

STAR FORMATION IN COMPACT GROUPS

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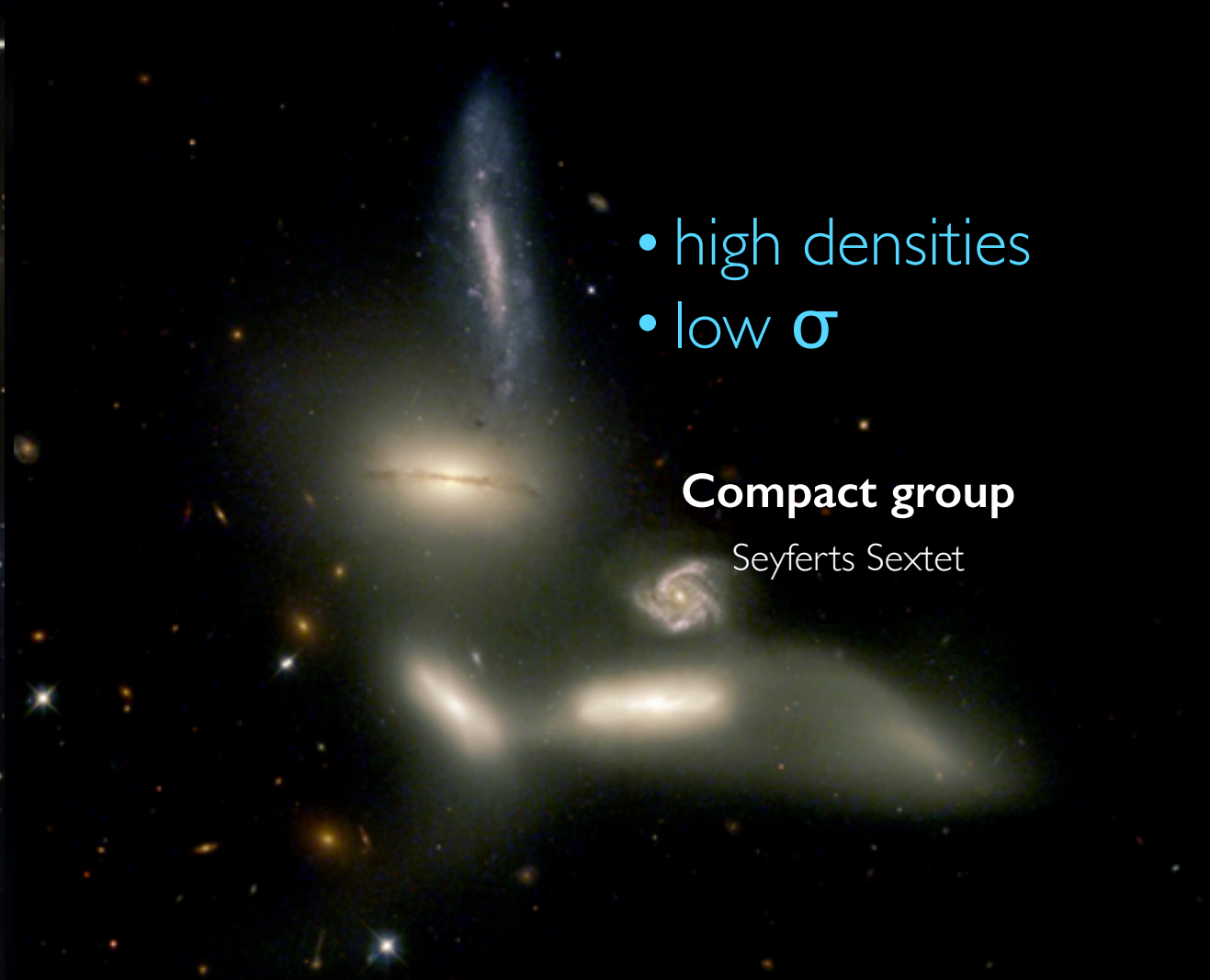




Field galaxy
NGC 2442

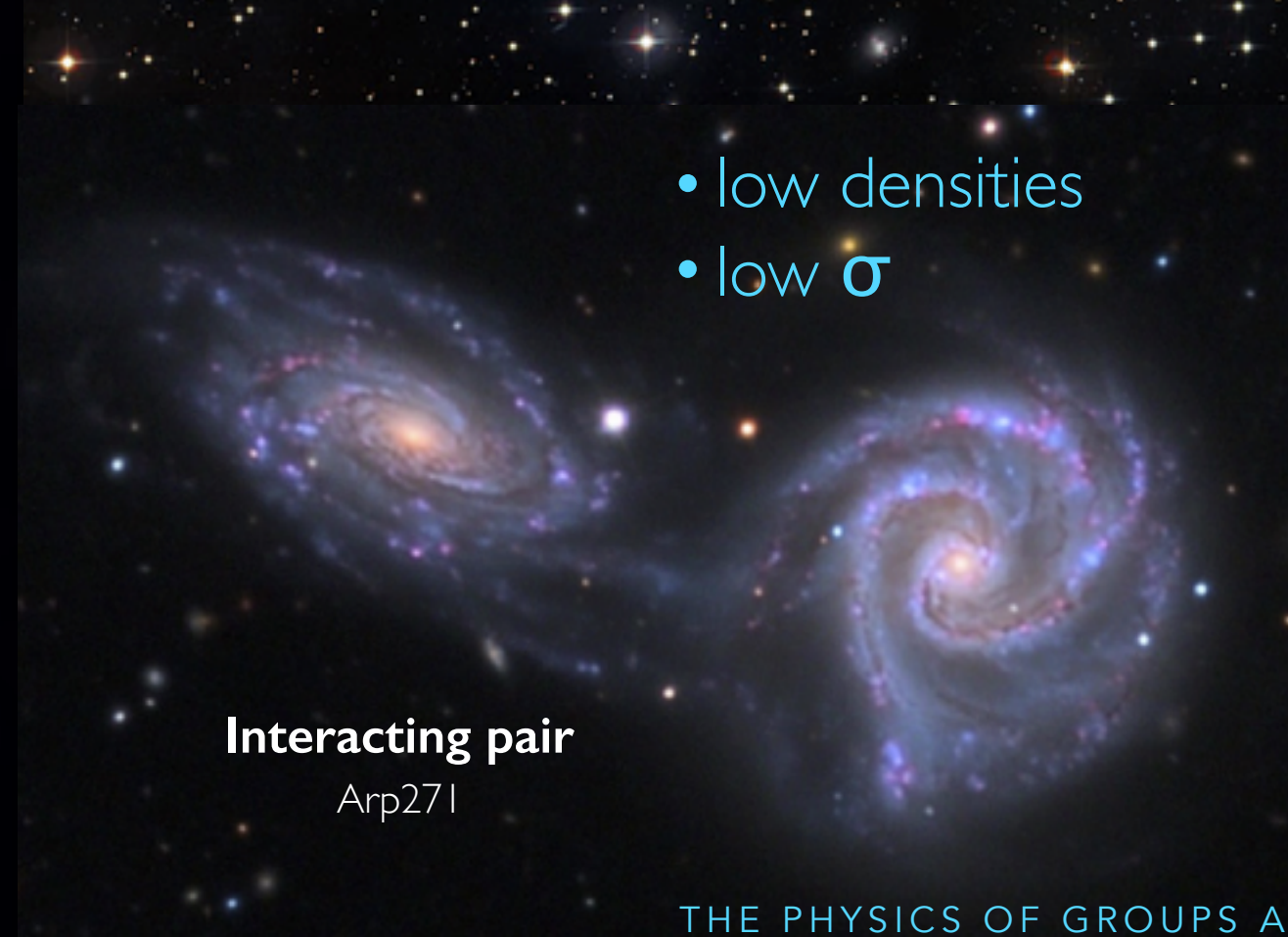
A detailed image of a field galaxy, NGC 2442, showing a complex, irregular structure with a bright central region and a diffuse, elongated outer envelope. The galaxy is set against a dark background filled with numerous distant stars.

- high densities
- low σ



Compact group
Seyfert's Sextet

A compact group of galaxies, known as Seyfert's Sextet, consisting of six galaxies in a very small volume. The galaxies are highly concentrated and show signs of interaction and star formation. The image is a deep-field view showing the intricate details of the galaxies' structures.

- 
- low densities
• low σ
- A photograph of an interacting pair of galaxies, Arp 271, showing two distinct spiral galaxies in the process of merging. The galaxies are separated by a small distance, and their gravitational interaction is evident from the distorted shapes and the presence of tidal tails. The background is dark with some distant stars.

Interacting pair
Arp 271

- 
- pre-processing in groups (Cortese+06)
- A large-scale view of a galaxy cluster, Abell 1689, showing a dense collection of galaxies of various types and sizes. The galaxies are concentrated in a central region, with many smaller galaxies visible in the surrounding space. The image is a deep-field view showing the intricate details of the galaxies' structures.

- high densities
- high σ

Galaxy cluster
Abell 1689

A detailed image of a single, isolated spiral galaxy, NGC 2442, set against a dark background filled with distant stars. The galaxy's structure is clearly visible, including its central bulge and the surrounding spiral arms.

Field galaxy
NGC2442

- high densities
- low σ

A cluster of six galaxies, known as the Seyfert's Sextet, showing a high density of galaxies in a small area. The galaxies are of various types, including spirals and ellipticals, and are closely packed together.

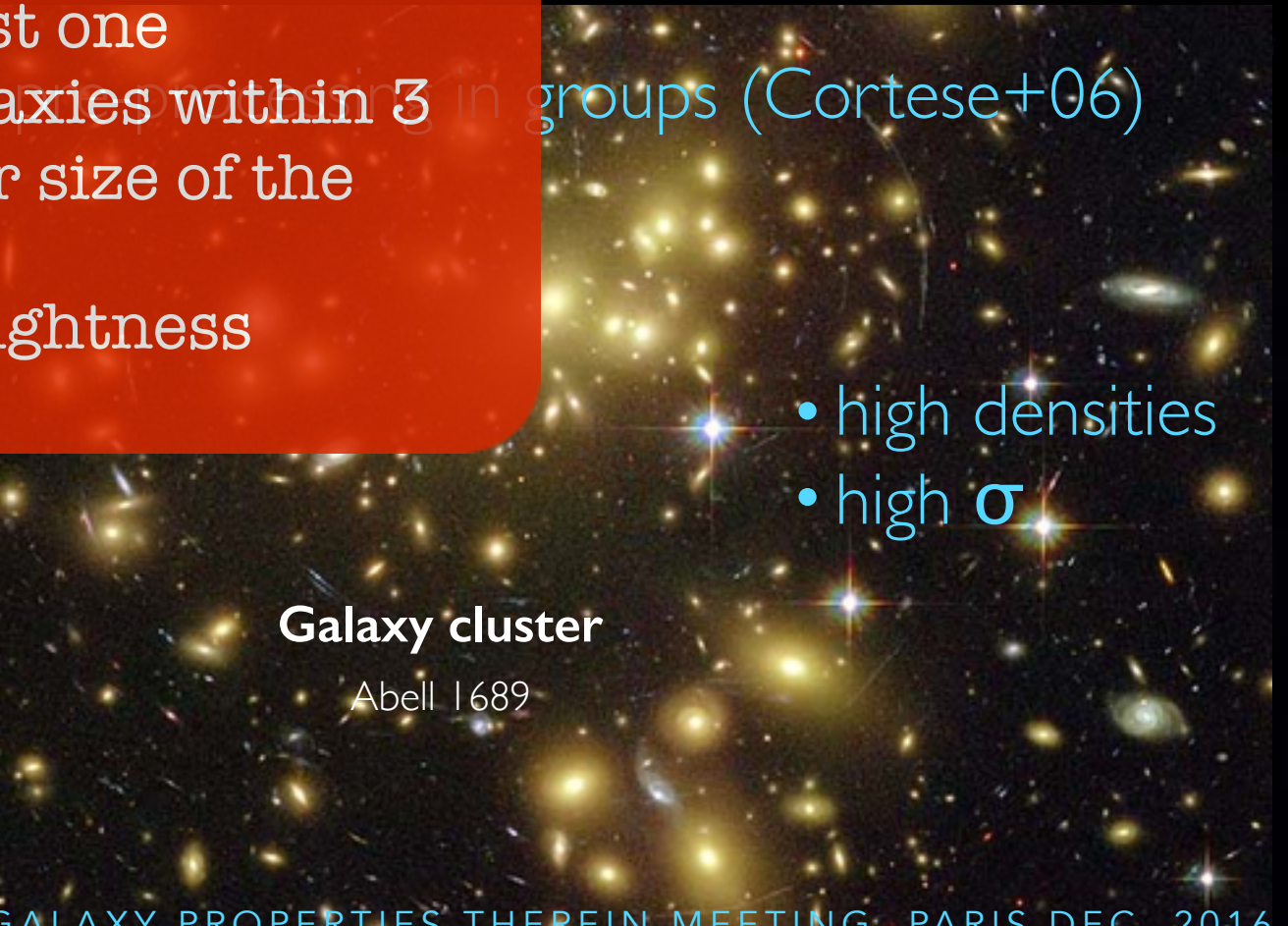
Compact group
Seyferts Sextet

Hickson compact groups

- at least 3 galaxies within 3mags from the brightest one
- no additional galaxies within 3 times the angular size of the group
- low densities
- low σ
- group surface brightness $< 26 \text{ mag/arcsec}^2$
- galaxies predominantly in groups (Cortese+06)

A pair of galaxies, Arp 271, in the process of interacting. The image shows two distinct spiral galaxies with visible tidal tails and distorted structures, indicating a recent or ongoing gravitational encounter.

Interacting pair
Arp271

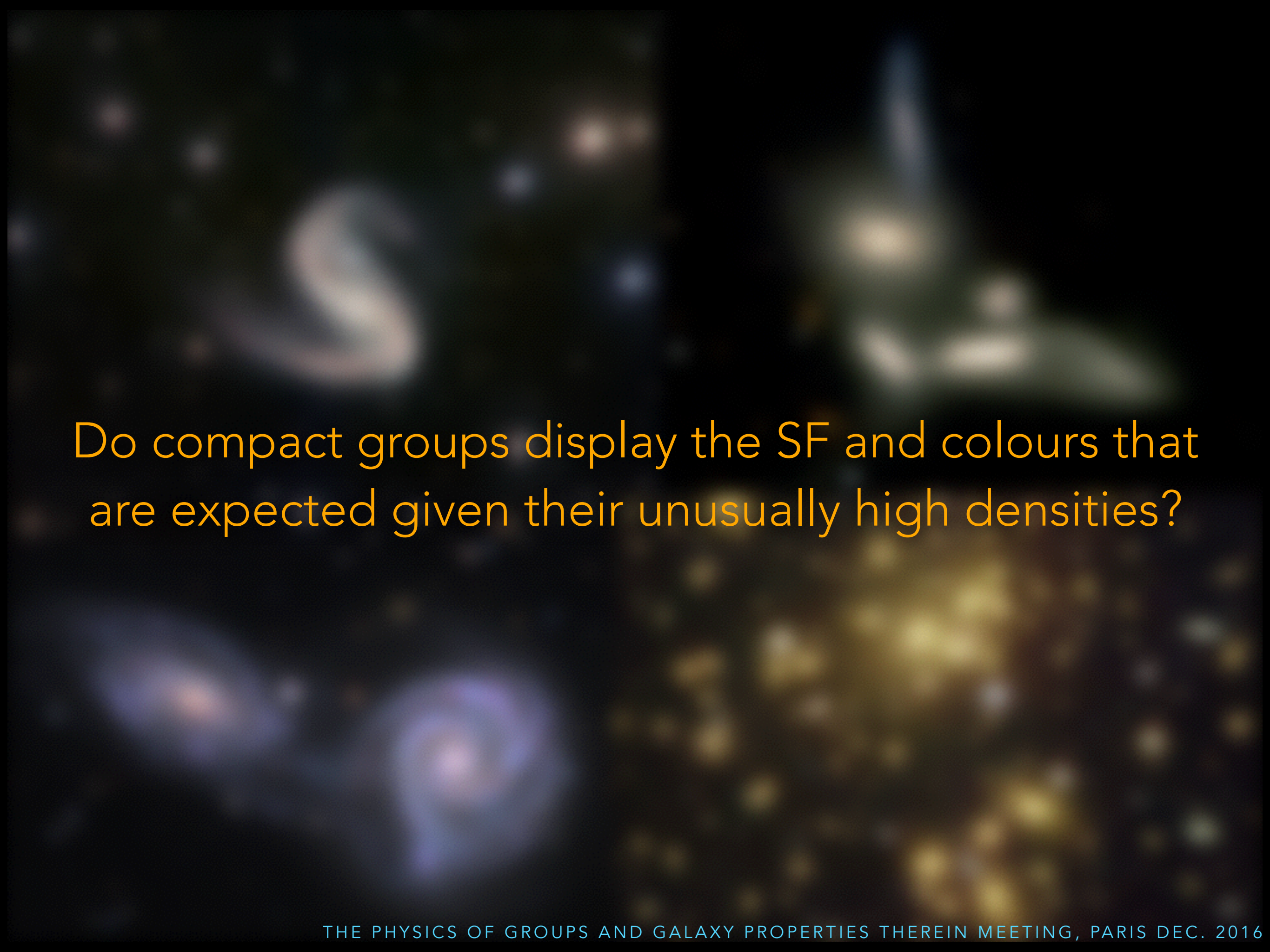
A large, dense galaxy cluster, Abell 1689, containing hundreds of galaxies. The galaxies are concentrated in a central region, with many bright, elliptical galaxies visible, illustrating a high-density environment.

Galaxy cluster
Abell 1689

- high densities
- high σ

Basic properties

- 31% E's and 43% S's
- 43% display **bridges, tails** and other tidal distortions (Mendes de Oliveira et al. 1994)
- Hot **X-ray intragroup gas** in 75% of them (Ponman et al. 1996)
 - **Ram pressure** inefficient (Rasmussen et al. 2008)
- 45% host **LLAGN** (with typical $L_{\text{H}\alpha} < 10^{40}$ erg/sec)



Do compact groups display the SF and colours that are expected given their unusually high densities?



But what do we expect?



SF enhancement
& bluer colours

- Nuclear H α enhancement (e.g. Keel+85)
- IR enhancement (e.g. Lonsdale+84, Joseph & Wright 85)
- Starburst increase with interactions (20-30% , Sanders & Mirambel 96)
- Interactions drive gas inwards (e.g. Mihos +93)



SF reduction
& red colours

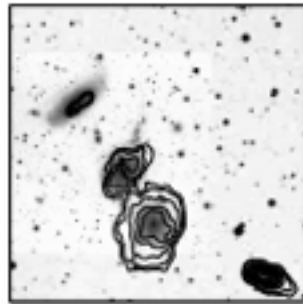
- Lower HI content in clusters than in field (Davis & Lewis 73)
- Ram pressure stripping (Gunn&Gott72)
- Strangulation (e.g. Larson+80)
- warm molecular gas due to collisional shocks (e.g. Guillard+12)

What do we really observe in compact groups?

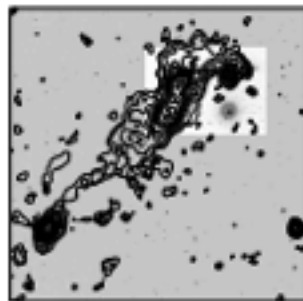
Phase 1:

Low level of interaction

HCG 88



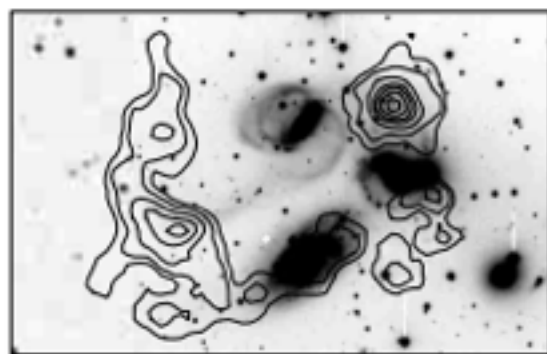
HCG 16



Phase 2

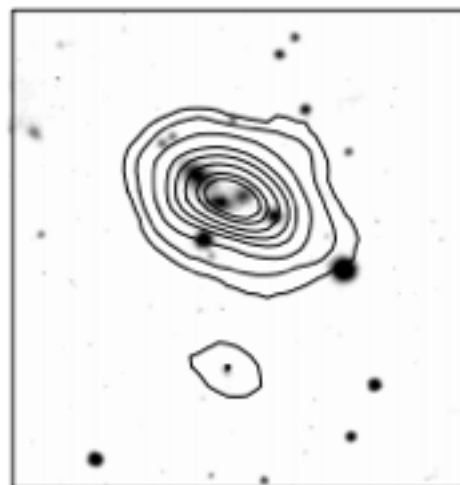
Multipled tidal features

Phase 3a: No HI in the galaxies

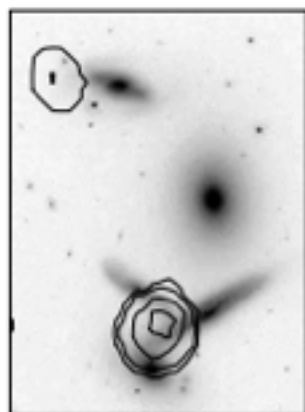


HCG 92

Phase 3b: HI in an envelope



HCG 49



HCG 40

Verdes-Montenegro+01

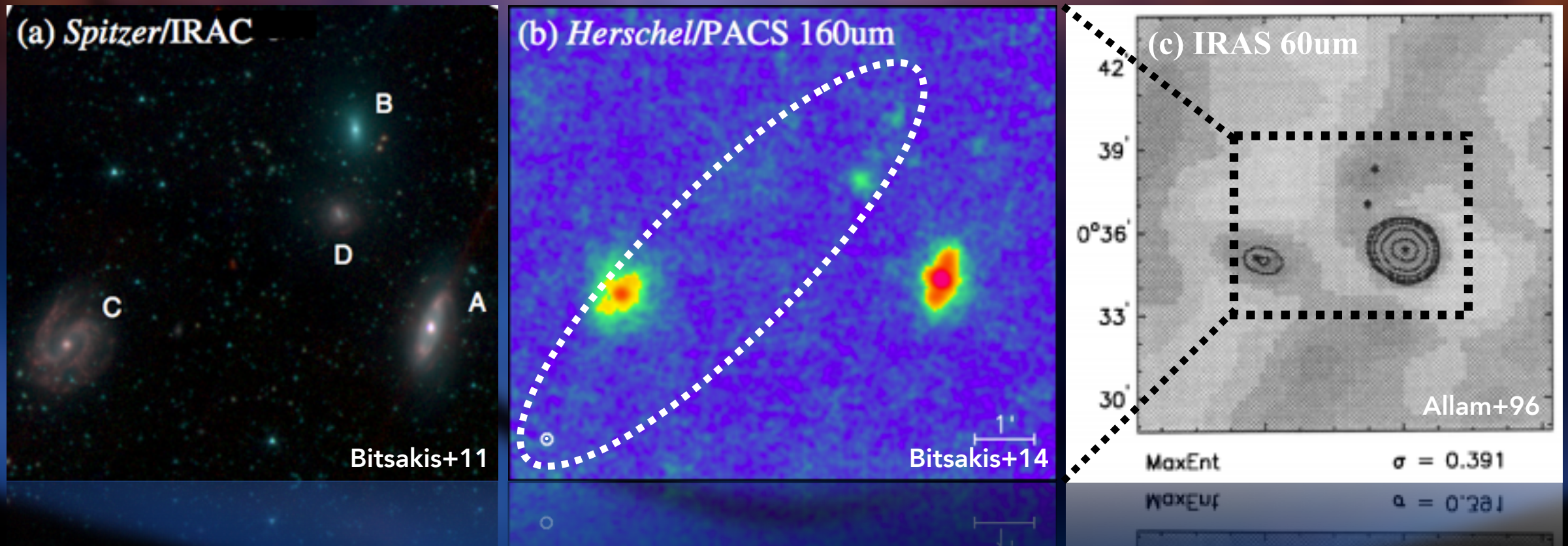
- HI fraction **half** from that of loose groups (Williams & Rood 87)
- **Interactions remove gas** from CG spirals (Menon+95)
- **24% of expected HI** in HCG galaxies and 40% in groups (Verdes-Montenegro+01) - Borthakur +10 enhanced the diffuse HI IGM fraction to ~50%
- Lisenfeld+14 found HCG galaxies with **reduced H₂ content**

Gas stripping must play a crucial role in the evolution of star formation!

First infrared observations

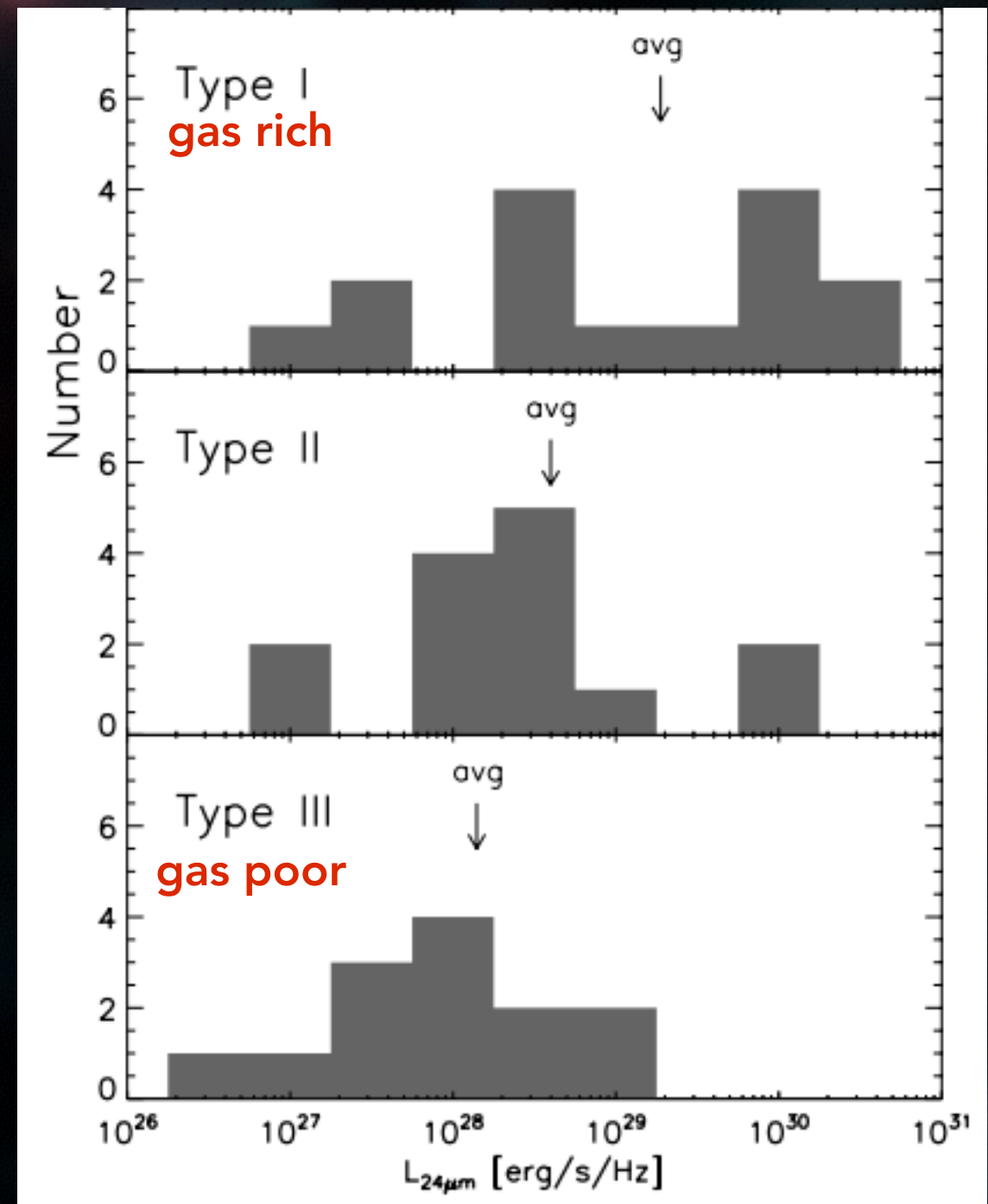
- Hickson+89 using IRAS data suggested enhanced IR luminosities
- However, Sulentic & De Mello 93 showed that these were overestimated due to the limited resolution of IRAS
- Allam+96 presented first complete catalog of IR properties of HCGs

HCG07



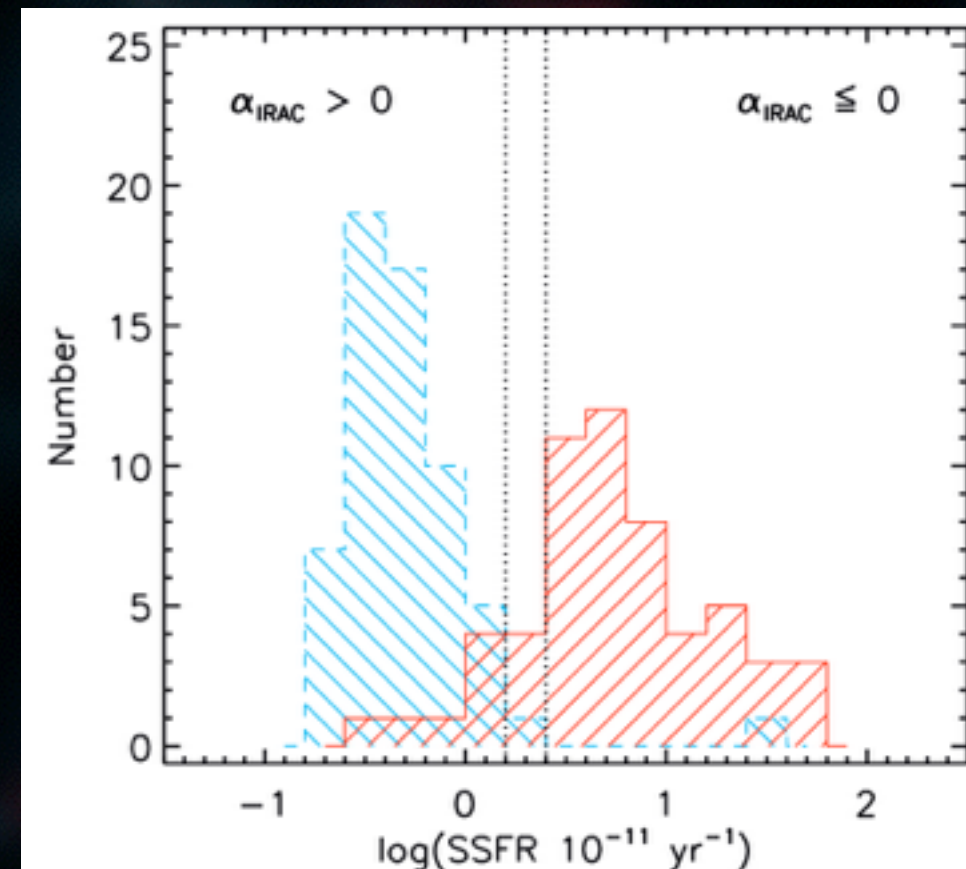
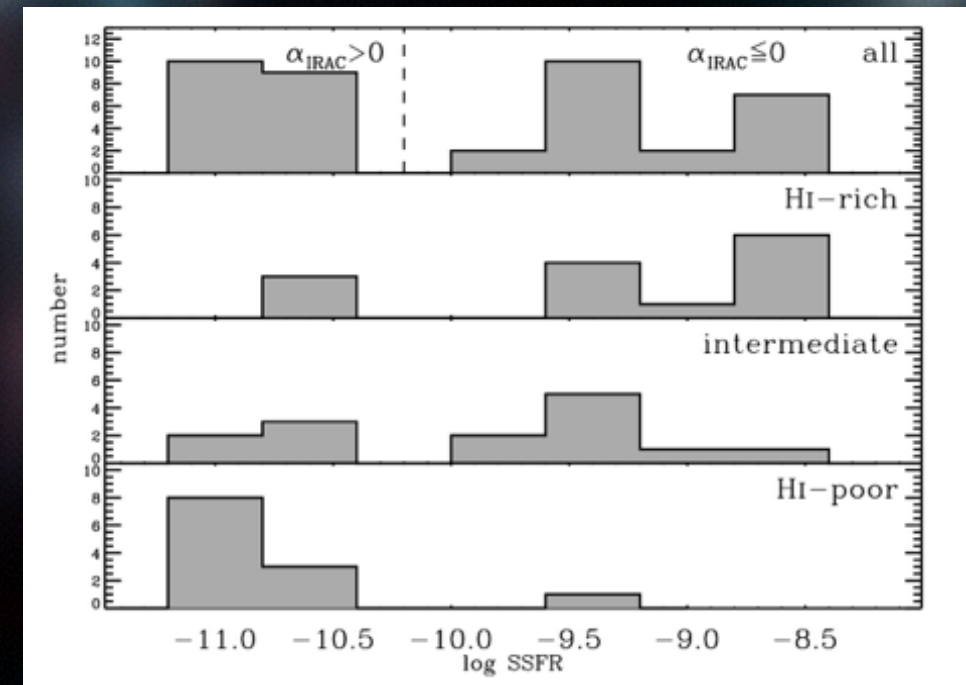
The advent of a new era

- Johnson+07 examined for first time the IR luminosities of individual galaxies



The advent of a new era

- Johnson+07 examined for first time the IR luminosities of individual galaxies
- Tzanavaris+10 used UV+IR data to derive the SFRs of 11 HCGs (expanded by Lenkic+16)

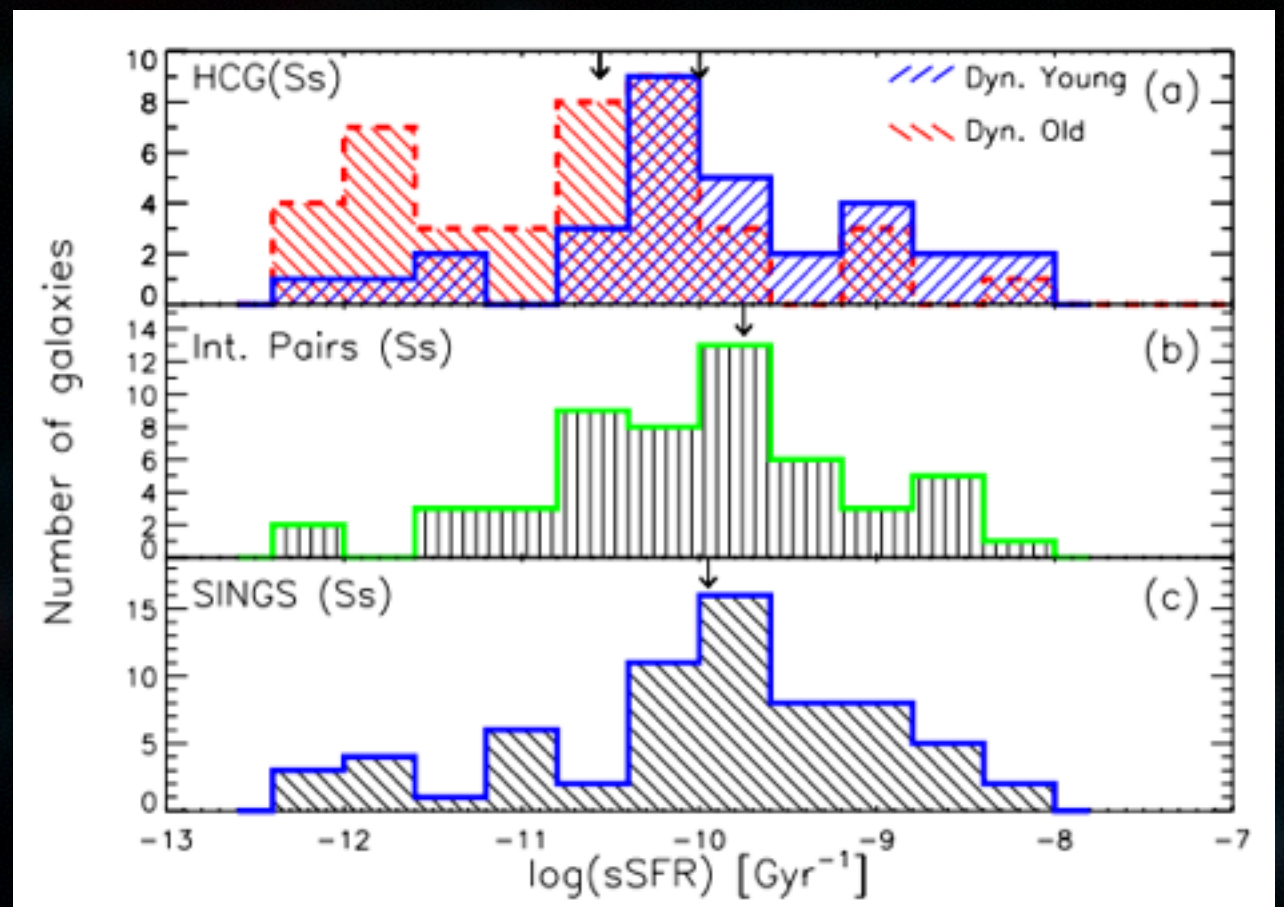


The advent of a new era

- Johnson+07 examined for first time the IR luminosities of individual galaxies
- Tzanavaris+10 used UV+IR data to derive the SFRs of 11 HCGs (expanded by Lenkic+16)
- Bitsakis+10,11 introduced a new dynamical classification and concluded that LTGs in Dyn. Old groups (gas poor) display reduced SF activity

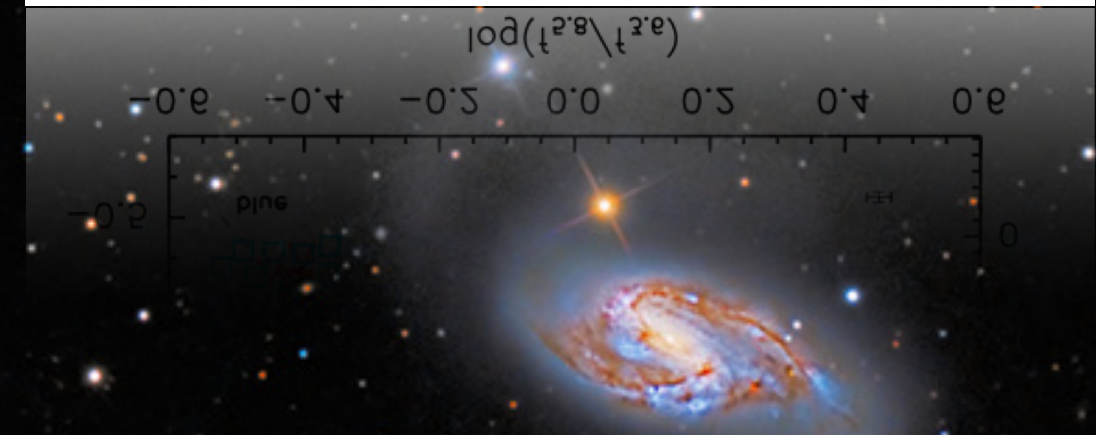
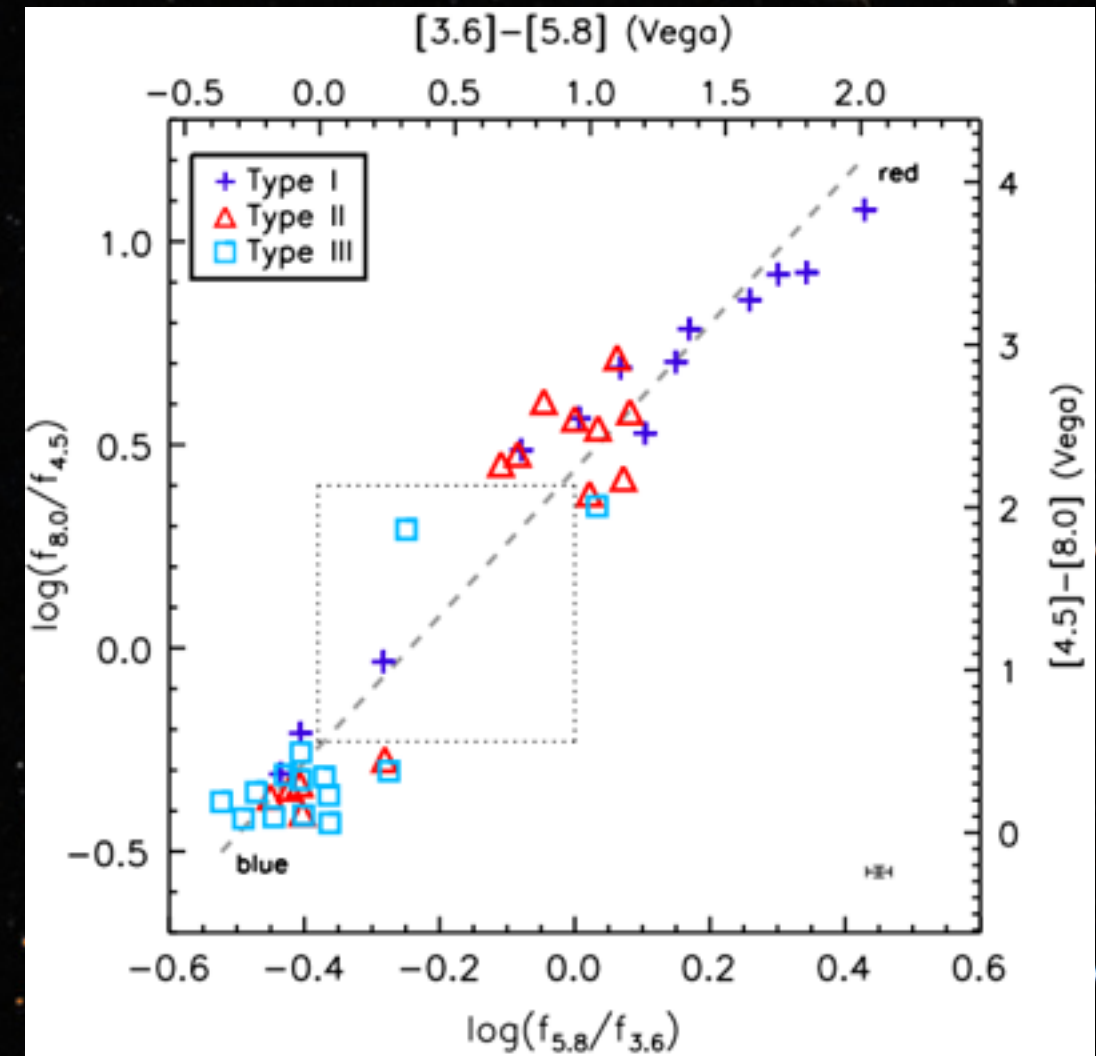
Dyn. young = S's dominated

Dyn. old = E's dominated



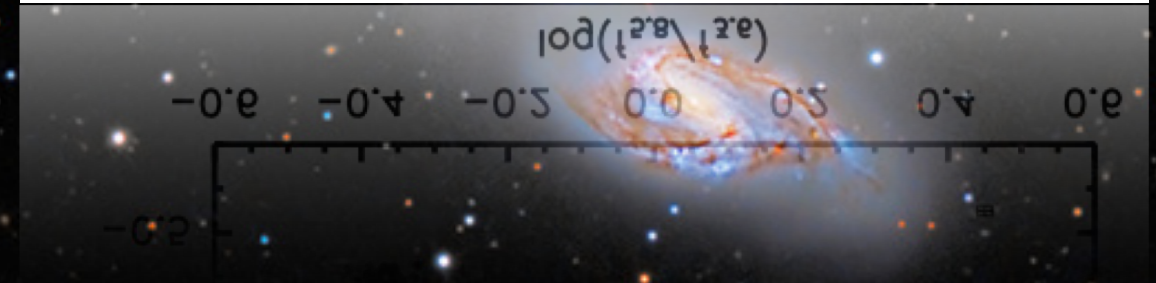
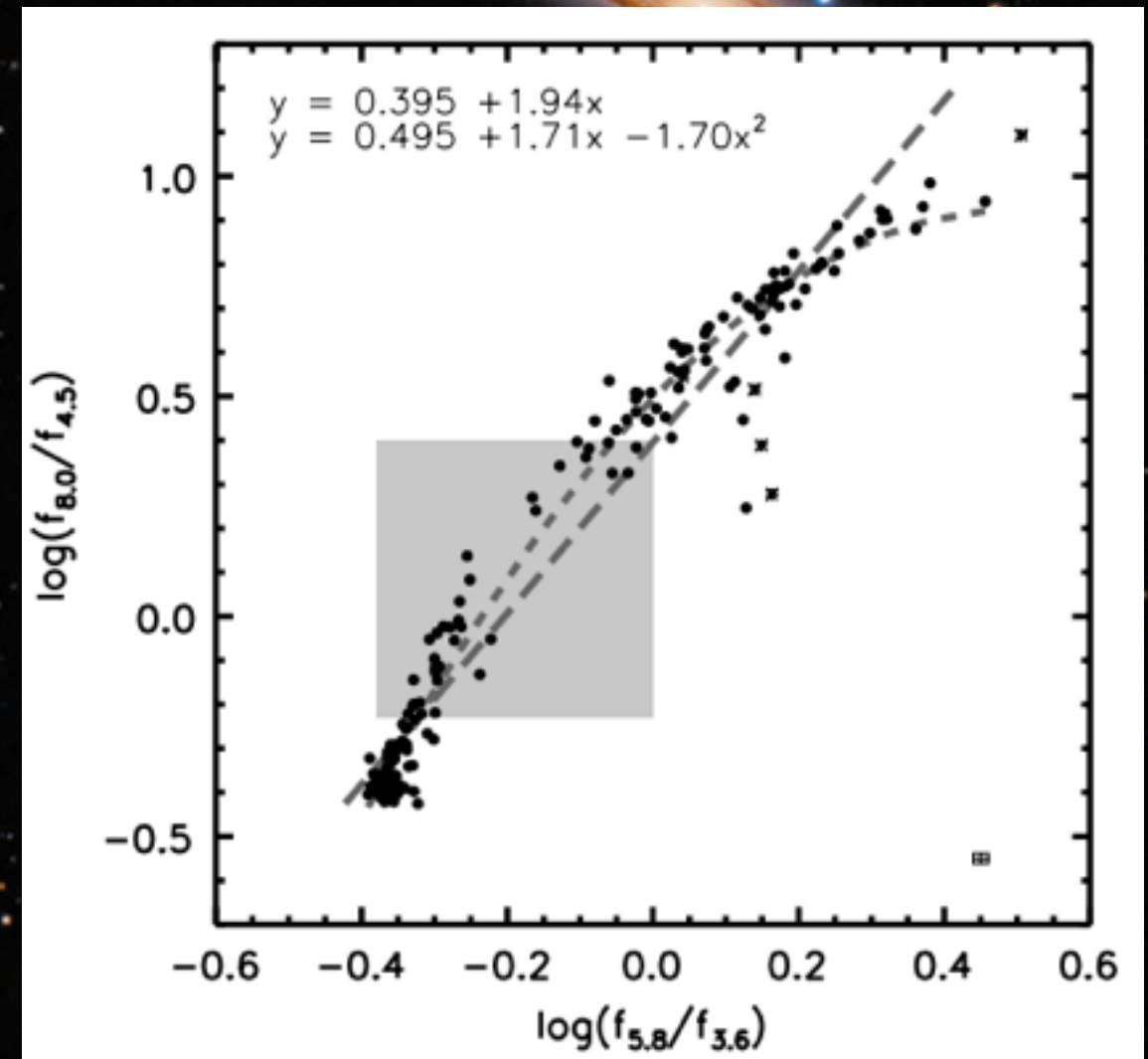
The galaxy colours

- Johnson+07 spotted a gap in the mid-IR colours and concluded accelerated evolution



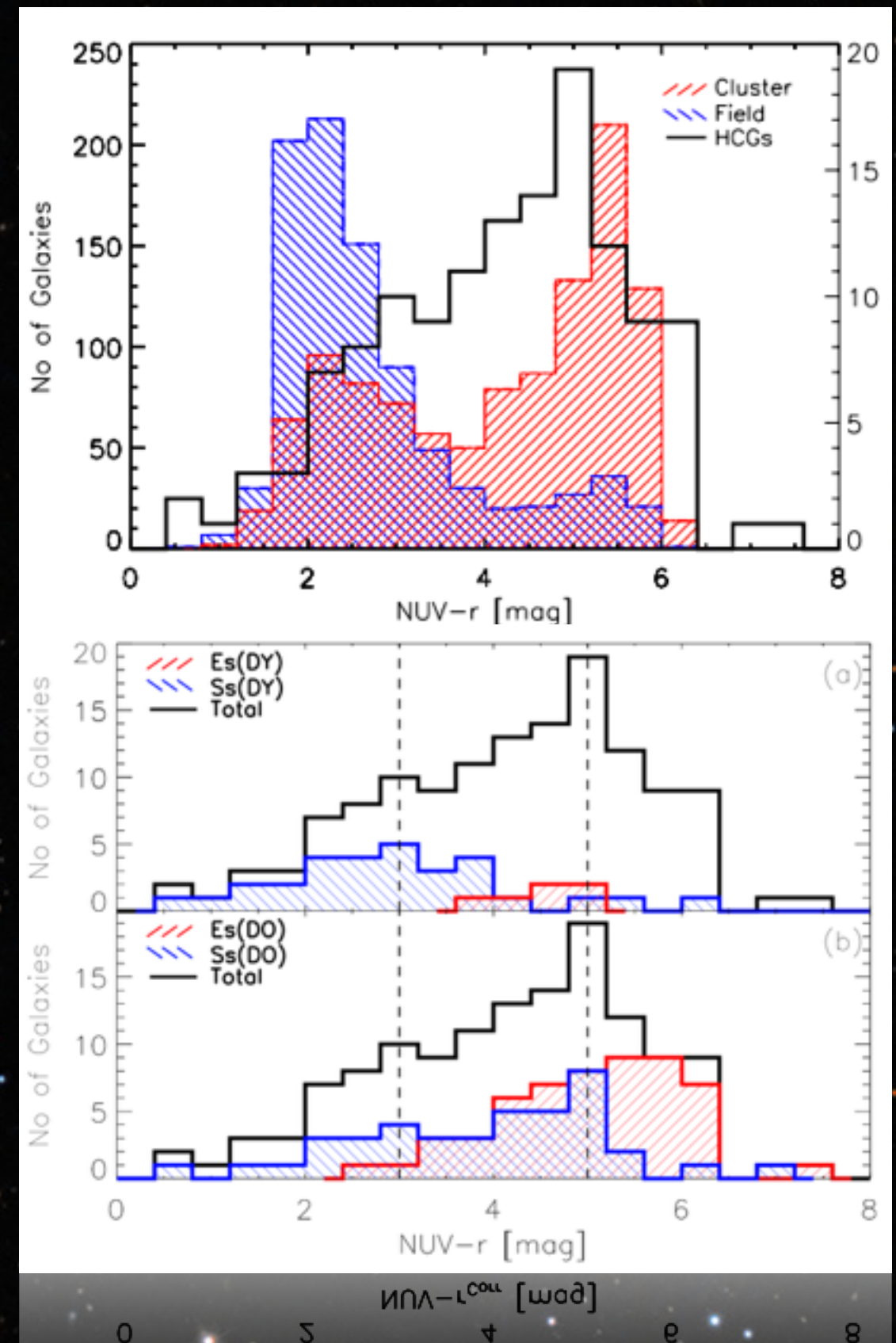
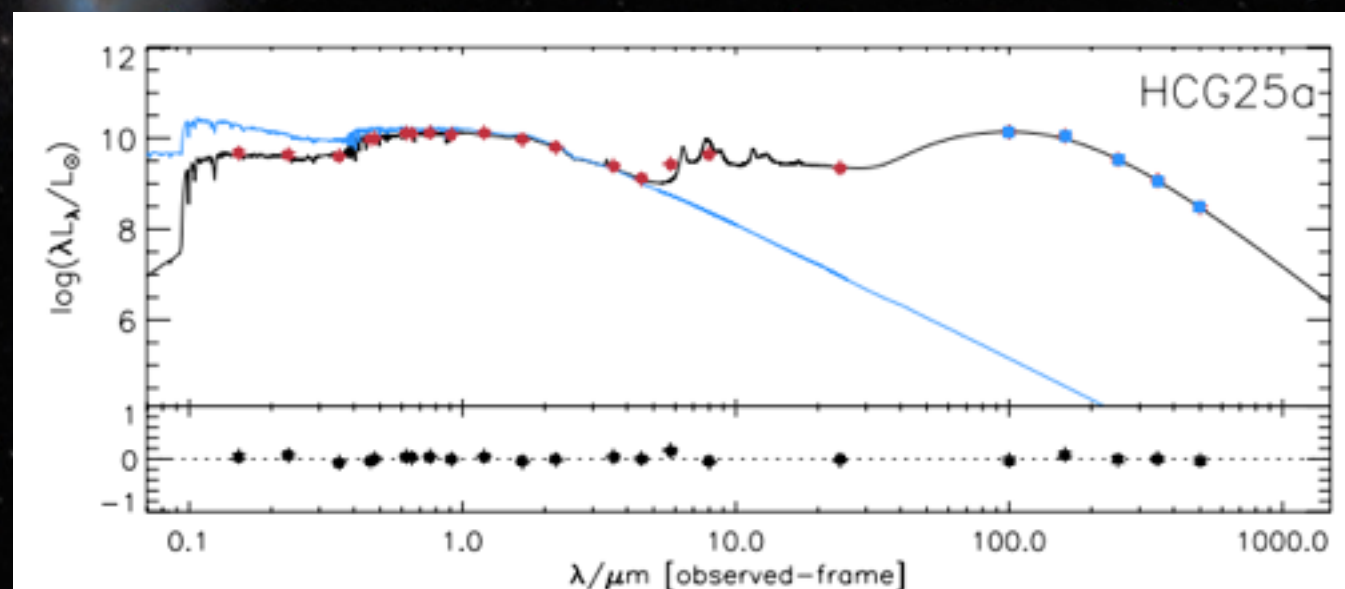
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- Walker+12 degraded the gap into a canyon



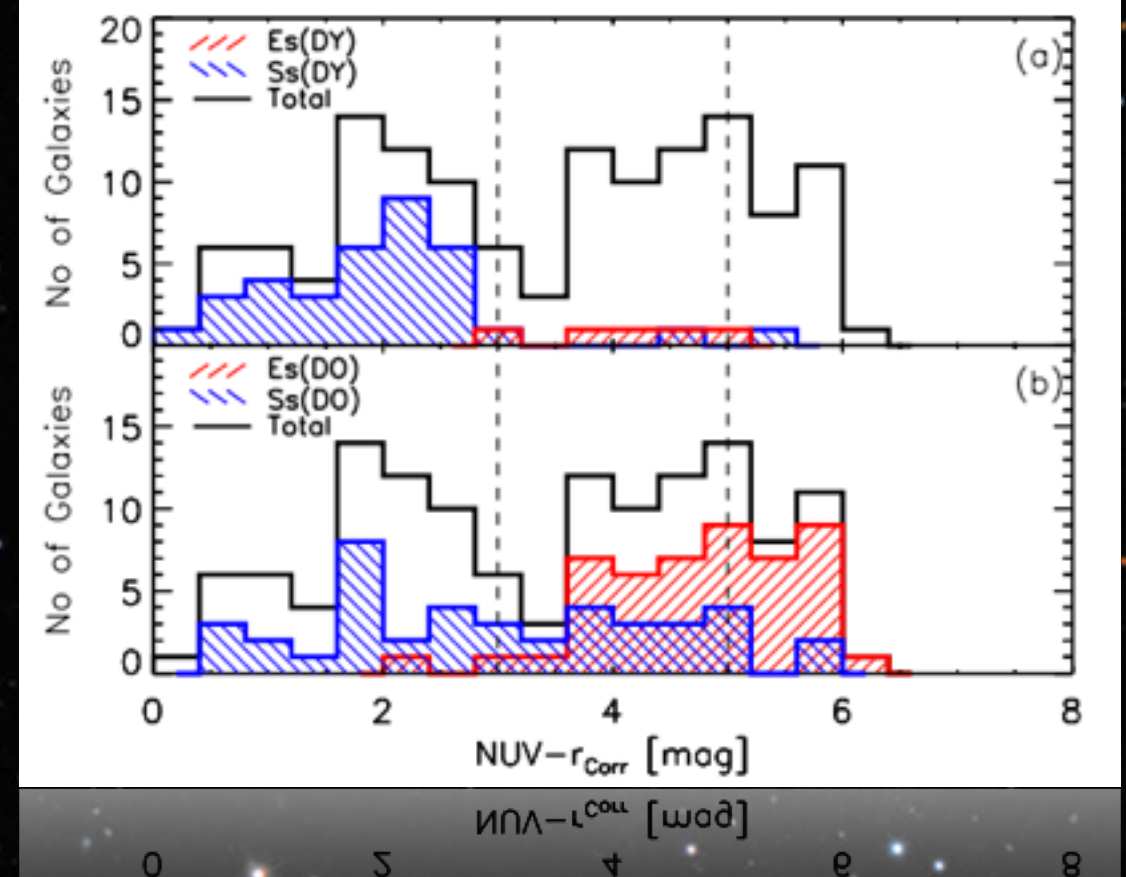
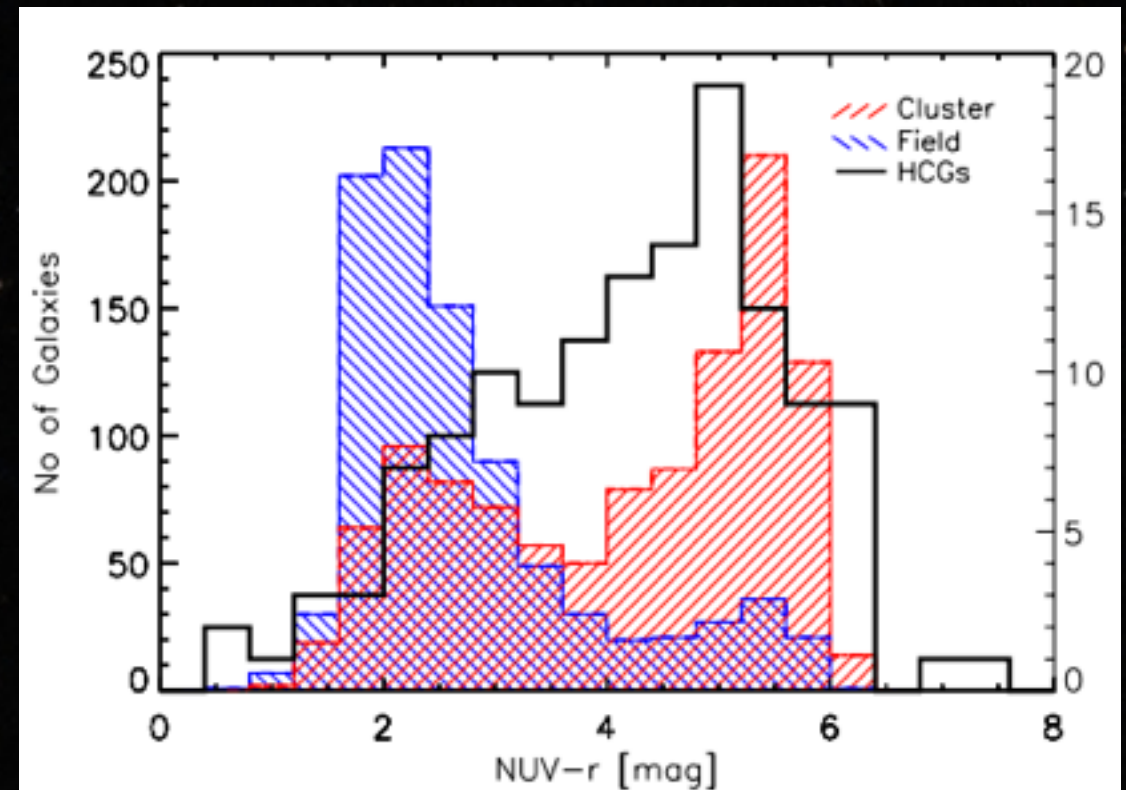
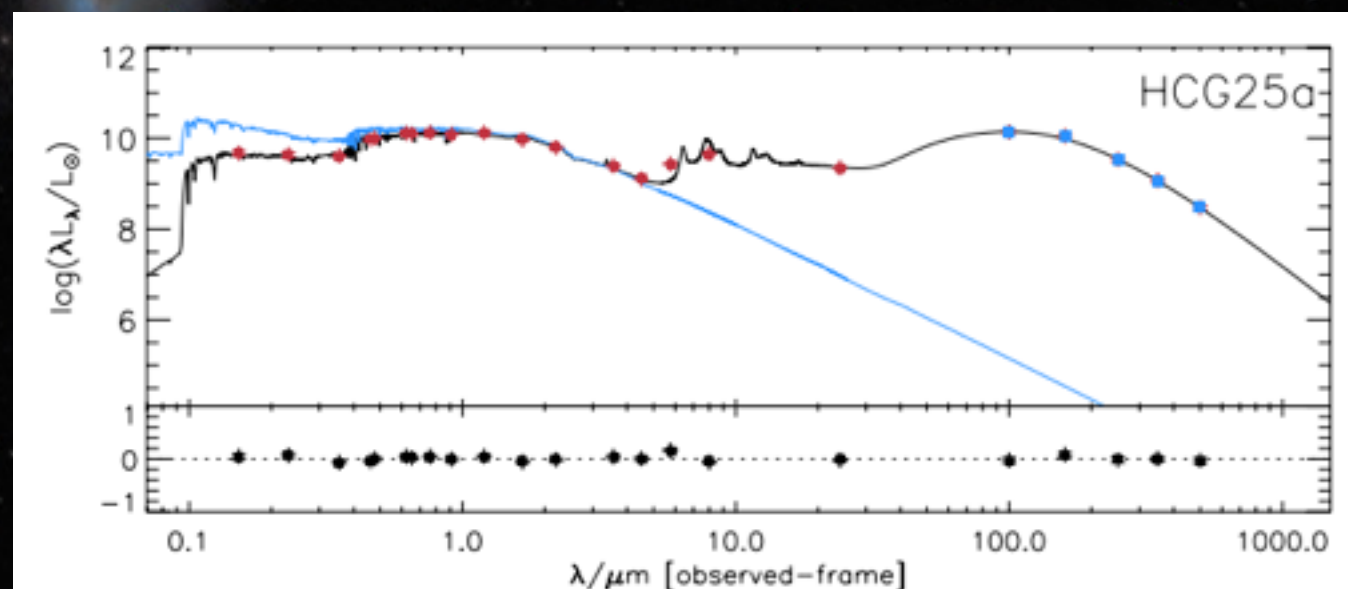
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- Bitsakis+11 studied the UV-optical colour bimodality



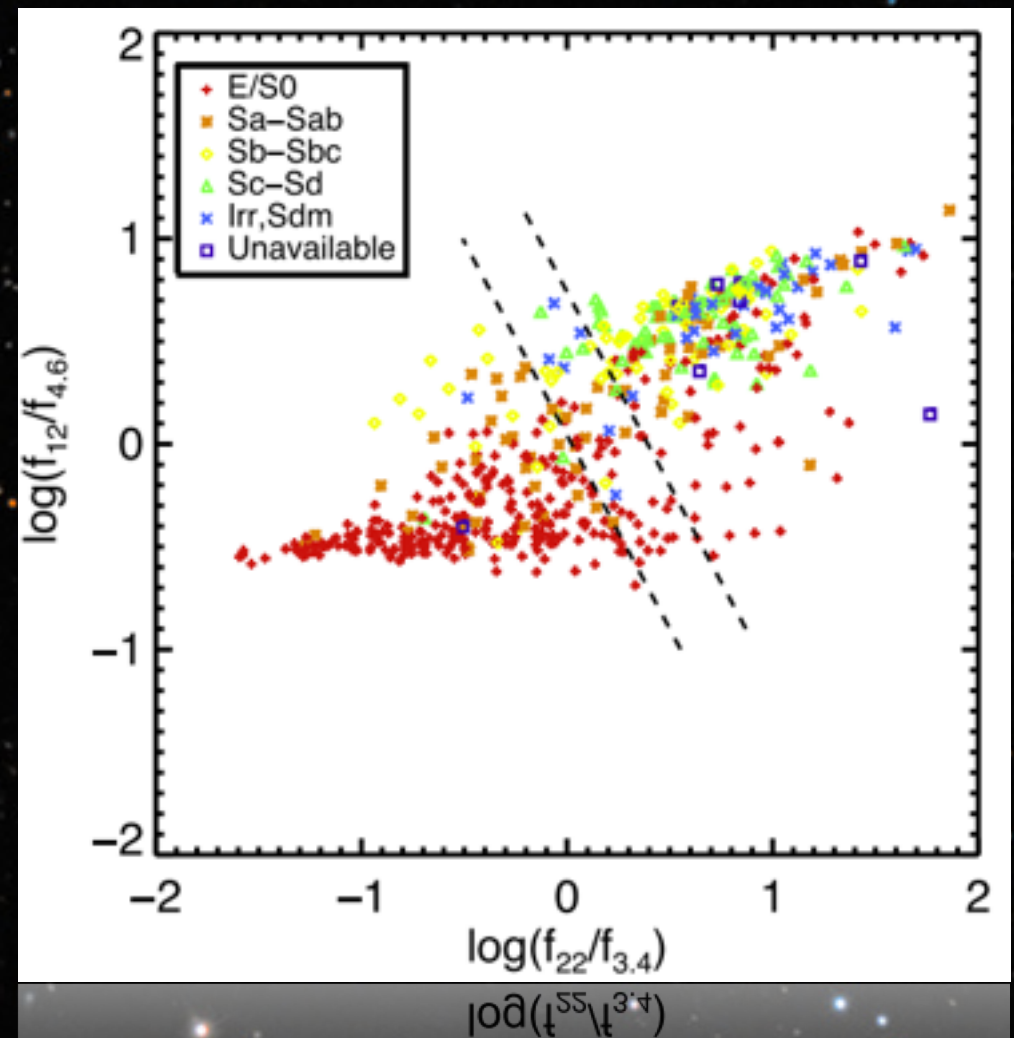
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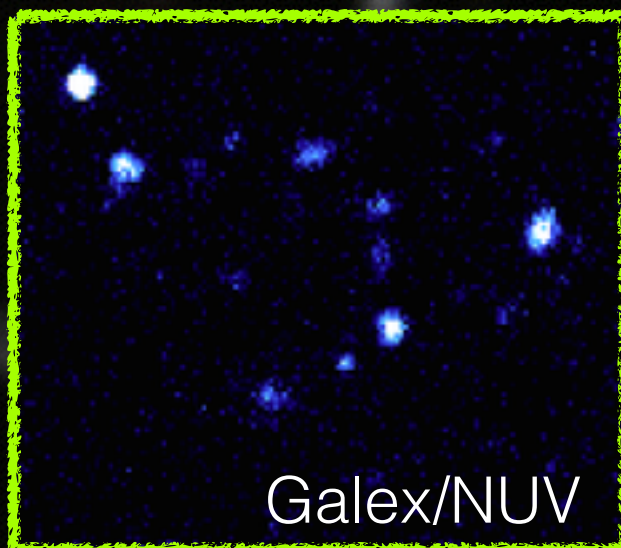
The galaxy colours

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- Walker+12 degraded the gap into a canyon
- Bitsakis+11 studied the UV-optical colour bimodality
- Zucker+16 studied WISE colours of 163 HCG galaxies and confirmed many LTGs in the quiescent sequence



Studying the evolution over the past 3 Gyr

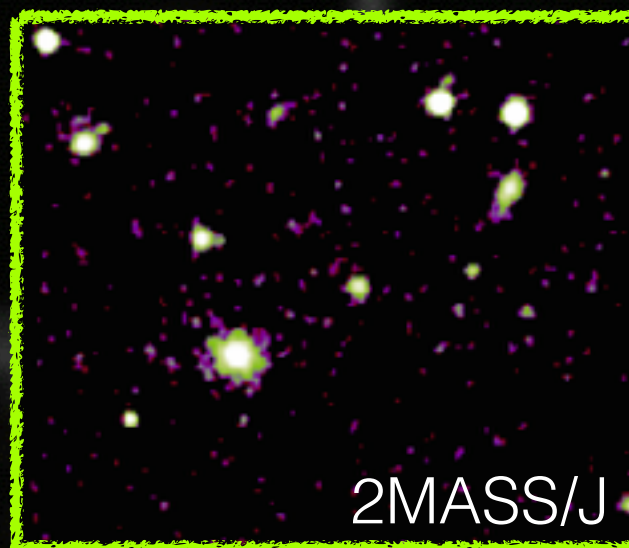
- We compile a new CG sample based on McConnachie+08,09 with available UV-to-IR colours for **1,770 CGs** (**~7,500** galaxies) => largest multiwavelength CG sample to-date
- Morphological classifications based on **radial profile fits** (Simard+11)
- $z=0.01-0.23$ (**looking-back time ~3Gyr**) [HCGs @ $z\sim 0.03$]



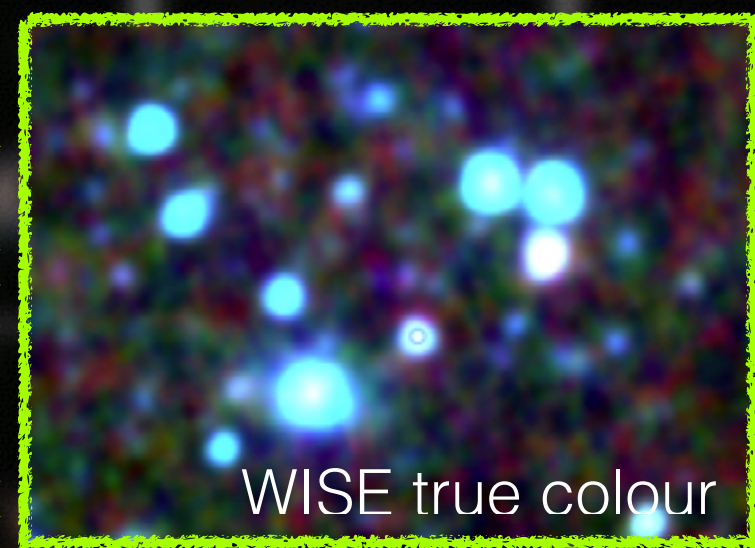
Galex/NUV



SDSS true colour



2MASS/J



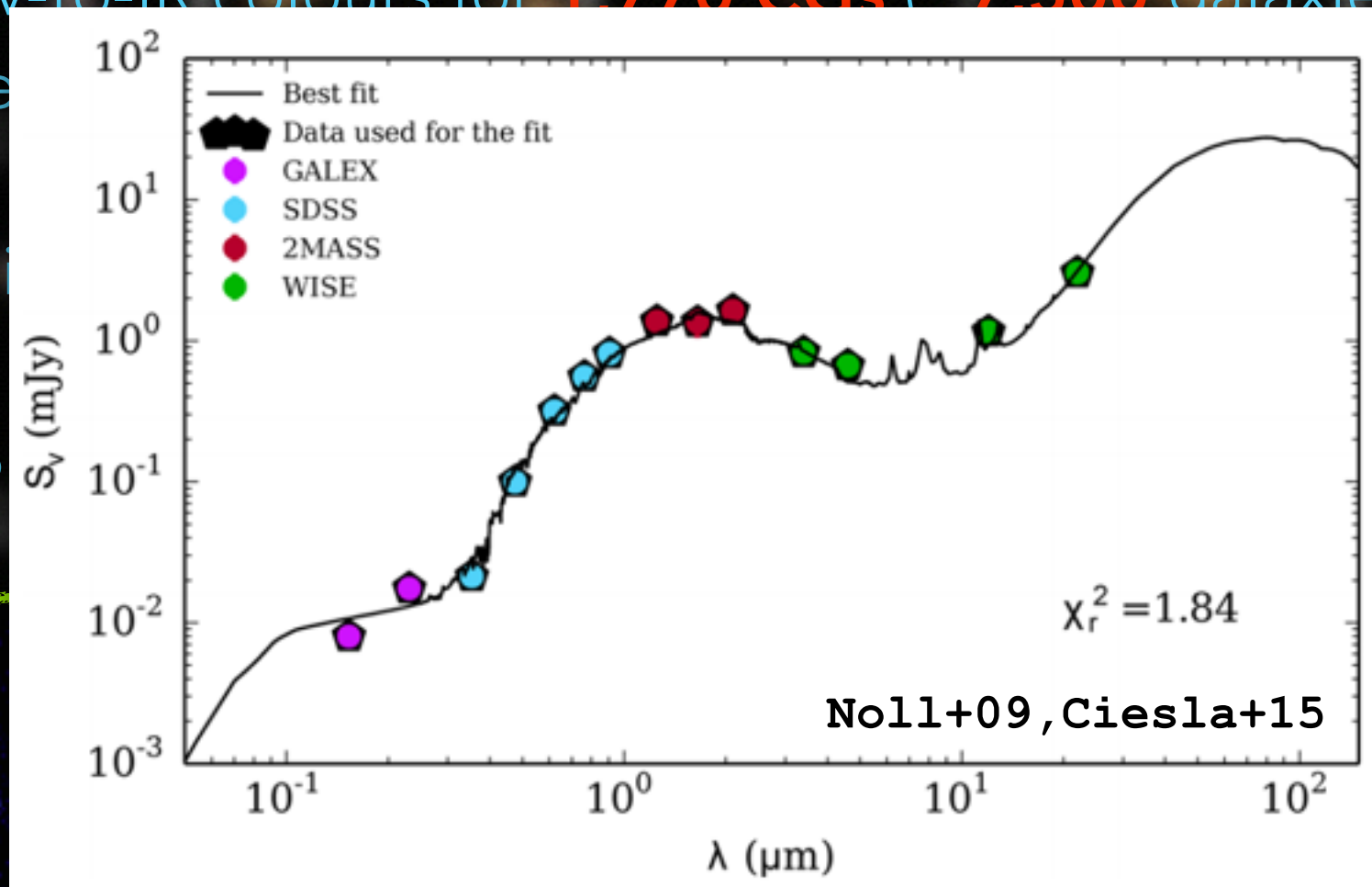
WISE true colour

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- Morphologi

- $z=0.01-0.23$



(Simard+11)

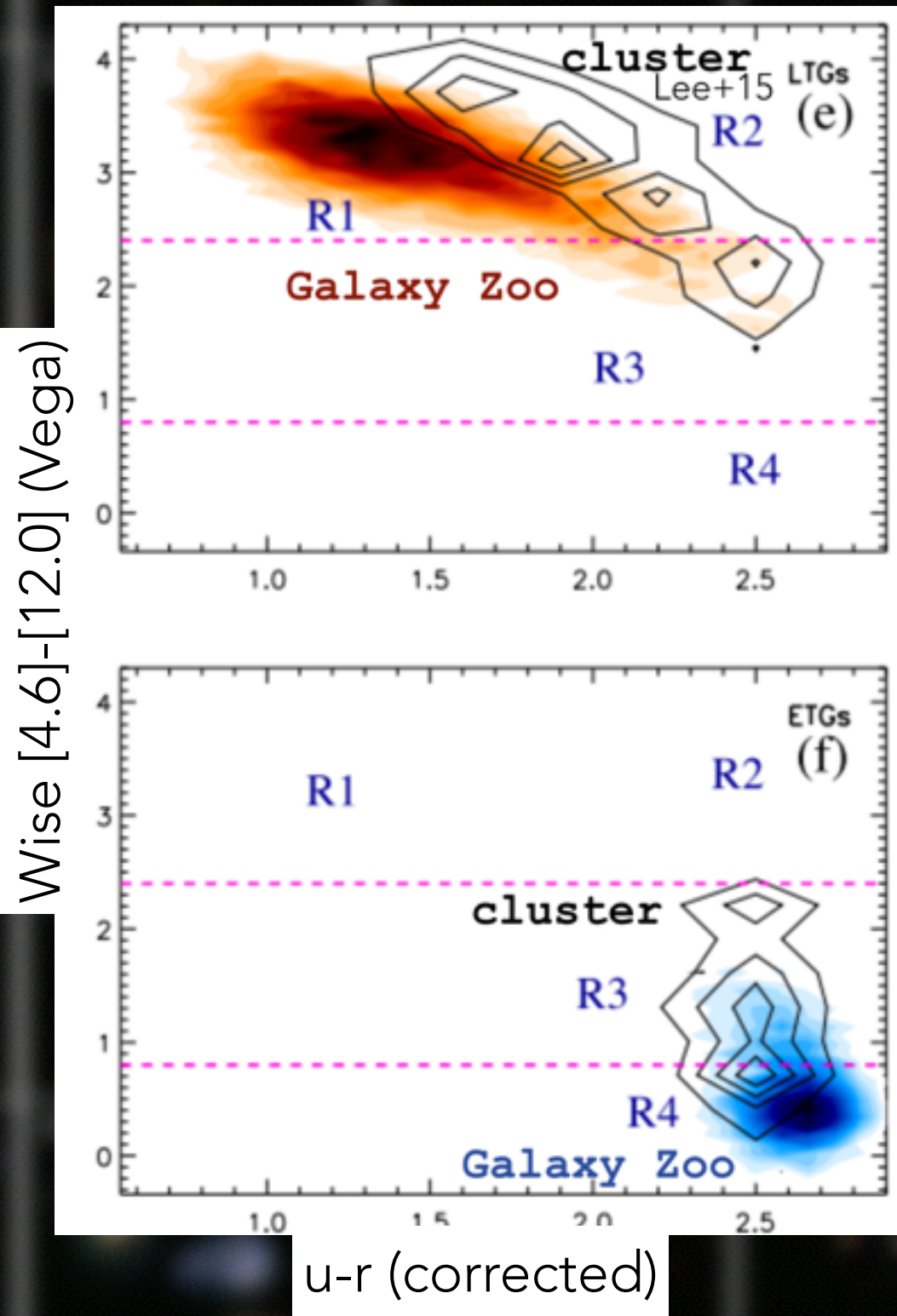
Galex/NUV

SDSS true colour

2MASS/J

WISE true colour

The evolution of colours



Late-type galaxies

Early-type galaxies

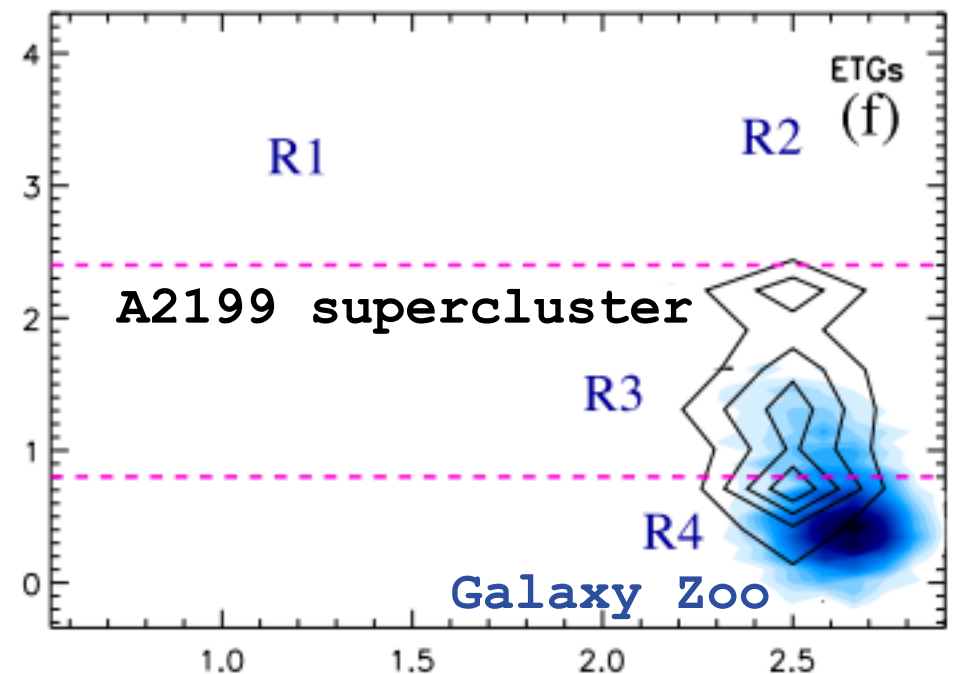
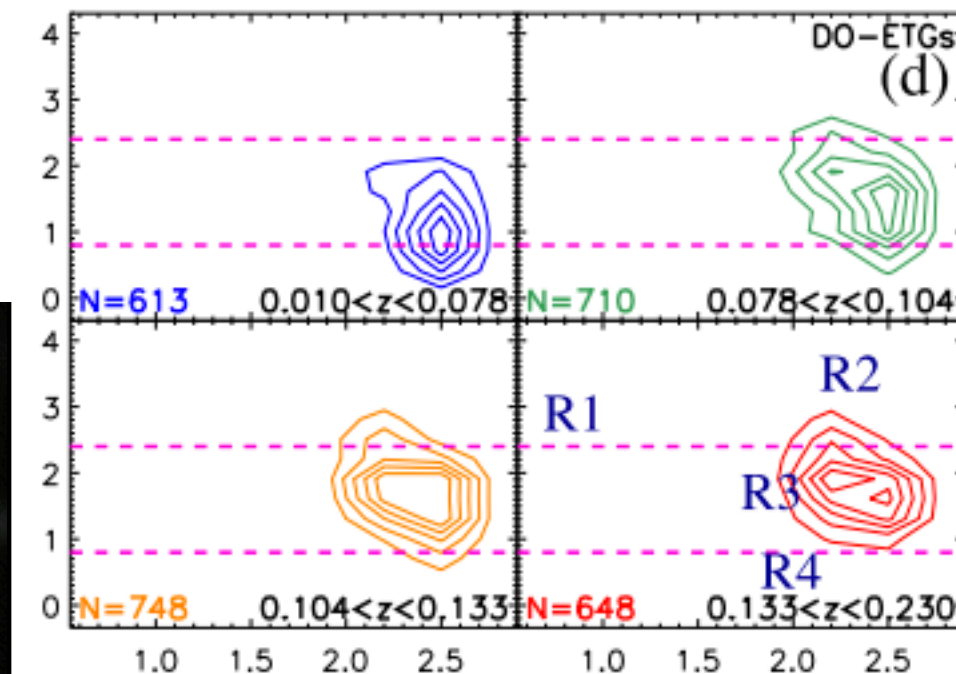
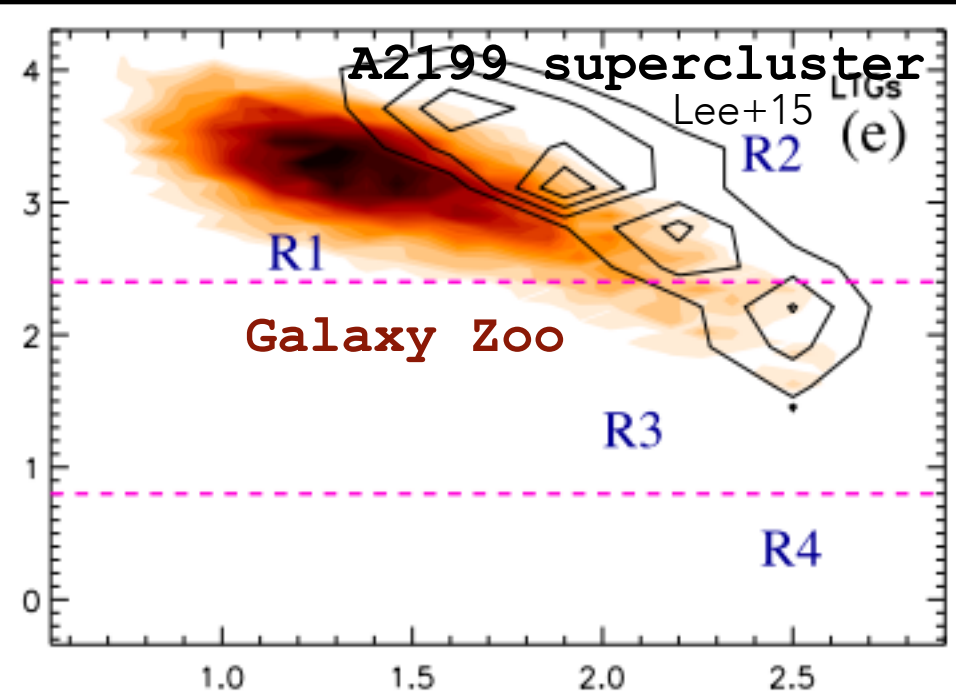
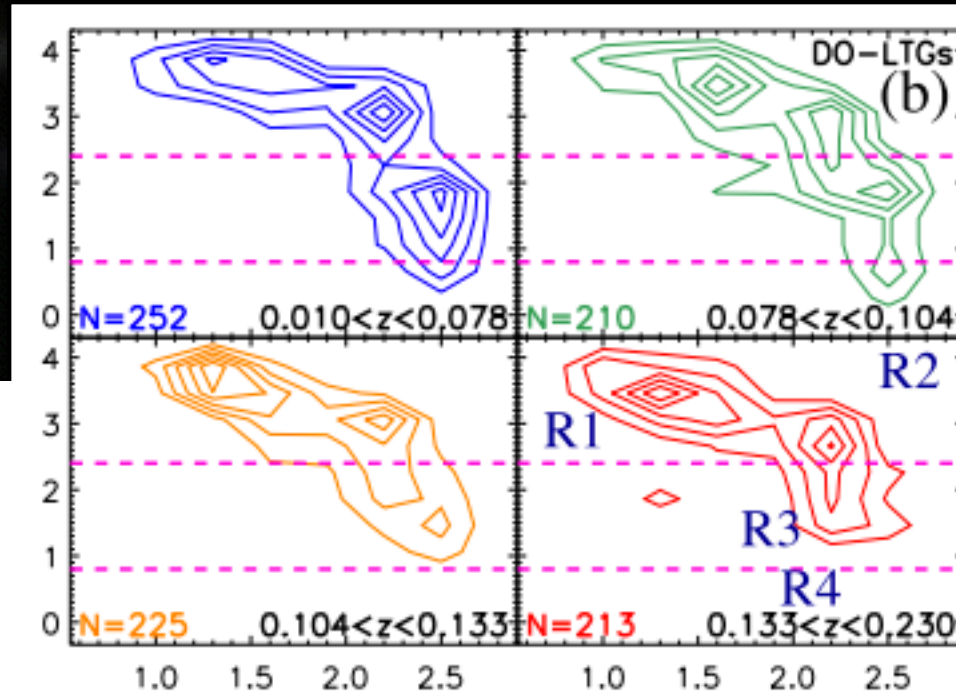
The evolution of colours

Dynamically old groups

Bitsakis+15, 16

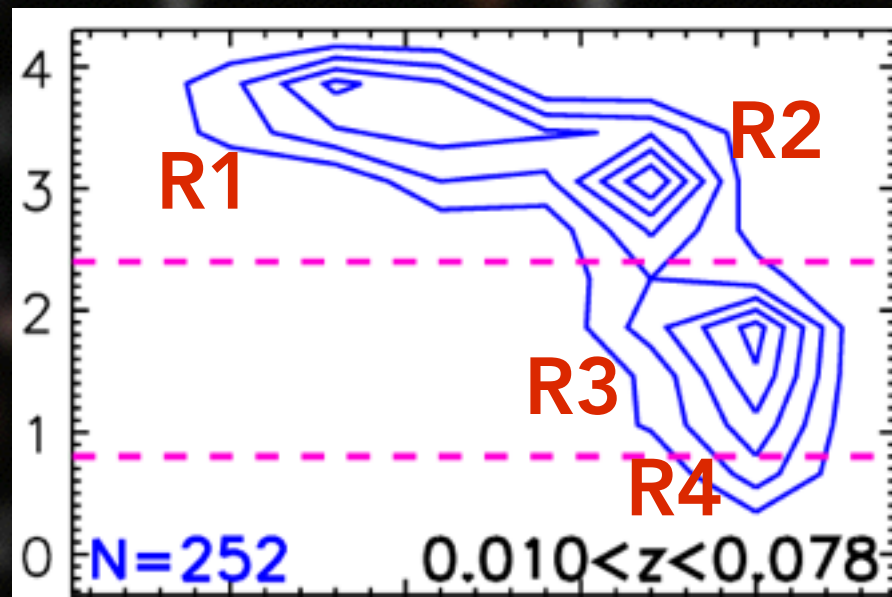
Late-type galaxies
Early-type galaxies

Wise [4.6]-[12.0] (Vega)



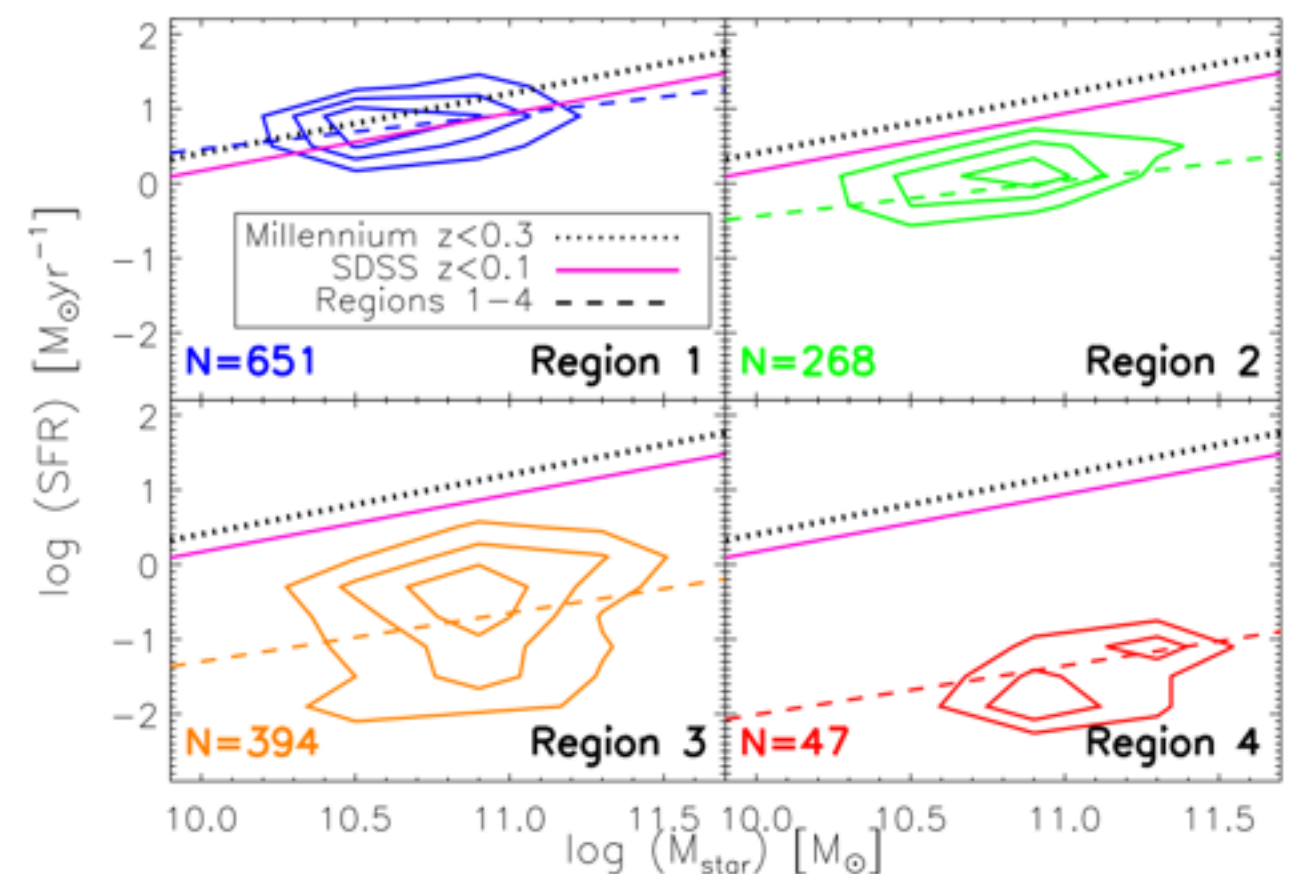
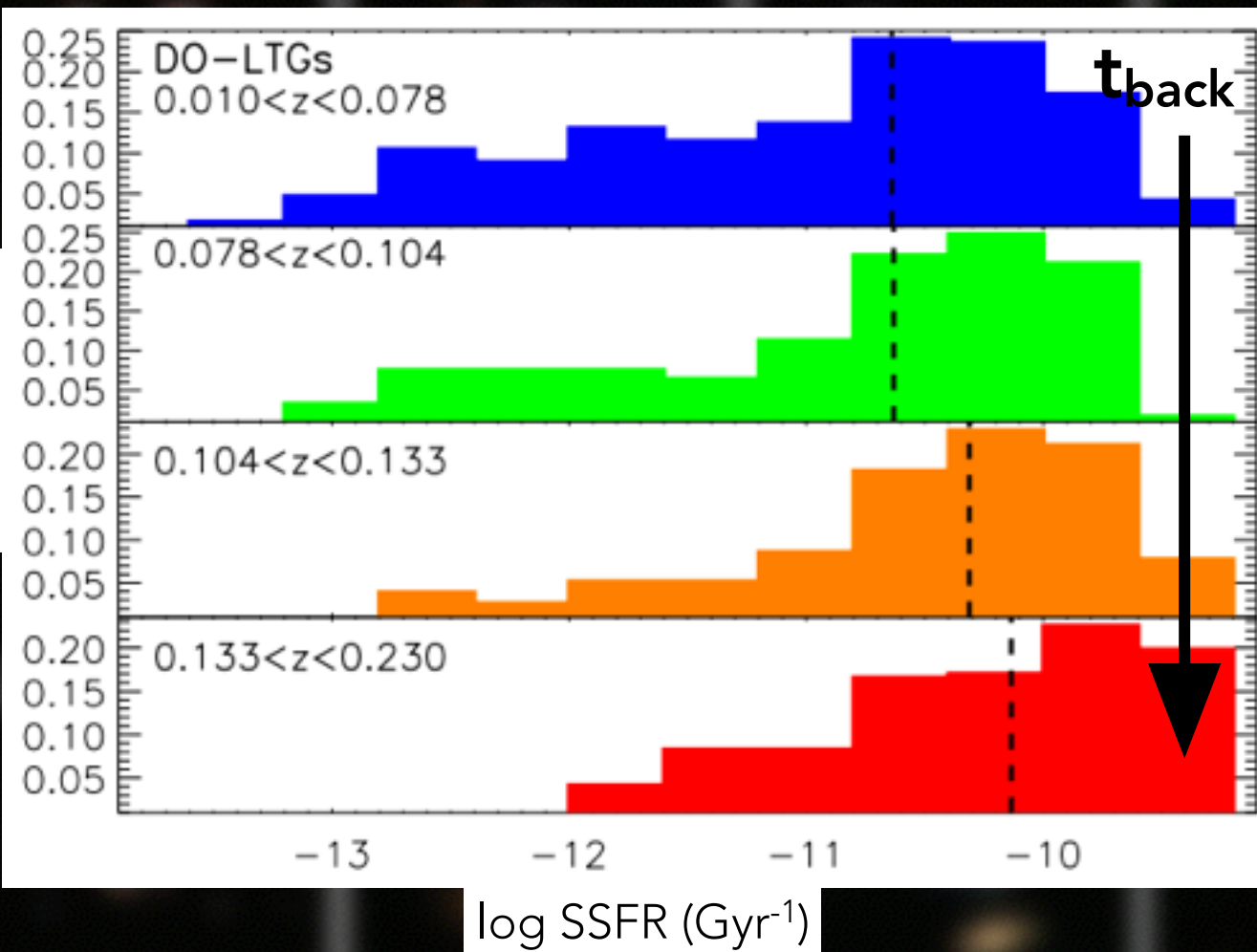
u-r (corrected)

The evolution of star formation

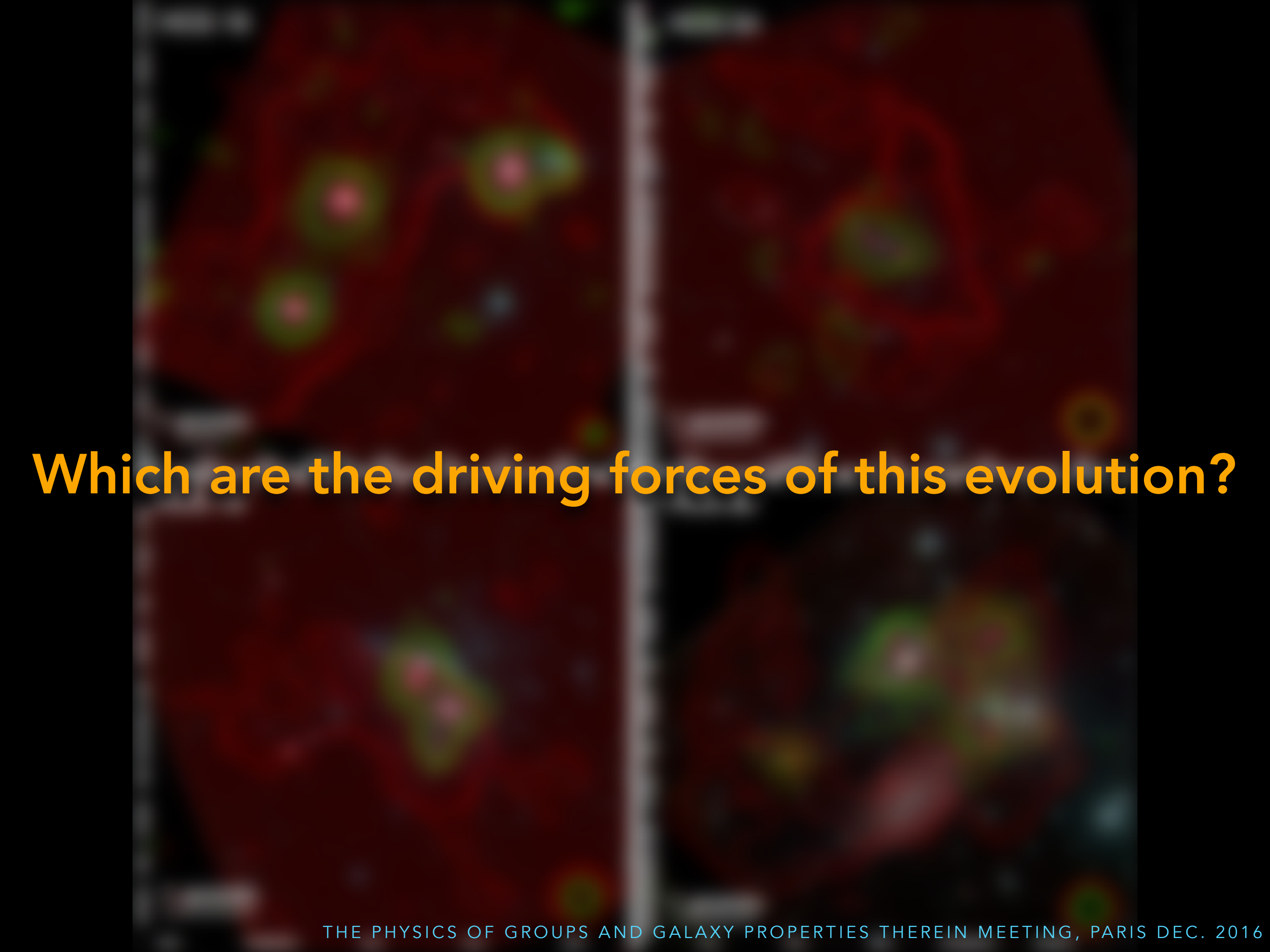


- R1 - star forming region
- R2 - "the elbow"
- R3 - Infrared Transition Zone (Alatalo+14)
- R4 - quiescent sequence

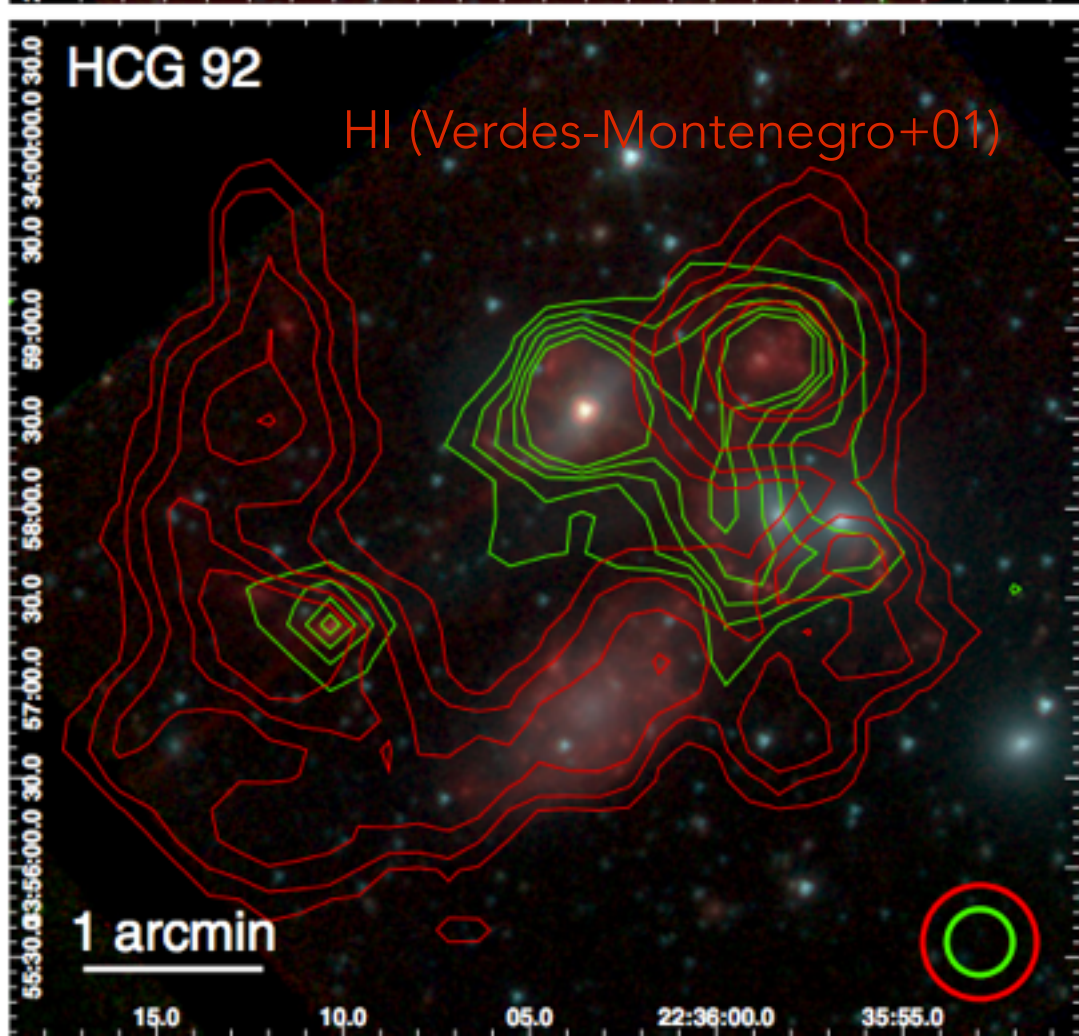
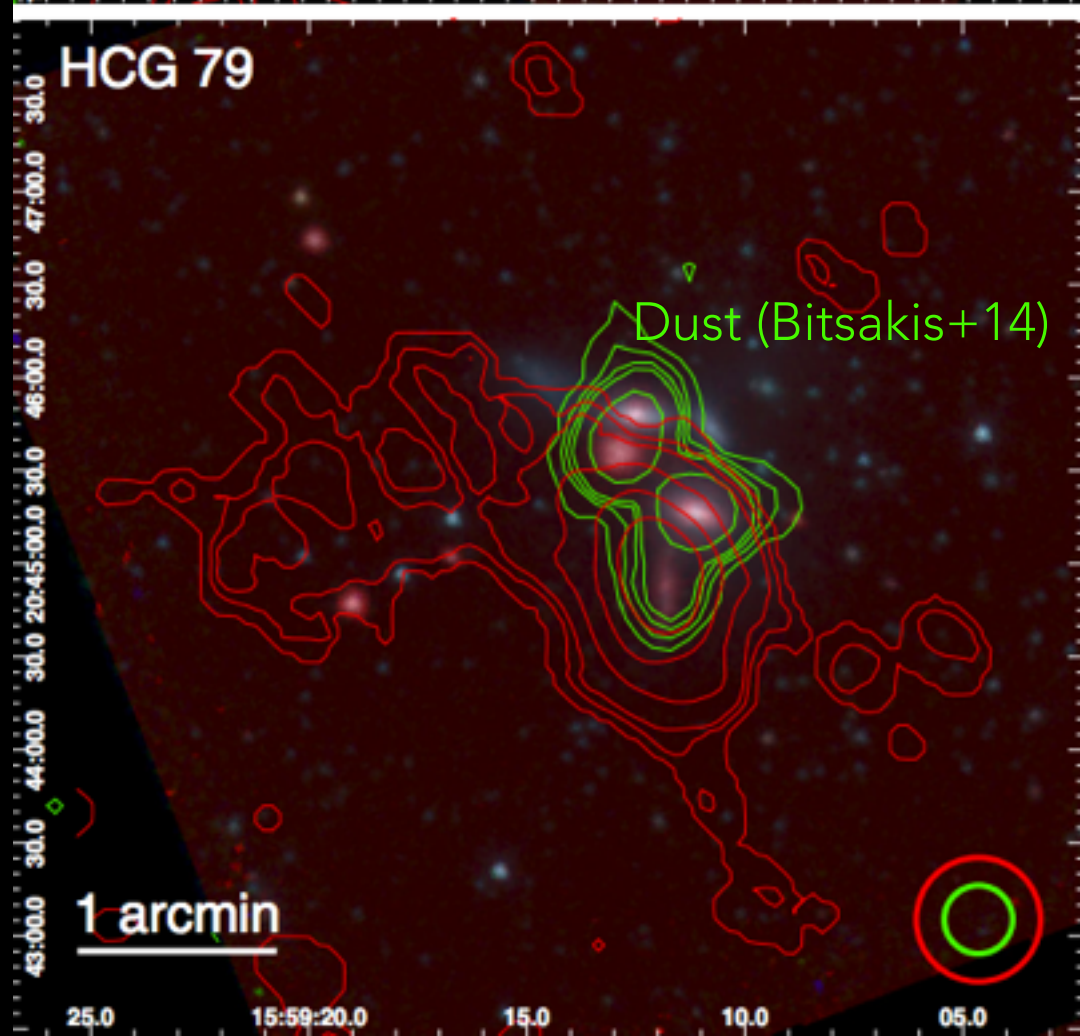
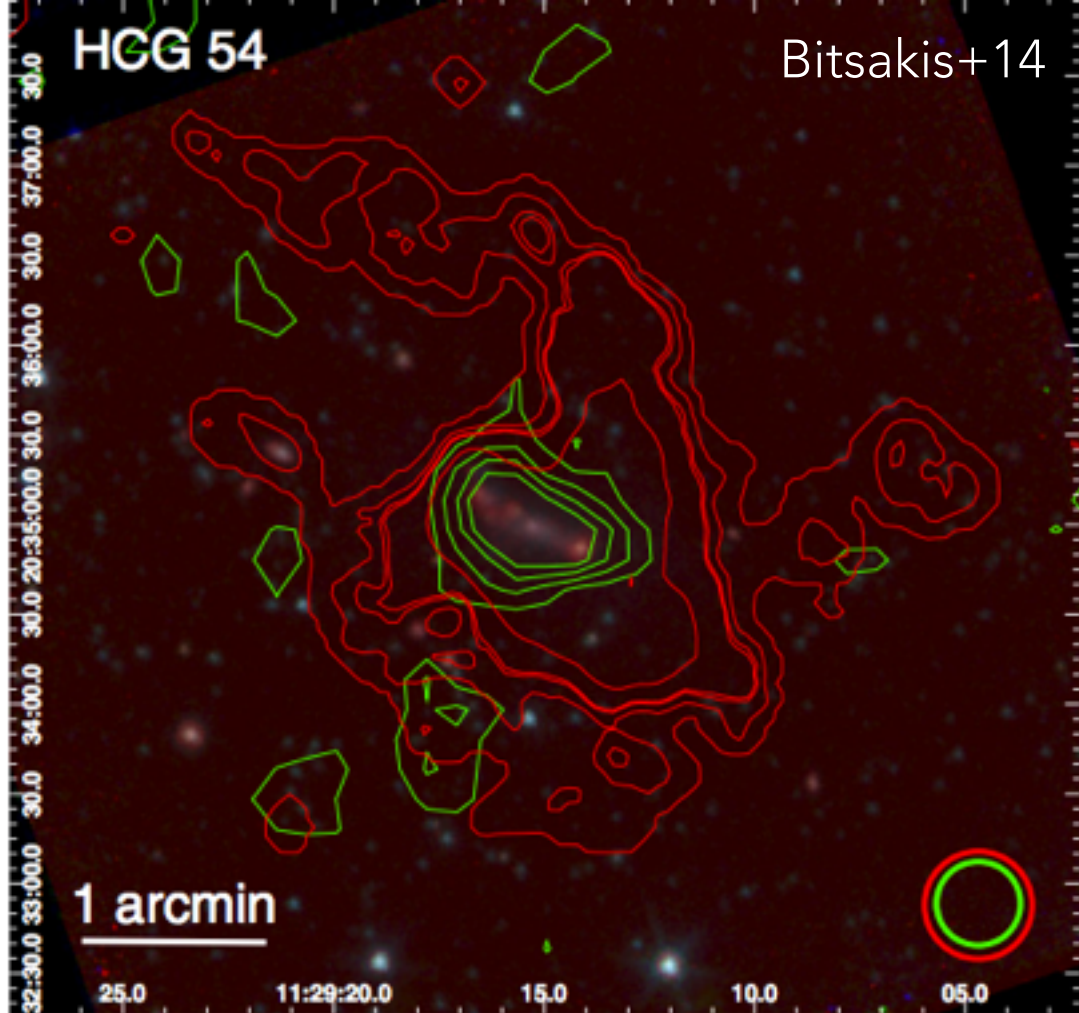
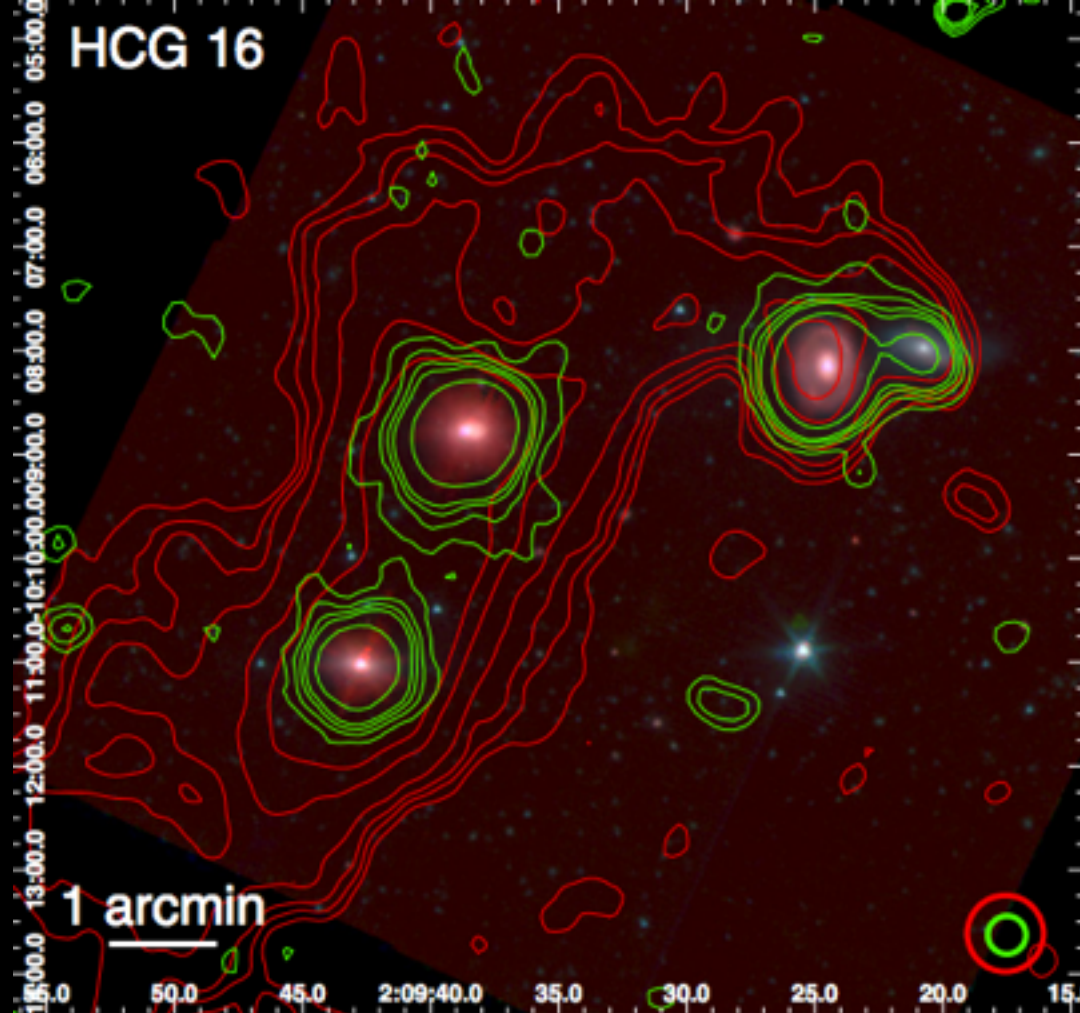
Galaxy Fraction



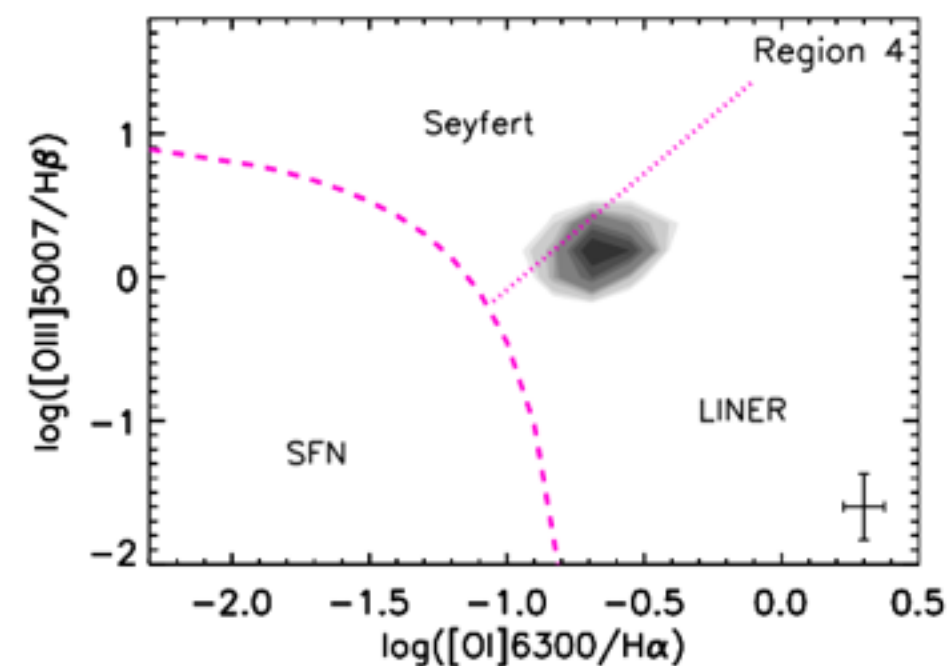
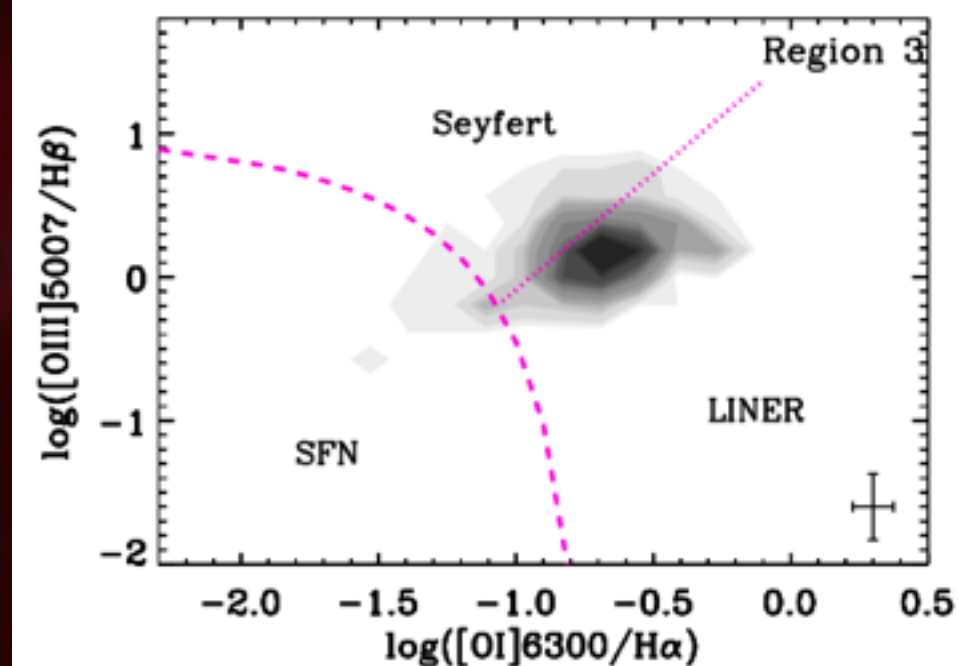
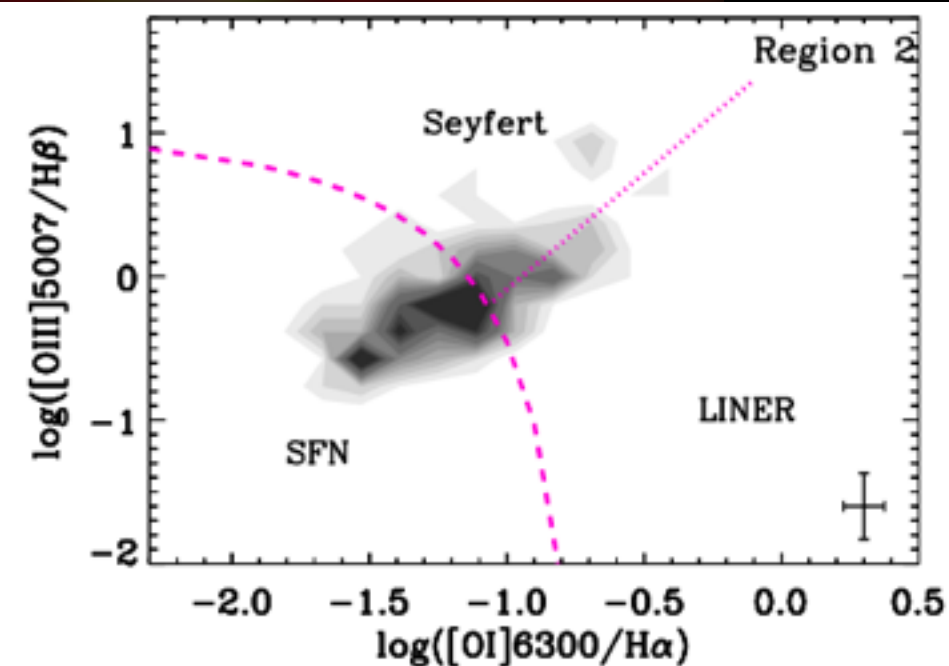
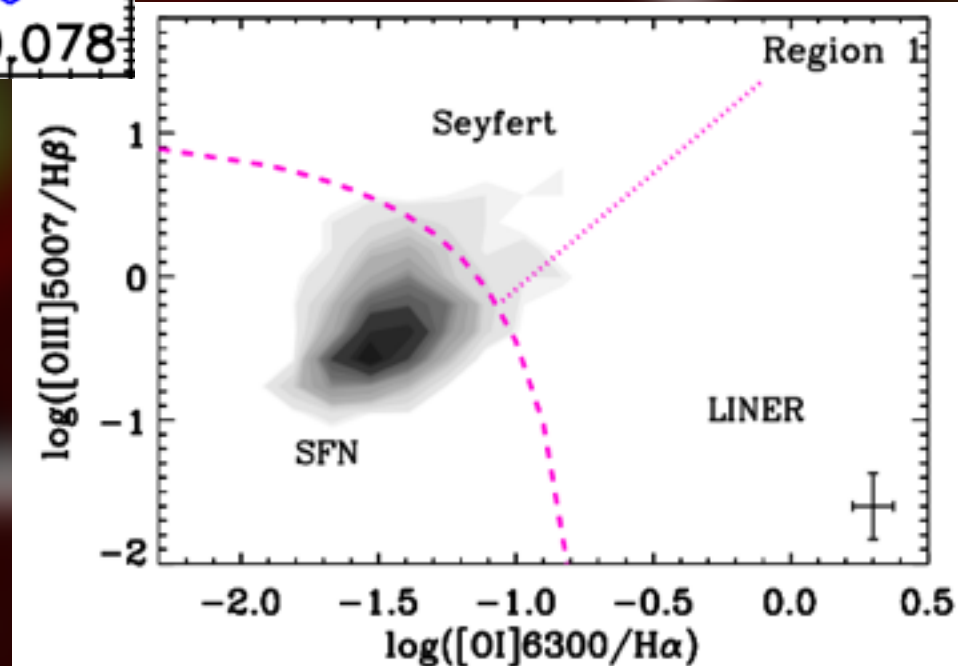
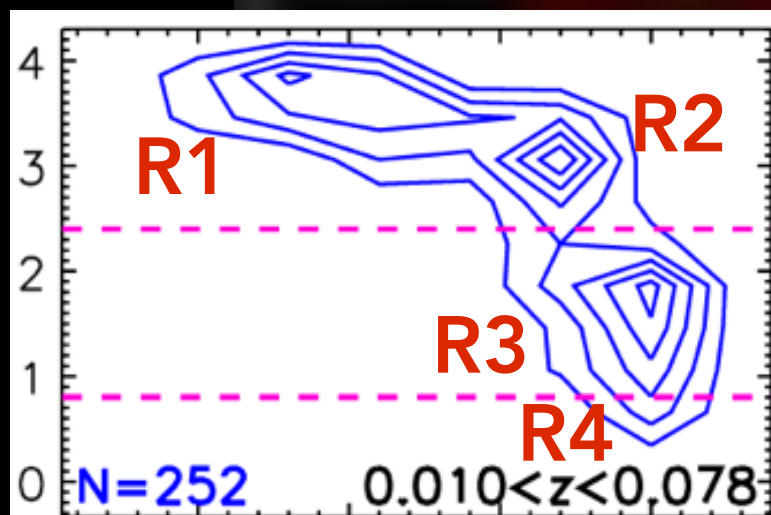
Bitsakis+15, 16



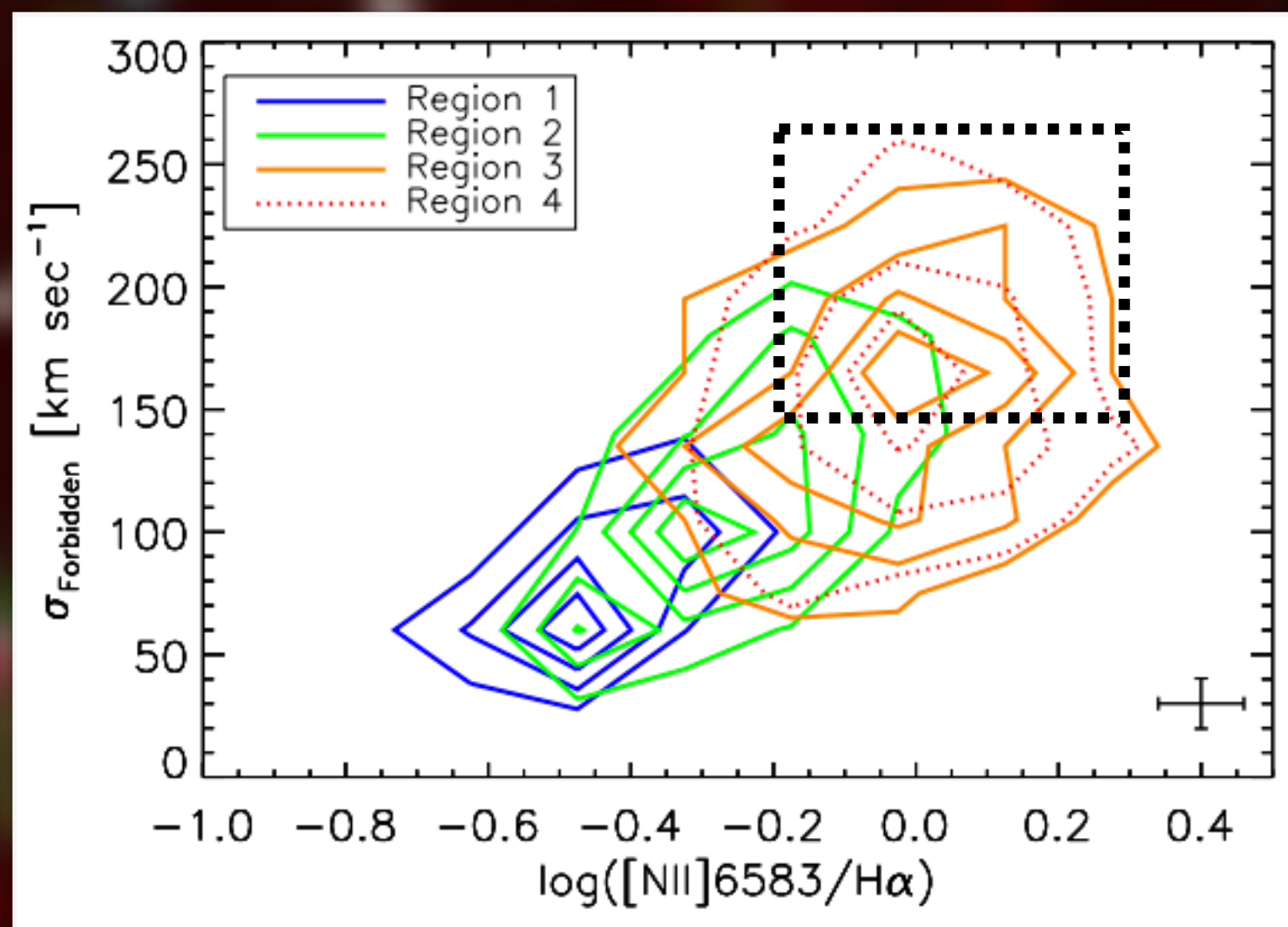
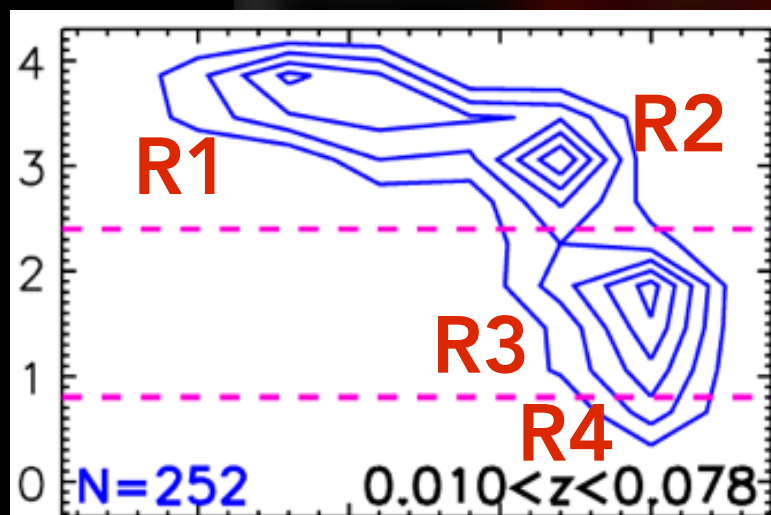
Which are the driving forces of this evolution?



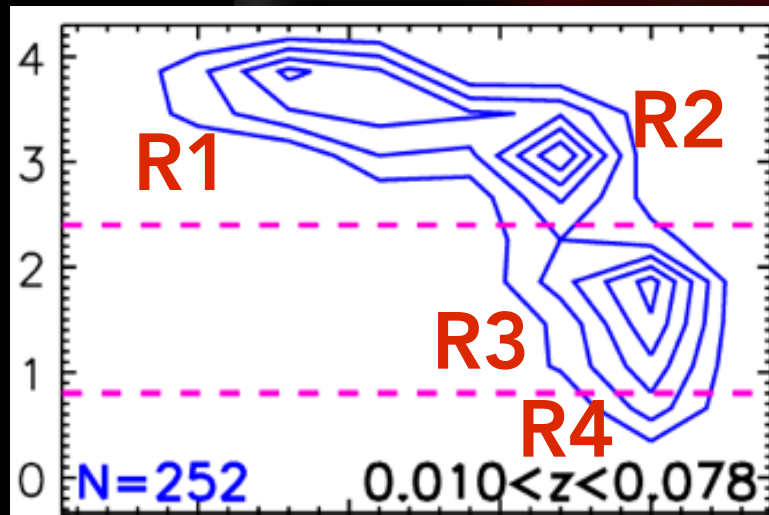
However, our data also suggest...



However, our data also suggest...



However, our data also suggest...



Future goals:

Use the unique capabilities of JWST and IFU spectroscopy to study the special properties of these galaxies

Region	SSFR $\times 10^{-11}$ [yr $^{-1}$]	σ_{median} [km sec $^{-1}$]	EW(NaD) Å
Region 1	12.21 $\pm$ 0.08	75.6 $\pm$ 2.5	1.91 $\pm$ 0.06
Region 2	2.07 $\pm$ 0.01	111.4 $\pm$ 7.3	2.90 $\pm$ 0.19
Region 3	0.24 $\pm$ 0.01	152.7 $\pm$ 8.6	3.34 $\pm$ 0.19
Region 4	0.07 $\pm$ 0.01	159.6 $\pm$ 11.0	3.50 $\pm$ 0.23

shocks and turbulence could bust up the σ_{gas} with result to further suppress SF (e.g. Guillard+12, Appleton+13, Alatalo+14,15, Cluver+13, Lisenfeld +14)

Do compact groups display the SF and colours that are expected given their unusually high densities?

Compact group environment influences uniquely the evolution of star formation in its members.

Multiple interactions have as a result to reduce the SF, by reducing the gas content (tidal stripping), but also suppress it by introducing turbulence/shocks that make the remaining gas inefficient to form stars

(see more in the presentations of K. Alatalo, P. Appleton, P. Guillard, U. Lisenfeld)