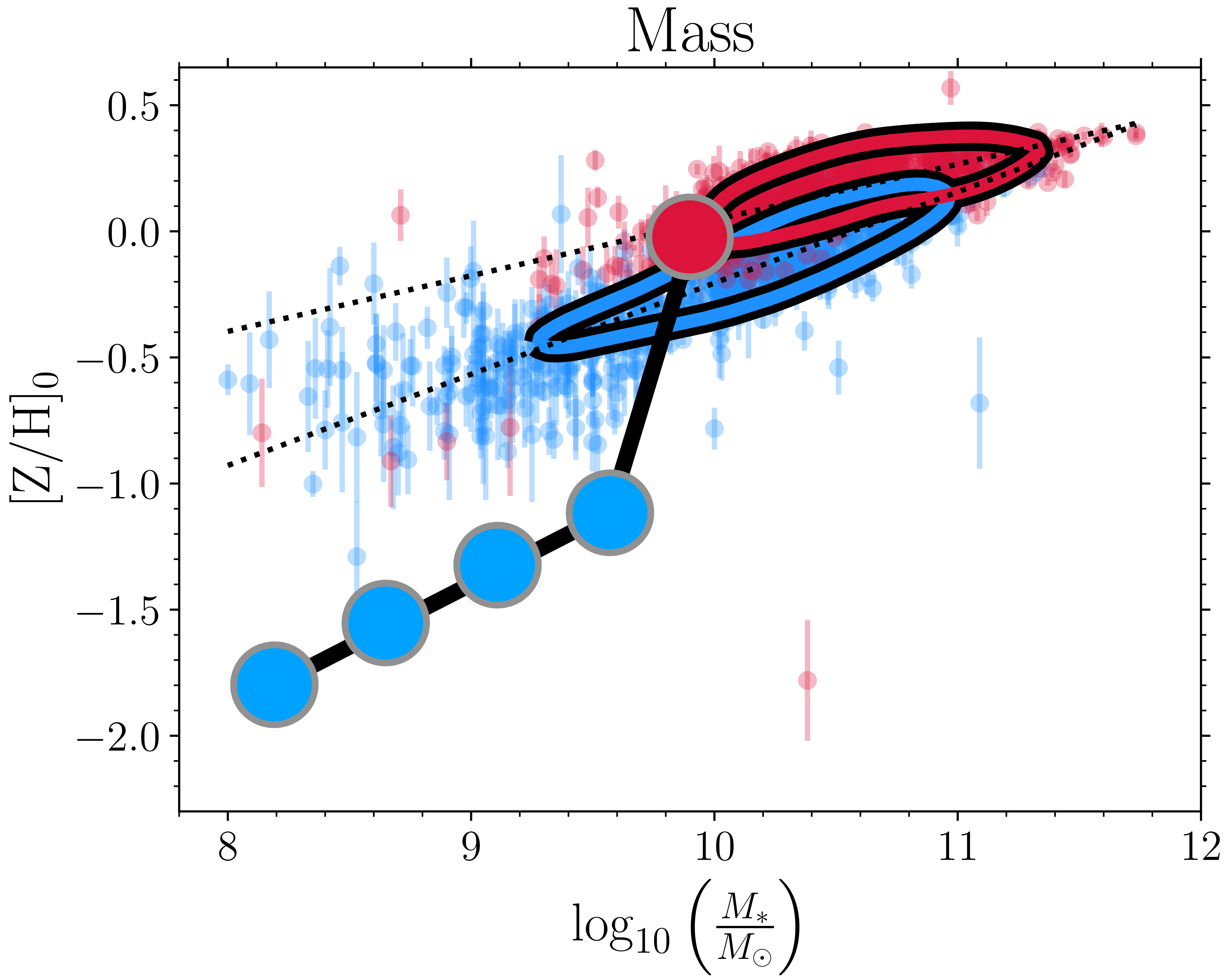
# A toy model of galaxy evolution

Work in progress!



# A toy model of galaxy evolution

- Slow quenching evolution in the mass-metallicity plane (Peng et al. & Trussler et al.)



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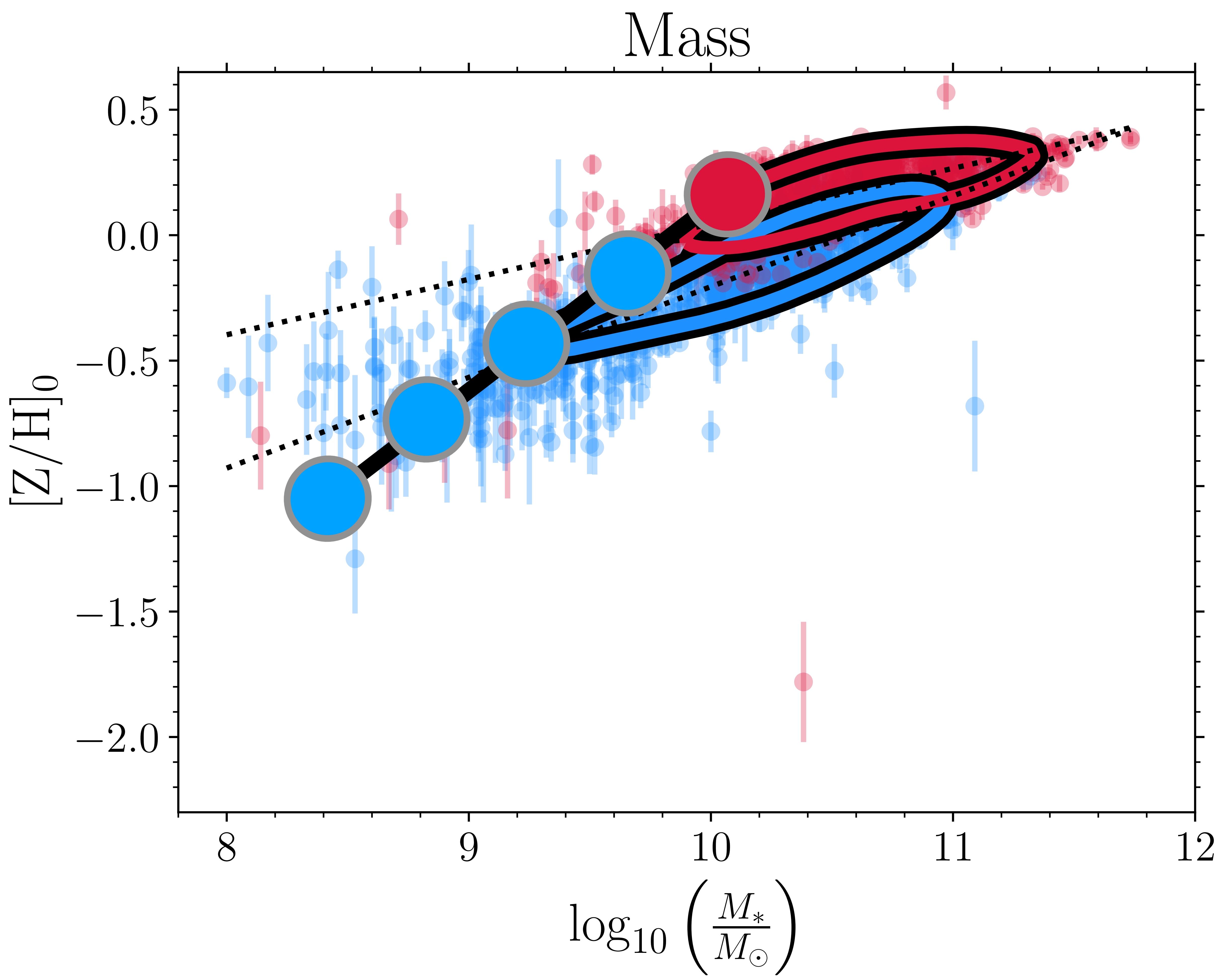
- Toy model evolution in the mass-size plane



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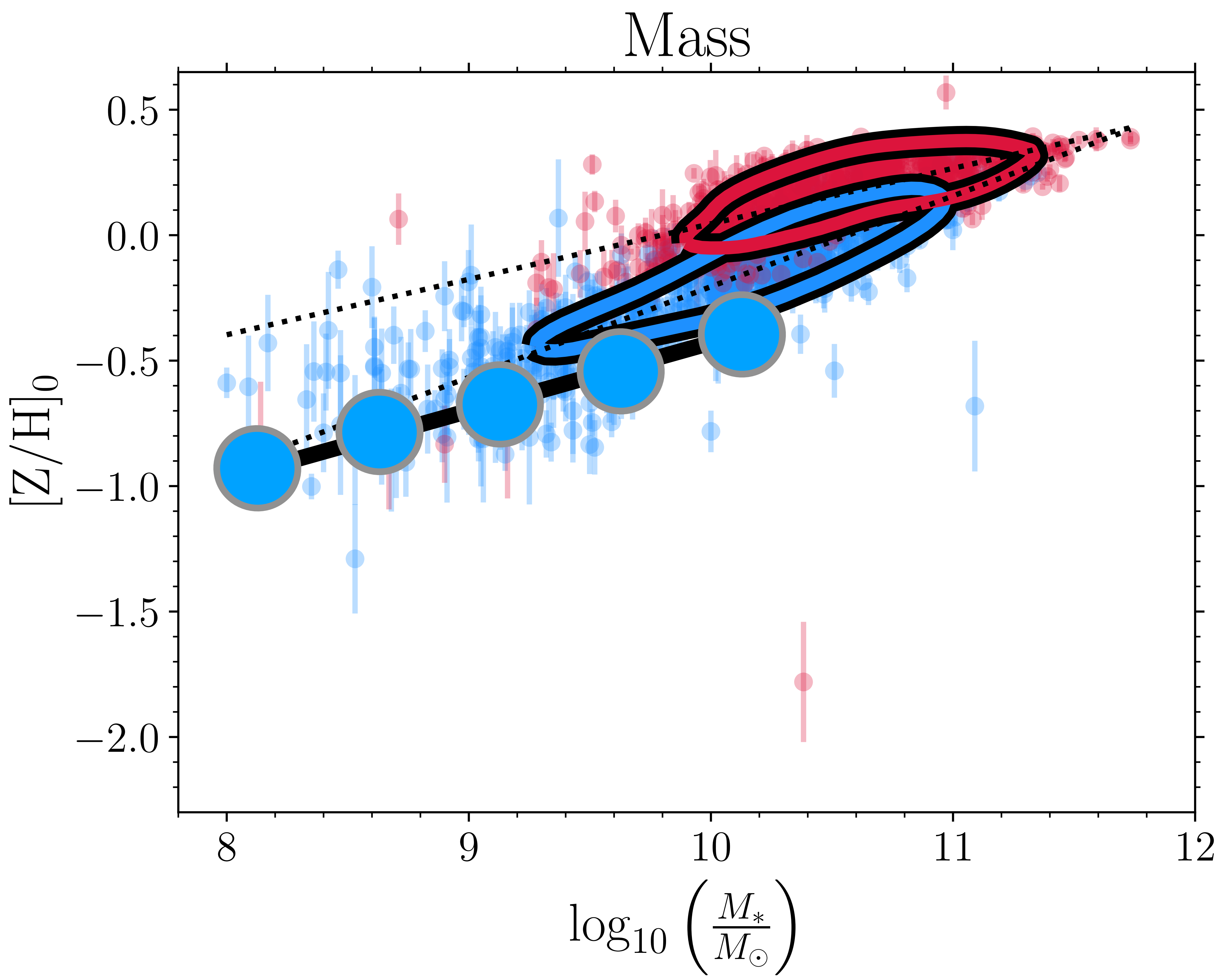
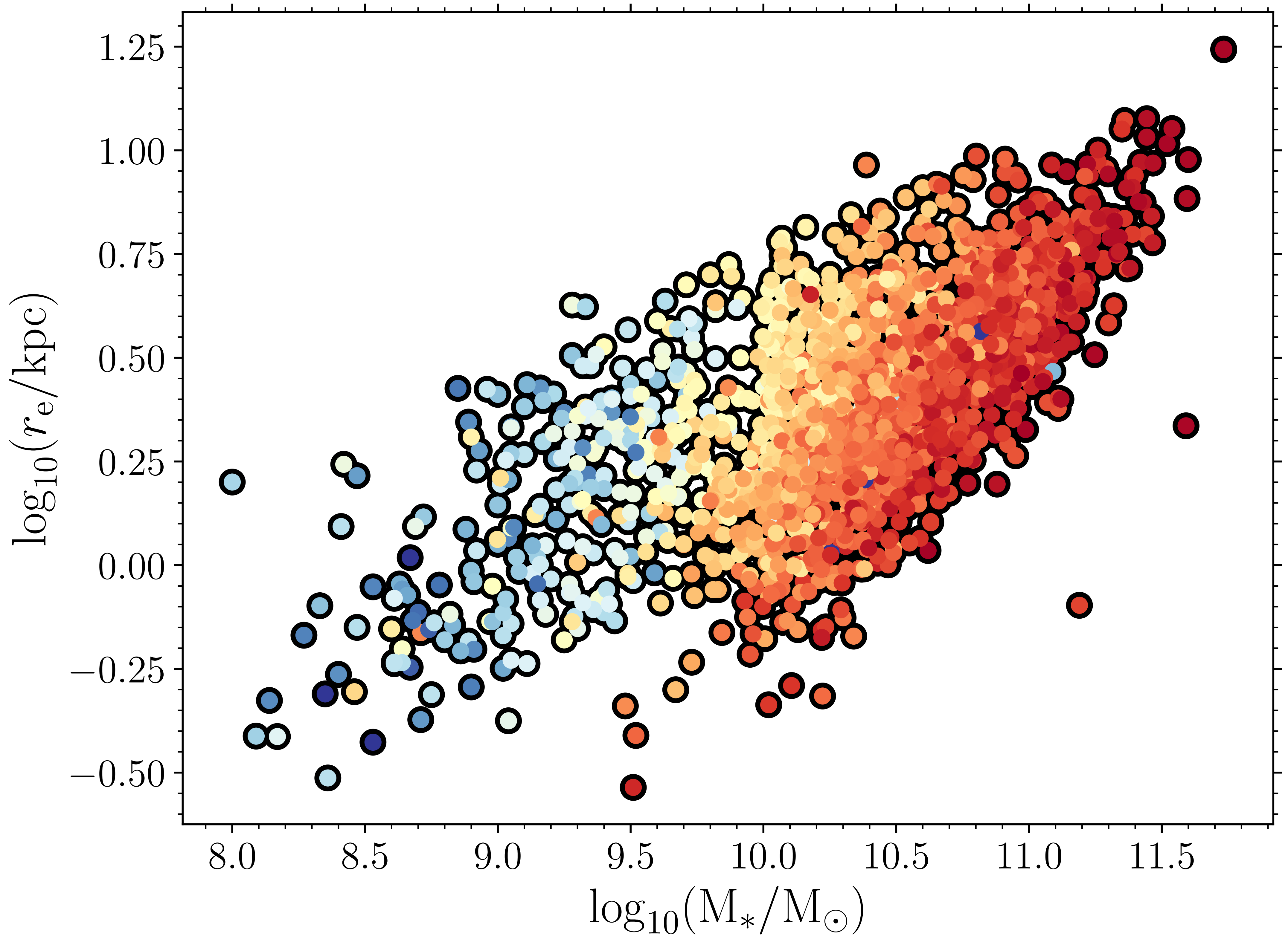


# Conclusions

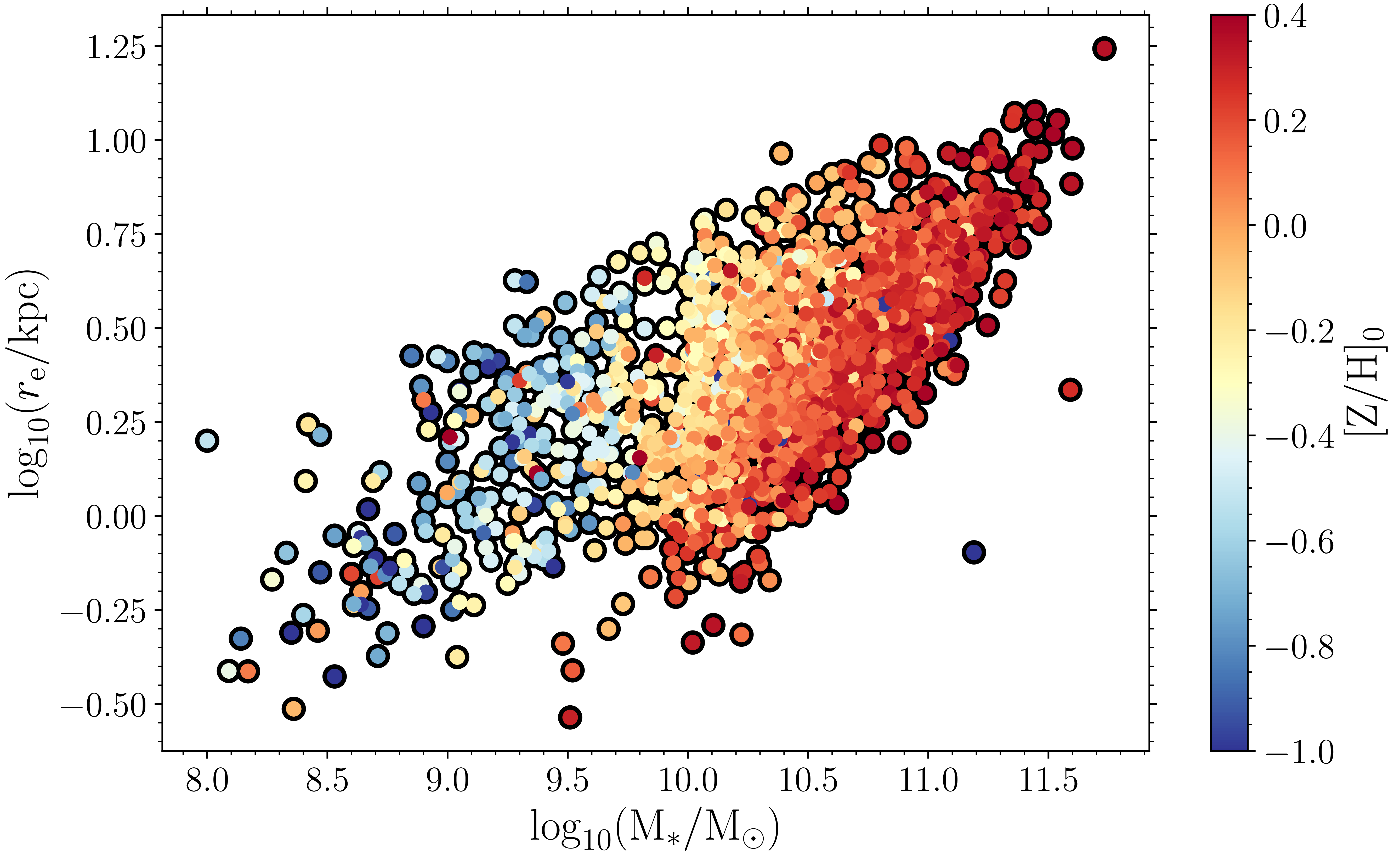
- I've measured stellar metallicity (and age) gradients for ~2k galaxies in the SAMI survey.
- Whilst some authors have used similar data to conclude that quenching is slow, my toy model shows that quenching can be fast as long as a galaxy's size influences the likelihood of quenching. This ties in with other recent work suggesting that extended galaxies quench later than "normal" sizes ones (Gupta et al. 2020)
- The combination of mass - 1.5 times size is a bit strange. Perhaps hinting that some quenching processes depend on potential, some depend on surface mass density, and these "average out"?
- There is still room for slow quenching processes!

# Results- not using a Hierarchical Model

## Hierarchical  Model




## Fitting each galaxy individually



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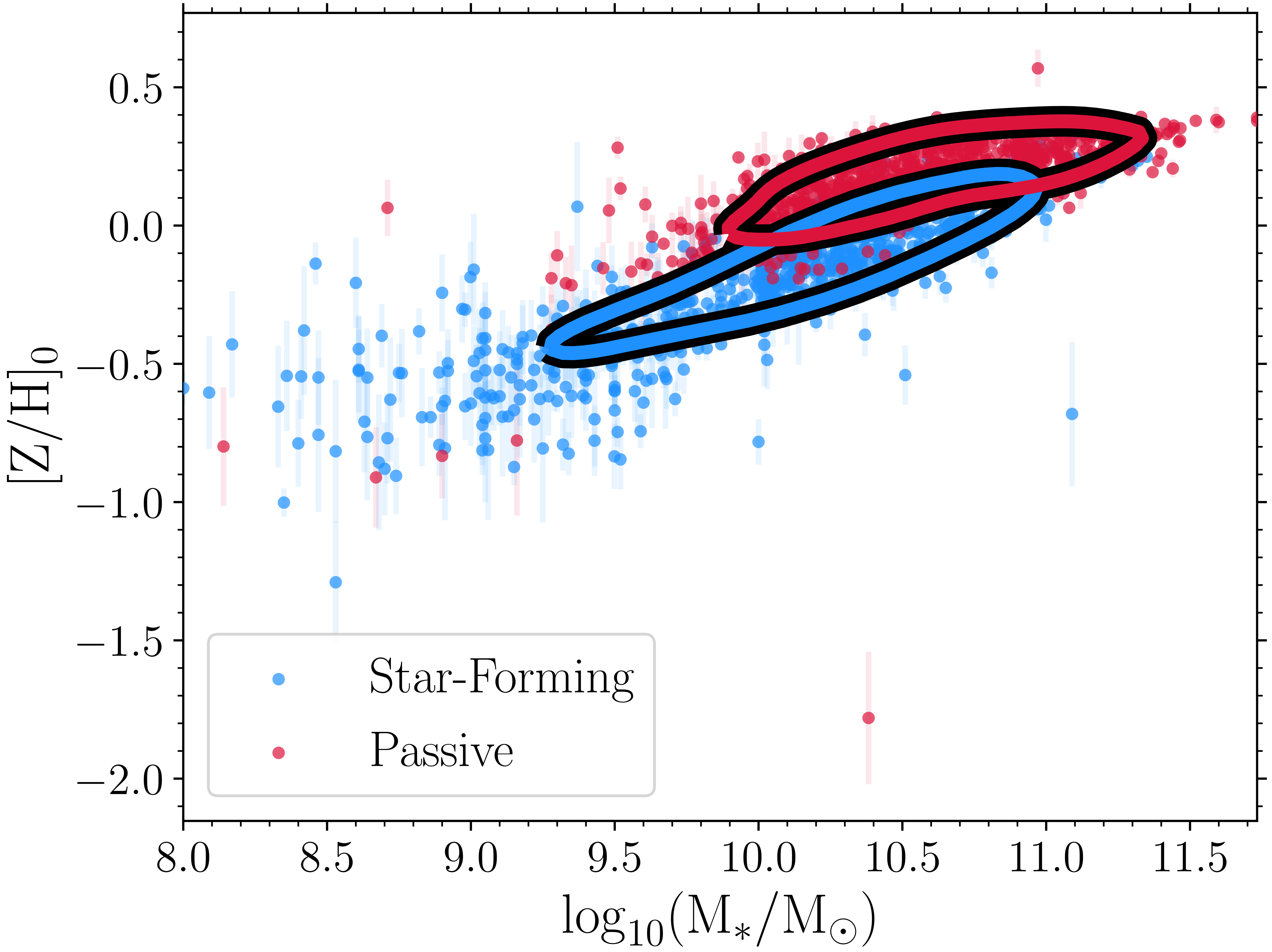


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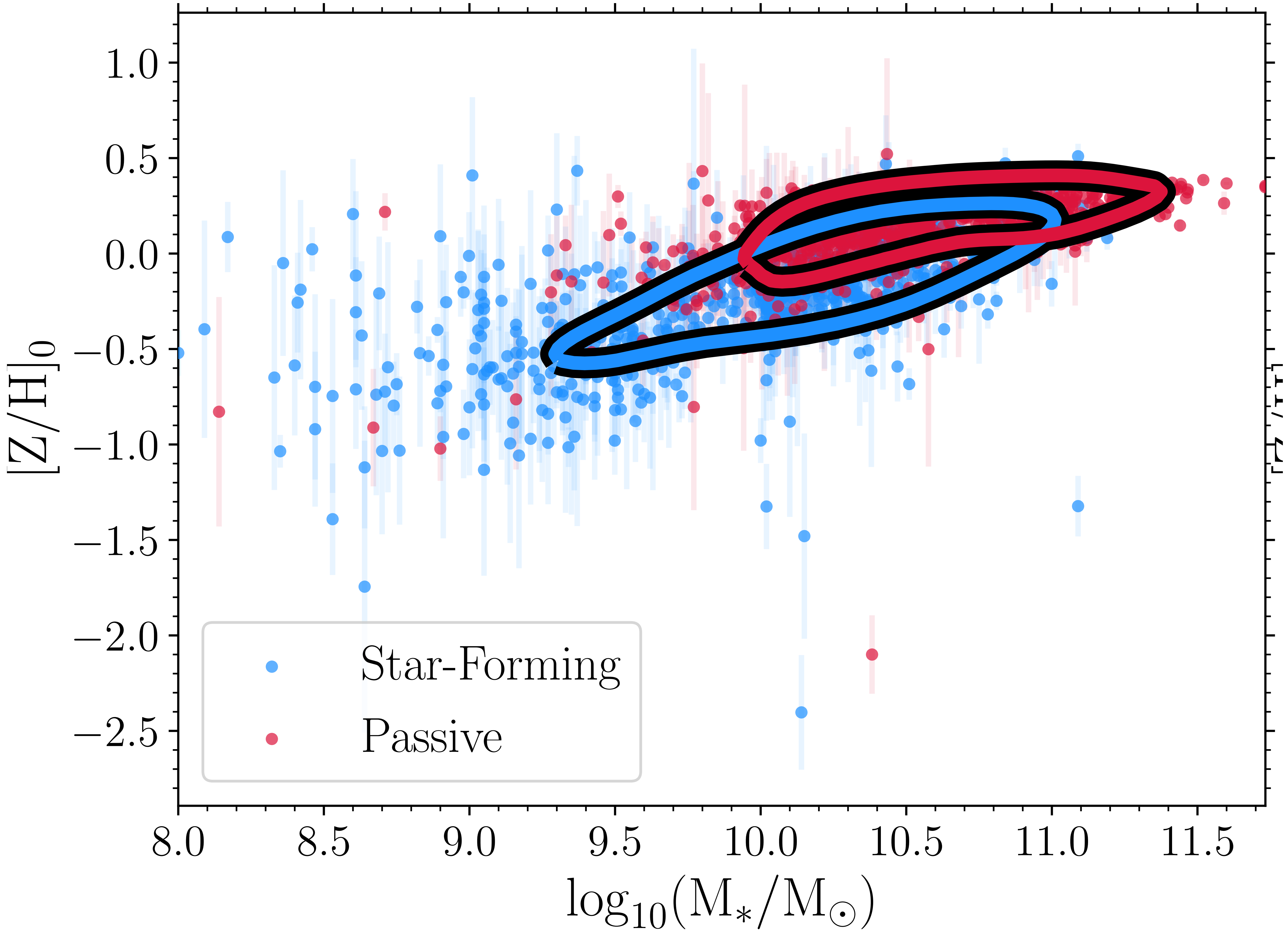

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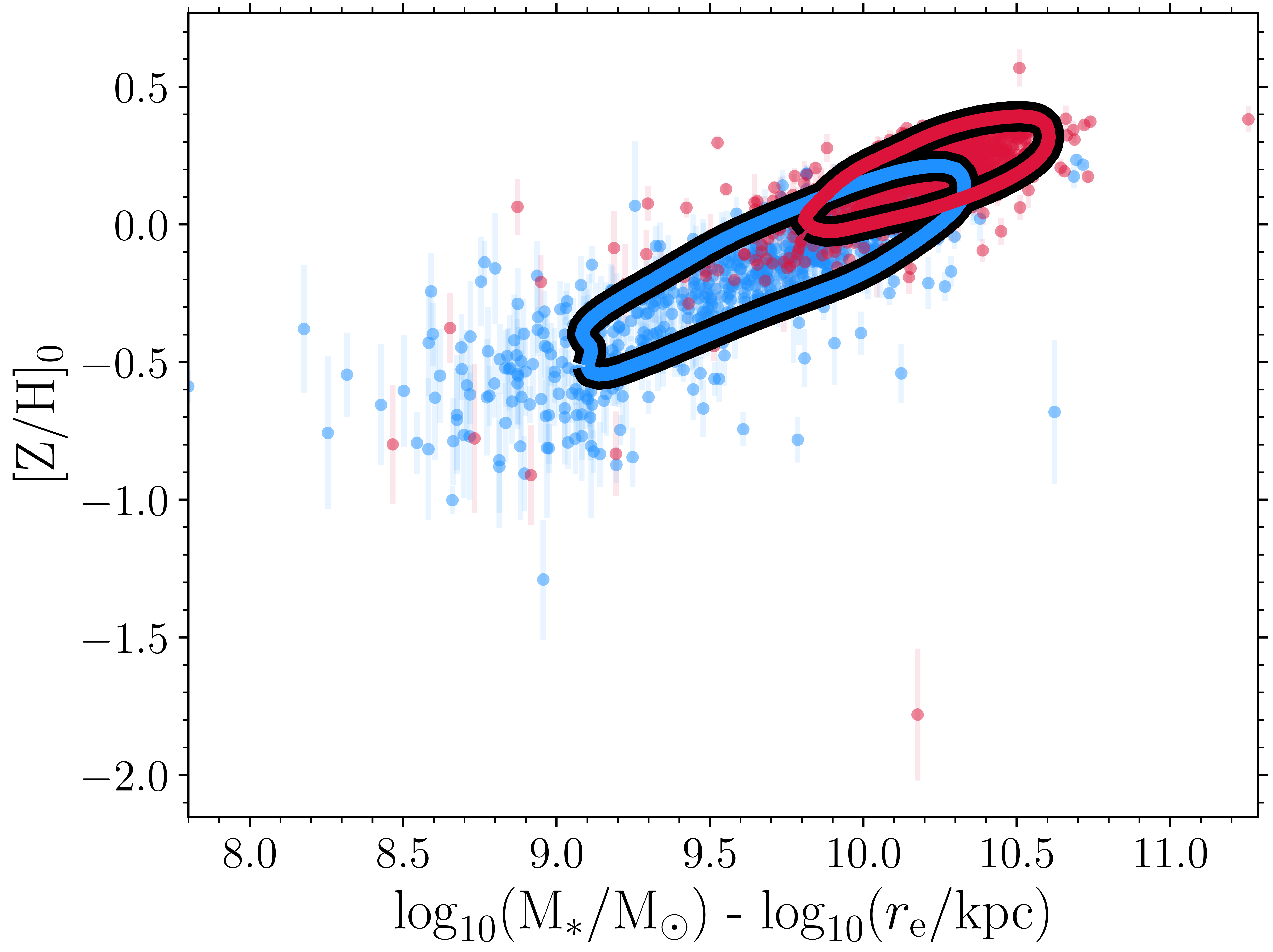


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