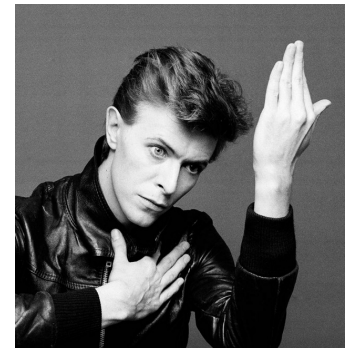




So long, Starman

FRONTIER FIELDS legacy: methods, photometry and rest-frame properties

**Emiliano Merlin,
Marco Castellano, Ricardo Amorin,
Adriano Fontana**
(Merlin+2016, Castellano+2016 – submitted to A&A)*

Sesto – Jan 14th, 2016

The FRONTIER FIELDS program



Abell 2744



MACS J0416.1-2403



MACS J0717.5+3745



MACS J1149.5+2223

HST (*Koekemoer Lotz Mack ...*, 7 bands)

+

Spitzer (*Capak*)

+

Hawki Ks (*Brammer*)

=

10 bands



Abell S1063



Abell 370

**+ 6
PARALLEL
FIELDS**

	Progress	2013			2014												2015												2016								
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
ABELL-2744	100.0%	WFC3	WFC3					ACS	ACS	ACS																											
ABELL-2744-HFFPAR	100.0%	ACS	ACS					WFC3	WFC3	WFC3																											
MACSJ0416.1-2403	100.0%			ACS	ACS					WFC3	WFC3	WFC3																									
MACSJ0416.1-2403-HFFPAR	100.0%			WFC3	WFC3					ACS	ACS	ACS																									
MACSJ0717.5+3745	100.0%	ACS										ACS	ACS	ACS			WFC3	WFC3																			
MACSJ0717.5+3745-HFFPAR	100.0%	WFC3										WFC3	WFC3	WFC3			ACS	ACS																			
MACSJ1149.5+2223	100.0%		WFC3				ACS							WFC3	WFC3	WFC3				ACS	ACS																
MACSJ1149.5+2223-HFFPAR	100.0%		ACS				WFC3							ACS	ACS	ACS				WFC3	WFC3																
ABELL-S1063	50.0%												ACS												ACS	ACS					WFC3	WFC3	WFC3				
ABELL-S1063-HFFPAR	50.0%												WFC3												WFC3	WFC3					ACS	ACS	ACS				
ABELL-370	34.3%																					WFC3				ACS	ACS	ACS					WFC3	WFC3	WFC3		
ABELL-370-HFFPAR	34.3%																					ACS				WFC3	WFC3	WFC3					ACS	ACS	ACS		

FRONTIER FIELDS

Challenges:

1 – Produce **photometric catalogs from UV to NIR**: conceptual and technical problems (different resolutions, depths, blending of sources...) - Both parallel and cluster fields

2 – Push to the deepest in the very central regions, where lensing magnification allows for **unprecedented depth** – Clusters fields in particular, but we need to get rid of the clusters themselves!

→ *Analitically fit and subtract foreground light from ICL and bright galaxies*

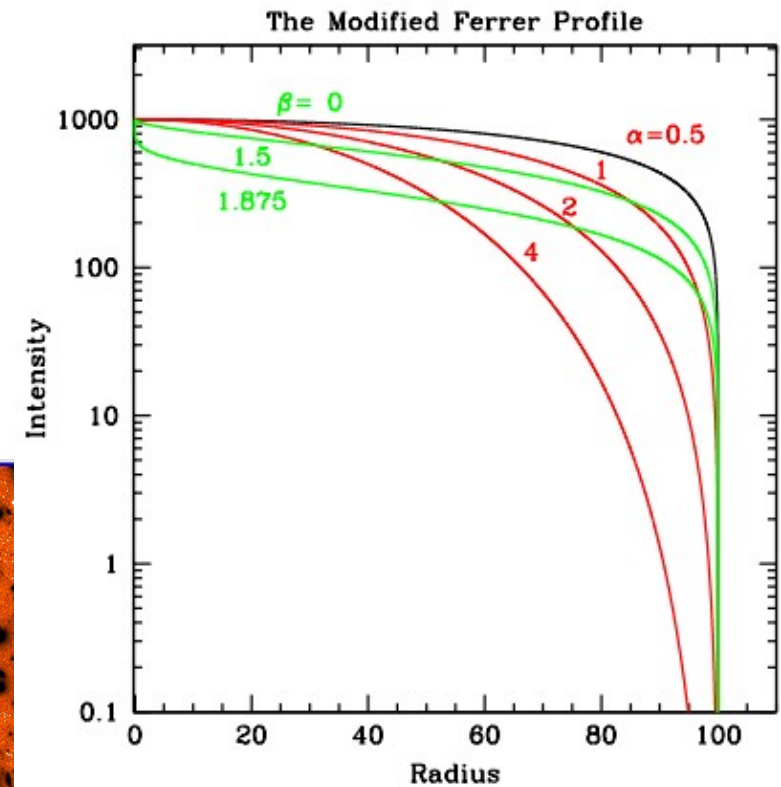
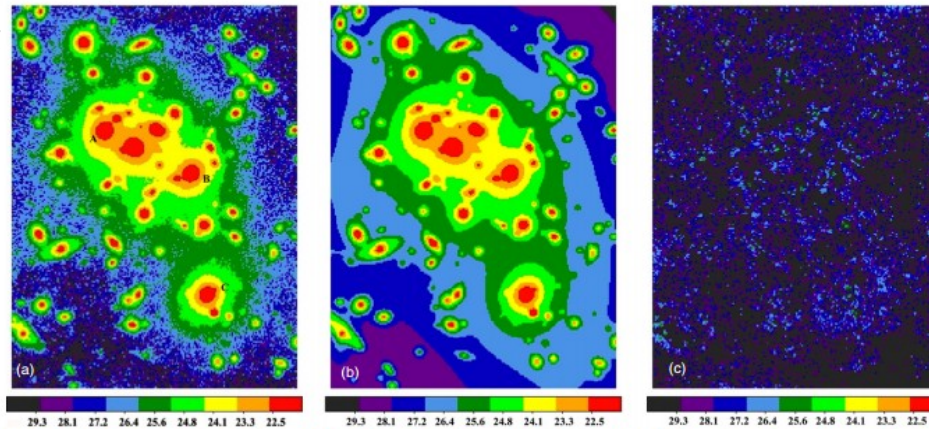


Item #1: Detection on HST H160 band

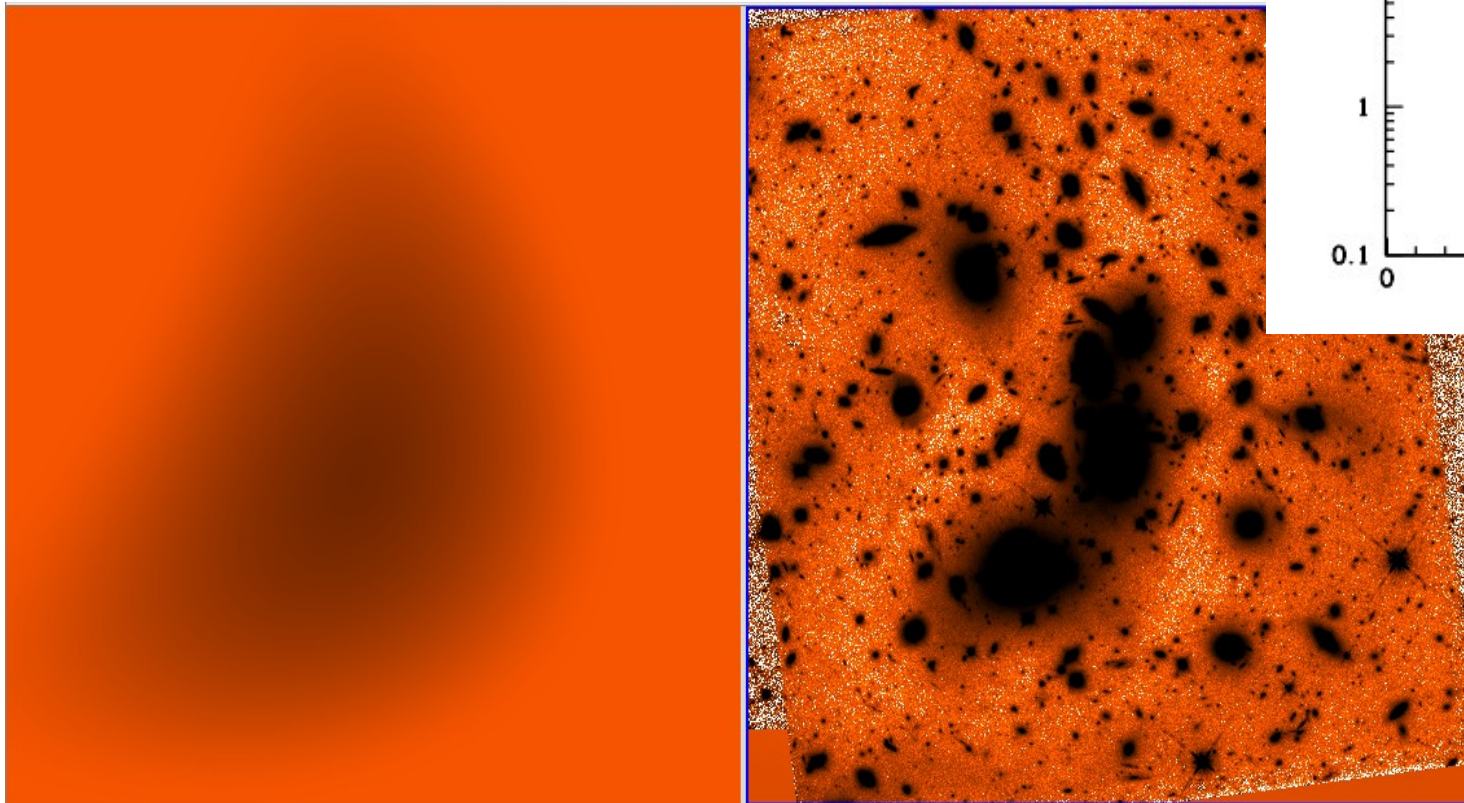
STEP 1

Fit the ICL with Ferrer profile using “masked” image

Giallongo+14



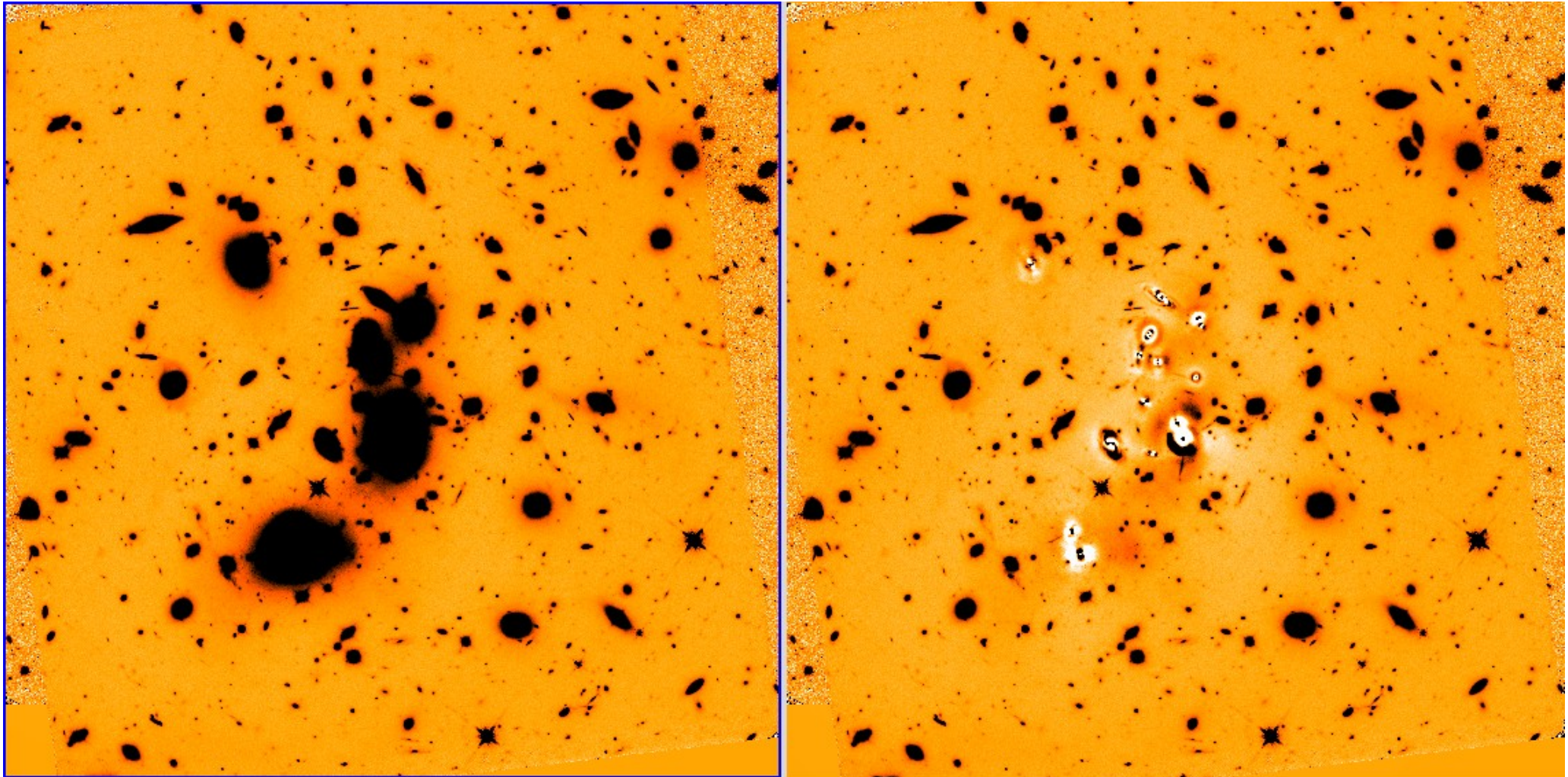
Cut at 8σ



STEP 2

**Fit the cluster big galaxies on the ICL subtracted image
with *Galapagos** (single Sersic component)**

*SExtractor + Galfit wrapper (Barden et al. 2009, Gray et al. 2009)

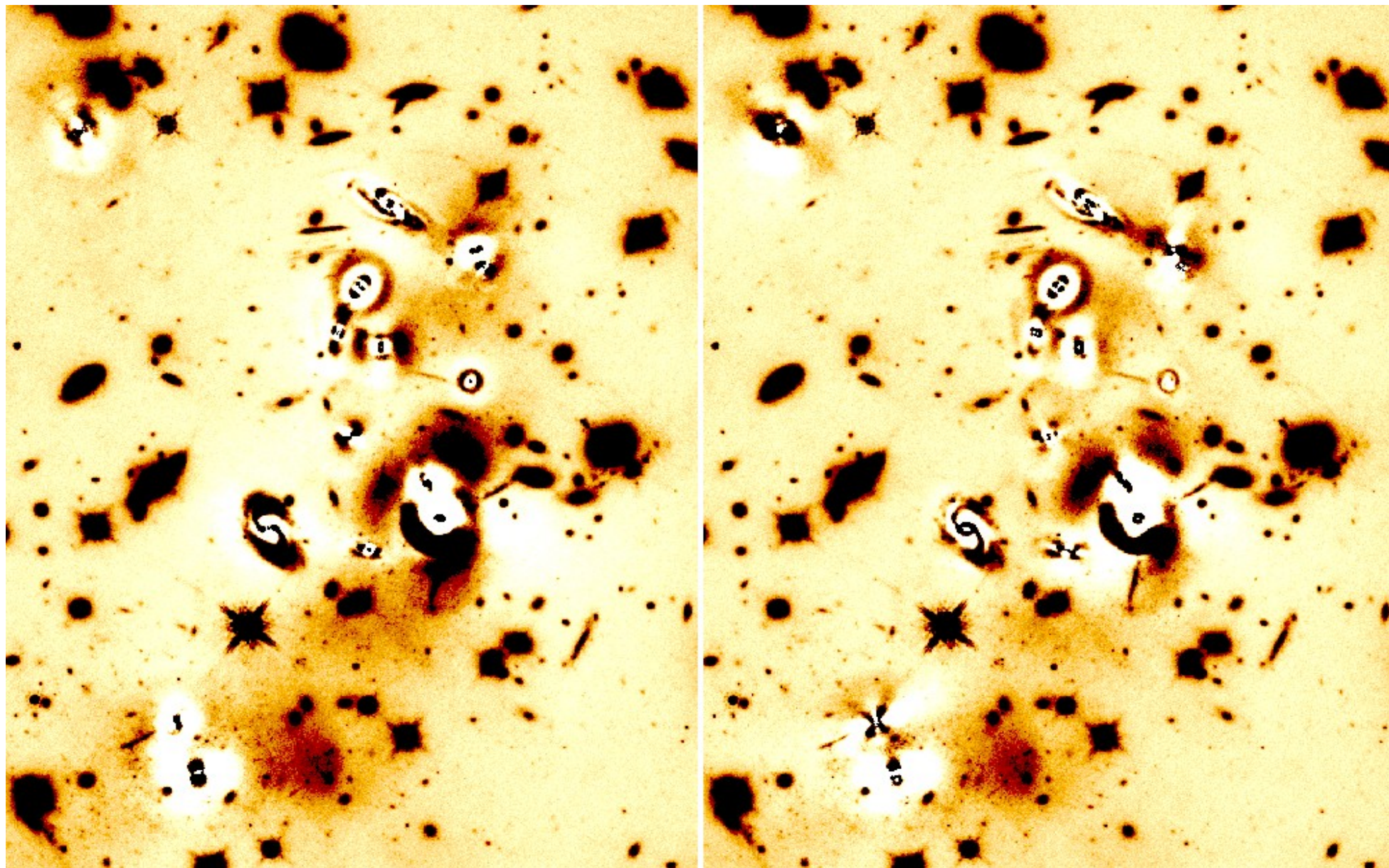


STEP 3

Re-fit the big galaxies on the ICL subtracted image with different options, and fixed ICL: 2 components (second component being the inner bulge) + *ad hoc constraints*

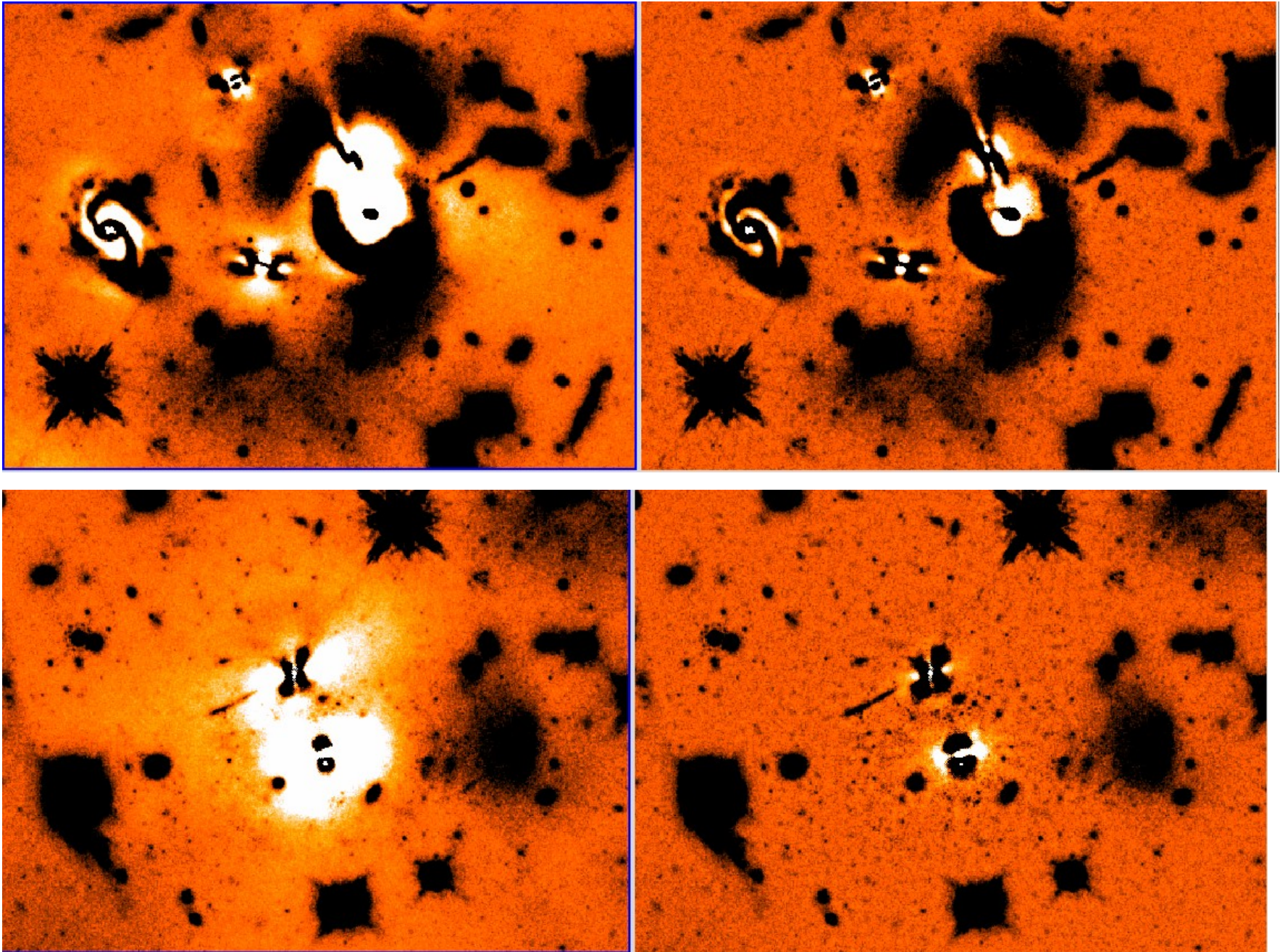
STEP 4

Final fit of the ICL with galaxies fixed



STEP 5: Application of a median filter to reduce residual features

Median computed on $1.5''$ cells considering pixels with $f < 1\sigma$



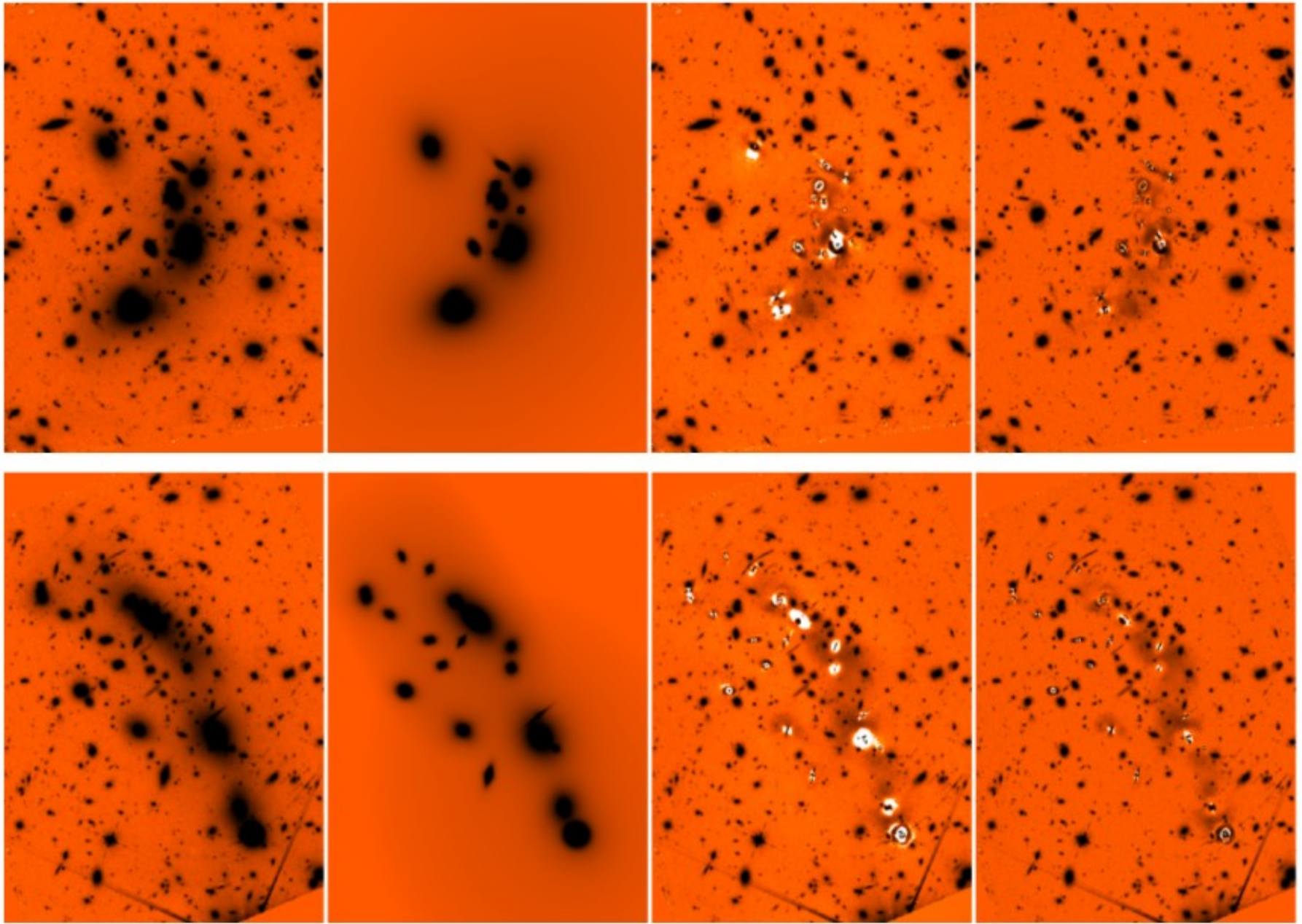
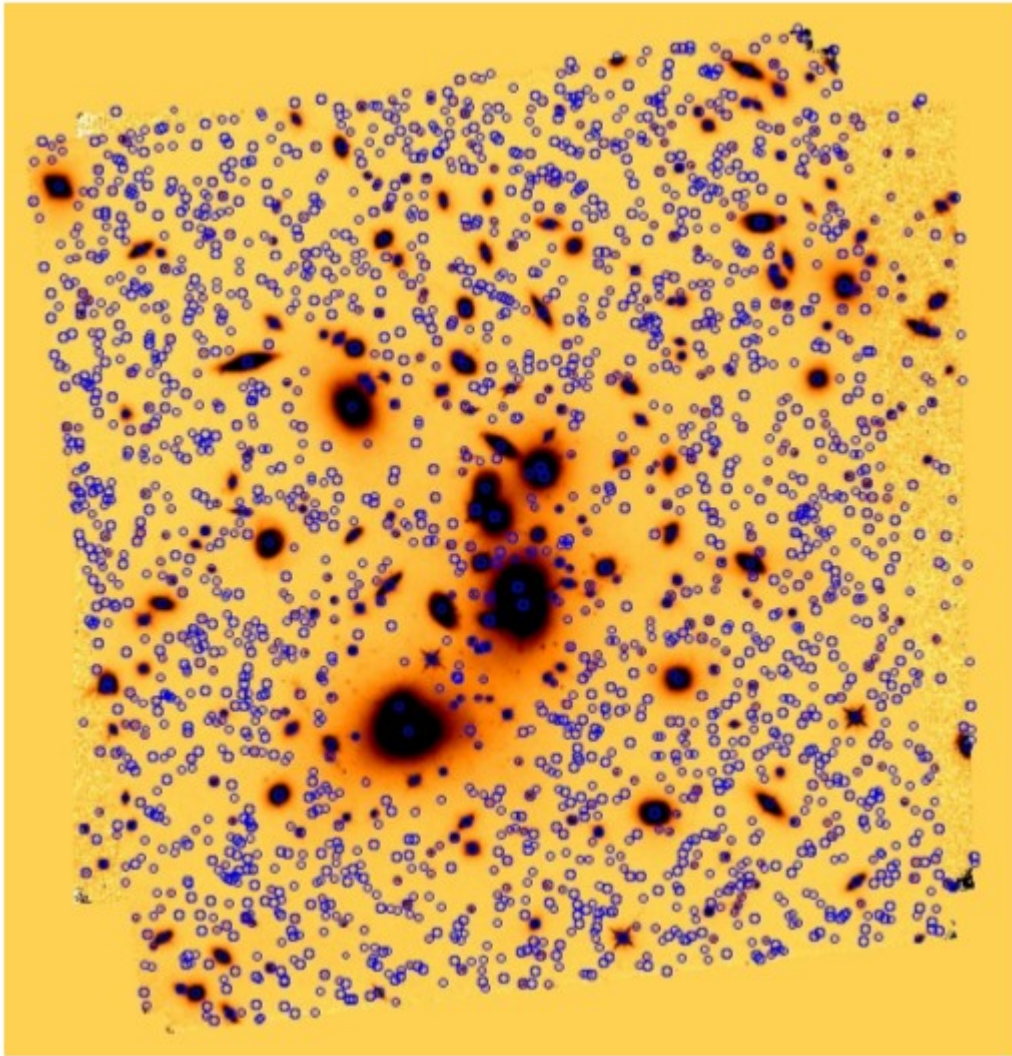


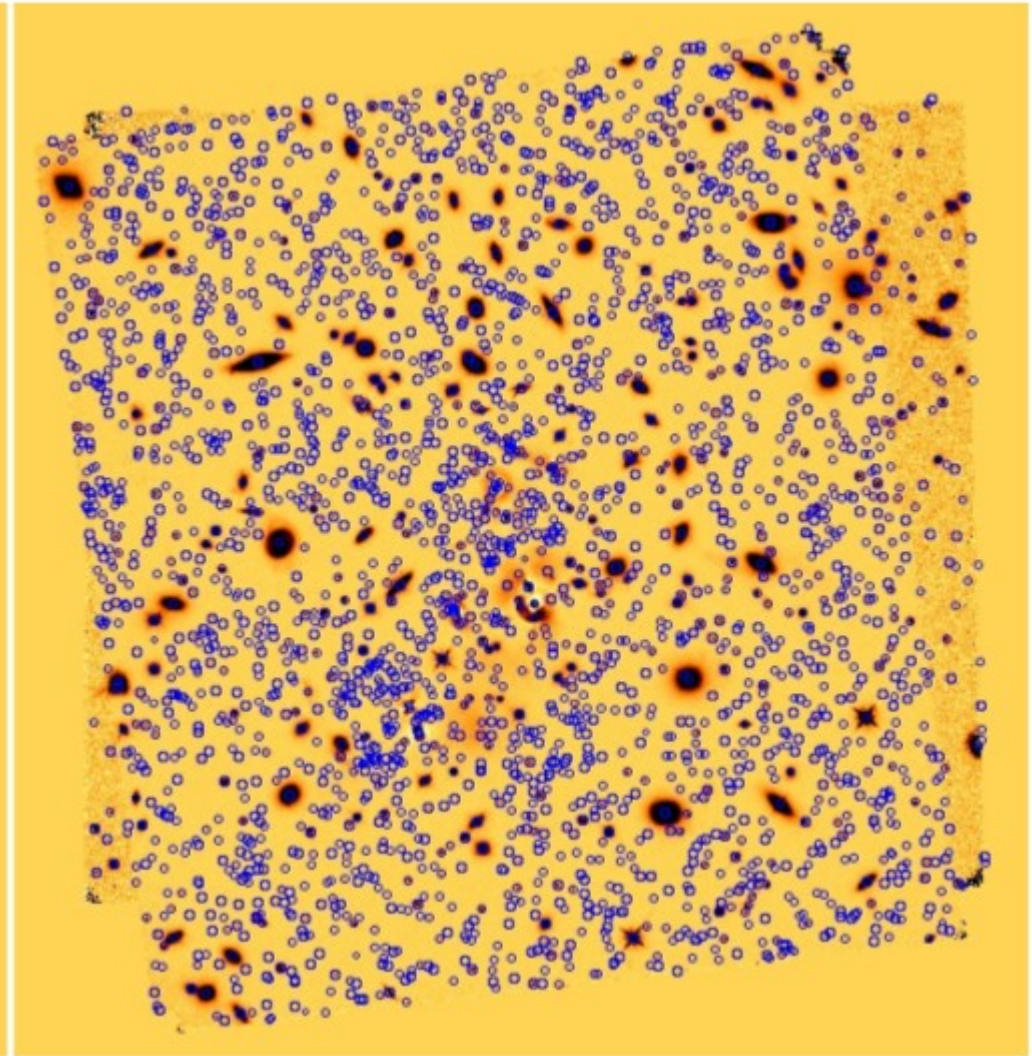
Figure 2. Effects of the procedure on the A2744 (top) and M0416 (bottom) $H160$ image. Left to right: original image, models of galaxies and ICL after STEP 4, processed image after subtraction of the models, final processed image after median filtering (STEP 5). All images have logarithmic greyscale with the same cuts.

SExtracted H160 catalog

HOT+COLD mode



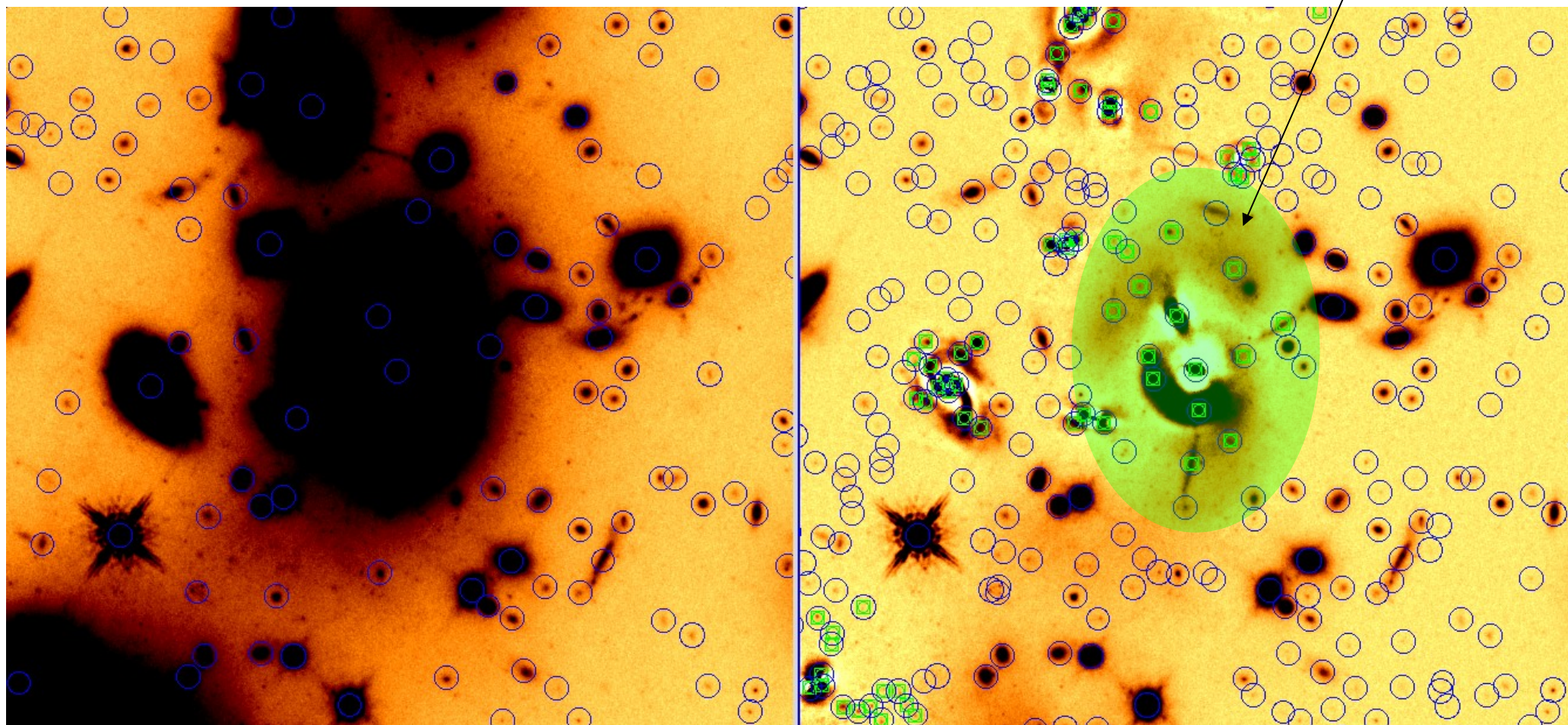
Not processed



Processed

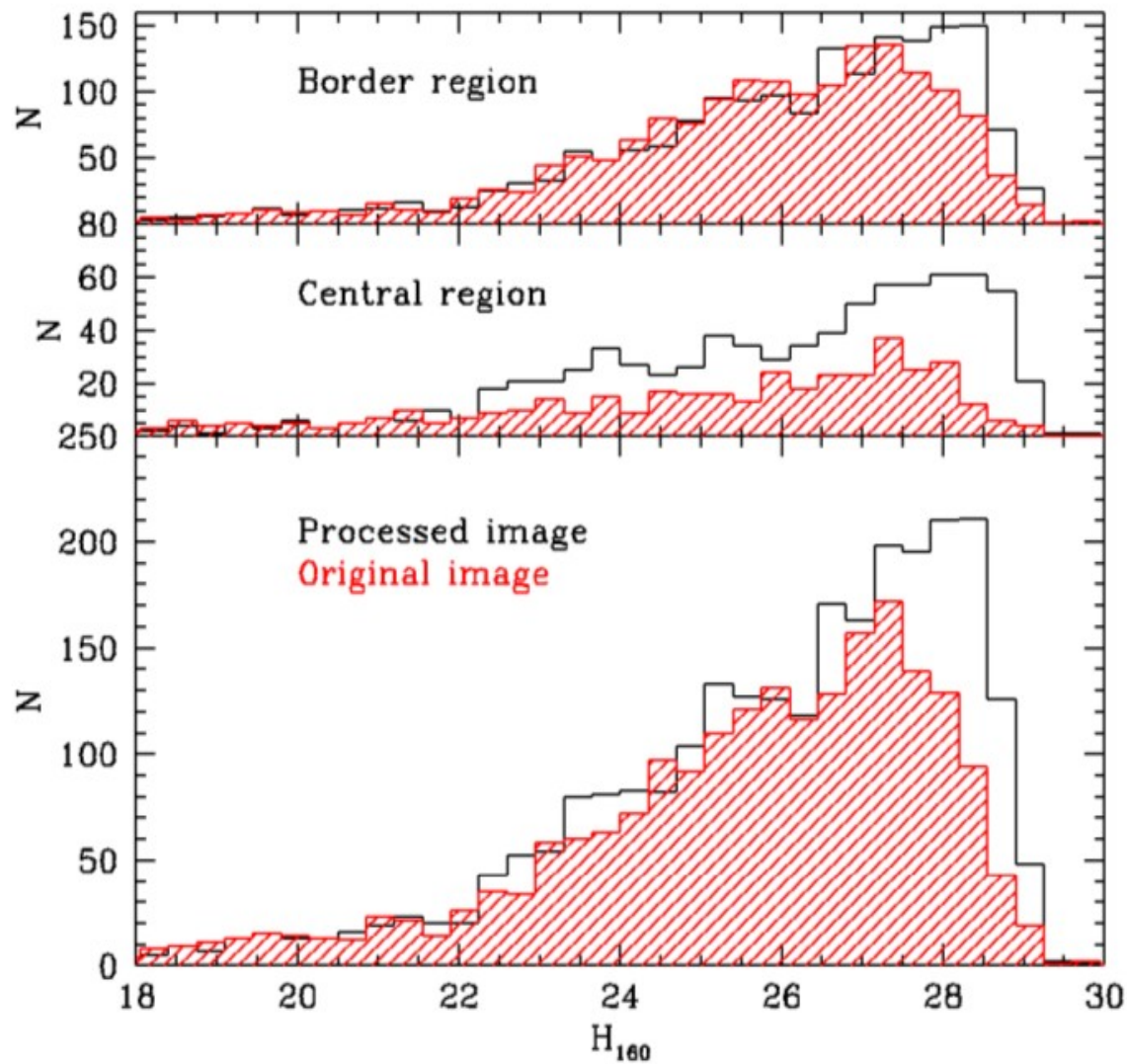
SExtracted H160 catalog

Flagged sources



Not processed

Processed



A2744 detections

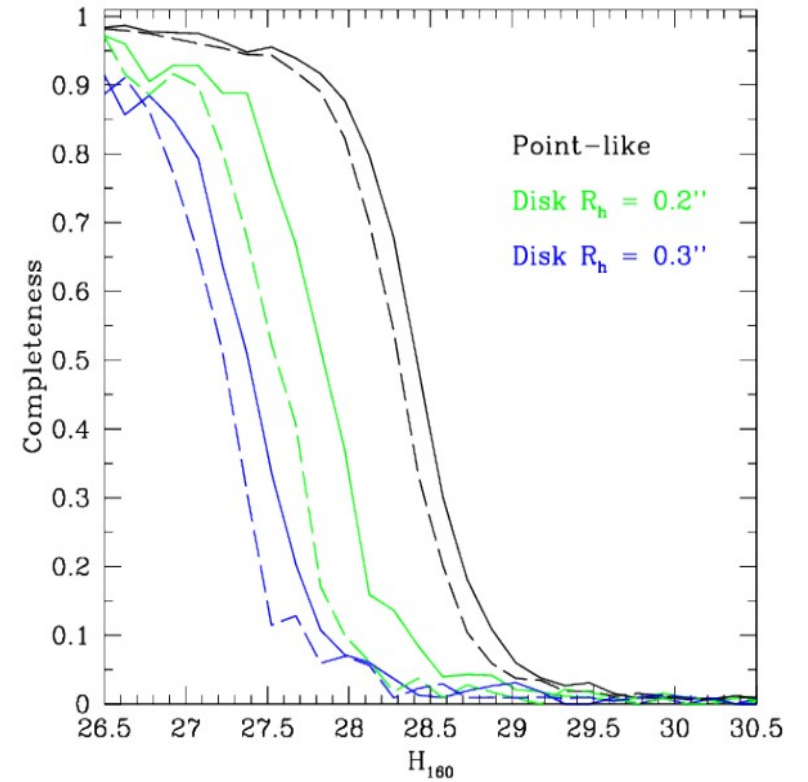


Image	N_{detect}	Image	N_{detect}
A2744 _{cl}	2596 (+15)	M0416 _{cl}	2556 (+20)
A2744 _{par}	2325	M0416 _{par}	2581

Table 2. Total number of detected sources on the H_{160} images in the four considered fields. The numbers among brackets are the models of cluster bright objects (15 for A2744_{cl}, 20 for M0416_{par}).

+ additional IR stack
($Y+J+JH+H$) detected catalogue

Image	N_{detect}	Image	N_{detect}
A2744 _{cl}	3541 (+15)	M0416 _{cl}	3164 (+20)
A2744 _{par}	3332	M0416 _{par}	3733

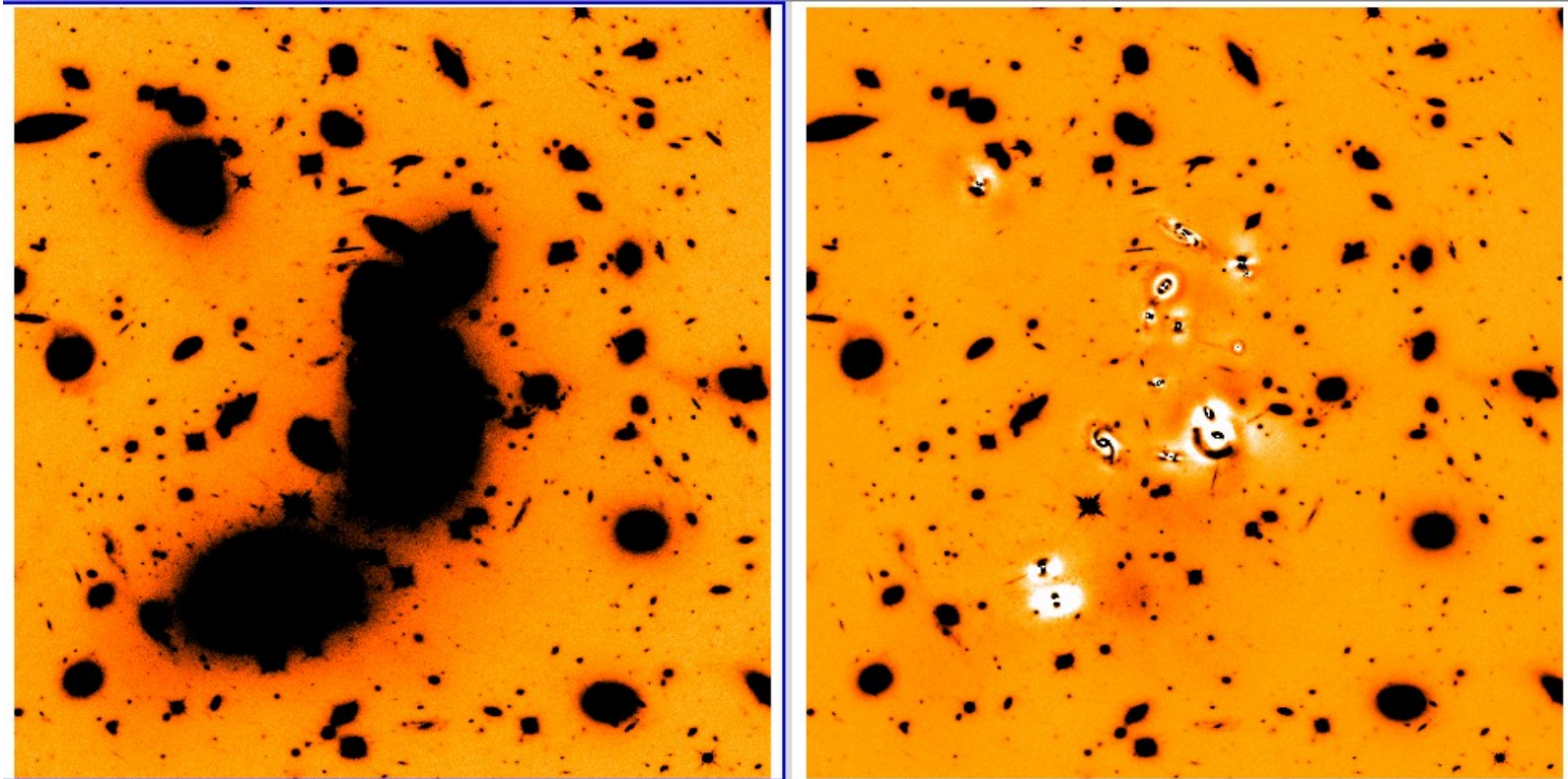
Item #2: HST multiband photometry

Building the HST multi-band catalog

Method to prepare the measurement images:

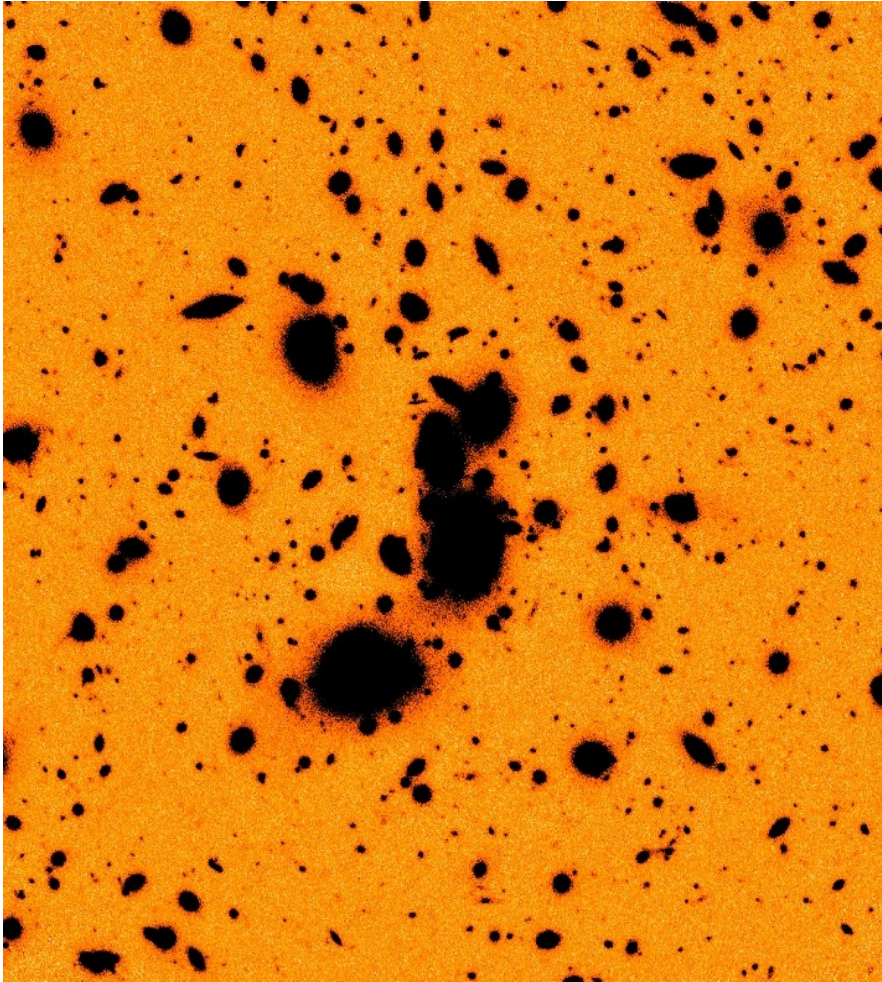
Similar procedure applied for detection band,
using as starting guess best fit of the nearest redder band

JH140 → J125 → Y105 → I814 → V606 → B435

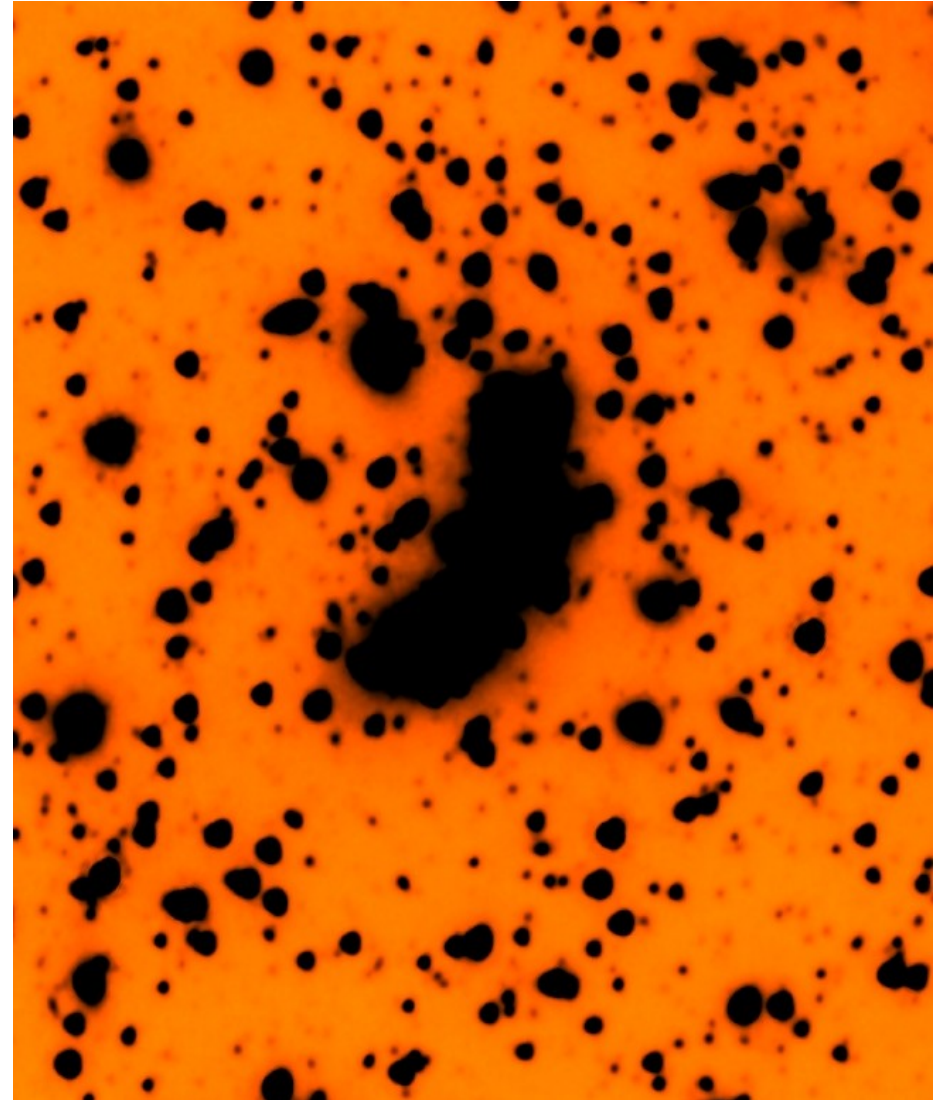


*Photometric catalogue build using SExtractor in
dual-mode on PSF matched processed images*

Item #3: K + IRAC photometry

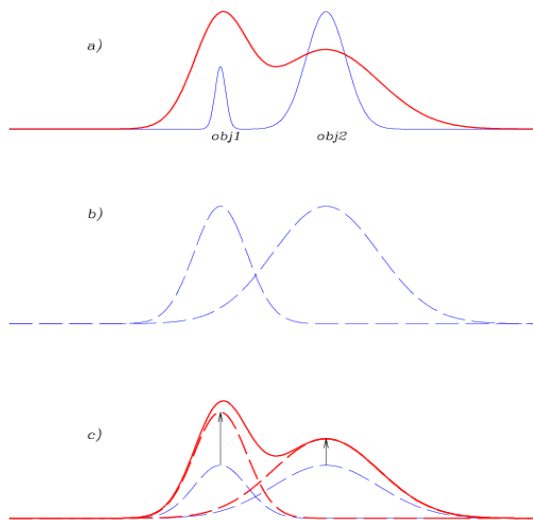
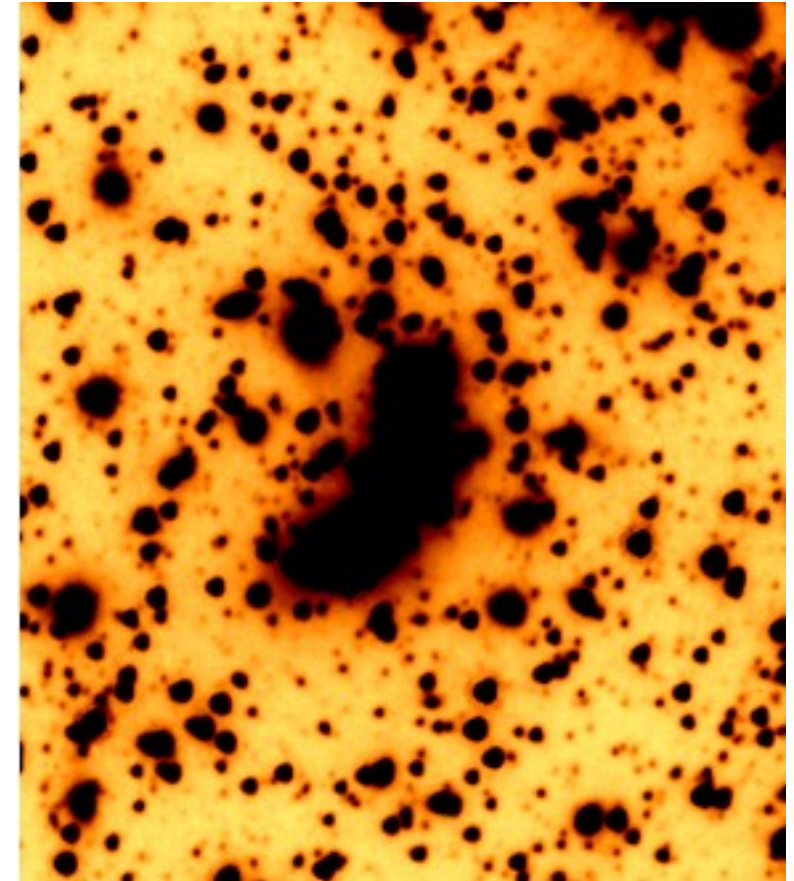
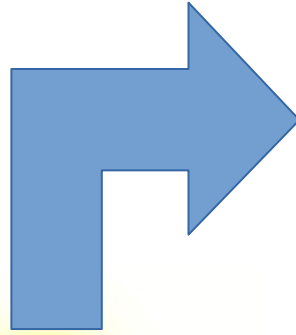
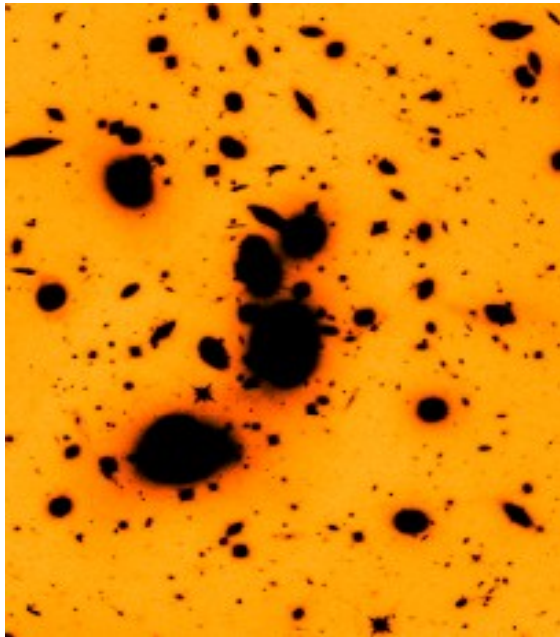


HawK-I K band (courtesy G. Brammer)

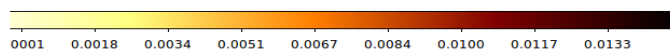
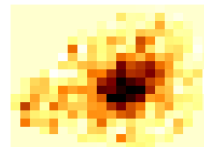
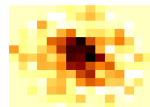
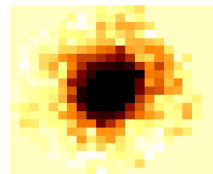


IRAC bands (courtesy P. Capak)

Processing K and IRAC bands: T-PHOT (Merlin+15) with *H* band “mixed” priors

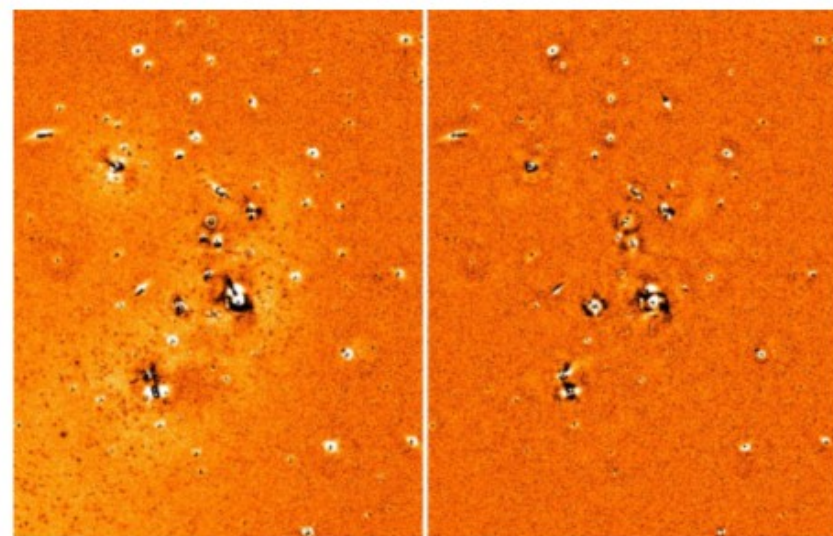
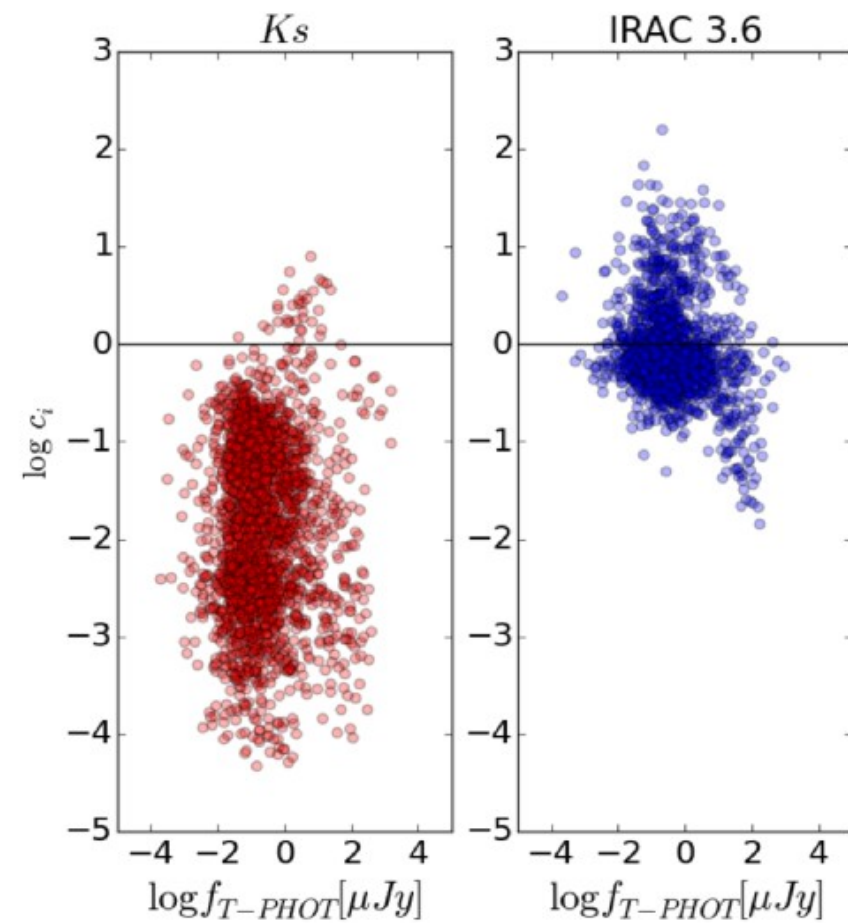
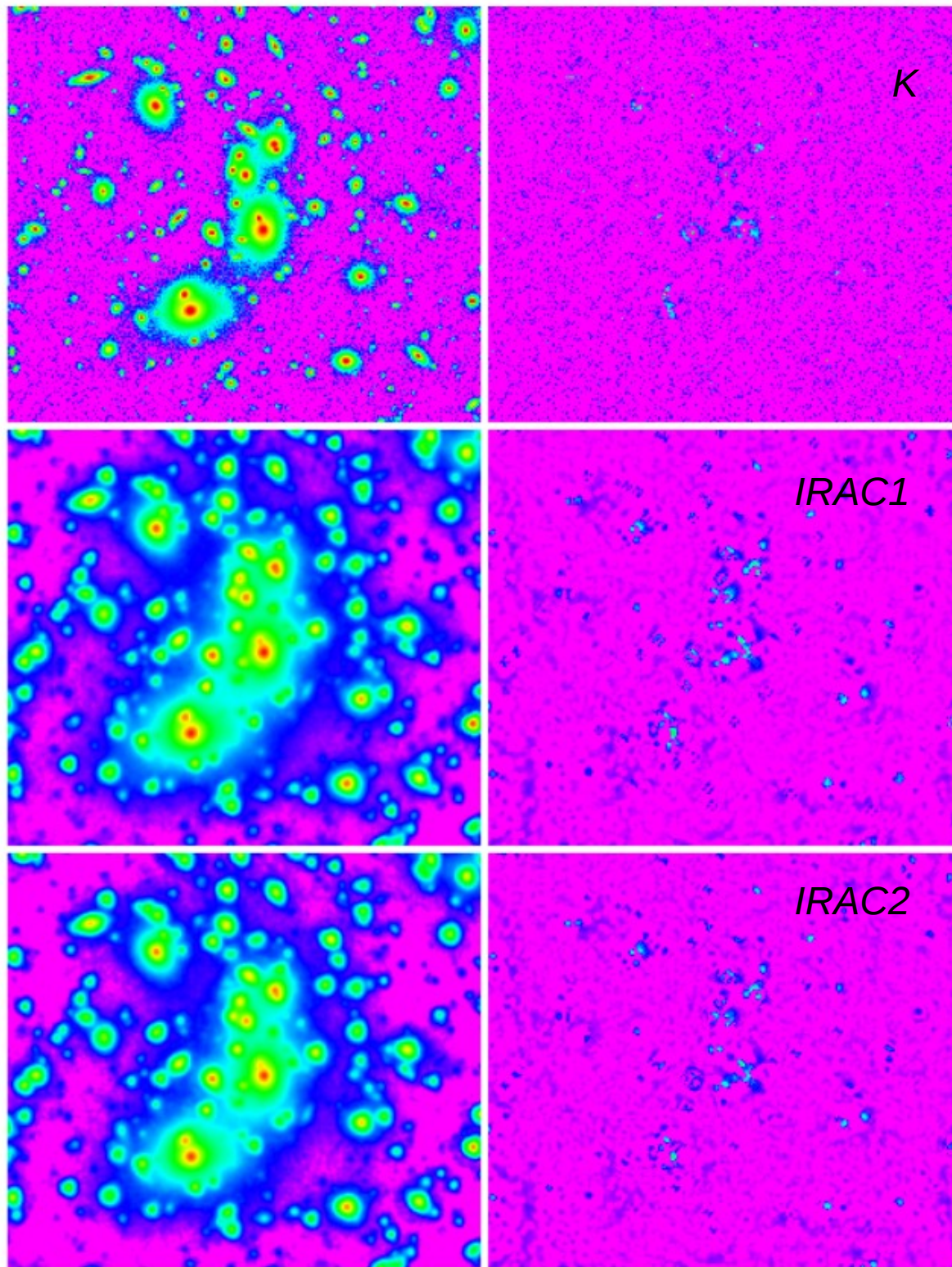


Galfit models
+ “real” cutouts



HawK-I K band (courtesy G. Brammer):
RMS refinement with fake sources
injection

IRAC bands (courtesy P. Capak):
Background and RMS refinement with
fake sources injection



Effects of local background subtraction in the T-PHOT fitting procedure.

Sanity checks on photometry

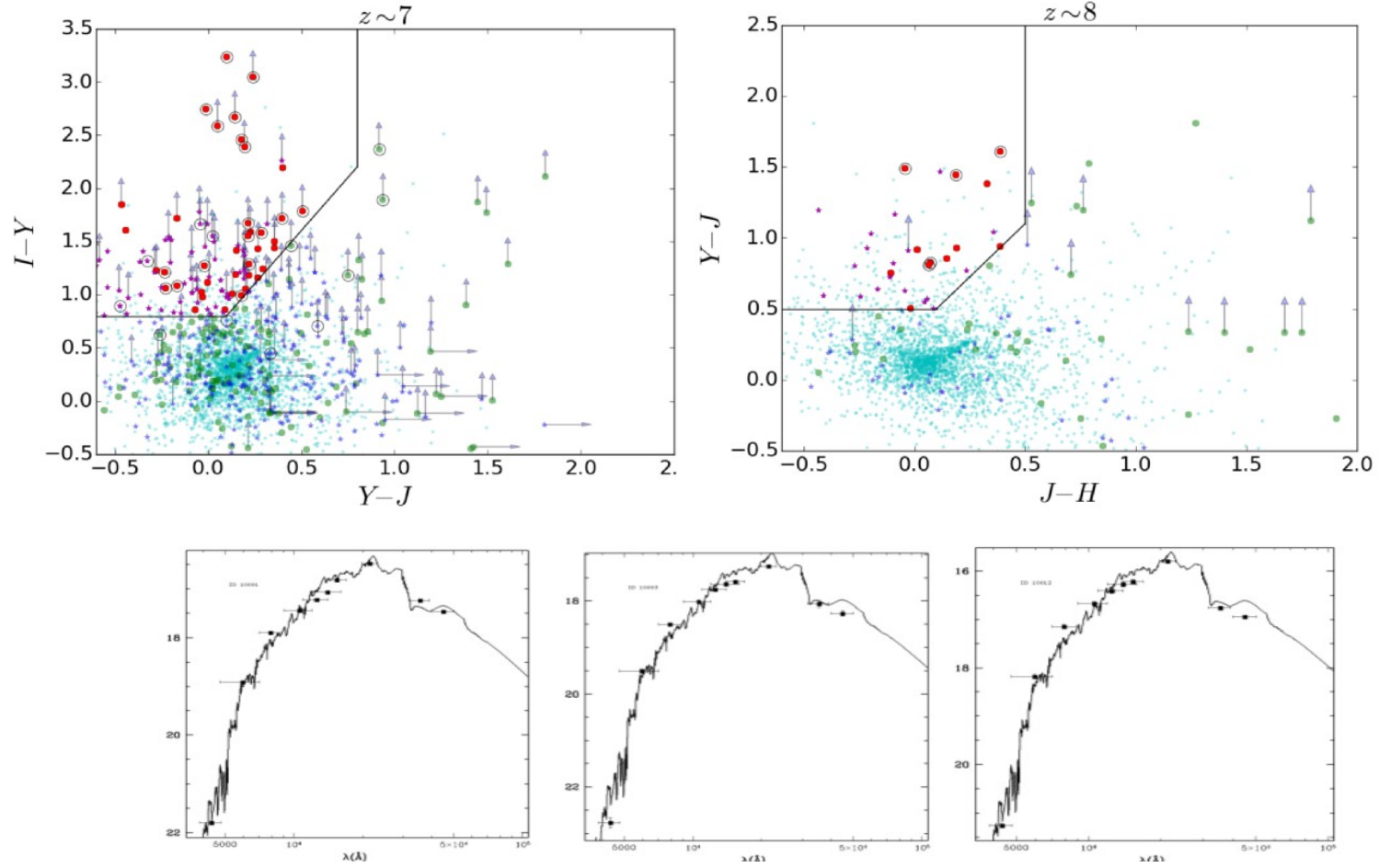


Figure 11. Examples of SED fitting with photometry from this work, for three models of bright cluster sources belonging to A2744 ($z = 0.308$).

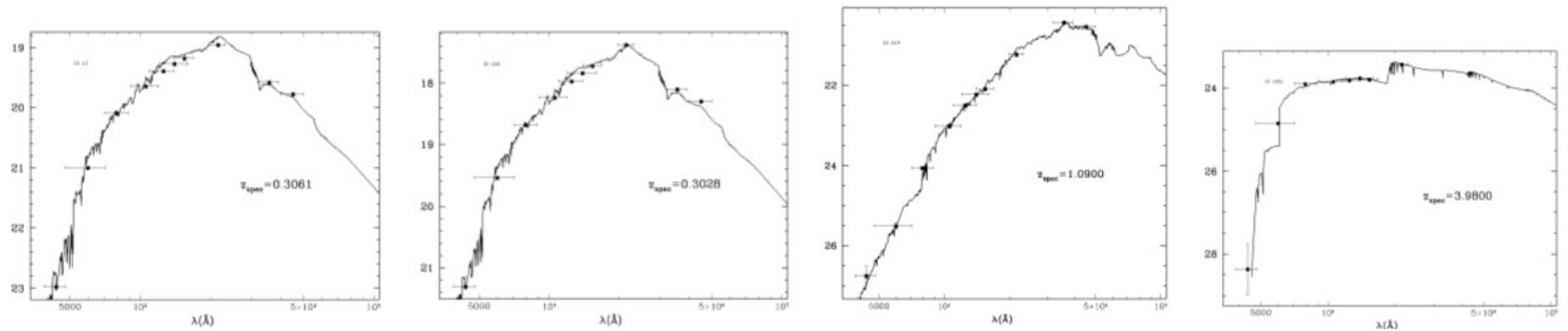


Figure 12. Examples of SED fitting with photometry from this work, for four objects with known confirmed spectroscopic redshift in the A2744 cluster field.

Rest-frame properties

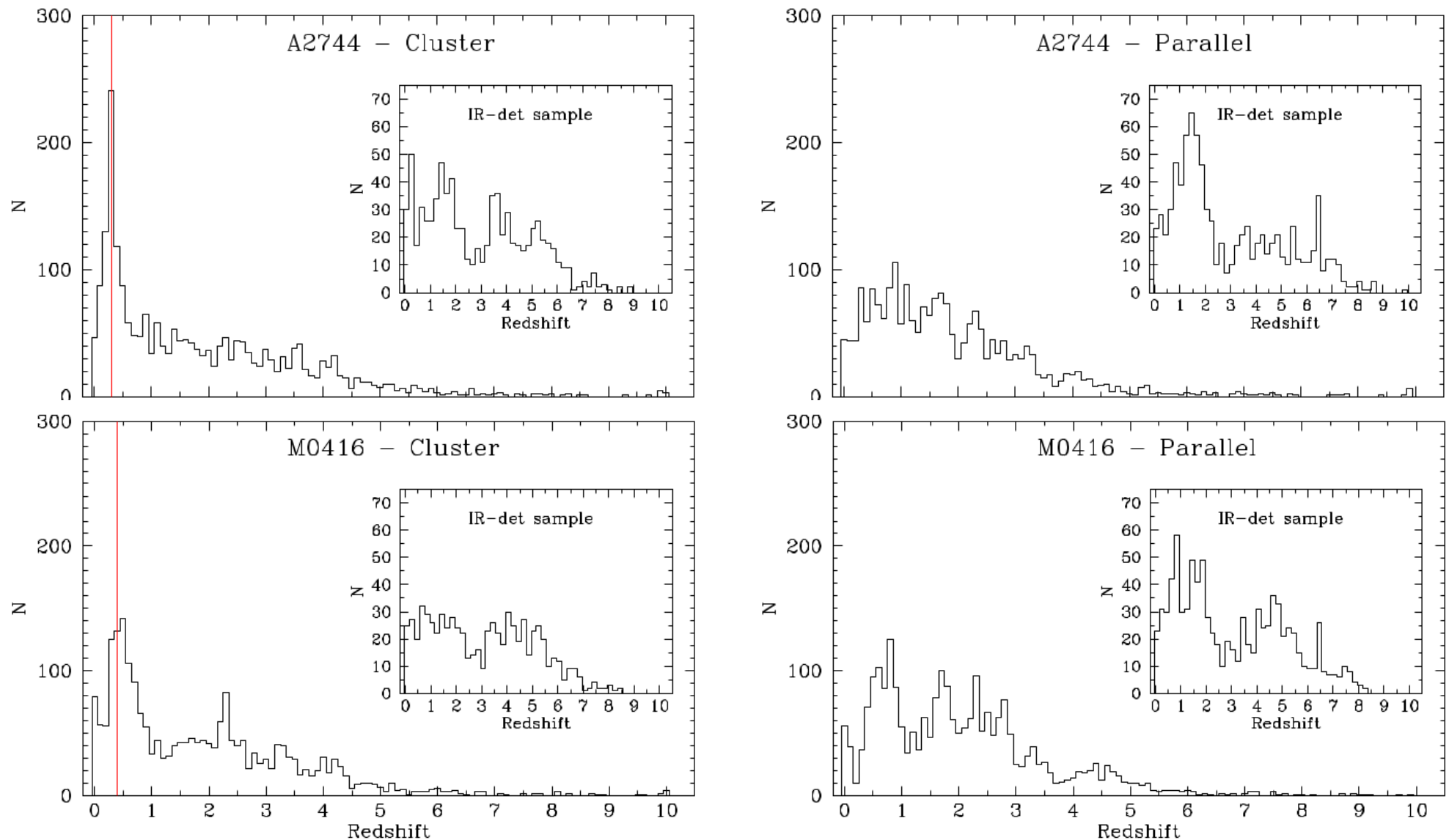


Fig. 2. Photometric redshift distribution of H-detected catalogues in, from top to bottom, left to right: Abell-2744 Cluster, Abell-2744 Parallel, MACS-0416 Cluster, MACS-0416 Parallel. Inset plots show the distribution of the additional IR-detected samples. Vertical red lines mark the redshift of the lensing clusters.

Median of photo- z 's: 1. OAR; 2. McLure; 3. Mortlock; 4. Parsa; 5. Marmol1; 6. Marmol2

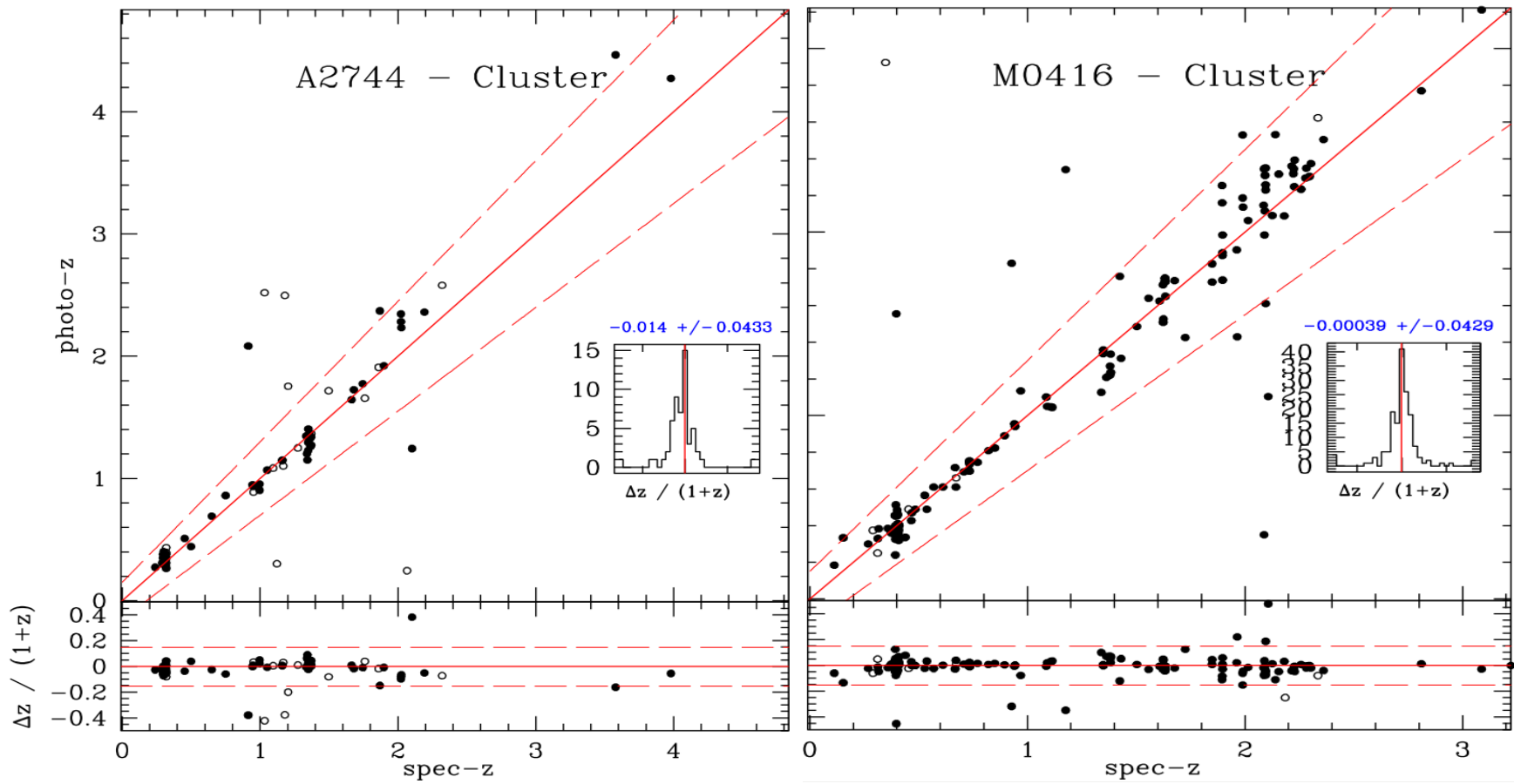
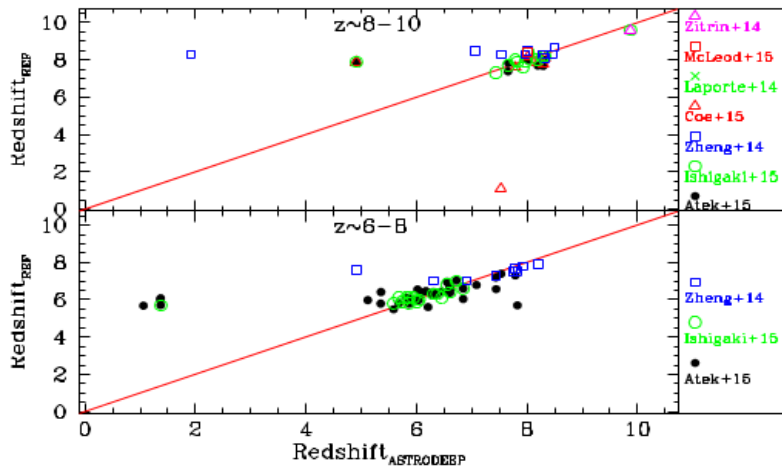


Fig. 3. Comparison between photometric and spectroscopic redshifts in the Abell-2744 (left) and MACS-0416 (right) clusters. Filled circles represent best quality spectroscopic redshifts, in the A2744 plot are also shown as empty circles objects with “reliable” redshift from the GLASS sample (quality flag = 3). Lower panels show the $\Delta z / (1 + z_{\text{spec}}) = (z_{\text{spec}} - z_{\text{phot}}) / (1 + z_{\text{spec}})$ as a function of z_{spec} . The inset in each of the upper panels present the relevant distribution of $\Delta z / (1 + z_{\text{spec}})$ with its average and rms after excluding $\Delta z > 0.15$ outliers as discussed in the text.



Field	Spec. sample	N. outliers (fraction)	$ \Delta z / (1 + z) $	$\sigma_{\Delta z / (1 + z)}$
A2744-Cl	54	4 (7.3%)	-0.0140	0.043
A2744-Par	9	0 (0%)	0.0004	0.056
M0416-Cl	73	6 (8.2%)	0.0083	0.041
M0416-Par	33	3 (10%)	-0.0299	0.0362

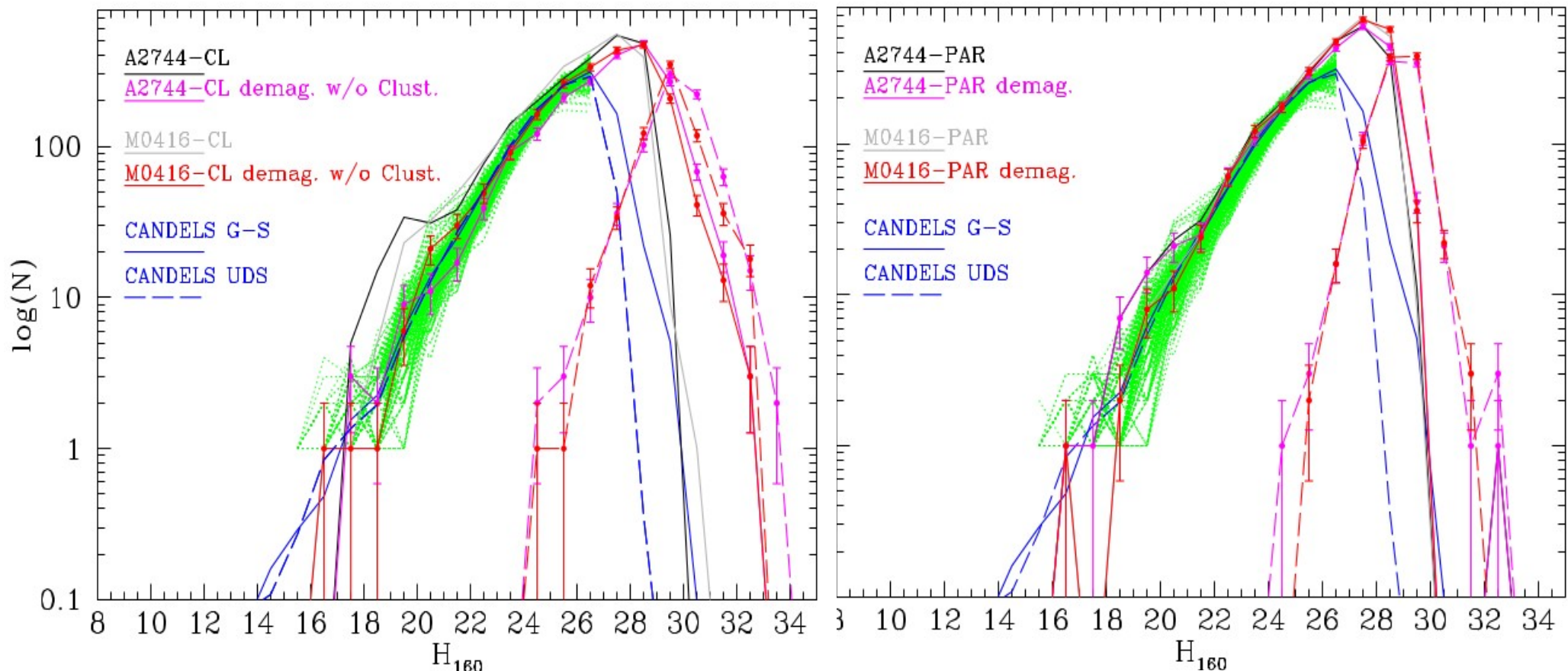
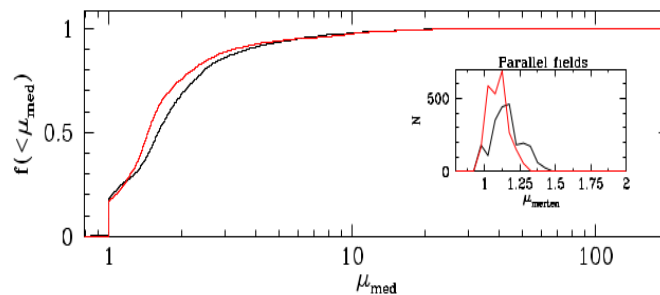
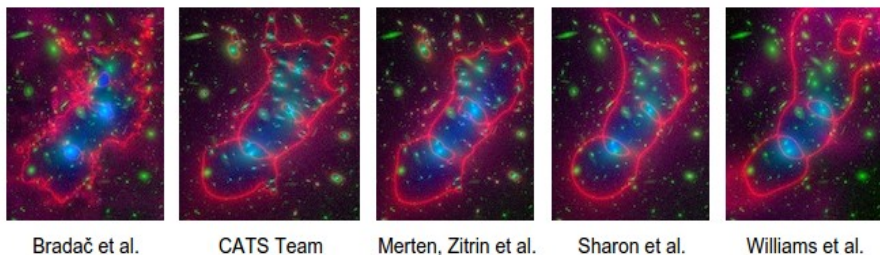
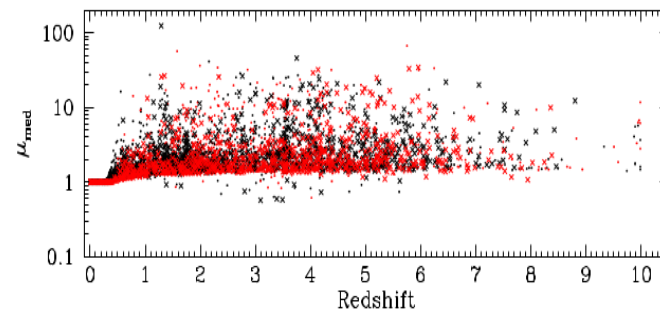


Fig. 6. Demagnified (median magnification, see text for details) H160 number counts in the cluster fields. Magenta and red continuous curves refer to Abell-2744 and MACS-0416 H-detected sources respectively after excluding all objects with photoz consistent with the redshift of the clusters. Magenta and red dashed lines show the demagnified number counts of additional IR-detected sources (with $S/N(H160) > 1$) in each field. As a comparison, number counts normalized to the FF area from the public CANDELS GOODS-South (Guo et al. 2013) and UDS (Galametz et al. 2013) catalogues are shown as continuous and dashed blue lines respectively. The green lines are number counts from randomly chosen portions of the CANDELS GOODS-South and UDS field having the same area as the FF pointings.



**Comparison
with theoretical
expectations
ongoing, more
from Marco**



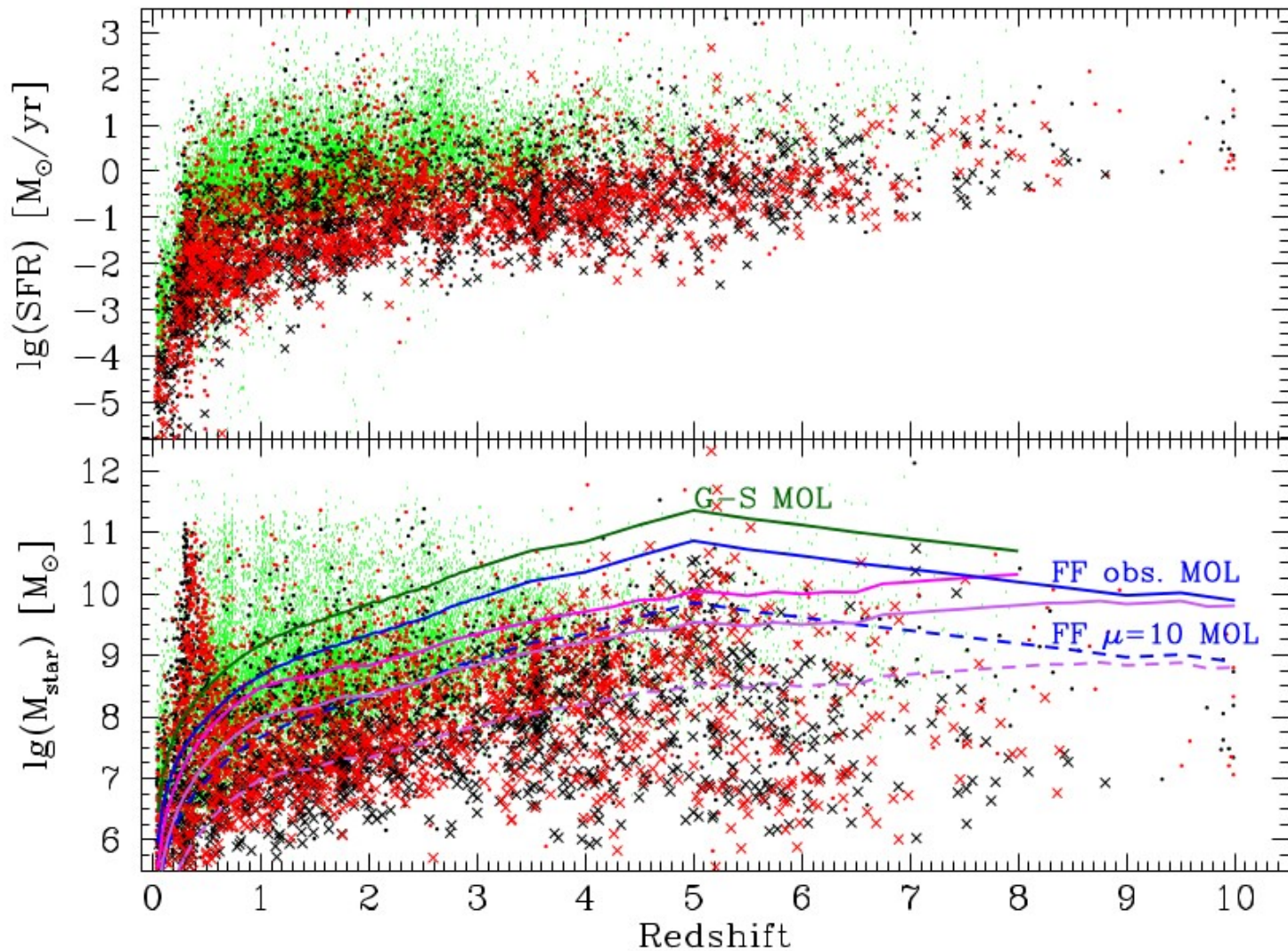


Fig. 9. Top panel: Demagnified SFR as a function of redshift in the A2744 (black) and M0416 (red) clusters. Filled circles and crosses refer to H-detected and IR-detected sources respectively. For reference SFRs of objects from the CANDELS GOODS-South field are shown as green dots. Bottom panel: demagnified stellar masses, same symbols as above. The continuous and dashed blue lines show the limiting M_{star} for a “maximally old model” at $H160=27.25$ (observed 90% completeness limit) and $H160=29.75$ (90% completeness limit for $\mu=10$). The continuous and dashed lines show the corresponding “completeness corrected” limiting M_{star} (see text for details). The dark green and magenta continuous lines show the “maximally old” and completeness corrected limiting M_{star} of CANDELS GOODS-South from Grazian et al. (2015).

SUMMARY

- We present **complete multi-wavelength photometric + rest frame properties catalogues on FF Abell2744 and MACS0416, cluster + parallel fields**
(*stay tuned for Merlin+2016, Castellano+2016, submitted* to A&A*)
- On **cluster fields**, we **remove foreground light from bright cluster galaxies and ICL** using SExtractor, Galfit and Galapagos, and perform detection on H band (and IR stack):

Image	N_{detect}	Image	N_{detect}
A2744 _{cl}	2596 (+15)	M0416 _{cl}	2556 (+20)
A2744 _{par}	2325	M0416 _{par}	2581

- HST multi-band catalog is then obtained via **PSF-matched SExtractor photometry**; NIR photometry (**Hawk-I Ks** and **IRAC**) using **T-PHOT** with “mixed” priors
- We get as faint as $H=29$ ($H=32$ after de-magnification) with median of 5 mass models)
- We obtain **photo- z** 's via **SED fitting** as the median of 6 independent determinations, fairly consistent with known spec- z 's ($\sim 4\%$ accuracy) and other studies; we find $z \sim 9-10$ candidates
- Physical **rest-frame properties** are obtained via SED fitting with BC03 τ -models and reach $M^*=10^7$ Msol and SFR=0.1 Msol/yr at $z>5$

CATALOGUES SOON PUBLICLY AVAILABLE:

<http://www.astrodeep.eu/> (work in progress)
CDS Astrodeep archive (work in progress)
emiliano.merlin@oa-roma.inaf.it
marco.castellano@oa-roma.inaf.it

TO GET T-PHOT:

<http://www.astrodeep.eu/t-phot/>
emiliano.merlin@oa-roma.inaf.it