IDCS J1426.5+3508: A Massive, Strong Lensing Cluster at z=1.75

Anthony Gonzalez

University of Florida

Mark Brodwin
Adam Stanford
Cosimo Fedeli
John Carlstrom
Arjun Dey
Peter Eisenhardt
Daniel Gettings
Buell Jannuzi
Marshall Joy
Erik Leitch
Conor Mancone
Dan Marrone
Tom Plagge
Greg Snyder
Daniel Stern
Greg Zeimann

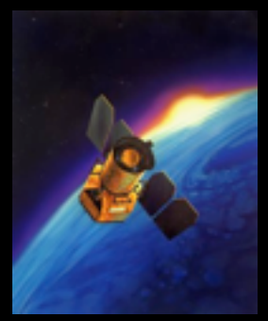
ESAC, September 12, 2012

The IRAC Shallow Cluster Survey (ISCS)

The NOAO/Spitzer Deep Wide-Field (NDWFS/SDWFS)

- ✔ **9 deg²**
- ✔ **Extensive Community Investment**

VLA & Westerbork



GALEX

NDWFS (B_wRI)
FLAMEX (JK_s)
IBIS (JHK_s)

IRAC Shallow Cluster Survey

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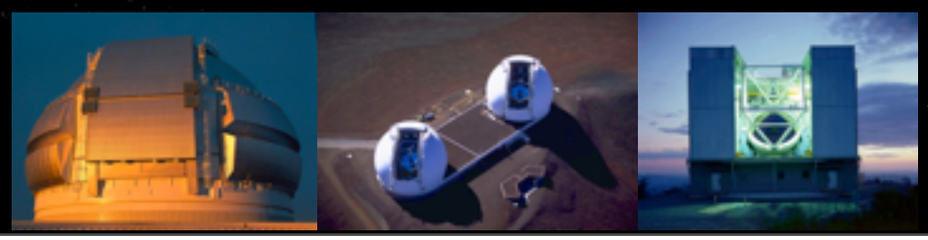
MAGES (MIPS)
Spitzer Deep Wide-Field Survey

Chandra XBootes Survey

Herschel GTO



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Keck & Gemini (>400 redshifts at z>1)

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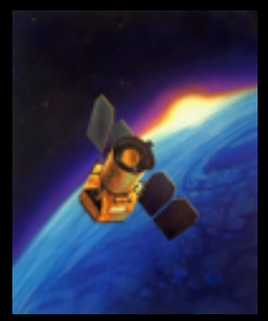

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Pushing to higher redshift

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Key New Ingredients:

Spitzer Deep Wide-Field Survey (SDWFS)

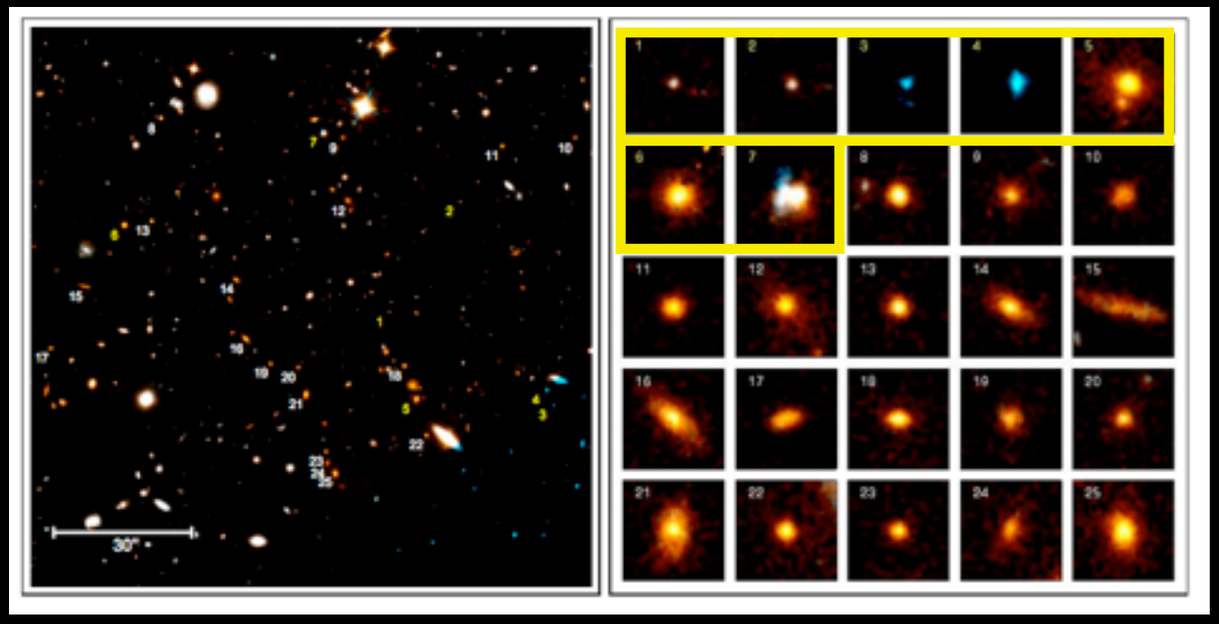
Factor of 4 increase in exposure time

Infrared Bootes Imaging Survey (IBIS)

JHKs over full field

Refined search algorithm

Sensitive to higher z and lower mass than IDCS



IDCS J1433.2+2306 at z=1.89; Zeimann+ (2012)

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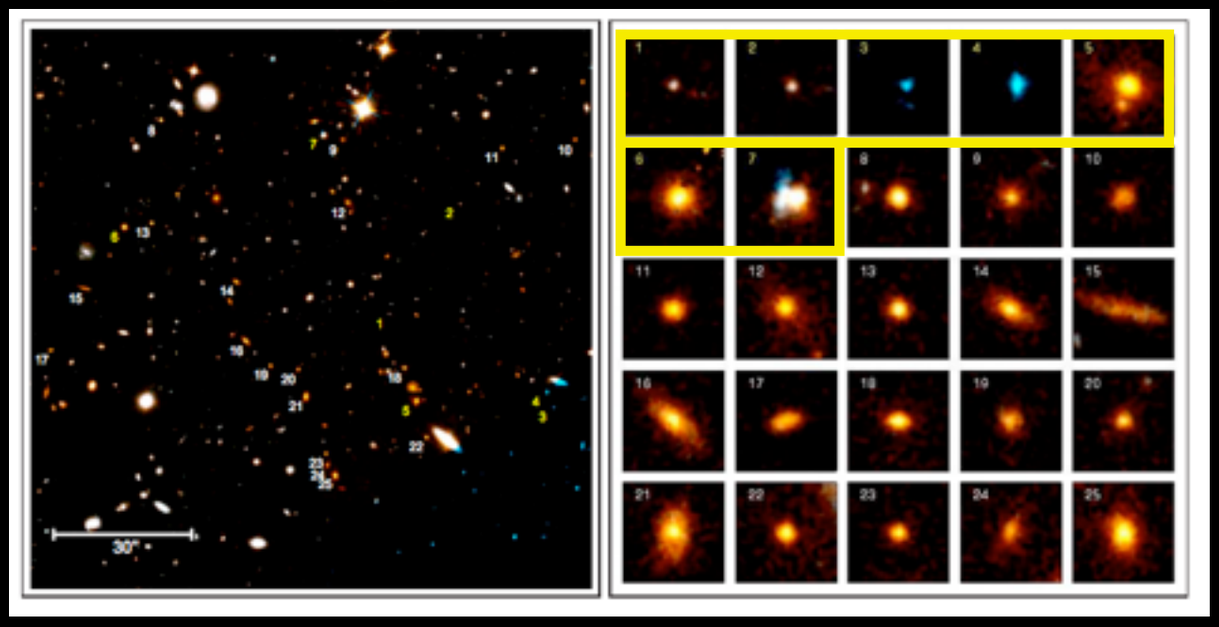

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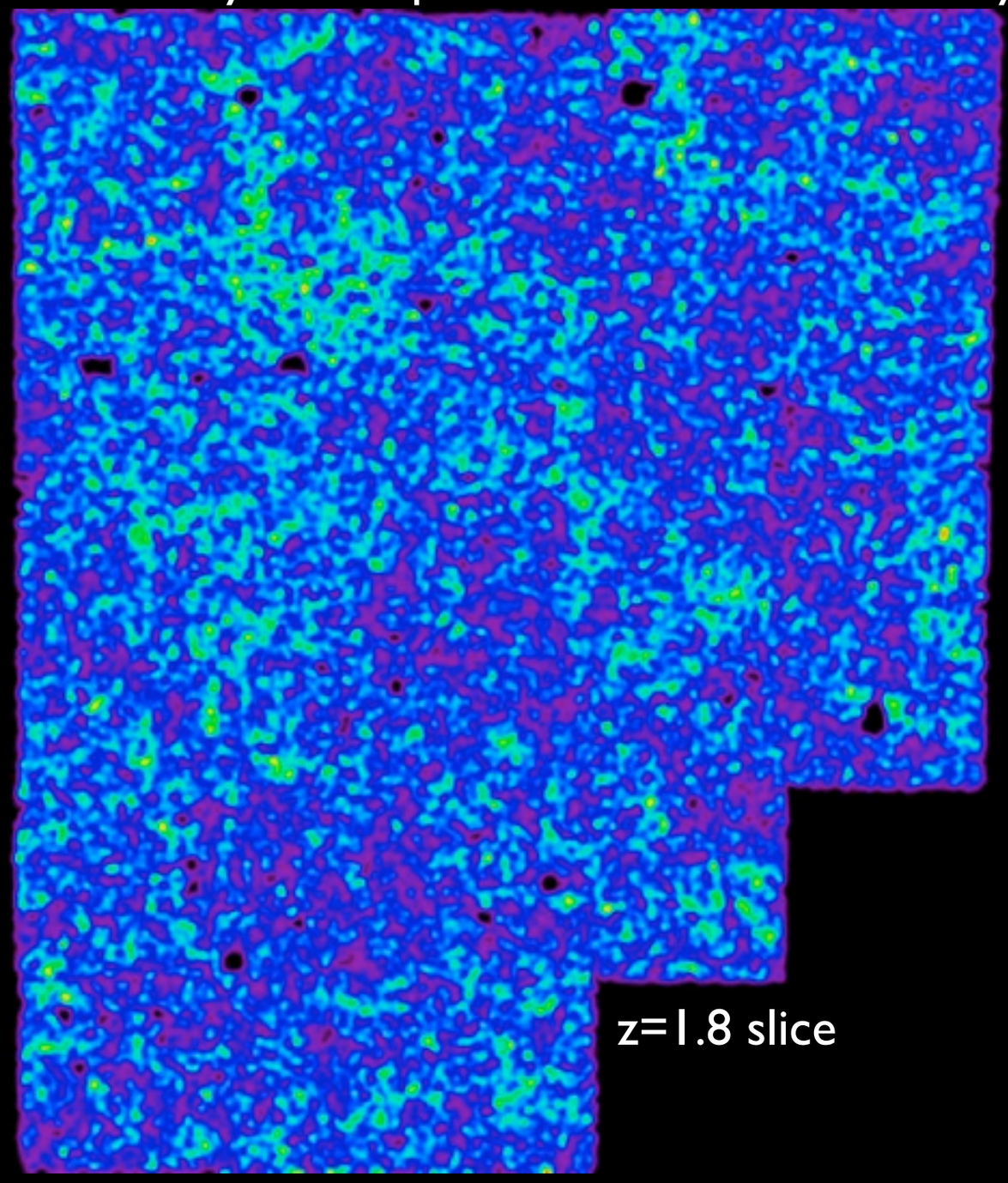
Preliminary search performed with SDWFS only



z=1.8 slice

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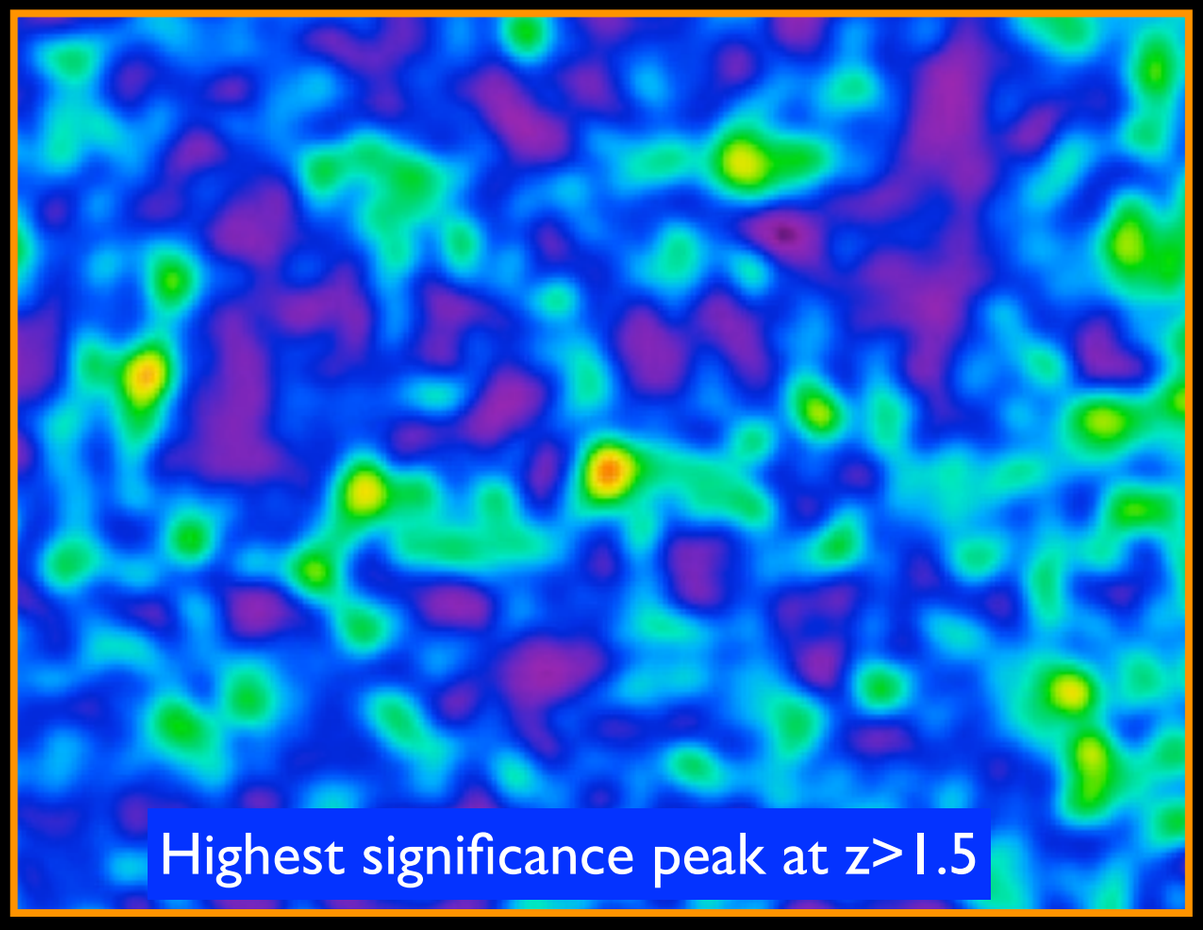

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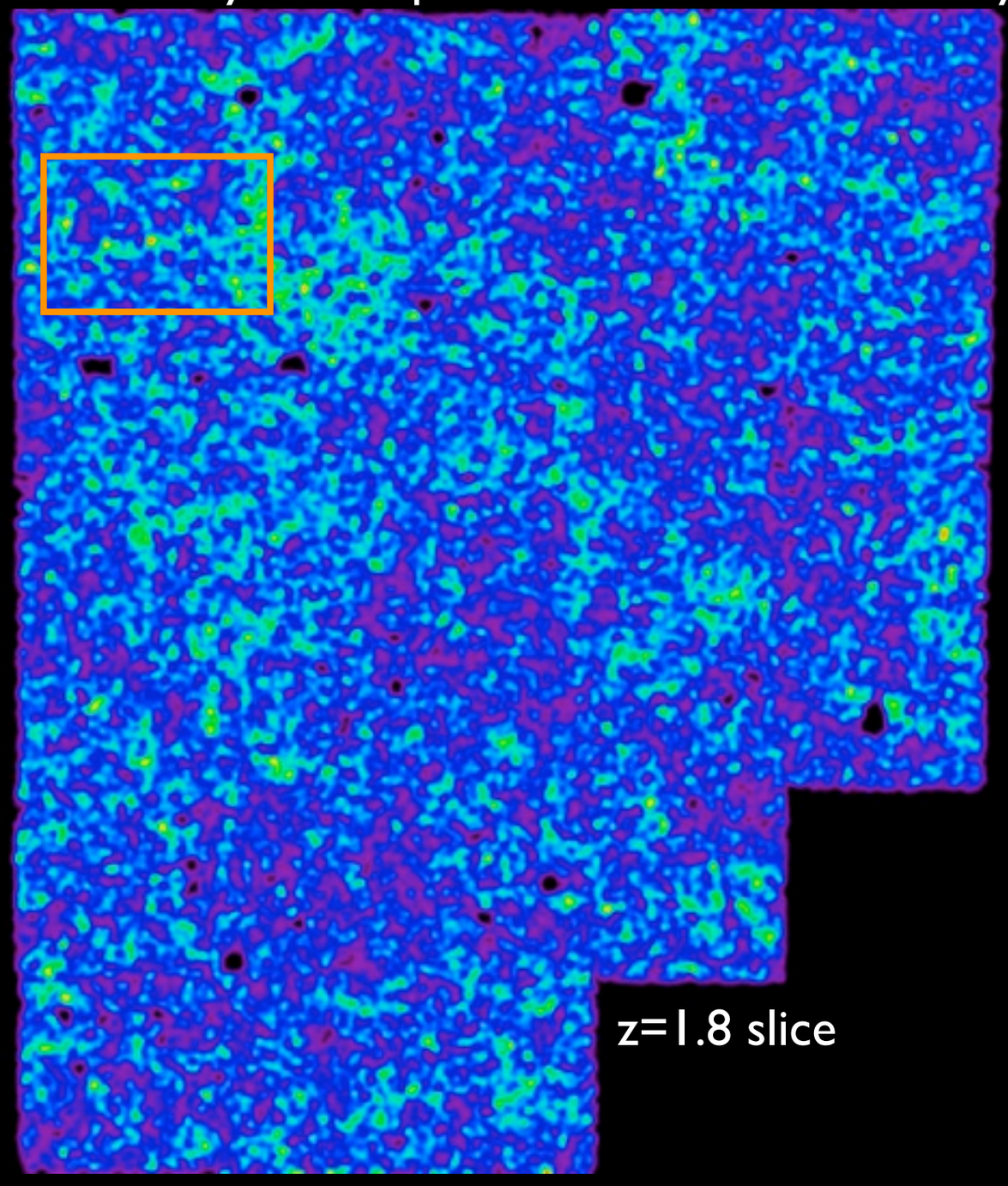

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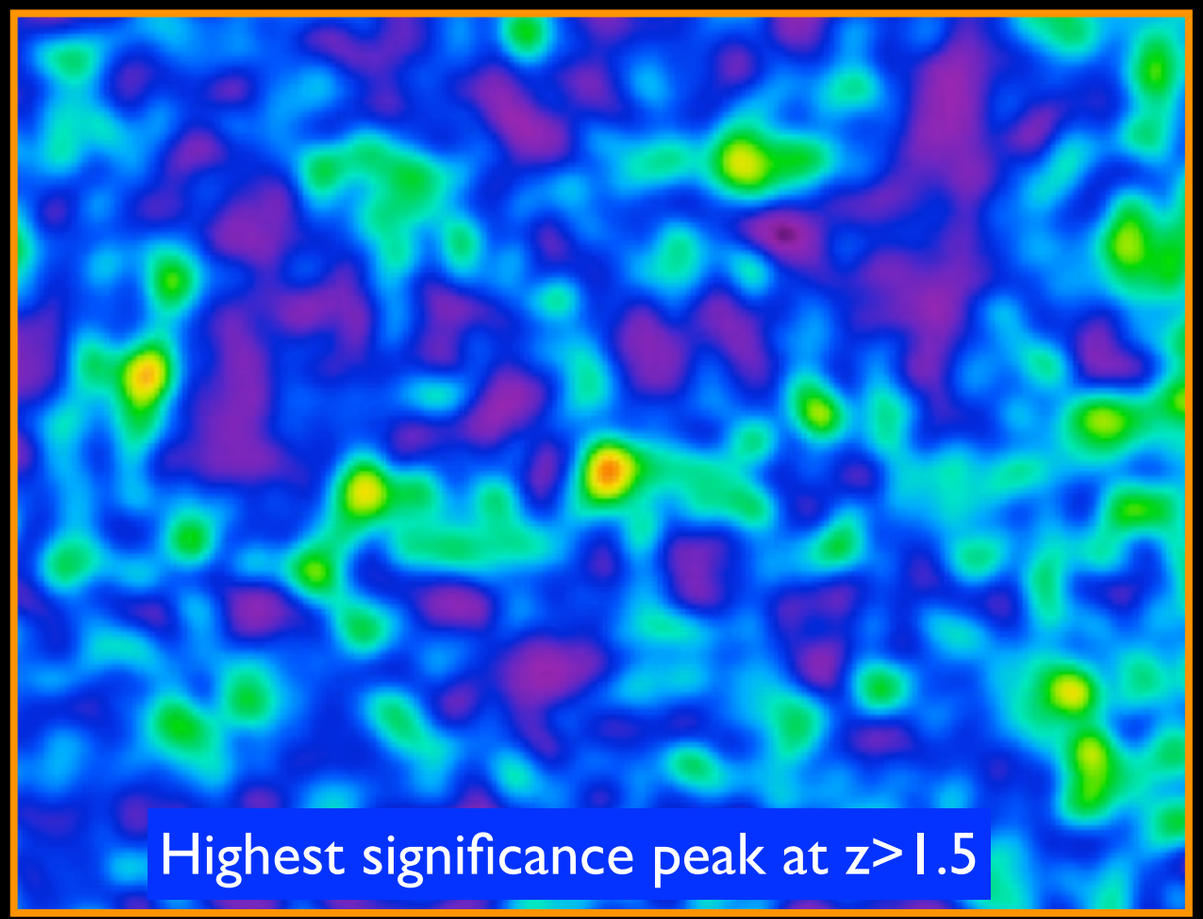

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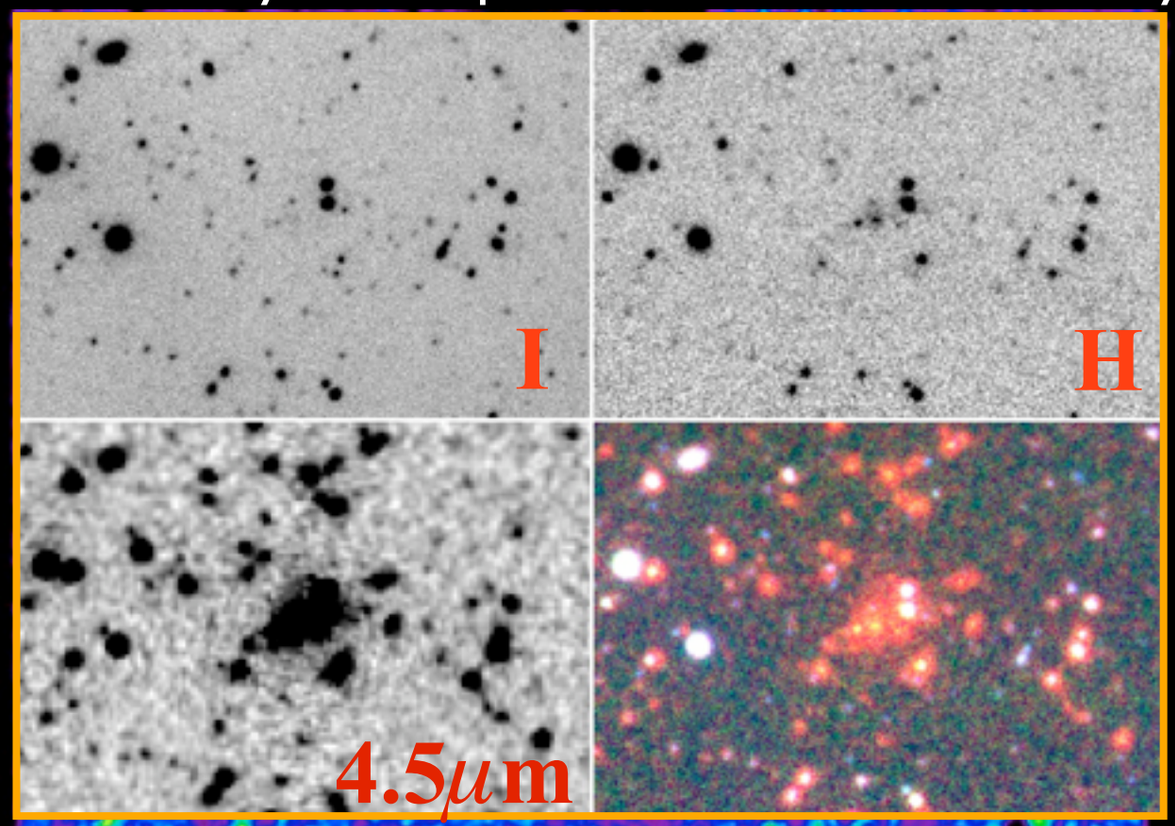
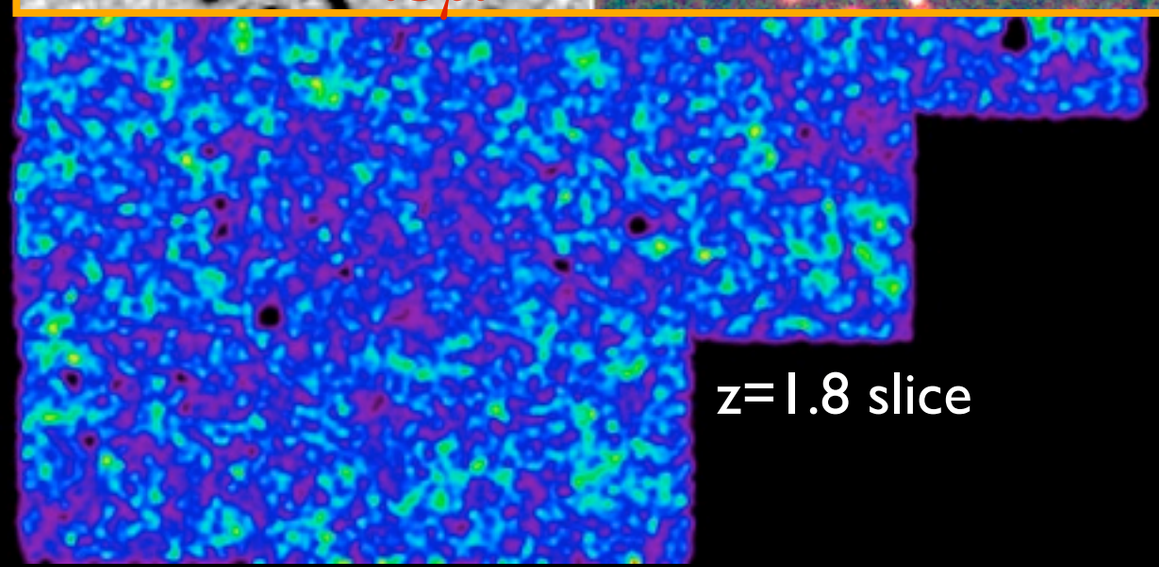
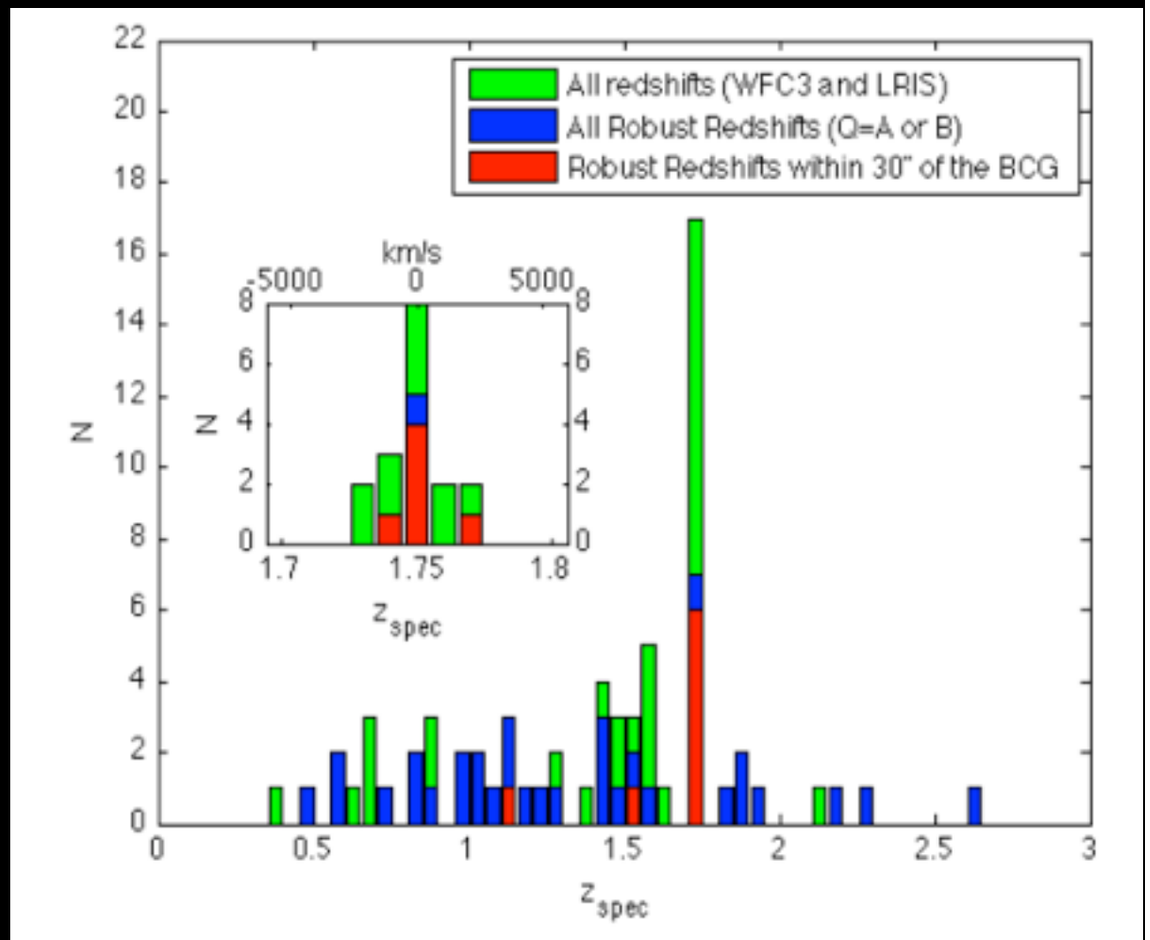




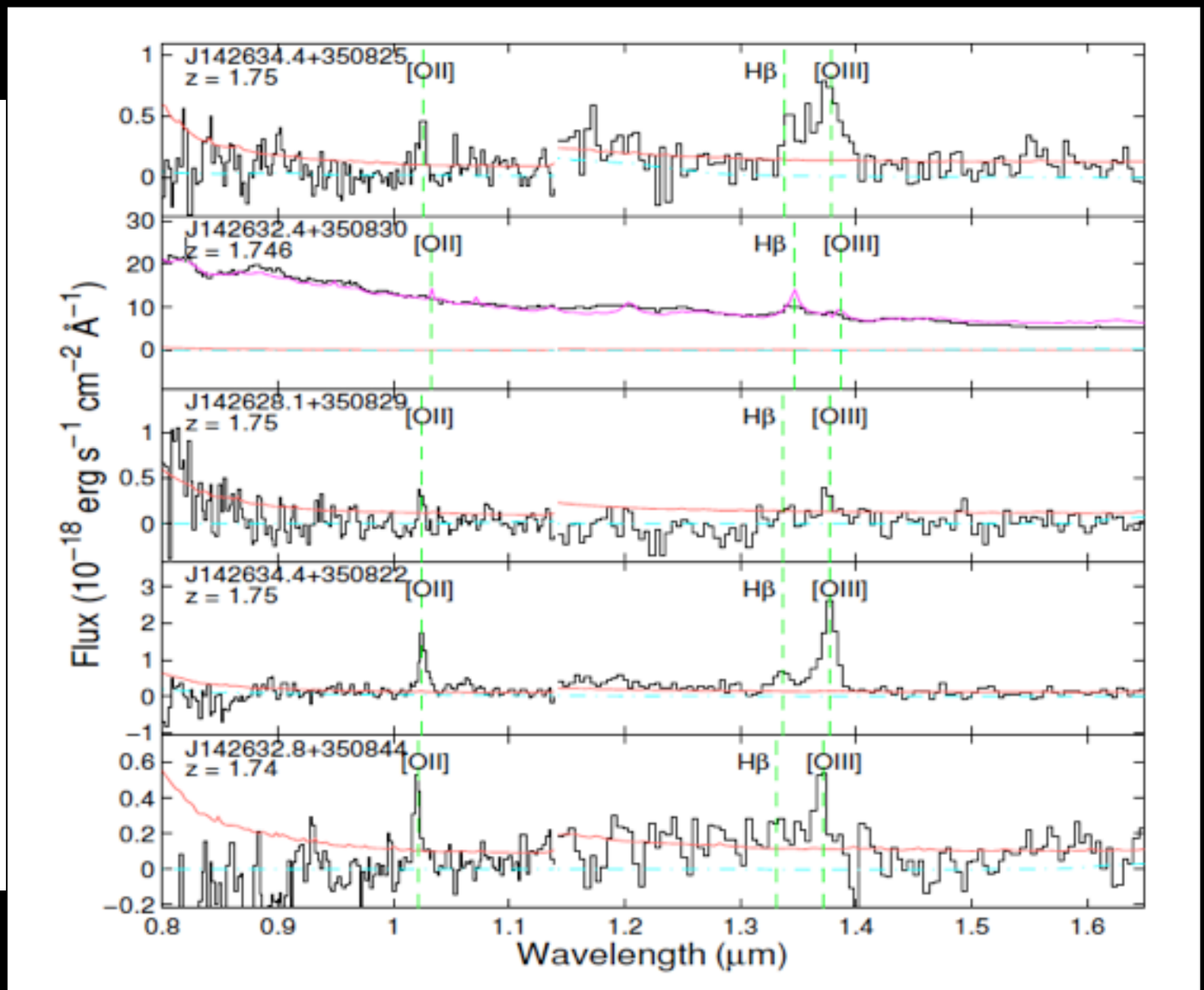
IDCS J1426.5+3508: Confirmation

Confirmation Spectroscopy with Keck/LRIS + WFC3 Grism

- **z=1.75**
- **7 spec-z confirmed members (6 within 30" of BCG), including 1 QSO**
- **10 additional lower quality grism spectra consistent with cluster redshift.**



Brodwin+ (2012)



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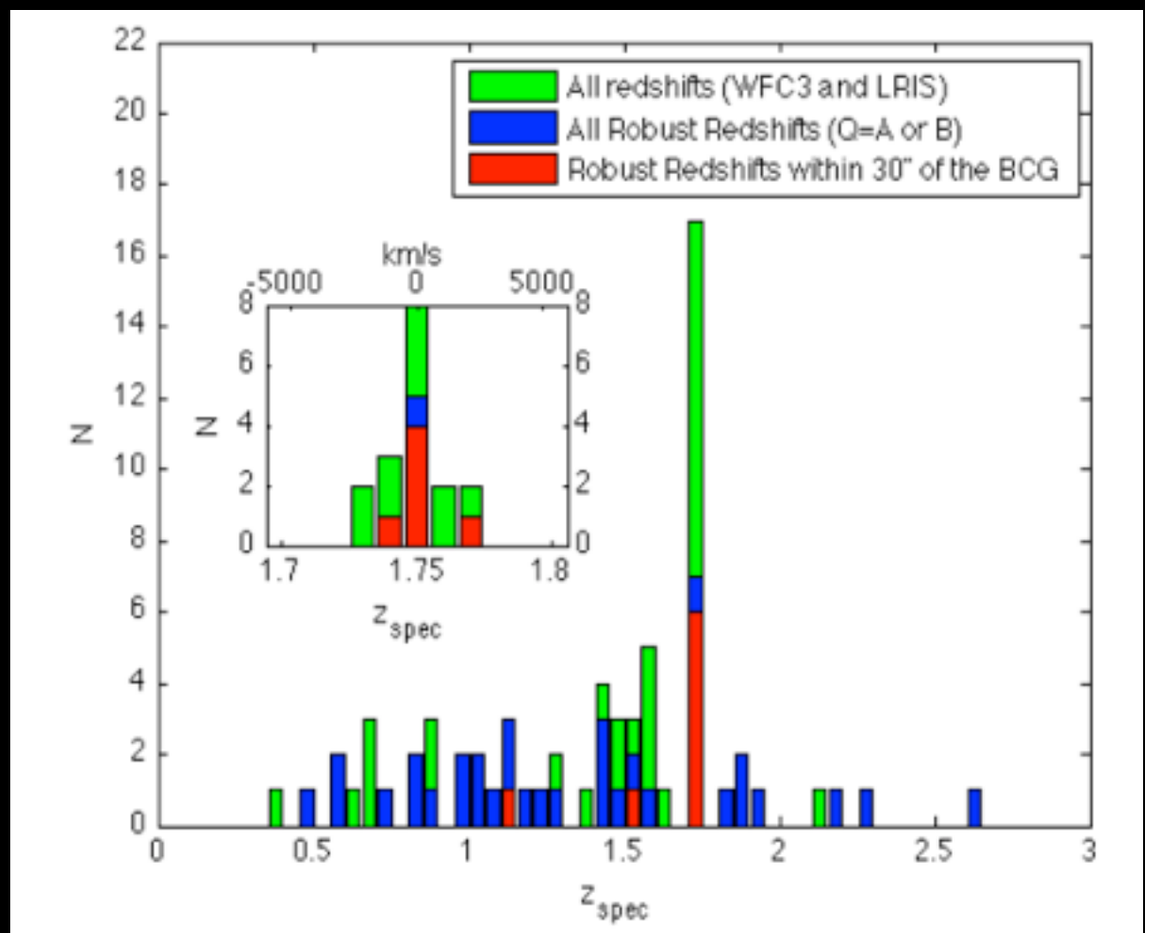

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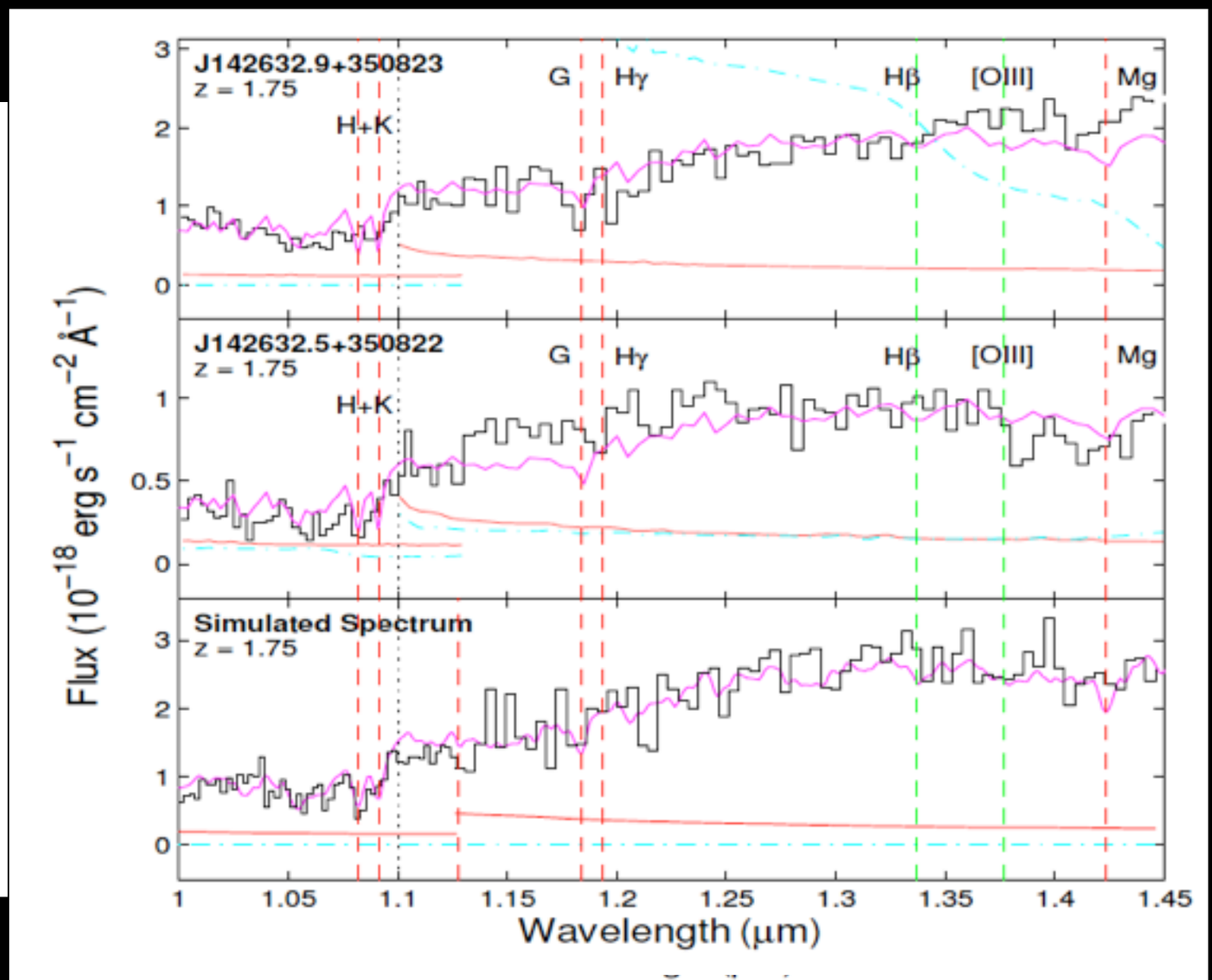
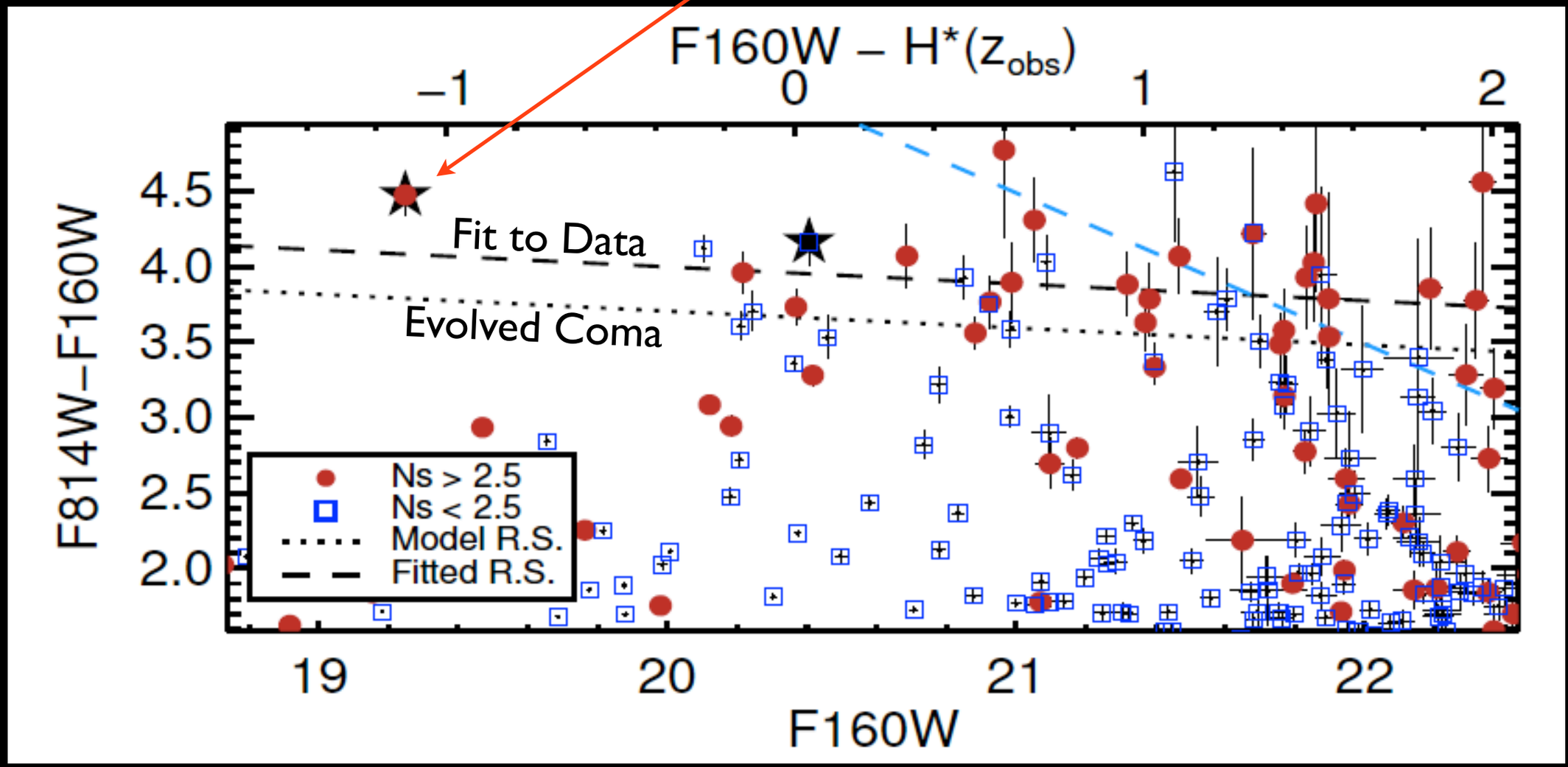


IDCS J1426.5+3508: Galaxy Properties

Red Sequence



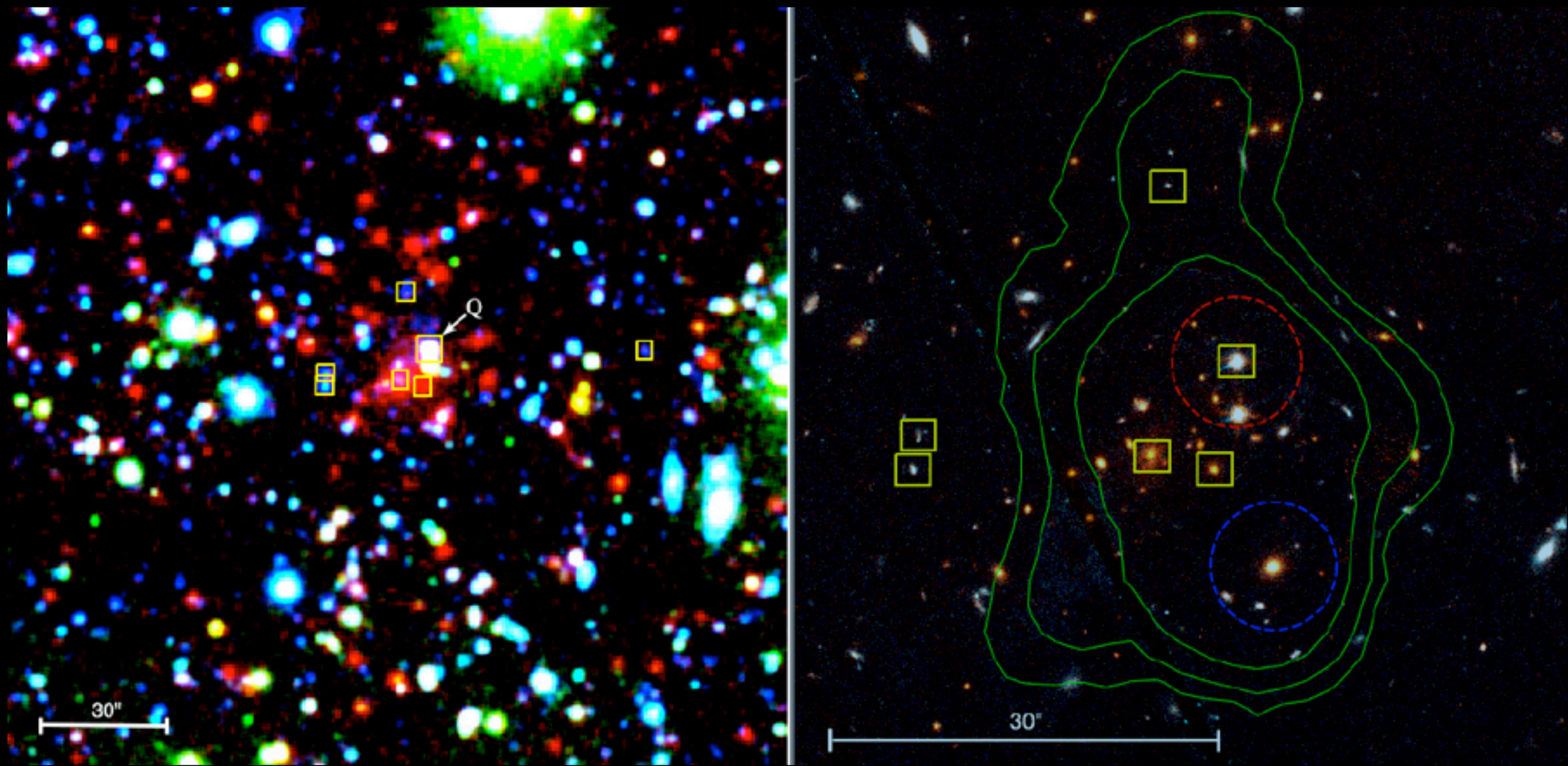
Starred symbols are spectroscopically confirmed members.

Stanford+ (2012)

IDCS J1426.5+3508: Mass

X-ray detection in 10 ks archival Chandra image ⇒ M_{200}~5.5x10^{14} $M_\odot$

Stanford+ (2012)



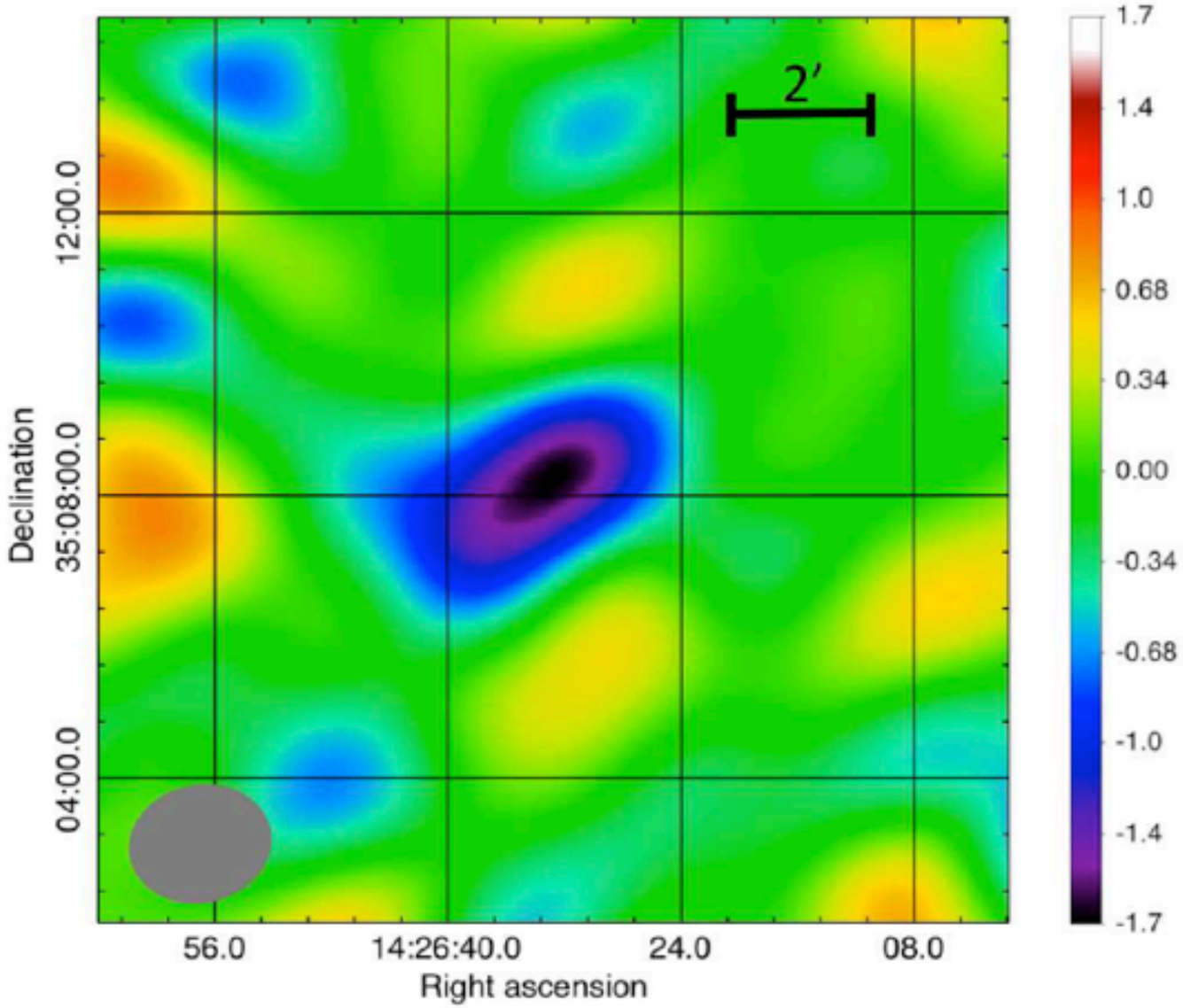
IDCS J1426.5+3508: Mass

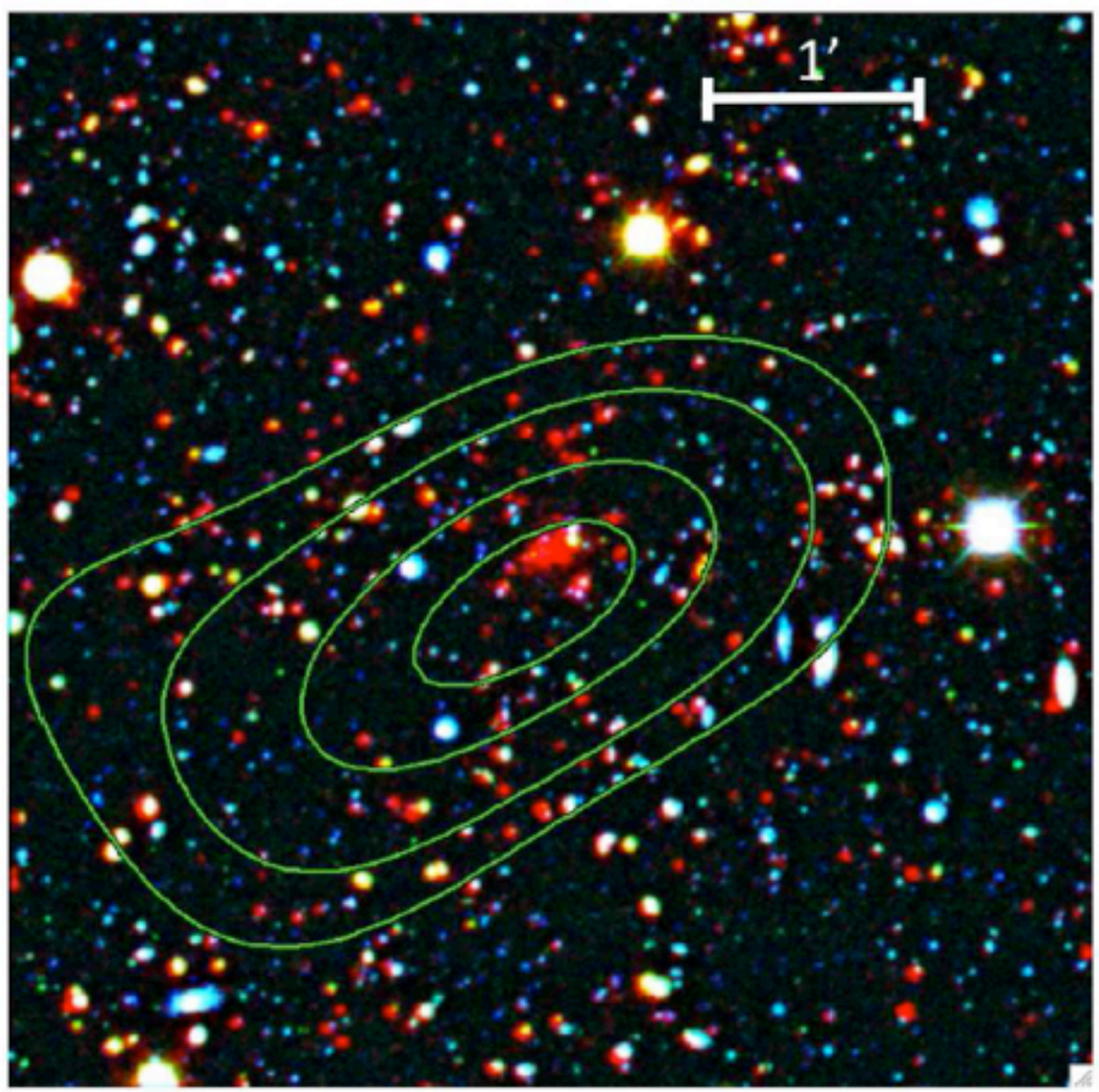
X-ray detection in 10 ks archival Chandra image ⇒ M_{200}~5.5x10^{14} $M_\odot$

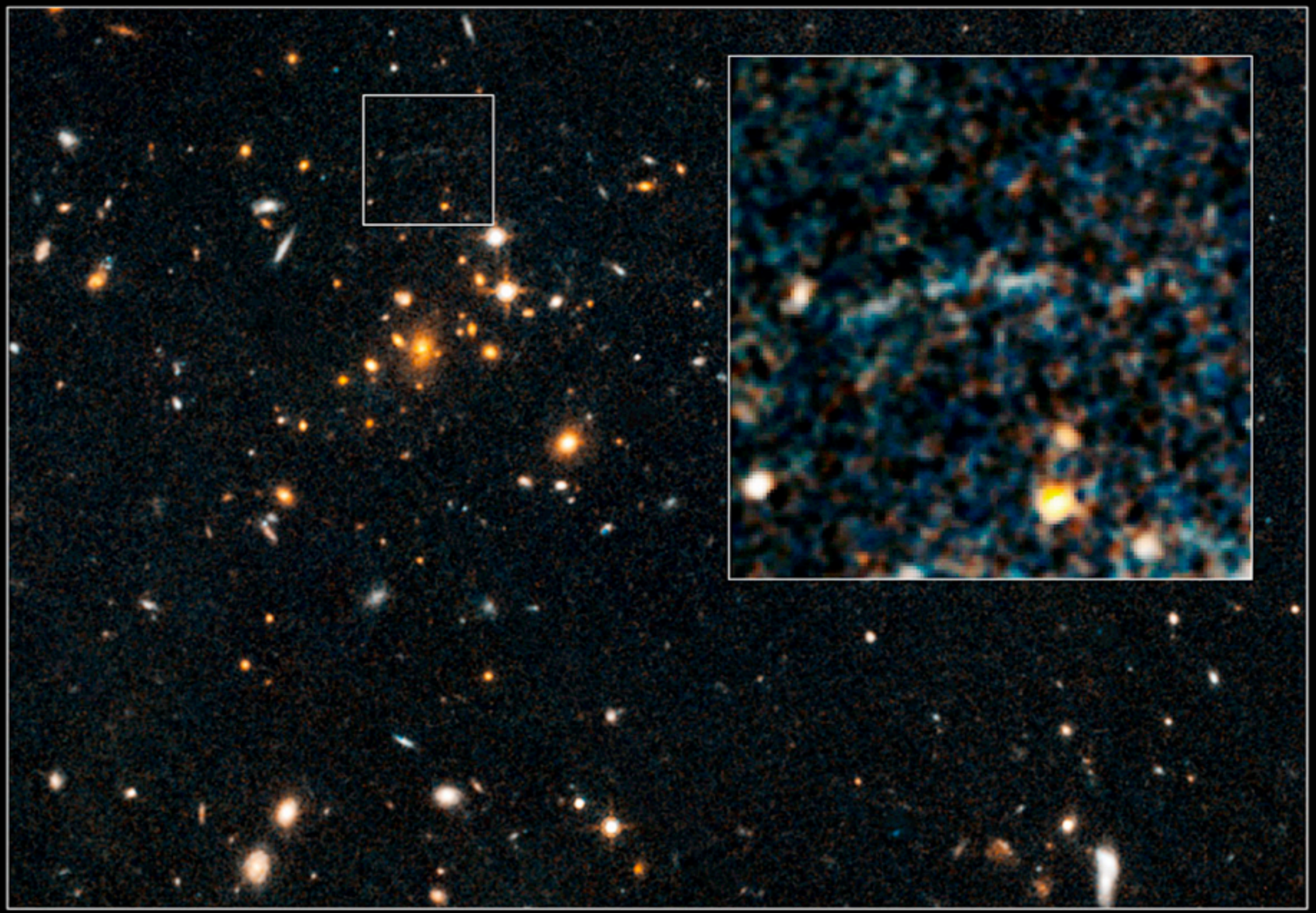
5.3 σ SZ detection with CARMA/SZA ⇒ M_{200}=4.1±1.1x10^{14} $M_\odot$

Most massive spec-z confirmed cluster at z>1.4

Brodwin+ (2012)





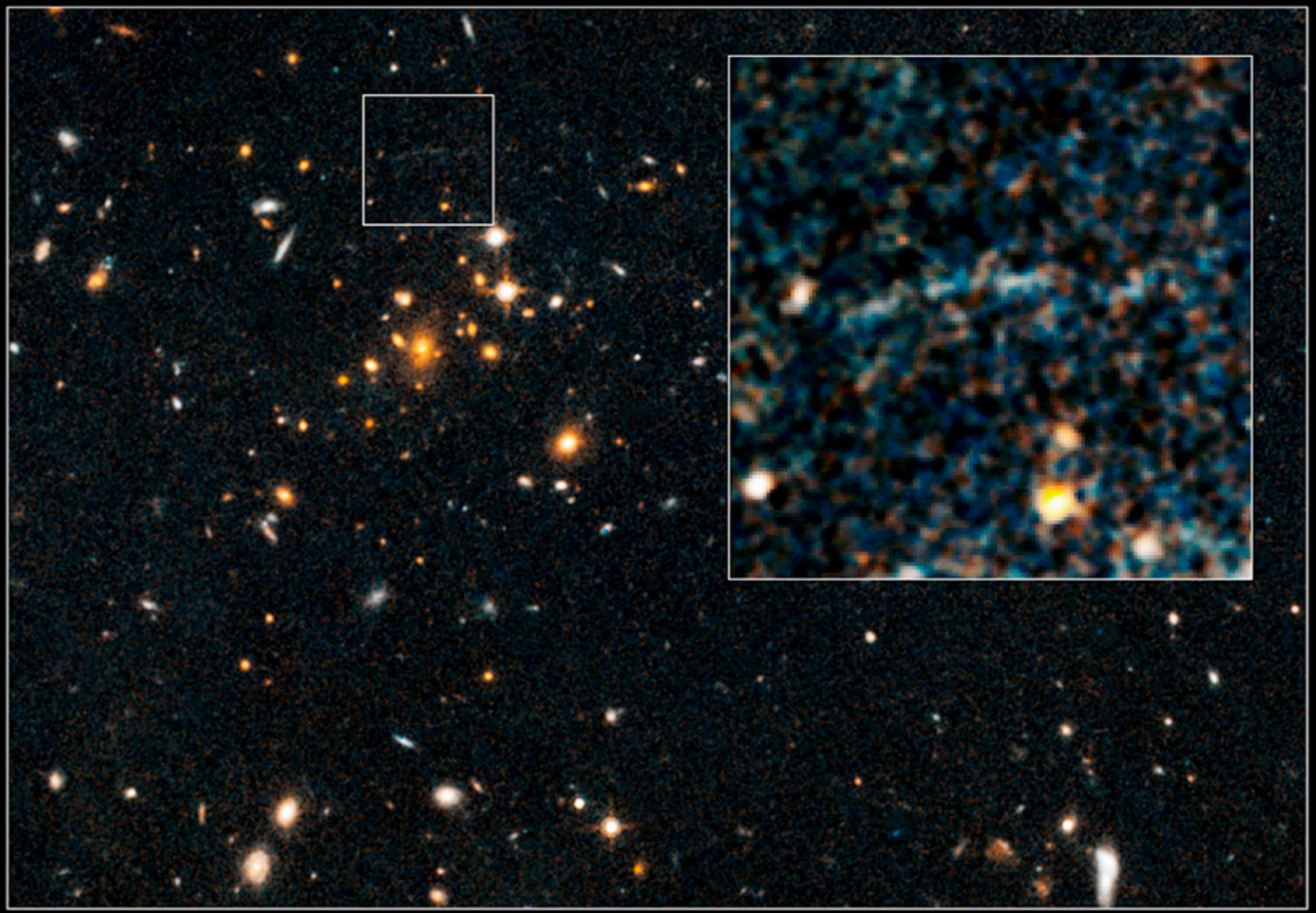


Distant Galaxy Cluster and Gravitational Lens

Hubble Space Telescope ▪ WFC3/IR ▪ ACS/WFC

NASA, ESA, and A. Gonzalez (University of Florida), A. Stanford (University of California), and M. Brodwin (University of Missouri)

STScI-PRC12-19a



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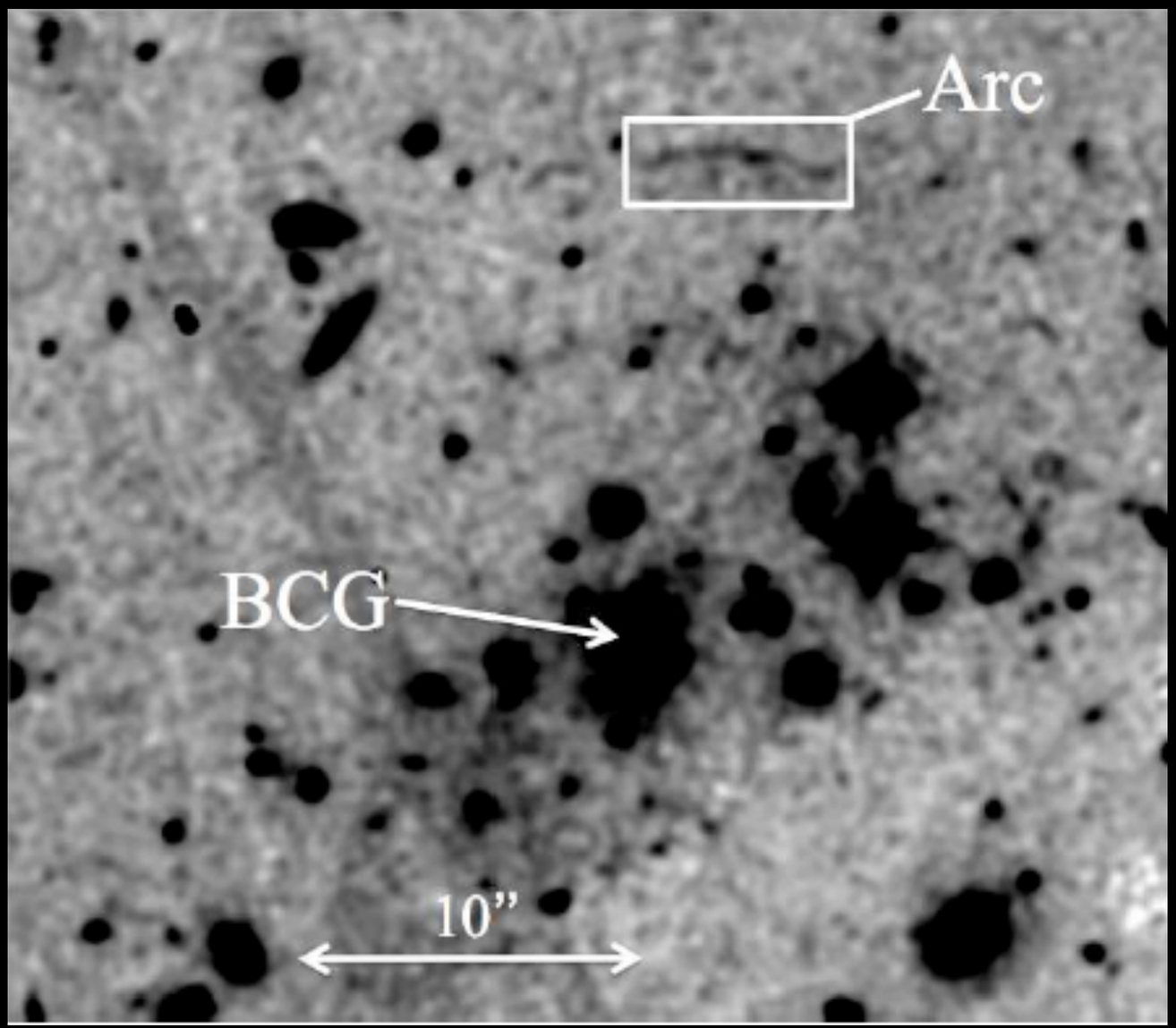
STScI-PRC12-19a

IDCS J1426.5+3508: Strong Lensing

A surprise: Detection of a giant arc.

Length-to-width ratio >>10 (4.8" long, unresolved width with HST)

Color consistent with star-forming galaxy at z=2-6.



No significant substructure near arc, so enclosed mass approximately described by standard lensing relation:

$$M_{enclosed} = \pi \Sigma_c \theta_{arc}^2$$

where

$$\Sigma_c = \frac{c^2}{4\pi G} \frac{D_s}{D_L D_{LS}}$$

...which depends on the unknown redshift of the arc...

The fact that the arc is not a dropout (z<6), implies a lower limit $M_{enclosed}>7x10^{13}M_\odot$.

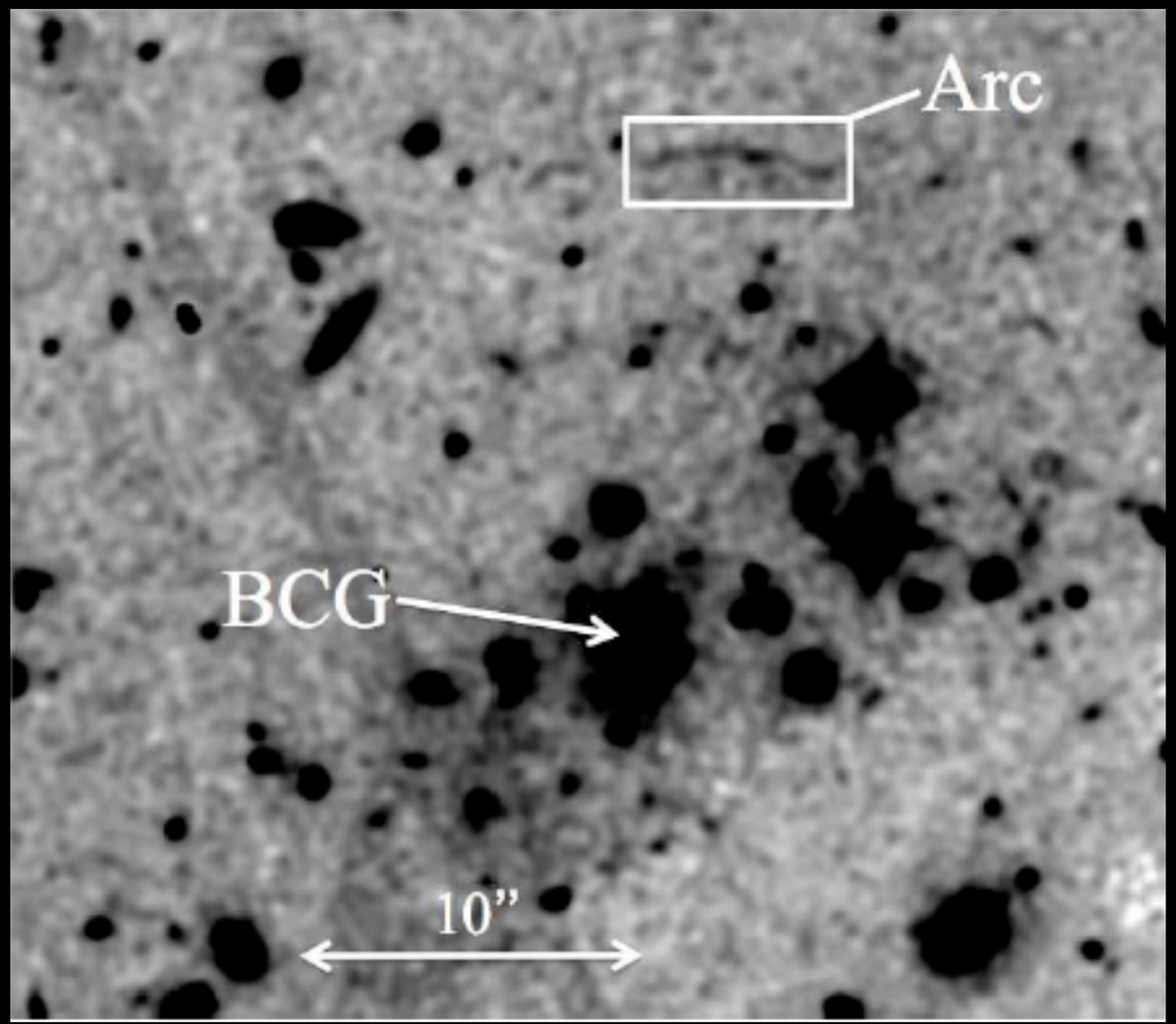
Gonzalez+ (2012)

IDCS J1426.5+3508: Strong Lensing

Estimating M_{200}

Must assume:

- **Halo concentration prescription**
- **Cluster ellipticity**



IDCS J1426.5+3508: Strong Lensing

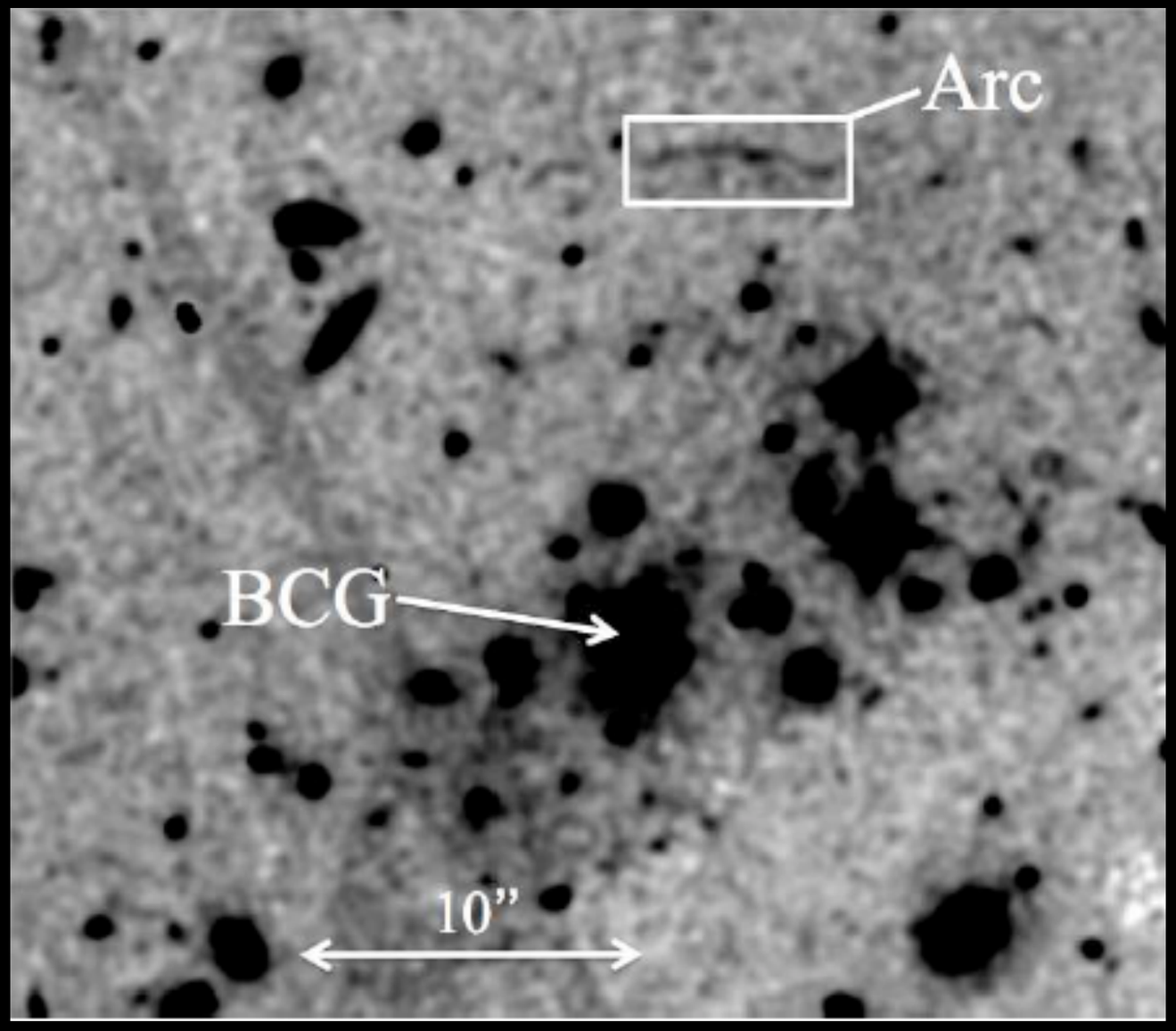
Estimating M_{200}

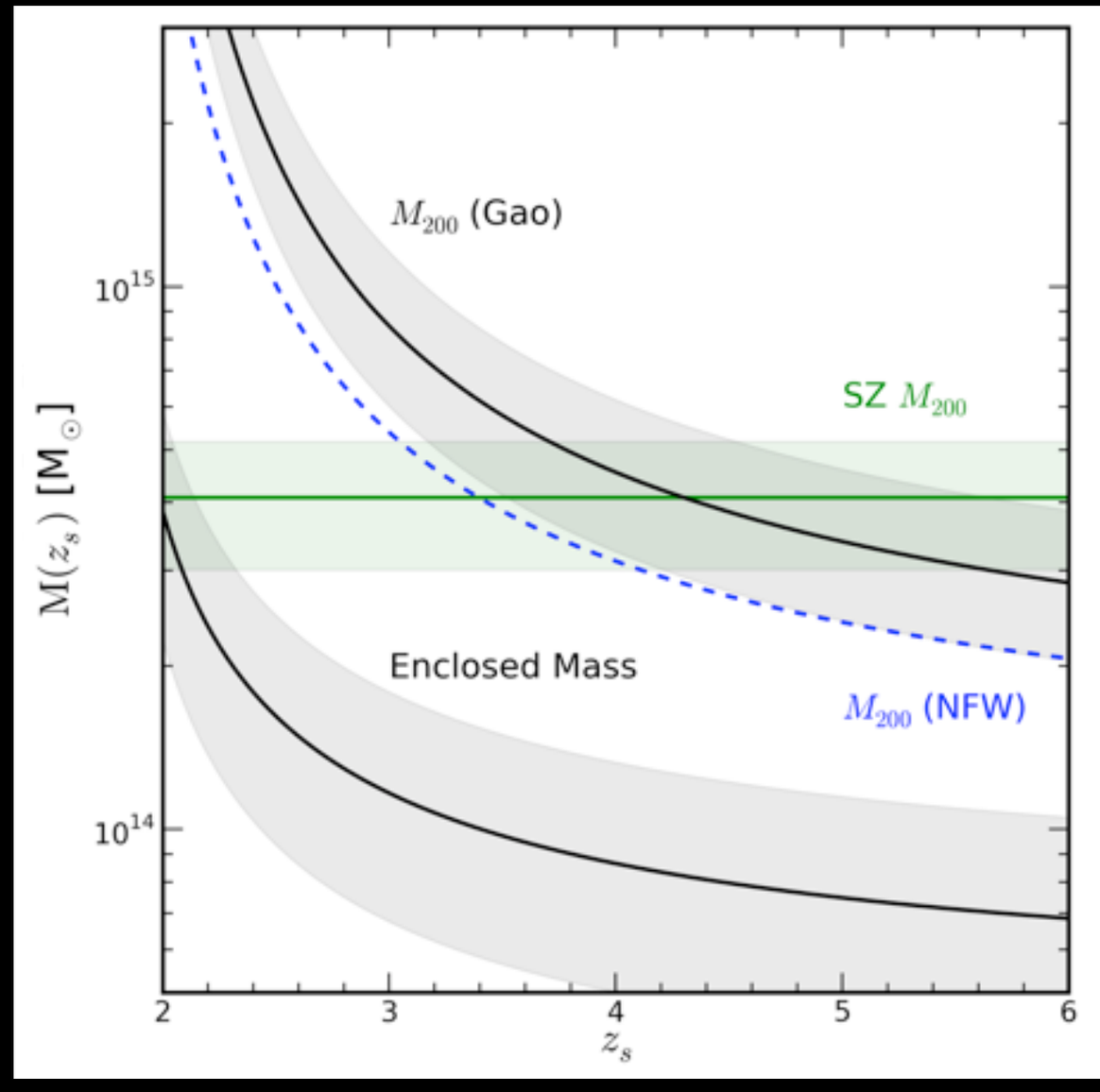
Must assume:

- **Halo concentration prescription**
- **Cluster ellipticity**

SZ and lensing masses roughly consistent for source redshifts z≳3

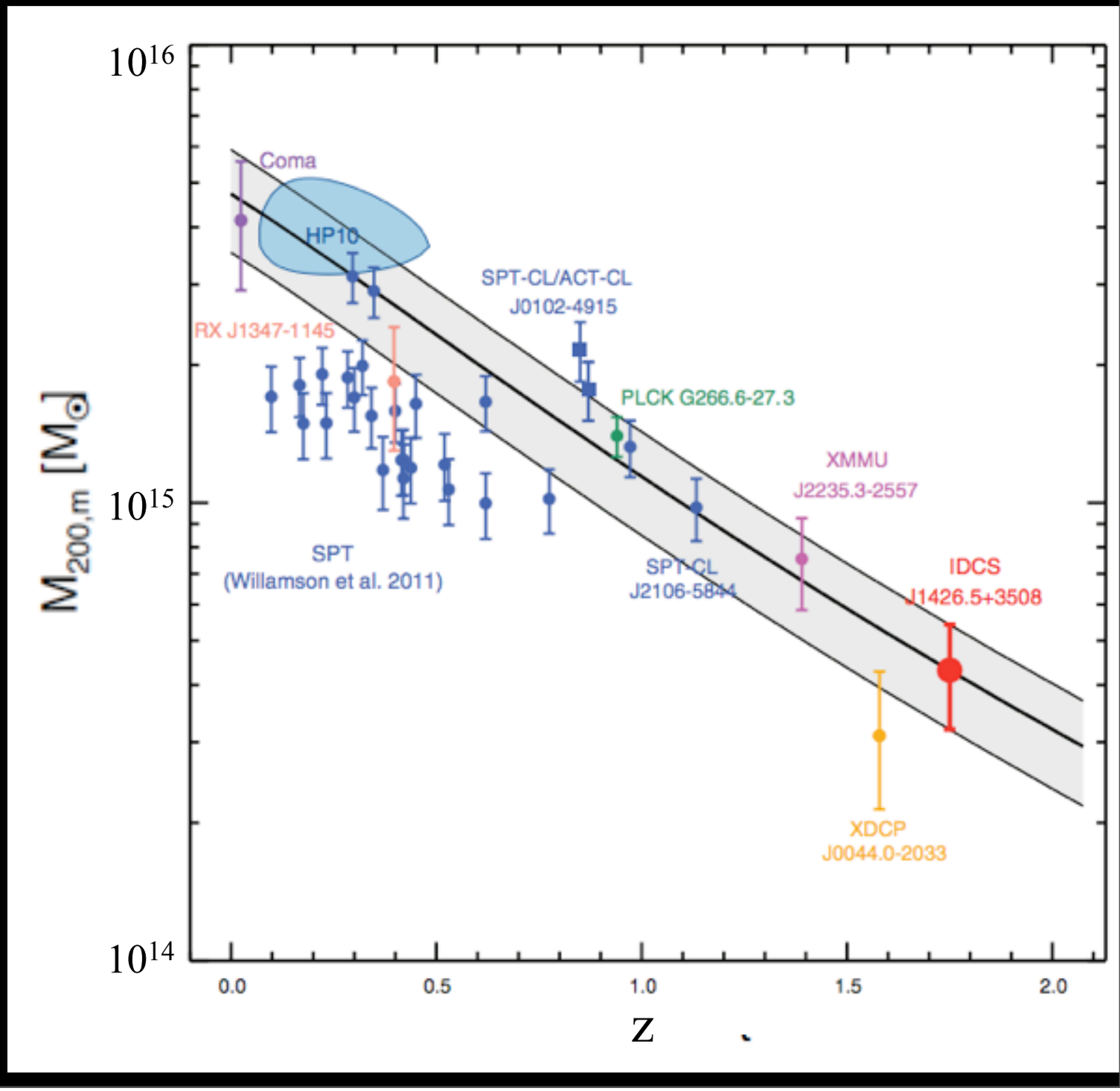
Gonzalez+ (2012)





IDCS J1426.5+3508: Rarity and Future Growth

How rare is this cluster?

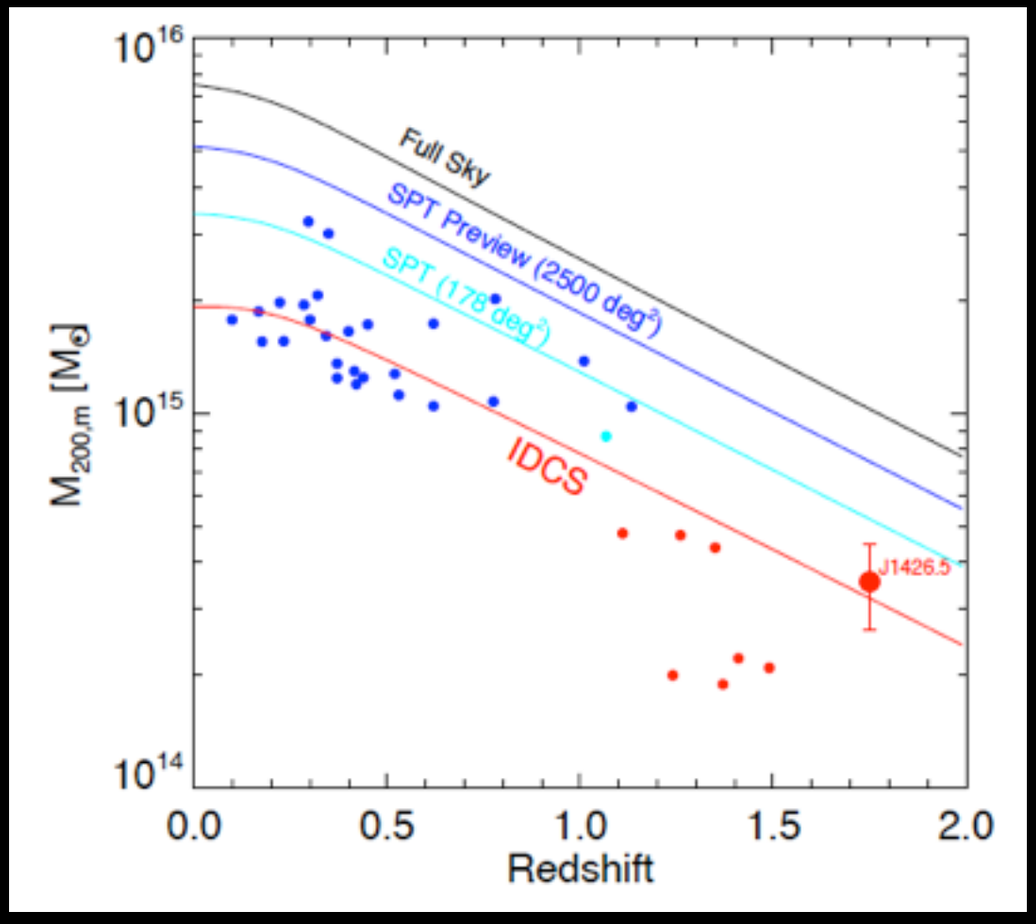


Brodwin+ (2012)

IDCS J1426.5+3508: Rarity and Future Growth

How rare is this cluster?

The mass is extreme, but not inconsistent with LCDM.



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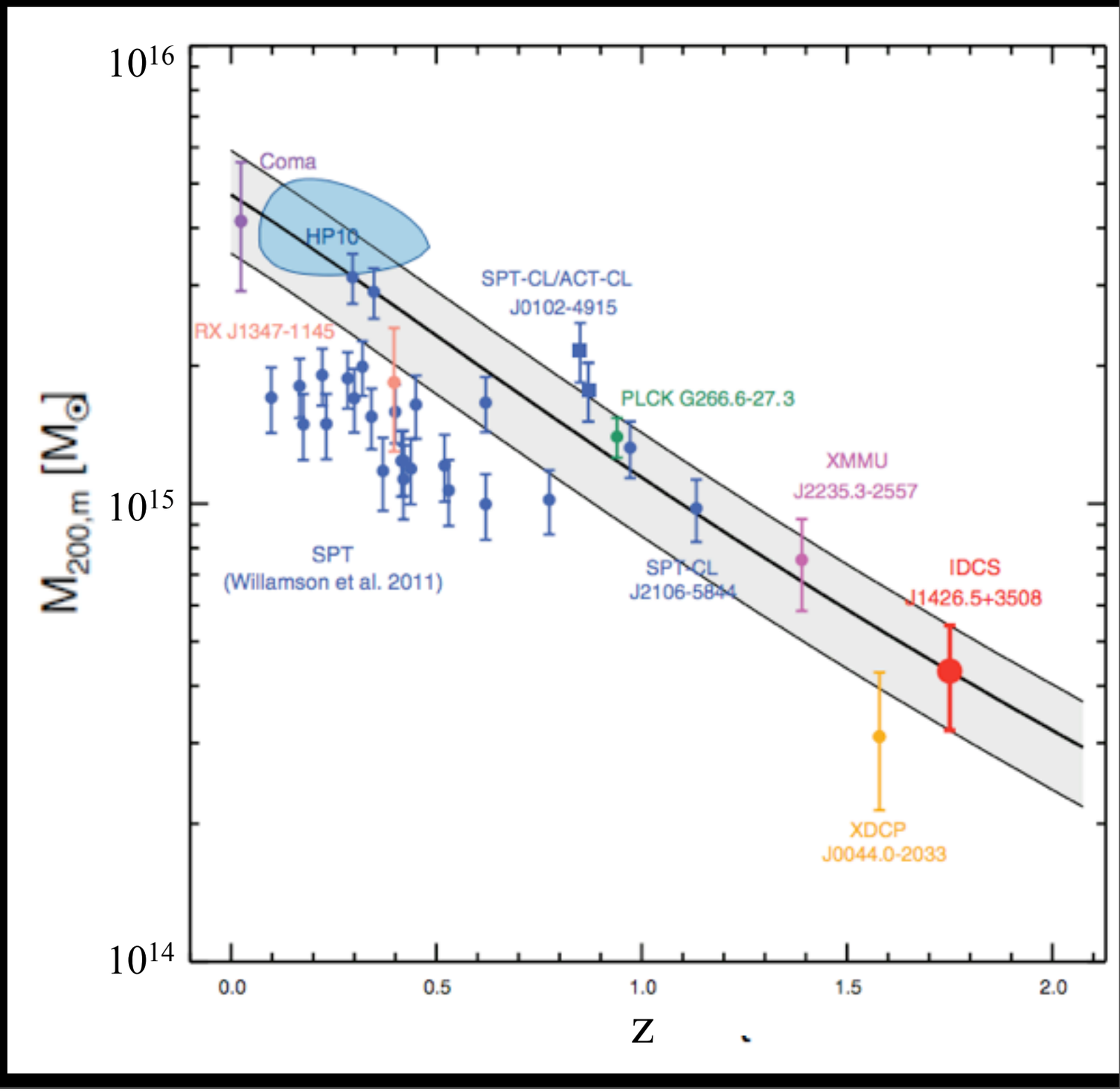


IDCS J1426.5+3508: The Arc Statistics Puzzle

How rare is this cluster?

The lensing is a different story...

Number of arcs all sky

$$N_{Arcs}(m) = 4\pi n_S(m) \int_{z_L}^{\infty} p(z_s, m)\tau(z_s)\mathrm{d}z_s$$

Background Galaxy Density

Redshift Distribution for Background Galaxies

Optical Depth

$$\tau(z_S) = \frac{1}{4\pi D_s} \int_{z_L}^{z_S} \mathrm{d}z \int_0^{\infty} \mathrm{d}M n(M,z) \left|\frac{\mathrm{d}V}{\mathrm{d}z}\right| \sigma(M,z)$$

Cluster Mass Function

Cross section (Efficiency for Lensing)

Inputs:

Background galaxy distribution: HUDF distribution

Cluster mass function: Tinker et al. (2008)

Cross section: Semi-analytic prescription from Fedeli et al. (2006)

IDCS J1426.5+3508: The Arc Statistics Puzzle

How rare is this cluster?

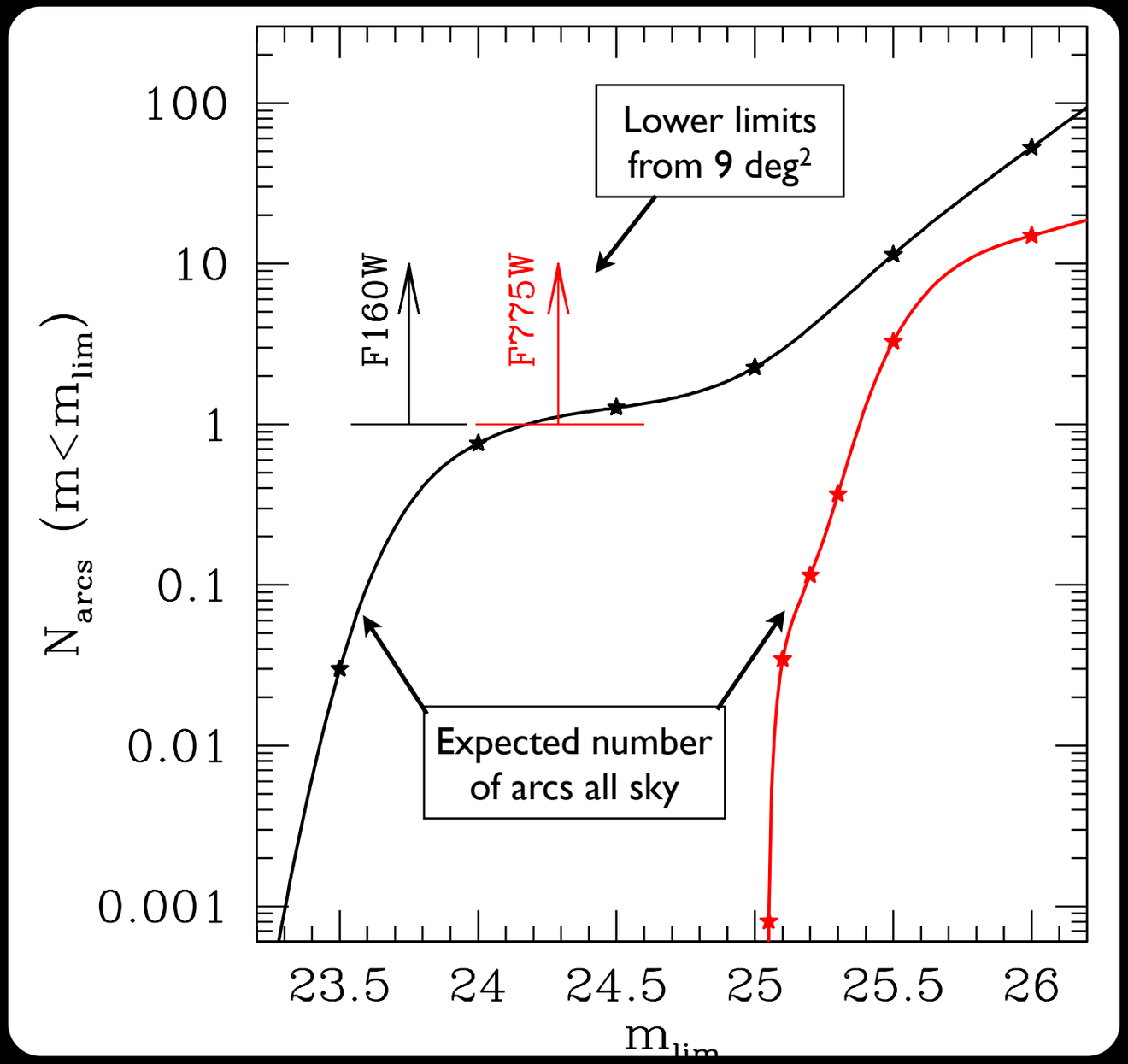
The lensing is a different story...

Possible Explanations

Source redshift distribution

Clusters more concentrated than theoretical halos.

Primordial Non-Gaussianity



Gonzalez+ (2012)

IDCS J1426.5+3508: The Arc Statistics Puzzle

How rare is this cluster?

The lensing is a different story...

Possible Explanations

Source redshift distribution

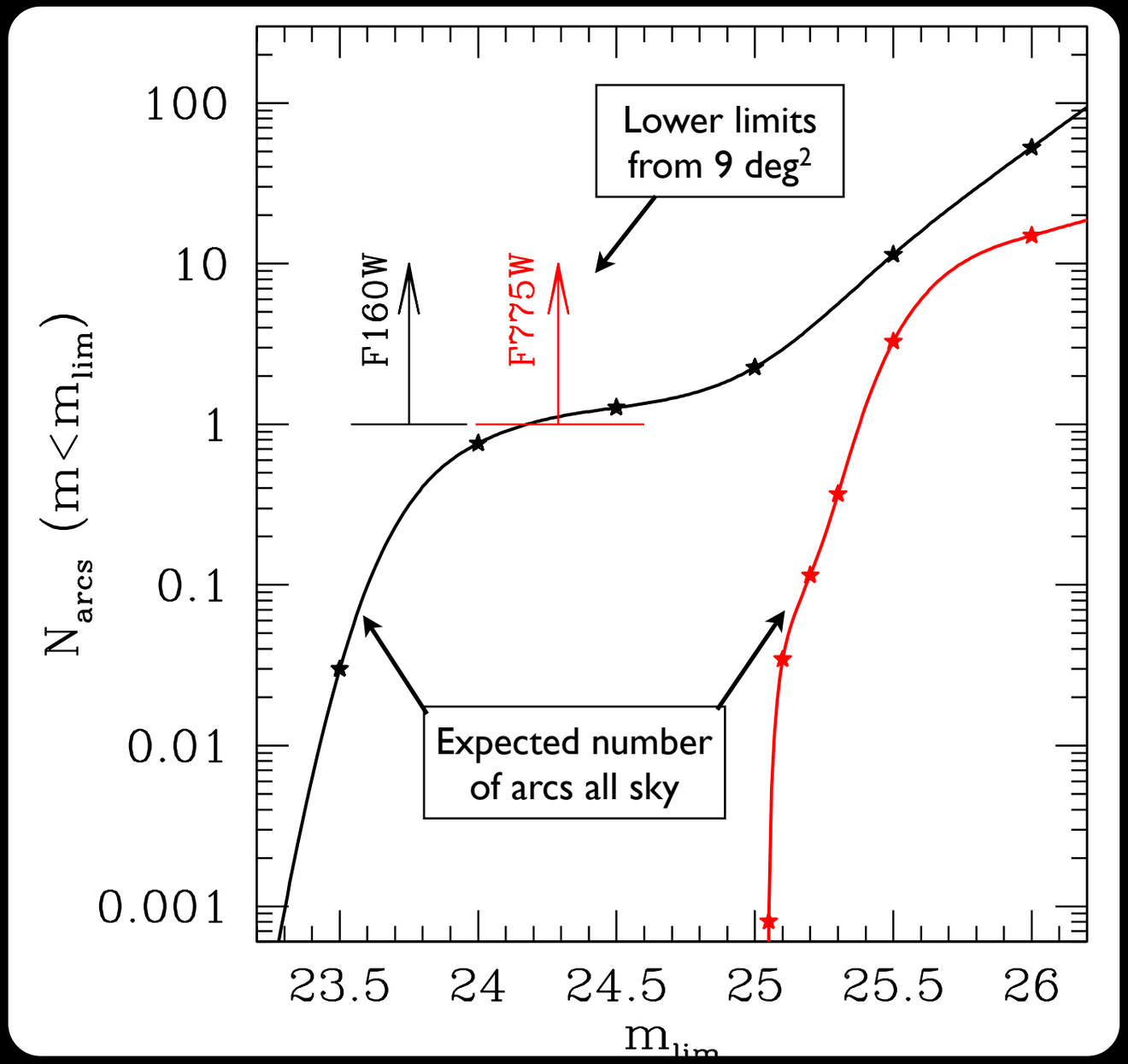
No.

Clusters more concentrated than theoretical halos.

Will help, but not enough...

Primordial Non-Gaussianity

Perhaps (not?)...



Gonzalez+ (2012)

IDCS J1426.5+3508

- Most massive spec-z confirmed cluster known at z>1.4
- First strong lensing cluster at z> 1.3
- Found within 8 sq. deg.
- Expect <1 arc this bright all sky for clusters at z≥1.75
- Upcoming: Approved Chandra, HST, and Herschel programs