

Ageing and quenching in the Local Universe

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MACQUARIE
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SYDNEY · AUSTRALIA



XIII ESTALLIDOS Workshop

Talk contents

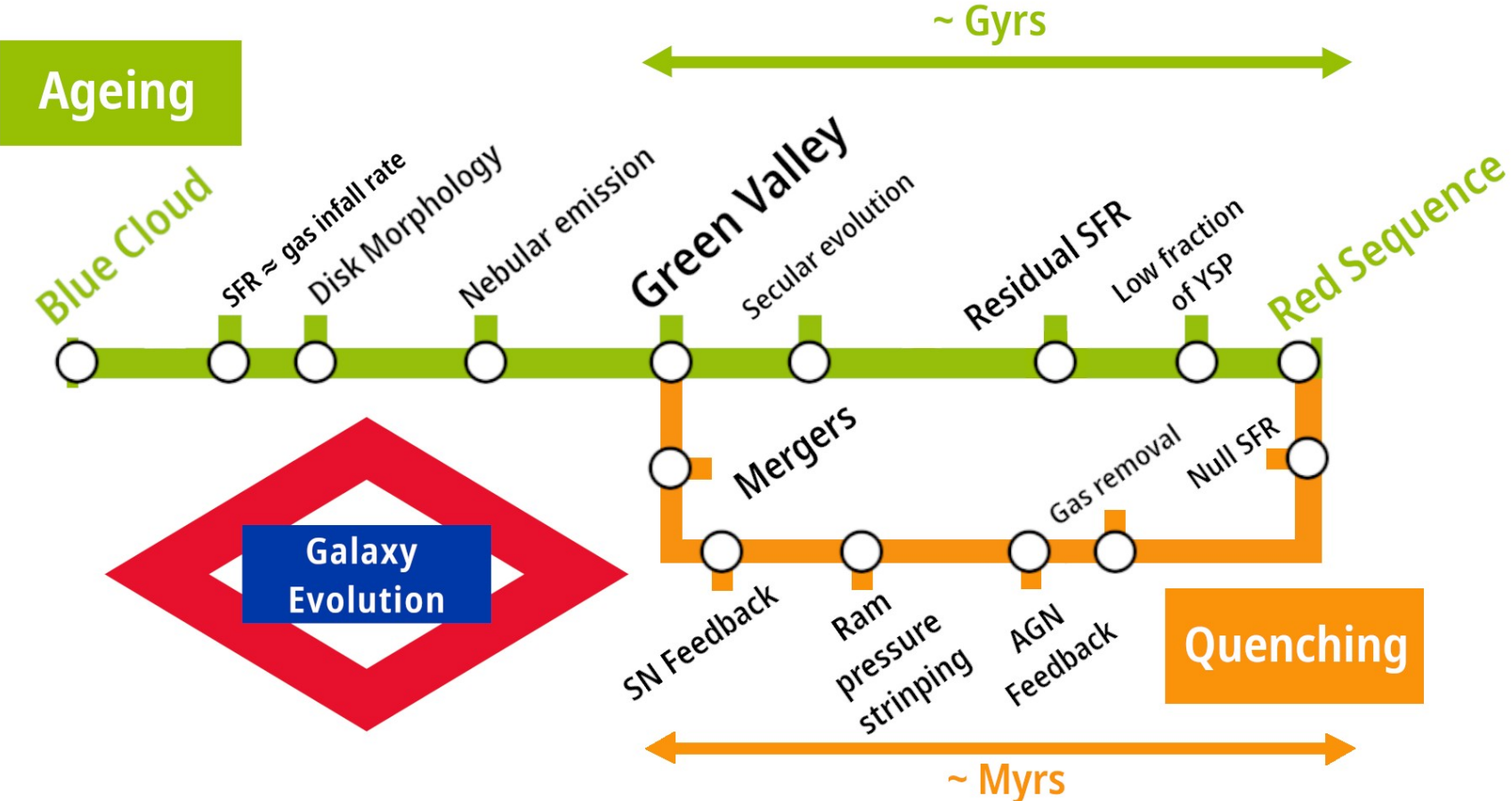
- Introduction: Galaxy bimodality
- Results
 - A single galaxy population
 - Do galaxies die?
 - Ageing vs queching
- Conclusions



Brace yourselves, talk is comming

Mind the gap

Galaxy bimodality in a nutshell



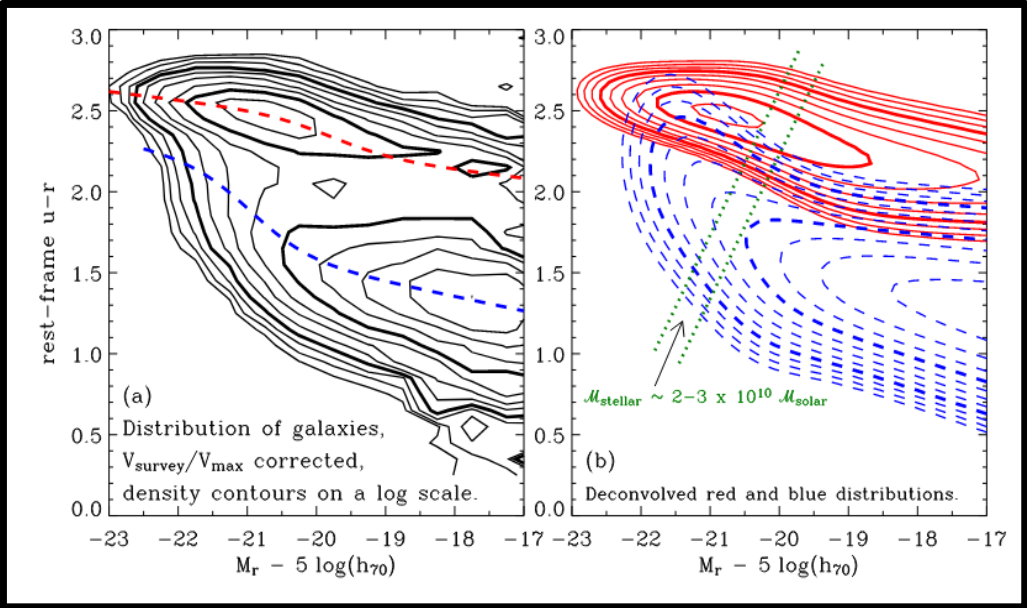
Mind the gap

Galaxy bimodality in a nutshell

Ageing

Blue Cloud

SFR \approx



Red Sequence

Null SFR

Quenching

\sim Gyrs

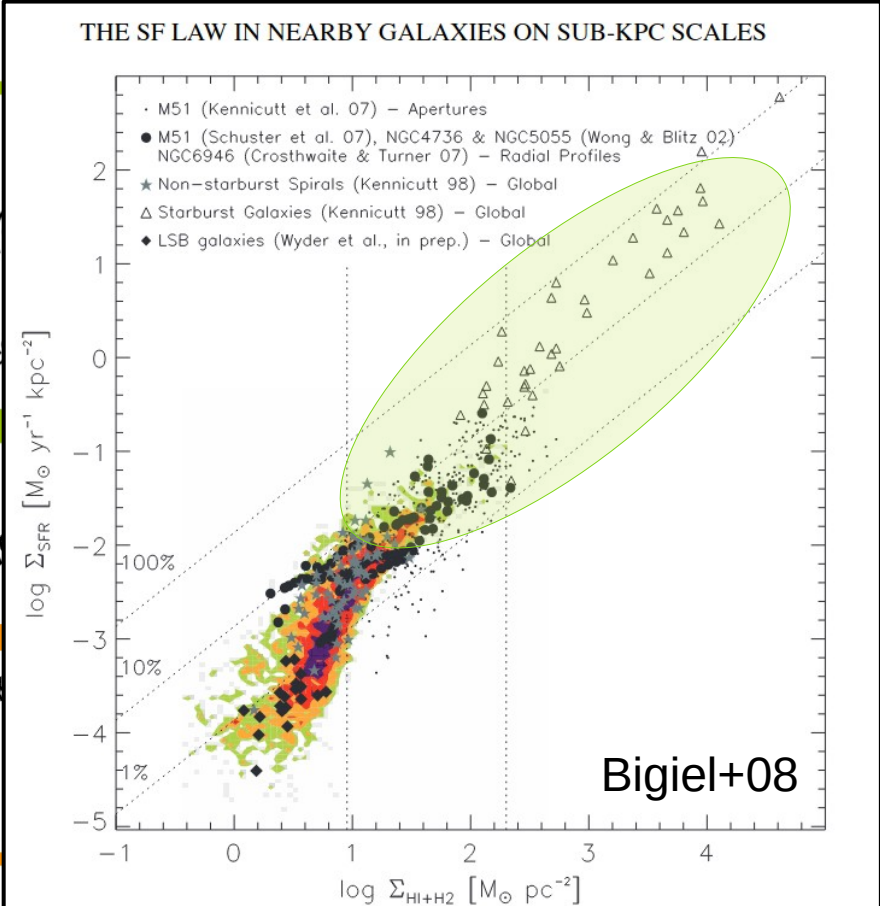
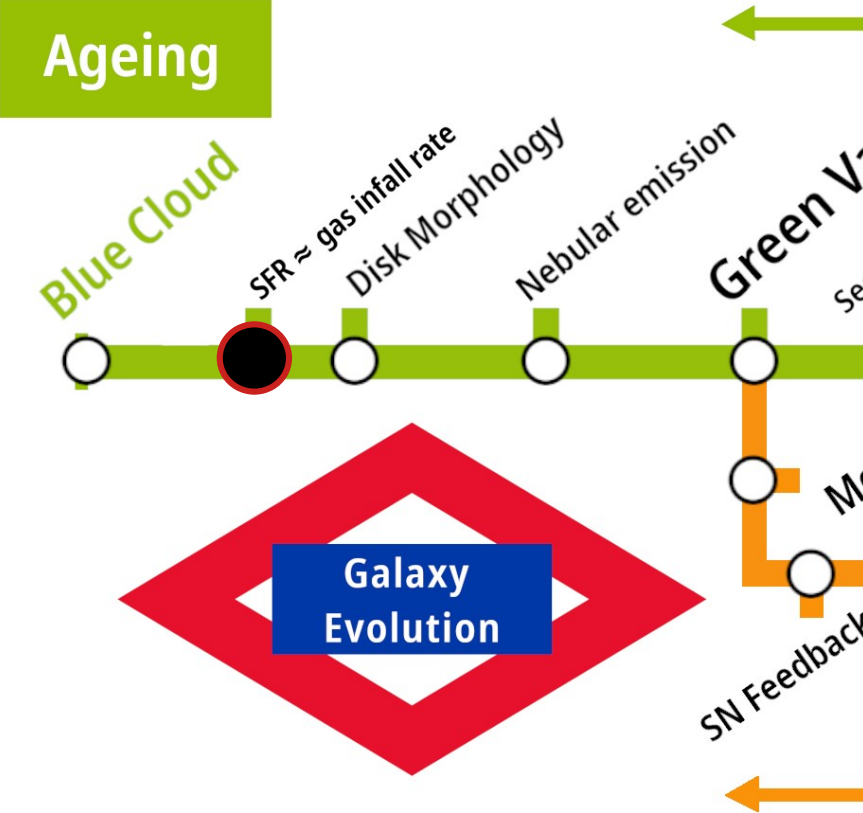
\sim Myrs

Baldry+04

SN Ia, pre-stripping, Feedback

Mind the gap

Galaxy bimodality in a nutshell



Mind the gap

Galaxy bimodality in a nutshell

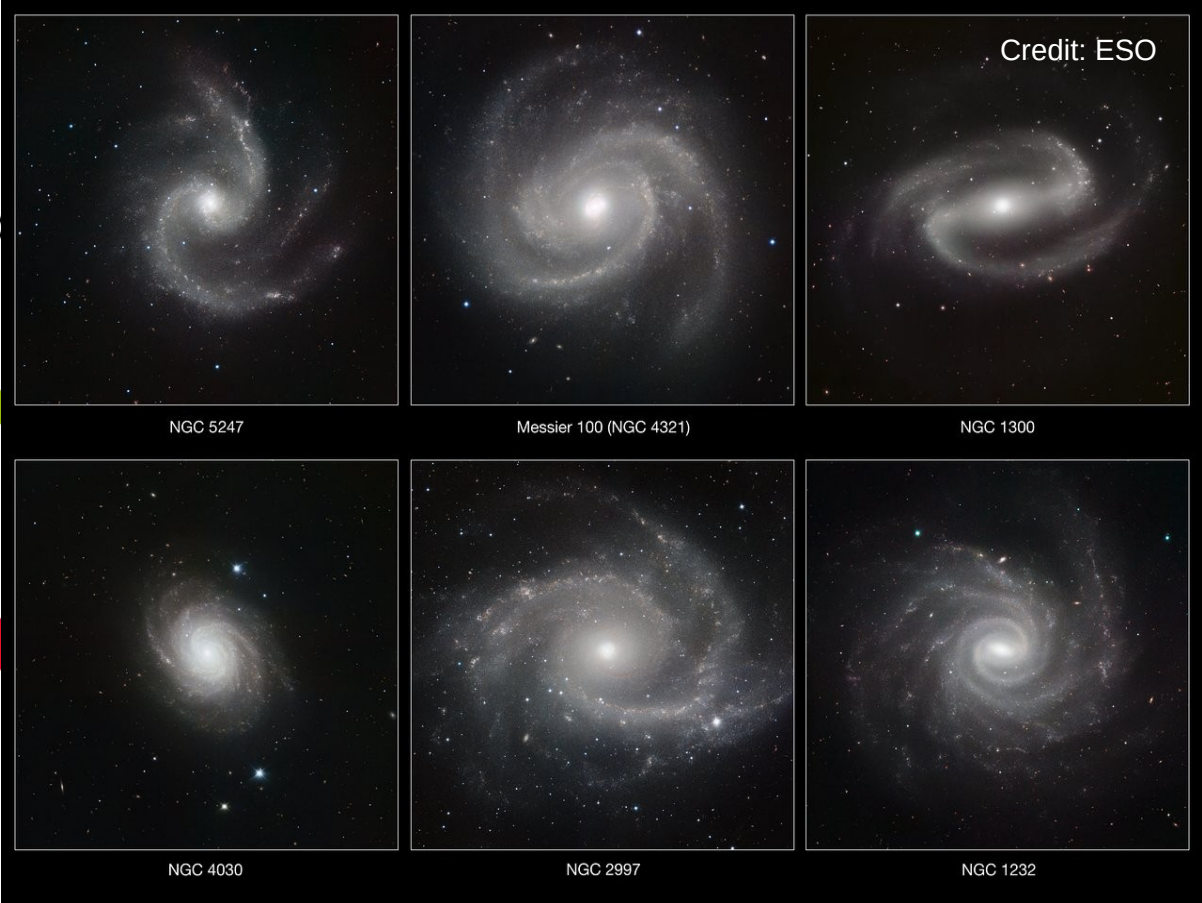
Ageing

Blue Cloud

SFR \approx gas infall rate

Disk Morphology

Nebular emission



Mind the gap

Ageing

Blue Cloud

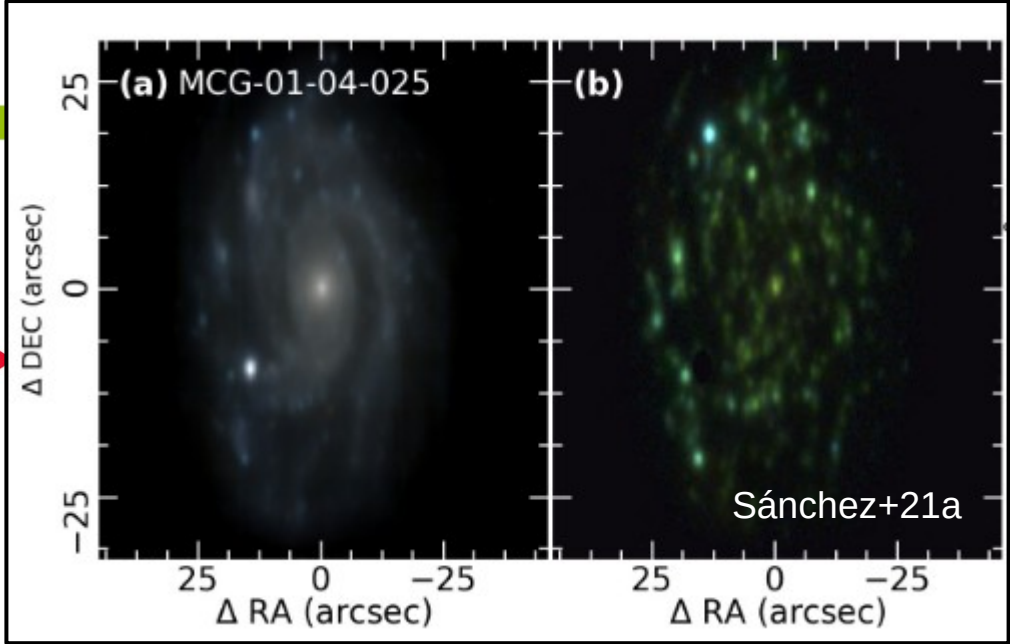
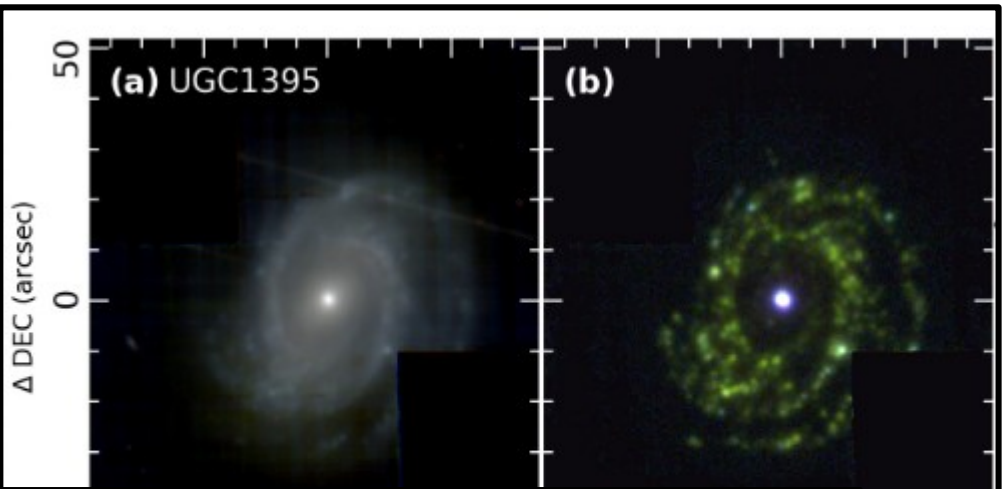
SFR \approx gas infall rate

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Nebular emission



Galaxy



Mind the gap

Galaxy bimodality in a nutshell

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Disk Morphology

Nebular emission

Green Valley

Secular evolution

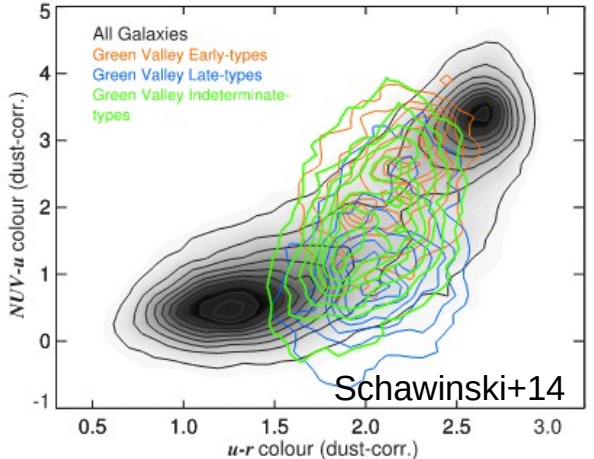
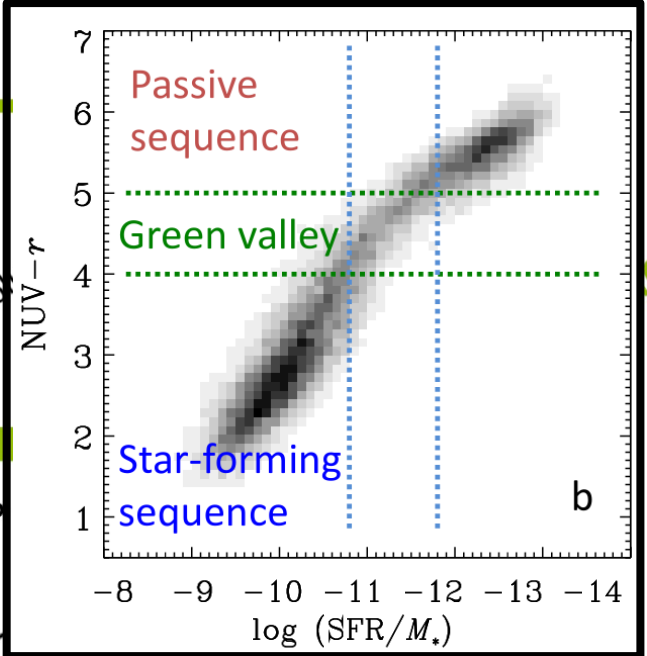
Mergers

AGN Feedback

Ram pressure stripping

AGN Feedback

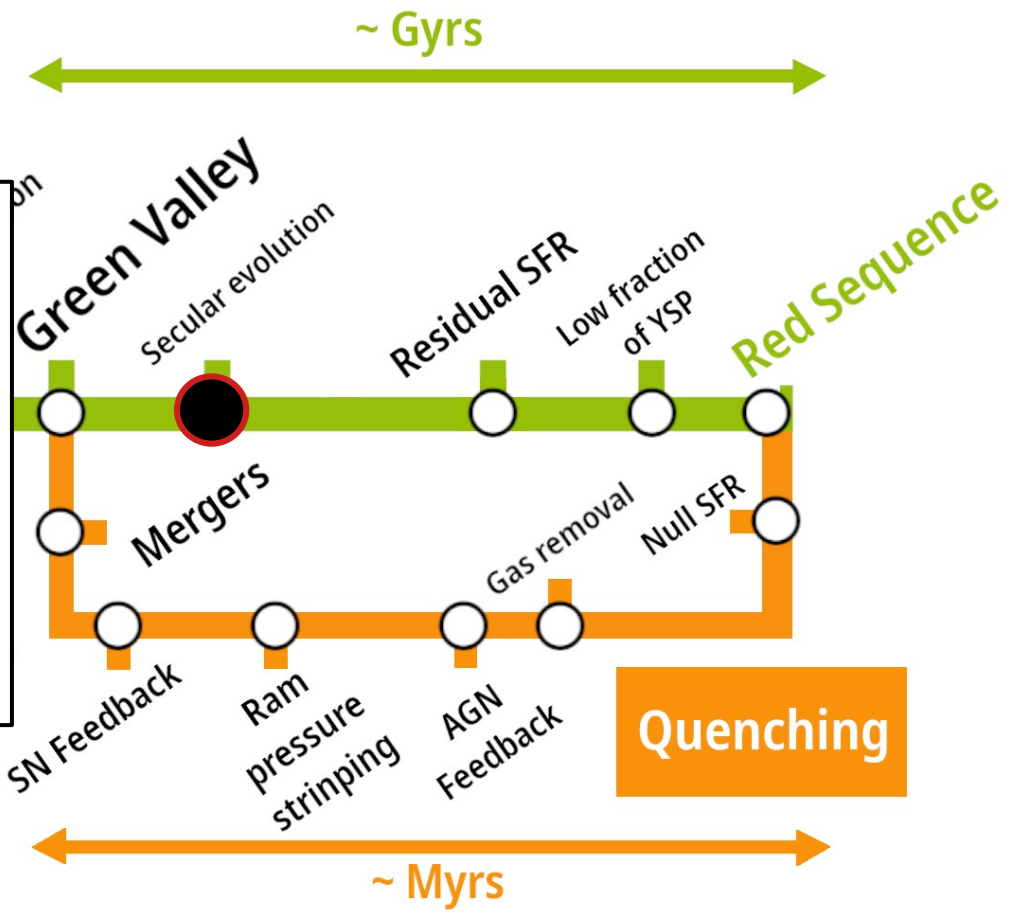
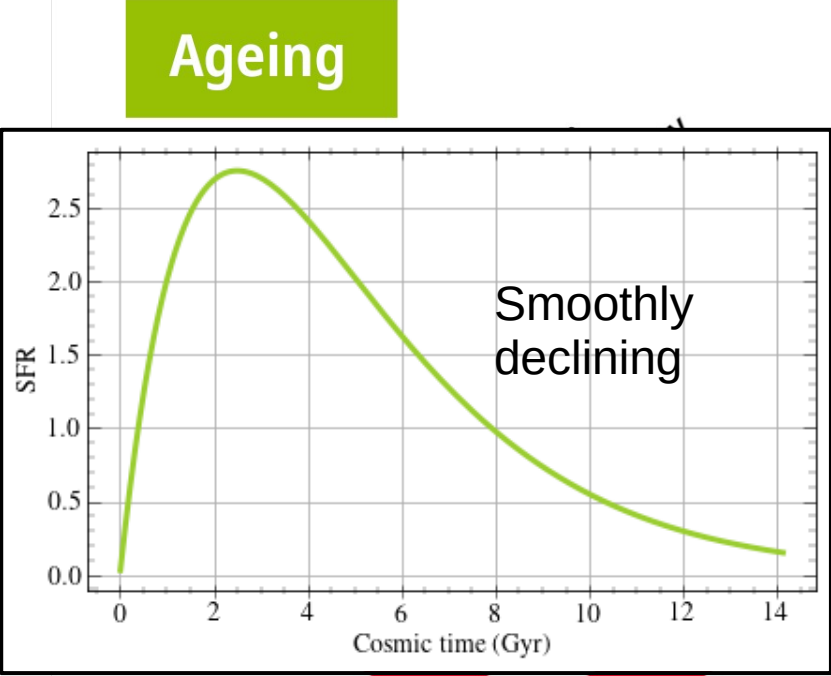
Quenching



~ Myrs

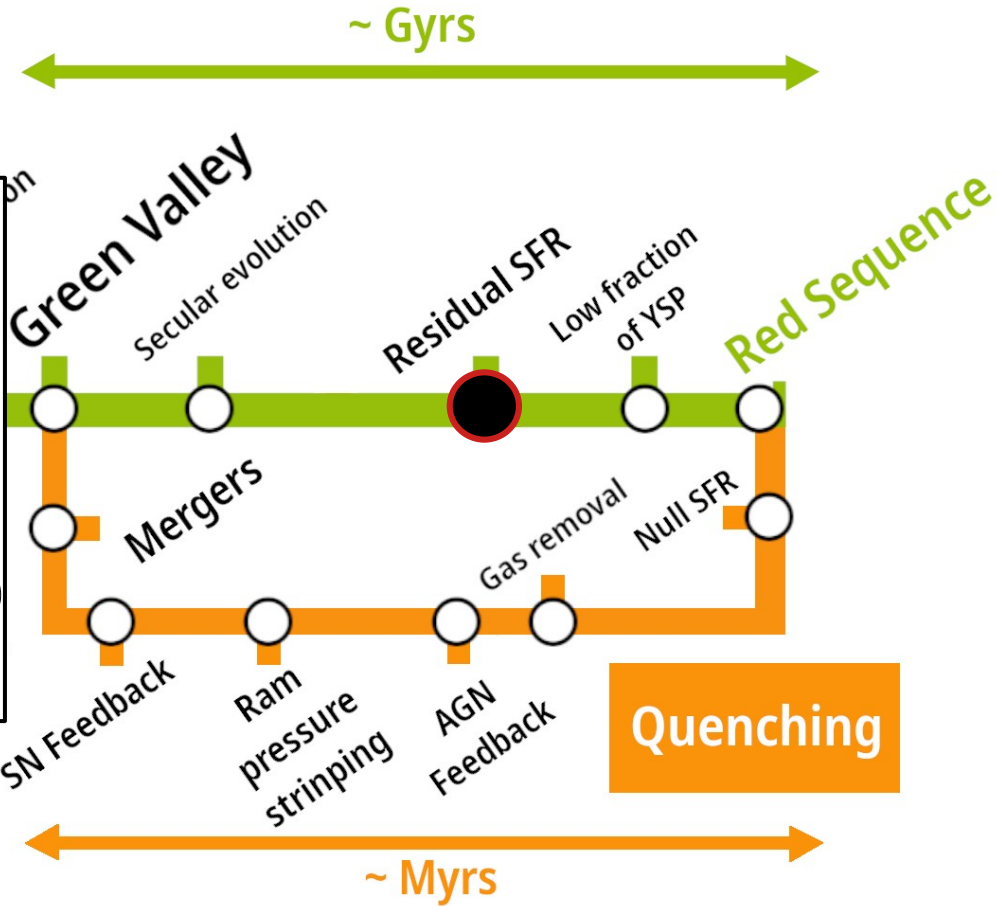
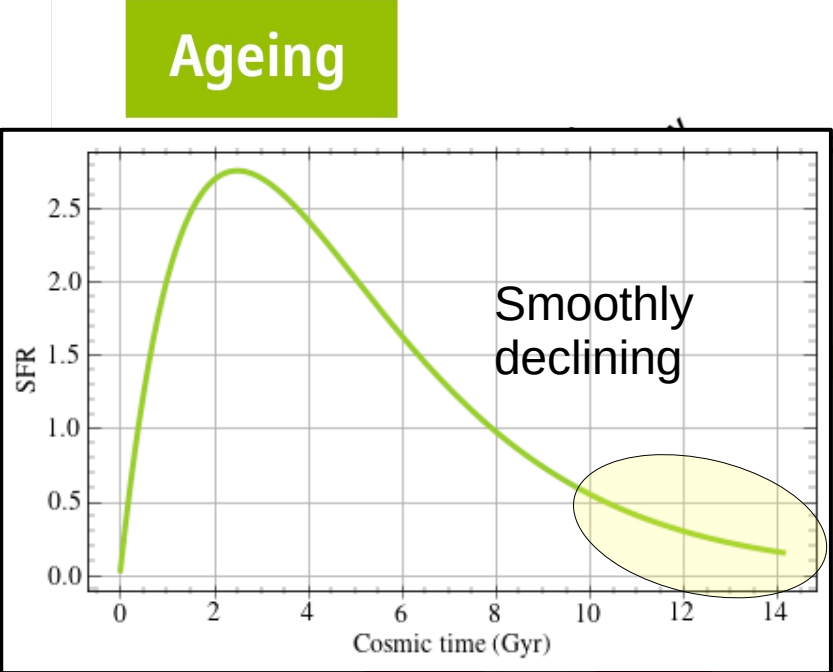
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Galaxy bimodality in a nutshell



Mind the gap

Galaxy bimodality in a nutshell

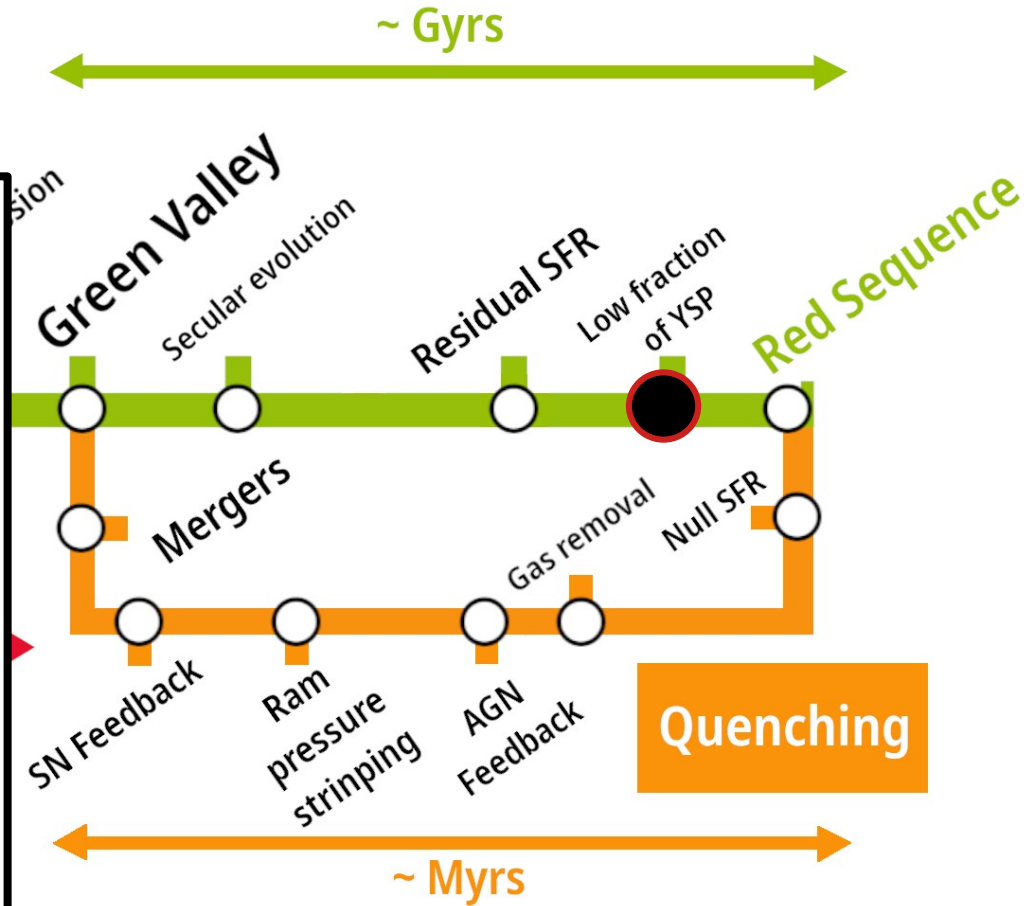
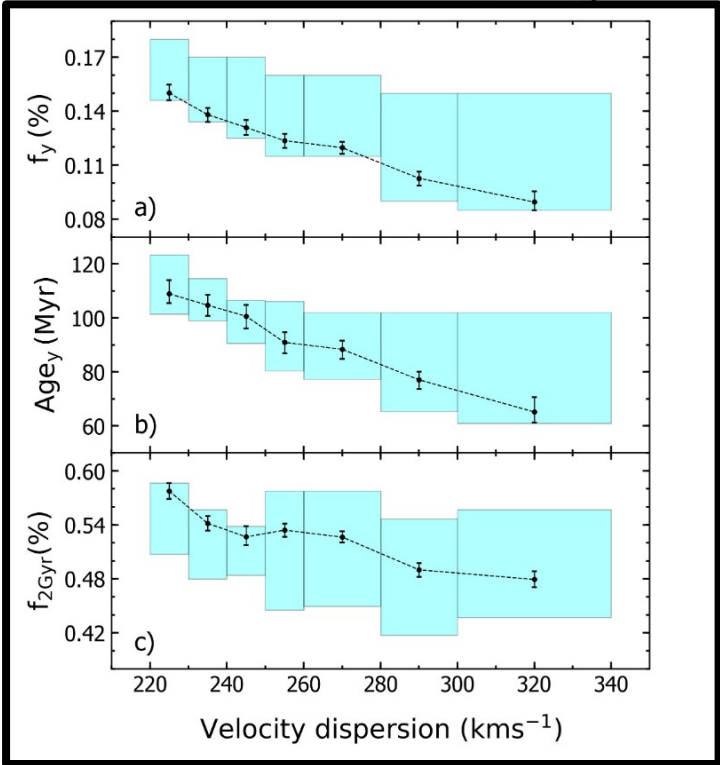


Mind the gap

Galaxy bimodality in a nutshell

Salvador-Rusiñol+20

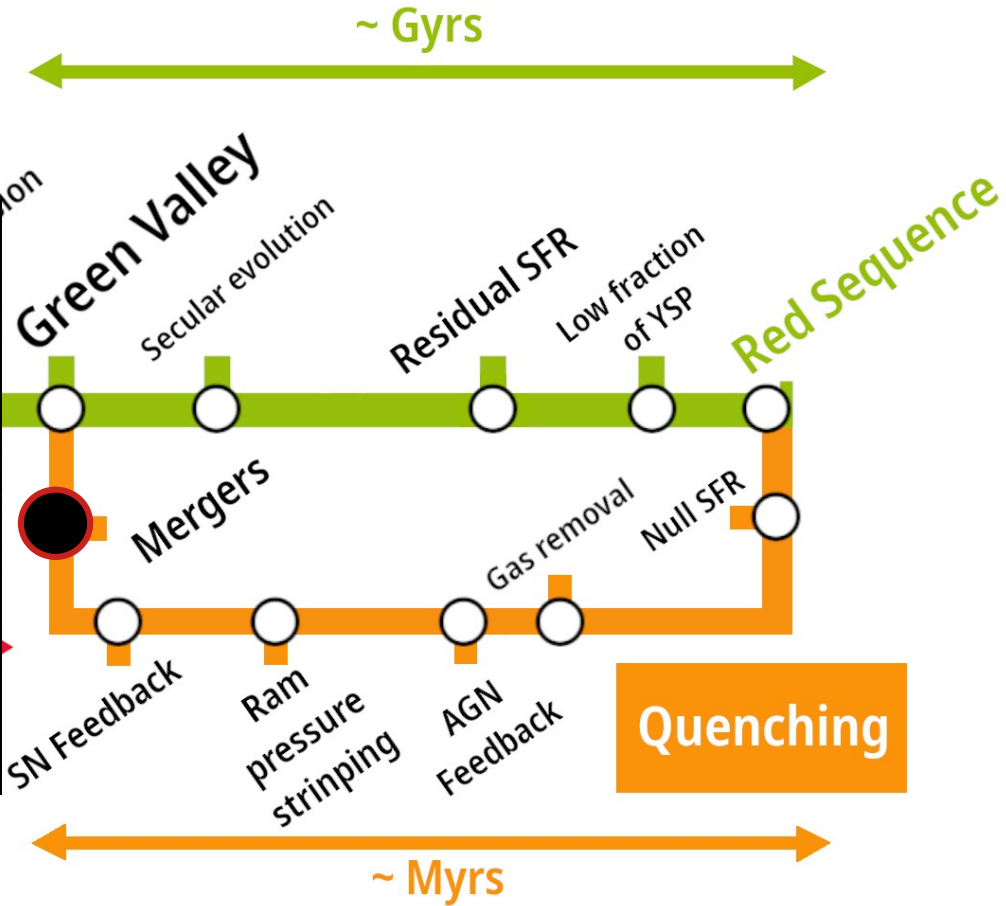
Ageing



Mind the gap

Galaxy bimodality in a nutshell

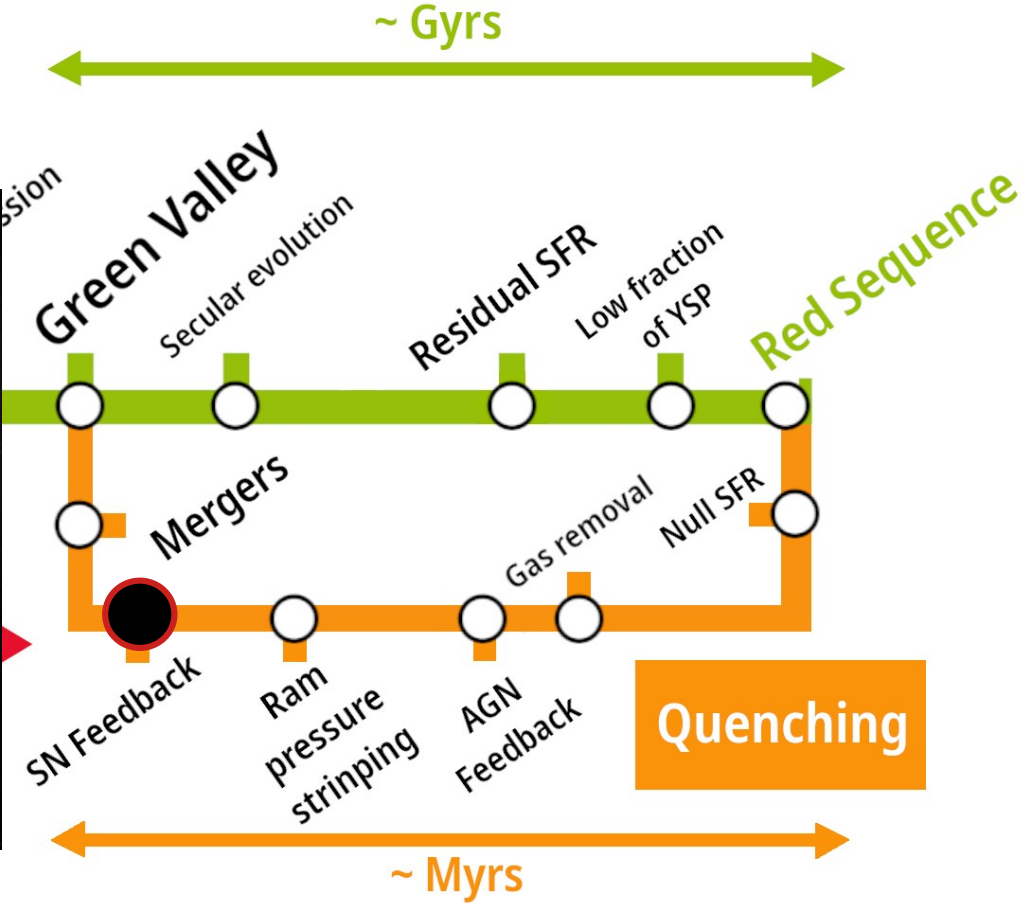
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Mind the gap

Galaxy bimodality in a nutshell

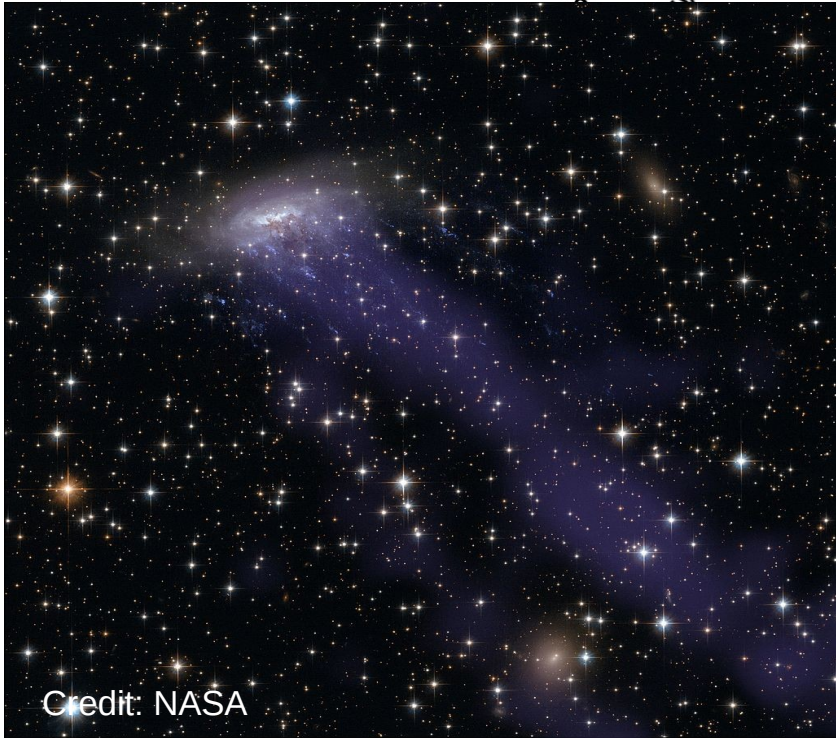
Ageing



Mind the gap

Galaxy bimodality in a nutshell

Ageing



~ Gyrs

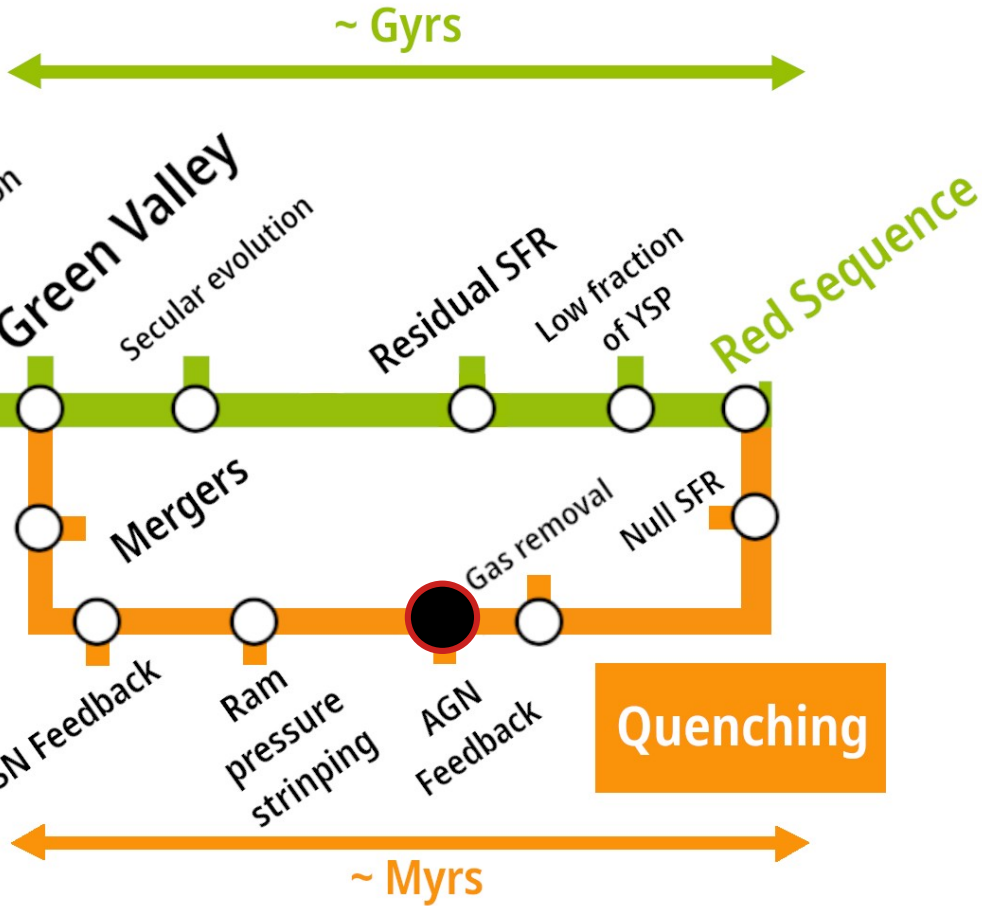
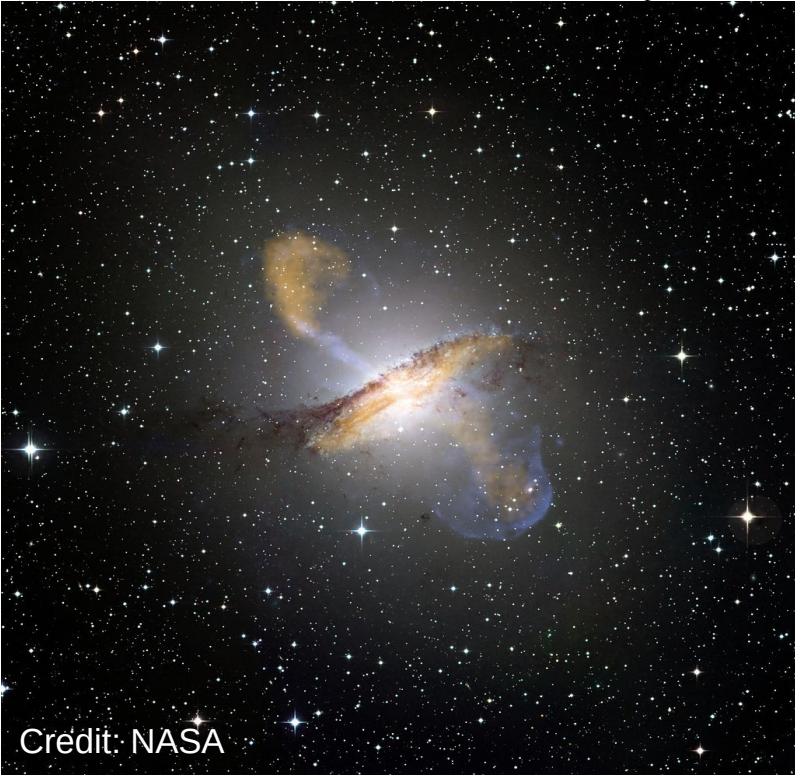


~ Myrs

Mind the gap

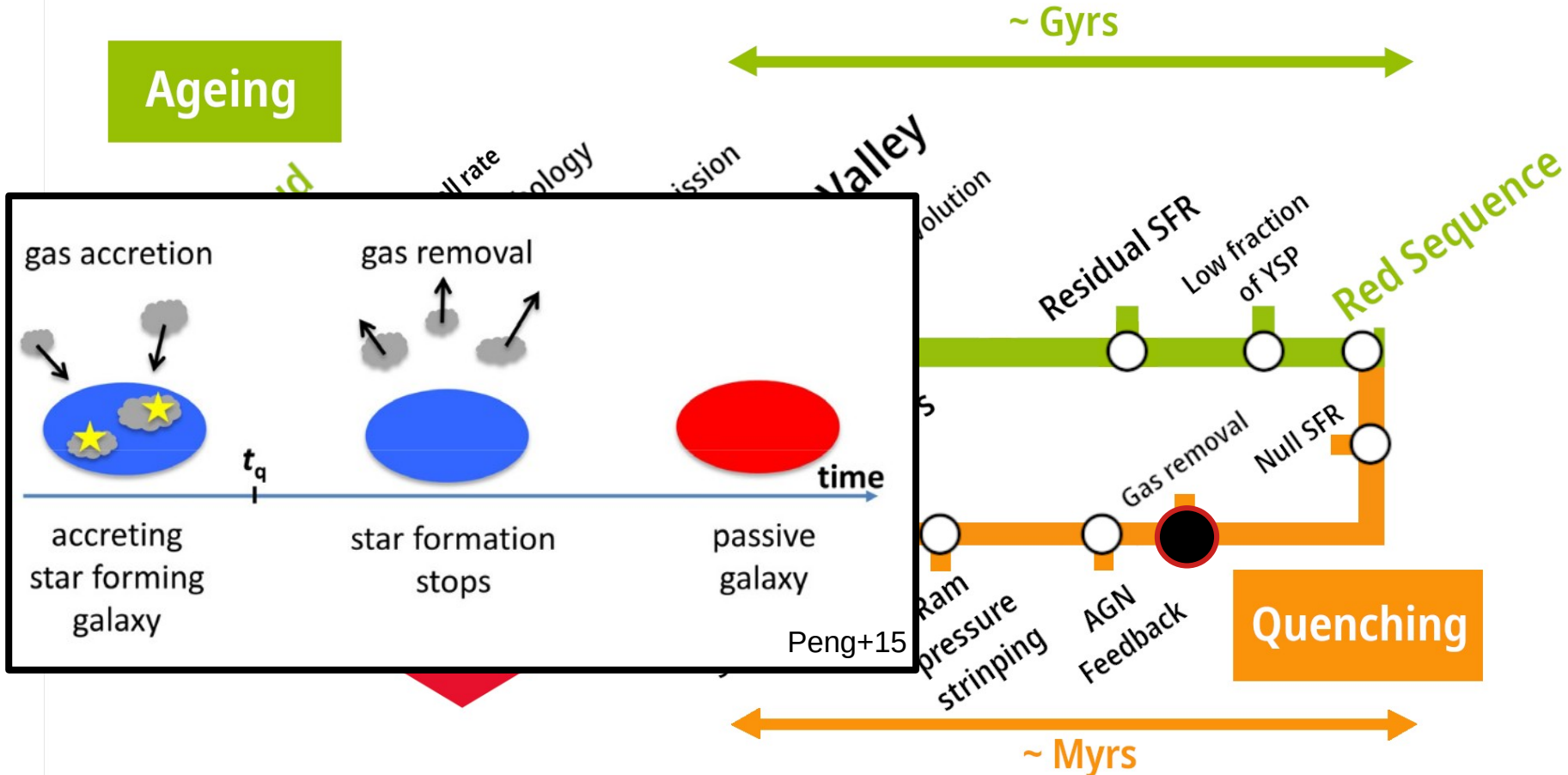
Galaxy bimodality in a nutshell

Ageing



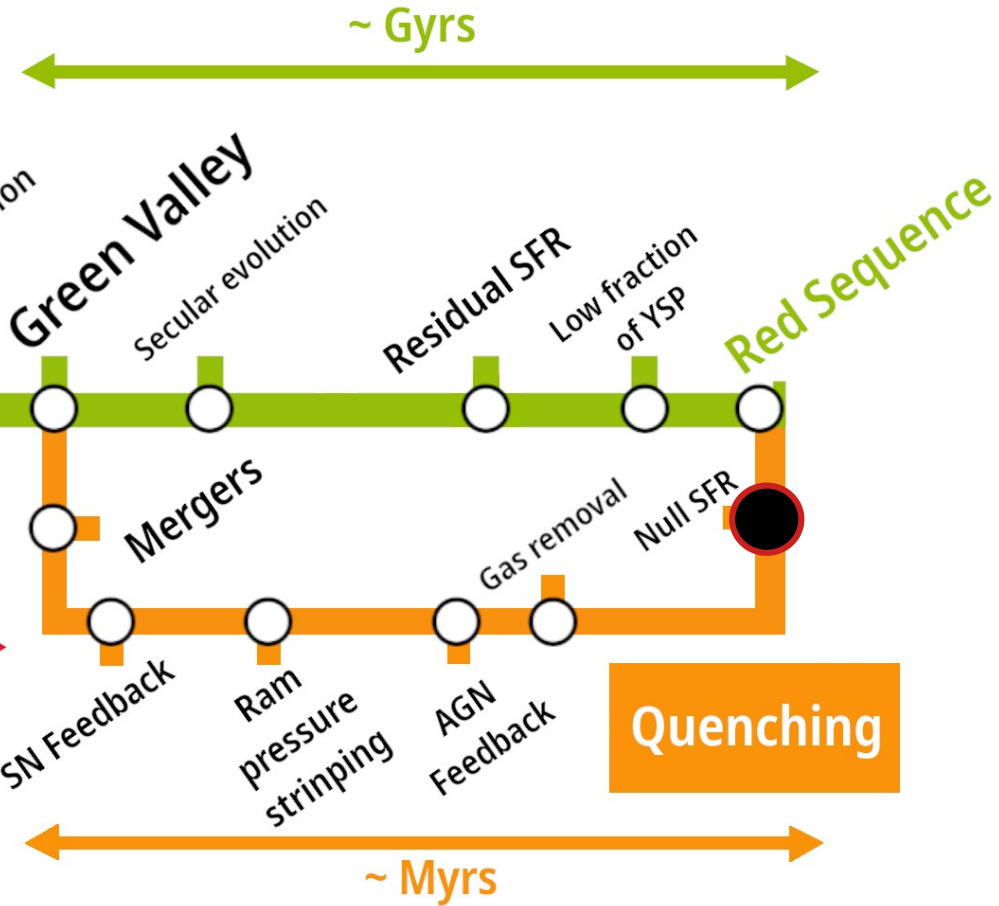
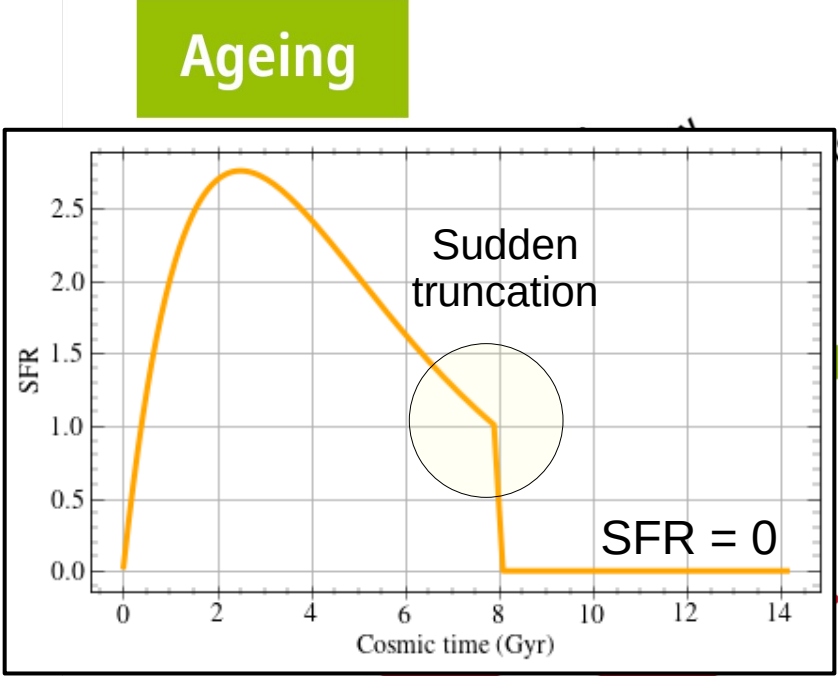
Mind the gap

Galaxy bimodality in a nutshell

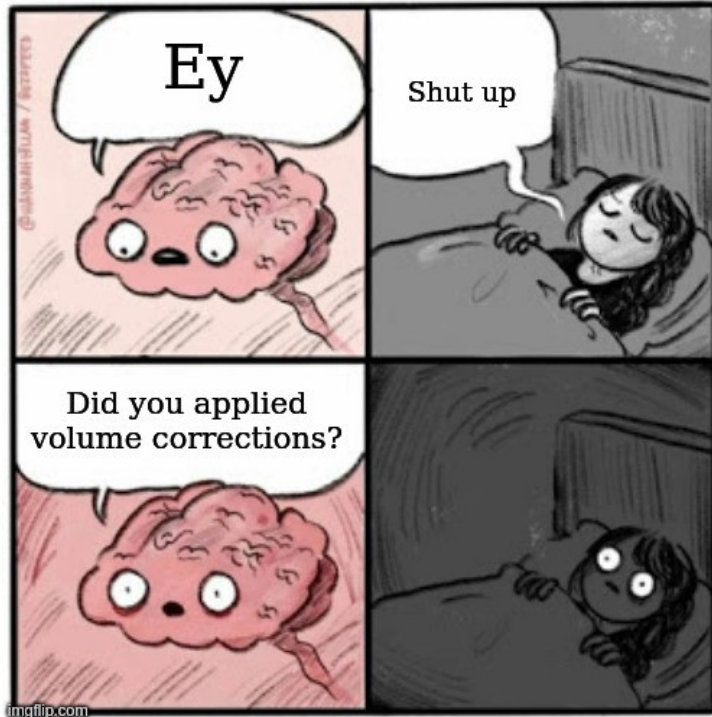


Mind the gap

Galaxy bimodality in a nutshell



Some questions that may keep you awake at night



- ◇ Do galaxies form two **physically distinct** populations?
- ◇ What can **theoretical models** tell us about galaxy bimodality?
- ◇ Are **quenching processes** the main **driver** of galaxy **evolution**?

Two galaxy populations?

Monthly Notices

of the
ROYAL ASTRONOMICAL SOCIETY

MNRAS **499**, 573–586 (2020)

Advance Access publication 2020 September 18



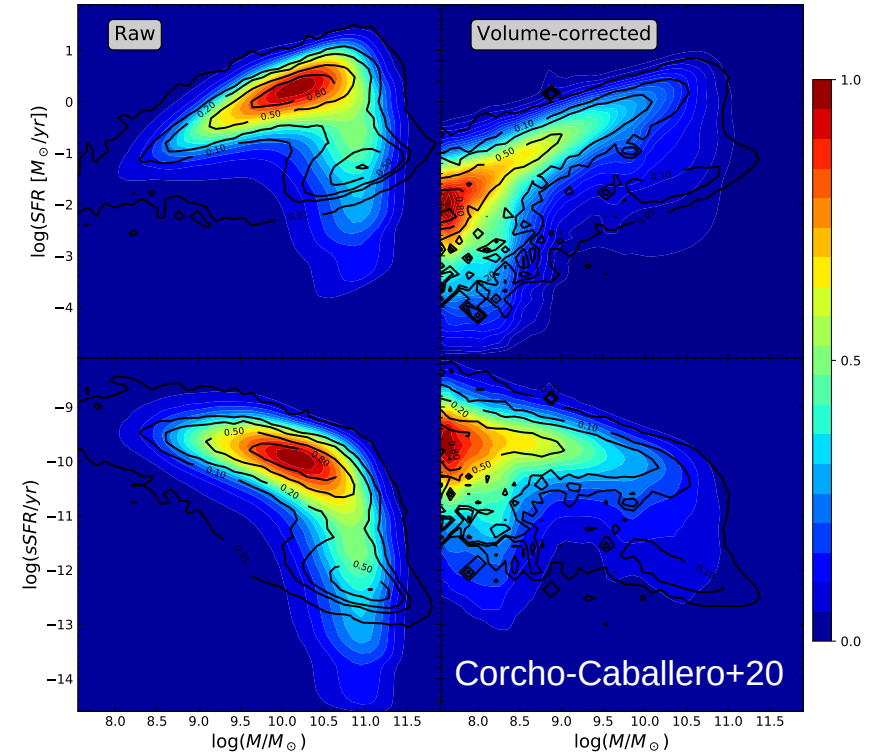
doi:10.1093/mnras/staa2818

A single galaxy population? Statistical evidence that the star-forming main sequence might be the tip of the iceberg

P. Corcho-Caballero¹,^{*} Y. Ascasibar¹ and Á. R. López-Sánchez^{2,3,4,5}

SDSS
~150.000 galaxies
GAMA
~15.000 galaxies

The distribution of galaxies in terms of **sSFR** and **stellar mass** in the Local Universe

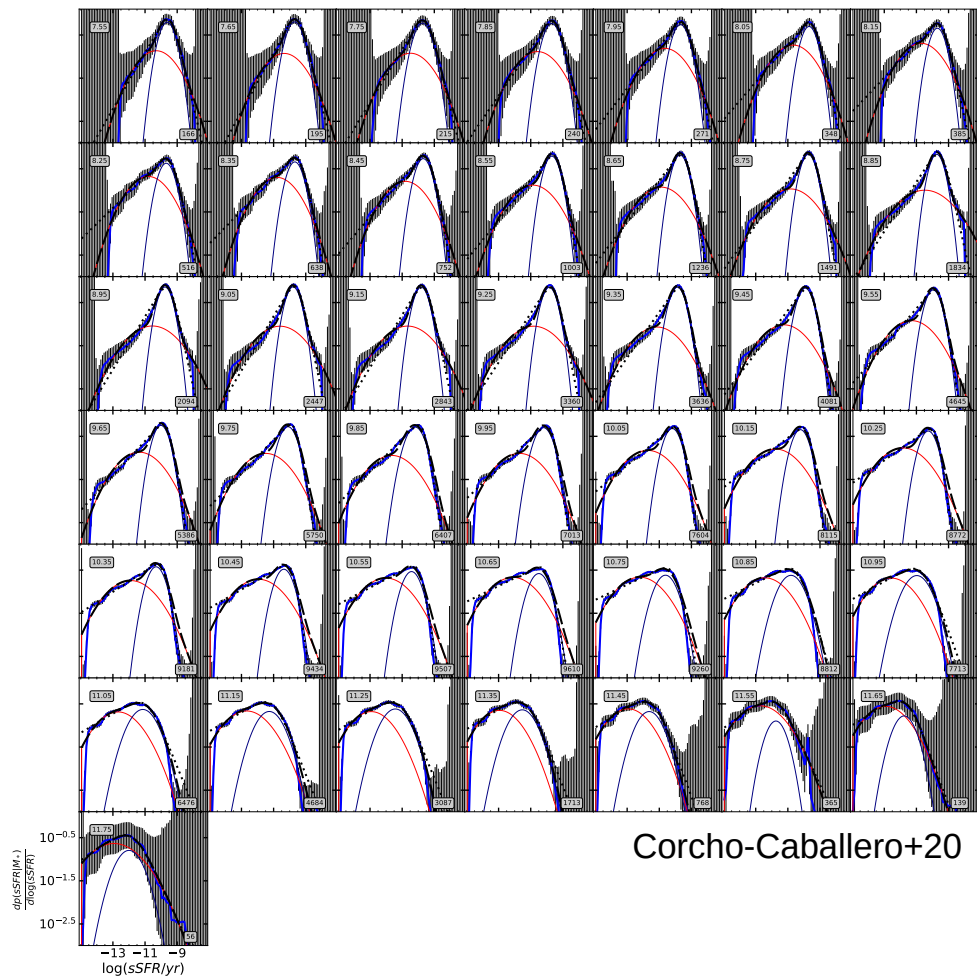


Two galaxy populations?

Conditional probability
distribution of sSFR

- Bimodal scenario: Double log-normal distribution
- Single population: Unimodal distribution with power-law tails

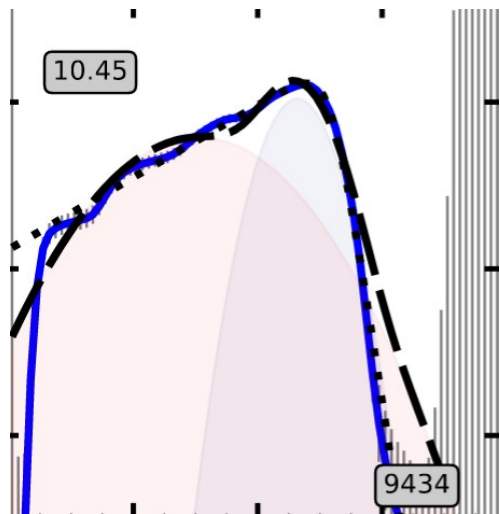
Equally consistent with current
observations



Two galaxy populations?

Conditional probability
distribution of sSFR

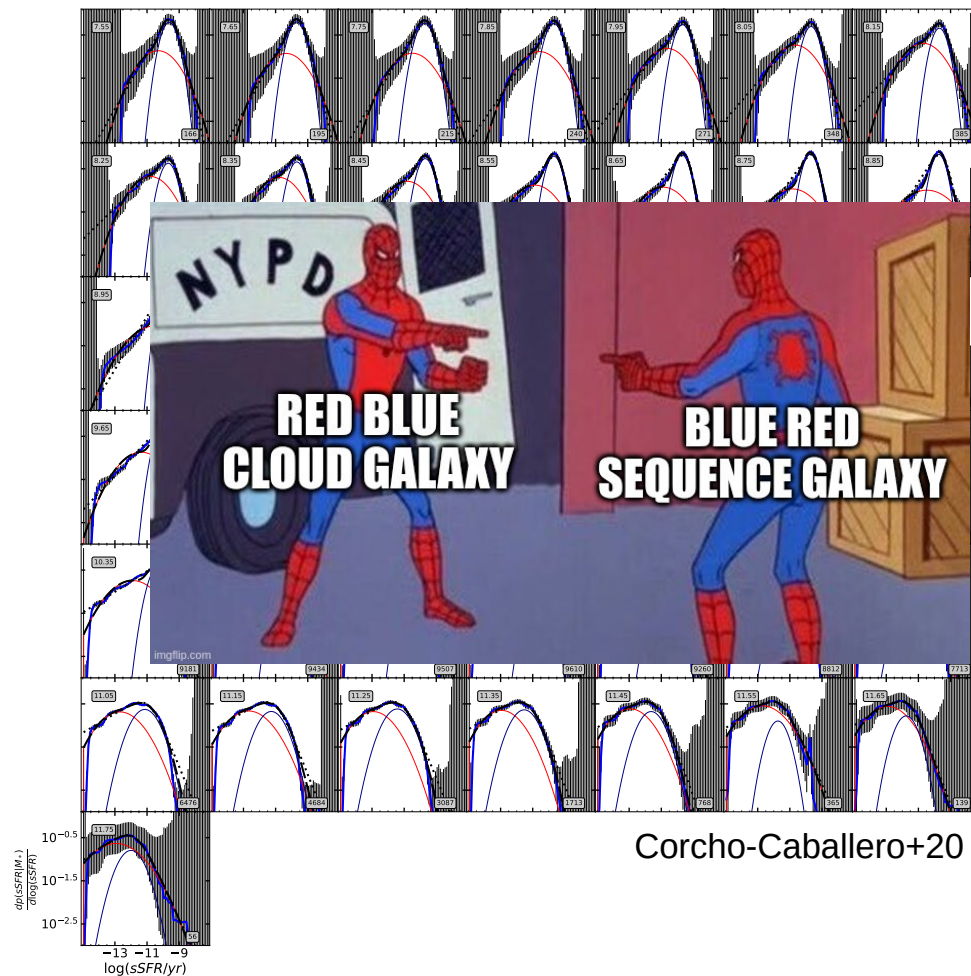
- Bimodal scenario: Double log-normal distribution
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Double log-normal



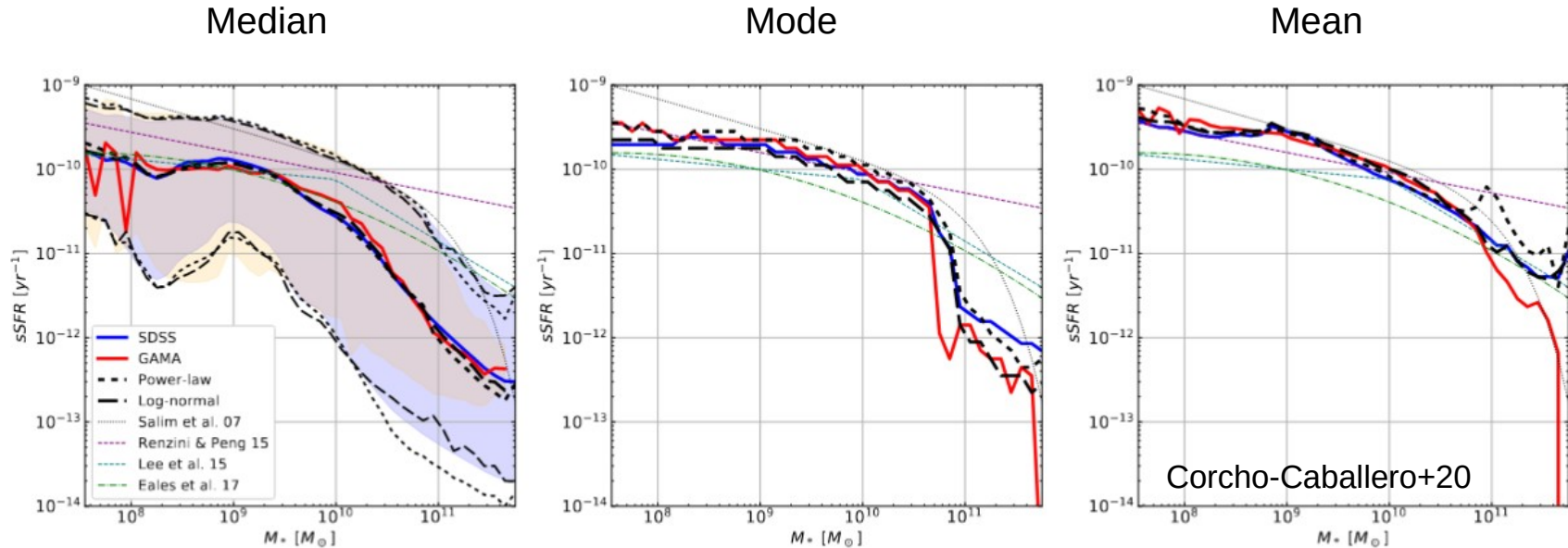
unphysical?



One PDF to rule them all...

Galaxies in the Local Universe can be described in terms of a **single population**

The **Main Sequence** of star forming galaxies is merely corresponds to the **mode** of the **bidimensional PDF**



The theoretical view from cosmological simulations

Monthly Notices

of the
ROYAL ASTRONOMICAL SOCIETY

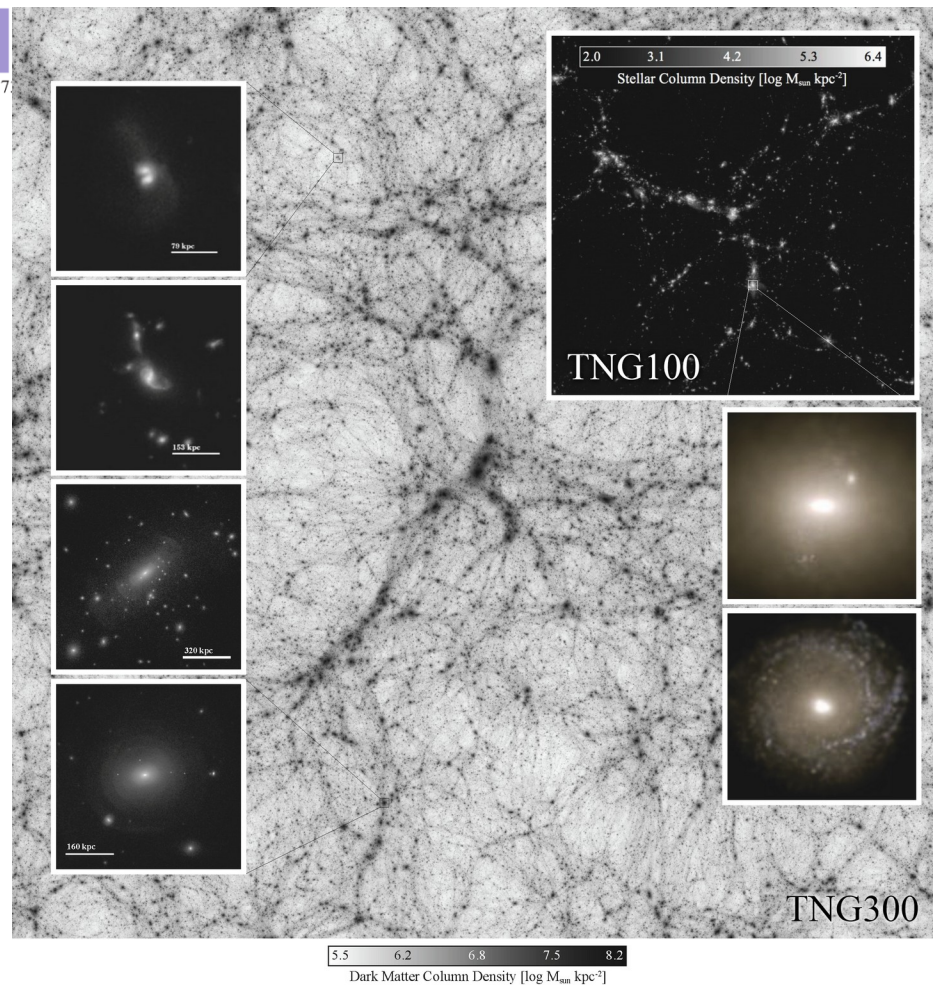
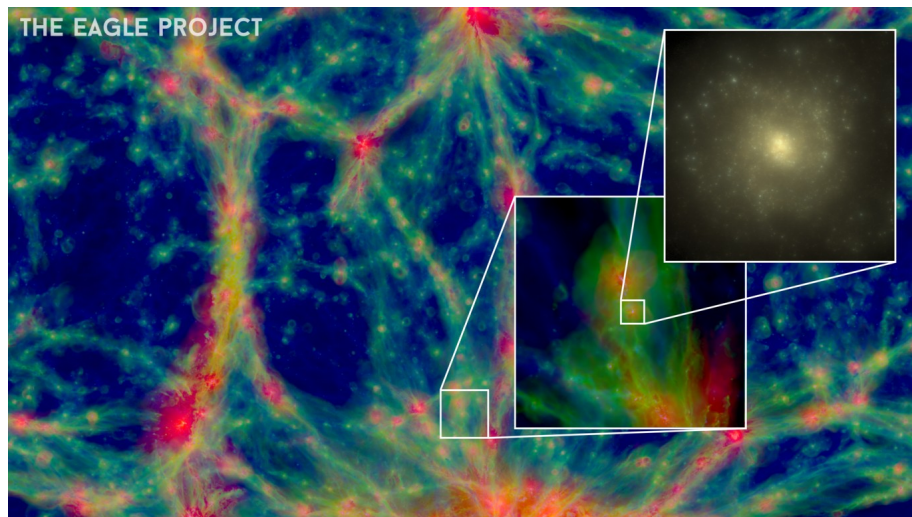
MNRAS **506**, 5108–5116 (2021)



<https://doi.org/10.1093/mnras/stab187>

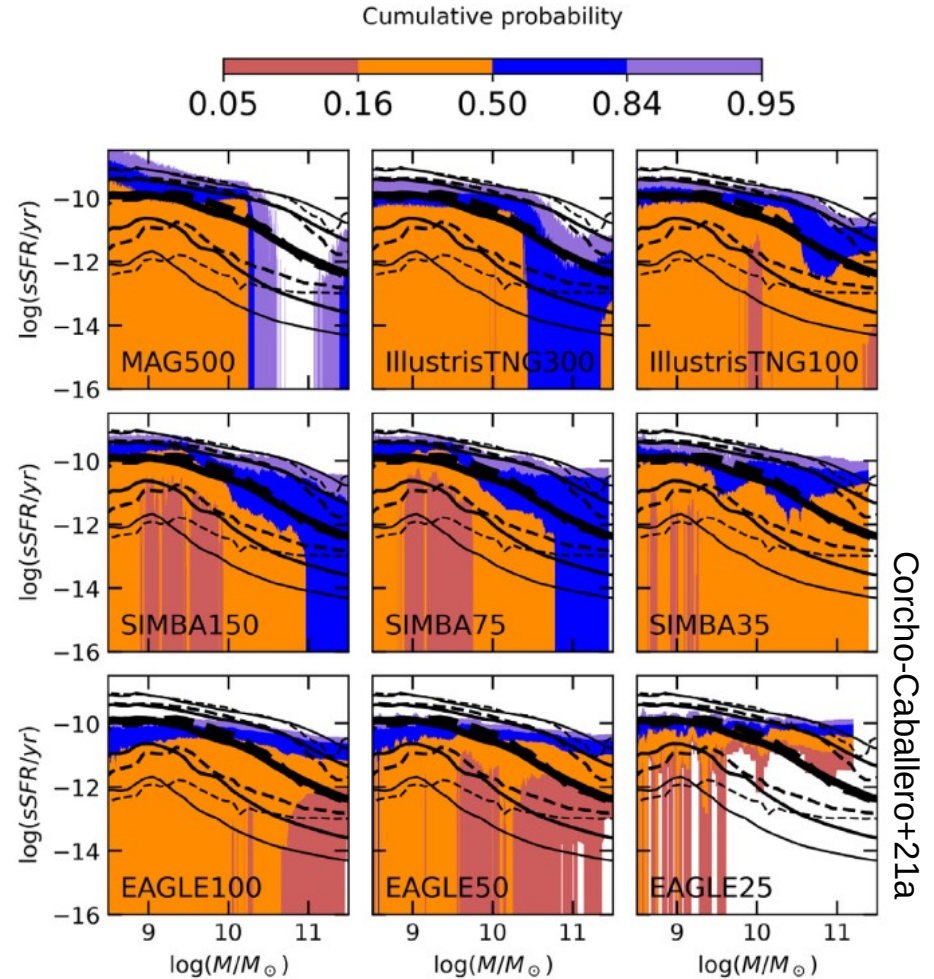
Do galaxies die? Different views from simulations and observations in the local Universe

Pablo Corcho-Caballero ^{1,2}★ Yago Ascasibar¹ and Cecilia Scannapieco ³



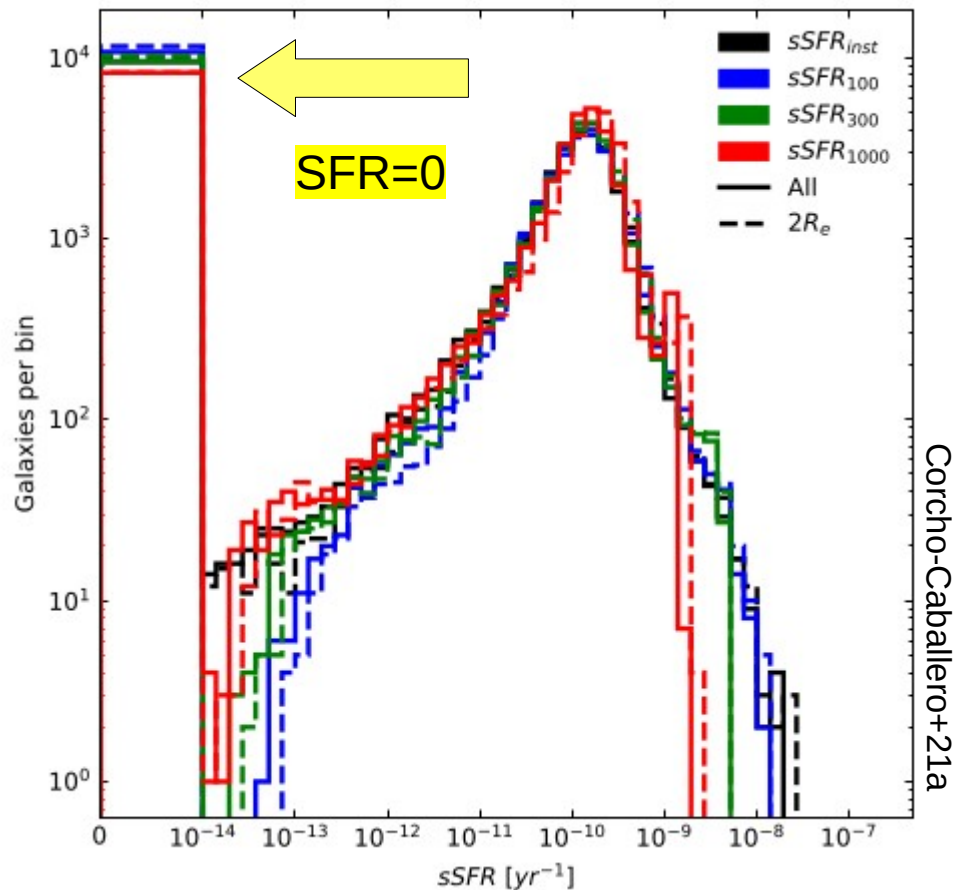
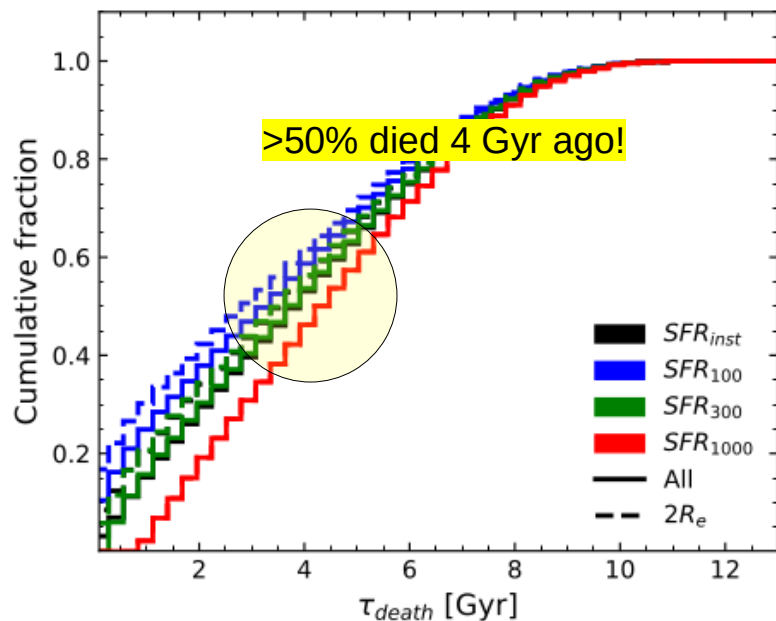
The theoretical view from cosmological simulations

- ◇ Cosmological simulations predict a **large fraction** of galaxies with **SFR = 0**
- ◇ The high number of quenched galaxies has a **strong impact** on the **M_* -sSFR distribution**



The theoretical view from cosmological simulations

- ◇ Resolution effects are not (entirely) responsible for the presence of dead galaxies



The theoretical view from cosmological simulations

RED SEQUENCE GALAXIES

Theoretical predictions

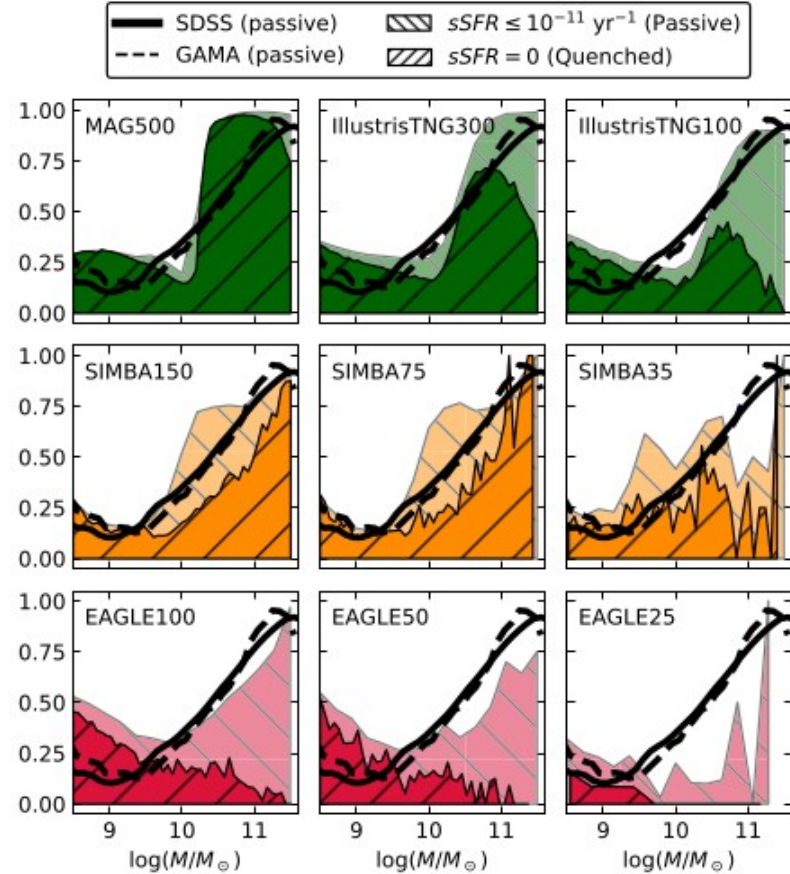
sSFR = 0

Quenched
several Gyr
ago

Observational estimates

sSFR > 0

Still retain
low levels
of SF



The theoretical view from cosmological simulations

RED SEQUENCE GALAXIES

Theoretical predictions

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The theoretical view from cosmological simulations

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Theoretical predictions

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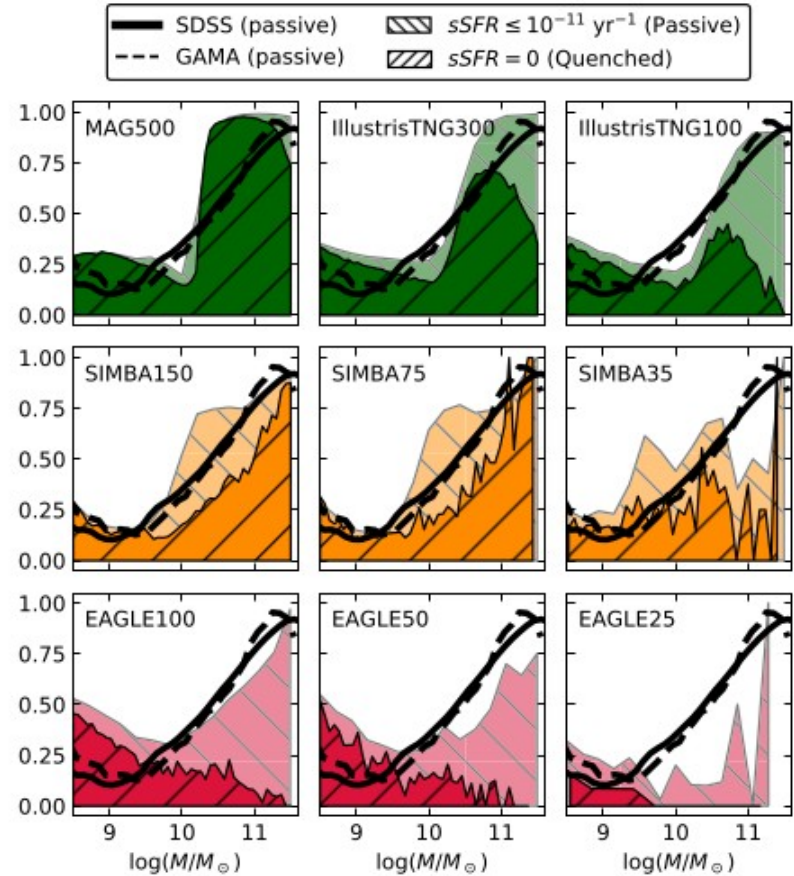
Extremely
sensitive to
subgrid physics

Observational estimates

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Very challenging
to measure



The theoretical view from cosmological simulations

RED SEQUENCE GALAXIES

Theoretical
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sensitive to
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estimates

sSFR > 0

Still retain
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of SF

Very challenging
to measure

Use the M-sSFR plane as a
benchmark for implementing
feedback recipes

Use alternative methods for
estimating SFR's (e.g. Jiménez-
López+21, see Dani's talk!)

Ageing vs Quenching



The **ageing diagram** provides an excellent tool for **discriminating** between recent **quenching** processes and **secular evolution** in galaxies

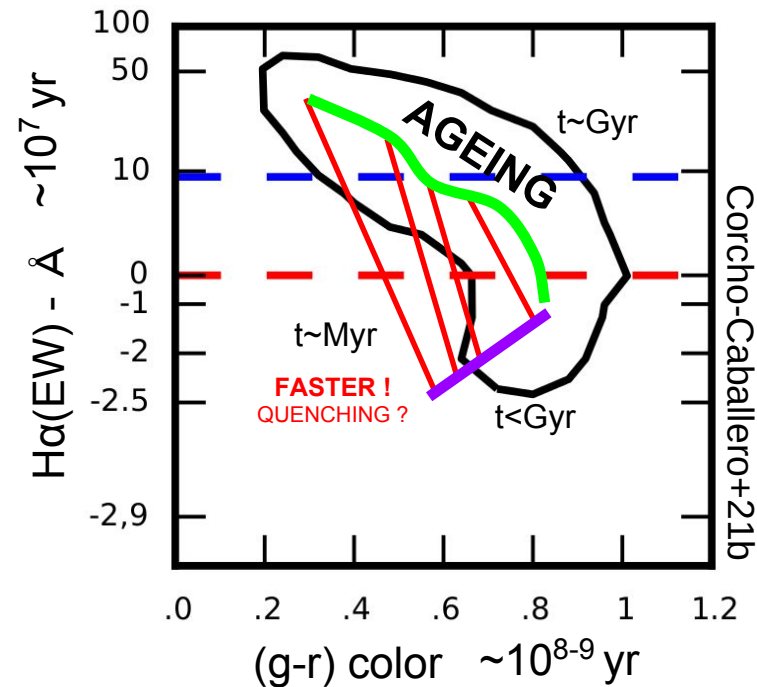
Two proxies for tracing SF

EW(H α): Fraction of stars formed on scales of tenths of Myr

g-r: Fraction of stars formed during the last several hundred Myr

Galaxy evolution on resolved scales: ageing and quenching in CALIFA

P. Corcho-Caballero ^{1,2}★ J. Casado,¹ Y. Ascibar¹ and R. García-Benito ³



Ageing vs Quenching

The **ageing diagram** provides an excellent tool for **discriminating** between recent **quenching** processes and **secular evolution** in galaxies

We divide the AD into four domains:

Blue Emission: $EW > 0$, $g-r < 0.7$

Blue Absorption: $EW < 0$, $g-r < 0.7$

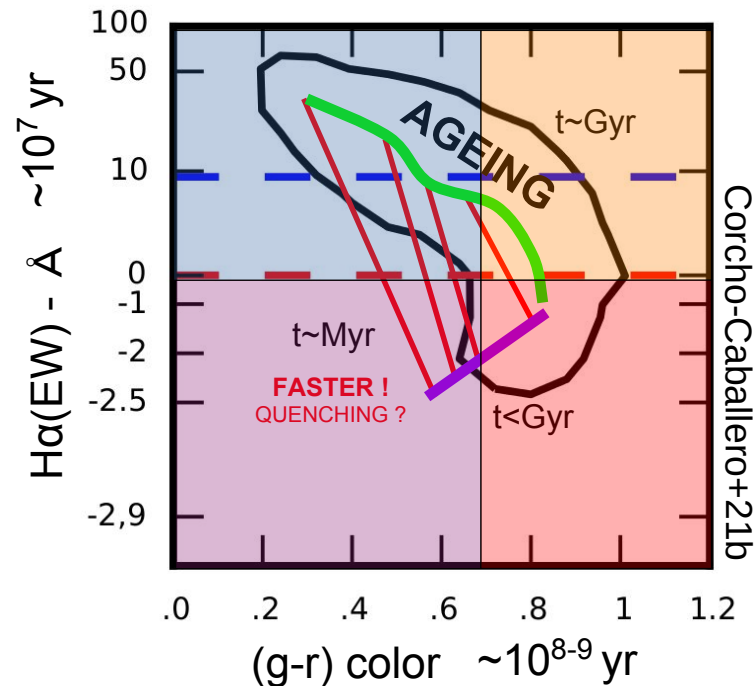
Red Emission: $EW > 0$, $g-r > 0.7$

Red Absorption: $EW < 0$, $g-r > 0.7$

Check also Casado+15!

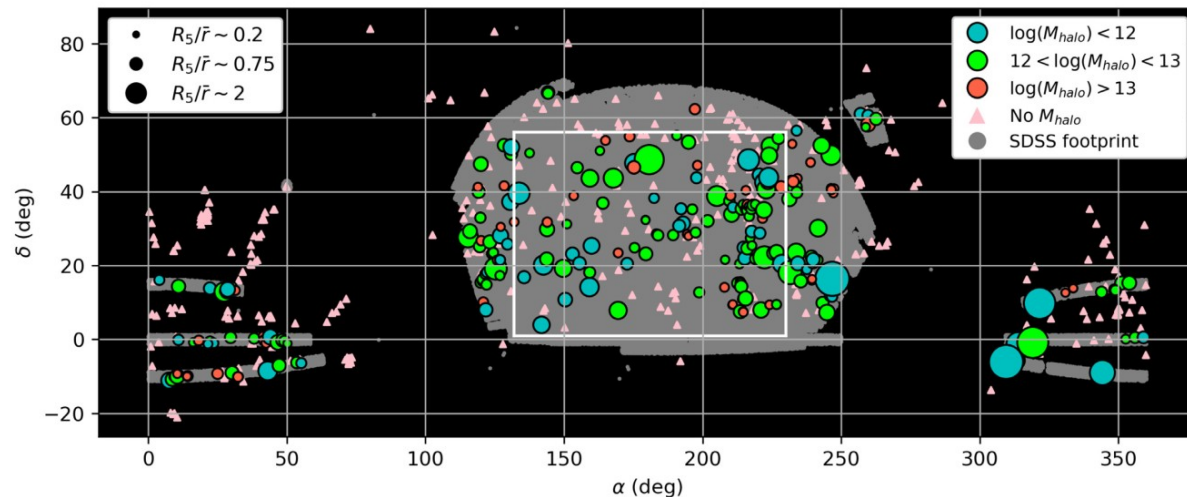
Galaxy evolution on resolved scales: ageing and quenching in CALIFA

P. Corcho-Caballero ^{1,2*}, J. Casado, ¹ Y. Ascibar ¹ and R. García-Benito ³



Ageing vs Quenching

We explore the distribution across the ageing diagram on resolved scales for **CALIFA mother and extended samples** (637 galaxies)

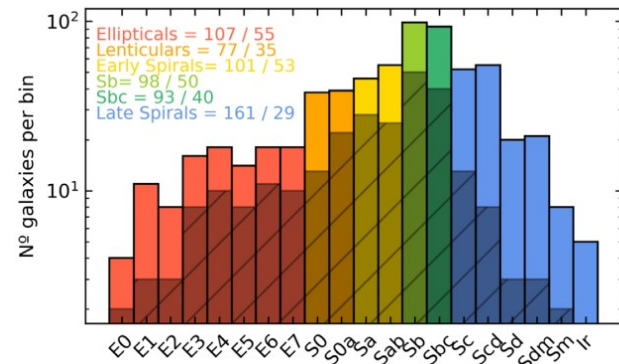
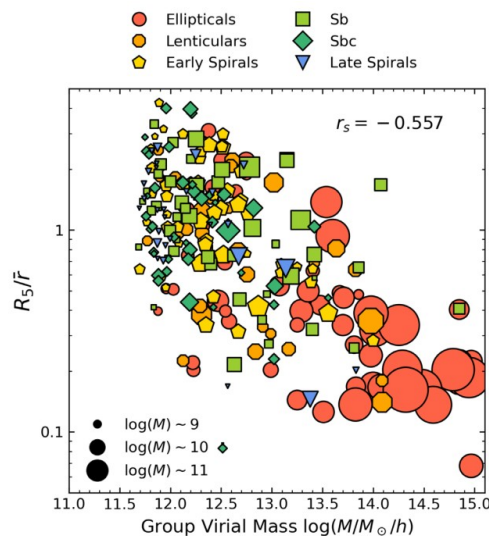


Global properties

- Environment
- Total stellar mass
- Morphology
- Nuclear classification

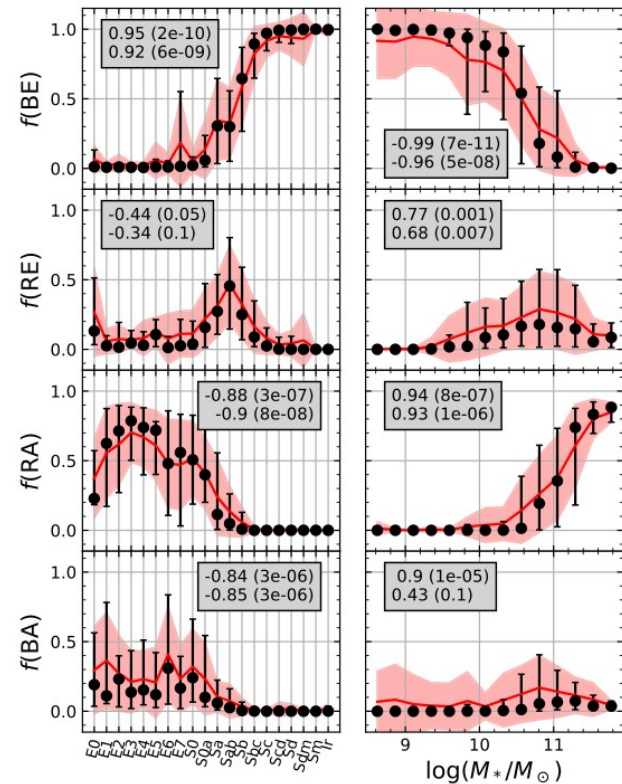
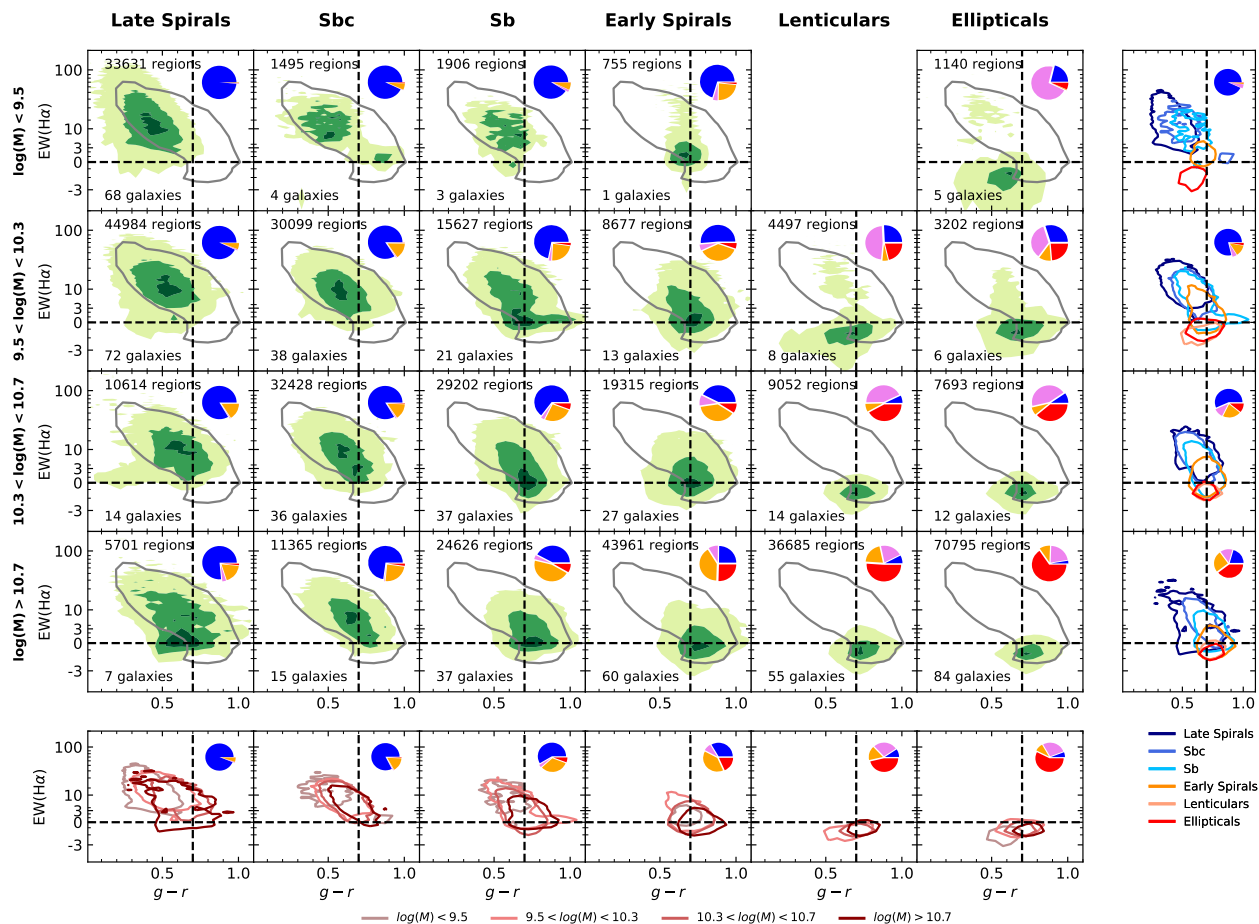
Local properties

- Stellar surface brightness
- Stellar metallicity



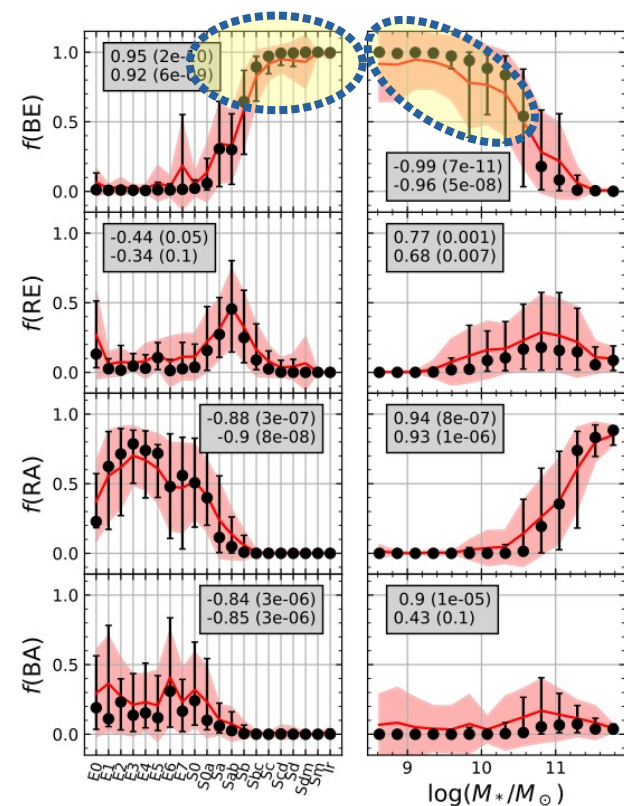
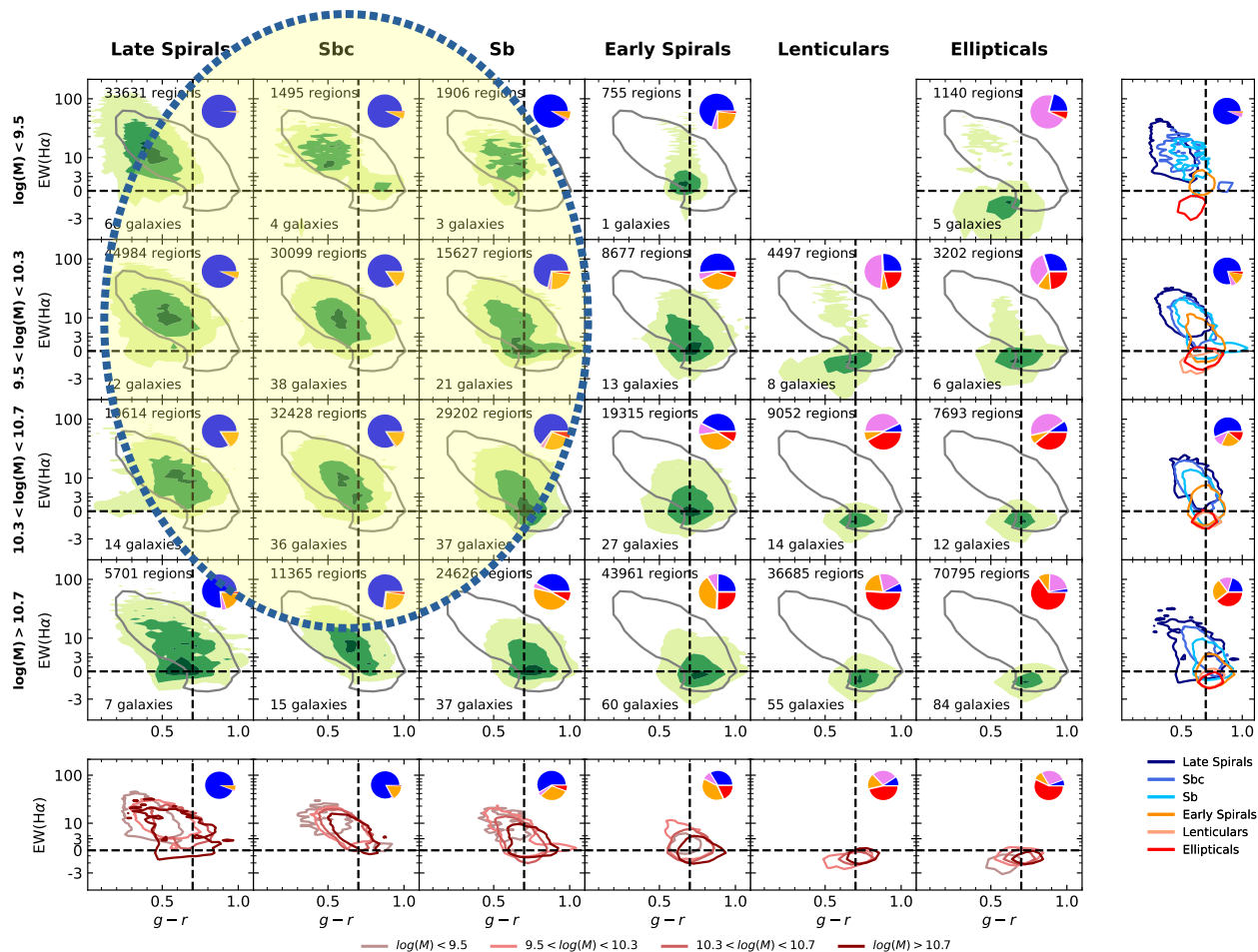
Corcho-Caballero+21b

Ageing vs Quenching



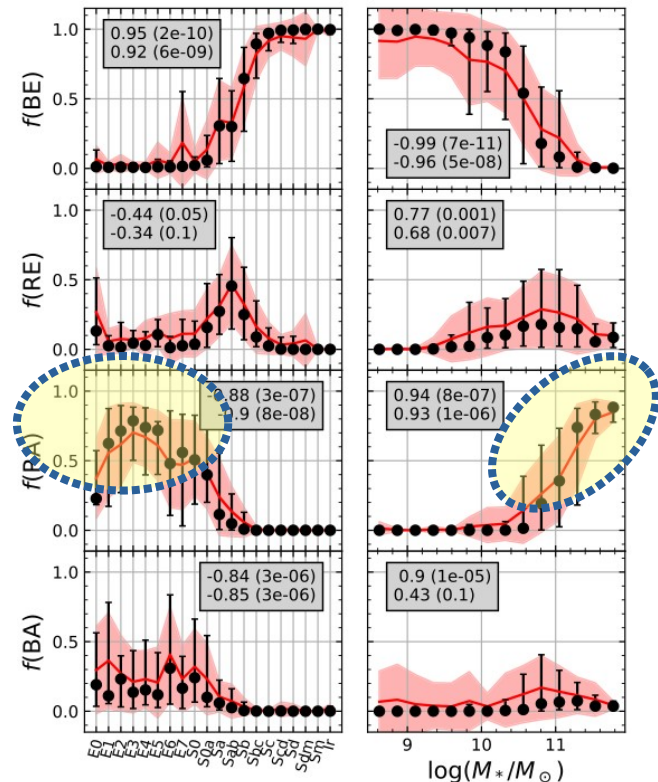
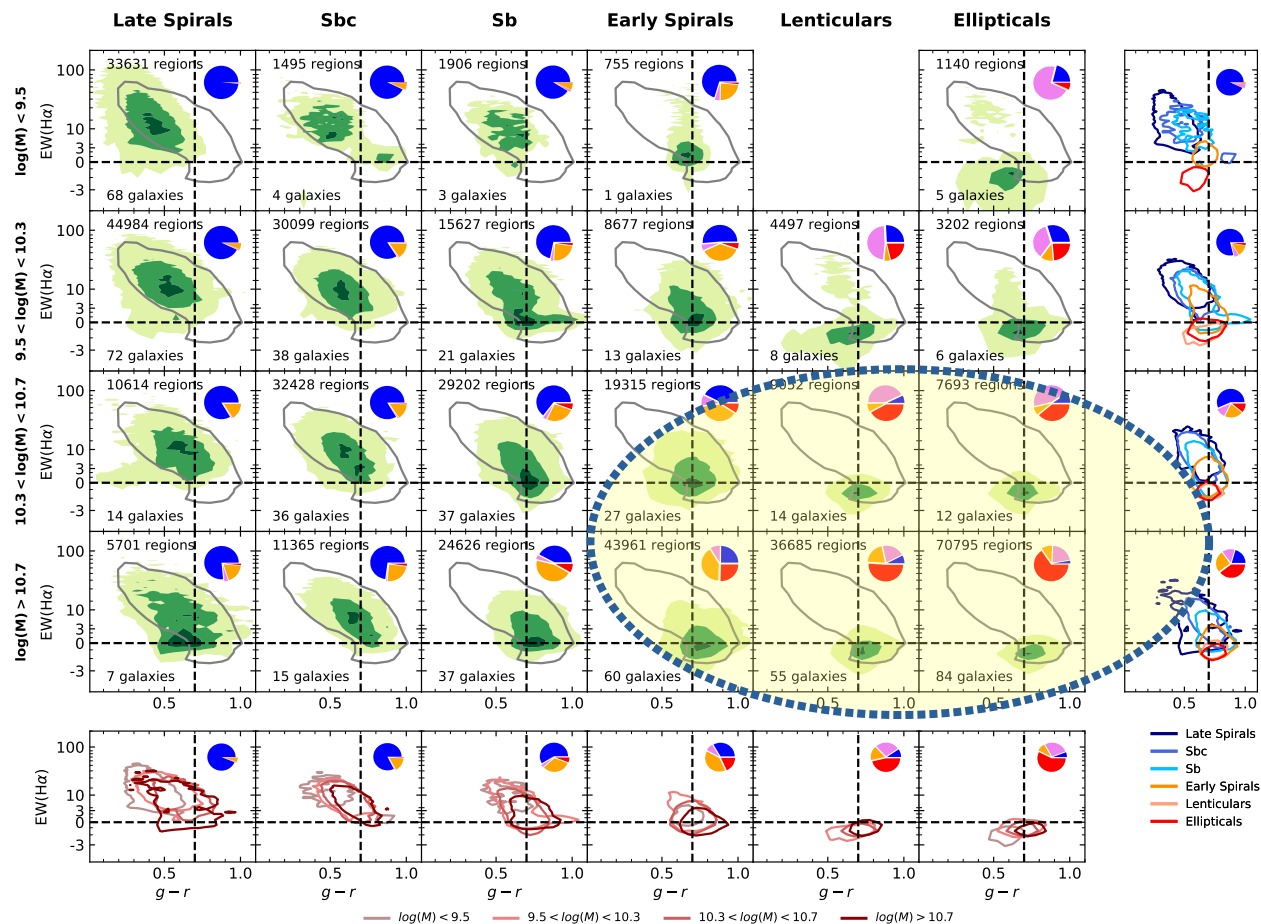
Corcho-Caballero+21b

Ageing vs Quenching



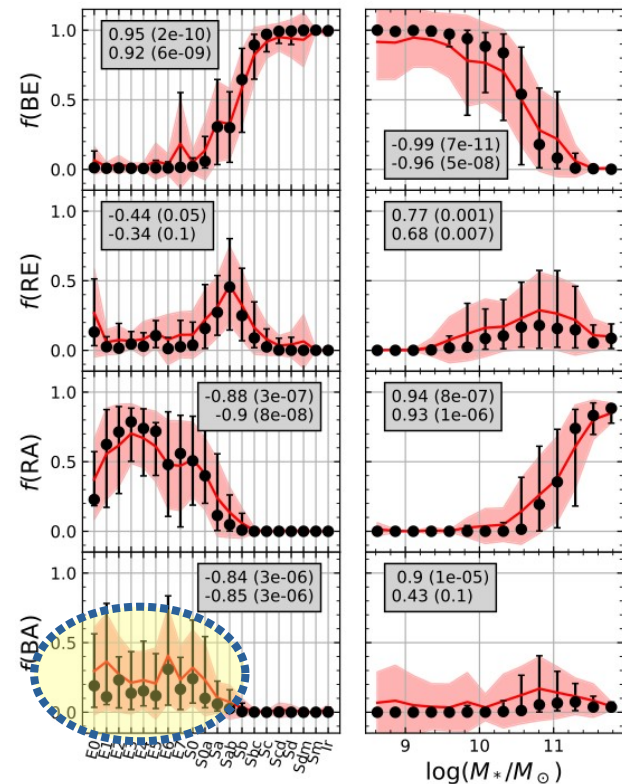
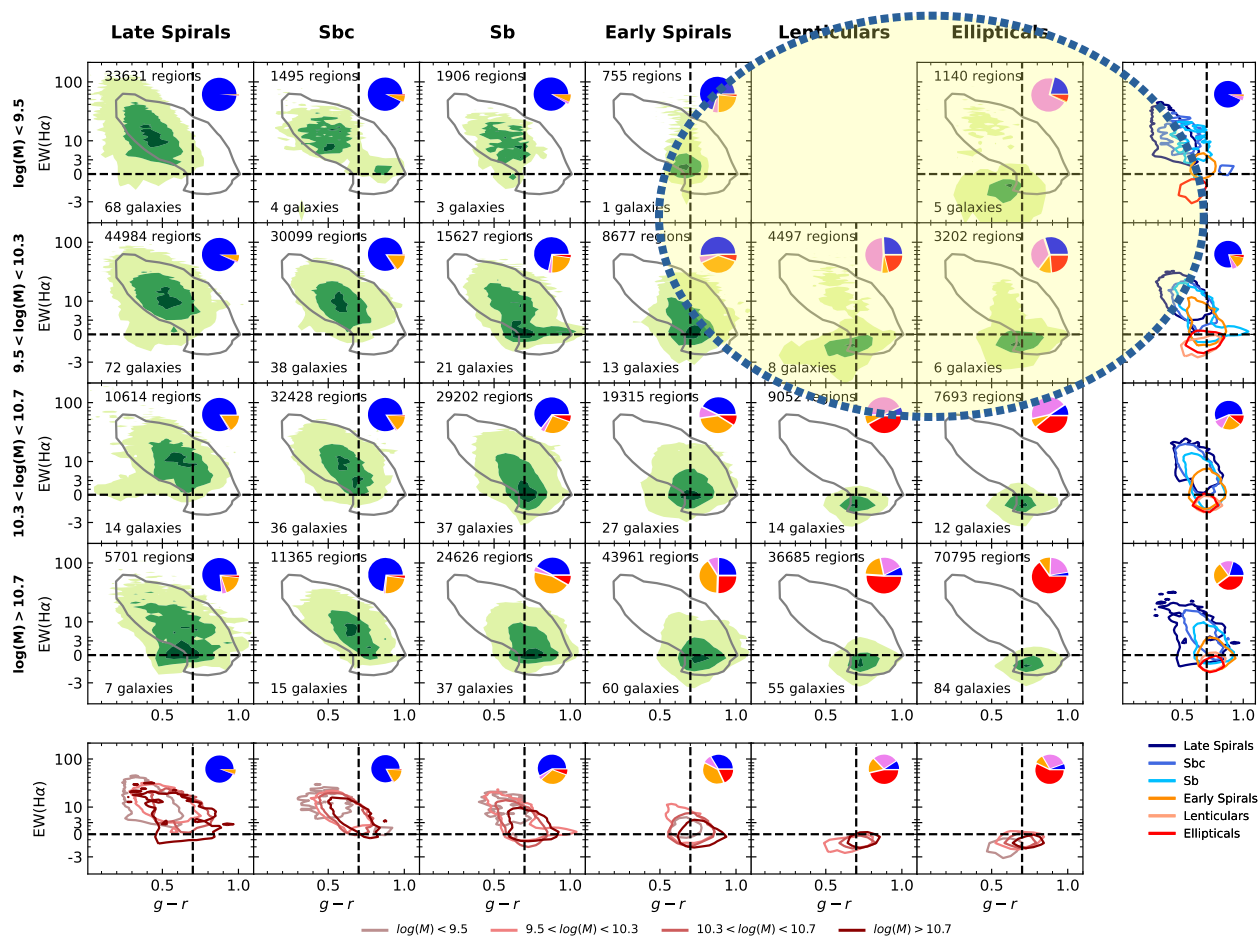
Corcho-Caballero+21b

Ageing vs Quenching



Corcho-Caballero+21b

Ageing vs Quenching

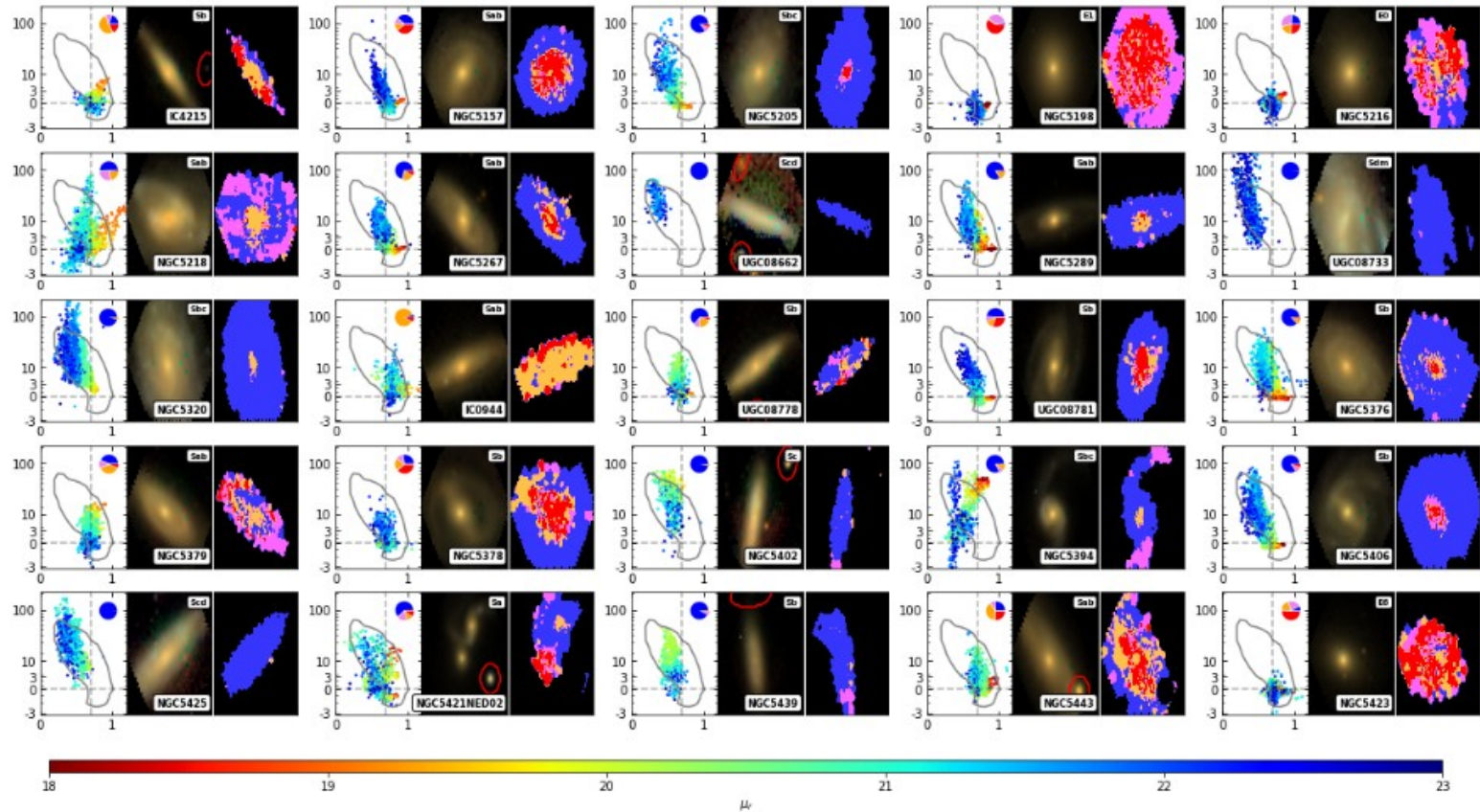


Corcho-Caballero+21b

Ageing vs Quenching

Individual galaxies

- **Broad** distributions
- **Inside-out** evolution
- **Continuous** transition
- Ageing and quenching are **local** processes
- **Late spirals** are located along the “**chemically primitive**” part of the sequence
- **Lenticulars** (S0a and S0) and **ellipticals** predominantly gather near the “**evolved**” end



Ageing vs Quenching

Individual galaxies

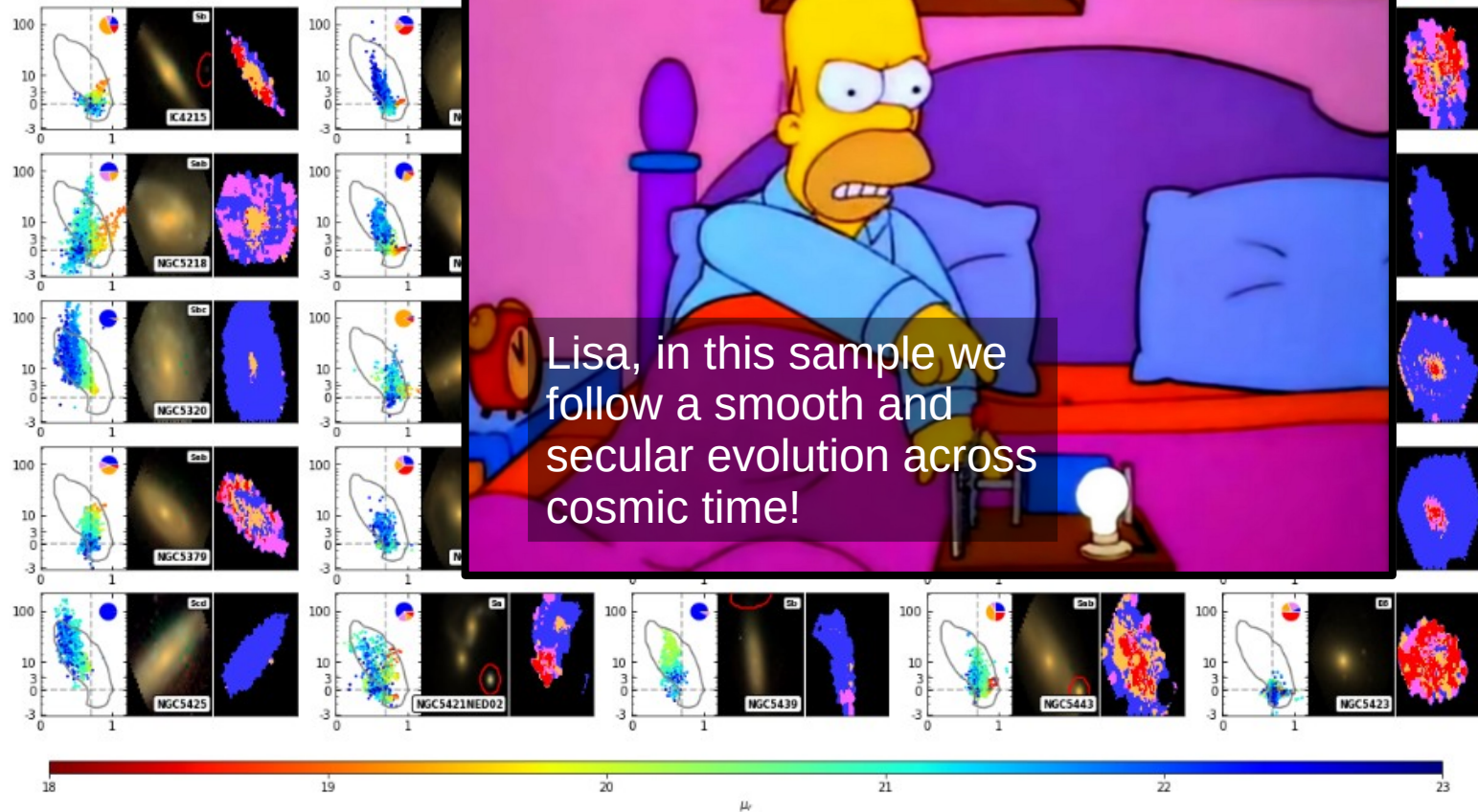
637 objects

84 (13%) $\rightarrow f(\text{BA}) > 0.25$

40 (6%) $\rightarrow f(\text{BA}) > 0.5$

19 (2%) $\rightarrow f(\text{BA}) > 0.75$

For galaxies with $f(\text{BA}) \geq 0.25$ only 13 present Sa (5), Sab (5), Sb (2), and Sbc (1) morphologies.

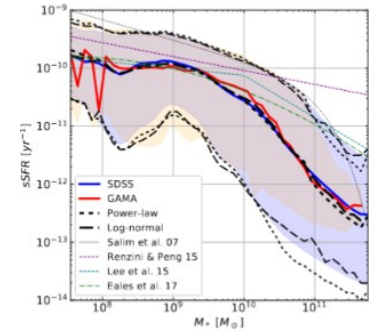


Conclusions

See Corcho-Caballero+20

Do galaxies form two **physically distinct** populations?

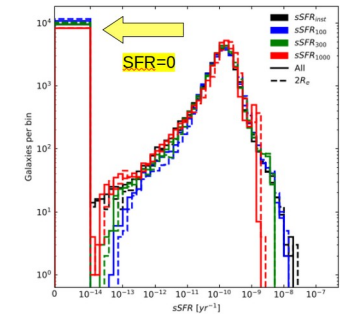
→ Galaxies can be described in terms of a **single population** governed by **smooth secular evolution**.



See Corcho-Caballero+21a

What can **theoretical models** tell us about galaxy bimodality?

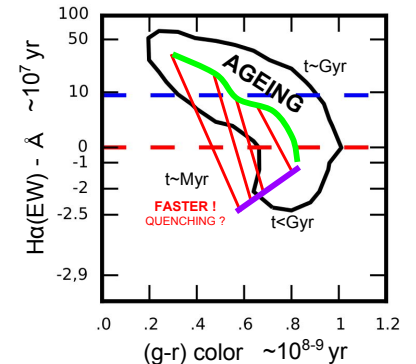
→ Cosmological simulations predict the existence of a large fraction of **dead galaxies** with $SFR=0$ whilst observational estimates not.



See Corcho-Caballero+21b

Are **quenching processes** the main **driver** of galaxy **evolution**?

→ **Ageing** is an **ubiquitous** process, strongly **correlated** with **global** and **local properties**, while **quenching** is only found on particular cases showing mild correlations with morphology.



Thanks!



A lot of stuff coming! See also Ángel's talk on the HI-KIDS survey!

