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

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What regulates the evolutionary history of galaxies?

Internal properties
- Mass
- Dynamics
- Nuclear activity
- ….

Environment
- Large-scale str.
- Merging
- Tides
- Stripping
- ….
Selection Criteria

- $15 < D < 25$ Mpc
- $K < 12$ for Spirals -- $K < 8.7$ for E/S0
- Gal. lat. $> +55^\circ$ -- $A(B) < 0.2$ mag

Multi-wavelength

- UV GALEX $\rightarrow$ Unobscured SF (P.I. Cortese/Boselli)
- Herschel/PACS $\rightarrow$ Obscured SF (P.I. Cortese/ Davies)
- Herschel/SPIRE $\rightarrow$ Dust masses (P.I. Boselli/Eales)
- 12mKittPeak $\rightarrow$ H2 properties (P.I. Boselli)
- Arecibo/VLA/WSRT $\rightarrow$ HI properties
- OHP $\rightarrow$ Gas metallicities (P.I. Boselli)
- SDSS+2Mass $\rightarrow$ Stellar masses

...and more

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
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

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)

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)

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)

`Starvation' scenario
Stop of gas infall, mimicking the removal of gas from just the halo

`Ram pressure' scenario
Stop of gas infall, plus gas stripping from the disk (Vollmer et al. 2001 technique)
The HI scaling relations and models

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

(see Boselli’s talk on Tuesday)

Ram pressure necessary to explain HI scaling relations in Virgo

(see also Boselli & Gavazzi 2006, Chung et al. 2007, Vollmer et al. 2009)
Less HI in cluster galaxies...

what about star formation?
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

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

“Truncated” dust disks in HI-deficient Virgo spirals
(see Davies’ talk on Tuesday)
The dust scaling relations

Remarkable resemblance to the HI scaling relations

Stellar Mass

Colour

Concentration ind. \((r_{75}/r_{25})\)

Stellar mass surf. density \((M^*/2\pi R^2)\)

HI

LC et al., in prep.
Dust scaling relations and environment

\[
\frac{M_{\text{dust}}}{M_\star} \quad \text{Red=HI-def} \\
\frac{M_{\text{dust}}}{M_{\text{HI}}} \quad \text{Black=HI-norm}
\]

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

Dust+HI stripped

Red=HI-def

Black=HI-norm
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
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

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