

The role of the cluster environment on the star formation cycle of galaxies

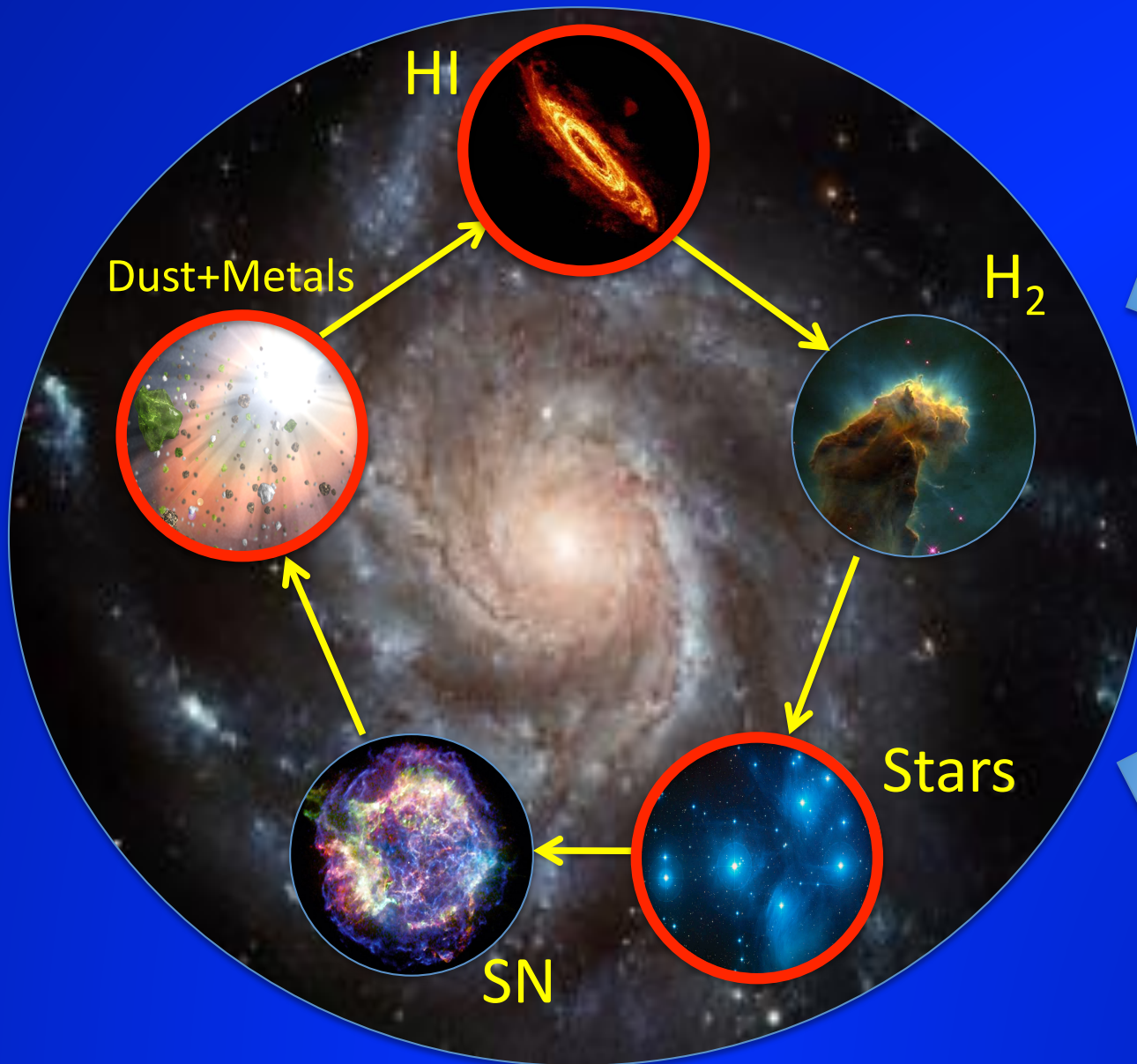


Luca Cortese (ESO)

A. Boselli (OAMP), B. Catinella (MPA), T. M. Hughes (Beijing), S. Boissier (OAMP),
L. Ciesla (OAMP), J. Davies (Cardiff), and the SAG2 and HeViCS teams



What regulates the evolutionary history of galaxies?



Internal properties

- Mass
- Dynamics
- Nuclear activity
-

Environment

- Large-scale str.
- Merging
- Tides
- Stripping
-

The Herschel Reference Survey

Boselli, Eales, LC et al. 2010, PASP, 122, 261

322 obj. (62 E/SO, 260 Sp./Irr)

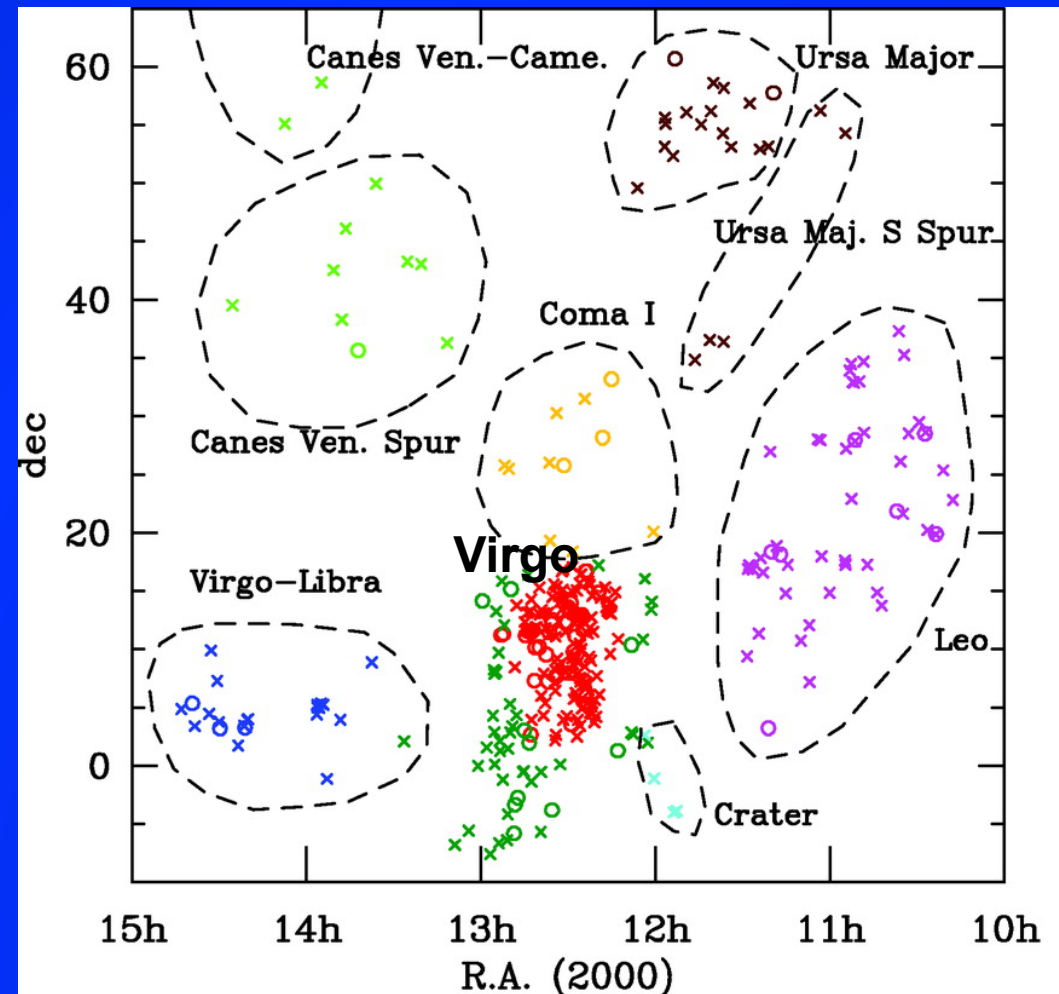
Volume/Stellar Mass limited - From isolated to cluster galaxies

Selection Criteria

- $15 < D < 25$ Mpc
- $K < 12$ for Spirals -- $K < 8.7$ for E/SO
- Gal. lat. $> +55^\circ$ -- $A(B) < 0.2$ mag

Multi-wavelength

- | | |
|--|-----------------------------|
| UV GALEX
(P.I. Cortese/Boselli) | → Unobscured SF |
| Herschel/PACS
(P.I. Cortese/ Davies) | → Obscured SF |
| Herschel/SPIRE
(P.I. Boselli/Eales) | → Dust masses |
| 12mKittPeak
(P.I. Boselli) | → H ₂ properties |
| Arecibo/VLA/WSRT | → HI properties |
| OHP
(P.I. Boselli) | → Gas metallicities |
| SDSS+2Mass | → Stellar masses |
- ...and more

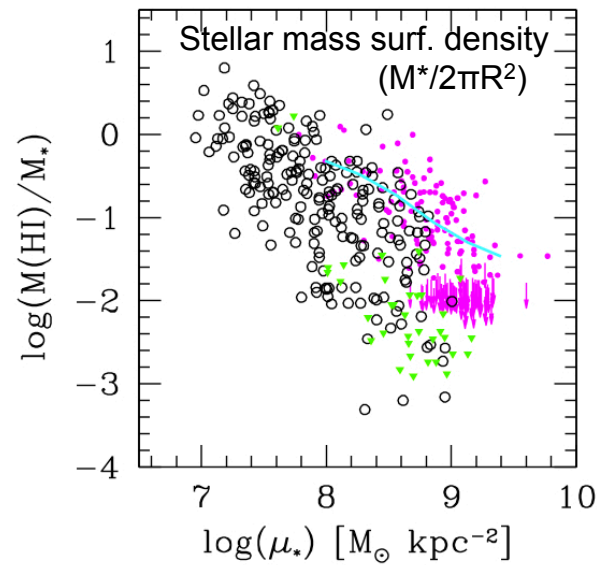
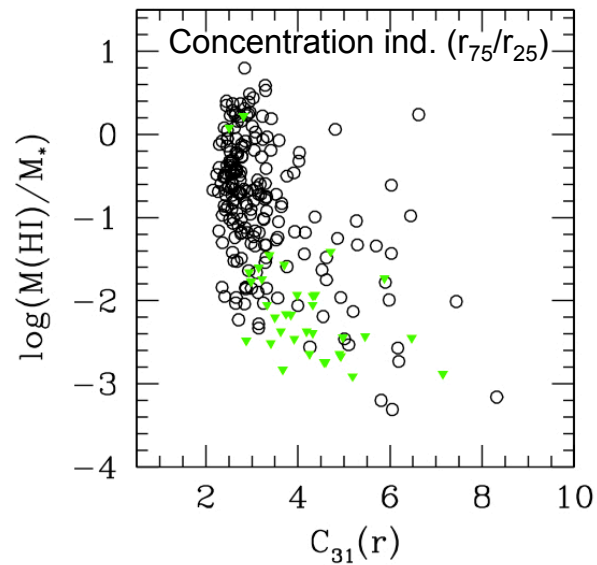
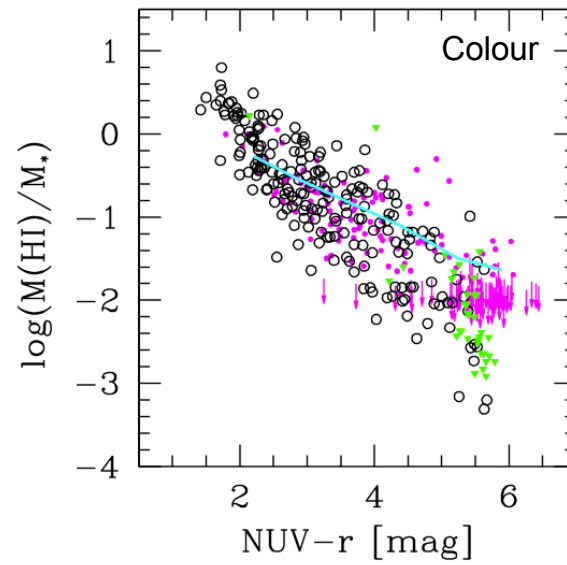
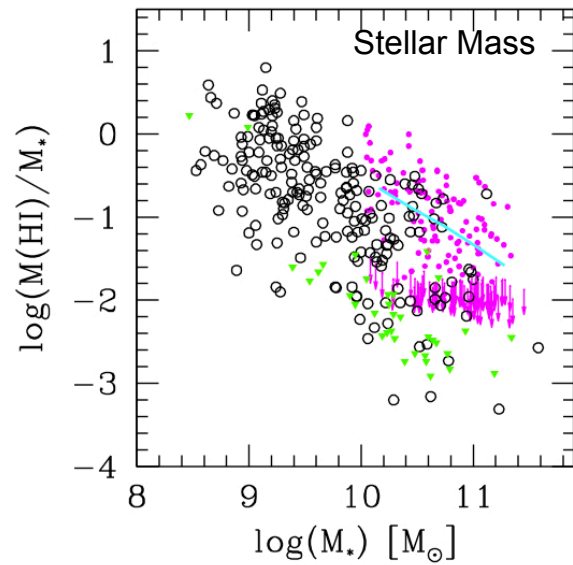


HI – Atomic Hydrogen

The HI scaling relations

(see also Catinella's talk)

All sample



Black: HRS HI det.

Green: HRS HI non-det.

Magenta: GASS

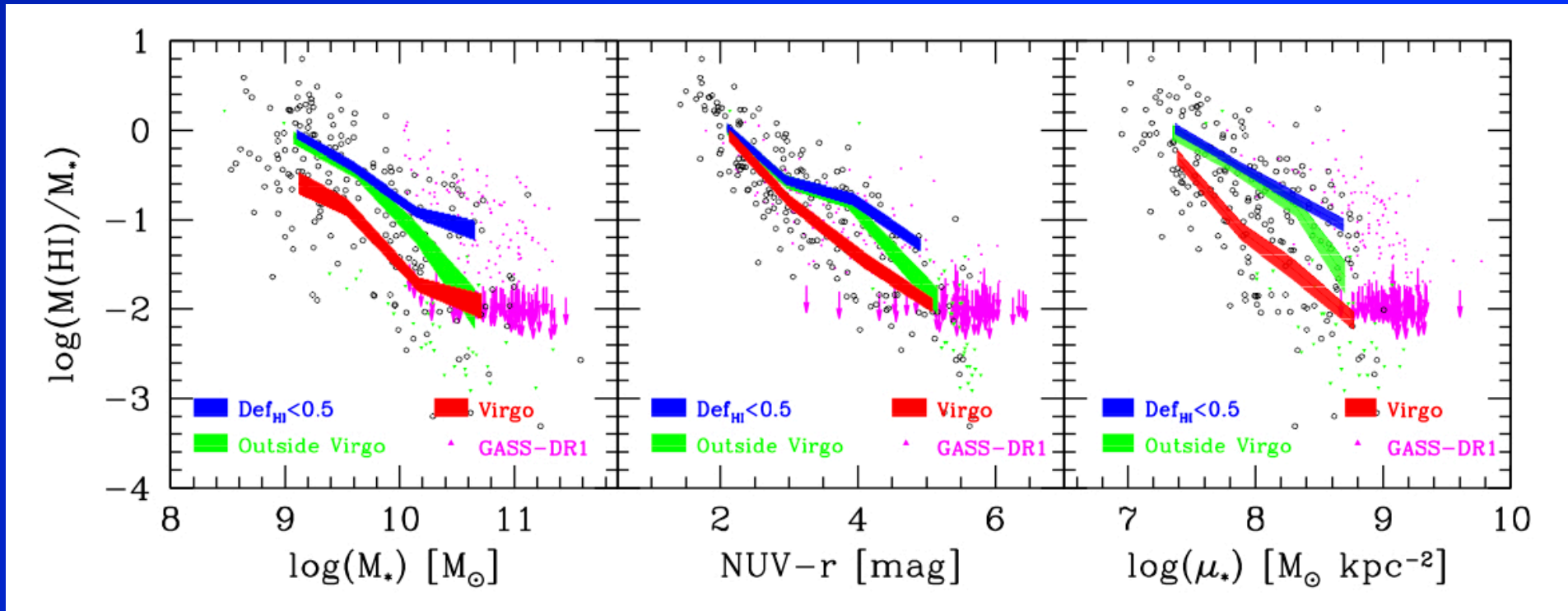
(Catinella et al. 2010)

Cyan: ALFALFA stacking

(Fabello et al. 2011)

The HI scaling relations

Remember $\text{Def}_{\text{HI}} = \log\langle M(\text{HI}, D_{\text{opt}}, \text{Type}) \rangle - \log M\text{HI}_{\text{obs}}$
(Haynes & Giovanelli 1984)

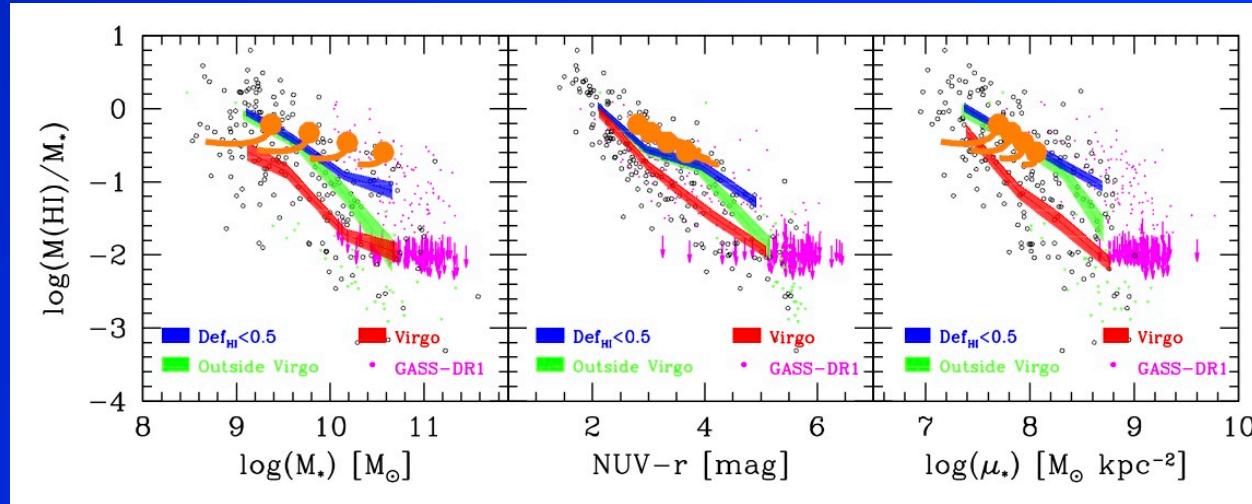


Virgo galaxies show similar scaling relations, but offset towards lower gas content

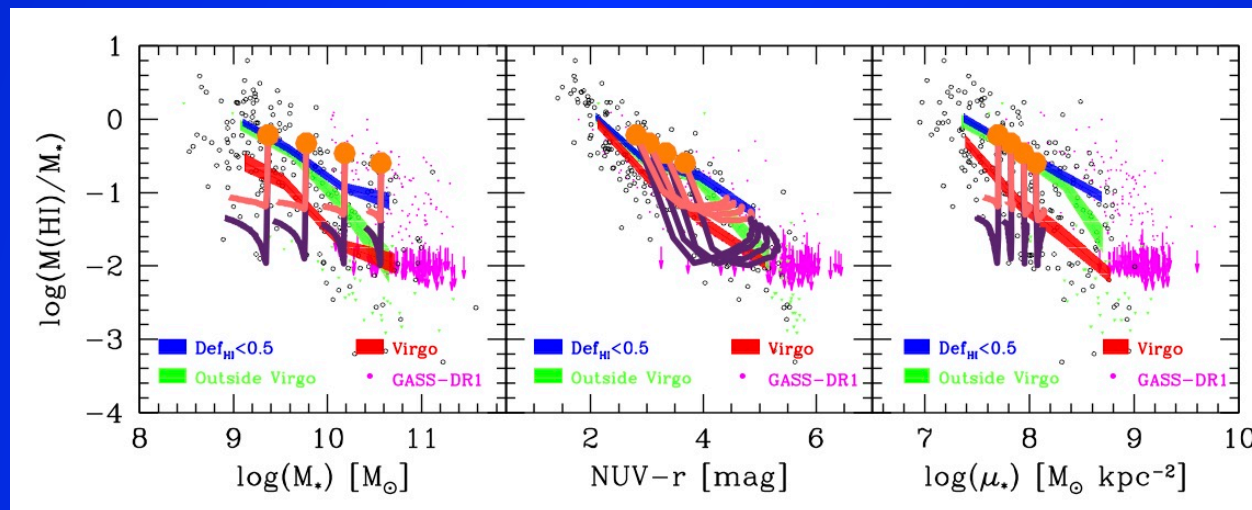
Difference between field and cluster less strong at high stellar masses
(i.e., where early-type systems dominate)

The HI scaling relations and models

Models of Boissier & Pranzos (2000) + Boselli et al. (2008)
calibrated on pure disk galaxies



Starvation



Ram-pressure

Ram pressure necessary to explain HI scaling relations in Virgo

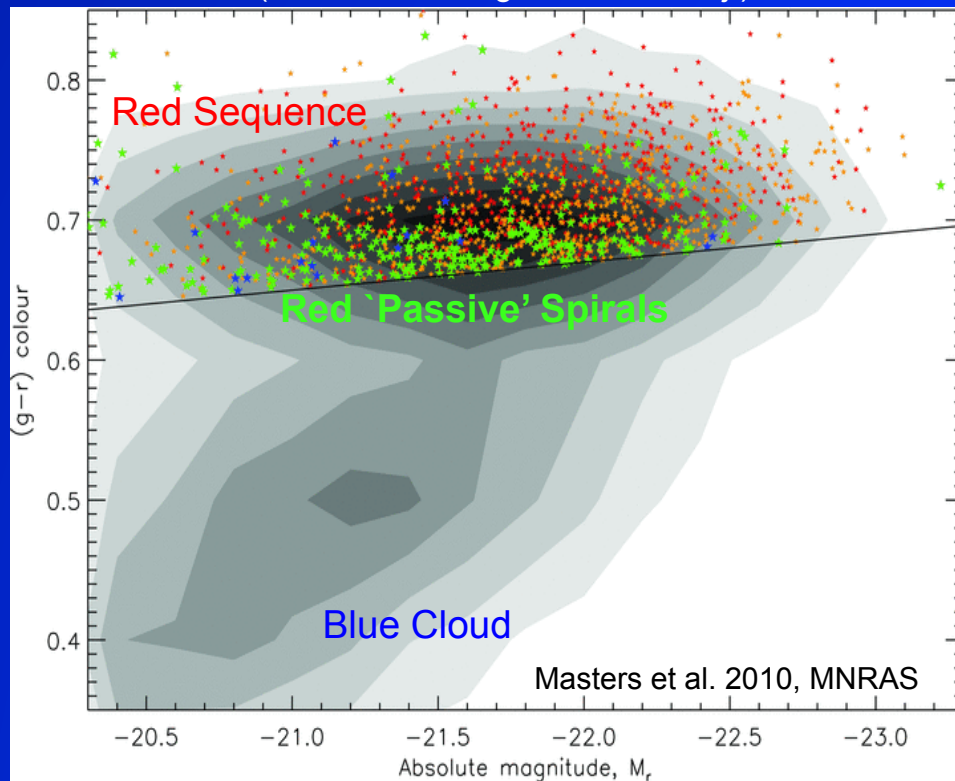
Less HI in cluster galaxies...

what about star formation?

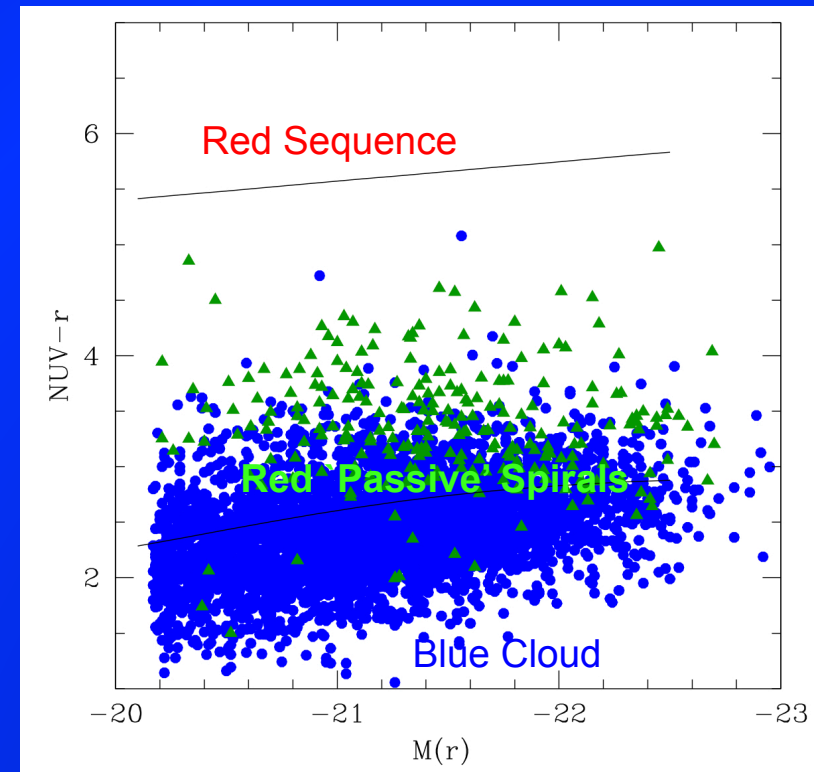
Color-magnitude diagram and environment

Optically red spirals are not quiescent!

Galaxy Zoo sample of Red 'passive' spirals
(i.e. face-on, bulge-less, red, obj.)



Same galaxies with GALEX data



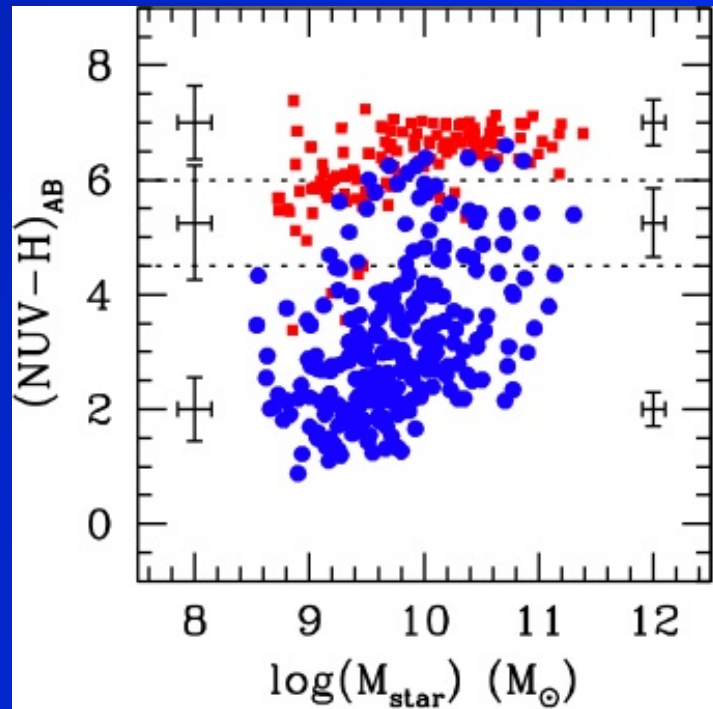
More than $\frac{1}{2}$ of red spirals have SFR consistent with normal SF galaxies

N.B. This does not even take into account dust attenuation!

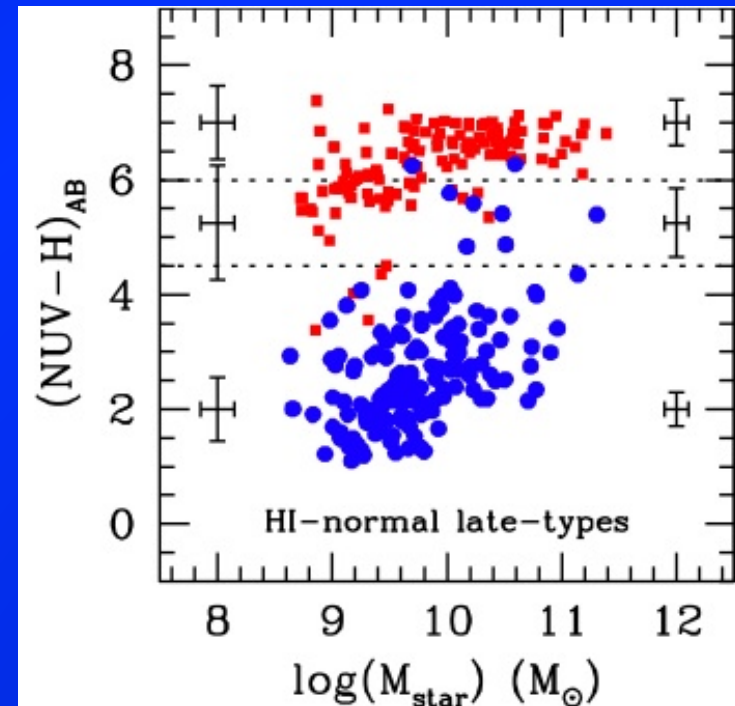
The local UV-NIR colour mass relation

Morphology+HI content

All sample



Excluding HI deficient spirals



Excluding HI-deficient obj. we start to see a transition region.

HI removed, SF quenched in cluster galaxies...

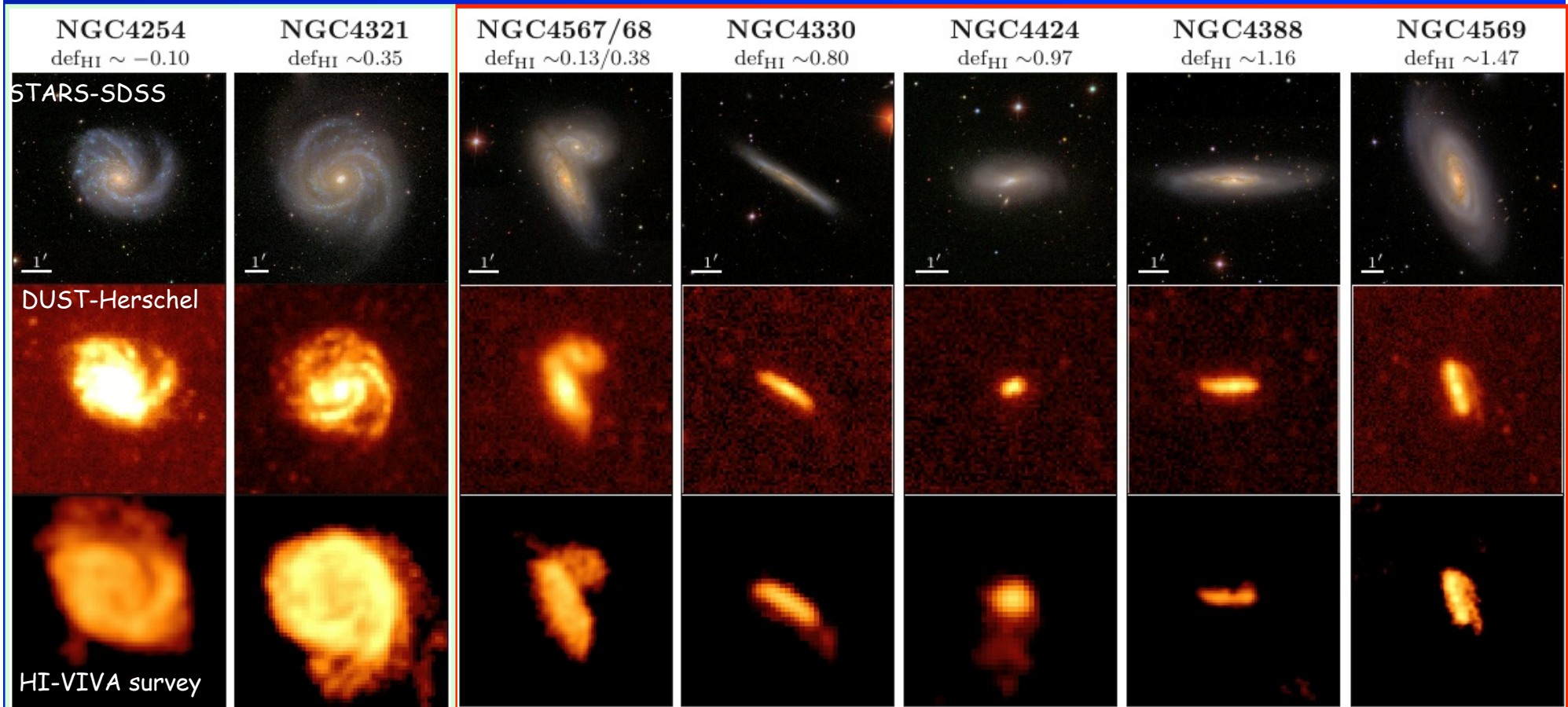
What about dust?

“Truncated” dust disks in HI-deficient Virgo spirals

HI-rich



HI-poor



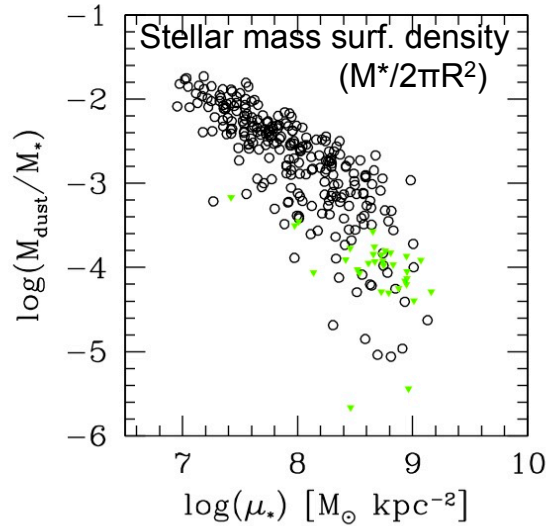
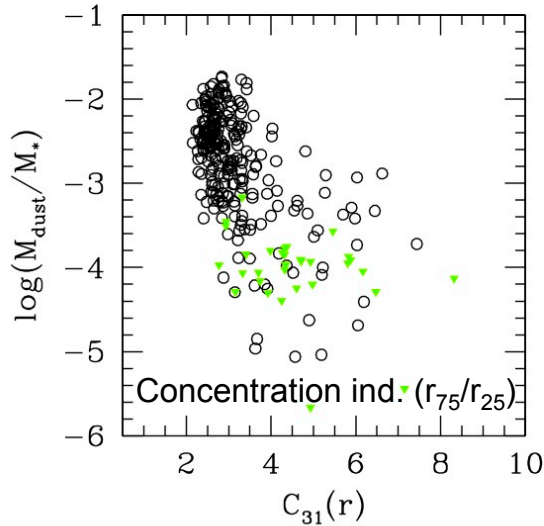
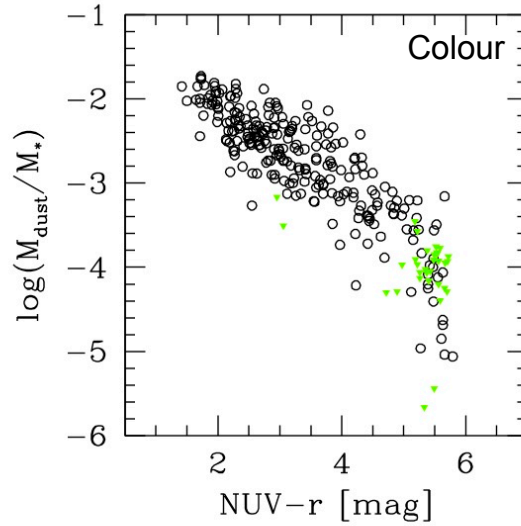
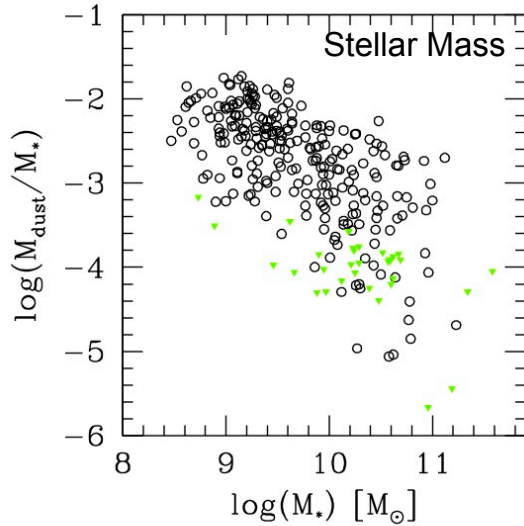
Pohlen, LC, Smith et al. 2010, A&A

LC, Davies, Pohlen et al. 2010, A&A

Gas removal is mainly outside-in: i.e. truncation of the gas and dust disk

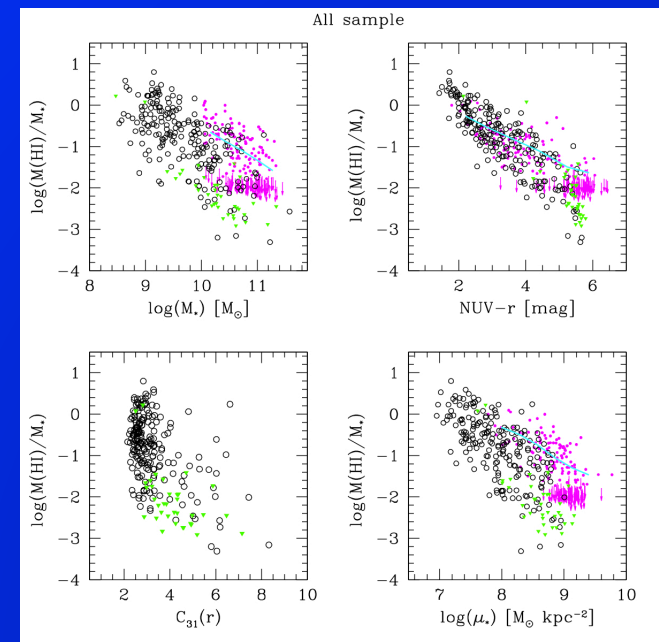
The dust scaling relations

Dust



Remarkable resemblance to the HI scaling relations

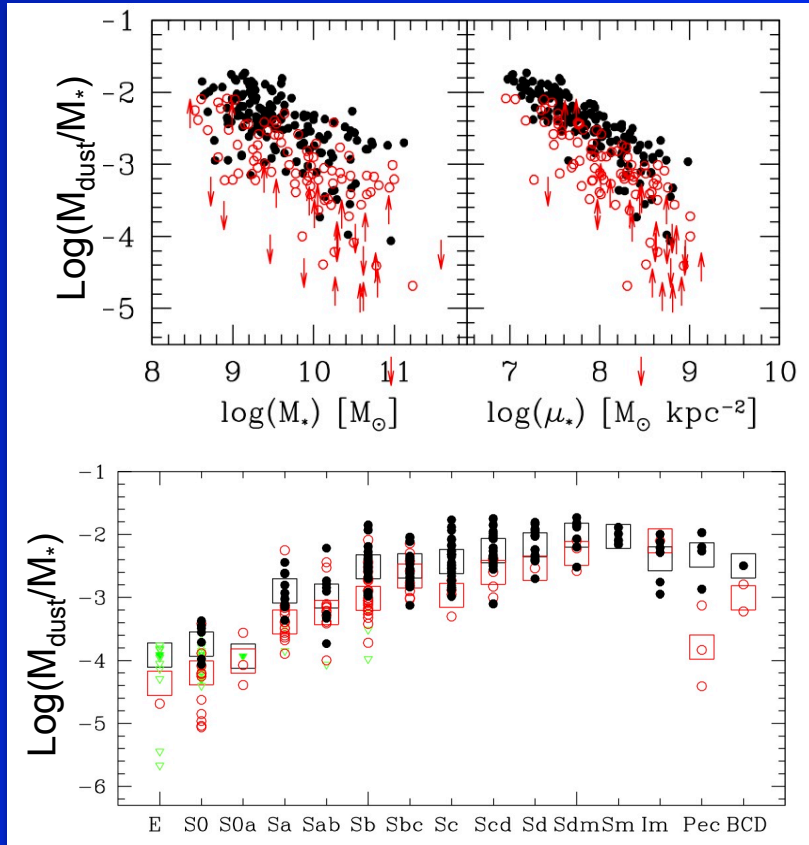
HI



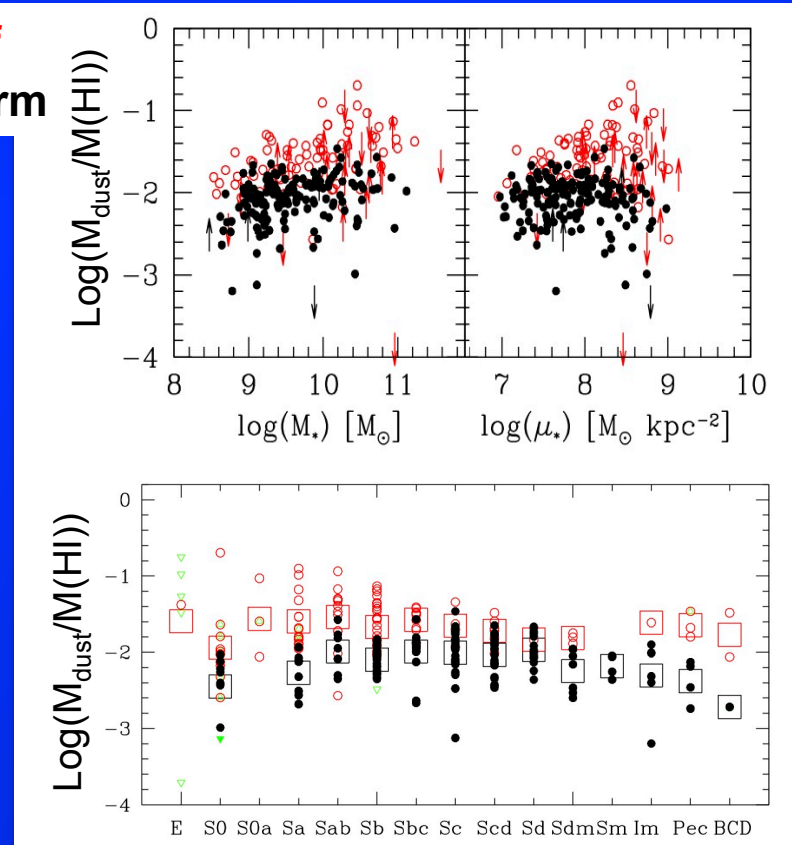
Dust scaling relations and environment

M_{dust}/M_*

$M_{\text{dust}}/M_{\text{HI}}$



Red=HI-def
Black=HI-norm

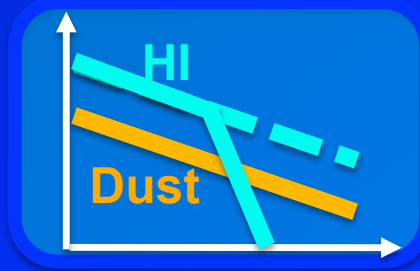


Dust is stripped but....

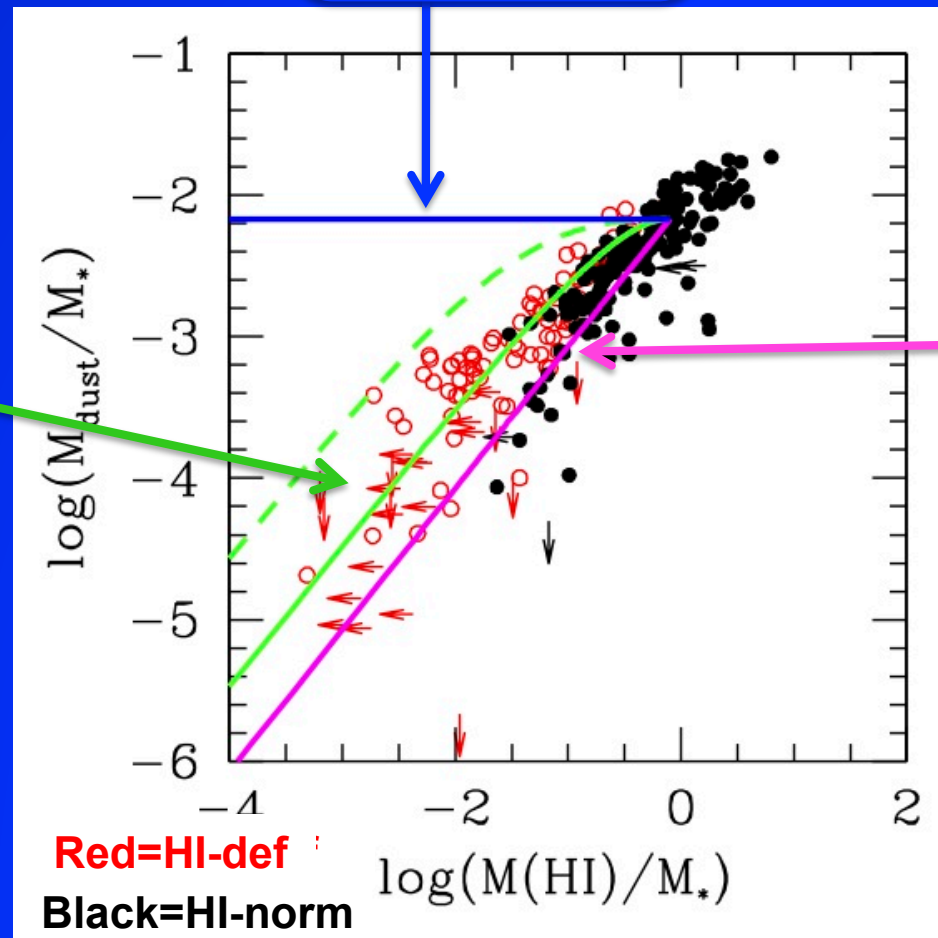
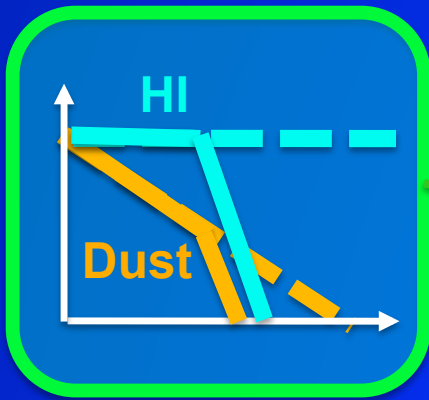
less than the HI

Dust is stripped but not as much as the HI

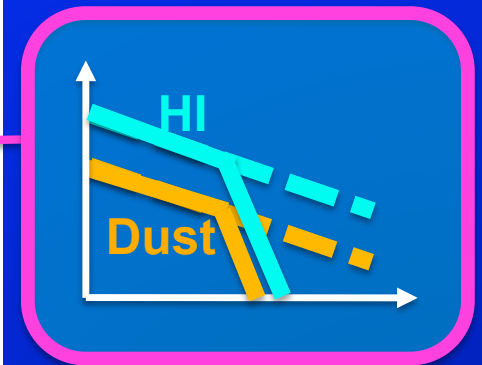
Dust not stripped



Dust stripped less than HI



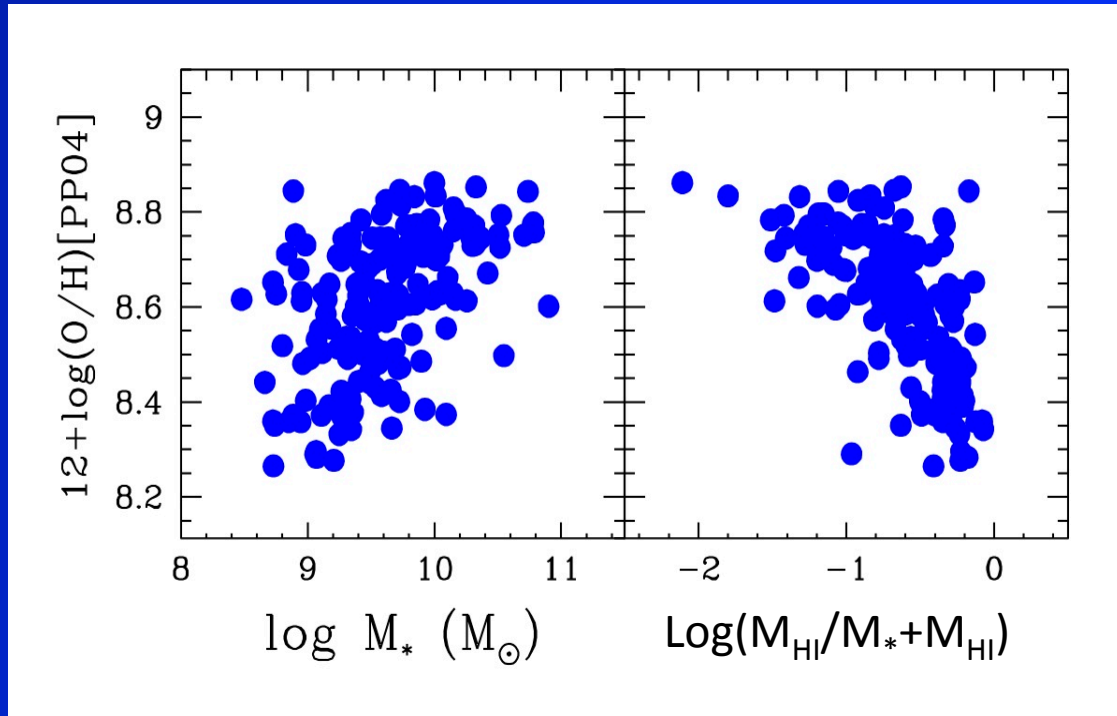
Dust+HI stripped



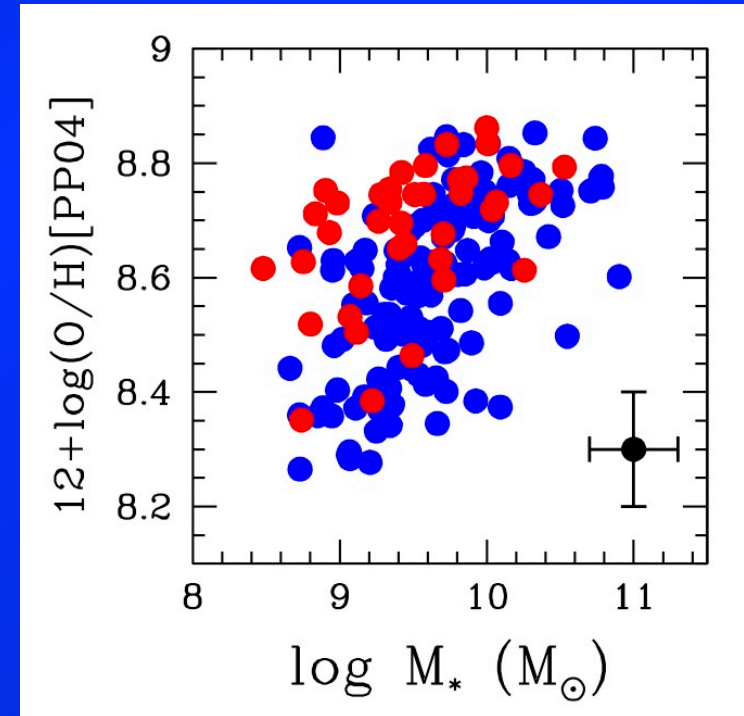
HI and dust removed, SF quenched in cluster galaxies...

at last, what about metals in the ISM?

The relation between gas metallicity, HI and stellar mass



O/H correlates with stellar mass and gas fraction

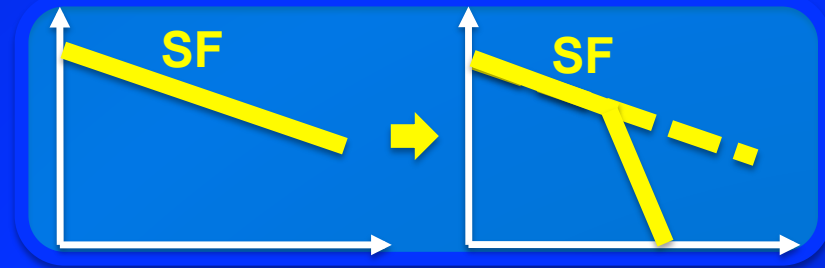
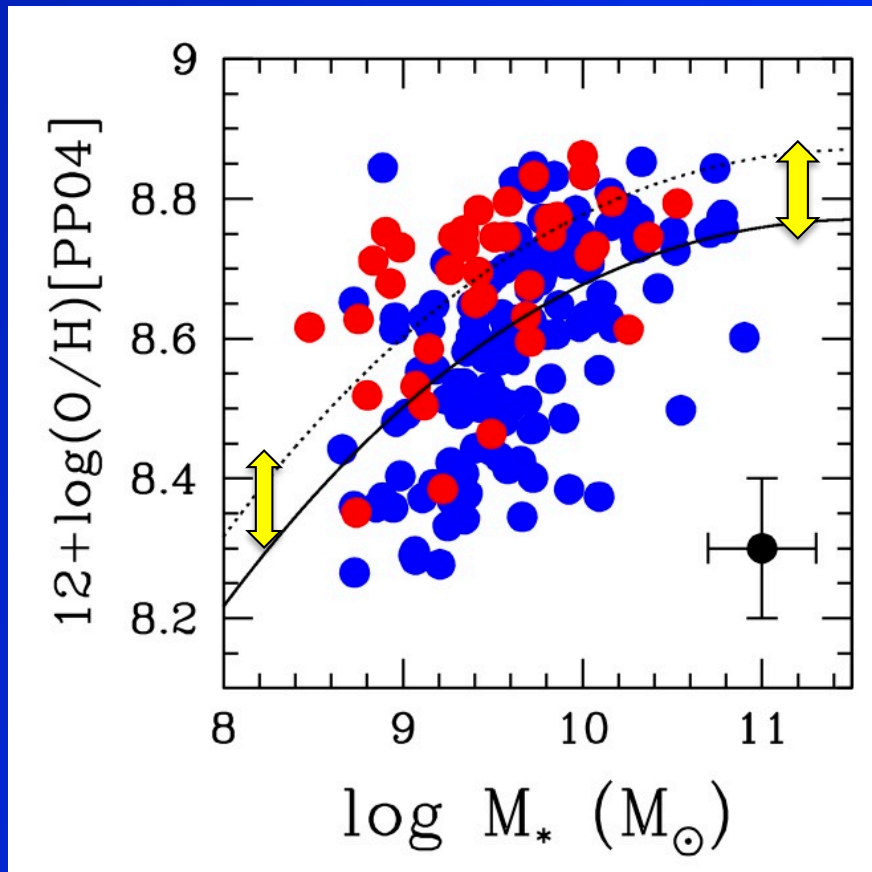


At fixed stellar mass HI-def/cluster galaxies more metal rich

(see Skillmann+1996, Boselli & Gavazzi 2006, Ellison+ 2009, Mouchine+2007)

Is this a real effect?

HI def. galaxies \rightarrow SF disk is truncated \rightarrow O/H only for the inner parts.



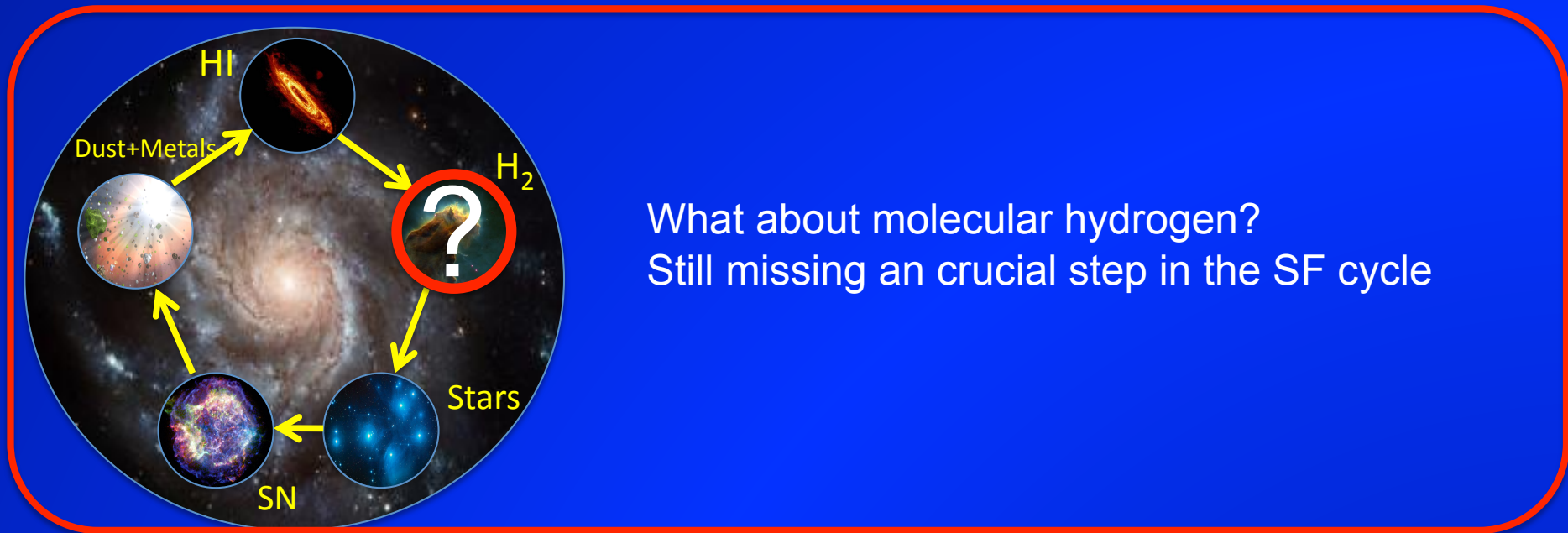
Offset of HI-def galaxies perhaps just an observations bias

Very difficult to use gas-metallicities to look for environmental trends

Summary

- **HI, SF and Dust give consistent picture about environment**
HI, Dust stripped and SF quenched in infalling systems
Dust less affected than HI just because more concentrated
- **Metals**
Still unclear if observations tell us something about environmental effects on gas metallicity
- **All observational evidence supports gas stripping (likely RP) as the main environmental mechanism going on in Virgo**

The next steps



What about molecular hydrogen?
Still missing an crucial step in the SF cycle

What about groups?

The SF cycle can also be affected in lower density environments

