LoCuSS: A Legacy Survey of Galaxy Clusters at z=0.2

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and the LoCuSS team

ESLAB Herschel First Results Meeting
May 6 2010

Local Cluster Substructure Survey

(P.I. Graham Smith)

http://www.sr.bham.ac.uk/locuss/

AIM: To understand the impact of recent hierarchical infall history of clusters on their baryonic content -- galaxies and hot intracluster gas.

- Observable cluster scaling relations show intrinsic scatter from cluster to cluster. How does this scatter relate to their recent assembly history?

- Transformation of infalling galaxies through different environments: field / filaments / groups / cluster cores.

Local Cluster Substructure Survey

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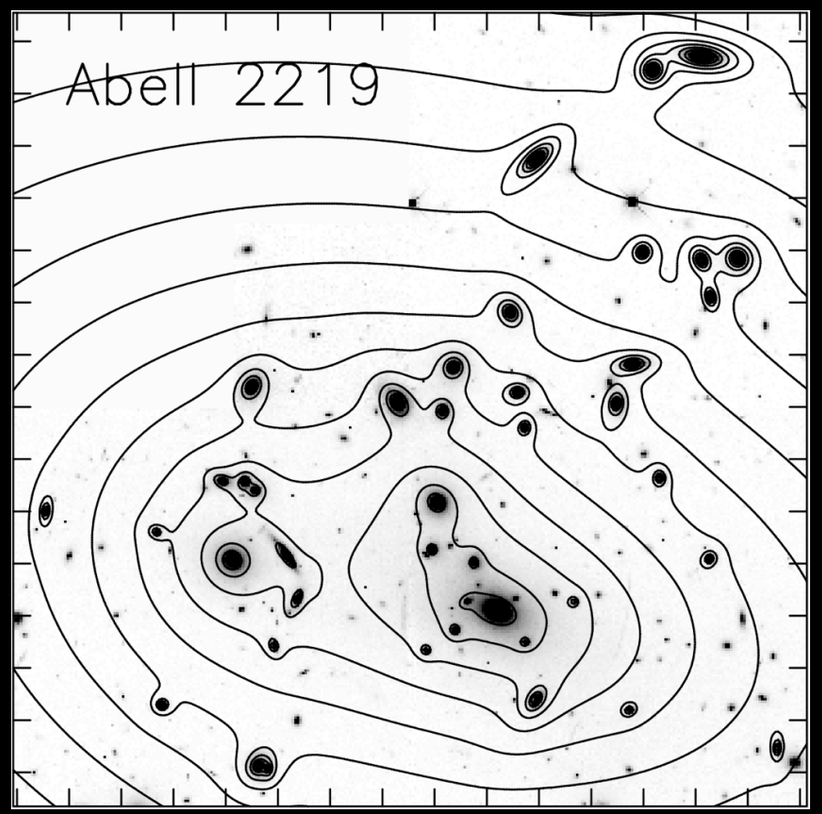
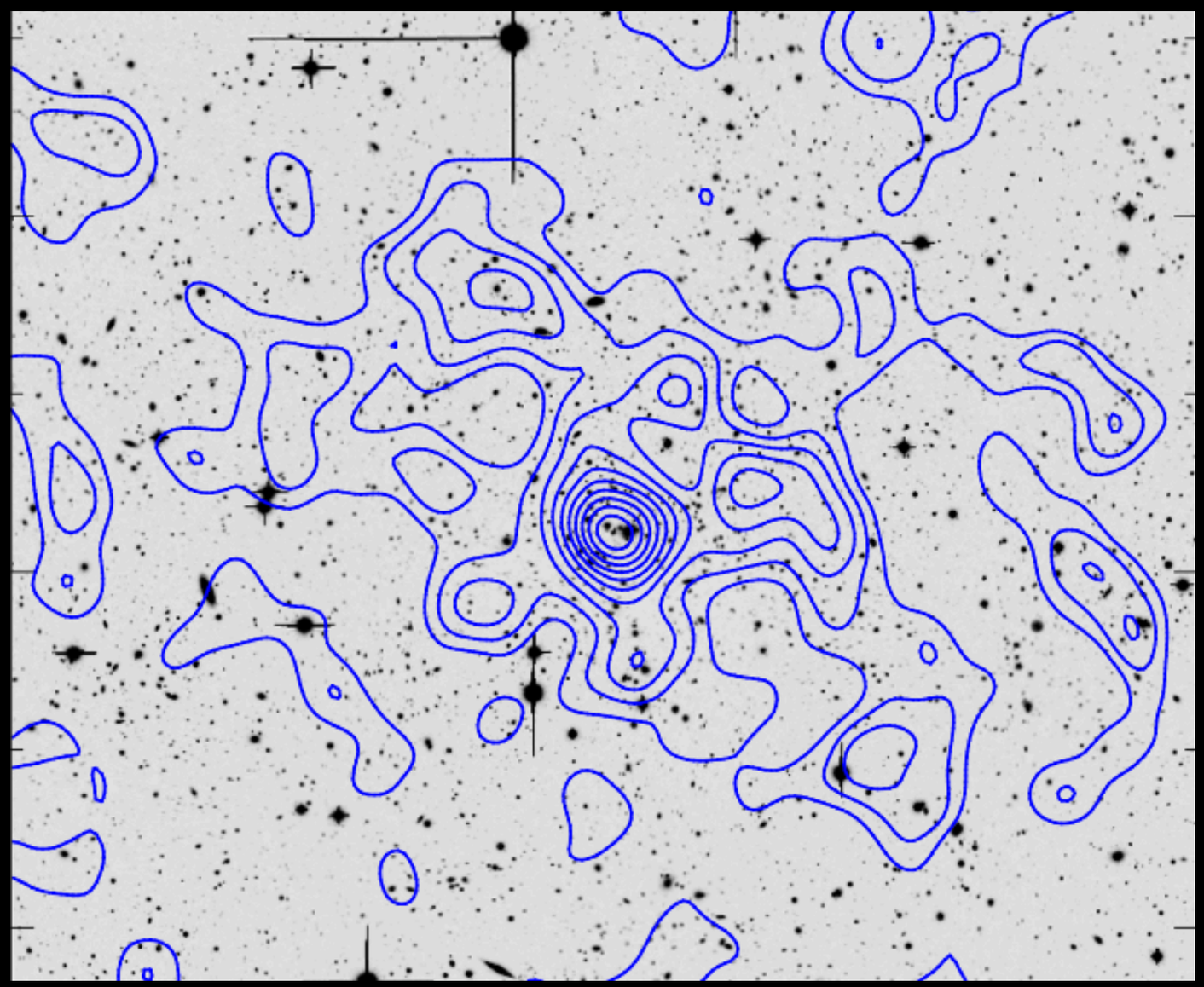
LENSING → SUBSTRUCTURE → ASSEMBLY HISTORY





Smith+2005
Okabe+2010
Smith&Taylor 2008

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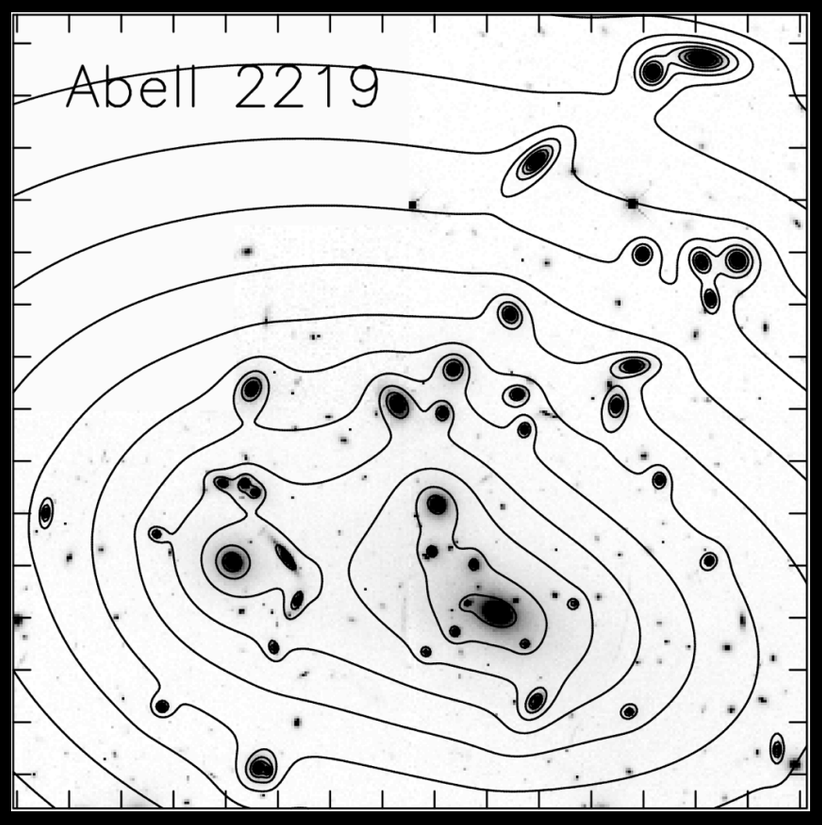

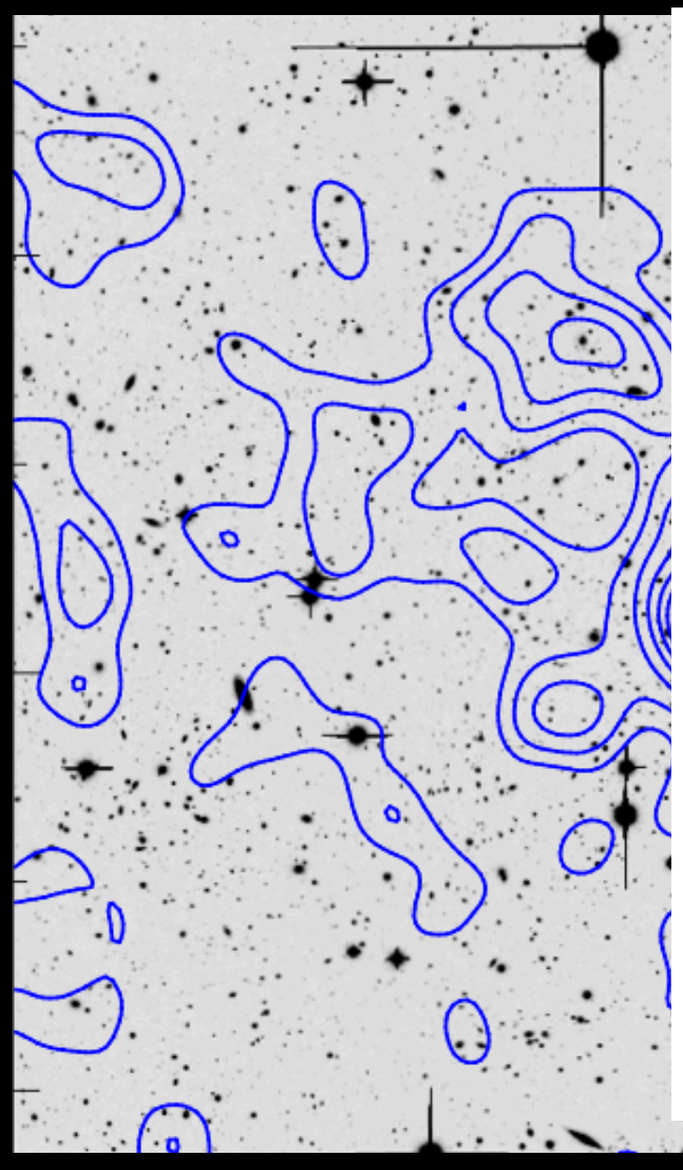

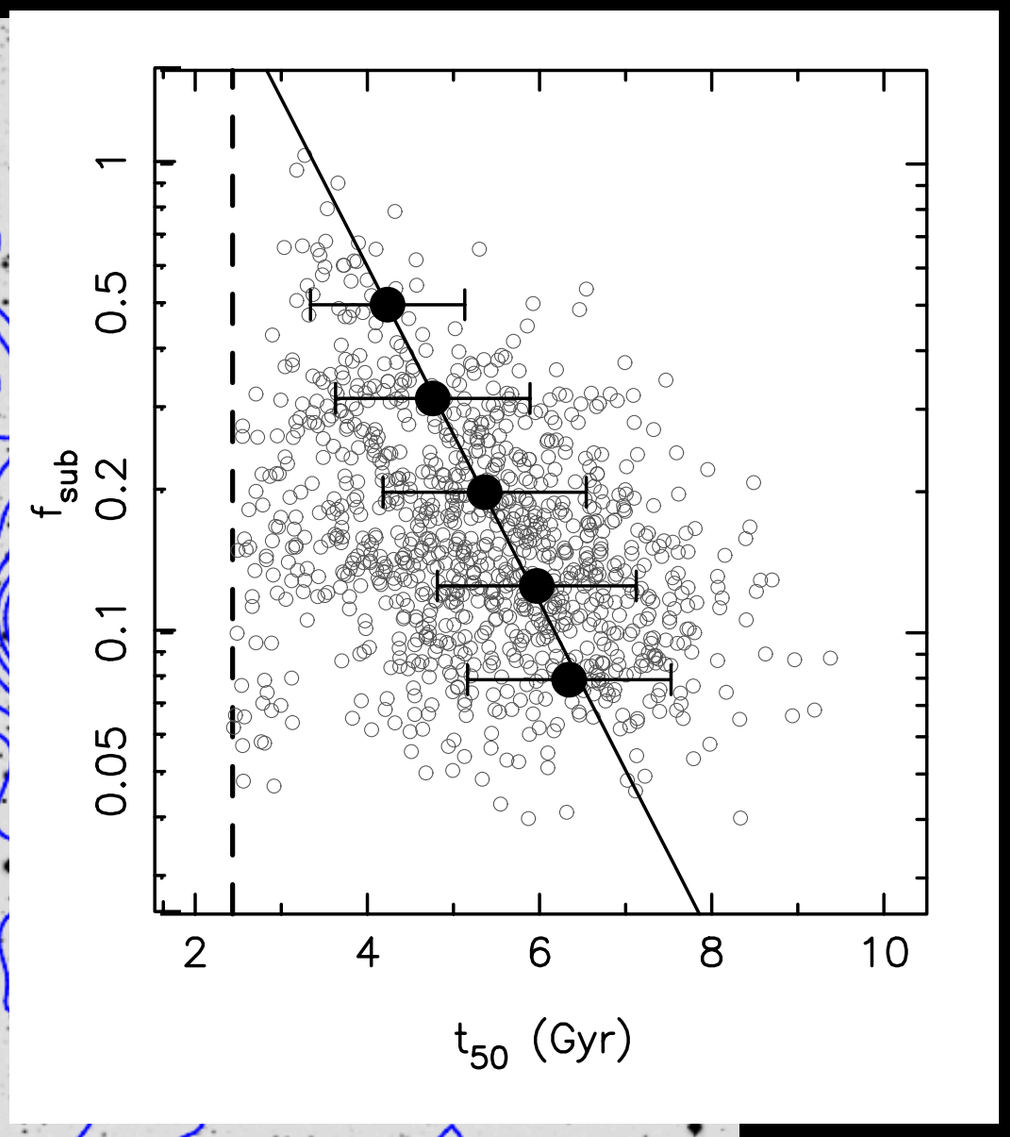

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LoCuSS: *Herschel* Key Programme

A legacy survey of clusters at z=0.2

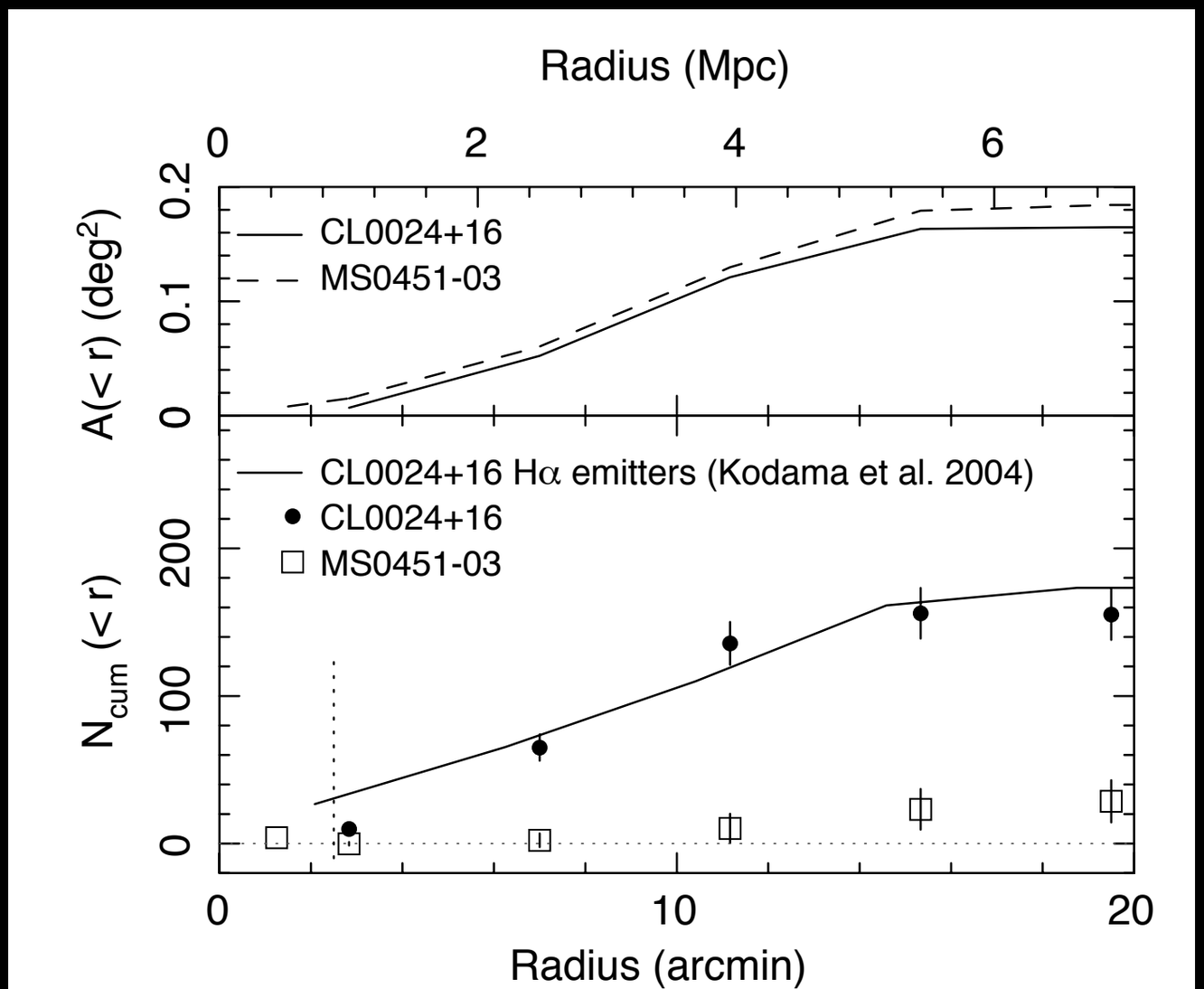
Summary of ISO/Spitzer results:

~10 clusters, heterogenous selection: depths, FoV

order of magnitude variations in IR populations of galaxies.

connection between cluster-cluster mergers and starburst galaxies? (Geach+ 2006; Haines + 2009; Bekki 2001)

Need: a large wide field homogenous survey of clusters



Geach+2006

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Morphologically unbiased sample:

- 0.15<z<0.3, -70<dec<+70deg, n_H<7E-20cm^{-2}
- ROSAT All Sky Survey catalogs: BCS, eBCS, REFLEX
- 165 clusters with L_X>2E44erg/s

Huge multi-wavelength effort (30-50% complete):

- Subaru, HST, Keck, VLT, Gemini, Chandra, XMM, SZA, Palomar, Spitzer (24um), GALEX, Herschel, MMT/Hectospec, KPNO, CTIO, UKIRT

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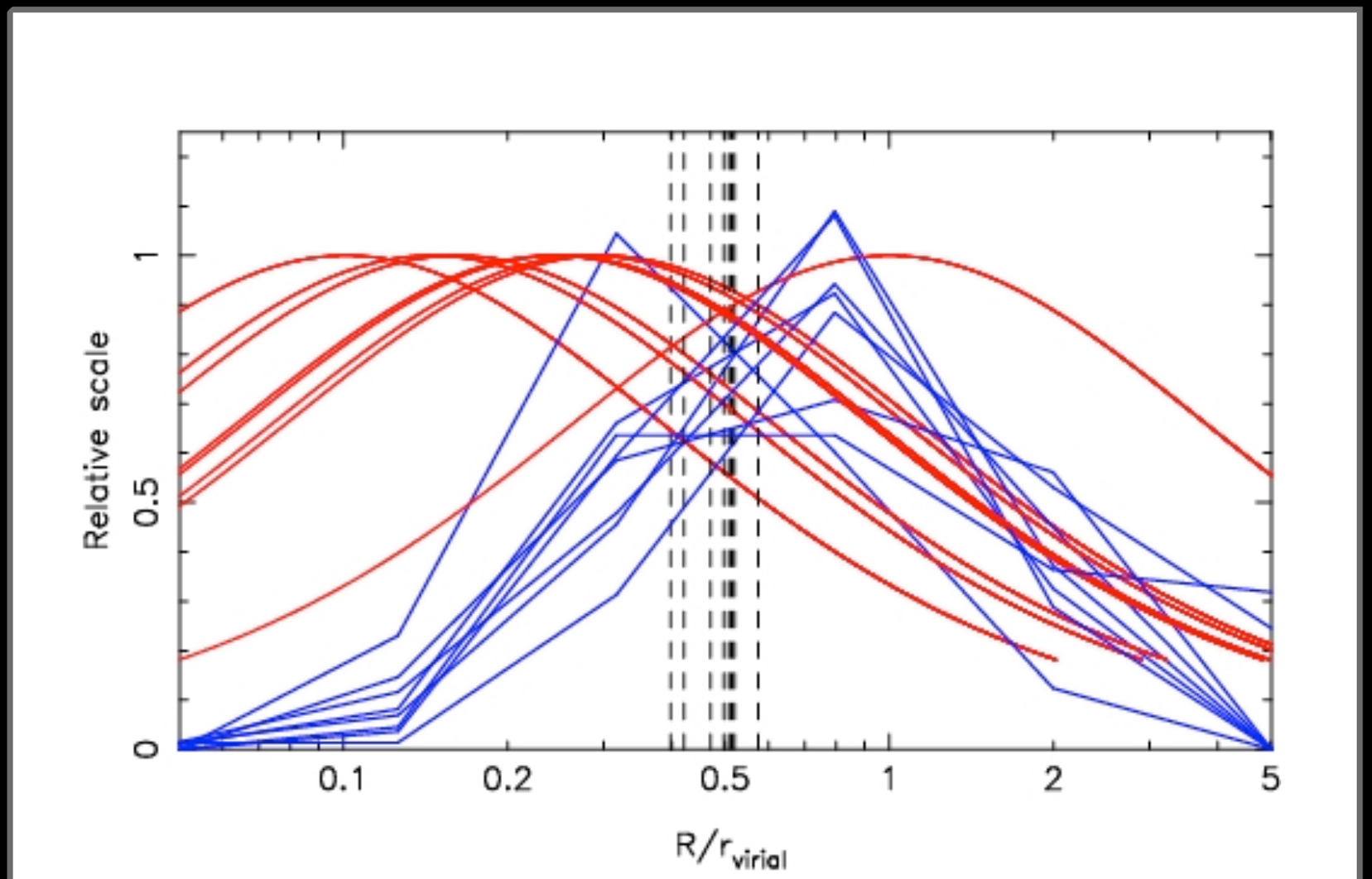
Relative importance of different environmental processes:

galaxy-galaxy mergers
$2<\rho_{3D}<10 Mpc^{-3}$

harassment $\sim \rho_{gal}\, r^2$

ram pressure stripping:

to strip the MW (Gunn&Gott 1972)



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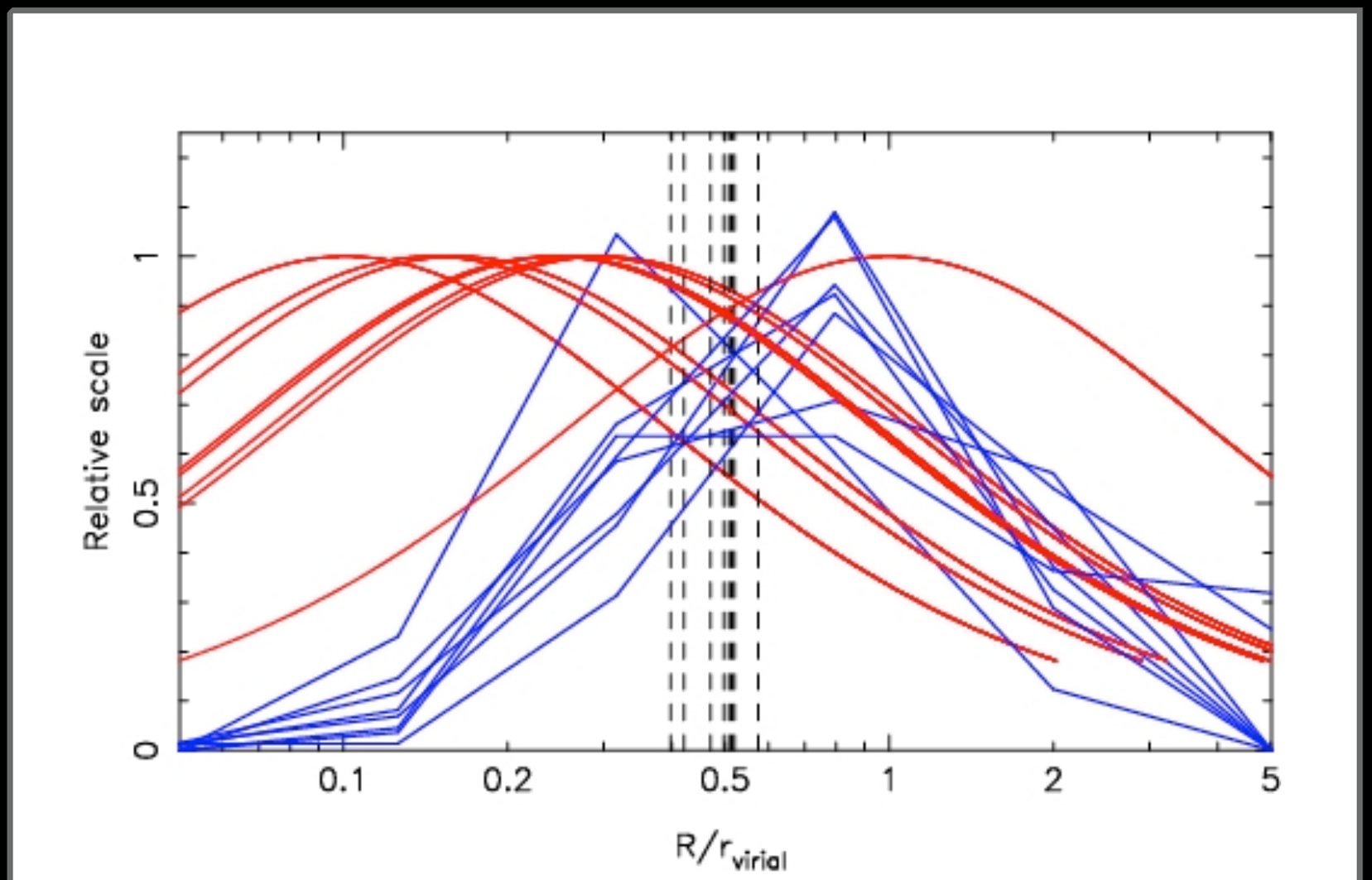
$\Delta(z=0.25) = 120$
$r_{200} = 0.75 r_{vir}$



Smith+2010

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Strategy

Large sample of clusters at "low" redshift ▪ 100/160um observations probe SED peak ▪ Probe out to ≥1.5r_{virial}

- A bit more detail:
- Global SFR (gas supply) is ~2-3× lower at z~0.2-0.3 than at z~1, but it is not negligible!
- Observations at z=0.2 are 5× cheaper than at z=0.8!
- Optical Butcher Oemler effect shows significant cluster-cluster variations at z~0.2
- Currently a large statistical sample is only feasible at z~0.2
- 32 clusters➔~600-1000 galaxies with $L_{IR}>5\times10^{10}L_{\odot}$

Observations

PACS 100um and 160um • 25x25arcmin maps • 110 sec on-sky per pixel

- Total 4.8 hours per cluster ▪

Status (as of May 2010)

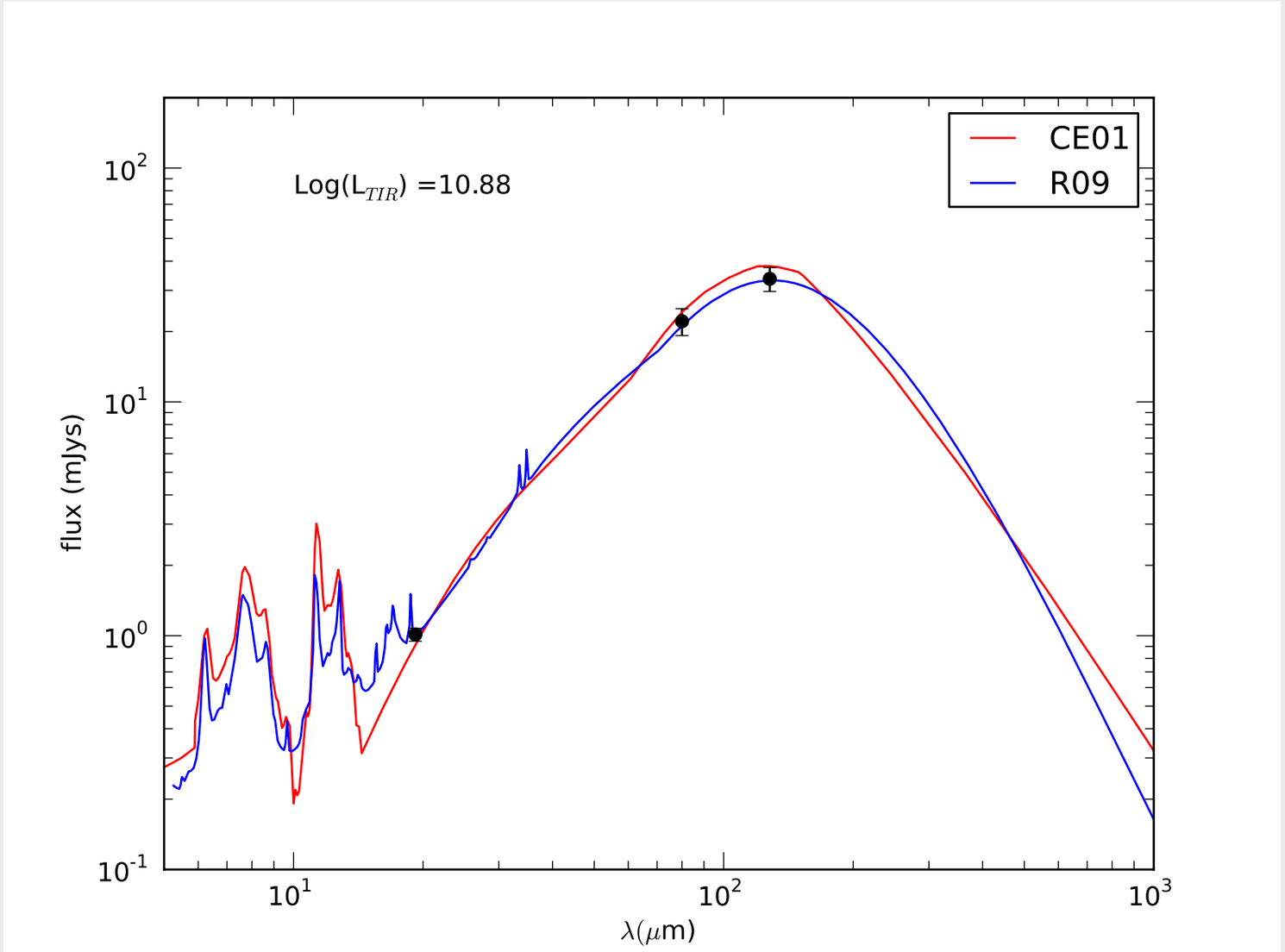
10 clusters observed, 8 analyzed in survey letter (Smith+ 2010, A&A Special Issue)

Abell 1689 - Haines+ 2010, A&A Special Issue

Abell 1835 - Pereira+ 2010, A&A Special Issue

L_{TIR} and dust temperature estimates:

100um, 160um probe the peak of the SED



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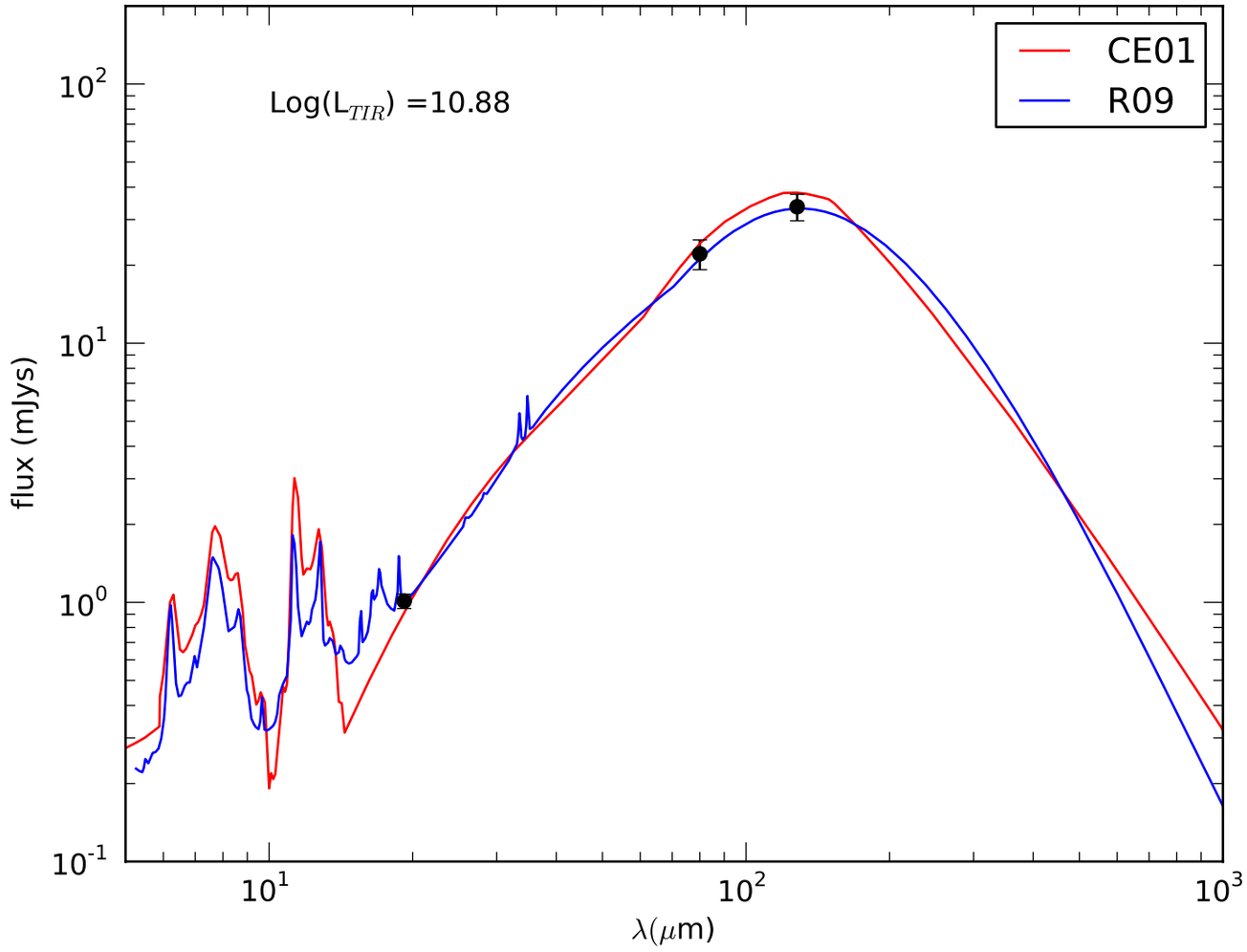

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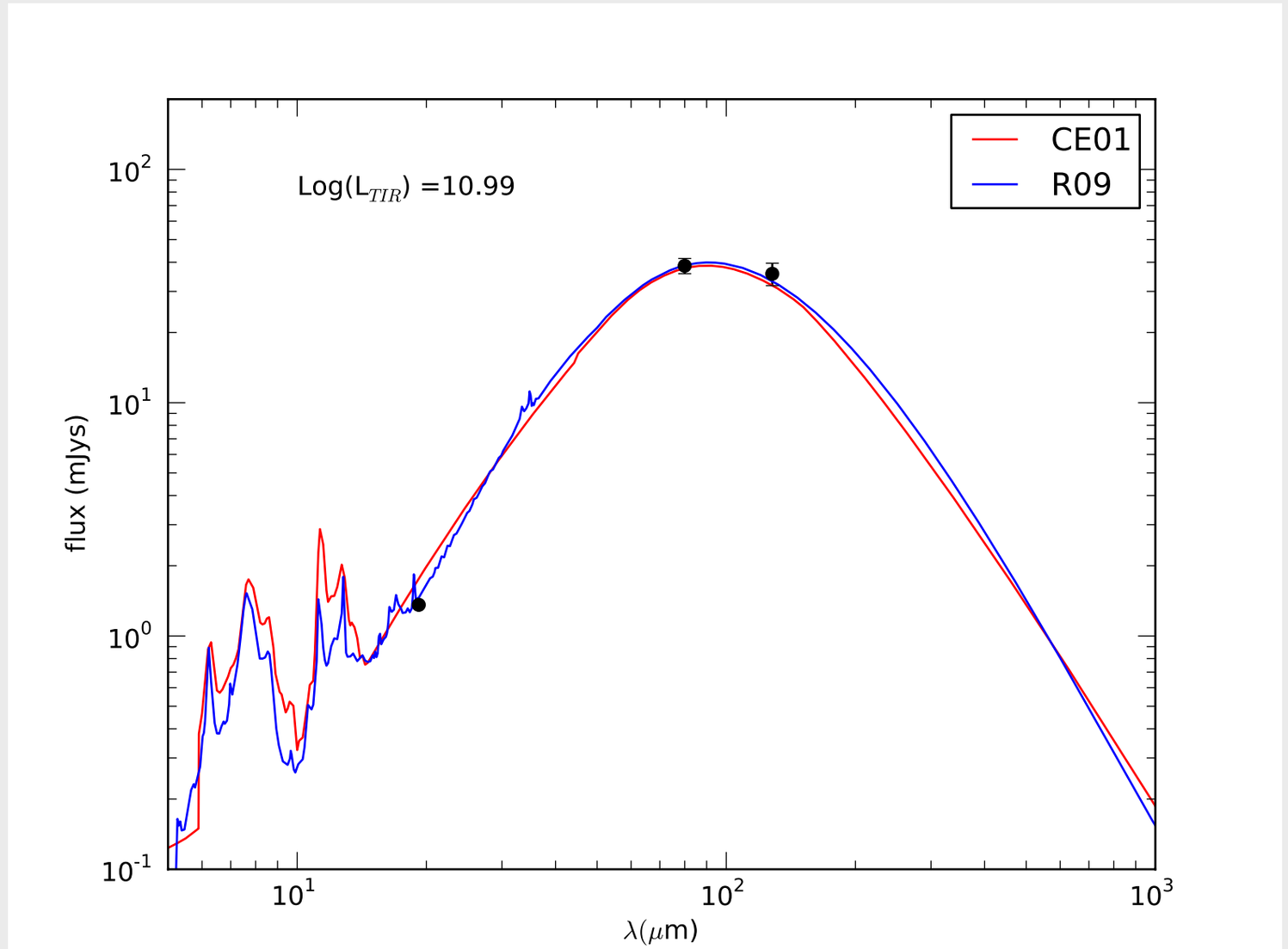

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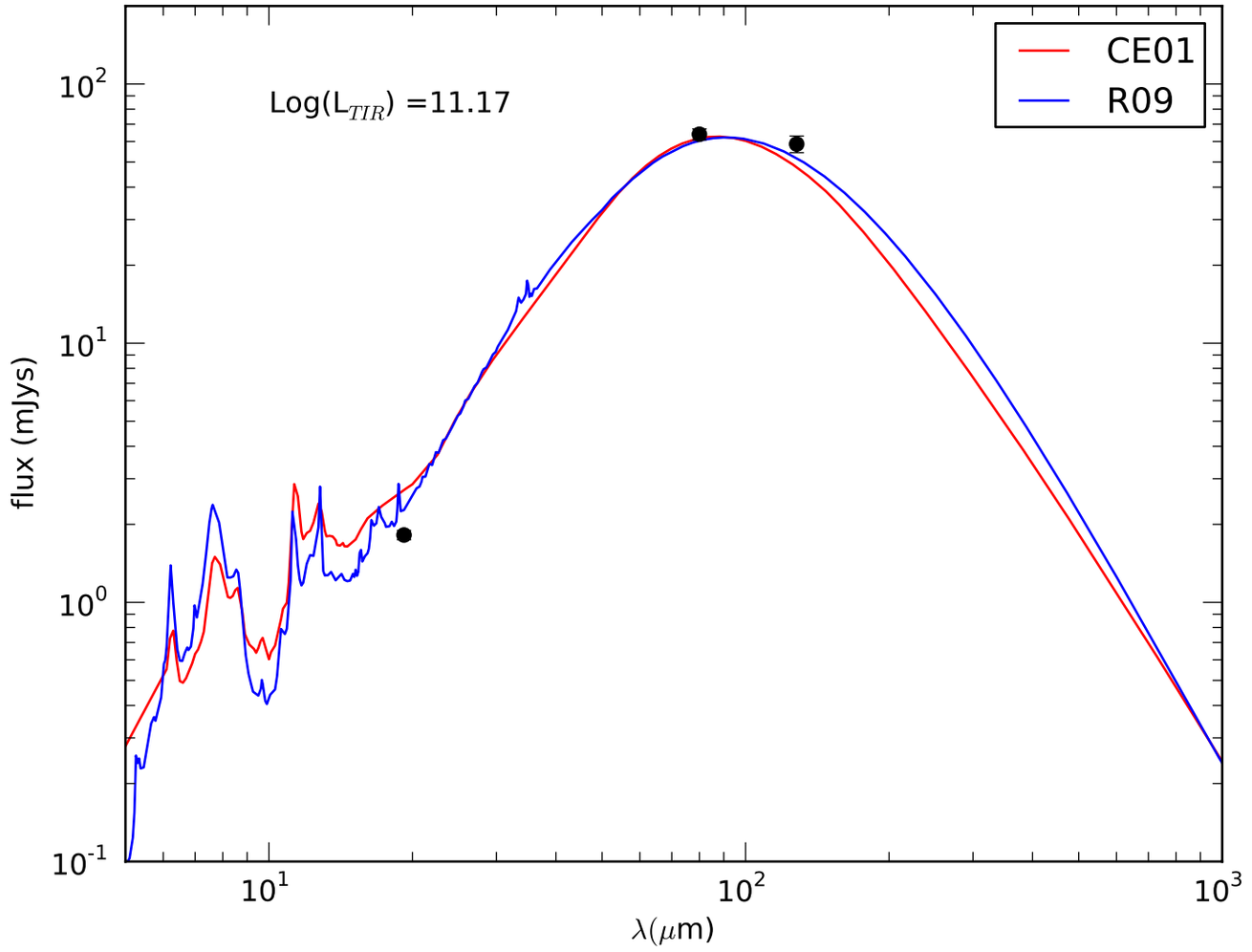

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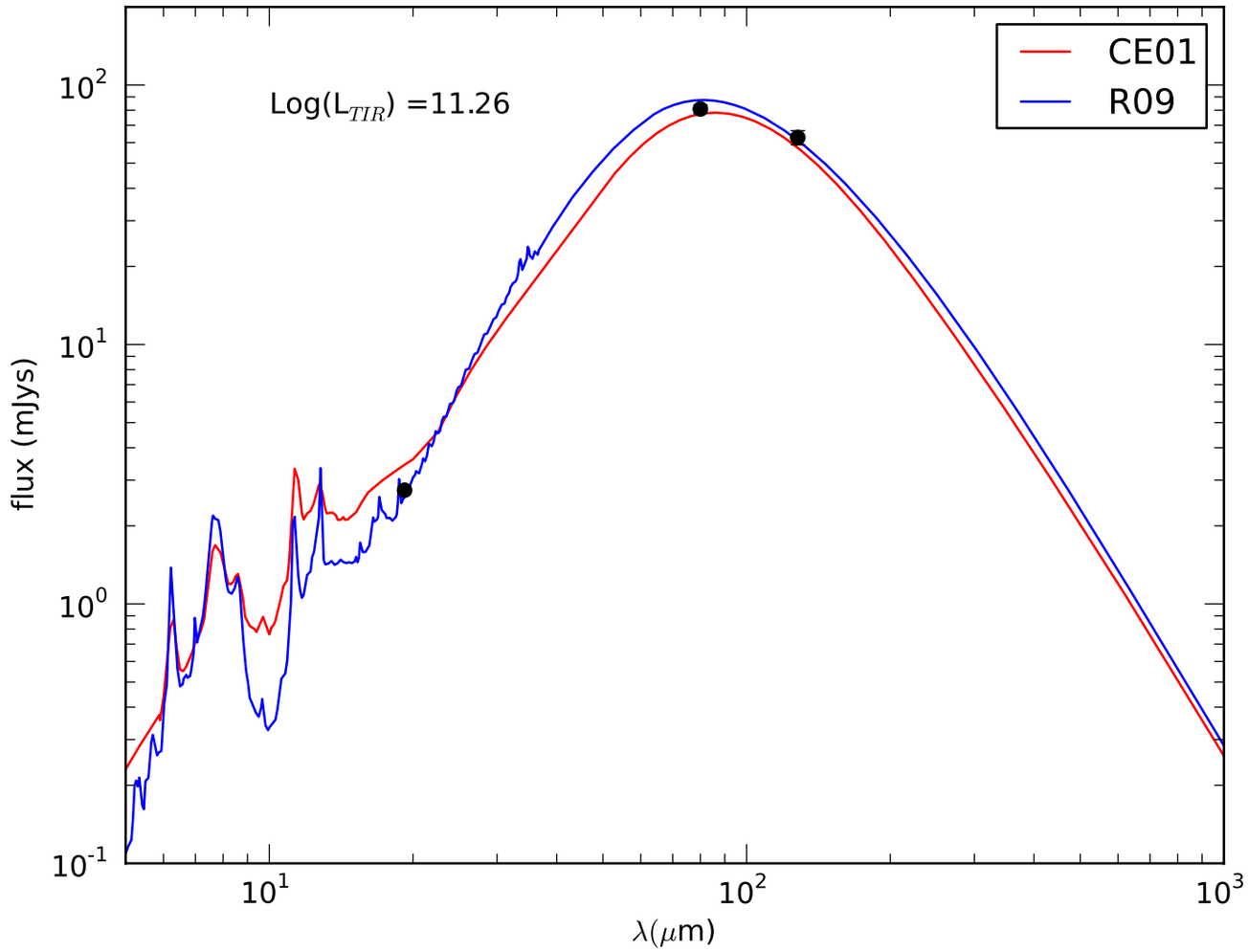

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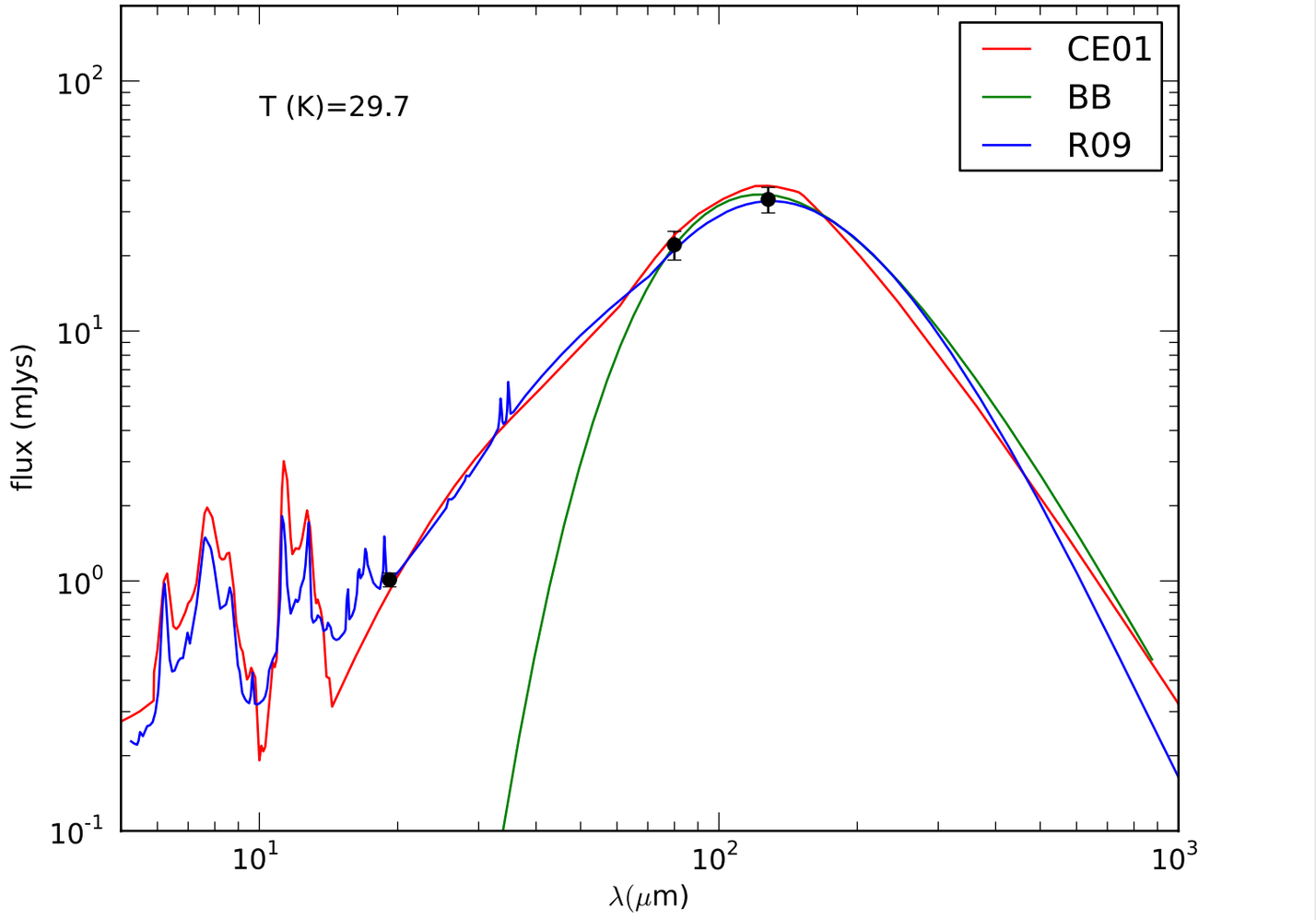

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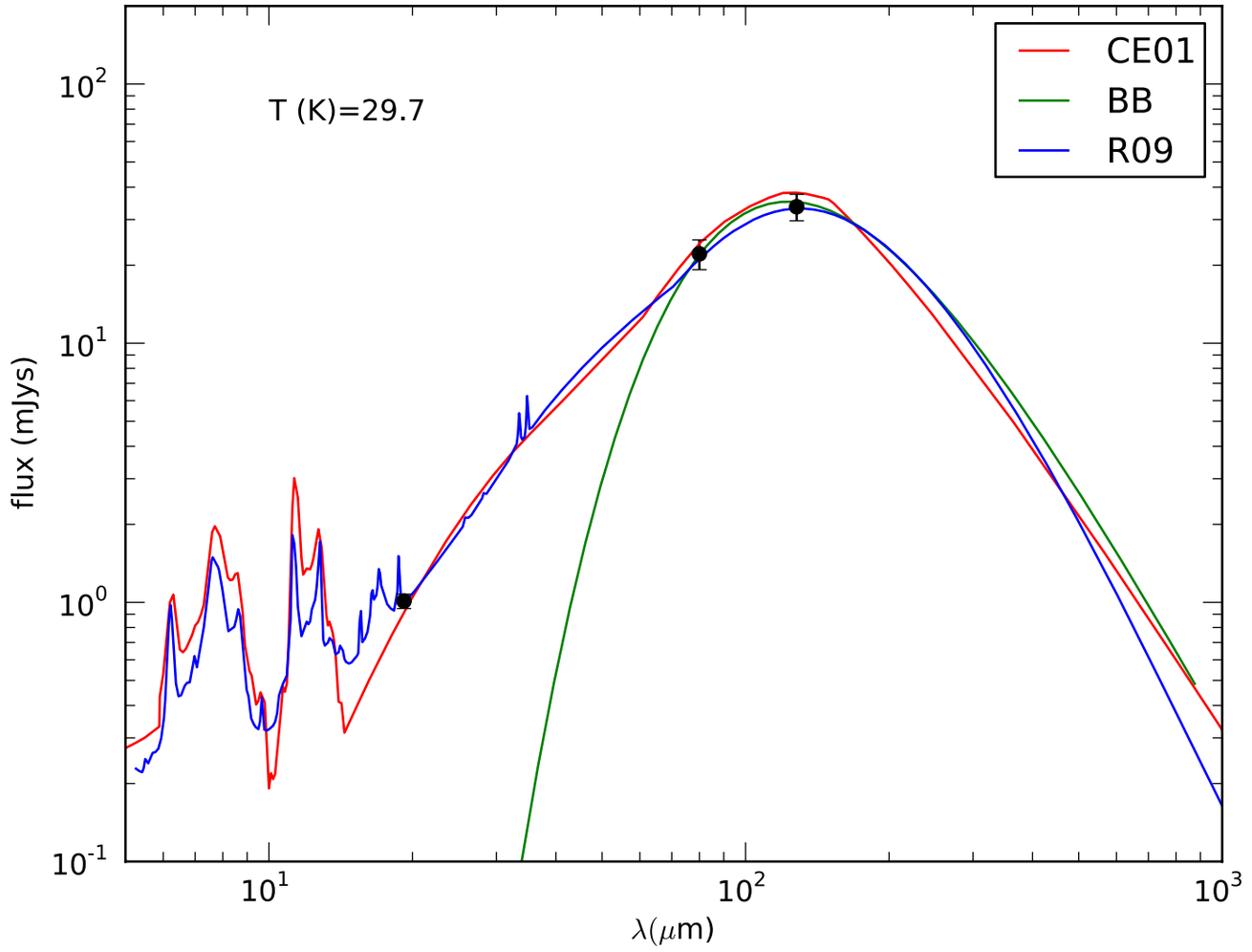

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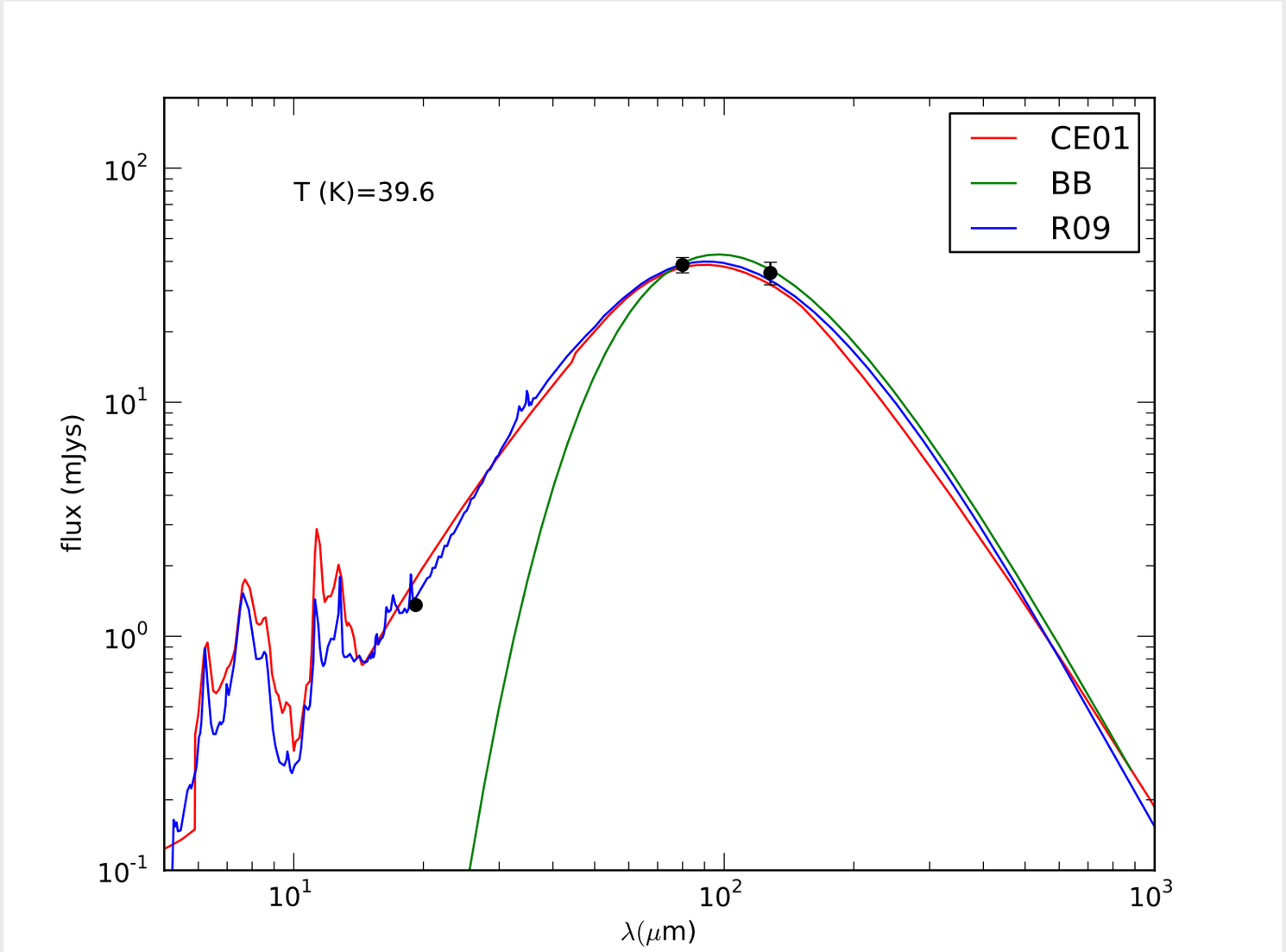

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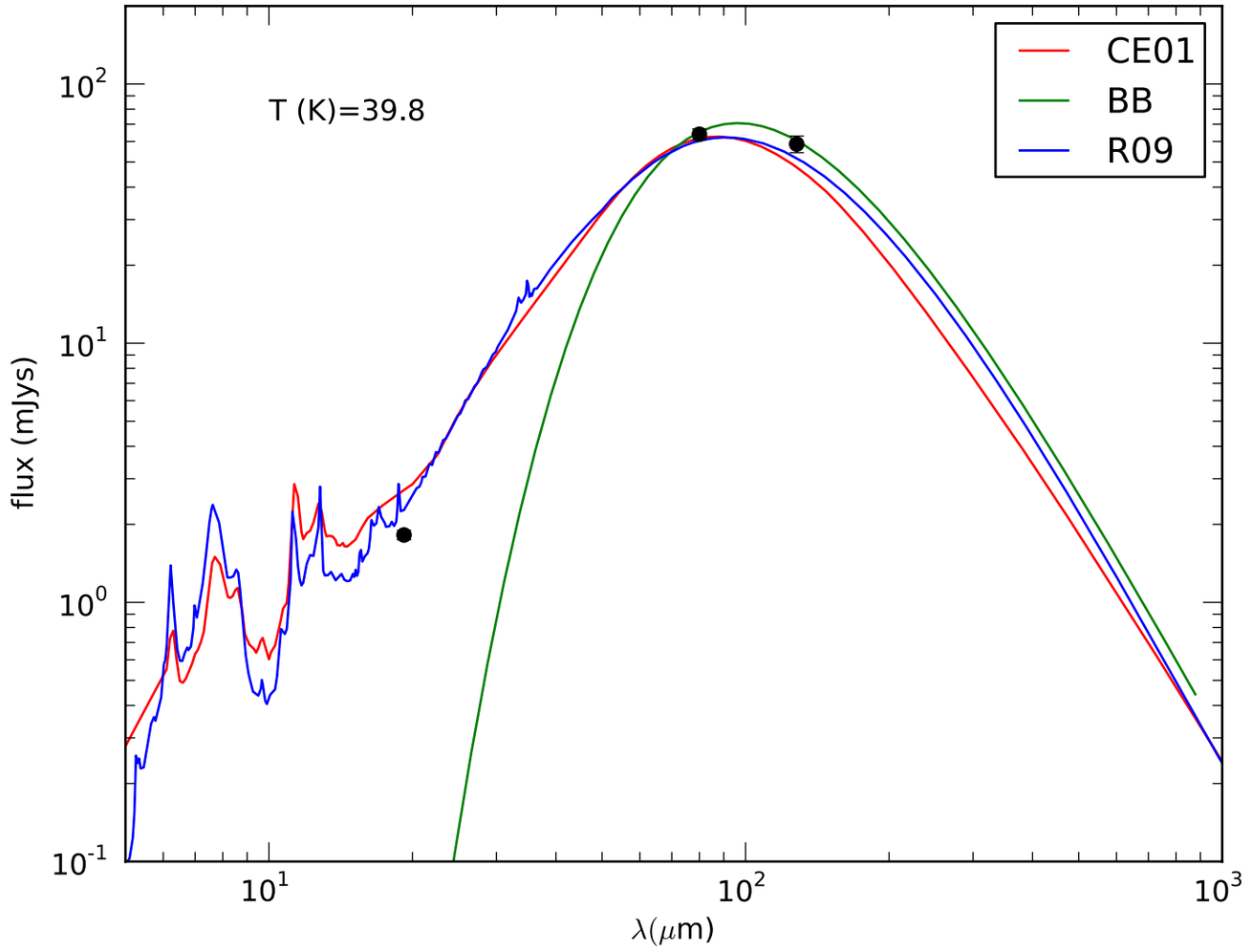

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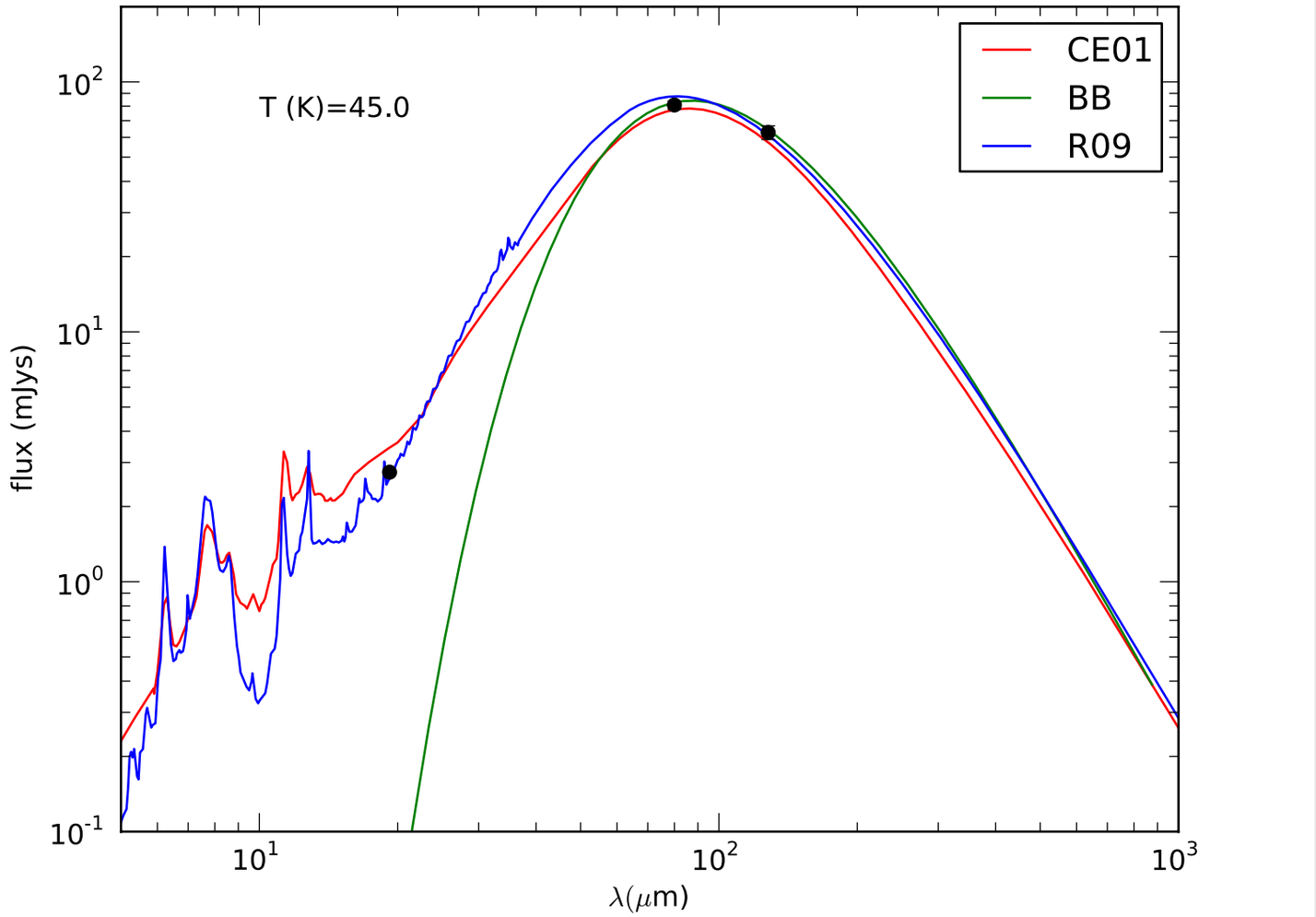
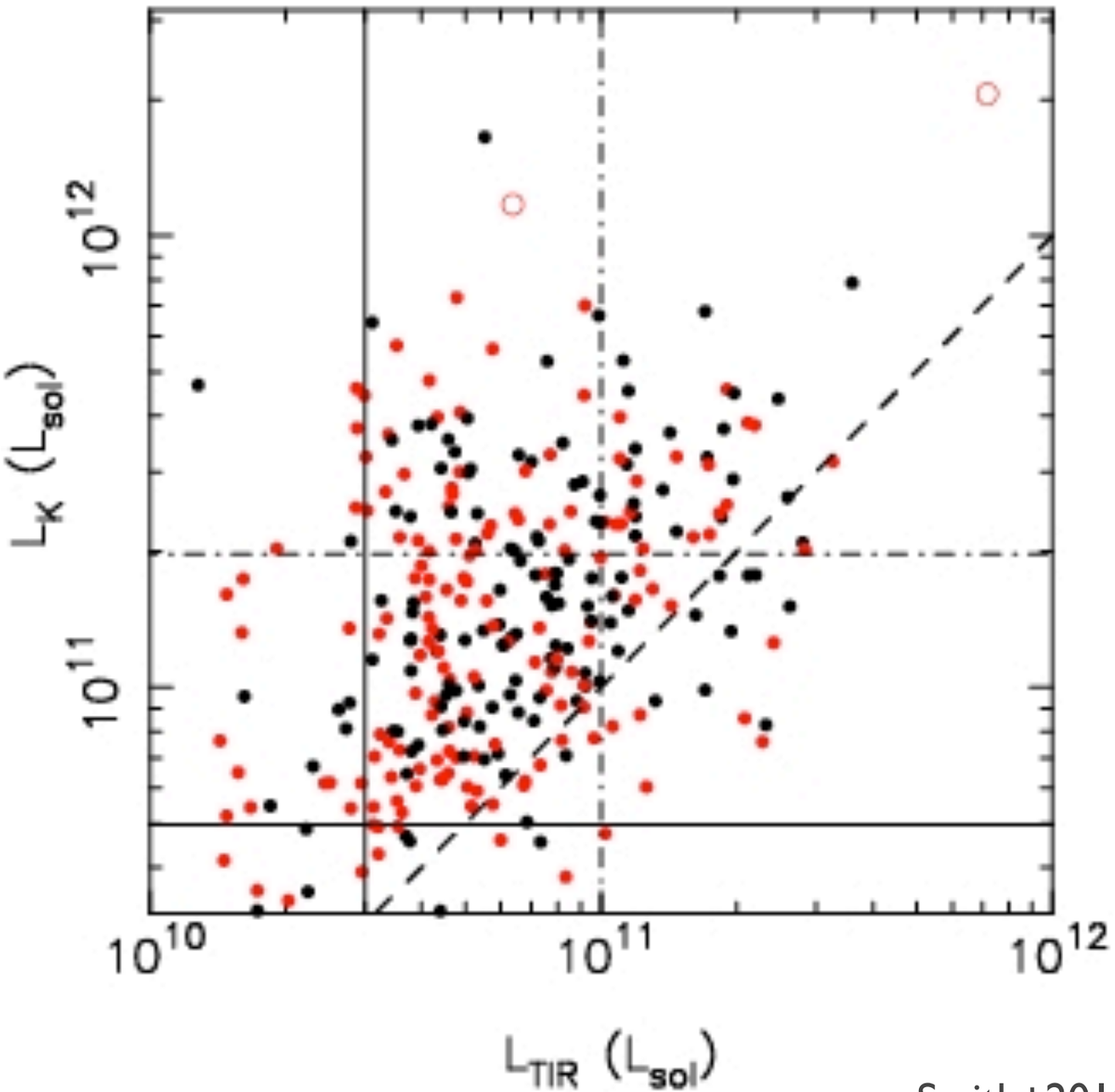


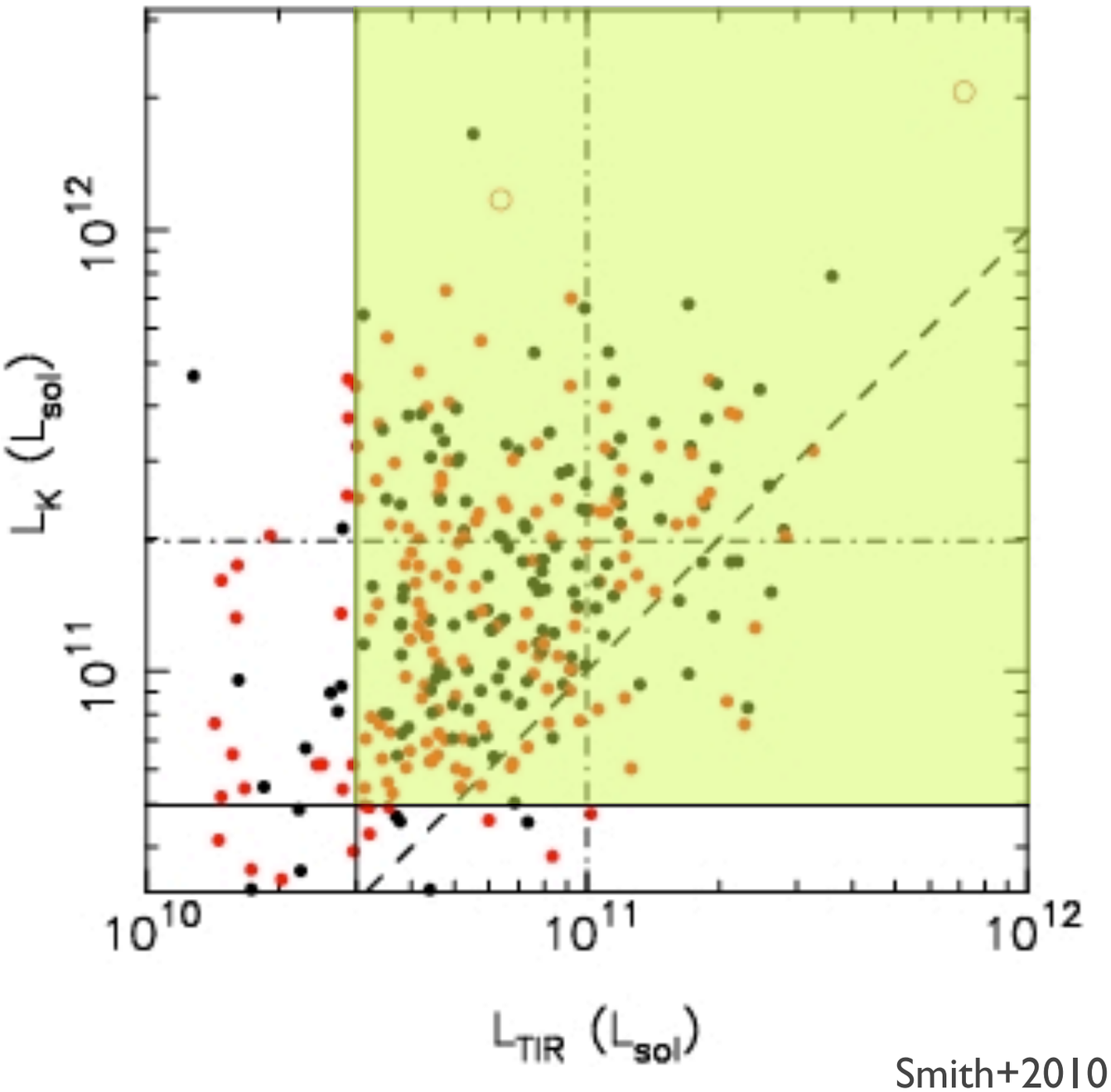
Far IR Luminosities



Smith+2010

220 cluster galaxies with PACS detections

Far IR Luminosities



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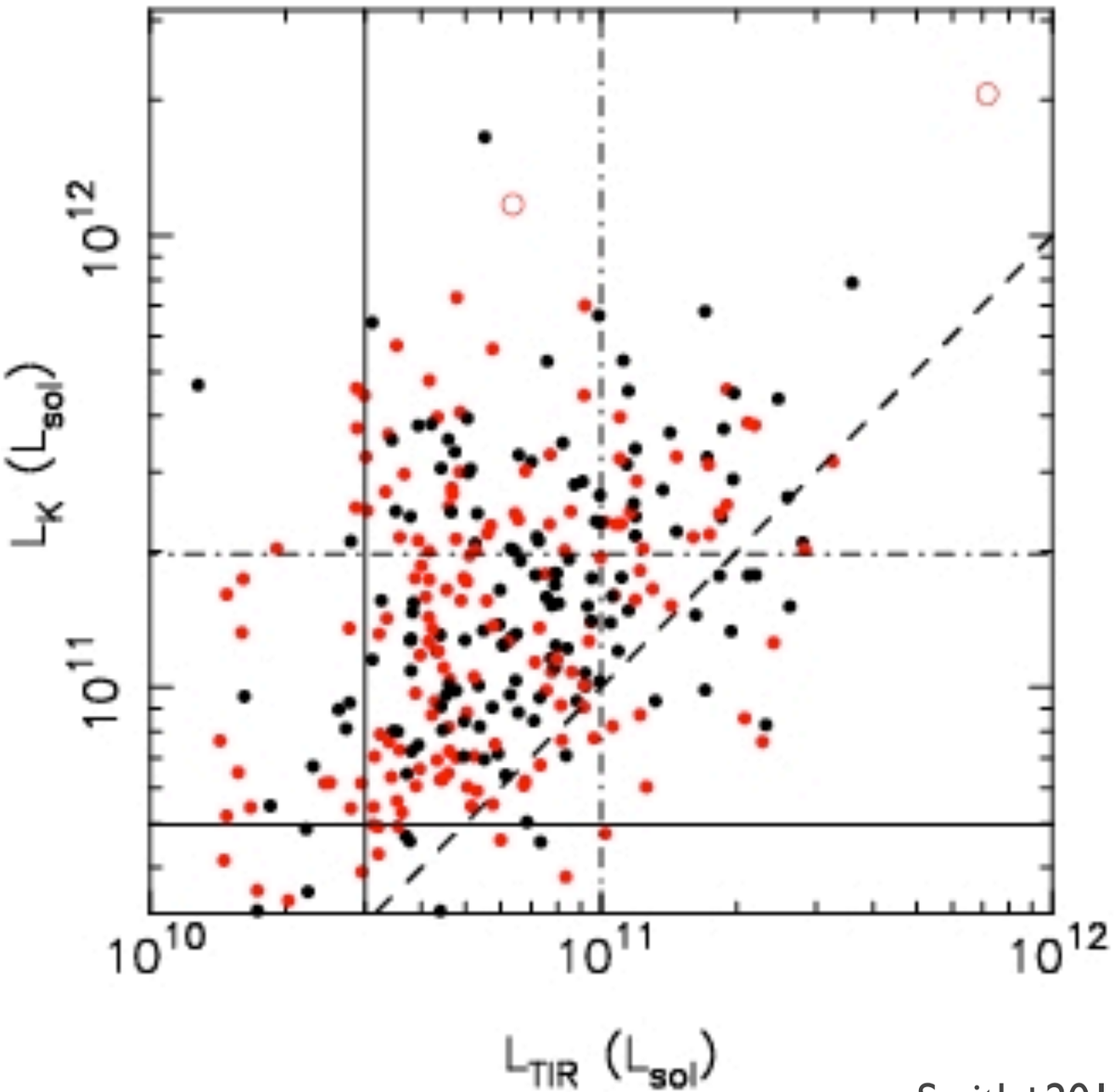

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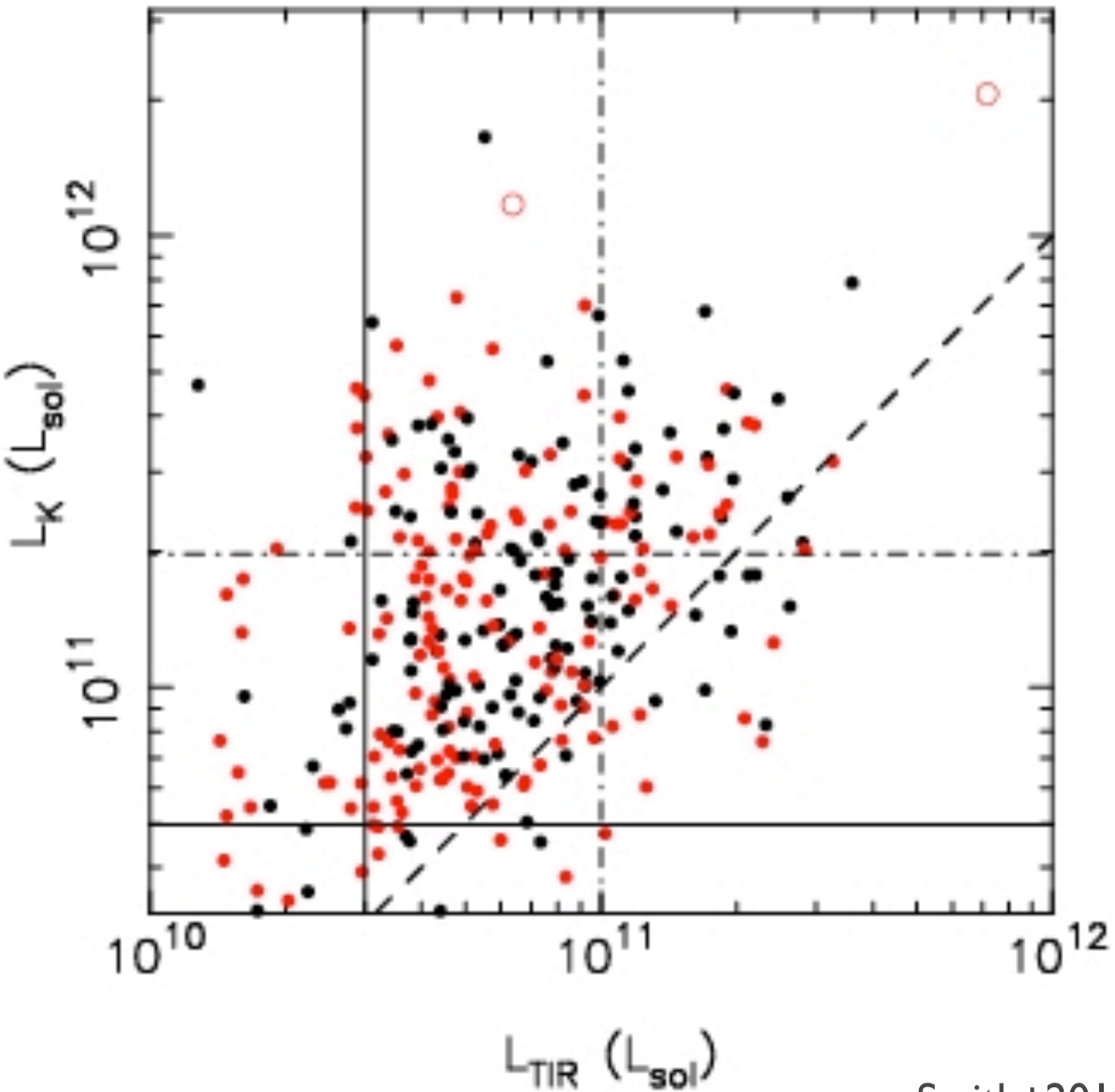

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Typical galaxy:
$L_k \sim L_k^*$, $L_{TIR} \sim 5 \times 10^{10}$

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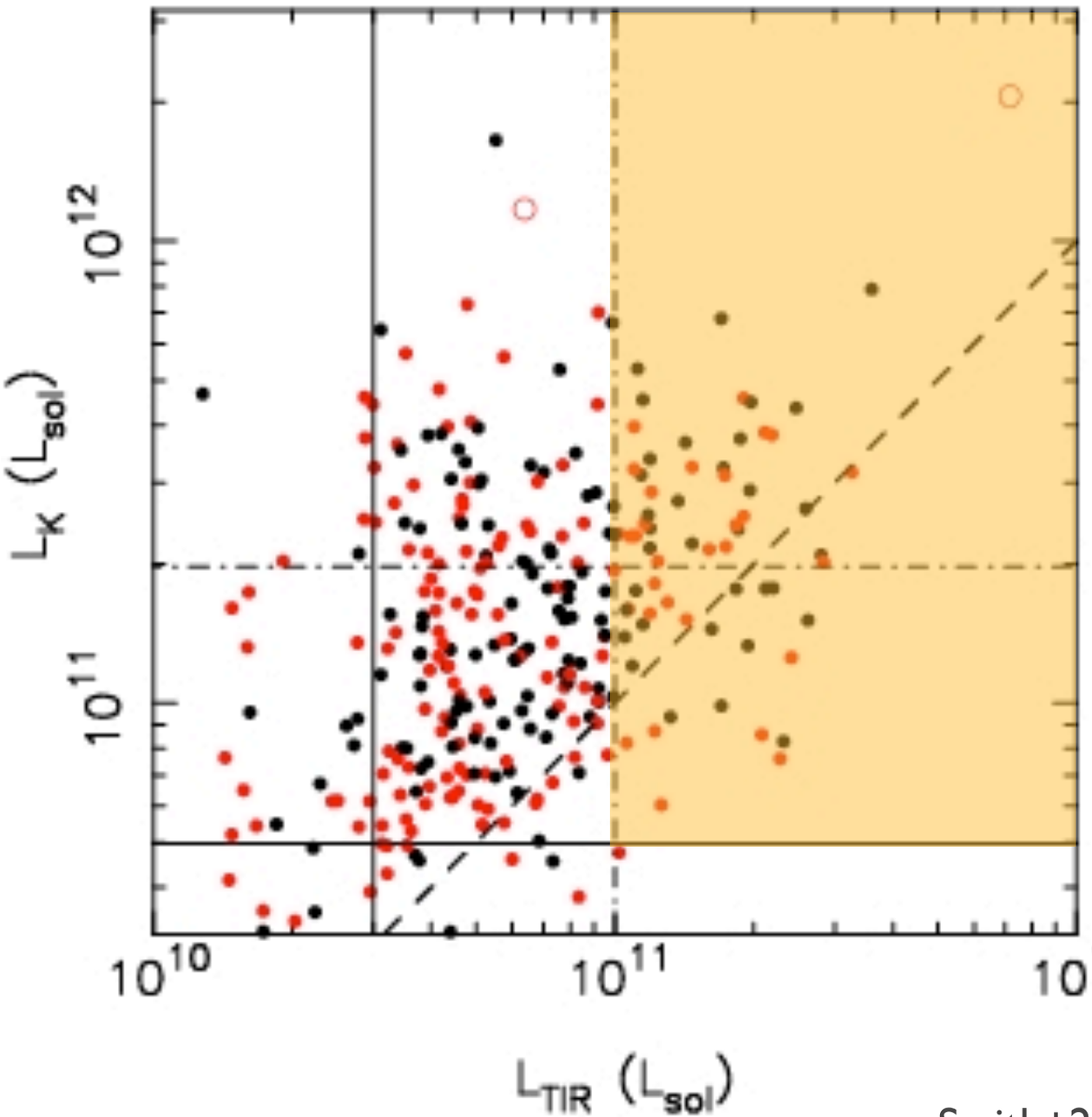

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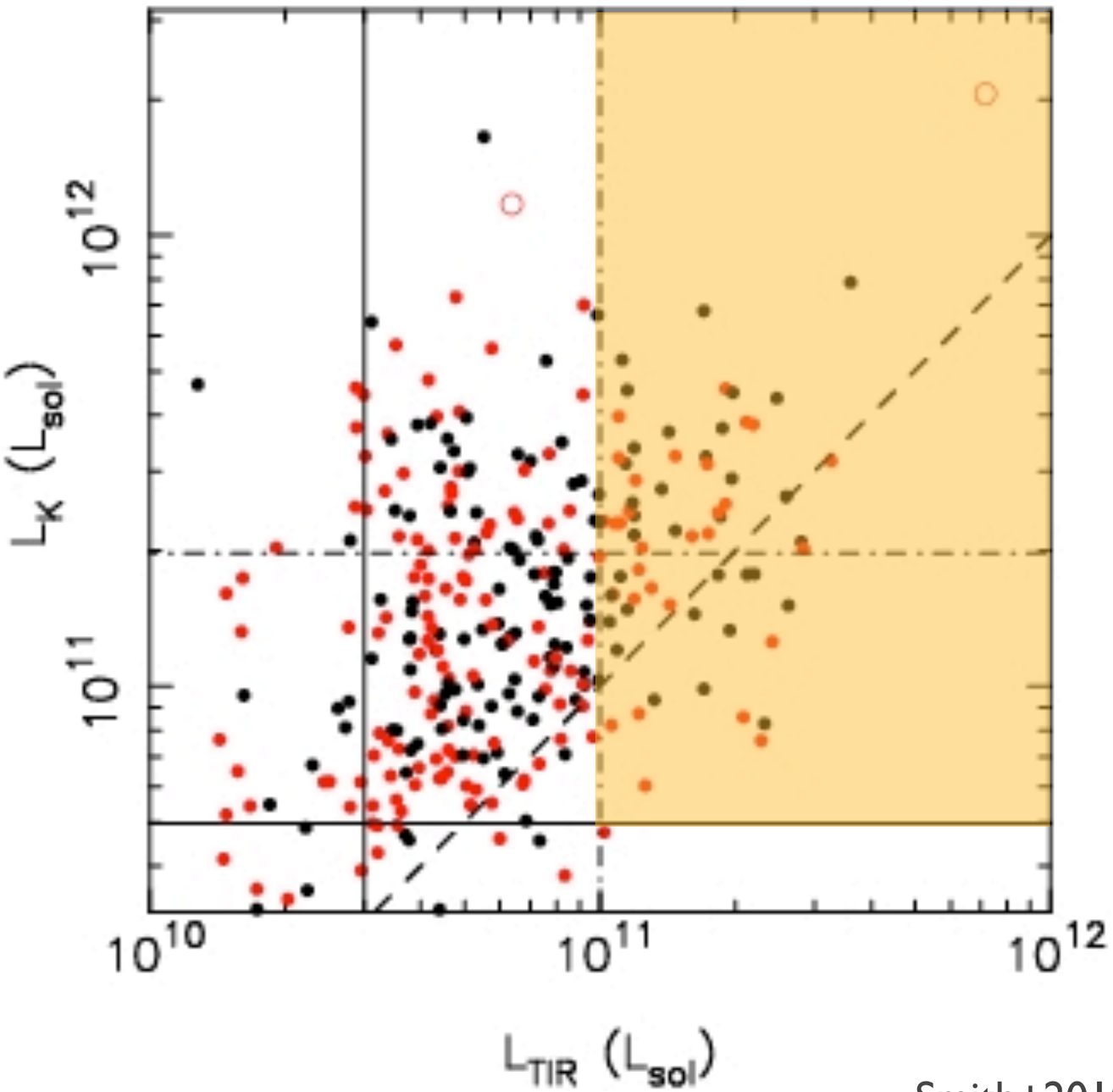

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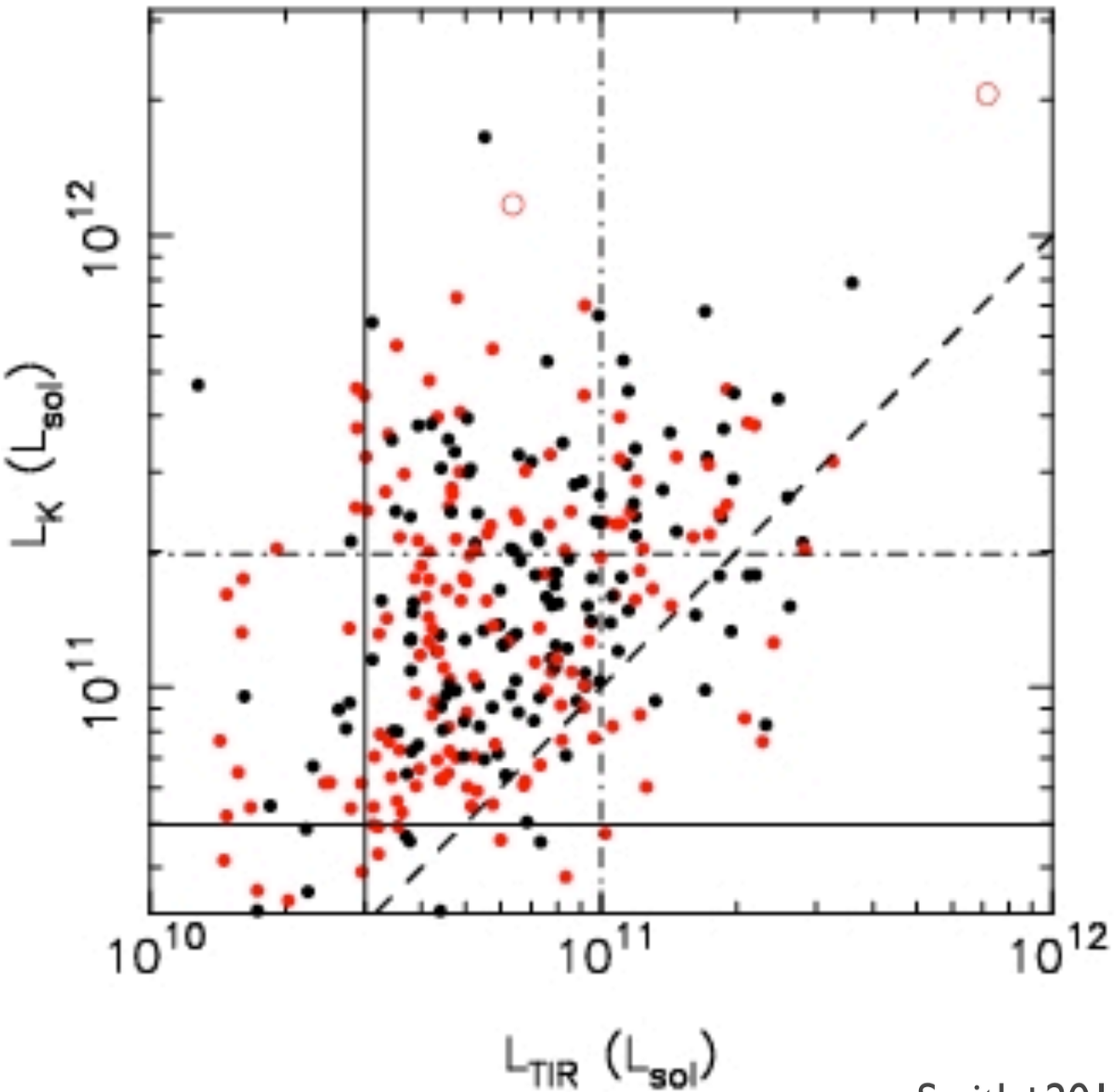

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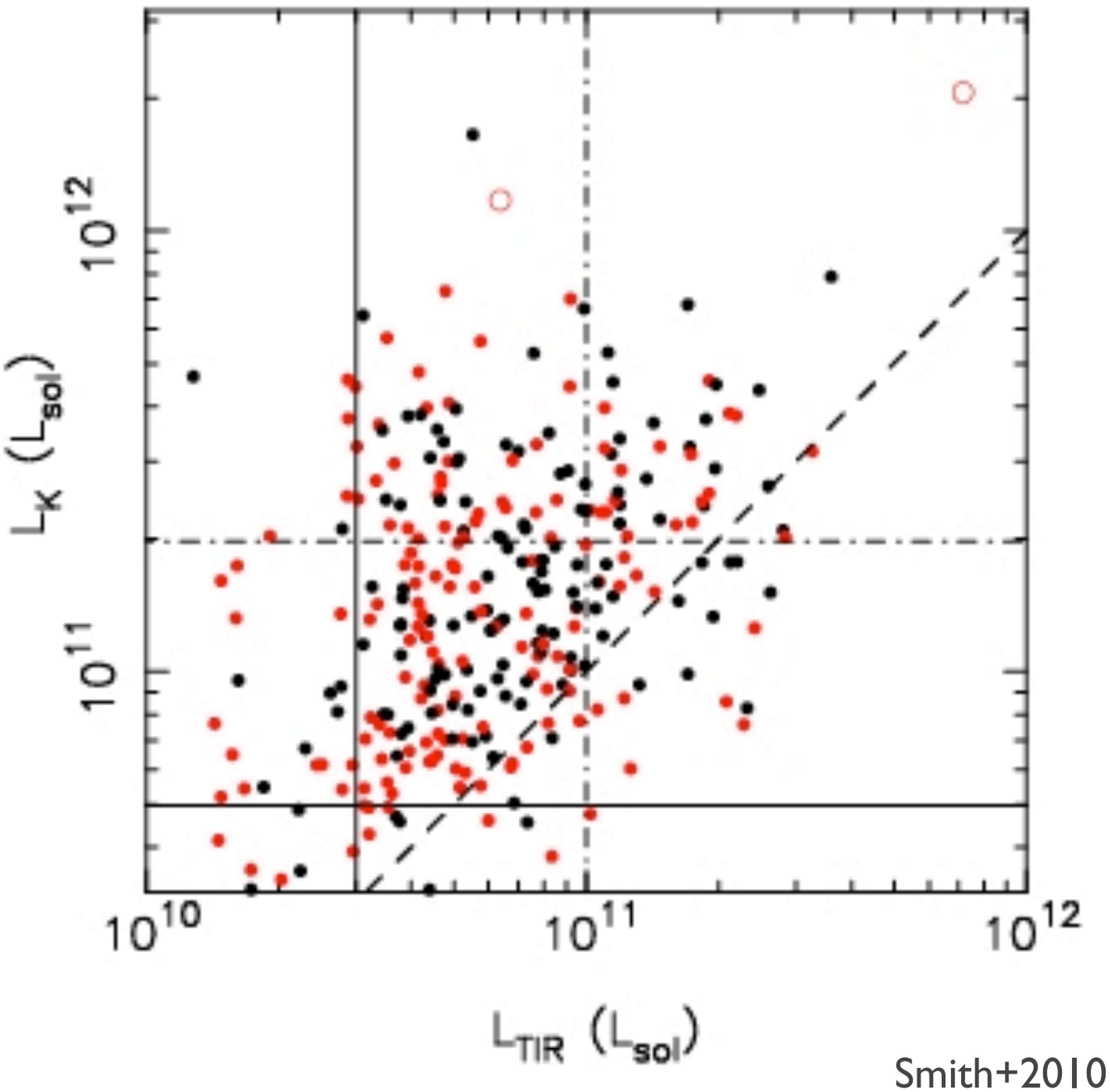

Smith+2010

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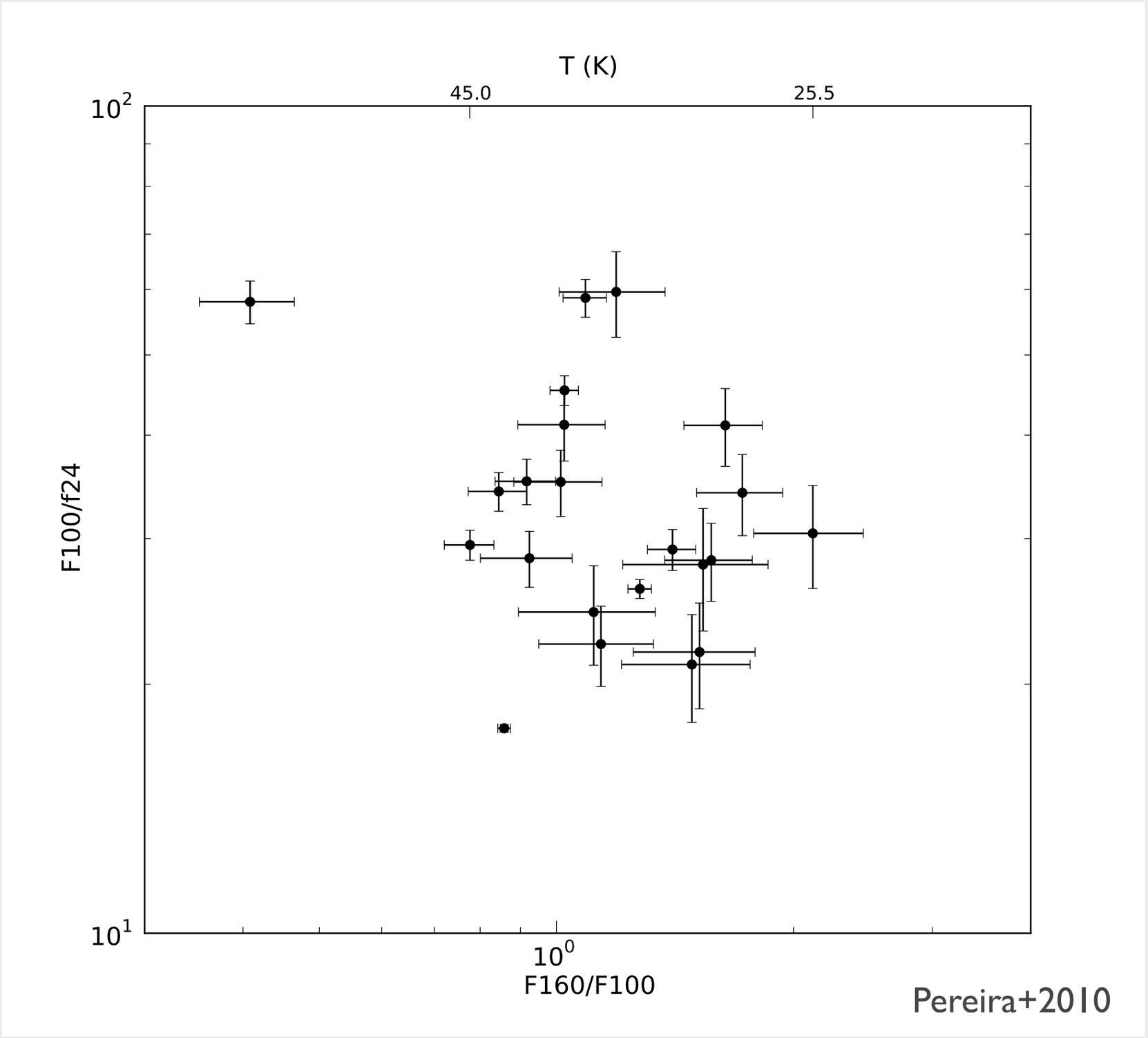
no ULIRGs

Far IR Colors of Cluster Galaxies:



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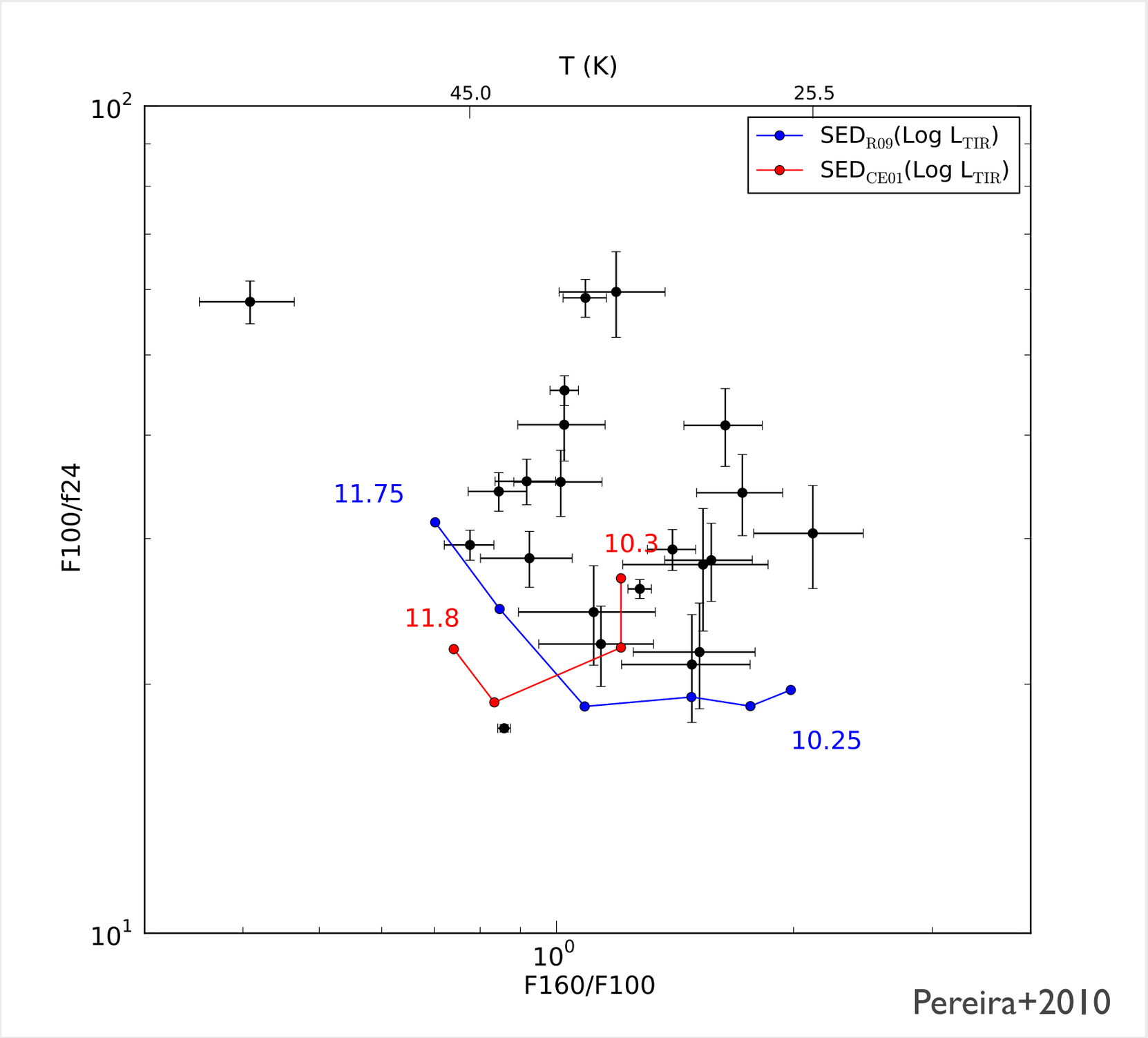

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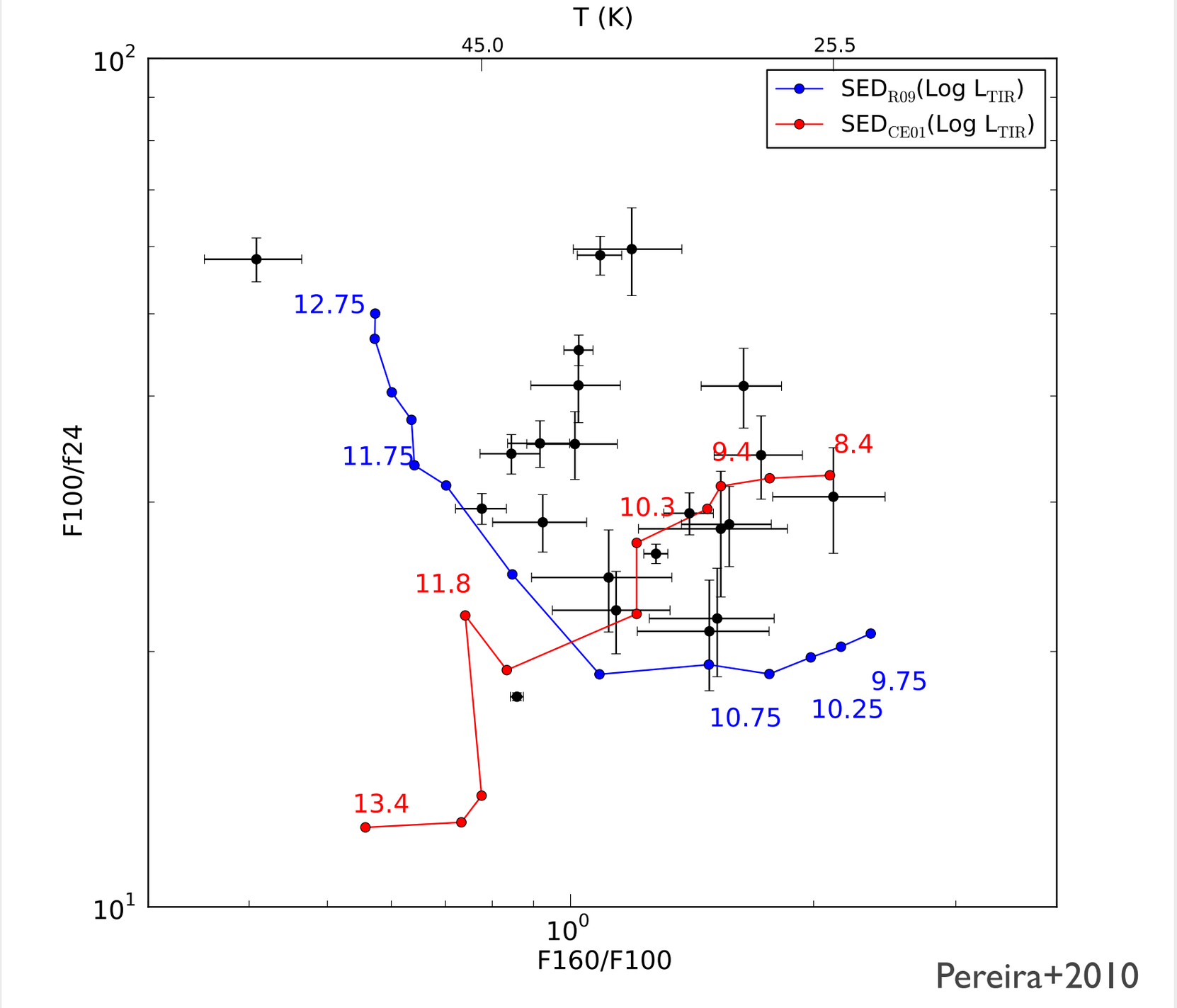

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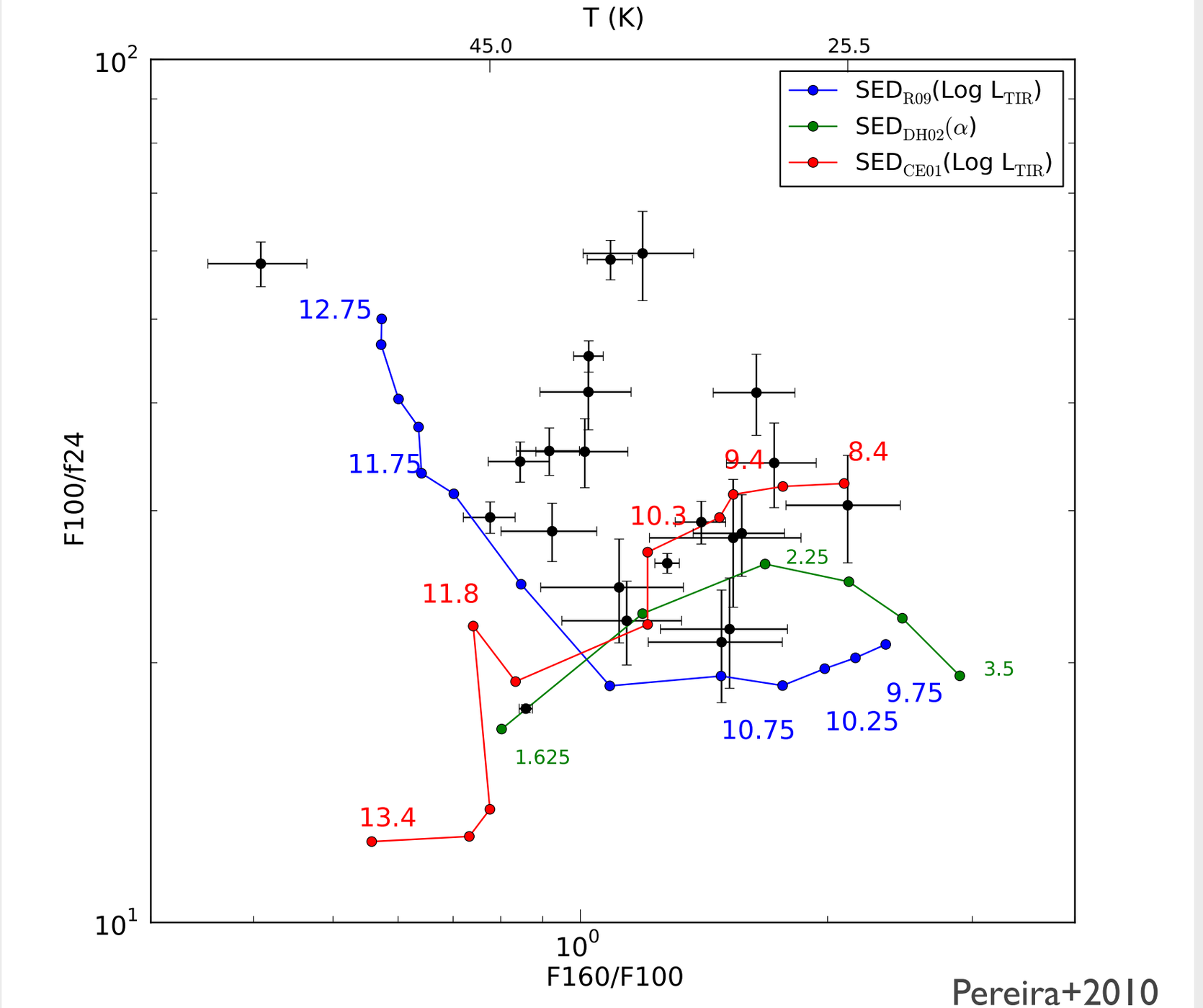
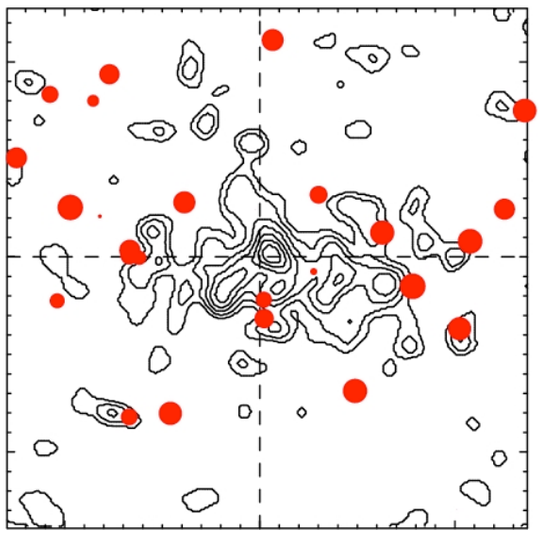
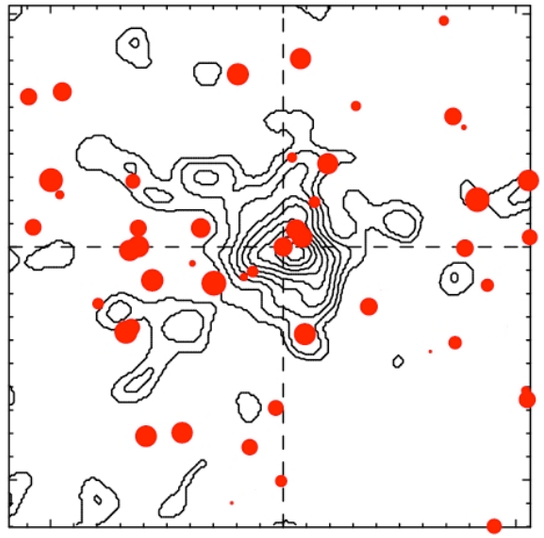


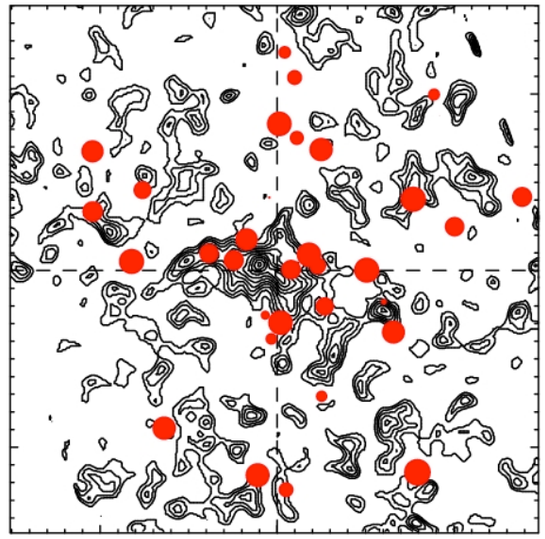
Pereira+2010



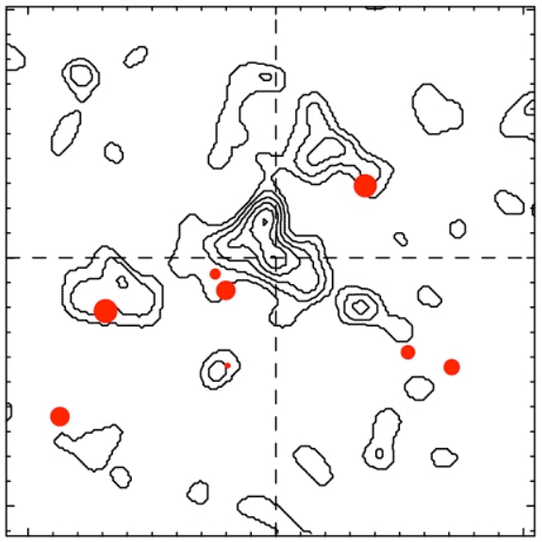
Abell 1763



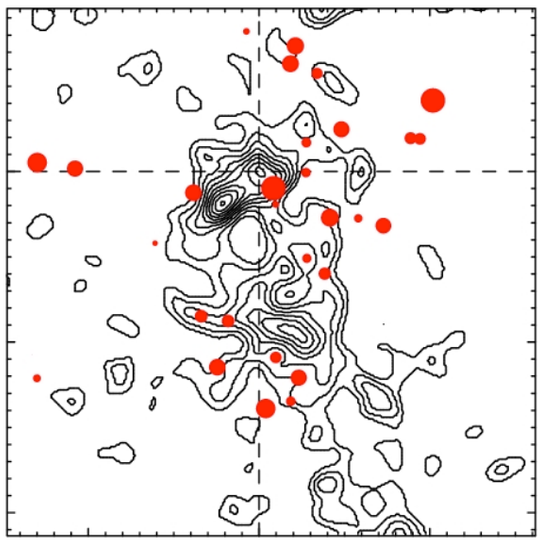
Abell 1835



Abell 1914



Z7160



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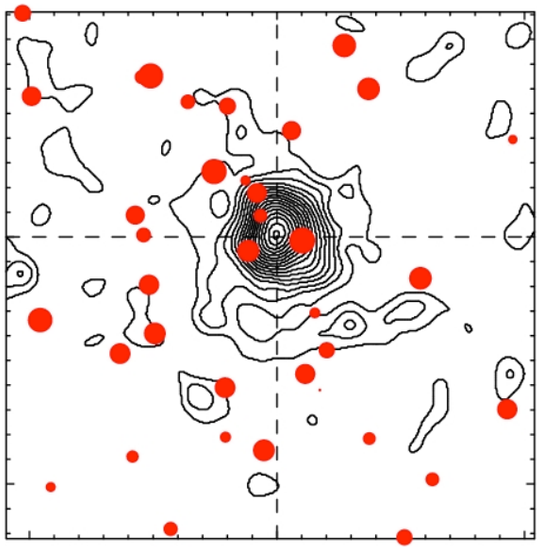

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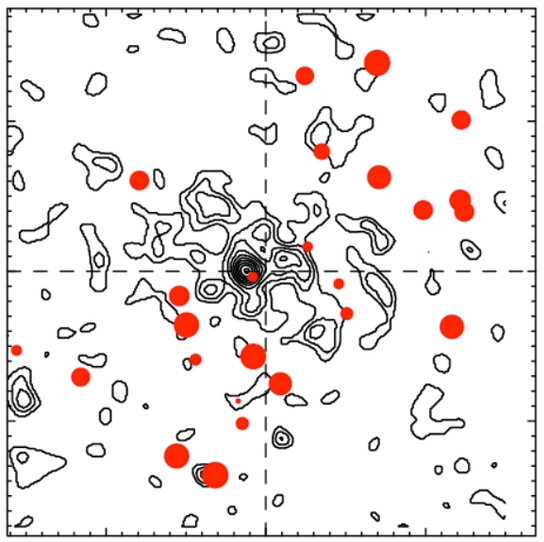
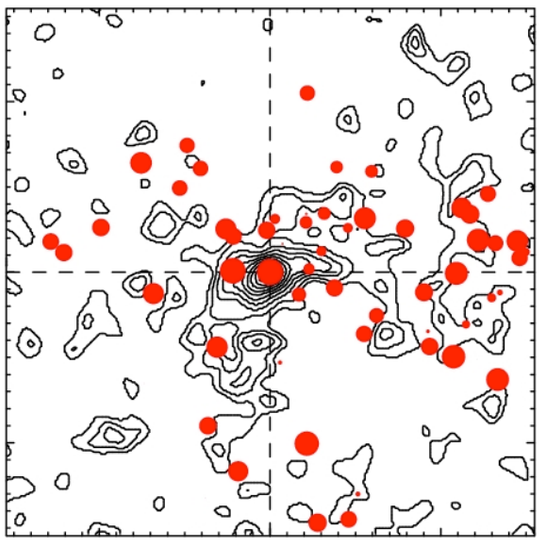
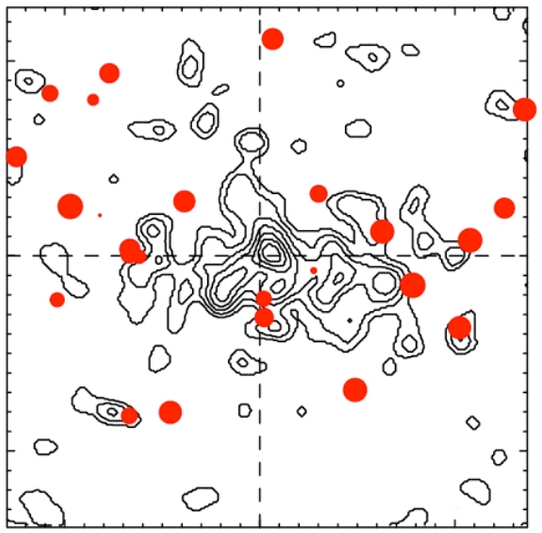


Abell 2219



Abell 2390

Smith+2010



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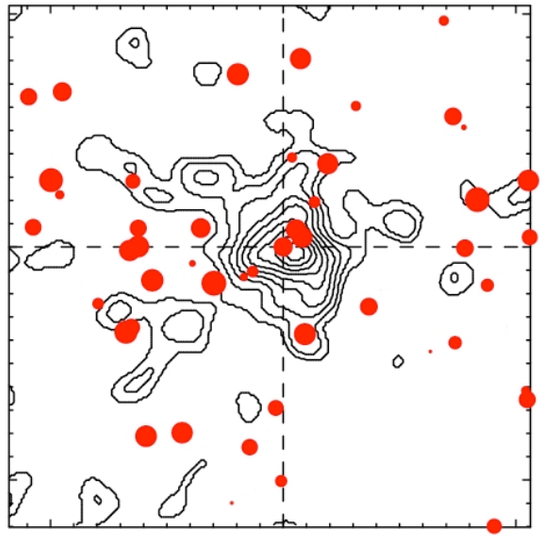
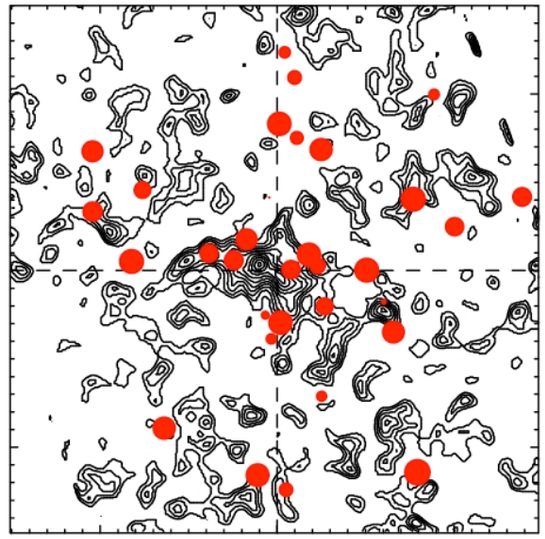
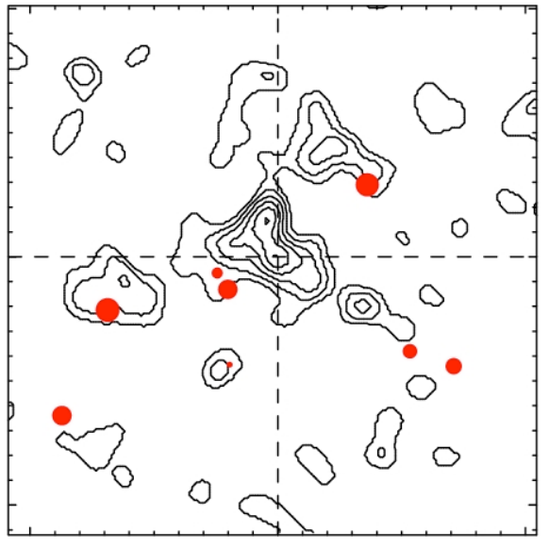


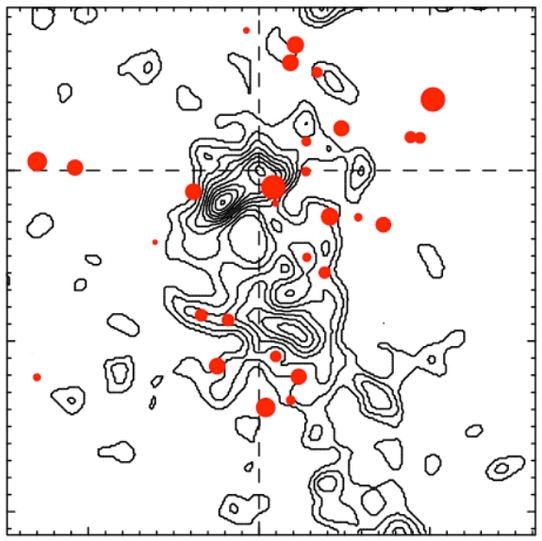
Abell 1835



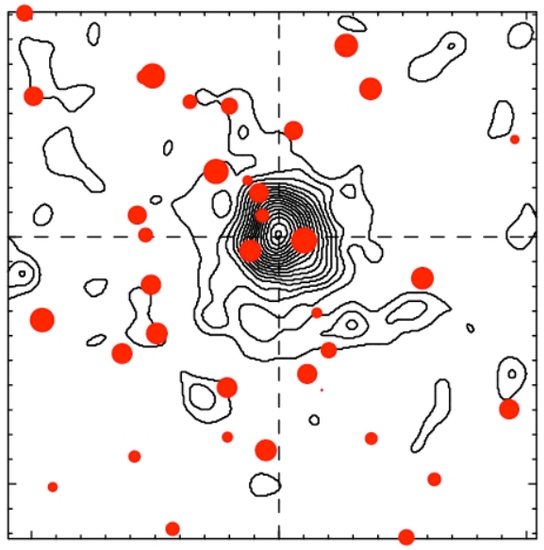
Abell 1914



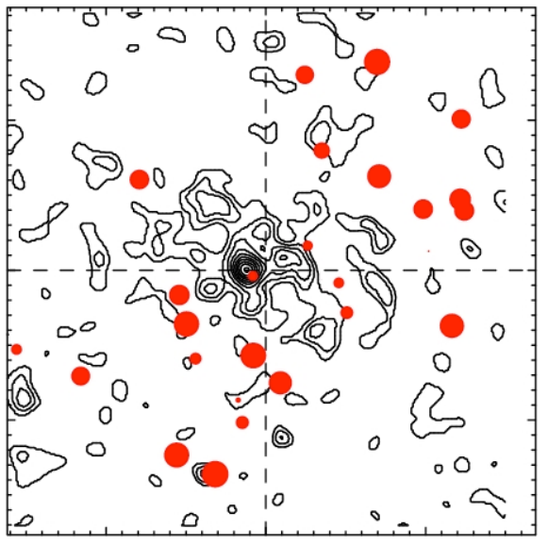
Z7160



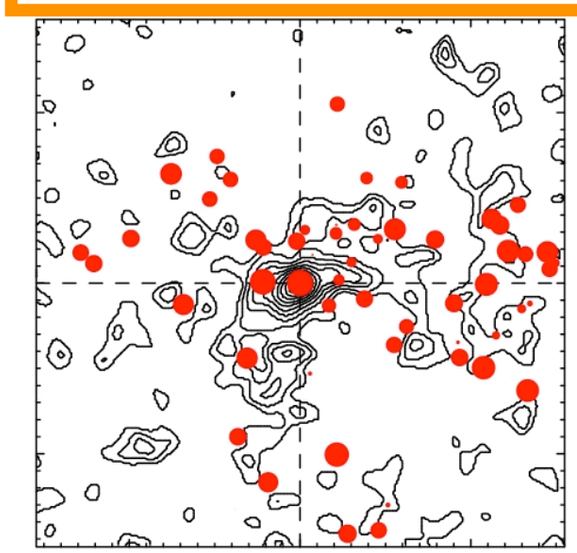
Abell 1758



Abell 1689

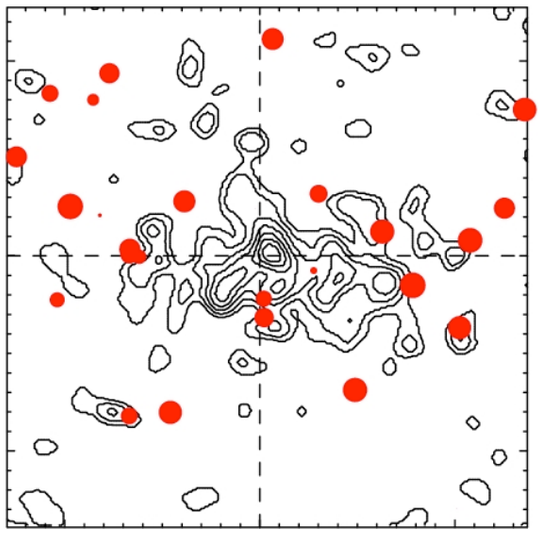


Abell 2219

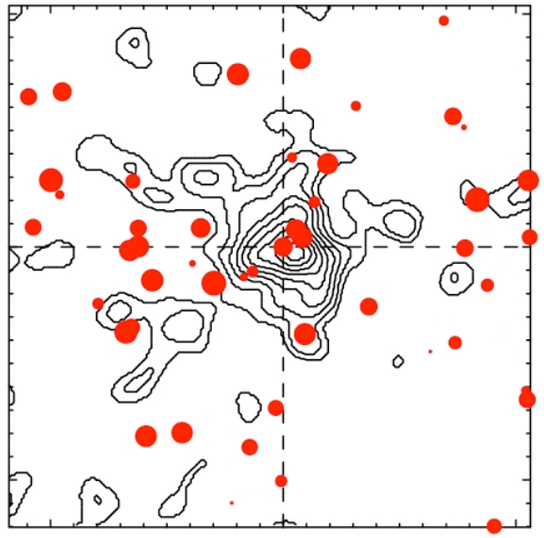


Abell 2390

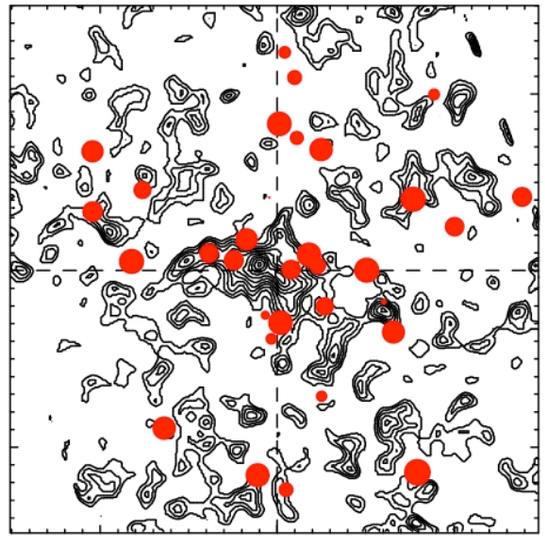
Smith+2010



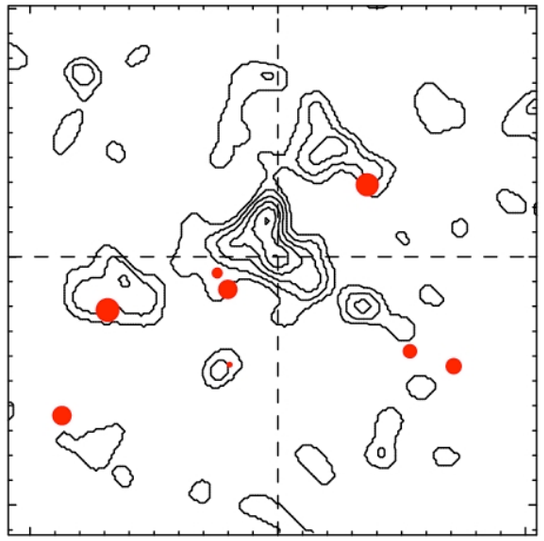
Abell 1763



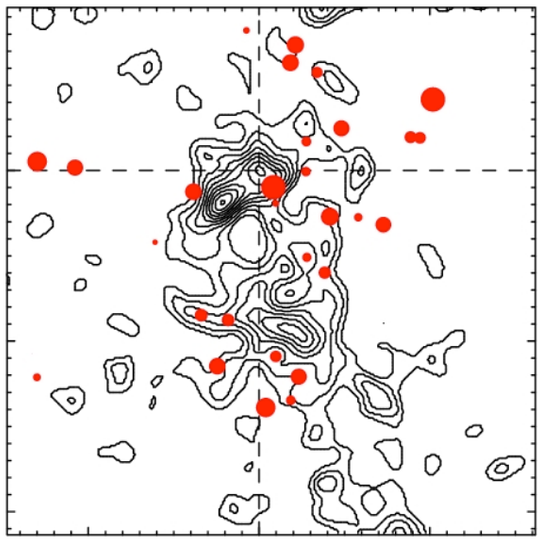
Abell 1835



Abell 1914



Z7160



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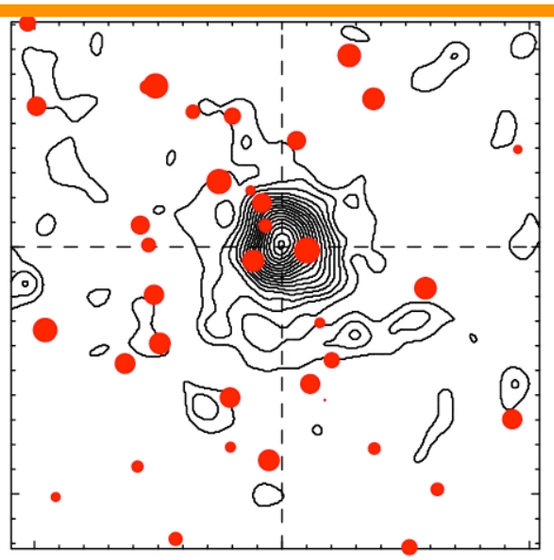

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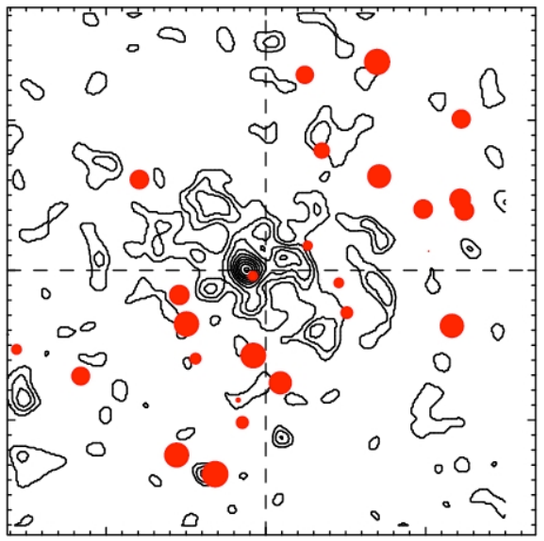
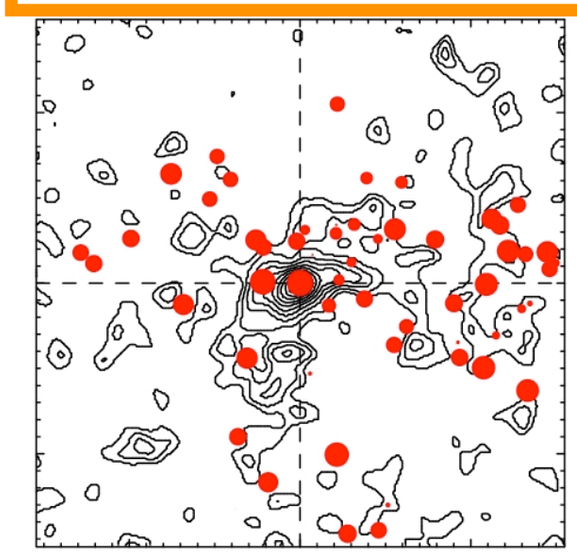
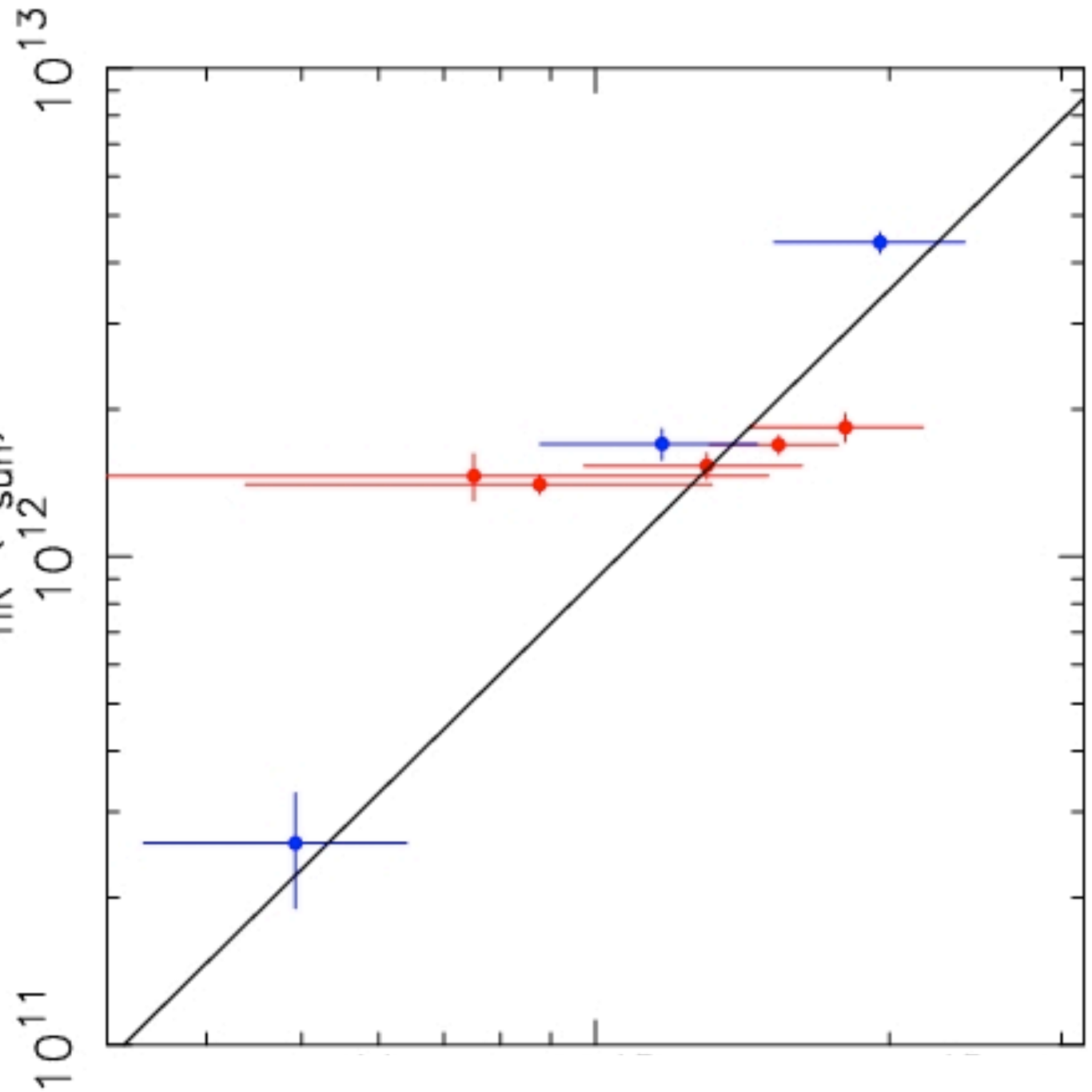


Abell 2219

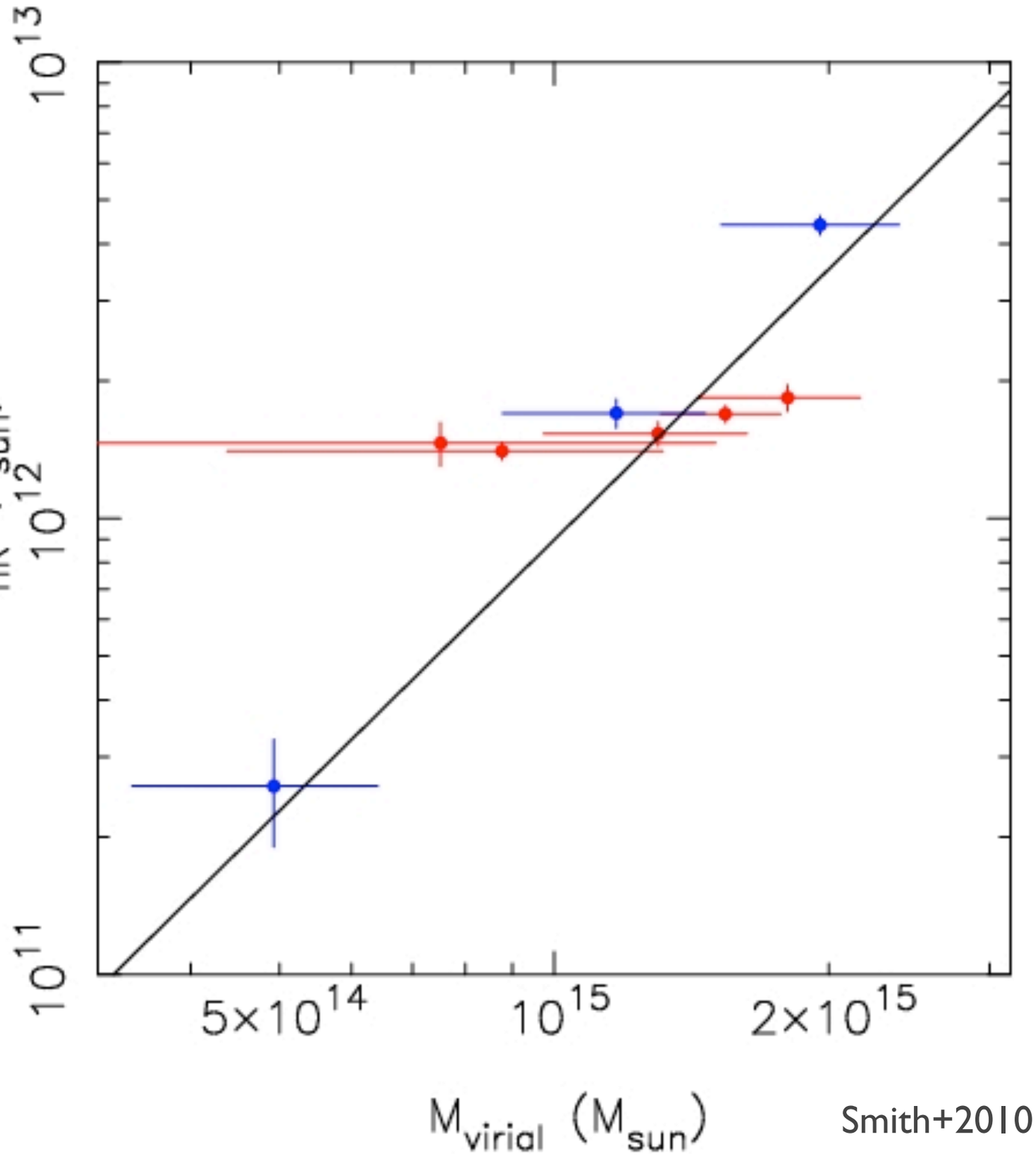


Abell 2390

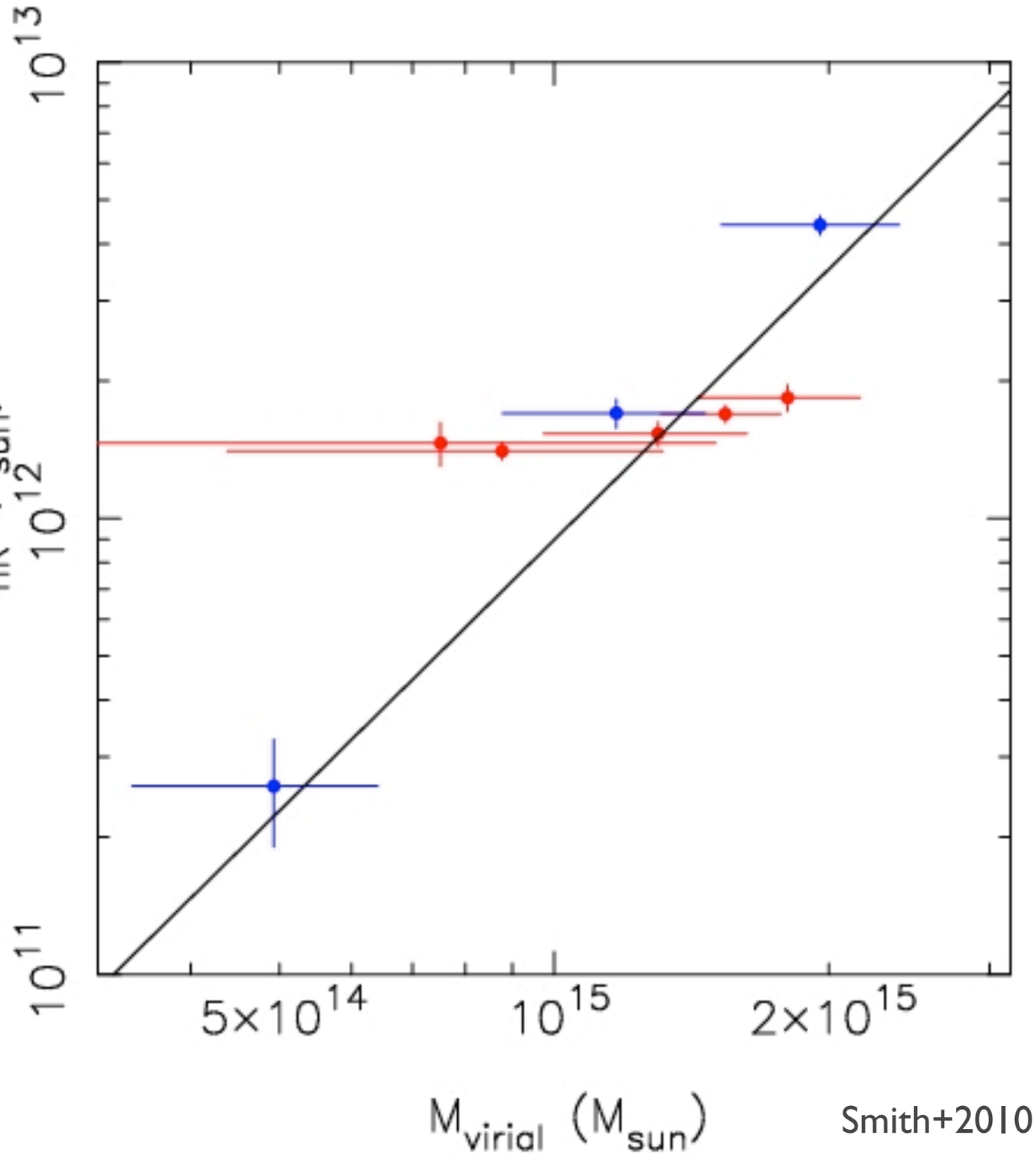
Smith+2010



Smith+2010

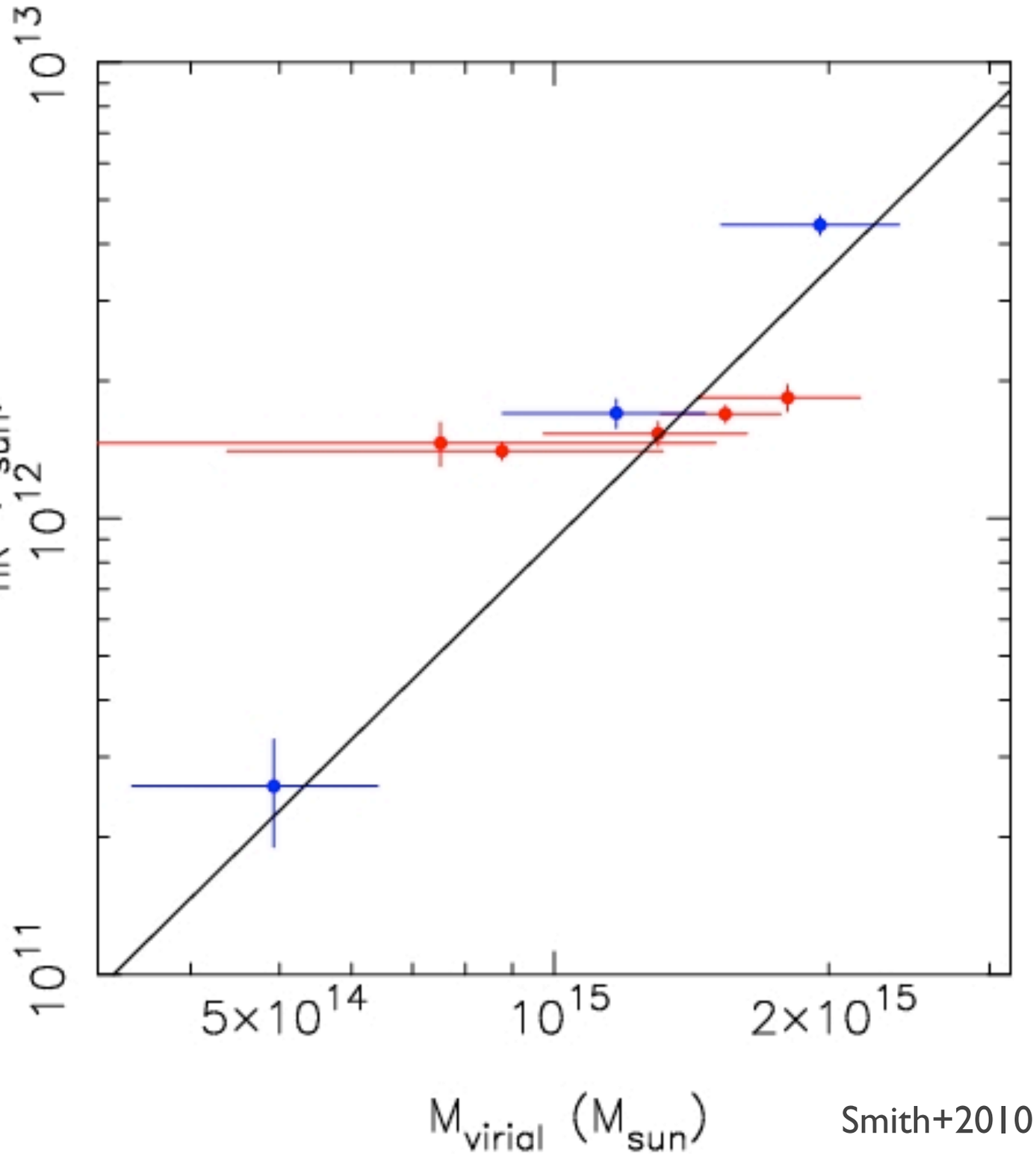

10^{13}
L_{TIR} (L_{sun})
10^{12}
10^{11}
5×10^{14}
10^{15}
2×10^{15}
M_{virial} (M_{sun})

Smith+2010



Smith+2010

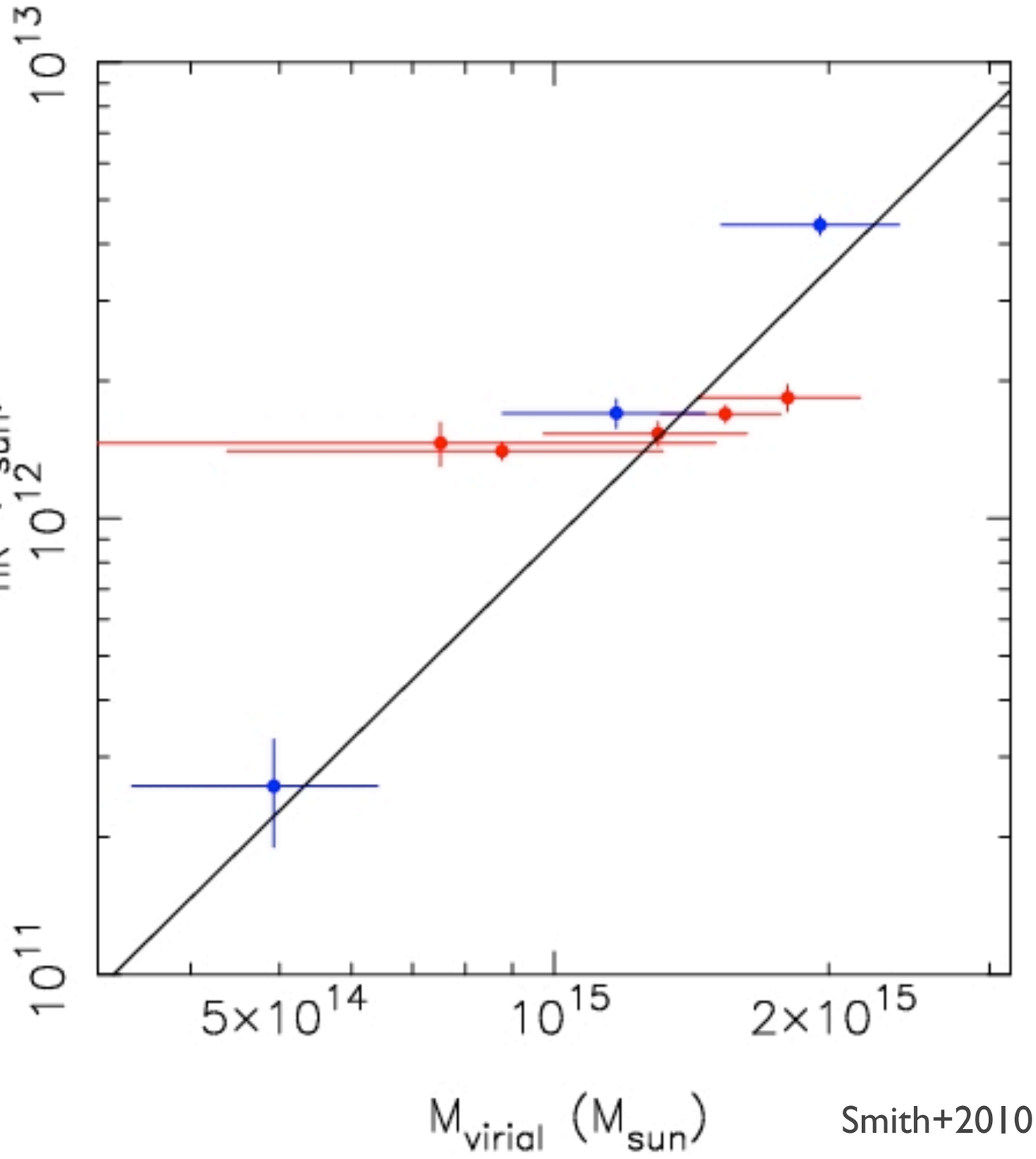
$L_{TIR}(< r_{vir}) = 10^{-17.8\pm2.8} M_{vir}^{2.0\pm0.2}$



Smith+2010

$L_{TIR}(< r_{vir}) = 10^{-17.8\pm2.8} M_{vir}^{2.0\pm0.2}$

$\dot{M} \propto M^{1.1}$ (McBride +2009)



Smith+2010

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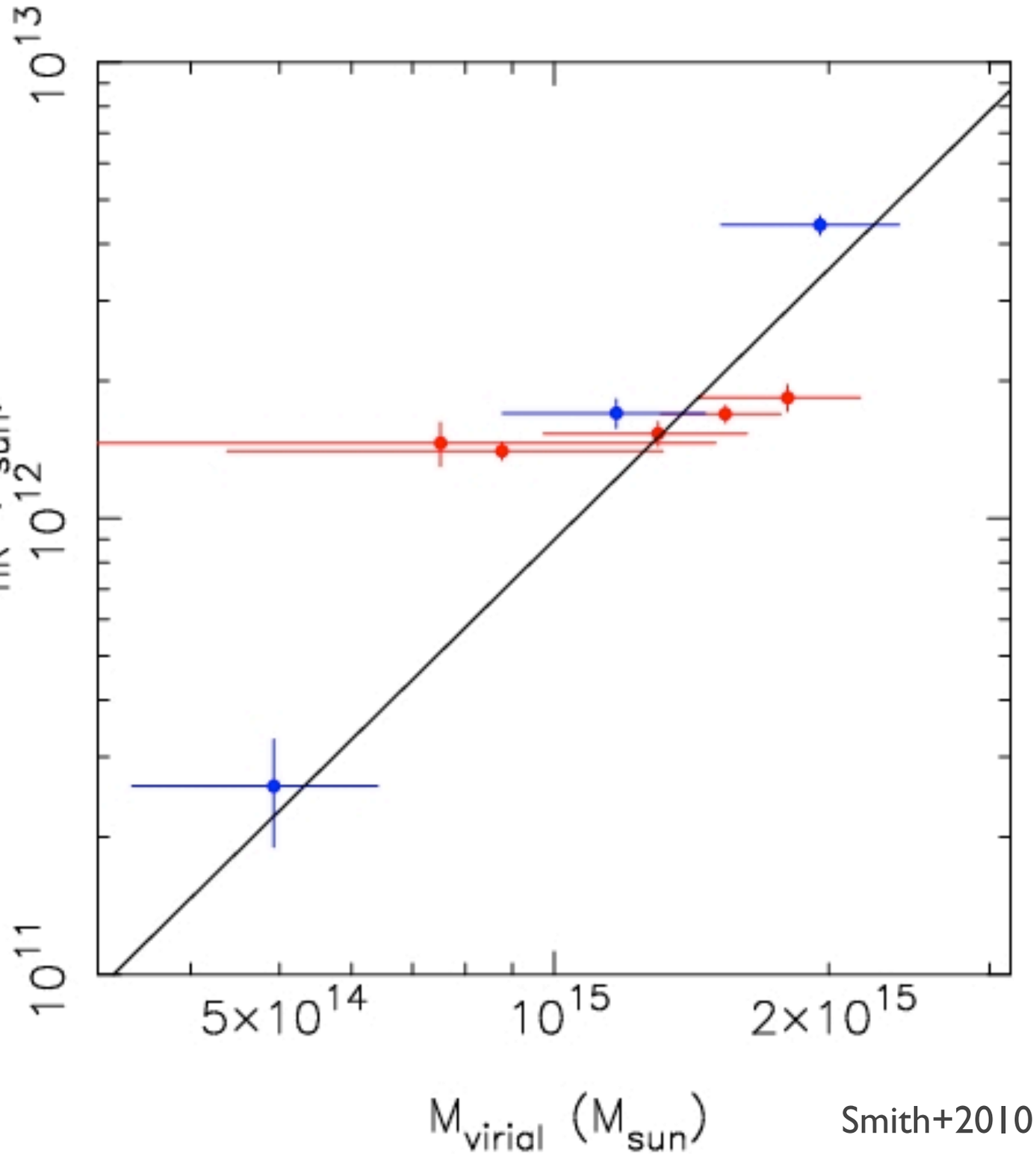
$\sigma_{slope} = 0.6$ (bootstrap)



Smith+2010

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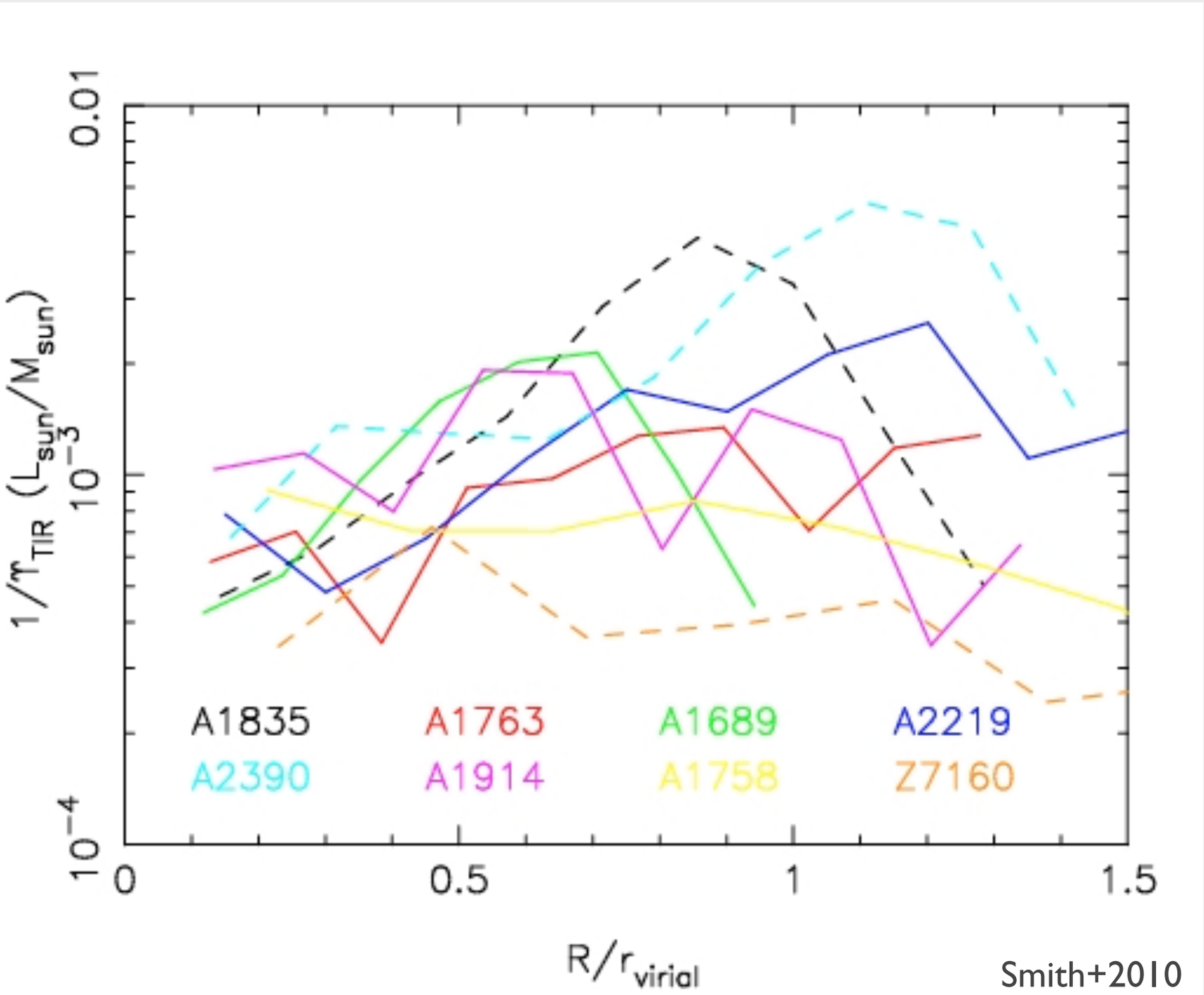
$\dot{M} \propto M^{1.1}$ (McBride +2009)

$\sigma_{slope} = 0.6$ (bootstrap)

cool core, relaxed

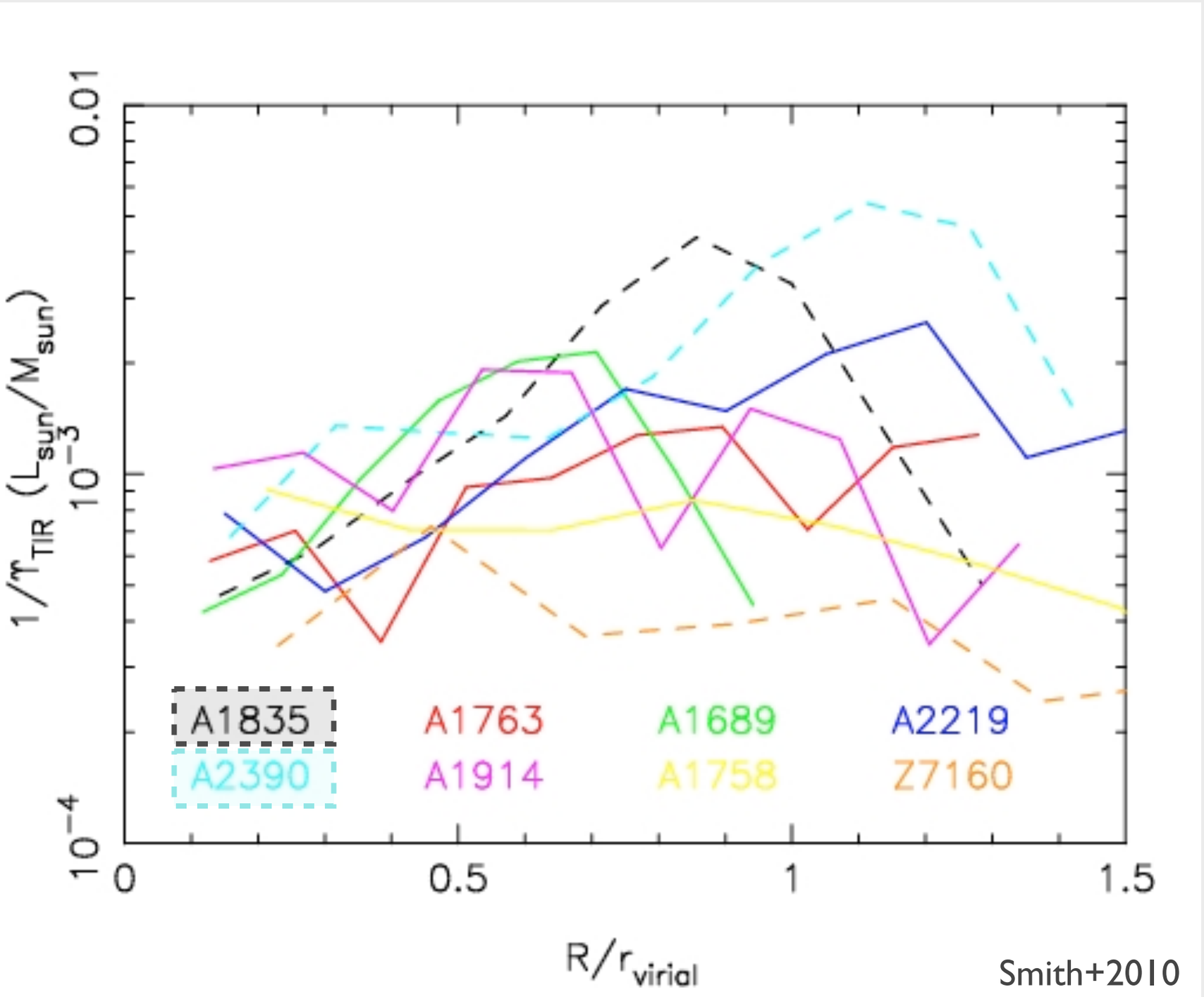
non cool core, disturbed

Far IR Luminosities -- radial profiles



Smith+2010

Far IR Luminosities -- radial profiles

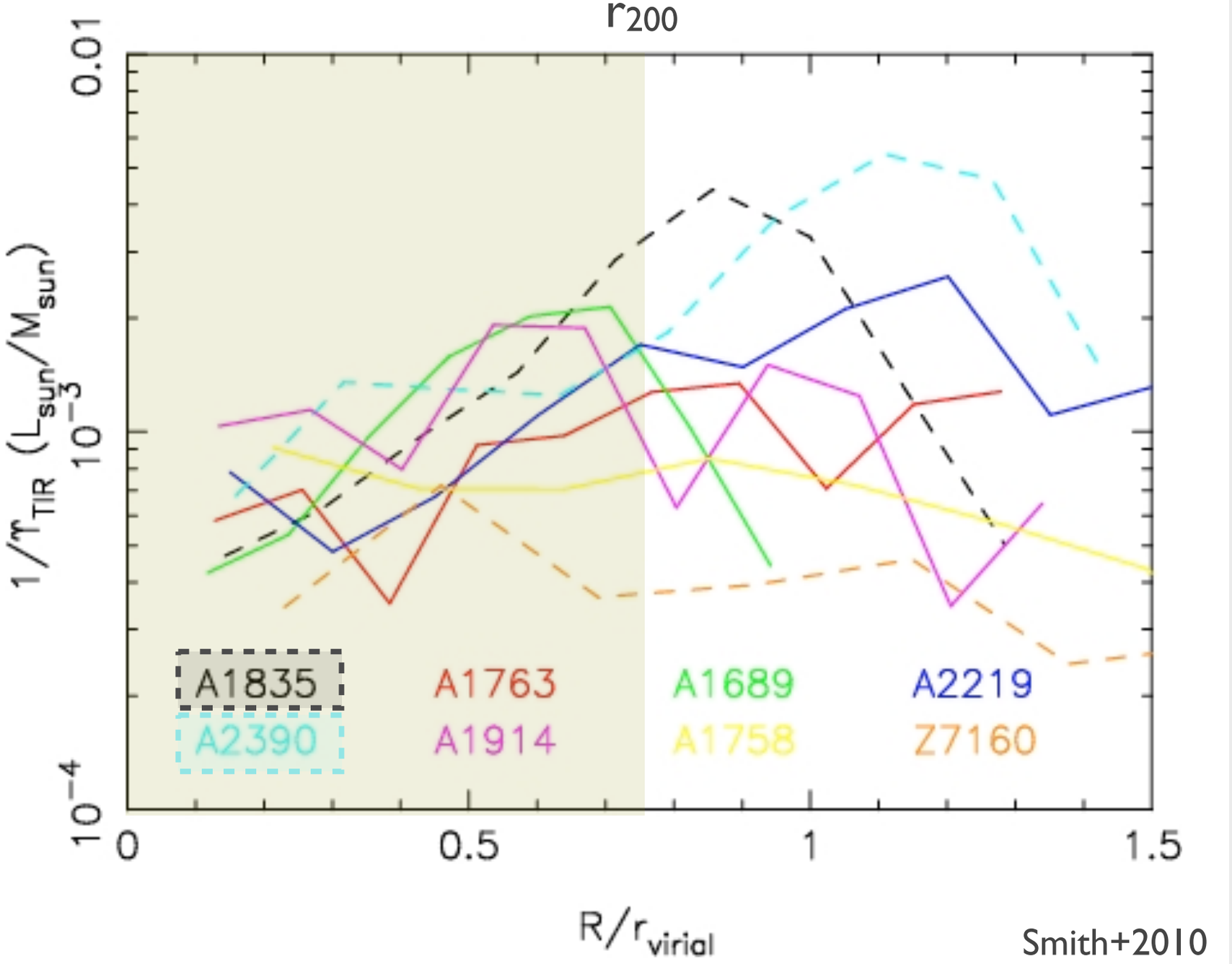


---- cool core

—— non cc

Smith+2010

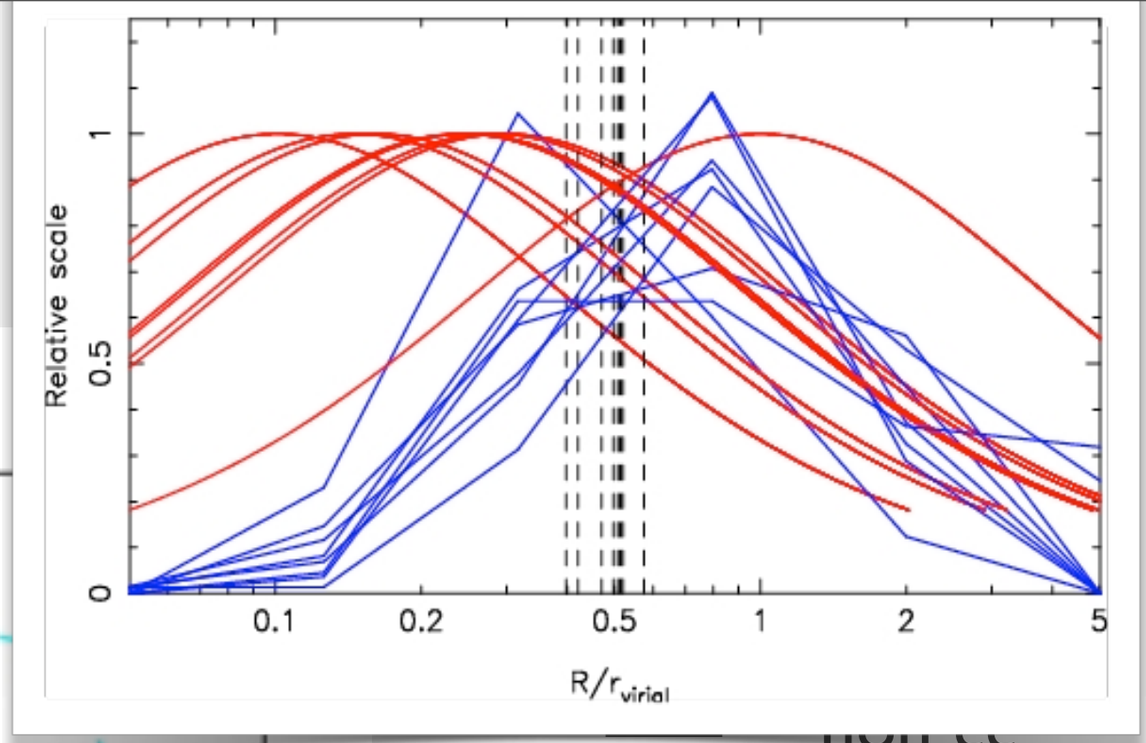
Far IR Luminosities -- radial profiles

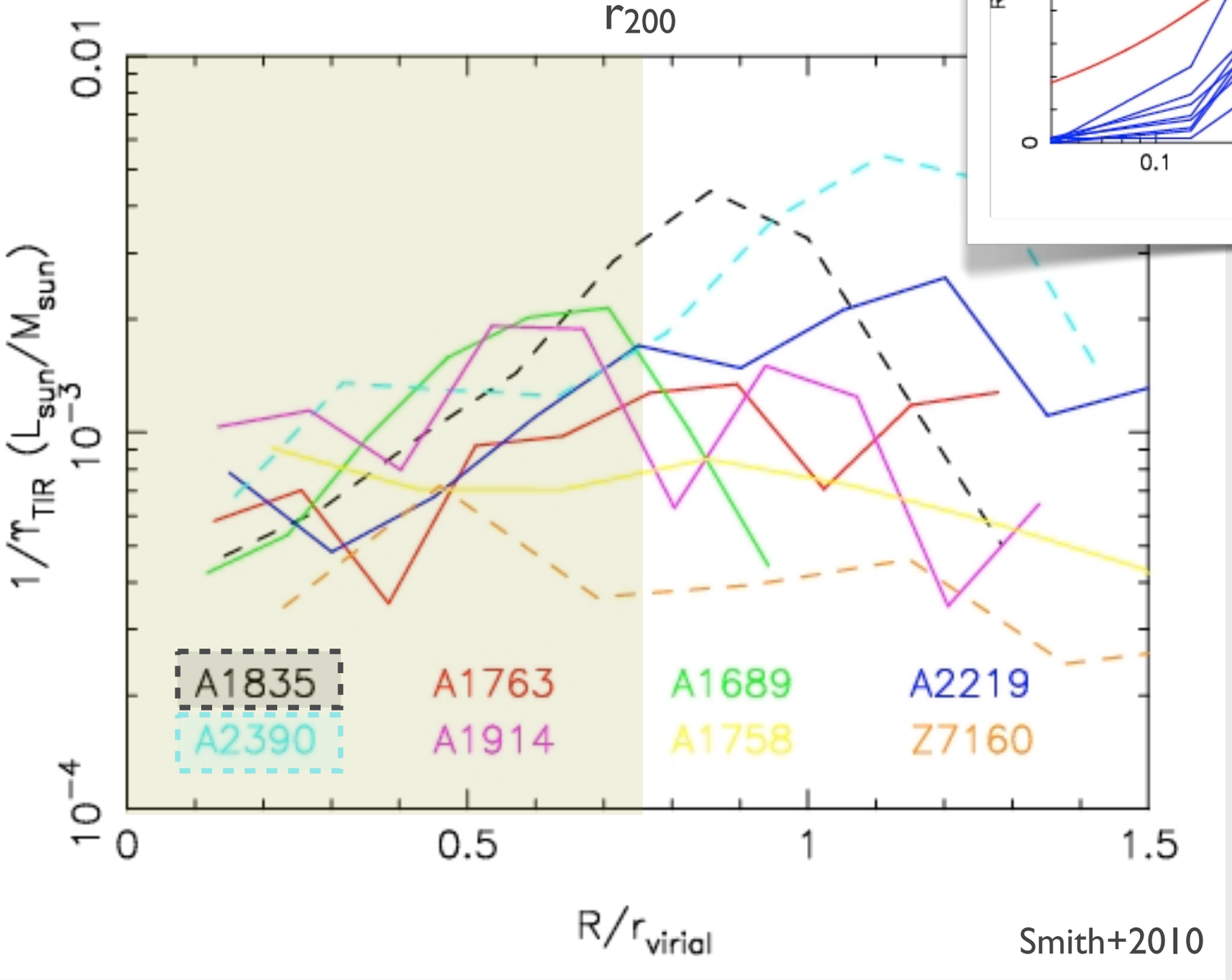


---- cool core

—— non cc

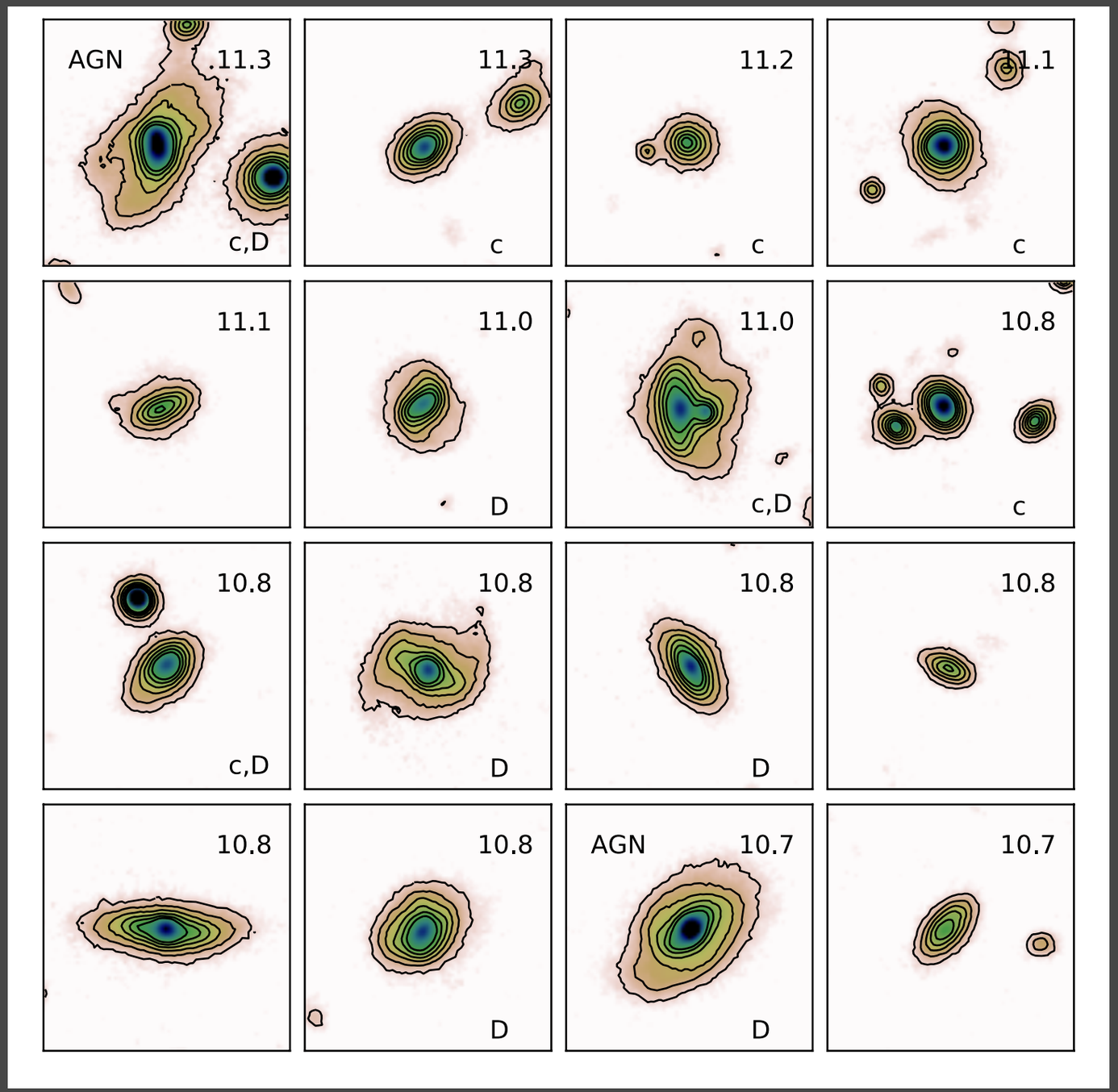
Far IR Luminosities -- radial profiles



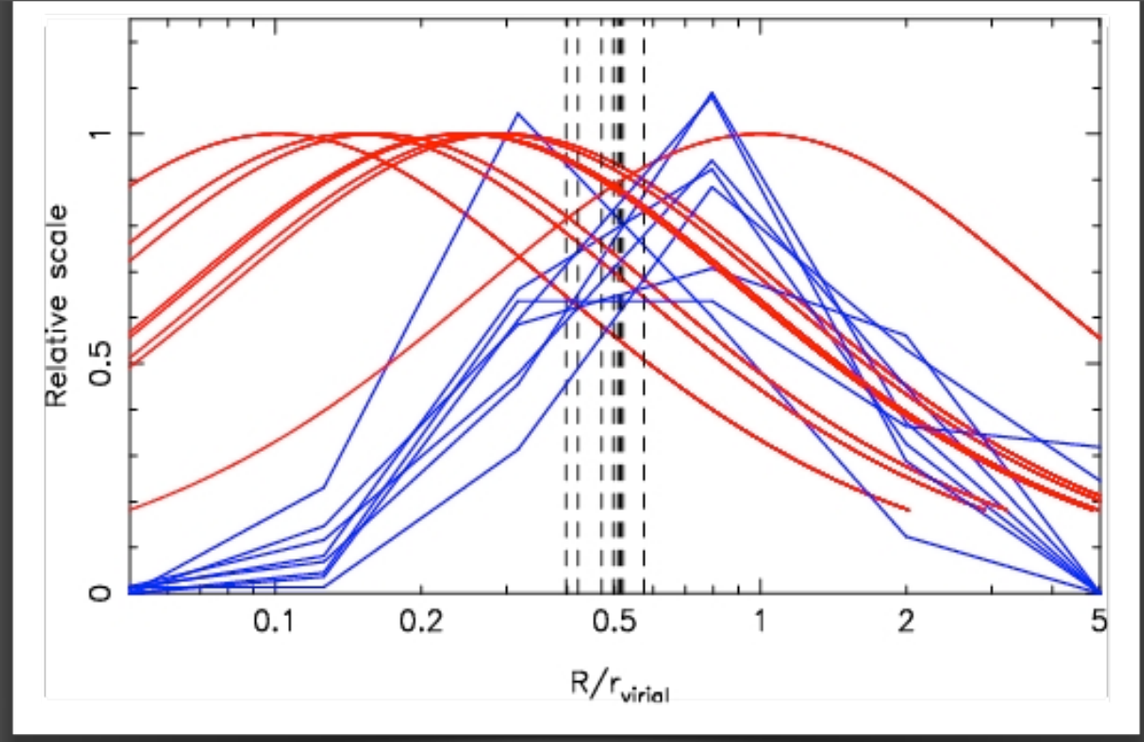


Smith+2010

Merging in Abell 1835



Pereira+2010



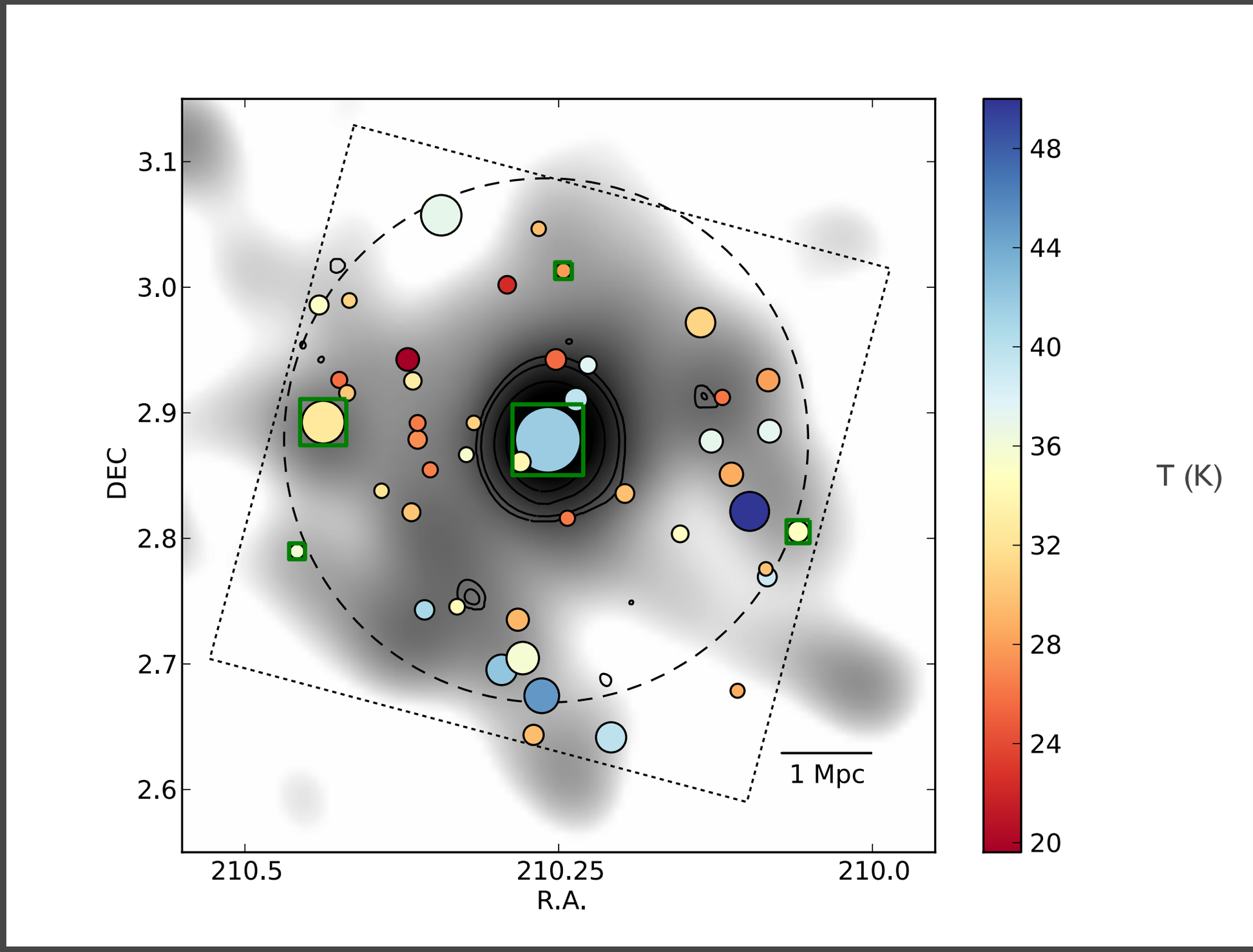
f_c : # of companions within

$\delta v < 300$km/s

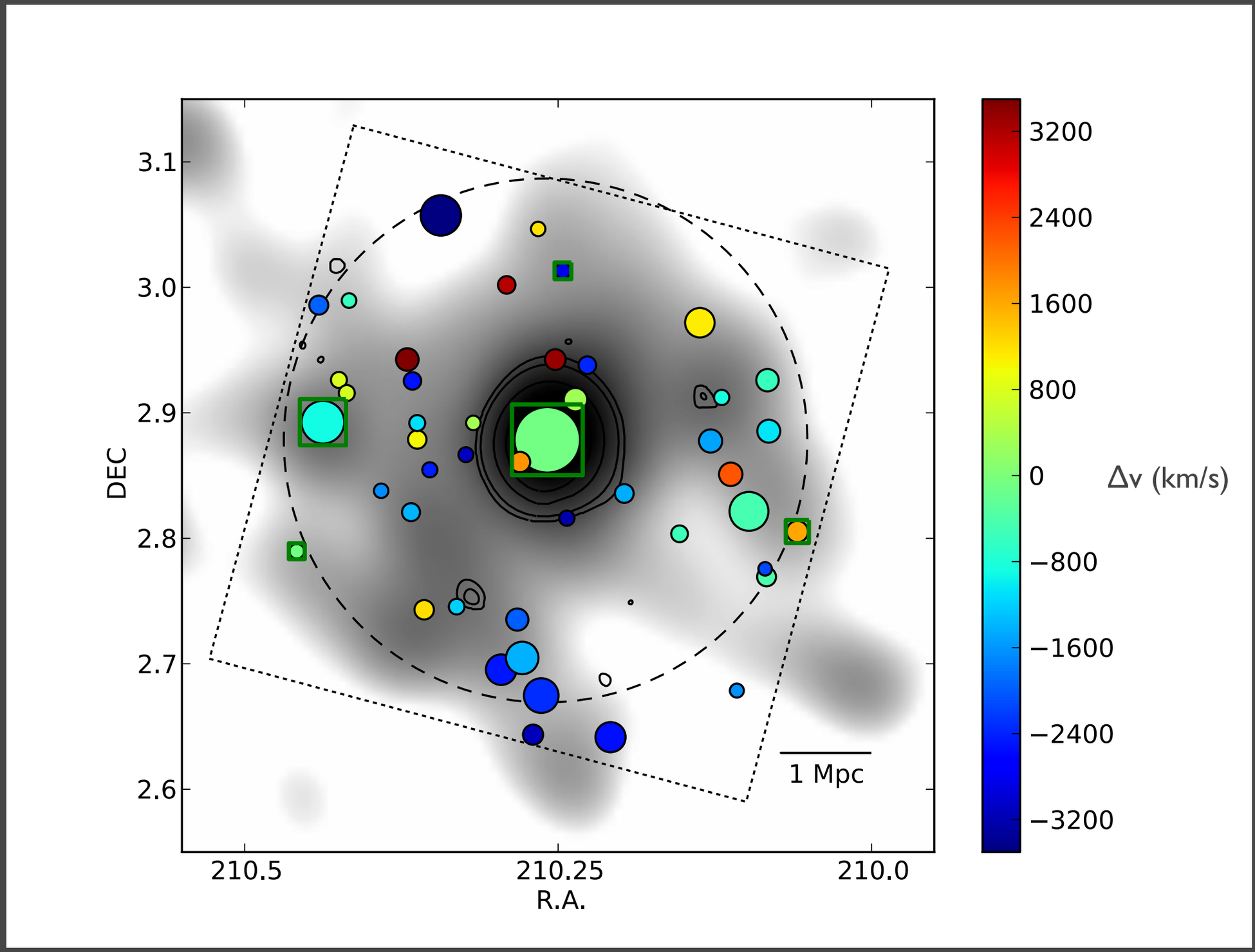
$\delta r < 50$kpc

$f_c \sim 30^{+21}_{-16}\%$ vs $9^{+3}_{-2}\%$

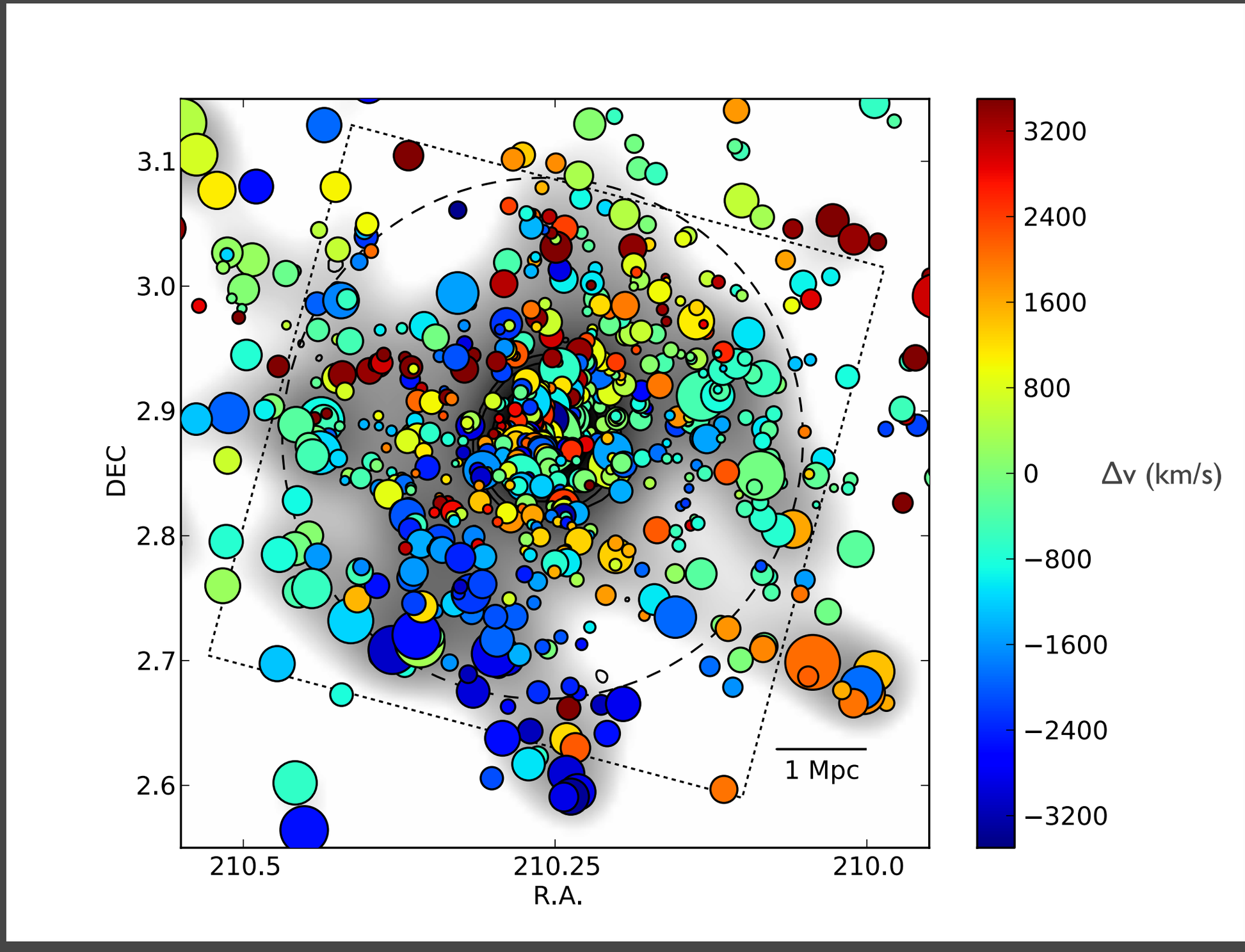
Abell 1835


3.1
3.0
2.9
2.8
2.7
2.6
DEC
210.5
210.25
210.0
R.A.
1 Mpc
48
44
40
36
32
28
24
20
T (K)

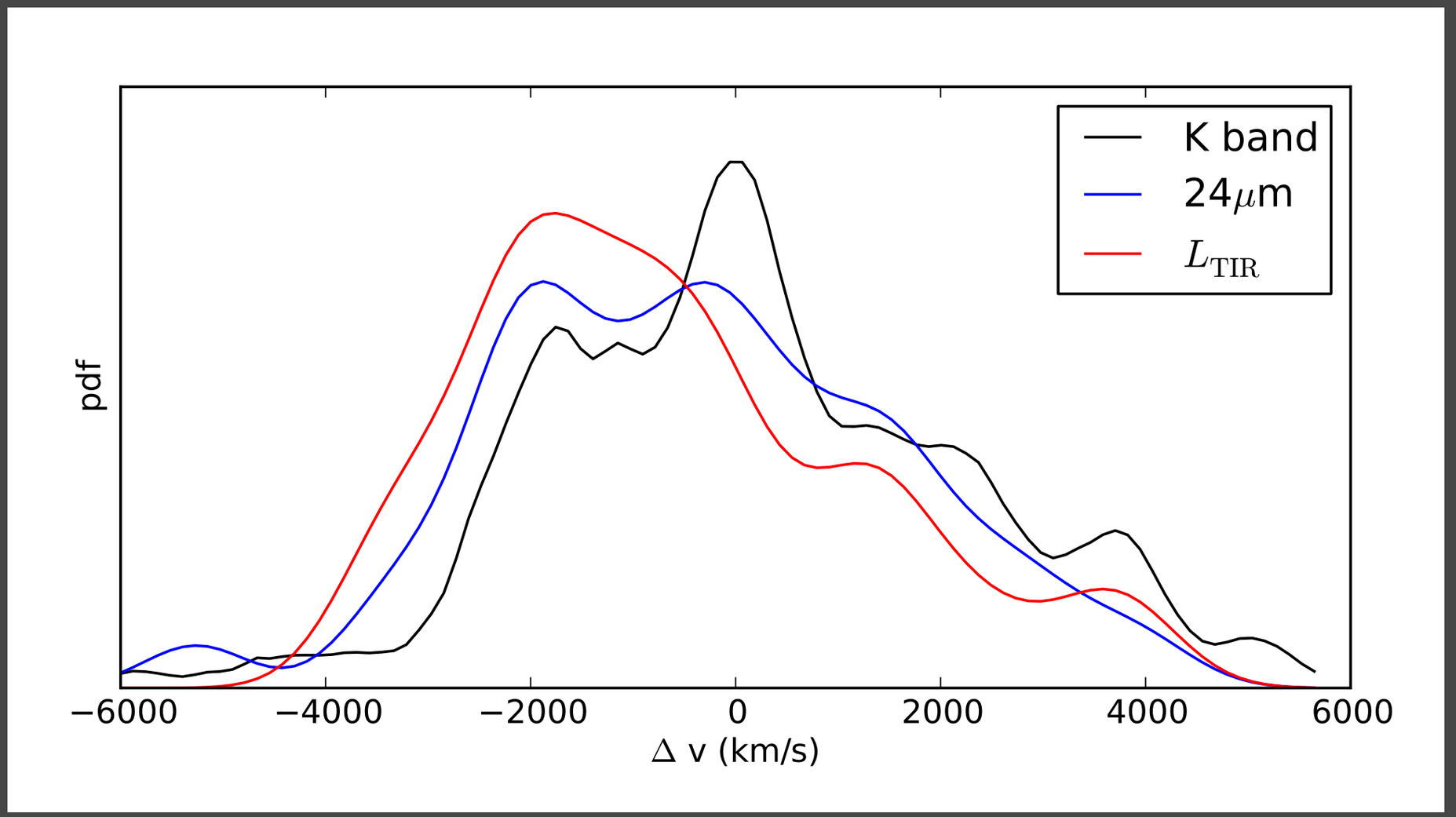
Abell 1835


3.1
3.0
2.9
2.8
2.7
2.6
DEC
210.5
210.25
210.0
R.A.
1 Mpc
3200
2400
1600
800
0
−800
−1600
−2400
−3200
Δv (km/s)

Abell 1835


3.1
3.0
2.9
2.8
2.7
2.6
DEC
210.5
210.25
210.0
R.A.
1 Mpc
3200
2400
1600
800
0
−800
−1600
−2400
−3200
Δv (km/s)

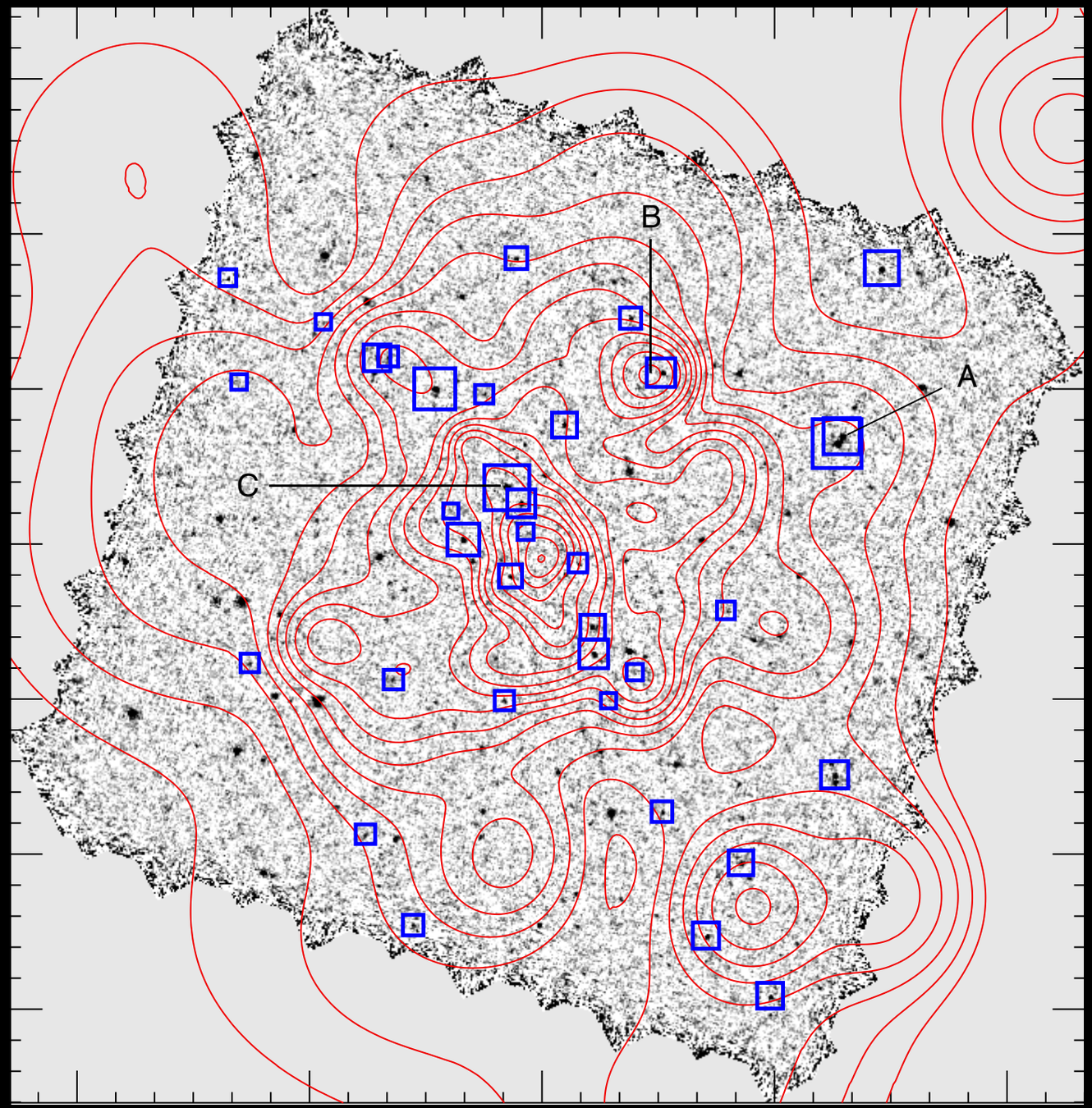
Abell 1835



Pereira+2010

Luminous infrared galaxies dynamically segregated from the cluster population
Infall regions of this massive relaxed cluster are extremely active!

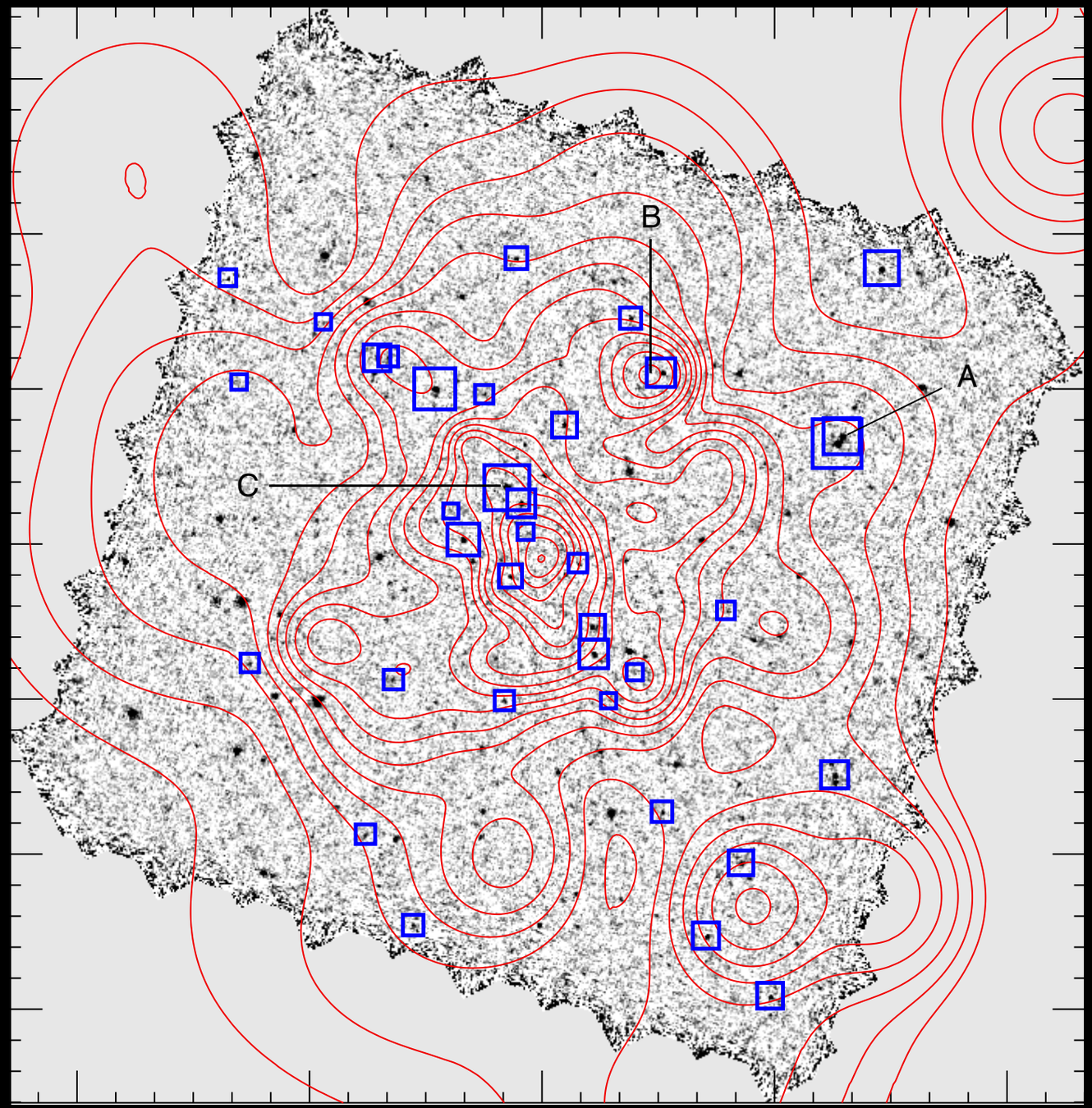
Abell 1689



Haines+2010

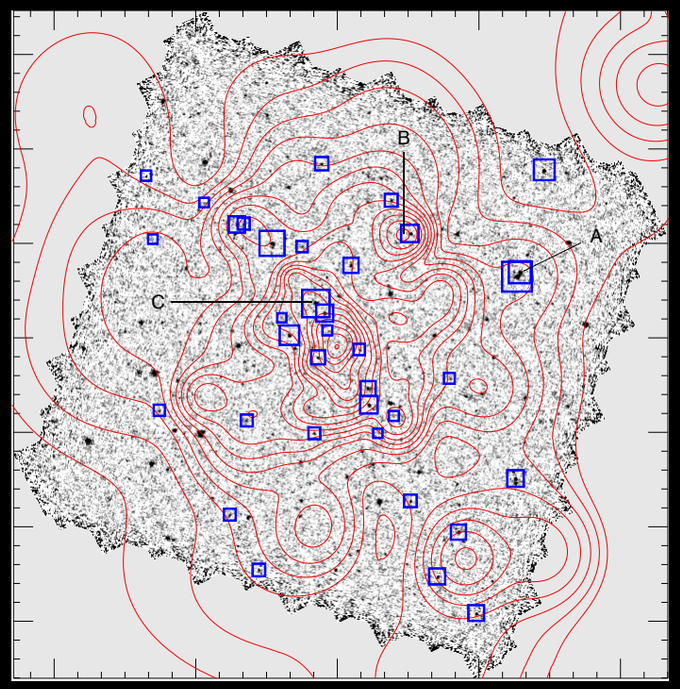
Abell 1689

anisotropic distribution: $P_{KS} = 0.96$



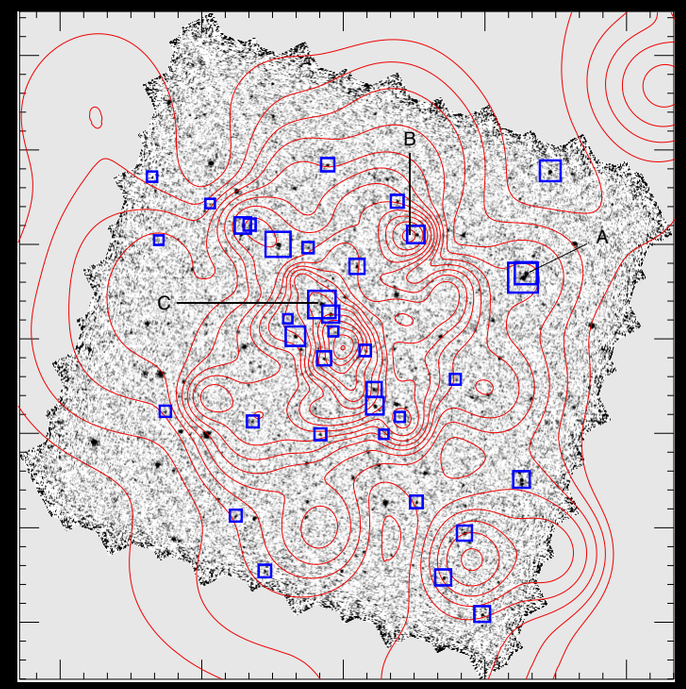
Haines+2010

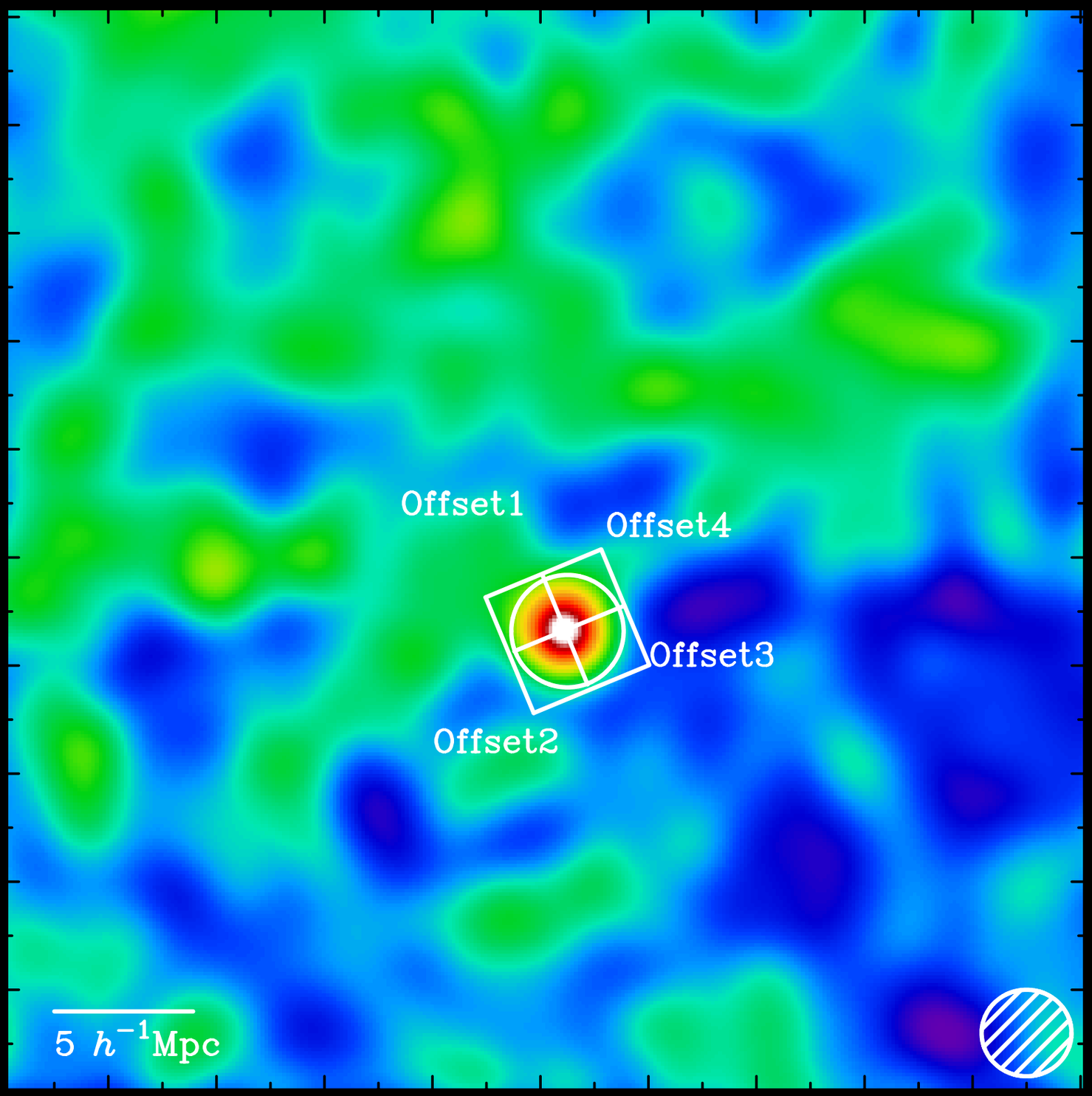
Abell 1689



Haines+2010

Abell 1689

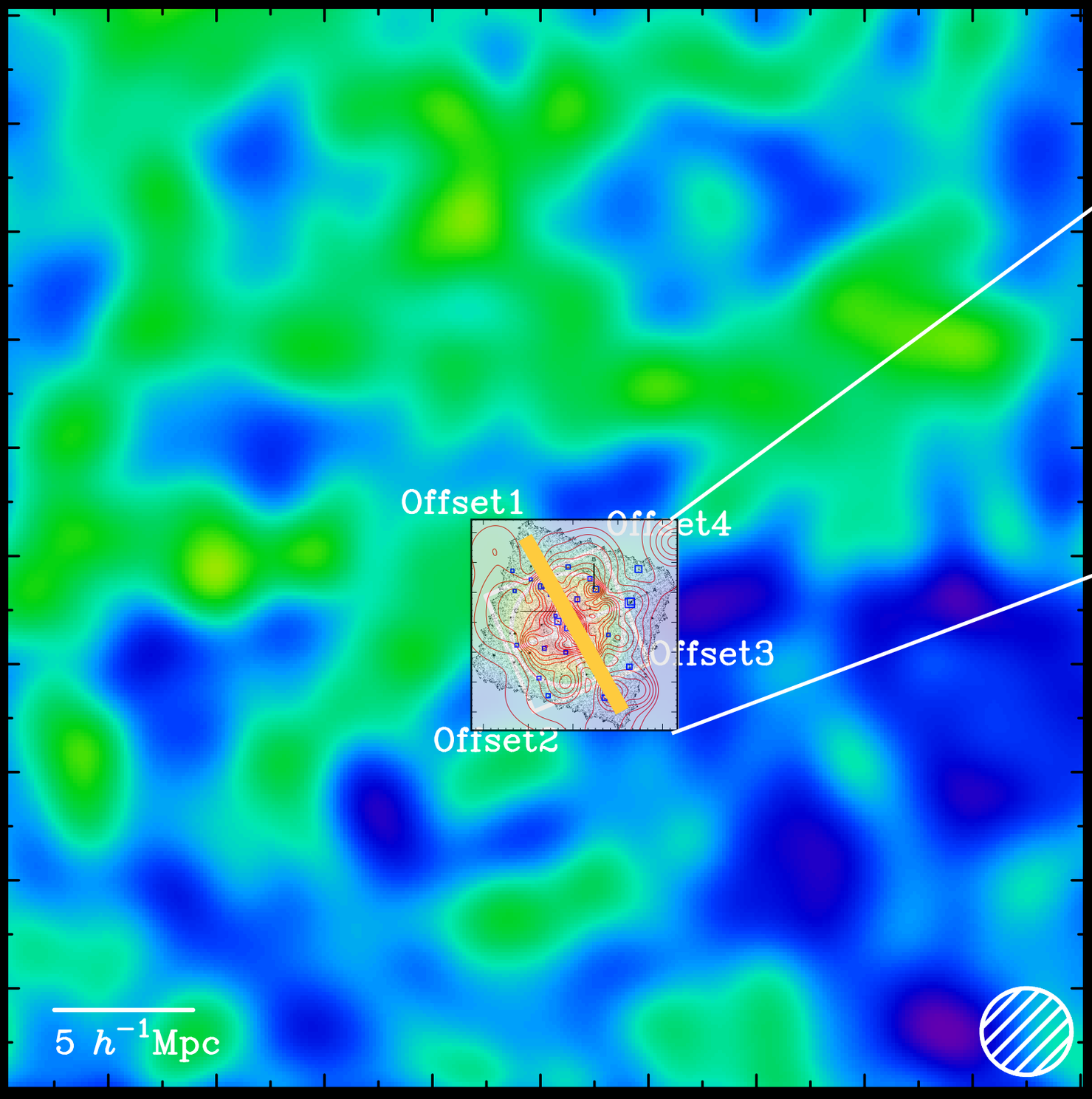


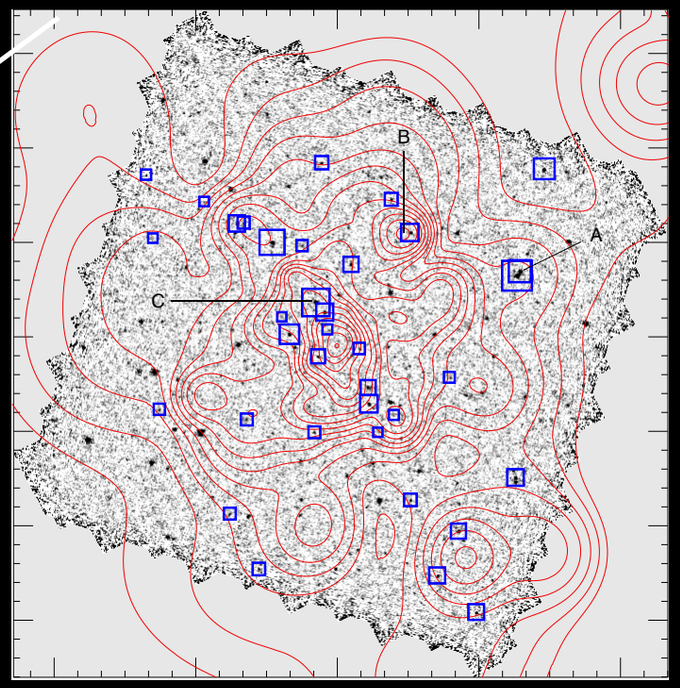


Kawaharada+ 2010

Haines+2010

Abell 1689

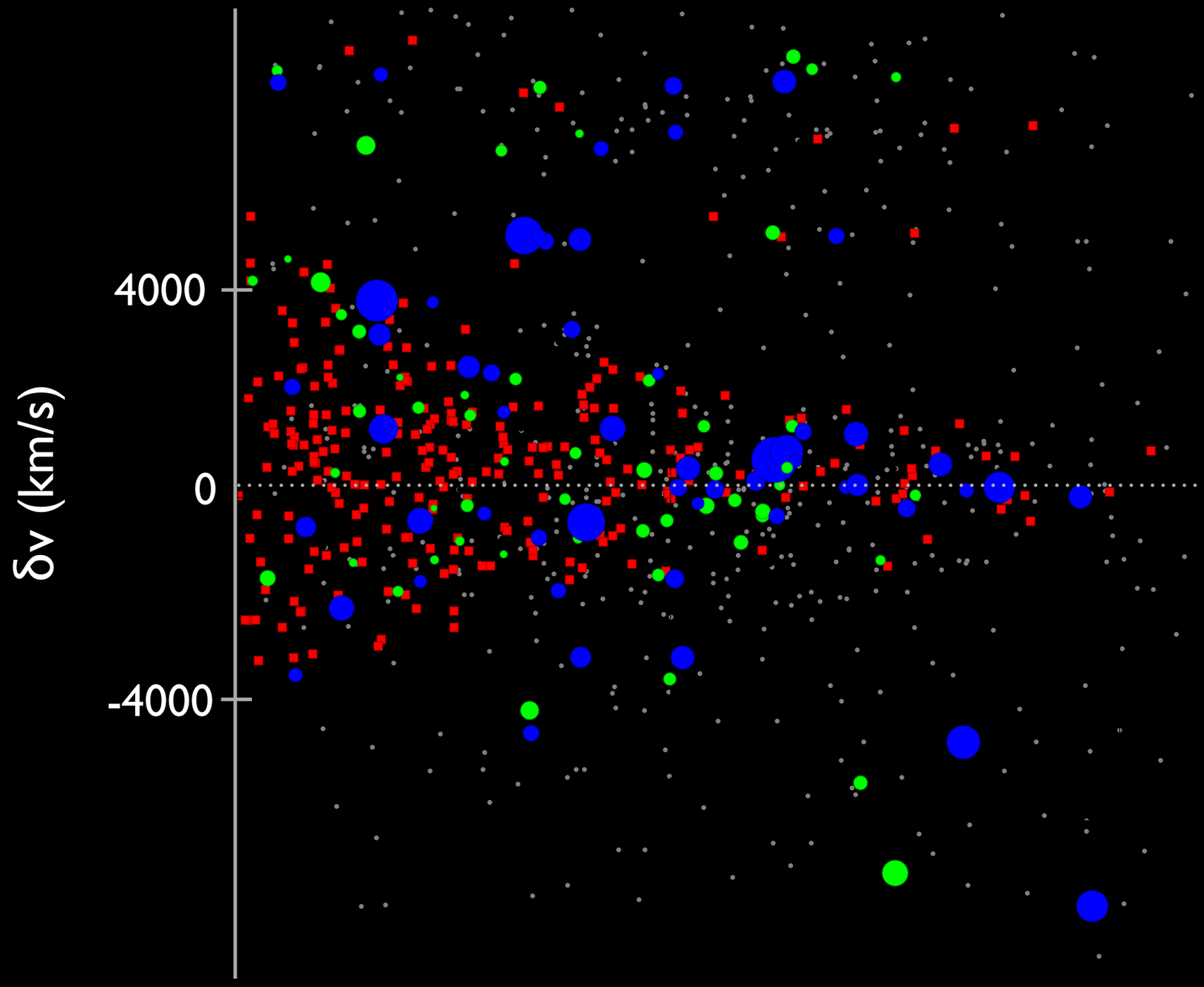




Kawaharada+ 2010

Haines+2010

Abell 1689



Herschel & 24um

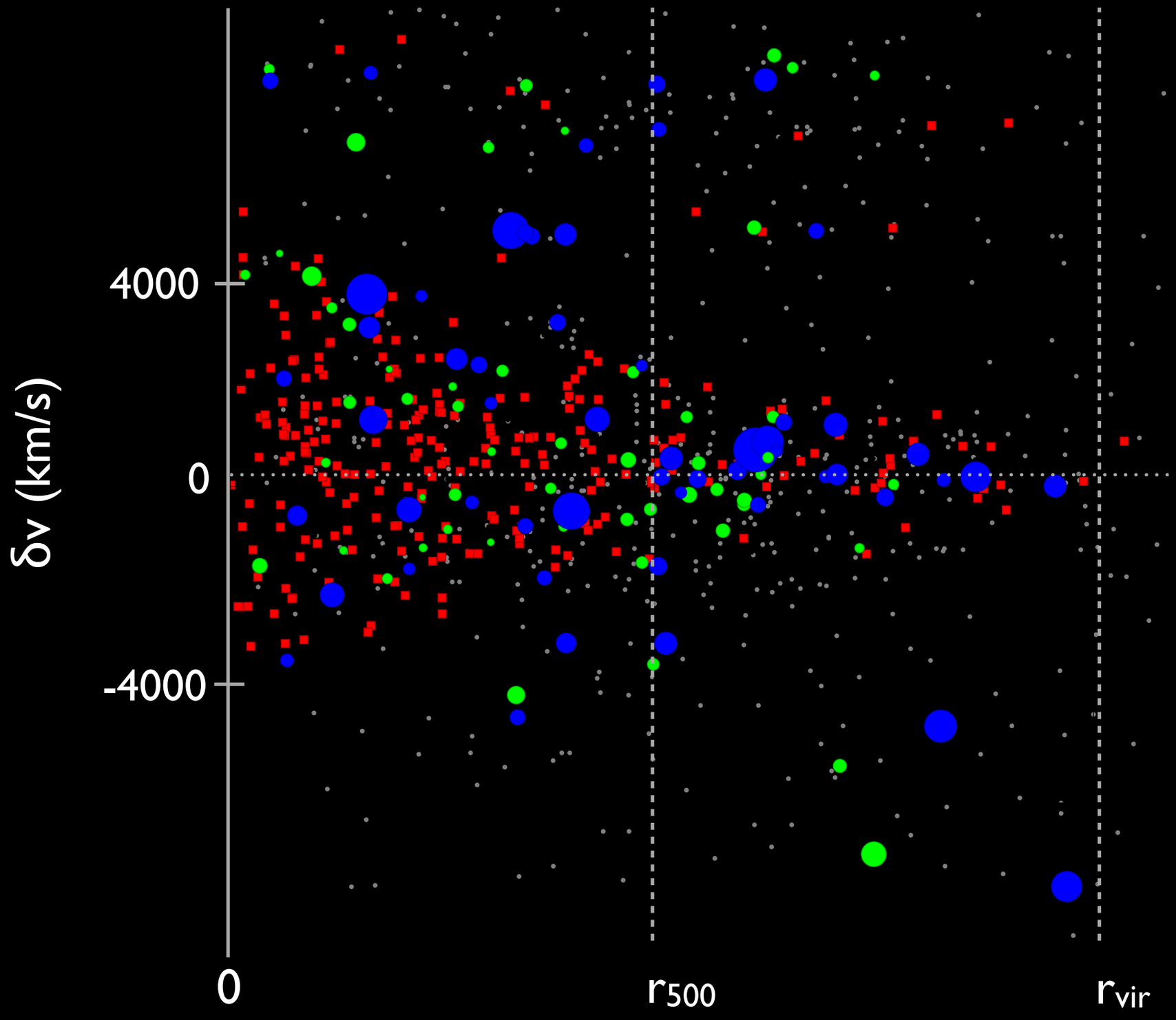
just 24um

neither

c.f. Fadda+2009 filament in A1763

Haines+2010

Abell 1689



Herschel & 24um

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neither

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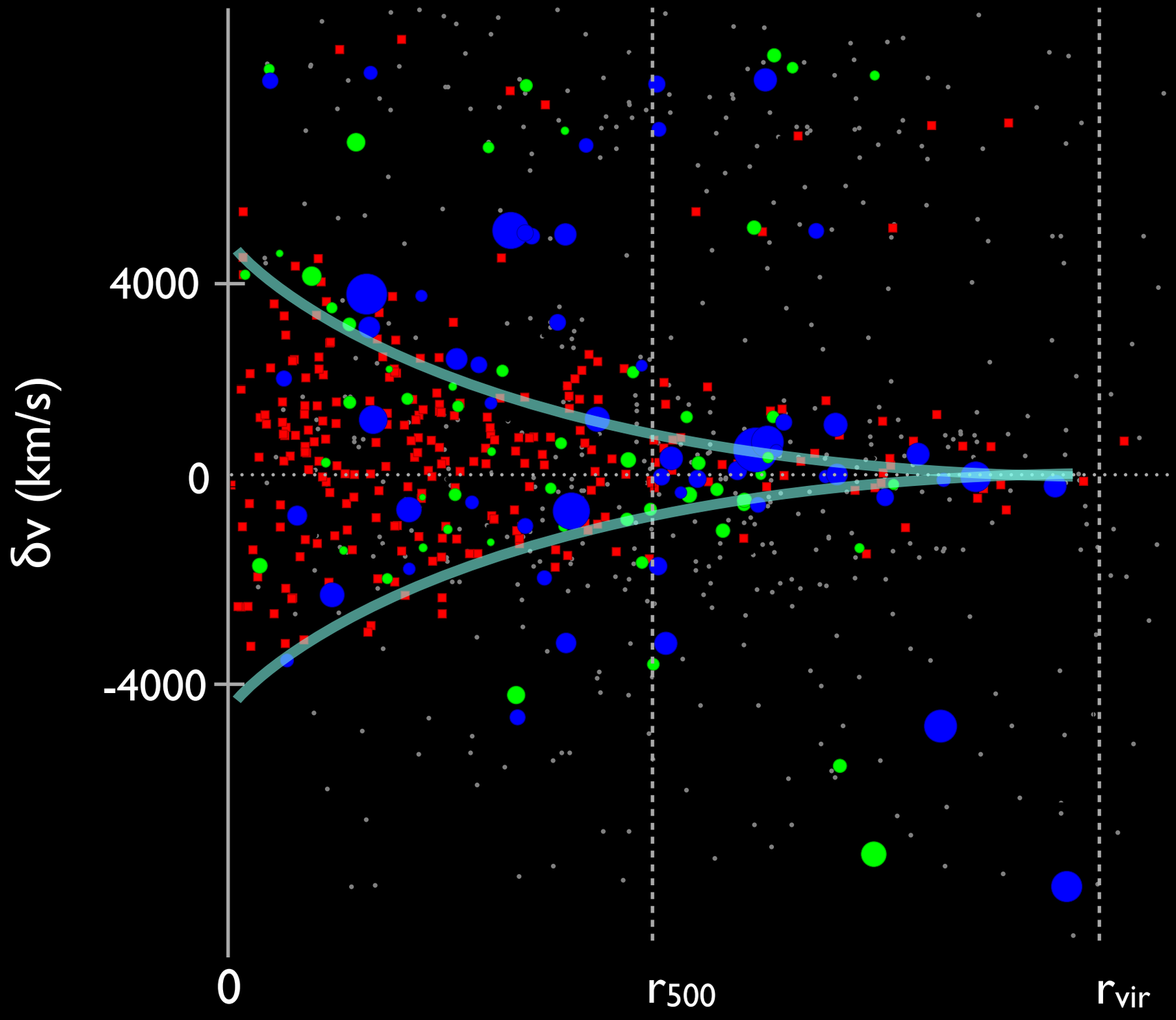
Haines+2010

Abell 1689



Herschel & 24um

just 24um

neither

c.f. Fadda+2009 filament in A1763

Haines+2010

Herschel & 24um

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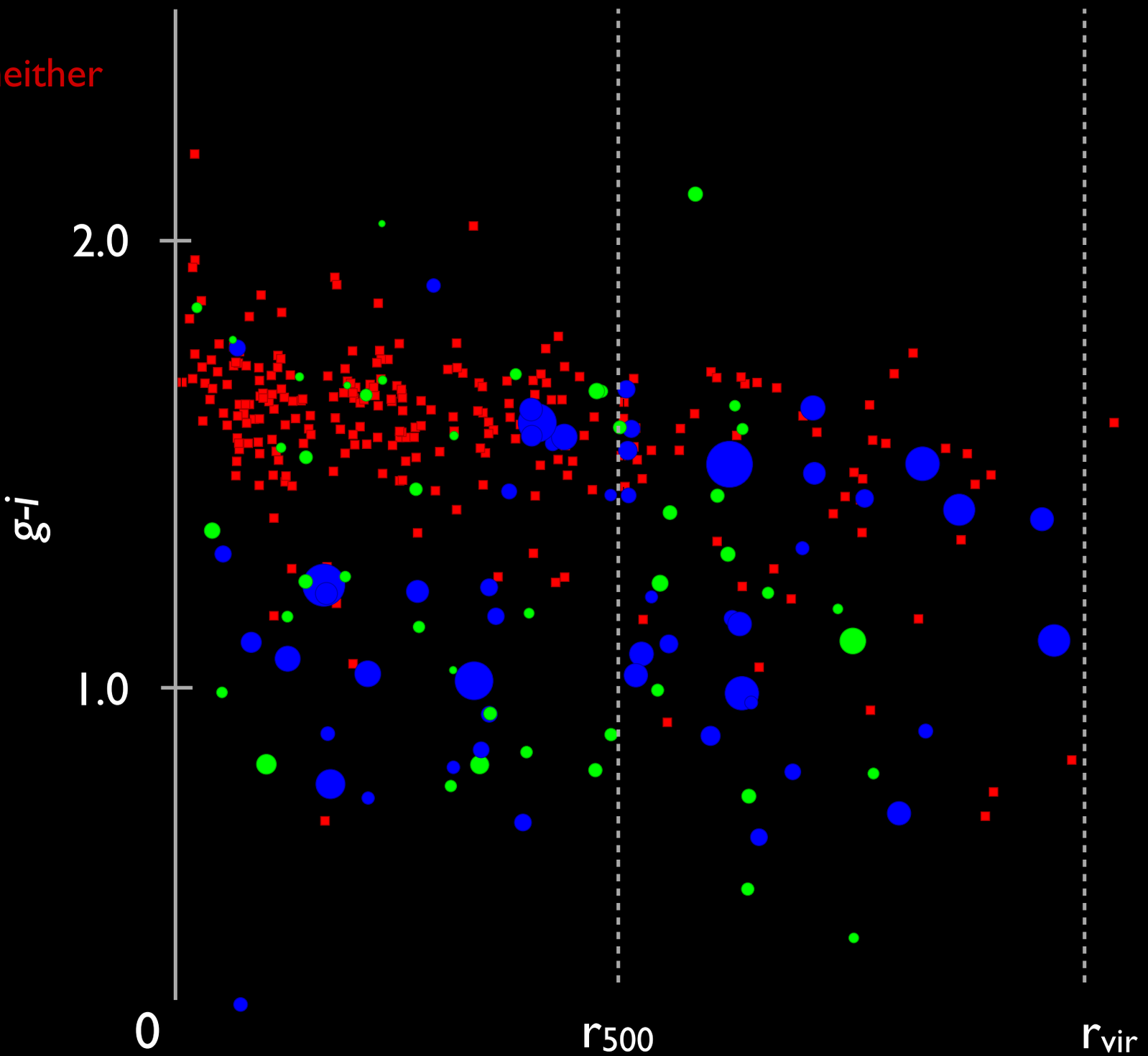
neither

Abell 1689



c.f. A901/2 STAGES
Wolf+ 2005,2009

Haines+2010

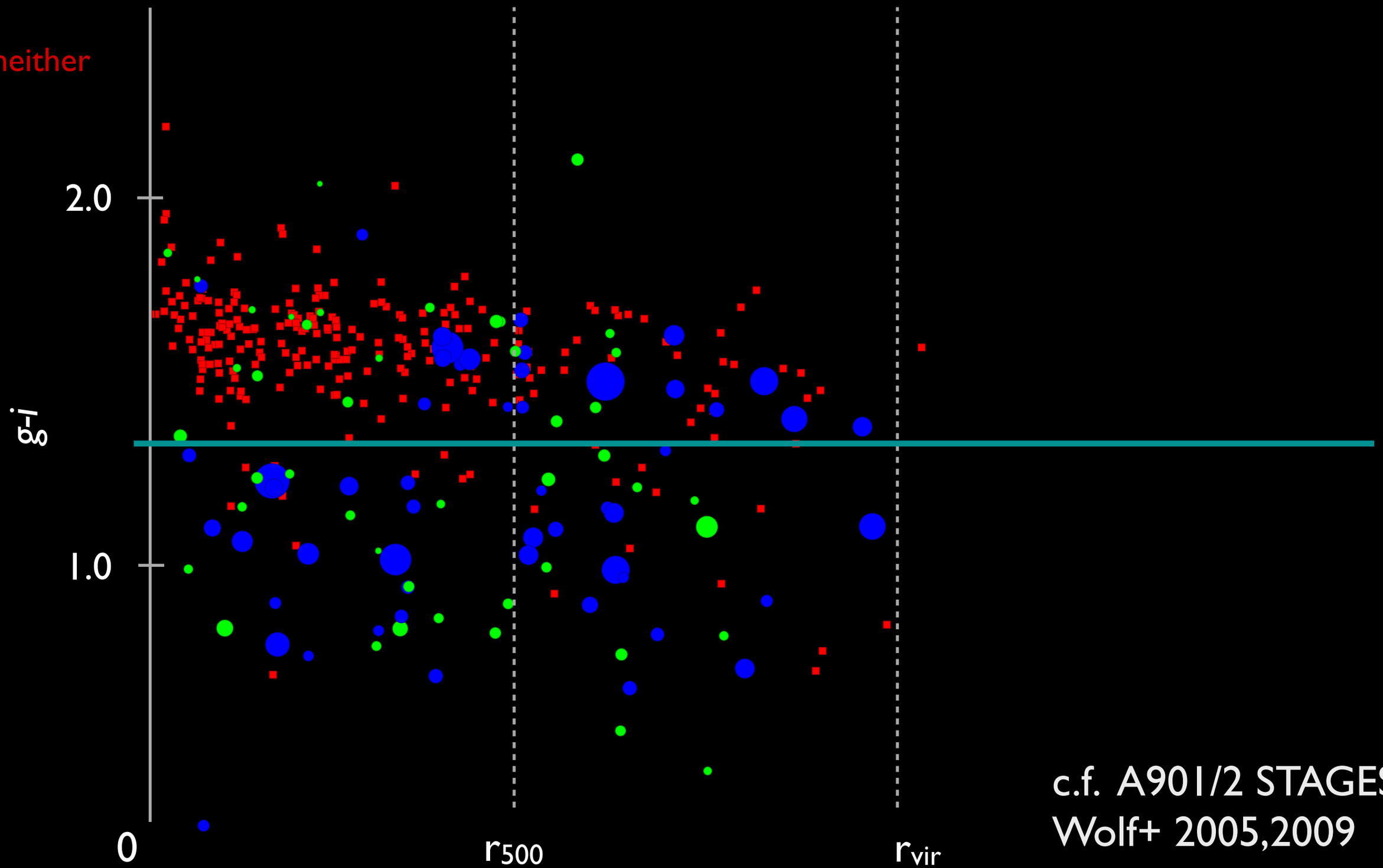
Maria J. Pereira, Steward Observatory

Abell 1689

Herschel & 24um

just 24um

neither



c.f. A901/2 STAGES
Wolf+ 2005,2009

Haines+2010

Maria J. Pereira, Steward Observatory

Abell 1689

Herschel & 24um

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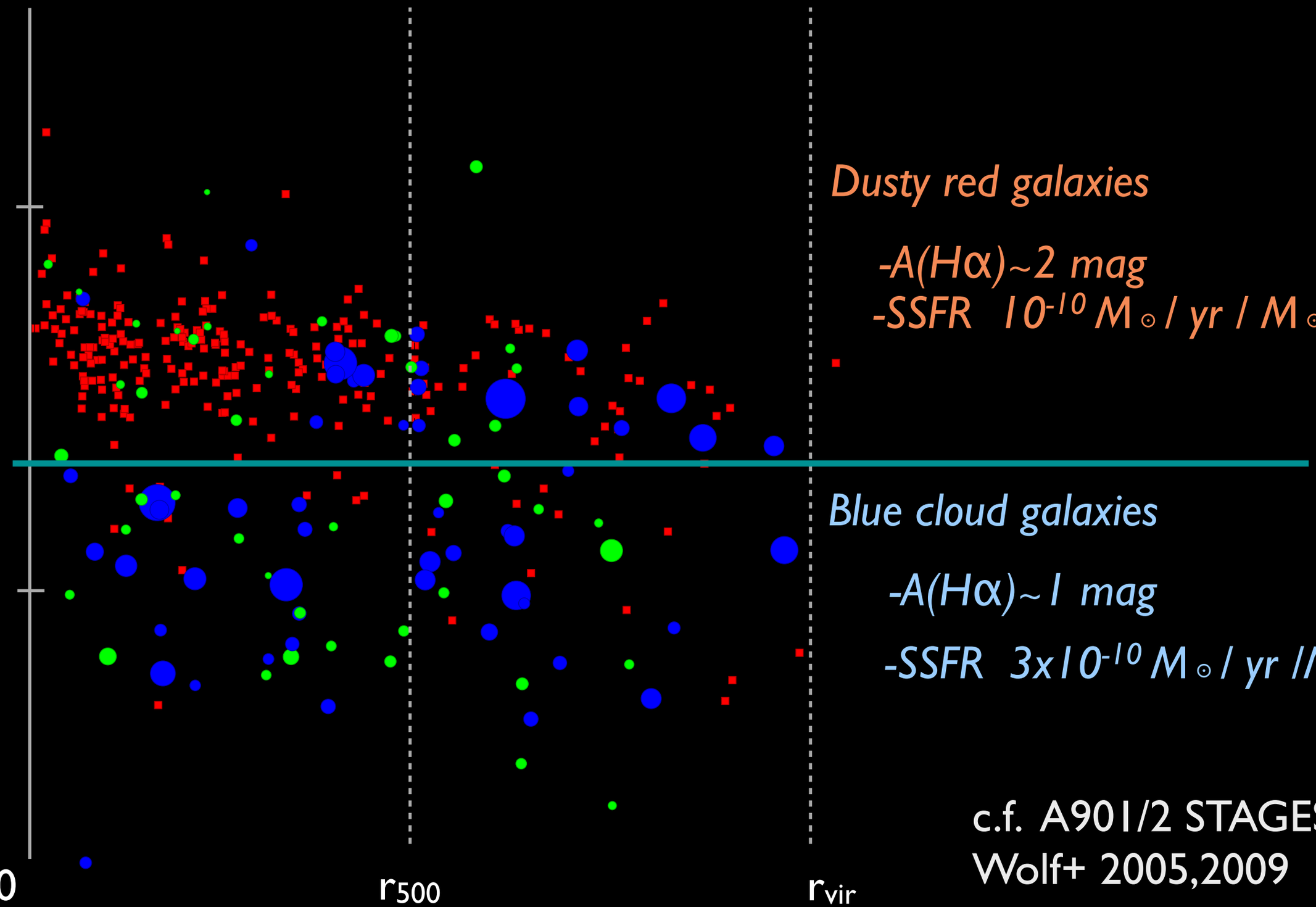
neither



Dusty red galaxies

-A(Hα)~2 mag

-SSFR 10^{-10} $M_\odot$ / yr / $M_\odot$

Blue cloud galaxies

-A(Hα)~1 mag

-SSFR $3x10^{-10}$ $M_\odot$ / yr /$M_\odot$

c.f. A901/2 STAGES
Wolf+ 2005,2009

Haines+2010

Conclusions:

- FIR colors of cluster galaxies at z=0.2 differ from local galaxy colors, as captured by CE01 and R09 SED templates -- an environmental effect?

- no correlation between cluster dynamical state and total infrared luminosity

- radial profiles peak at ~r_{vir} for the cool core clusters, indicating merging may be main driver of induced star formation in clusters

- L_{IR} is generally anisotropic: the brightest infrared regions in A1835 and A1689 appear to be associated with filaments which are currently feeding the clusters.