Herschel Lensing Survey (HLS)

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Outline

Galaxies in the far-infrared (FIR)

The limitations of Herschel blank-field surveys

The Herschel Lensing Survey (HLS)

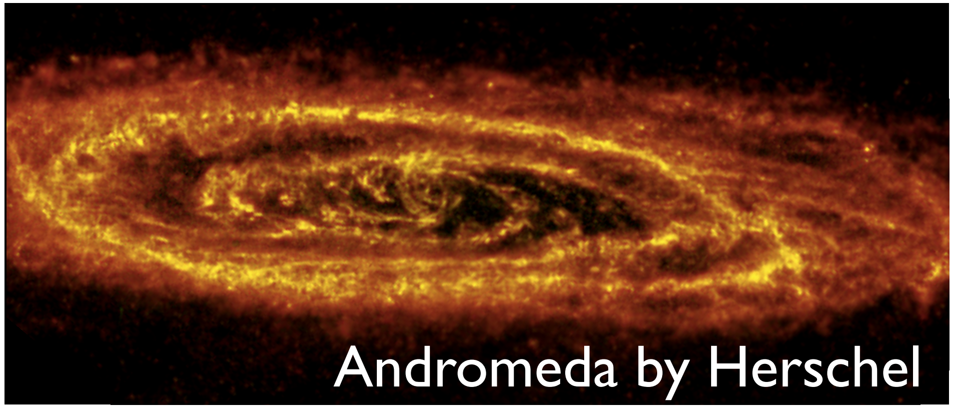
- The power of cluster lensing
- IR-bright, strongly-lensed sources
  - A few interesting examples
  - HLS0918: z=5.2 system behind A773 [Combes+12, Rawle+14a, Boone+prep]
- The Herschel View of the Frontier Fields [Rawle+prep]

Summary

Galaxies in the Far-Infrared (FIR)

- UV photons heat dust, and are re-emitted at longer λ: FIR probes dust properties

- Dominant heat sources:
    1. young stellar populations
    2. AGN



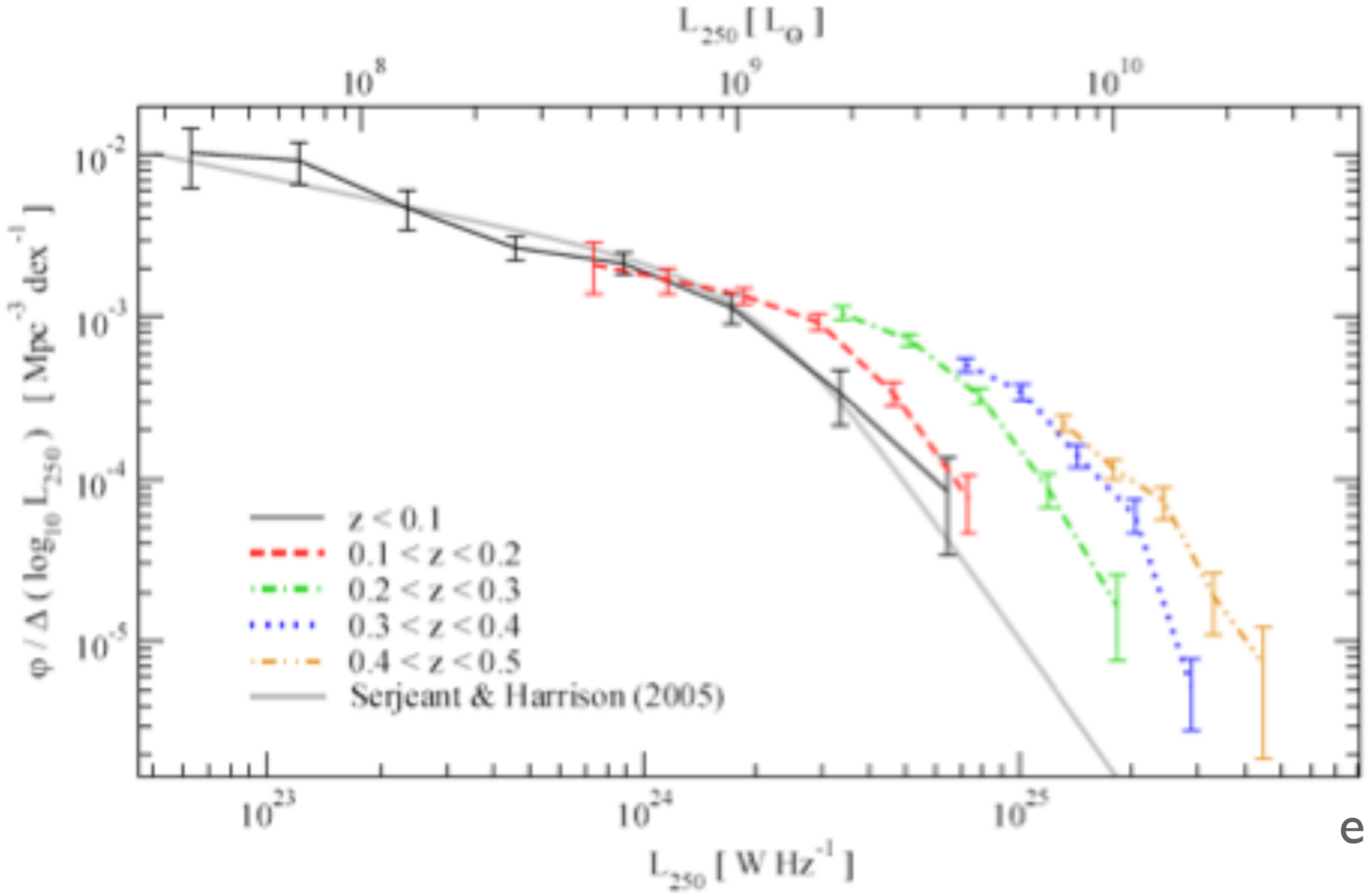
- In the absence of AGN, FIR traces dusty star formation

- The peak of the dust component is shifted into SPIRE bands at $z \sim 1 - 5$:

  FIR colour crudely traces redshift (but degenerate with dust temperature)

- Negative K-correction implies there are abundant IR-bright systems at high redshift
- BUT... confusion noise sets the fundamental sensitivity of Herschel surveys

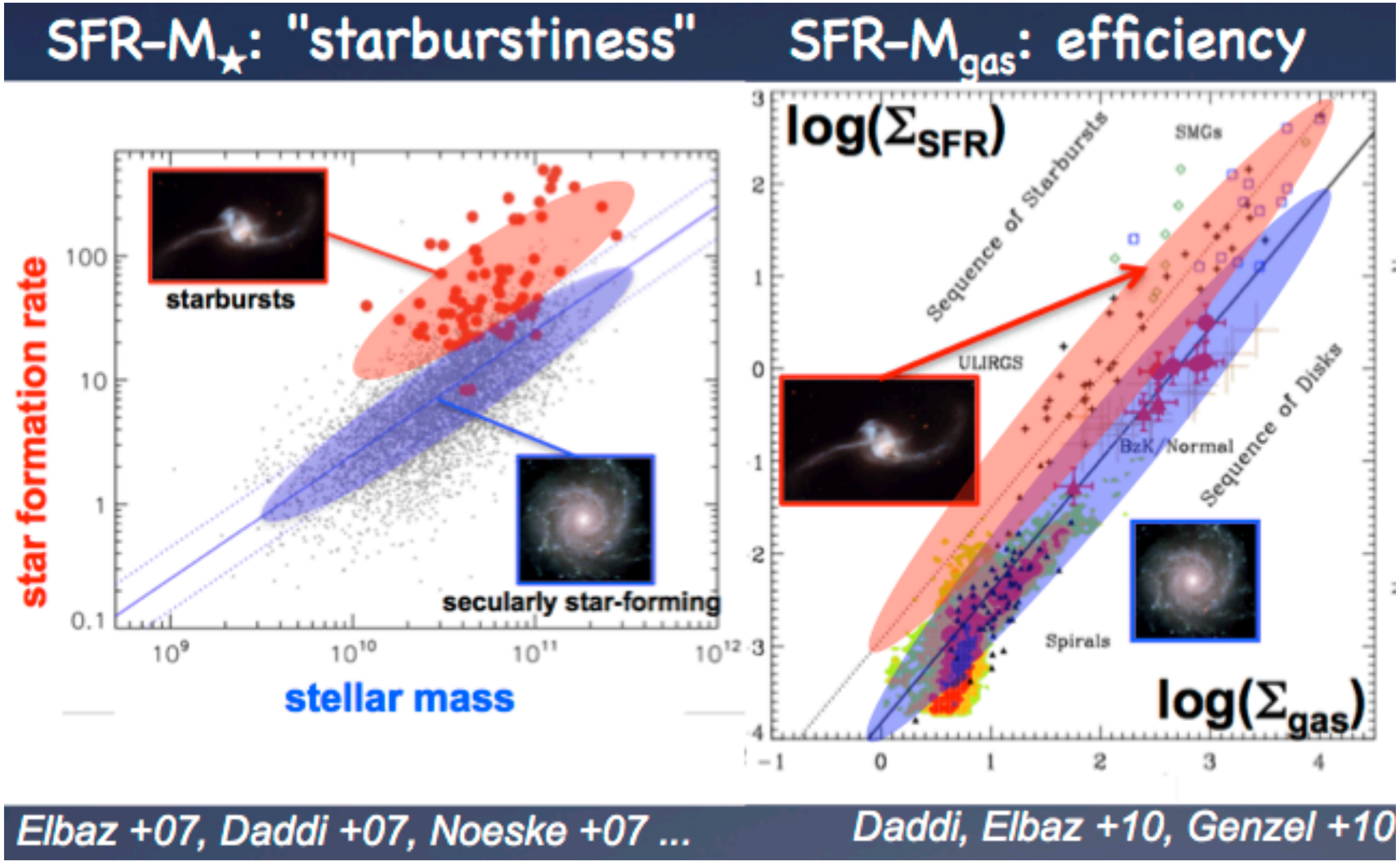
Exploring Dusty Star Formation



e.g. Dye+10

At z < 0.5, blank field IR surveys show rapid recent evolution

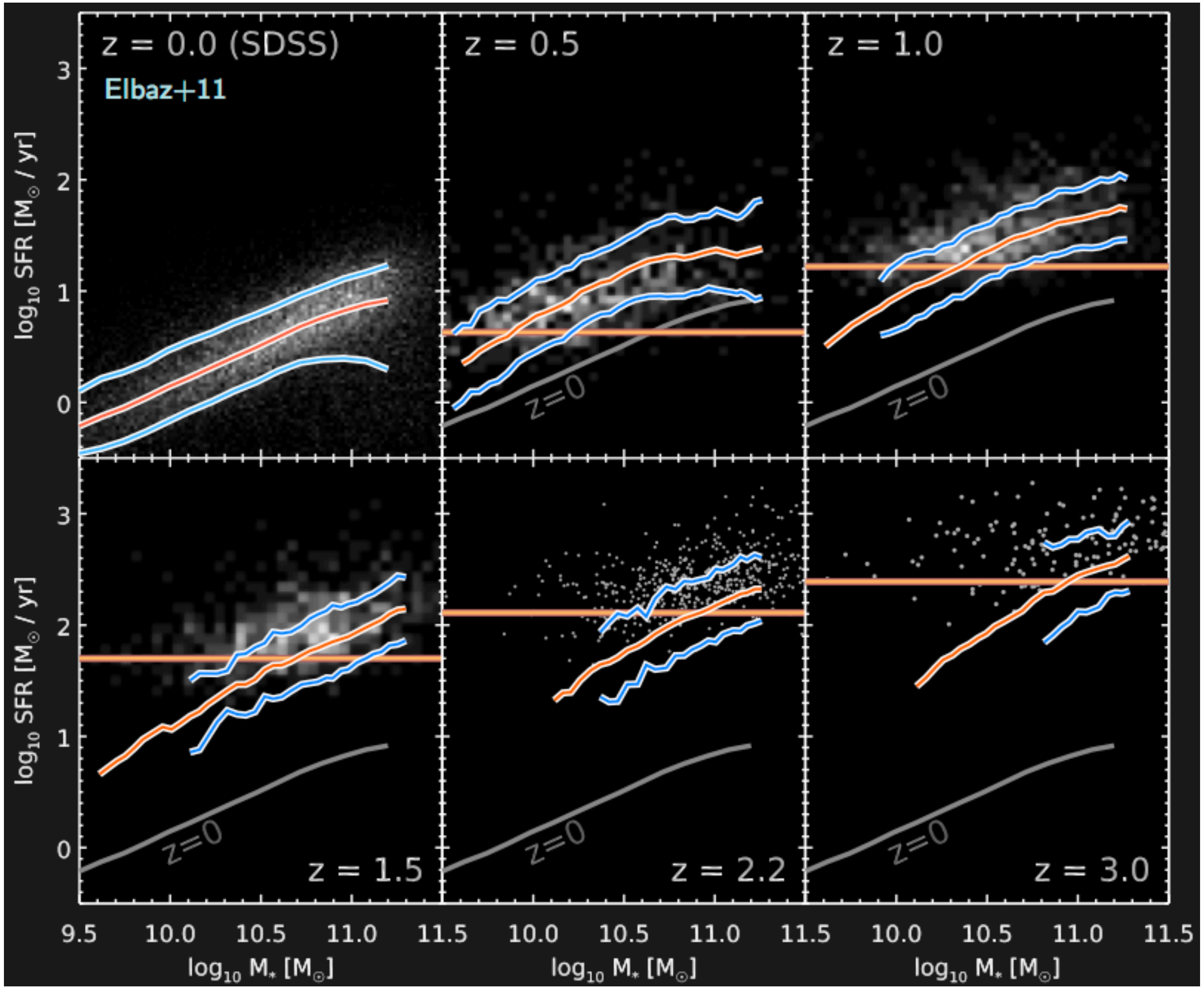
The Main Sequence Paradigm



At z < 1.5, the majority of galaxies lie on a star-forming "main sequence"

But a "star-burst" population are seen to have a higher SFR at fixed stellar mass or at fixed gas surface density

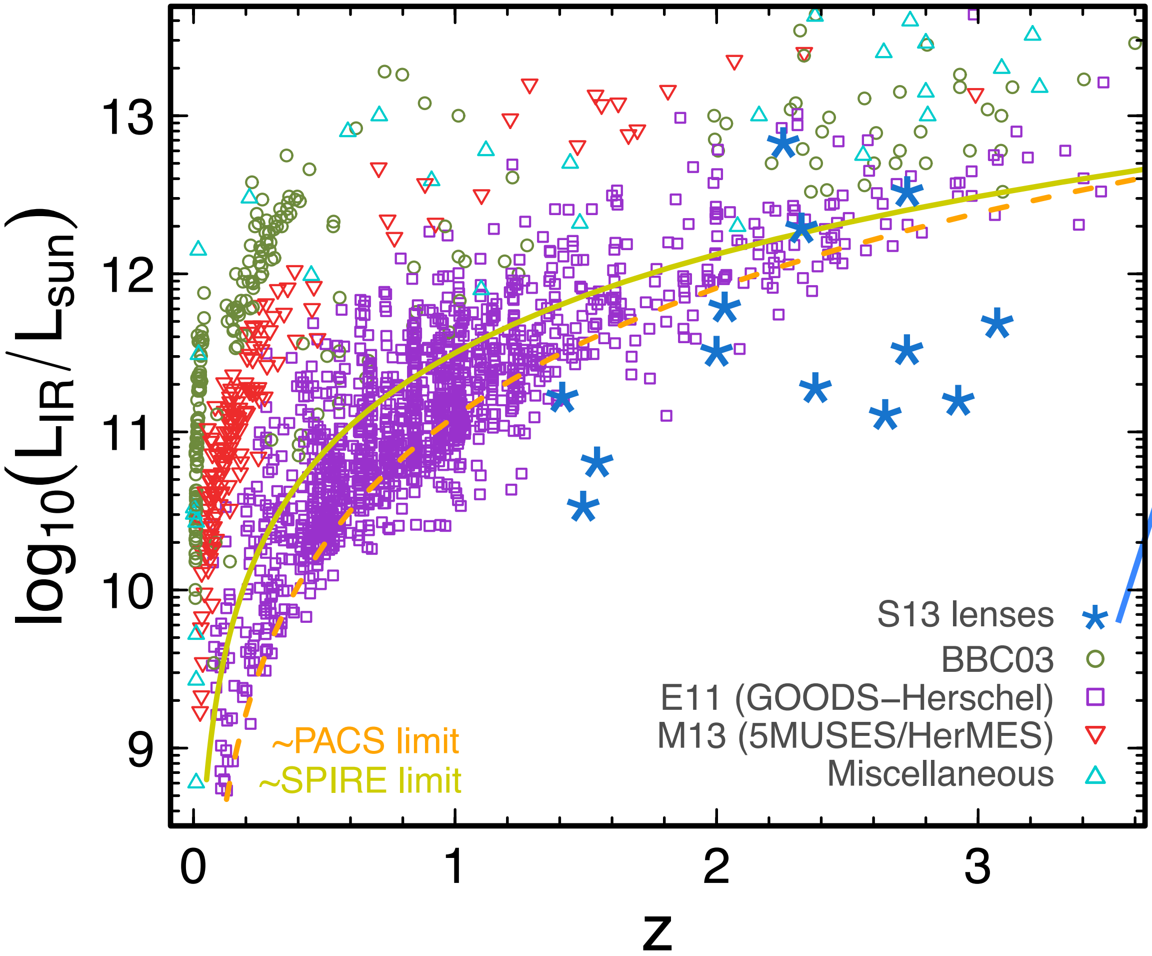
In the High Redshift Universe?



Schreiber+14

At z > 1.5, blank field surveys only probe the LIRG+ regime

High Redshift from Herschel Blank Fields



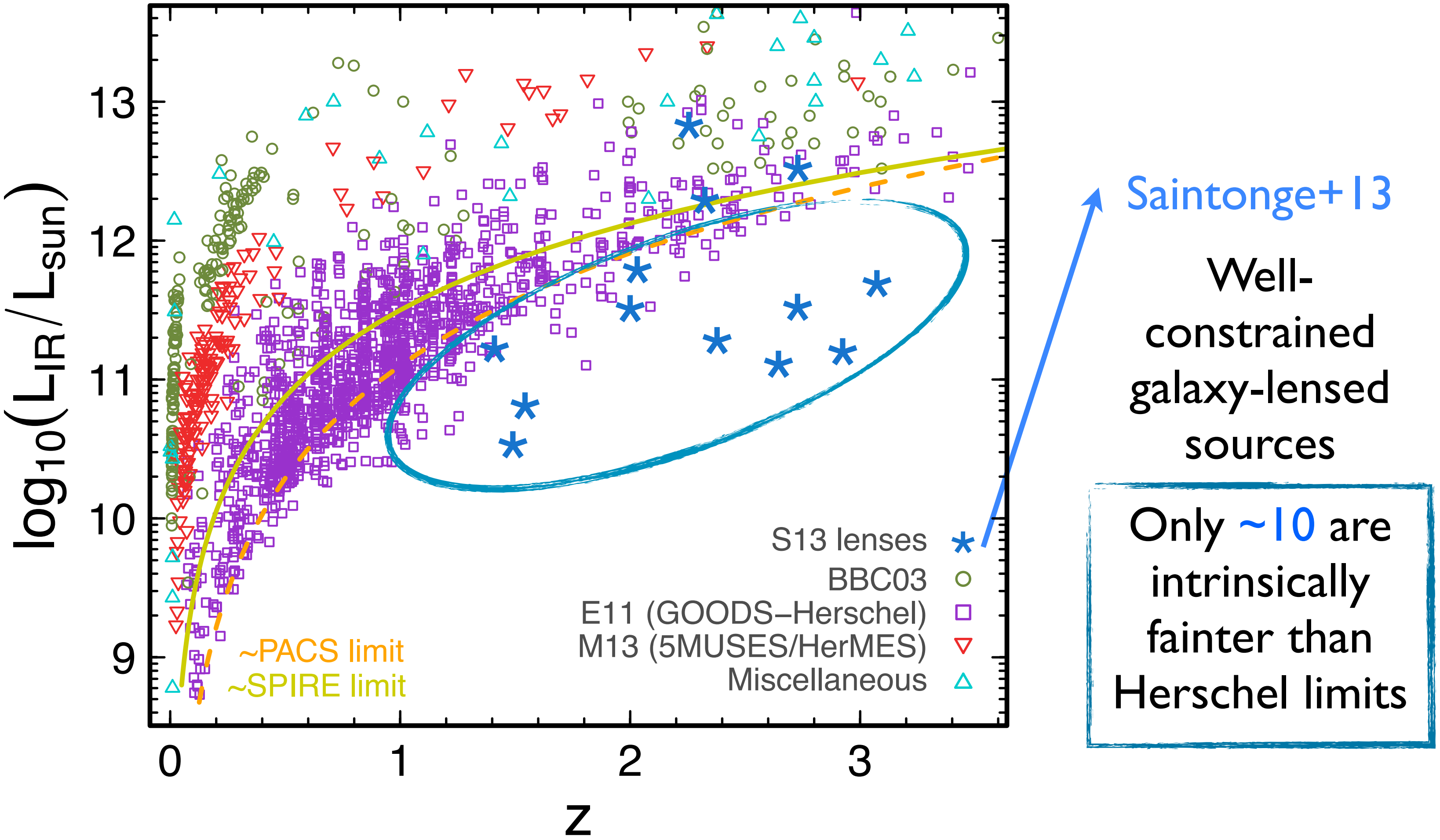
Saintonge+13

Well-constrained galaxy-lensed sources

(some serendipitous cluster lensing)

Individual foreground galaxies can be great lenses

High Redshift from Herschel Blank Fields

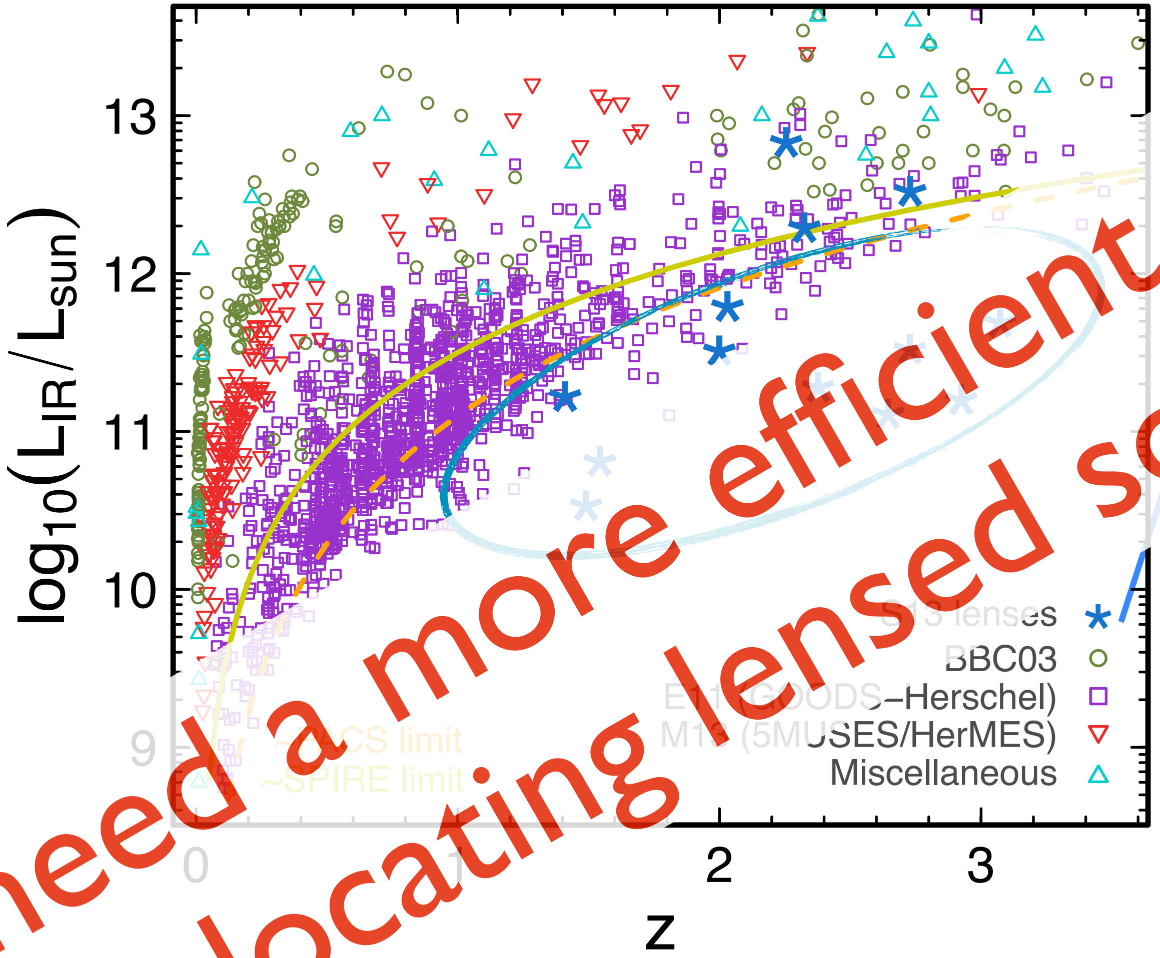


Individual foreground galaxies can be great lenses... BUT

1) galaxy-galaxy lenses are only discovered serendipitously in large blank-field surveys

2) blended lens and background sources can be hard to disentangle

High Redshift from Herschel Blank Fields



Saintonge+13

Well-constrained galaxy-lensed sources

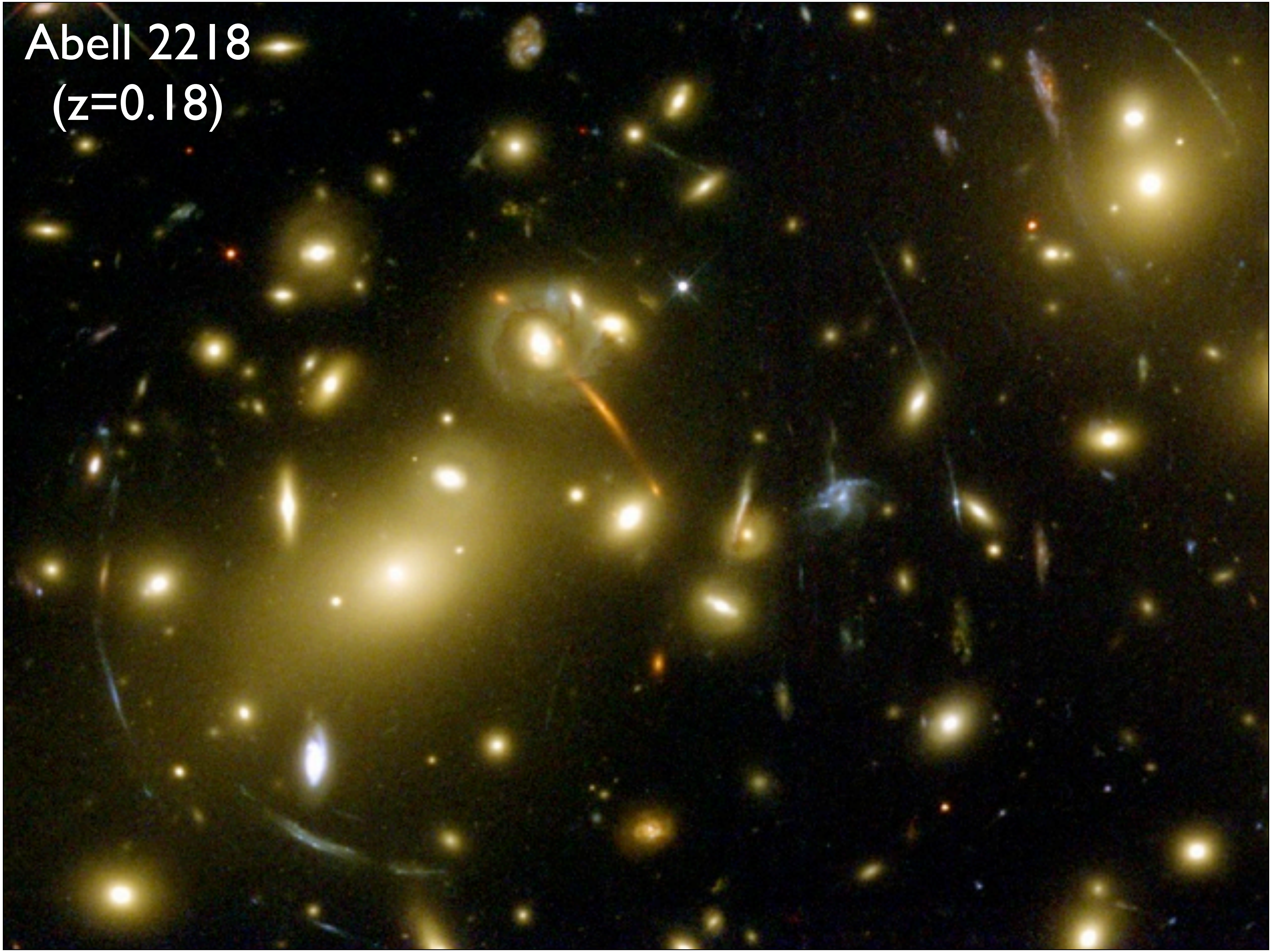
Only ~10 are intrinsically fainter than Herschel limits

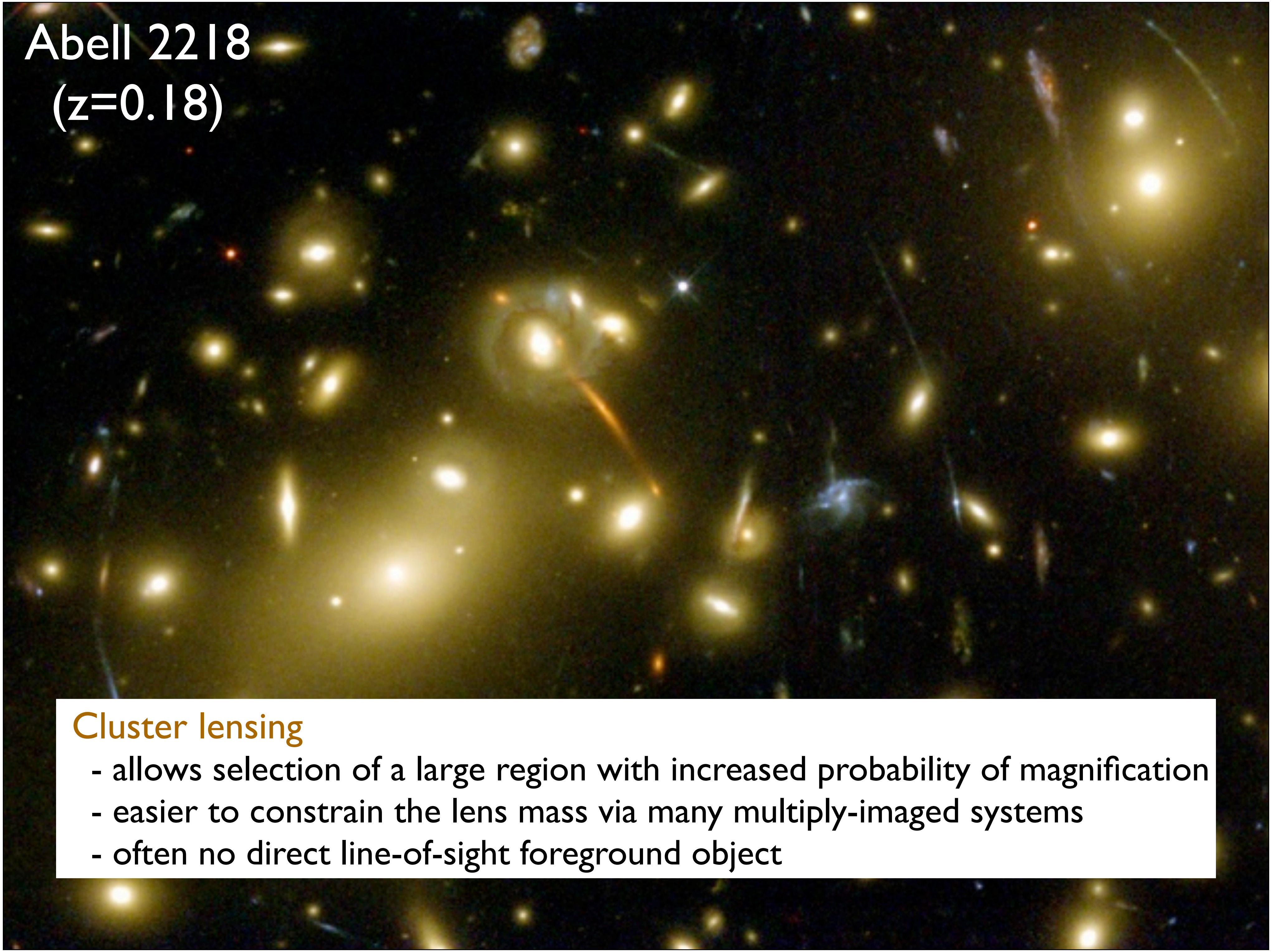
We need a more efficient method for locating lensed sources

Individual foreground galaxies can be great lenses... BUT

1) galaxy-galaxy lenses are only discovered serendipitously in large blank-field surveys

2) blended lens and background sources can be hard to disentangle


Abell 2218
(z=0.18)



Cluster lensing

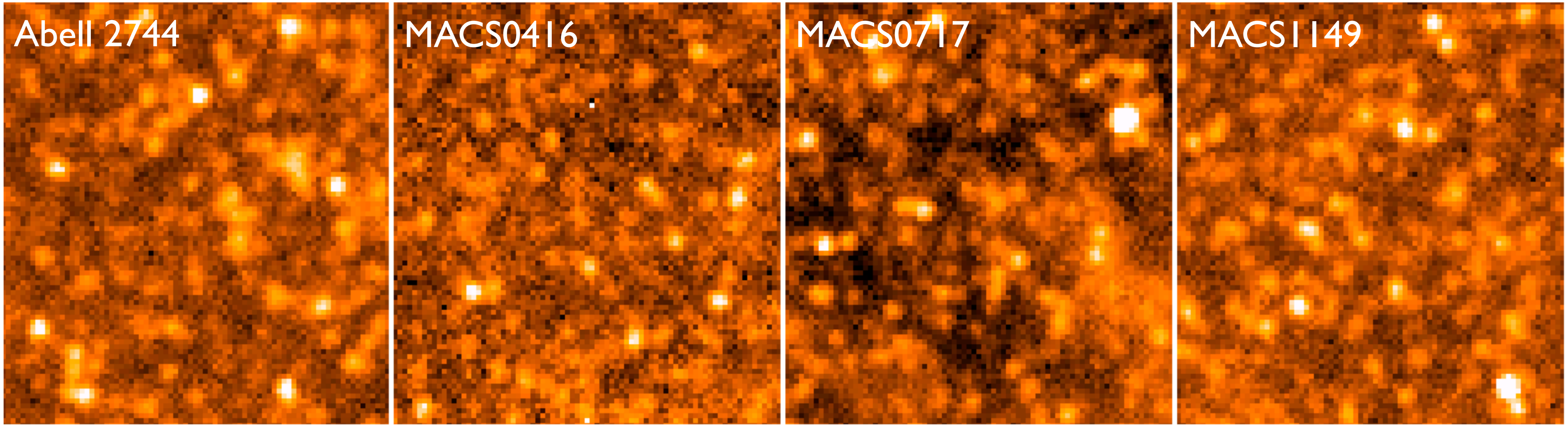
- allows selection of a large region with increased probability of magnification
- easier to constrain the lens mass via many multiply-imaged systems
- often no direct line-of-sight foreground object

The Herschel Lensing Survey (HLS)

PI: Eiichi Egami (Steward Observatory, Arizona)

- HLS-deep + GT clusters (~370 hours)

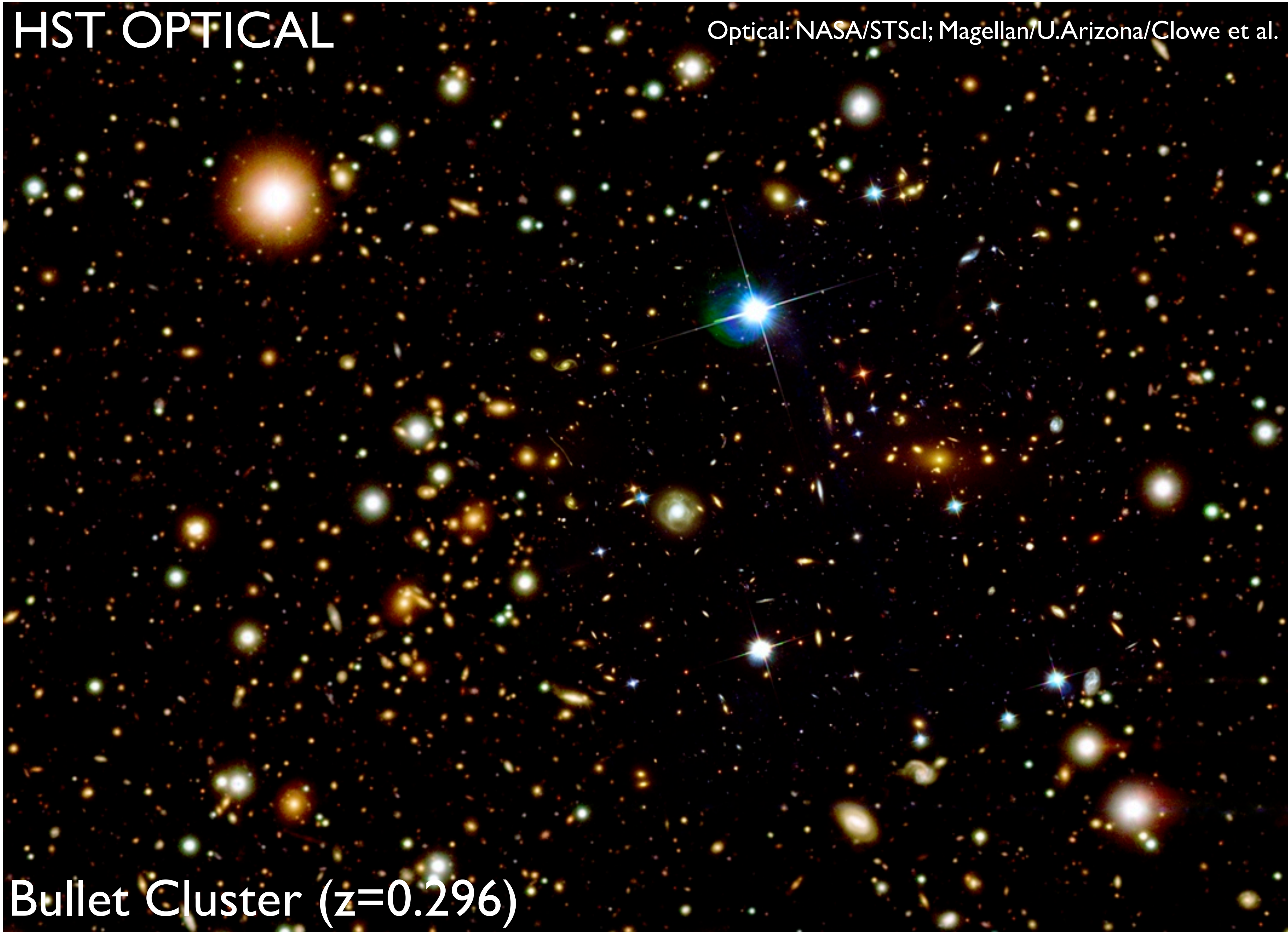
- 65 well-studied massive galaxy clusters (0.1 < z < 1.0)... ~5 deg^2
- Sample includes all 25 CLASH clusters (HST Treasury Survey with 16 UV-NIR bands)
- Sample includes all 6 HST Frontier Fields (ultra-deep HST DDT program)



- HLS-snapshot (~50 hours)

- 537 clusters (0.1 < z < 1.0) from ROSAT, MACS, SPT and CODEX... ~10 deg^2

The power of Herschel



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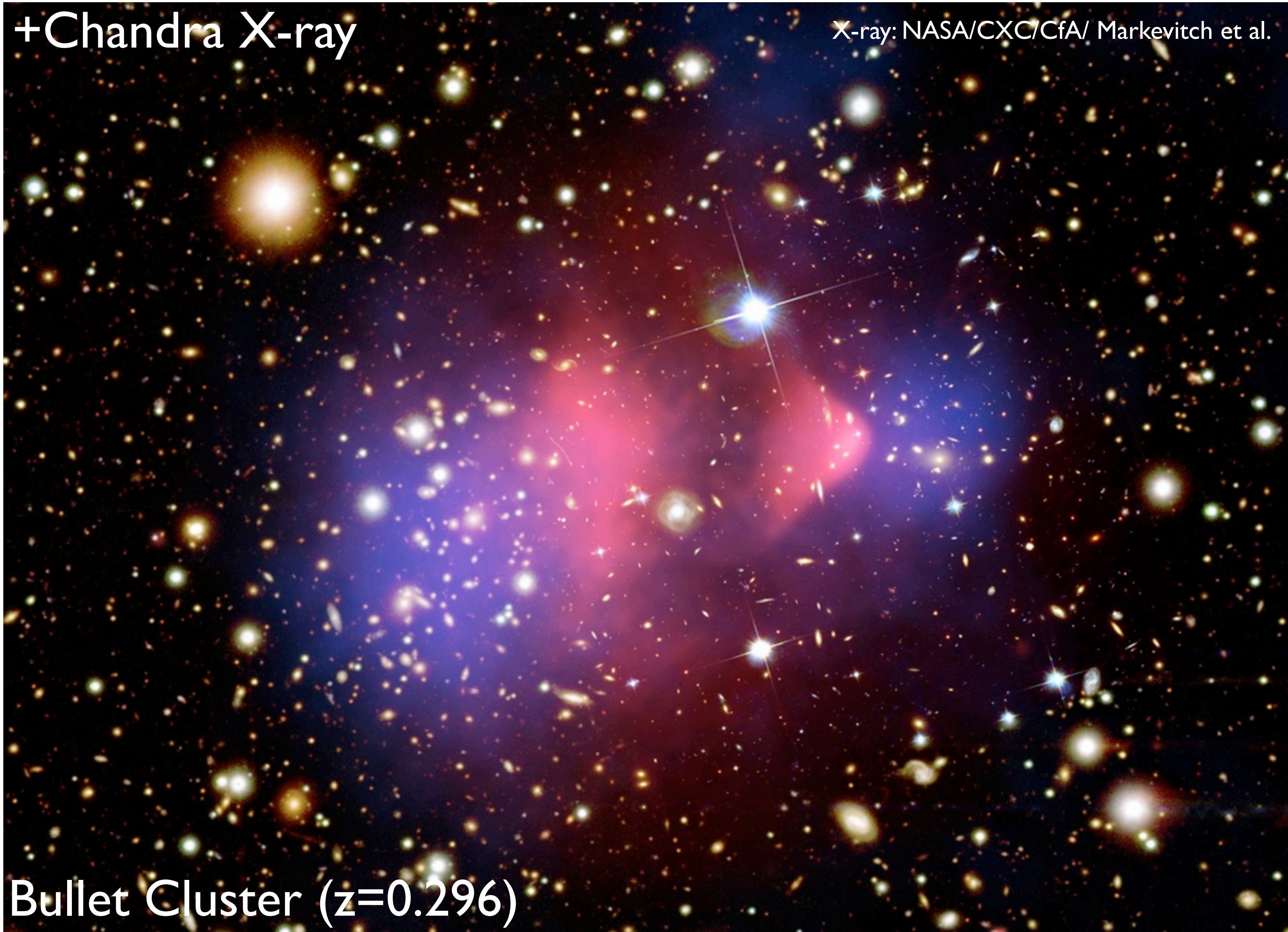
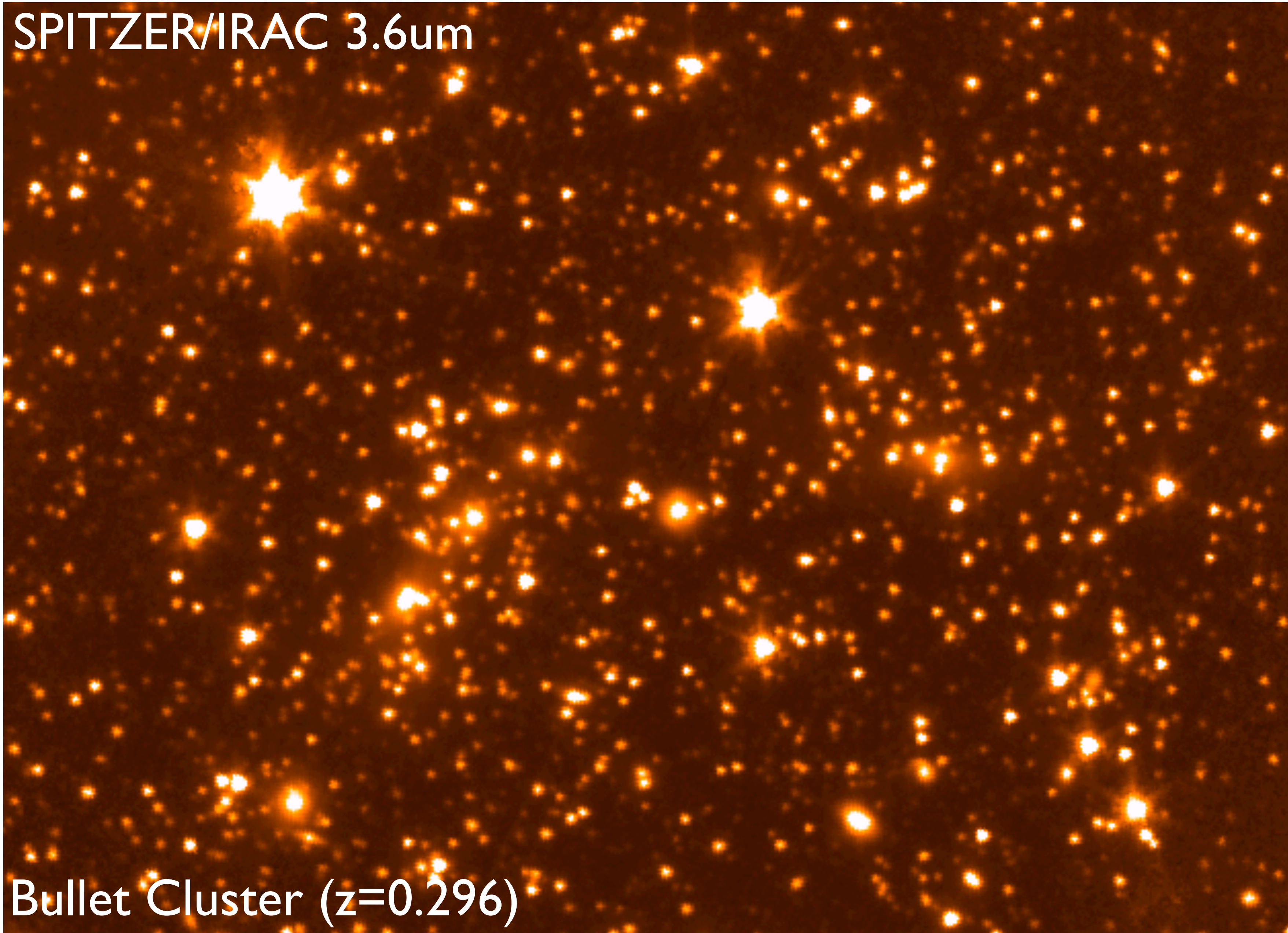
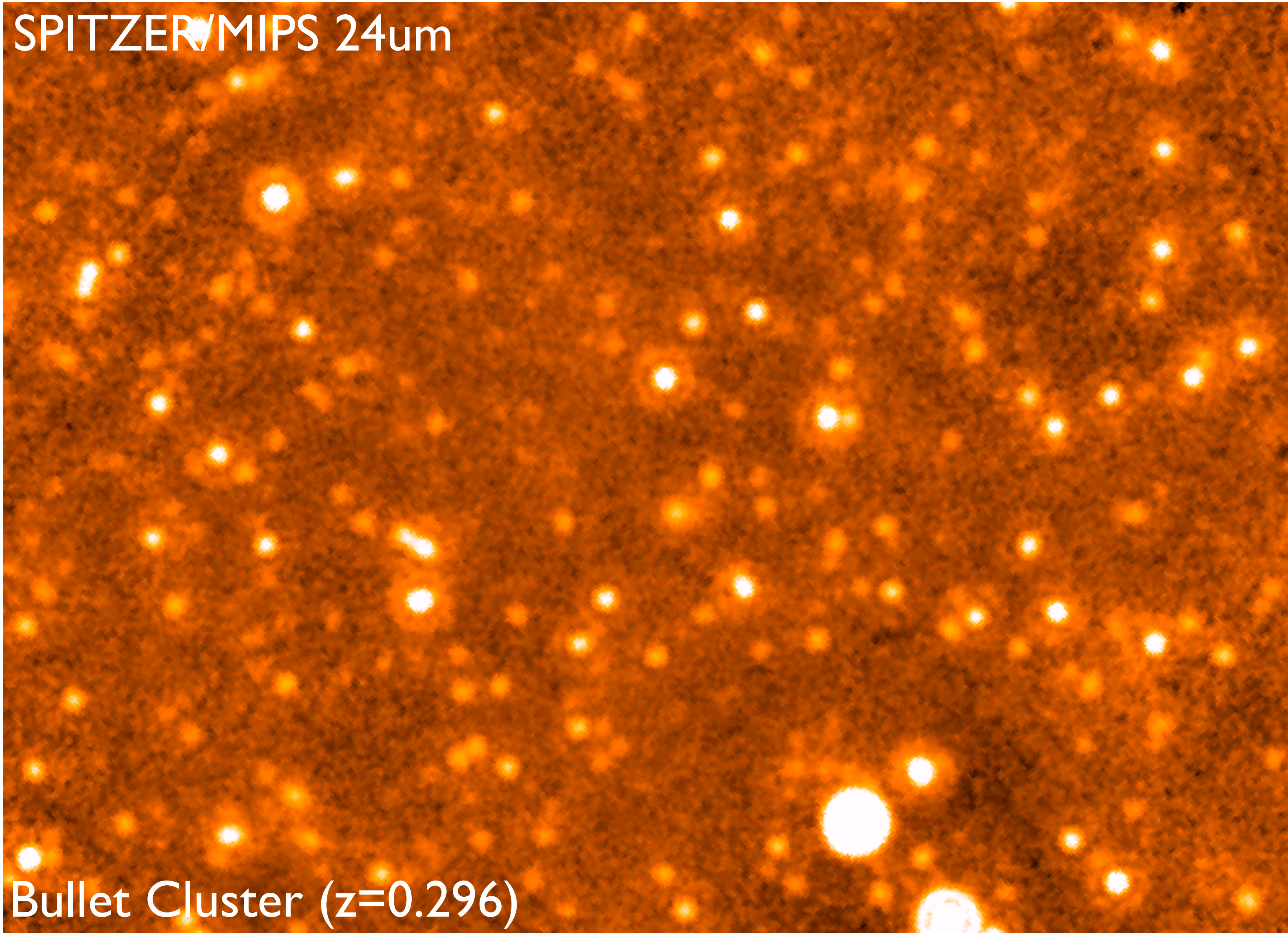


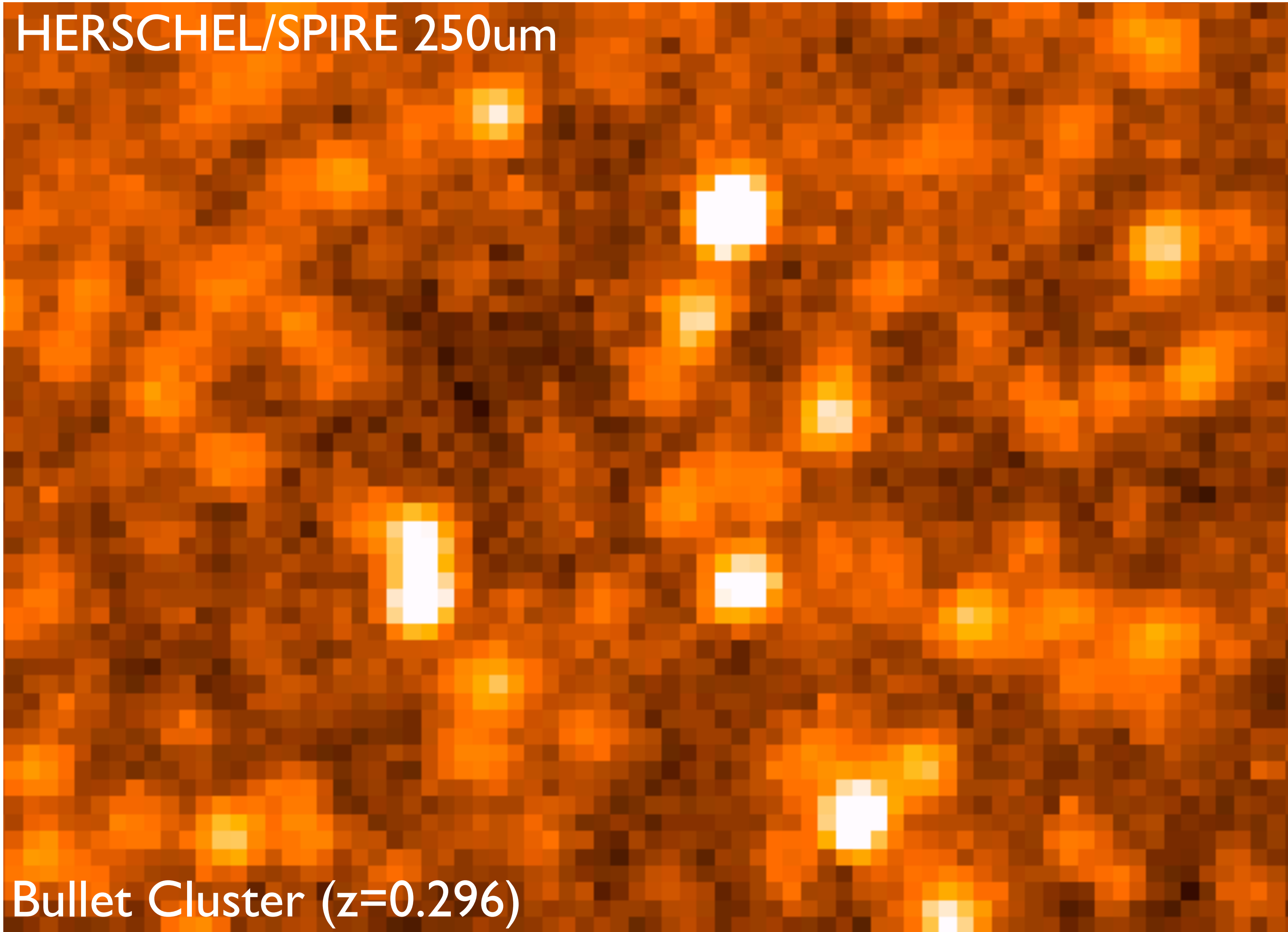
The power of Herschel



The power of Herschel



The power of Herschel



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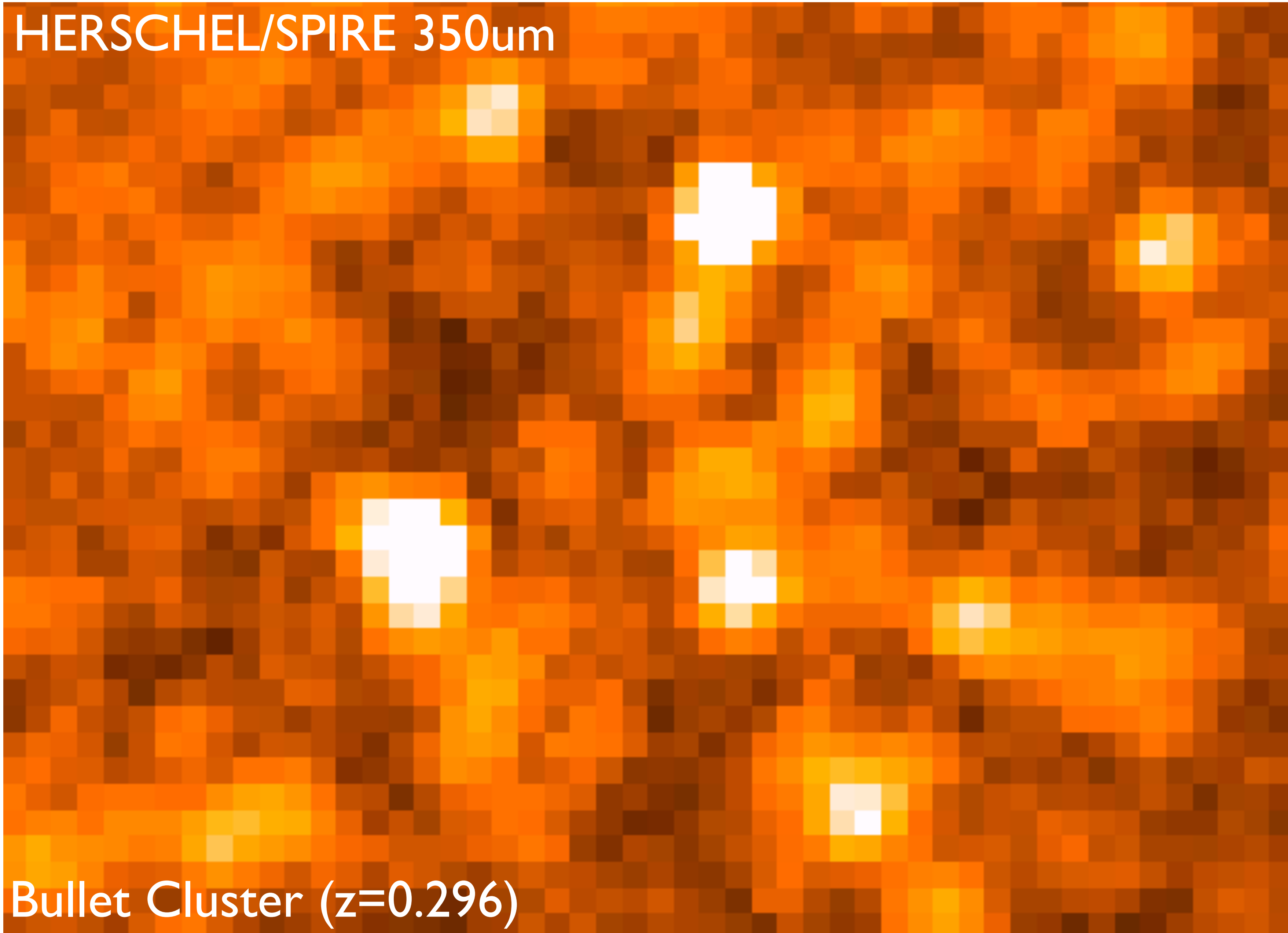
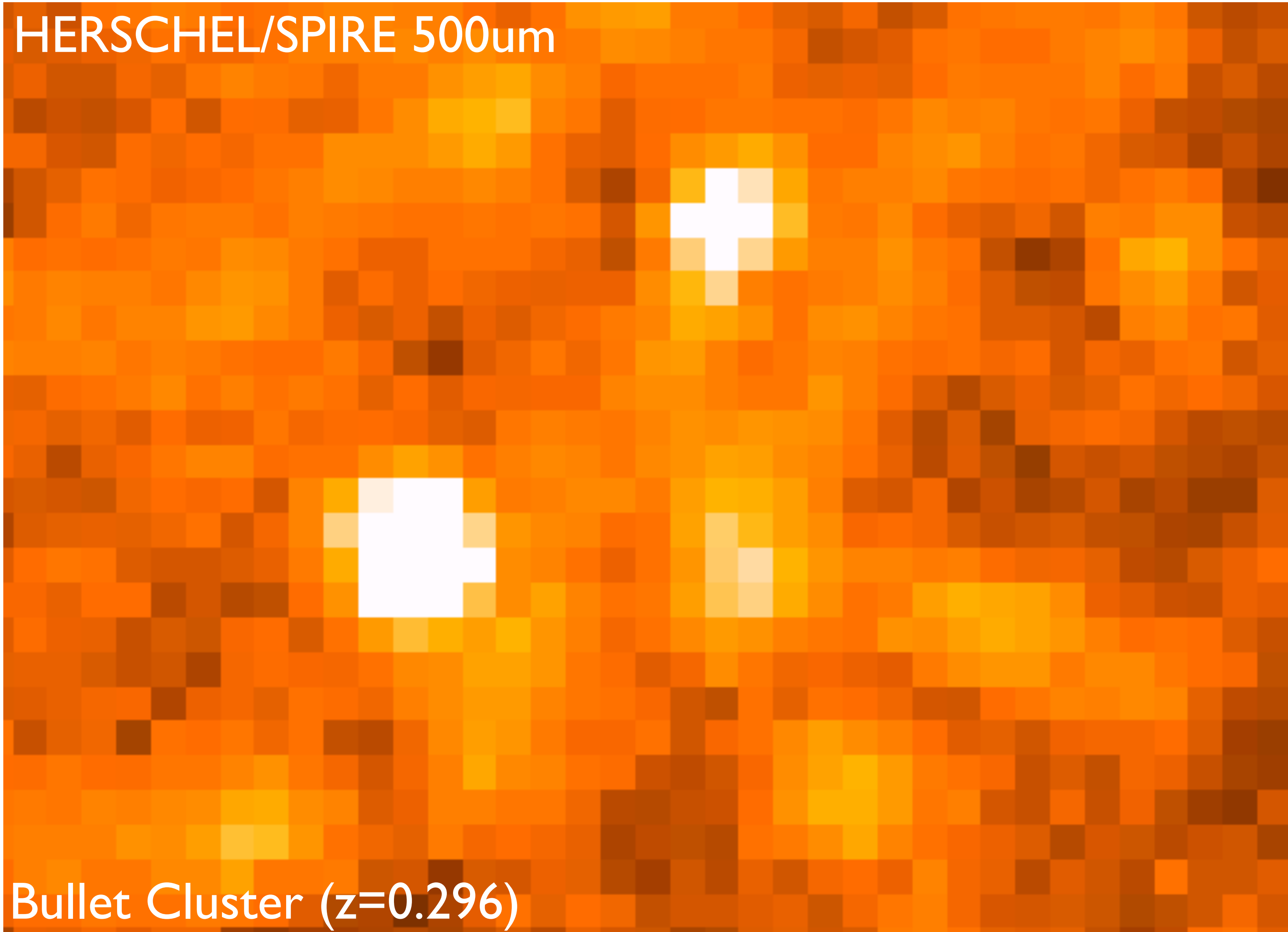
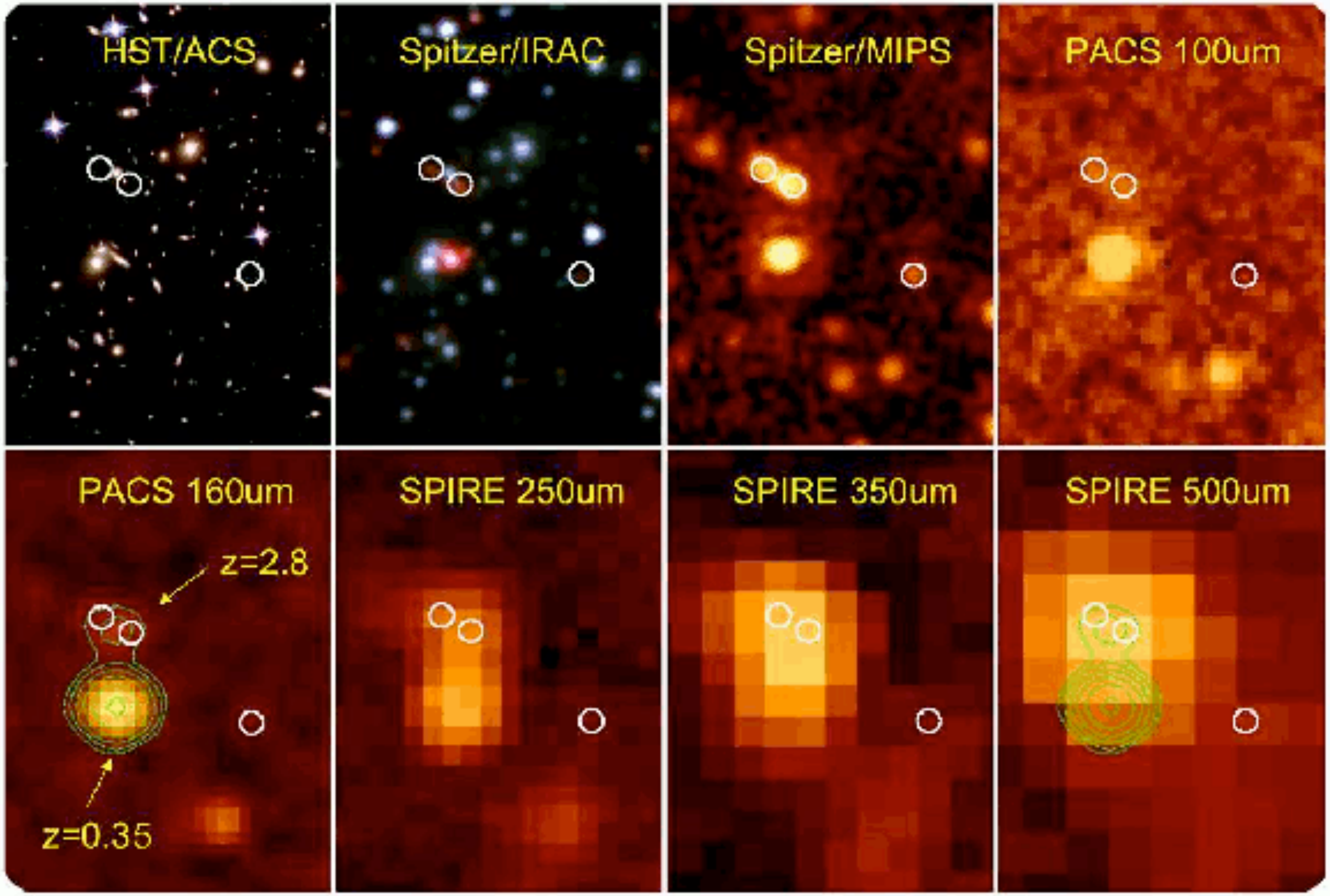


The power of Herschel



Faint (LIRG; 5×10^{11} $L_\odot$) lensed source at z=2.8

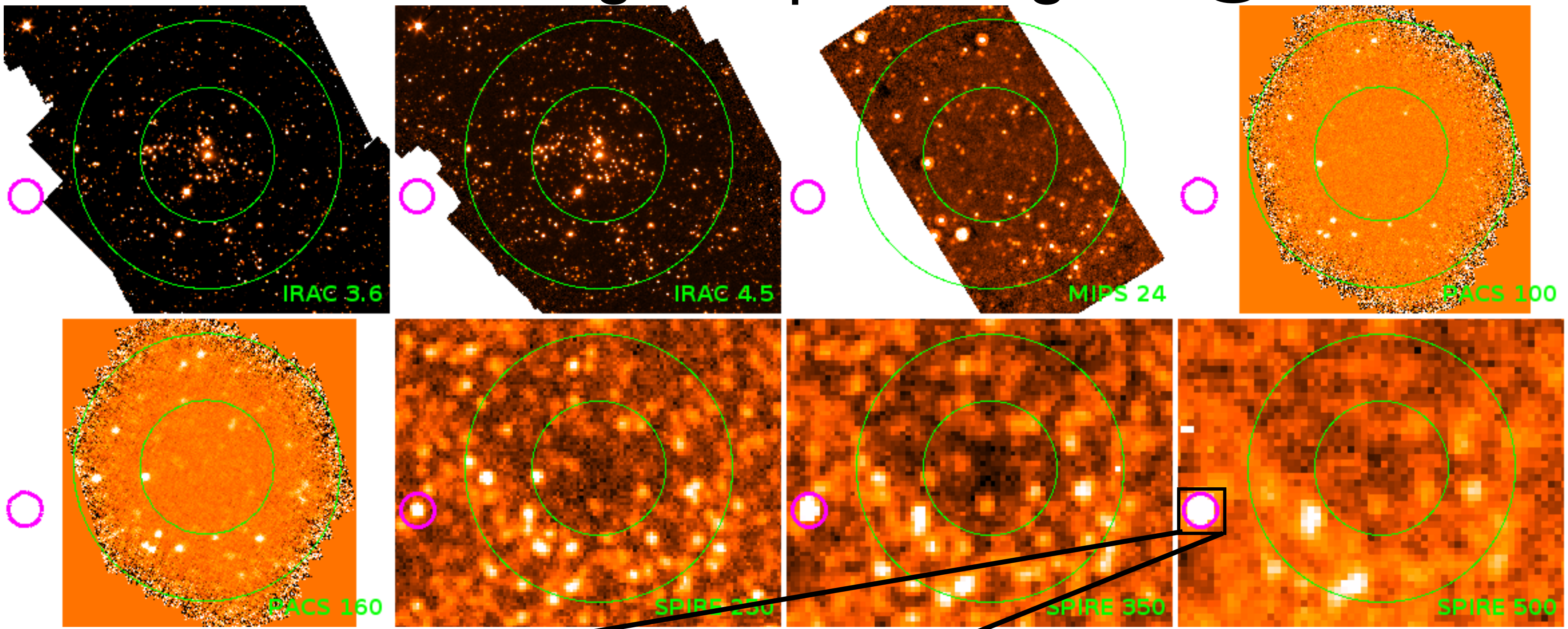


[Rex+10]

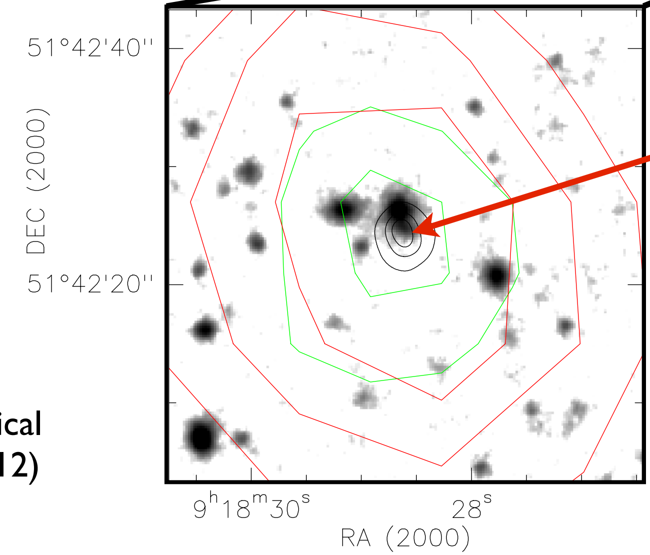
Magnification factor of ~75x
Observed Herschel flux densities: 7.0, 24.5, 65.3, 98.6, 101.4 mJy
Corrected for lensing: 0.09, 0.3, 0.9, 1.3, 1.4 mJy

Such a source would be impossible to observe without lensing

A773: Resolving multiple SF regions @ z>5



[Rawle+14]

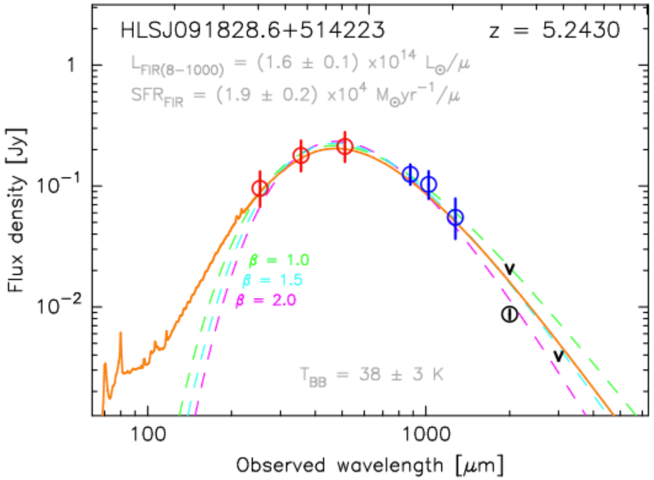


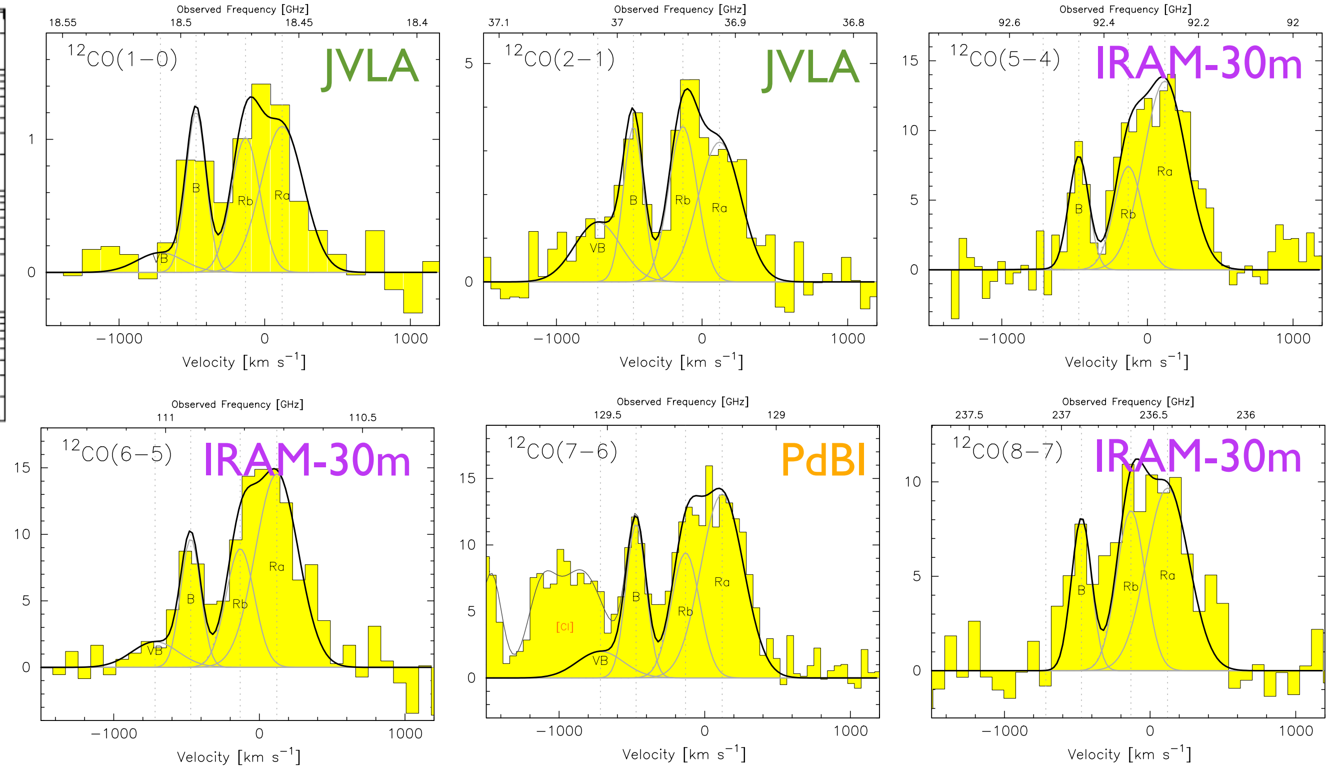
Subaru optical
(Combes+12)

Herschel source primarily magnified by a background source @ z=0.63

Black contour = 880μm
(SMA)
2'' FWHM PSF

A773: continuum and line emission



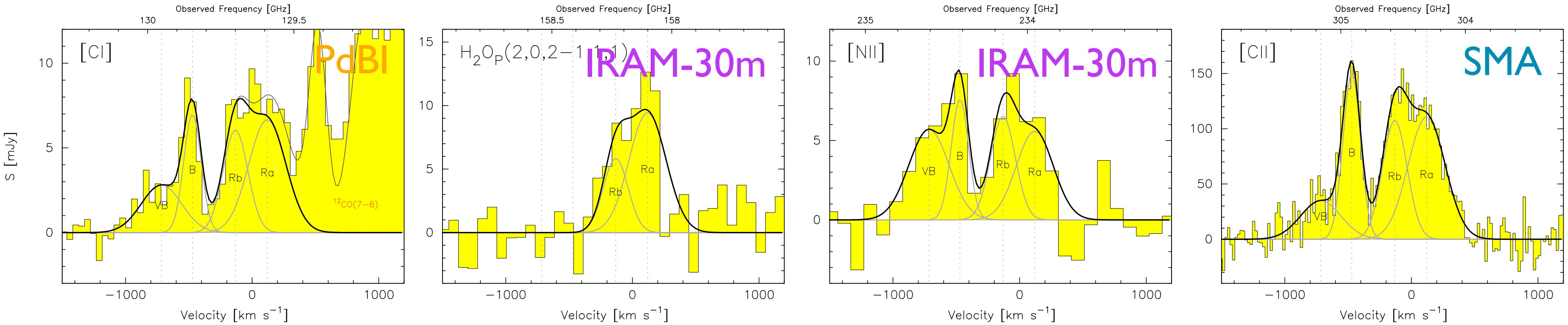


$\mu = 9 \pm 2$

$T_{dust} = 38 \pm 3K$

$L_{FIR} = (1.8 \pm 0.4) \times 10^{13}\ L_\odot$

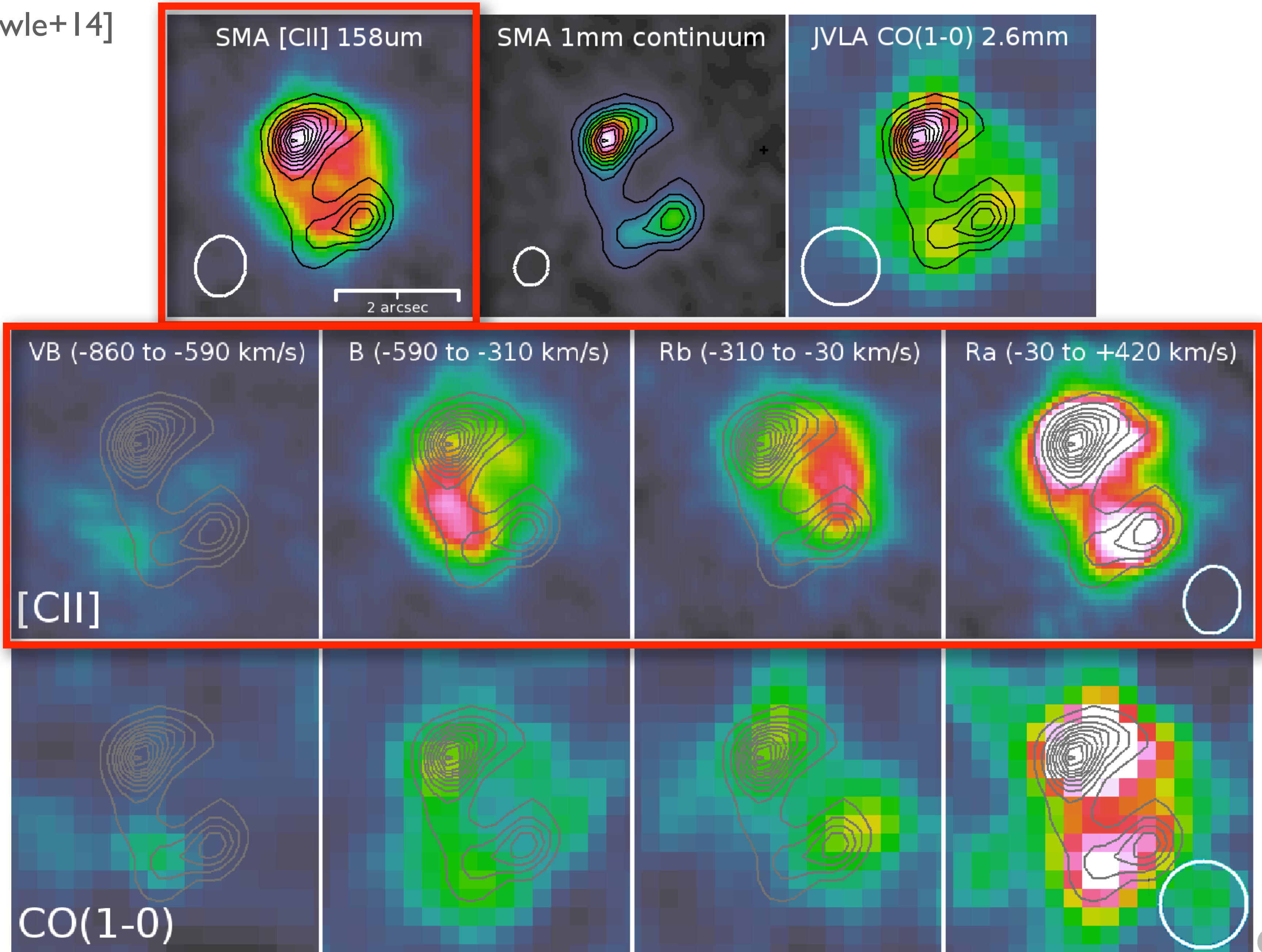
$SFR = 2130 \pm 200\ M_\odot/yr$



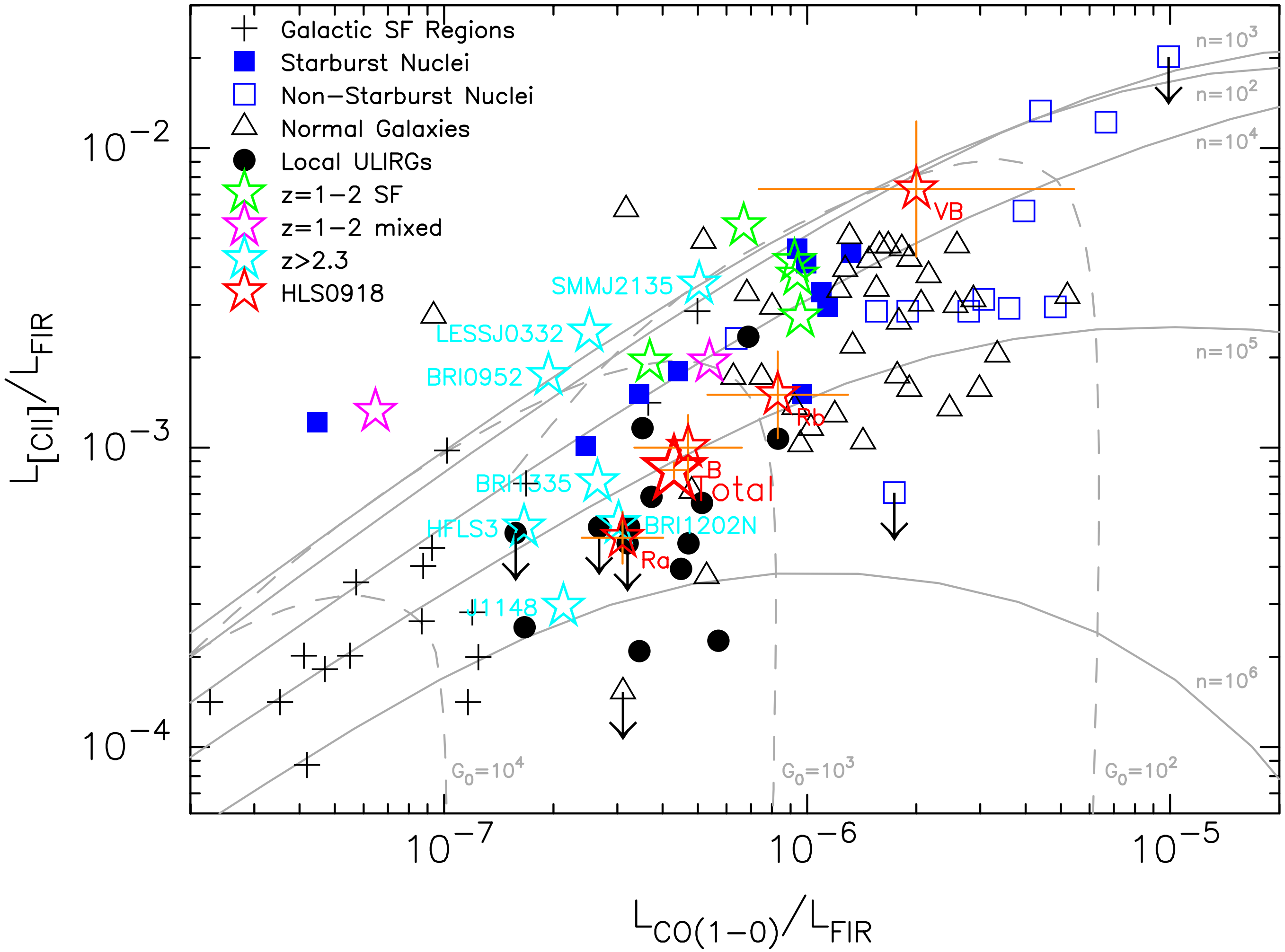
[Rawle+14]

A773: Spatially resolved emission

[Rawle+14]



A773: Physical properties of the star-forming regions

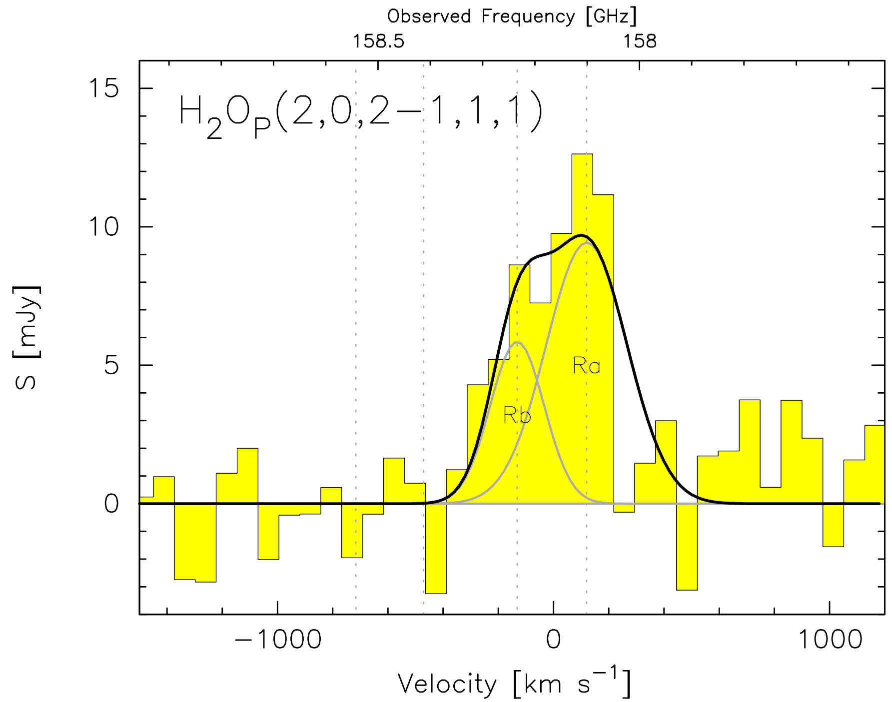


[Rawle+14]

adapted from De Breuck+11

- Grey lines represent (solar metallicity) PDR models with varying gas density (*n*) and FUV field strength (*G₀*) from Kaufman+99
- Ra, Rb and B similar to local ULIRGs (Ra resembles high-z quasar hosts)
- VB exhibits characteristics of normal local galaxies

A773: H_2O emission



H_2Op(2,0,2-1,1,1)

@ 304μm

IRAM-30m
(Combes+12)

- Water emission is excited by strong FIR radiation field, from intense star formation
- Only detected from Ra and Rb
- Ra emission consistent with ULIRG trend $L_{H2O} = L_{FIR}^{\alpha}$ where α=1.1±0.1 (Omont+13)
- Rb has very strong water emission for given L_{FIR} (α=2.5±0.7)

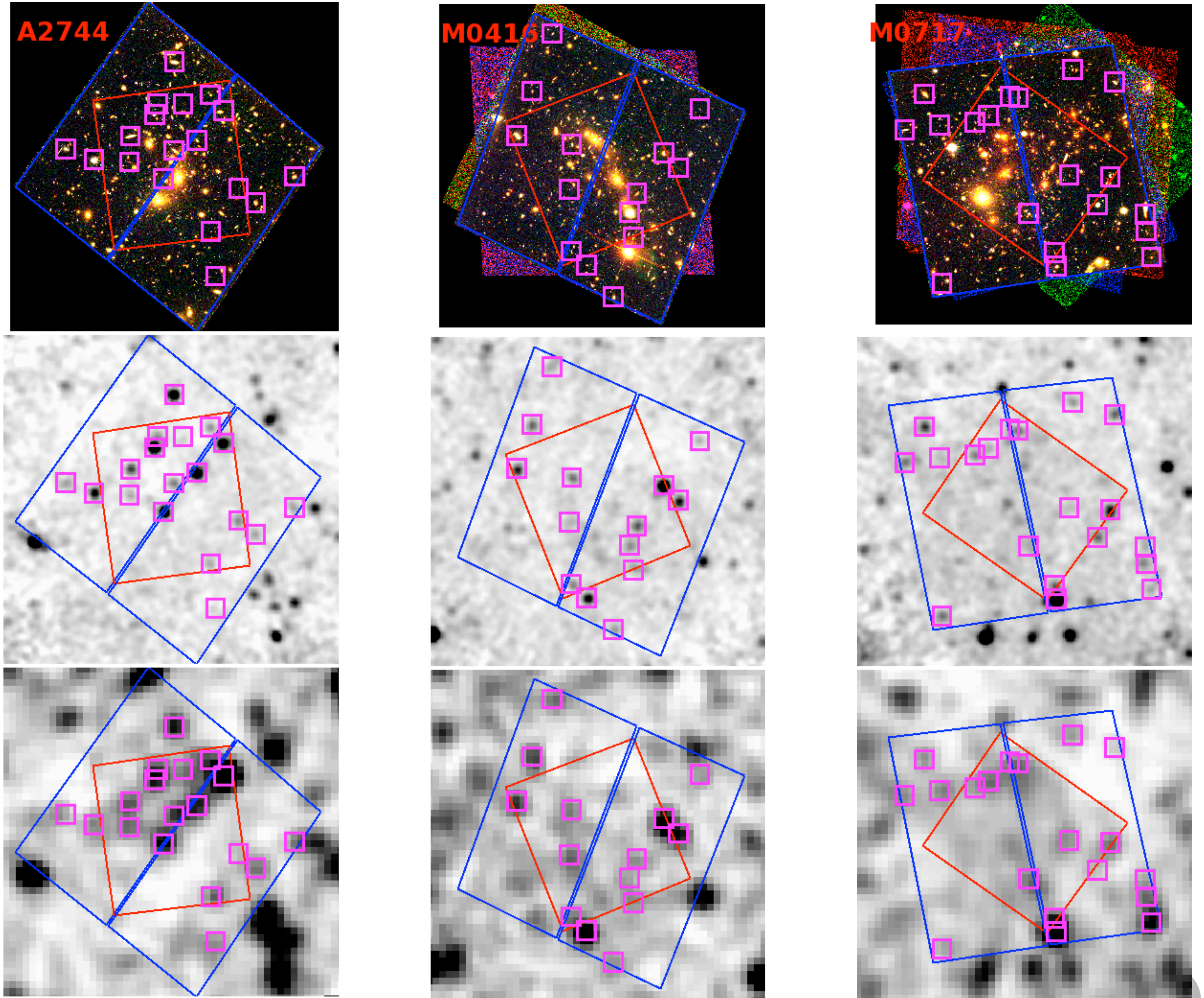
- Ra ($L_{FIR,Ra} \approx 10^{13}\ L_{\odot}$) excites water emission in both components
- Ra and Rb have ΔV=250 km/s and a source plane separation of <1kpc
- Ra-Rb are two neighbouring components in the nucleus of a massive galaxy

The Herschel View of the Frontier Fields [Rawle+in prep]

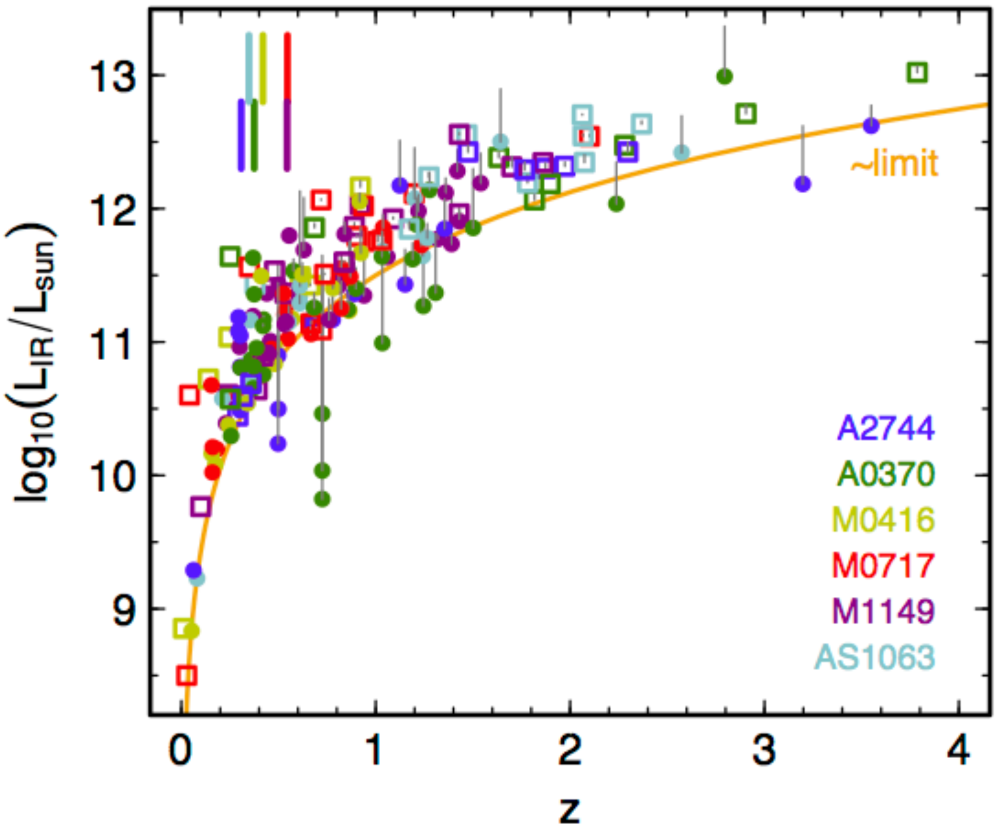
HST

PACS 100

SPIRE 250

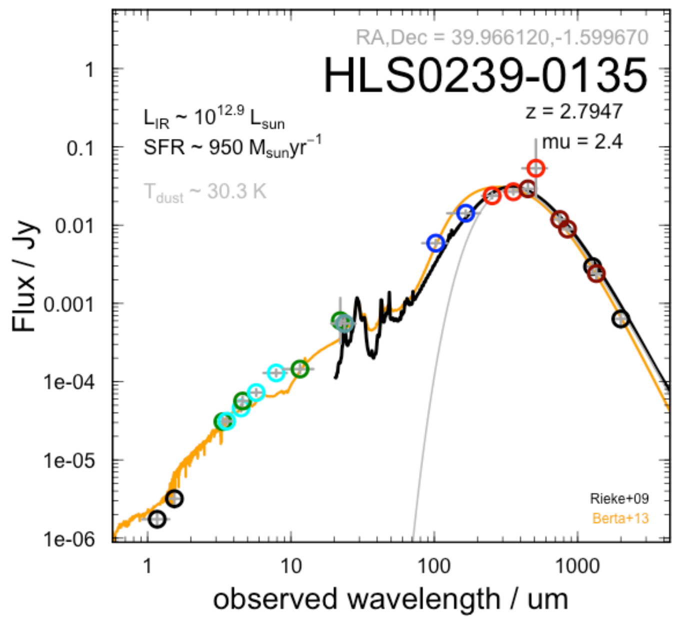


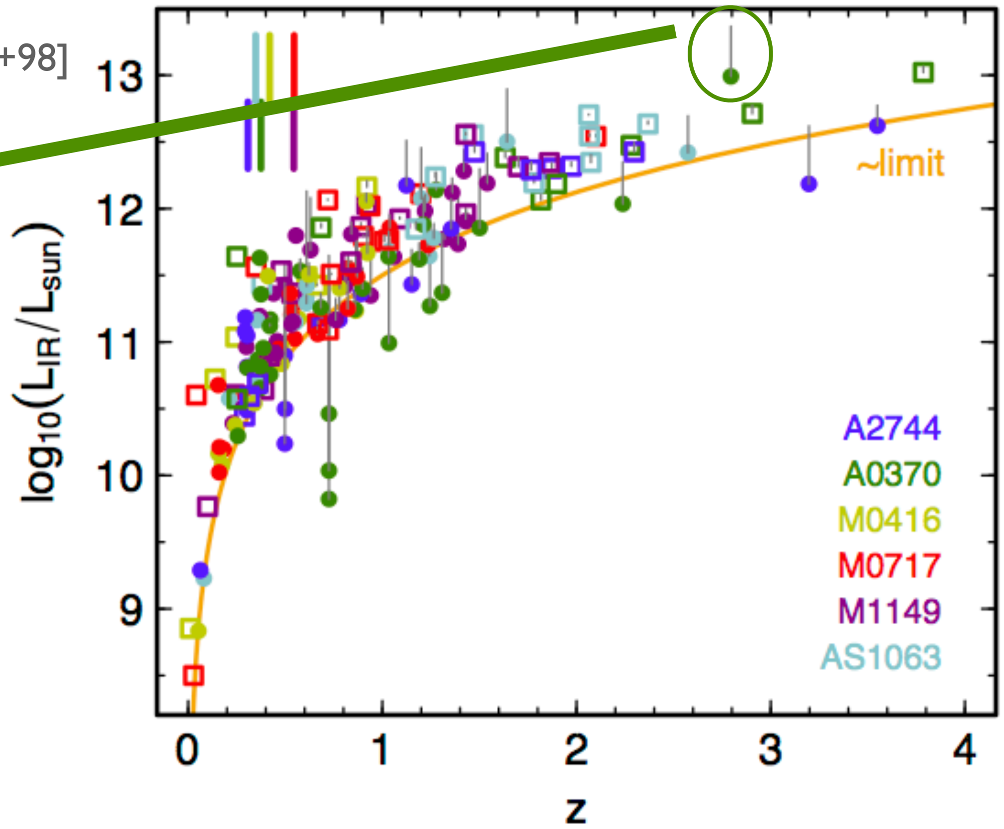
The Herschel View of the Frontier Fields [Rawle+in prep]



The Herschel View of the Frontier Fields [Rawle+in prep]

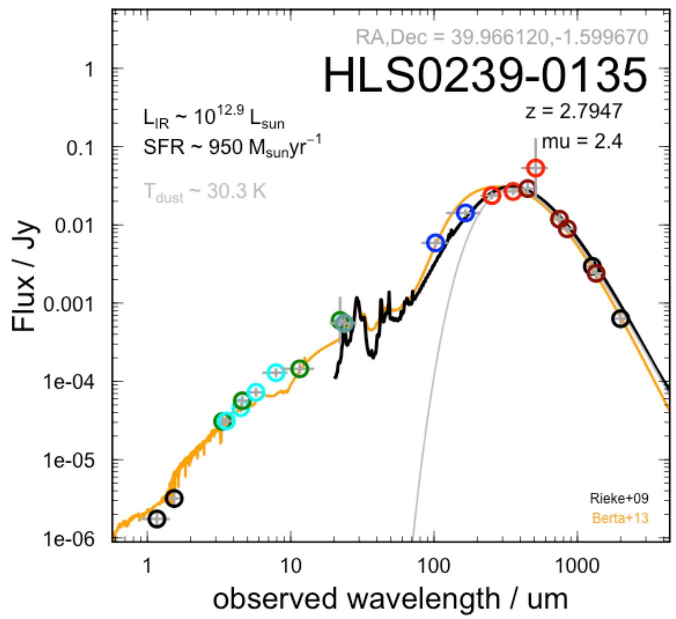
SMM02399-0136 [Ivison+98]

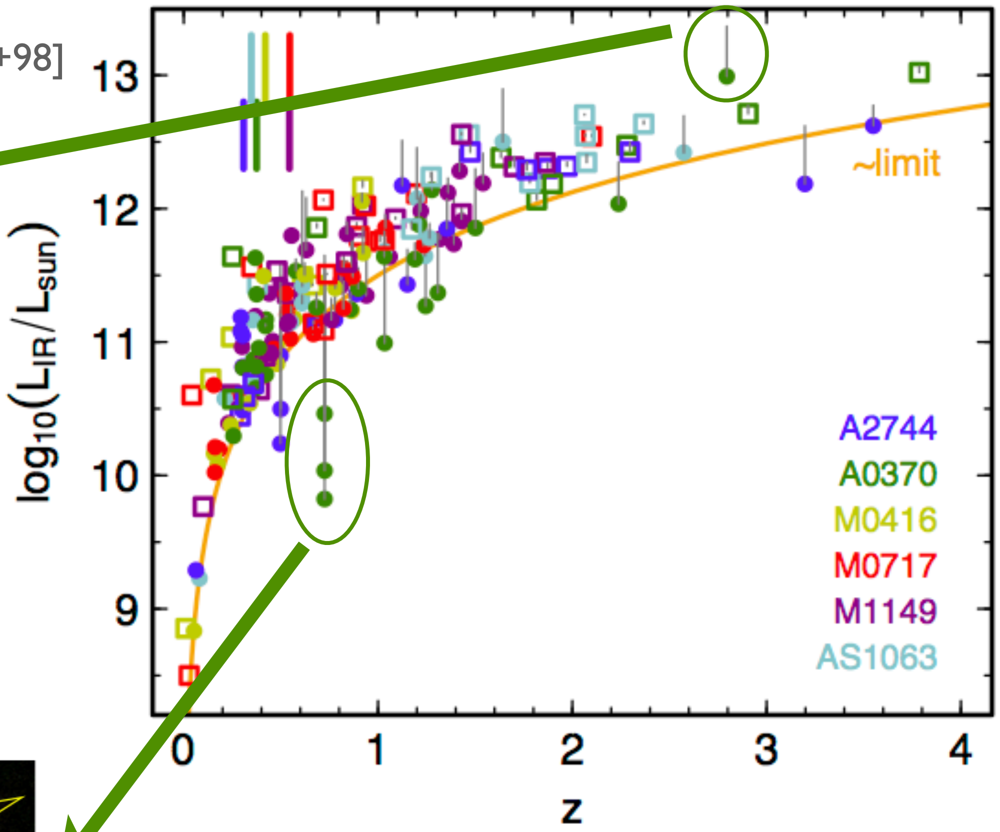


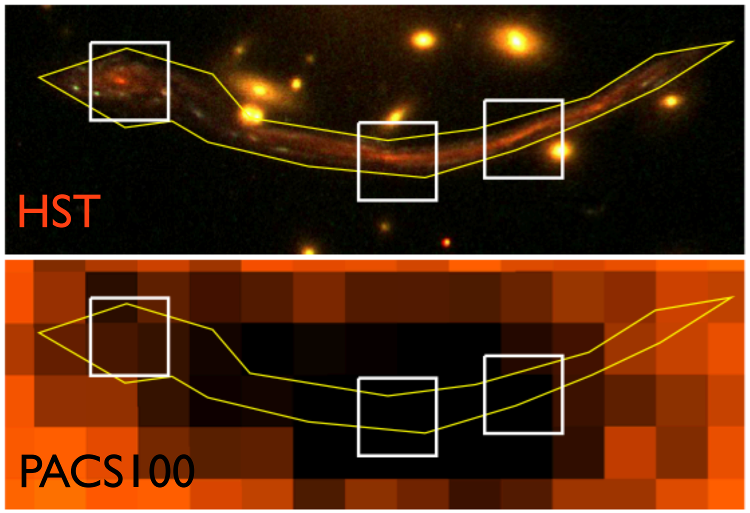


The Herschel View of the Frontier Fields [Rawle+in prep]

SMM02399-0136 [Ivison+98]

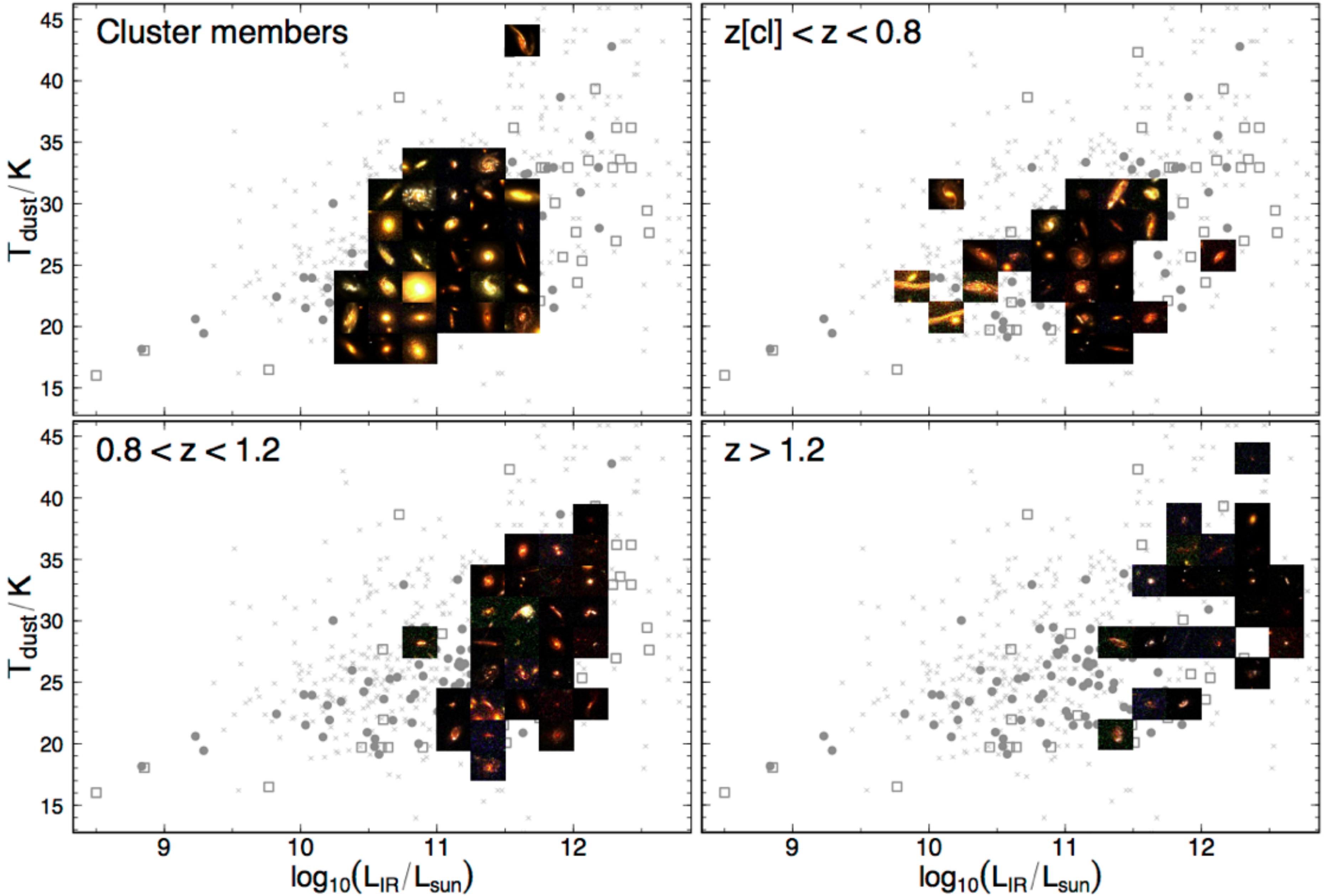






- Arc @ z=0.725 behind A370 [Soucail+88]
- Five separate images are detected as three individual Herschel sources [Richard+10]
- Total magnification ~ 110x

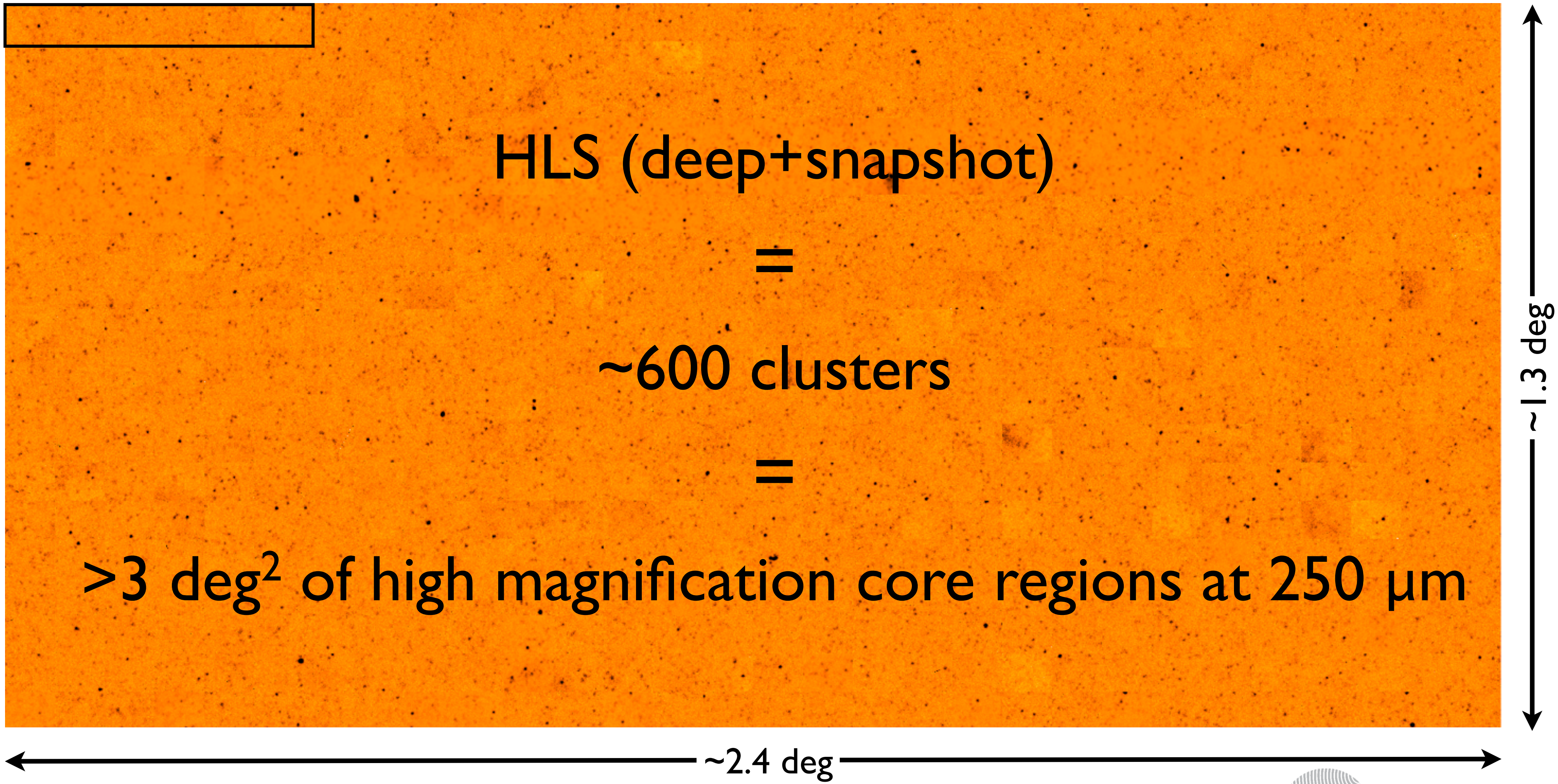
The Herschel View of the Frontier Fields [Rawle+in prep]

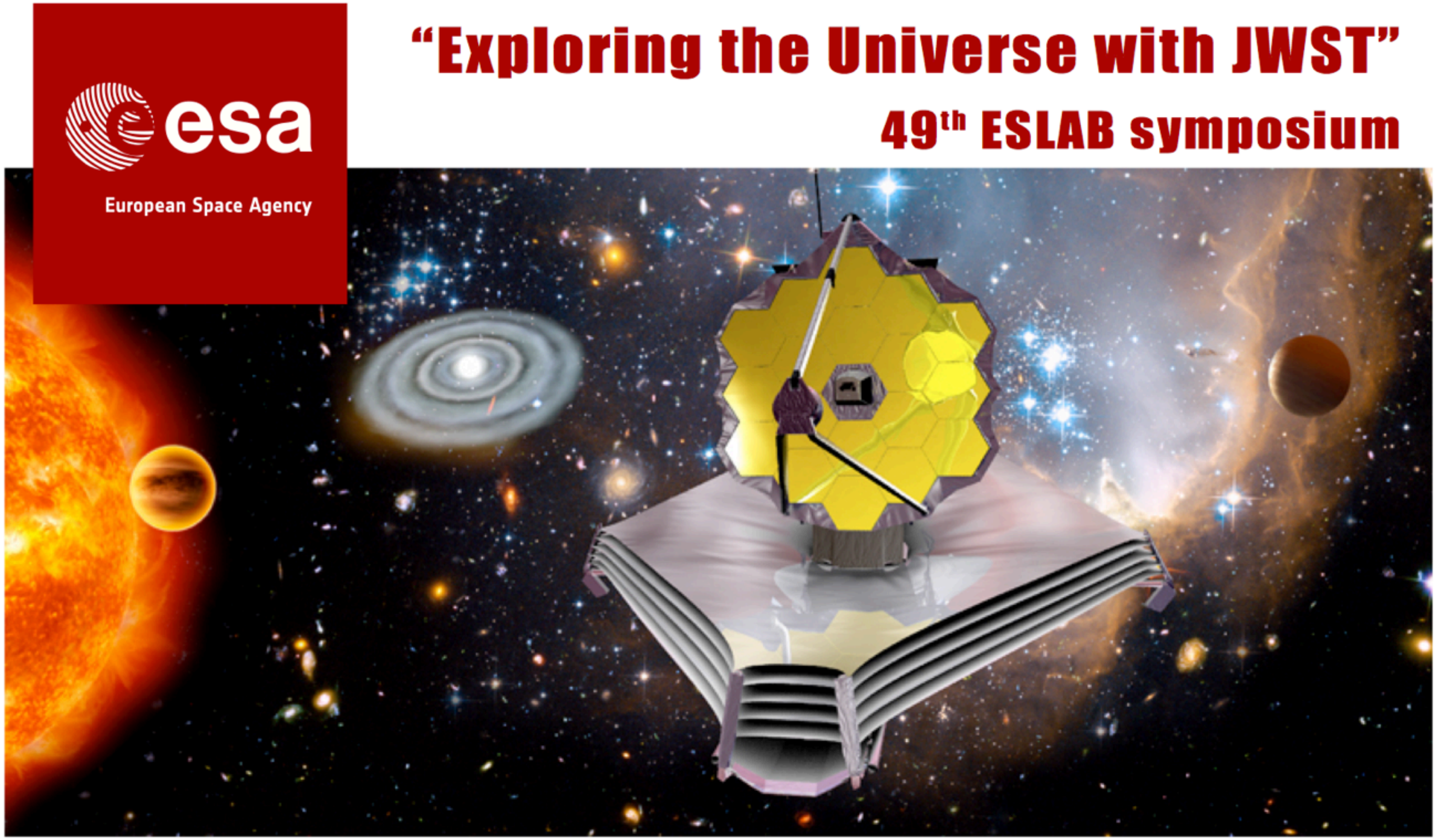


Summary - Herschel Lensing Survey

Lensing gives us:

- Enormous gain in sensitivity for free
- Extraordinary spatial resolution at high redshift





12-16 October 2015
ESTEC, Noordwijk, NL

http://congrexprojects.com/15a02/

Registration opened Monday