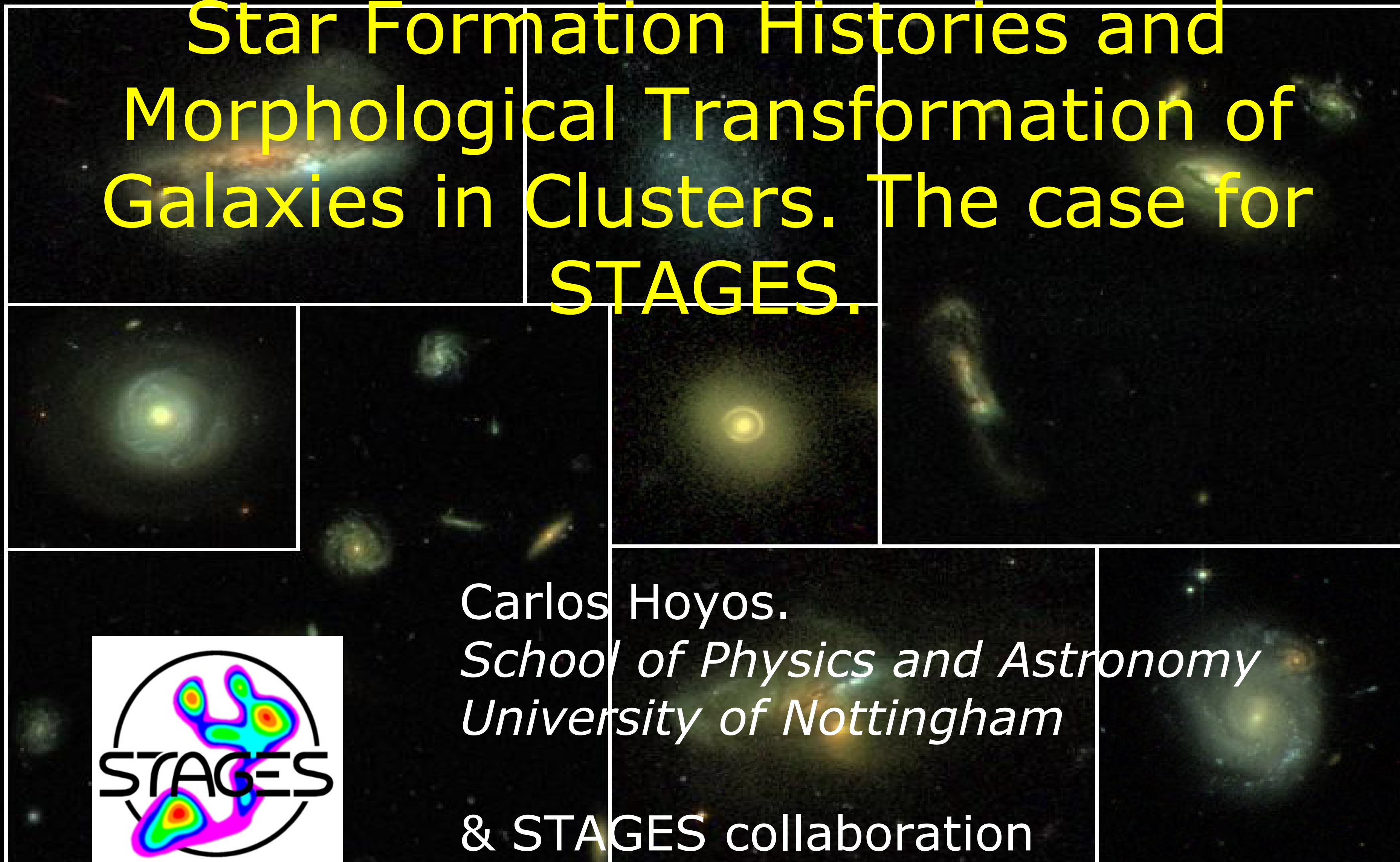
The University of Nottingham

Star Formation Histories and Morphological Transformation of Galaxies in Clusters. The case for STAGES.

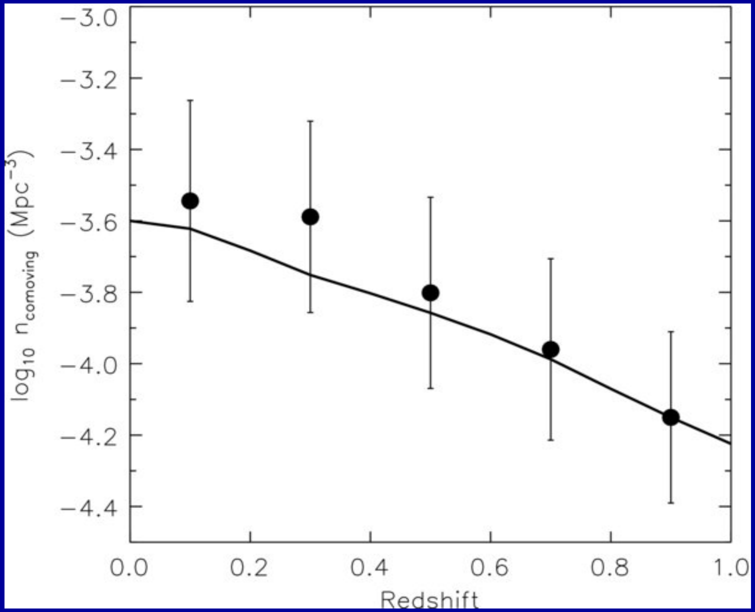


Carlos Hoyos.
School of Physics and Astronomy
University of Nottingham

& STAGES collaboration

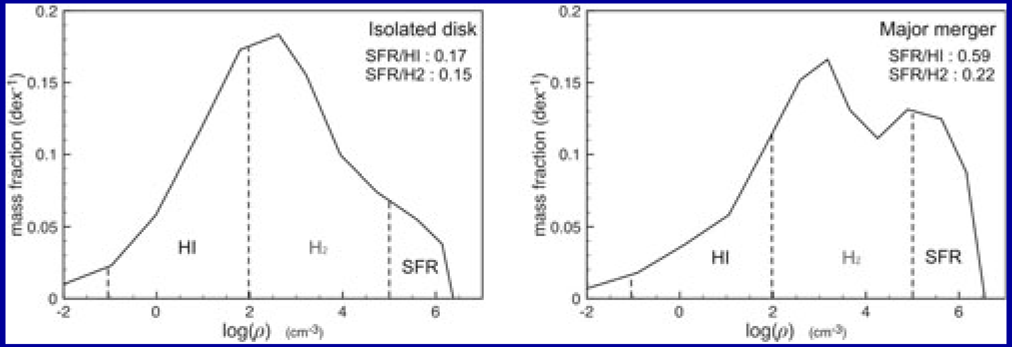
Motivation. Galaxy Mergers.

Number density evolution of red, massive ($M>10^{11}$) ETGs model.



Mergers:

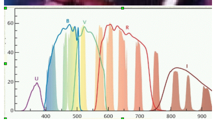
- Disrupted morphologies.
- High SFRs.



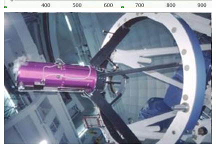
Is disruption somehow coupled with the SFH?

Space Telescope A901/2 Galaxy Evolution Survey.

Hubble Space Telescope — 80-orbit mosaic: morphologies, weak gravitational lensing



COMBO-17 survey (Wolf) — 17-band optical imaging: photo-zs + SEDs for 15000 objects

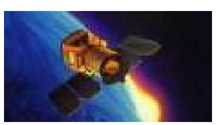


Omega2000 @ Calar Alto (Meisenheimer) — near-infrared extension (Y, J1, J2, H): M*, photo-zs

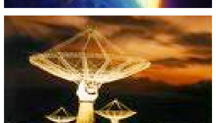
2dF spectrograph — spectroscopy of ~300 cluster galaxies: dynamics, star-formation histories

XMM-Newton — 90 ks X-ray imaging/spectroscopy: ICM, AGN

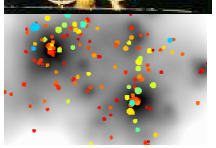
Spitzer (Bell) — infrared imaging (8 and 24 μm): obscured star formation, AGN



GALEX (GALEX team) — NUV + FUV imaging: unobscured star formation



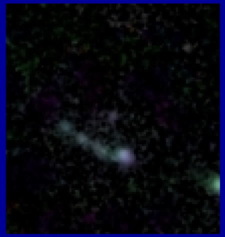
GMRT (Green, Beswick, Saikia) — radio imaging (610 and 1400MHz) obscured SF, AGN

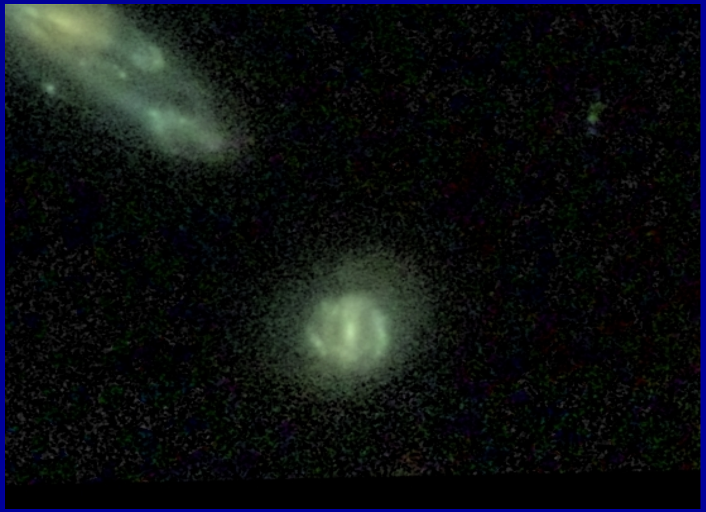


constrained simulations (van Kampen) — N-body + hydro + semi-analytic models dark matter, gas, galaxies

Galaxy Sample.

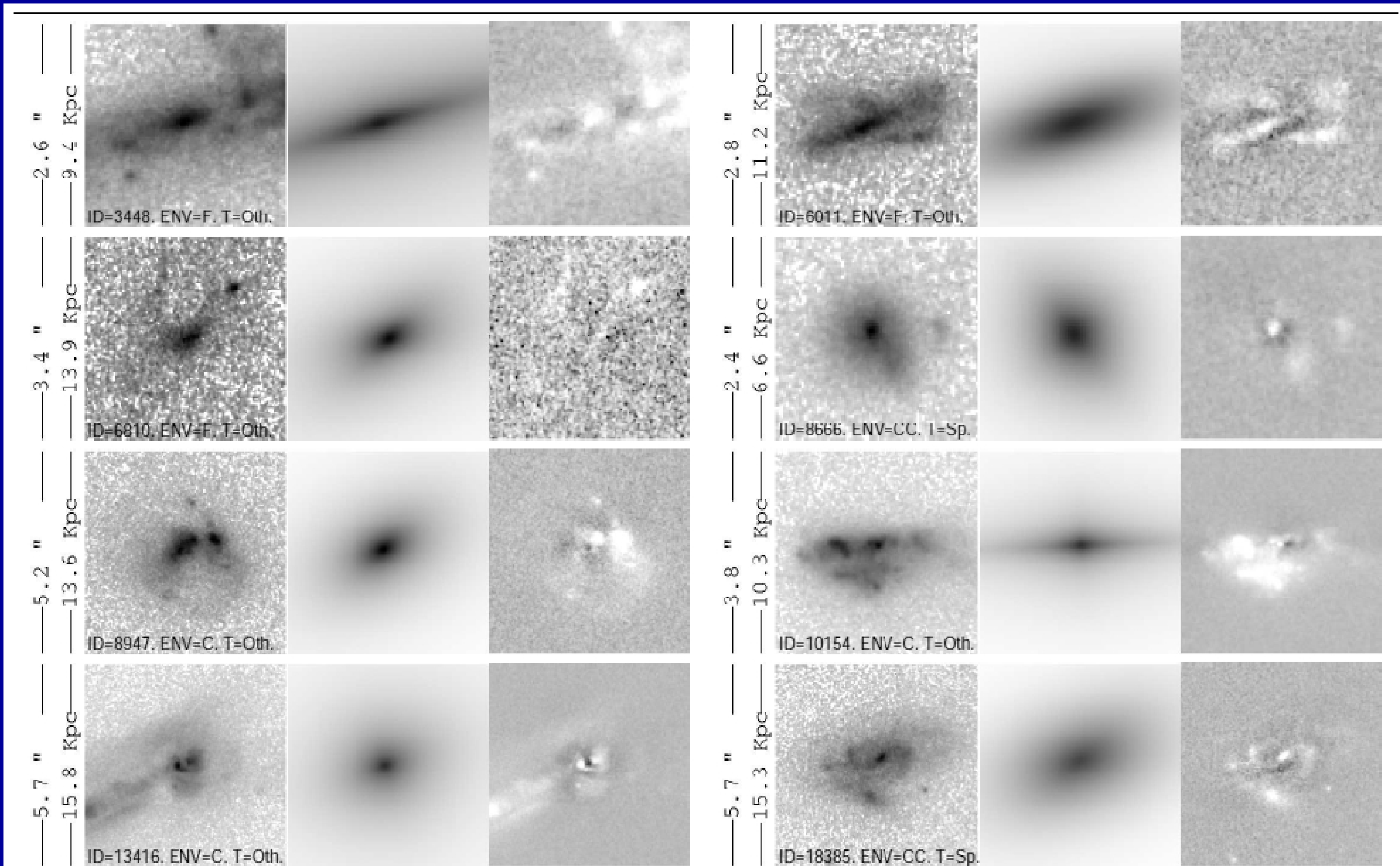
1) Mass/magnitude sample ($9.0 < \log(M/M_{\odot})$, $R_{Vega} < 23.5$).
2) $0.05 < z_{Phot} < 0.30$.
3) 905 Cluster (192E, 216S0, 383Sp, 114Irr).
4) 655 Field (100E, 60S0, 318Sp, 177Irr).




Merger Detection Technique.

Hoyos, C., et al. (2012)



Structural Parameters of Residuals.

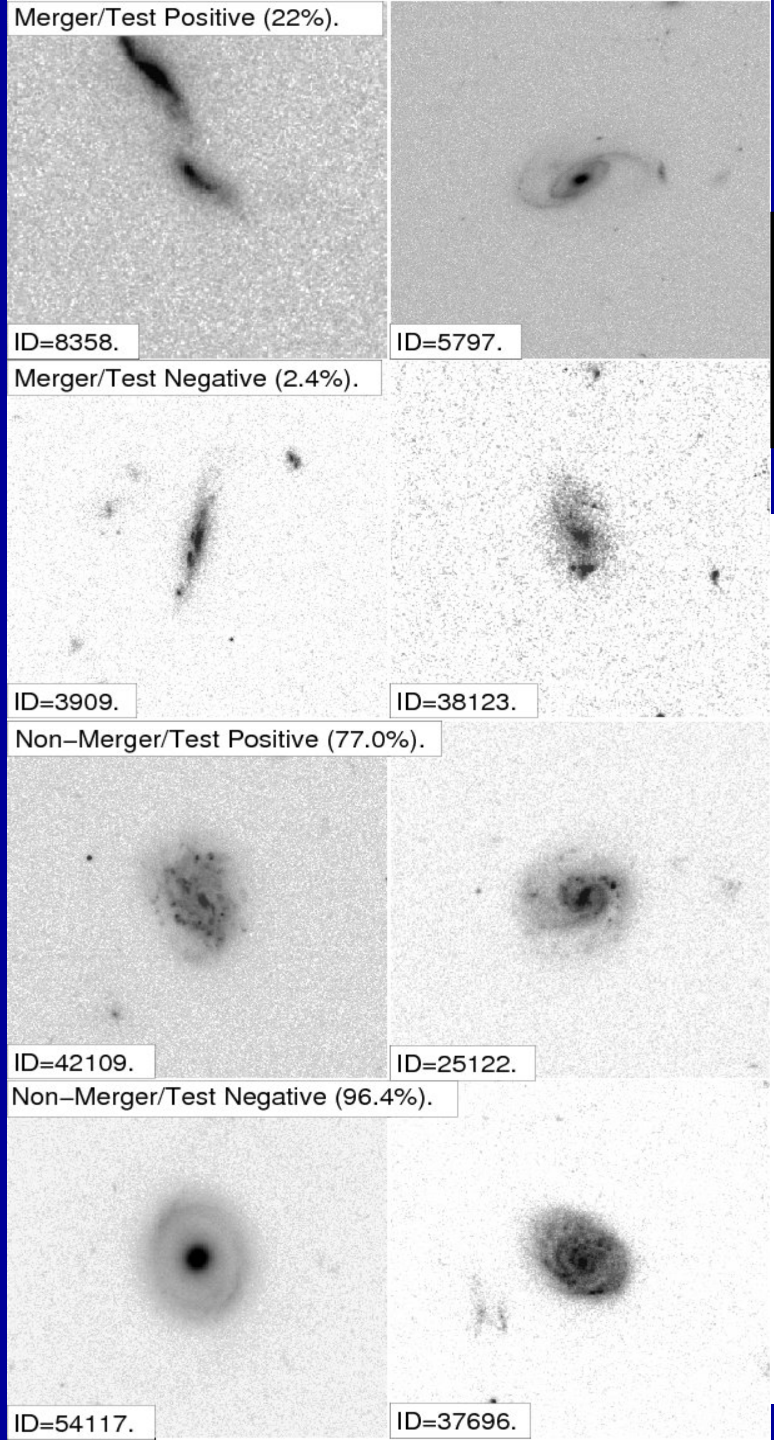
- GALFIT used to create **smooth Sérsic model**.
- Structural properties of residual image explored.

RFF: Signal present or absent in the **residuals** that **cannot be explained by the photometric errors**.

$$RFF = \frac{\sum_{i,j\in A} |I_{i,j} - I_{i,j}^{\mathrm{GALFIT}}| - 0.8 \times \sum_{i,j\in A} \sigma_{\mathrm{Bkg}\; i,j}}{\sum_{i,j\in A} I_{i,j}^{\mathrm{GALFIT}}},$$

Asymmetry of residuals.

$$A = \left(\frac{\sum_{i,j} |I_{i,j} - I_{i,j}^{180}|}{\sum_{i,j} |I_{i,j}|}\right) - \left(\frac{\sum_{i,j} |B_{i,j} - B_{i,j}^{180}|}{\sum_{i,j} |I_{i,j}|}\right),$$

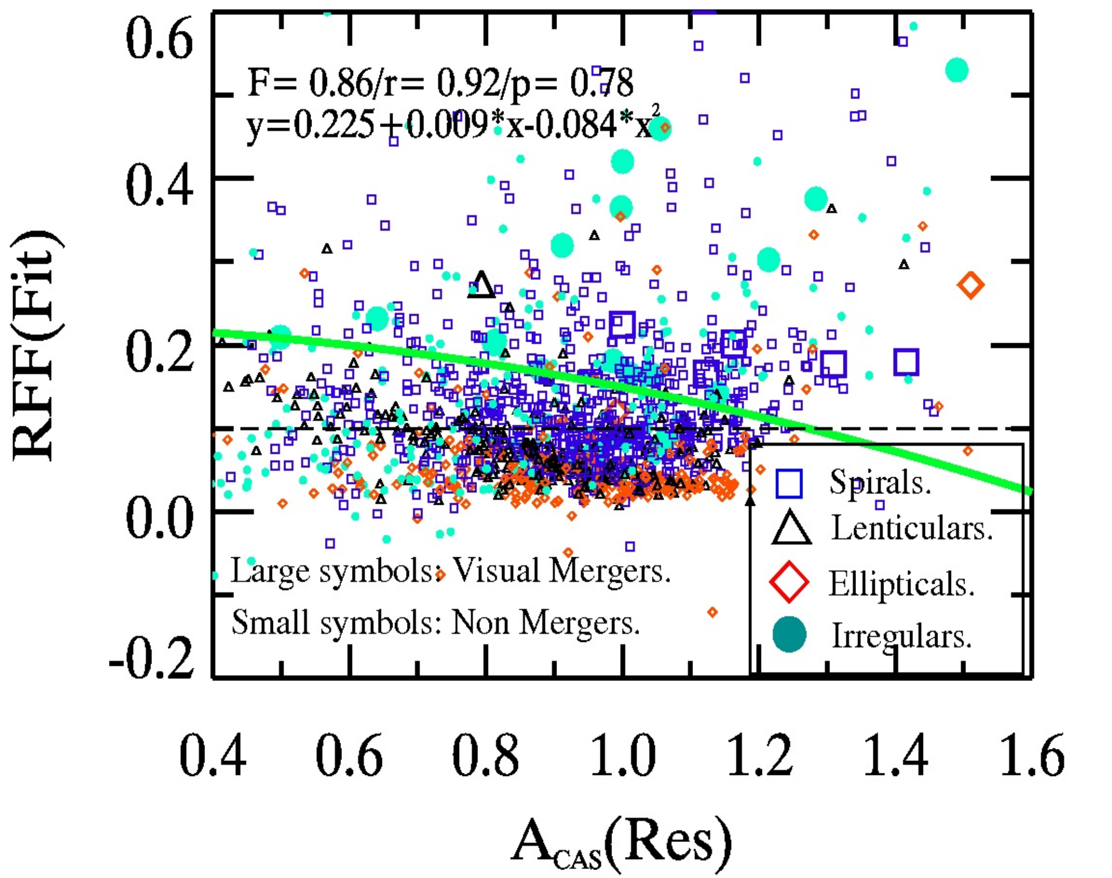


Samples.

Merger sample: 70% Contamination.

NON MERGER SAMPLE: 97% PURE

Excellent non-merger test.



Some Thoughts.

Very good pre-filter. One question:

What are the **SFHs** of the different galaxy sets produced by the automated diagnostics and visual inspection?

Specifically:Is there any difference between a **visual merger and a disturbed non merger**?

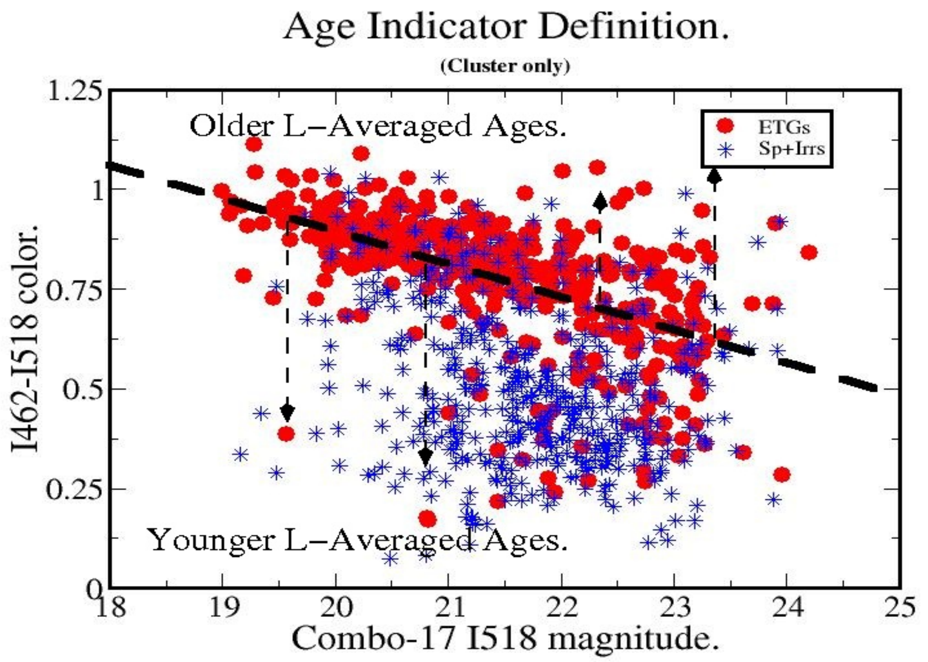
These questions spell out explicitly the goals of this research.

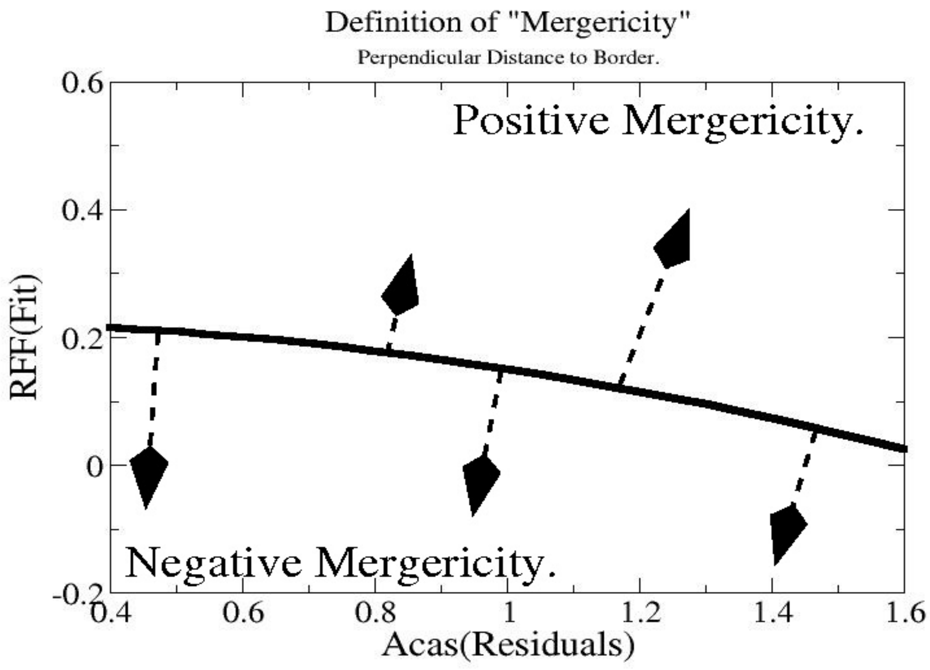
Tools.

1)SFRs
SEDs+Spitzer 24μ (PEGASE models).

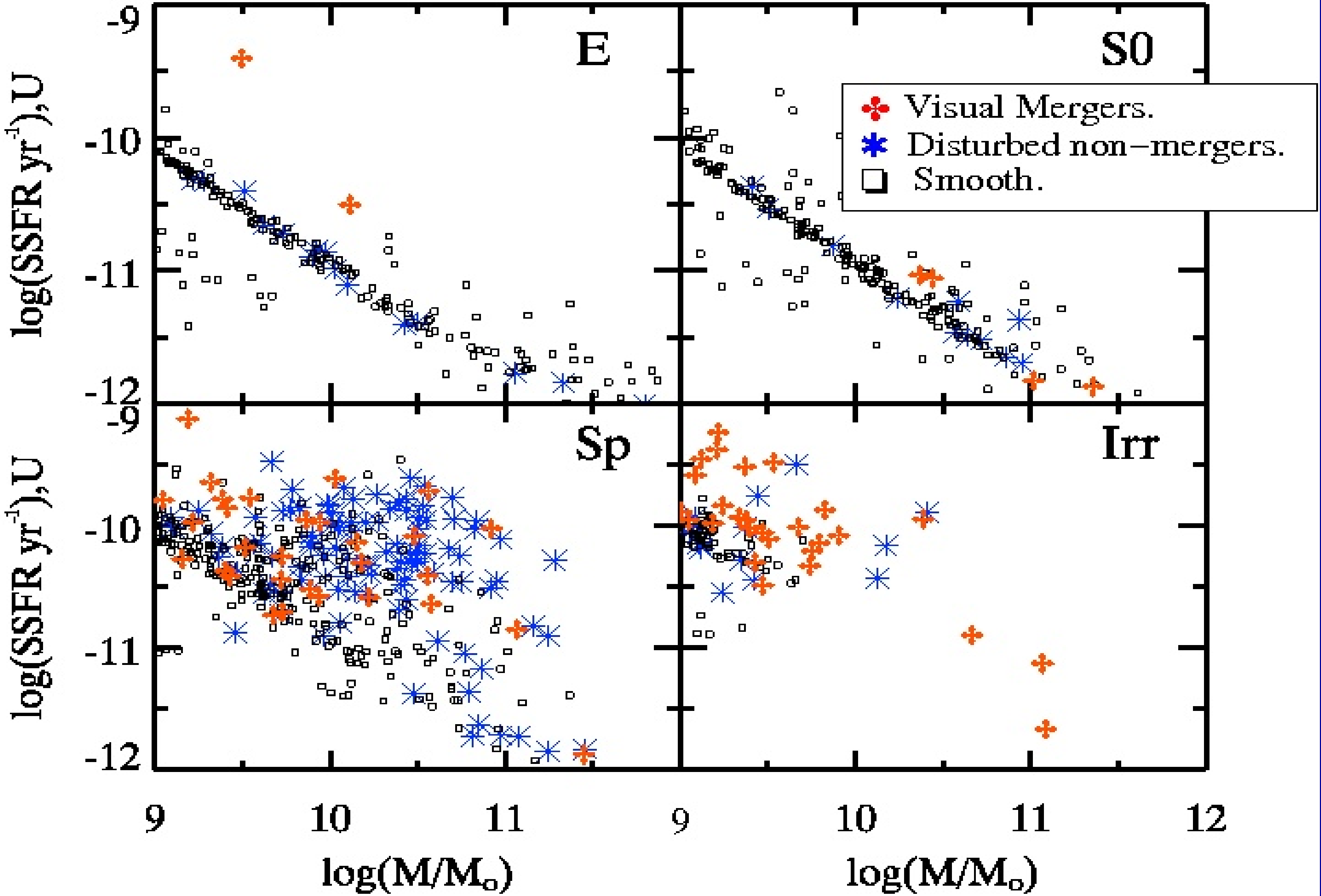
2)Color-based Age Indicator.

3)"Mergericity".
Structural disruption diagnostic.

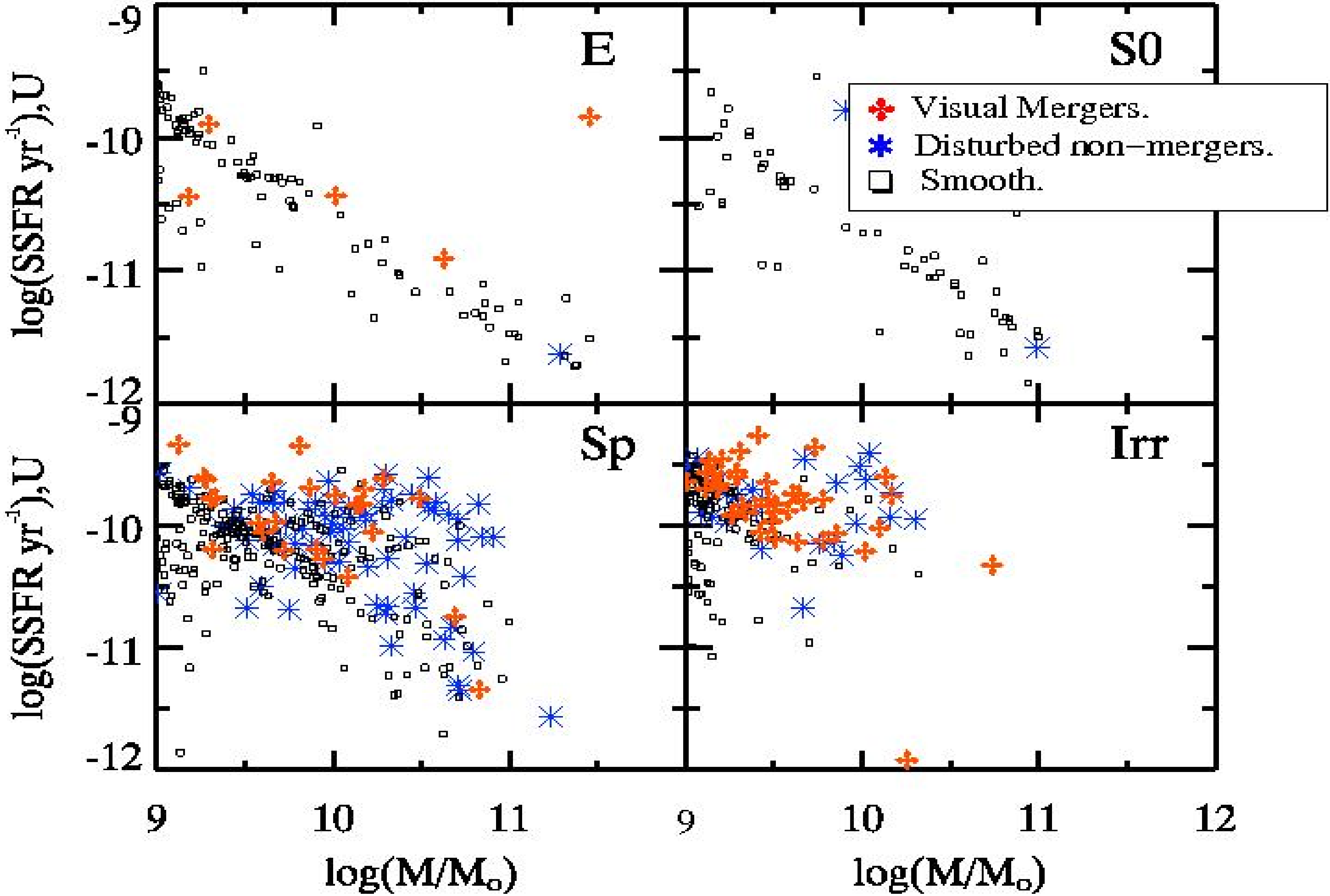




Recent Mass Assembly Histories (Cluster).



Recent Mass Assembly Histories (Field).

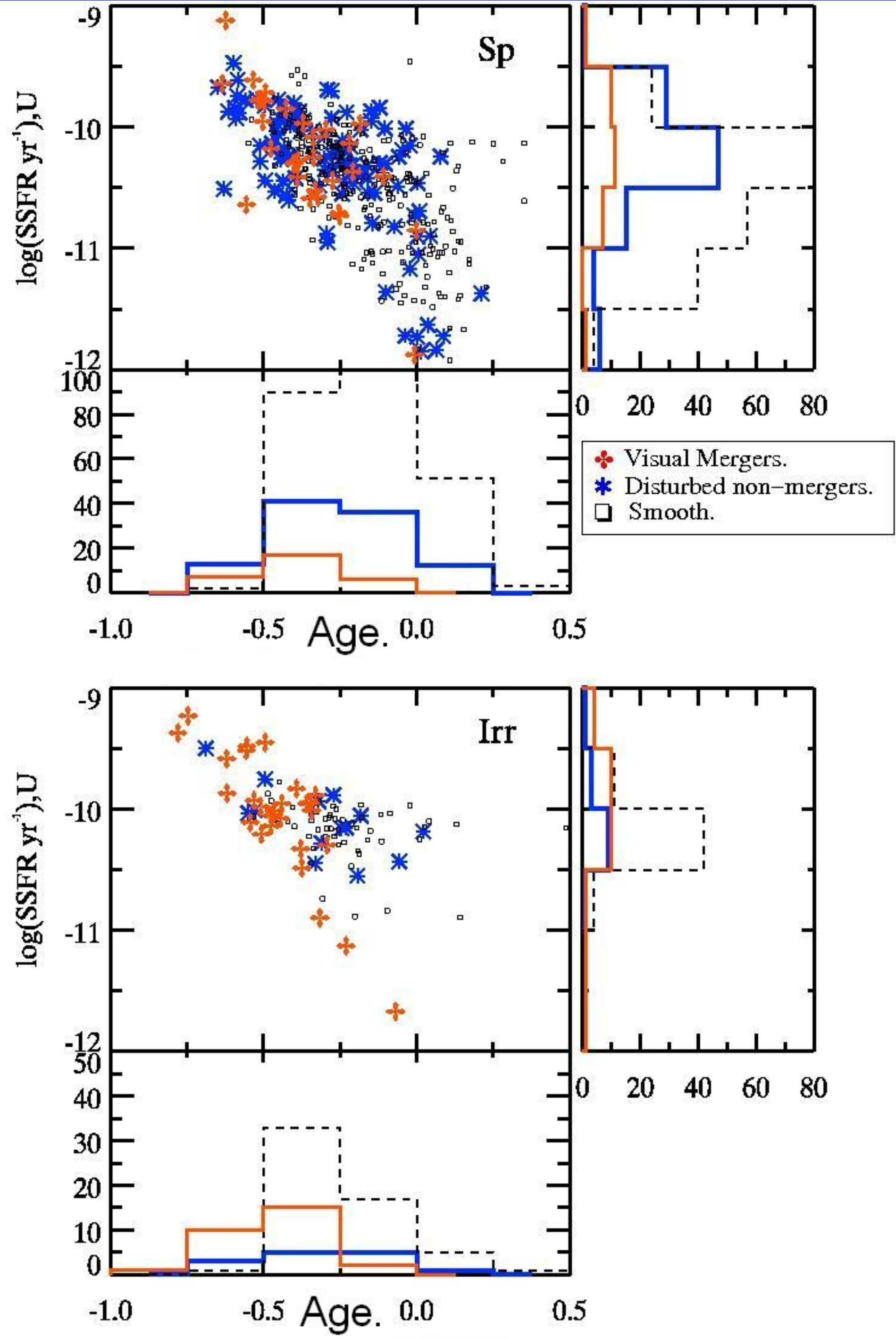


Star Formation History (Cluster).

1)Es, S0s:
Smooth and Passive.

2)Sps, Irrs:
Smooth and Disturbed
differ in SFR, Age.
Disturbed and Mergers
fully compatible.

Disturbed non-mergers and visual mergers same SFH.



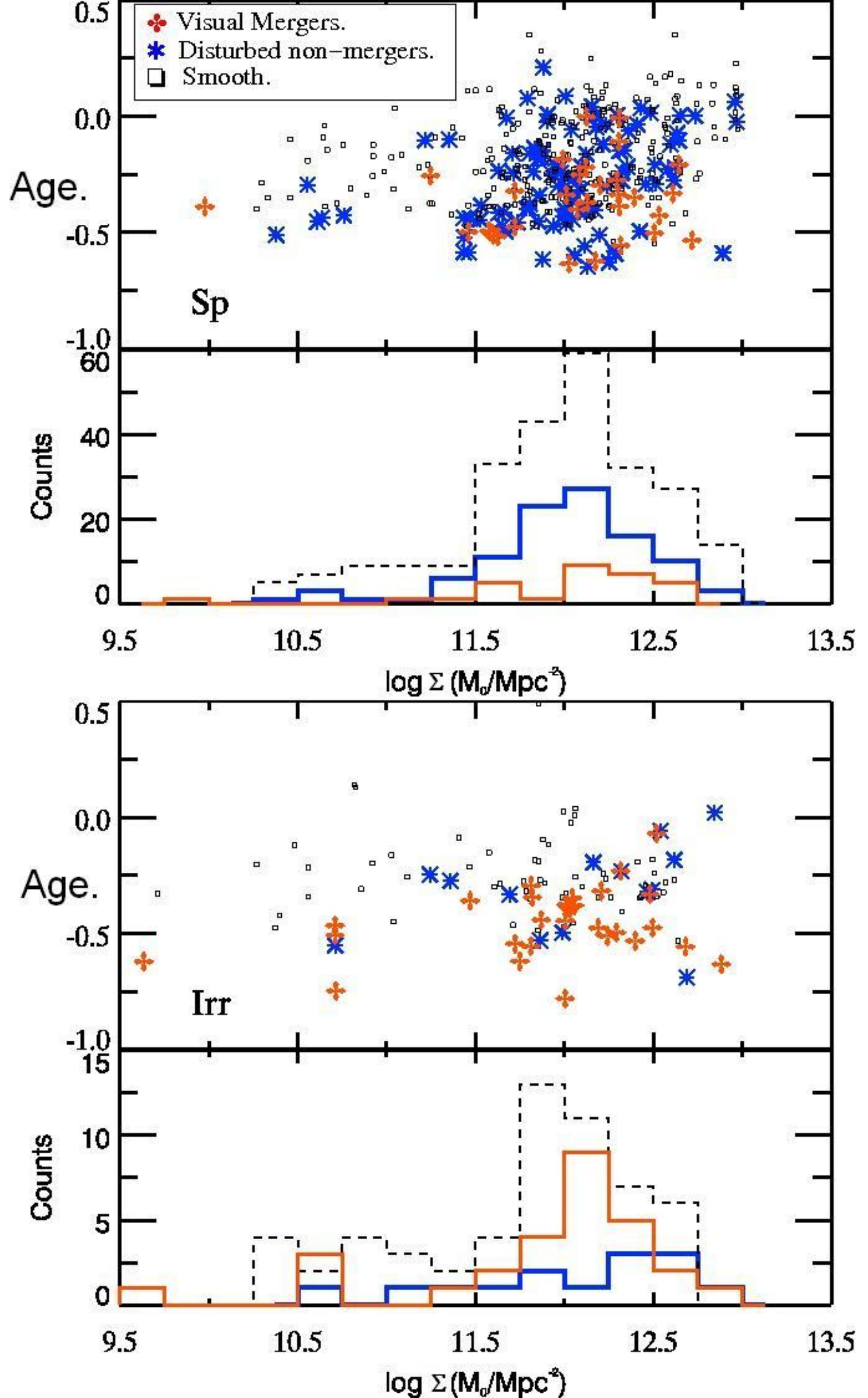
Environment.

1)Density segregation.

Low density, relaxed.

Higher density, well mixed.

2)Young stellar populations at even the highest densities.

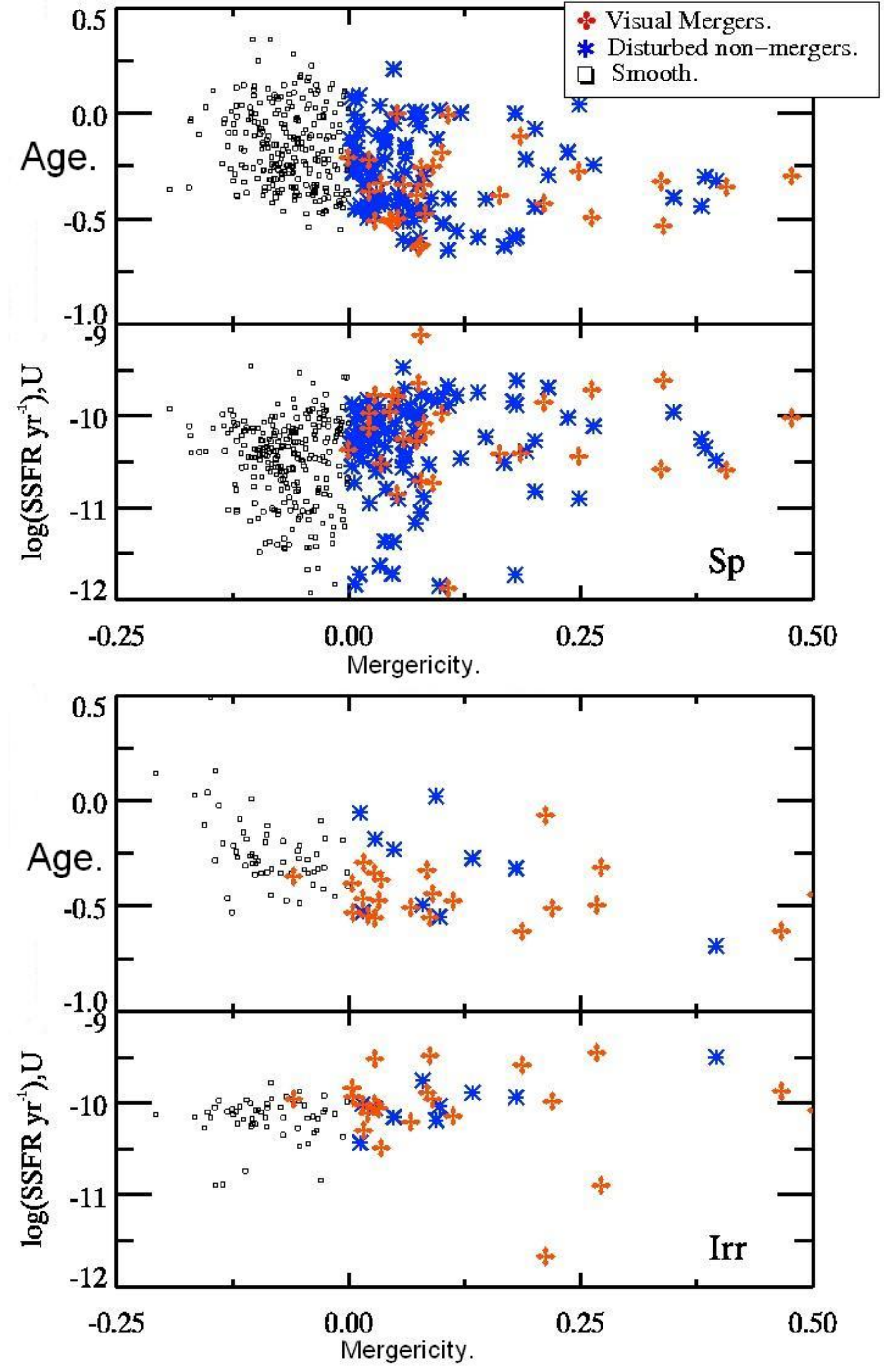


"Mergericity".

SFH-Disturbance correlation:

Disturbed objects have younger stellar populations.

Conclusion for SSFR is weakened by SFR saturation!!!



Optically Passive Spirals.

Important for evolution of spiral galaxies in clusters (Wolf, C., et al 2009).

Have $(U\text{-}V)_{Rest}>1.0$, $E_{(B\text{-}V)}>0.1$, $M>10^{10}M_{\odot}$.

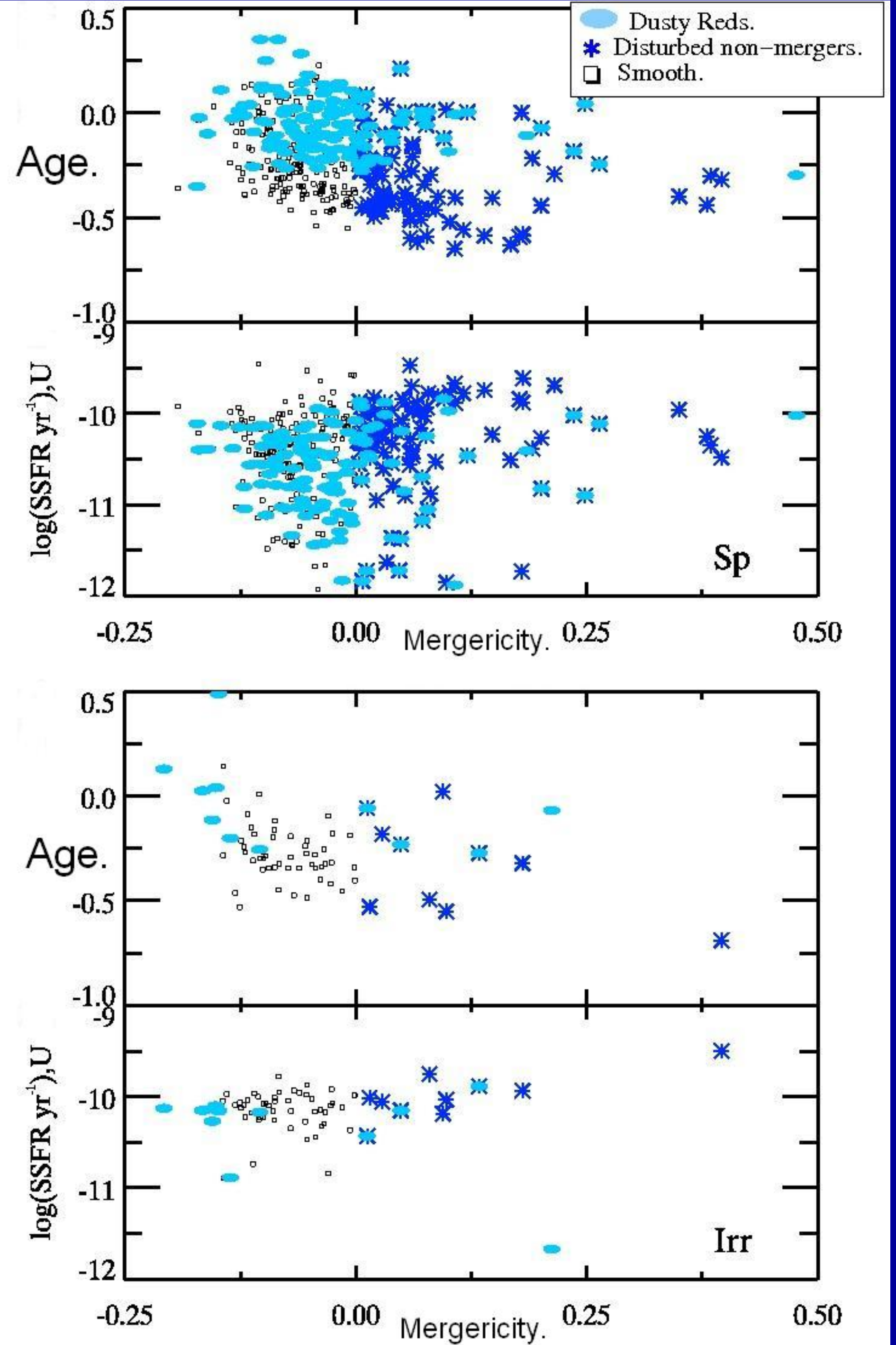
- **Star forming with reduced rate.**
- Average dust obscuration.
- Possibly turning into S0.
- Showing effects of hostile environment.

They should have smooth morphologies.
Do they?

Optically Passive Spirals Morphology.

Mostly have relaxed morphologies.

SFH and morphology linked as in other galaxy types.



Conclusions.

1) Es and S0s **have completed their morphological transformation** and are passively evolving.

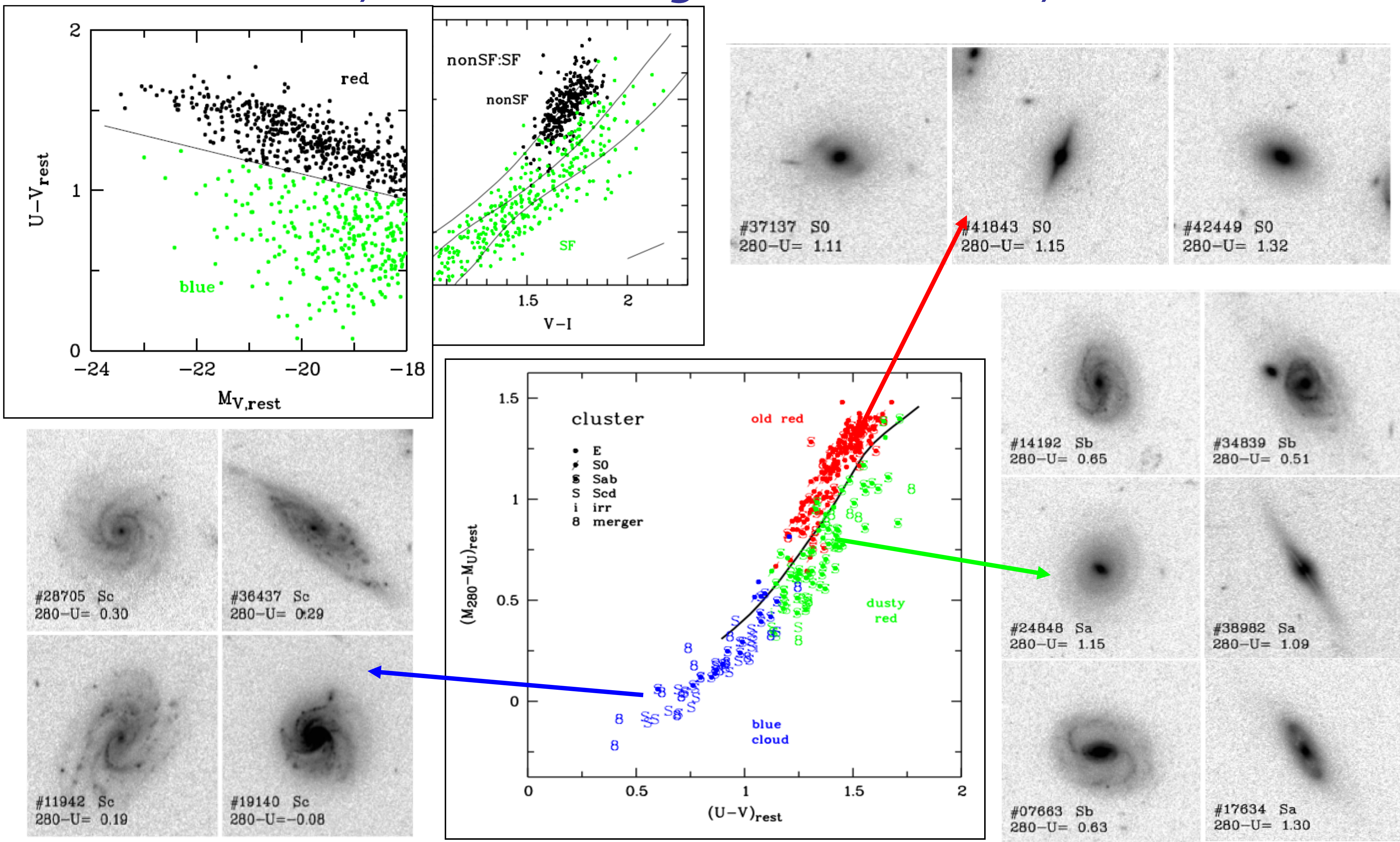
2) Disturbed Sps and Irrs have younger stellar populations than their relaxed counterparts.

3) Disturbed non-mergers and visual mergers have very similar SFHs.

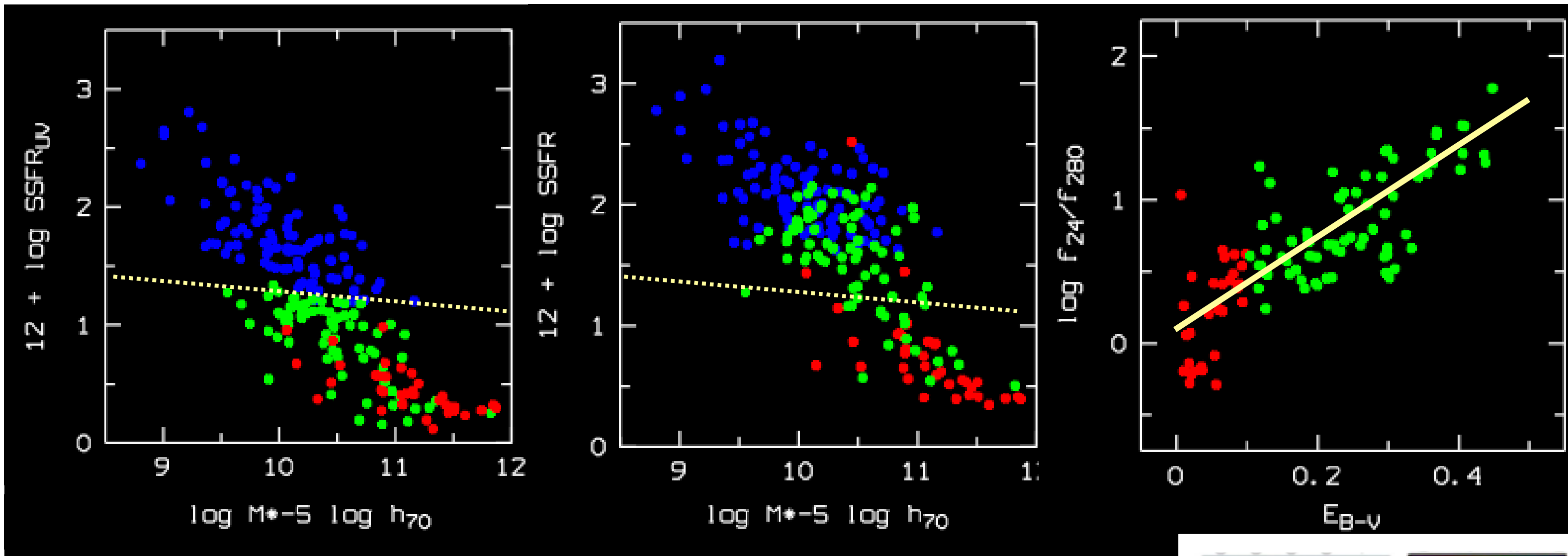
4) Optically Passive Spirals, which have started to quench their star formation knots, also show **smoother morphologies.**

Old Red & Dusty Red Galaxies

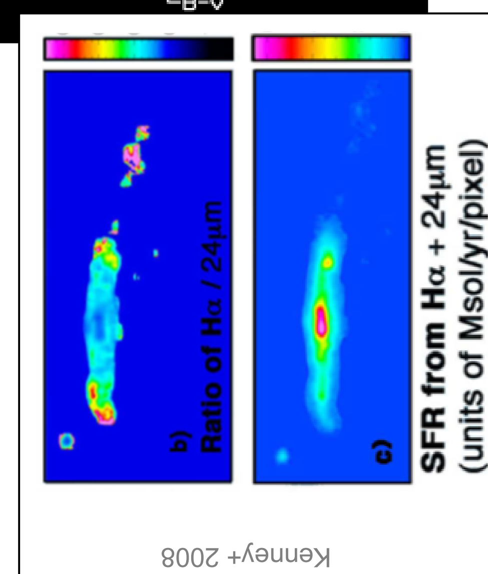
Chris Wolf, Alfonso Aragón-Salamanca, et al. 2009



Dusty Red Spirals: Obscured Star Formation



Optically passive, but FIR-bright:
SFR ~1/2 dex semi-suppressed
24μ flux/L_{280} correlates with Extinction



Centrally-concentrated, more obscured SF in Virgo spirals

Aspects of Transformation

Type — Blue spiral — Red spiral — S0 galaxy

SFR

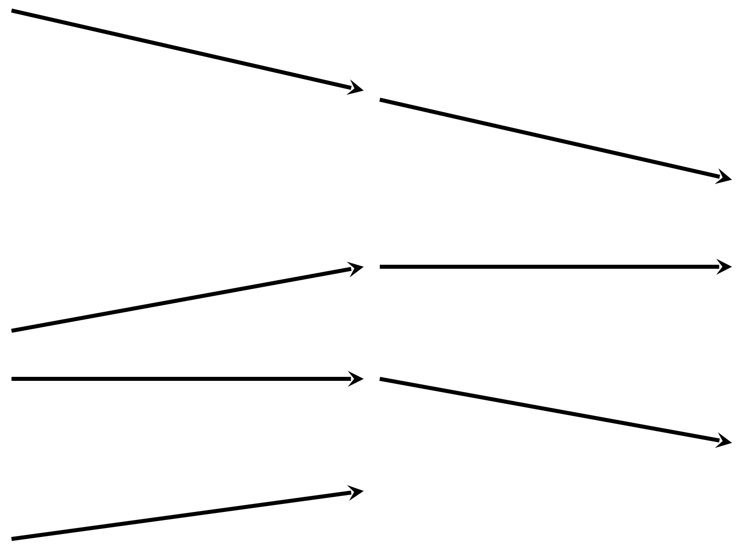
$-(280\text{-}U)_{rest}$

clumpiness

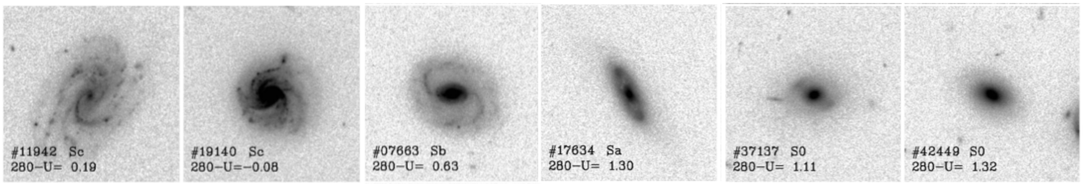
$(U\text{-}V)_{rest}$

$E_{B\text{-}V}$ stars

$E_{B\text{-}V}$ SF

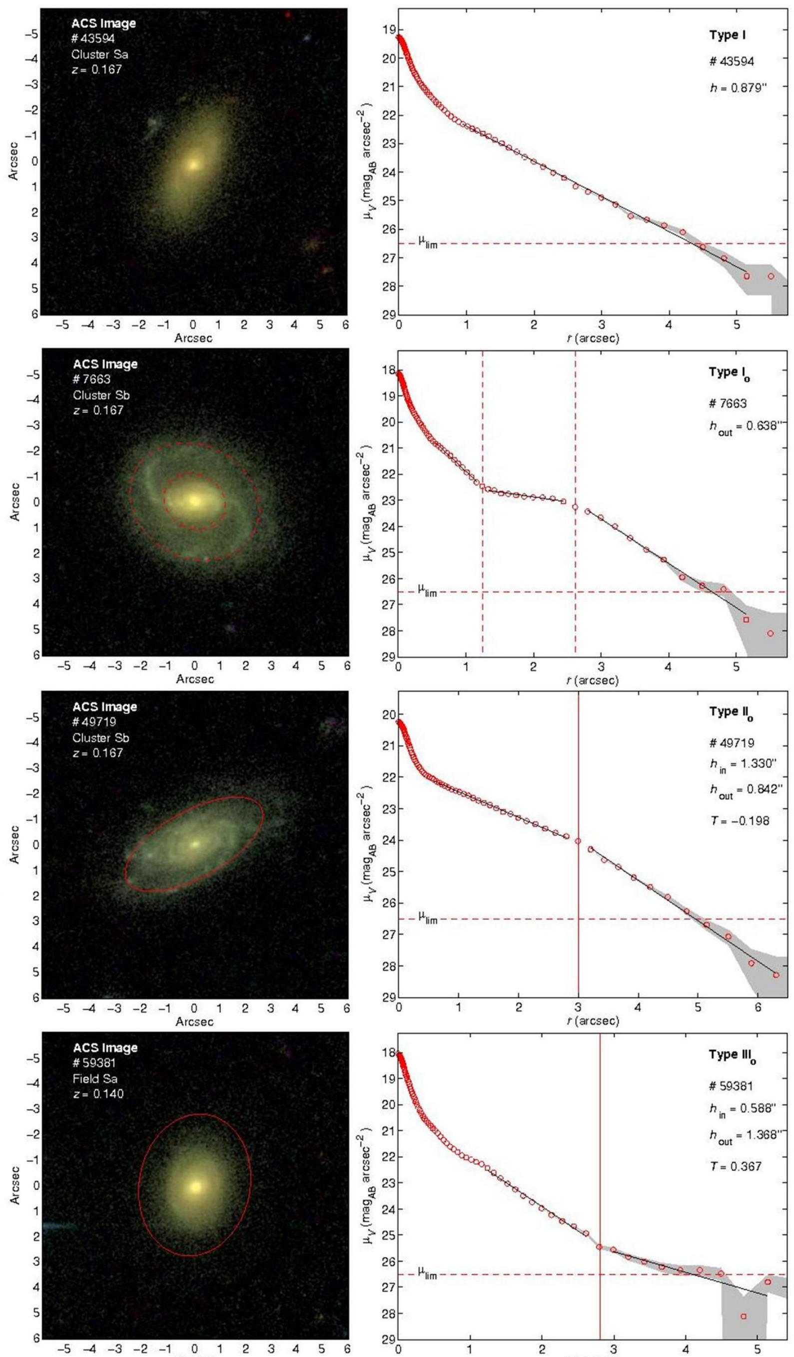


Examples



Galaxy Structure and Environment

David Maltby, et al. 2012



There are no significant environmental differences in the detailed structure of spiral galaxy disks!!!

- Blue spirals become (dusty) red spirals and then S0s.
- SF truncation proceeds outside-in, helping to grow bulges.
- The driving mechanism is “gentle”: it preserves disks.