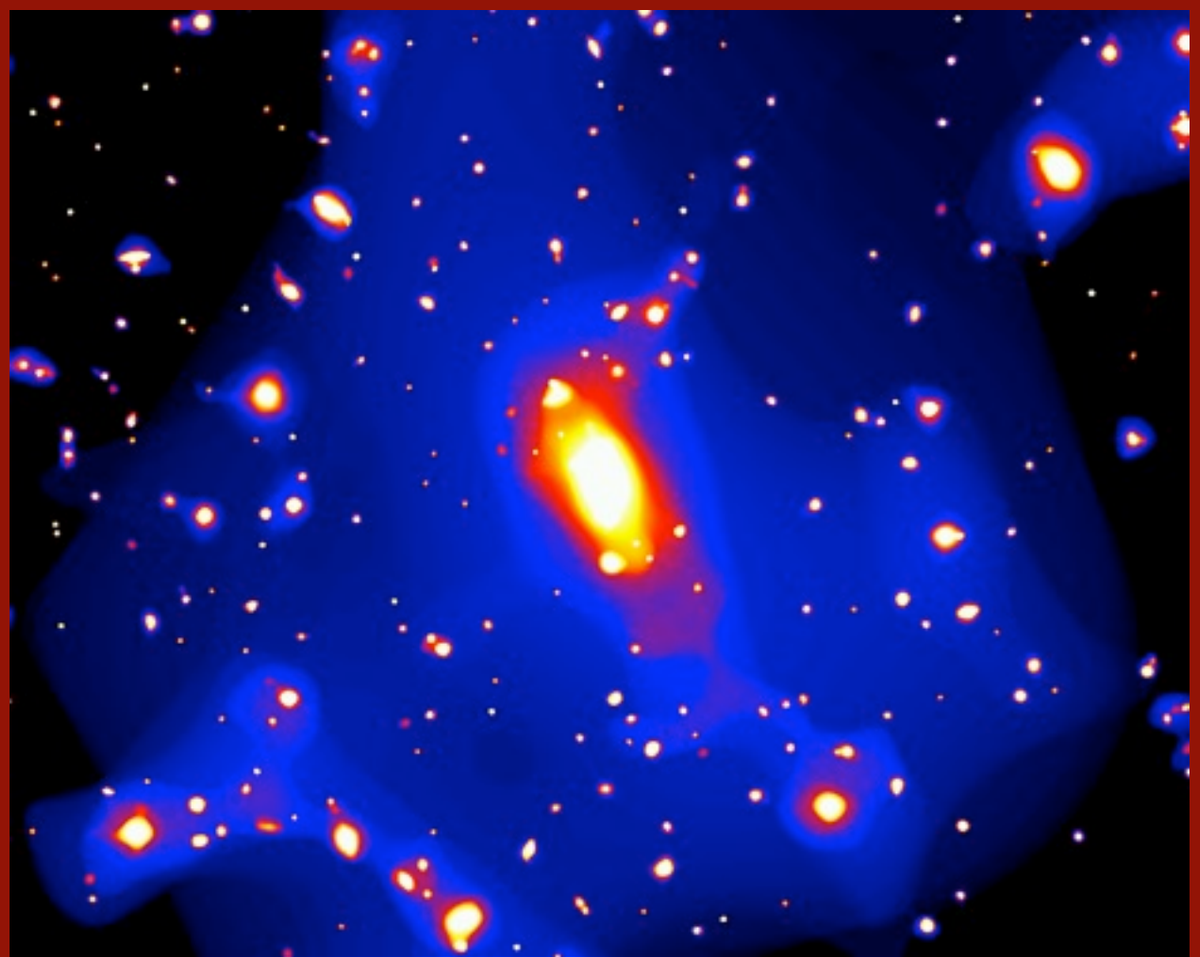
Balancing the Baryon Budget in Groups and Clusters

A. Zabludoff (Arizona), S. Sivanandam (UToronto),
A. Gonzalez (Florida), D. Zaritsky (Arizona)



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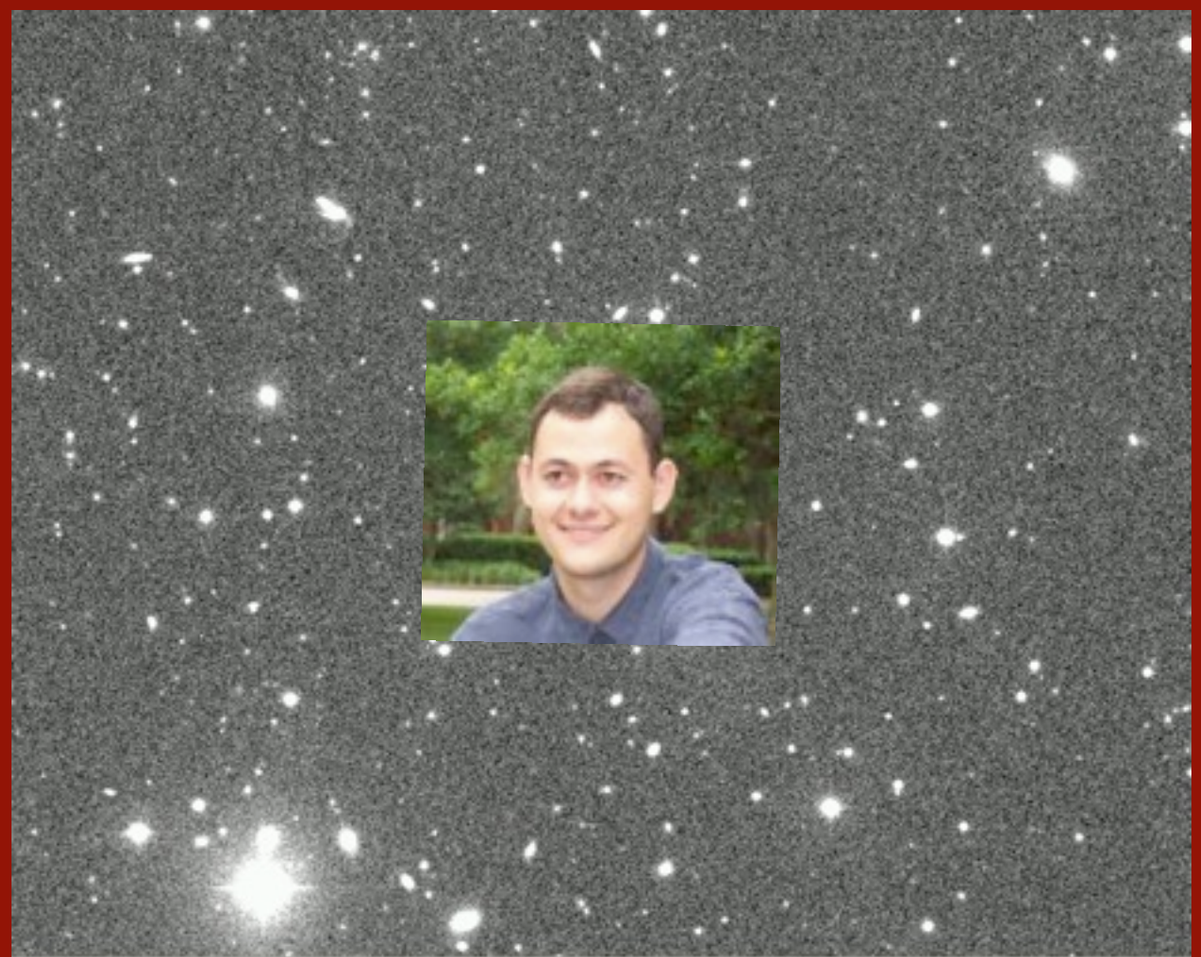

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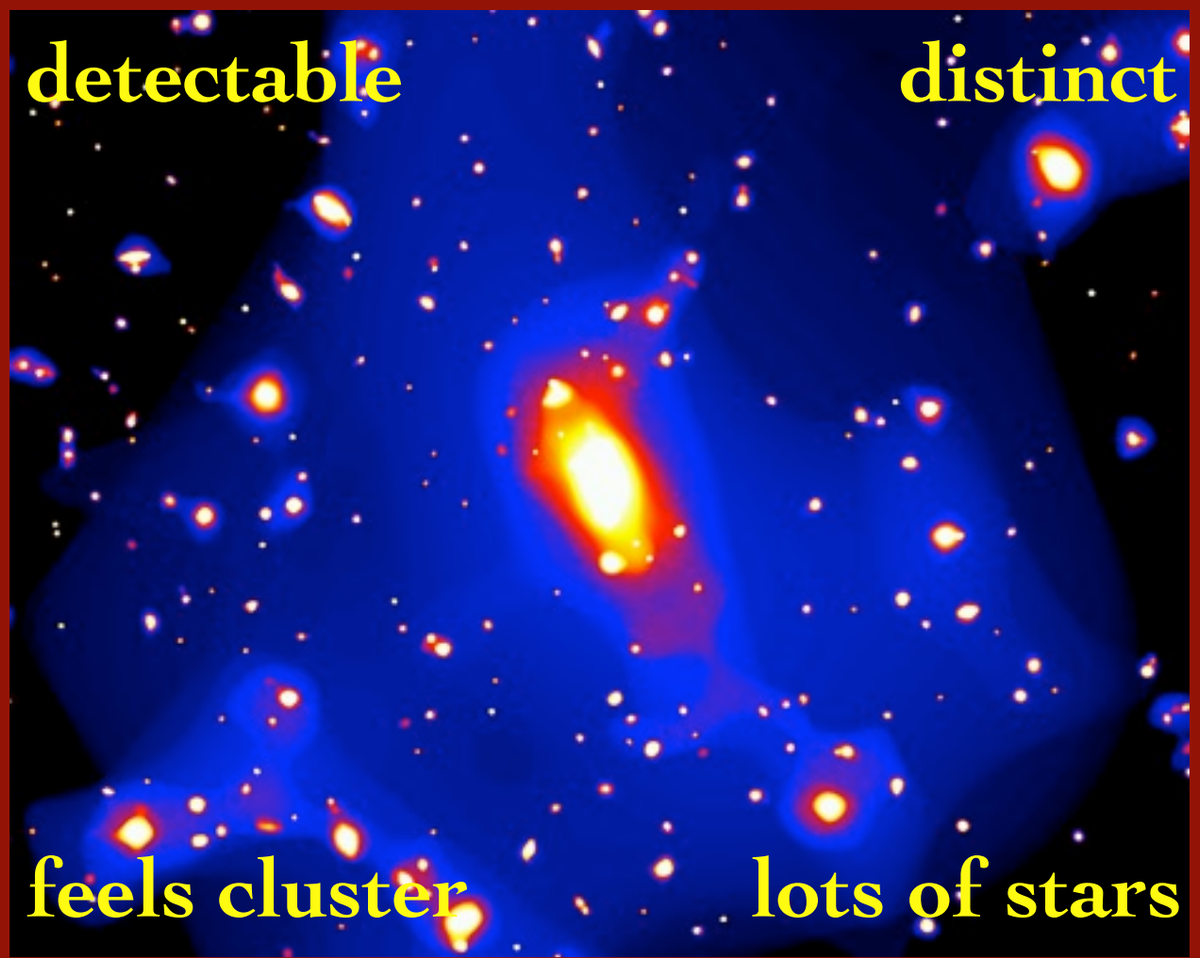

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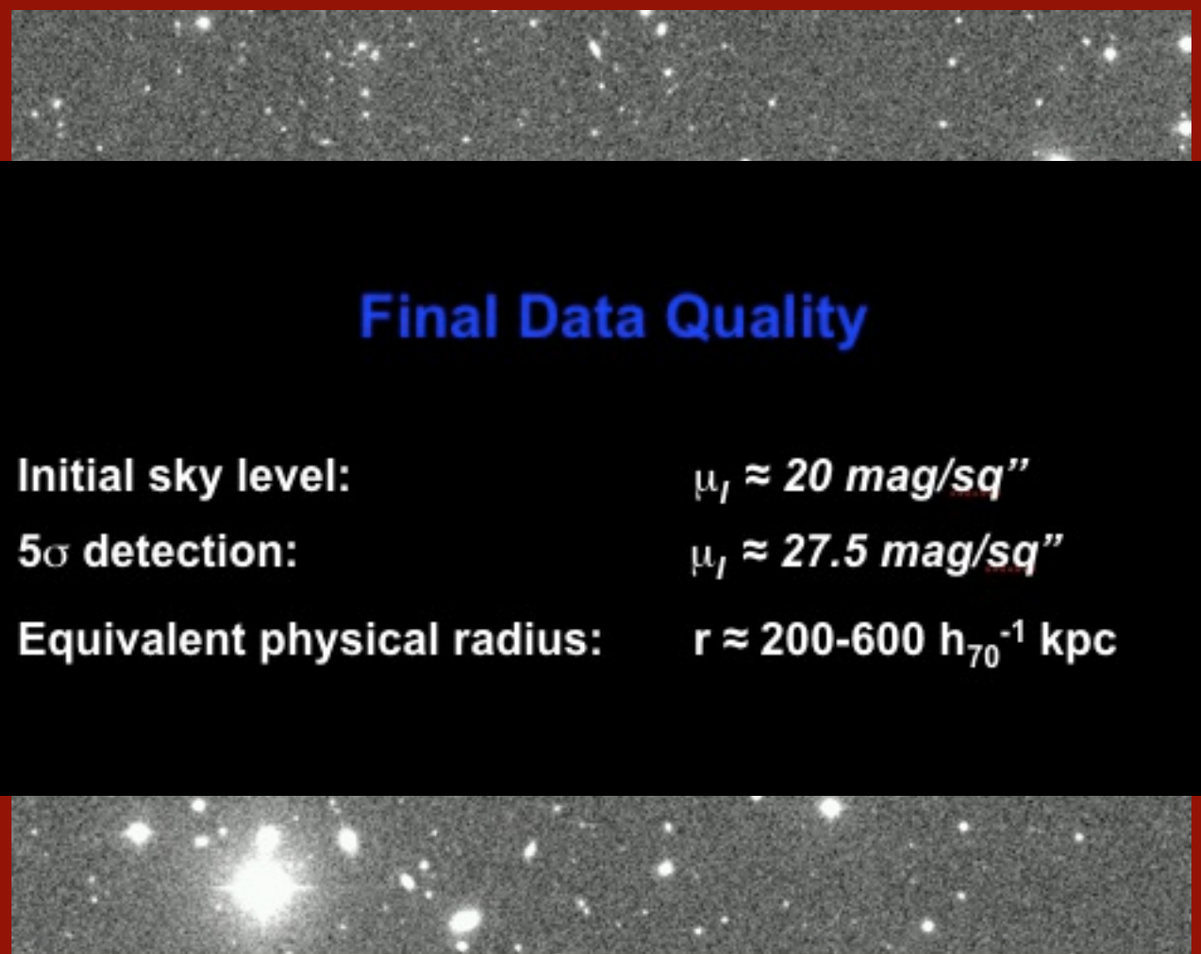
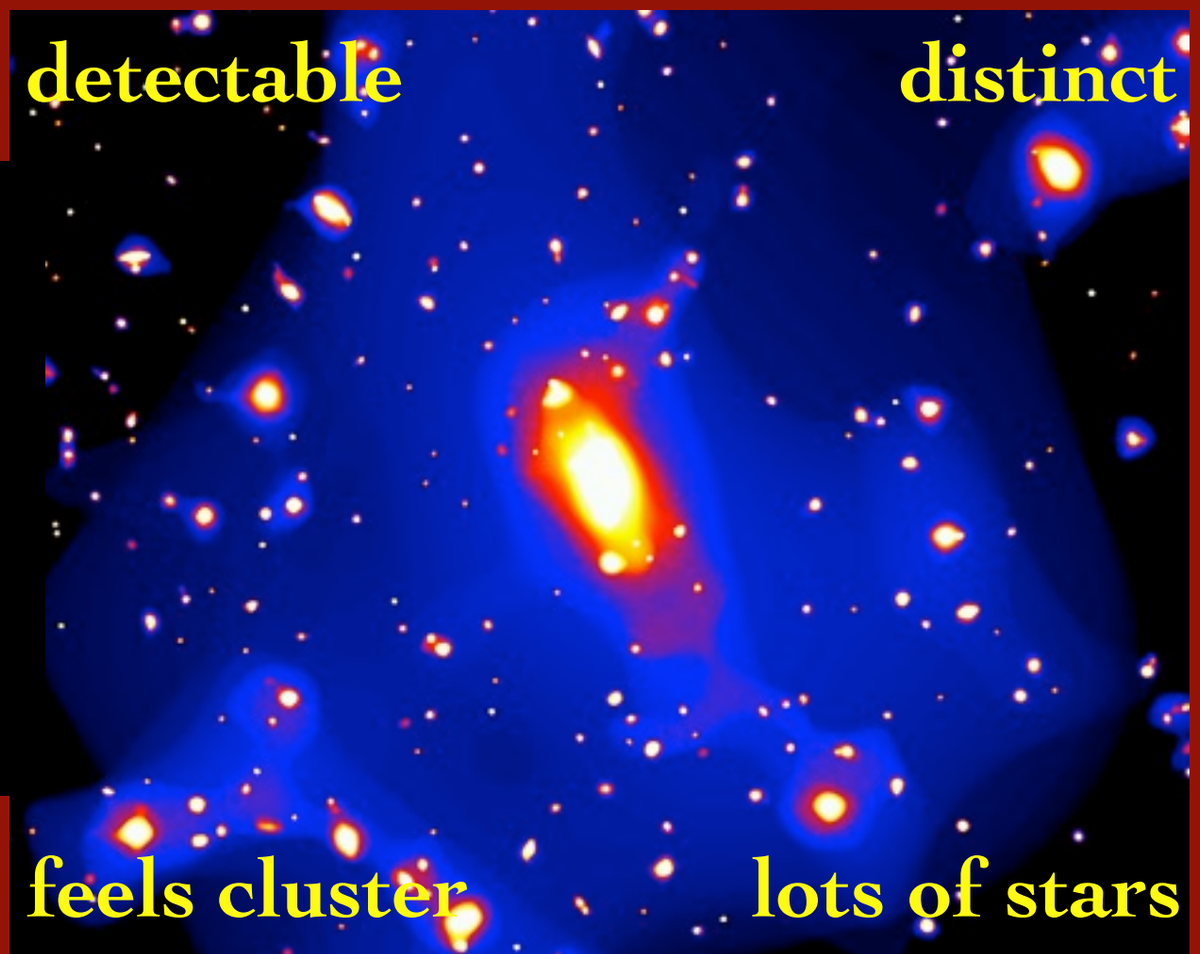




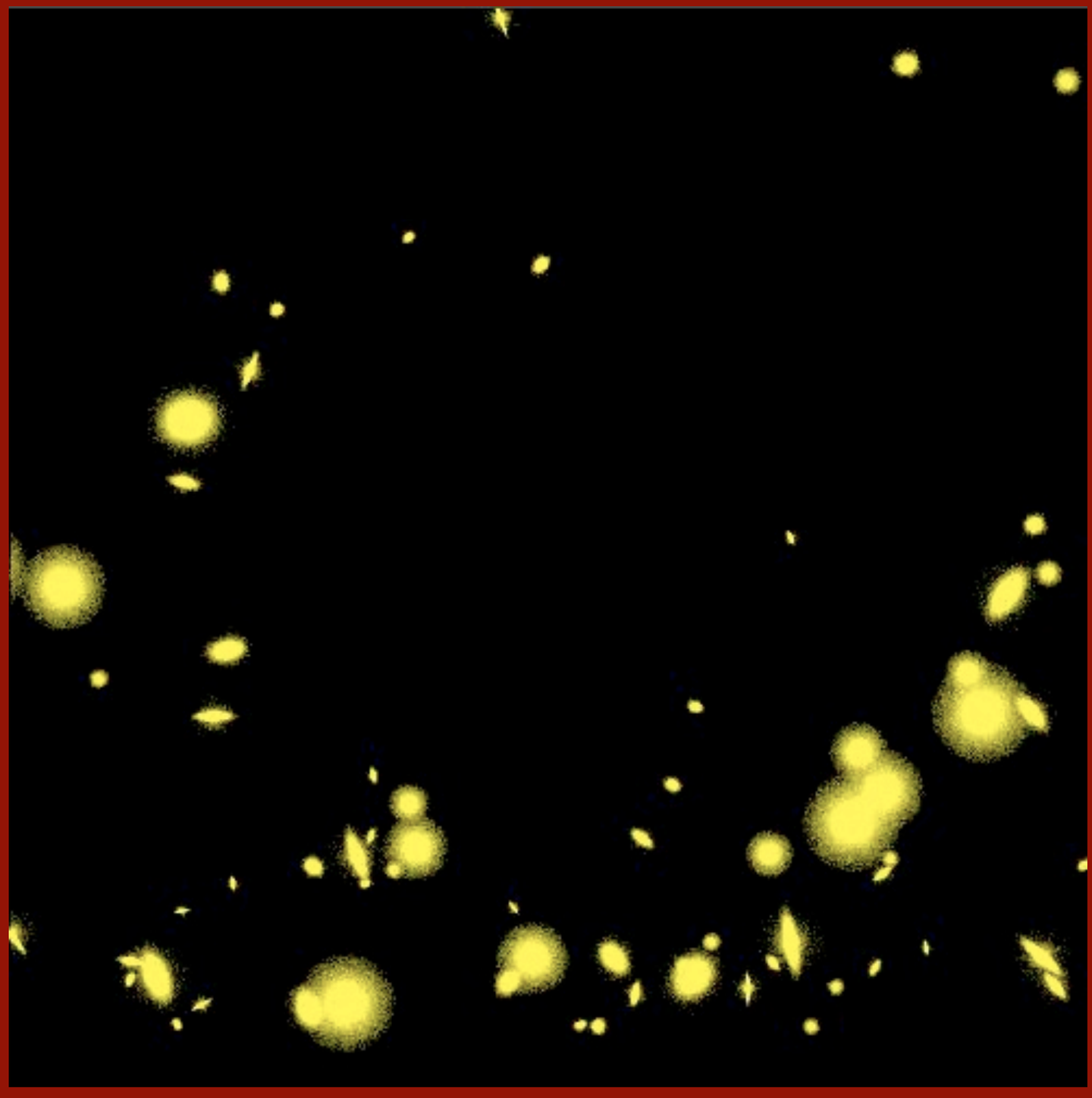
Intracluster Stars and Structure Evolution

account for *all* baryons

intracluster stars hard to count, but significant

trace potential, enrich cluster gas, address missing baryons and lack of bright LF evolution, constrain star formation efficiency, trends impact cluster cosmology

arise in groups?



C. Mihos & C. McBride

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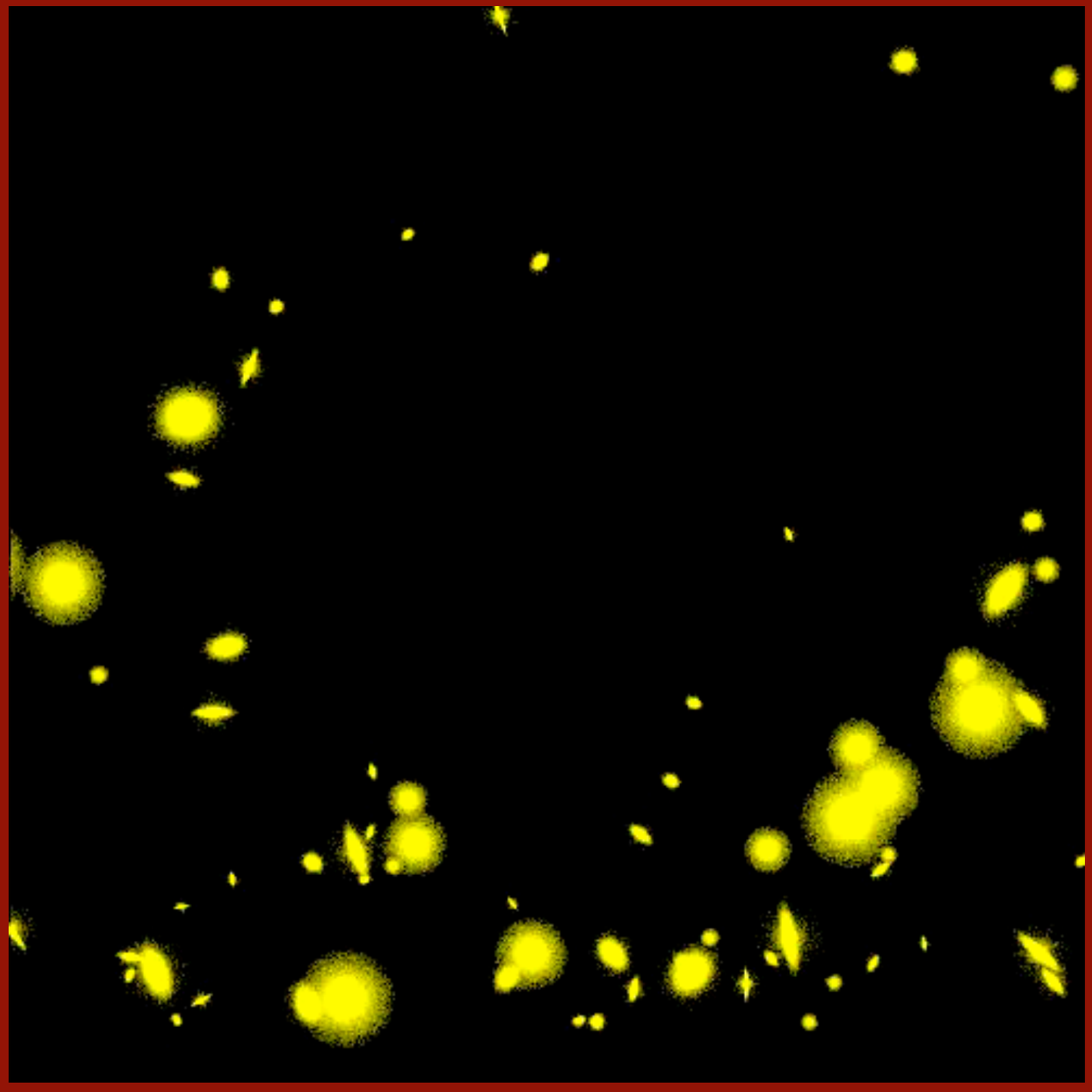
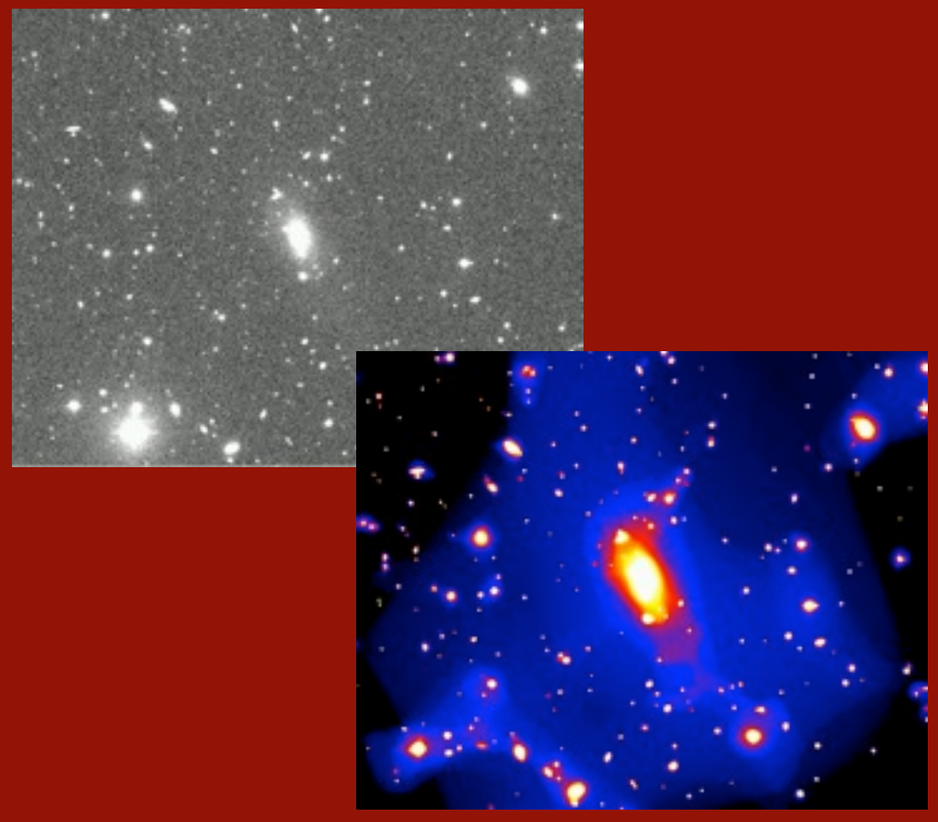


C. Mihos & C. McBride

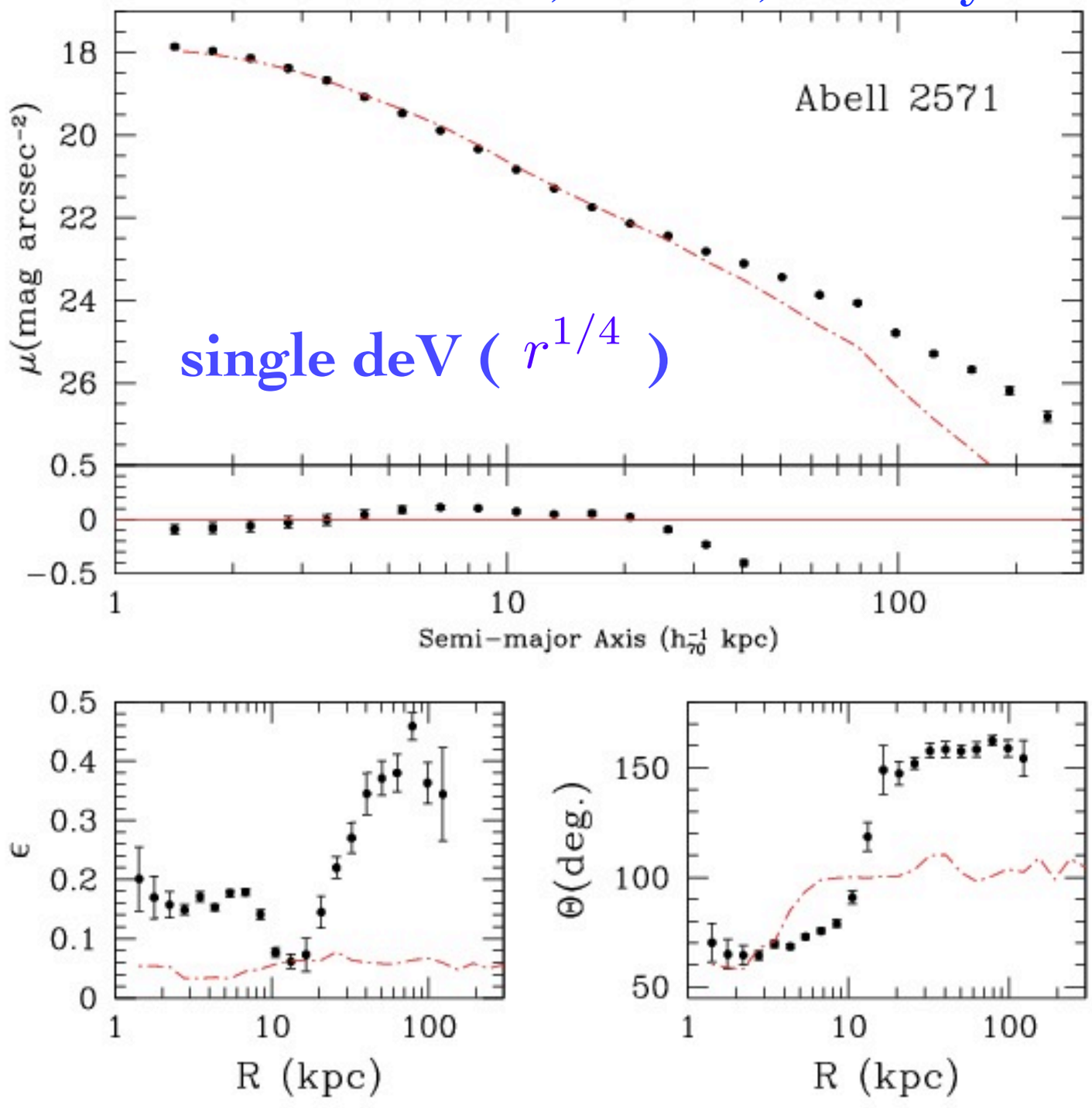
Detection of Intracluster Starlight

2-D fit with single deV profile poor at large R

fails on ellipticity and position angle profiles



Gonzalez, Zabludoff, & Zaritsky 2005

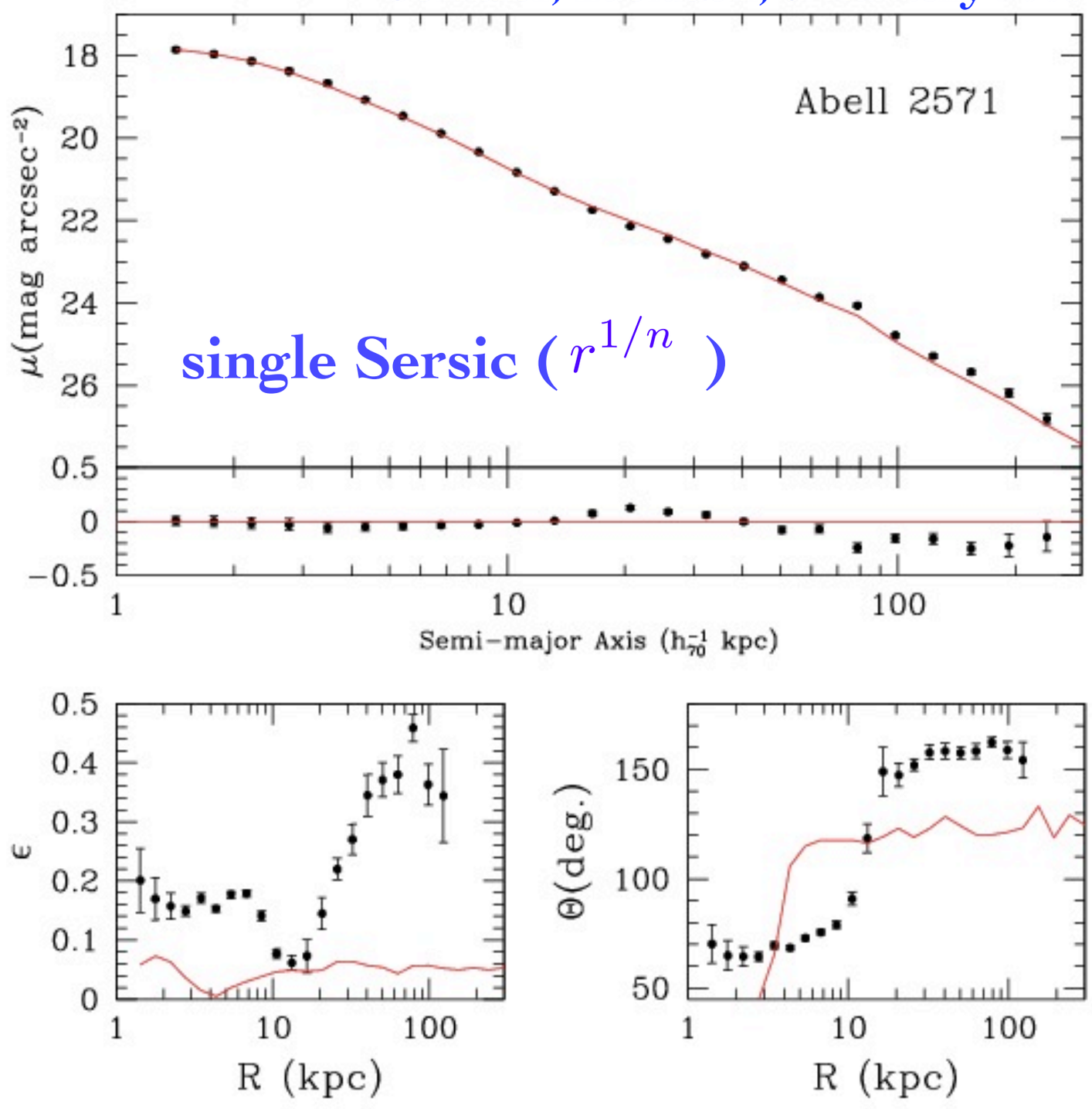


Detection of Intracluster Starlight (cont.)

2-D fit with single Sersic profile better

fails on ellipticity and position angle profiles

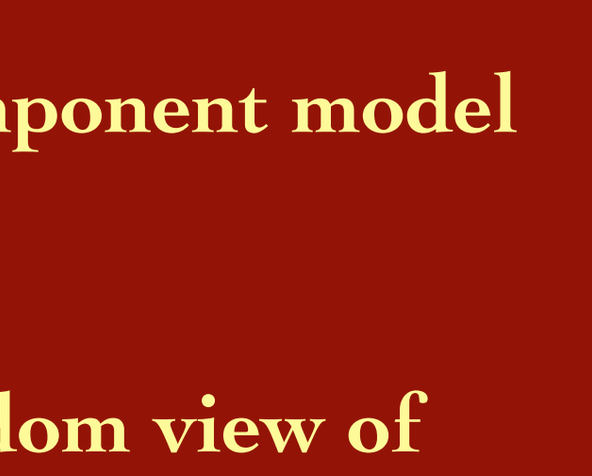
Gonzalez, Zabludoff, & Zaritsky 2005



Detection of Intracluster Starlight (cont.)

two component model best fit

not random view of triaxial system



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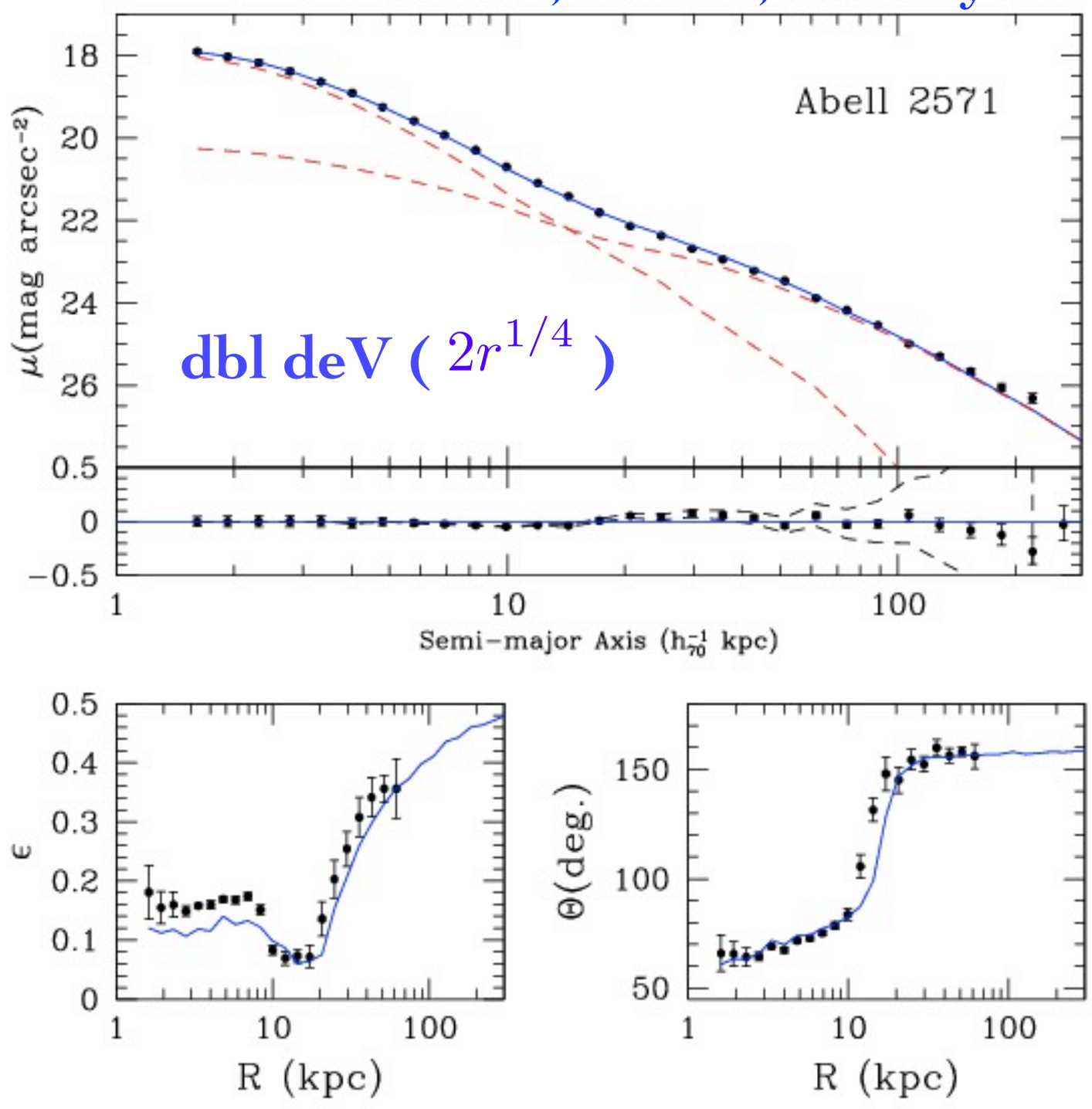


Properties of Intracluster Starlight: Summary

distinct, ubiquitous

80-90% of two components (~40% of total stars within r_{500})

aligned with brightest cluster galaxy (BCG), but exceptions

10-40x bigger than BCG, ~cluster halo

more elliptical than BCG, ~cluster members

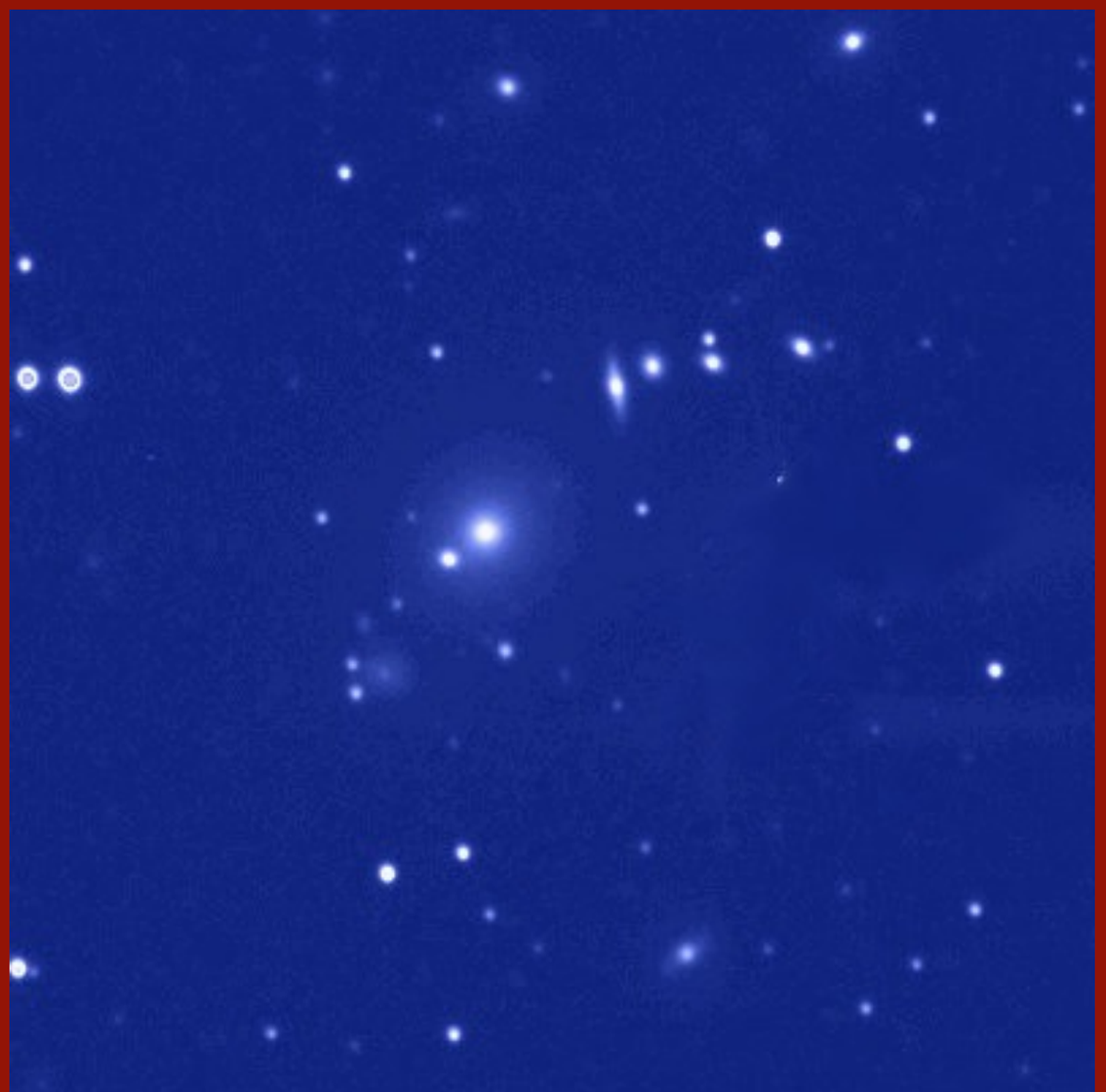
responds to cluster potential (velocity dispersion rises)

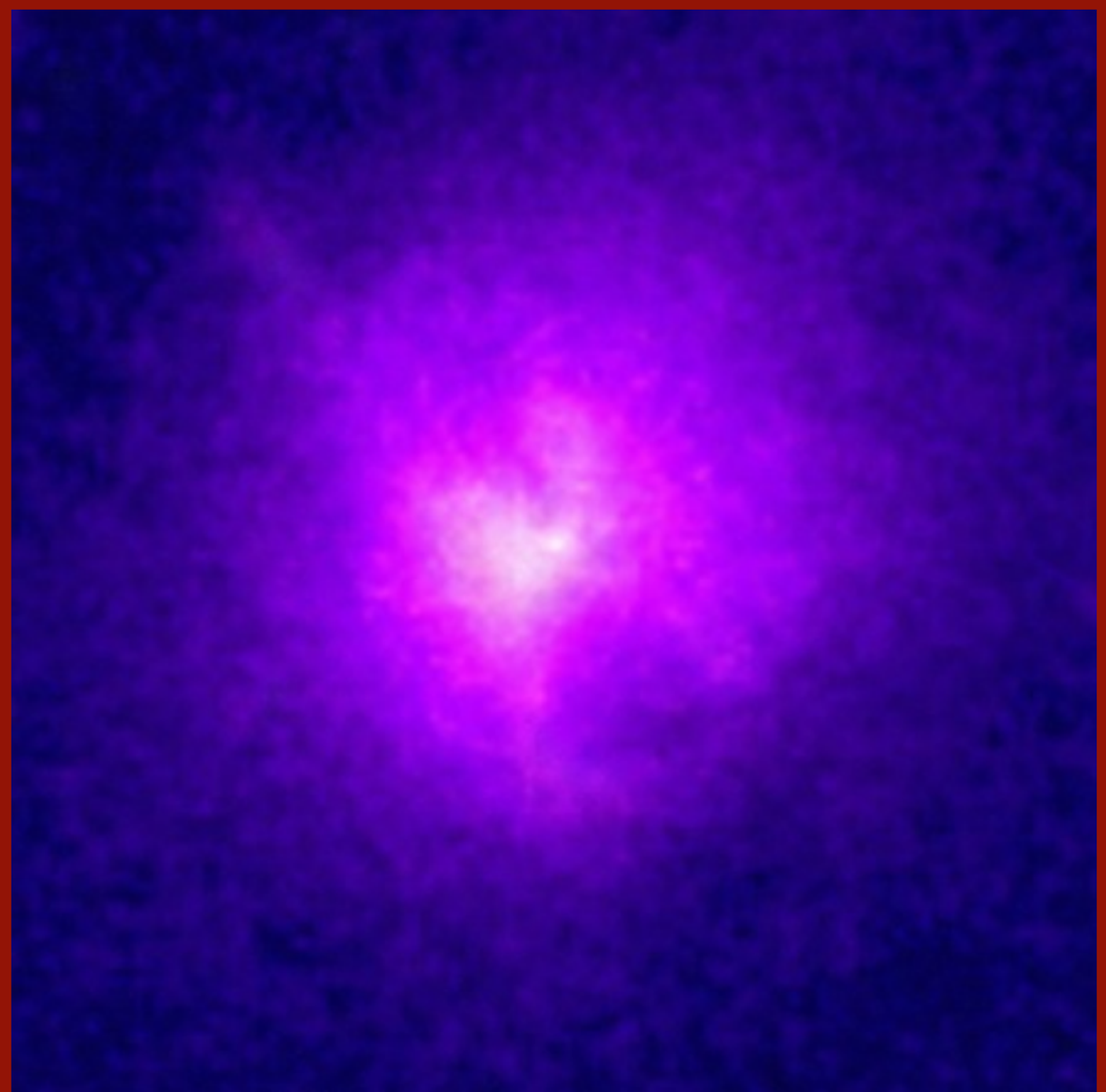
dynamically-relaxed, old stars, metal-poor progenitors ==> formed early, growth slowed

Enrichment of Intracluster Medium

[Fe/H] ~ 0.3 solar hard via galactic winds,

but intracluster stars deposit all their metals

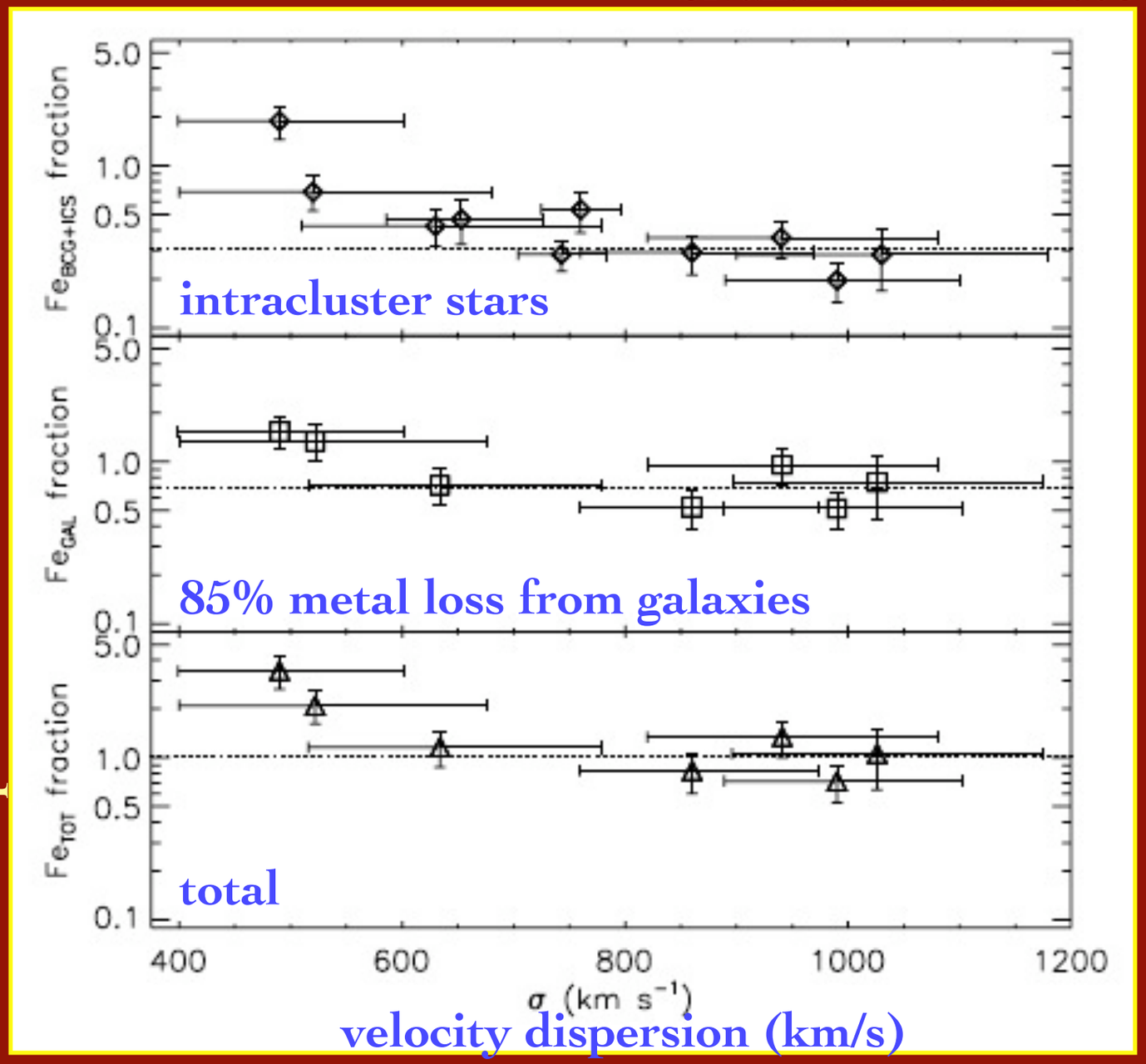




evolve old population (= L_{ICL}), SNe and Fe at z, integrate over z

Enrichment of Intracluster Medium (cont.)

Sivanandam et al. 2008

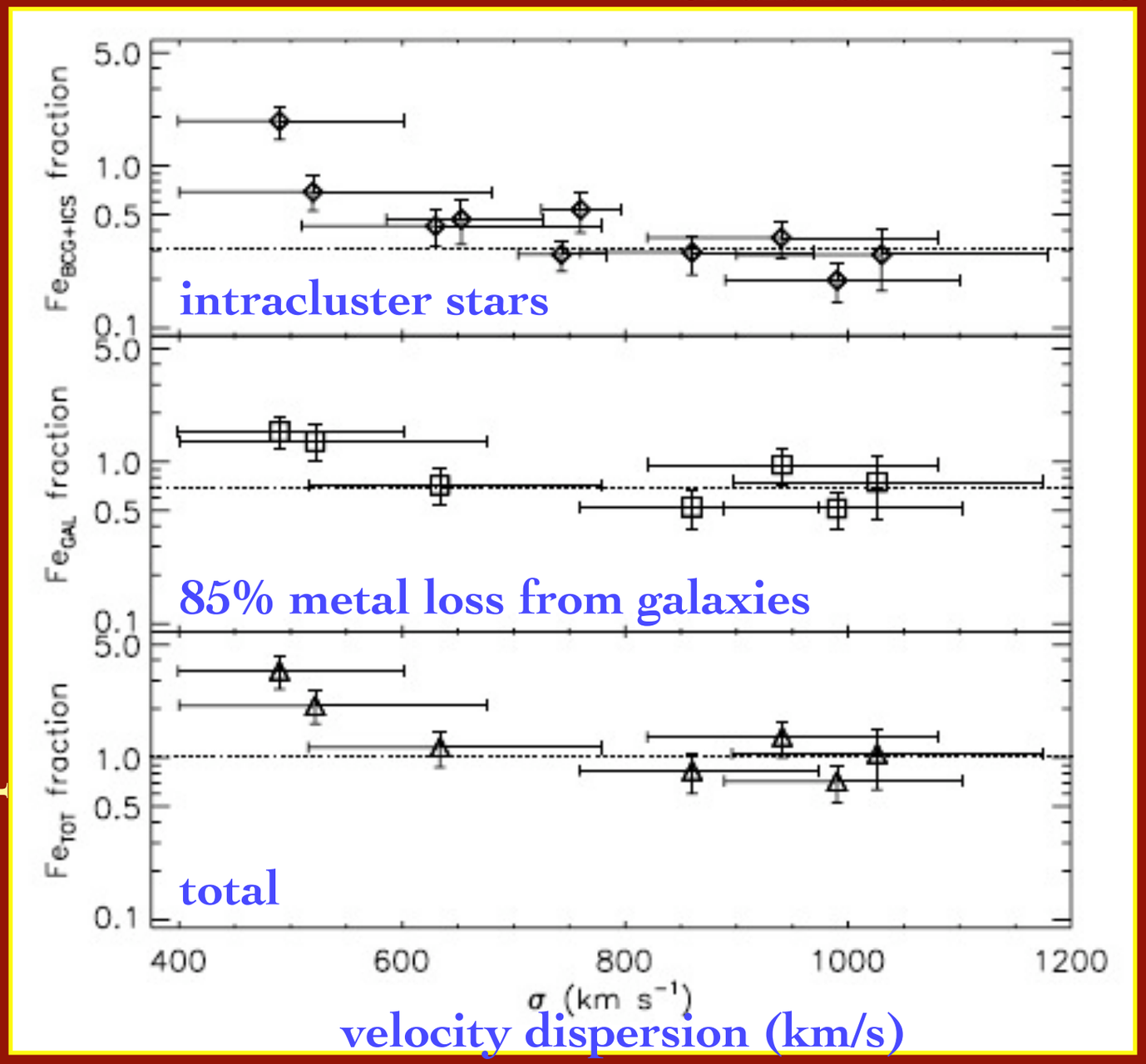


~30% of Fe within r_{500}

need galaxies + intracluster stars, but 85% metal loss?

Enrichment of Intracluster Medium (cont.)

Sivanandam et al. 2008



~30% of Fe within r_{500}

need galaxies + intracluster stars, but 85% metal loss?

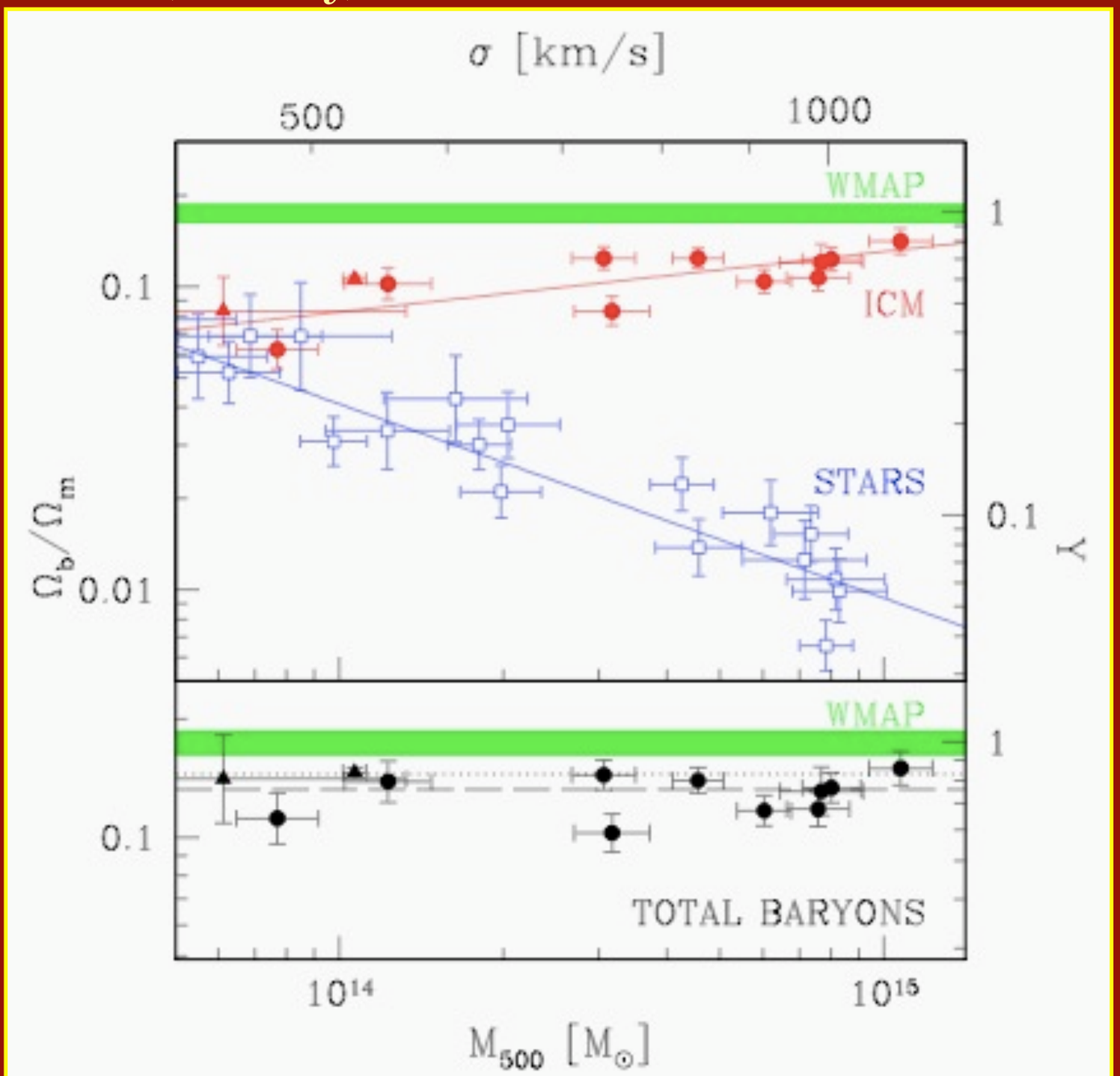
SN Ia rate upper-bound gives 35% metal loss

can now account for all Fe

what about trend? SN Ia rate change with environment?

Baryon Budget of Clusters

Gonzalez, Zaritsky, & Zabludoff 2007



baryon fraction within 20% of WMAP

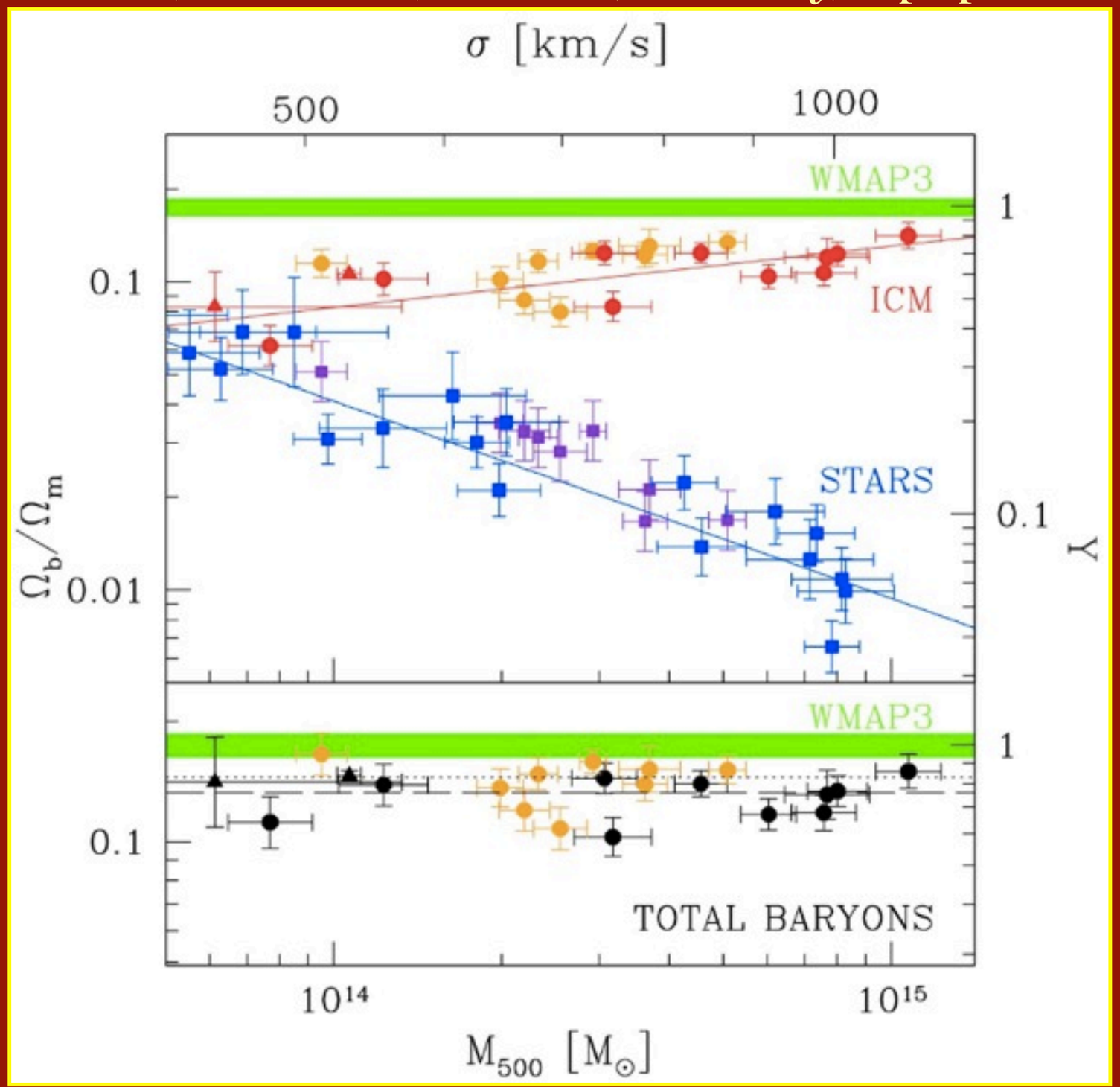
constant from groups to clusters

little if any undetected component

gas up, stars down ==> star formation efficiency down

Baryon Budget of Clusters

Gonzalez, Sivanandam, Zabludoff, & Zaritsky, in prep.



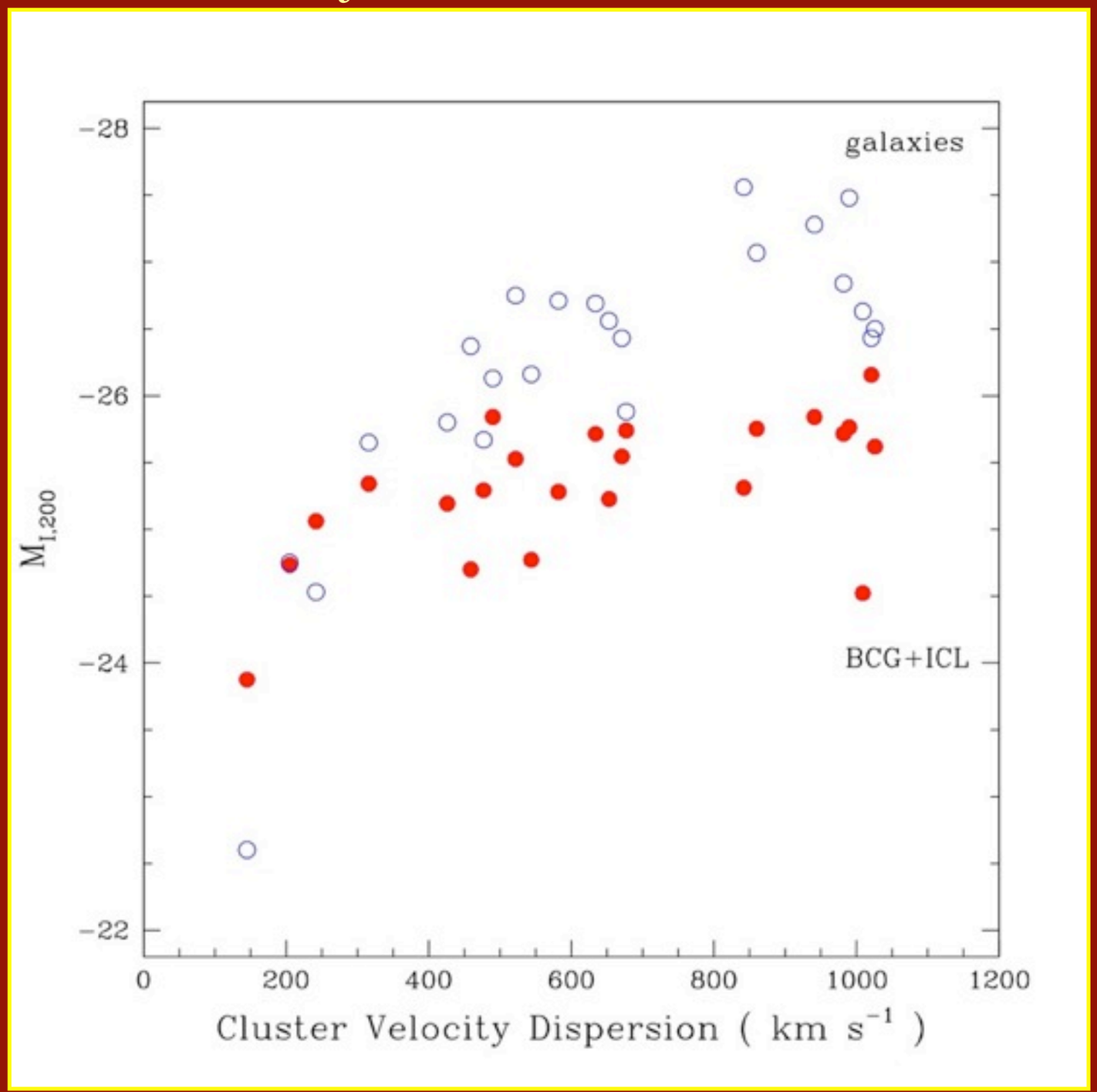
new results for uniform X-ray, optical measurements of 8 systems

~same values, trends as before

now within ~10% of Universal

Apportionment of Cluster Stellar Baryons

Gonzalez, Zaritsky, & Zabludoff 2007

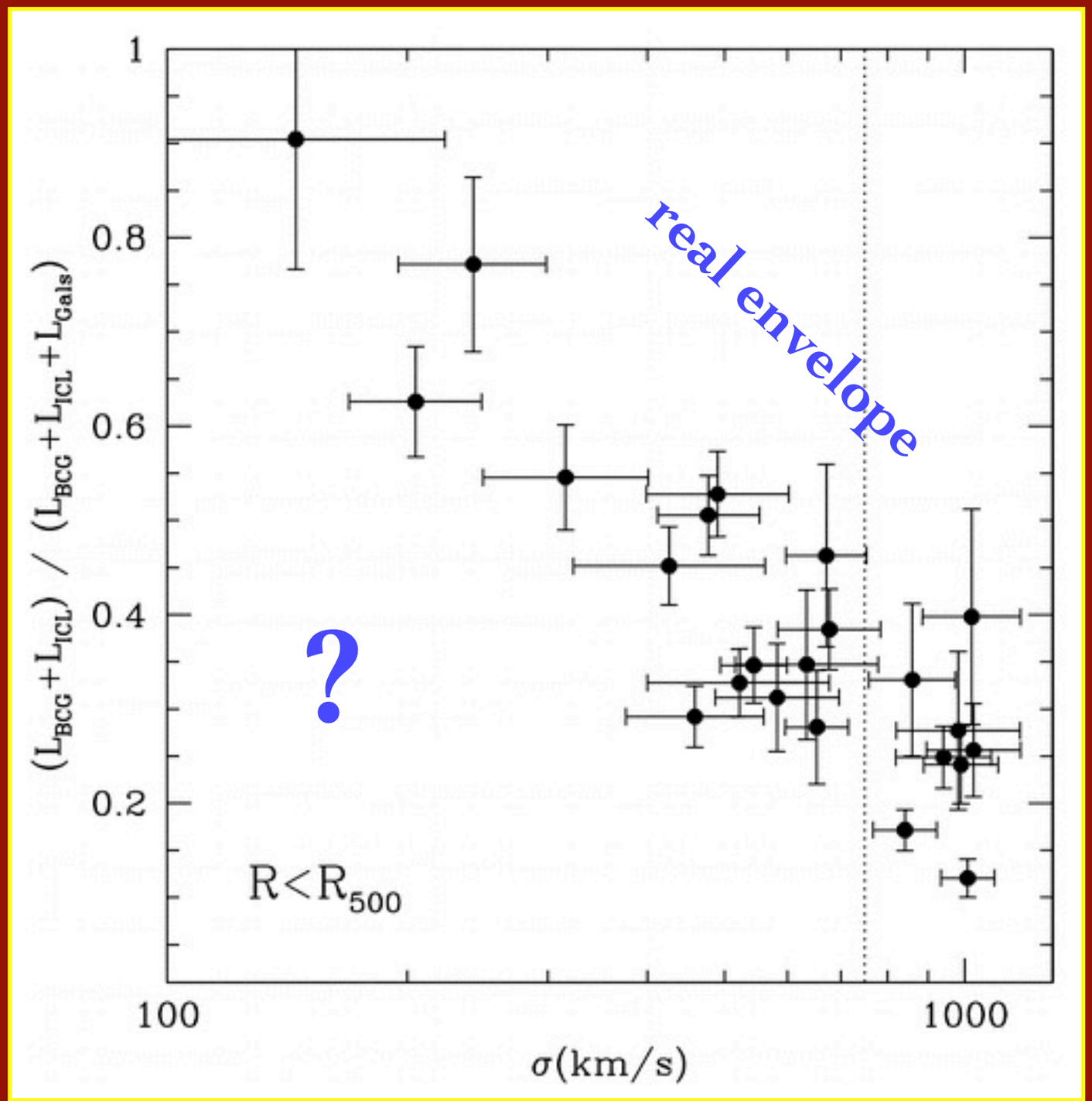


intracluster stars rise slower than galactic stars

reason that total stars rise more slowly than total mass

Apportionment of Cluster Stellar Baryons (cont.)

Gonzalez, Zaritsky, & Zabludoff 2007



intracluster stars rise slower than galactic stars

fewer intracluster stars, more galactic stars ==> less efficient stripping?

intracluster stars do not need cluster

selection effects? do other groups have our ICL fractions?

Conclusions

intracluster starlight: distinct, significant, tracer of cluster potential, old

intracluster metals: from stars in and out of galaxies

baryon fraction: ~Universe, constant with mass, not missing many baryons

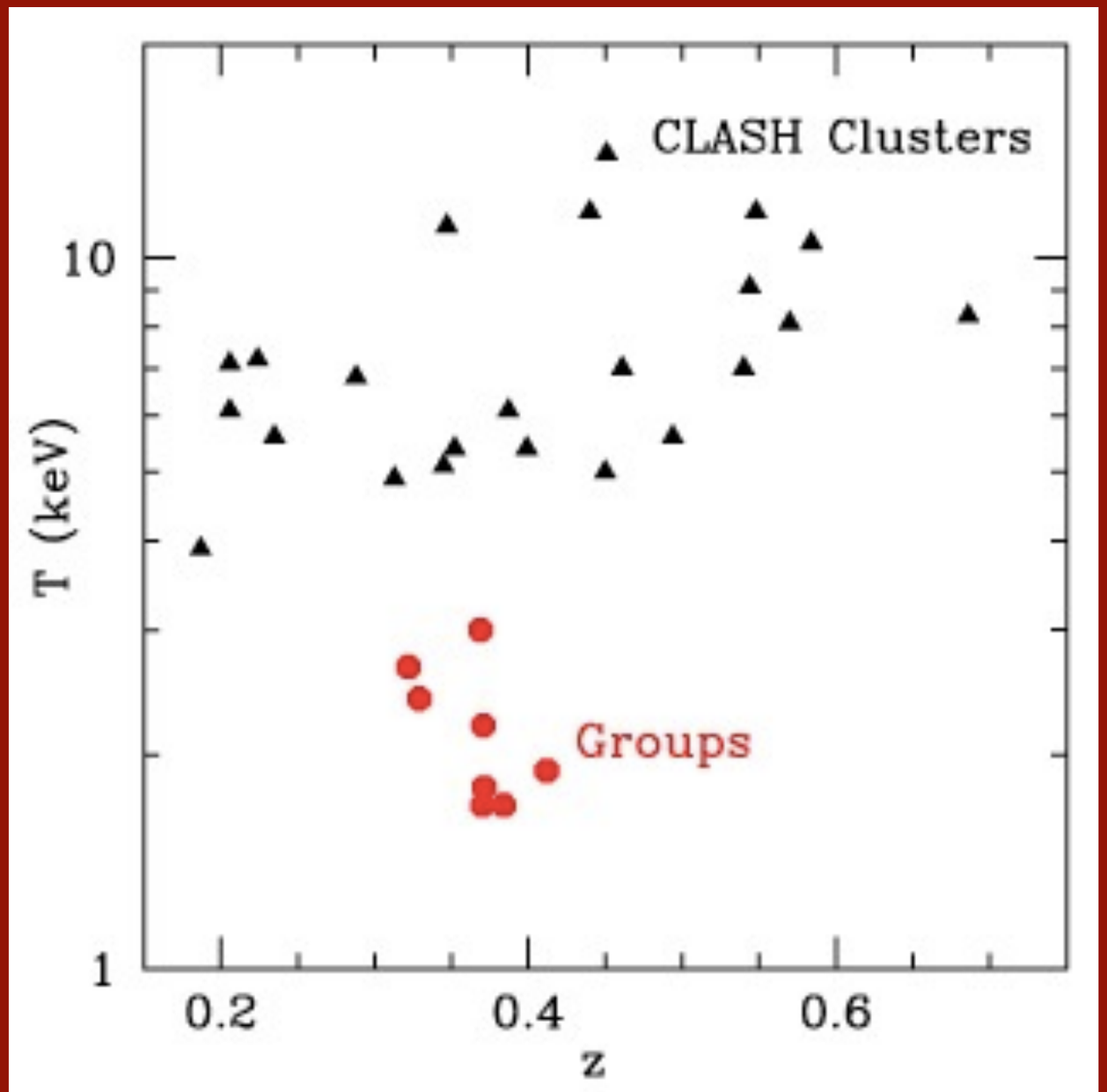
Conclusions

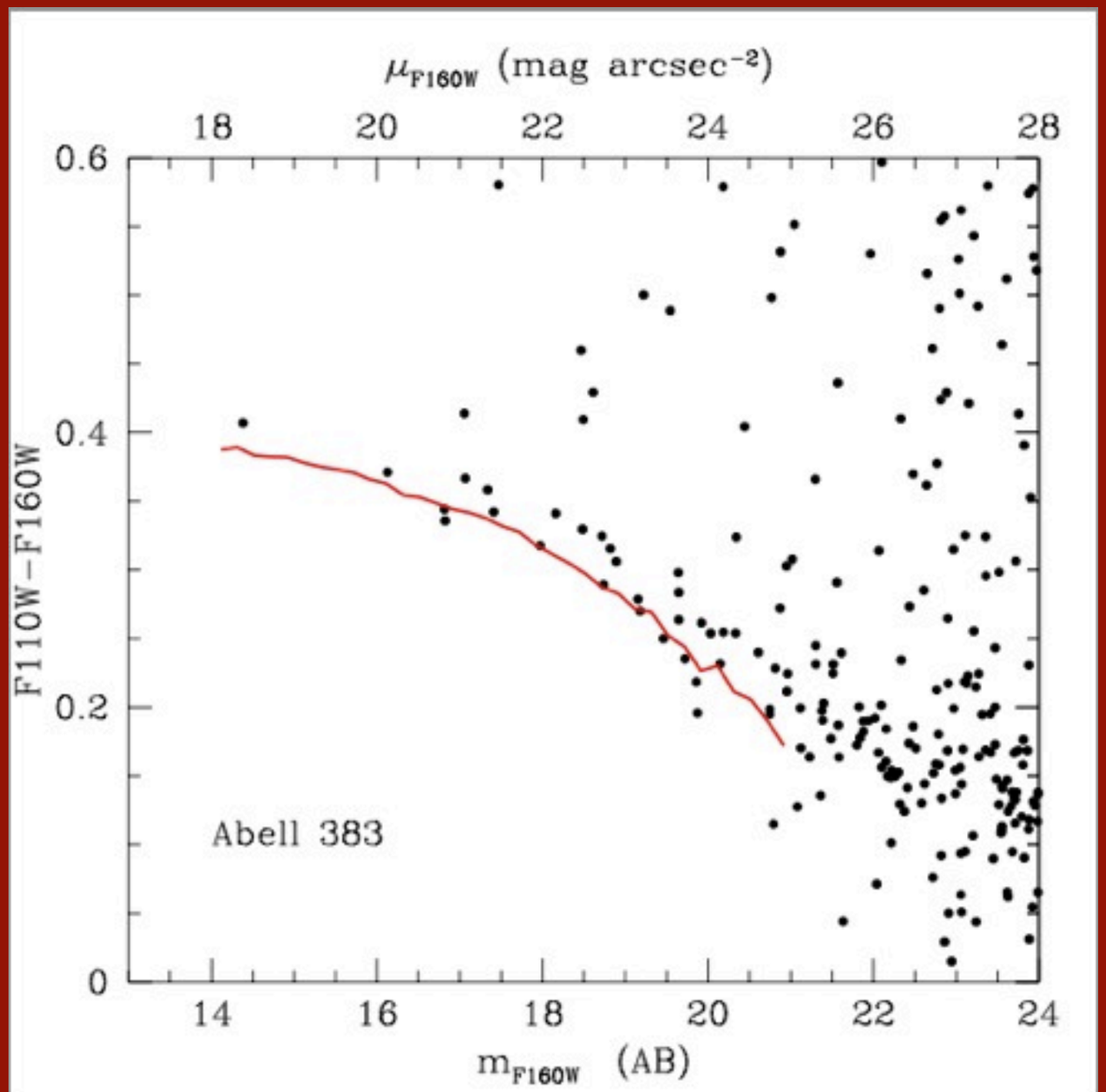
baryon phases: more gas, fewer stars vs. mass
(star formation efficiency decreases)

fewer intracluster stars, more galactic stars
vs. mass
(early formation, growth via stripping stalled)

Conclusions

sampling intracluster stars, gas of lower mass groups with HST WFC3/IR, XMM critical





Conclusions

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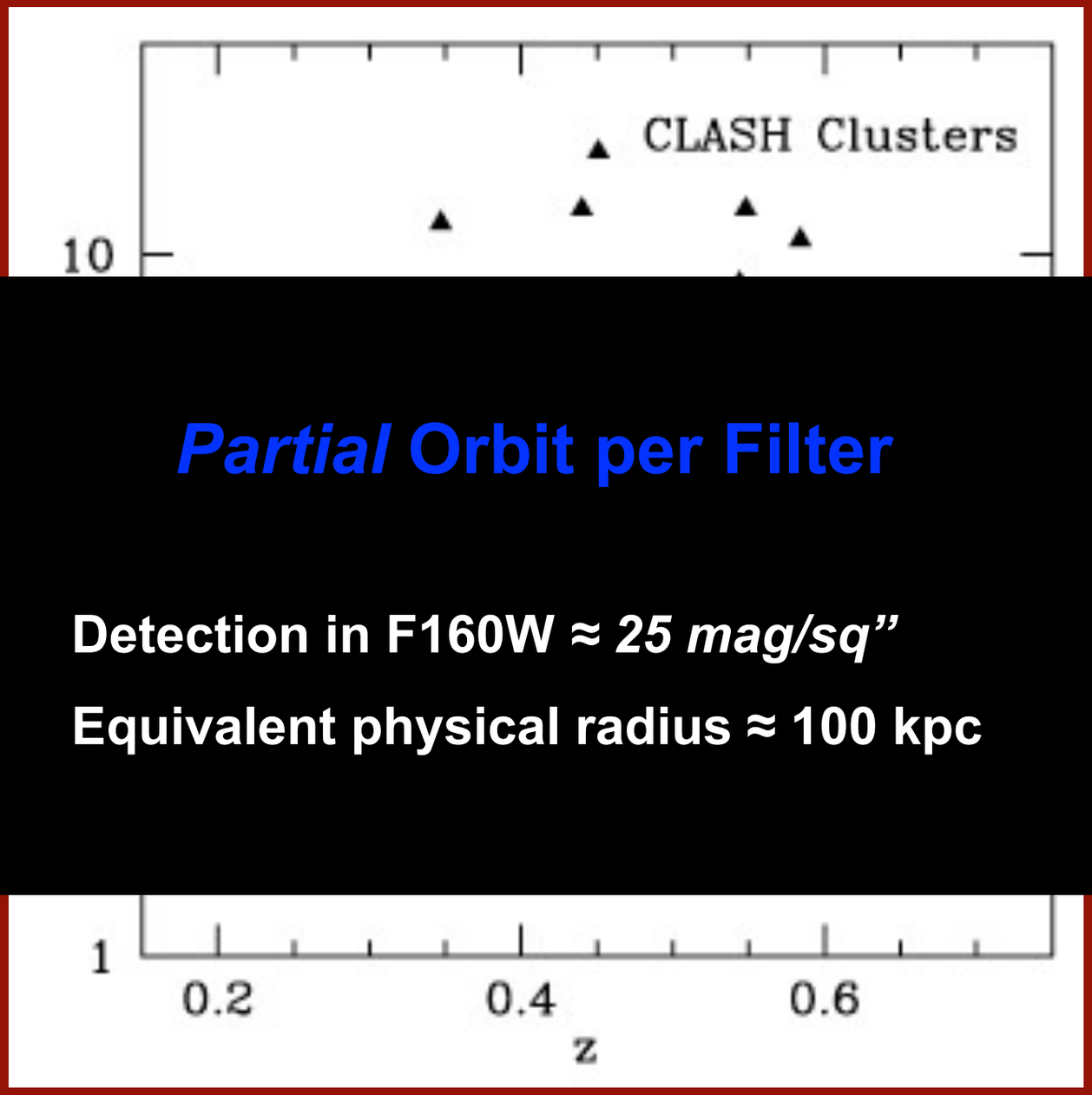
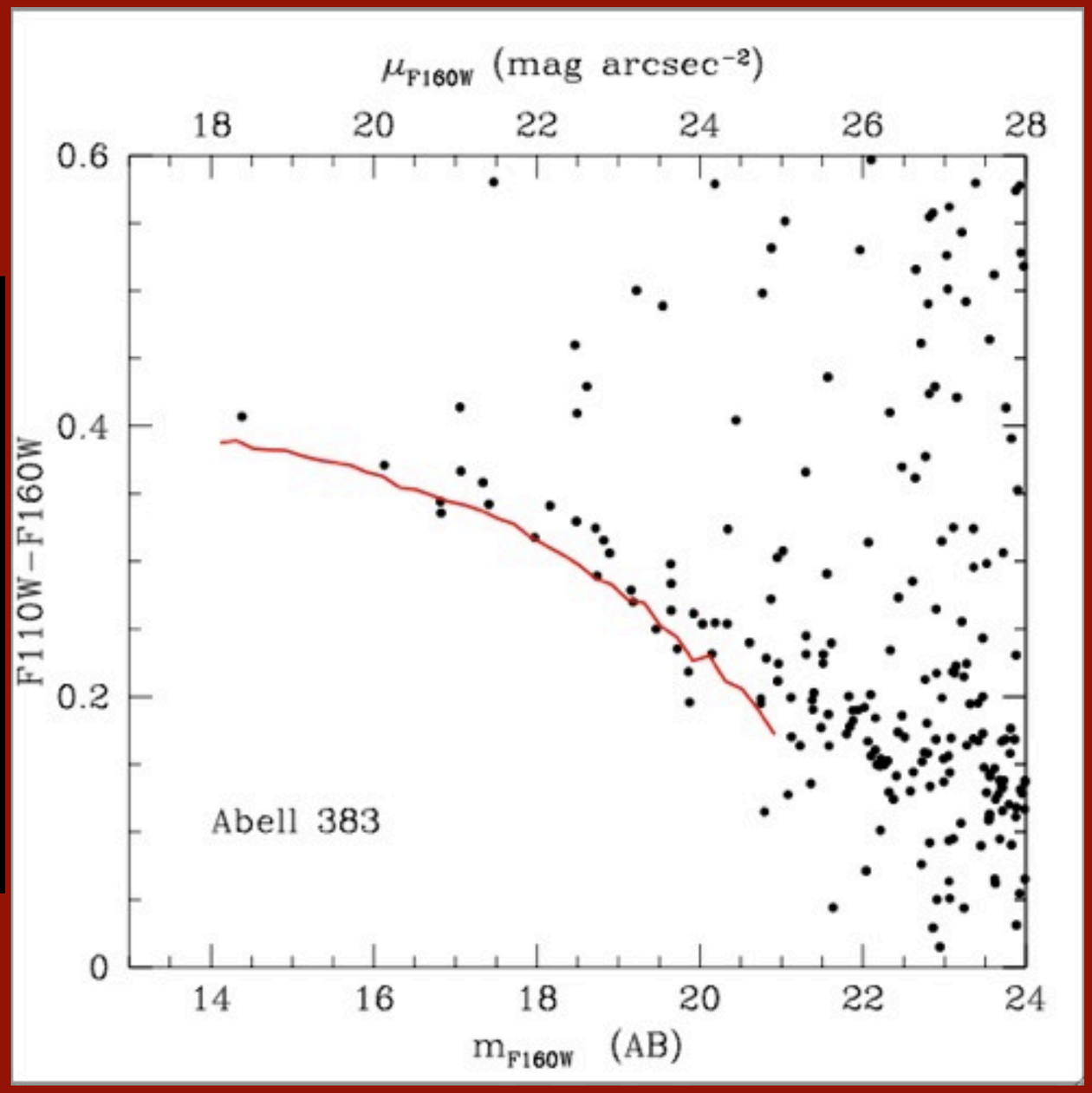


Partial Orbit per Filter

Detection in F160W ≈ *25 mag/sq”*

Equivalent physical radius ≈ 100 kpc



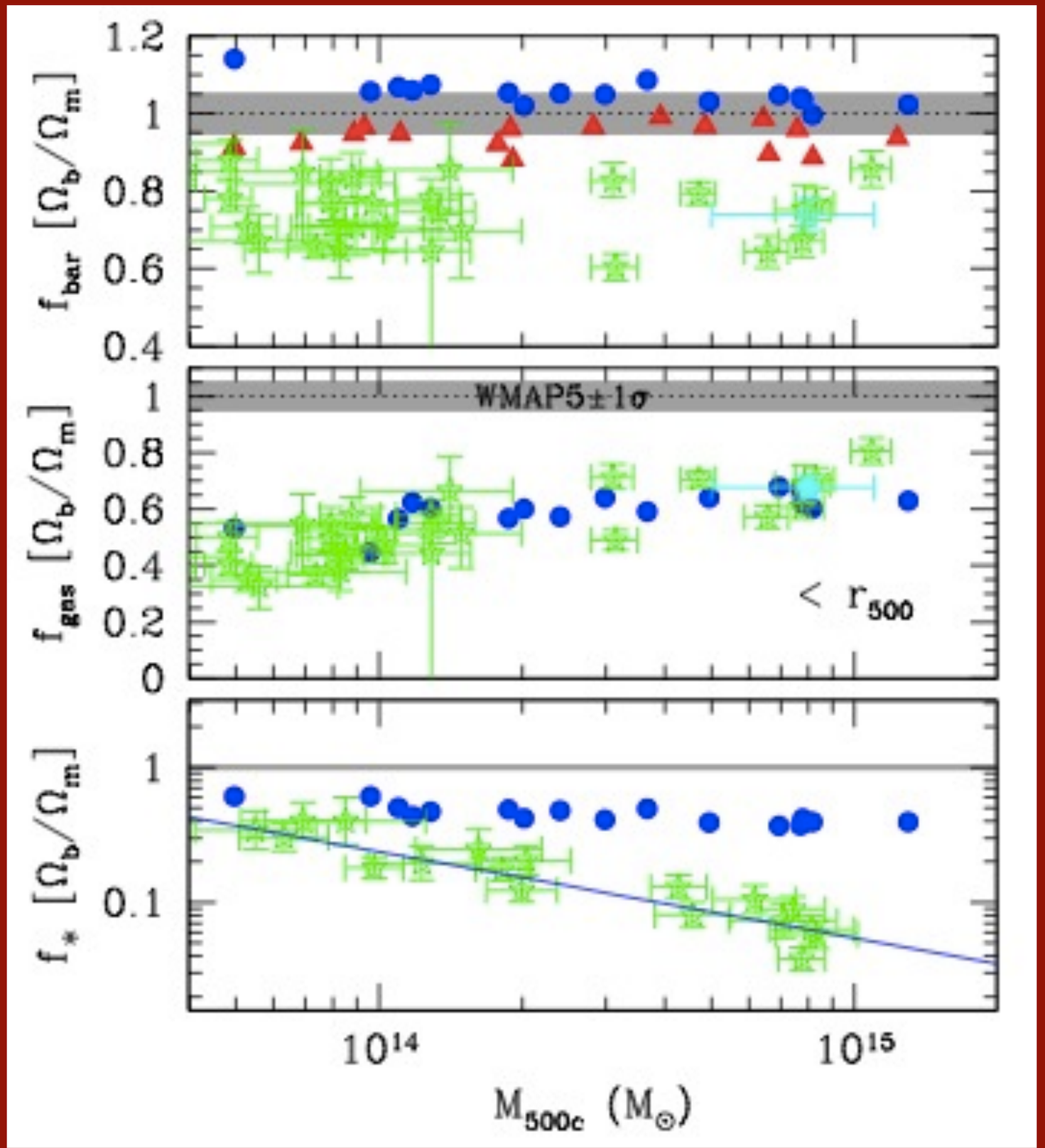
Conclusions

models need to match baryon trends (Kravtsov)

implications for cluster cosmology: 1) stellar mass rises slower than cluster mass, 2) X-ray luminosity rises faster than cluster mass

breaks self-similar relation between X-ray and SZ observables, fair sample hypothesis (Vikhlinin)

Comments on Baryon Fraction vs. Mass

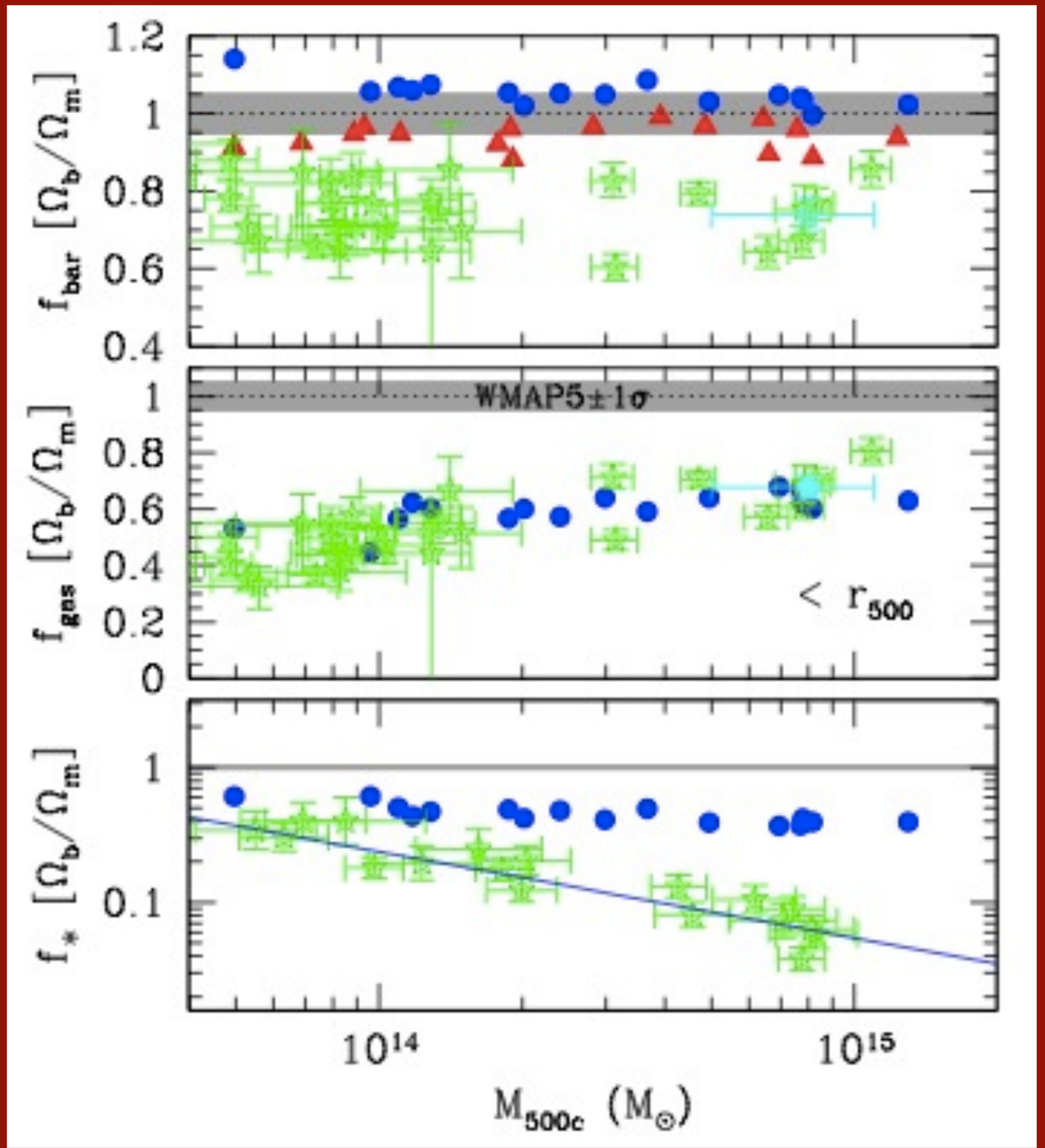


cooling problem/
missing physics, or...

missing stellar baryons in clusters? not too many or super-WMAP!
many fewer in groups?

missing galactic stars, missing ICL (Puchwein), non-representative clusters

Comments on Baryon Fraction vs. Mass



fraction of stars in ICL and its declining trend with mass confirmed by intracluster SNe (Sand et al.)

studies with shallower stellar baryon fraction slopes assume fraction of stars in ICL is constant or zero

cannot assume either

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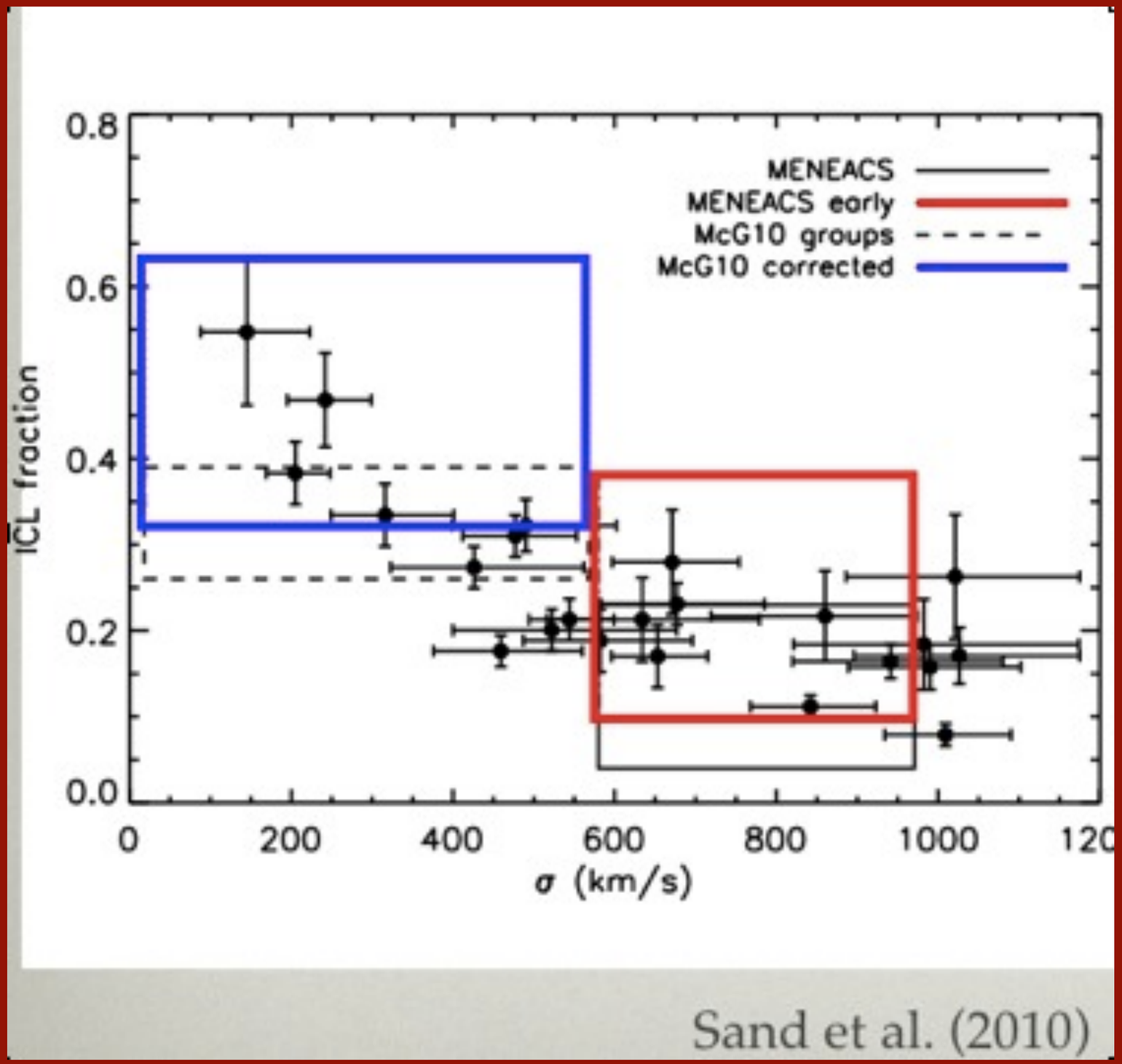

Sand et al. (2010)

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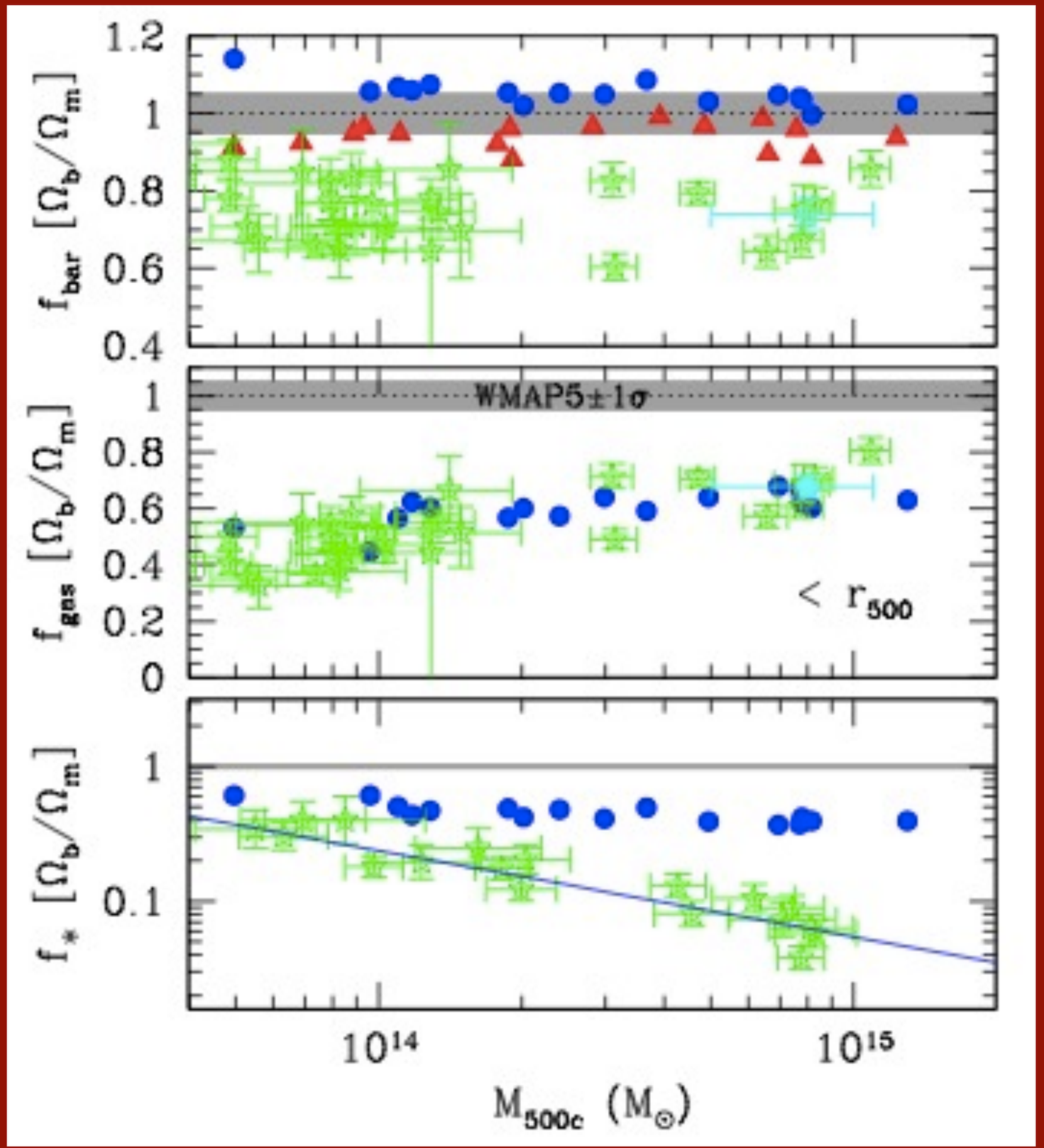


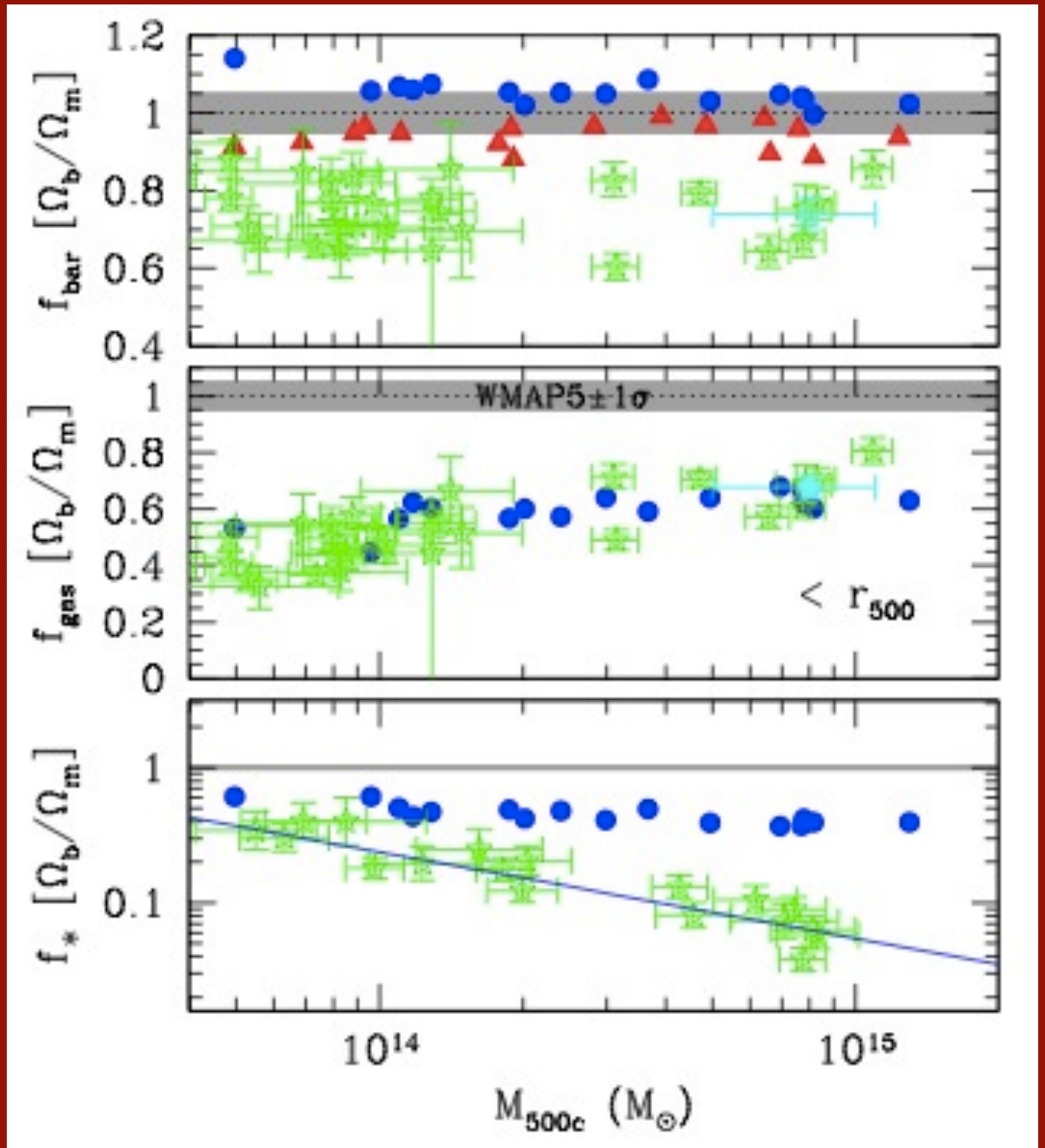
not missing ICL

unlikely that we miss many more galactic stars in clusters than groups

so, could cluster sample be unrepresentative?

big BCG, more relaxed ==> fewer total stars?

Comments on Baryon Fraction vs. Mass



simulations must select similar systems for comparison

other samples/methods get steep stellar baryon slope, if ICL included or in region of little ICL (Andreon)

what about model gas fraction?