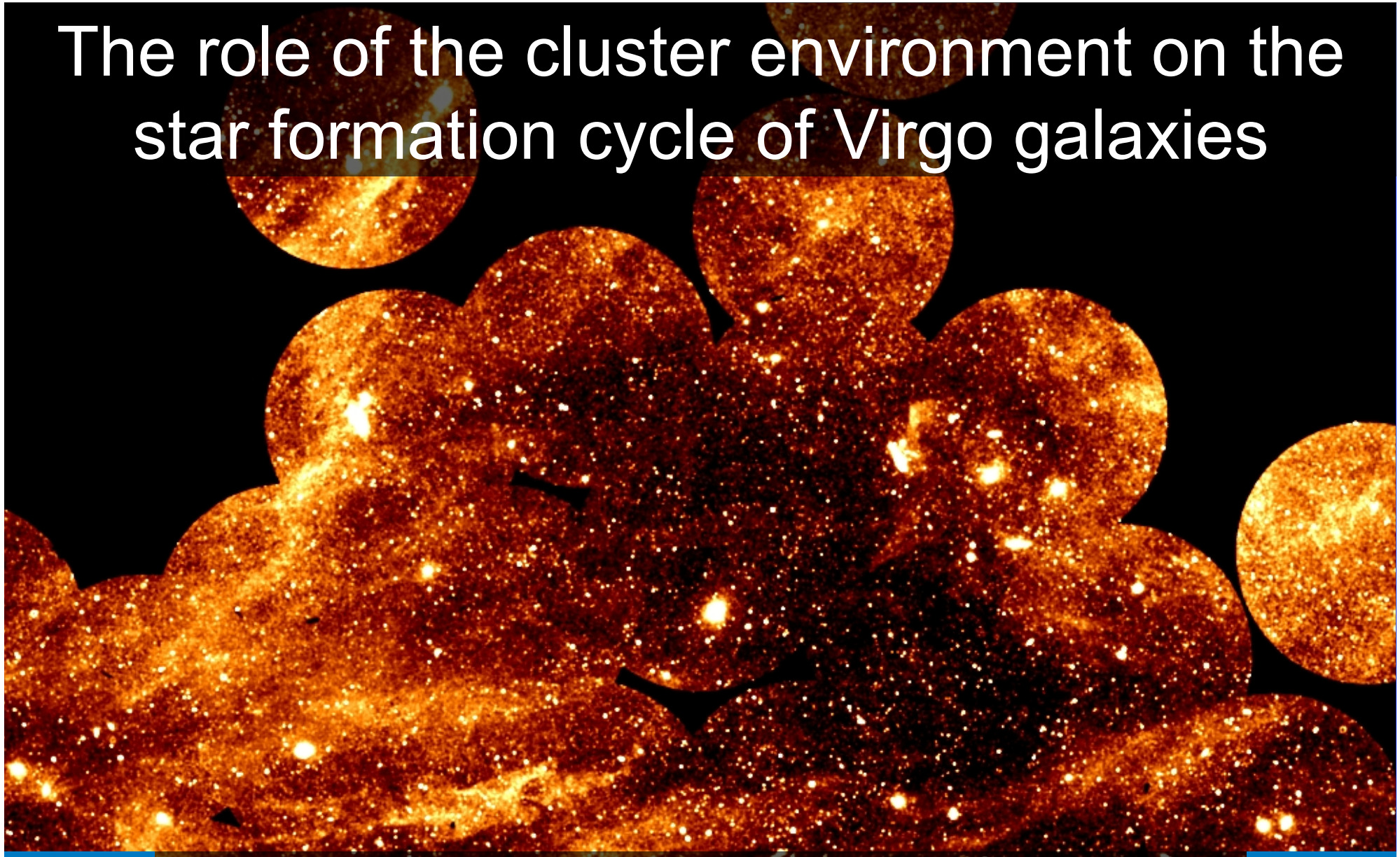
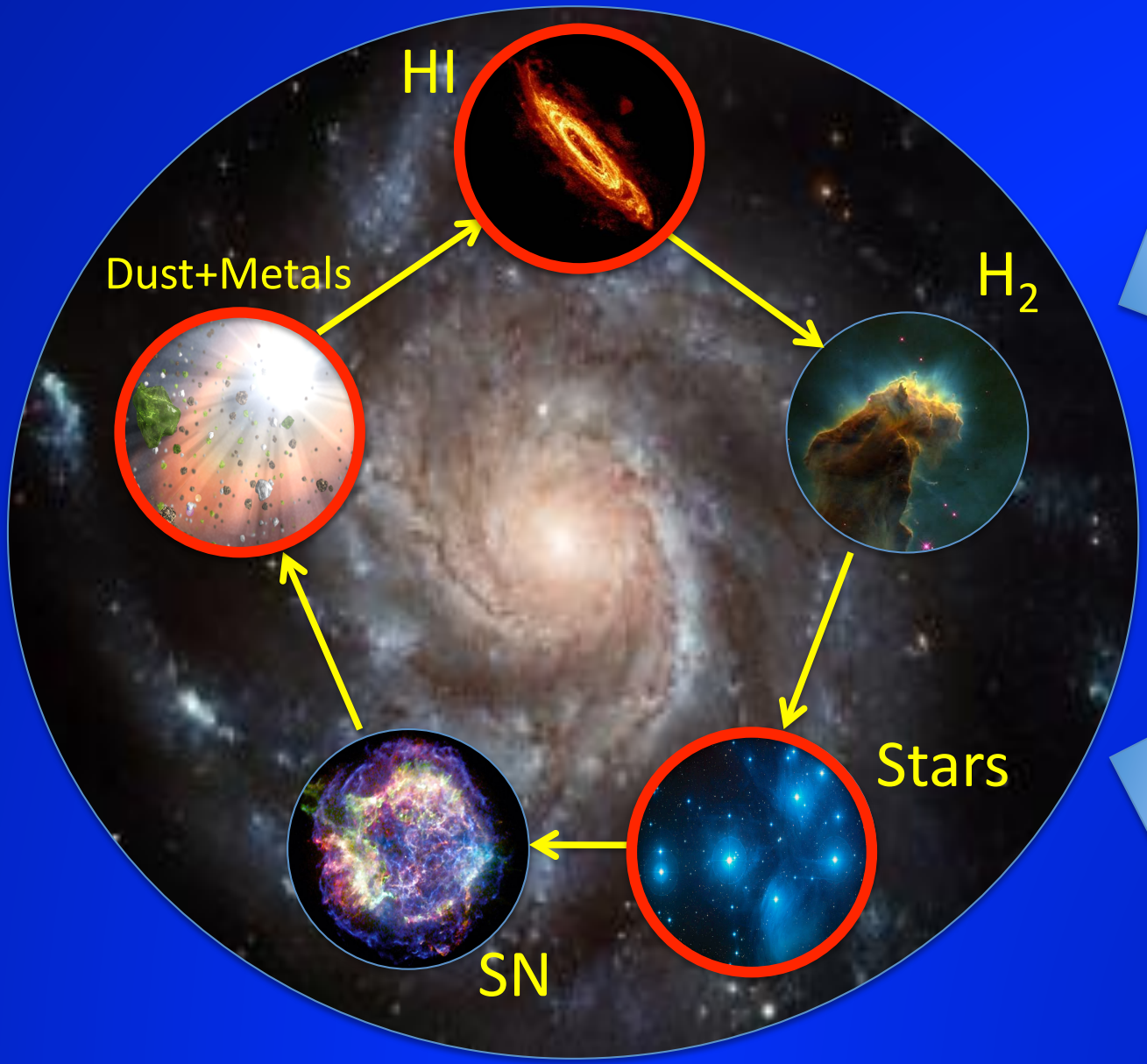
The role of the cluster environment on the star formation cycle of Virgo galaxies



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

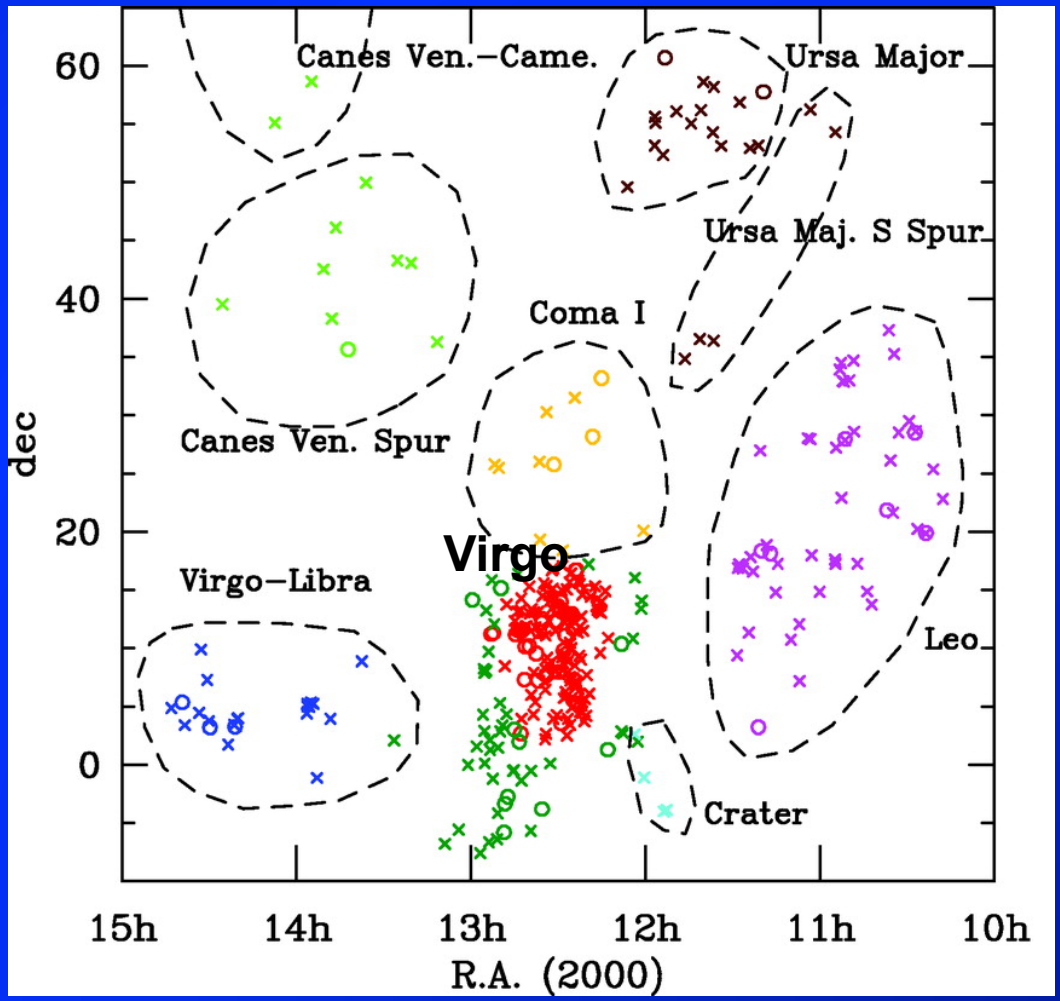
Selection Criteria

- 15<D<25 Mpc
- K<12 for Spirals -- K<8.7 for E/S0
- Gal. lat. > +55° -- 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)	➔ H2 properties
Arecibo/VLA/WSRT	➔ HI properties
OHP (P.I. Boselli)	➔ Gas metallicities
SDSS+2Mass	➔ Stellar masses

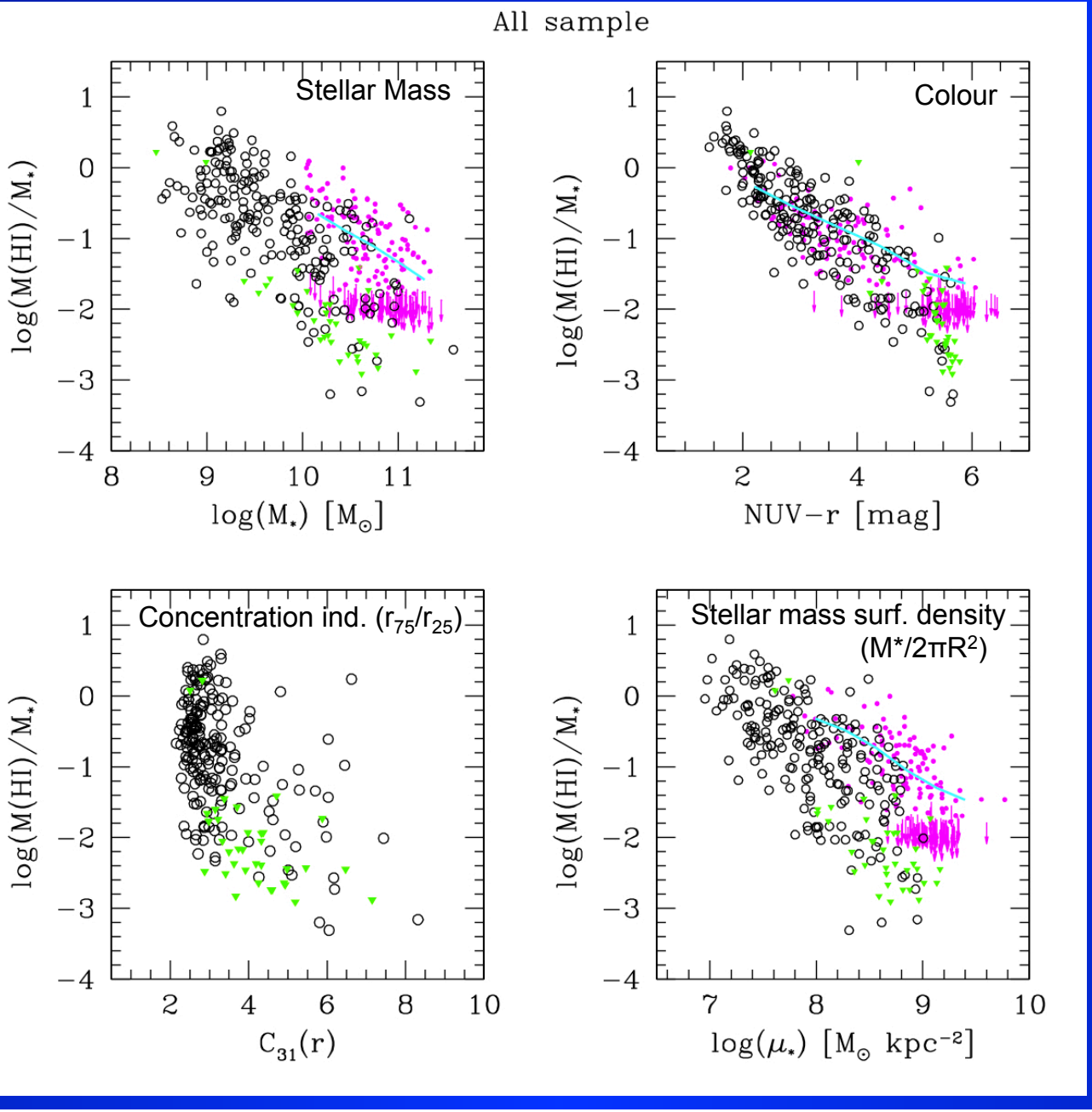
…and more



HI – Atomic Hydrogen

The HI scaling relations

(see also Gavazzi's talk on Tuesday)



Black: HRS HI det.

Green: HRS HI non-det.

Magenta: GASS
(Catinella et al. 2010)

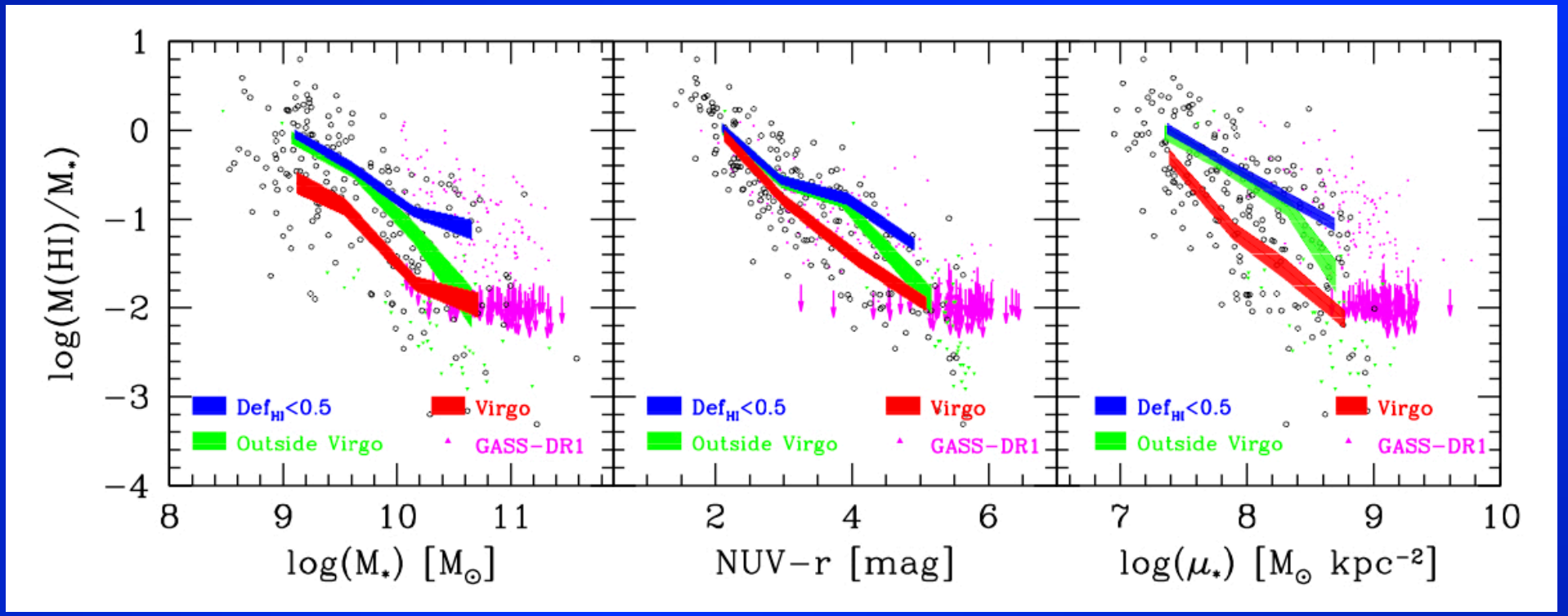
Cyan: ALFALFA stacking
(Fabello et al. 2011)

LC, Catinella, Boissier et al. 2011, MNRAS

The HI scaling relations

Remember Def_{HI} = log<M(HI, D_{opt},Type)> - log MHI_{obs}

(Haynes & Giovanelli 1984)



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

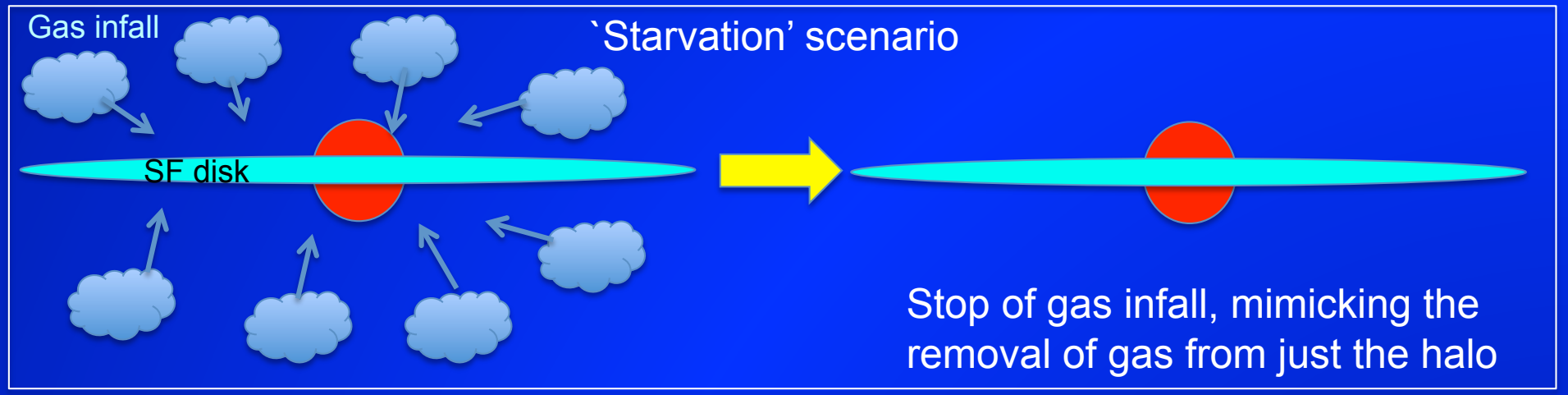
Difference between field and cluster less strong at high stellar masses
(i.e., where early-type systems dominate)

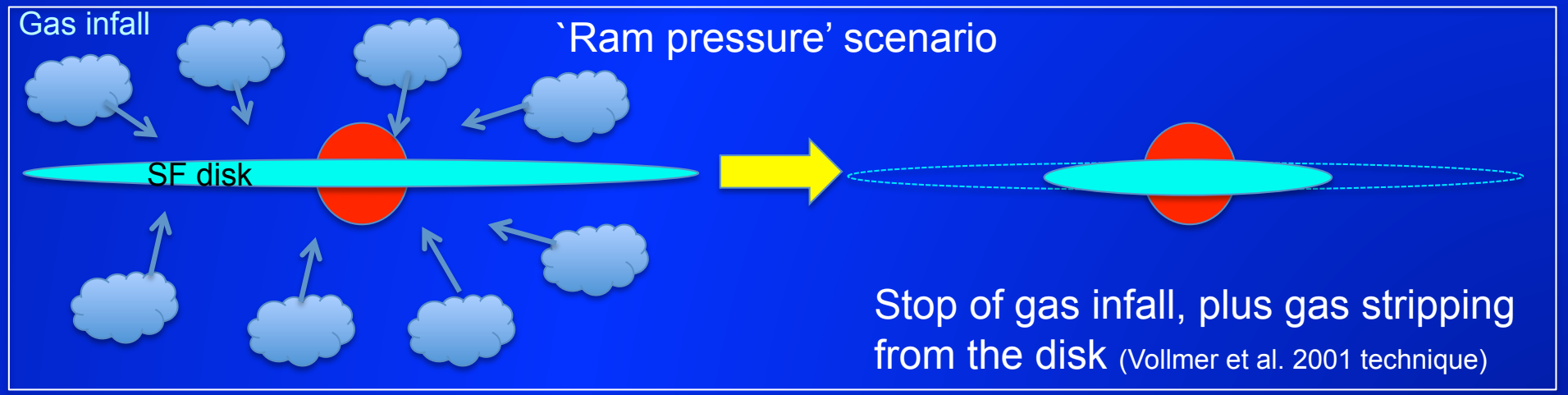
LC, Catinella, Boissier et al. 2011, MNRAS

The HI scaling relations and models

Models of Boissier & Pranzos (2000) – calibrated on pure disk galaxies

(see Boselli's talk on Tuesday)





The HI scaling relations and models

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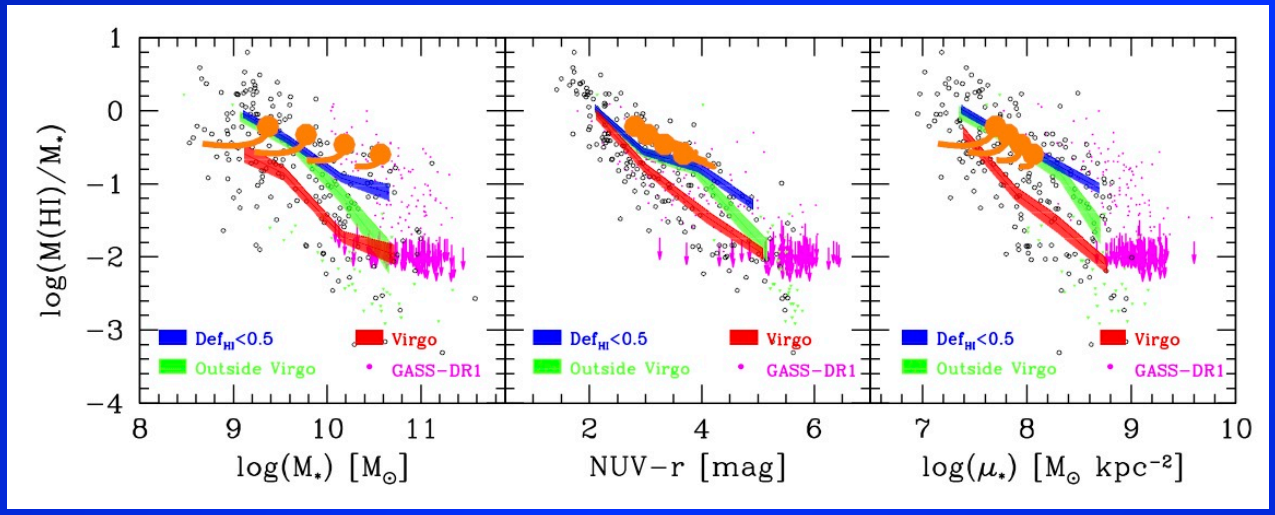
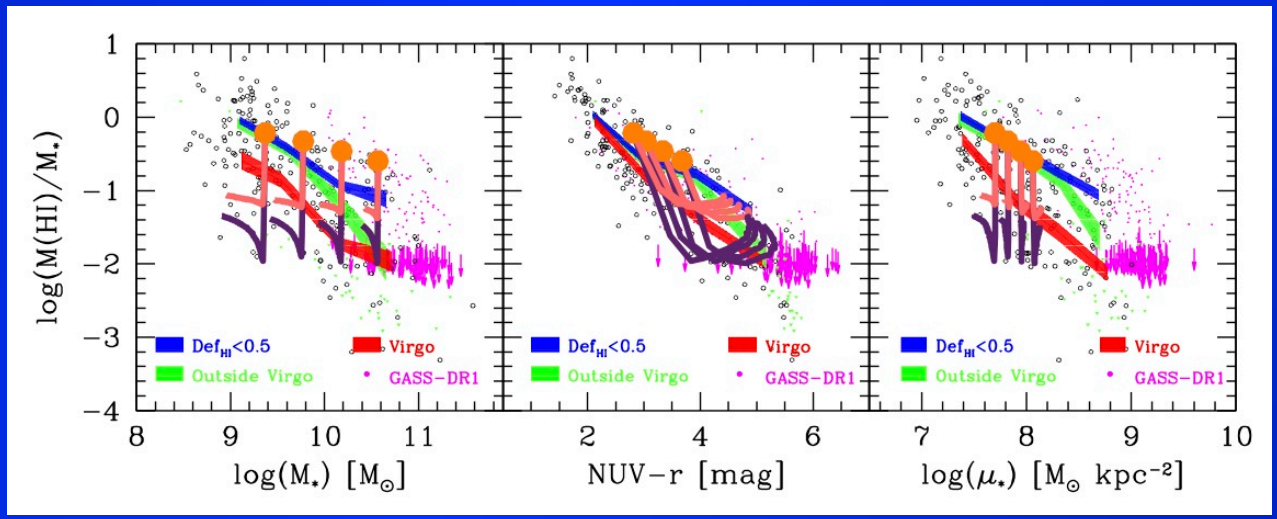


Starvation



Ram-pressure

Ram pressure necessary to explain HI scaling relations in Virgo

(see also Boselli & Gavazzi 2006, Chung et al. 2007, Vollmer et al. 2009)

LC, Catinella, Boissier et al. 2011, MNRAS

Less HI in cluster galaxies…

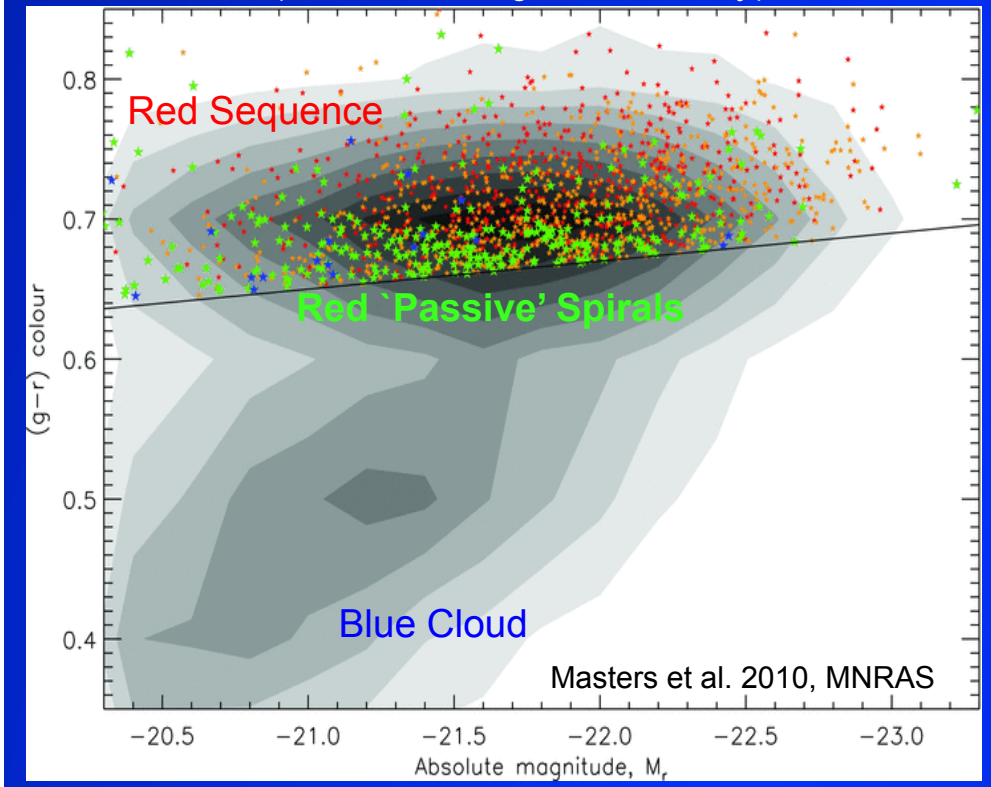
what about star formation?

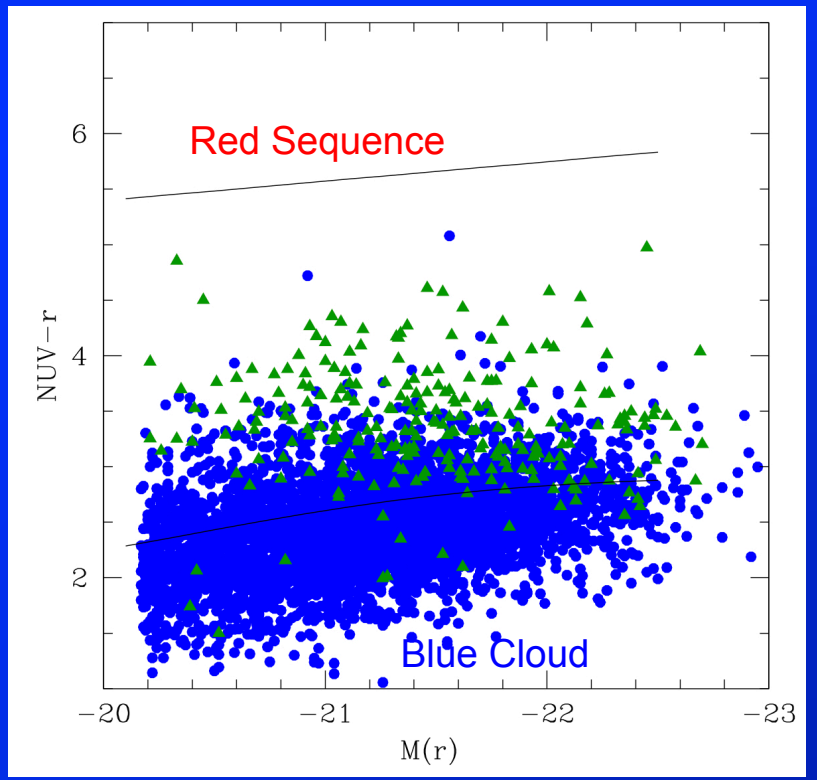
Color-magnitude diagram and environment

Optically red spirals are not quiescent!

Galaxy Zoo sample of Red `passive' spirals

(i.e. face-on, bulge-less, red, obj.)





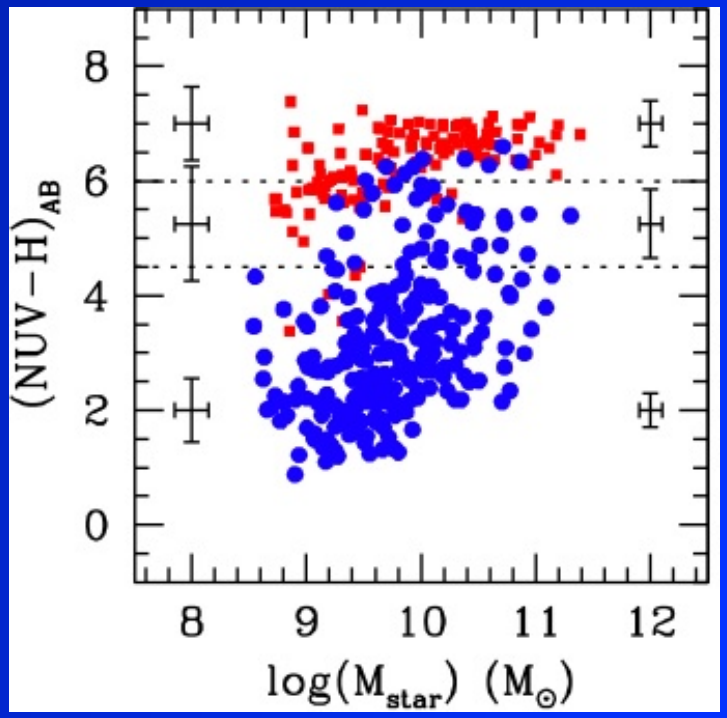
More than ½ of red spirals have SFR consistent with normal SF galaxies

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

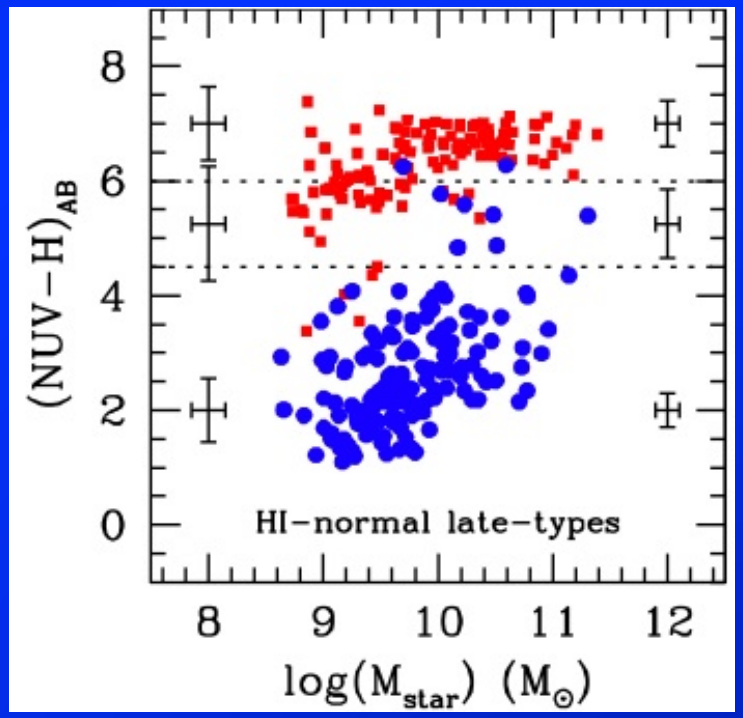
The local UV-NIR colour mass relation

Morphology+HI content

All sample



Excluding HI deficient spirals



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

LC & Hughes, 2009, MNRAS

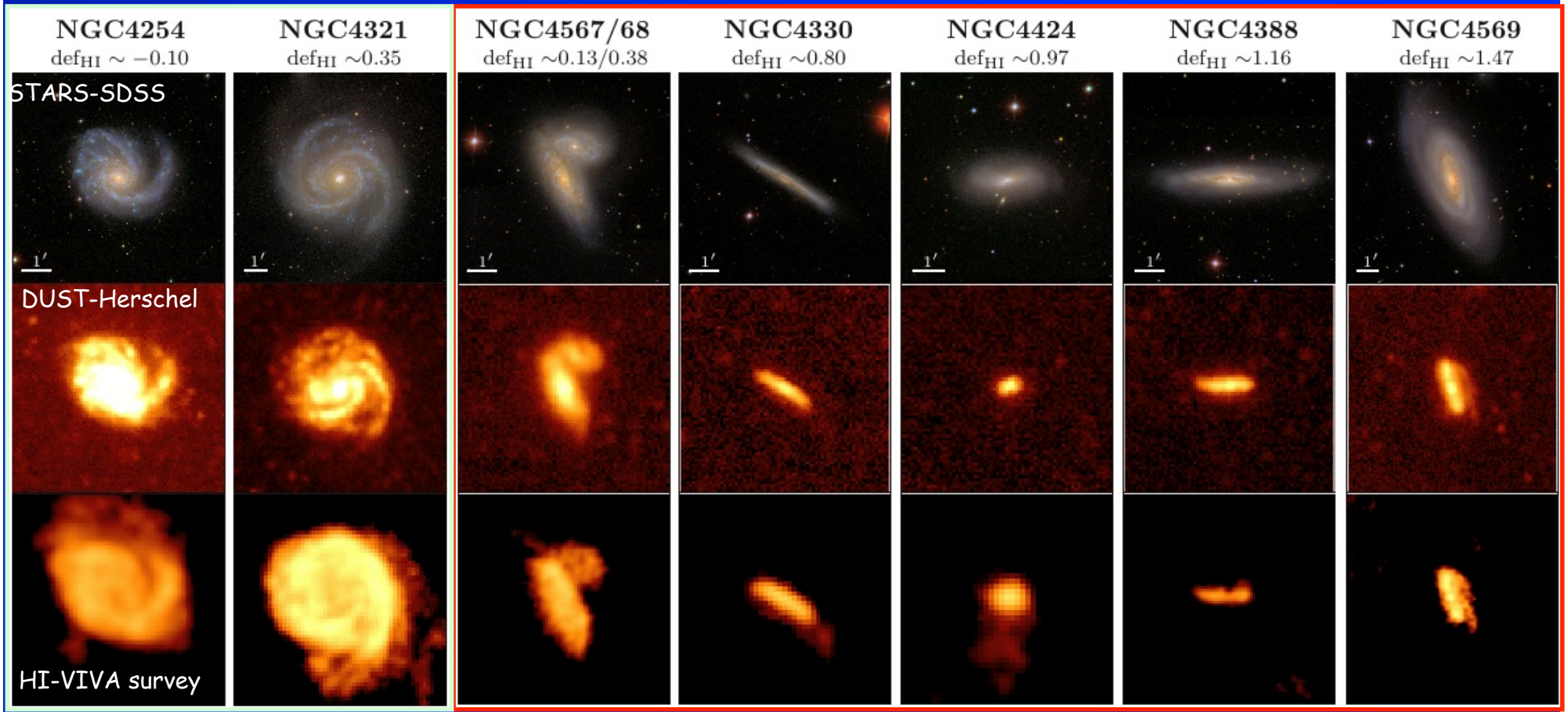
HI removed, SF quenched in cluster galaxies…

What about dust?

“Truncated” dust disks in HI-deficient Virgo spirals

(see Davies’ talk on Tuesday)

HI-rich → HI-poor



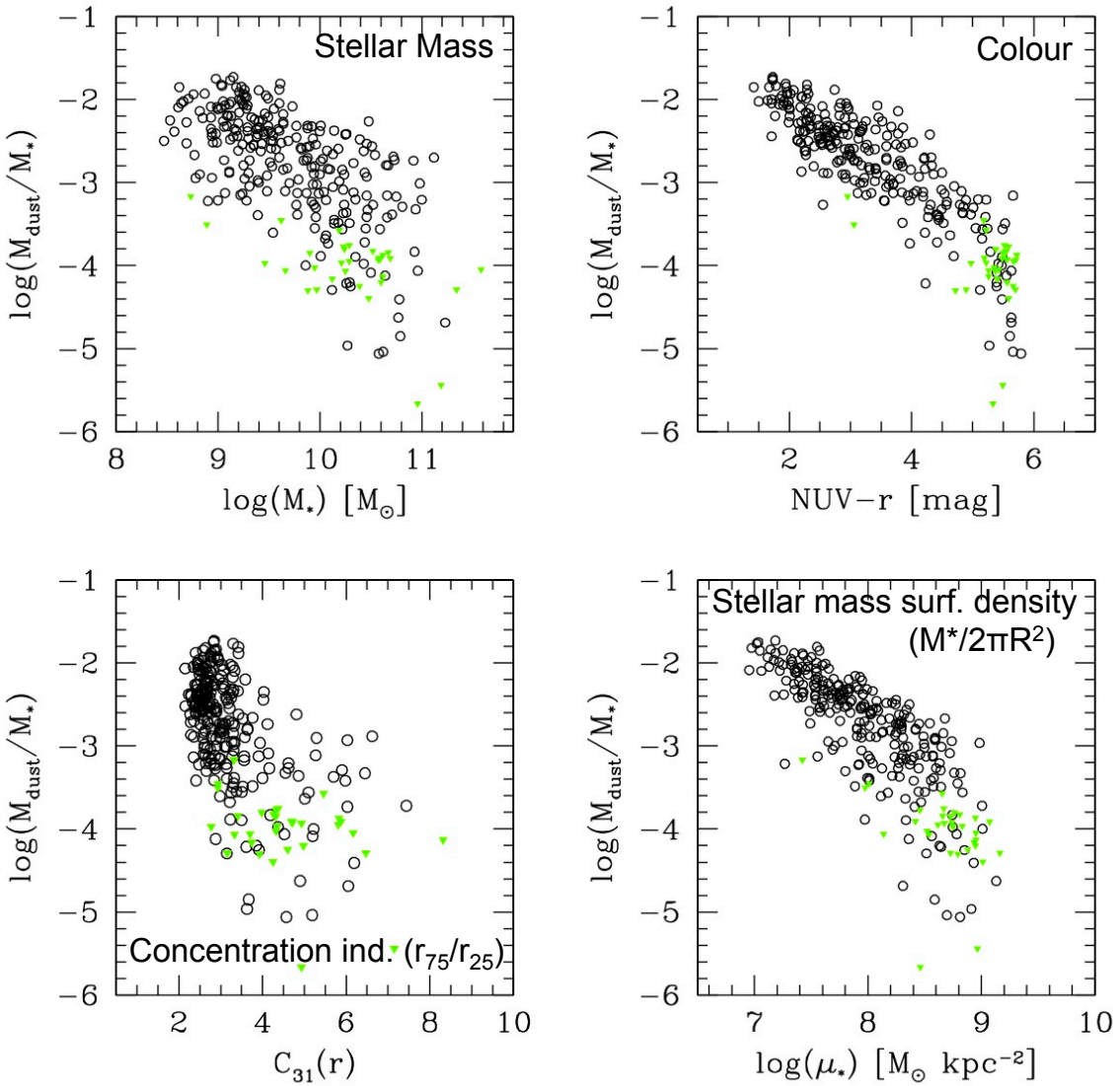
Pohlen, LC, Smith et al. 2010, A&A

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

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

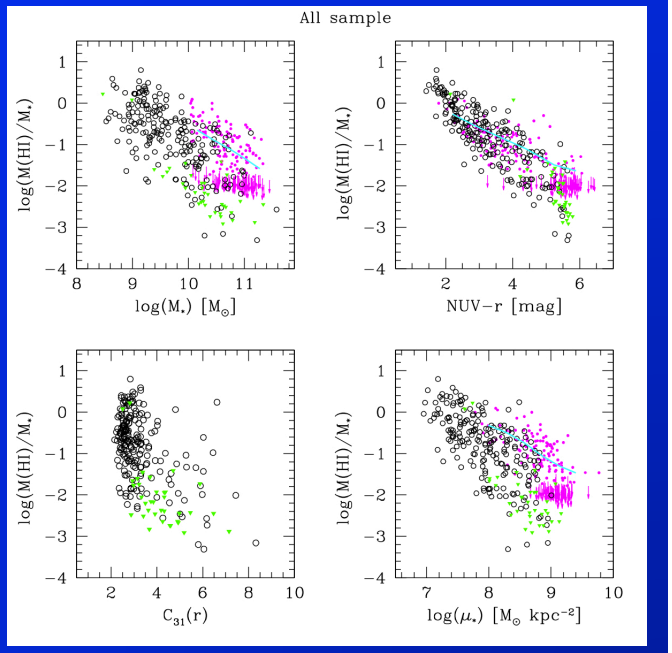
The dust scaling relations

Dust



Remarkable resemblance to the HI scaling relations

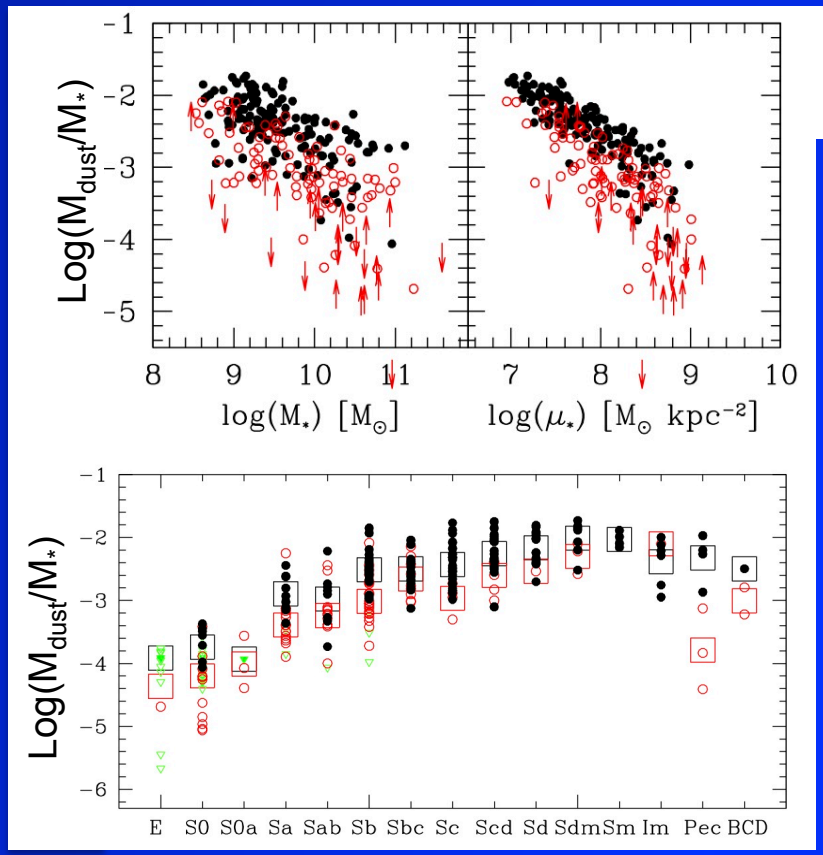
HI



LC et al., in prep.

Dust scaling relations and environment

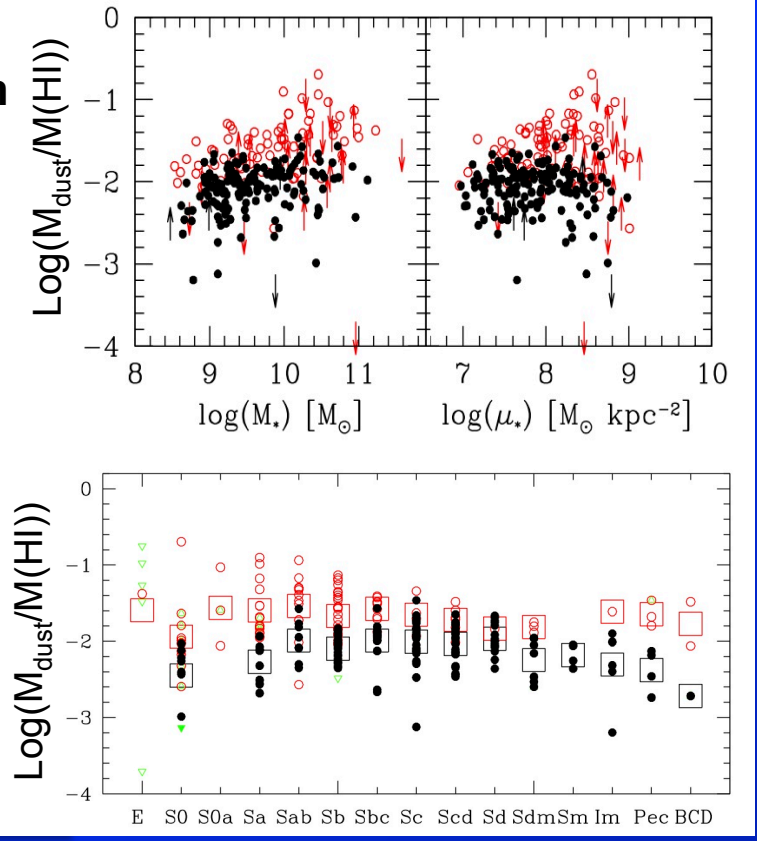
M_{dust}/M_*



Red=HI-def

Black=HI-norm

M_{dust}/M_{HI}



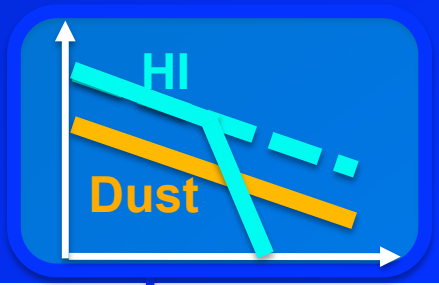
Dust is stripped but….

less than the HI

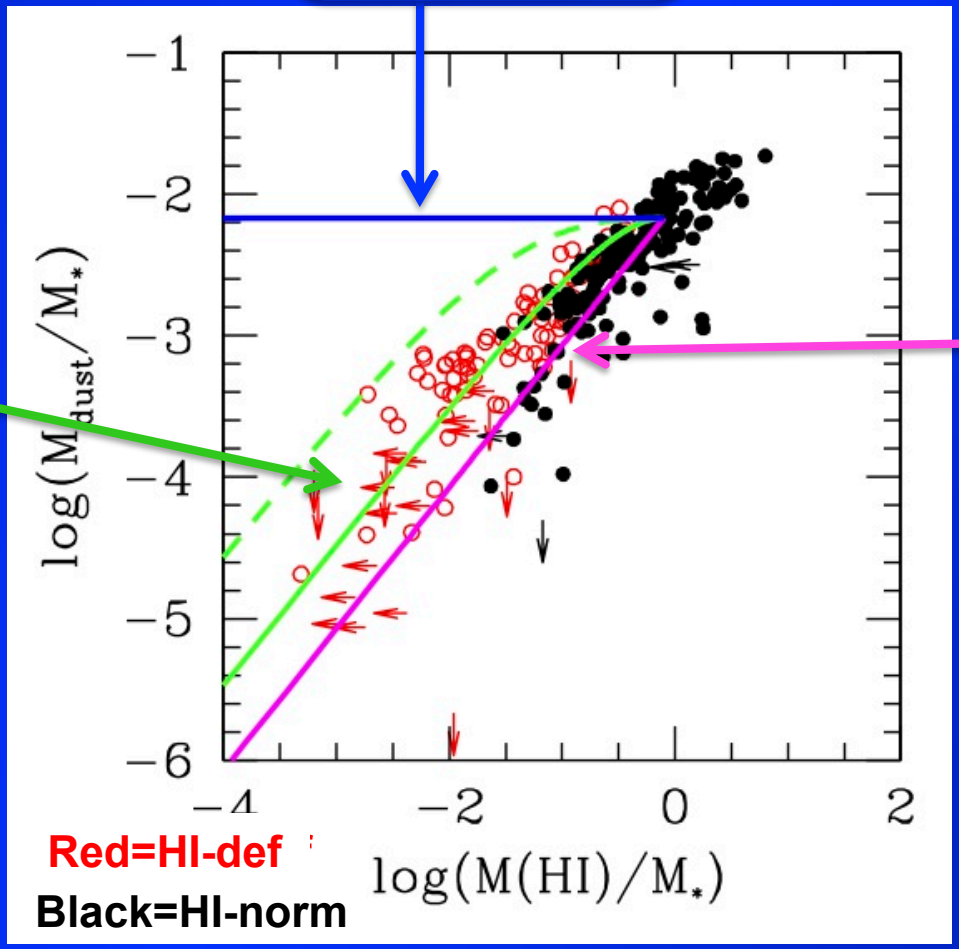
LC et al., in prep.

Dust is stripped but not as much as the HI

Dust not stripped



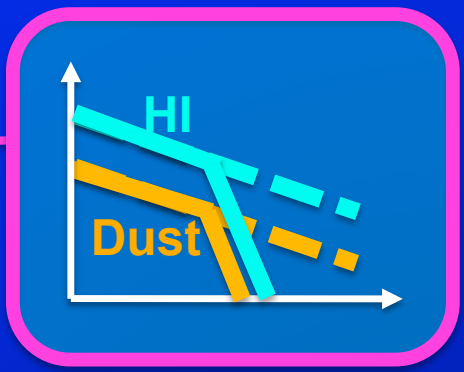
Dust stripped less than HI



Red=HI-def

Black=HI-norm

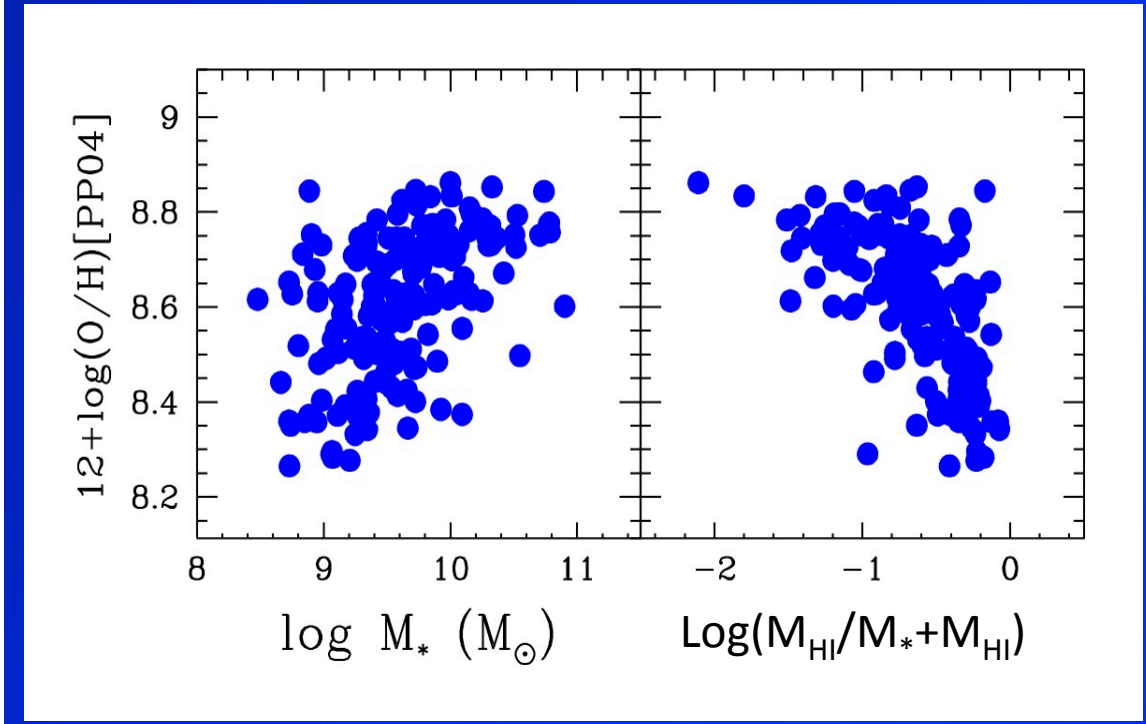
Dust+HI stripped



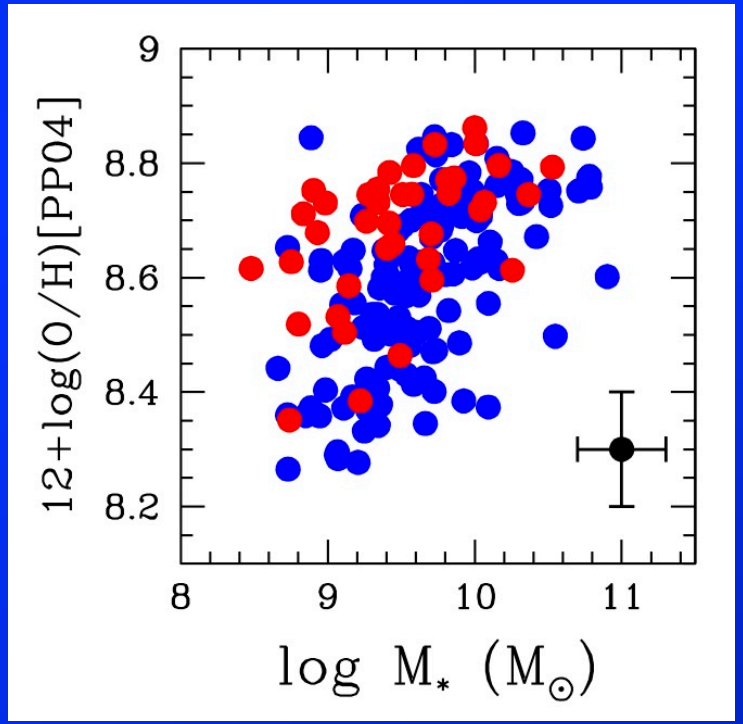
HI and dust removed, SF quenched in cluster galaxies…

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. galaxies more metal rich

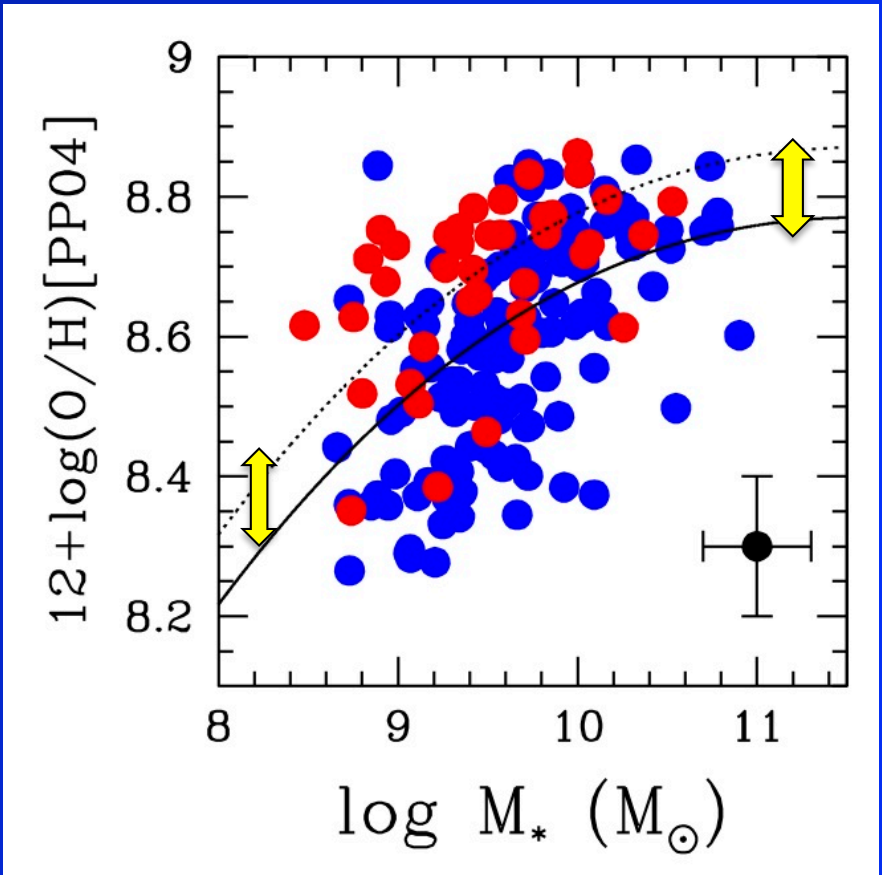
(see Skillmann+1996, Boselli & Gavazzi 2006)

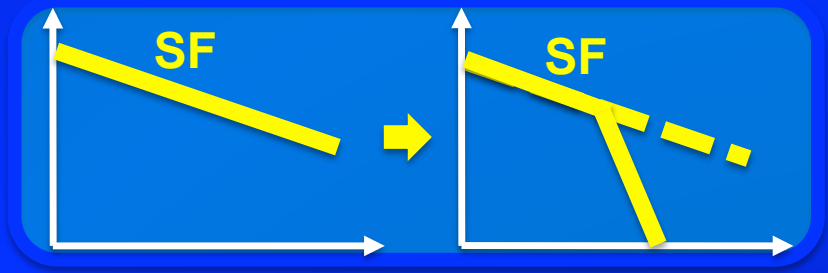
See poster by Thomas Hughes for more details

Hughes, LC et al. in prep.

Is this a real effect?

HI def. galaxies ➔ SF disk is truncated ➔ 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

See poster by Thomas Hughes for more details

Hughes, LC et al. in prep.

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