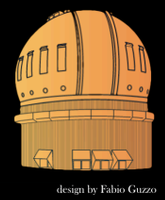








# Caught in the Cosmic Web: Framing the Big Picture of the Slow Quenching of Massive Galaxies (since cosmic noon)

KITP, Feb 8, 2023

**Thibaud Moutard**

*Collab.: S. Arnouts, N. Malavasi, O. Ilbert +*

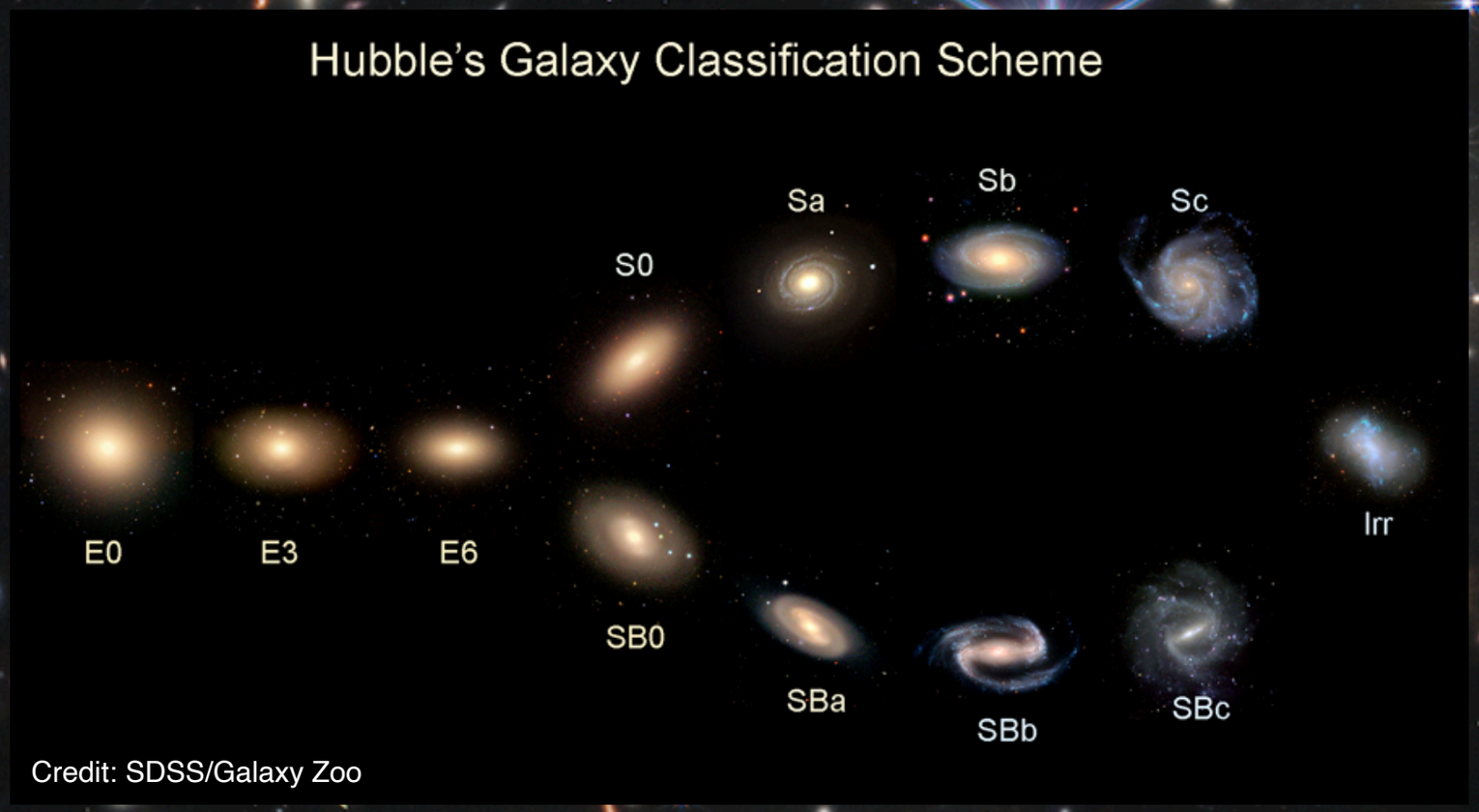

# GALAXIES DIVERSITY

Credit: NASA, ESA, CSA, and STScI

MULTI-WAVELENGTH OBSERVATIONS HAVE REVEALED TO TREMENDOUS DIVERSITY OF GALAXIES
(MORPHOLOGIES, SPECTRAL TYPES & ENVIRONMENTS)

# GALAXY EVOLUTION SCHEME

ON AVERAGE, SPIRALS ARE (OPTICALLY) BLUE, ELLIPTICALS ARE RED ( ~90% OF GALAXIES IN THE LOCAL )

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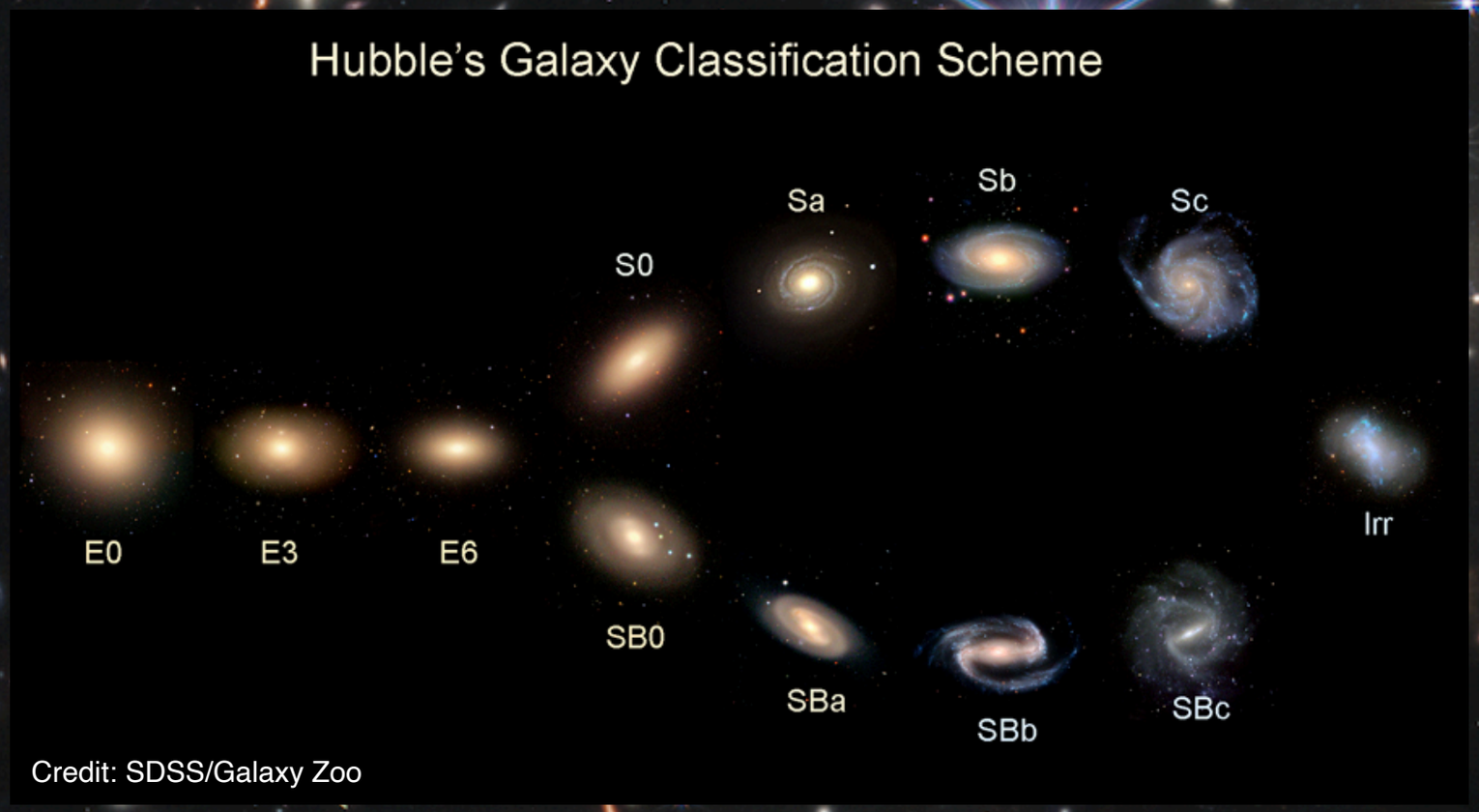



*gri* - z ~ 0.05

*Schawinski et al. (2014)*

*gri* - z ~ 0.2

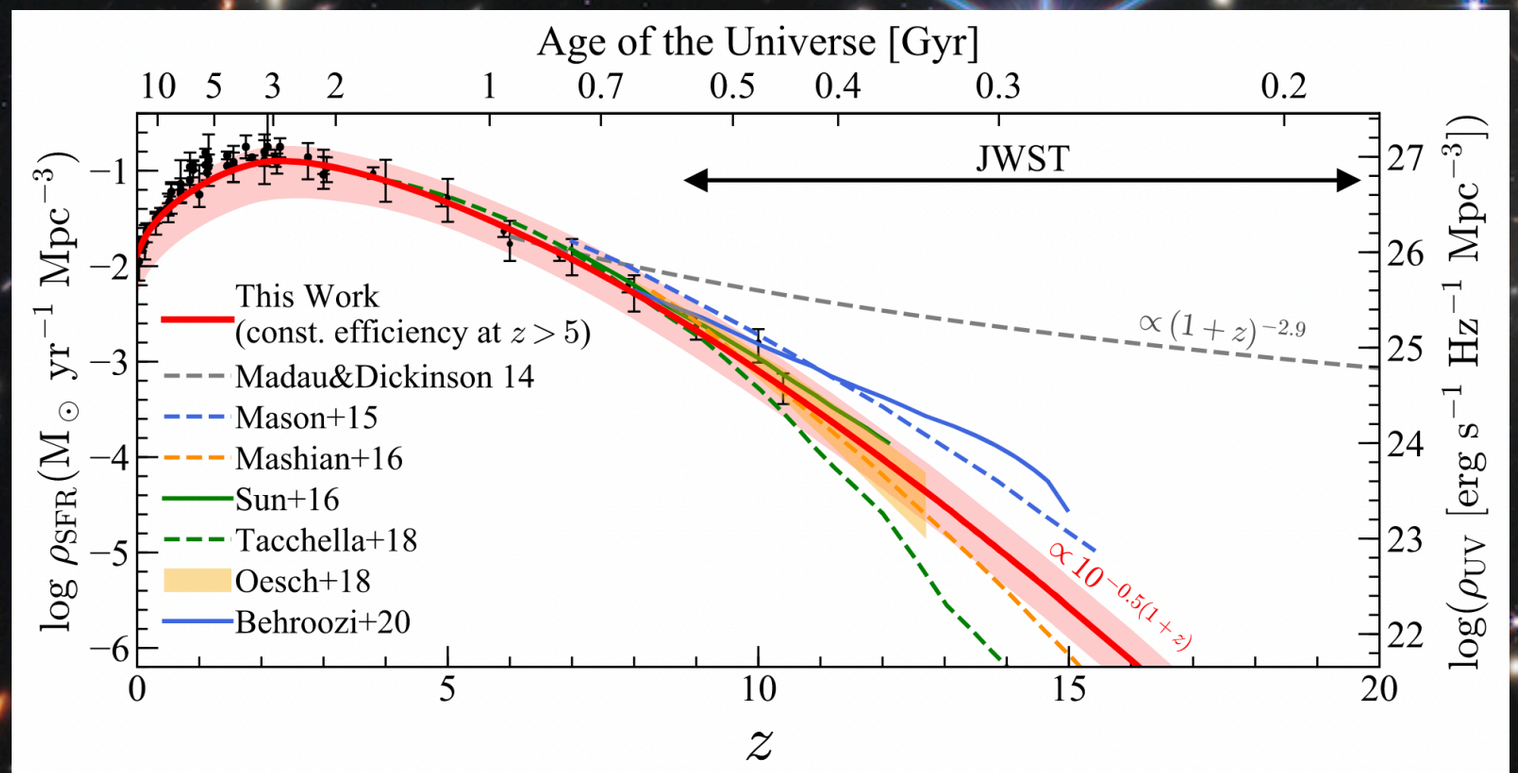
*Moutard et al. (2016a)*

ACTUALLY, SLIGHTLY MORE COMPLICATED…

Credit: NASA, ESA, CSA, and STScI

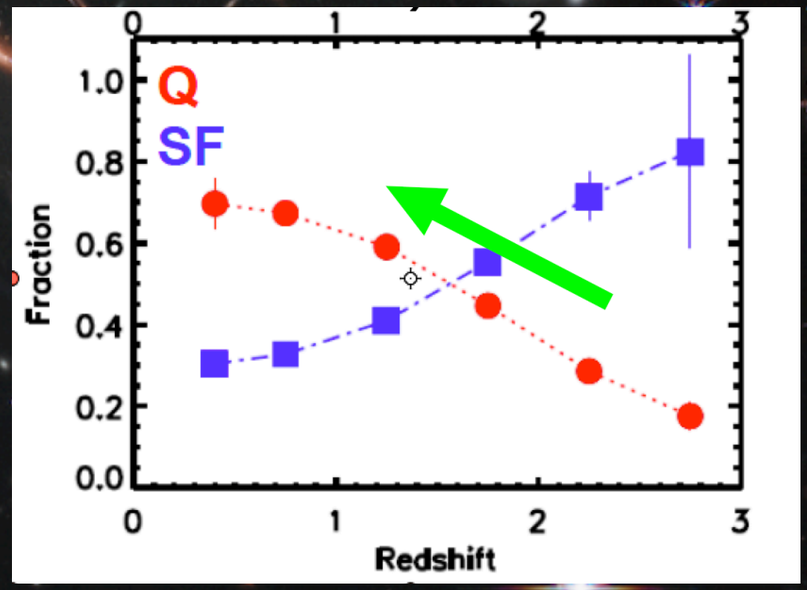
# GALAXIES FATE

## COSMIC STAR FORMATION HISTORY EXHIBITS A MAXIMUM AT 1 < z < 3, AT COSMIC NOON




Harikane et al. 2021

## QUIESCENT GALAXIES FRACTION CONTINUOUSLY RISING SINCE z ~ 4




Mortlock et al. 2015

## EVENTUALLY, GALAXY STAR FORMATION IS OBSERVED TO BE QUENCHED. WHY & HOW?

# GALAXIES FATE

## DIFFERENT FLAVOURS OF STAR FORMATION QUENCHING

### Slow Quenching of Evolved, Massive Galaxies

**Faber et al. 2007**
**Peng et al. 2010, 2015**
**Schawinski et al. 2014**
**Moutard et al. 2016a,b, 2020b**

### Fast Quenching of Low-Mass Satellite Galaxies

**Faber et al. 2007**
**Peng et al. 2010, 2012**
**Schawinski et al. 2014**
**Moutard et al. 2016a,b, 2018**

### Fast Quenching of Massive Galaxies at Early Epochs

**Davidson et al. 2017**
**Merlin et al 2019**


STARVATION


MERGERS


AGN FEEDBACK


STARBURST


RAM PRESSURE

WHAT ARE THE PRECISE MECHANISMS AT PLAY IN THOSE DIFFERENT QUENCHING CHANNELS, AND WHAT IS THE IMPACT OF THE COSMIC LARGE-SCALE STRUCTURE GROWTH?

# GALAXIES FATE

## WHAT IS THE PRECISE SCENARIO OF MASSIVE M* GALAXY STAR FORMATION QUENCHING?

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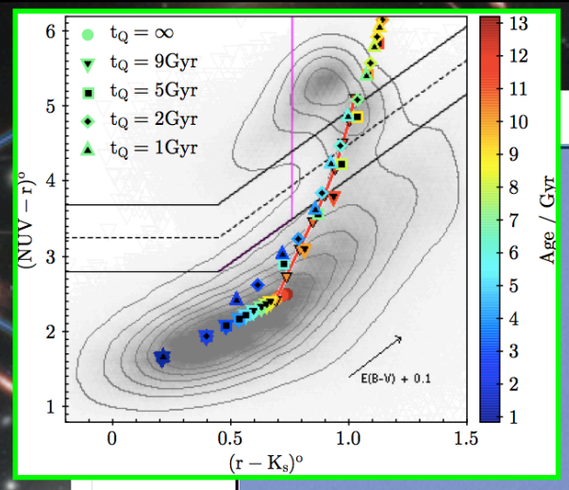





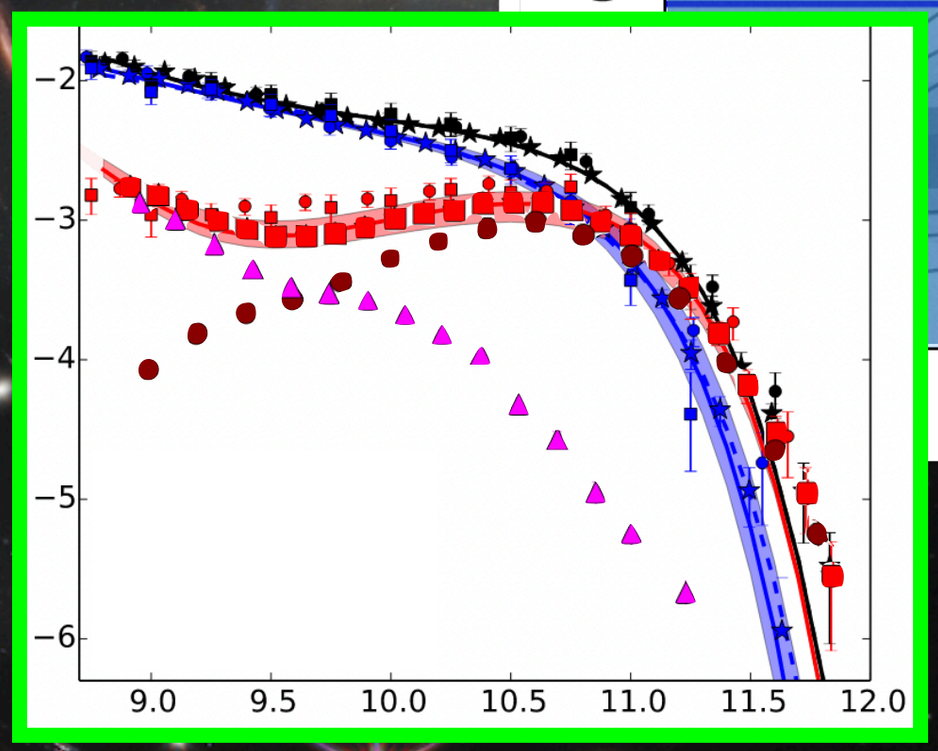

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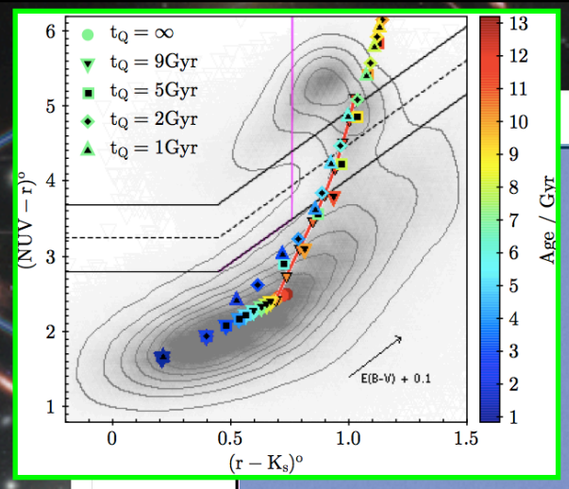
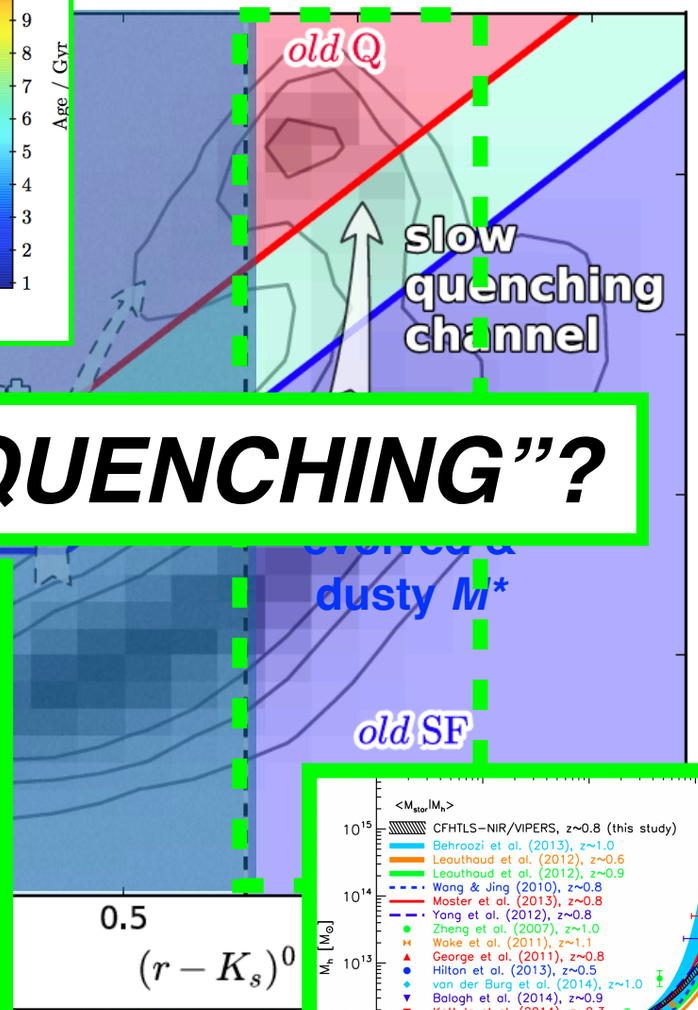
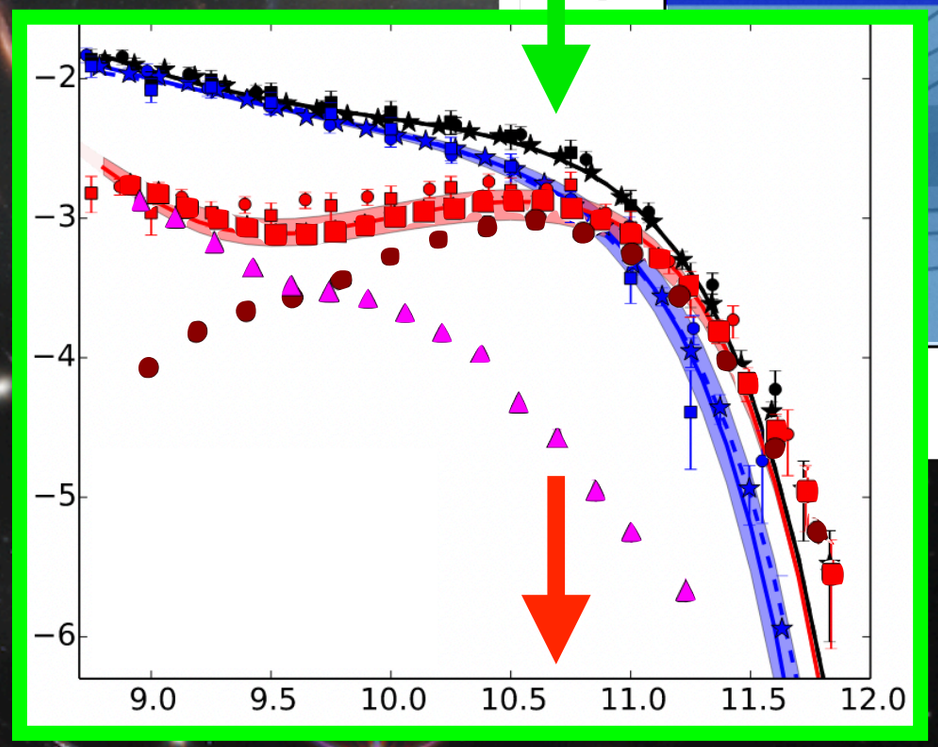
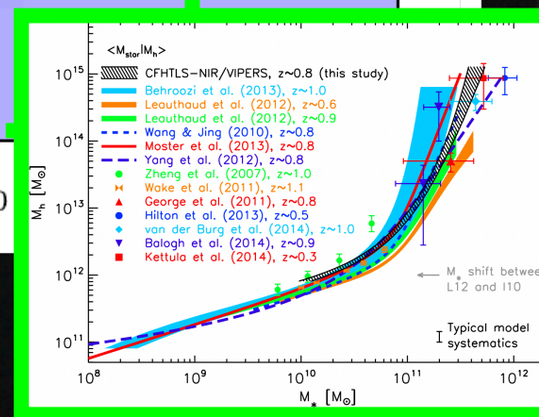



## "MASS QUENCHING"?




Credit: NASA, ESA, CSA, and STScI

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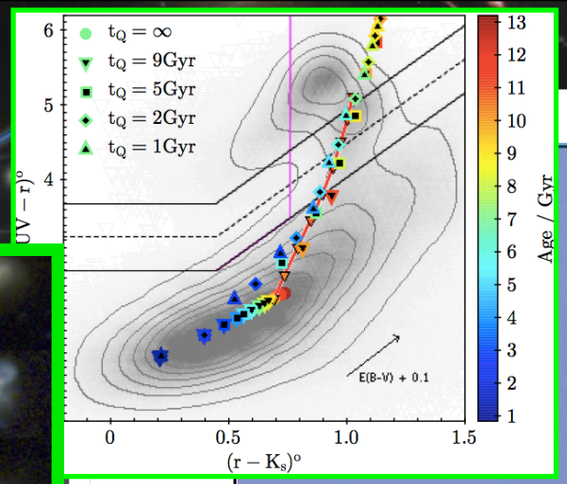


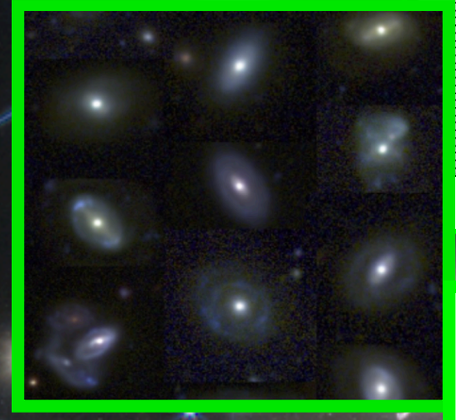

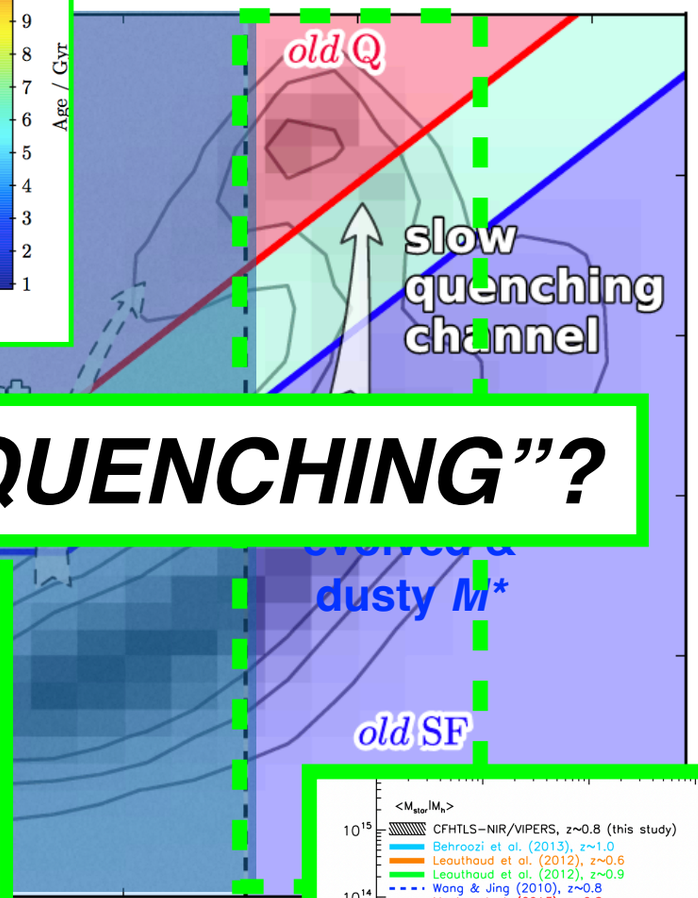


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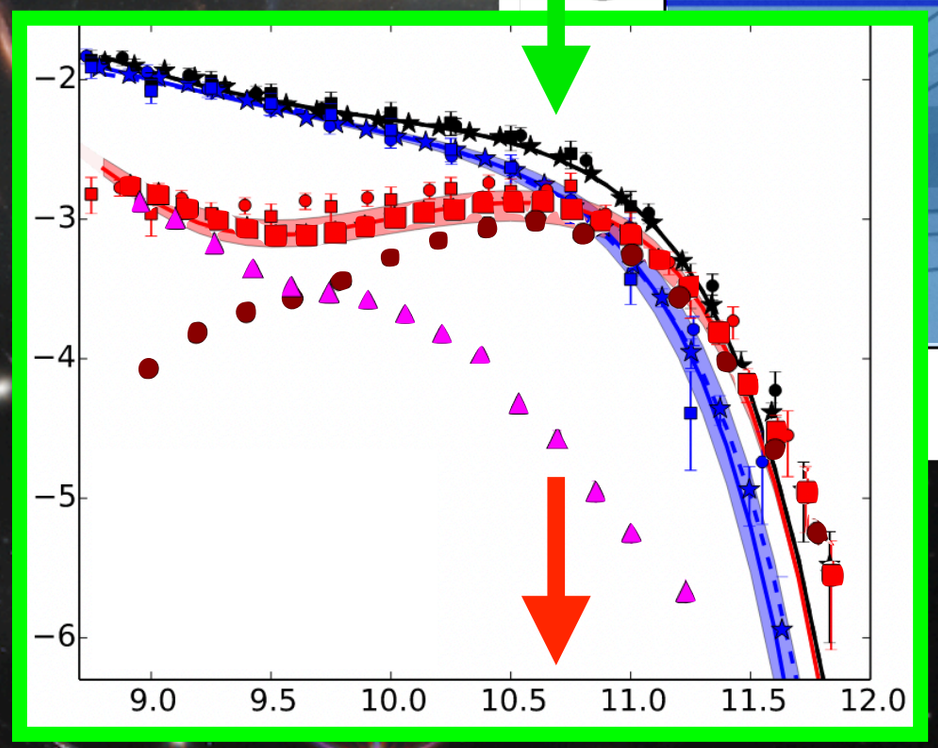


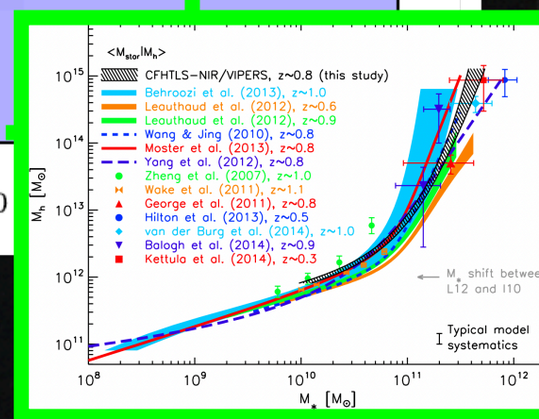


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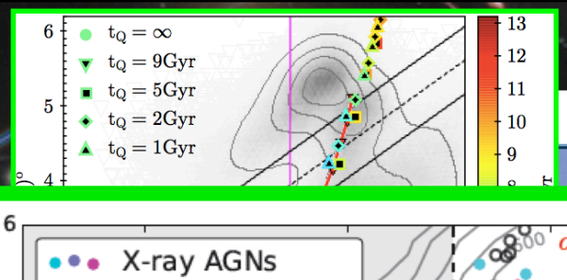


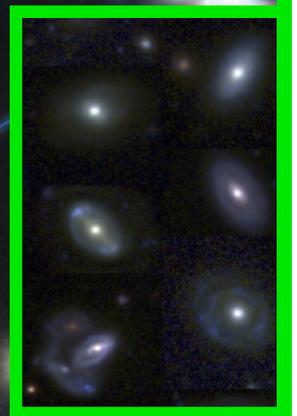

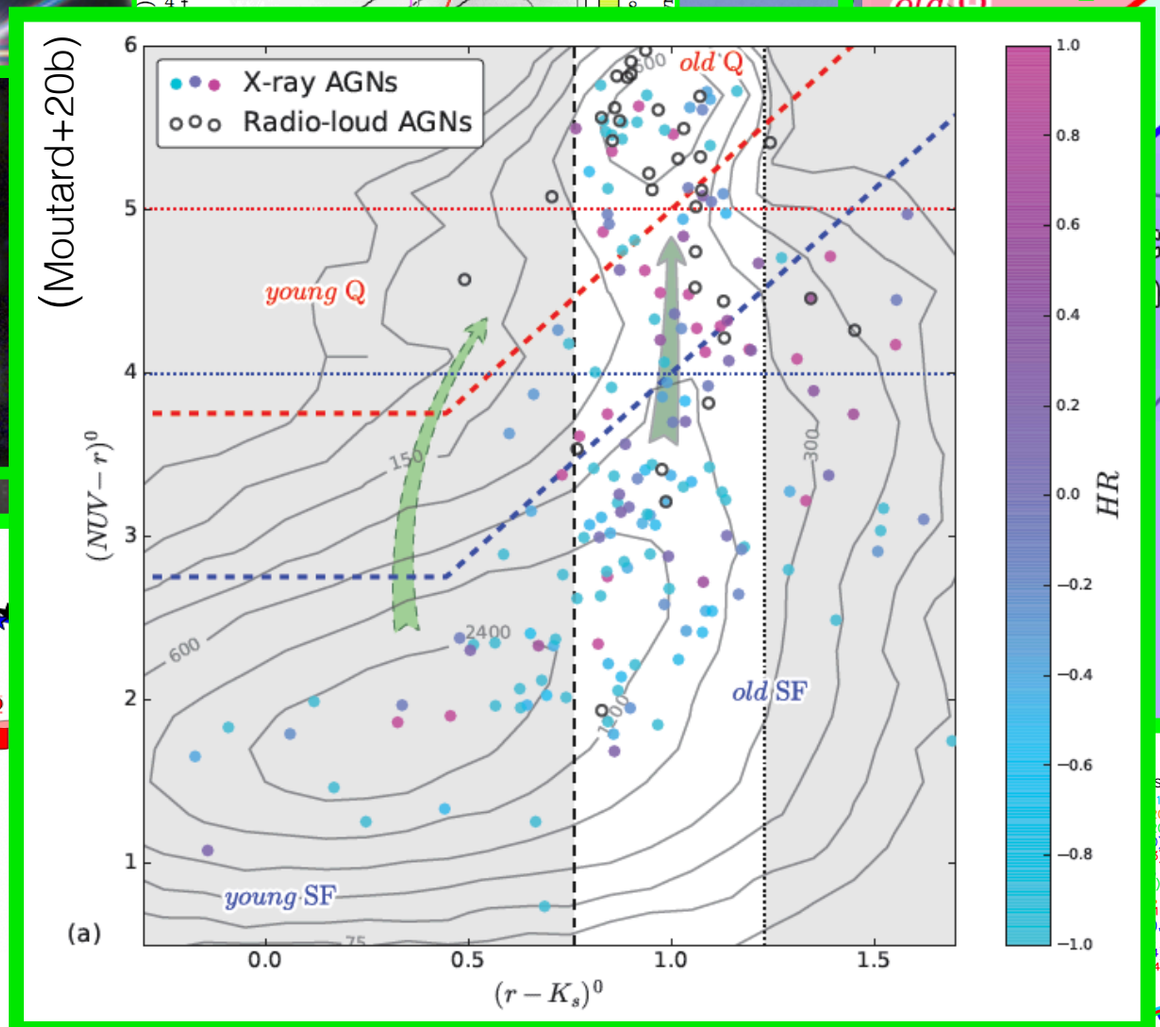


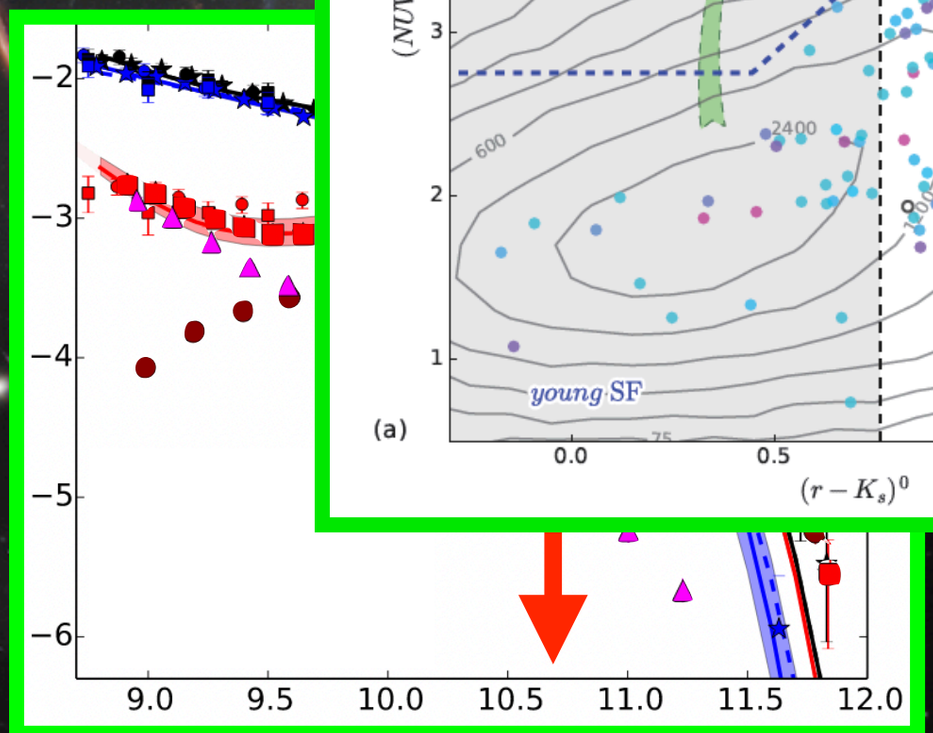







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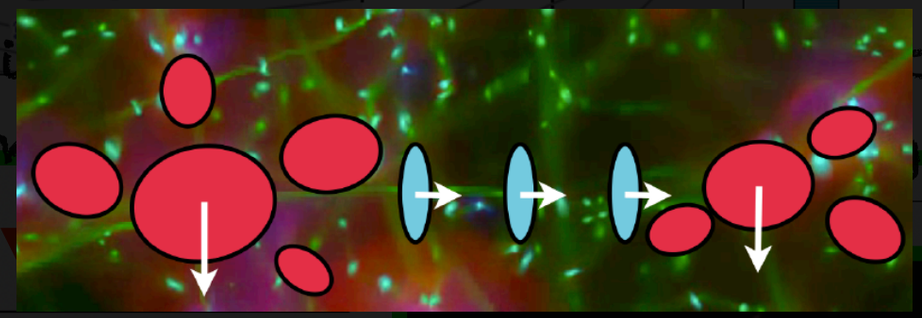
Possible avenue:

Galaxies are predicted to form within DM halos with spin parallel to their closest filament, due to interplay with cold-gas streams (e.g. Pichon+11).
Eventually, DM halos' spin flips as they merge and grow in mass along cosmic filaments (Welker+14) toward clusters: precisely predicted to happen around $M_h \sim 10^{12} M_\odot$, typically the mass of the hosts of $M^*$ ($\approx 10^{10.6} M_\odot$) galaxies...

→ Can we li… cosmic filam… …ce to …?



(Codis+18)

Credit: NASA, ESA, CSA, and STScI

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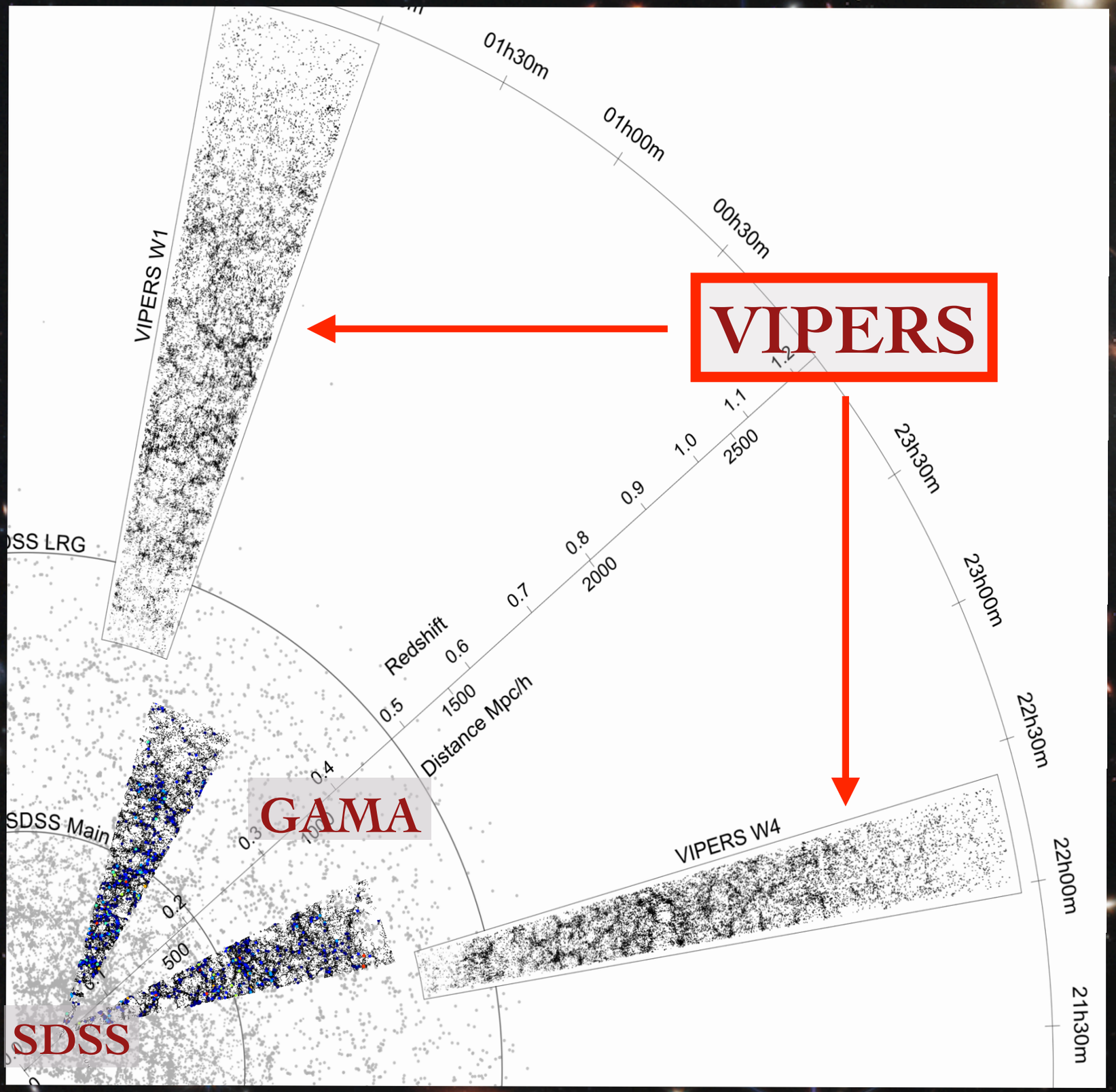
→ Can we link DM halo mergers, distance to cosmic filaments & M* galaxy quenching?
(from observations!)

Credit: NASA, ESA, CSA, and STScI

# VIPERS IN A NUTSHELL




– **VIPERS** i<22.5 **24 deg²**
**at 0.5<z<1.2**
(Guzzo +2014)

– **GAMA** r<19.8 **150 deg²**
**at z<0.3**
(Driver + 2011)

– **SDSS** r<17.8 **5000 deg²**
**at z<0.1**
(York + 2000)

Credit: NASA, ESA, CSA, and STScI

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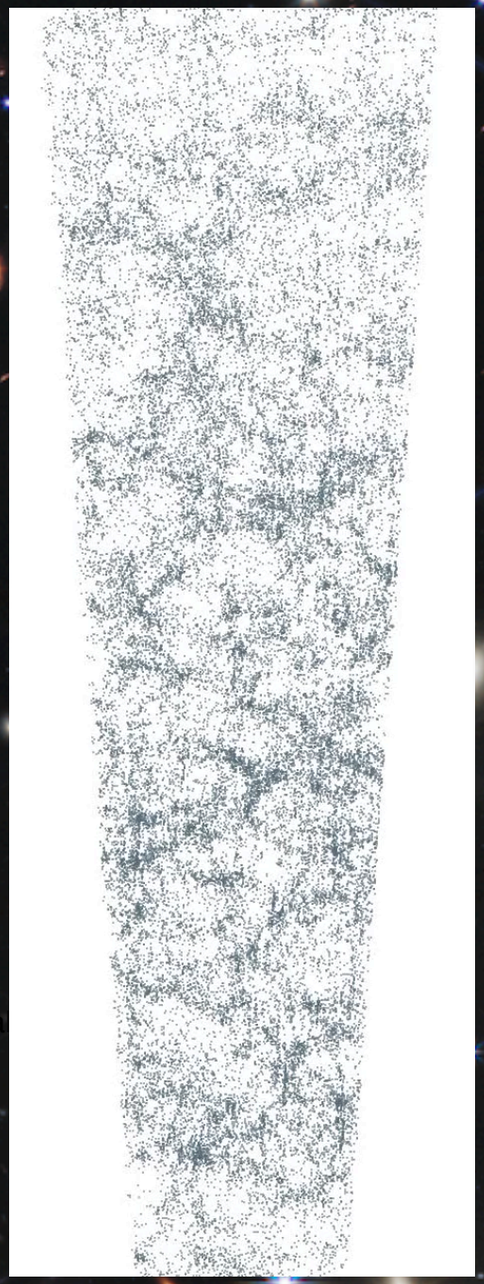
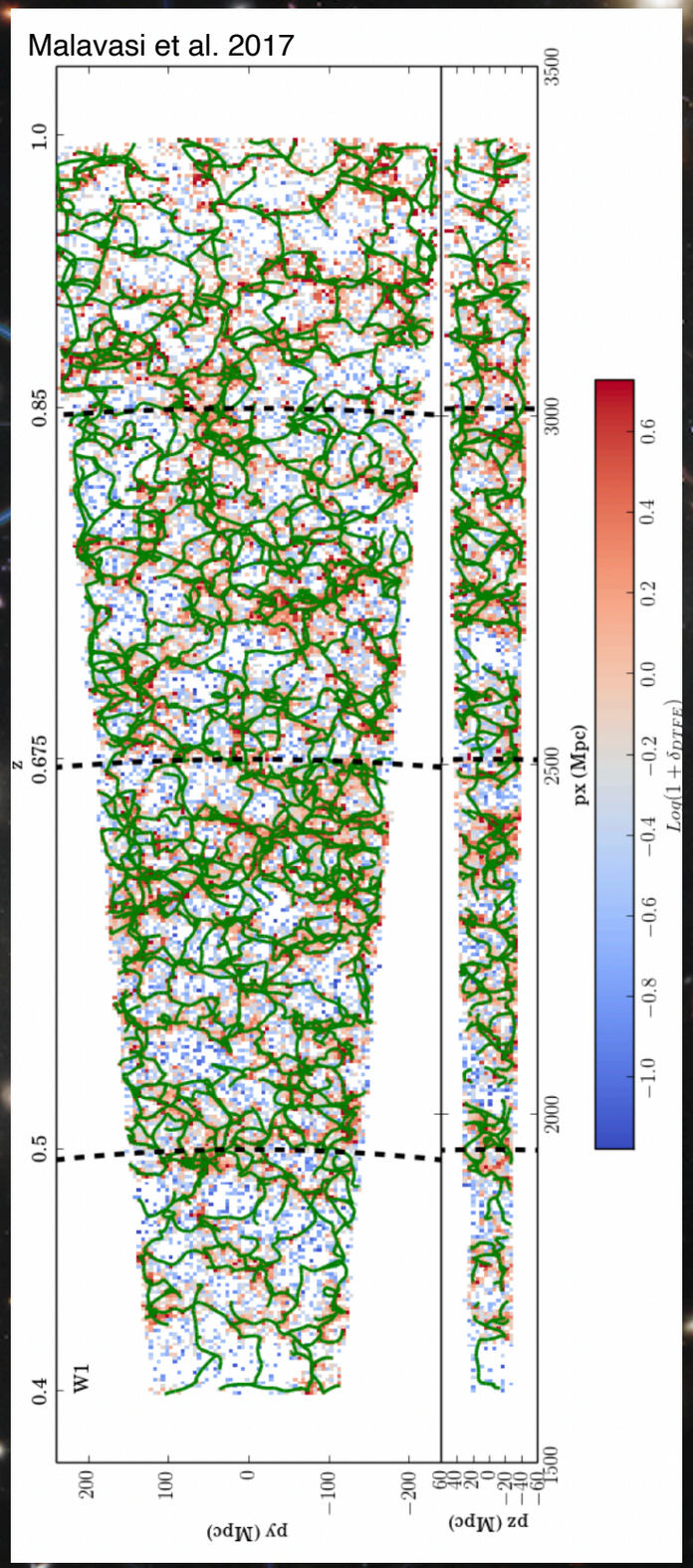





Credit: NASA, ESA, CSA, and STScI

# IDENTIFYING GALAXY PAIRS

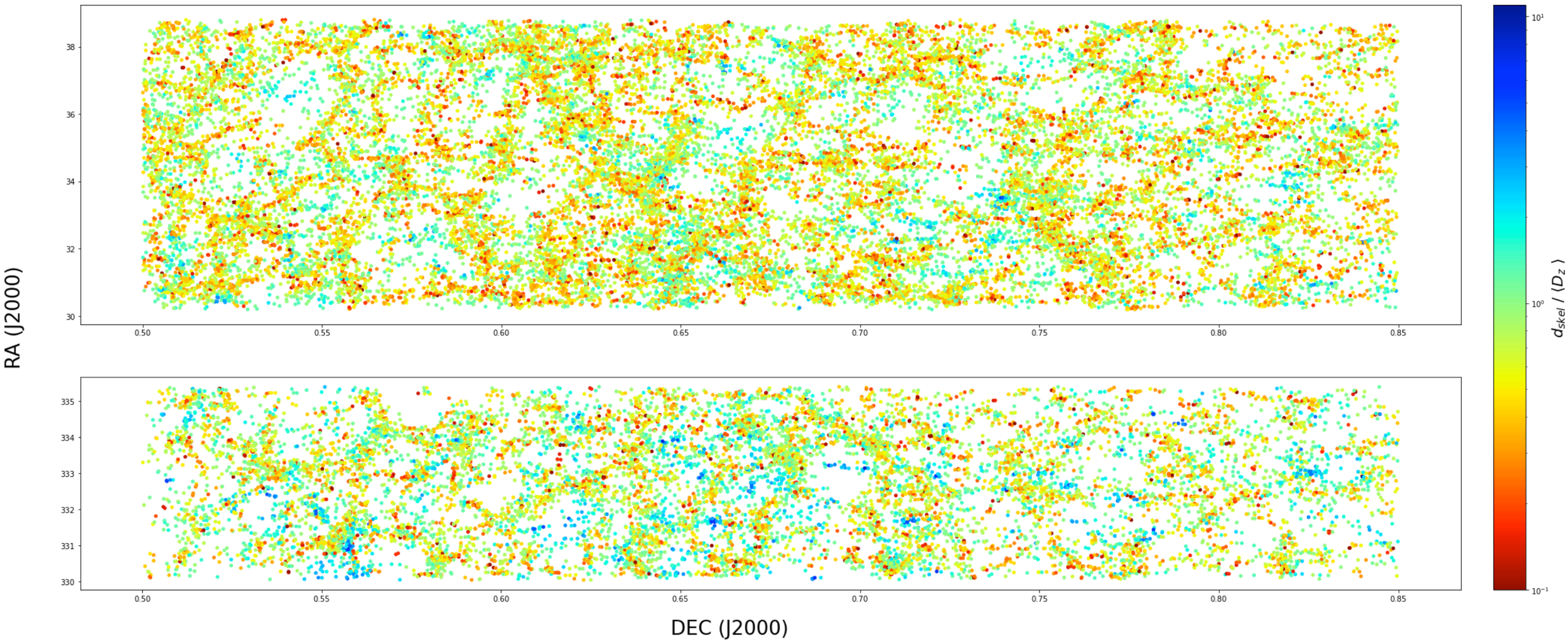
1 initial selection
  * Transverse physical separation ≤ 100 kpc
  * | Radial v1 - v2 |  ≤ 1000 km/s
2 refined selection
  * Transverse physical separation ≤ r200
  * | Radial v1 - v2 | ≤ $v_{esc}$ (r200, M200)
3 "major" pairs
  * | M*1 - M*2 | / M*2 ≤ 4  with M*1 > M*2

---

total: 967 pair gals / 35868 gals at 0.5 < z < 0.85
576 "major" pair gals ($d_{nodes}$ > 5 Mpc)

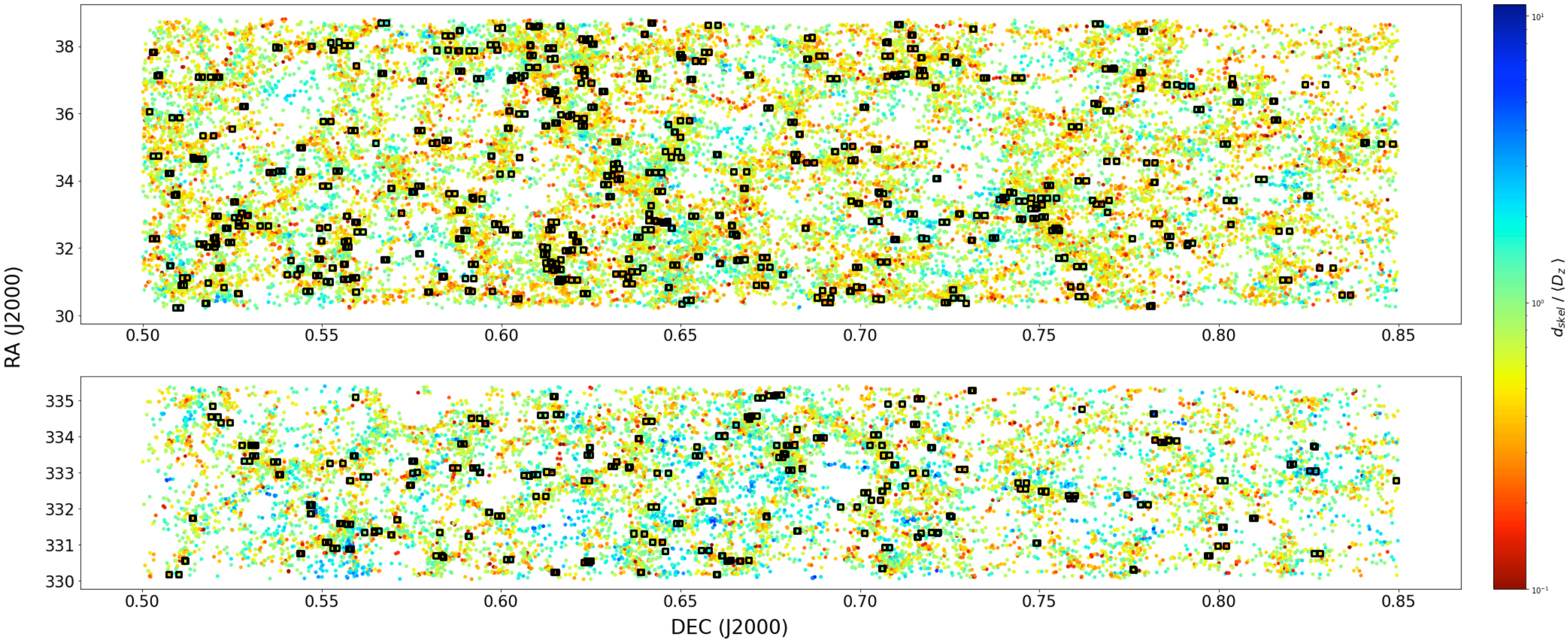
GALAXY PAIRS "SHARE" THE SAME DARK MATTER HALO, BY DEFINITION

# GALAXY PAIRS WITHIN THE COSMIC WEB



# GALAXY PAIRS WITHIN THE COSMIC WEB

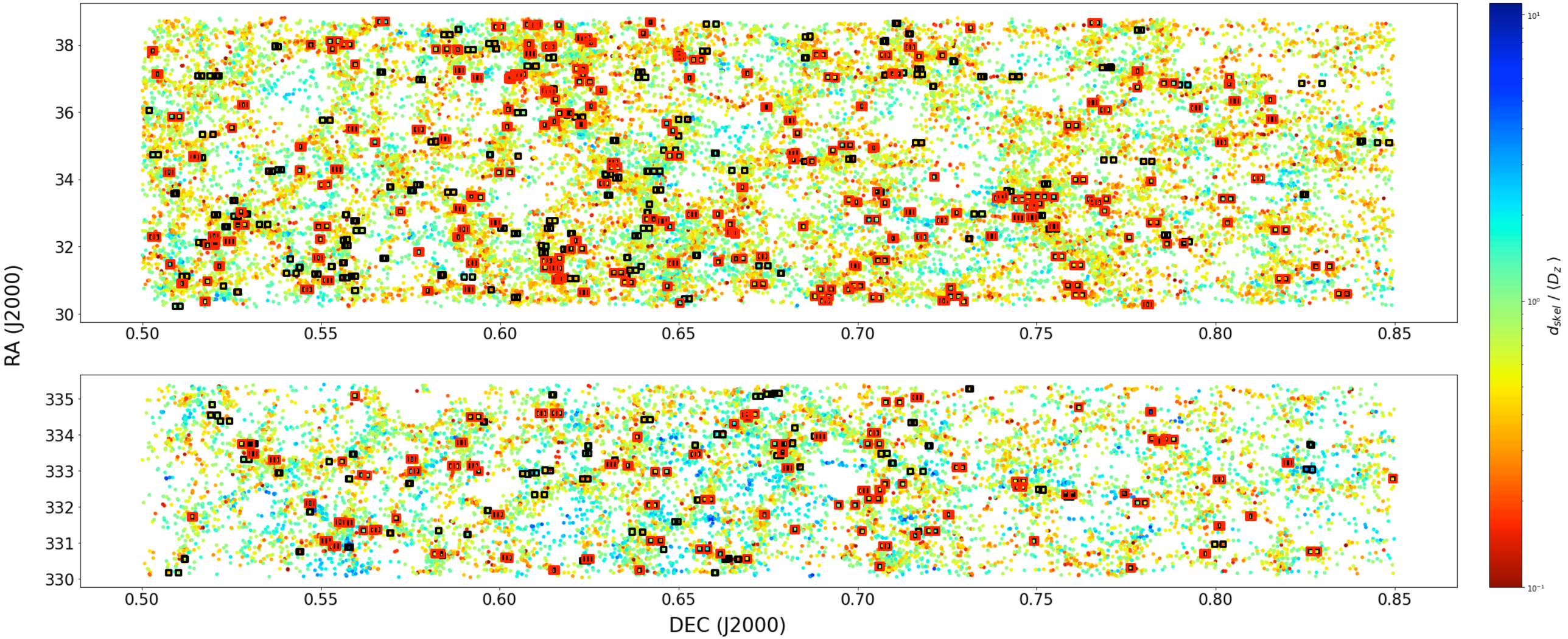
## PAIRS




## GALAXY PAIRS FOLLOW THE COSMIC WEB

# GALAXY PAIRS WITHIN THE COSMIC WEB

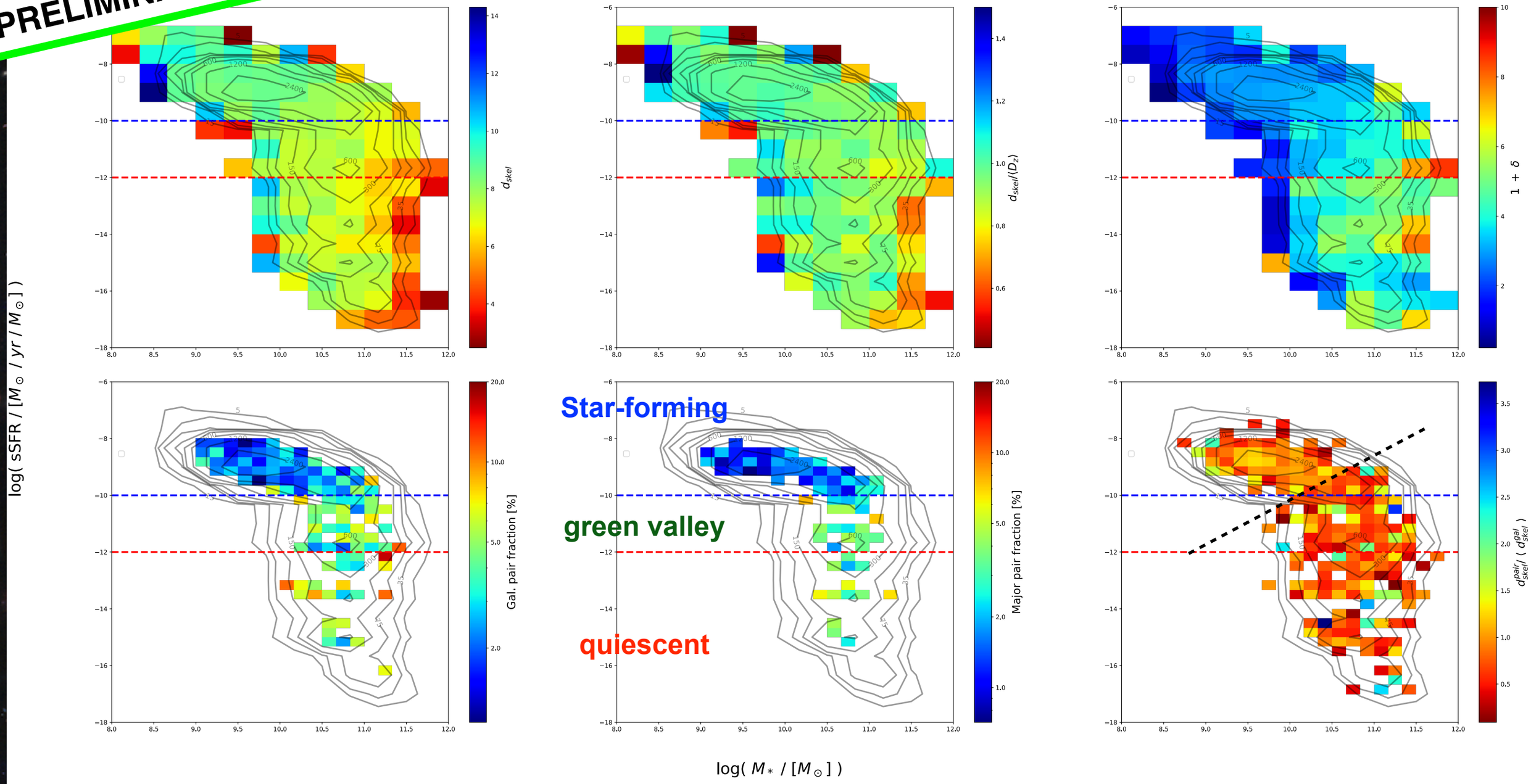
PAIRS MAJOR PAIRS




## “MAJOR” PAIR GALAXIES MAY APPEAR TO BE CLOSER TO COSMIC FILAMENTS

# GALAXY PAIRS WITHIN THE COSMIC WEB

**PRELIMINARY RESULTS**




## 1. DM HALO MERGER PROBABILITY INCREASES UPON QUENCHING

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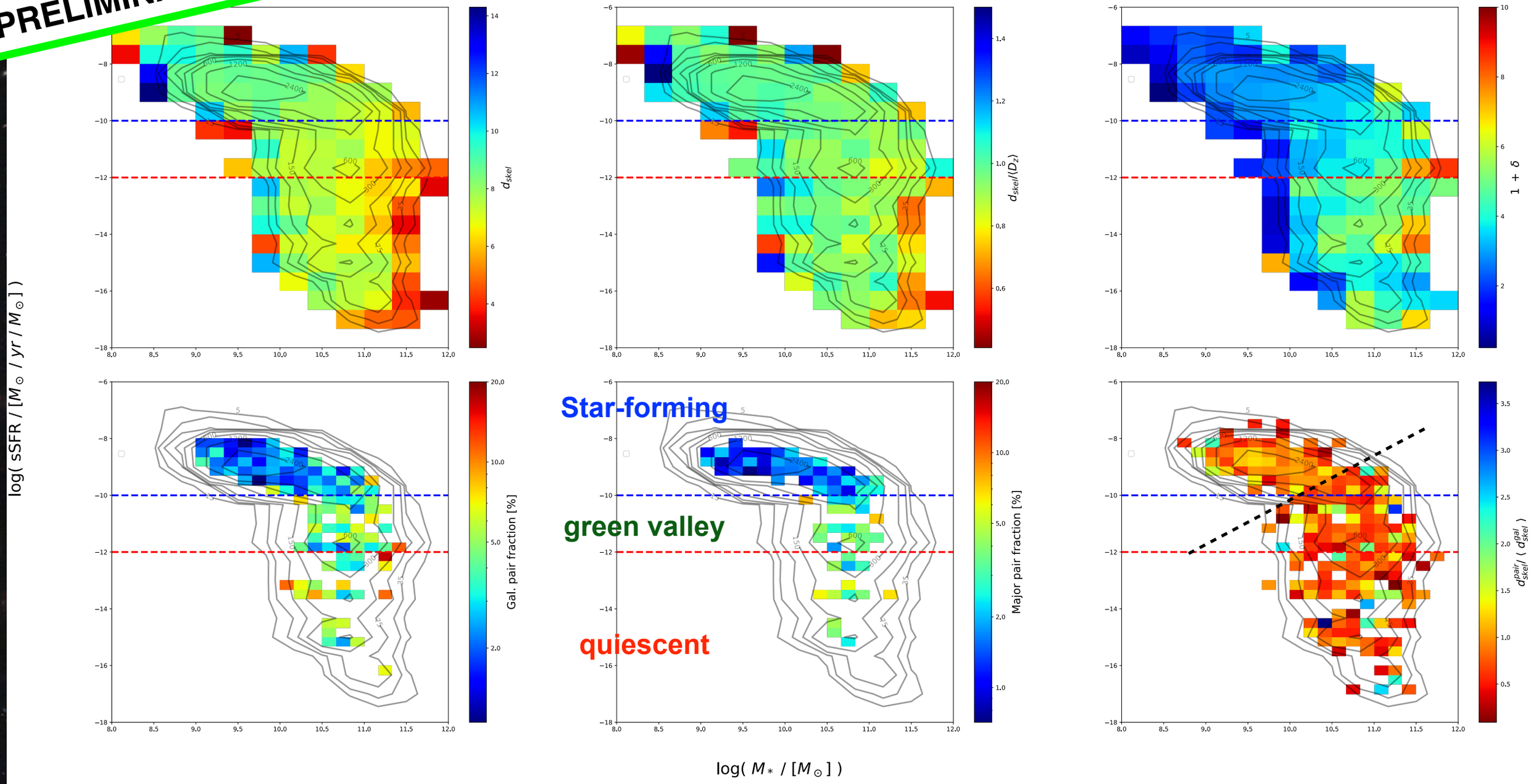


1. DM HALO MERGER PROBABILITY INCREASES UPON QUENCHING
2. MASSIVE DM HALO MERGER DISTANCE TO FILAMENTS DECREASES RAPIDLY BEFORE QUENCHING

# SUMMARY

1 massive galaxy mergers confirmed to be more likely to happen along filaments

2 halo mergers and the quenching of their massive host M* galaxies appear to be simultaneous

---

Conclusion:

The so-called "mass quenching" is very likely jointly driven by large-scale environment

Question:

Does the decrease of M* pair galaxy distance to cosmic filaments initiate their quenching process?

Feedback welcome.Thank you