The Different Physical Mechanisms that Drive the Star-formation Histories of Giant and Dwarf Galaxies

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11th Birmingham-Nottingham Extragalactic Workshop Semi-analytic models: are we kidding ourselves ?
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The Bimodal Galaxy Distribution

The global properties of galaxies have been found to be bimodally distributed, indicating two separate populations having different:

- Colours
- Morphologies
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- Mean stellar ag
- High mass/lum
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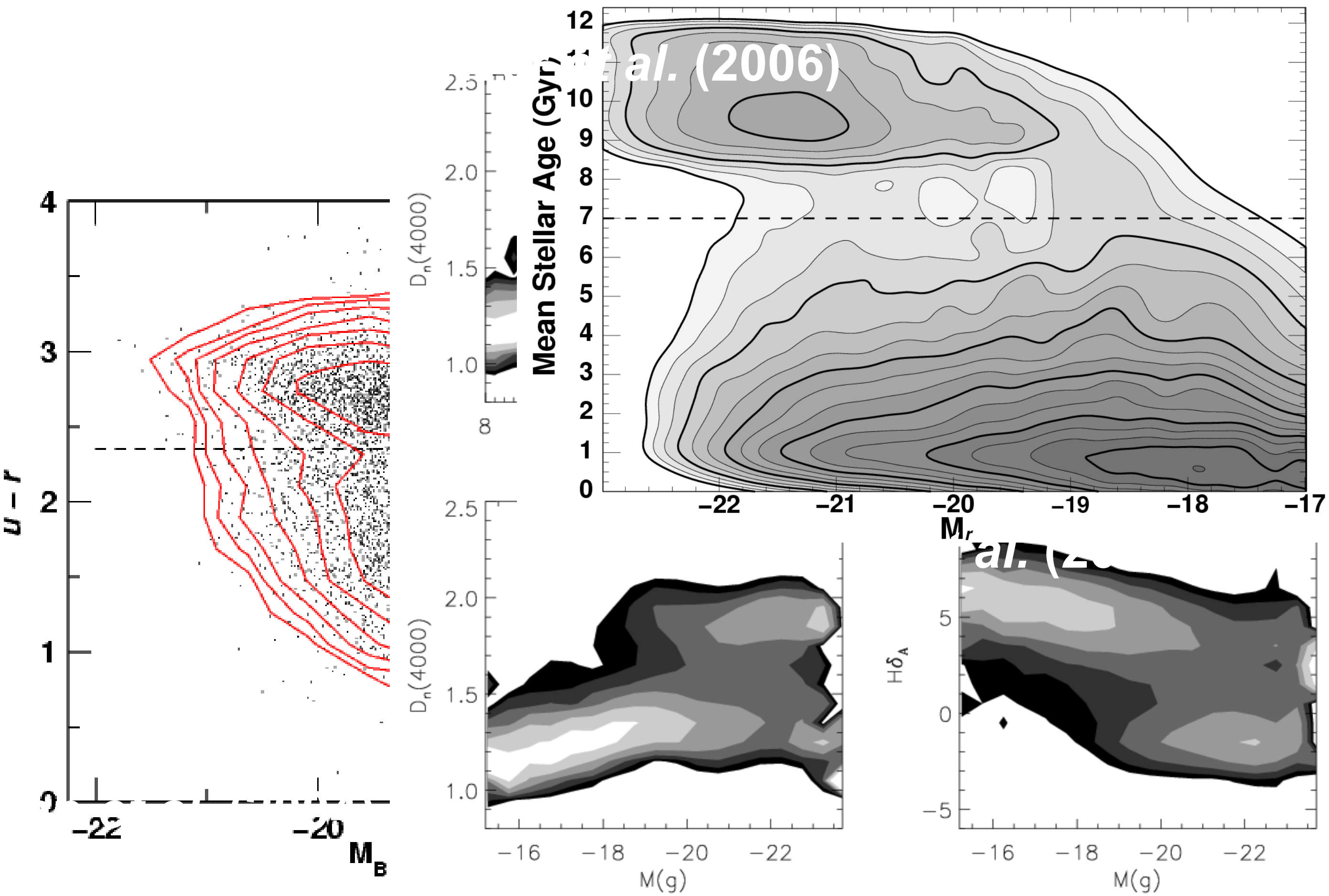
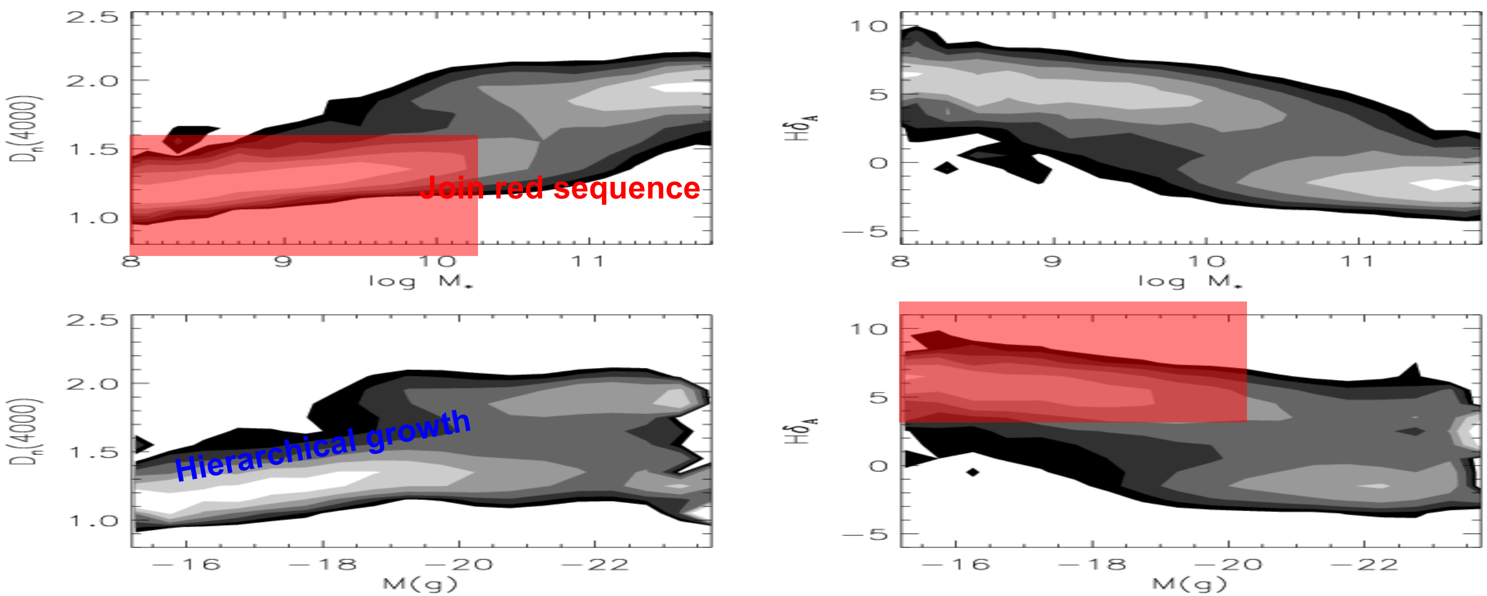
- Low mass/lum
galaxies whose l



The Bimodal Galaxy Distribution

- What produces this bimodality in galaxy properties ?
- If galaxies grow hierarchically through merging/accretion, what causes the blue, star-forming disk galaxies to become red passively-evolving spheroids at 3x1010M⊙(~M*+1) ?
- Why are there so few low-mass passive galaxies ?



Environmental effects

Clusters dominated by high-mass passively-evolving spheroids

Field galaxies typically low-mass star-forming disks

Are these trends due to the initial conditions in which the galaxy forms ("nature" – formation epoch, merger history) or produced later by environmental related processes ("nurture" - e.g. ram-pressure stripping, galaxy harassment, starvation ?

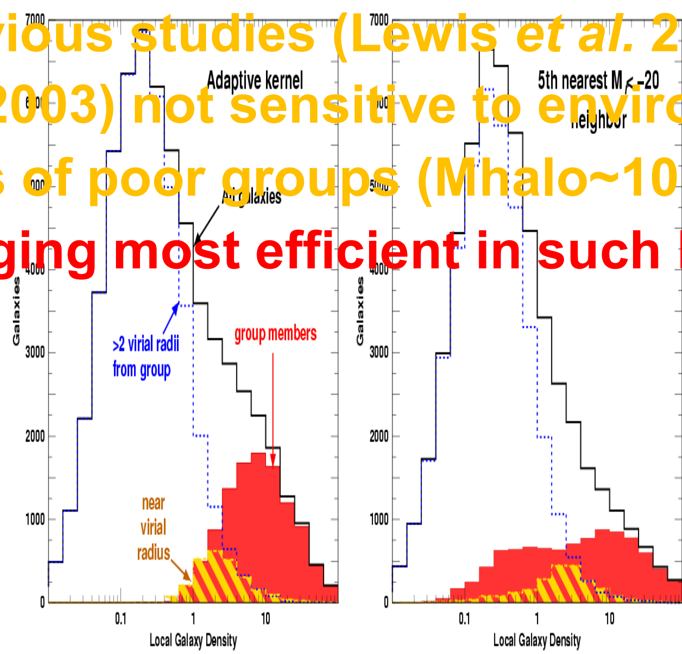
Comparison of environmental trends of giant and dwarf galaxies could provide insights into origin of bimodal galaxy distribution

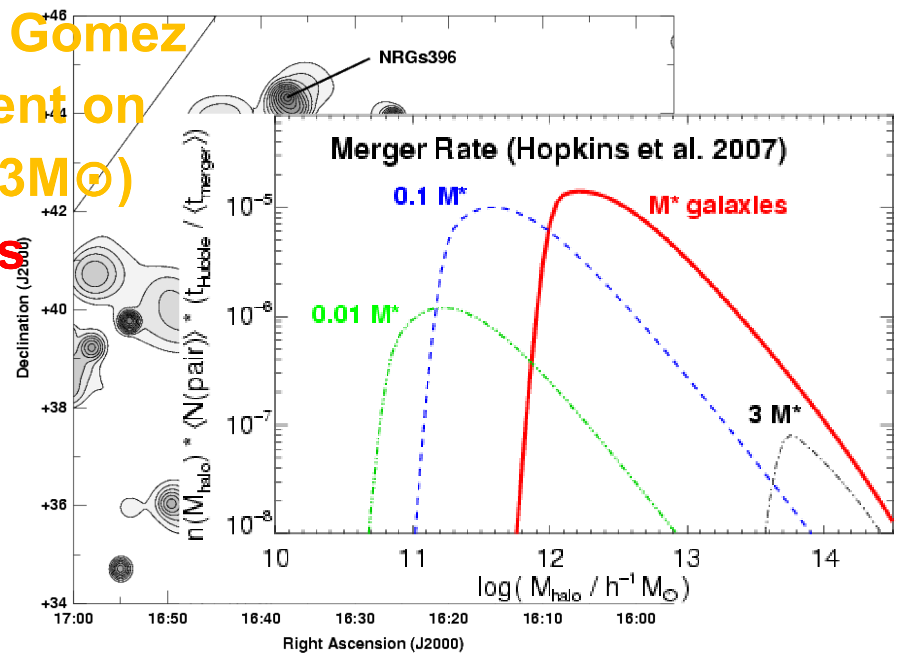
Summary of SDSS DR4 analysis: Haines *et al.* 07

Sensitive to structures as poor as the Local Group. Tested on Millennium simulation

Robust separation of field and group galaxies. ρ<0.5 => field galaxy

- **Previous studies (Lewis *et al.* 2002, Gomez *et al.* 2003) not sensitive to environment on scales of poor groups (Mhalo~1012-13M⊙)**
- **Merging most efficient in such halos**





Summary of SDSS DR4 analysis

§ Use Hα as it is the best understood and well-calibrated indicator of star-formation over the last 20 Myr (Kennicutt 1998; Moustakas *et al.* 2006)

§ Robust separator of passive and star-forming galaxies about EW(Hα)=2Å

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§ Estimate r-band lum

mean stellar ages usi

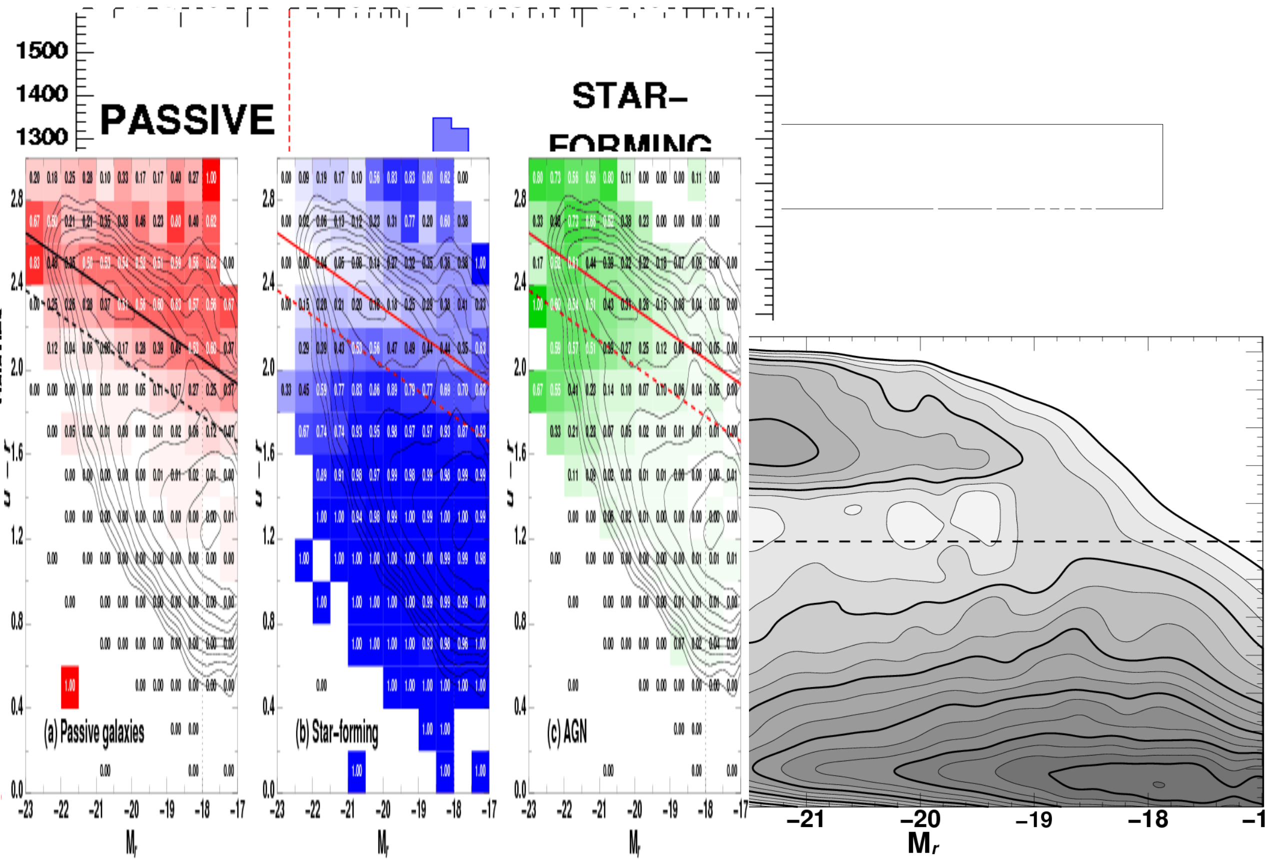
d4000 indices and *g-r*

§ Find best-fitting Bru

models with varying S

§ Get robust separati

dominated by old or y



Star-formation as a function of luminosity / stellar mass and environment: Haines *et al*. (2007)

Fraction of passive galaxies as a function of luminosity and environment

- At high-densities (i.e. within groups or clusters) passive galaxies dominate independent of luminosity
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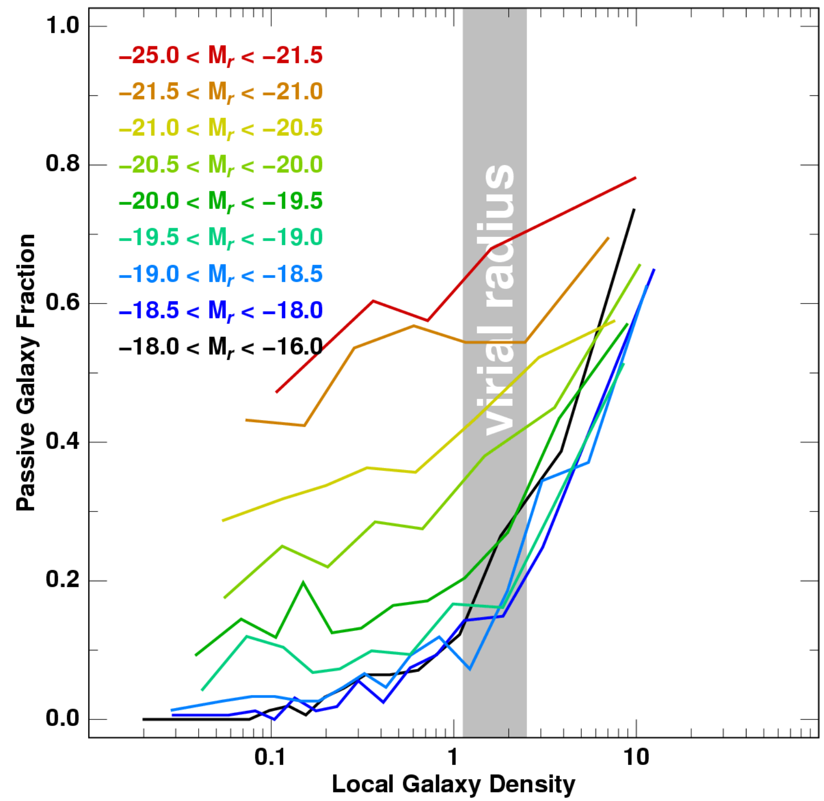
- In low-ρ regions environment-related processes not effective: SF must stop due to internal mechanisms (AGN/SN feedback, merging, gas exhaustion)
- Dwarf galaxies do not become passive through internal processes



Comparison to semi-analytic models

Repeat analysis using the semi-analytic models of Croton *et al.* (2006) and Bower *et al.* (2006) based on the Millennium simulation

- **Create "mock SDSS" catalogues, calculating local density in same way combining dz and νz to give "redshift"**
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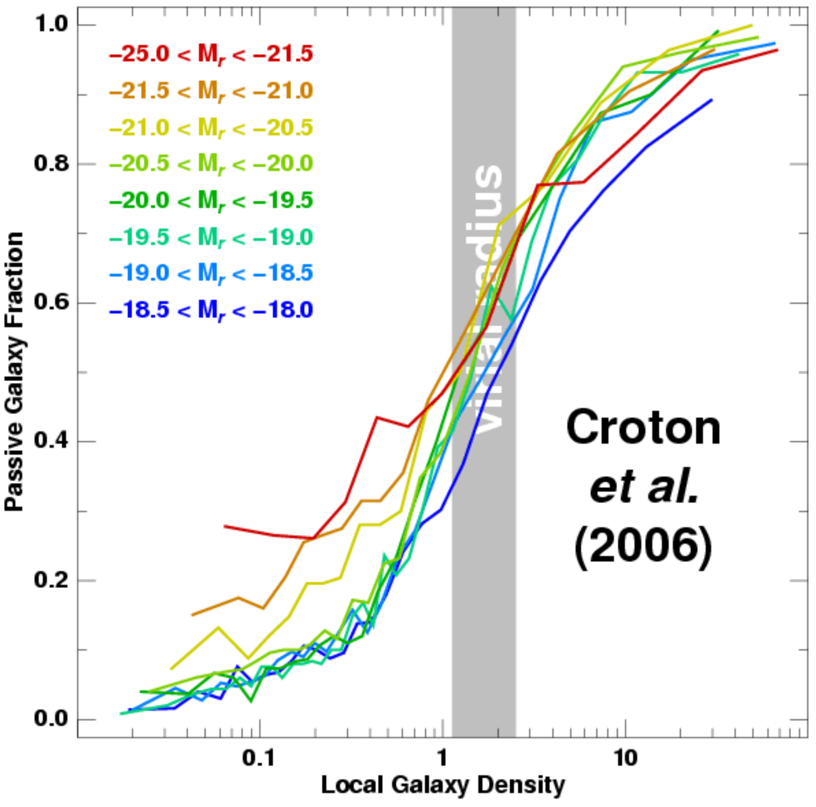
- **For Bower model use L(Hα)/L*r* to give EW(Hα): EW(Hα)<2Å => passive**



Comparison to semi-analytic models

Repeat analysis using the semi-analytic models of Croton *et al.* (2006) and Bowker *et al.* (2006) based on the Millennium simulation

- Much stronger density trends than observed, particularly for >L* gals: From 30% in field increasing to >90% at high-ρ;SDSS rise just 50% to 80%
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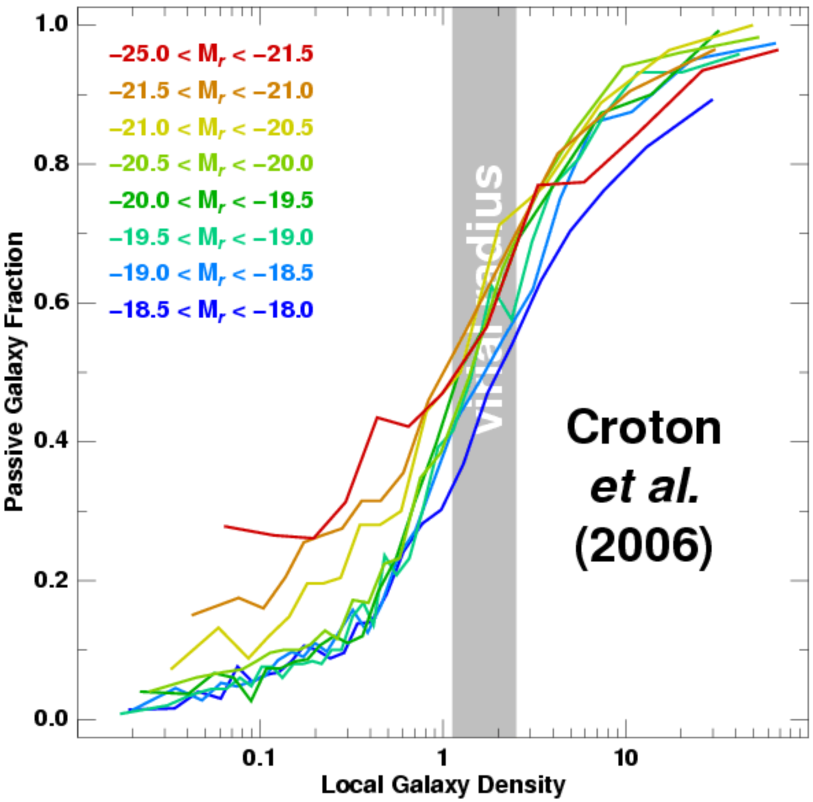
- Still find passive dwarfs in even the most isolated regions unlike SDSS
- 65-170% overabundance of faint (-19<M*r* <-18) satellites around M*r* <-20 galaxies in Croton model
- Will accounting for effects of tidal stripping resolve this excess ?



Comparison to semi-analytic models

Repeat analysis using the semi-analytic models of Croton *et al.* (2006) and Bower *et al*. (2006) based on the Millennium simulation

- **Luminosity-dependence at low-ρ closer to SDSS than Croton**
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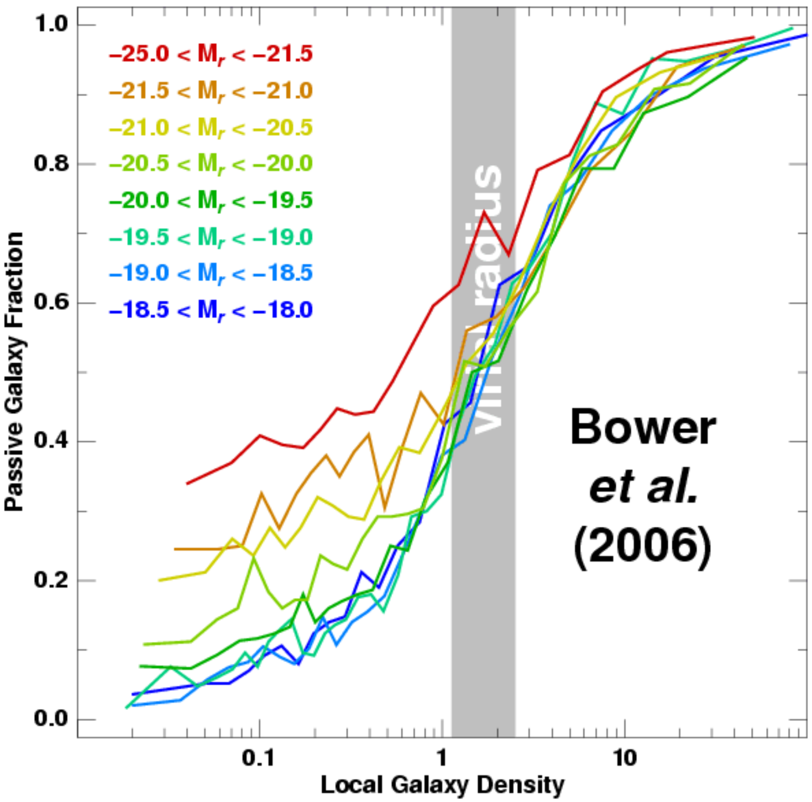
- **Shortage of passive >L* field gals => internal mechanisms such as AGN feedback/merging not strong enough**
- **Remnant passive dwarf population in isolated regions of both models => some internal process must still be quenching SF in these dwarfs**



AGN activity as a function of luminosity / stellar mass and environment

AGN activity identified from BPT diagnostics (e.g. Baldwin *et al.* 1981)

- **AGN fraction independent of local environment for all luminosities**
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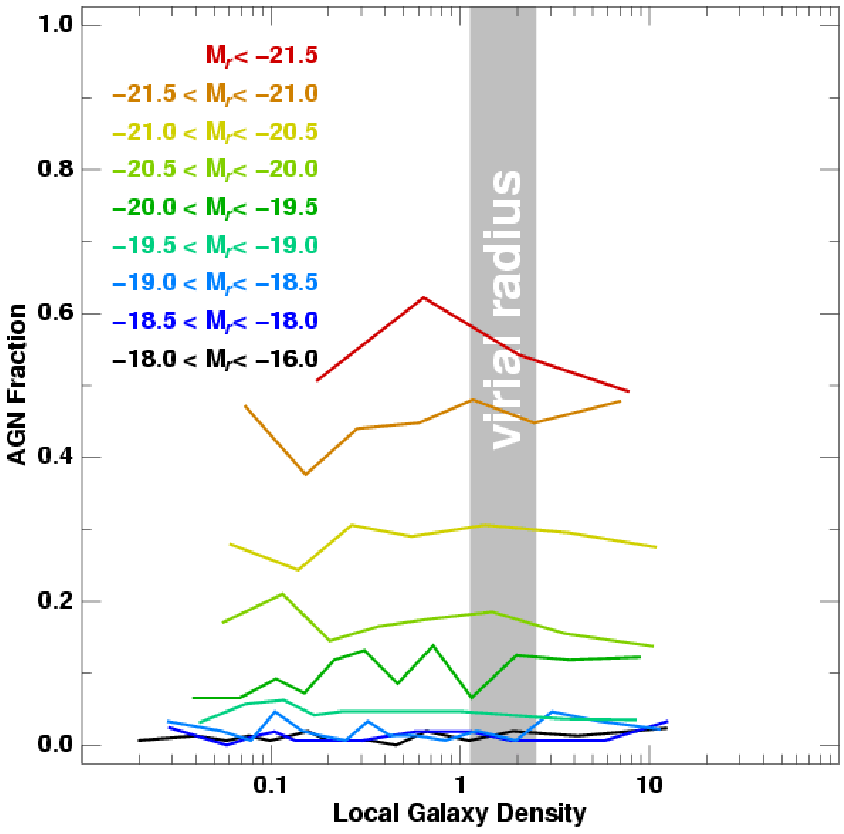
- **Luminosity dependence of AGN exactly parallels that of the passive fraction in low-density regions**
- **Reflects increasing importance of AGN feedback with galaxy mass for their evolution as expected from the MBH-σ relation (Ferrarese & Ford 2005)**



Star-forming galaxies

How does the EW(Hα) distribution of star-forming gals vary with density ?

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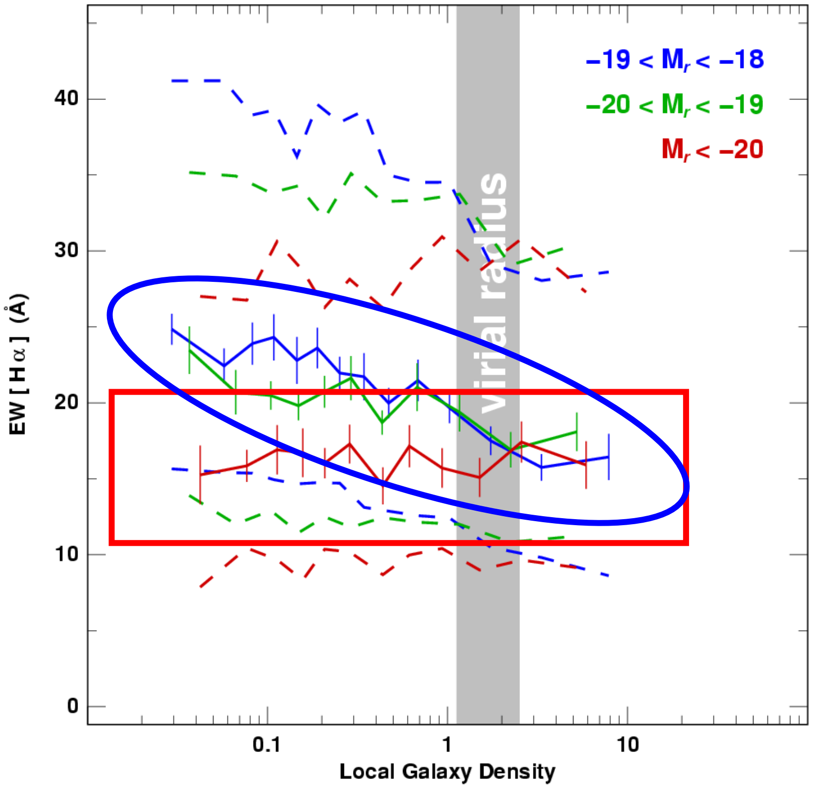
§ **Giant star-forming galaxies show no change in Hα distribution with density: rapid truncation or at high redshifts (e.g. Balogh *et al*. 04; Tanaka *et al.* 04)**

§ **Dwarf star-forming galaxies show systematic drop of ~30% in EW(Hα) from low- to high-densities (10σ)**

§ **Slow truncation of SF in <u>*most* dwarf star-forming galaxies in groups/clusters</u>**



Age versus supercluster environment

How do the mean stellar ages of massive galaxies directly relate to their local environment in the vicinity of the A2199 supercluster at z~0.03 ?

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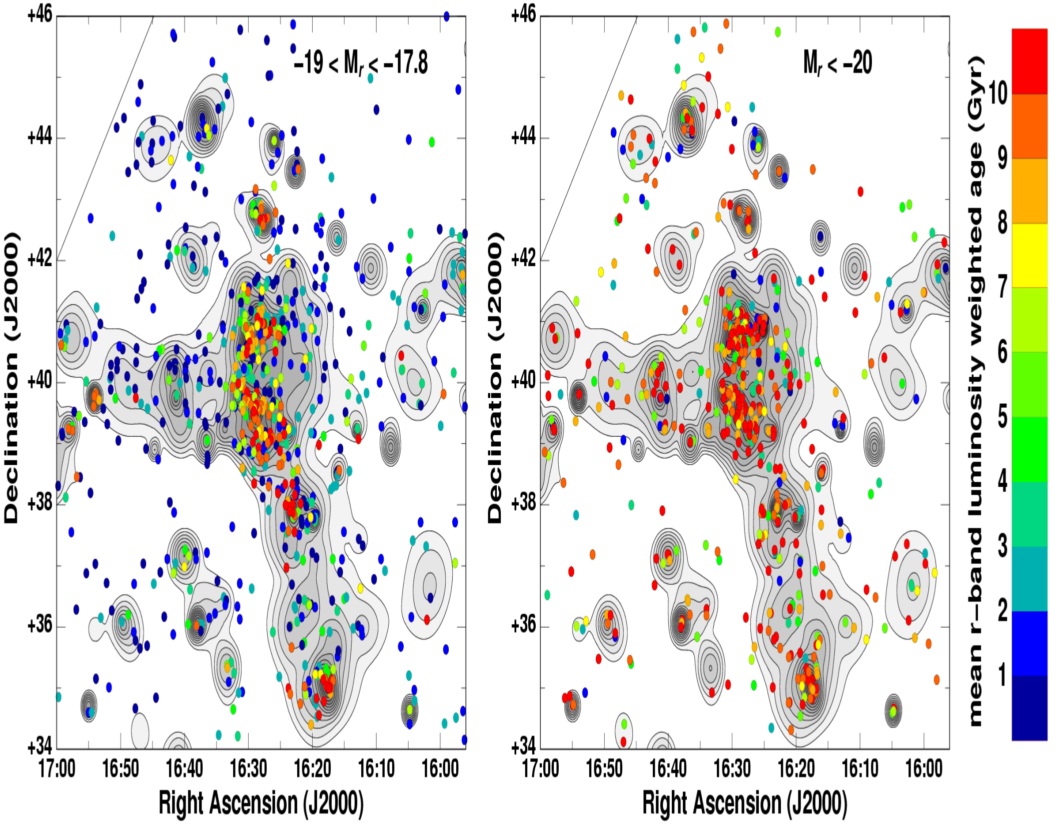
§ **Well outside of the clusters there is a complete spread of ages, with an equal interspersed mixture of young and old giant galaxies**

§ **Evolution primarily driven by <u>mergers</u>**



Age versus supercluster environment

How does the relation between the mean stellar ages of dwarfs and their spatial position within the supercluster differ from that of massive gals ?

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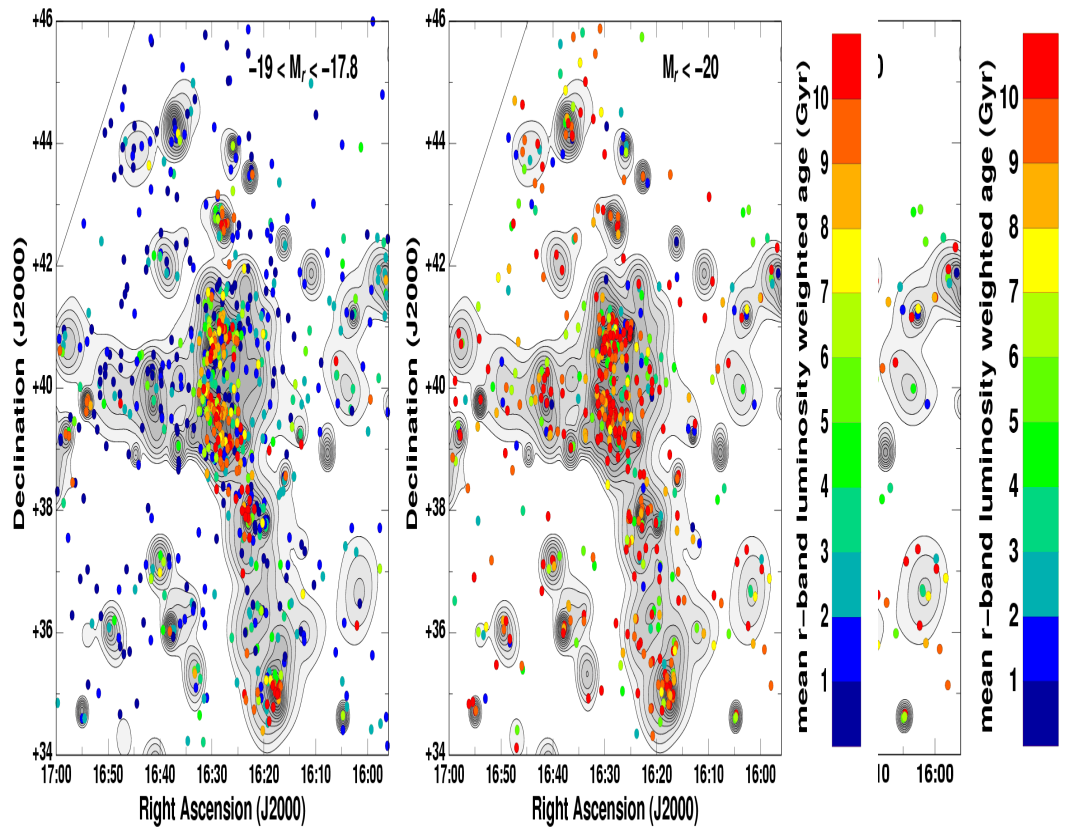
§ **Outside of clusters >95% of dwarfs are young (<3Gyr)**

§ **All of the few remaining old dwarf galaxies are in poor groups or <250kpc of an old massive galaxy**

§ **There are no isolated old dwarf galaxies**

§ **Same results obtained using EW(Hα) to separate passive and SF galaxies**



Effects of neighbouring galaxies

Are the star-formation histories of galaxies dependent on the presence of their immediate neighbours or only the larger scale density field ?

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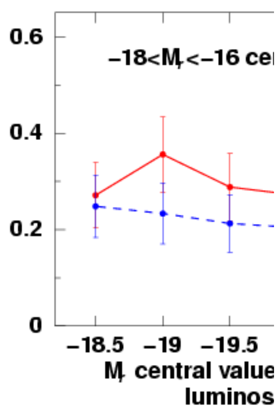
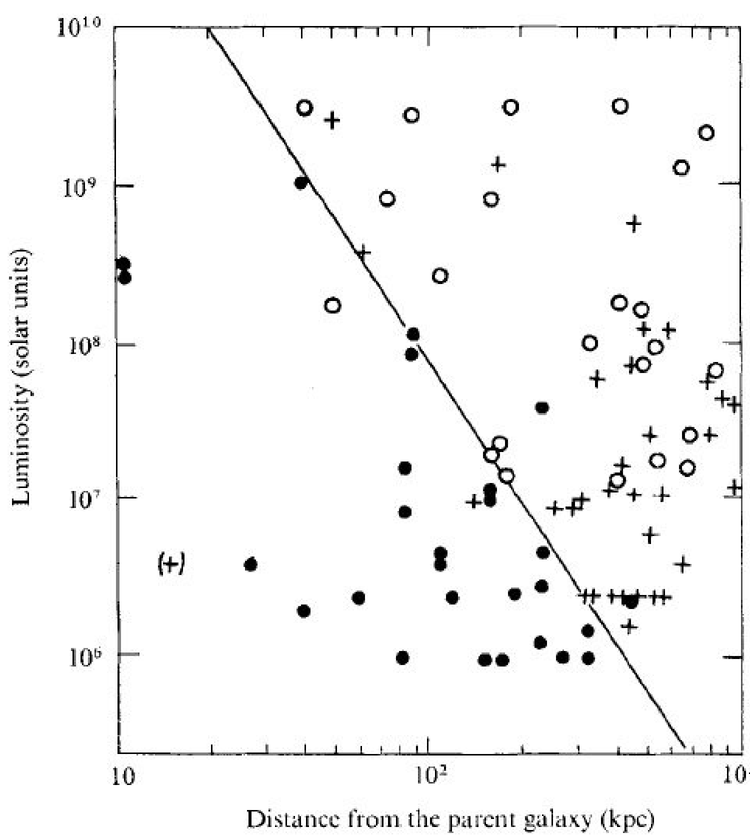
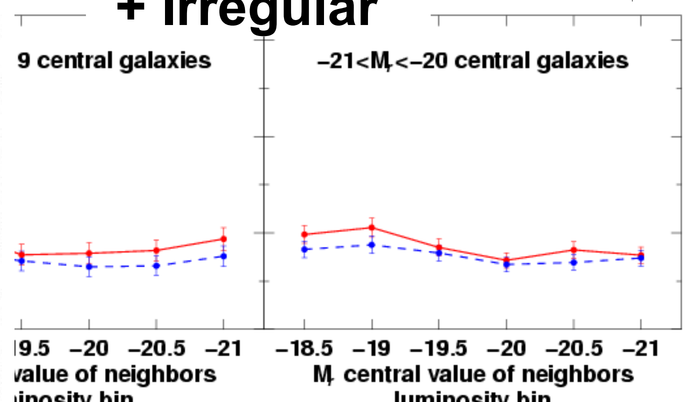
§ We comp… anc… g "field" galaxies tha… icu… ty range w…







§ Massive g… for neighbours of any kind

A Possible Physical Framework

Two giant gas-rich galaxies merge

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Gas driven inwards triggering starburst and rapid BH growth

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BH undergoes quasar phase producing powerful wind which expels the remaining gas from the galaxy stopping star-formation

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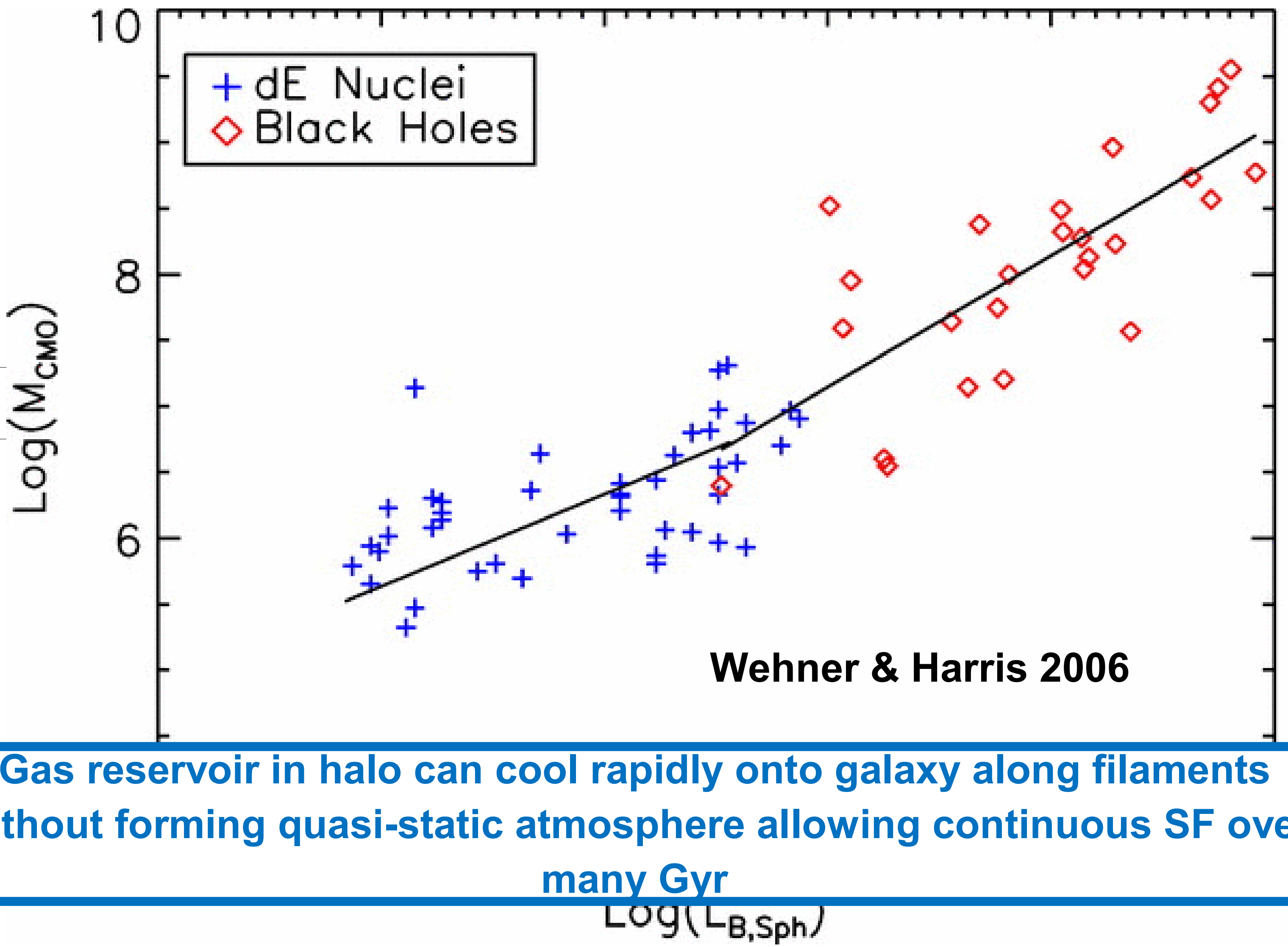
Diffuse gas in halo prevented from cooling by feedback from quiescent AGN activity so galaxy becomes permanently passive

A Possible Physical Framework



Gas reservoir in halo can cool rapidly onto galaxy along filaments without forming quasi-static atmosphere allowing continuous SF over many Gyr

Conclusions

§ **The evolution of galaxies with stellar masses ≳3x1010M⊙ is primarily driven by internal processes, e.g. AGN feedback, merging**

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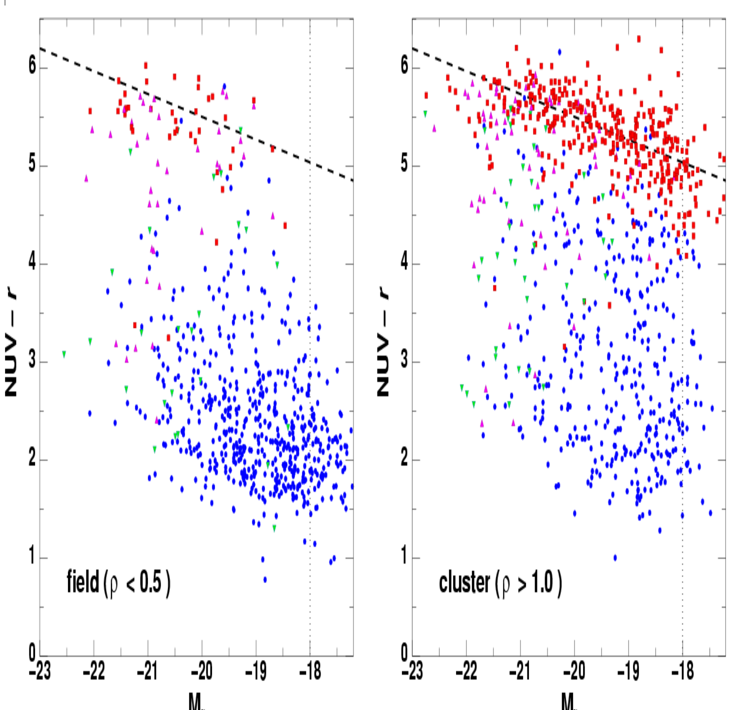

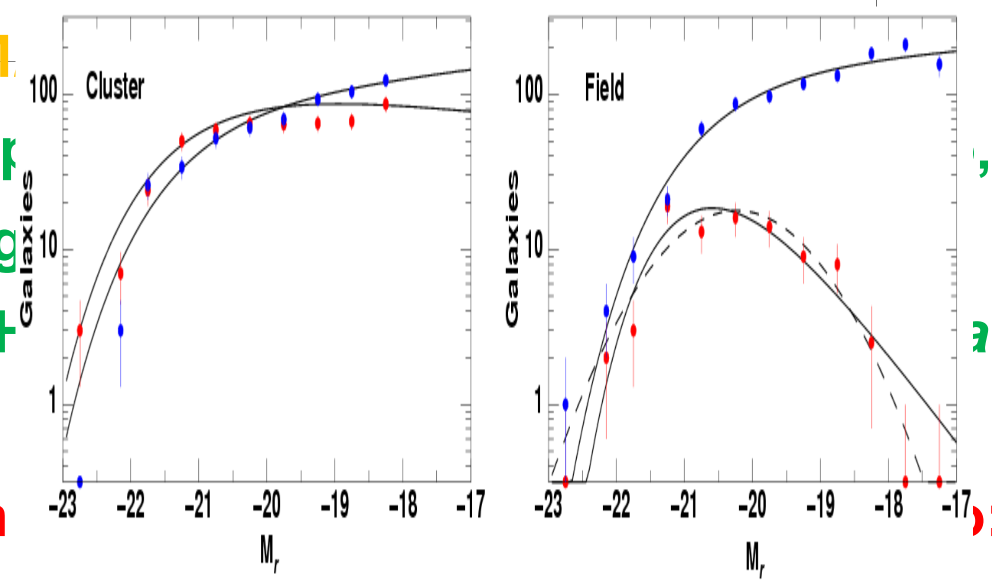

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Conclusions

- **Measuring environmental trends allows the effects of internal and environmental mechanisms on galaxy evolution to be separated, both in observations and in simulations**
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- **Still unclear which physical mechanisms are dominant in transforming high-and low-mass galaxies when they encounter massive halos**
- **Need to catch galaxies "in the act" of transformation, a process which may be heavily dust-obscured**
- **Infrared observations by Spitzer and Herschel may well provide crucial insights: numbers of cluster LIRGs can be used to distinguish between transformation processes (Zhang 2008)**