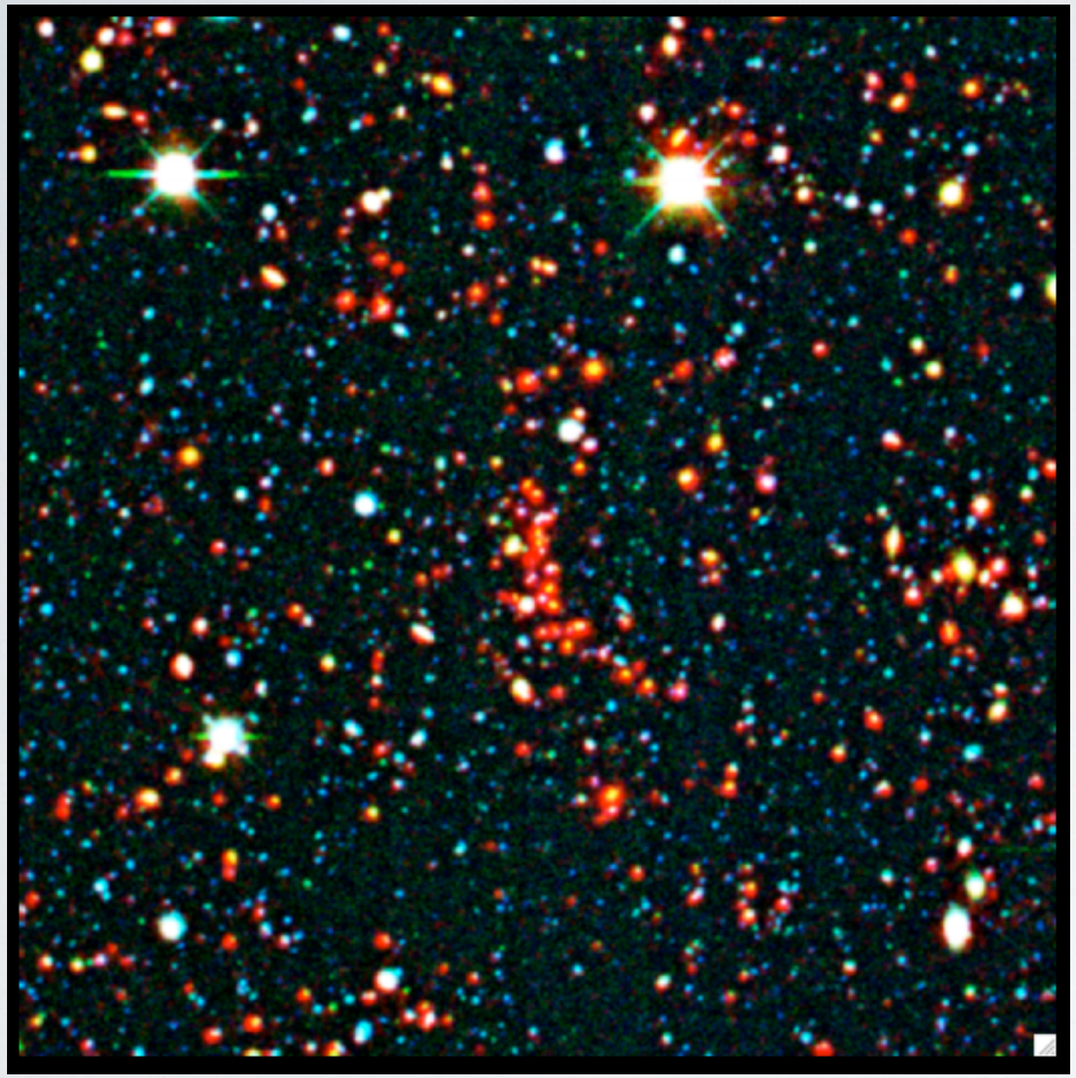


z = 1.243 (Eisenhardt+08)

THE EFFECTS OF ENVIRONMENT IN Z=1-2 GALAXY CLUSTERS

Stacey Alberts

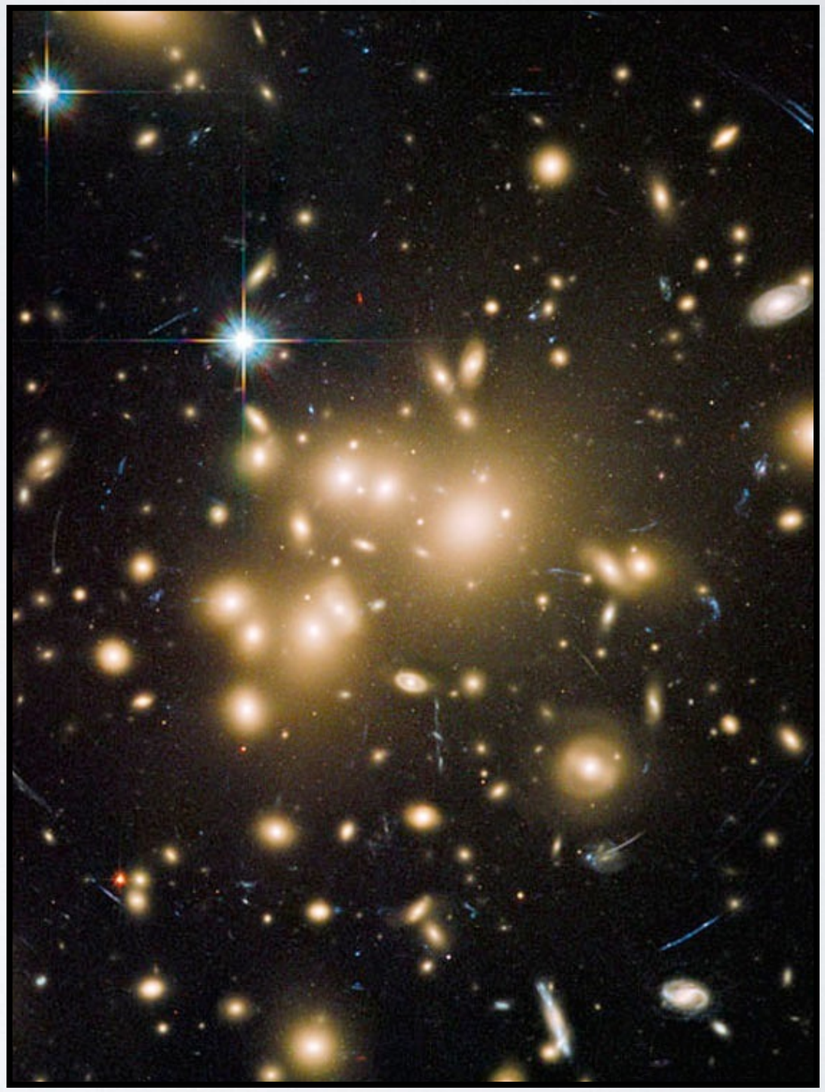
Transformational Science in the Era of ALMA: Multi-Wavelength Studies of Galaxy Evolution
Charlottesville, VA 2014

Galaxy properties are linked to environment...

Can we identify an epoch of active star formation in clusters cores?

What does this transition tell us about galaxy evolution?

(credit: NASA, ESA, Hubble Heritage Team, J.Blakeslee, H. Ford)



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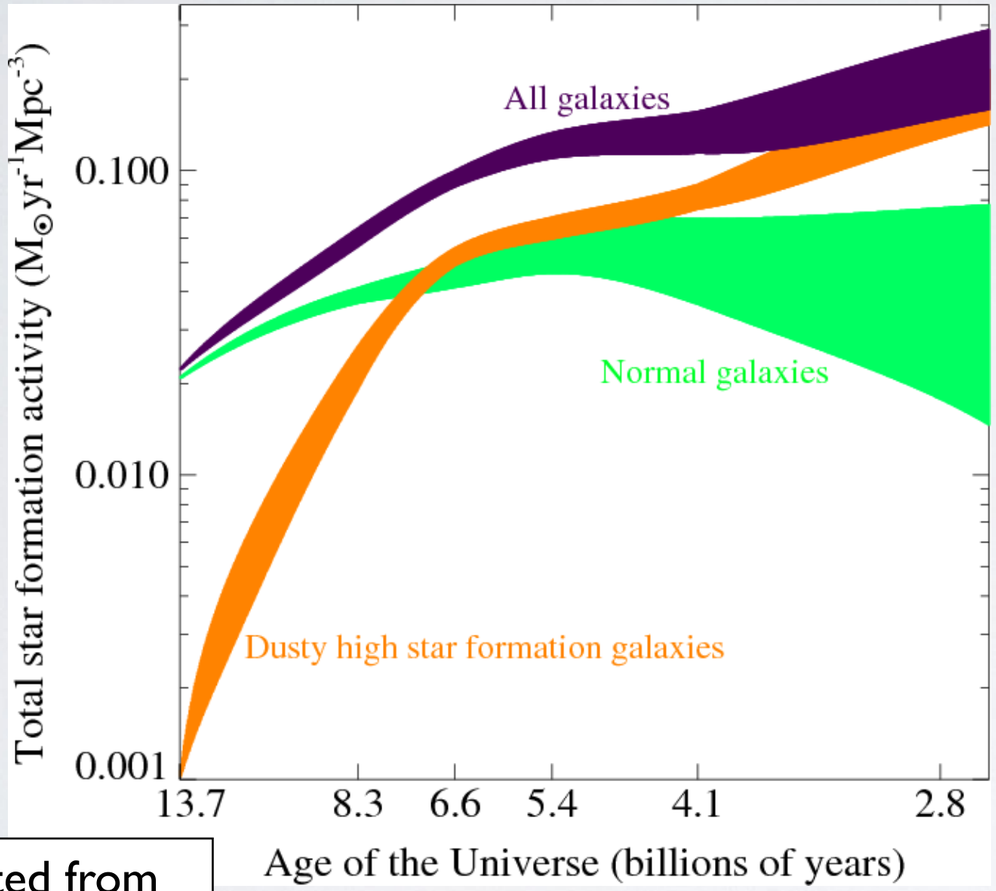
THE EPOCH OF STAR FORMATION IN CLUSTERS



Adapted from Murphy+11

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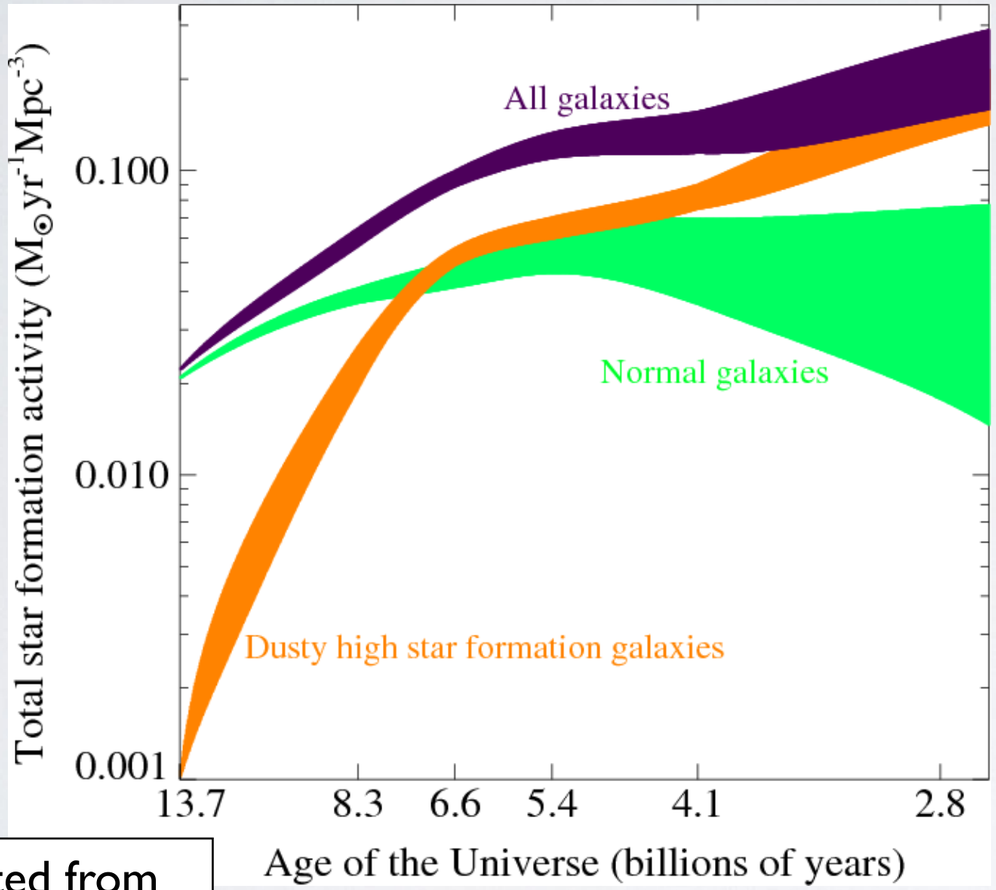
University of Massachusetts

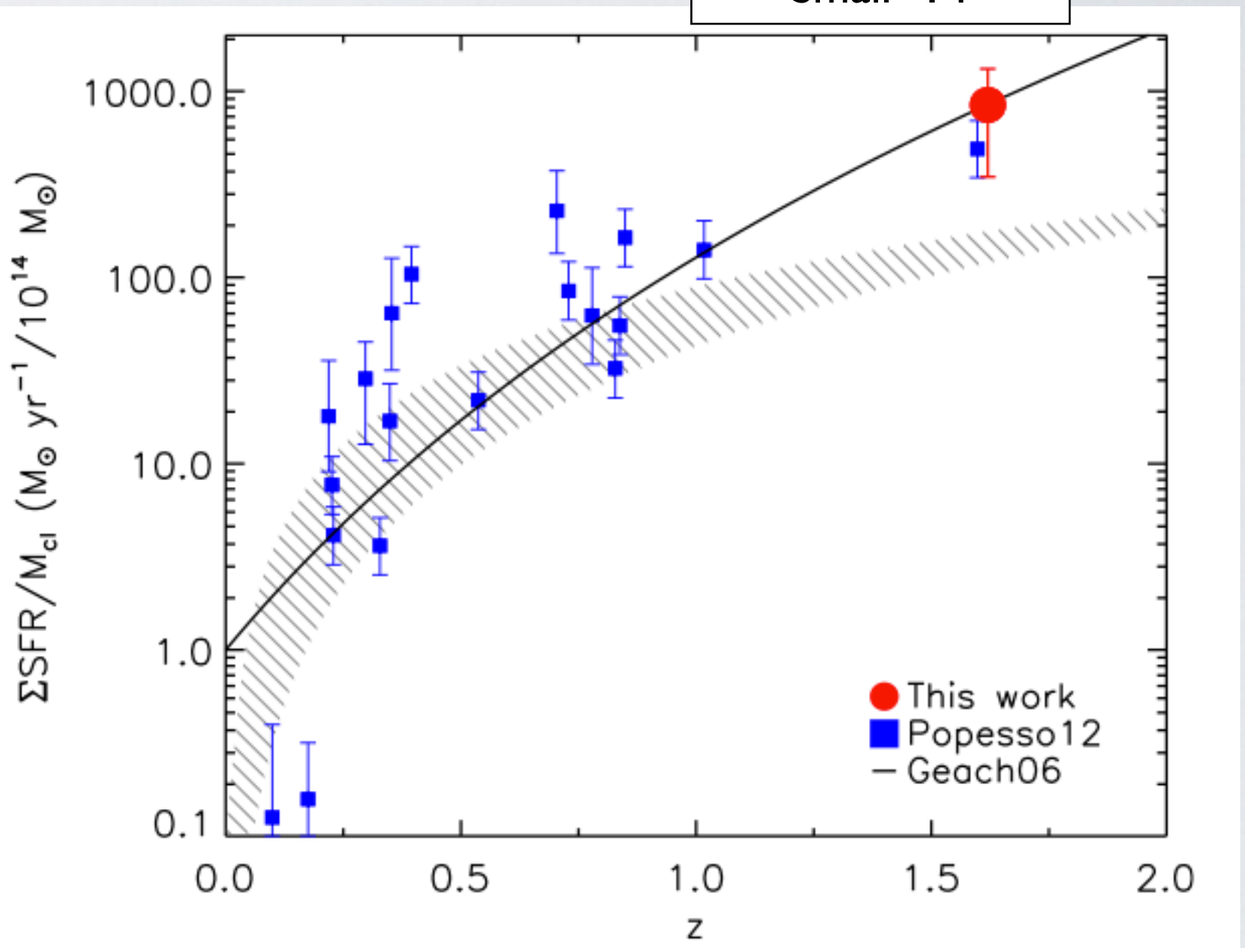
THE EPOCH OF STAR FORMATION IN CLUSTERS

at z~1, SF still quenched in cluster cores...



Adapted from Murphy+11

Smail+14



Individual clusters show increased SF fraction in clusters at z>1.4 (e.g. Tran+10, Hilton+10, Hayashi +11, Fassbender+11, Santos+14, and more)

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University of Massachusetts

THE EPOCH OF STAR FORMATION IN CLUSTERS

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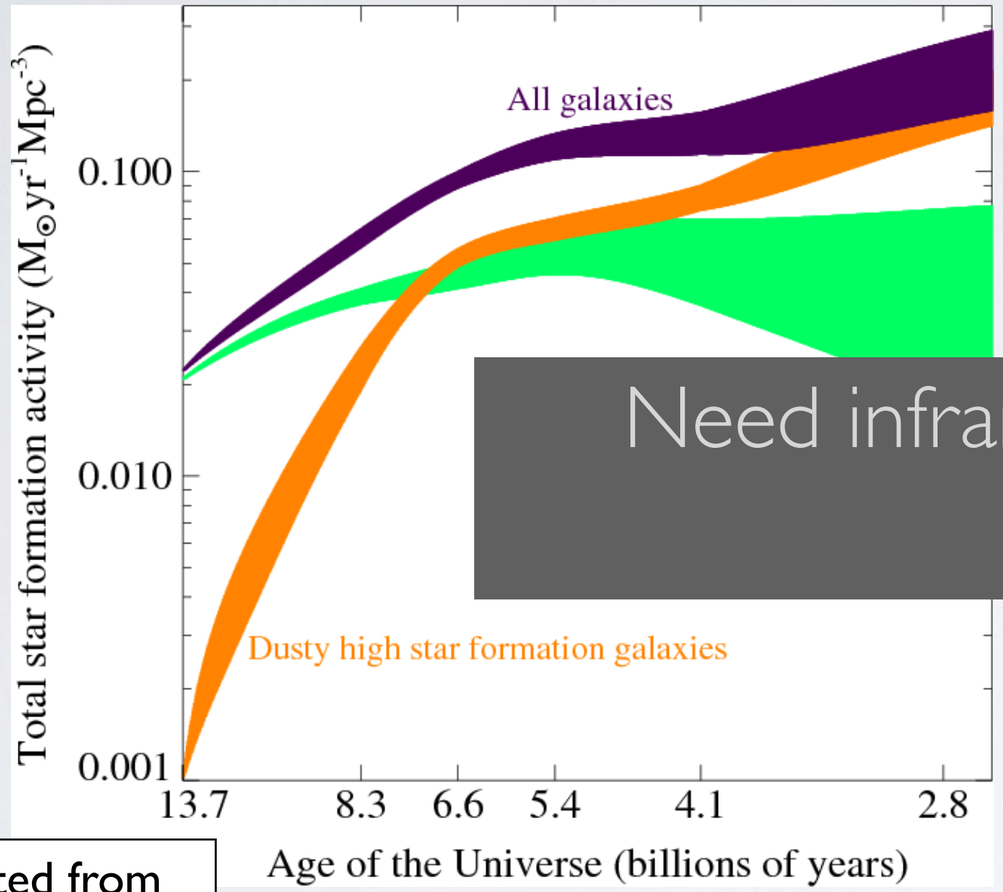
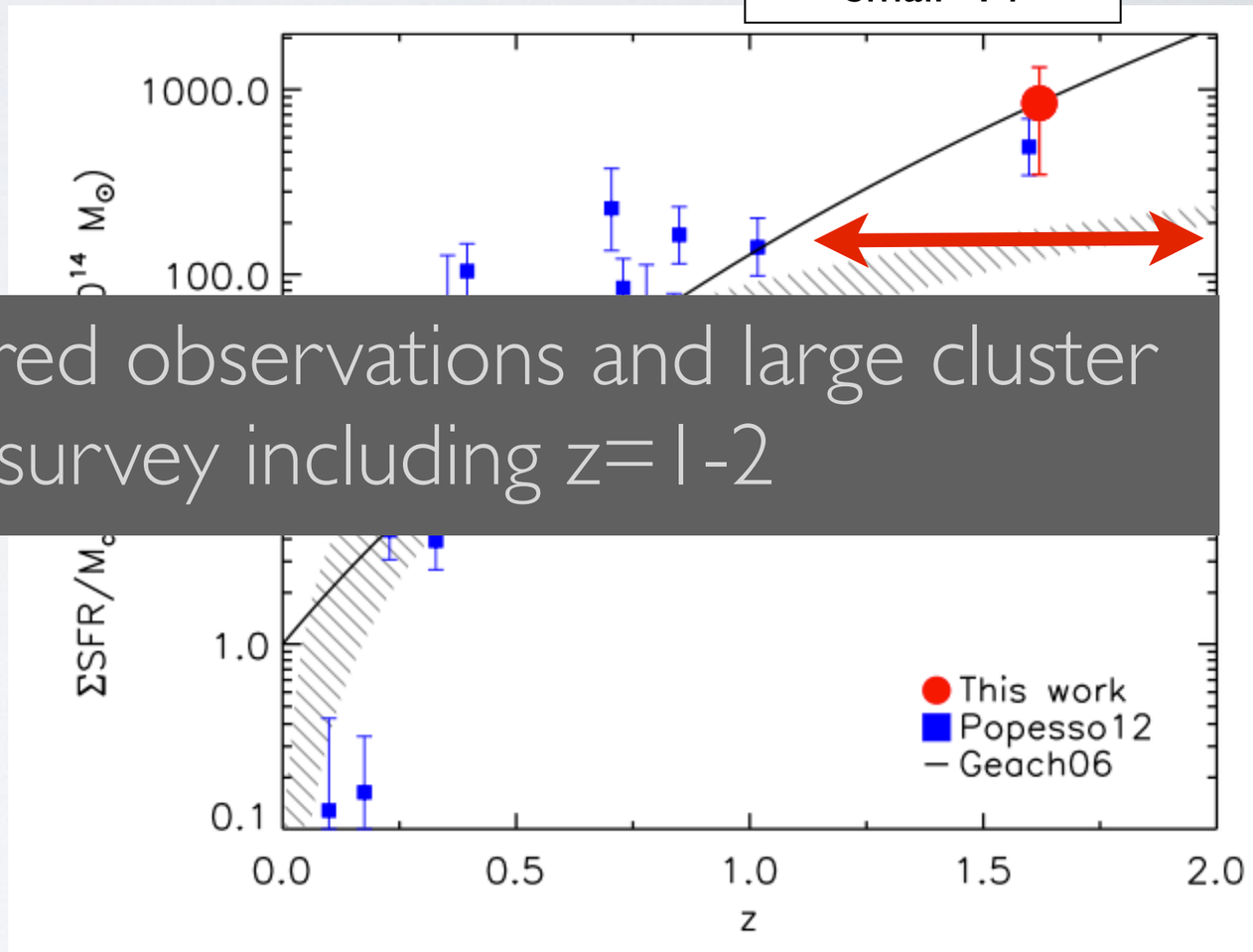


Adapted from Murphy+11

Smail+14



Need infrared observations and large cluster survey including z=1-2

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- IRAC Shallow/Distant Cluster Survey (Eisenhardt+08)
  - 9 square degrees, 300 clusters with uniform mass ($M_{halo} \sim 10^{14}\ M_\odot$)
  - IRAC overdensities
  - spec-z or photo-z and stellar mass estimates
  - mass limited cluster and field samples ($M_\star \geq 10^{10}\ M_\odot$)

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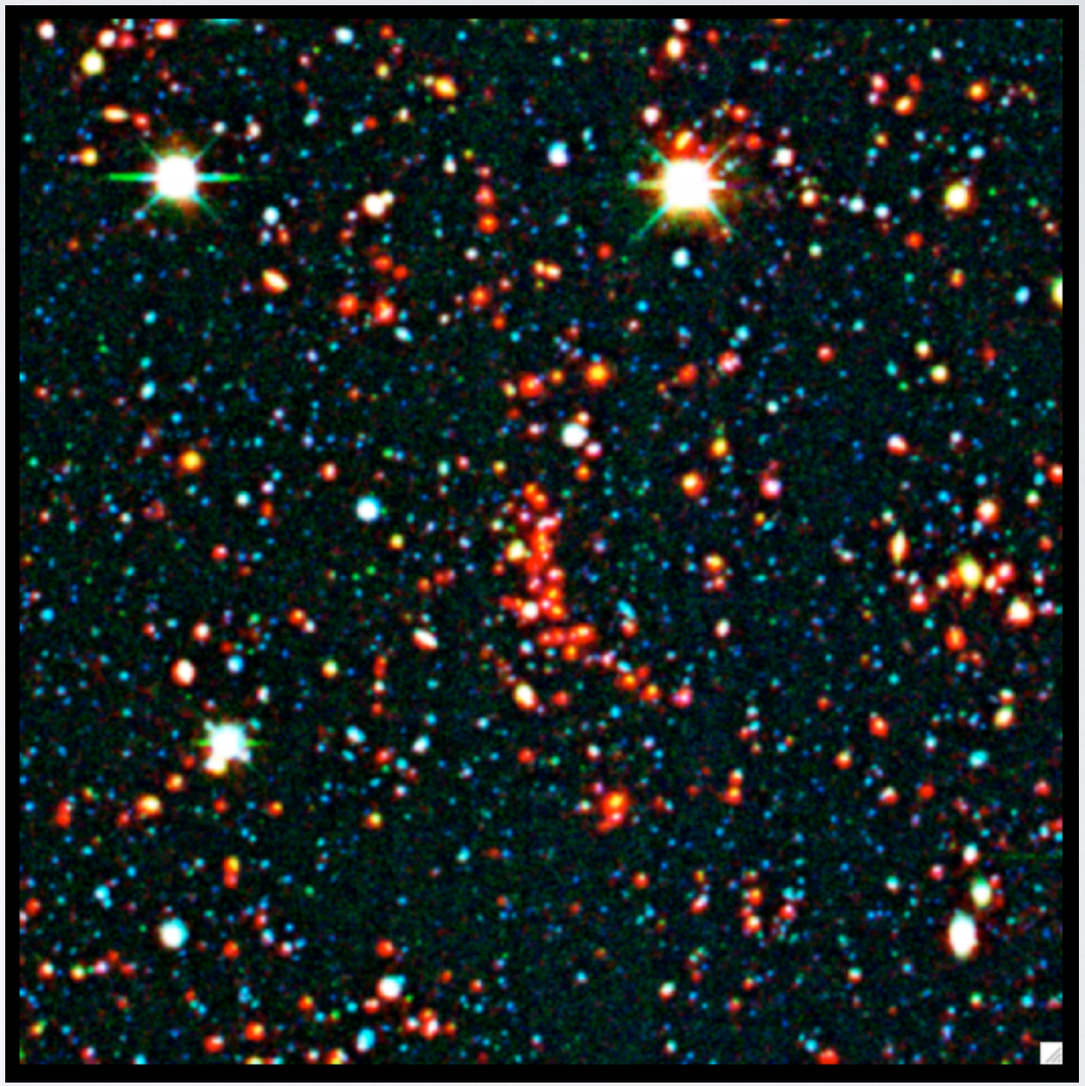

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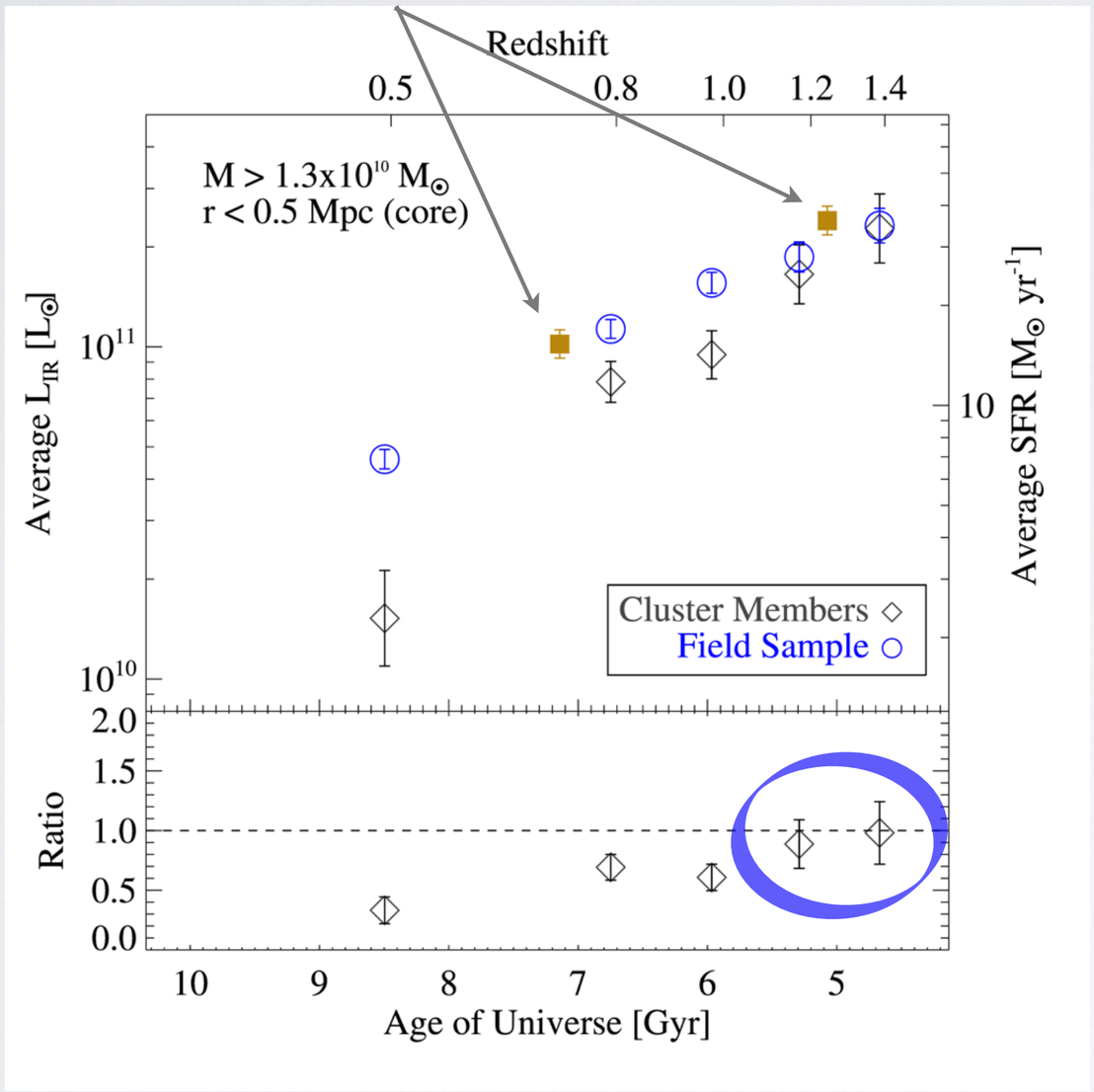
THE EPOCH OF STAR FORMATION IN CLUSTERS

see also Brodwin et al. 2013

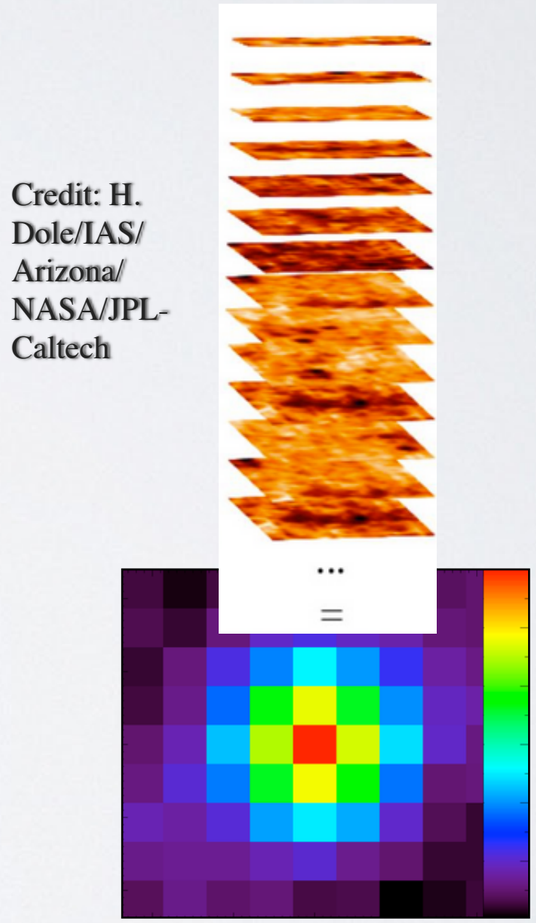
UDS Field Galaxies (Viero+13)



Alberts et al. 2014

Mass-limited cluster and field galaxy samples

Stack on HerMES SPIRE imaging



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PACS (and SCUBA-2) Analysis of z=1-2 cluster galaxies

Alberts et al. (a,b), in prep

Alex Pope (UMass)
Mark Brodwin (UMKC)
Ranga-Ram Chary (Caltech)
Arjun Dey (NOAO)
Peter Eisenhardt (Caltech)
Anthony Gonzalez (UFlorida)
Buell Jannuzi (Steward Obs.)
Greg Snyder (STScI)
Adam Stanford (UC Davis)
Dan Stern (JPL/Caltech)
Greg Zeimann (UPenn)
Ryan Cybulski (UMass)
Jim Geach (UHertfordshire)
Sun Mi Chung (Ohio State)

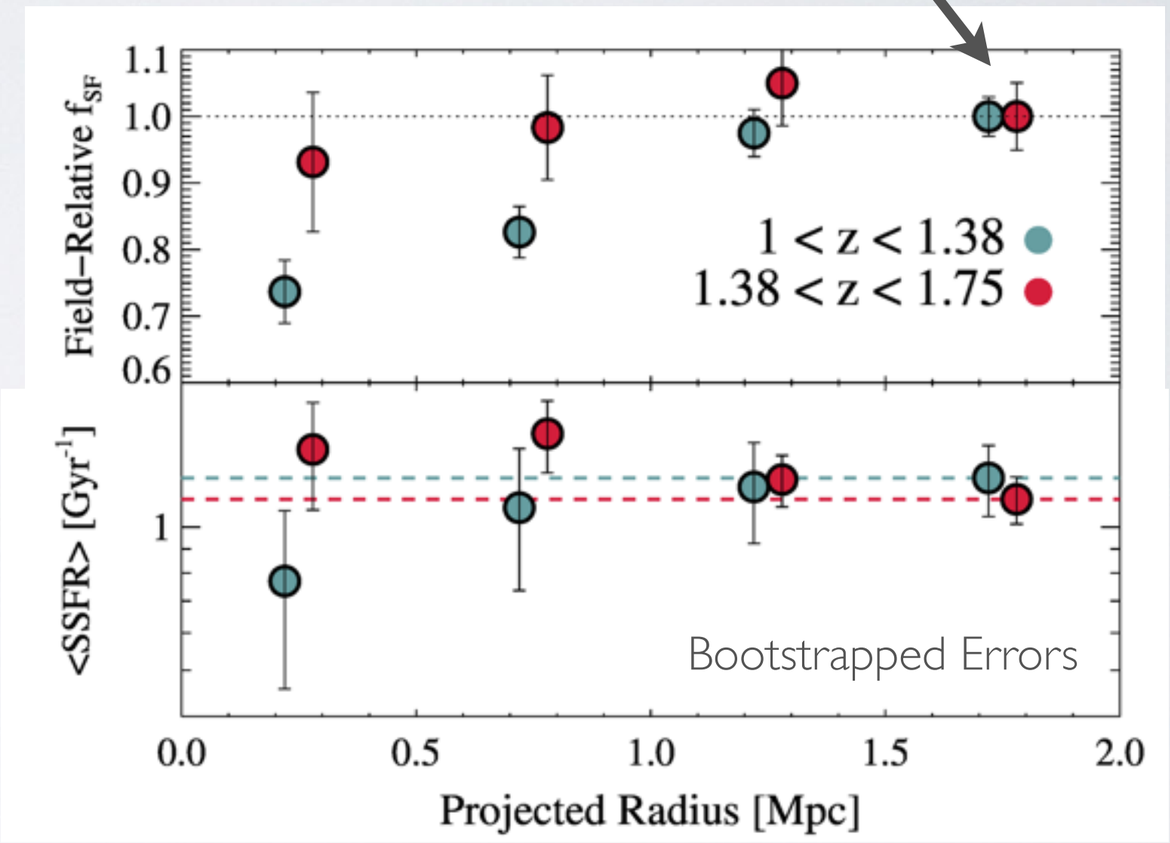
IR-LUMINOUS CLUSTER GALAXIES WITH PACS

DEEP PACS maps, typical SFGs (SFR>~100 $M_\odot$/yr)

11 spectroscopically-confirmed clusters ($M_{halo} \geq 10^{14}$ $M_\odot$)

z=1-1.8

Assume as field value



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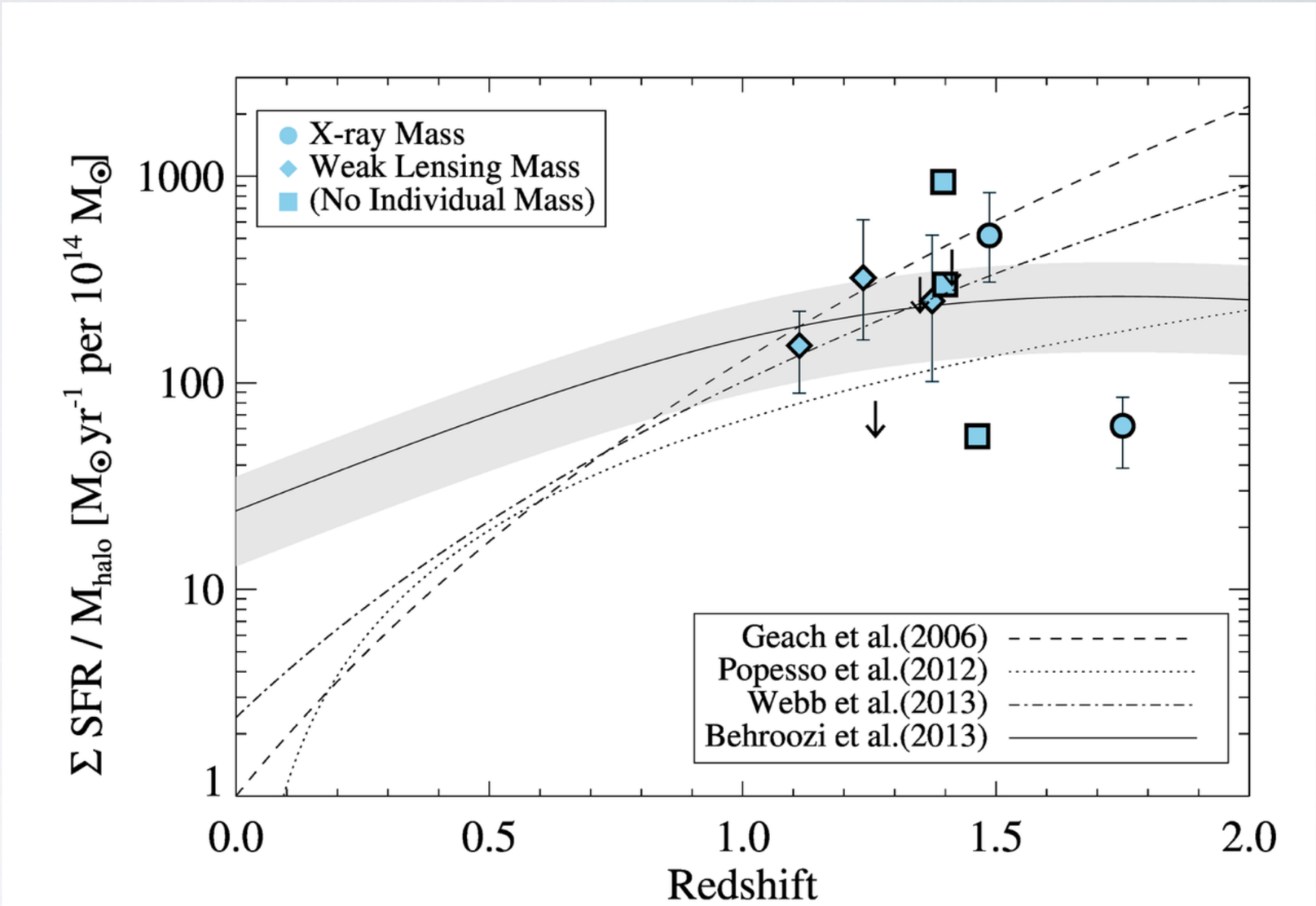
MASS NORMALIZED TOTAL SFR

LARGE CLUSTER-TO-CLUSTER VARIATION!



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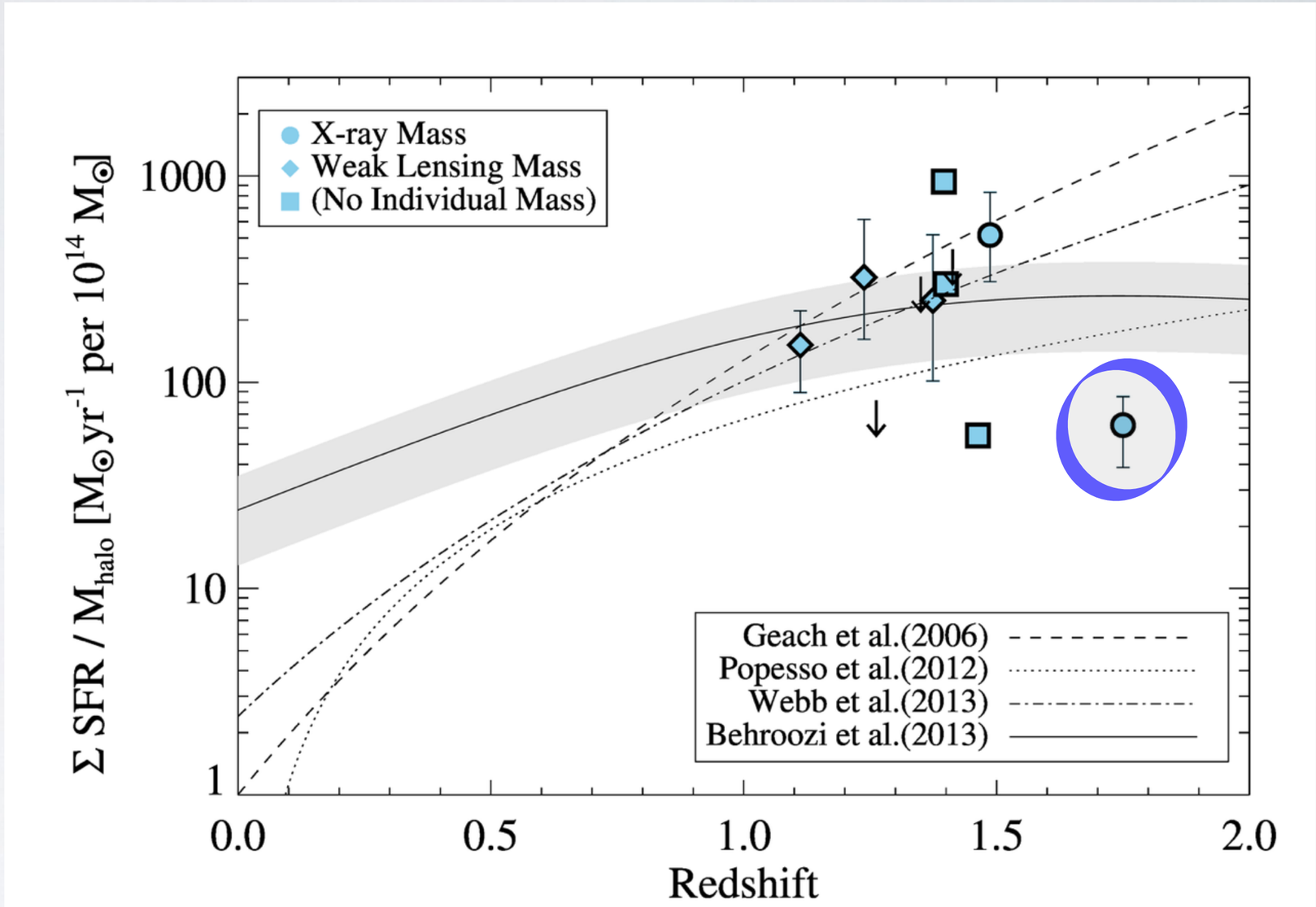

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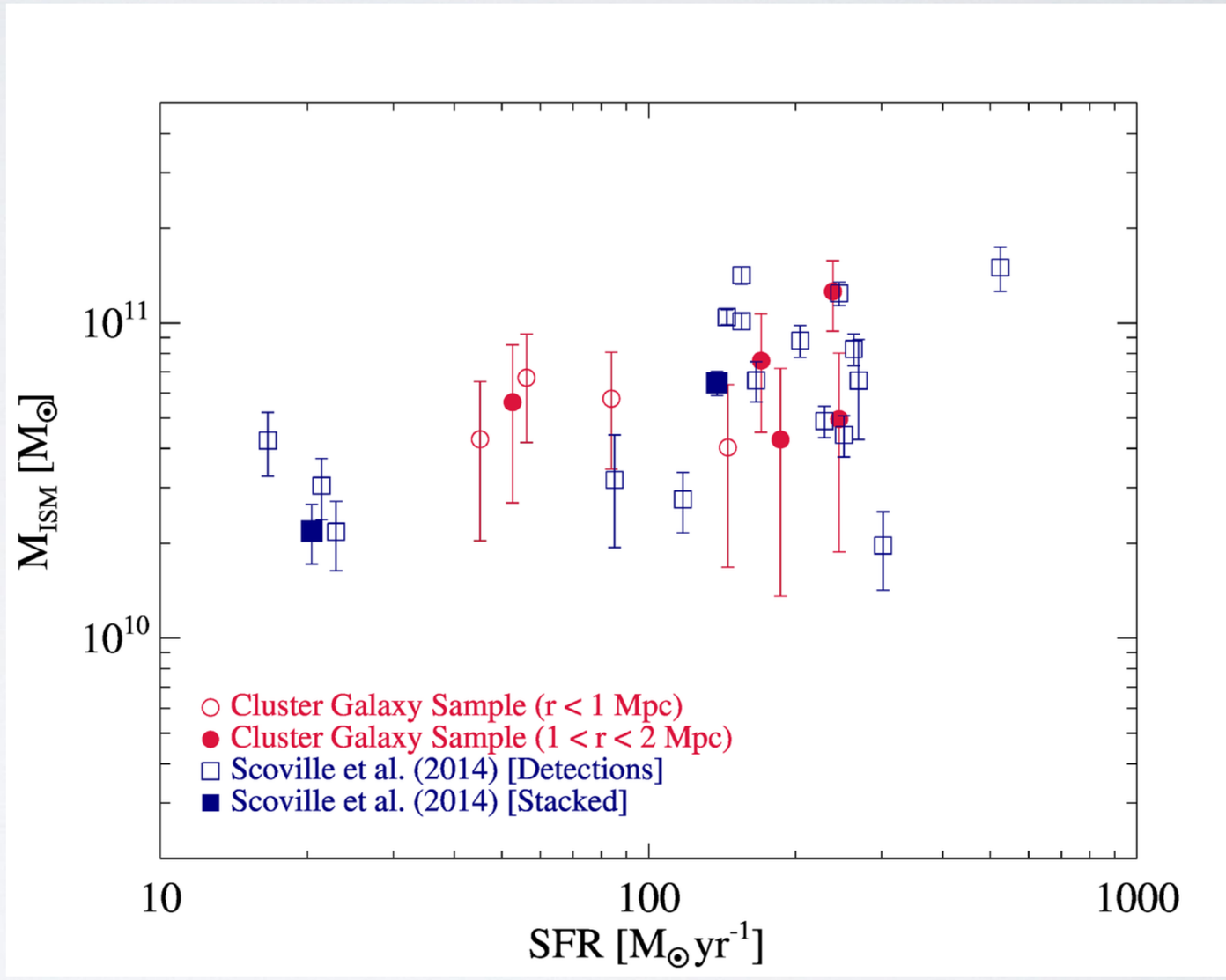
THE ISM IN Z=1.75 CLUSTER GALAXIES

M_{ISM} DETERMINED USING DEEP SCUBA-2 MAP

ASSUME T_{DUST} = 25 K



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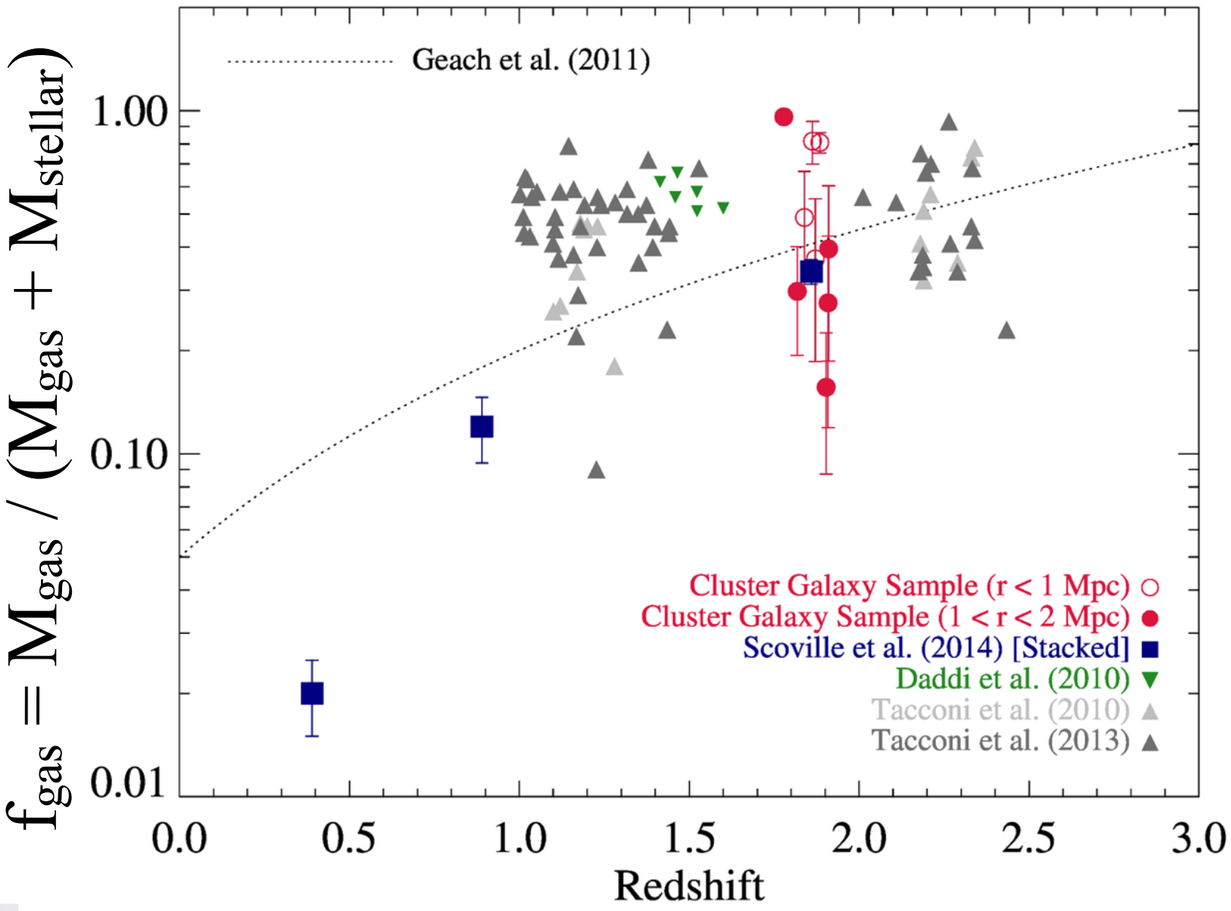
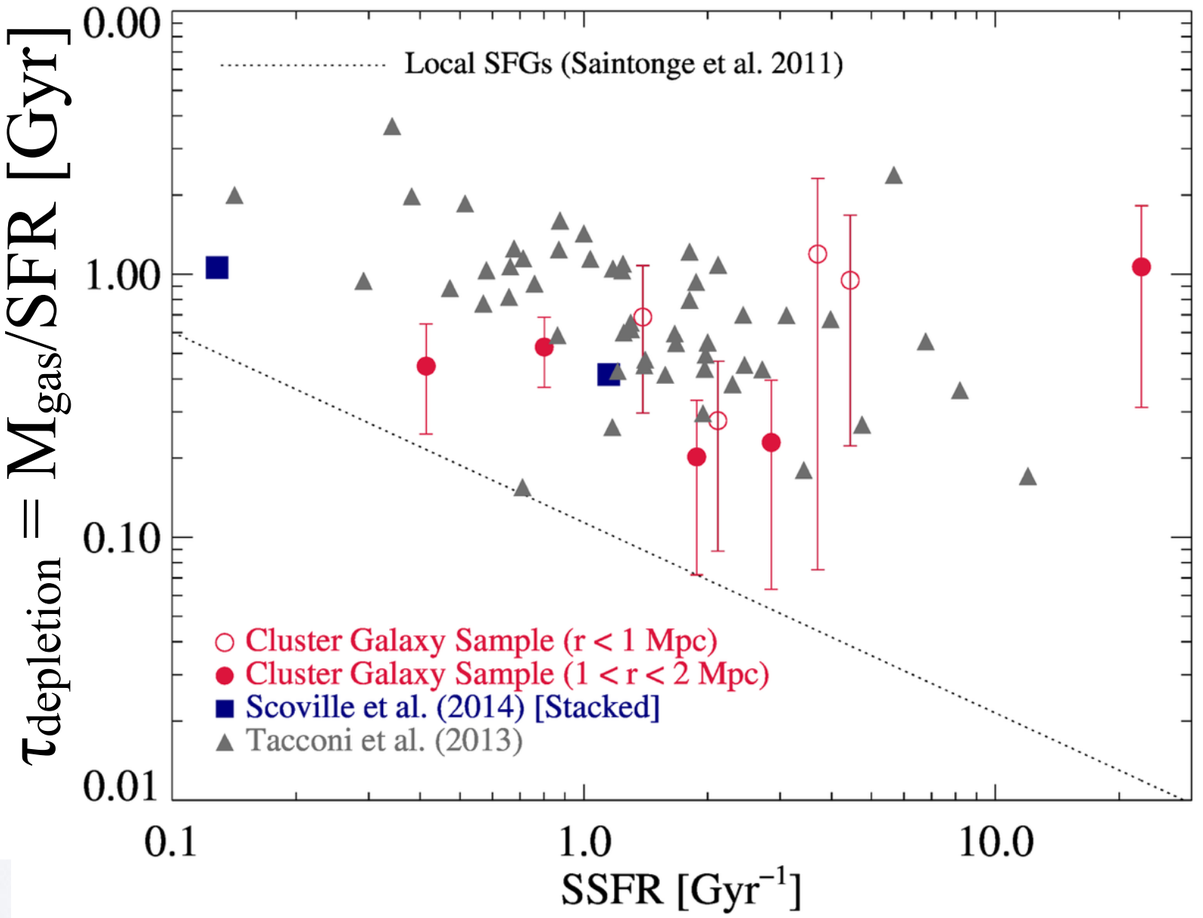
Assume $M_{ISM} \sim M_{gas}$



median $f_{gas} = 0.4$



median $\tau_{depletion} = 0.5$ Gyr

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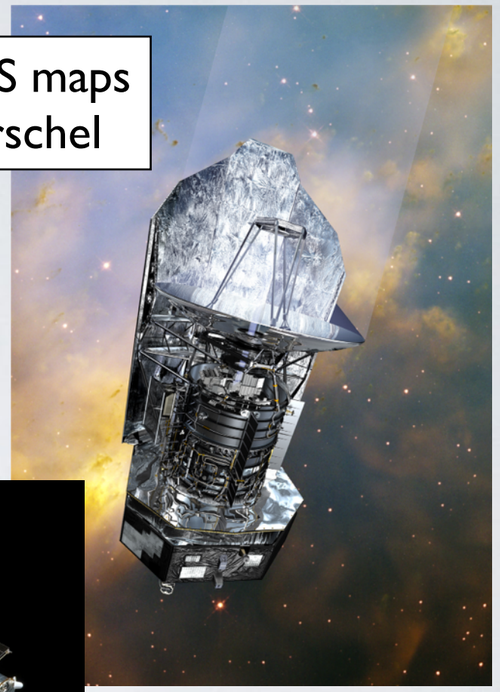
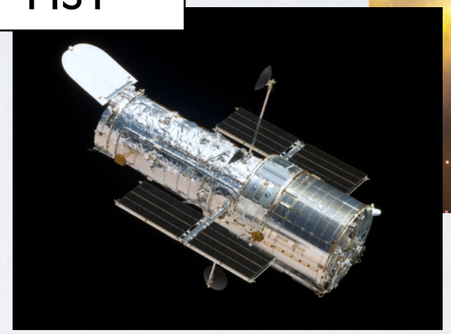
Conclusions

+ Active star formation in clusters at z>1.4
+ Transition epoch to effective environmental quenching
+ Have field-like M_{ISM} and short gas depletion timescales
+ Follow-up with ALMA:
  + Redshifts
  + CO gas mass and M_{ISM}
    + molecular vs atomic?
    + α_{CO} in clusters?

Deep PACS maps from Herschel



HST



LMT

VLA

ALMA