From the Field to the Cluster

The Many Paths of Galaxy Transformation with *Euclid*

Galaxy Cluster France

Meudon, November 26th 2026

Fabrizio Gentile

Département D'Astrophysique - CEA Paris-Saclay

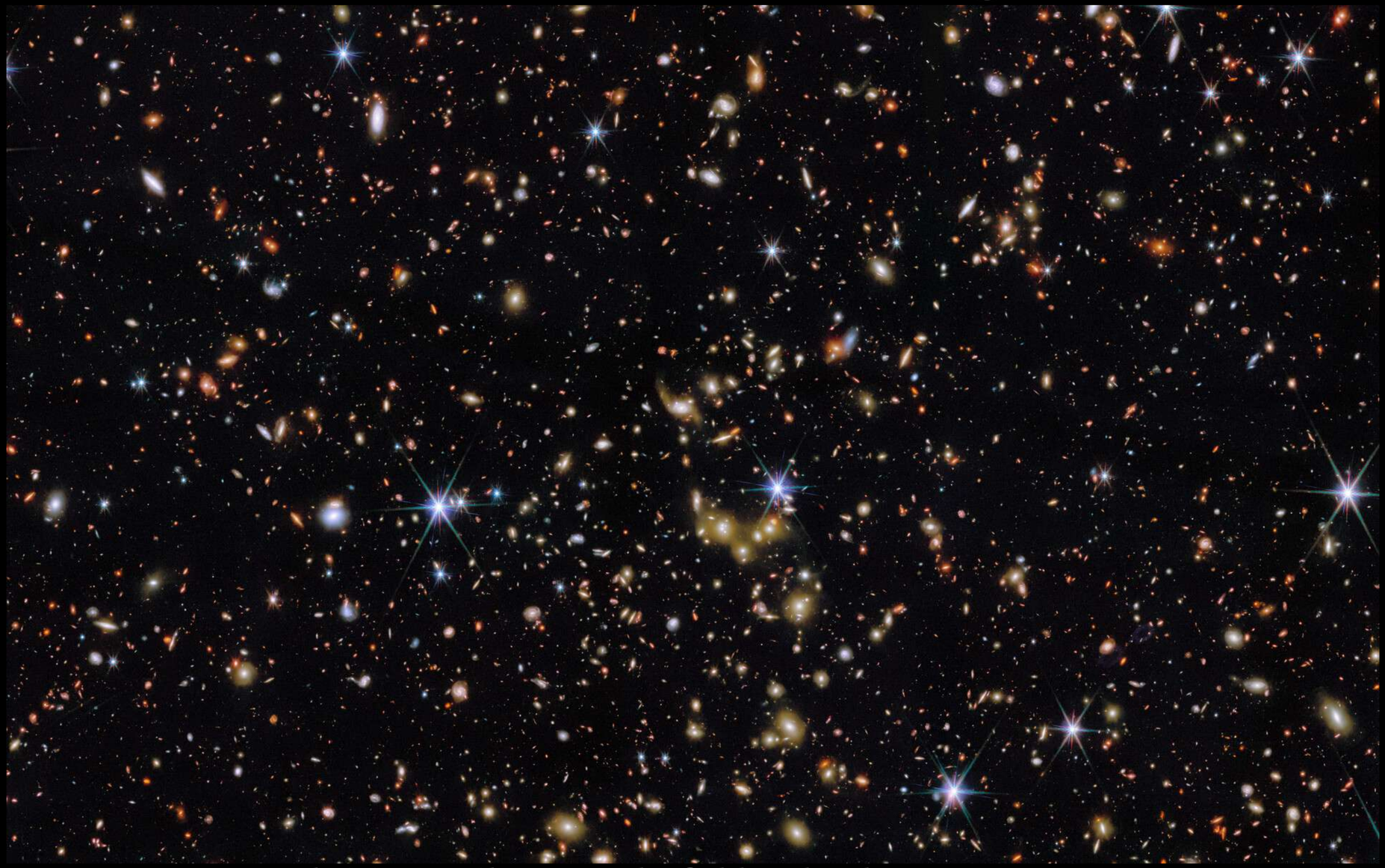
INAF - Osservatorio Astronomico Di Bologna

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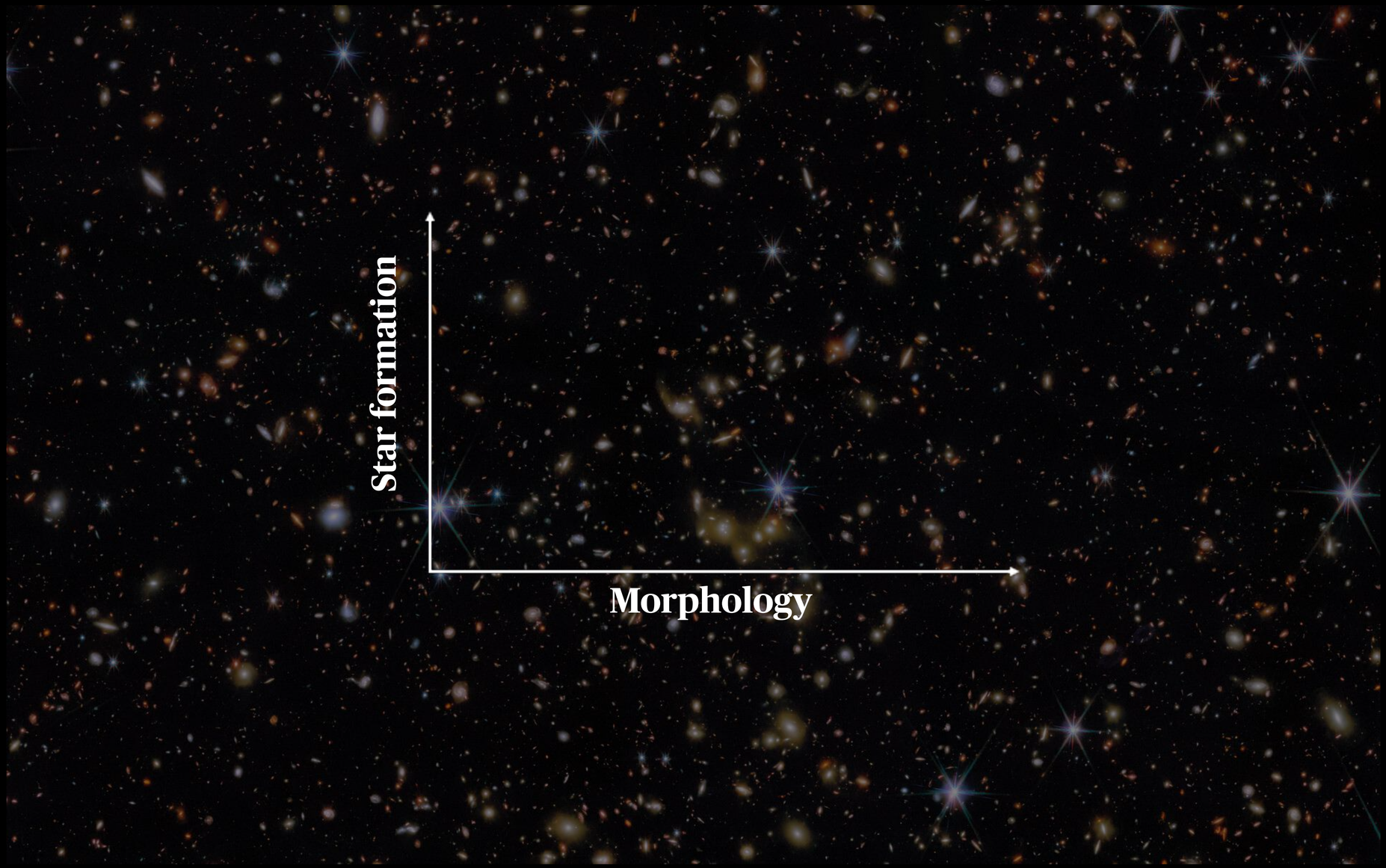
"ELSA: Euclid Legacy Science Advanced analysis tools" (Grant Agreement no. 101135203) is funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or Innovate UK. Neither the European Union nor the granting authority can be held responsible for them.

A fundamental observation in extra-galactic astronomy

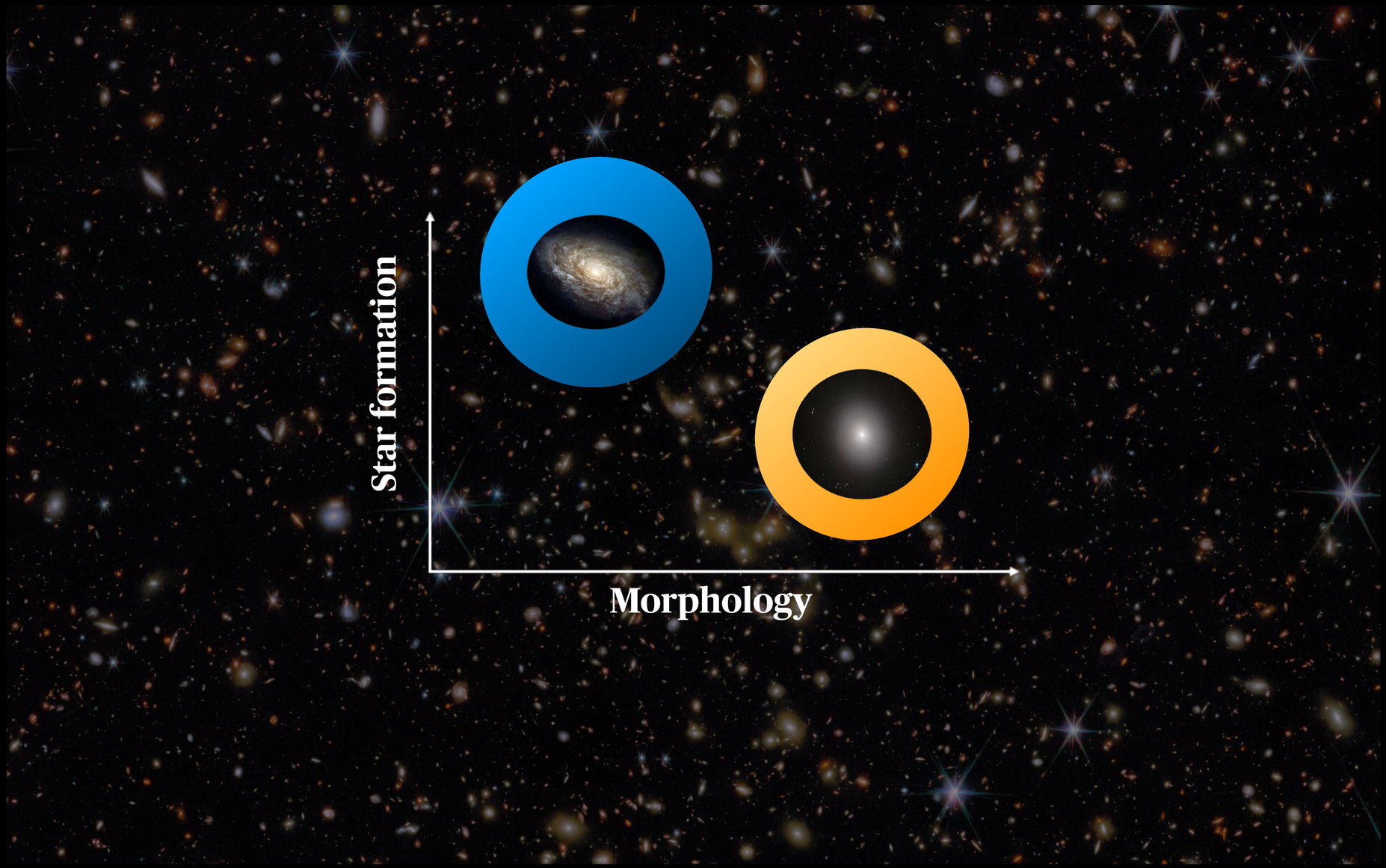
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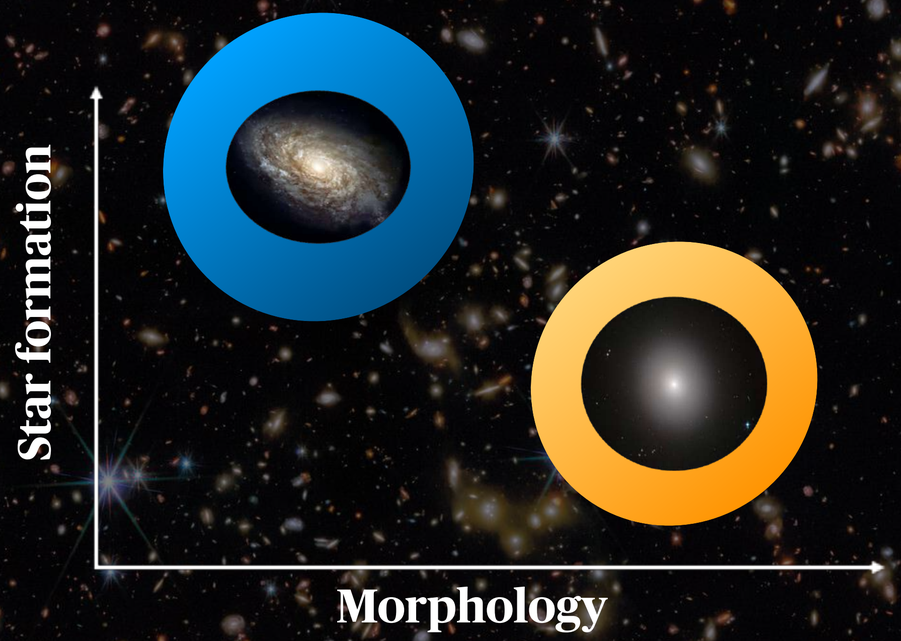


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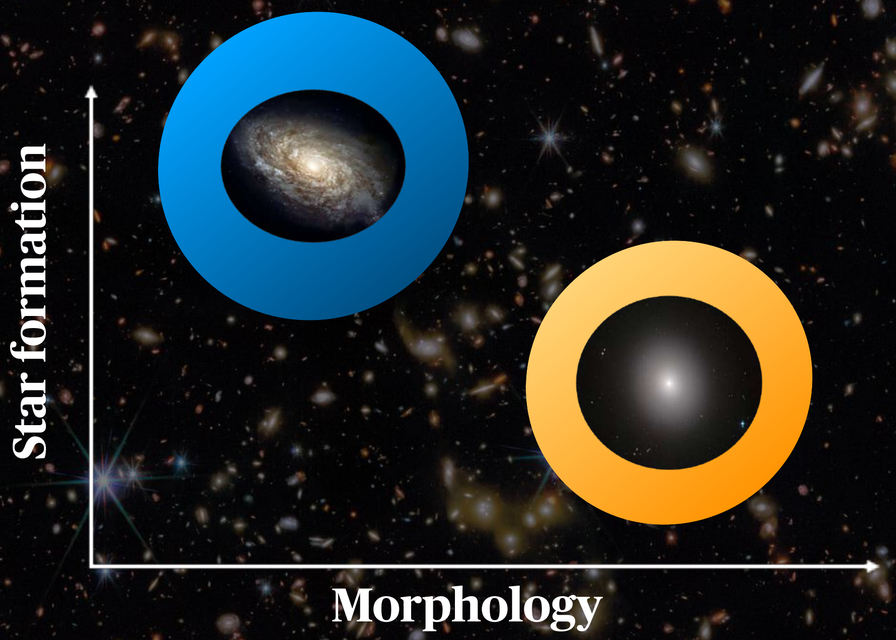
Star formation activity and morphology are connected



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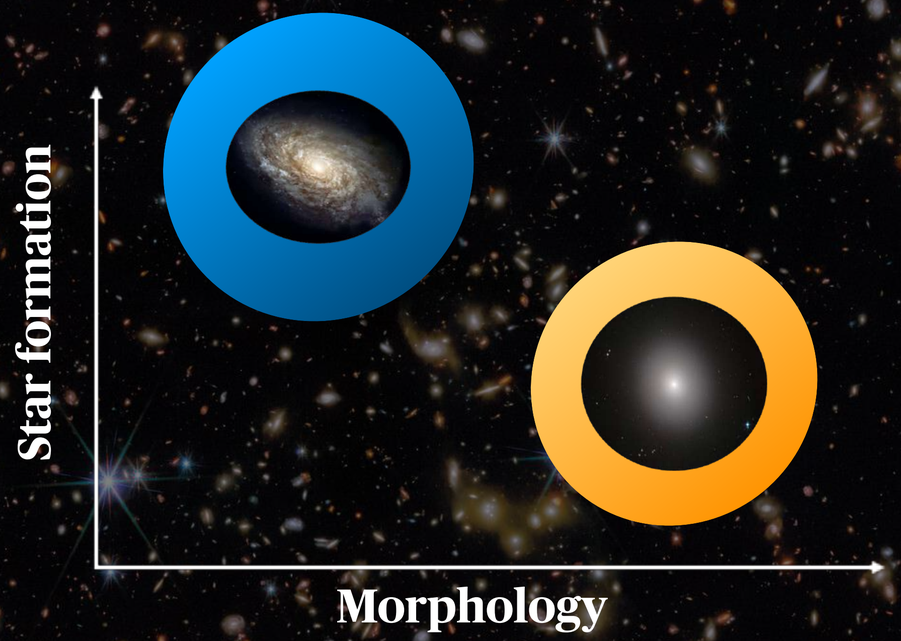
The timescale of the transition is much shorter than the lifetime of a galaxy



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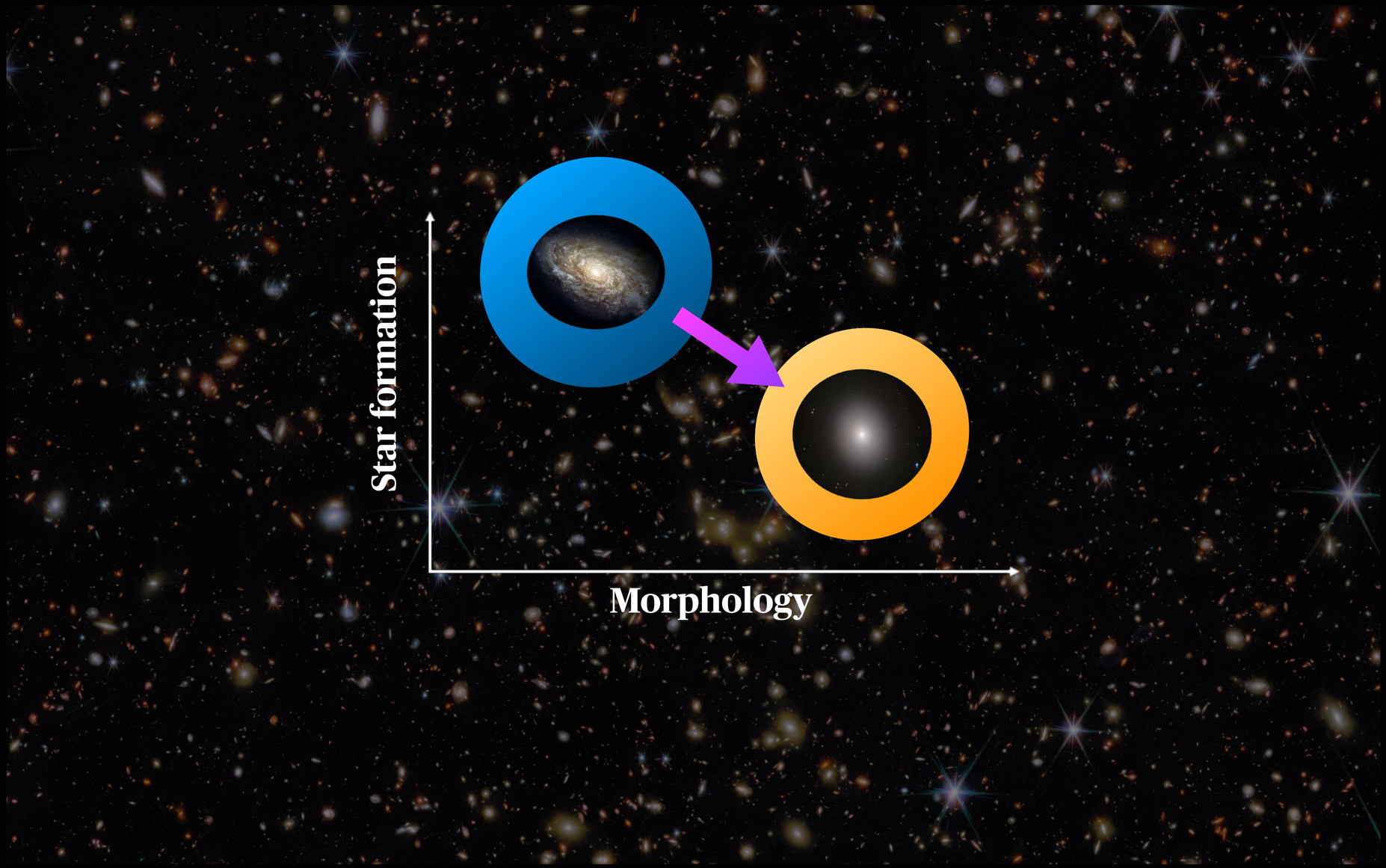
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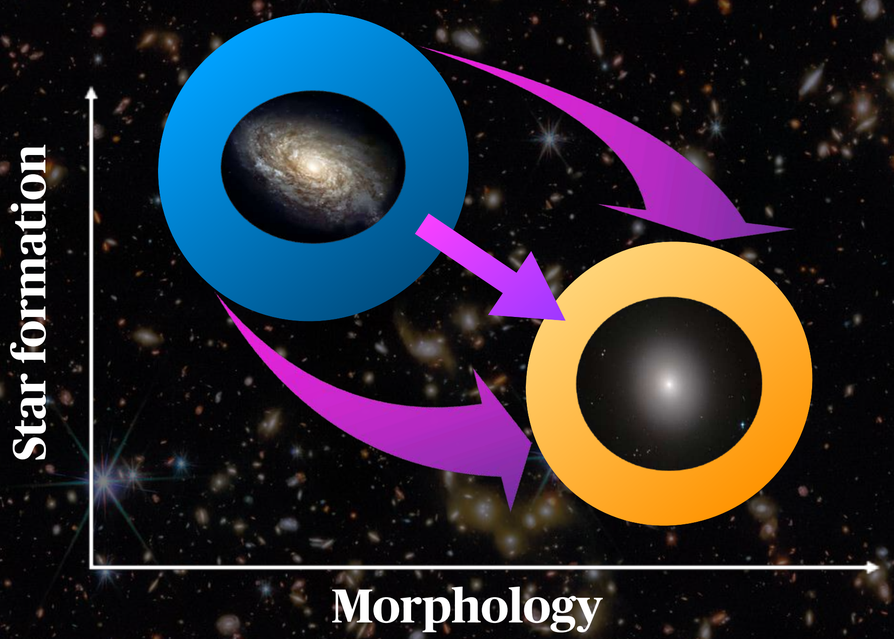


What are the physical mechanisms driving the onset of the galaxy bi-modality?

A fundamental observation in extra-galactic astronomy

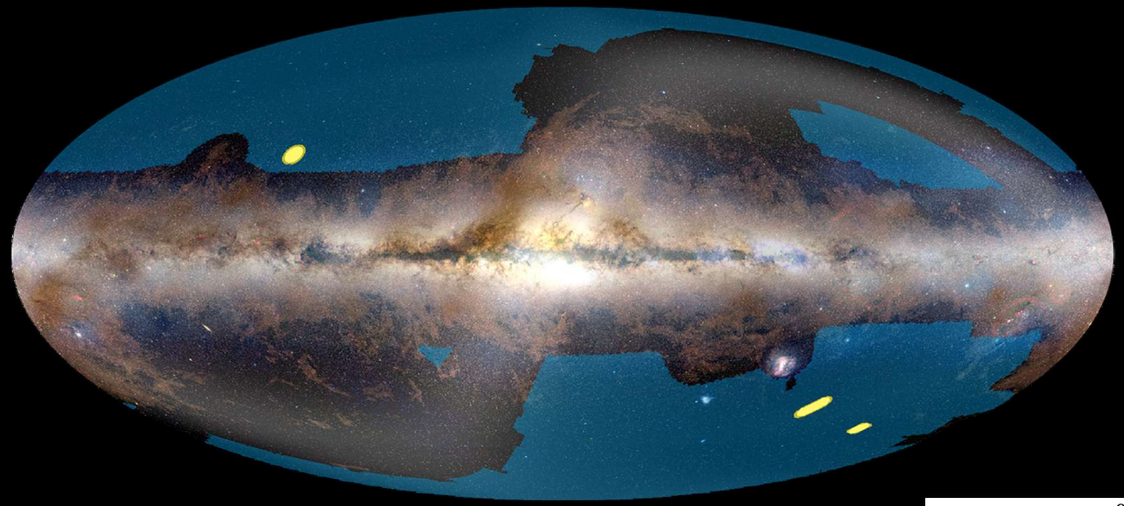


A fundamental observation in extra-galactic astronomy



Euclid Q1 release

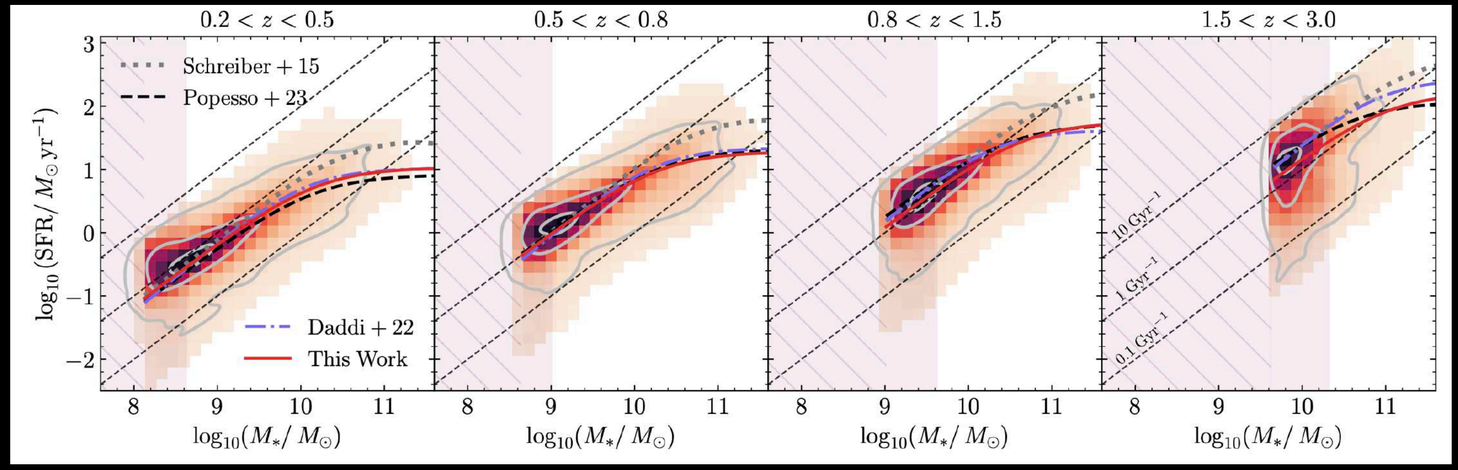
Euclid Q1 release



~60 deg^2 of extra-galactic sky

After cuts, ~1 million galaxies
in the range 0.25<z<1.00

ML-derived photo-z and physical properties

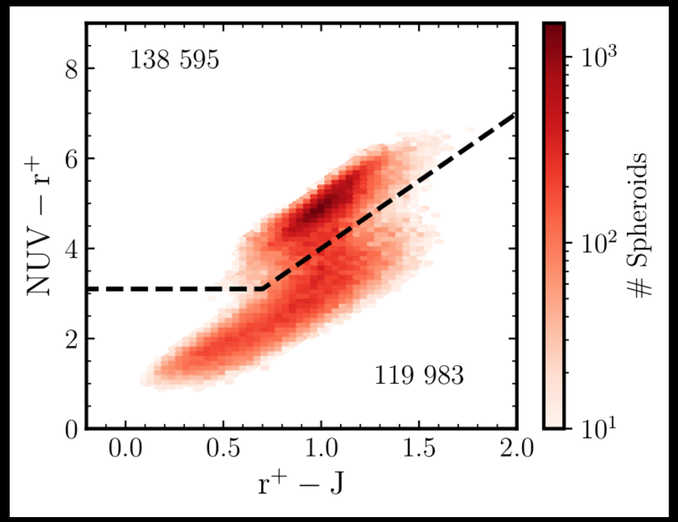


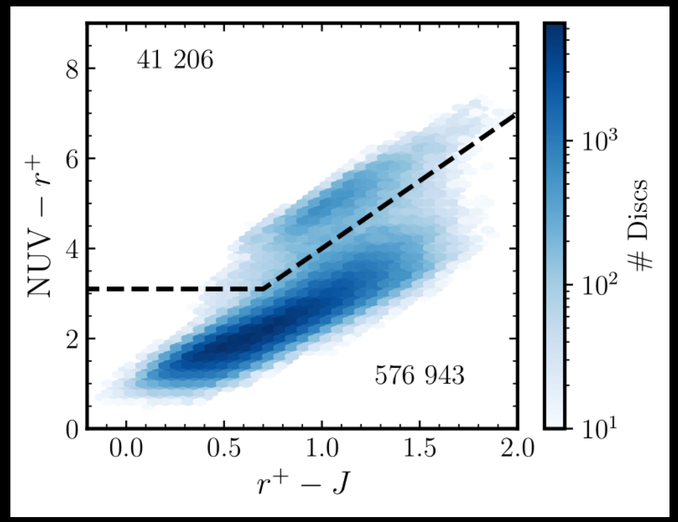
EC: Enia+26

Four populations of galaxies

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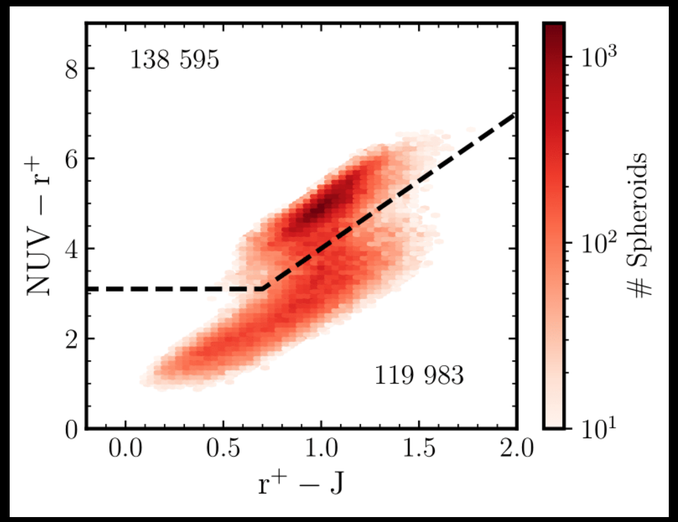
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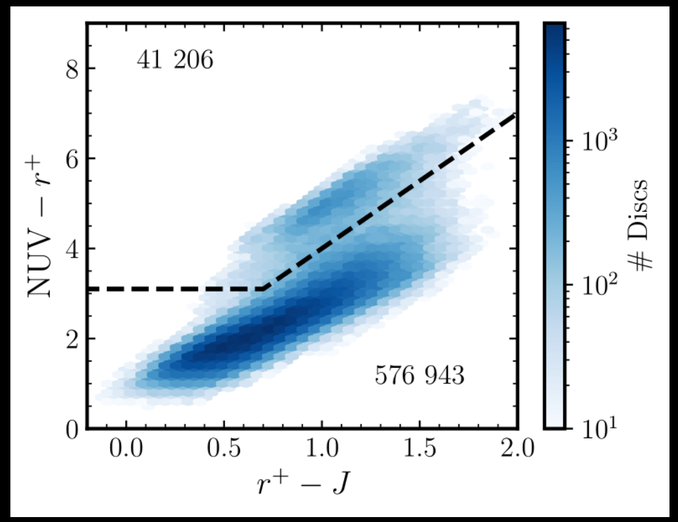




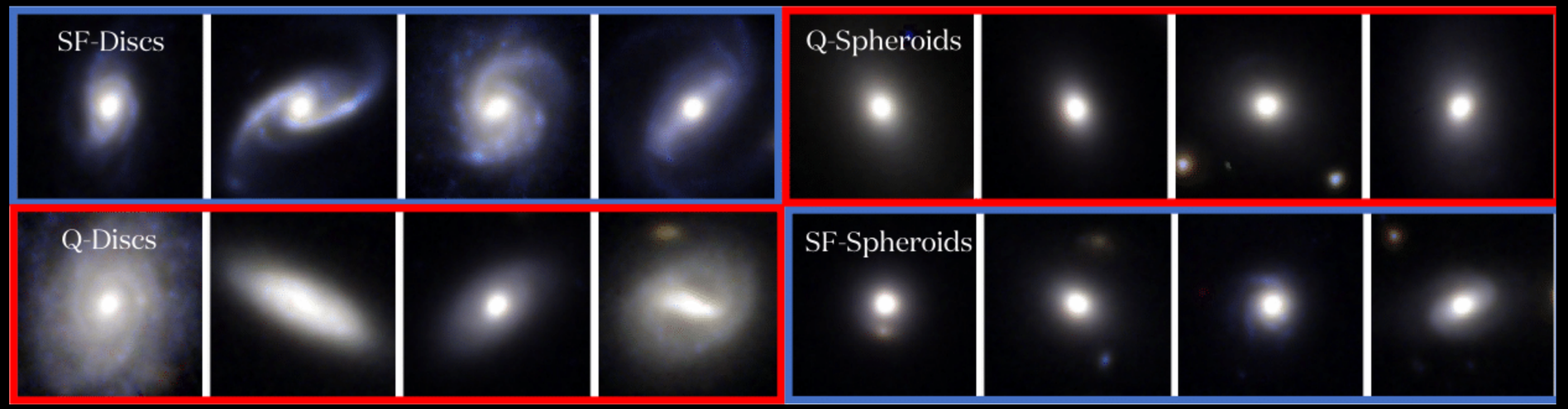
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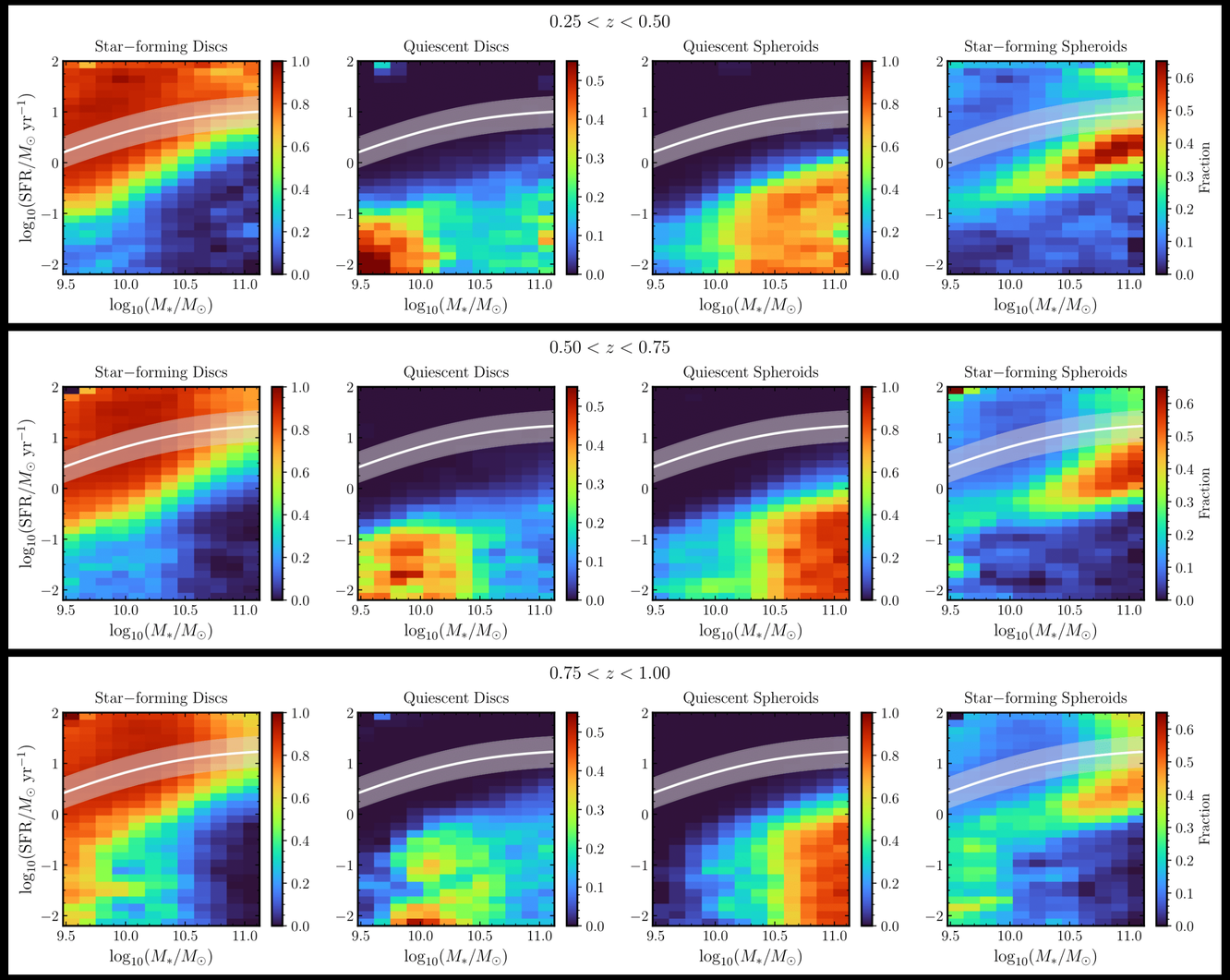


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Physical properties

EC: Gentile+26



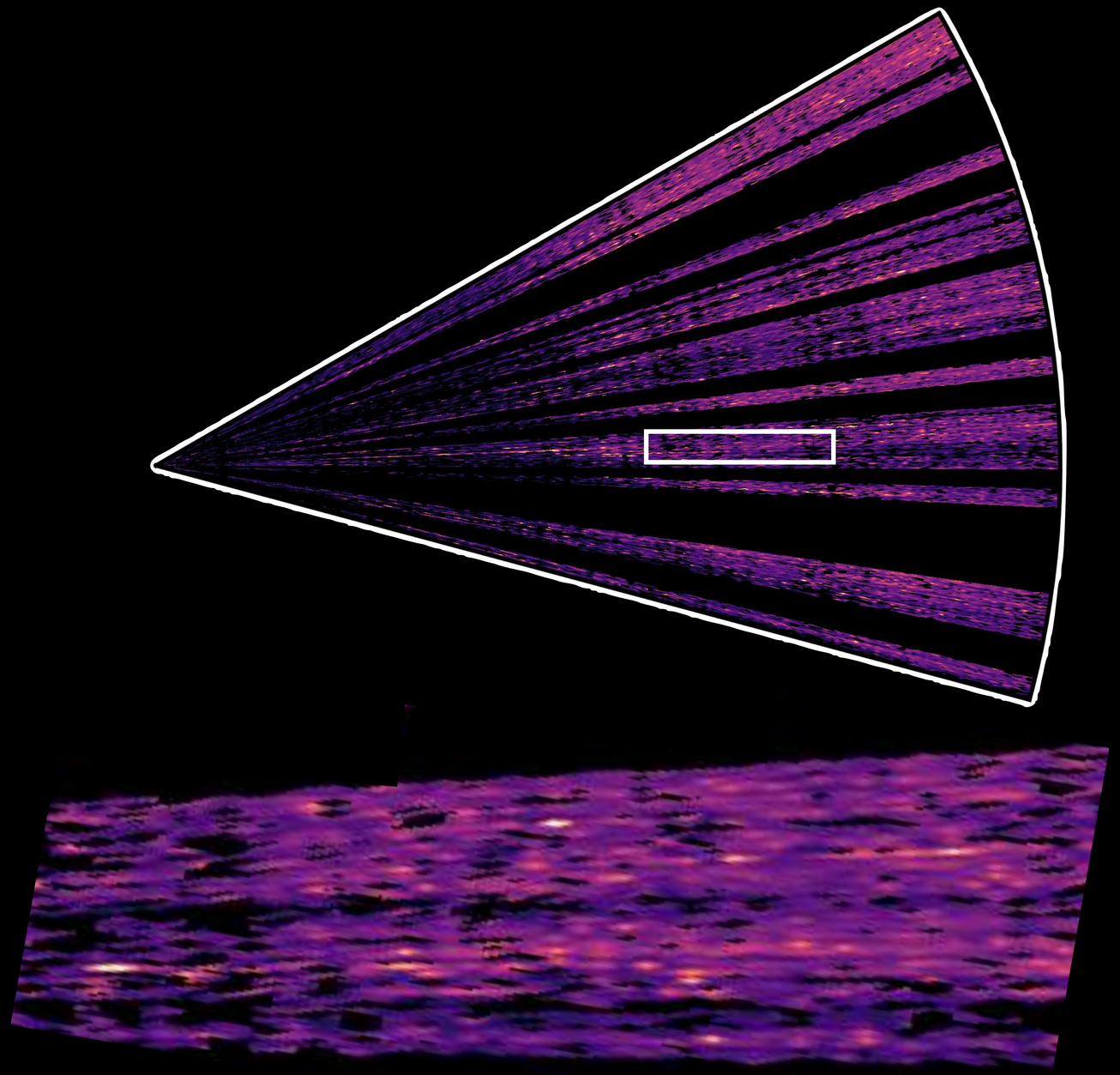
- SF-Disks mainly in the main sequence
- Q-Disks mainly in the low-mass end of the red sequence
- Q-Spheroids in the high-mass end of the red sequence
- SF-Spheroids in the green valley

The role of environment

The role of environment

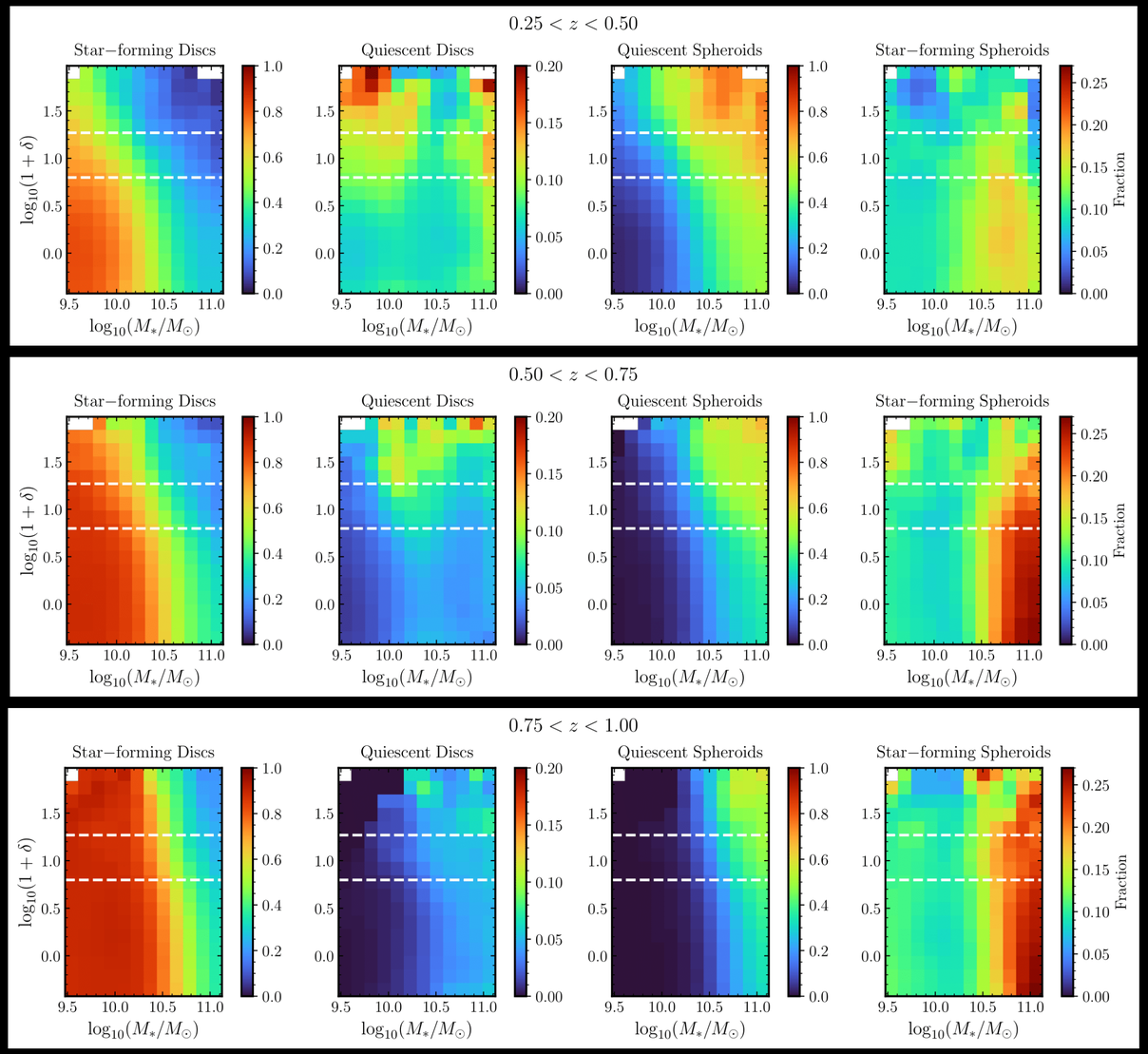
$$\Sigma_N = \frac{N+1}{\pi R_N^2} \text{ (N=5)}$$

$$\log(1+\delta) = \log\left(1 + \frac{\Sigma - \bar{\Sigma}}{\bar{\Sigma}}\right)$$



The role of environment

EC: Gentile+26

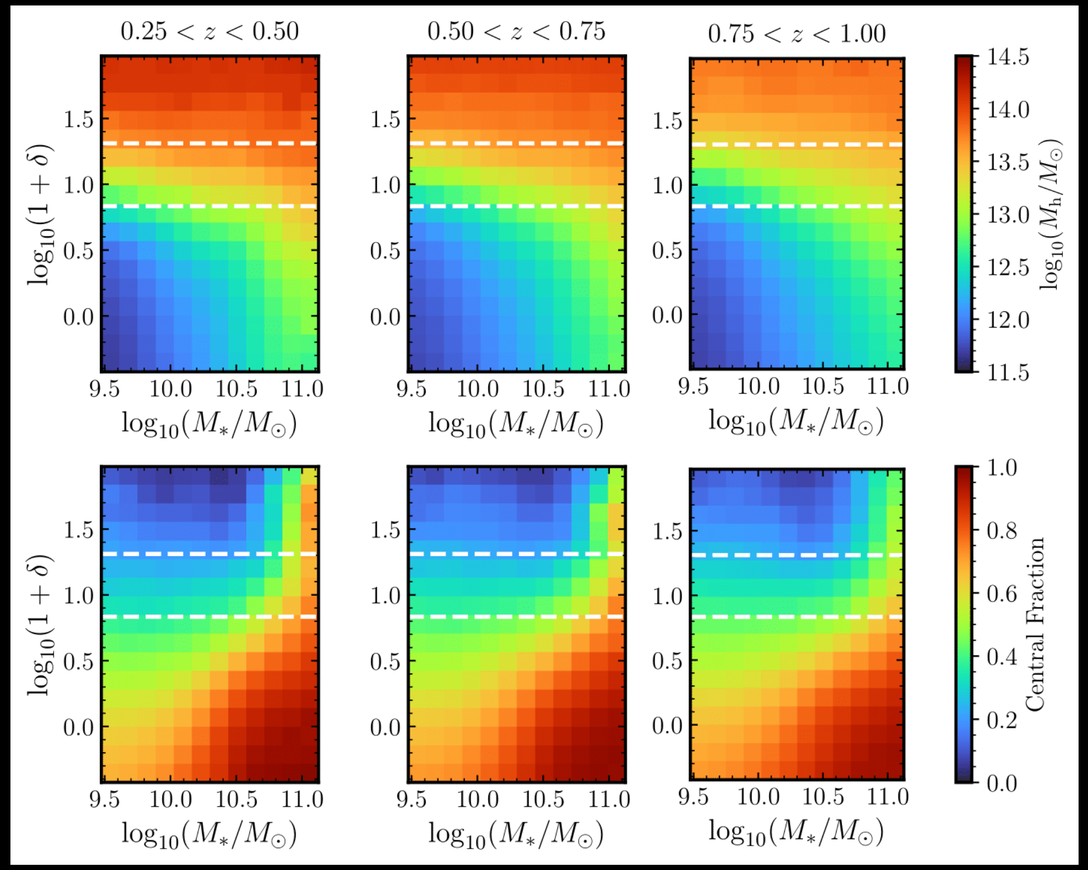


- Confirming the interplay between mass- and environmental-quenching, with increasing intensity with cosmic time
- Negligible abundance of Q-disks in the field: more present in dense environments and abundances increasing with redshift
- High abundance of SF-spheroids in the field, decreasing with cosmic time. Lower fractions in dense environments and low masses

Linking to halo masses

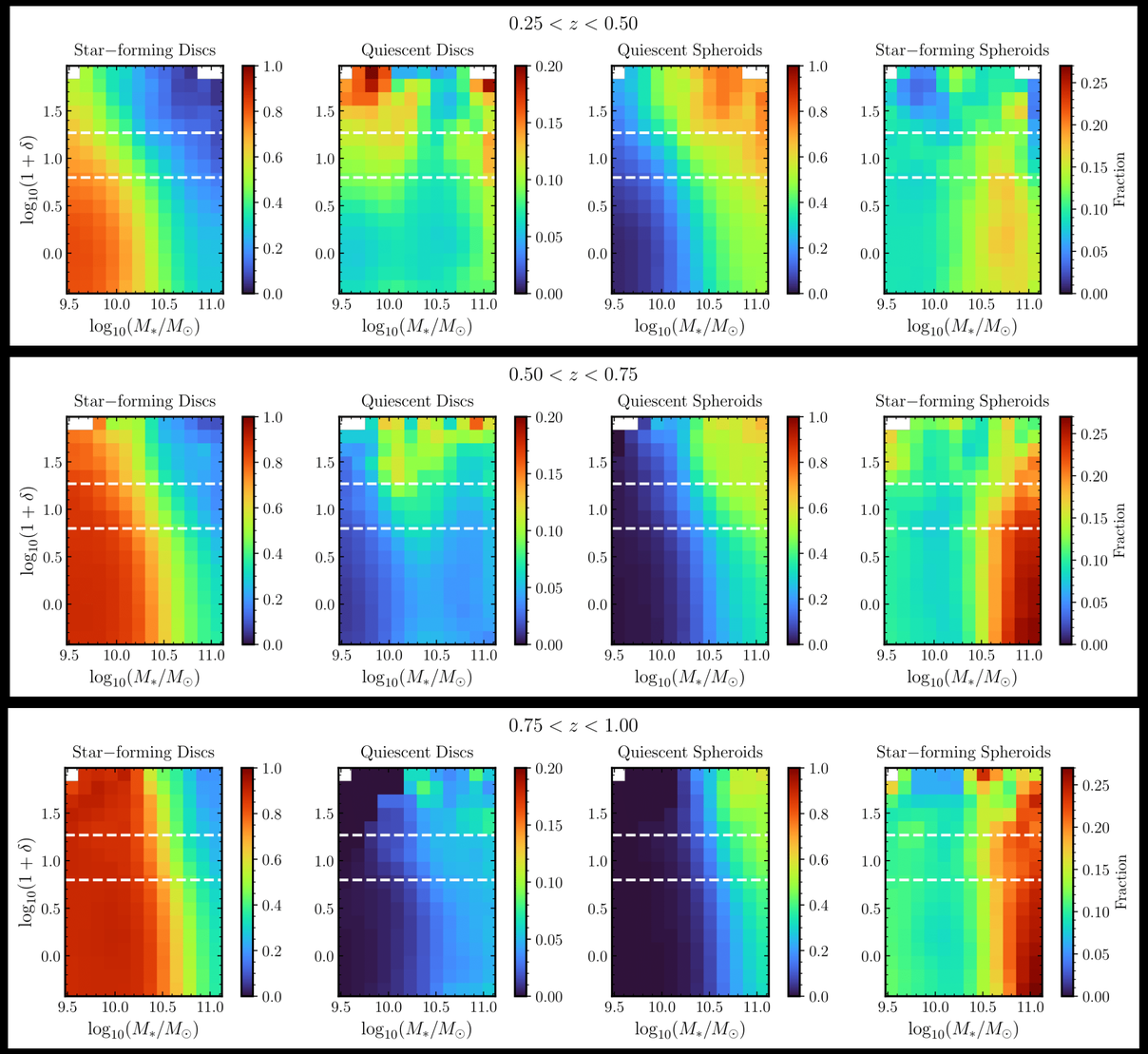
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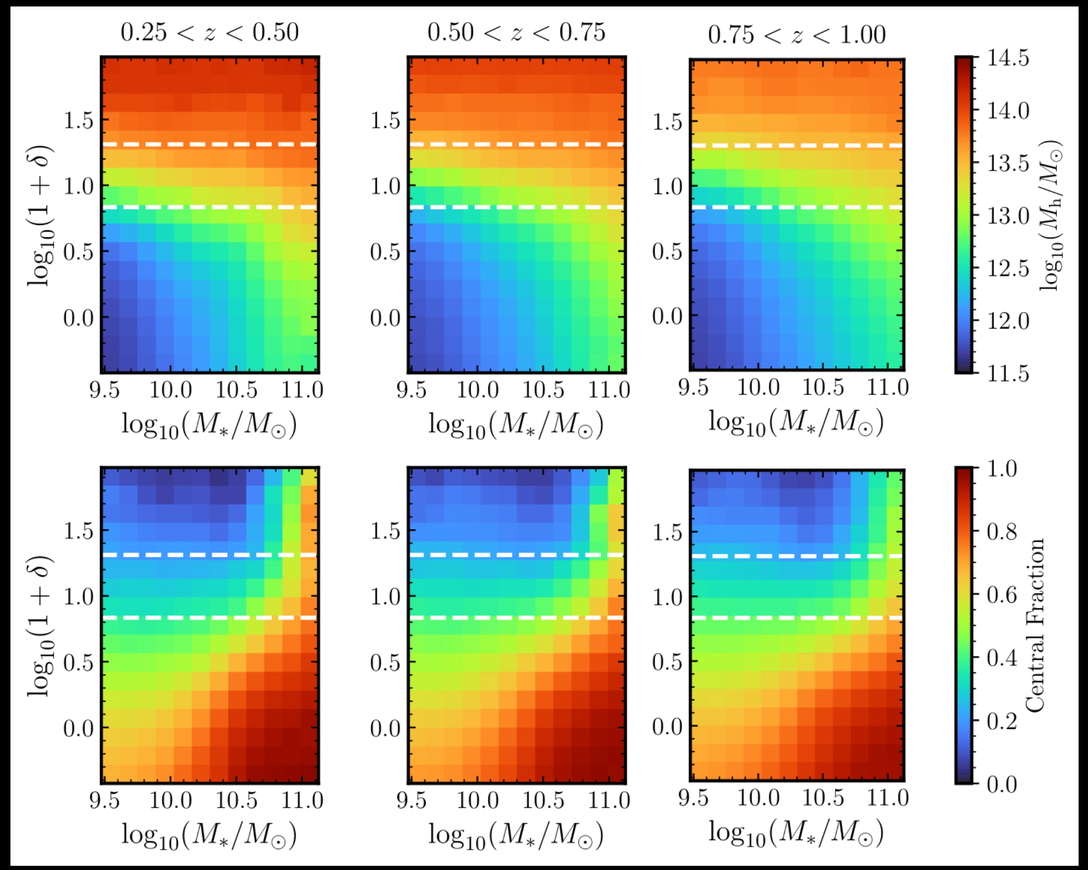


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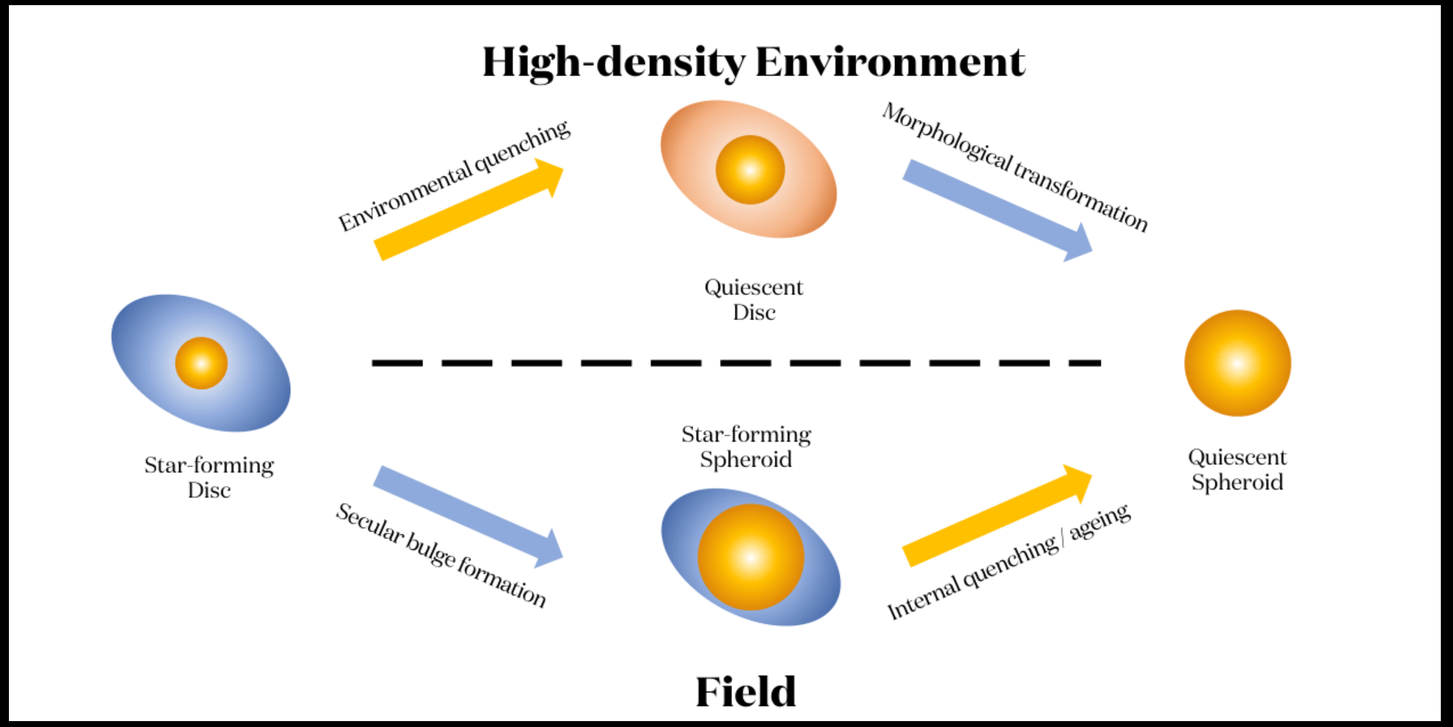


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A likely evolutionary scenario

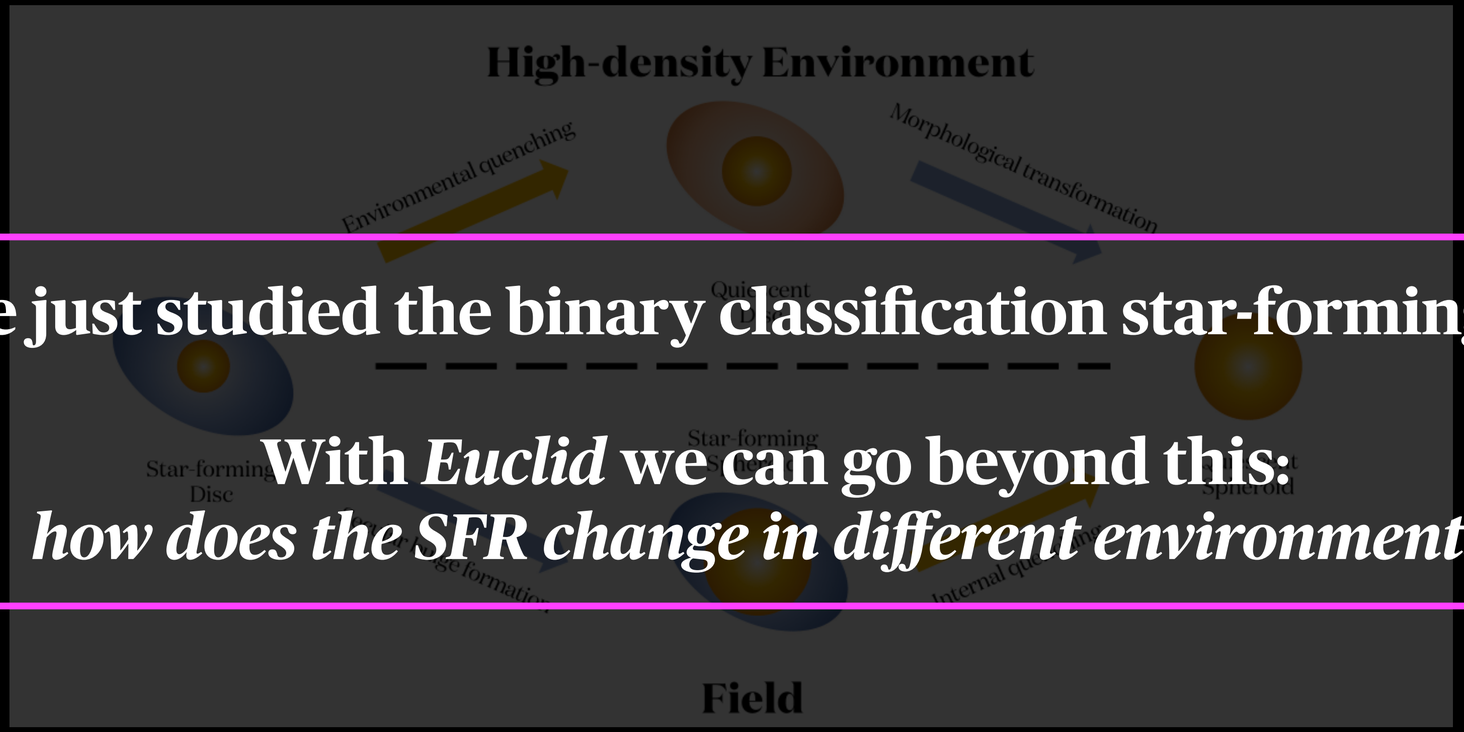
EC: Gentile+26



Read more!

A likely evolutionary scenario

EC: Gentile+26



So far we just studied the binary classification star-forming/quiescent

With *Euclid* we can go beyond this:
how does the SFR change in different environments?

Read more!

Environmental dependence of the main sequence

Environmental dependence of the main sequence



Théo Domingues
Univ. Paris-Saclay

Euclid DR1 - The wide survey

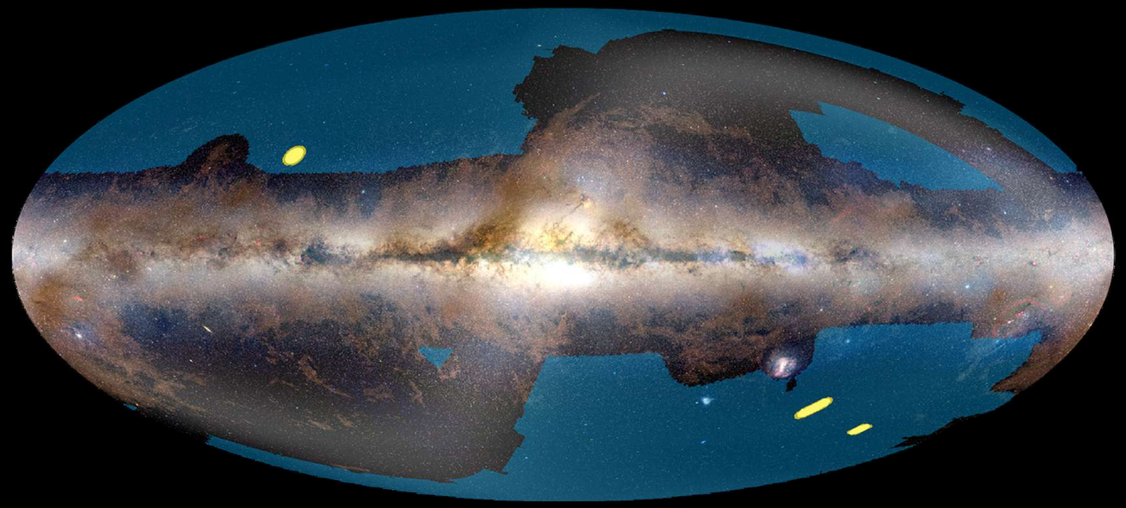
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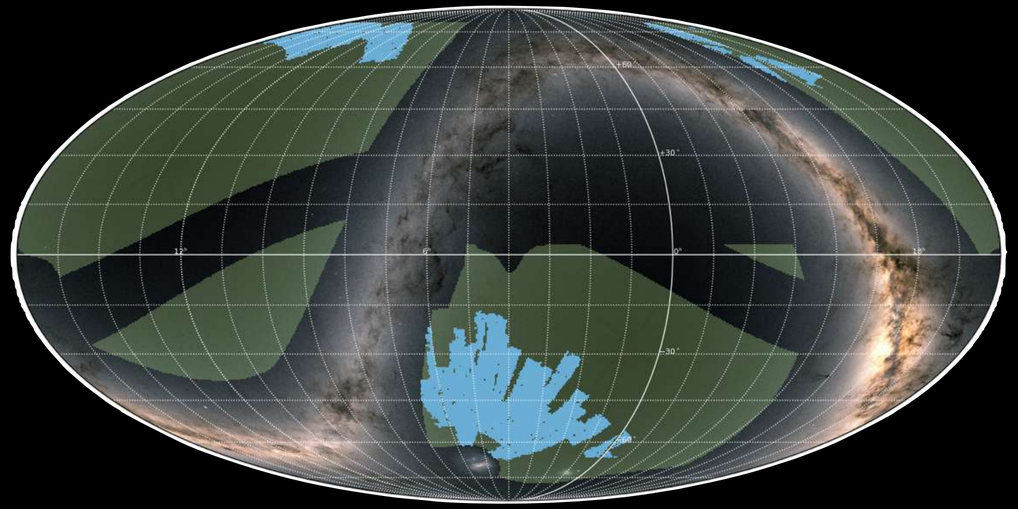
~1 900 deg^2

~~~~60 deg^2~~ of extra-galactic sky

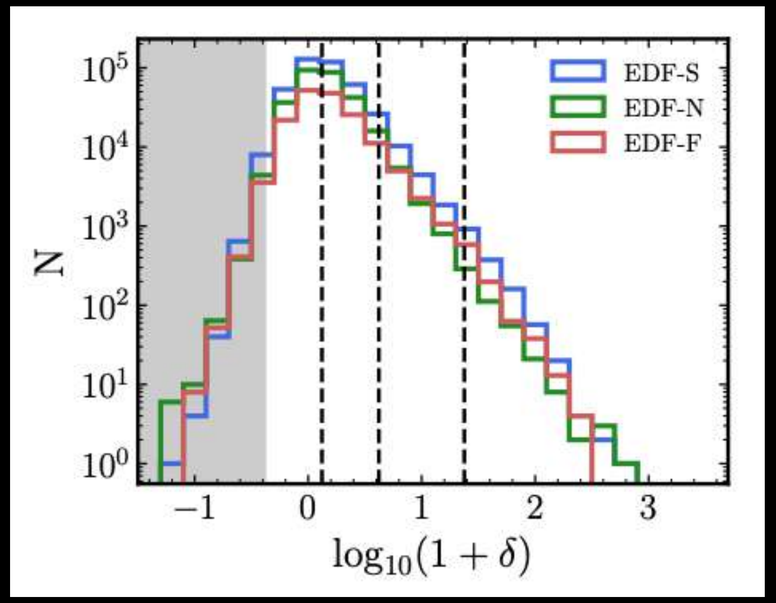
~106 million galaxies

After cuts, ~~~~1 million galaxies~~
in the range 0.25<z<1.00



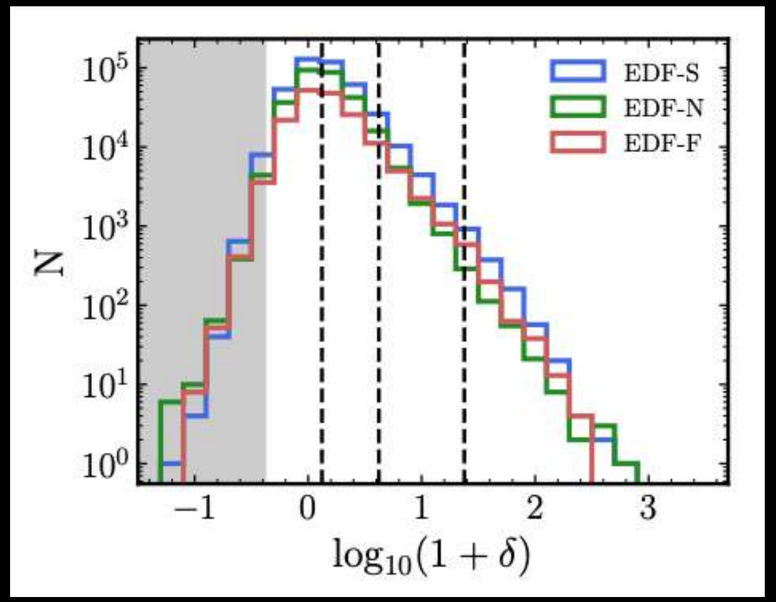

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Continuous SFR, discrete environment



EC: Gentile+26

Continuous SFR, discrete environment



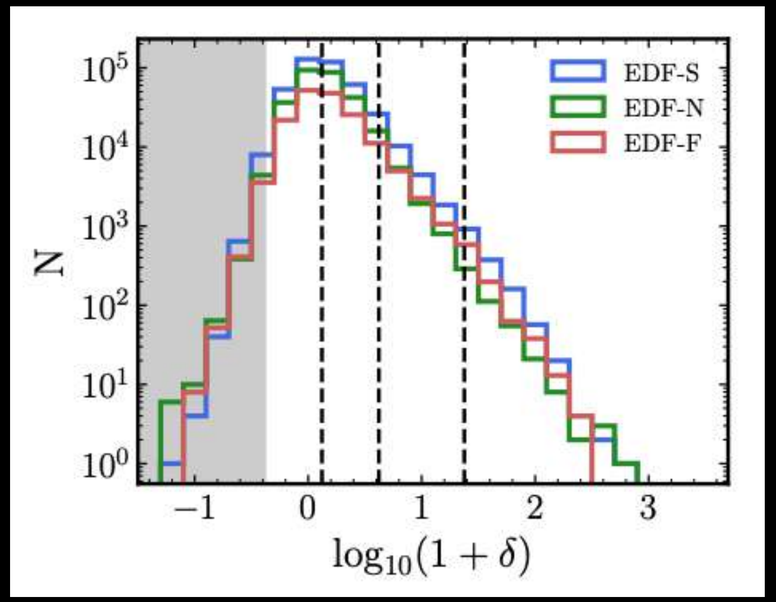
EC: Gentile+26

Field: $-2\sigma_\Delta < \log_{10}(1+\delta) < 2\sigma_\Delta$

Intermediate density: $2\sigma_\Delta < \log_{10}(1+\delta) < 5\sigma_\Delta$

High density: $\log_{10}(1+\delta) > 5\sigma_\Delta$

Continuous SFR, discrete environment



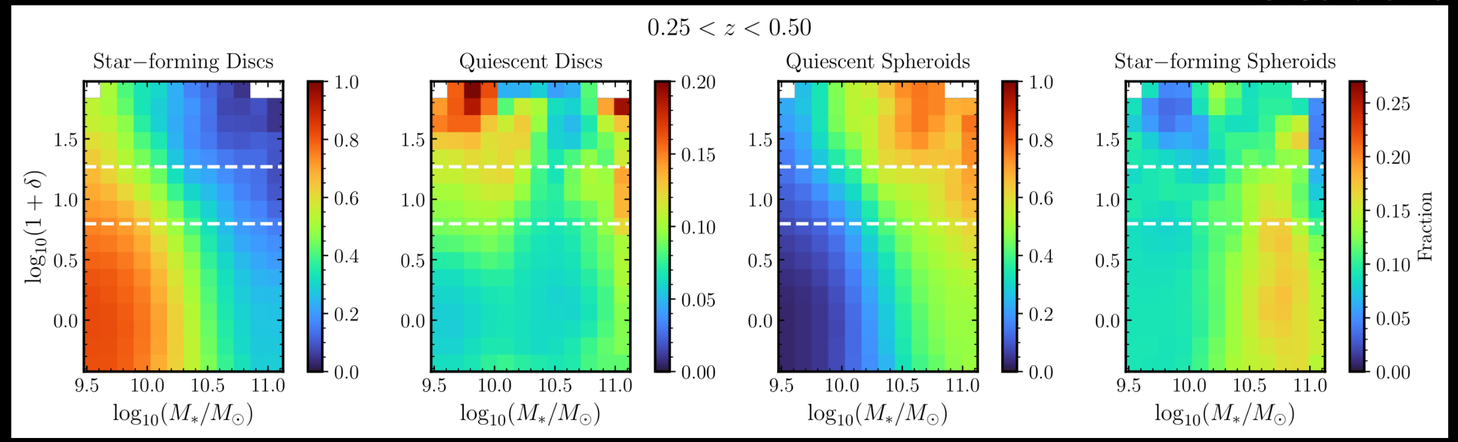
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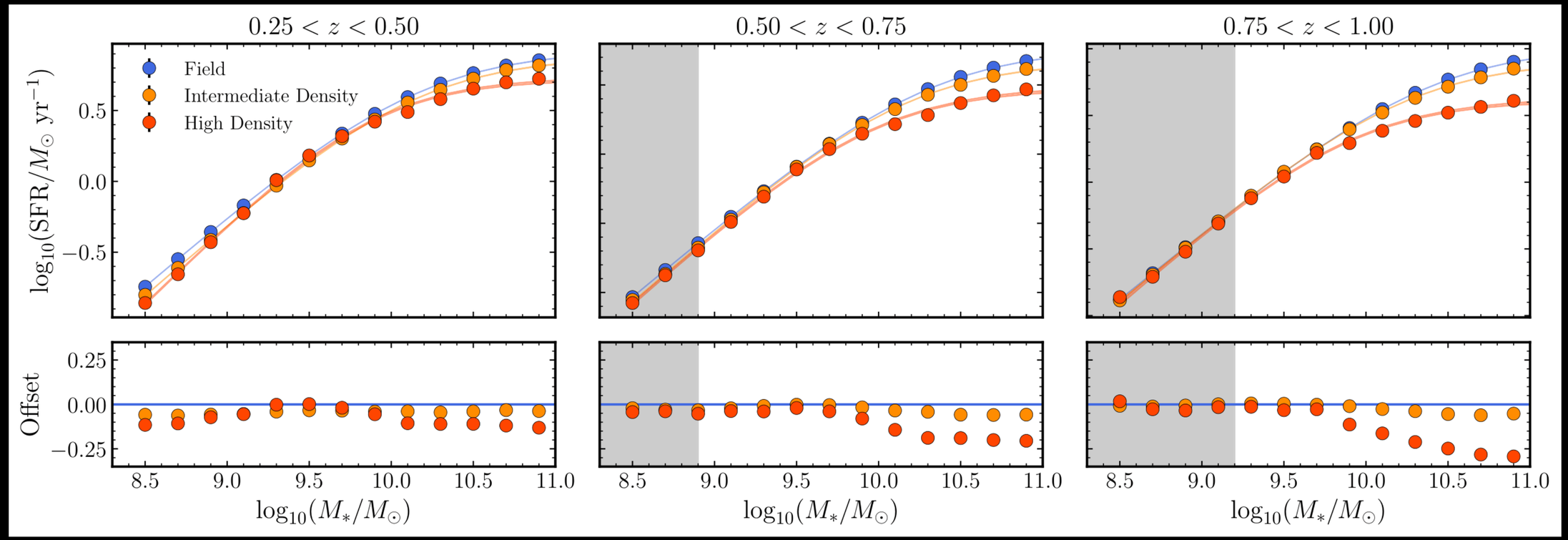
Observational results

Observational results

We select SFGs in each environment and
compute the median SFR as a function of stellar mass

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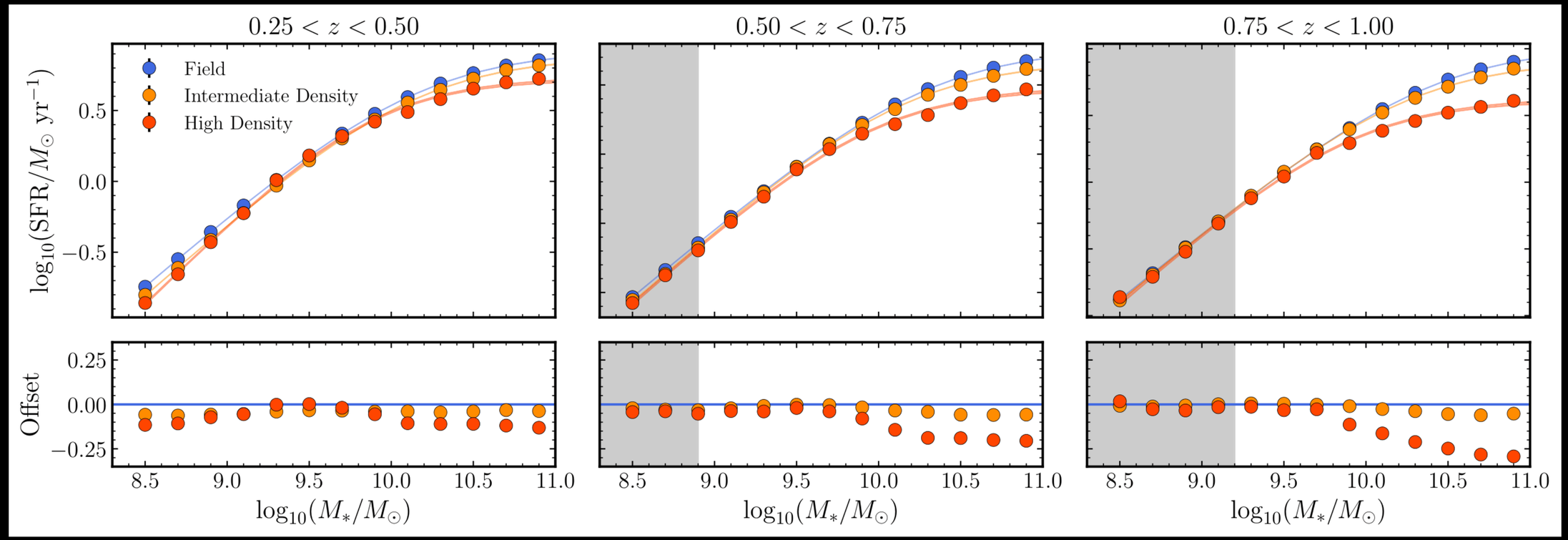
Observational results



EC: Gentile+*in prep.*

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Observational results

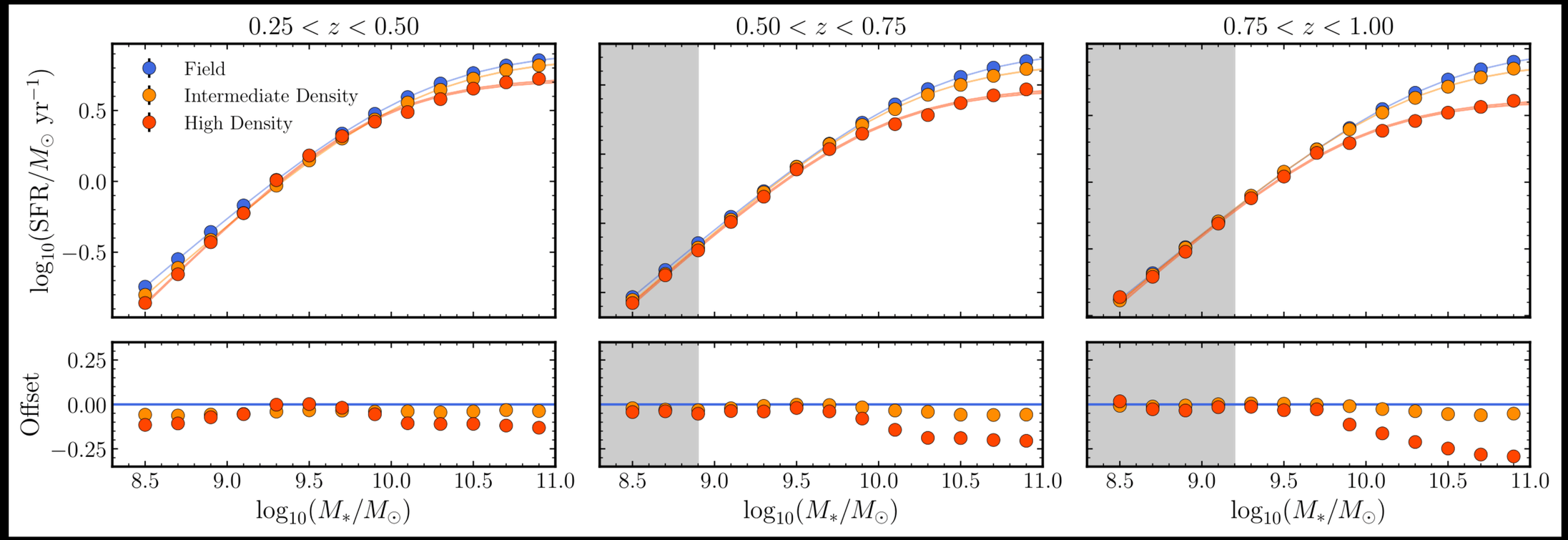


EC: Gentile+*in prep.*

$$\mathrm{SFR} = \frac{\mathrm{SFR}_{\mathrm{max}}}{1 + (M_0/M_*)^{\gamma}} \quad \text{(Lee+15)}$$

EUCLID PRELIMINARY

Observational results



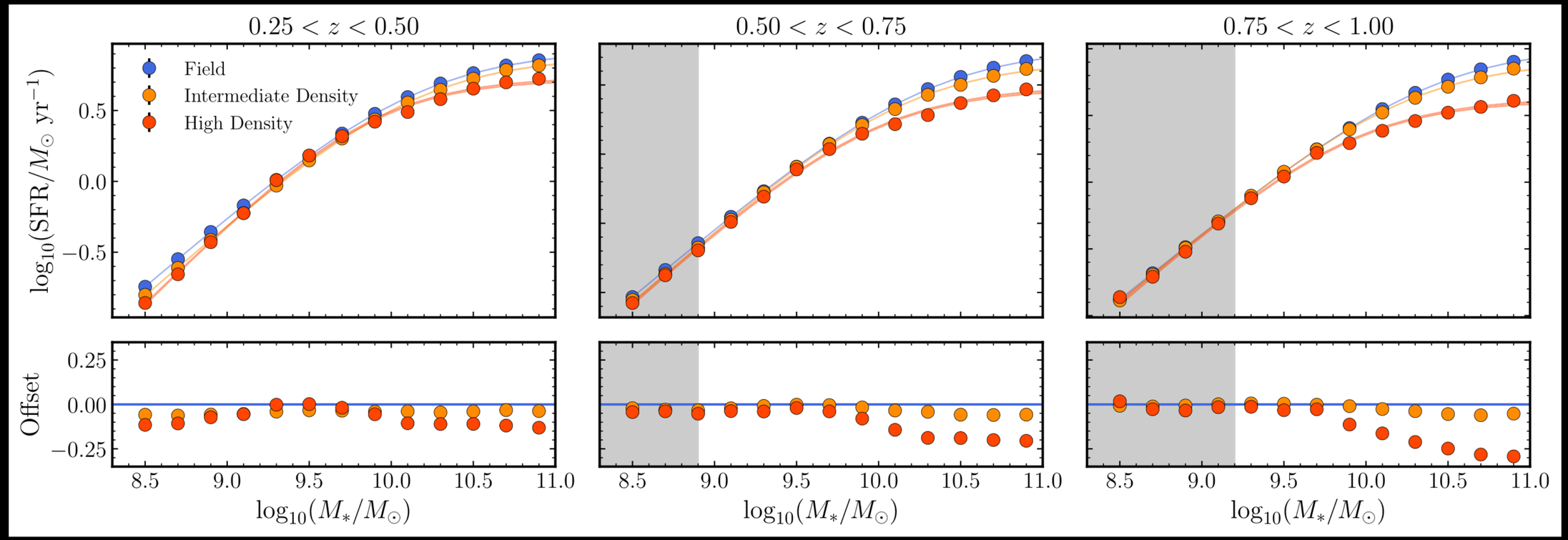
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- $\mathrm{SFR}_{\mathrm{max}}$ decreases with local density
- M_0 decreases with local density
- No significant impact on γ if not at low-z

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EUCLID PRELIMINARY

Observational results



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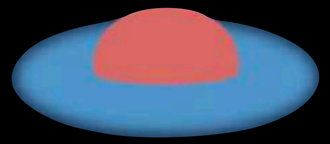
→

- Decrease of SFR for high-mass SFGs
- Limited impact on low-mass SFGs

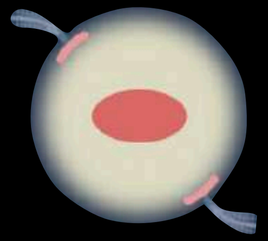
Sketches from Curtis-Lake+23

Possible explanations

Morphological quenching

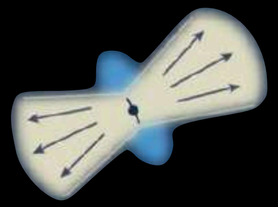


Virial shock heating

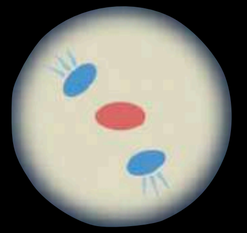


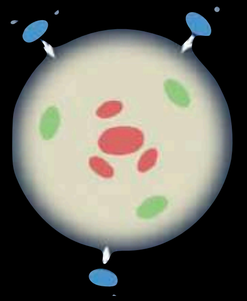
AGN Feedback





Satellite quenching





Halo masses and satellite fraction

Halo masses and satellite fraction

We use an hydrodynamical simulation to (statistically) associate halo properties to our galaxies



Schaye+23

<u>High-resolution box:</u>

Simulated box of $1\,\mathrm{Gpc}^3$
Baryonic resolution of $m_g = 1.3 \times 10^8\ M_\odot$

The main sequence in FLAMINGO

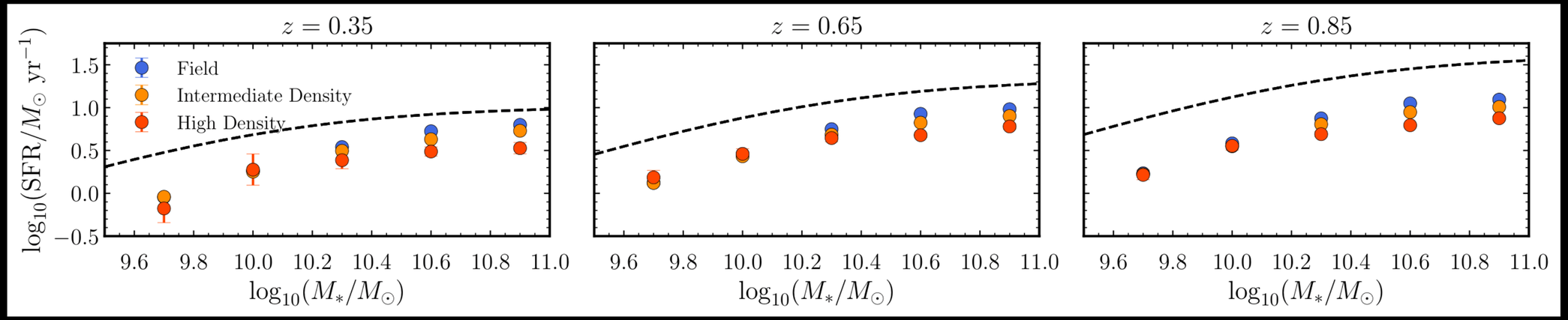
The main sequence in FLAMINGO

We run the same algorithm for the environment estimation and performed an (analogous) SFG selection

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The main sequence in FLAMINGO

We run the same algorithm for the environment estimation and performed an (analogous) SFG selection



EC: Gentile+*in prep.*

FLAMINGO reproduces the observed trend
(but not the redshift dependance)

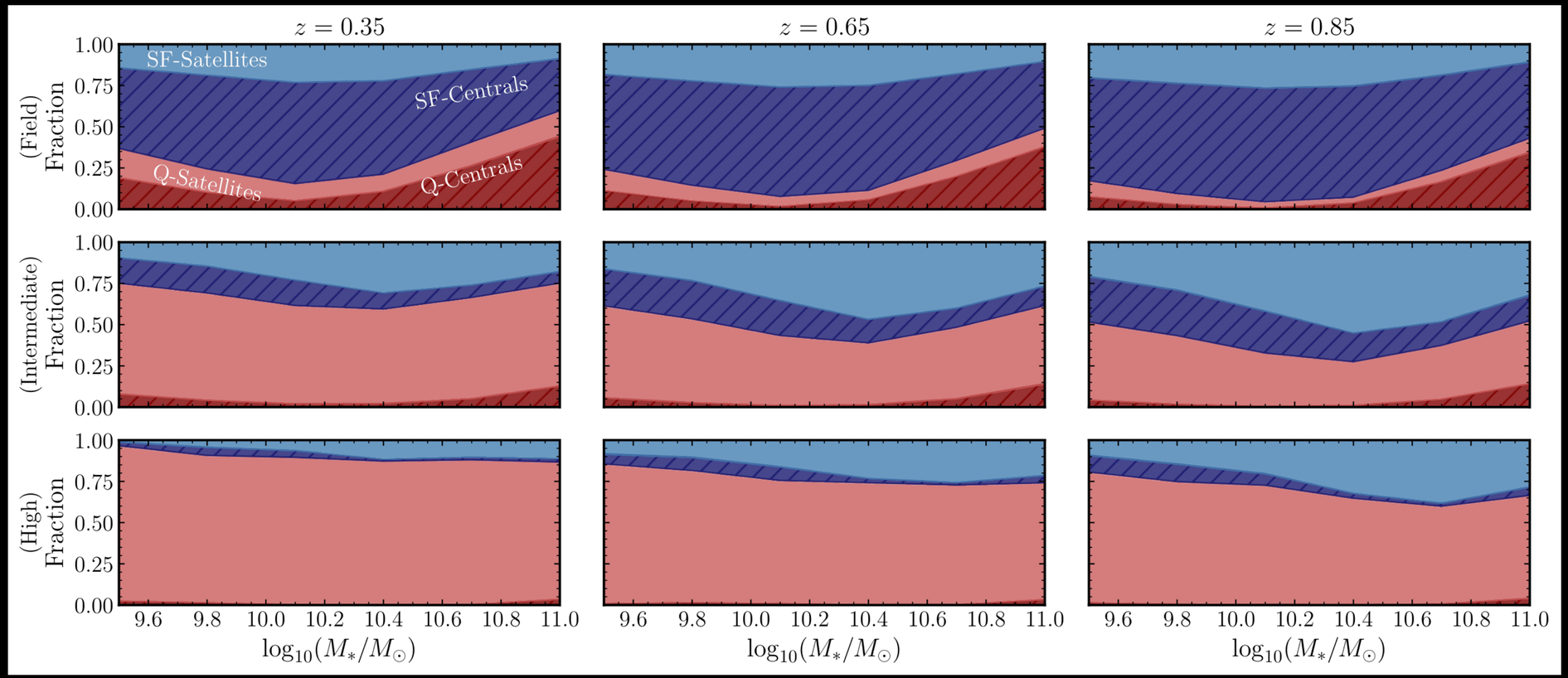
We can investigate (some of) the physical mechanisms with this simulation

Satellite fraction in FLAMINGO

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Satellite fraction in FLAMINGO

EC: Gentile+*in prep.*

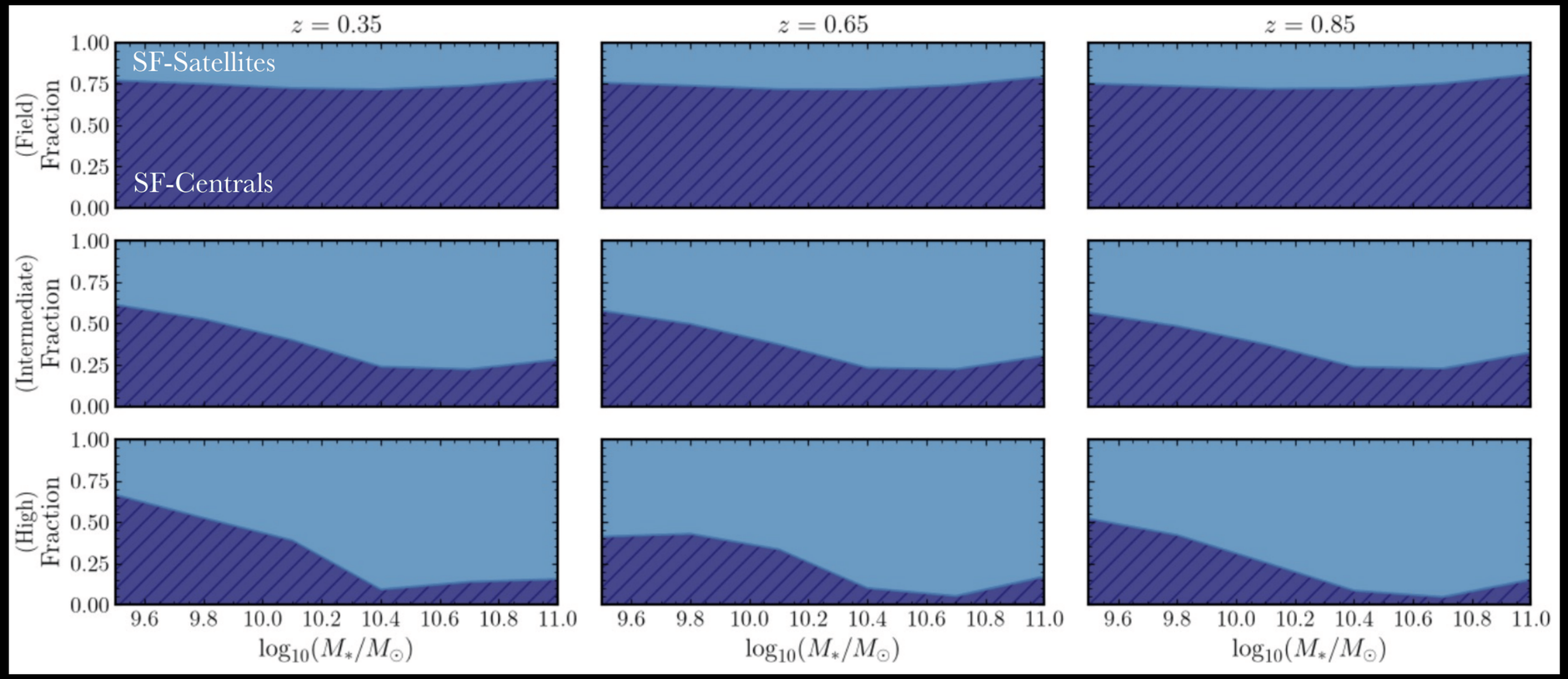


- At high masses and dense environments, the MS is dominated by star-forming satellites
- At low masses, the fraction of star-forming satellites decreases and it is followed by an increase of quiescent satellites

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Satellite fraction in FLAMINGO

EC: Gentile+*in prep.*



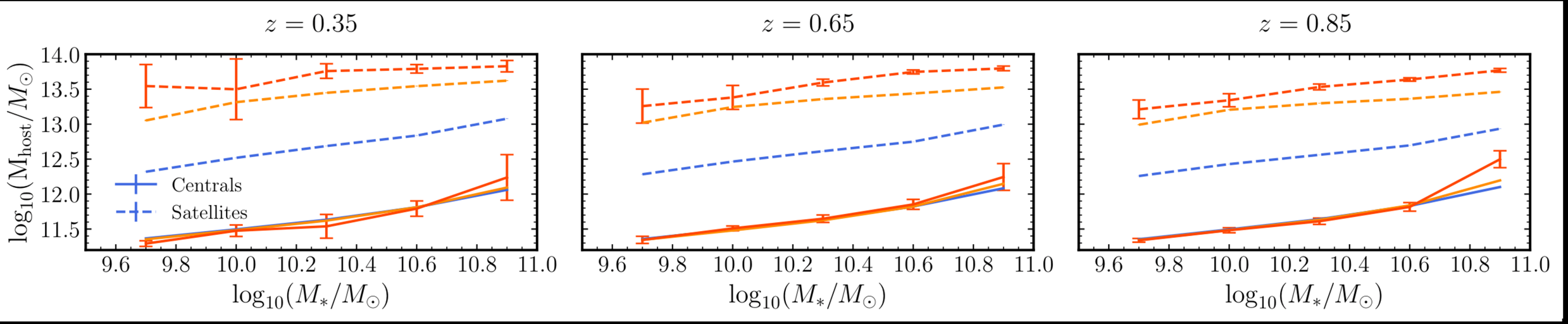
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Halo masses in FLAMINGO

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Halo masses in FLAMINGO

EC: Gentile+*in prep.*

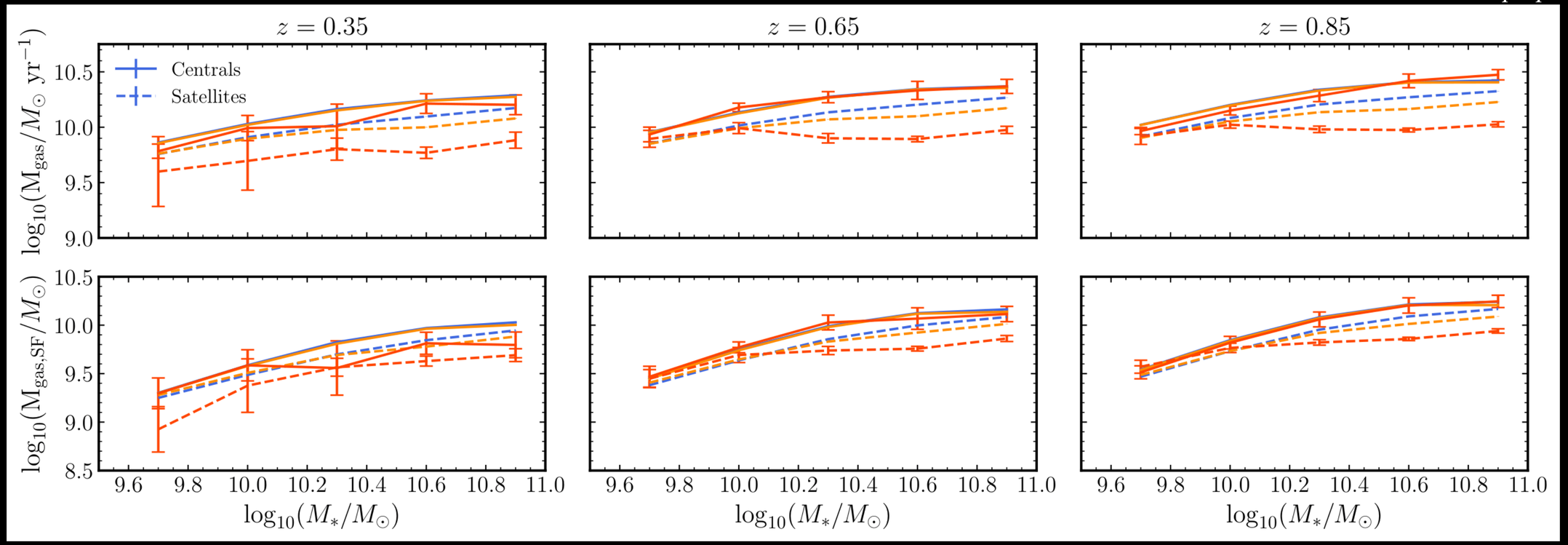


- The change of local density does not change the stellar-to-halo mass relation for centrals
- There is a strong impact on the hosting halo mass of the satellites
- **Intermediate density:** More or less massive groups ($M_h \sim 10^{13} - 10^{13.5} M_\odot$)
- **Intermediate density:** Massive groups - low-mass clusters ($M_h \sim 10^{13.5} - 10^{14} M_\odot$)

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Gas masses in FLAMINGO

EC: Gentile+*in prep.*

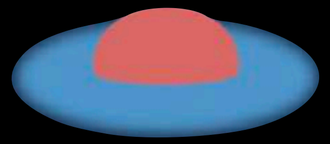


- No significant environmental dependence for the gas mass of central galaxies
- Strong effect on the gas mass of satellite galaxies
- The effect is visible for both the total and “molecular” gas mass

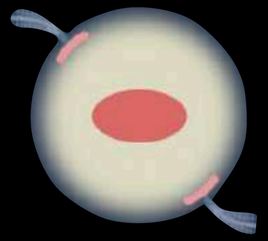
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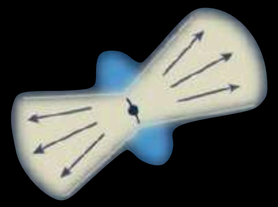


Virial shock heating

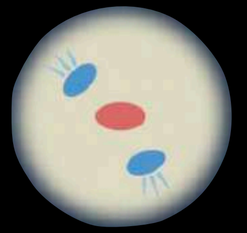


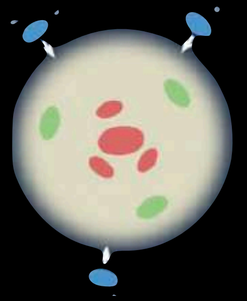
AGN Feedback





Satellite quenching





Sketches from Curtis-Lake+23

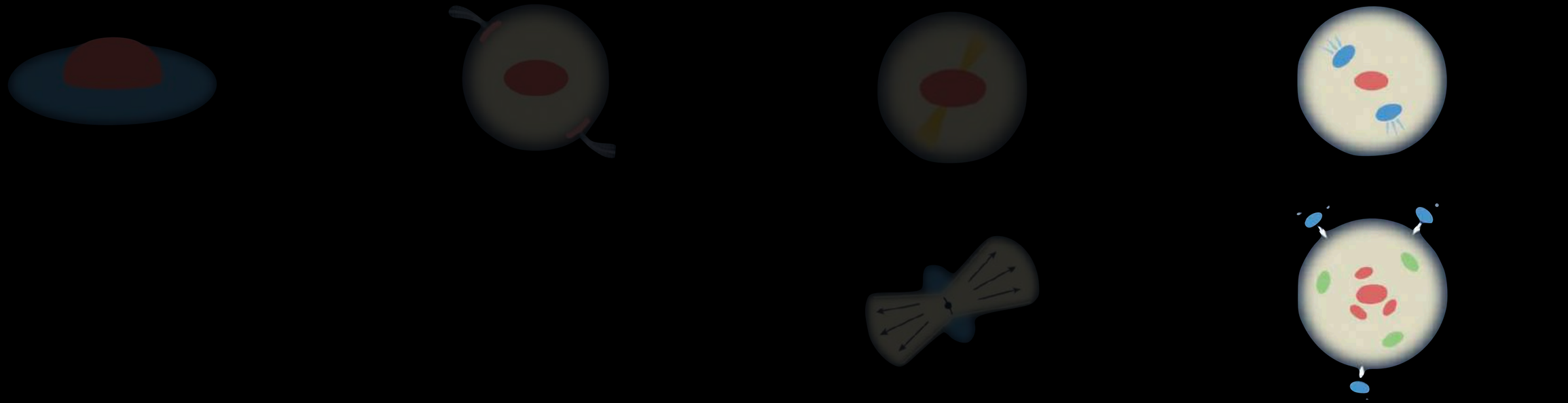
Possible explanations

Morphological quenching

Virial shock heating

AGN Feedback

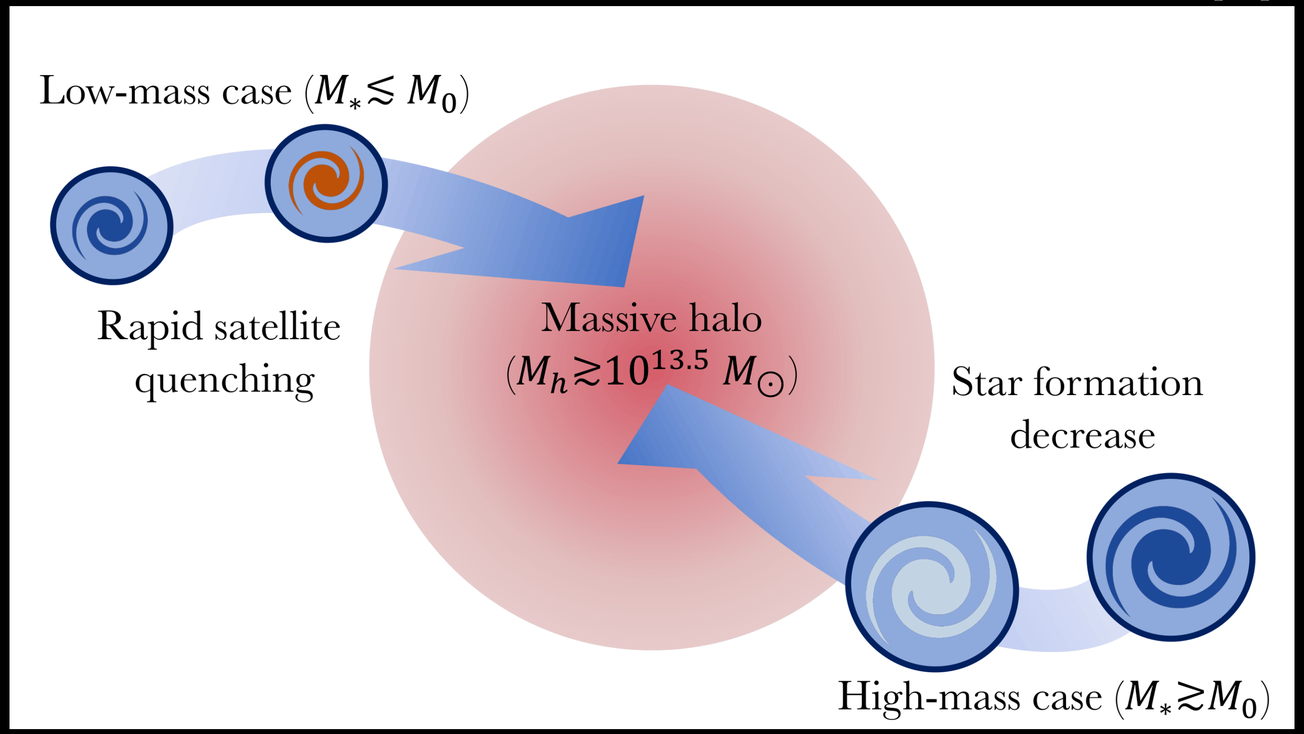
Satellite quenching



Fiducial scenario

Fiducial scenario

EC: Gentile+*in prep.*

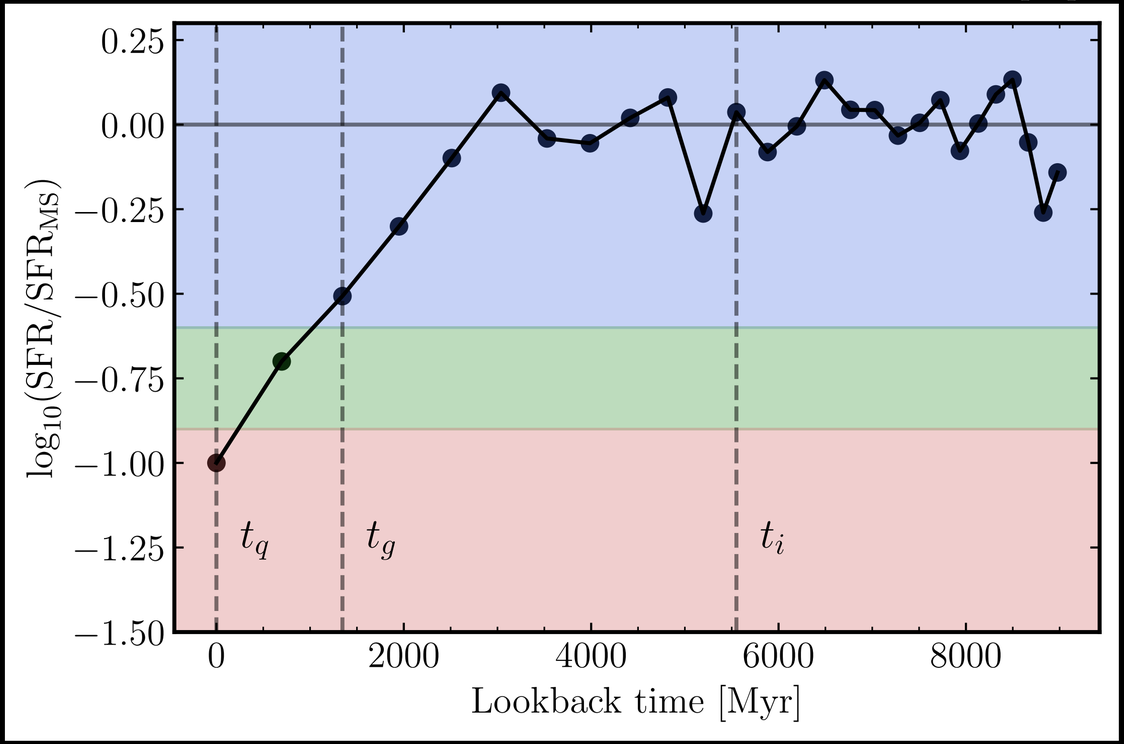


- The difference in the main sequence is mainly driven by satellite quenching
- The quenching at low masses takes place on a short timescale: galaxies go “directly” out of the main sequence
- The quenching at high masses requires more time: galaxies still in the MS, but with lower SFR

EUCLID PRELIMINARY

Fiducial scenario

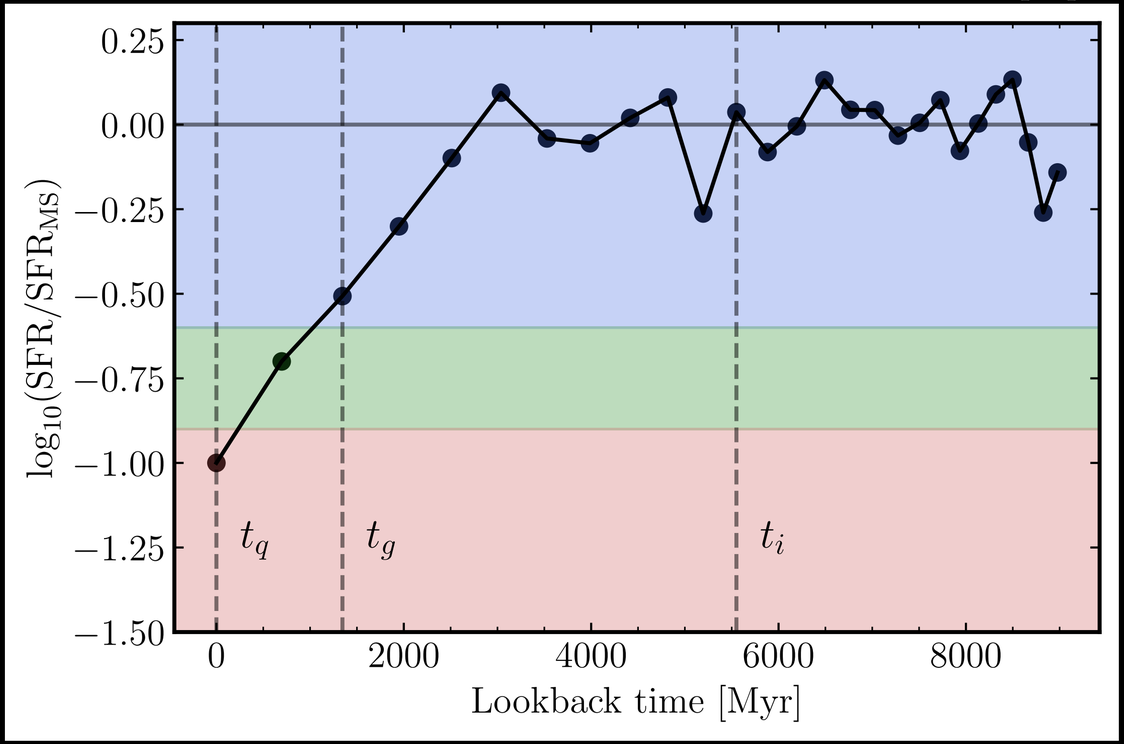
EC: Gentile+*in prep.*



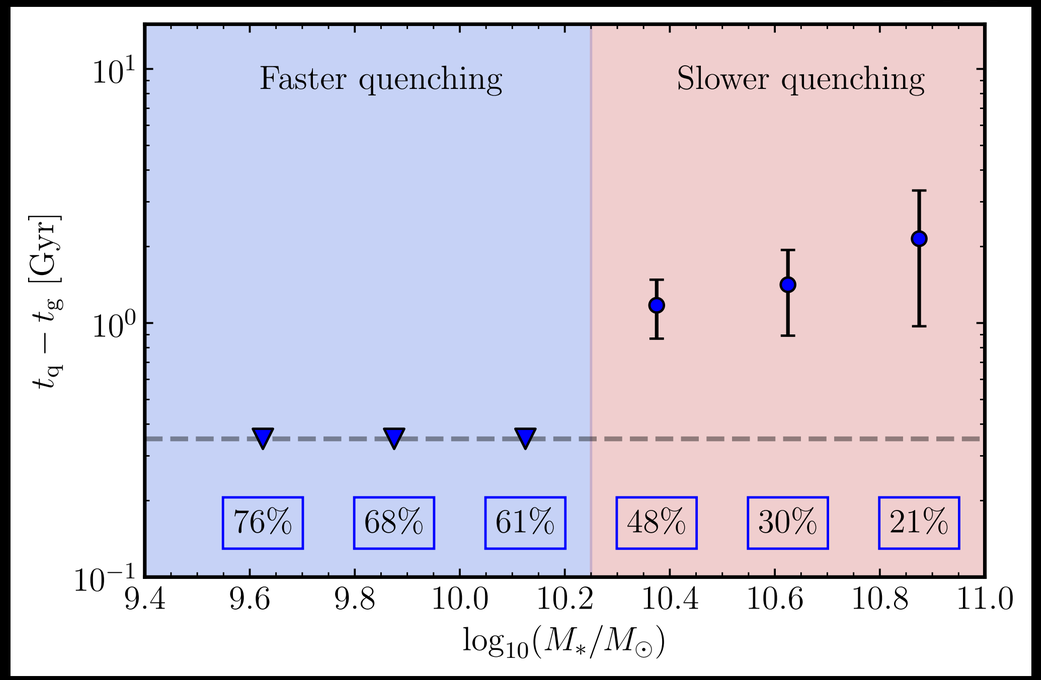
EUCLID PRELIMINARY

Fiducial scenario

EC: Gentile+*in prep.*



EC: Gentile+*in prep.*



Take home messages

- *Euclid* gives us an **unprecedented opportunity** of studying galaxy evolution in different environments

- Our analysis shows that **bulge formation precedes quenching in the field but follows it in dense environments**

- We report a **strong environmental dependence of the main sequence of star-forming galaxies**, probably related to the different efficiency in gas stripping for low- and high-mass galaxies in groups and clusters

Thank you, questions?

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