A mid and far-IR view of the star formation activity in galaxy systems and their surroundings

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Astronomy & Astrophysics

Spitzer observations of Abell 1763

III. The infrared luminosity function in different supercluster environments

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The evolution of the star formation activity per halo mass up to redshift ~1.6 as seen by *Herschel*★

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Outline:

- mid-IR & multiwavelength observations of a z=0.23 supercluster (A1763+A1770+large-scale filament):

  constraining the star-formation activity of galaxies in different environments (cluster virial region, cluster outskirts, intra-cluster filament)

- far-IR observations of clusters and groups identified in GOODS and COSMOS:

  constraining the global star-formation activity of galaxy systems at different redshifts (cmp. with the field)

- Interpretation

What do we want to do with these data?

gain a better understanding of
galaxy star formation = f(environment)

➔ determine the *differential* distributions of galaxy SFRs (≡ IR galaxy luminosity function)

as well as the *total* SFR (≡ total IR luminosity)

for different regions of the supercluster

$$\mathrm{SFR}\,[M_\odot\,\mathrm{yr}^{-1}] = 1.7\ 10^{-10}\ L_{IR}\,[L_\odot]$$

(Kennicutt 98)

To determine the IR galaxy luminosity function
and total IR luminosity
for different regions of the supercluster...

...select sample of IR emitters
members of the supercluster,
153 from z, 314 from z_{phot}

Base the selection on our 24 μm survey,
≈80% complete down to 0.2 mJy

*[it is deeper than the surveys at 70 and 160 μm,
and the 24 μm emission is also closely
related to recent star formation]*

To determine galaxy IR luminosities and stellar masses, fit galaxy Spectral Energy Distributions (SEDs) with model templates:

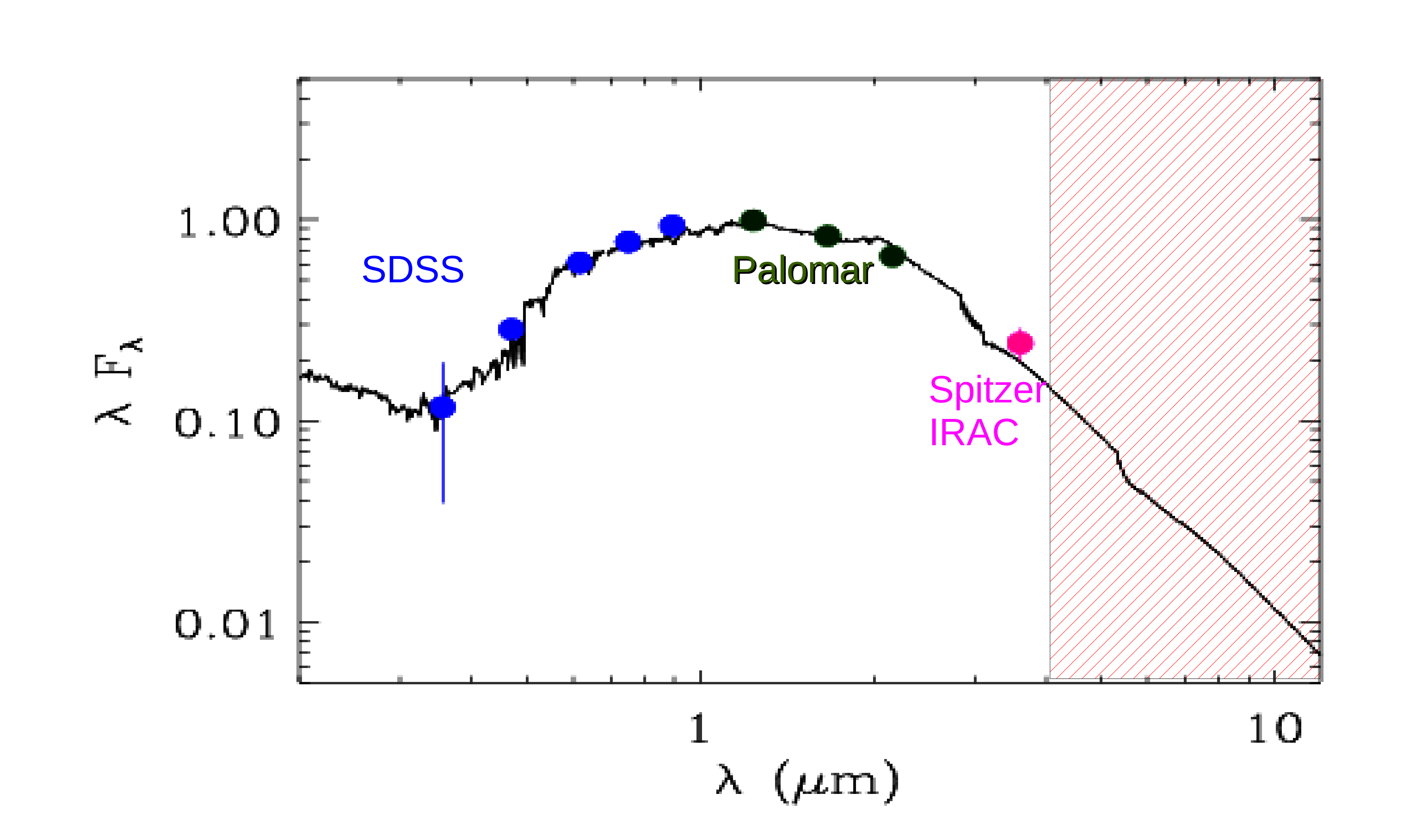
for L_{IR}:

Use GRASIL (Silva+98) & Polletta+07 models
and integrate best-fit model SEDs from 8 to 1000 μm
to determine the total IR luminosity of each galaxy

for $M_\star$:

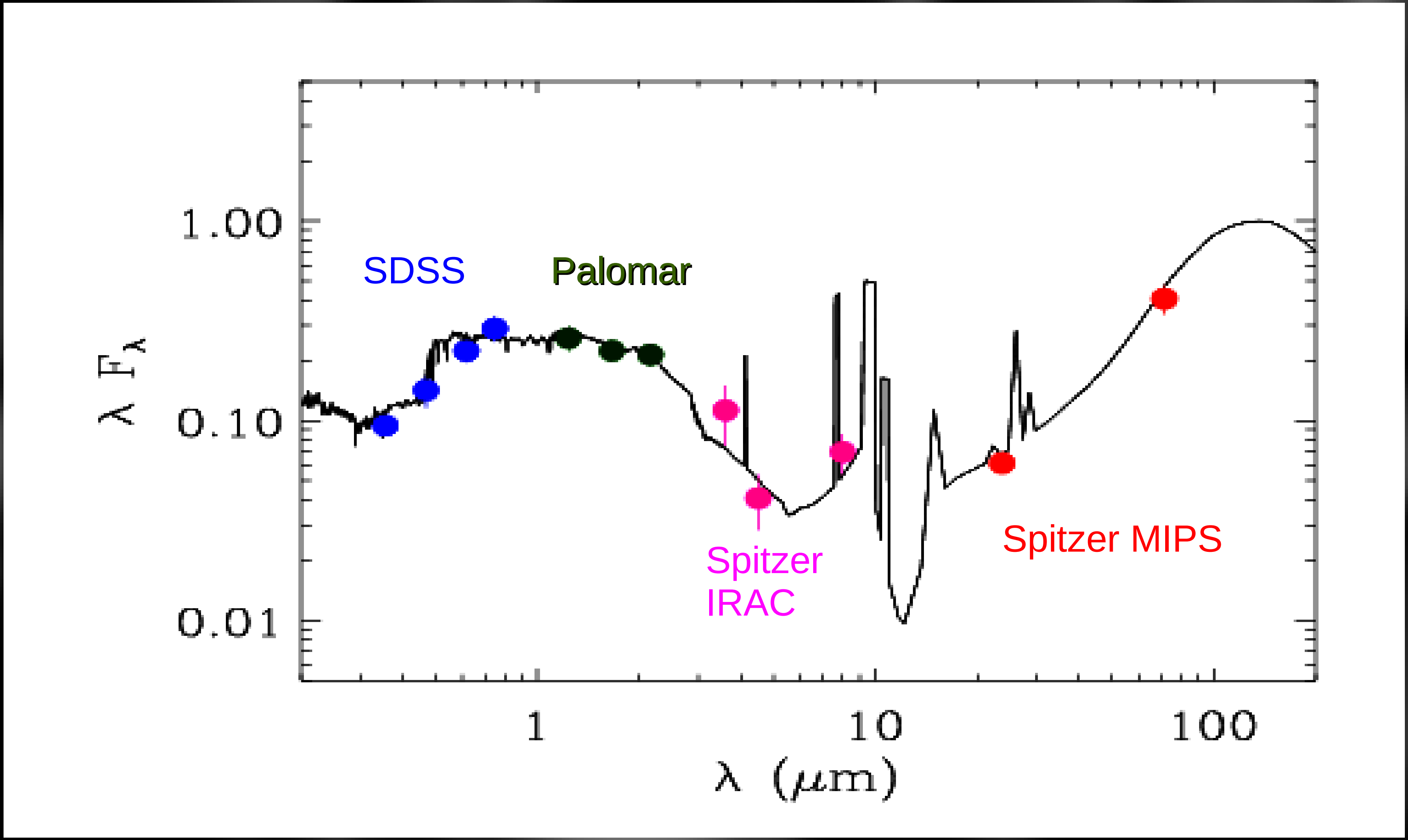
Use models of Maraston 05,
correct for absorption (Calzetti+00) with E(B-V) free to vary,
and restrict the fit to λ<4 μm
to determine the stellar mass of each galaxy

Example of restricted (λ<4 μm) SED template fit:



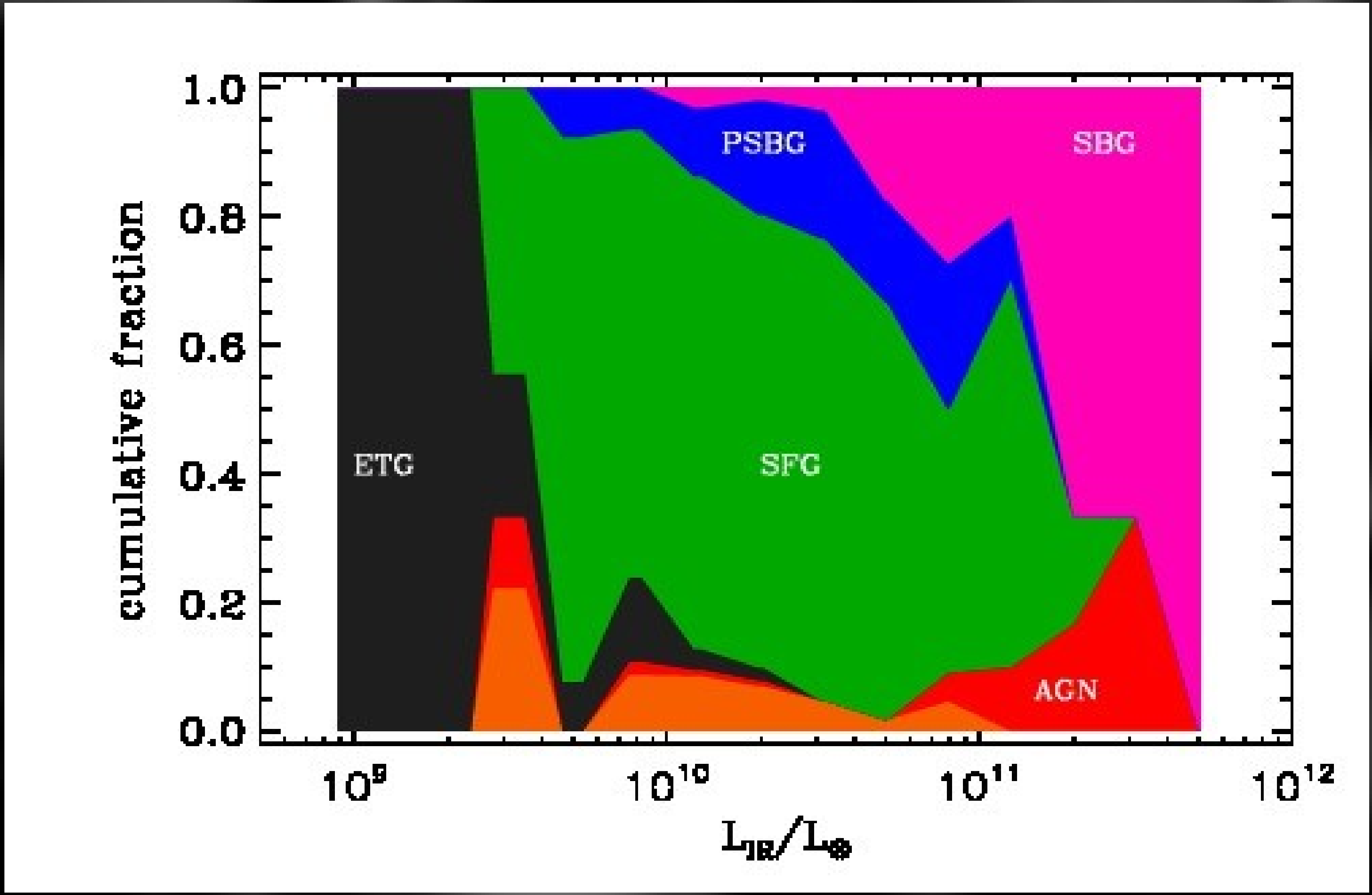
Extinction E(B-V) is a free parameter, varying from 0 to1 mag,
no dust emission in model ⇨ stop fit at λ<4 μm

Example of full SED template fit:



61 templates (GRASIL & Polletta's models) in 5 broad classes:
ETG, SFG, SBG, PSBG, AGN

The contribution of the different SED classes to the IR LF:



AGNs identified by their SED, and also using other diagnostics (from optical spectroscopy, X-ray and radio data, IRAC colors)

→ AGN contribution subtracted from IR LF

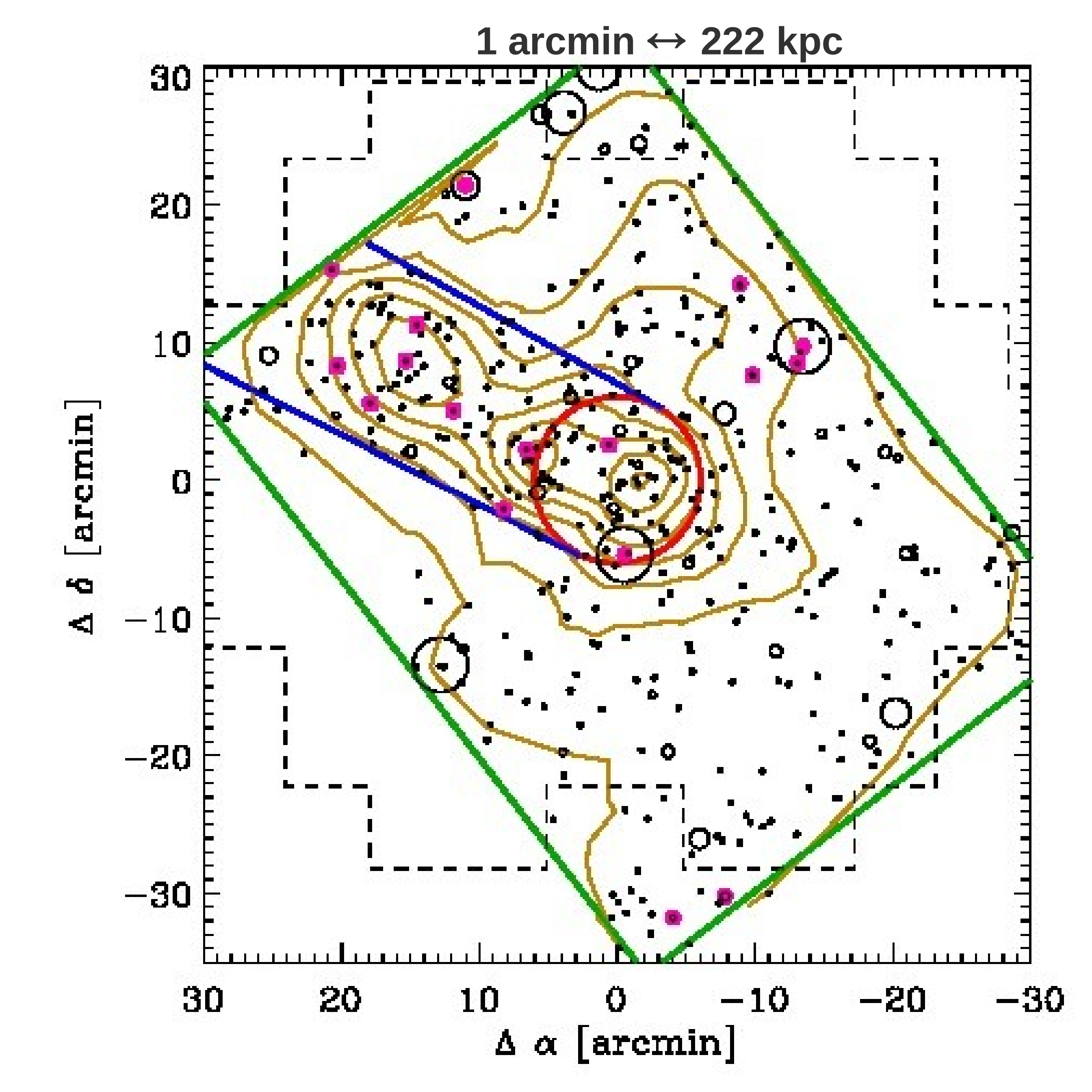
What is the effect of the environment?

We identify
3 environments:

core ($<r_{500}$)

large-scale filament

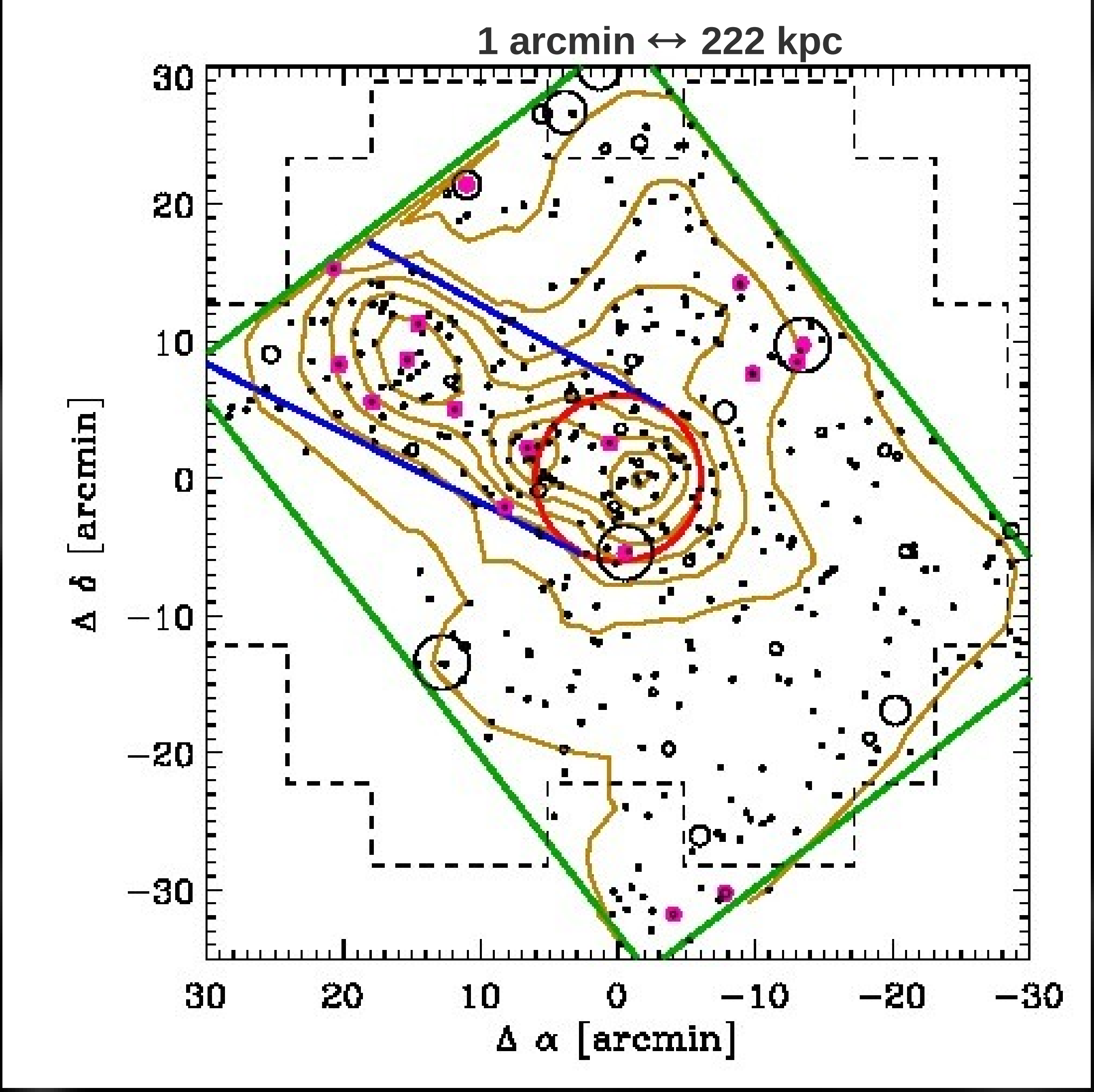
outskirts
(= the whole field except the core and the filaments)



What is the effect of the environment?

LIRGs ($L_{IR}>10^{11}\ L_{\odot}$) are located mostly in the region of the filaments

They do *not* have high SFR/$M_{\star}$ ($\propto$ circle size)



Completeness and purity corrections

By counting the number of supercluster members in bins of L_{IR} we do ***not*** obtain the IR luminosity function (IR LF),

because our sample is neither complete nor pure (contamination from non-members).

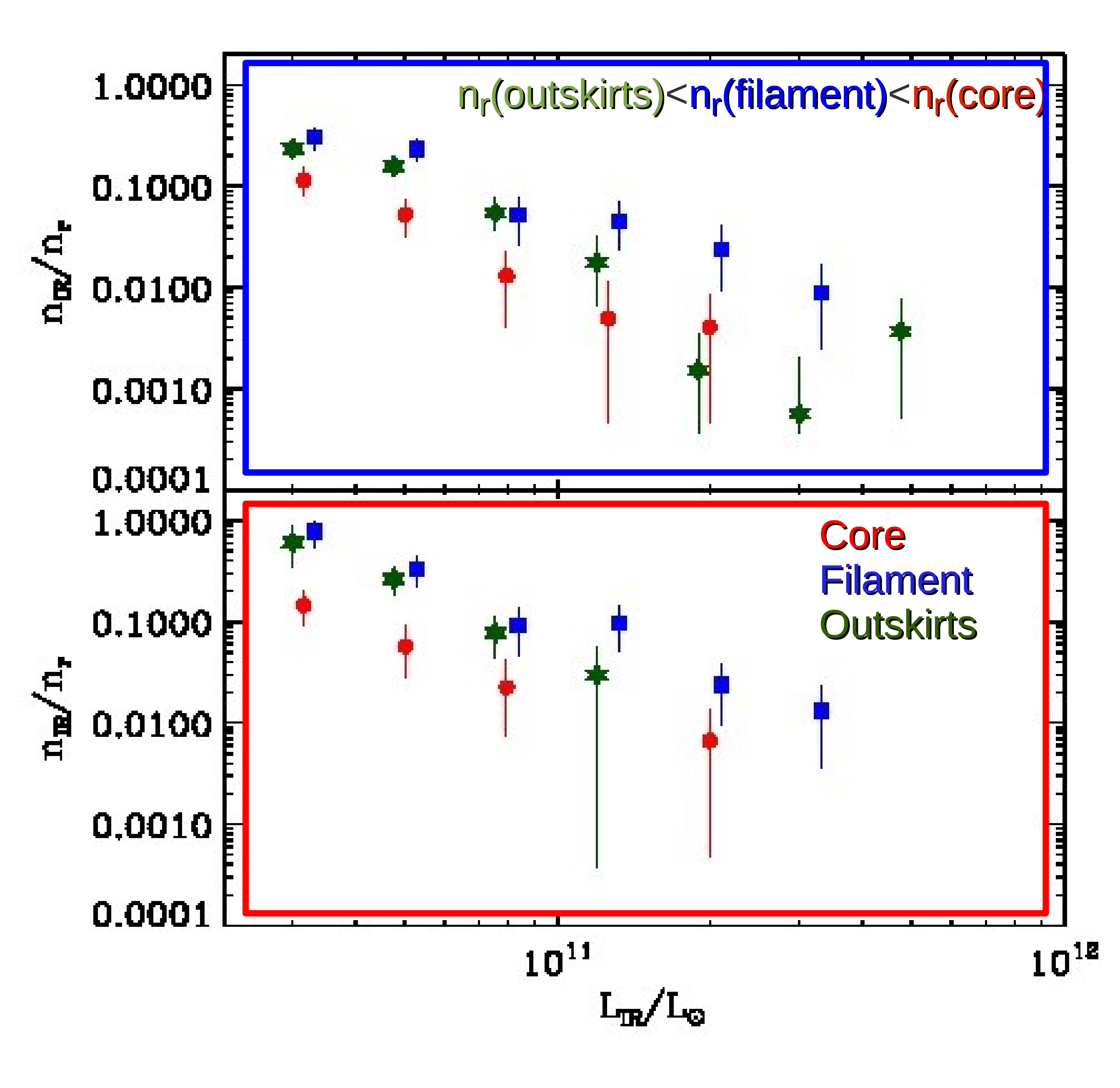
Therefore we evaluate:

Completeness = $C(f_{24})$ & Purity = $P(f_{24})$

both for the spectroscopic sample only
and for the full (spectroscopic+photometric) sample.

We then correct the IR counts to get the
pure & complete (P=1 & C=1) IR LF

The IR LFs in 3 different supercluster environments



The densities of IR-emitting galaxies, n_{IR}, are normalized by the densities, n_r, of normal, r-selected galaxies in the same regions

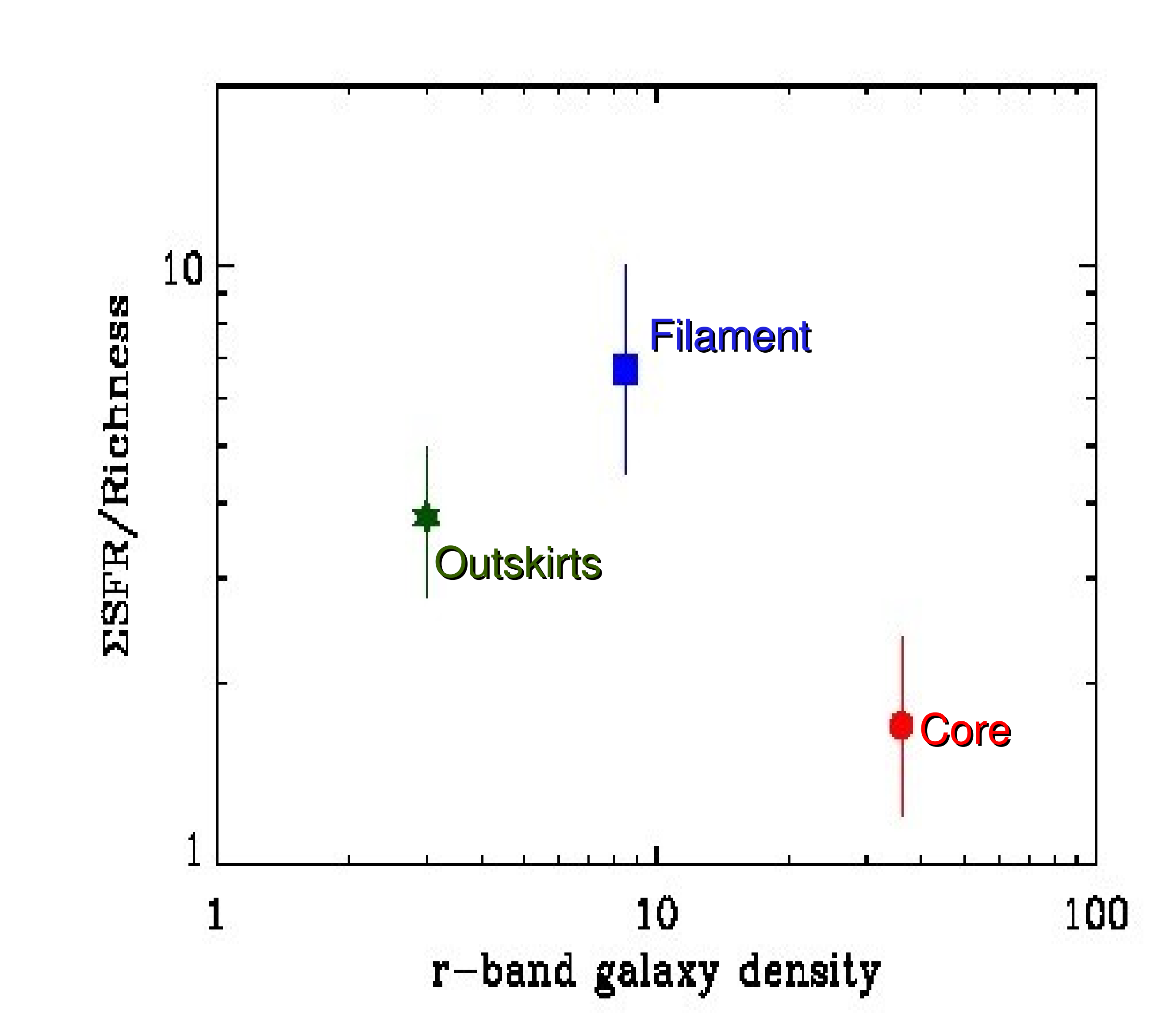
full sample

spectroscopic sample

The total SFR in the different environments

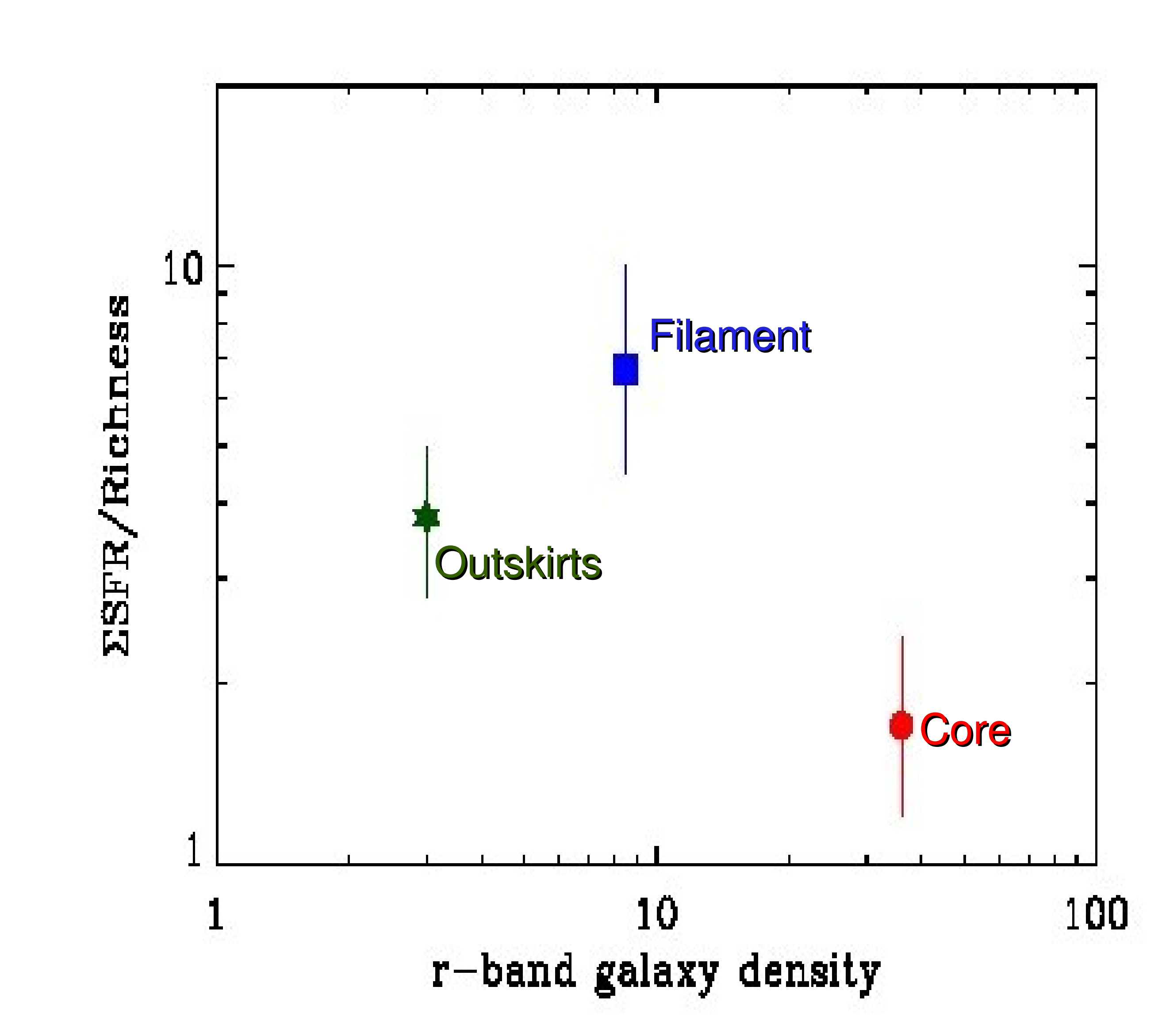
Integrate the IR LFs
of the core,
the filament,
& the outskirts
to get their total
IR luminosities
(and total SFRs,
∑SFRs,
from Kennicutt's
relation)

Divide these ∑SFRs
by the number of
normal,
r'-band selected
galaxies in the
3 regions

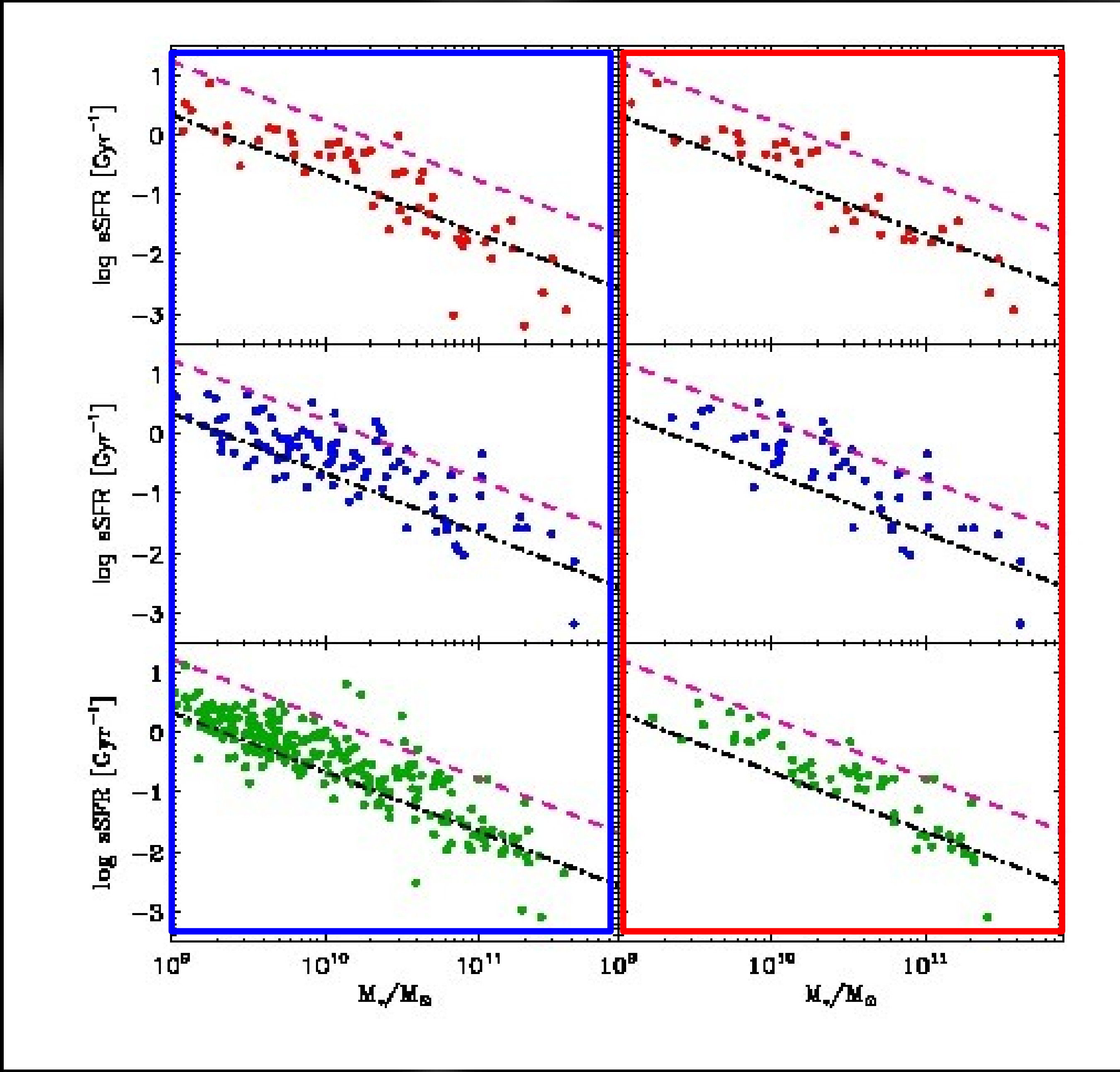


The total SFR in the different environments

higher fraction of IR-emitters
&
milder decline of IR LF at bright end
⬇
The filament is the supercluster region with the strongest star-formation activity



SFR/M$_\star$ vs. M$_\star$ for IR-emitting galaxies



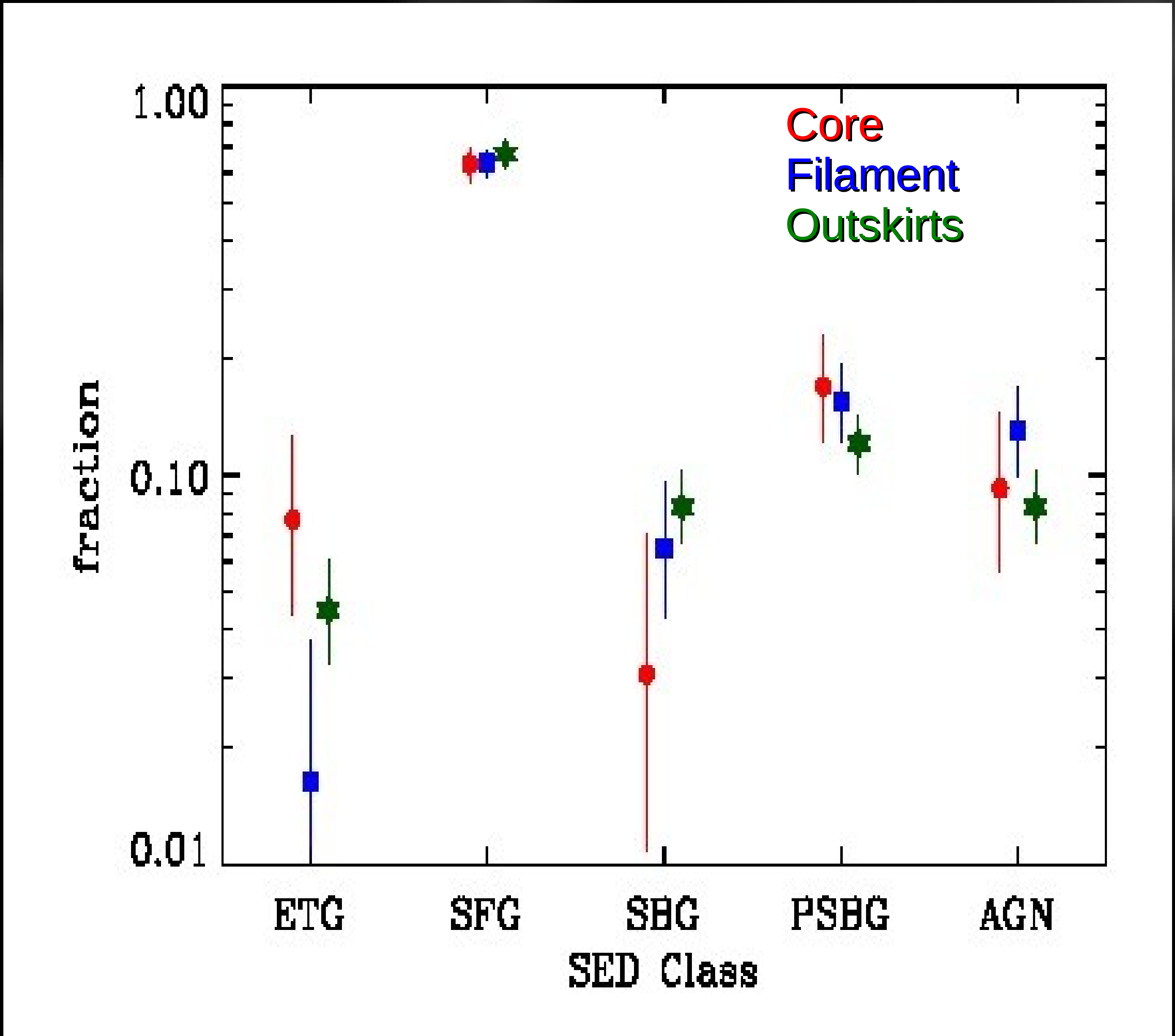
The relation is ≈ in different supercluster regions

Core
Filament
Outskirts

full sample

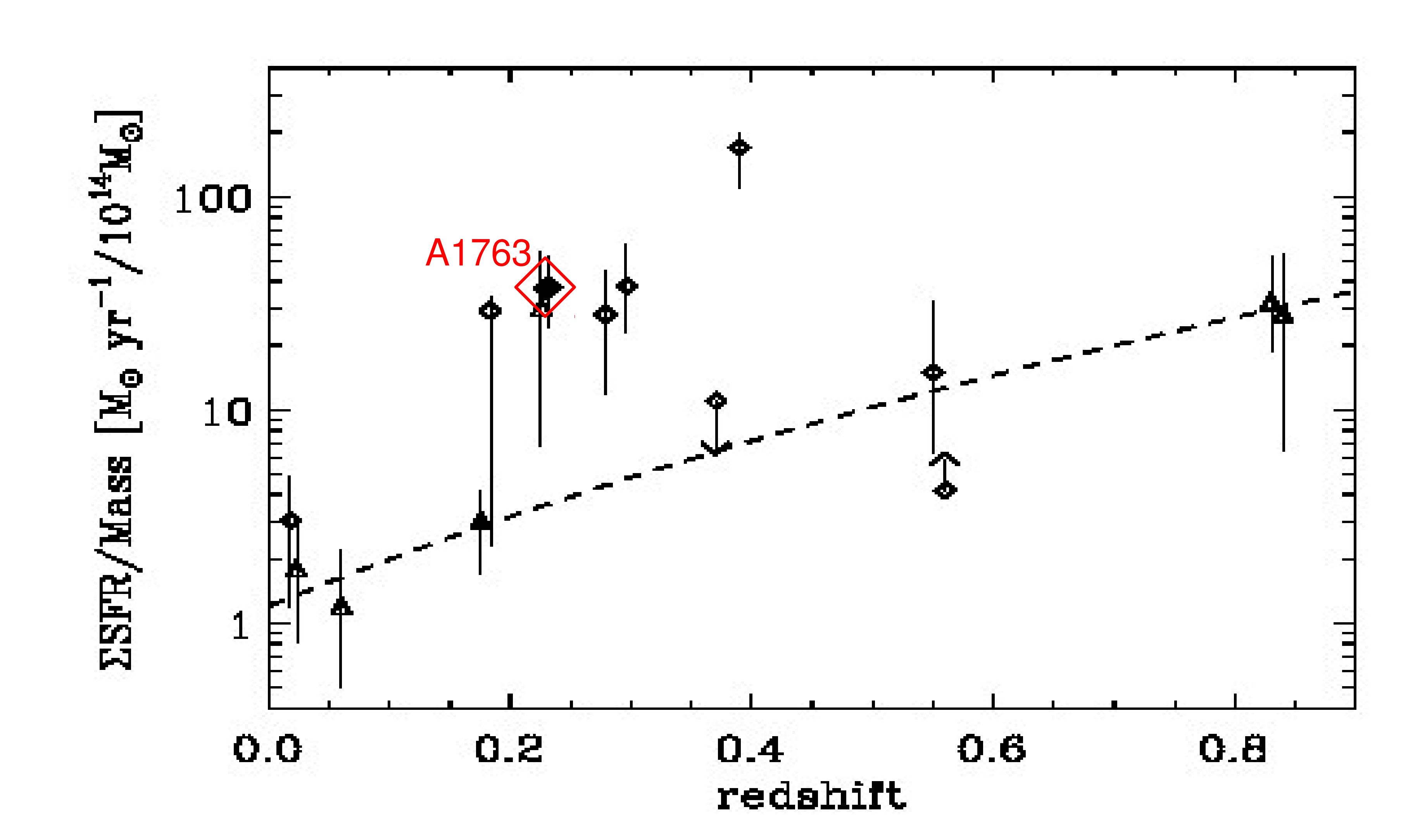
spectroscopic sample

SED-class fractions of IR-emitting galaxies in different supercluster regions



The fraction of different SED classes is ≈ in different supercluster regions

Comparison with previous works



The galaxy ∑SFR / total mass in cluster cores increases with z *(but not as predicted by Bai+09)*

Herschel observations of bright IR-luminous galaxies

in X-ray detected galaxy systems at $0.1 \leq z \leq 1.6$

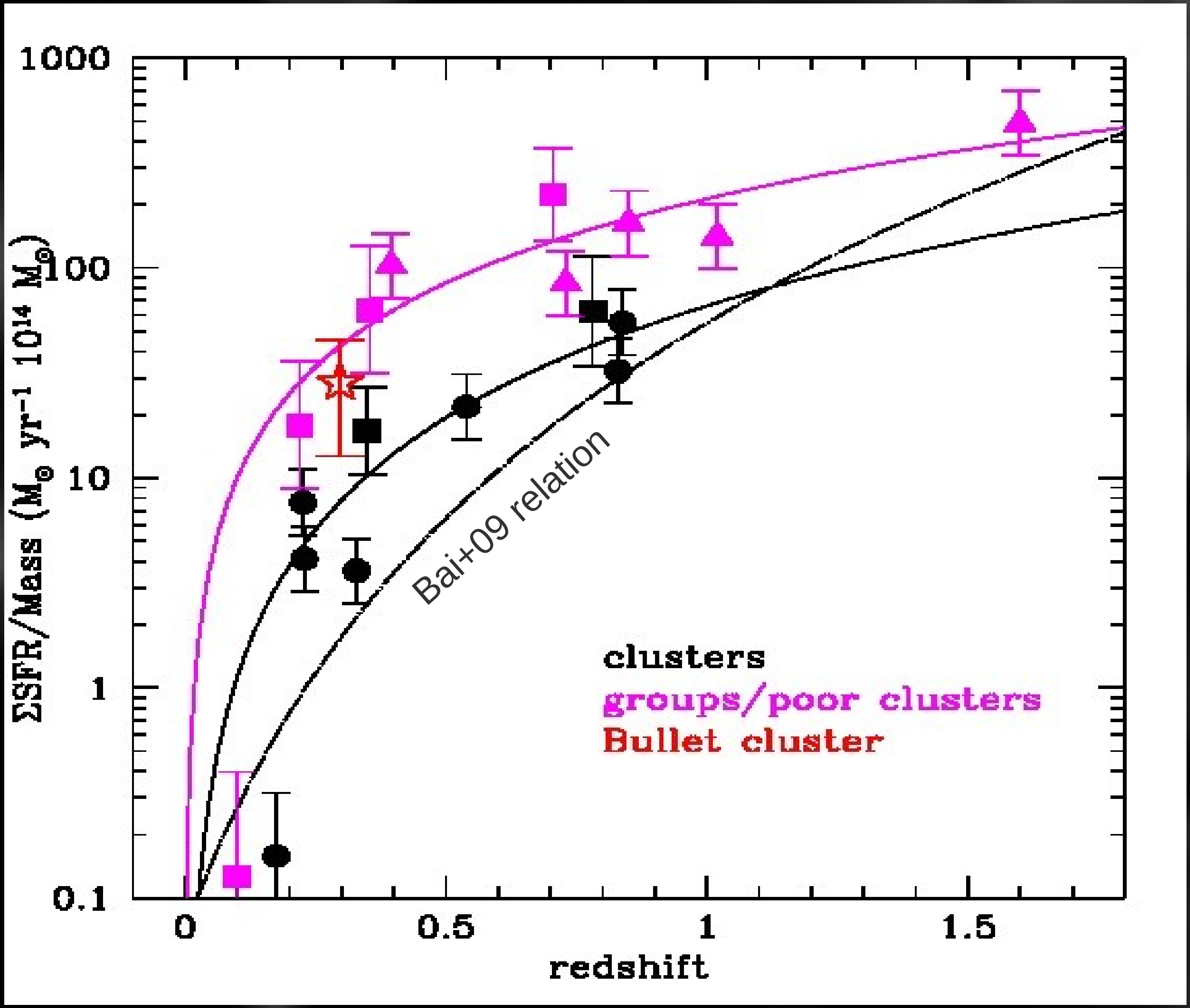
Sample:

(Mostly) Herschel-based IR luminosities for galaxies in groups ($M < 3 \times 10^{14}\ M_\odot$) and clusters ($M \geq 3 \times 10^{14}\ M_\odot$) at $0.1 \leq z \leq 1.6$

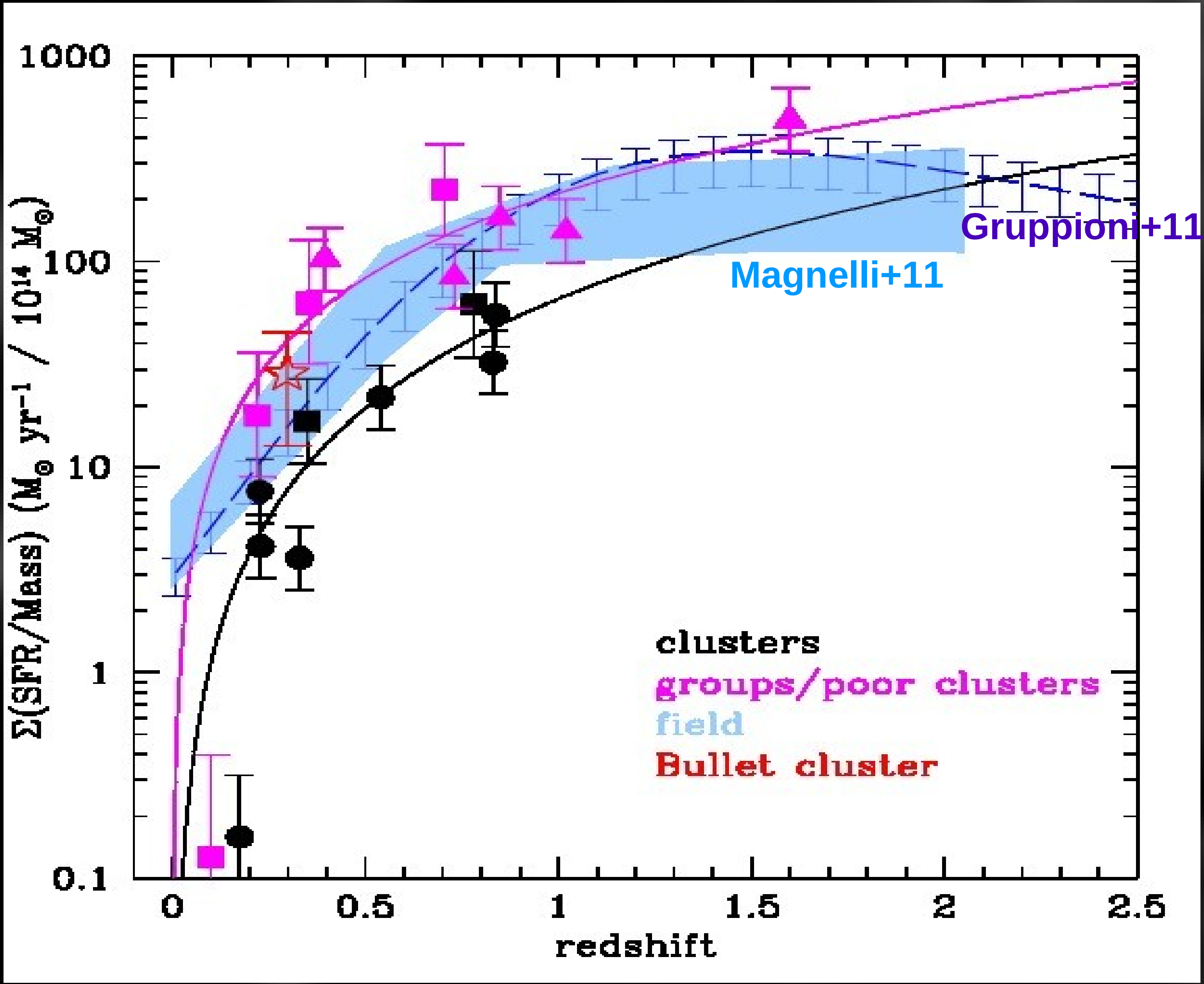
[PACS Evolutionary Probe GT pgm, Lutz+11,
groups in COSMOS field, Finoguenov+, in prep.
PACS GOODS-Herschel pgm, Elbaz+11]

Spectroscopic completeness:
50-85% for **LIRGs** ($L_{IR} \geq 10^{11}\ L_\odot$)

Total SFR (<r$_{200}$) / M$_{200}$ vs. redshift



Total SFR ($<r_{200}$) / M_{200} vs. redshift



Summary:

- At $z \geq 0.2$,
  SF activity in filaments, groups $\geq$ SF activity in the field
- At all z,
  SF activity in cluster cores < SF activity in other environments
- sSFR vs. $M_{\star}$ $\approx$ in all environments (for IR-emitting galaxies)
- SED-class distribution of IR-emitting galaxies $\approx$ in all environments
- Main SED class is that of normal, star-forming galaxies;
  (post-) starburst mode concerns $\leqslant$1/3 of all IR-emitting galaxies
  (but a higher fraction of LIRGs)
- The total SFR per unit mass increases with z in all galaxy systems

Interpretation:

- ★ *Must quench SF in cluster cores (but not in groups); must do so rapidly (sSFR vs. M_* does not change in clusters);*
  → interaction with dense intra-cluster gas

- ★ *Must (slightly) enhance SF in filaments, groups wrt the field, especially for massive (10^{10} $M_\odot$) galaxies;*
  → major galaxy-galaxy interactions and mergers

- ★ *Must reduce SF activity per unit mass in galaxy systems with time;*
  → SF of field galaxies ⬇ due to gas consumption
  + infall rate of field galaxies ⬇ as Universe expands
  + quenching SF of infallen field galaxies in cluster cores

What next?

➔ A1763:

analysis of galaxy spectral line-indices

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analysis of GALEX UV data covering the full supercluster

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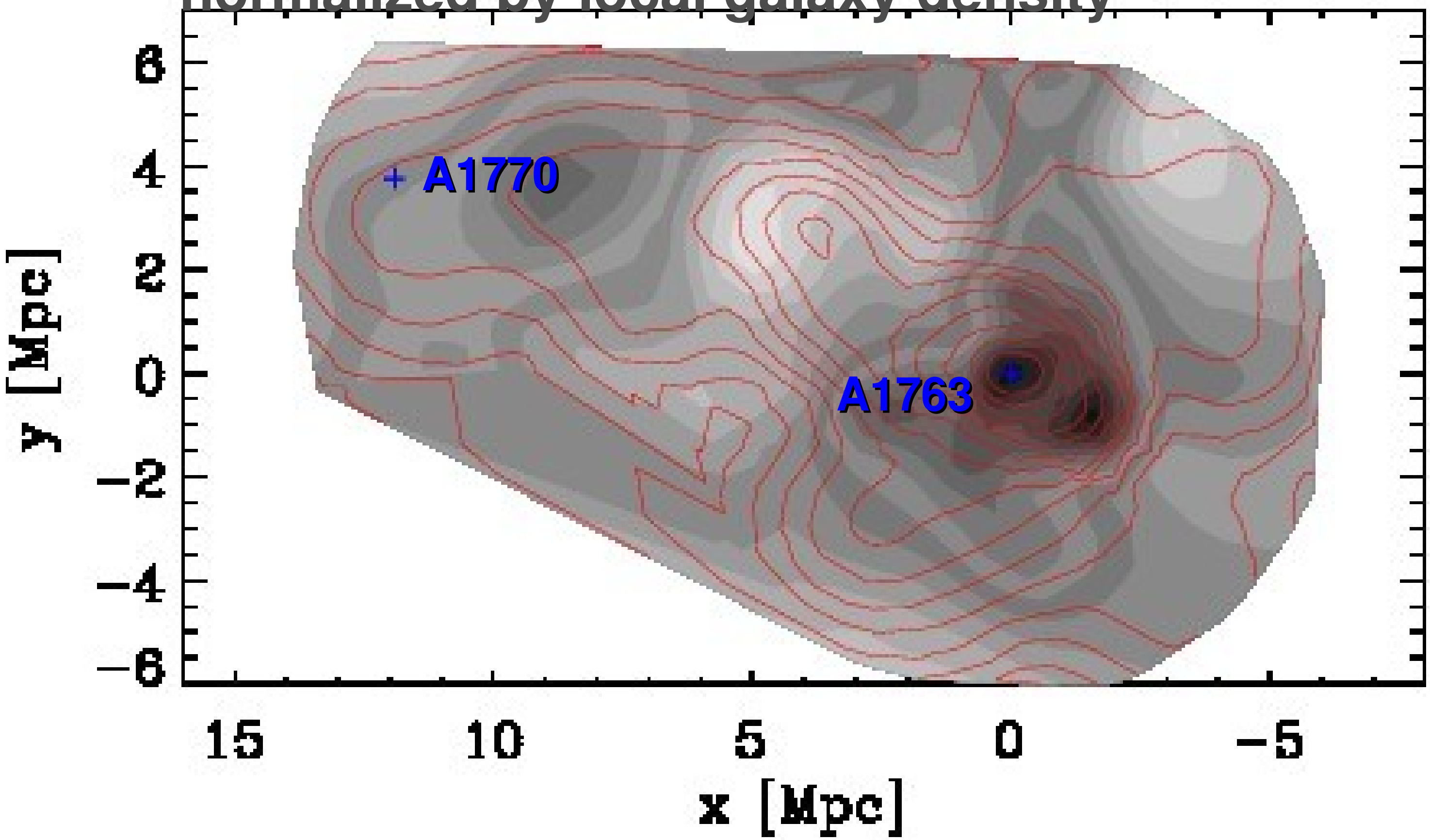
Red iso-density contours
of cluster spectroscopic members
Gray scale: map of UV-based SFR
normalized by local galaxy density



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➔ A1763:

analysis of galaxy spectral line-indices

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Herschel OT proposal to cover the full supercluster in far-IR

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➔ Other clusters:

48$^{\text{hrs}}$ on 8 (proto)clusters at $0.9<z<2.4$
(Herschel GT accepted, p.i. B. Altieri)

97$^{\text{hrs}}$ on 8 clusters at $1.4<z<1.8$
(Herschel OT accepted, p.i. P. Popesso)