Galaxy Cluster Mergers & Star Formation

Chiara Ferrari

In collaboration with:

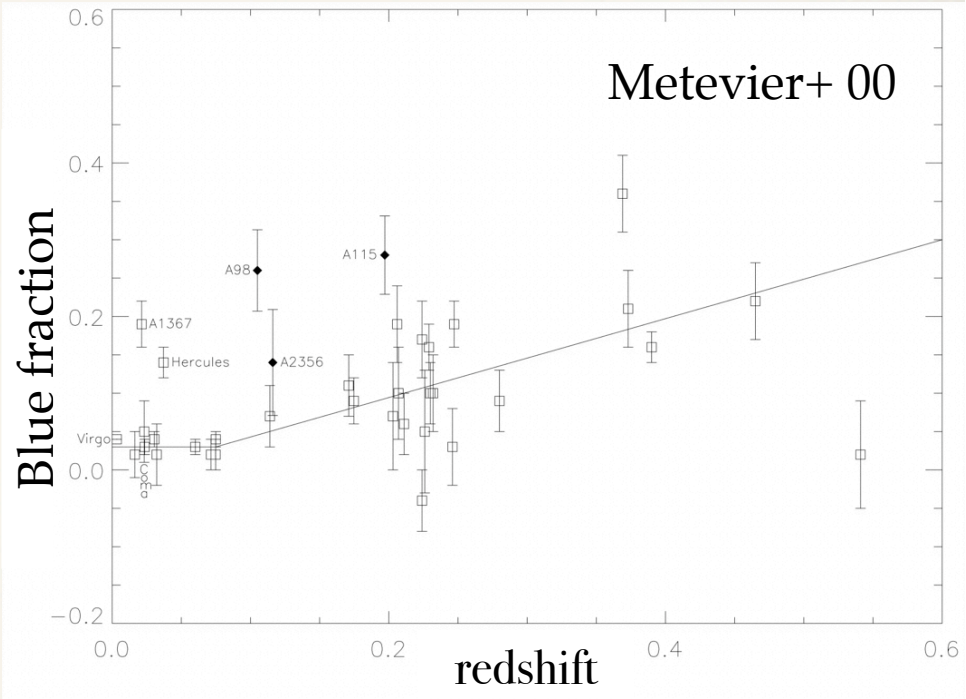
C.Benoist, J.Brinchmann, A.Cappi, A.Diaferio, L.Feretti, R.Hunstead, W.Kapferer, T.Kronberger, J.C.Mauduit, S.Maurogordato, J.L.Sauvageot, S.Schindler, E.Slezak

Outline of the talk

- Introduction: merging clusters & star formation
- Observational analysis of the galaxy cluster Abell 3921
  - **Dynamical state** (Optical & X-rays: Ferrari+ 05; Belsole+ 05)
  - **Star formation (SF) properties** (Optical & Radio: Ferrari+ 05; 06; in prep.)
- Comparison with numerical simulations
  - **Ram-pressure on spiral galaxies** (Kronberger+ 08; Kapferer+ 09)
  - **Ram-pressure on interacting galaxies** (Kapferer+ 08)

Star formation in (merging) clusters

- Observed evolution in the star formation properties of cluster galaxies with redshift
  - Increasing fraction of blue galaxies with z (e.g. Butcher & Oemler 78)
  - Increasing fraction of star forming/post-star forming galaxies with z (e.g. Dressler+ 87,99)
- Evolution of cluster members ⇔ hierarchical growth of large scale structures ?
- Debated observational evidence that cluster mergers may trigger star formation (e.g. Caldwell+ 93; Bardelli+ 98; Miller+ 05; Owen+ 05)



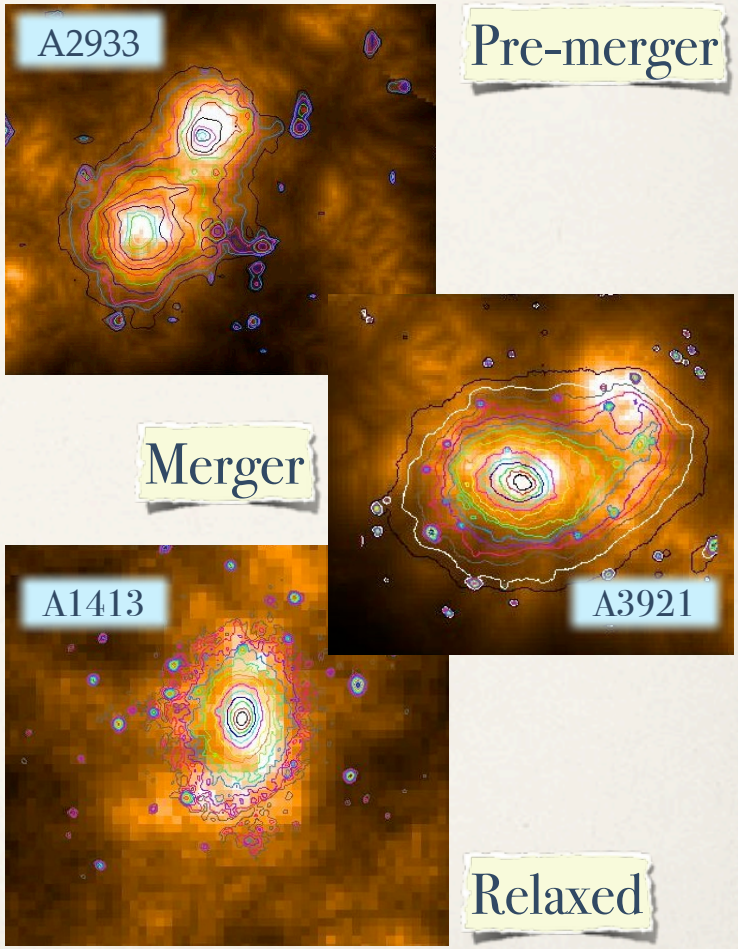
Multi-λ analysis of merging clusters

- Optical: WFI, EFOSC2,VIMOS@ESO, 2dF@AAT
- X-rays: XMM, Chandra
- Radio: VLA, ATCA

➡ Dynamical state of clusters
(Belsole+ 05,04; Ferrari+ 03,06a; Maurogordato+ 08; Sauvageot+ 05)

➡ Correlation with star formation properties
(Ferrari+ 05,06b; Maurogordato+ in prep.)

➡ Presence of diffuse intra-cluster radio emission
(Ferrari+ 06a)



Galaxy iso-density maps + X-ray surface brightness cts.
(DSS + ROSAT)

A detailed multi-λ analysis of A3921

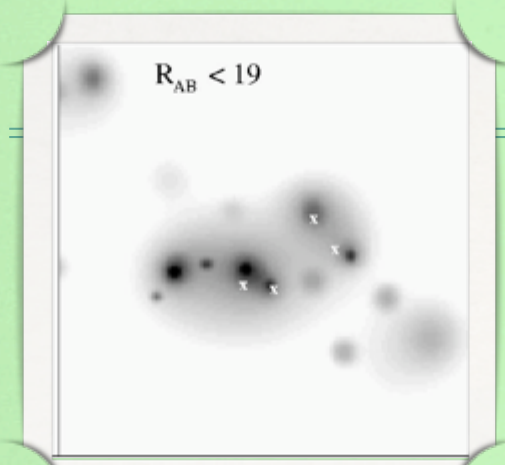
Why this cluster ?

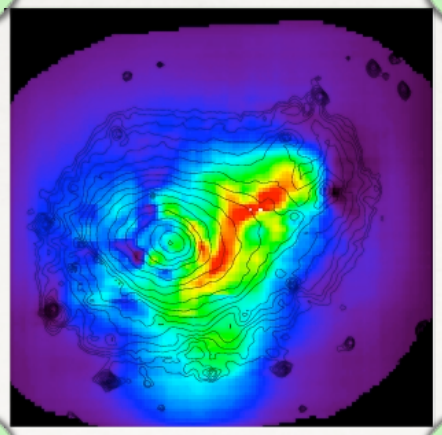
- Precise knowledge of the dynamical state of the cluster
- Quite simple and well determined merging scenario

→ Analysis of the correlation between star formation

& cluster-cluster collision

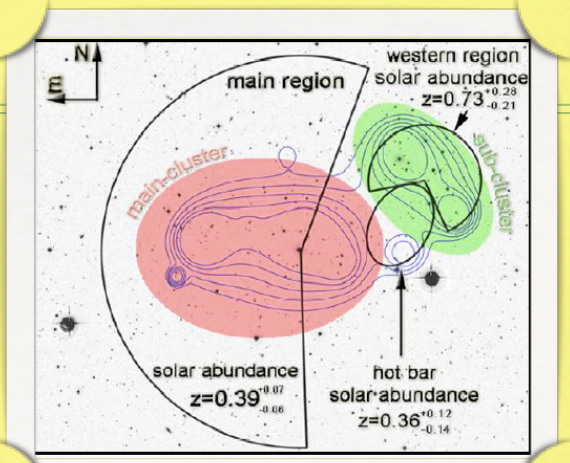
A3921: an off-axis pre-merger event



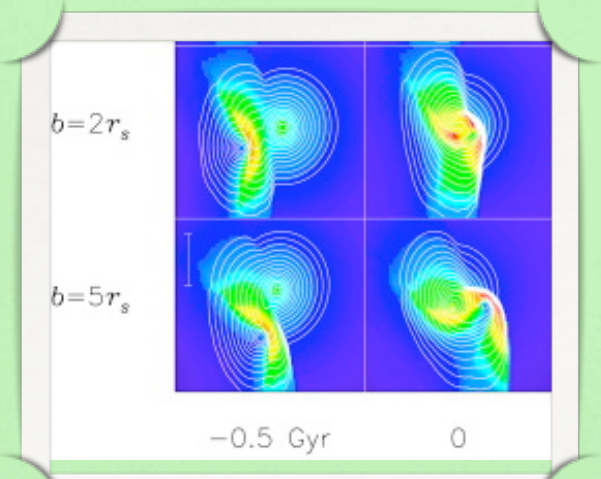


Galaxy iso-density map + **ICM temperature map & surface brightness contours**
(ESO: Ferrari+ 05 ; XMM: Belsole+ 05)

Observations

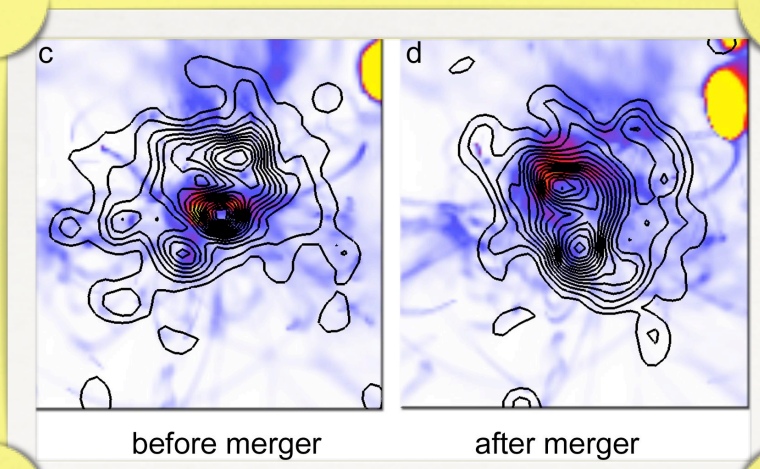


ICM metallicity distribution
(XMM: Belsole+ 05)



ICM temperature map + **X-ray surface brightness**
(Ricker & Sarazin 01)

Simulations



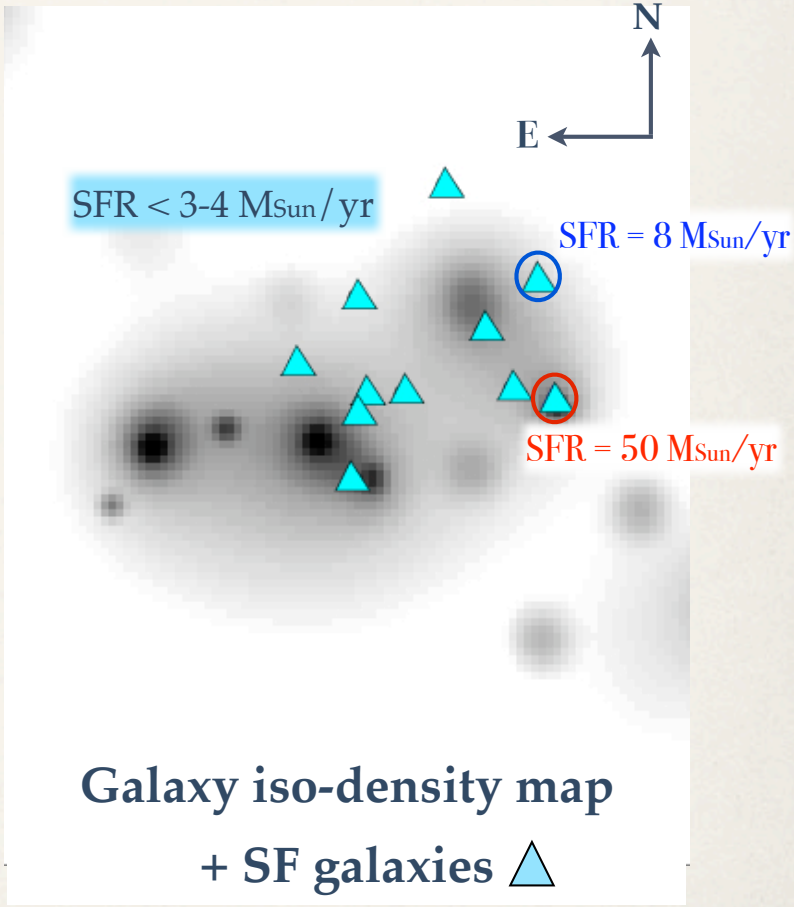
ICM metallicity distribution + **galaxy iso-density** contours (Kapferer+ 06)

SF in the collision region

Optical (EFOSC2+WFI) + Radio (ATCA) - Ferrari+ 05, 06

A3921 galaxies

- k (old population of stars) - 71%
- k+a (recent star formation) - 16%
- e (ongoing star formation) - 13%



Star formation enhanced by cluster collision ?

SF enhanced by cluster collision?

- Completeness in the central cluster field
- Precise determination of cluster members
- Discrimination between star forming galaxies and AGNs
- Physical mechanisms driving the observational properties

SF enhanced by cluster collision?

2dF spectroscopy from [OII] to [NII]

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- Precise determination of cluster members
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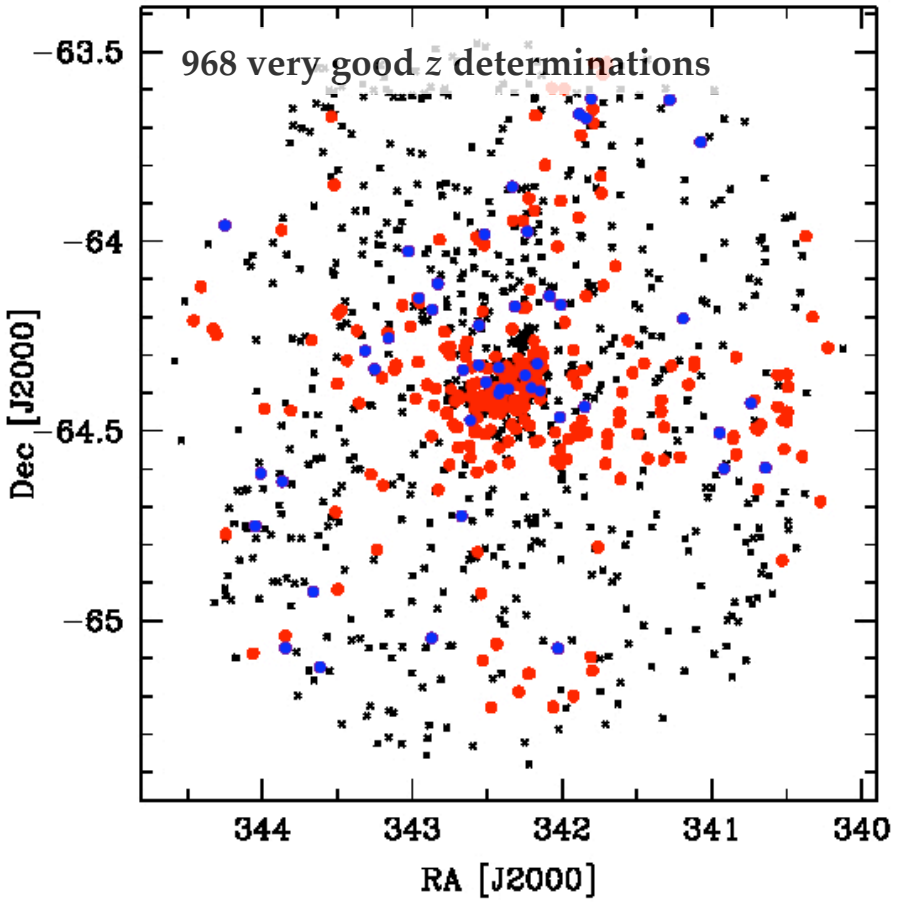
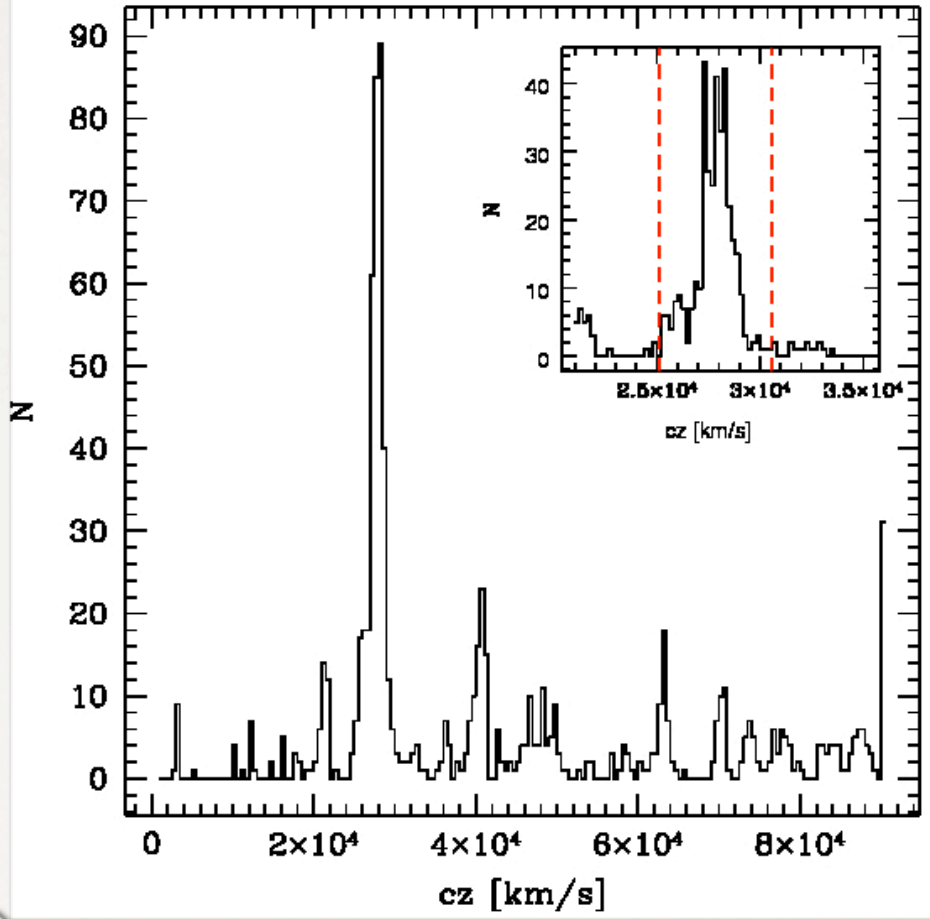
- Physical mechanisms driving the observational properties

Numerical simulations

2dF spectroscopy from [OII] to [NII]

Ferrari+ in prep.





Spatial and velocity distribution of objects with high quality *z* determination

2dF spectroscopy from [OII] to [NII]

Ferrari+ in prep.

+ Katgert+ 98; Ferrari+ 05; Pimbblet+ 06

- Completeness in the central cluster field
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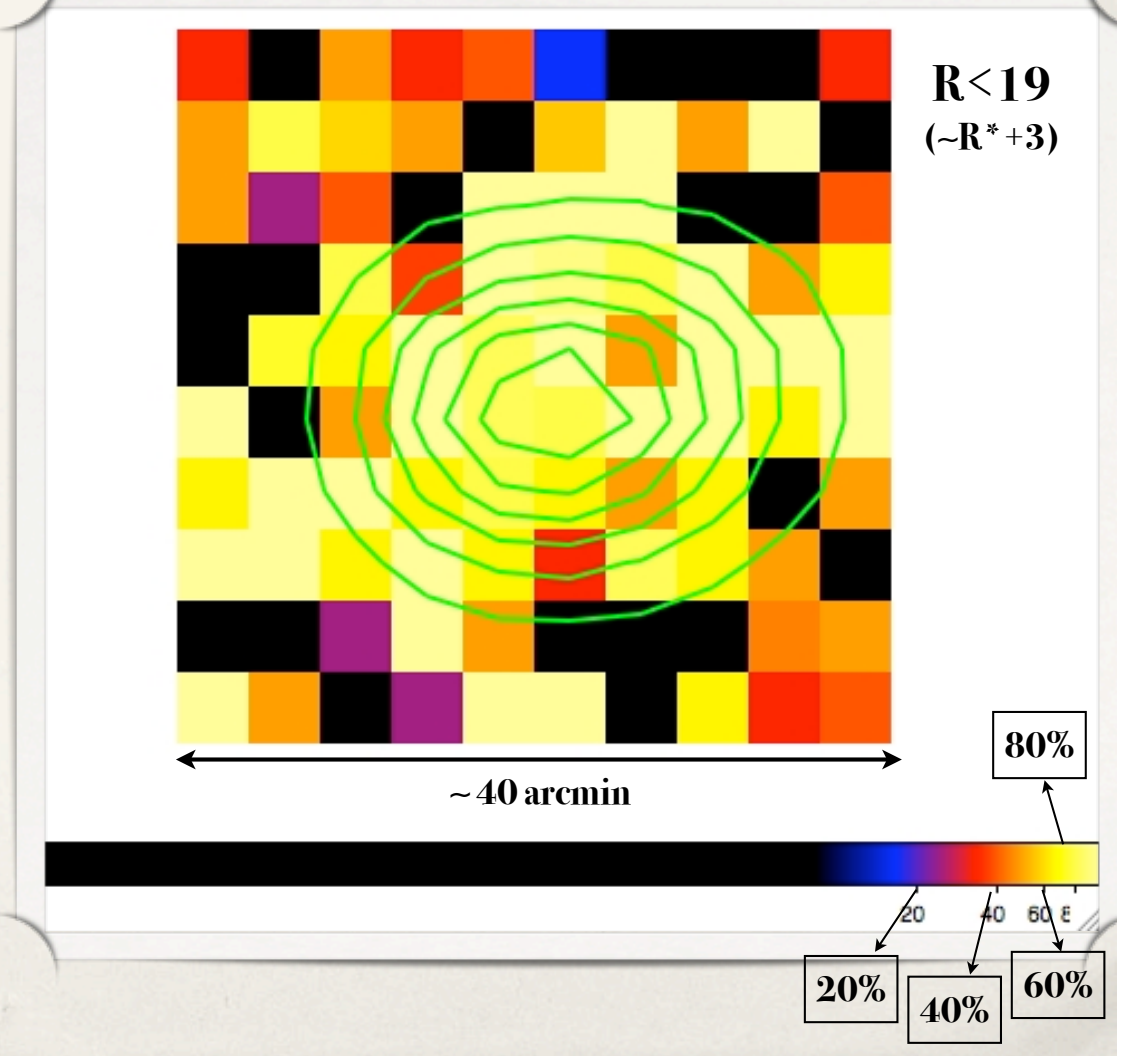

2dF spectroscopy from [OII] to [NII]

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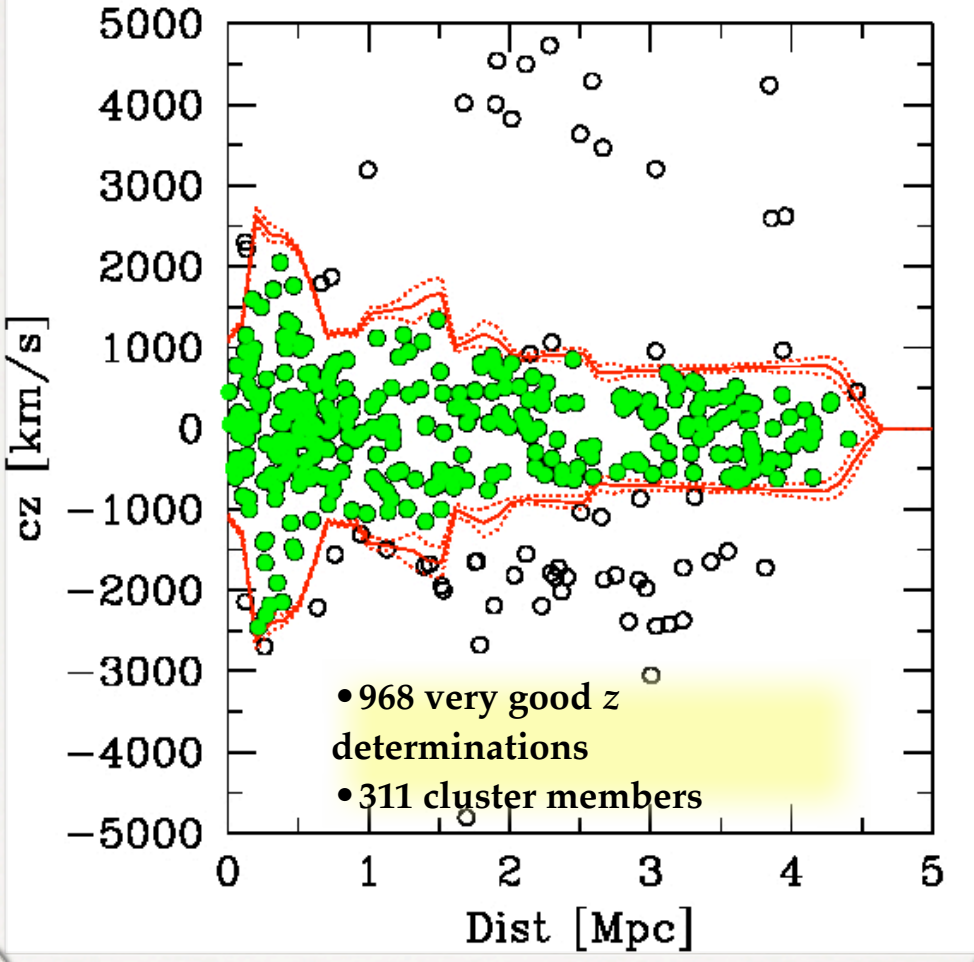

Caustic method: Diaferio 99

2dF spectroscopy from [OII] to [NII]

Ferrari+ in prep.

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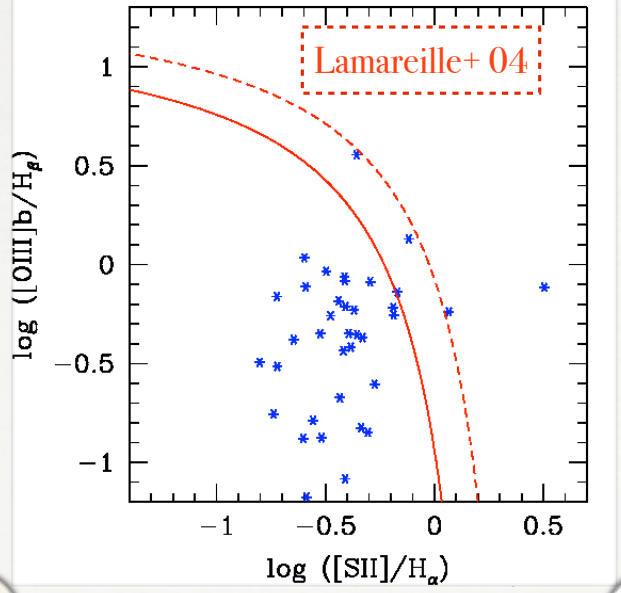
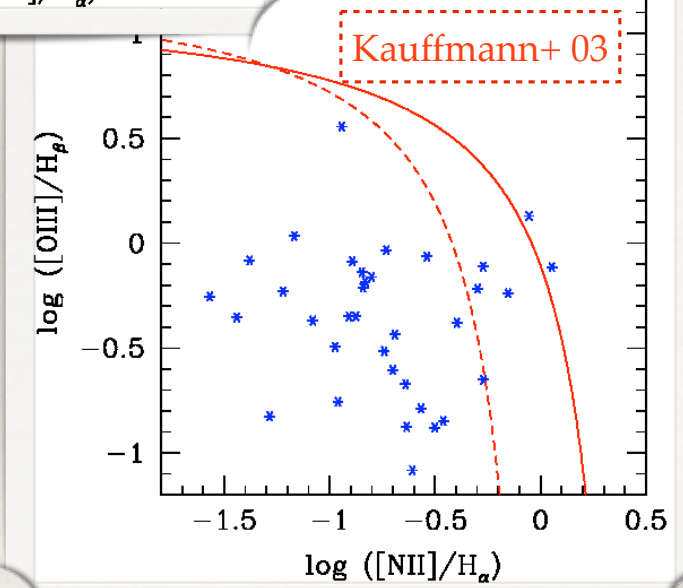
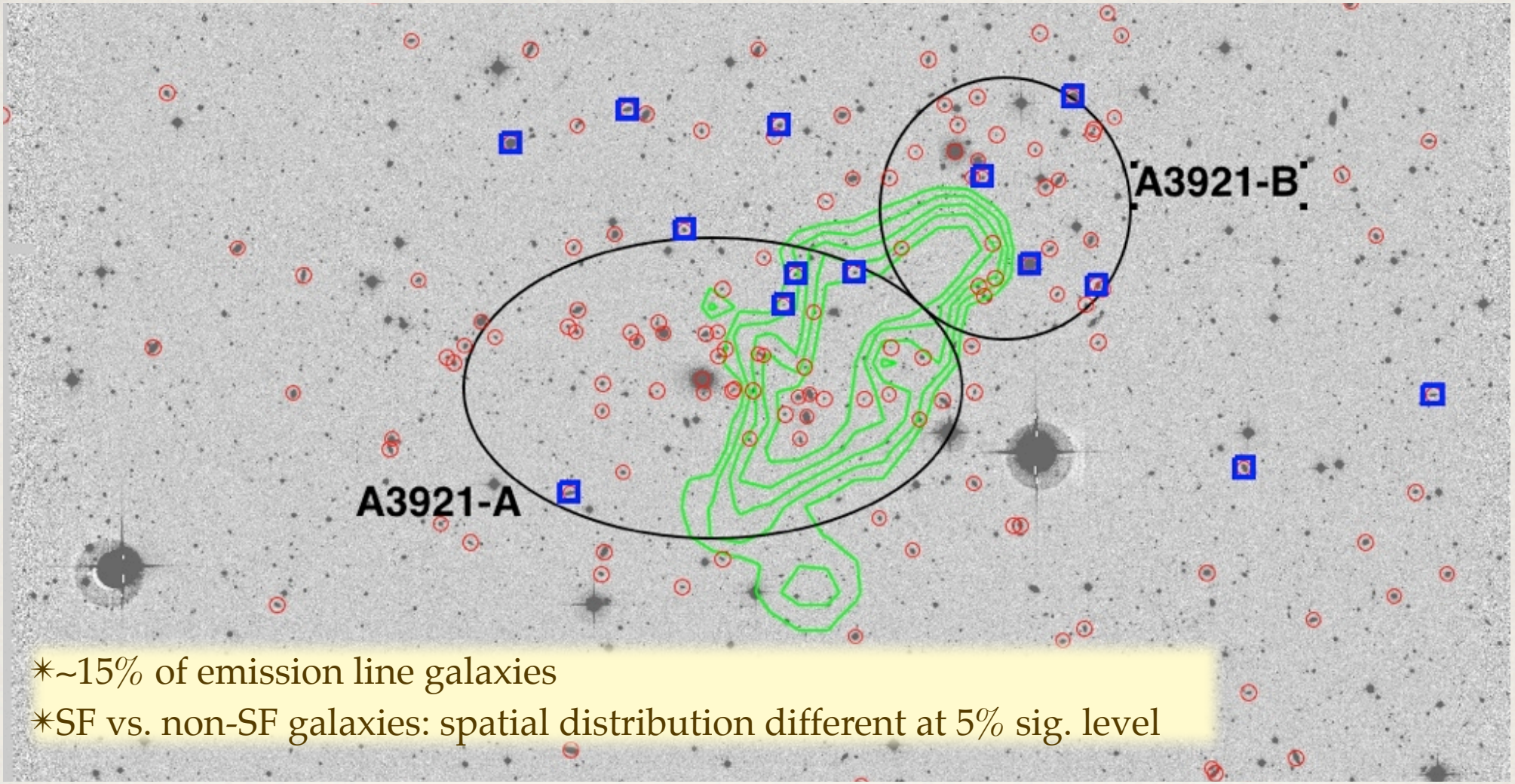


Kewley+ 01



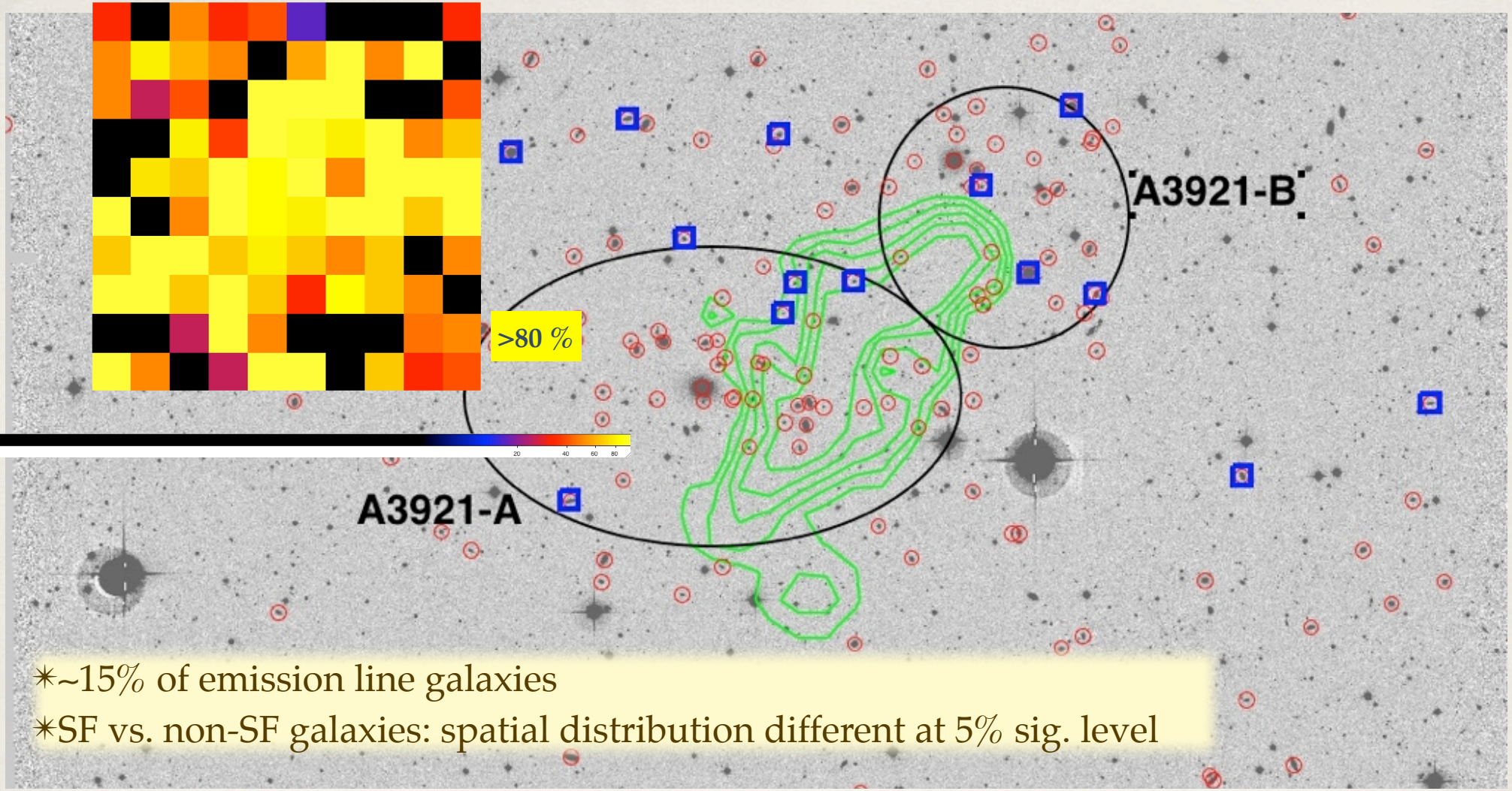


✳~15% of emission line galaxies

✳SF vs. non-SF galaxies: spatial distribution different at 5% sig. level

Star formation & merging event

Clear correlation between SF galaxies & collision region



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Star forming galaxies vs. AGNs

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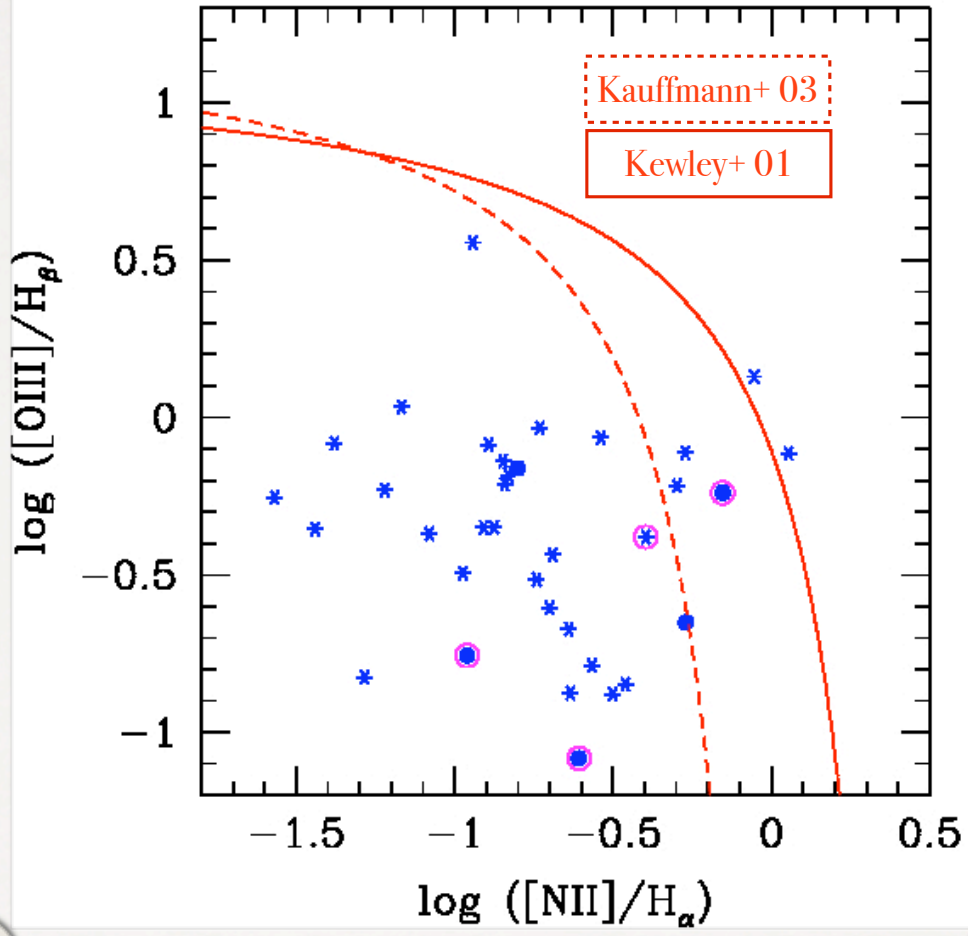
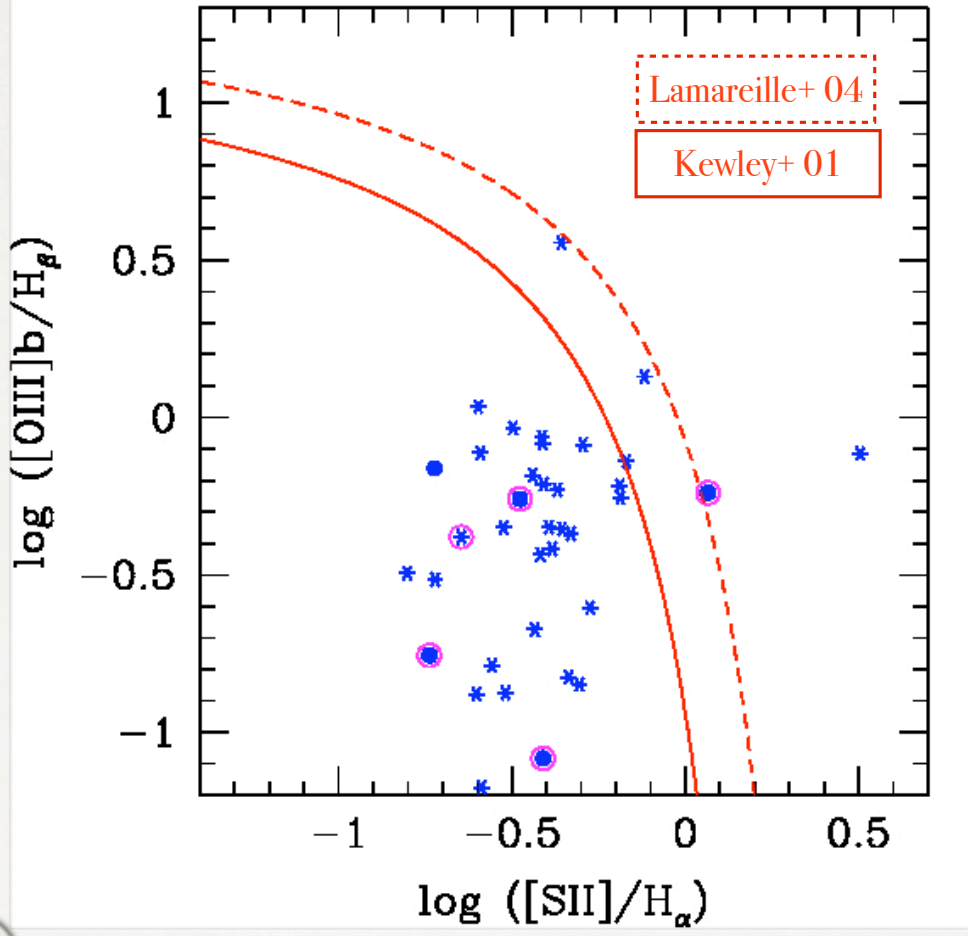
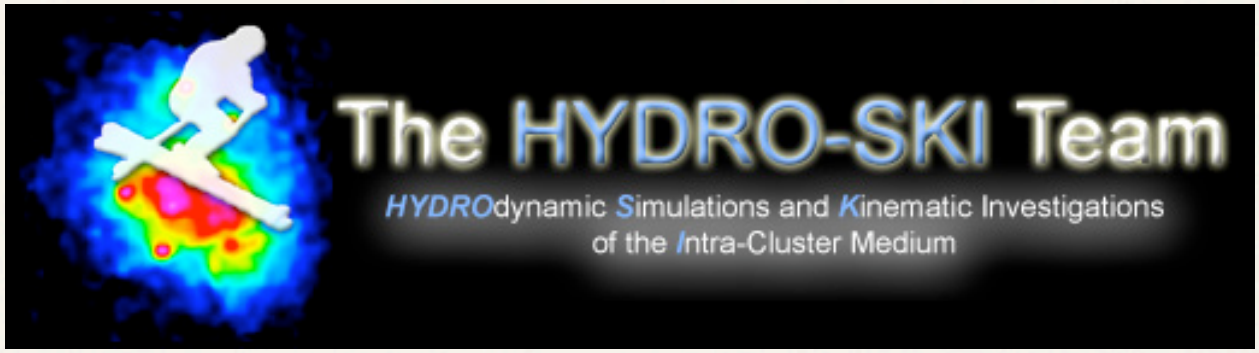




SF enhanced in the collision region: why?

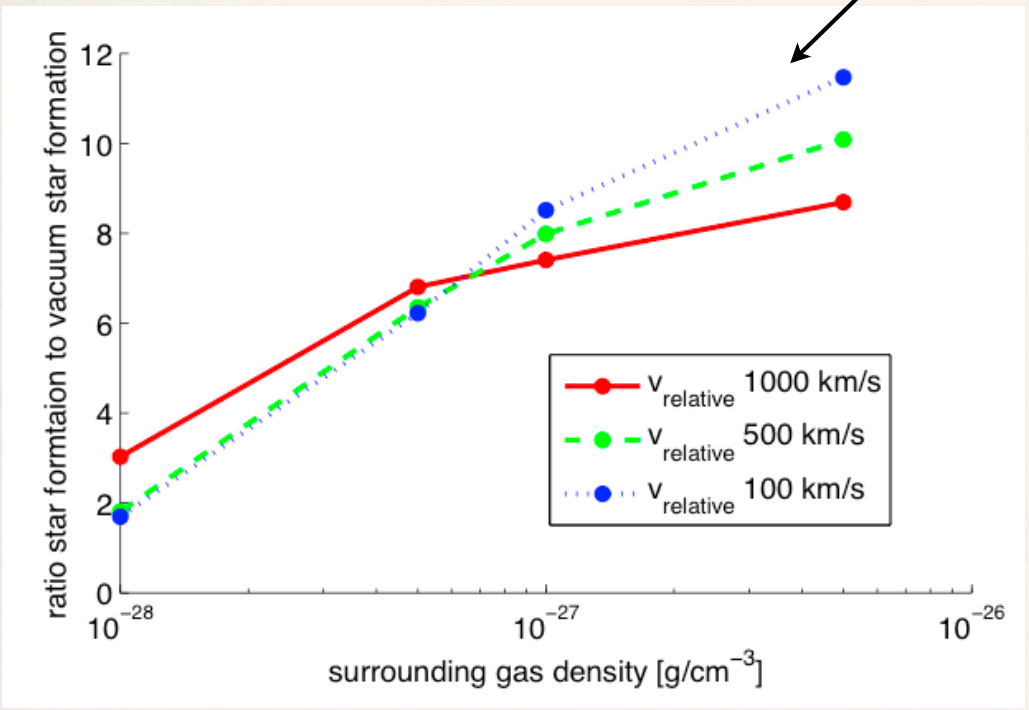
Comparison with numerical simulations by “Hydro-Ski” team

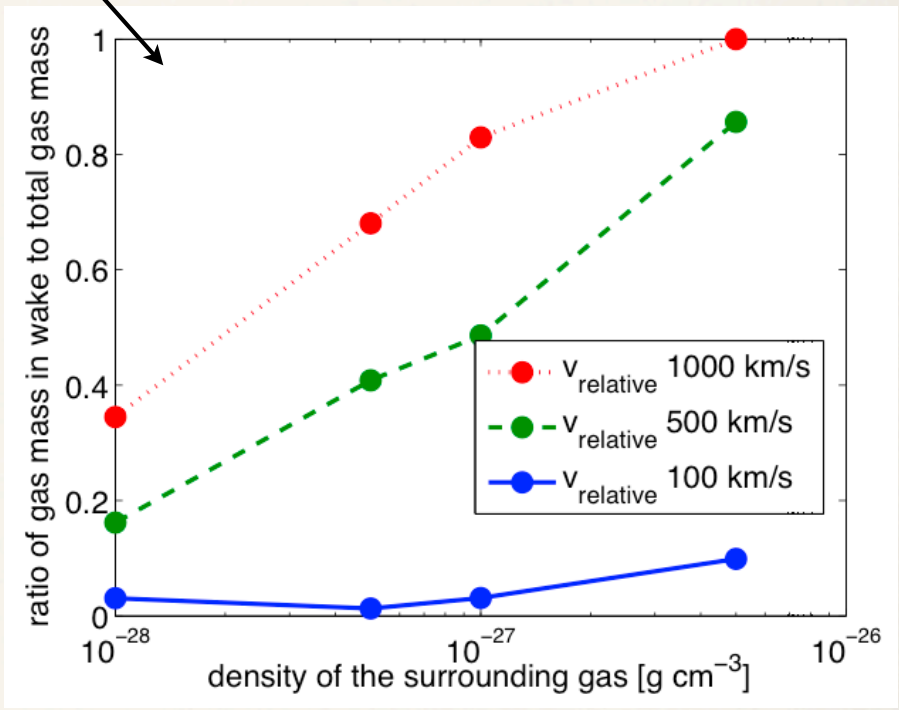
S. Schindler & Collaborators @ Innsbruck University



SF enhanced in the collision region: why?

500 Myr after the galaxy starts to feel the ram-pressure

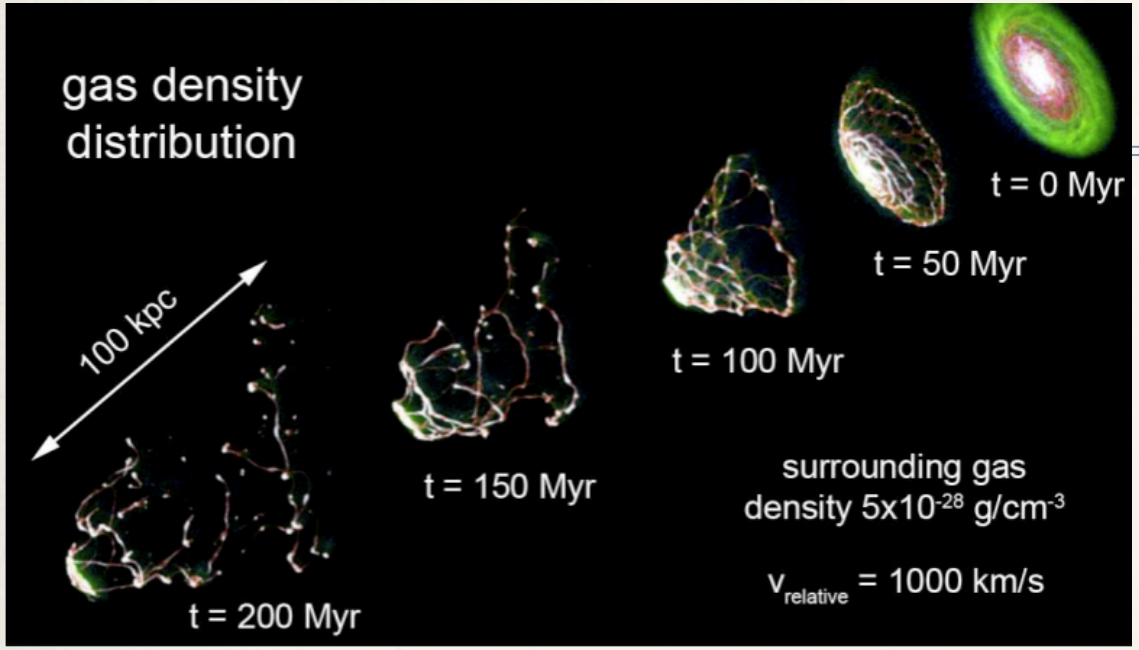




Kapferer+ 09

➞ Ram-pressure can enhance star formation in a galaxy

Where do stars form?



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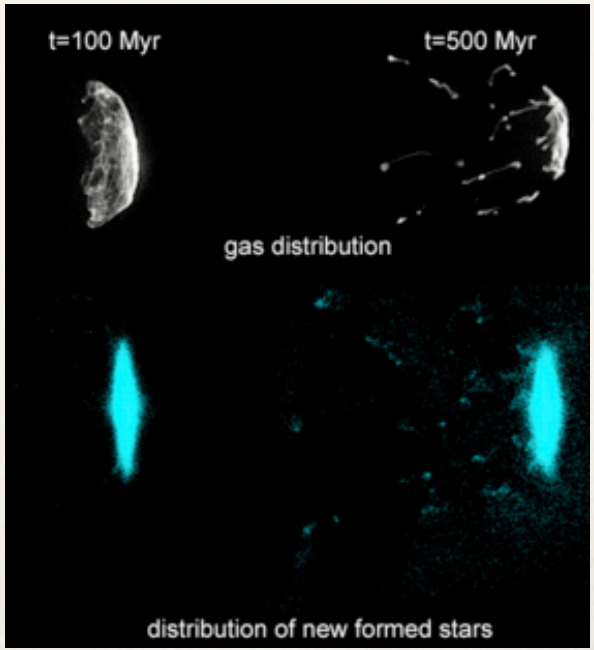
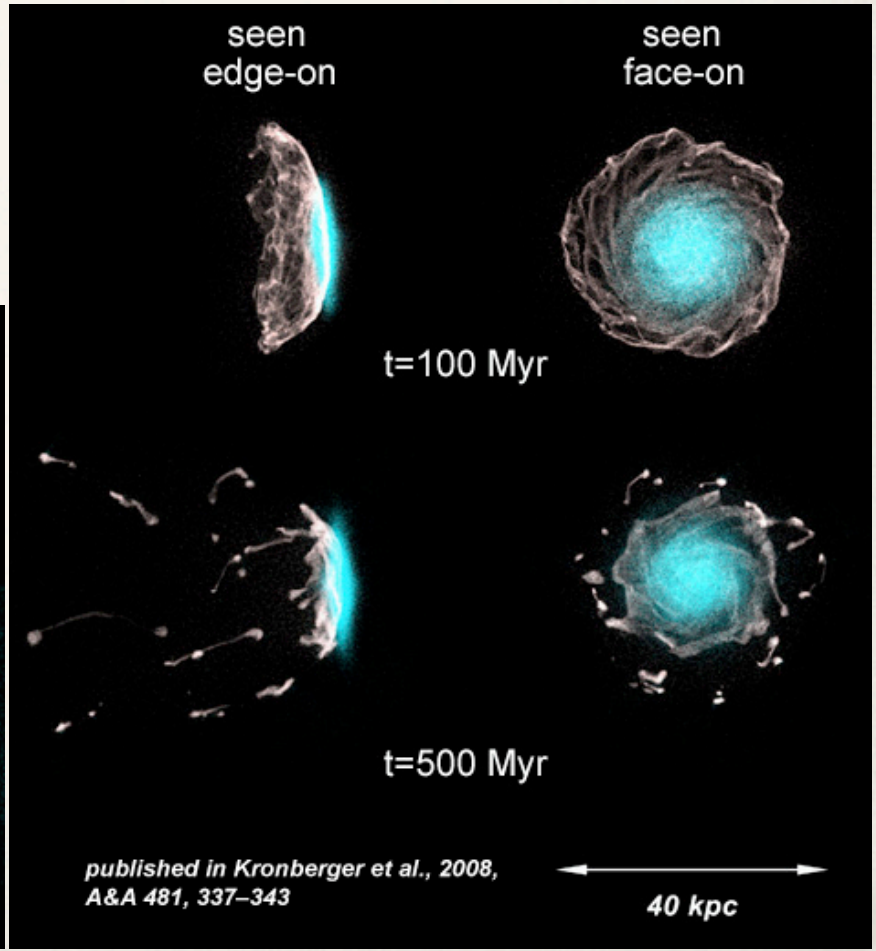


Kronberger+ 08



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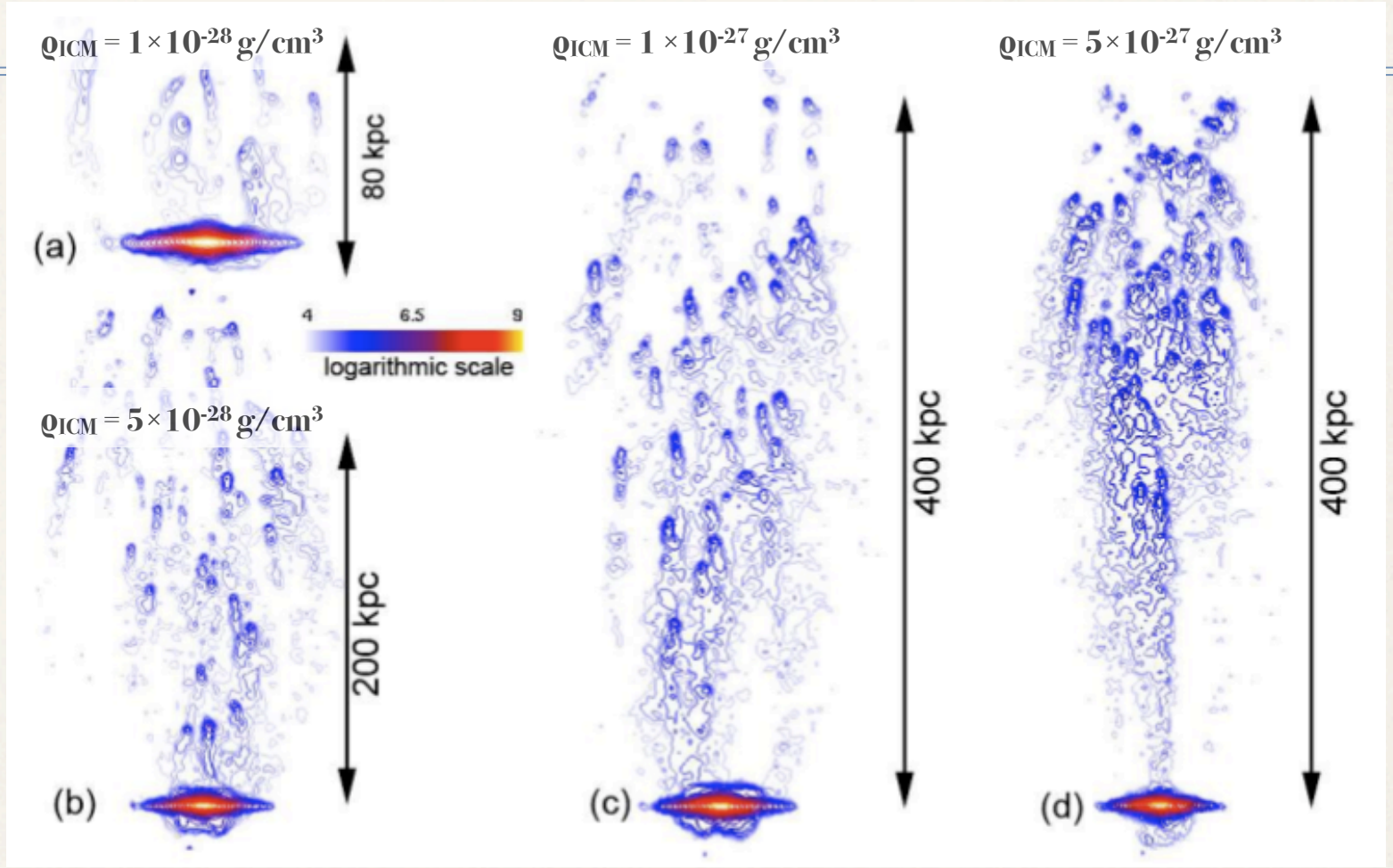


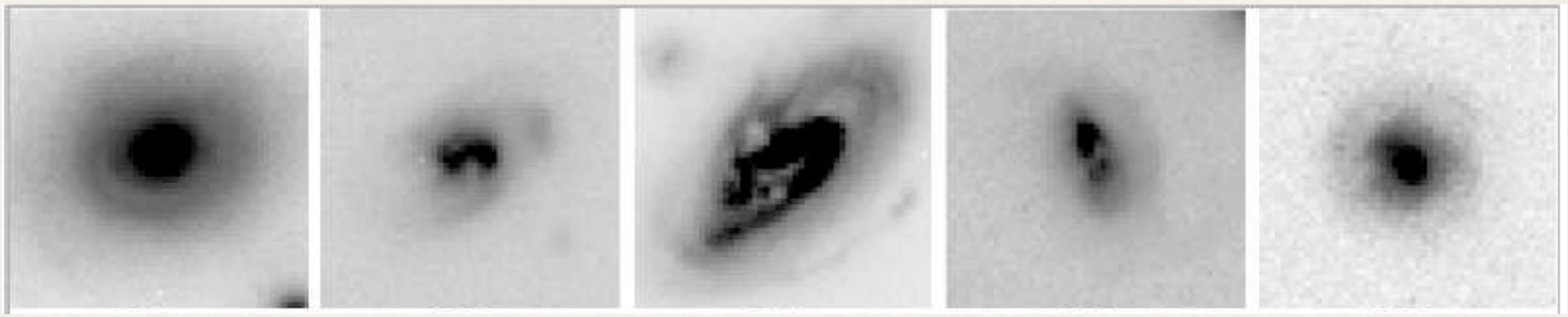
$v_{rel} = 1000$ km/s

Surface density of stellar component 500 Myr after ram-pressure has started

Kapferer+ 09

SF enhanced in the collision region: why?

- Galaxy-galaxy interactions and mergers (e.g. Duc+ 97)
- Galaxy mergers + ram-pressure (e.g. Kapferer+ 08)
- Galaxy mergers + cluster tidal field (e.g. Martig & Bournaud 08)

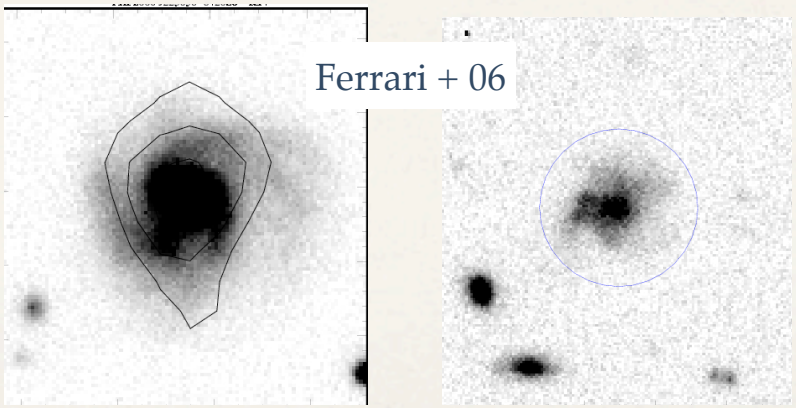


HST observations of dusty star forming galaxies at the center of the merging cluster A851 (Oemler+ 09)

SF enhanced in the collision region: why?

- Galaxy-galaxy interactions and mergers (e.g. Duc+ 97)
- Galaxy mergers + ram-pressure (e.g. Kapferer+ 08)
- Galaxy mergers + cluster tidal field (e.g. Martig & Bournaud 08)

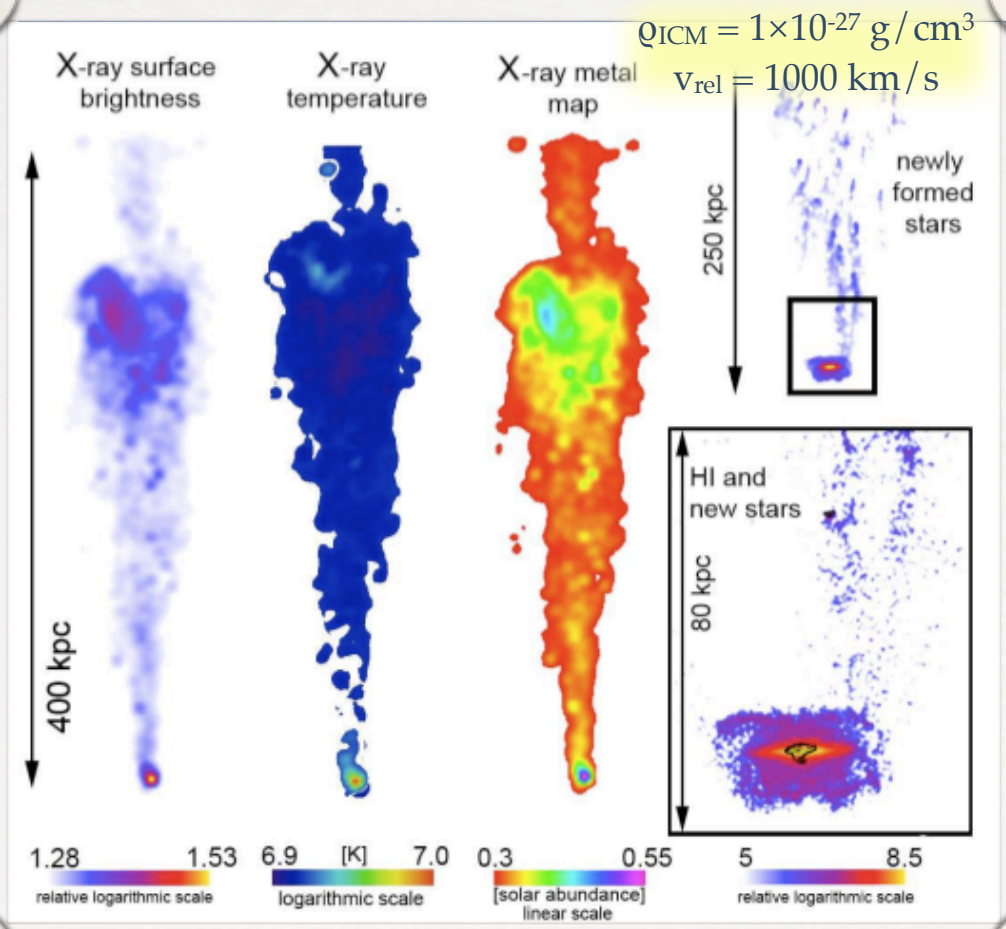
- No emission lines
- log (L_{22cm}(W/Hz)) = 22.20 (SFR=19.6)
- Not in the collision region



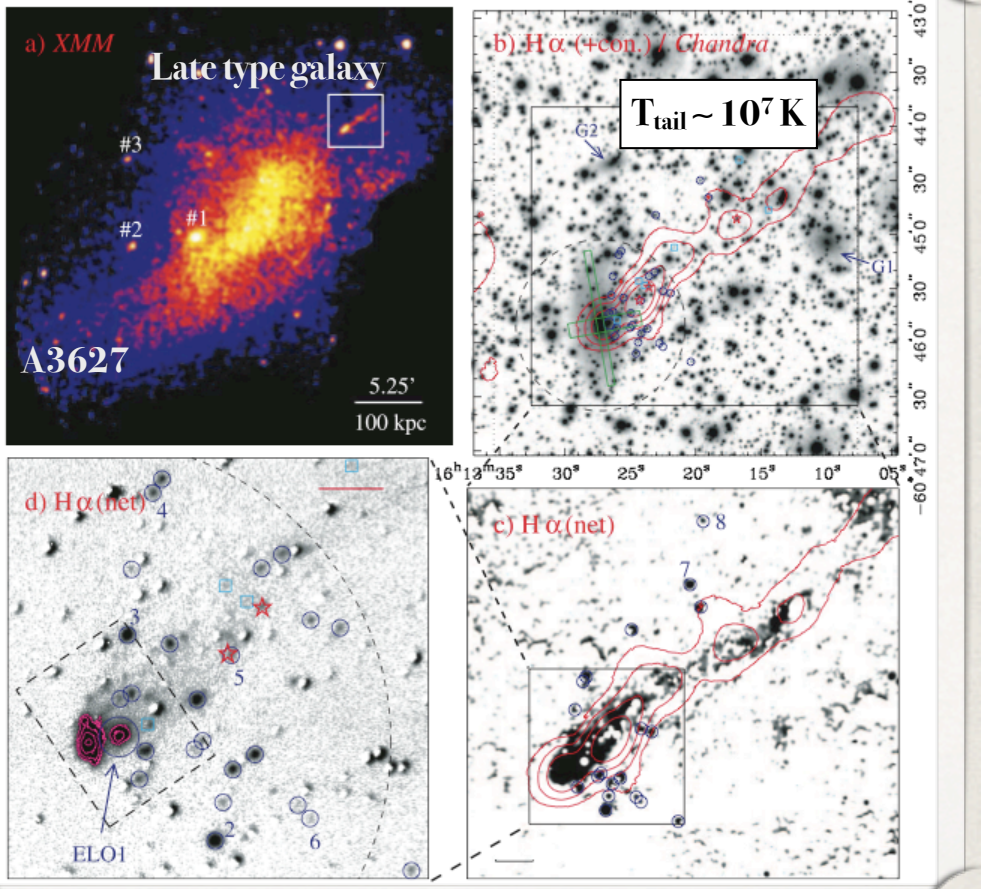
Ferrari + 06

- e(b) spectral type (SFR=1.74)
- log (L_{22cm}(W/Hz)) < 21.34 (SFR<3.05)
- In the collision region

Simulations *vs.* other observations



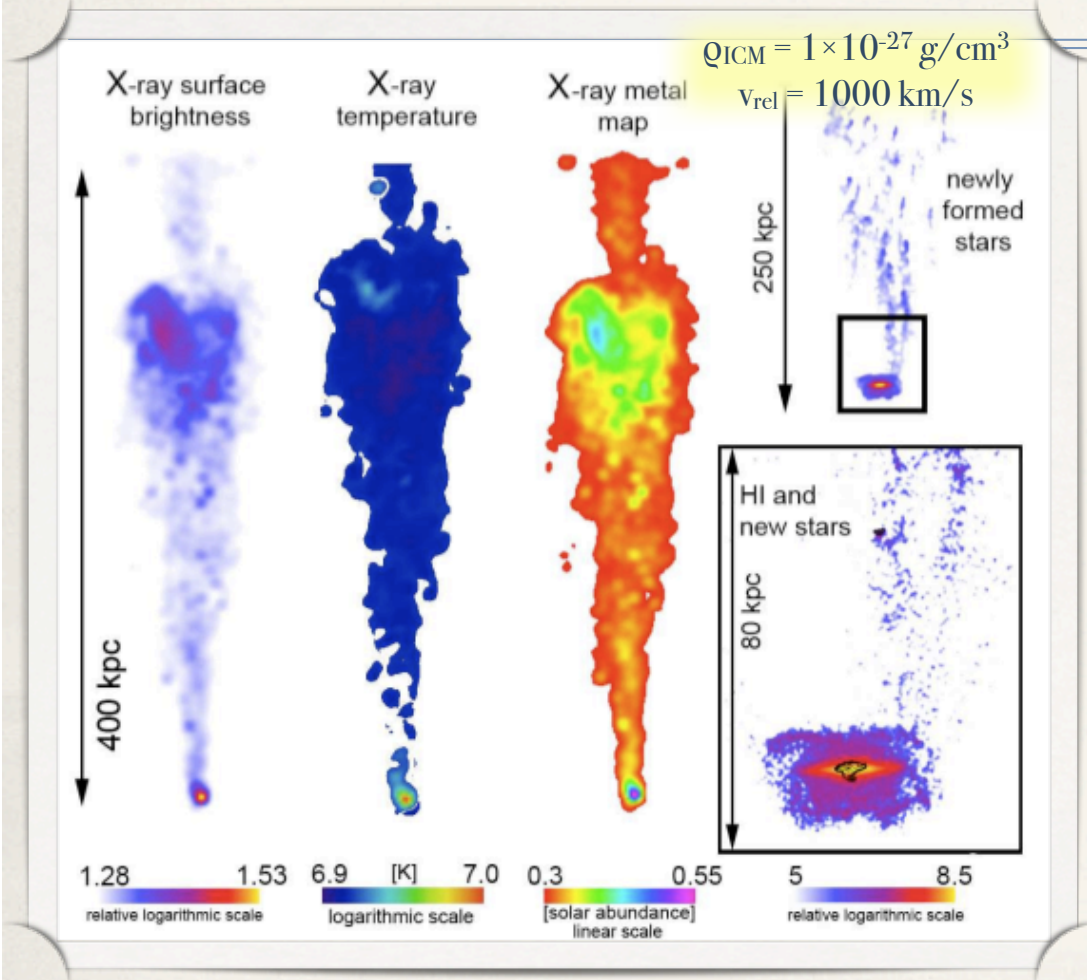
Kapferer+ 09



Sun+ 06,07

See also e.g. Randall+ 08; Kim+ 08

Simulations *vs.* other observations



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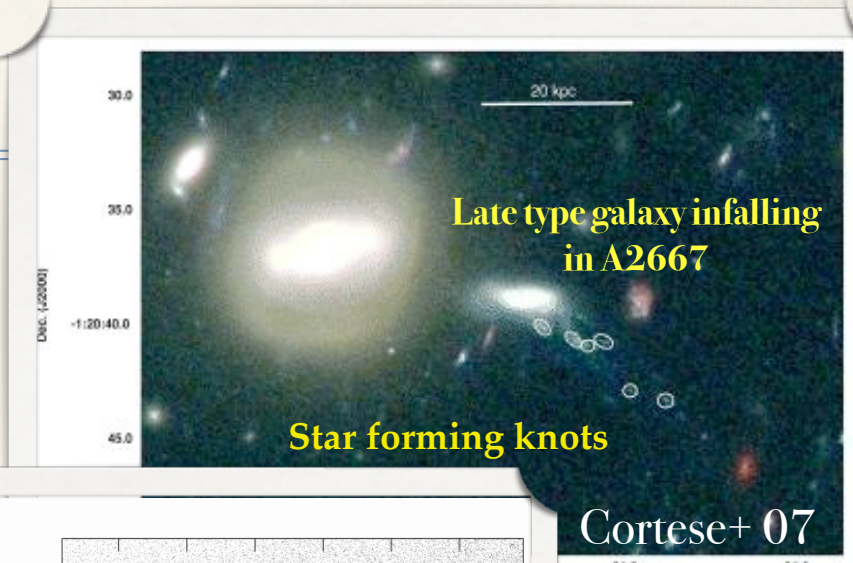
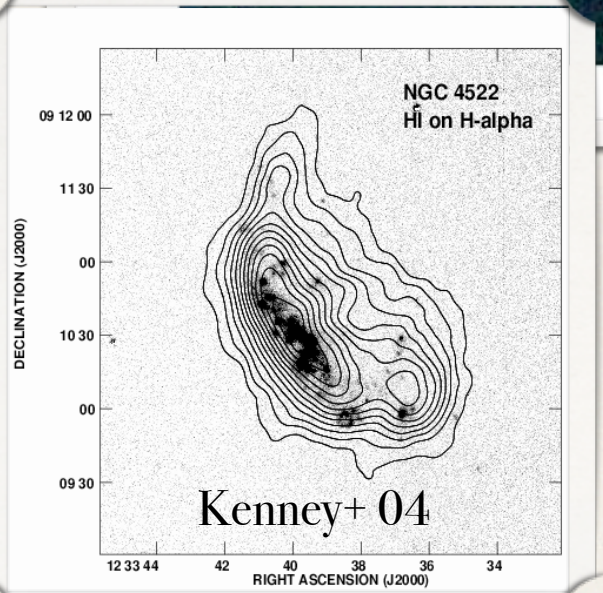
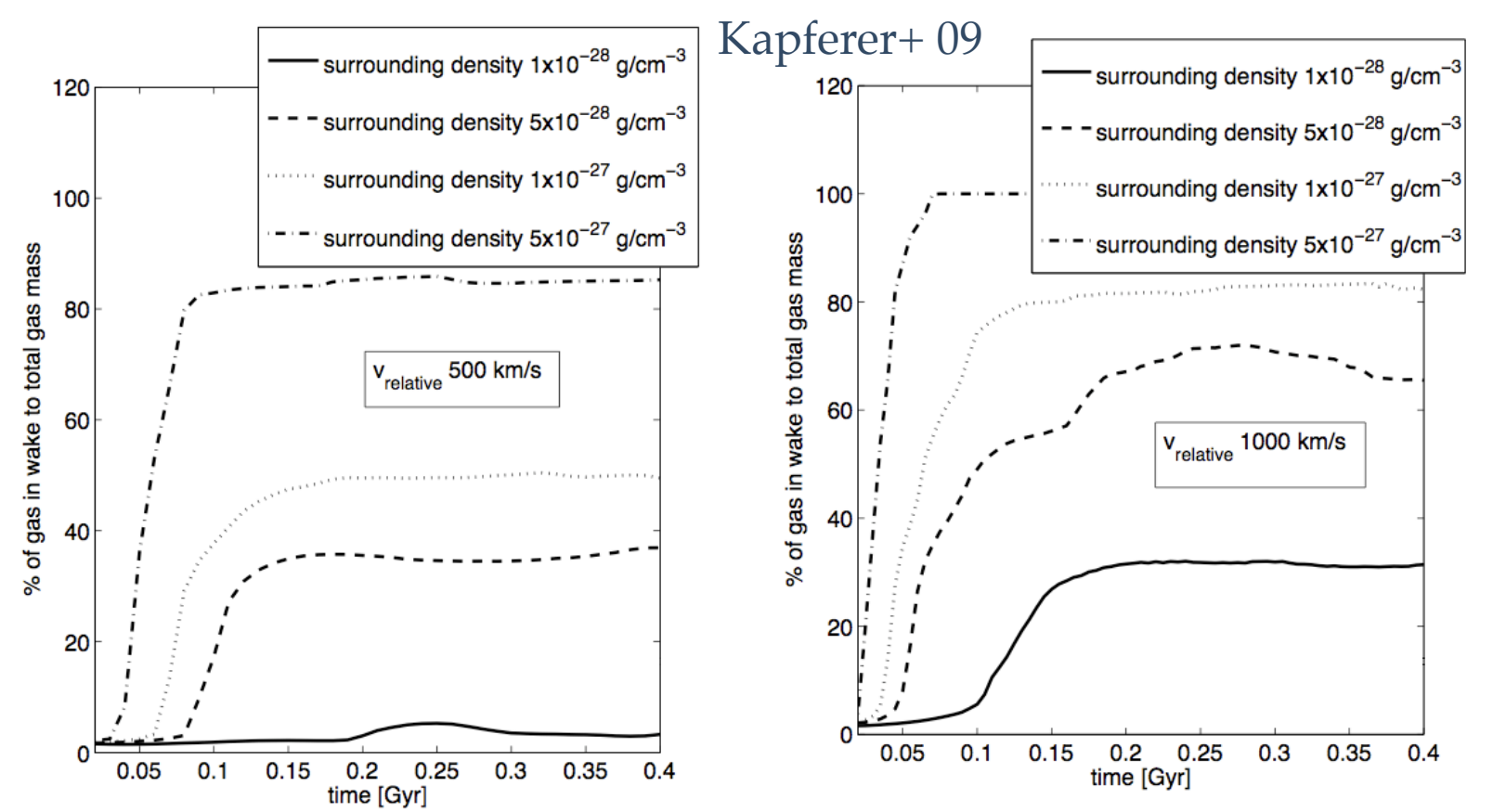




See also, e.g.: Crowl+ 05; Oosterloo+ 05; Cortese+ 06; Yoshida+ 02,04,08

Simulations *vs.* other observations

Kapferer+ 09



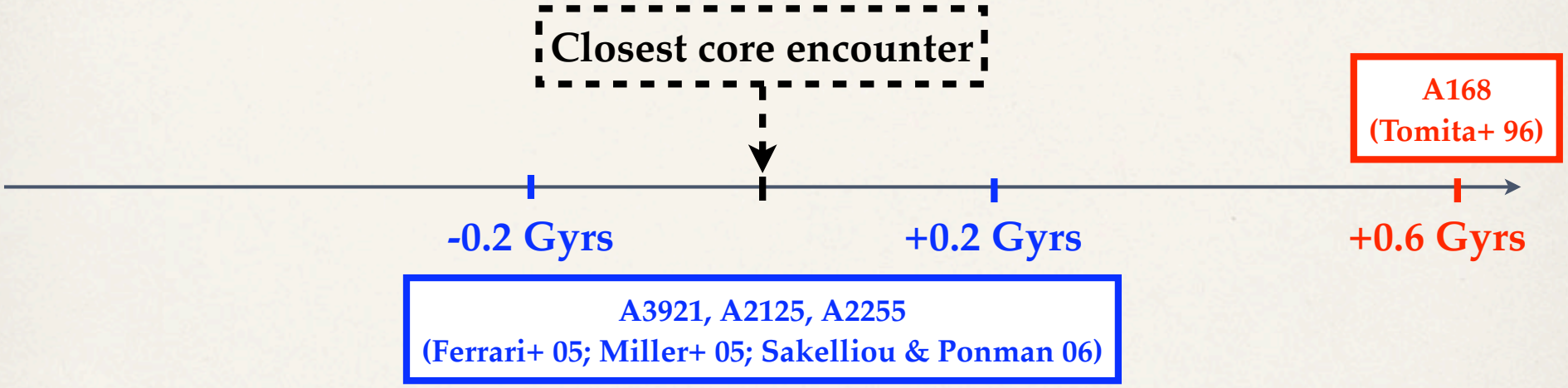
➞ Fast (<< 1 Gyr) gas depletion of the disk by ram-pressure

In agreement with observational evidence that the physical mechanism(s) switching off star formation in dense environments must act on short timescales

(e.g. Balogh+ 04; Cassata+ 07; Poggianti+ 09)

Cluster Mergers & Star Formation

- Star formation enhanced in the collision region of A3921
- Possible physical origin: ram-pressure ⇒ **enhancement** and subsequent **quenching** of star formation in cluster galaxies

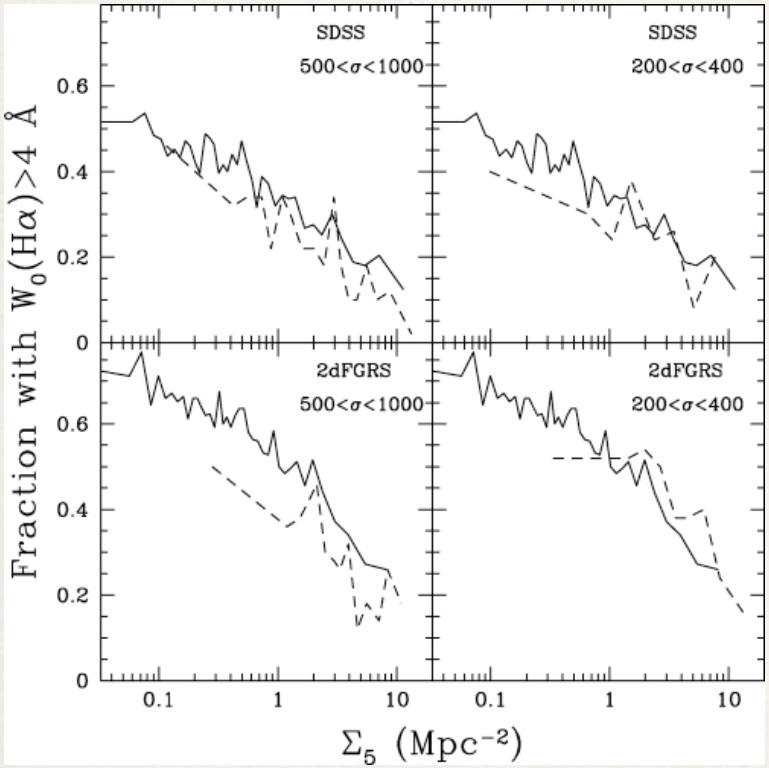


- Need of detailed multi-wavelength analyses of significant samples of merging clusters at different redshifts

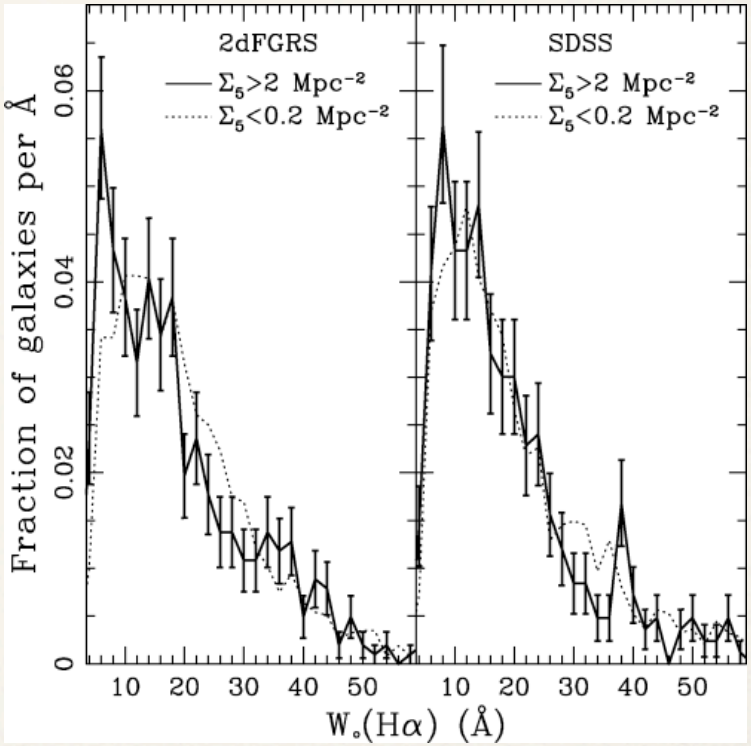
Increasing fraction of **red galaxies** with **density**

and / or

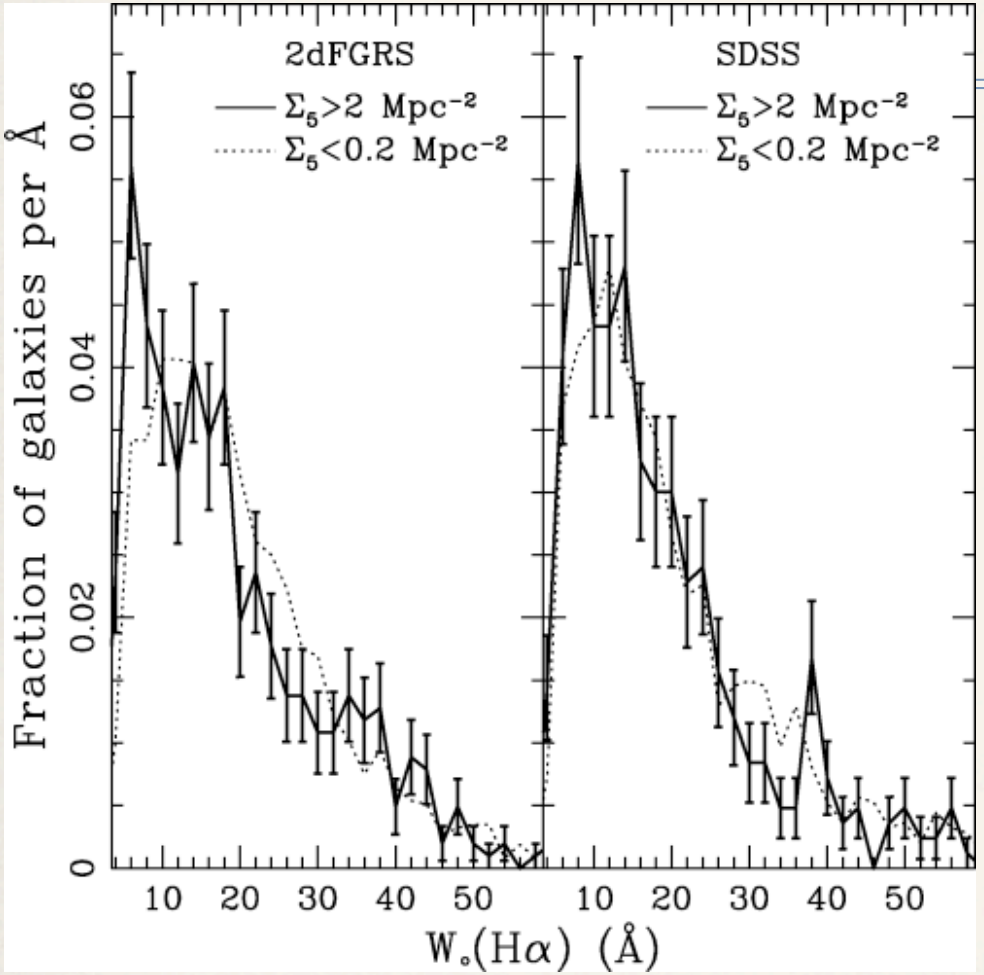
difference in the
fraction of star forming galaxies



difference in the
SFR of star forming galaxies



Balogh et al. 2004



Distribution of EW(Hα) for galaxies in:

Low density environment (dotted line)

High density environment (solid line)

Balogh et al. 2004

The **physical mechanism(s)** switching off SF in dense environments must act on **short timescales** (< 1 Gyr)