Morphological Composition of z~0.4 Groups: The site of S0 Formation?

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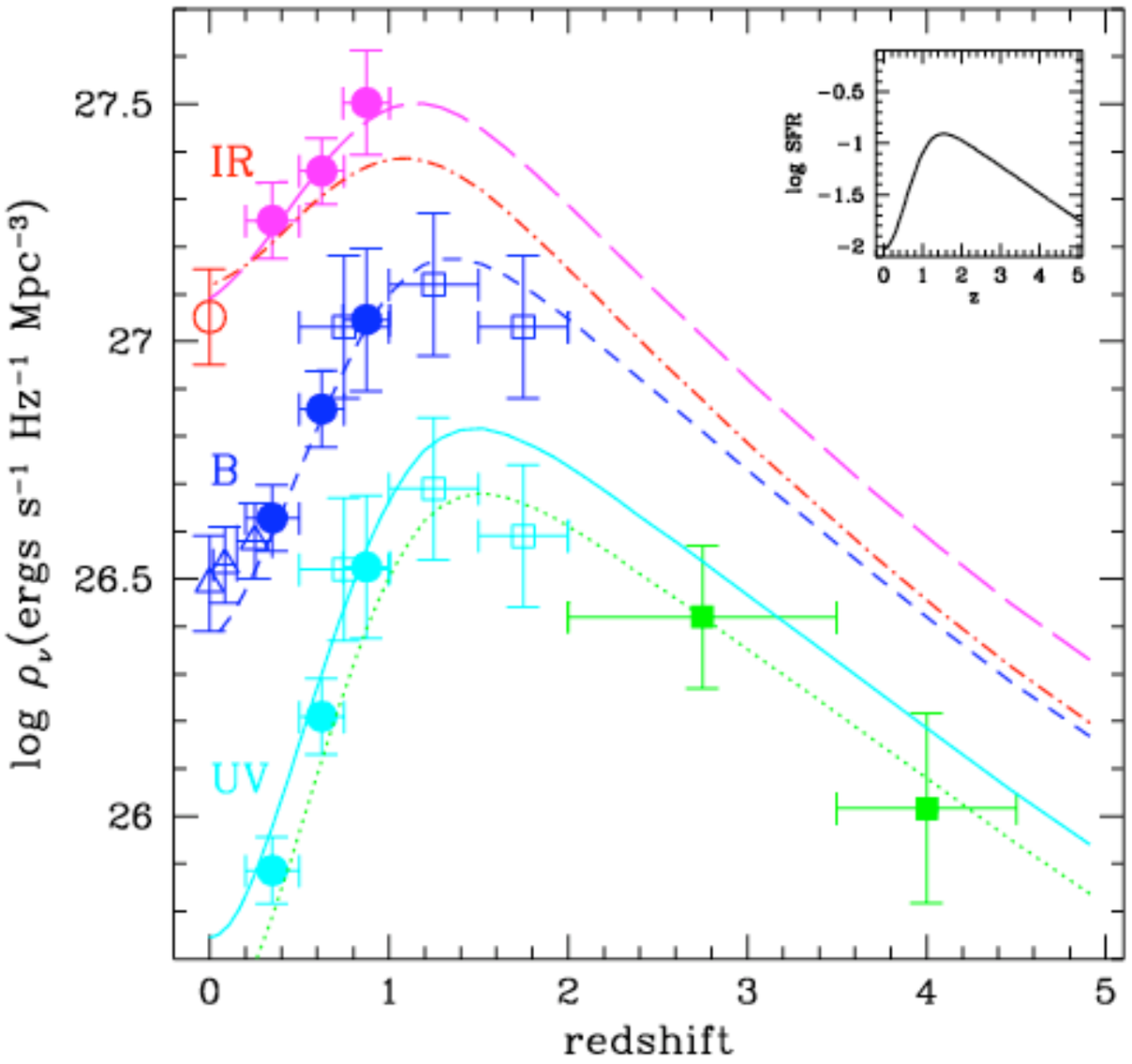
Wilman, Oemler, Mulchaey, McGee, Balogh & Bower

2009, ApJ, 692, 298 *

*Also described as a 'Research Highlight' in Nature, March 5 2009, Vol 458, Issue 7234

Decline of Star Formation at low z

Madau et al, 98



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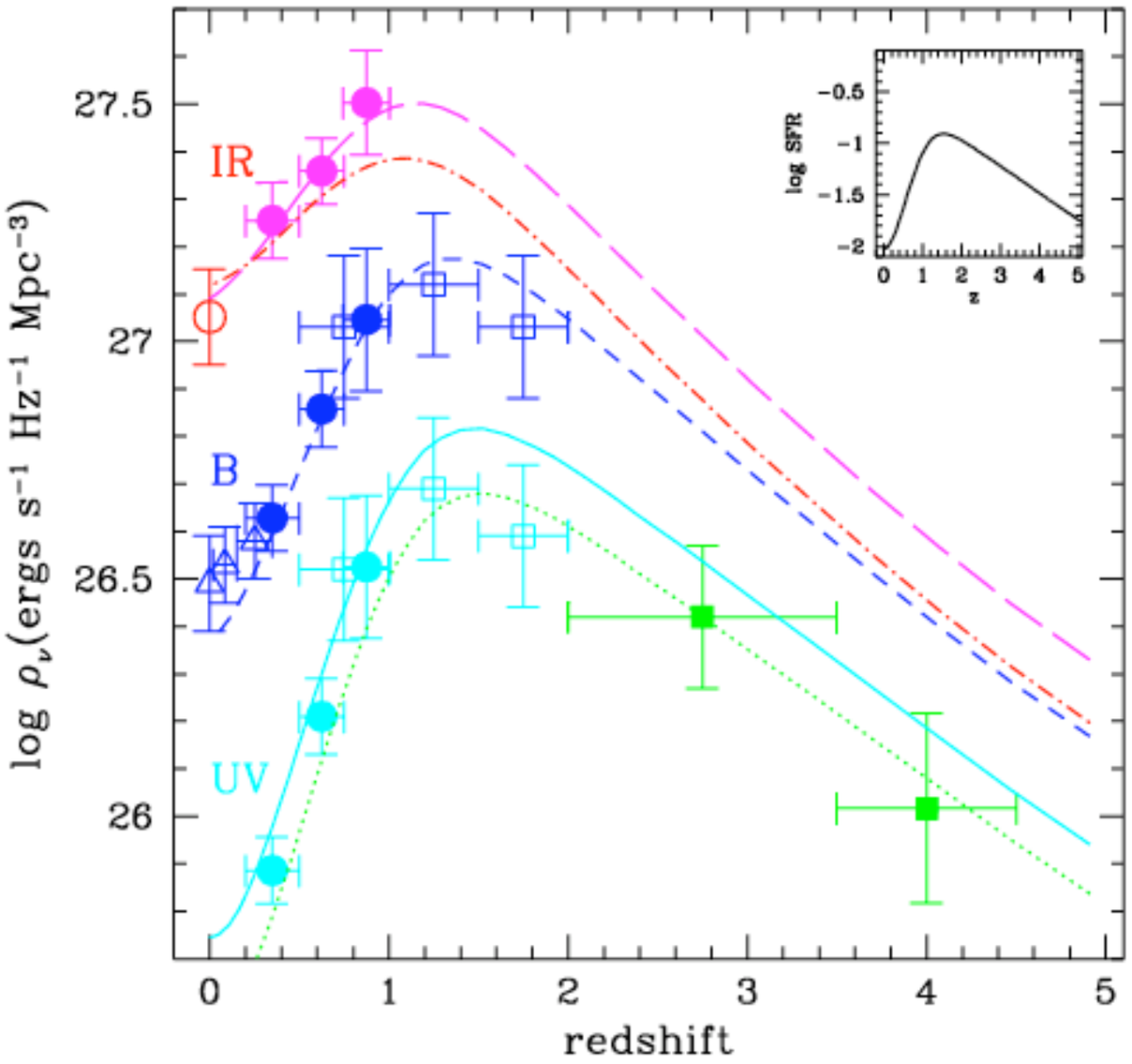


COMBINED:

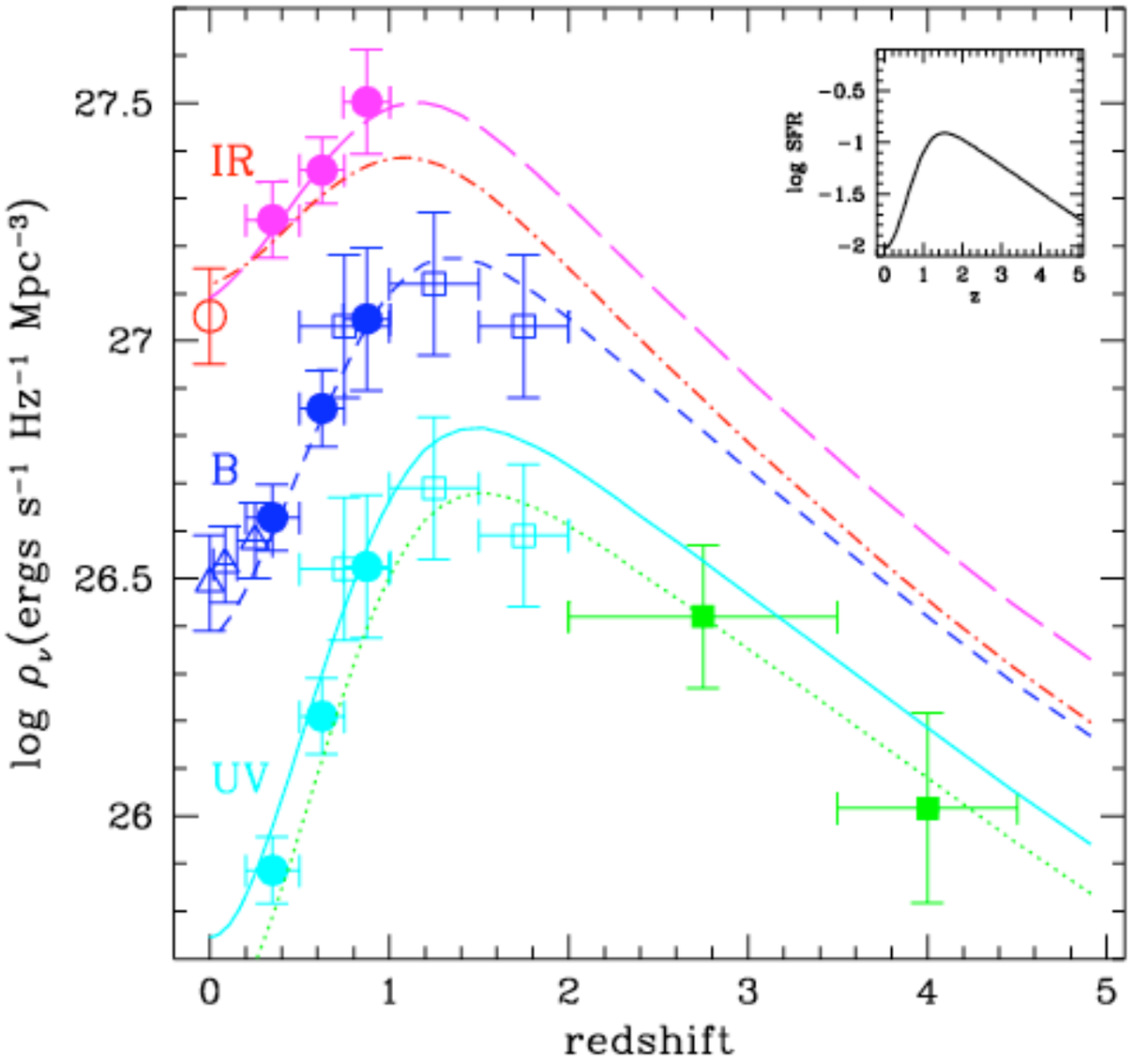
Declining SFR in individual galaxies

AND

Lower fraction of star forming galaxies

Decline of Star Formation at low z

Madau et al, 98



COMBINED:

Declining SFR in individual galaxies

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Lower fraction of star forming galaxies

Evolution in Clusters - Blue Galaxies

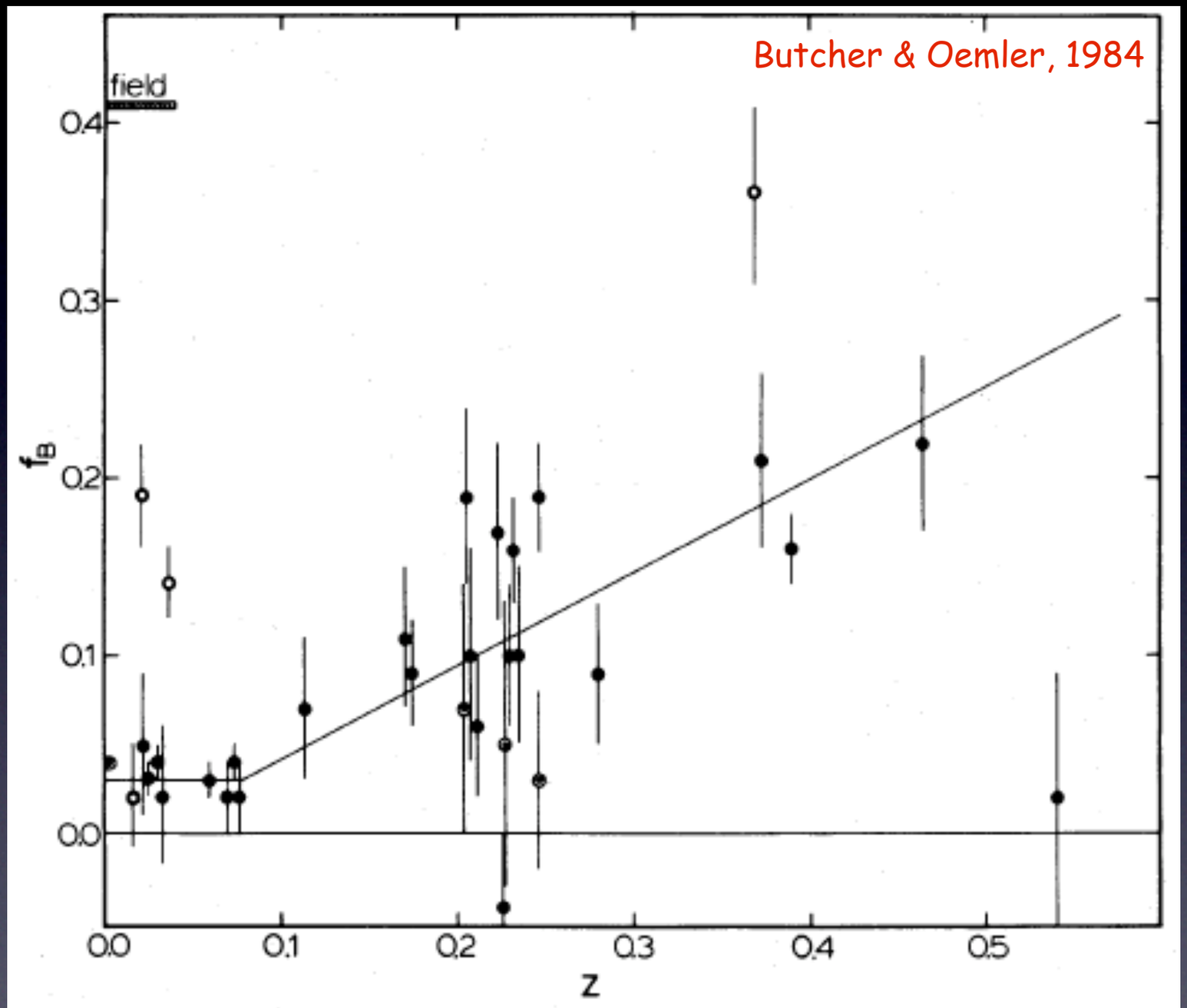
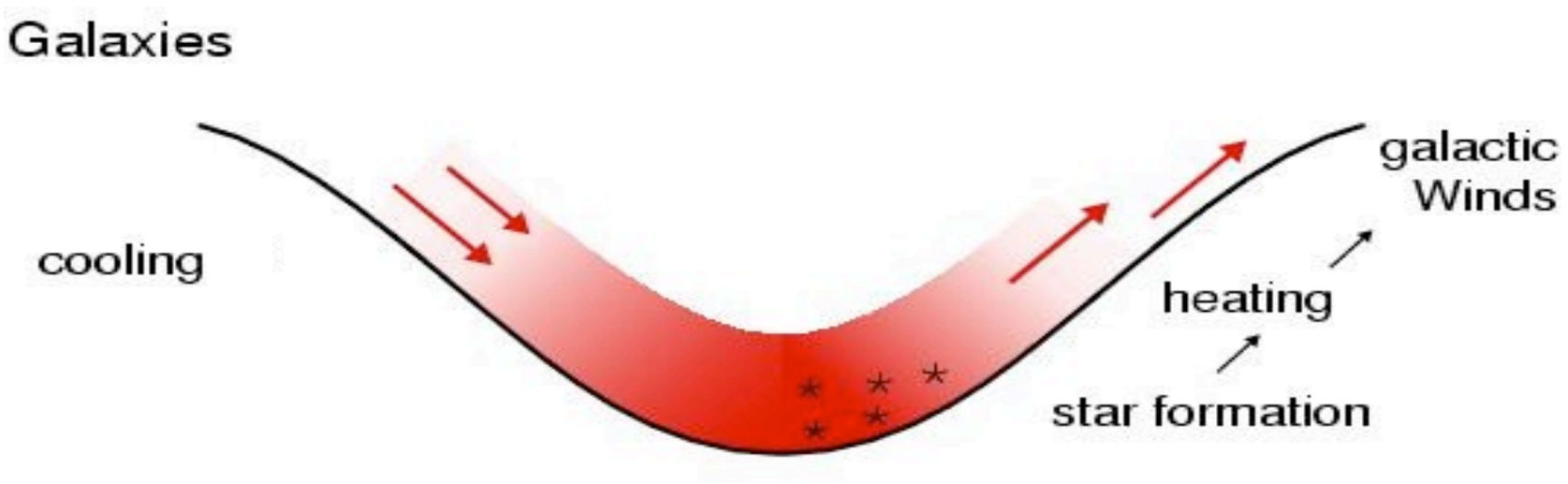
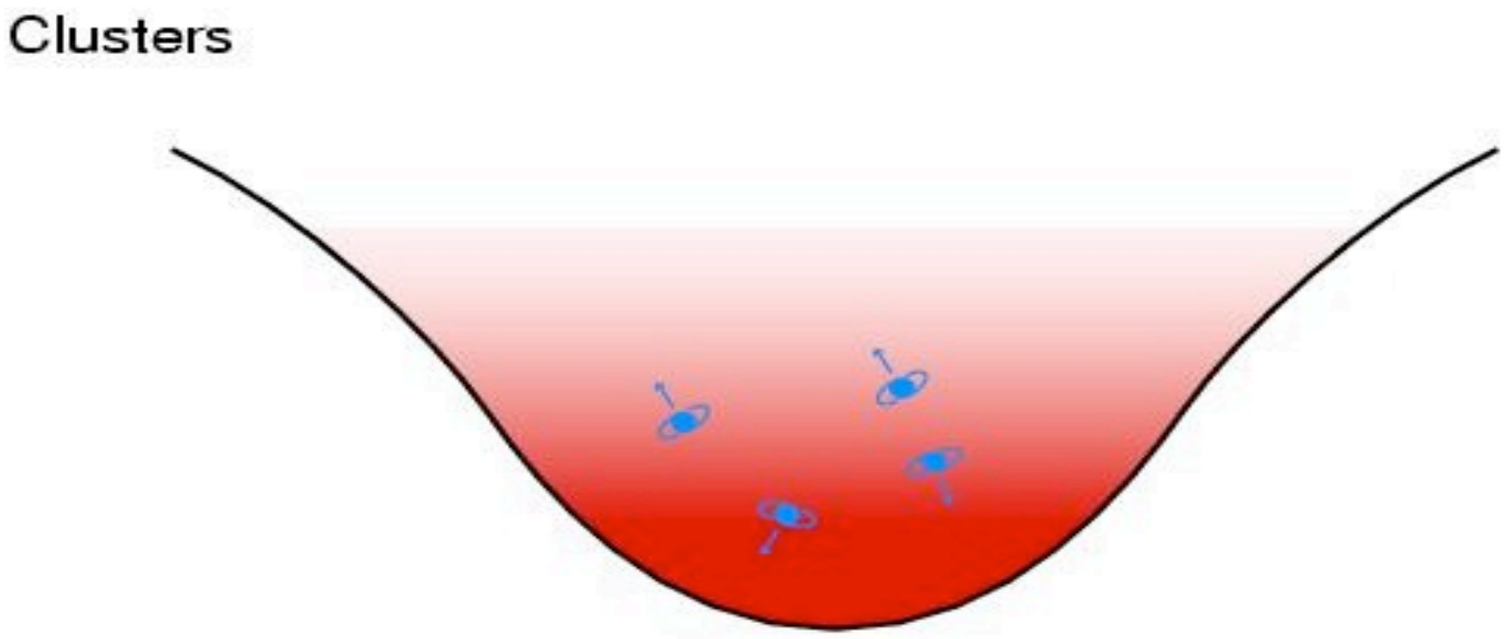


FIG. 3.—Blue galaxy fraction versus redshift. *Filled circles*, compact clusters ($C \geq 0.40$); *open circles*, irregular clusters ($C < 0.35$); *dotted circles*, intermediate clusters ($0.35 \leq C < 0.40$).

Strongly evolving fraction of blue (star forming) galaxies

Gravity and Gas Physics





Small Scales

Galaxies — Heating and Cooling

Pairs — Mergers and Interactions between galaxies

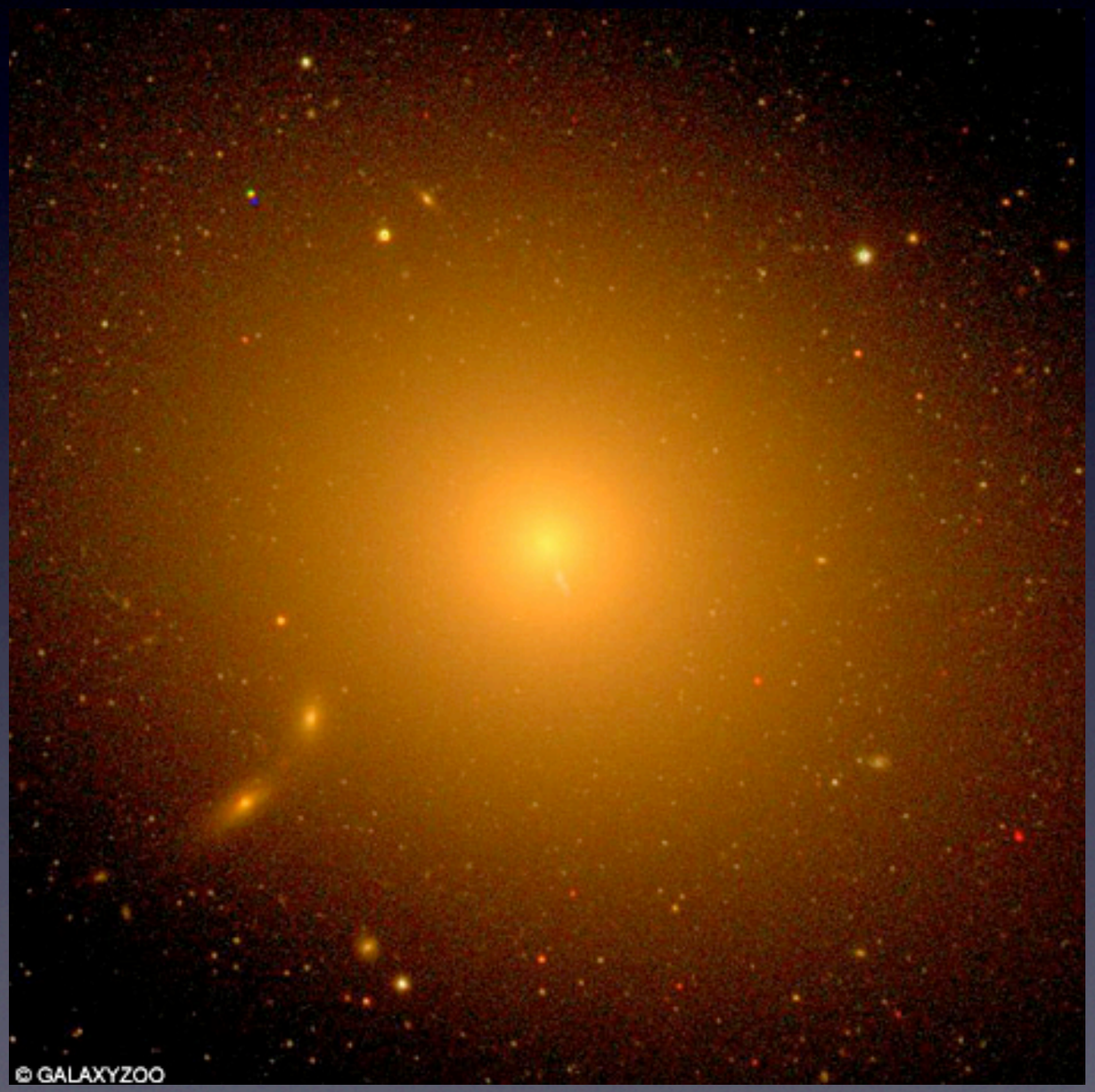
Groups

Clusters — Interaction with IGM/ICM

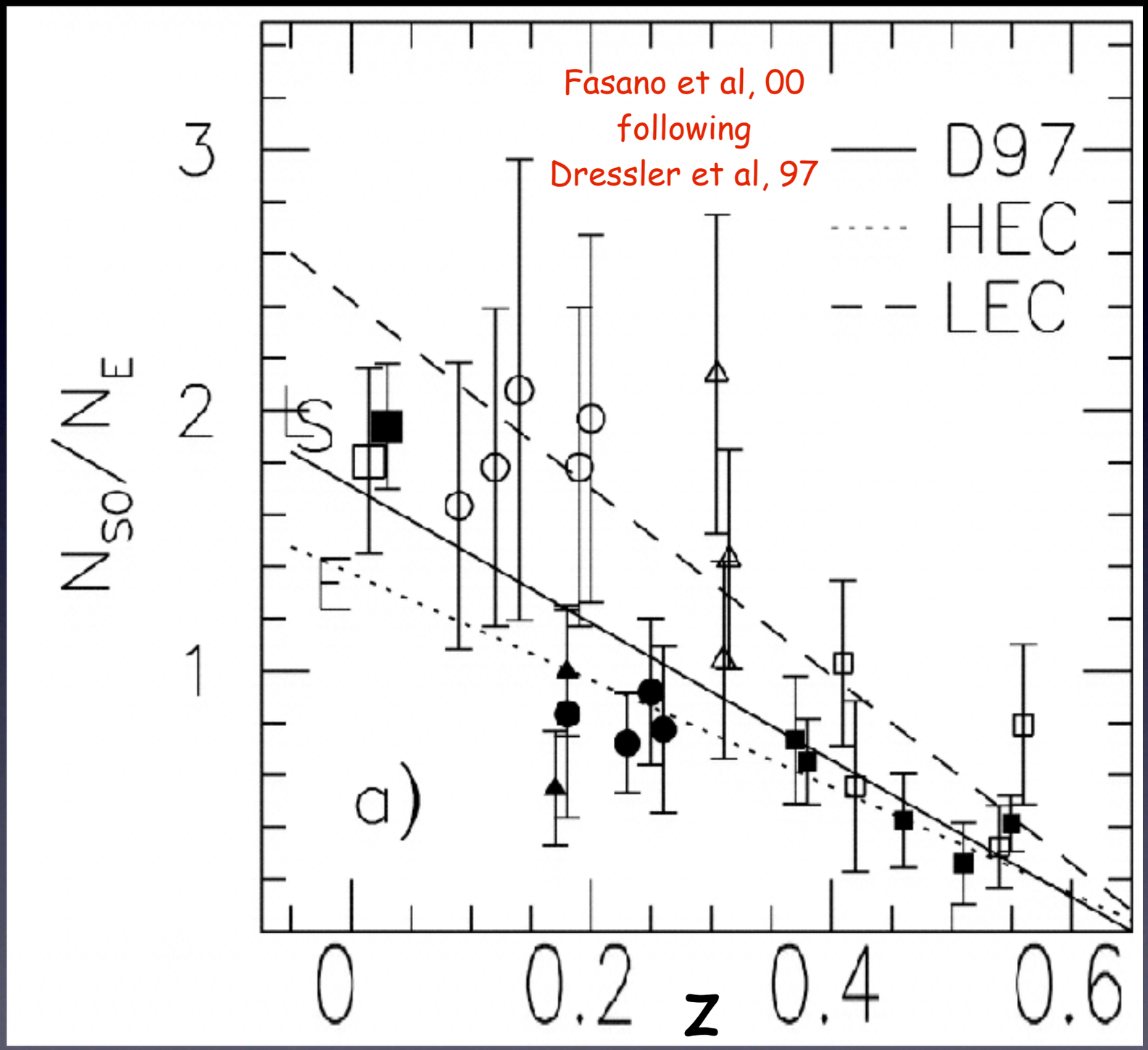
Large Scales

Ellipticals and S0s

Both typically passive - but morphologies relate to dynamical state of galaxy - information about formation



Morphologies of cluster early-types



Strongly increasing fraction of S0s

~ 5 Gyr from z=0.5 to z=0

Morphology traces local density

Dressler, 1980

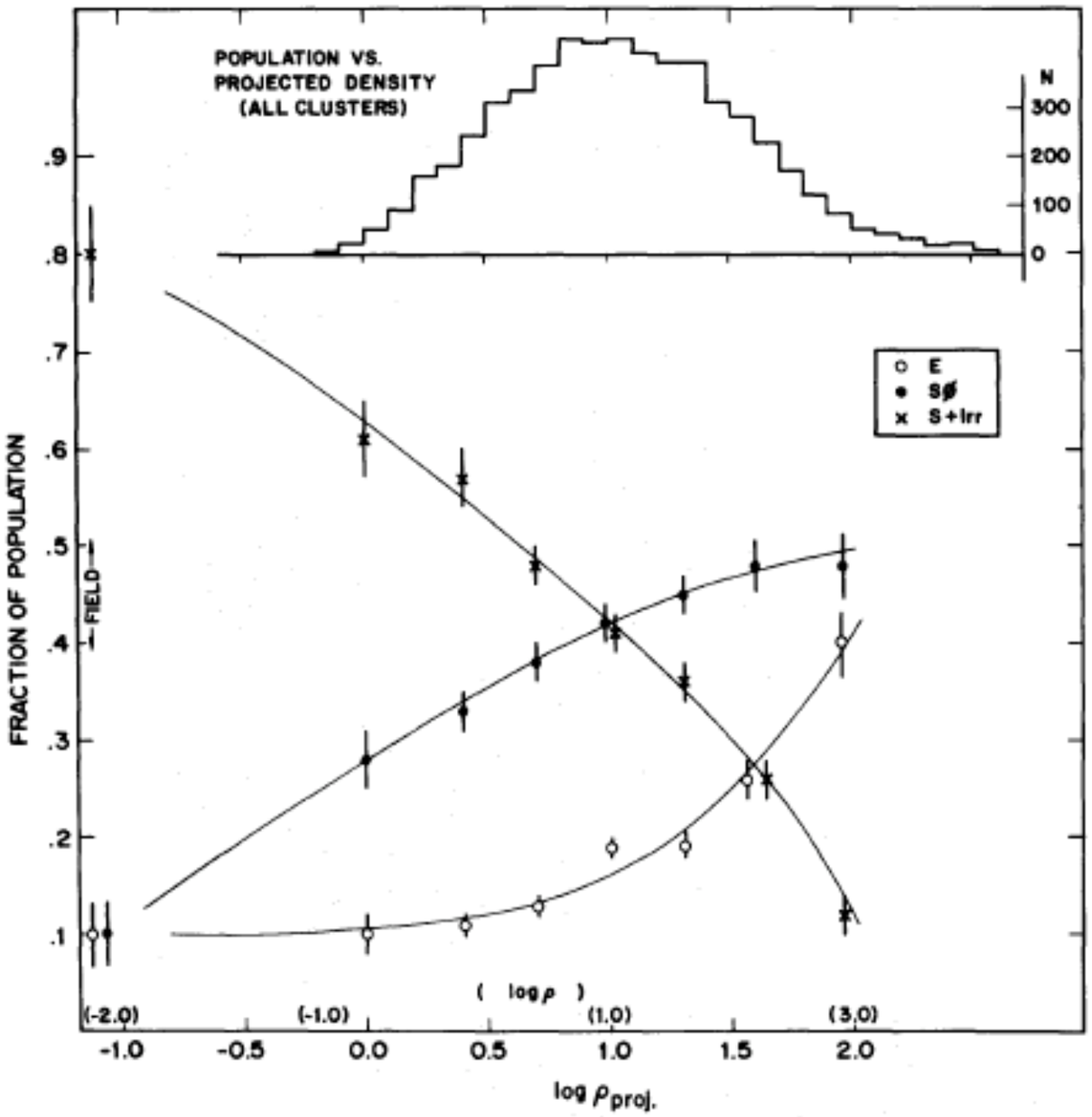


FIG. 4.—The fraction of E, S0, and S+I galaxies as a function of the log of the projected density, in galaxies Mpc^{-2}. The data shown are for all cluster galaxies in the sample and for the field. Also shown is an estimated scale of true space density in galaxies Mpc^{-3}. The upper histogram shows the number distribution of the galaxies over the bins of projected density.

Morphology imprinted inside groups prior to infall?

or

by cluster-centric processes?

The group regime

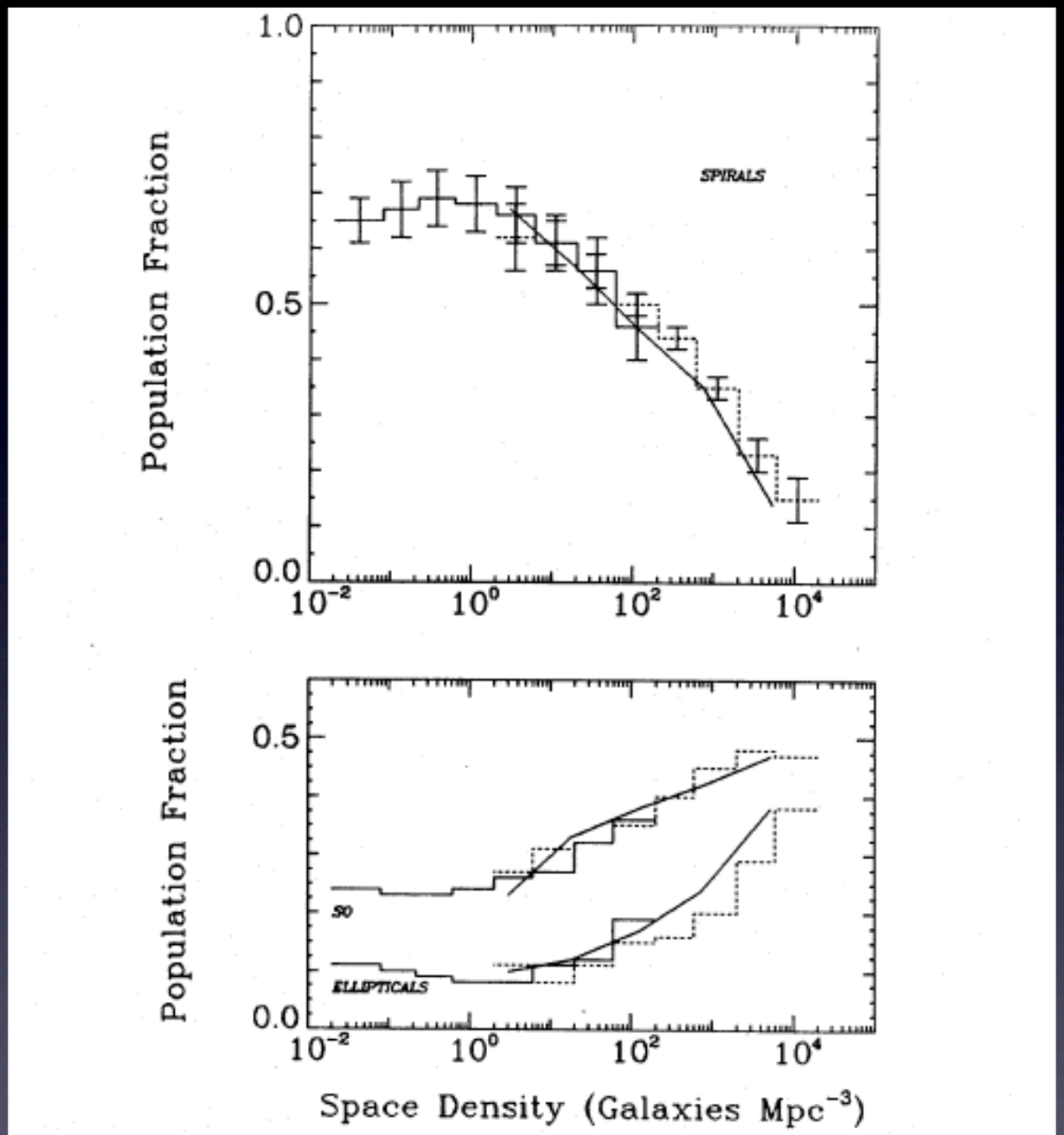


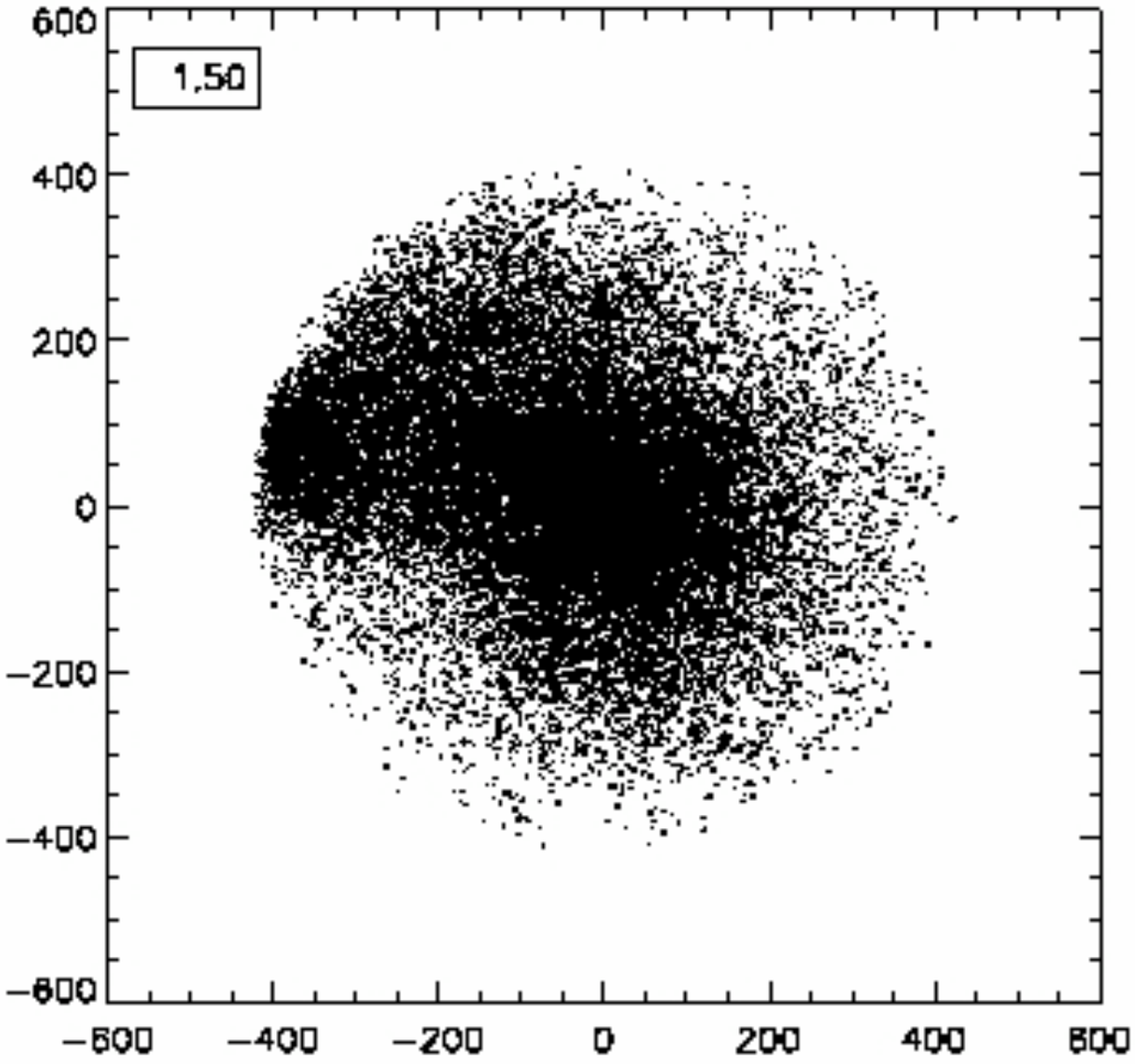
FIG. 1.—Population fraction as a function of space density for the CfA sample. The group contribution to the morphology-density relation is indicated by the solid histograms; the cluster contribution, by the dashed histograms. Dressler's morphology-density relation is indicated by the solid curves which are color corrected and shifted to correspond to $H_0 = 100$ km s^{-1} Mpc^{-1}.

Postman & Geller, 1984

Morphology - 3D density
at low z
NOT ONLY CLUSTERS
(extends to groups)

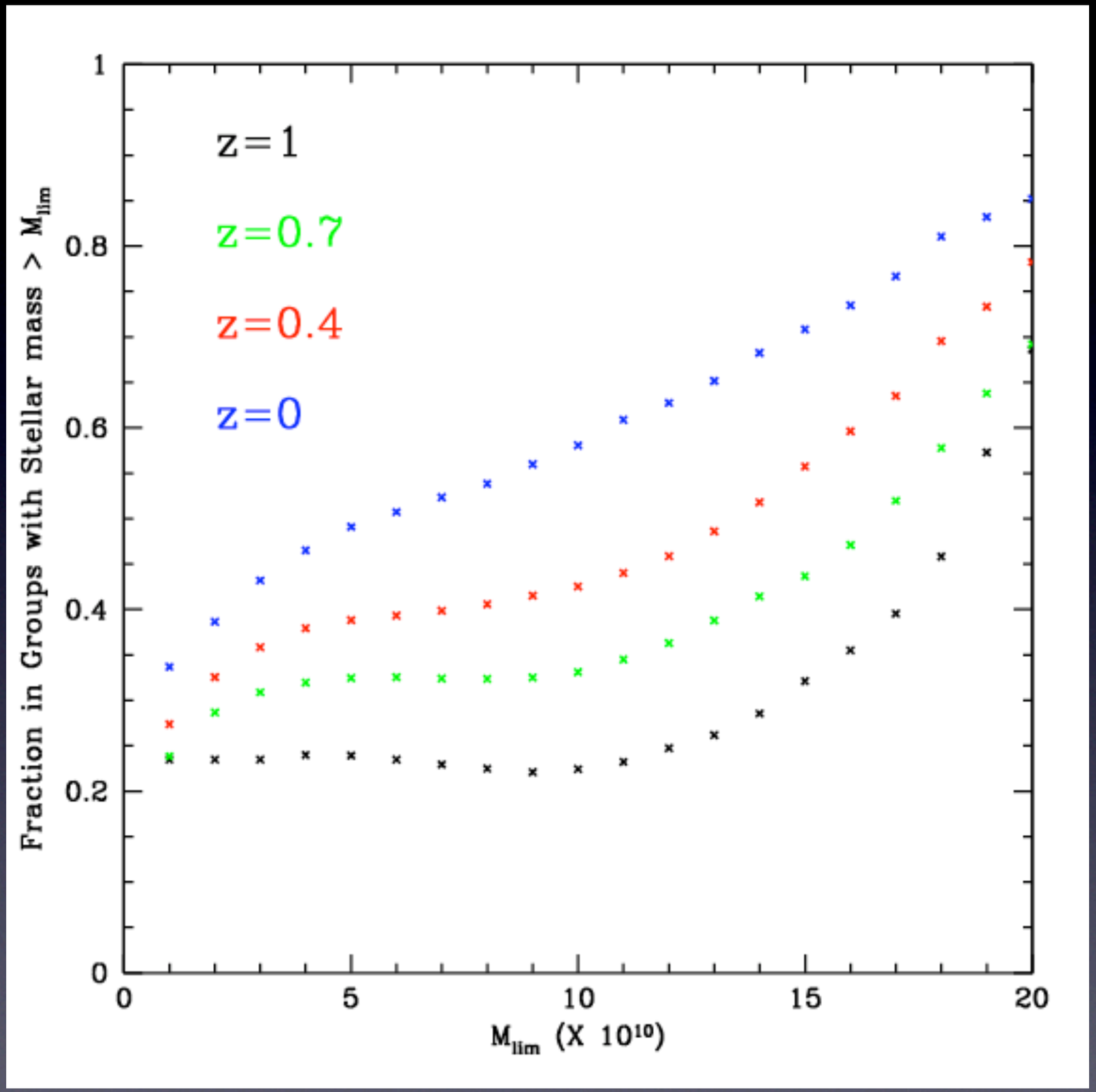
The Group and its relavence

from work with Rhea Remus and Roland Jesseit



Groups vary in:
mass; accretion history; dynamics; galaxy properties

Global Contribution of Groups



P(galaxy in group | M_*,z)

Millenium Simulation
Bower et al, 06 Semi-Analytic Model

for groups
$M_{halo}>5\times10^{12}M_o$

- Integrated environmental history is what really matters!

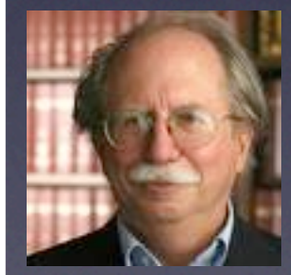
CNOC2 groups project

HST-ACS

ACS F775W

26 Groups
0.3<z<0.55
Serendipitous field

Classify Morphologies



GIM2D

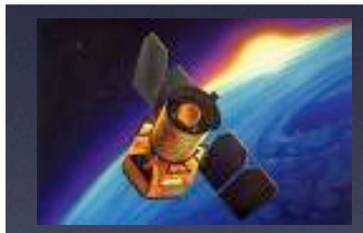
Magellan VLT

Groups:
Targetted Spectroscopy
(Wilman et al, 2005)

CFHT

CNOC2 Survey: (Yee et al, 00)
~6000 redshifts 0.1<z<0.55
UVBRI Photometry

FOF groups (Carlberg et al, 2001)



SEDs / SFR / M*

GALEX

NTT (SOFI)

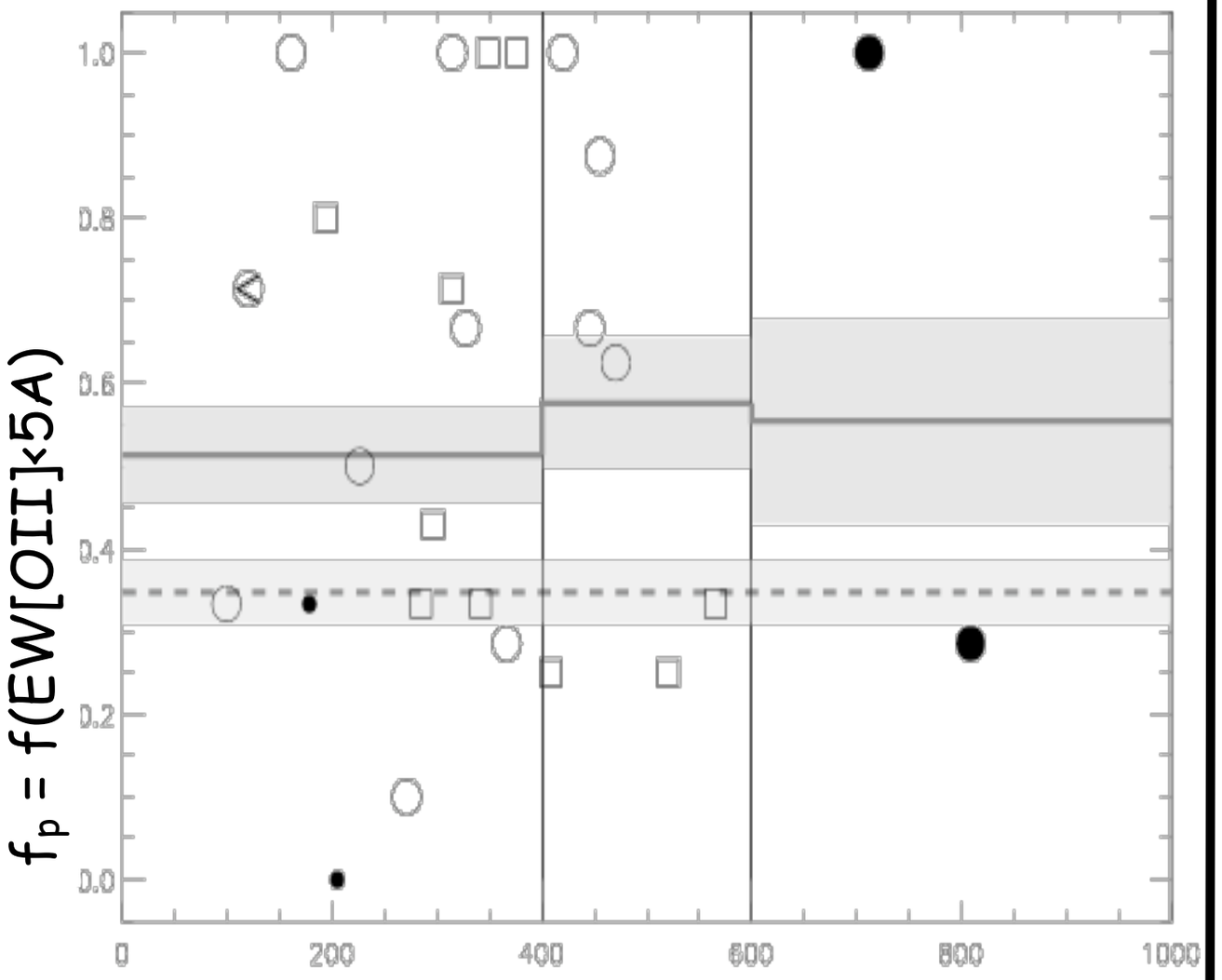
Spitzer

IGM / AGN

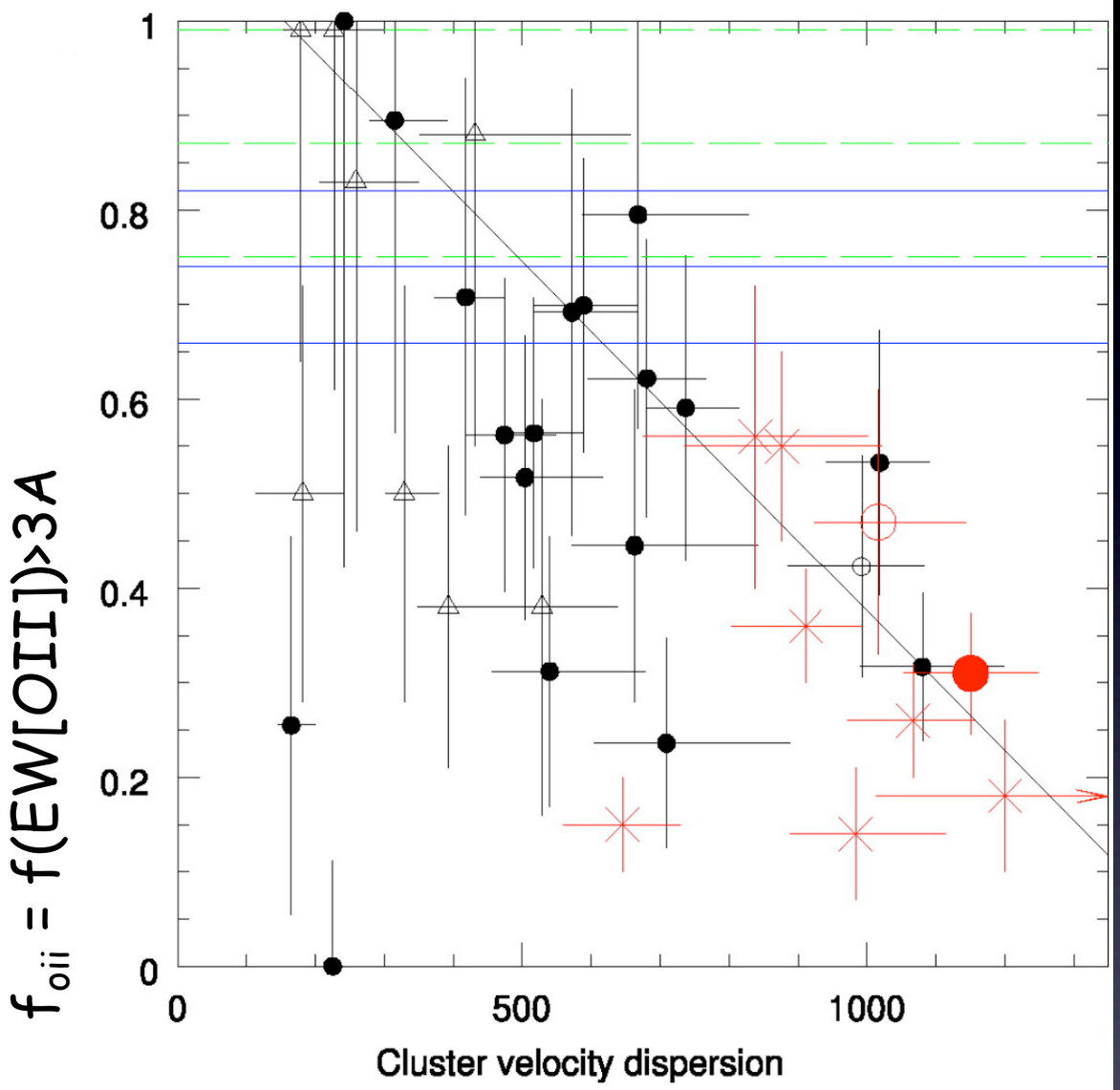
XMM

Chandra

Fraction of [OII]-weak galaxies

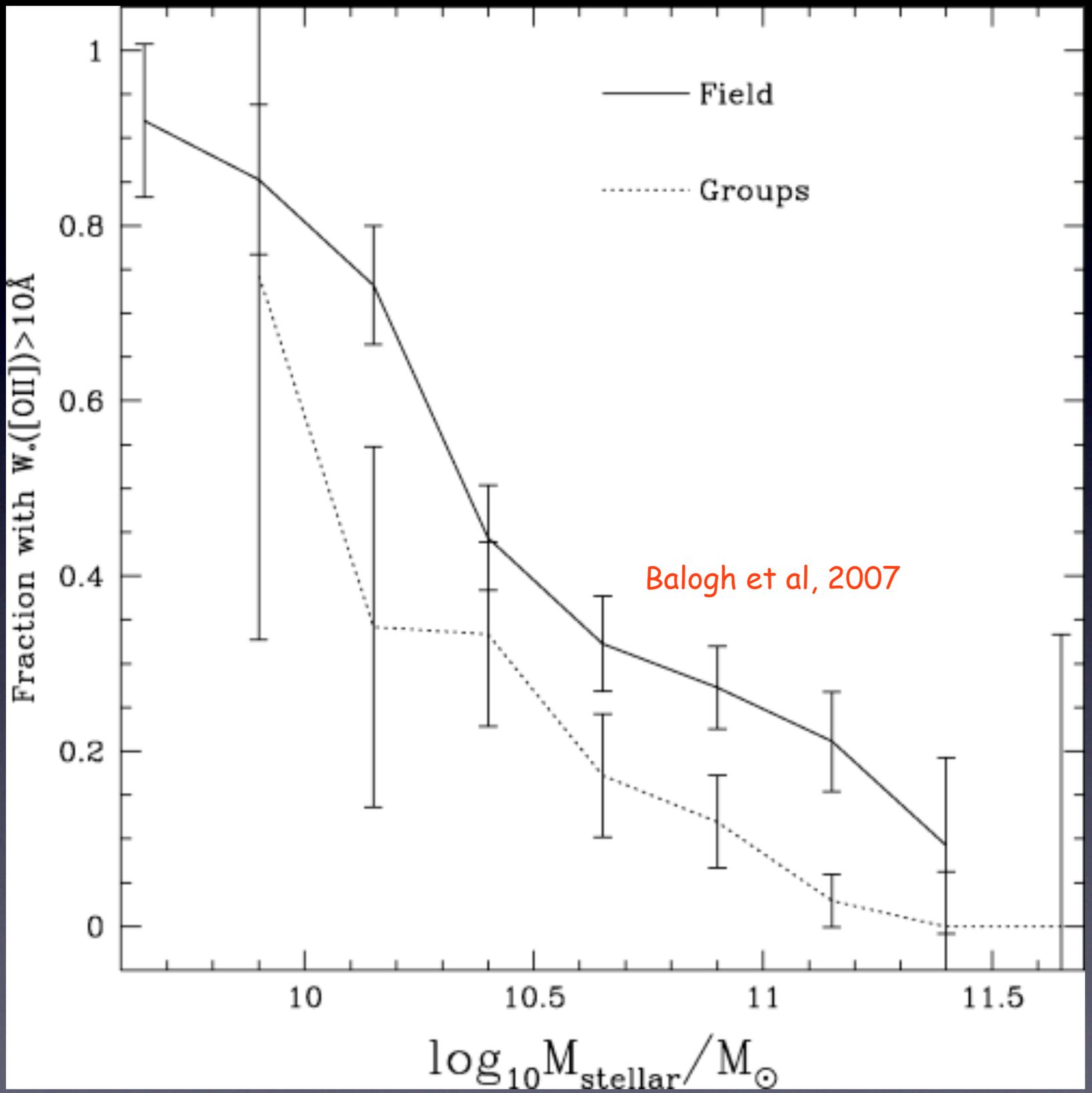


Wilman et al. 2005



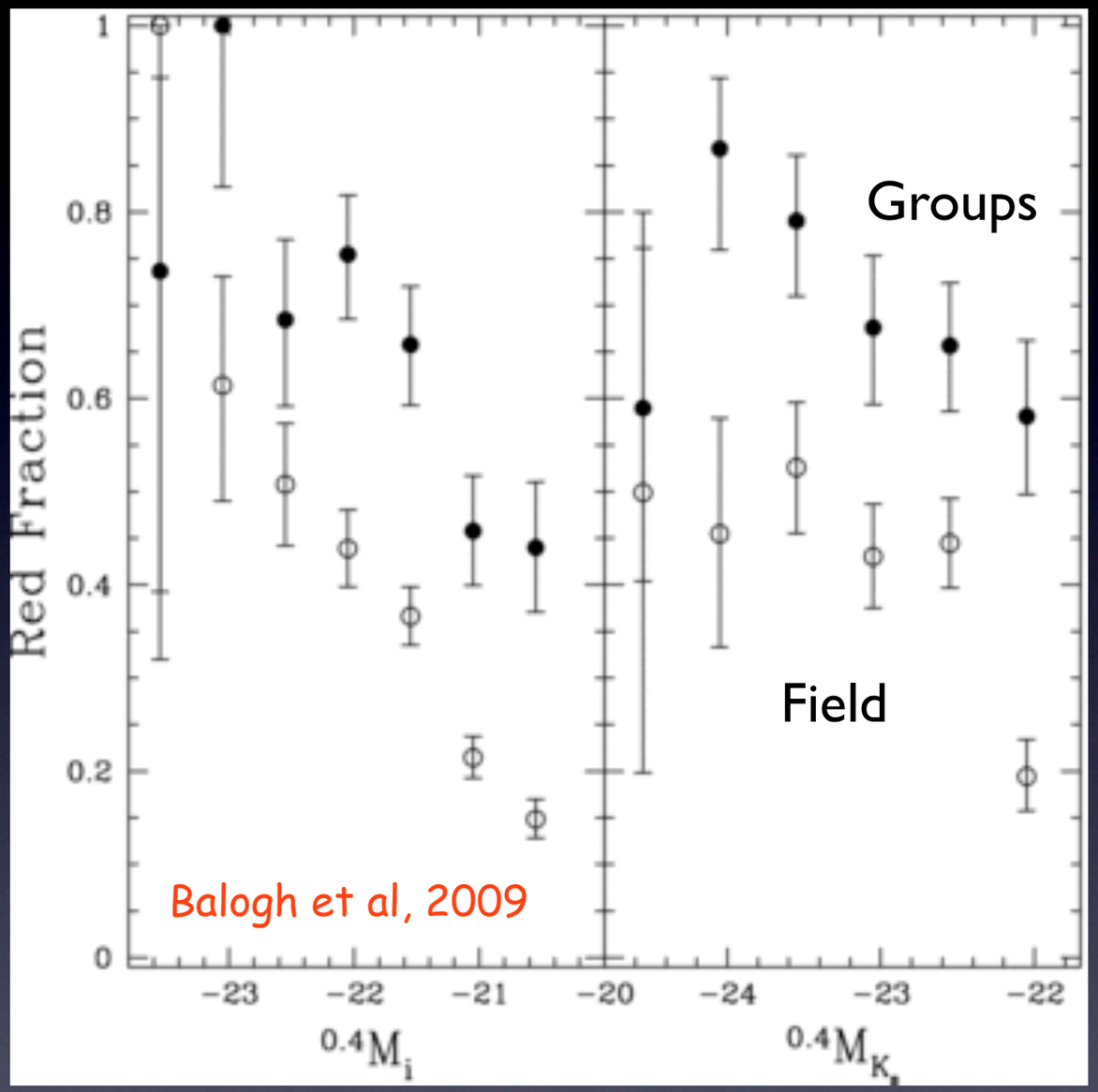
Poggianti et al., 2006

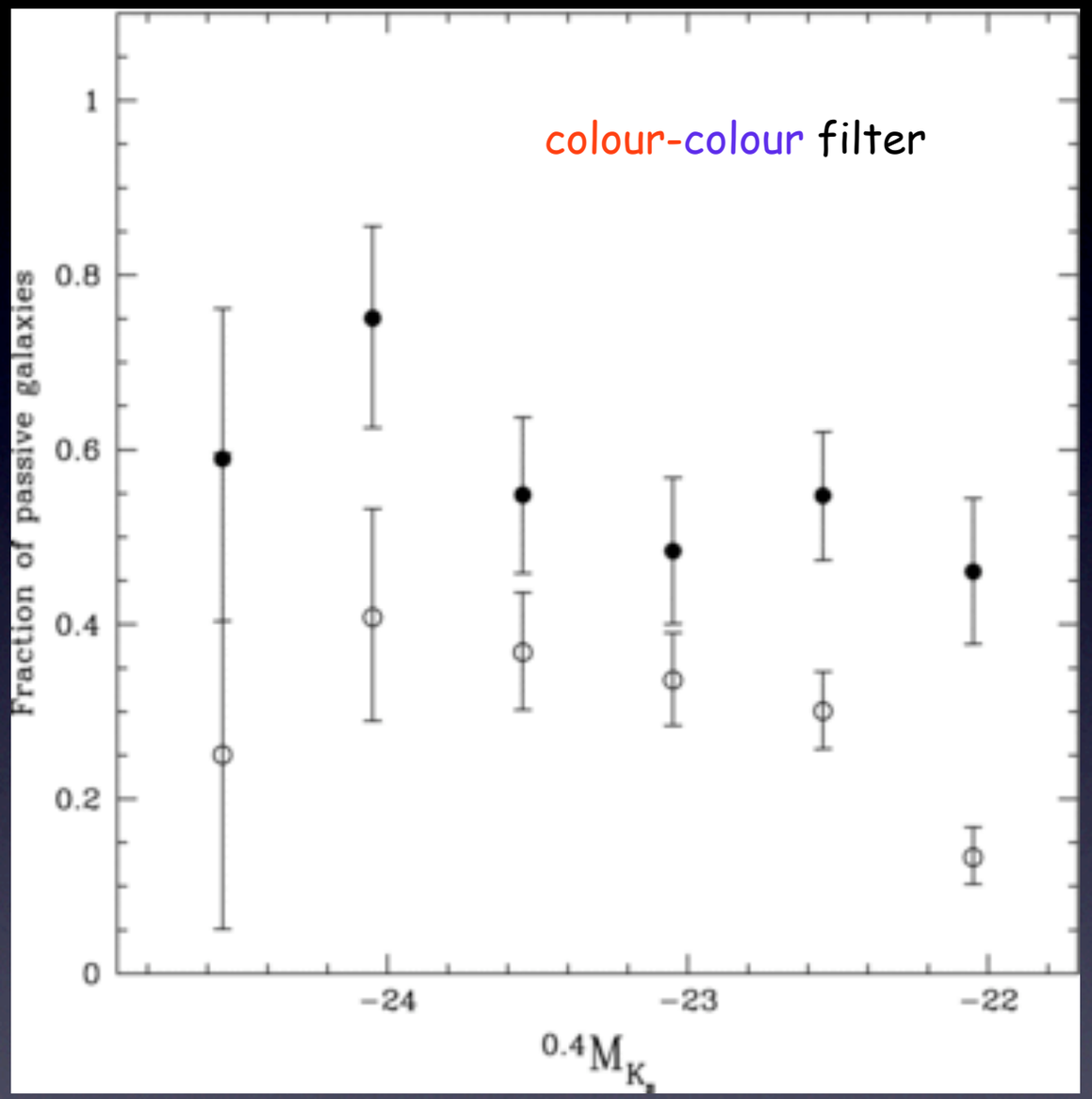
Fraction of [OII]-weak galaxies



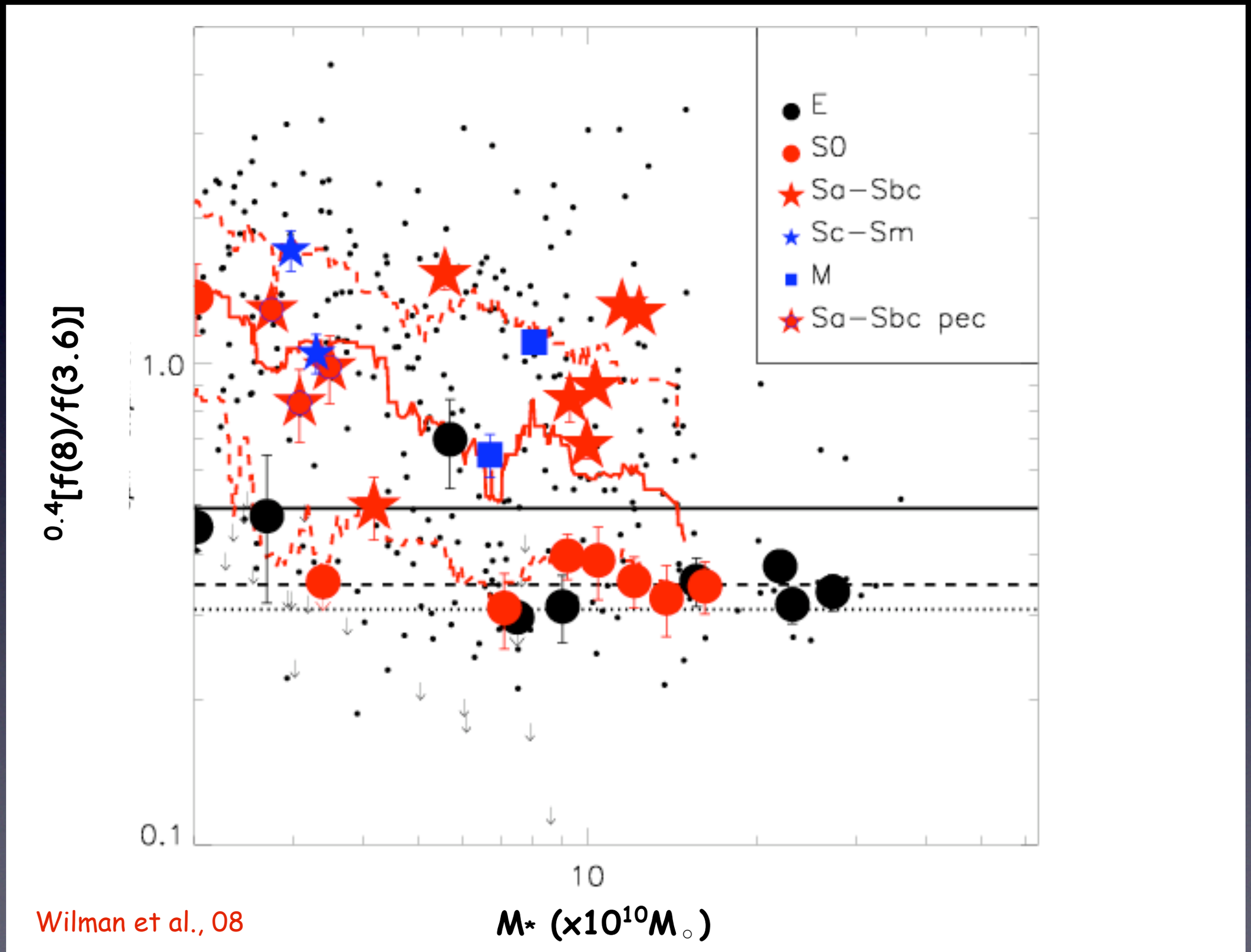
Balogh et al, 2007

Fraction of red galaxies



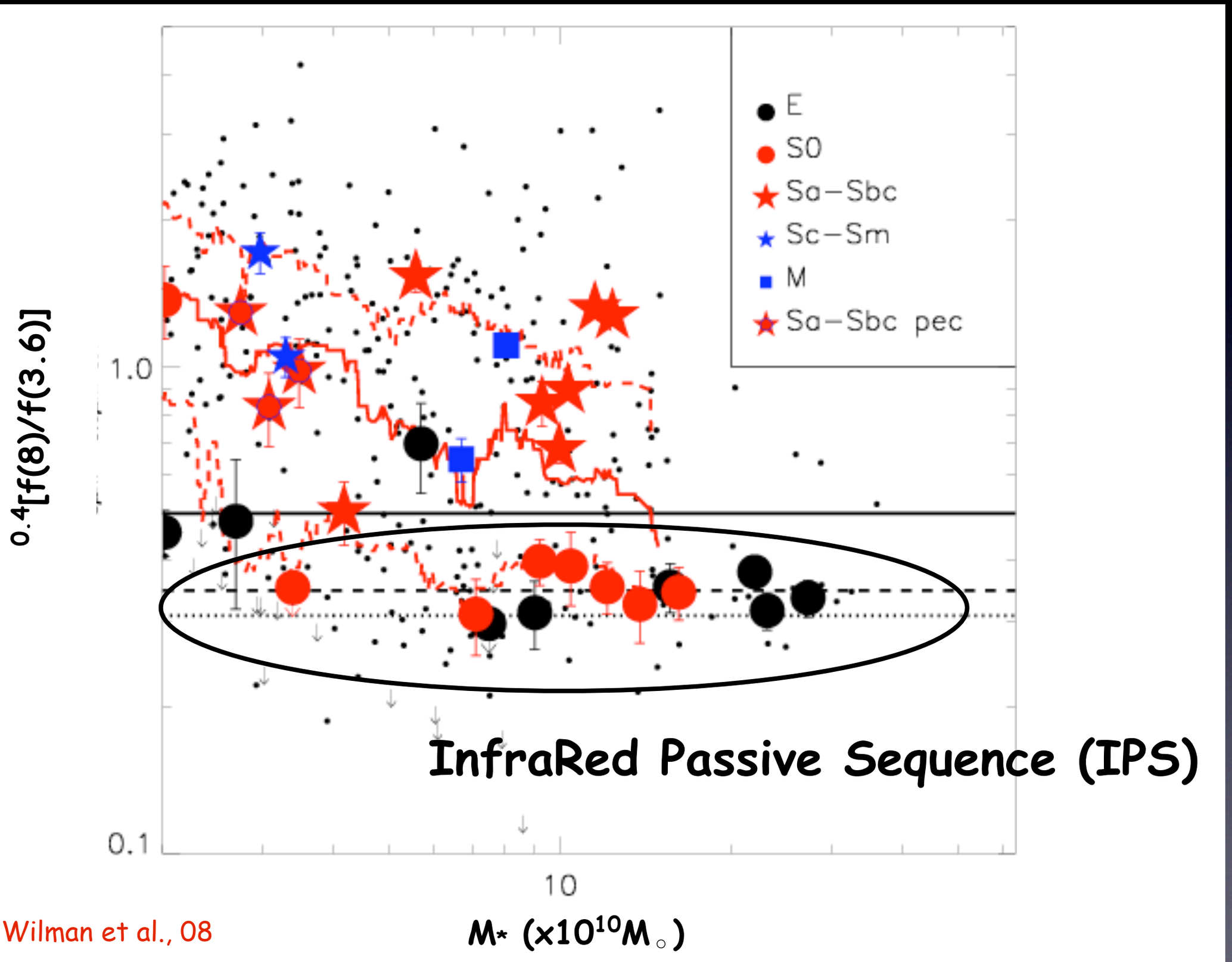


8 μm-weak galaxies



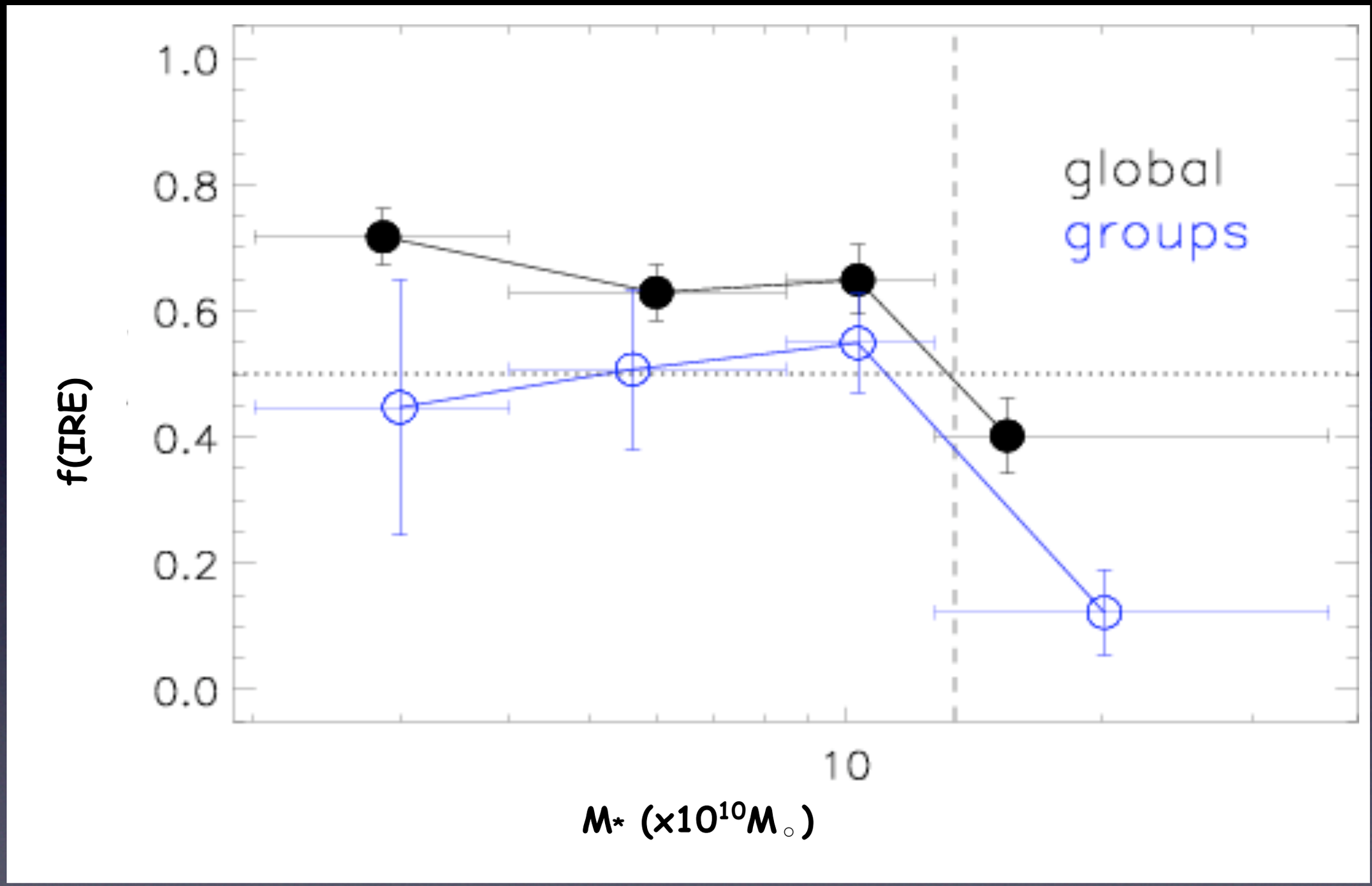
Wilman et al., 08

8 μm-weak galaxies



Wilman et al., 08

Fraction of 8 μm-weak galaxies



Morphological Classifications

S0 E

vs

Break in Surface brightness profile

S0 spiral

vs

Surface brightness irregularities in disk

E, S0, eSp (Sa-Sbc), lSp (Sc+), Irr

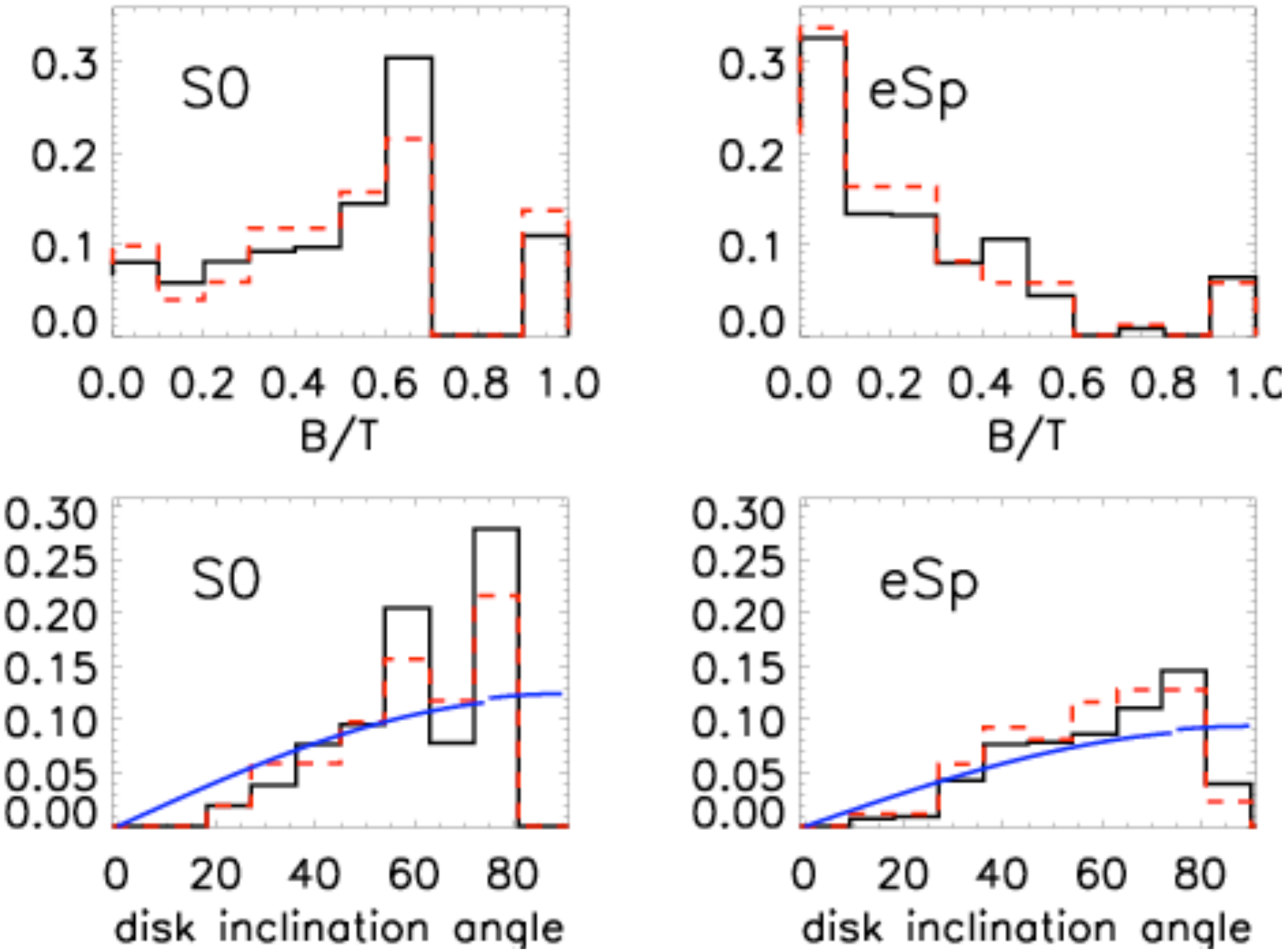
290 galaxies classified by Oemler & Mulchaey - consistent

179 in 26 groups (0.3<z<0.55)

111 in field (0.3<z<0.55)

GIM2D Decompositions of S0s, eSps

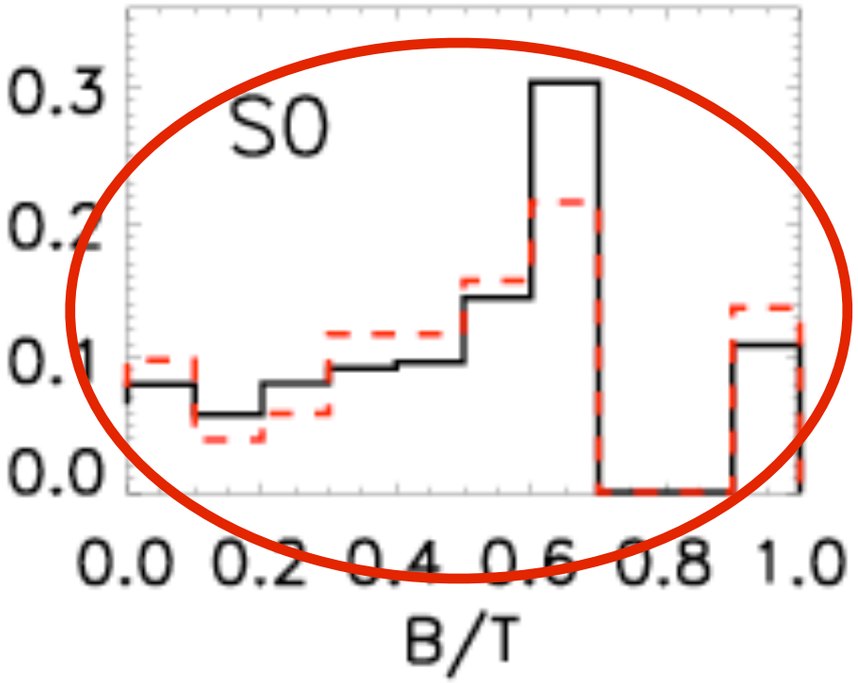
Decompositions: McGee et al, 08

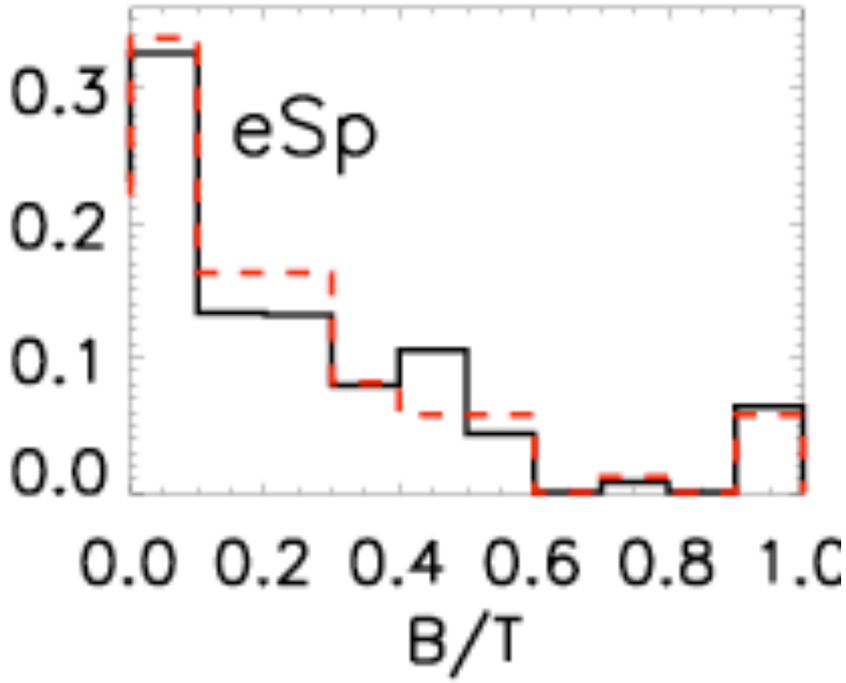


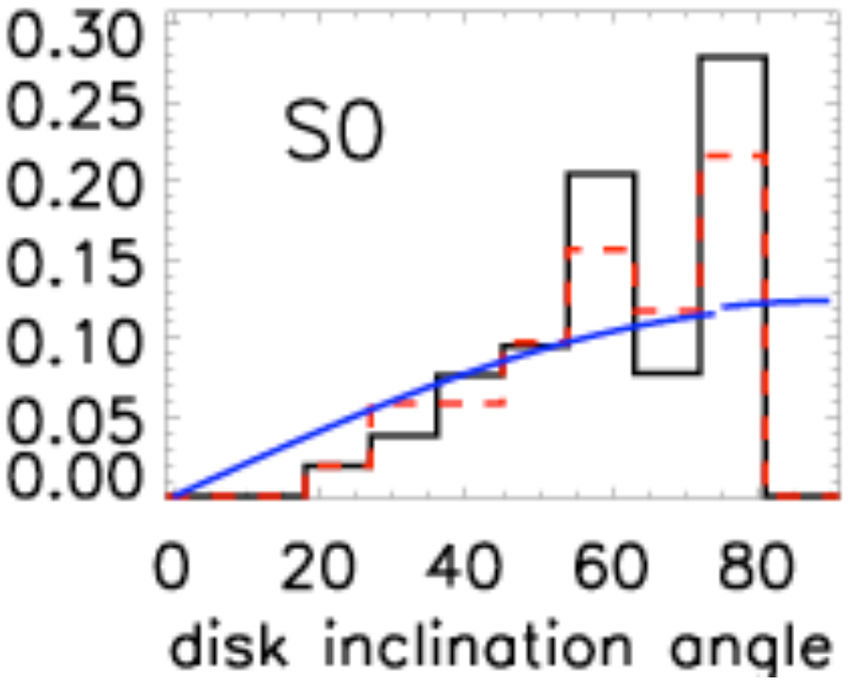
GIM2D Decompositions of S0s, eSps

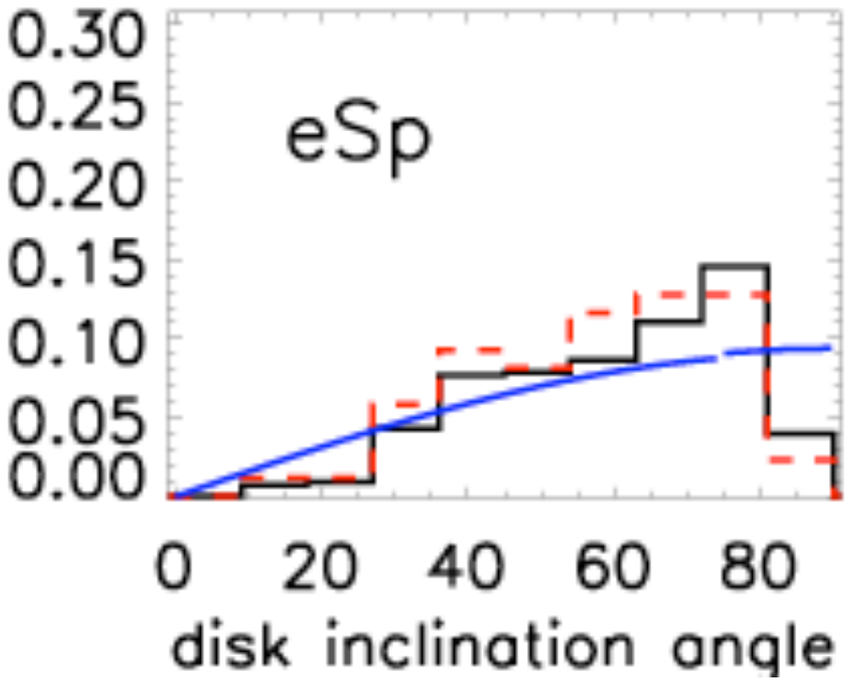
S0s have MUCH higher B/T than spirals

Decompositions: McGee et al, 08

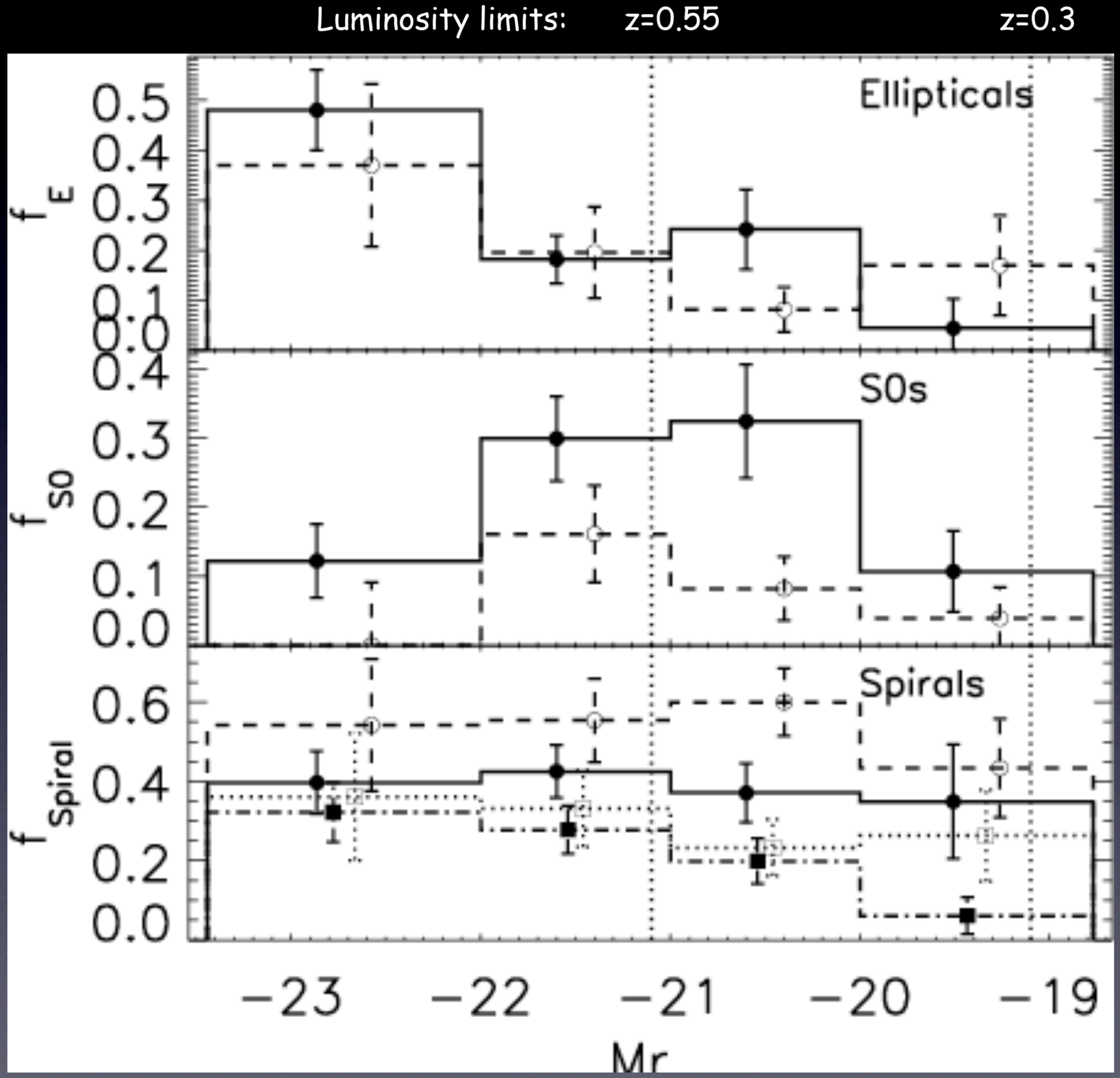








Composition of Groups/Field as f(luminosity)

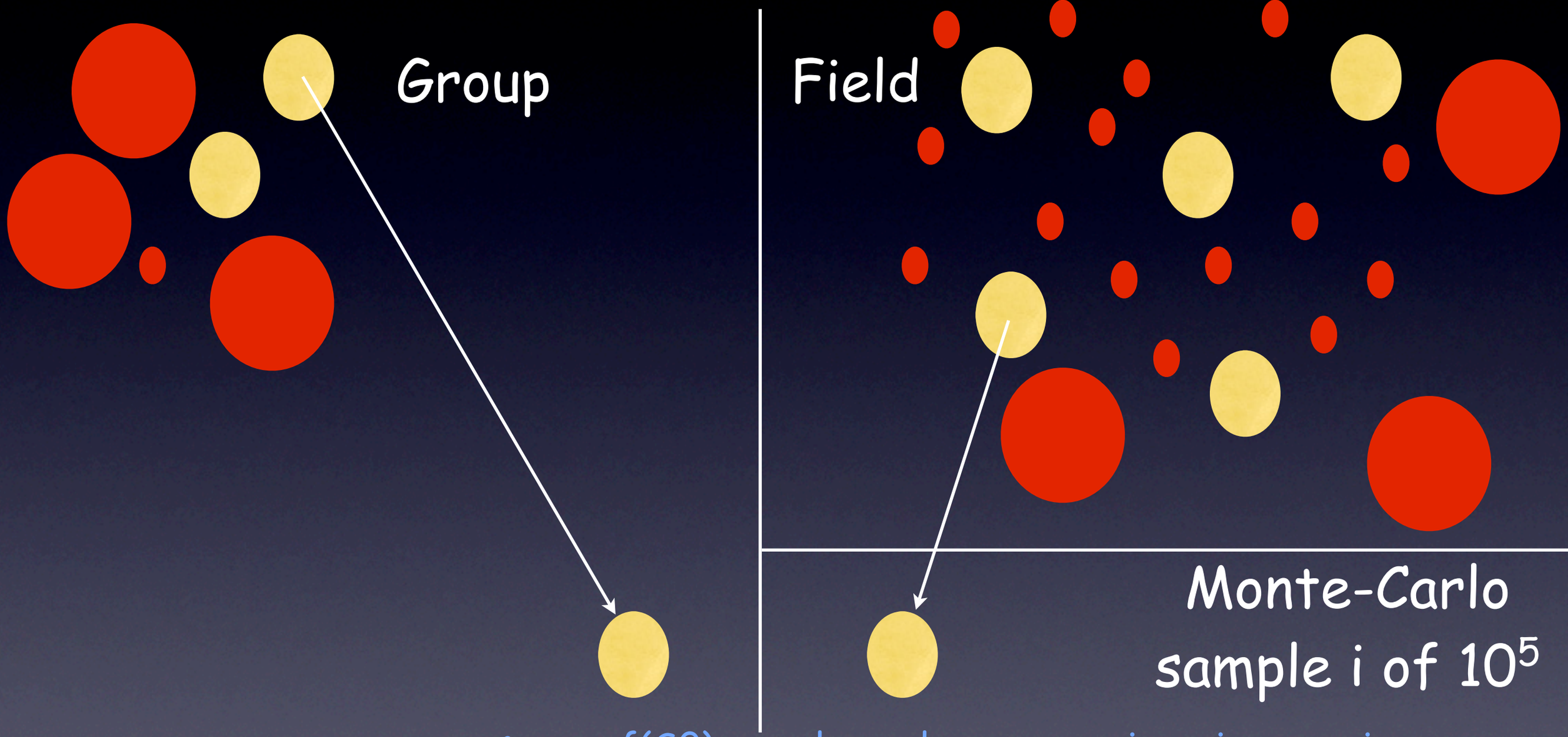


S0s:
40/178 group
10/109 field

All Spirals (eSp+lSp)

Early-Type Spirals (eSp)

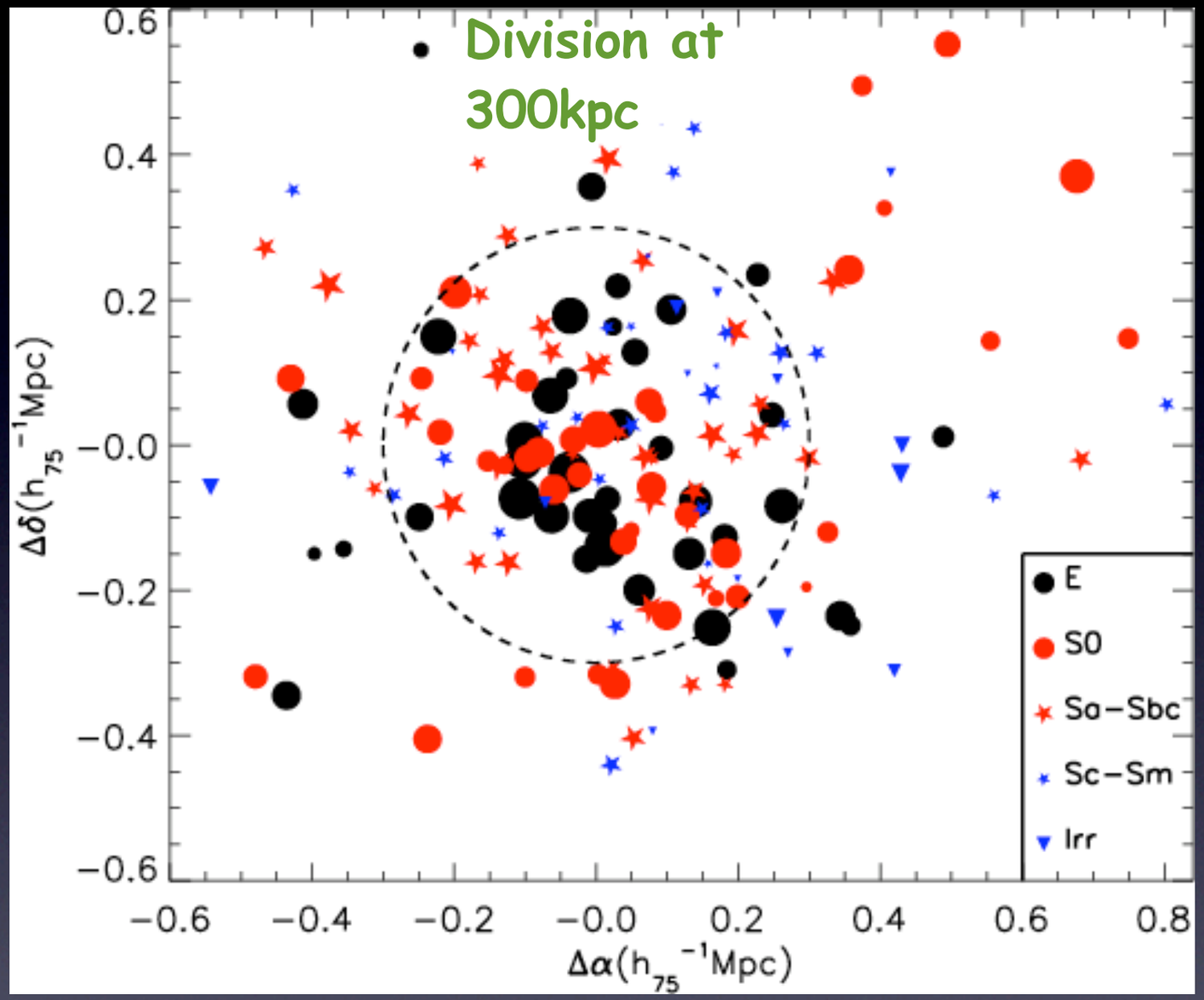
Significance of Difference between Group and Field



Results:

f(S0)	always lower, even ignoring massive groups
f(Sp)	99.95% higher
f(E)	85% lower

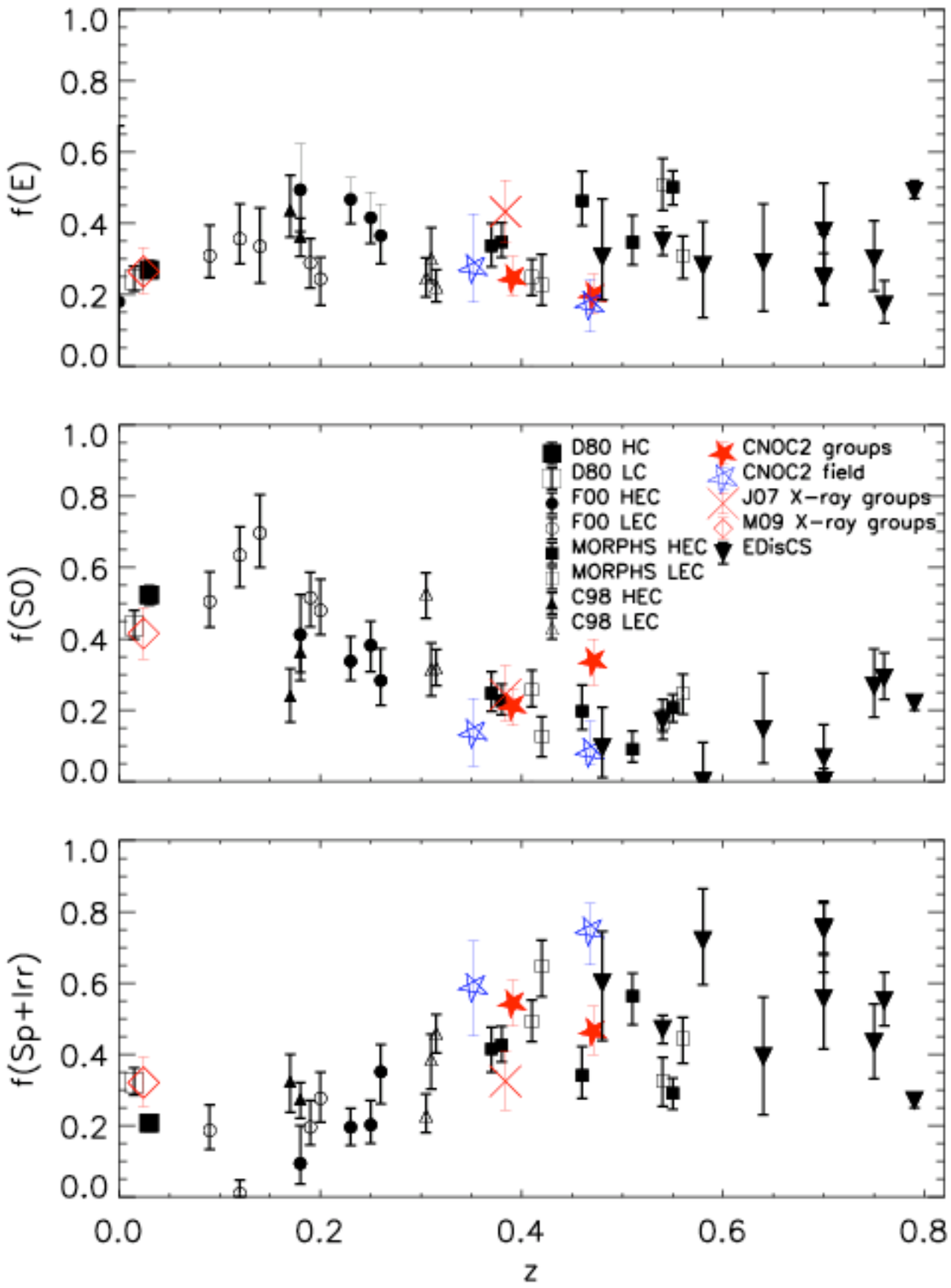
Segregation within groups



Results:

< 300kpc	> 300kpc : resampled 10^5 times
f(E) (M_r<-21)	Always lower
f(S0)	97% higher

Composition vs environment and z



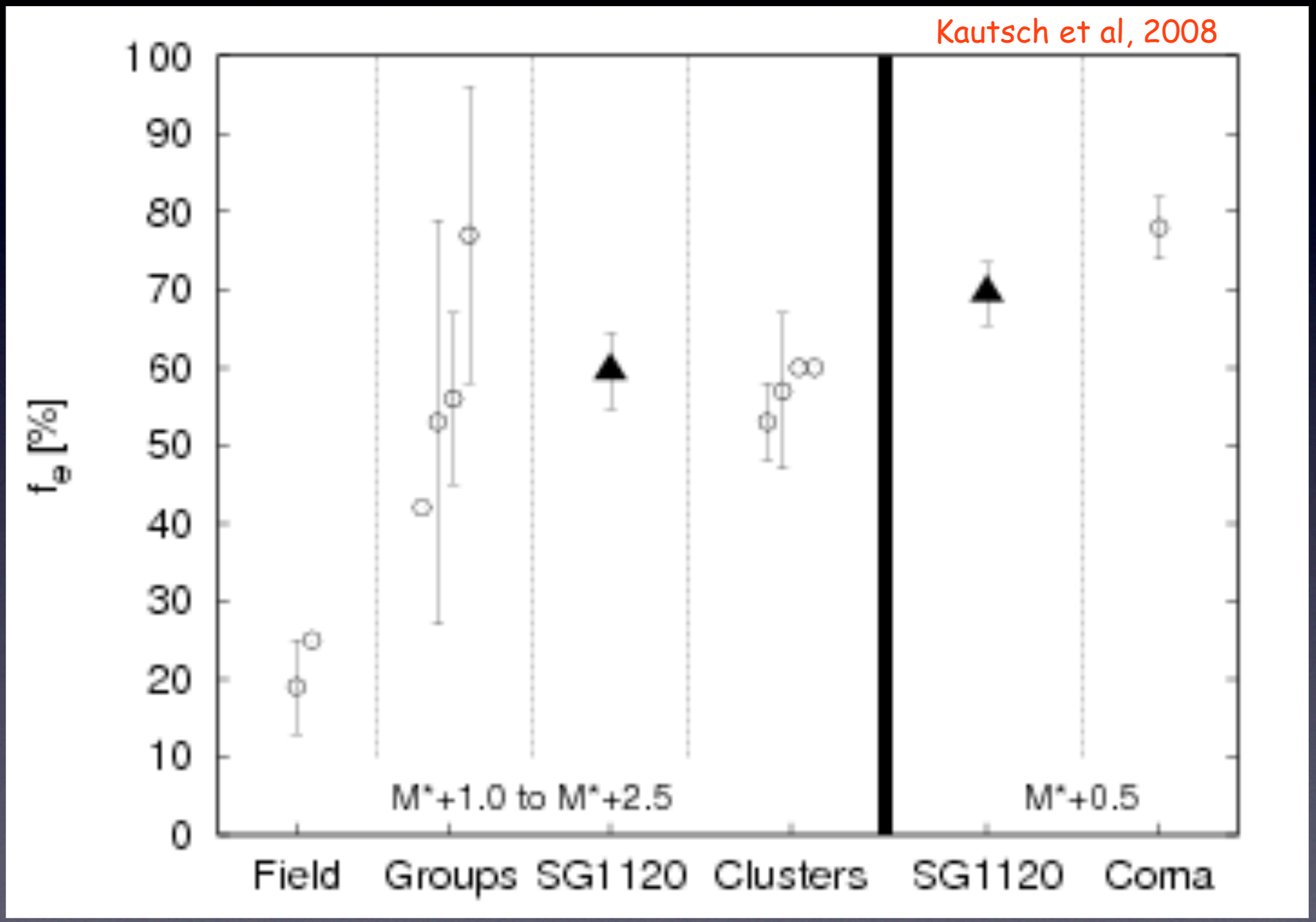
to M_V=-20.53, for comparison with Fasano et al, 00

Ellipticals: No clear dependence on environment OR z

S0s: Clear dependence on z
As populous in Groups as Clusters

Spirals:Clear dependence on z. As populous in Clusters as Groups

Similar early-type fraction in the supergroup SG1120 to clusters

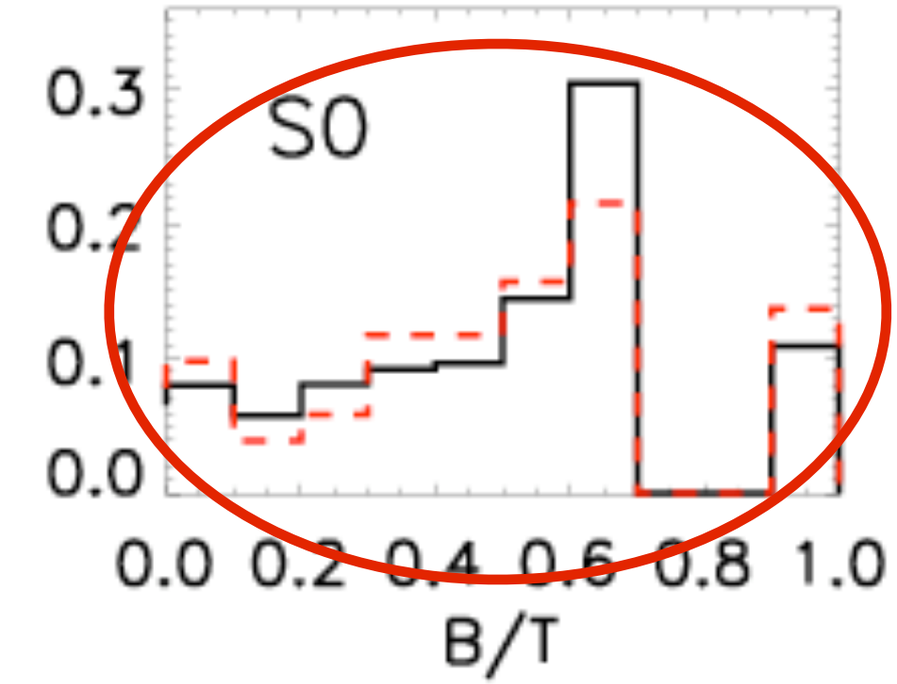


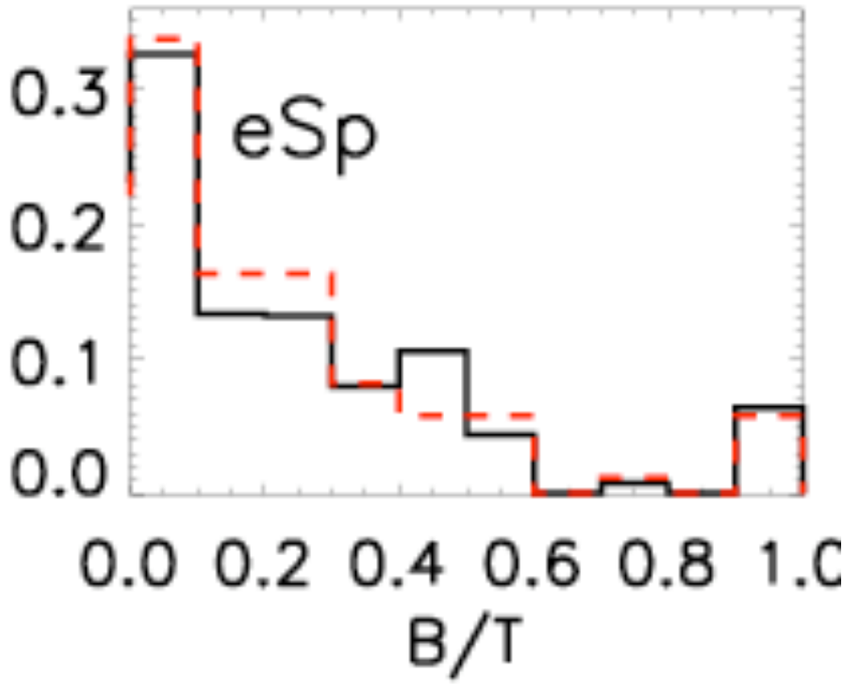
also:
Postman & Geller, 84
Helsdon & Ponman

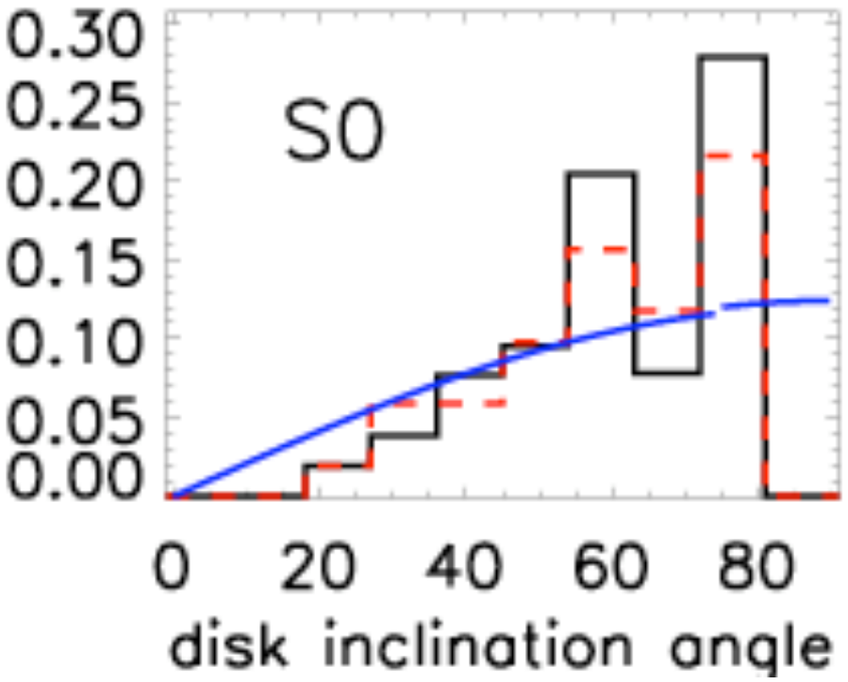
Bulge Growth

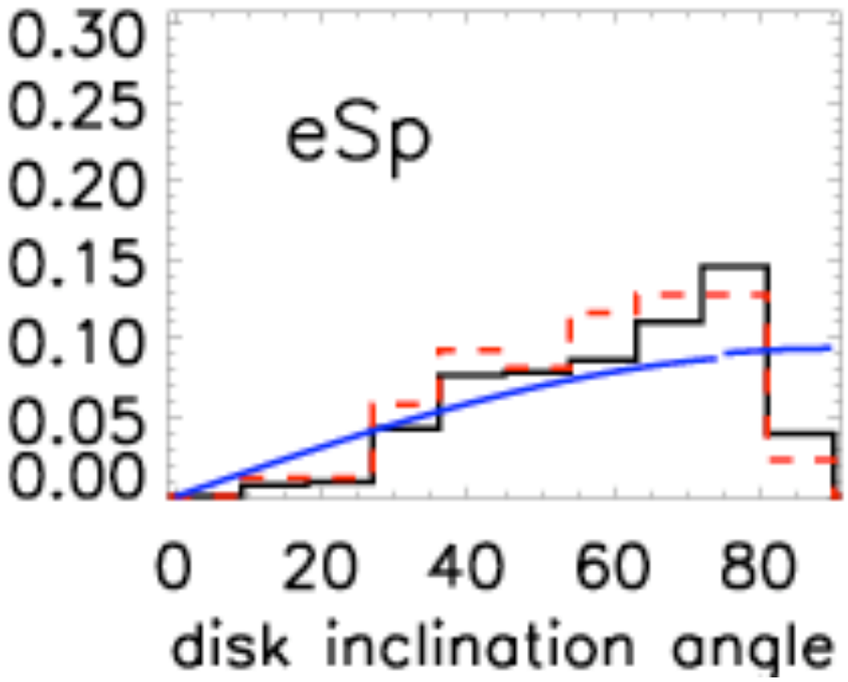
SOs have MUCH higher B/T than spirals

Decompositions: McGee et al, 08



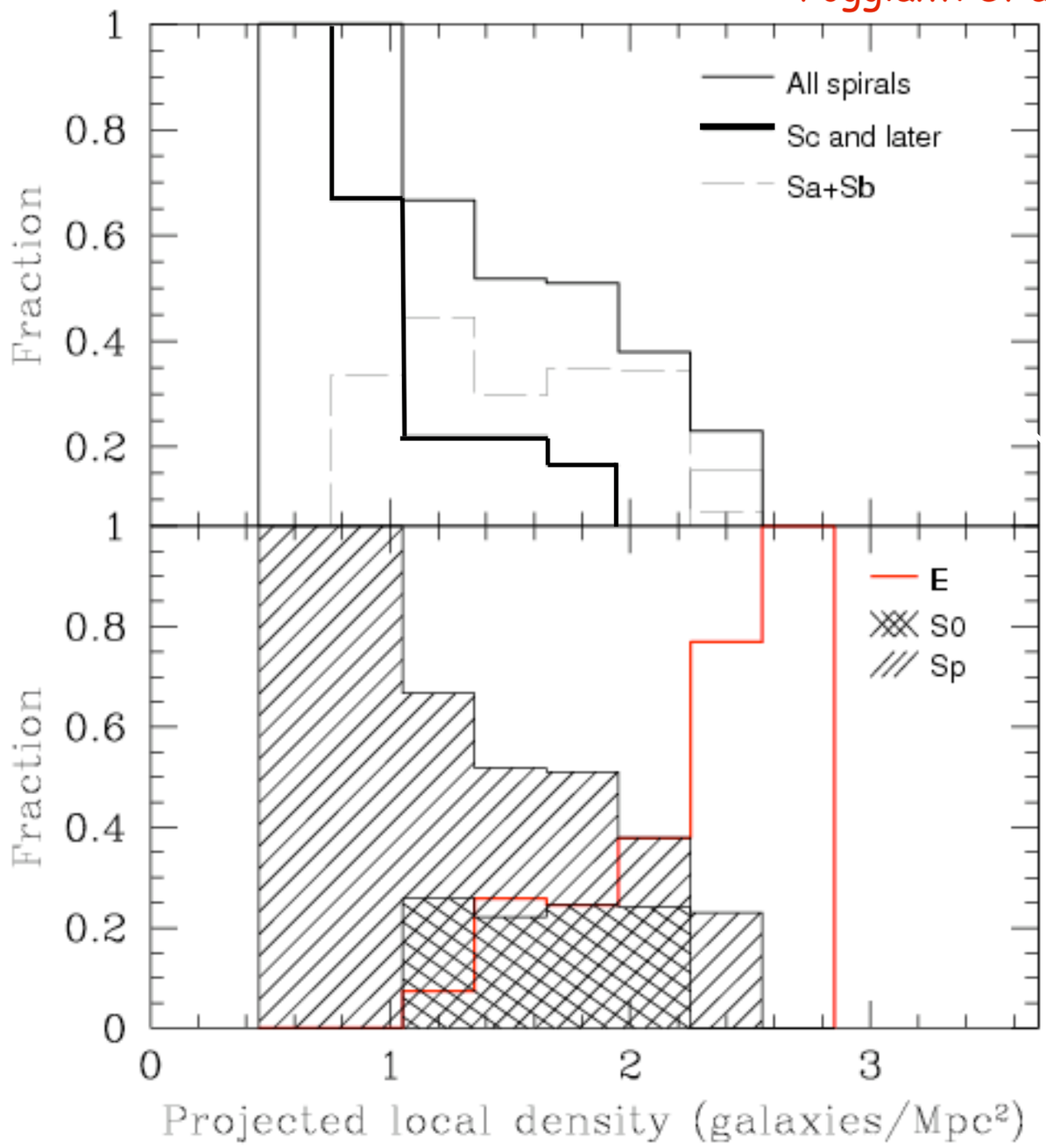






Late-Type Spiral -> S0?

Poggianti et al, 2008



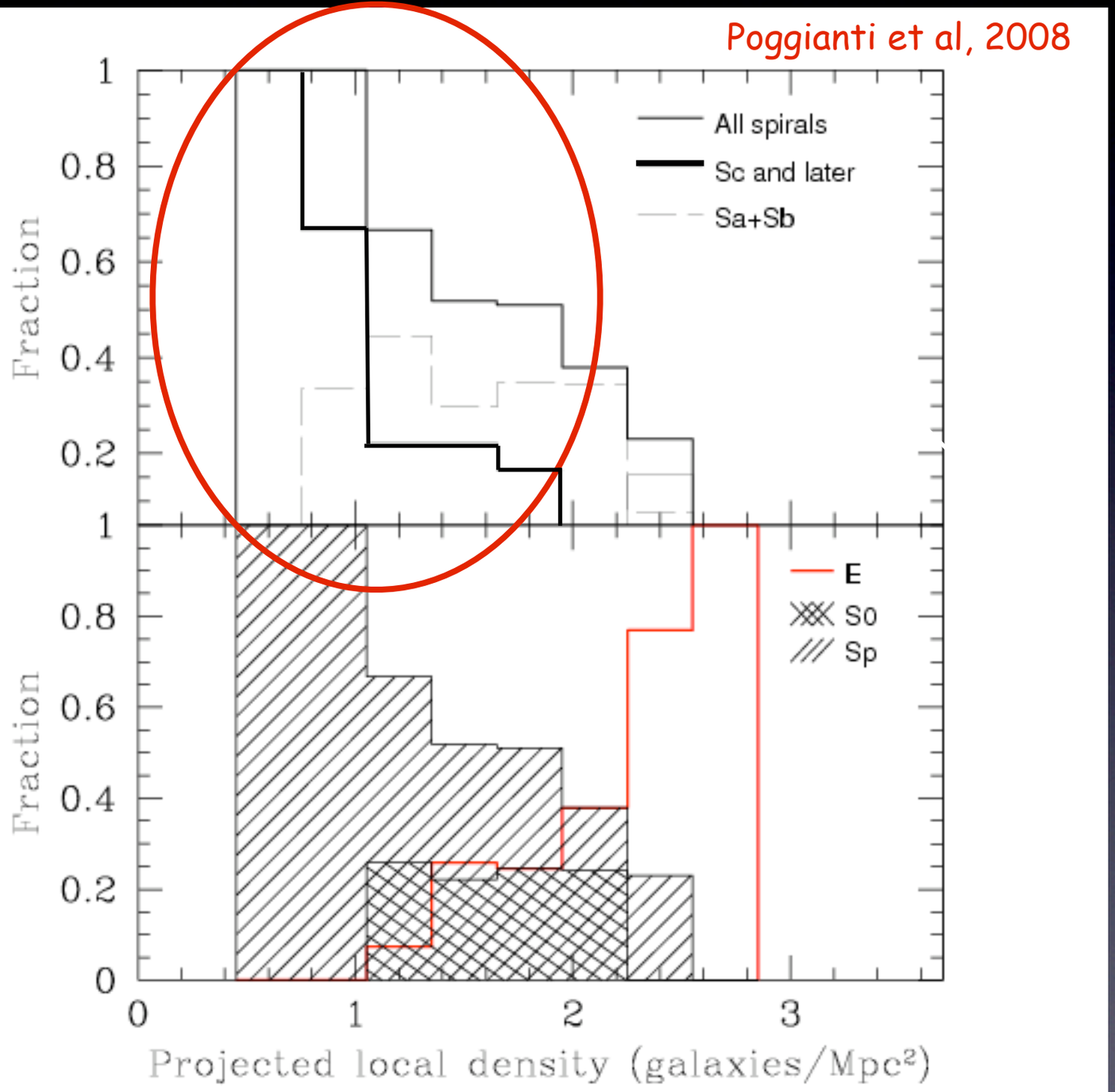
will need:

- significant bulge growth (will be eSp for a stage)

and eventually:

- a truncated gas supply (stop SF)

Late-Type Spiral -> S0?



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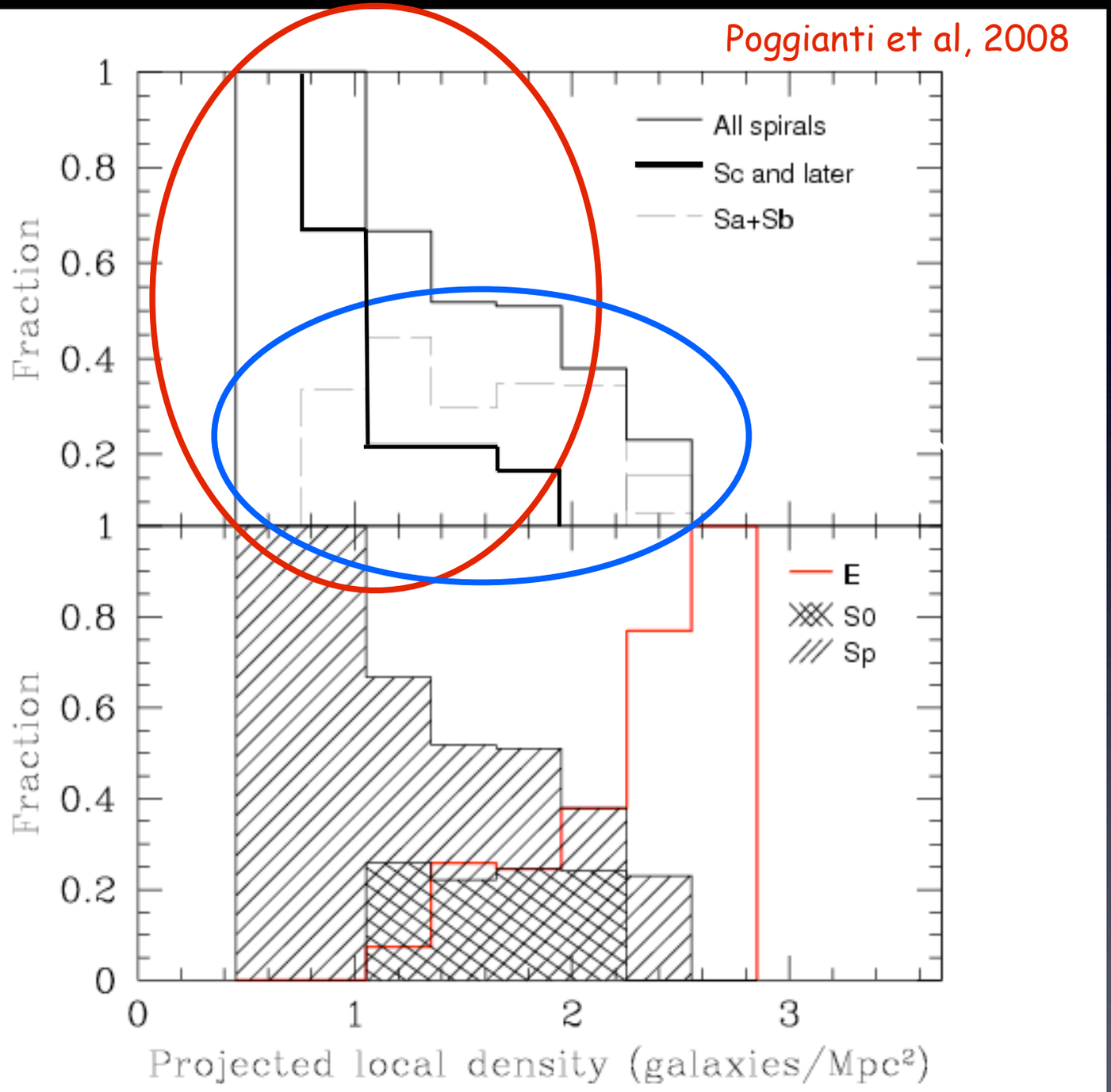

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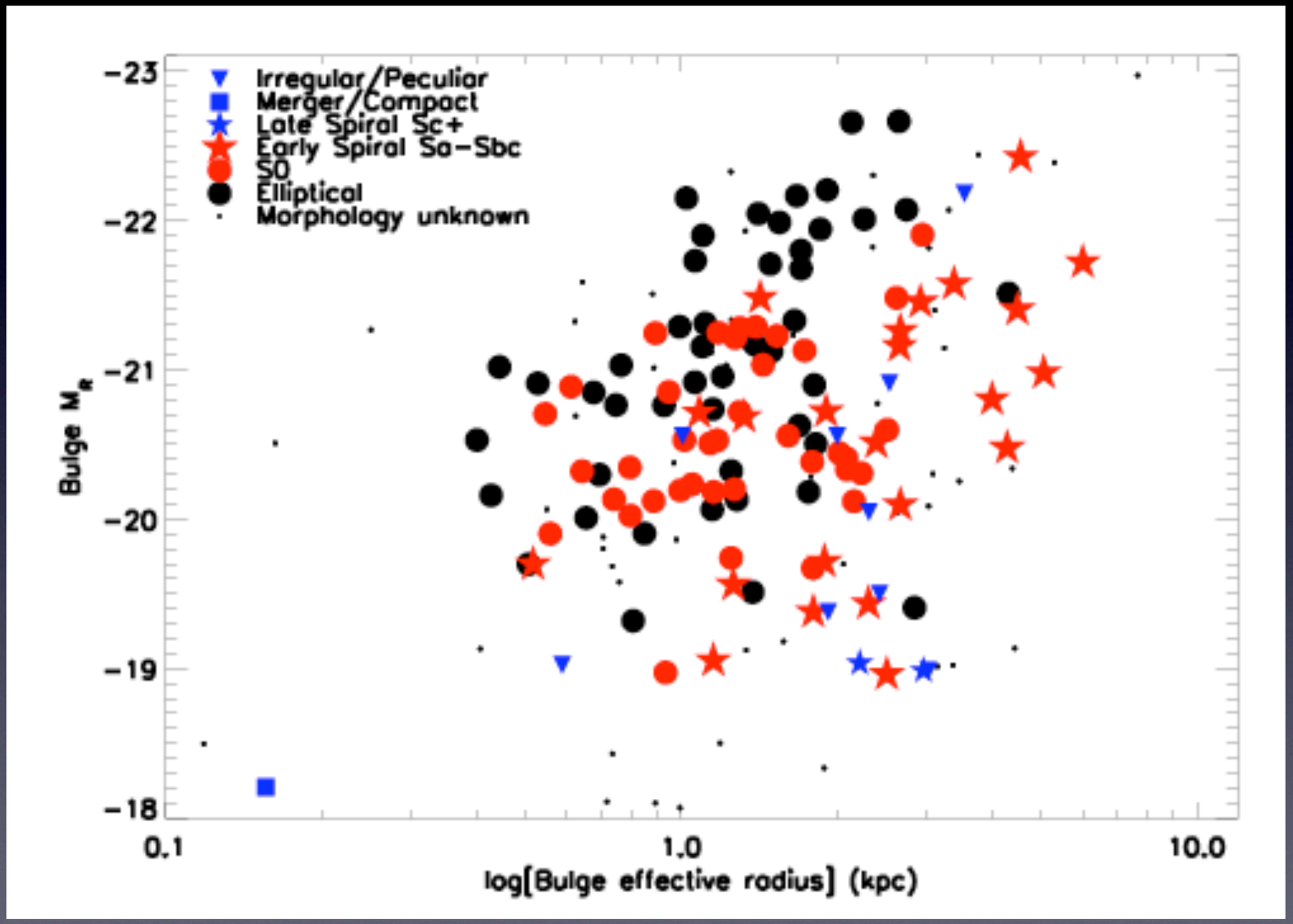
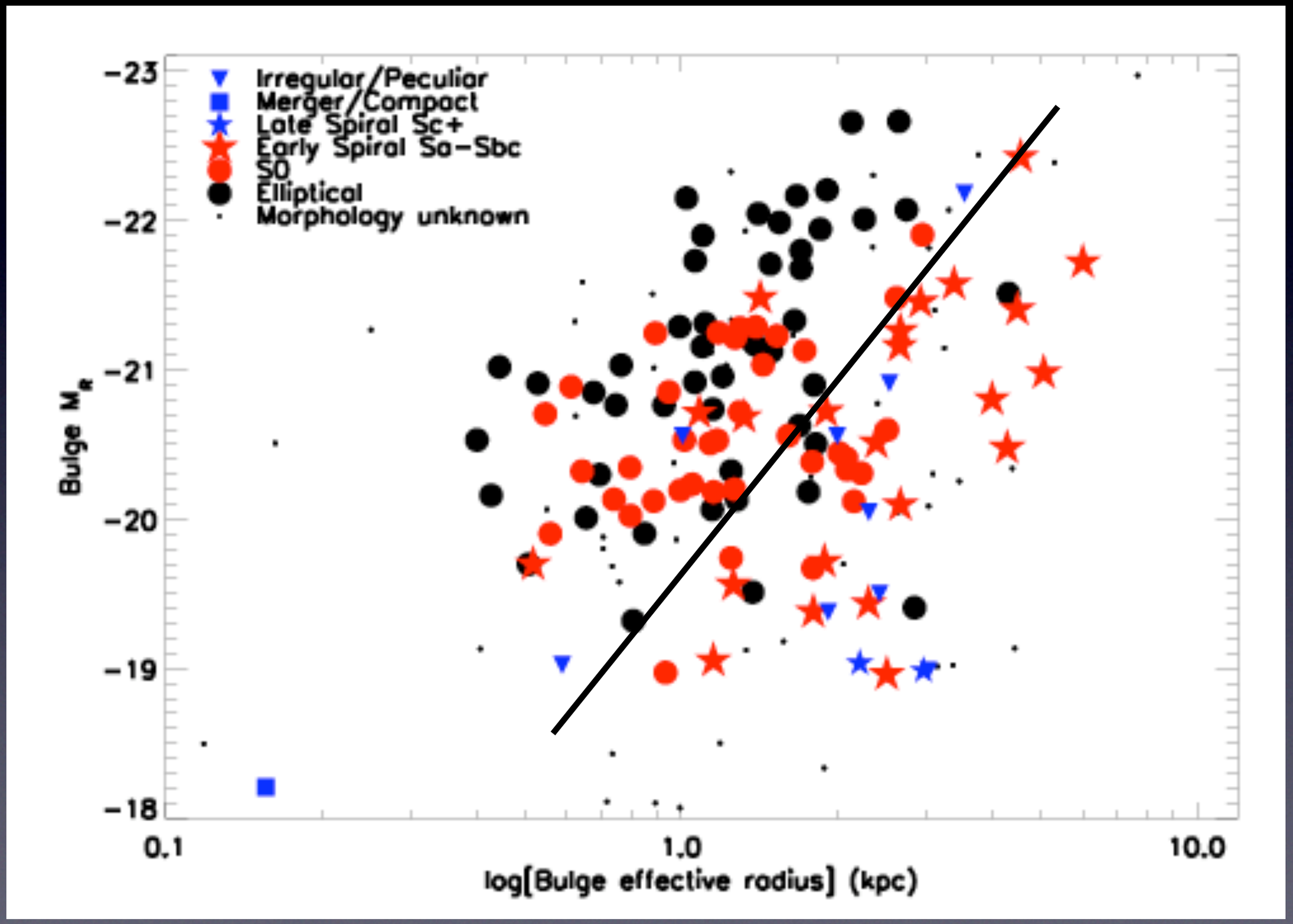
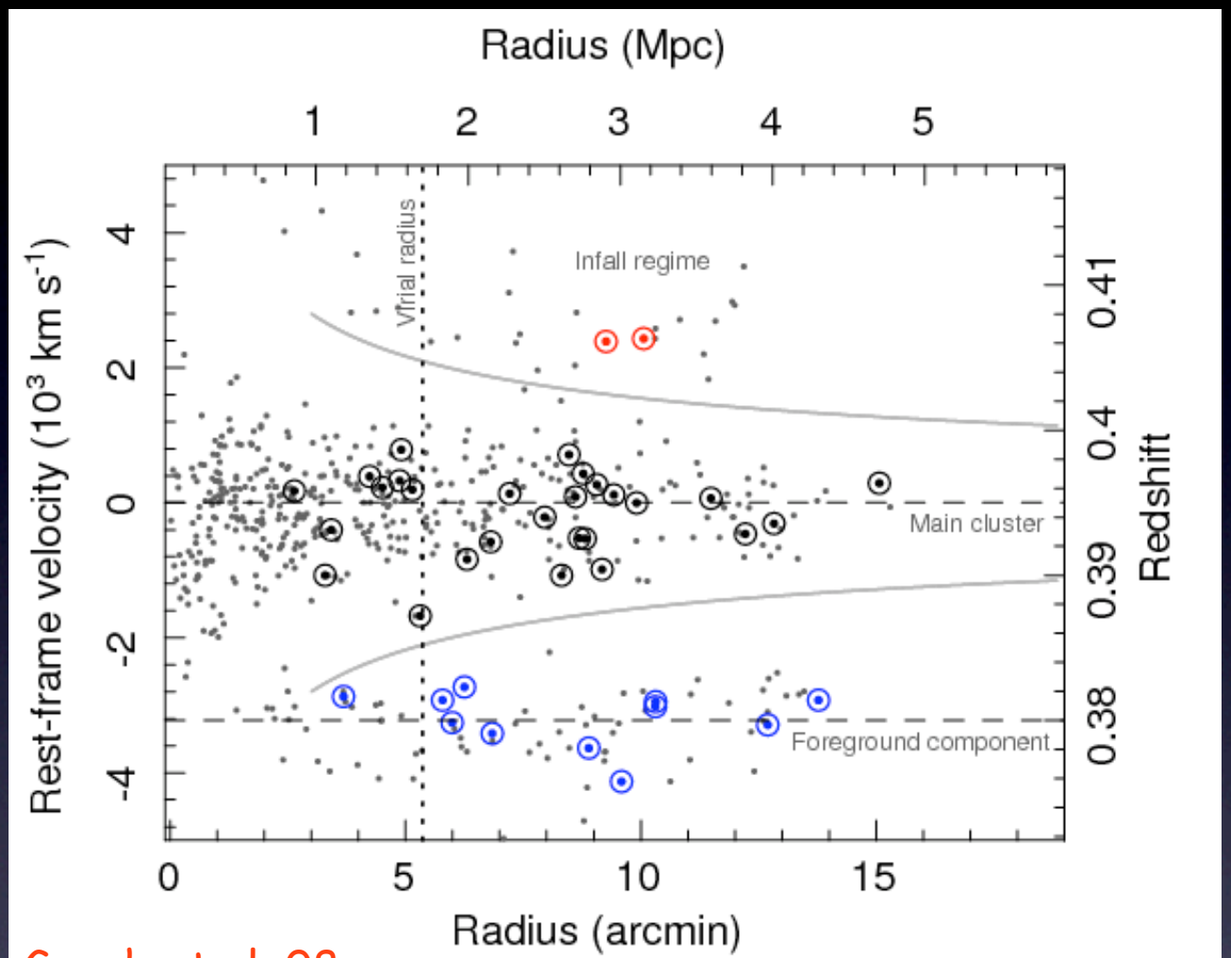
Bulge Properties as f(Hubble Type)



Bulge Properties as f(Hubble Type)



IR-bright progenitors?



Geach et al, 08

also see Bell et al, 05; Bai et al, 07; Marcillac et al, 07; Saintonge et al, 08

24 μm bright galaxies

mainly in infall regime

A maximal growth Model

B/T=0, 6×10^{10} M_{sol}

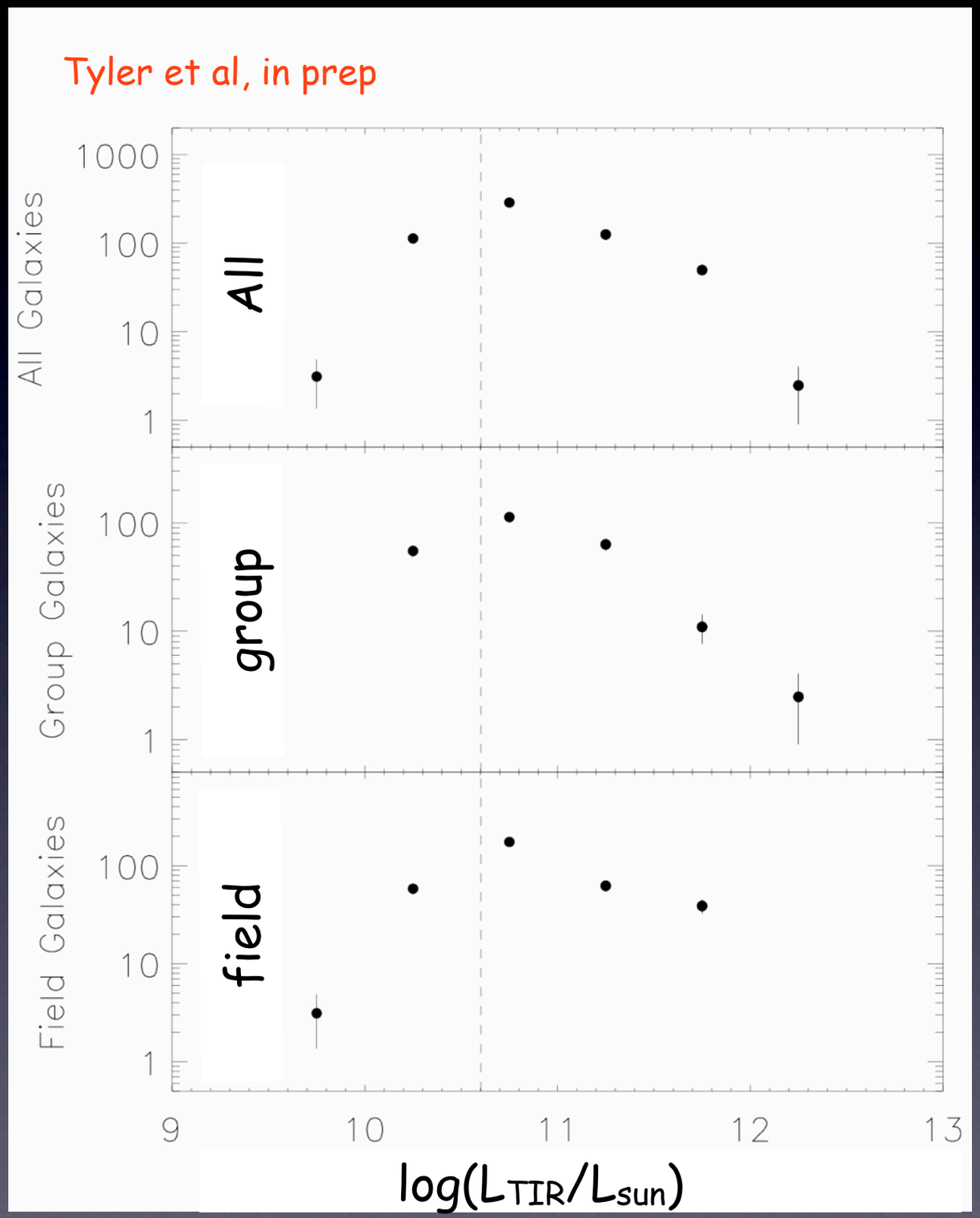
SFR~35M_{sol}/yr

bulge growth

4 Gyr

B/T=0.7, 2×10^{11} M_{sol}

IR-bright progenitors?

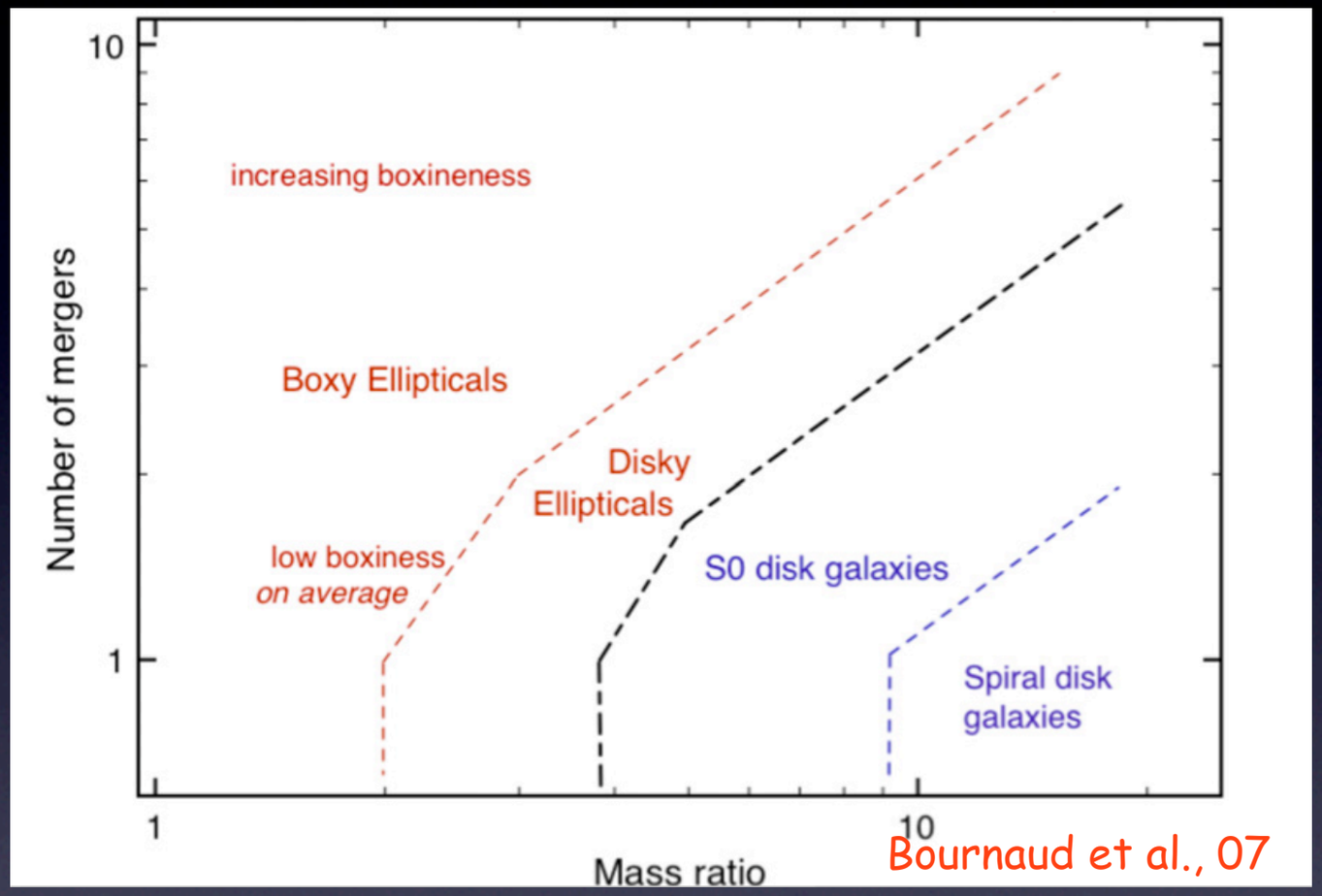


MIPS 24 μm data:

Groups do not contain unusual number of IR-bright starbursts

Merger Origin?

Structural Parameters:

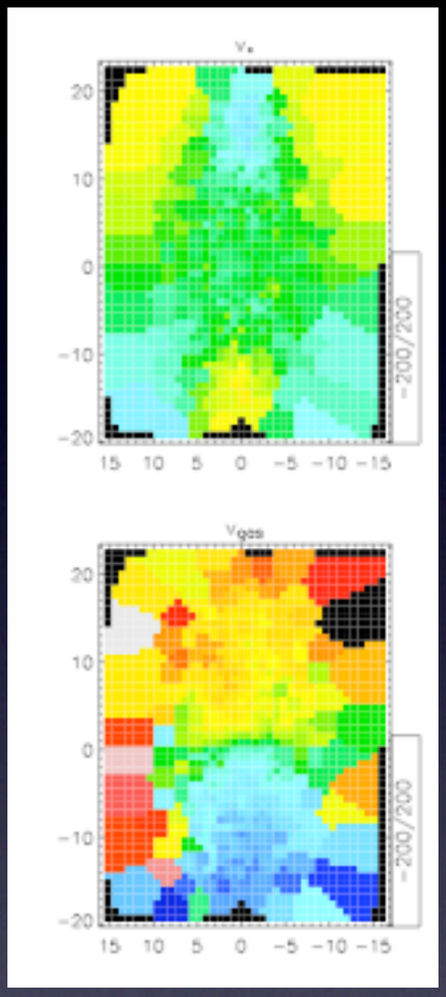


Bournaud et al., 07

SAURON field S0s:

- SF core
- significant gas
- Counter-rotating
- Minor merger origin

Shapiro et al, 09



Dynamical Friction:

P(Merger) ↑ at halo centre → Elliptical

S0s in less massive haloes, small groups / filaments?

and higher gas fractions → more disk regrowth Hopkins et al, 09

Conclusions

What we know:

S0s common in groups (not only cores): Stripping unlikely
(but rare in low density field)

Sc+ abundance ↓ with density: progenitors?
BULGE GROWTH!!!

Bright Ellipticals ↑ only in group cores:
Major / many Mergers (dynamical friction)

Most new early types are S0s
Minor Mergers, Tidal Interactions / Group Harassment