- Frontier Field Goals
- Observing Program
  - year 3: Abell S1063 + Abell 370
- Early Science Highlights

Jennifer Lotz, STScI
with Matt Mountain and the Frontier Fields Team

ANSWER:

use Hubble +
nature's telescopes x 6
(strong lensing clusters)

⇒ Go intrinsically deeper than HUDF

⇒ Go wider than HUDF+parallels

6 Lensed Fields +
6 parallel "Blank Fields"
= New Parameter Space

Hubble Deep Fields Initiative Science Working Group:
James Bullock (Chair, UCI), Mark Dickinson (NOAO), Steve Finkelstein (UT), Adriano Fontana (INAF, Rome), Ann Hornschemier Cardiff (GSFC), Jennifer Lotz (STScI), Priya Natarajan (Yale), Alexandra Pope (UMass), Brant Robertson (Arizona), Brian Siana (UC-Riverside), Jason Tumlinson (STScI), Michael Wood-Vasey (U Pitt)

Brammer, VLT/Hawk-I K

6 strong-lensing clusters

+ 6 adjacent parallel fields

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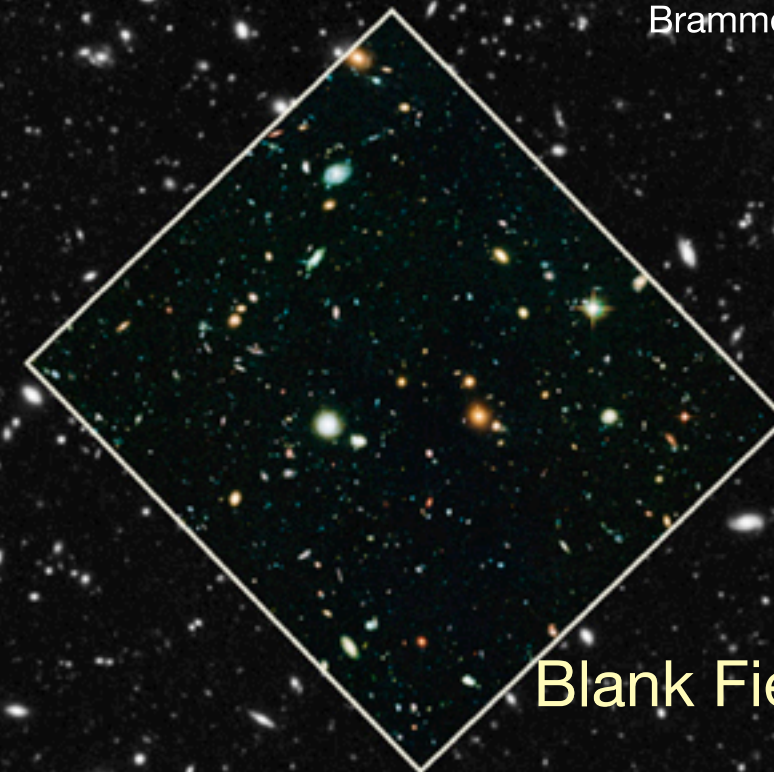
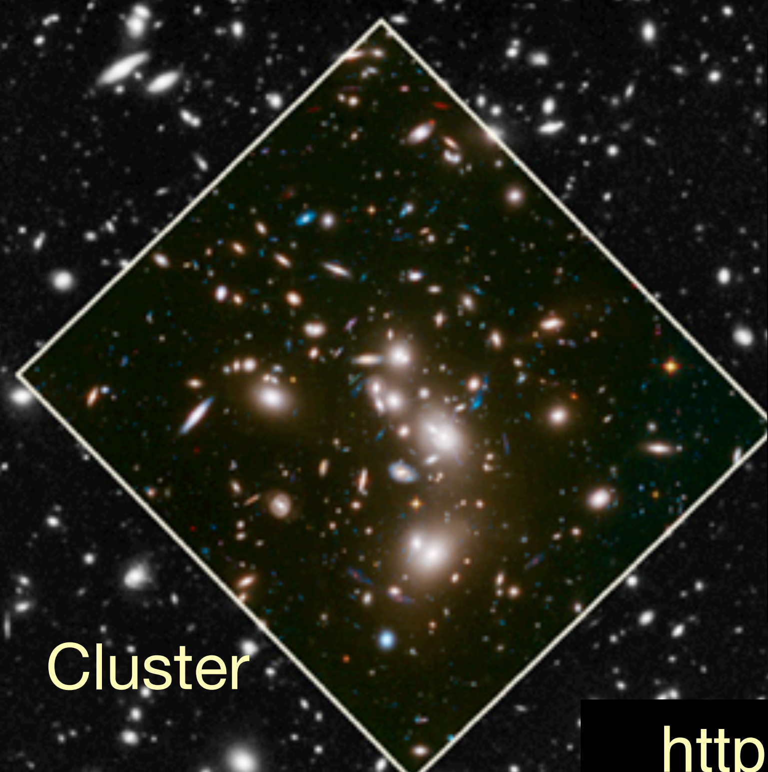
140 HST DD orbits per pointing

ACS/ WFC3-IR in parallel

~29th ABmag in 7 bands



Blank Field



Cluster

2 clusters per year x 3 years

→ 840 total orbits

1000 hours Spitzer DD time for

~26.5 ABmag in IRAC 3.6, 4.5 μm

http://www.stsci.edu/hst/campaigns/frontier-fields/

Deep observations of the Frontier Fields will:

- probe galaxies 10-50x intrinsically fainter than any seen before, particularly those before and during reionization

- study the early formation histories of galaxies intrinsically faint enough to be the early progenitors of the Milky Way

- study highly-magnified high-z galaxies in detail: structures, colors, sizes and provide targets for spectroscopic followup

- provide a statistical picture of galaxy formation at early times

+ deep and high-spatial resolution studies of $z\sim1\text{-}4$ galaxies, (UV escape fraction, sub-kpc structures and star-formation)

+ map out dark matter and substructure in clusters

+ study cluster galaxies, dwarfs, intracluster light in clusters

+ search for (lensed) SN, transients in distant universe

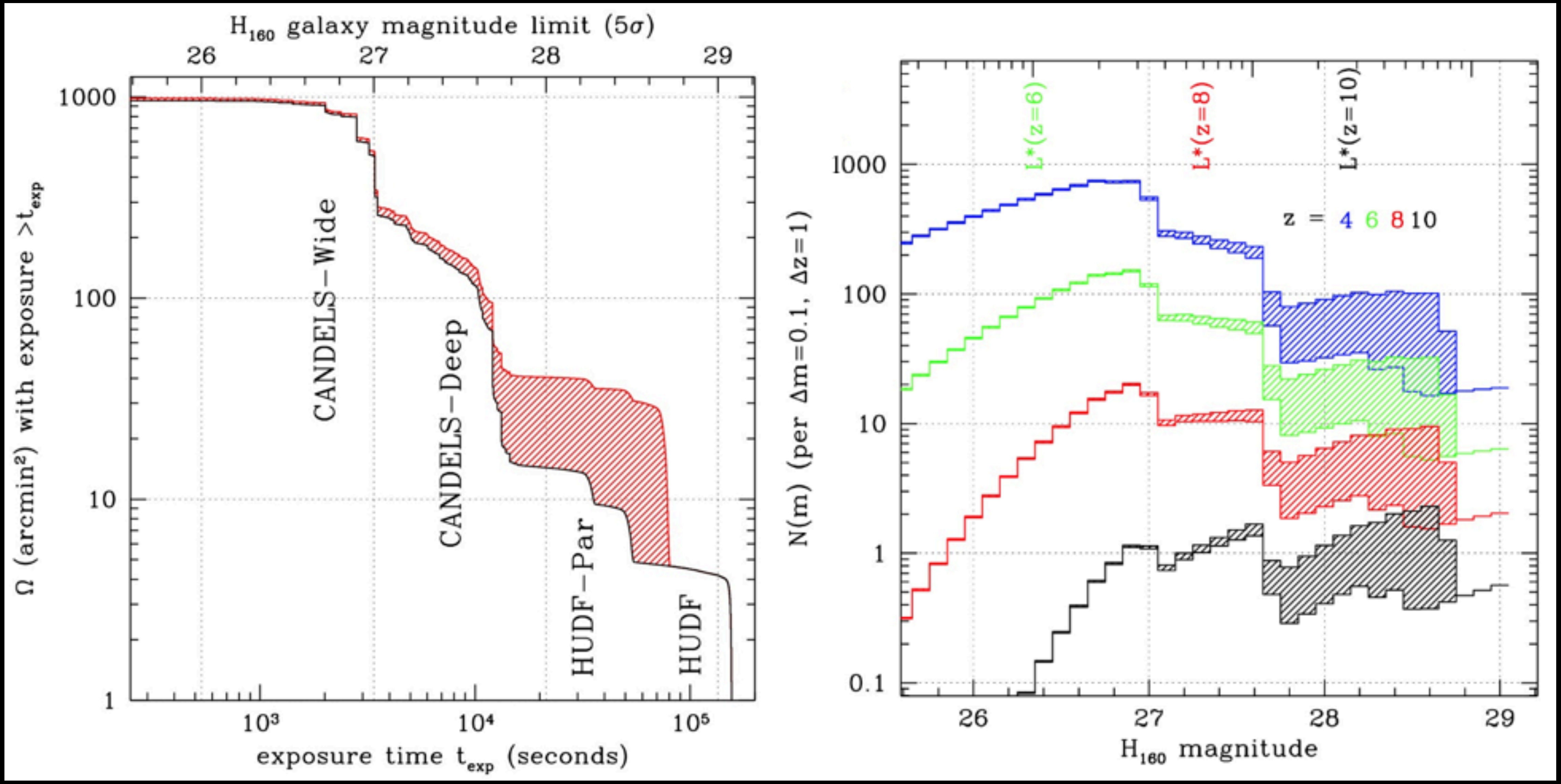
+ use 100s of multiple images as probe of distance, DE

+ give proper motions of Milky Way stars

+ search for asteroids in solar system

+ ???

why 6 clusters + 6 parallels?

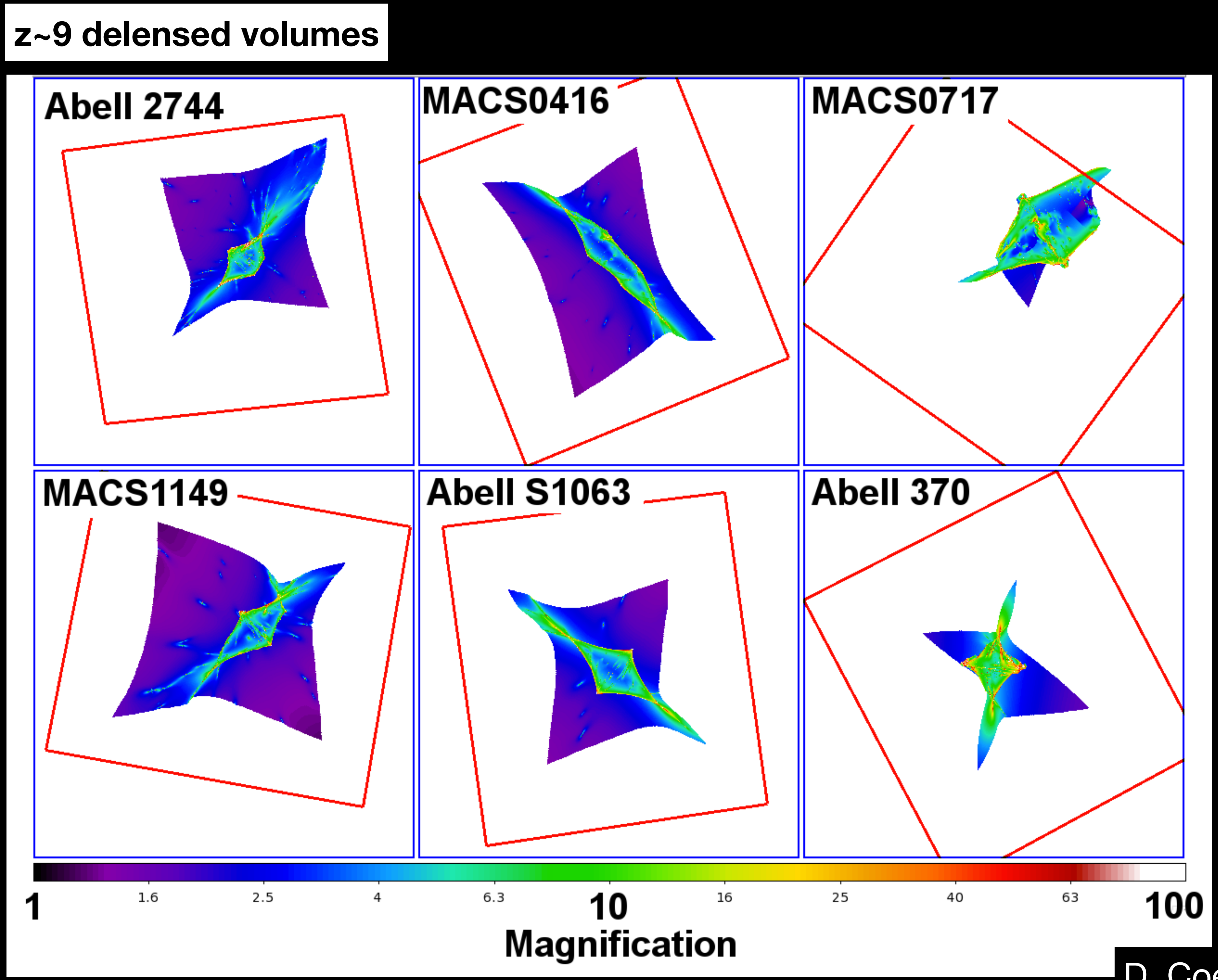


HDFI SWG report 2012:

Six “blank” parallel fields give you 3x more area than existing HUDF+pars

⇒ “3-5x more faint galaxies + doubling of numbers of z~8-10 galaxies”

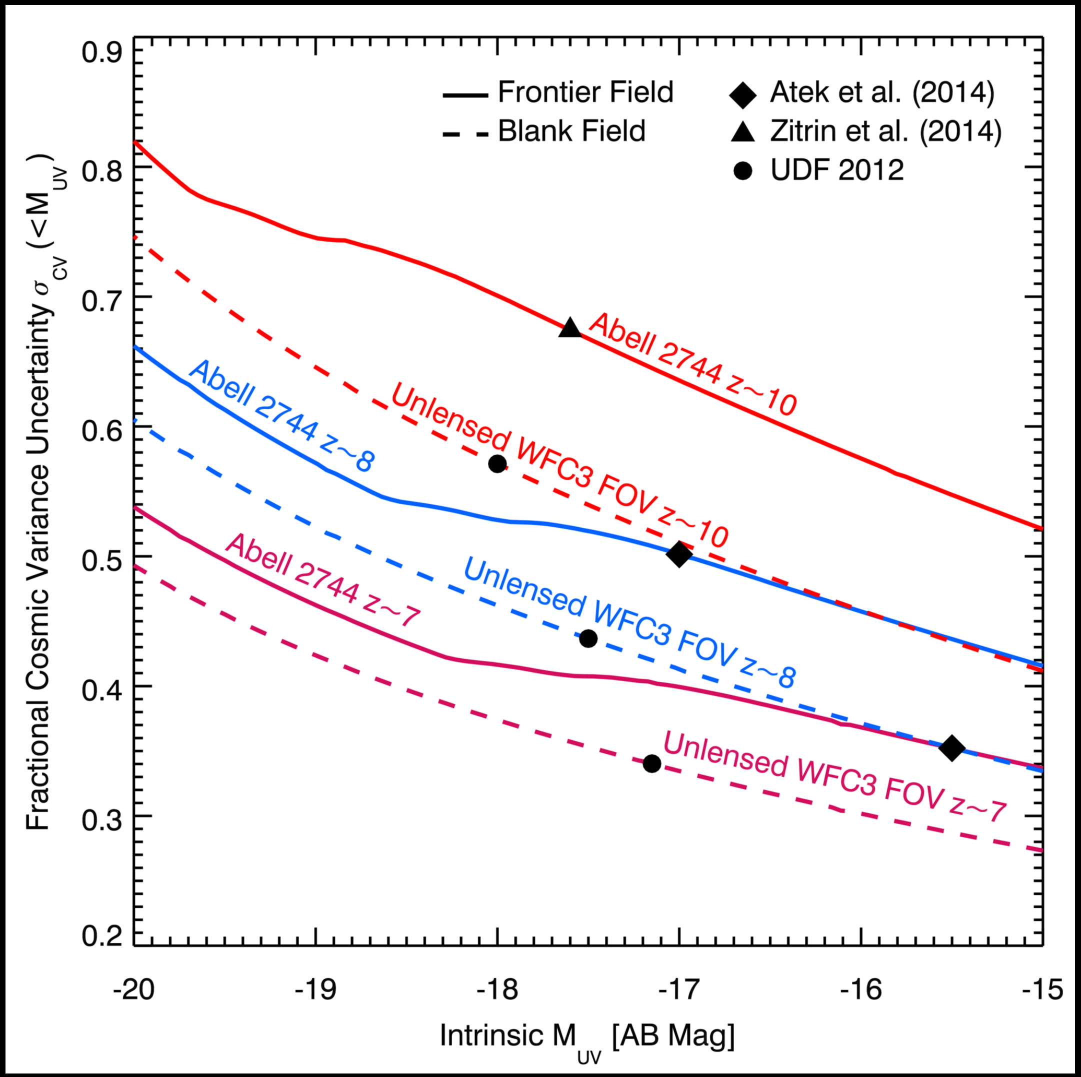
why 6 clusters + parallel fields?

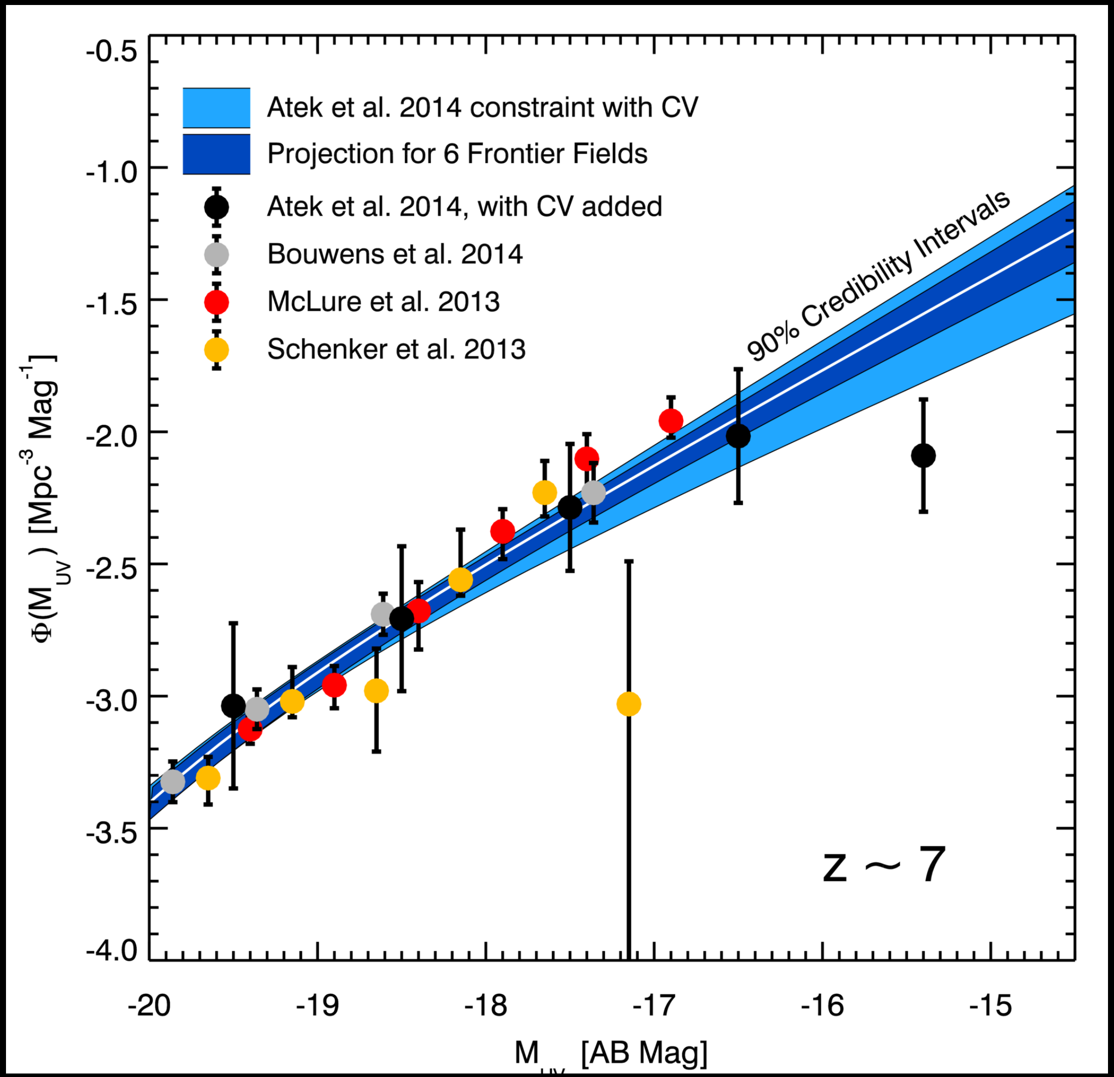


D. Coe et al, 2014

high-redshift volumes probed by strong lensing is small

why 6 clusters + parallel fields?

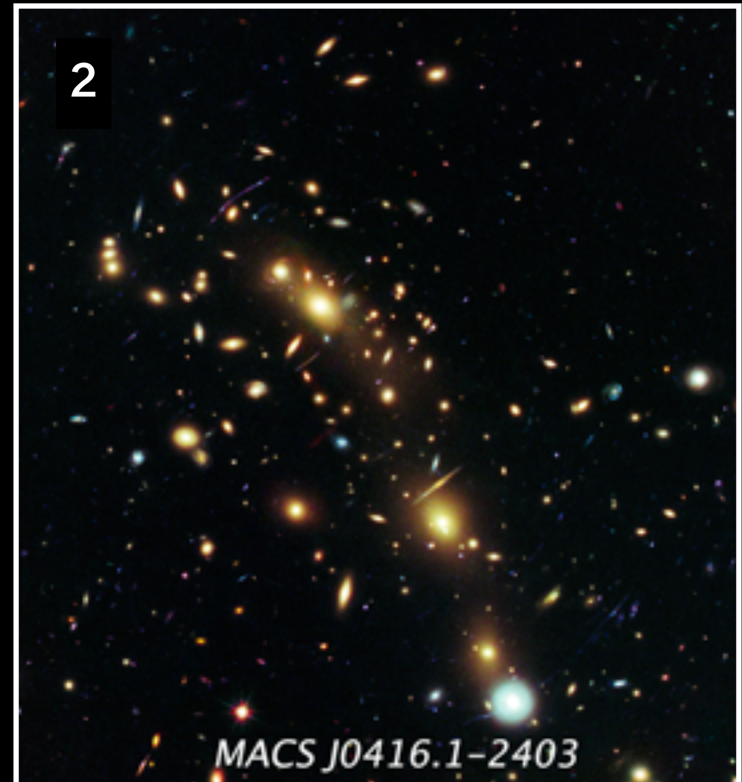


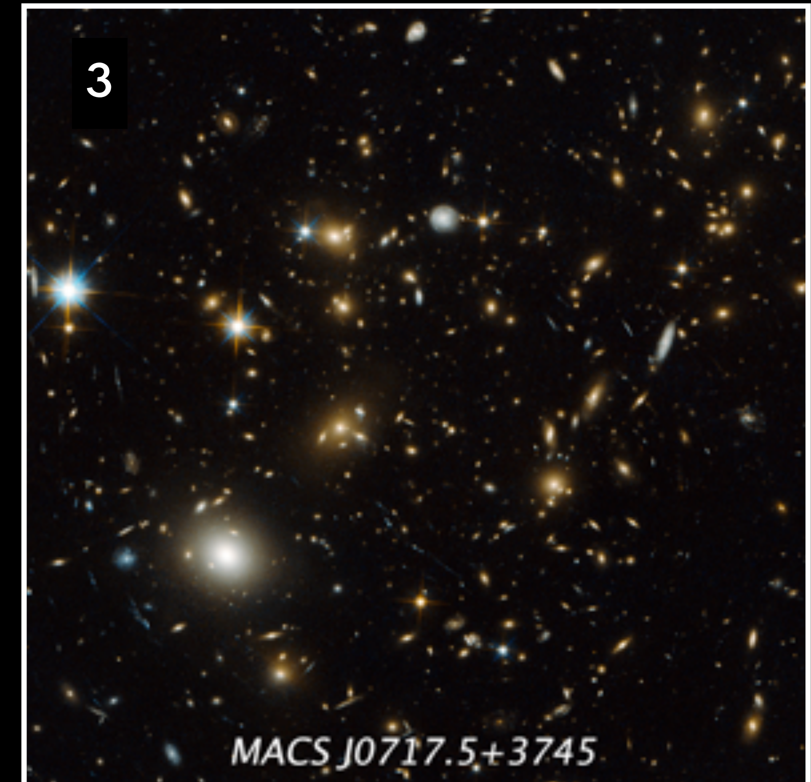


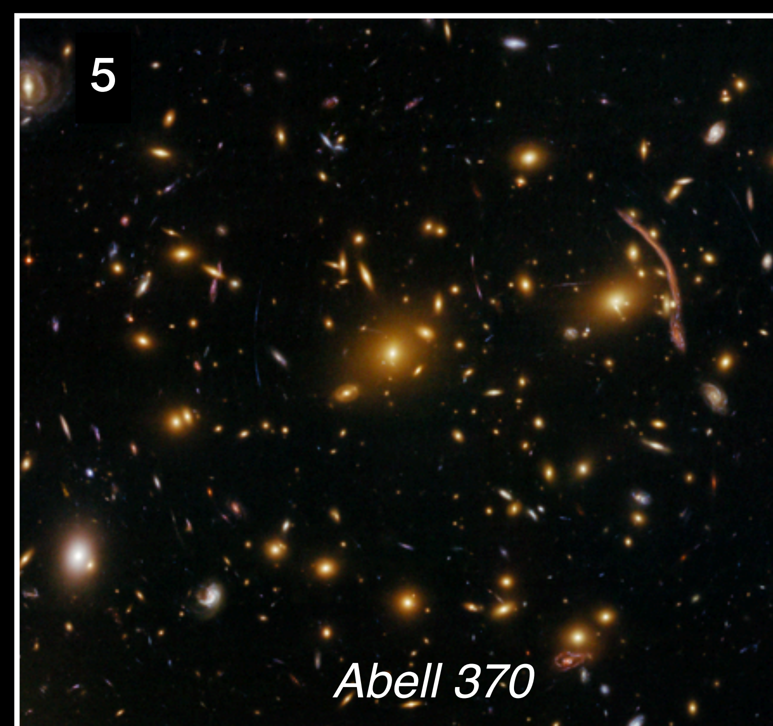
B. Robertson et al, 2014

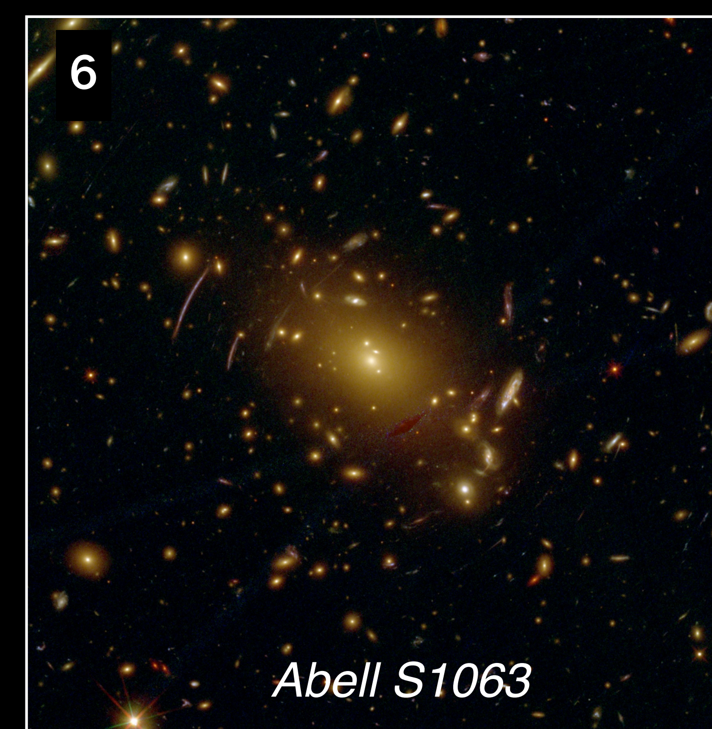
cosmic variance 10-30% higher in 1 lensed field vs. HUDF;
but 6 fields can provide critical constraints
on faint galaxies required to reionize the universe

HST Frontier Fields









chosen based on known lensing strength, sky location, ancillary data

year 3 - Abell 370

one of the strongest known lensing clusters (first discovered strong lensing arc); merging cluster

z=0.375,
M_{vir} ~10^{15} M_{sun}, L_X~ 10^{45} erg/s
E(B-V) = 0.032
zodi ~ 20.5 - 22.5 V per sq arcsec

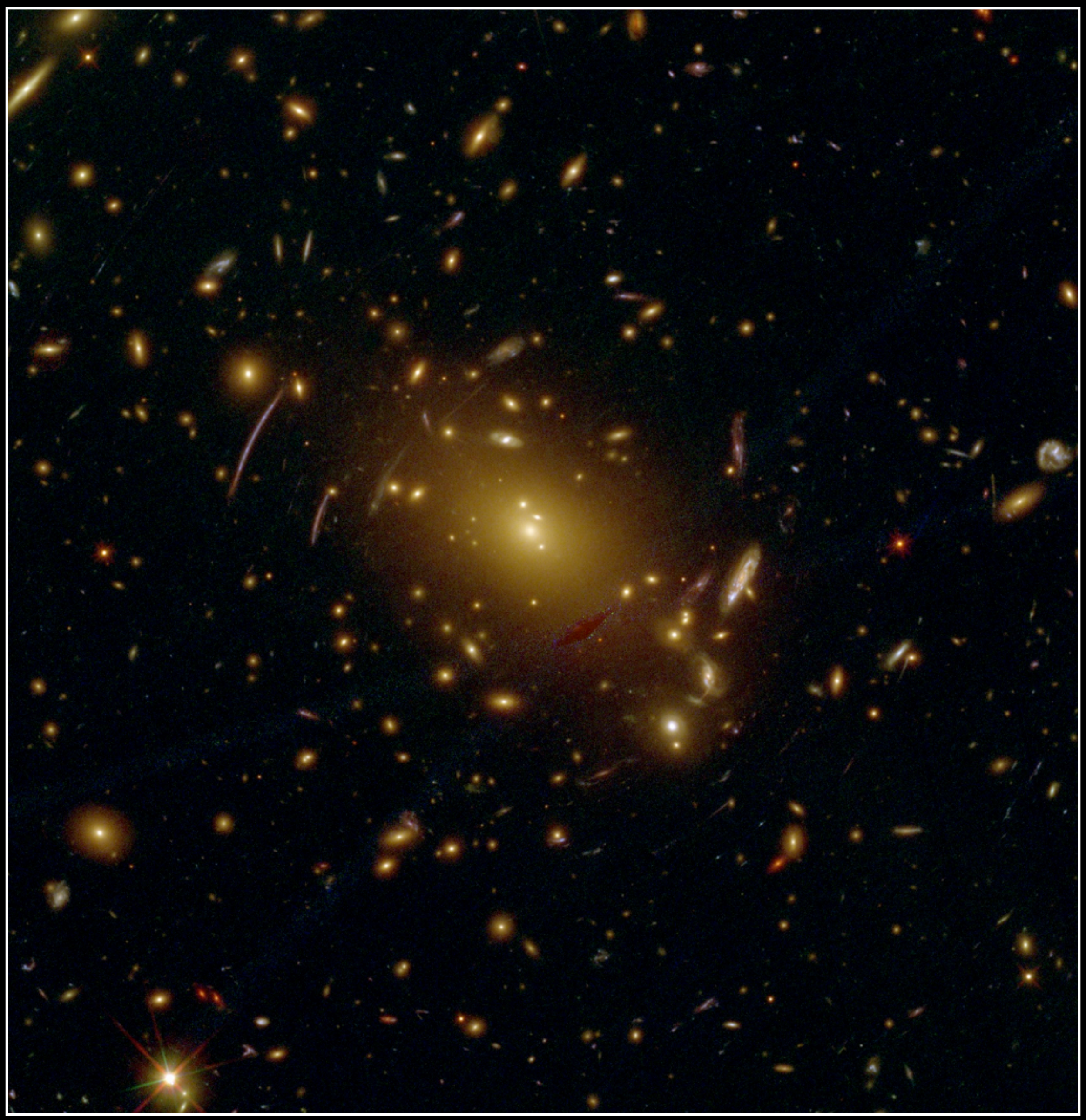
observable with ALMA, Maunakea

archival Spitzer cryo, Herschel, Chandra data

suitable for AO (Gemini GEMS)

not a CLASH cluster

year 3 - Abell S1063



brightest S-Z cluster in southern sky; relaxed; darkest sky

z=0.3461,
$M_{vir} \sim 1.4 \times 10^{15}$ M_{sun}, $L_X \sim 2 \times 10^{45}$ erg/s
E(B-V) = 0.011
zodi ~ 22.1 - 22.9 V per sq arcsec

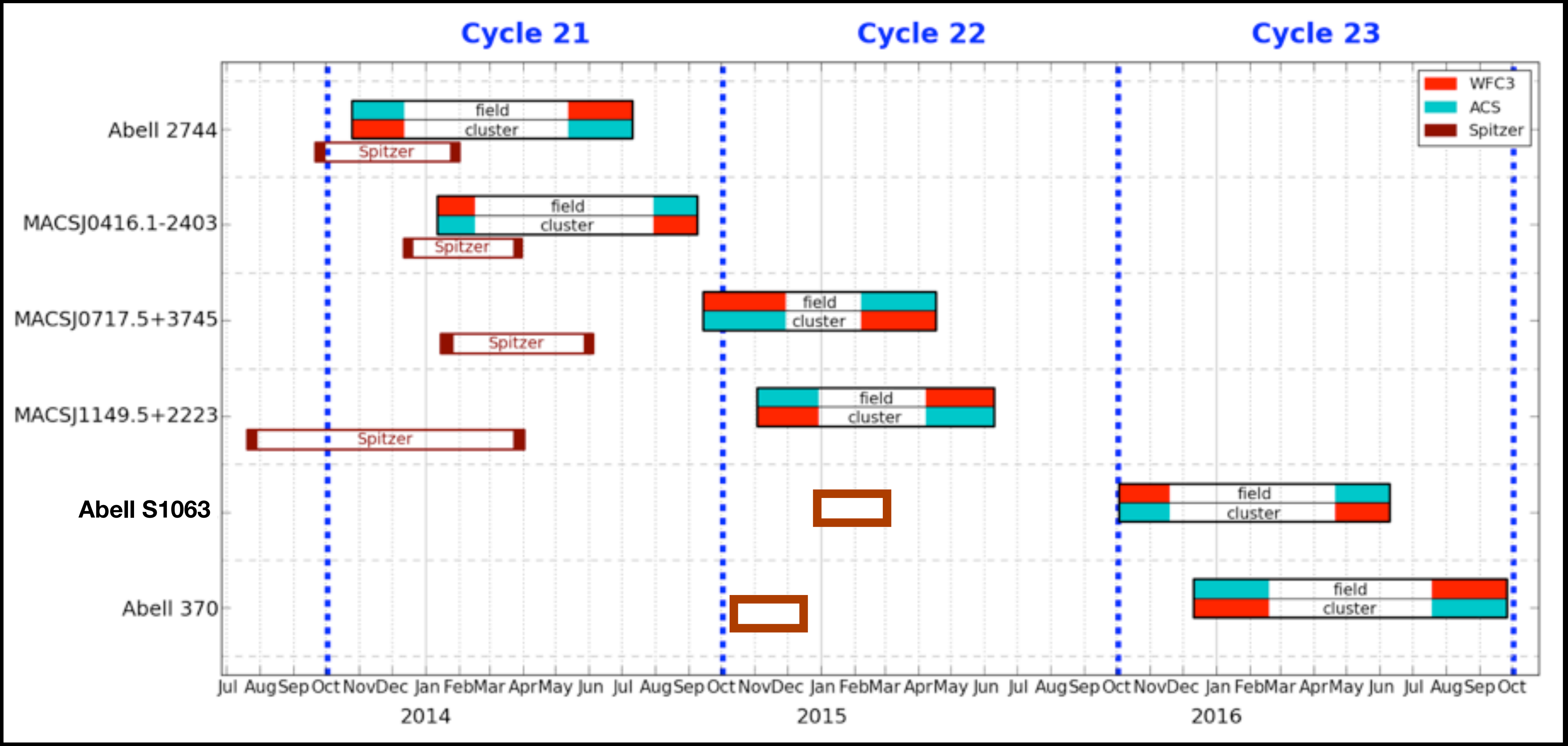
observable with ALMA
not observable Maunakea

archival Spitzer cryo, Herschel, Chandra data

CLASH cluster

recent spectroscopic studies have found multiply imaged z~3, 4, 6 galaxies (Monna 2012; Karman 2014)

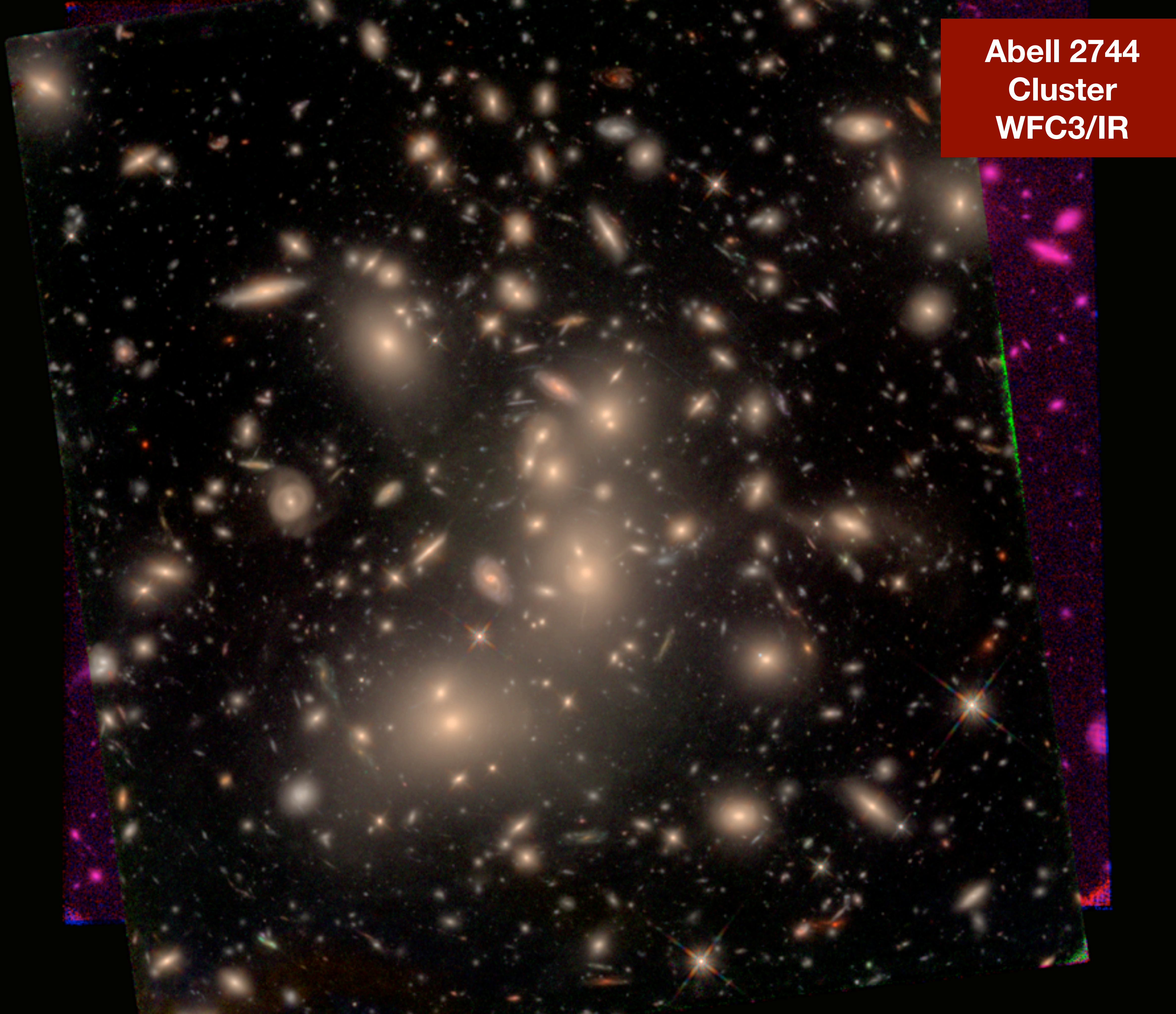
Frontier Fields Schedule

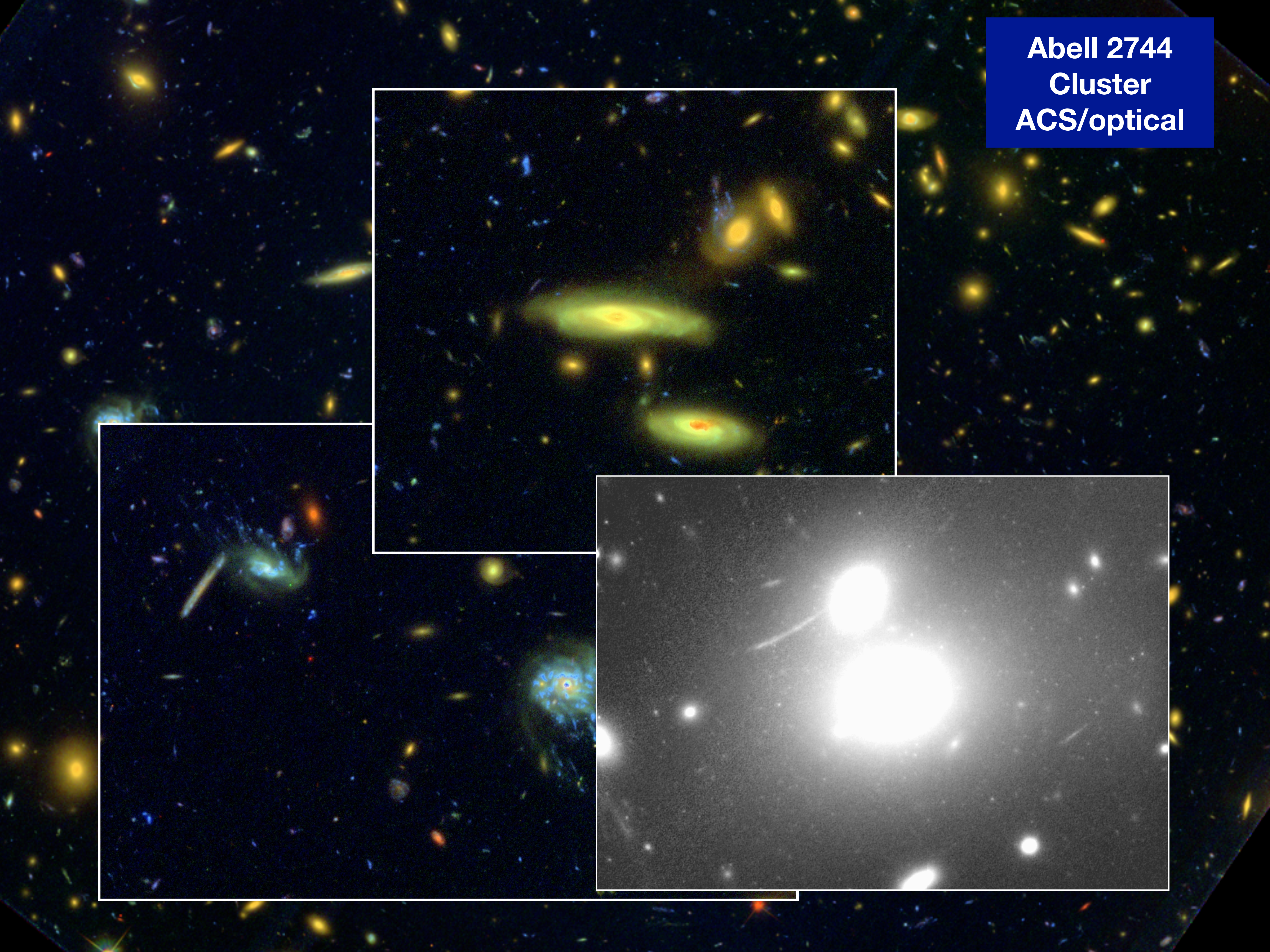


year1 observations Abell 2744, MACS0416 are complete
Spitzer observations of 1st four clusters complete

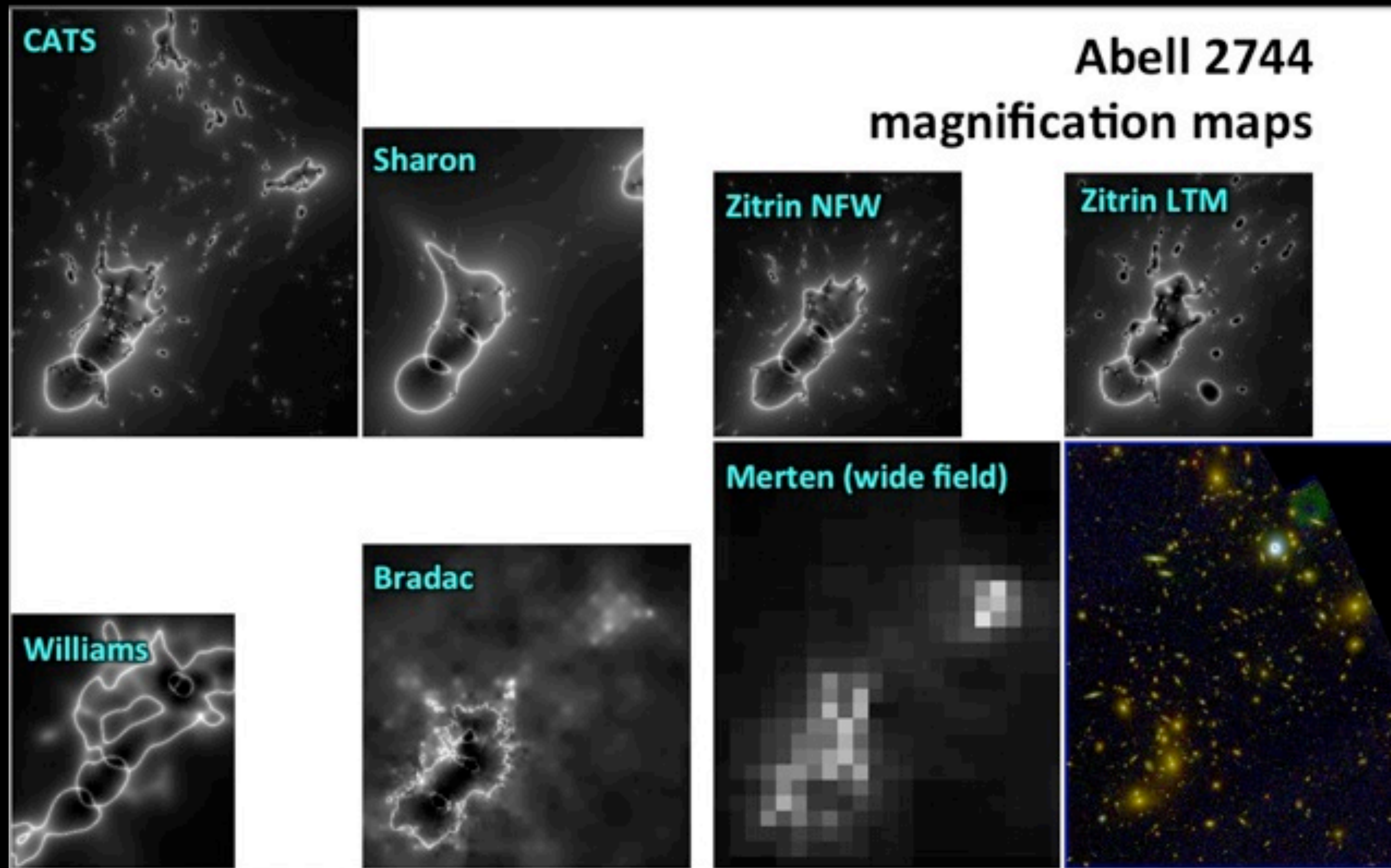
MACS0717, MACS1149 HST observations starting now
AbellS1063, Abell 370 Spitzer observations planned Winter 2015

Abell 2744
Cluster


Abell 2744
Cluster
WFC3/IR


Abell 2744
Cluster
ACS/optical

Frontier Fields Lensing Maps



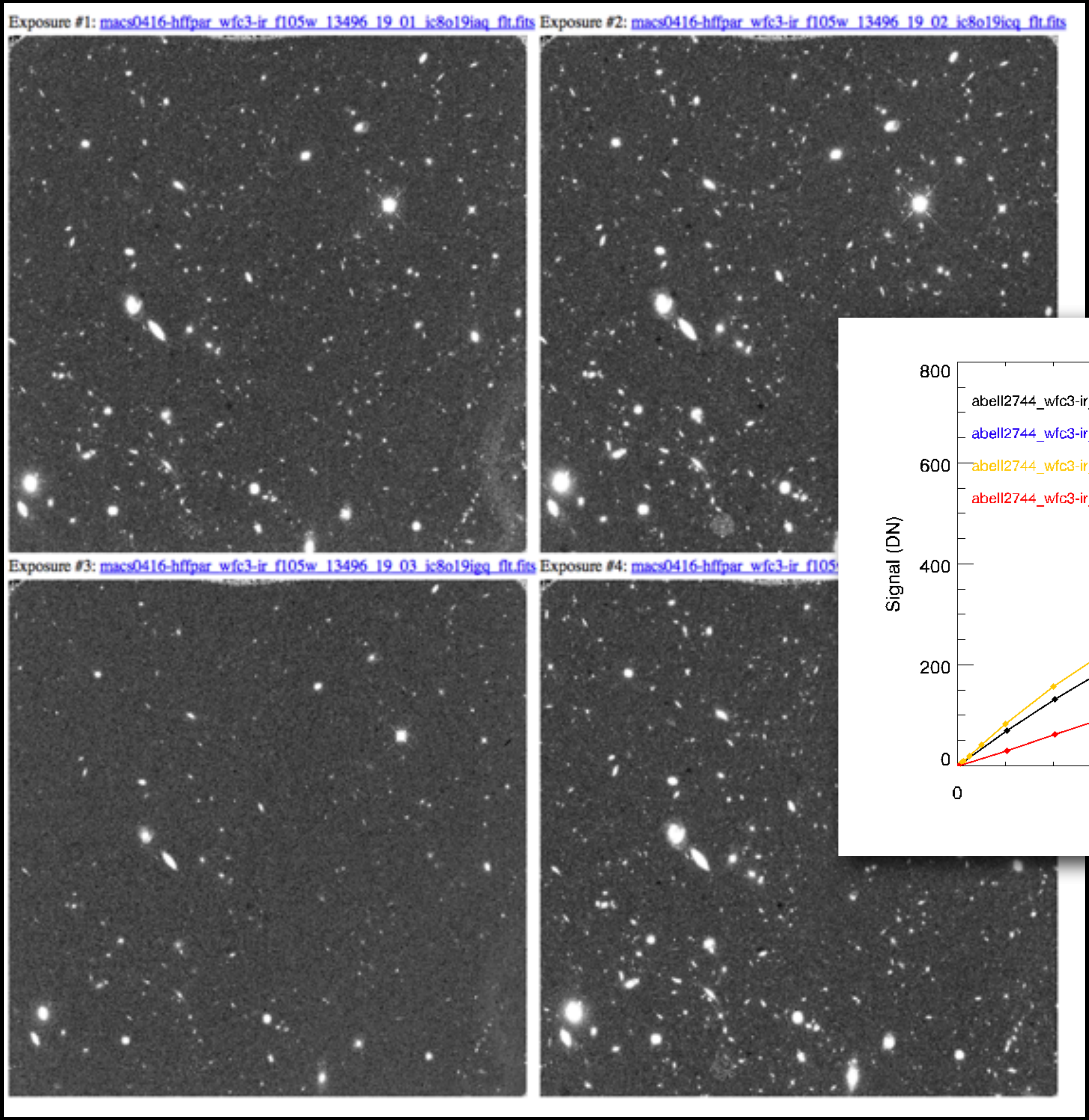
lensing models are key to interpreting luminosities of background galaxies

5 groups have made magnification maps for FF <u>before</u> 1st observations

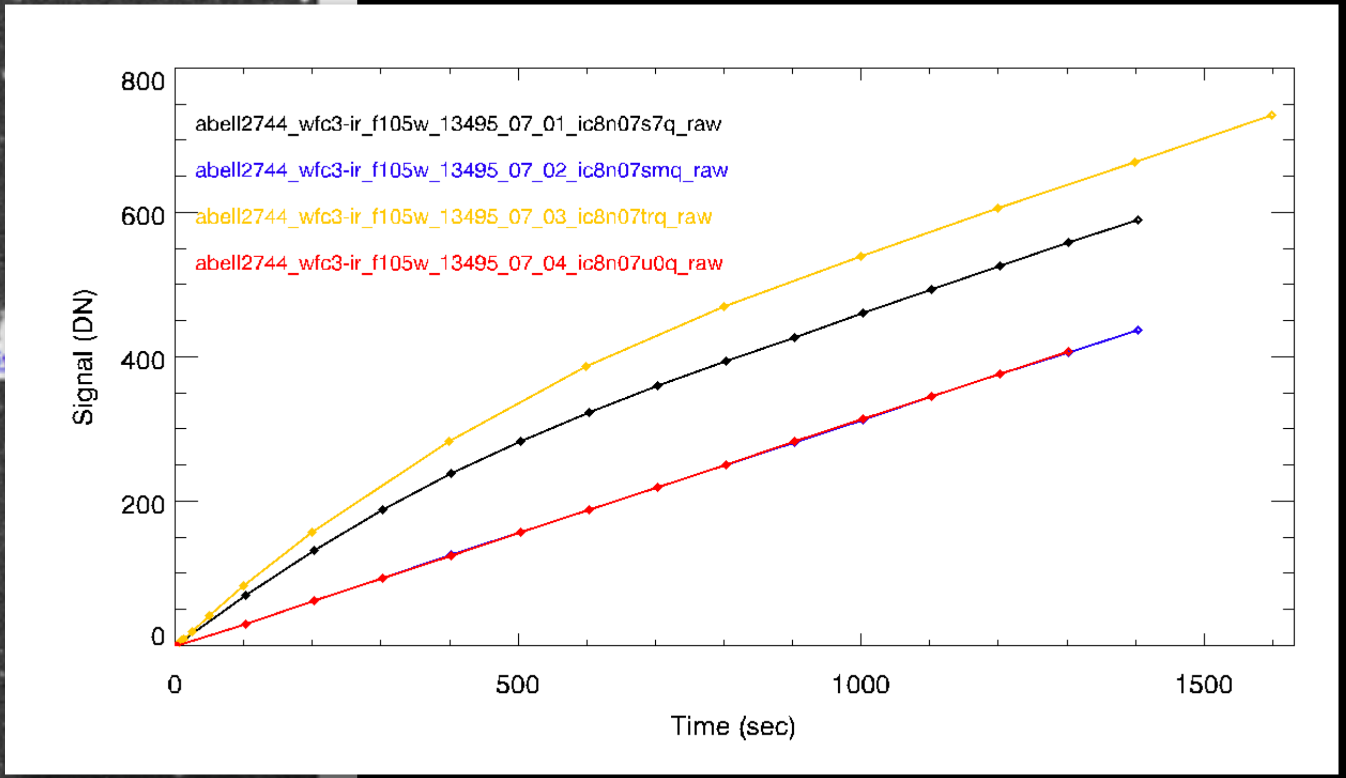
100s of arcs expected in FF data ⇒ tighter constraints on lensing models

http://archive.stsci.edu/prepds/frontier/lensmodels/

HST Data Release and Products



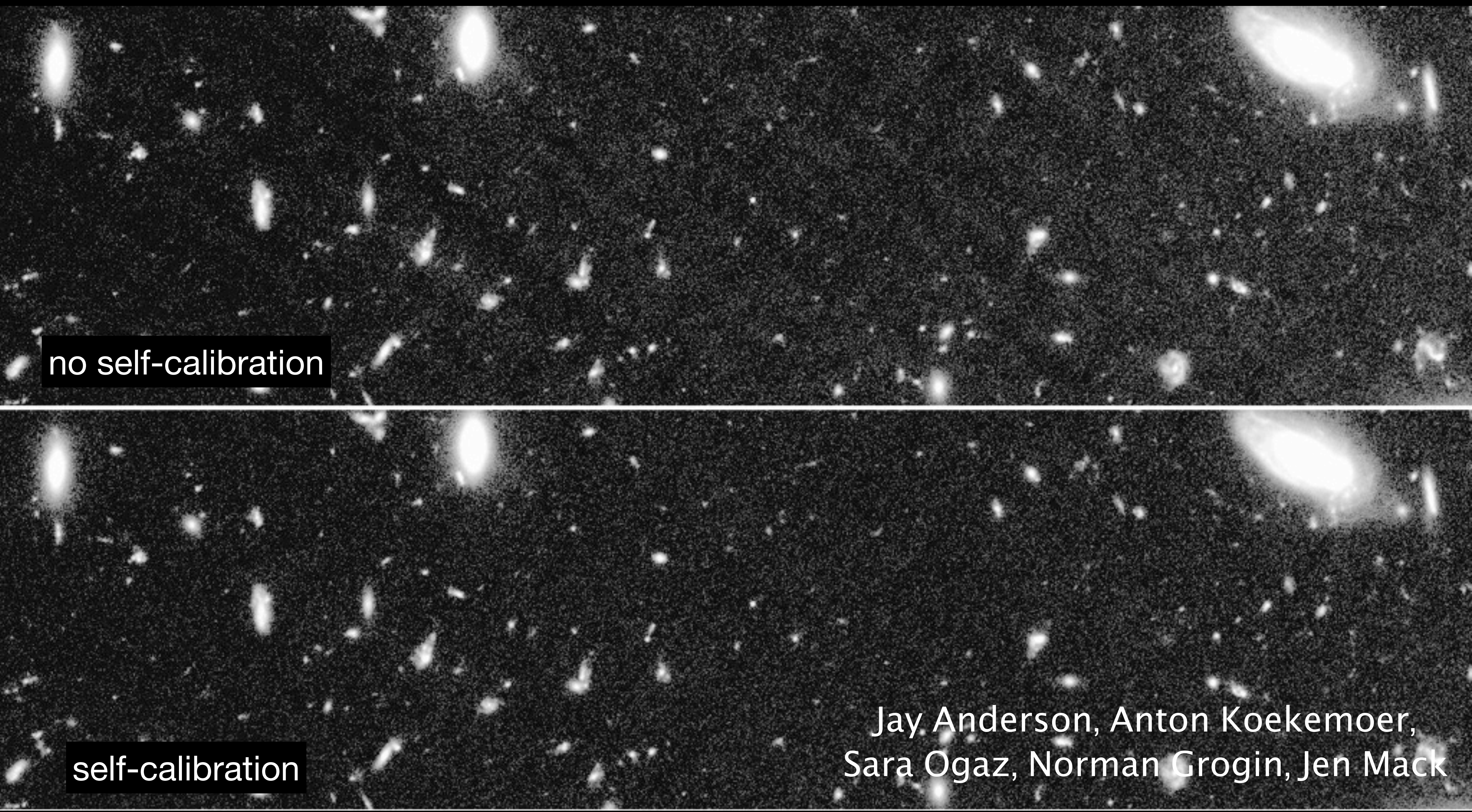
v1.0 data products
WFC3/IR F105W
variable sky correction,
IR 'blob' + persistence masking



Anton Koekemoer,
Bryan Hilbert,
Jen Mack, Roberto Avila,
Massimo Robberto

HST Data Release and Products

v1.0 ACS images -- bias destriping,
"self-calibration" to capture CTE in darks



Jay Anderson, Anton Koekemoer,
Sara Ogaz, Norman Grogin, Jen Mack

broader impacts for HST community

- astrodrizzle/drizpac testing by HFF data pipeline team
- improved ACS bias striping algorithms
- developed ACS "self-calibration" of CTE effects in dark
- testing of WFC3/IR "blob" mask, sky flats
- WFC3/IR variable sky ramp fitting algorithm
- testing WFC3/IR bright sky avoidance observing strategy
- better scheduling buffers for severe WFC3/IR persistence events
- first set of theoretical models in MAST directly linked to HST data

coming soon: ACS astrometric solution testing; ACS sky flat testing; improved approach to ACS darks

Early science - year 1

- ADS - 41 articles with “Frontier Field” in abstract since 2012
  (> 50% use FF data or lensing maps)

- HST - 14 funded Cycle 21, 22 programs with “Frontier Fields” in abstract (3 GO - Treu, Siana, Rodney)

- Chandra, ALMA, VLA, VLT Hawk-I, MUSE, Gemini GEMS AO, Keck ancillary observing campaigns underway

- 3 Frontier Fields workshops planned for 2014-2015

  Yale Frontier Fields Workshop, Nov 2014

  Sesto, Italy, Feb 2015 “ Science from the Frontier Fields”

  IAU Focus Meeting, August 2015 “The Frontier Fields: Transforming our Understanding of Cluster and Galaxy Evolution”

Early science (lensing maps)

- improved lensing models based on >150 lensed images; give factor 2.5x improved statistical uncertainty (Jauzac +14 a, b)

HFF strong-lensing analysis of MACSJ0416 1553

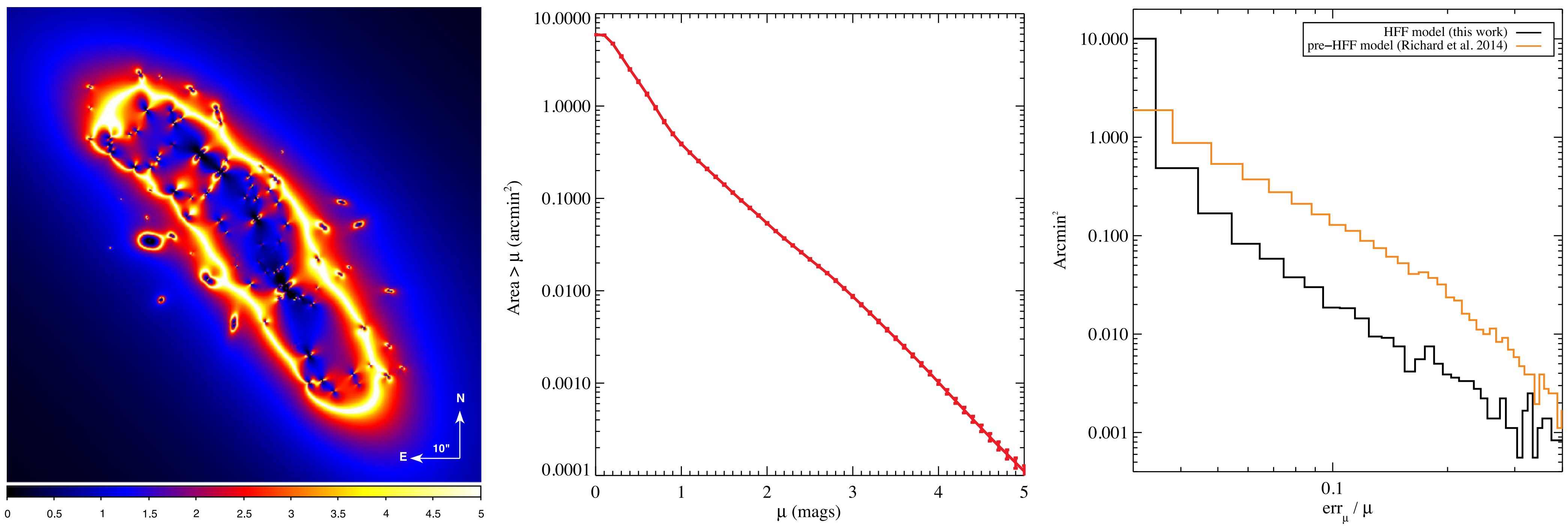
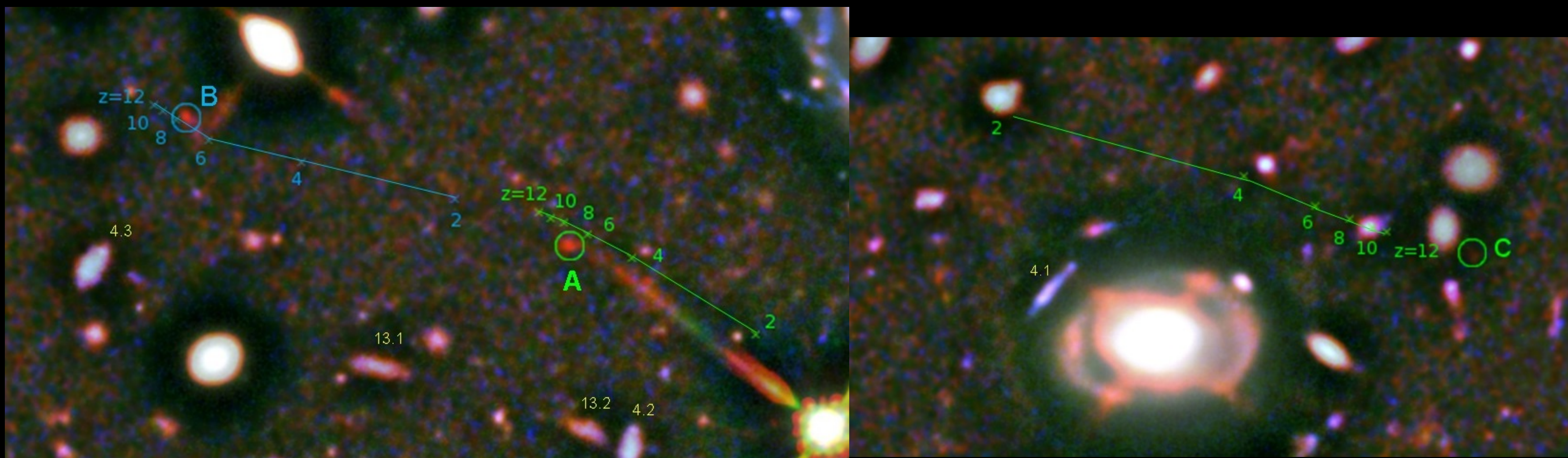


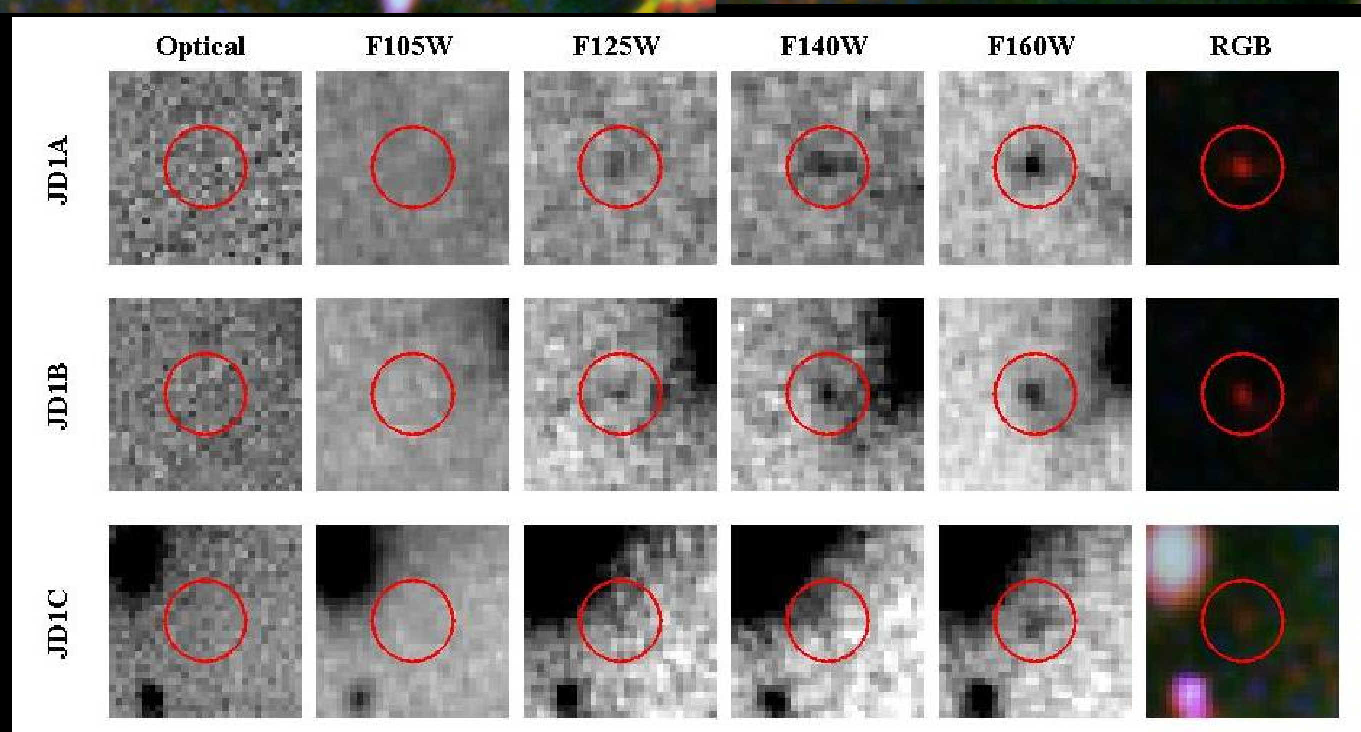
Figure 2. Left-hand panel: magnification map obtained from our *HFF* lens model for a source at $z_S = 9$. Middle panel: surface area in the source plane covered by ACS at a magnification above a given threshold μ. Right-hand panel: histograms of the relative magnification errors (in linear units) for the pre-*HFF* lens model of Richard et al. (2014, orange) and our new mass model (black).

- Abell 2744 dark matter substructure detected by lensing (Grillo+ 14)

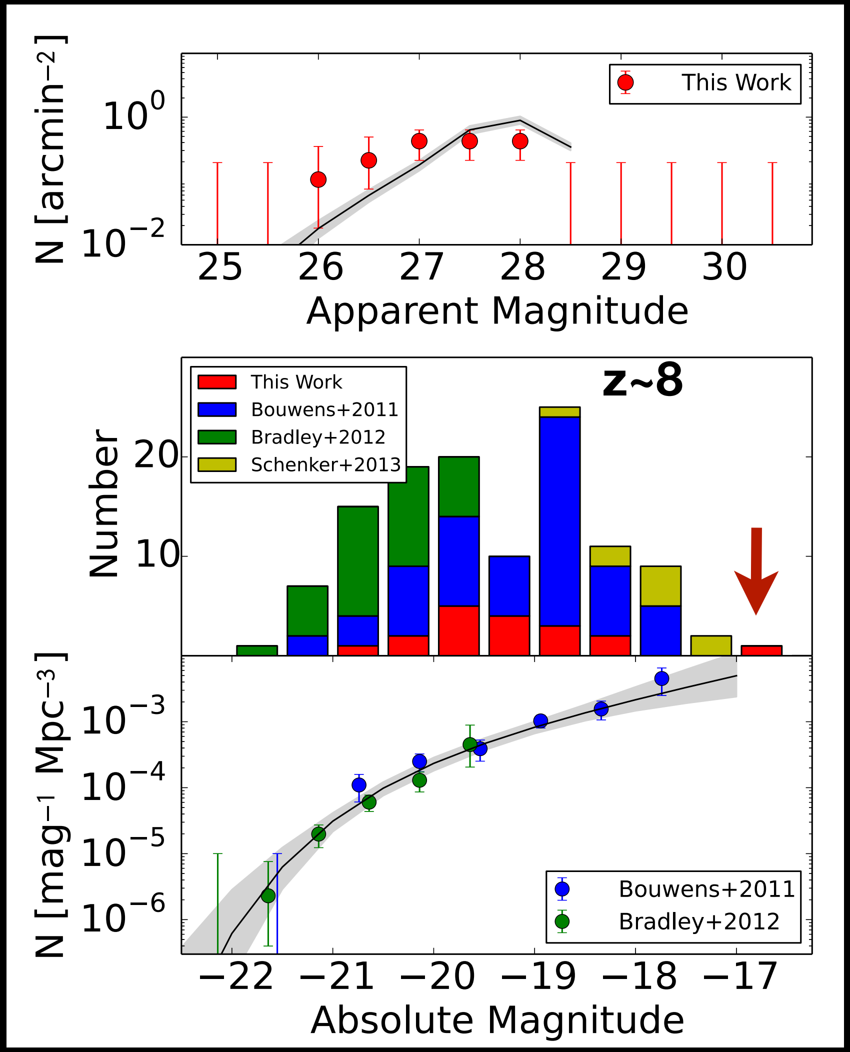
Early science (Abell 2744)

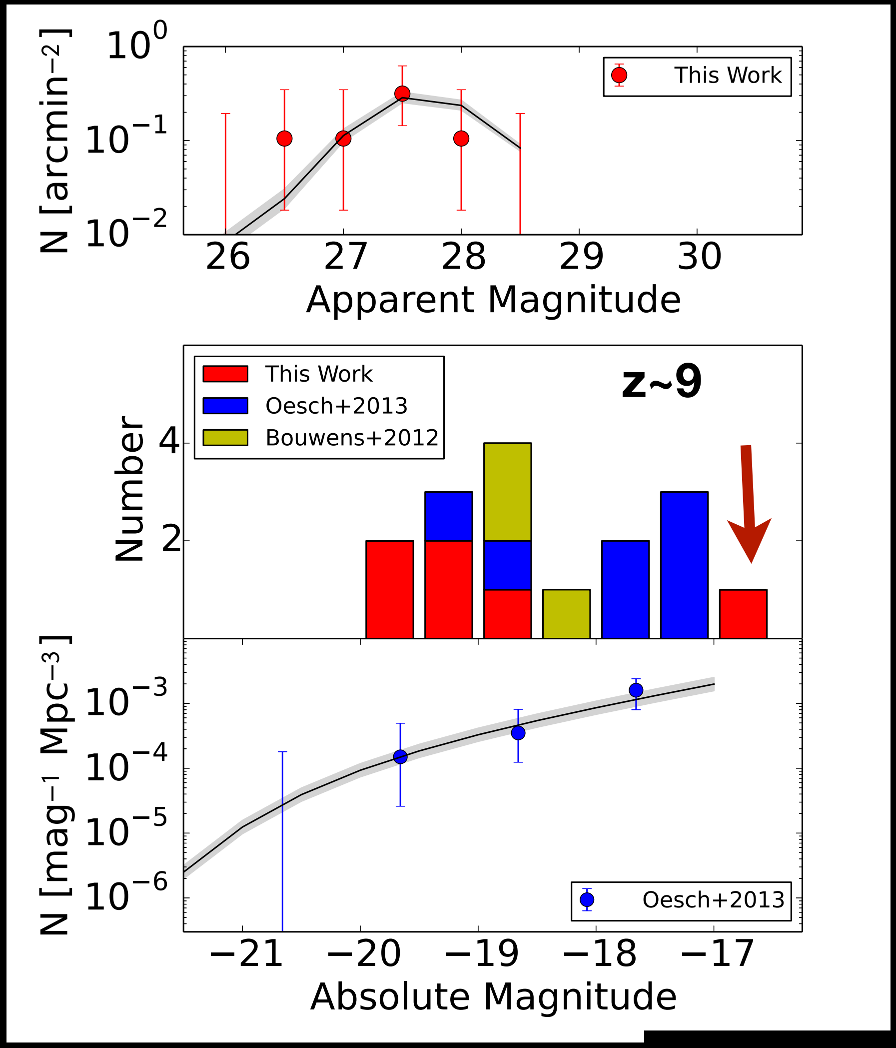
- triply imaged z~10 galaxy candidate (Zitrin +14)





Early science (high-z galaxies)





Ishigaki et al, 2014

54+ z~5-10 objects detected in Abell 2744 + parallel, including 3 with magnifications >10

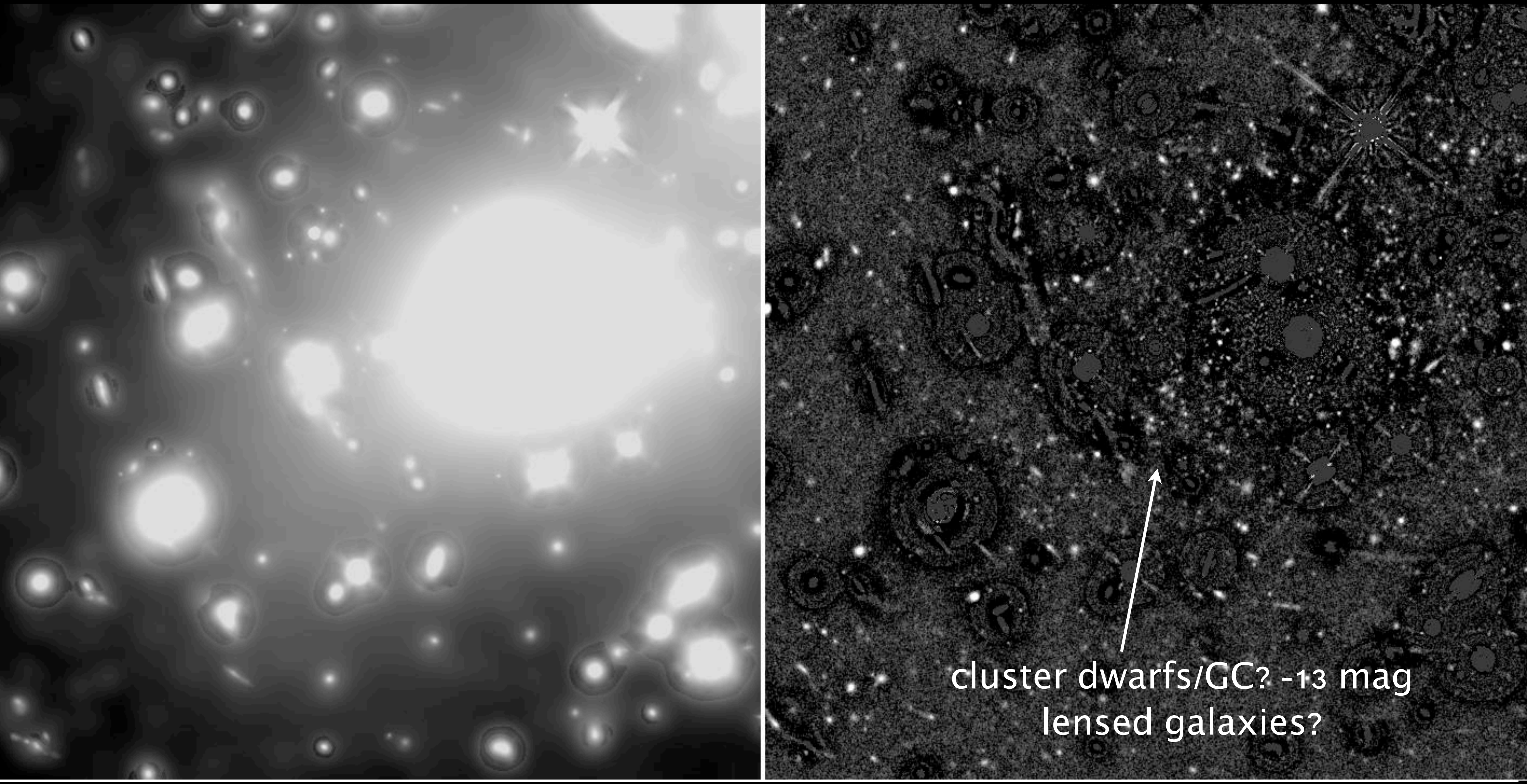
(Ishigaki; Atek; Zheng; Coe; Laporte; Zitrin; Oesch)

deficit of z~9 objects ?

standard Source Detection in Cluster highly incomplete (Oesch et al.2014)

⇒ need to subtract large-scale “foreground” (cluster + ICL)

+ identify small-scale structures (Livermore talk)



- MACSJ0717 epoch 1 is now
- MACSJ1149 epoch 1 starts in Nov
- started to collect new lensing models from community (Jauzac, Lam)
- FF review for year 3 - need to announce for Cycle 24 Call for Proposals