EXPLORING THE SOURCES OF REIONIZATION BEHIND LENSING CLUSTERS WITH MUSE

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CONTEXT

Faint Star Forming Galaxies (SFGs) are likely to be the main drivers of cosmic reionization (**Finkelstein+2015,Bouwens+2015, Bouwens+2017,Drake+2017, Atek+2018** and many more…)

- Studying the **galaxy LF of SFGs**

Need to go **fainter and deeper** to reach more definitive conclusions

- Use of **lensing clusters** that really took off since HFF (**Lotz+2017**)

Two ways of selecting SFGs : **LAE or LBG**

- Are they intrinsically the same population ?
- UV LF extensively studied, the LAE LF not so much

OVERVIEW

VLT/MUSE instrument

MUSE observations of lensing clusters

Effective volume behind lensing clusters

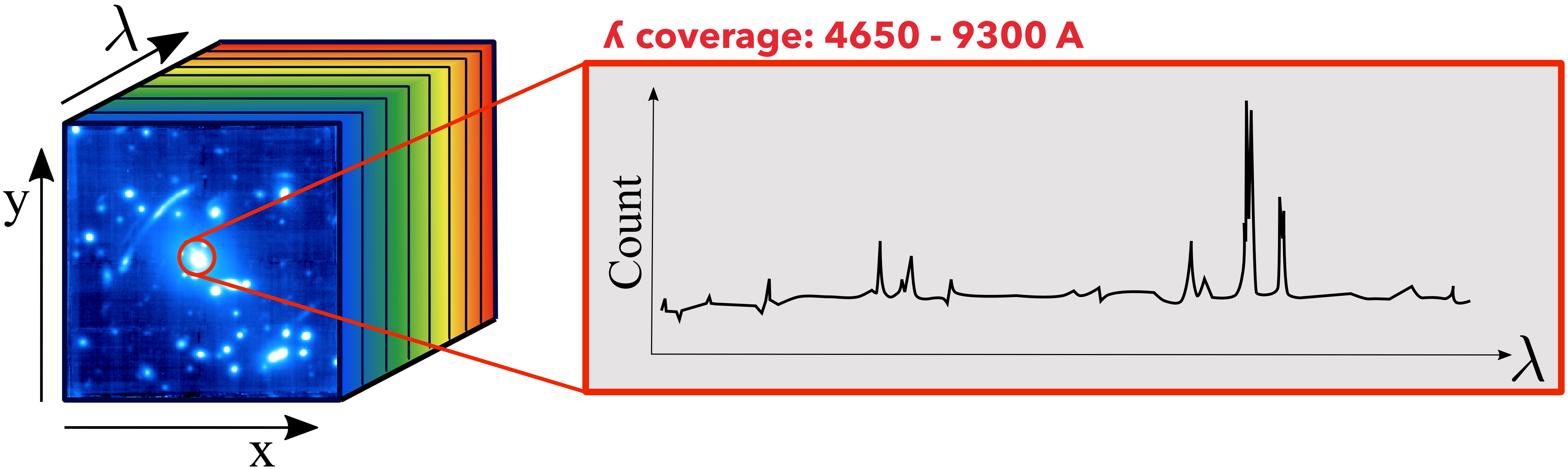
The LAE LF: results and implications for reionization

Interrelation between LAE and LBG population

Conclusion

THE MUSE VLT/INSTRUMENT (Bacon+2010, Bacon+2015)

ʎ coverage: 4650 - 9300 A



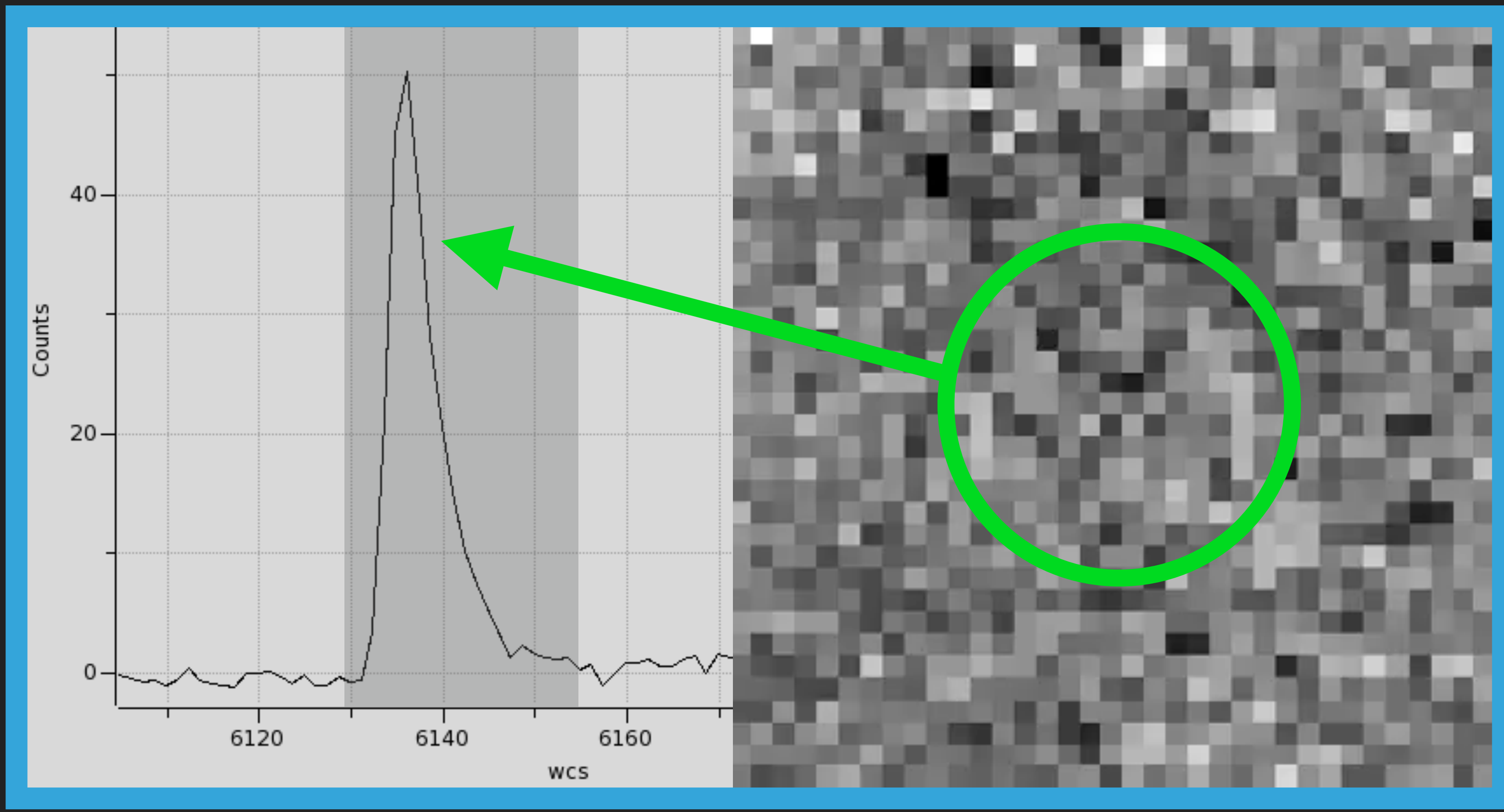
IFU in the optical

1′ X 1′ FoV

Most efficient to detect e-lines

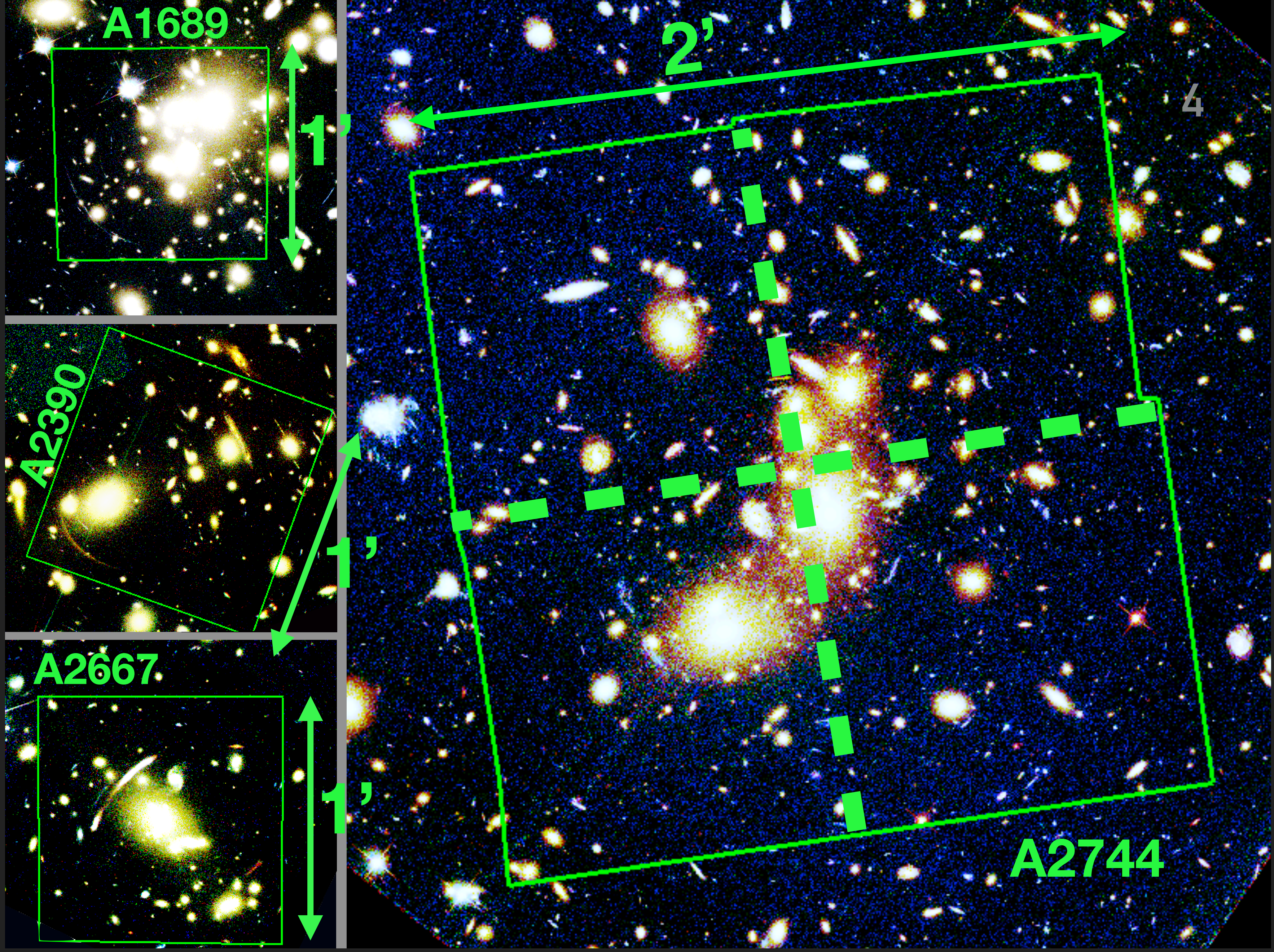
LAE with **2.9 < z < 6.7**

Blind, and complete selection of LAEs with better flux recovery



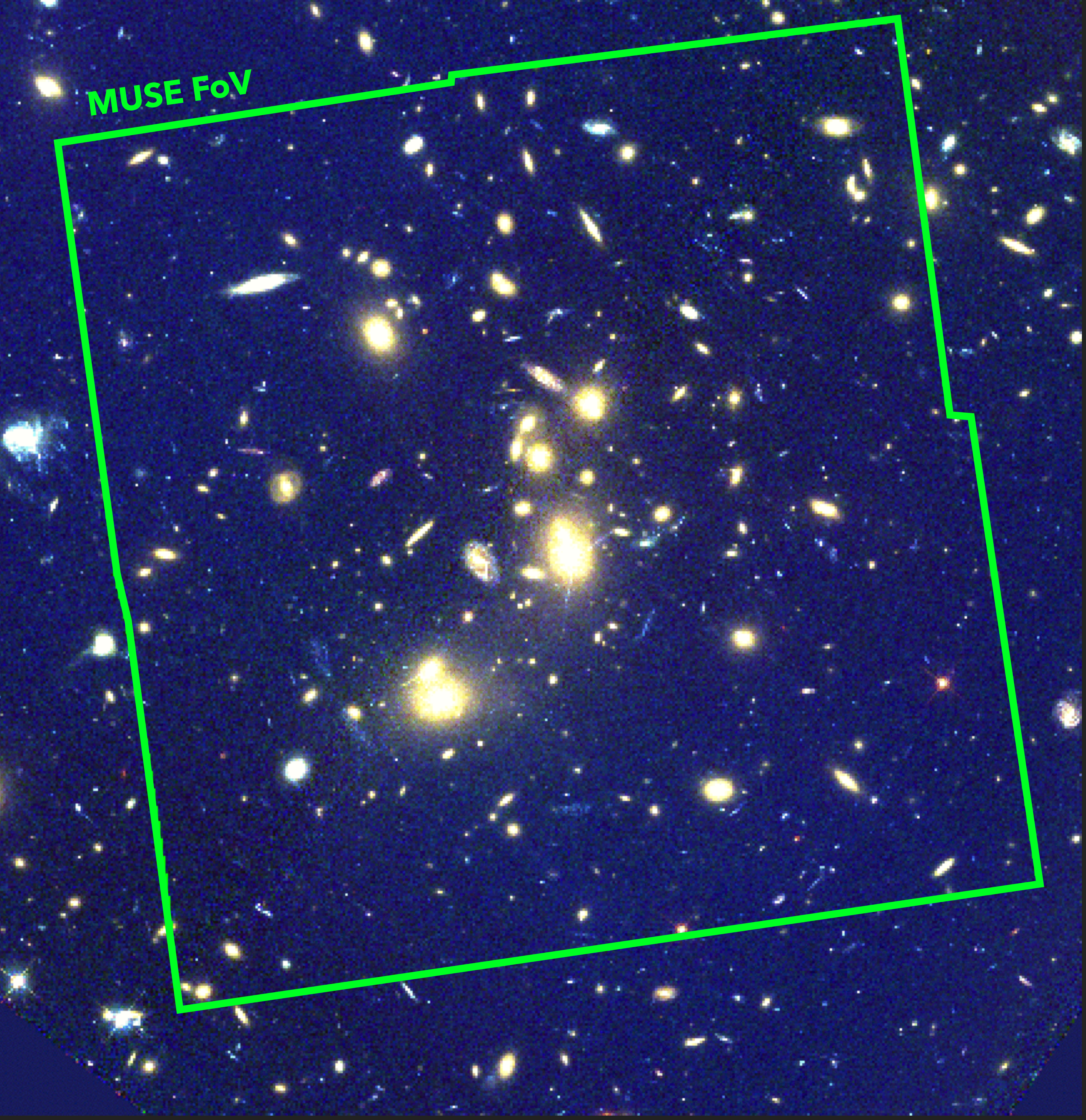
MUSE OBSERVATIONS

- 7 MUSE pointings in total as part of the GTO
- **25 hours of exposure** (~18h for A2744)
- ~16 000 Mpc^3 explored
- **152 LAEs selection with 2.9 < z < 6.7**



Majority of our LAEs are found behind A2744 (see **G. Mahler et al. 2018)**

- 2x2 MUSE mosaic: larger area covered
- Observations extend further away from highly magnified regions
- Small over density at z = 4 ?

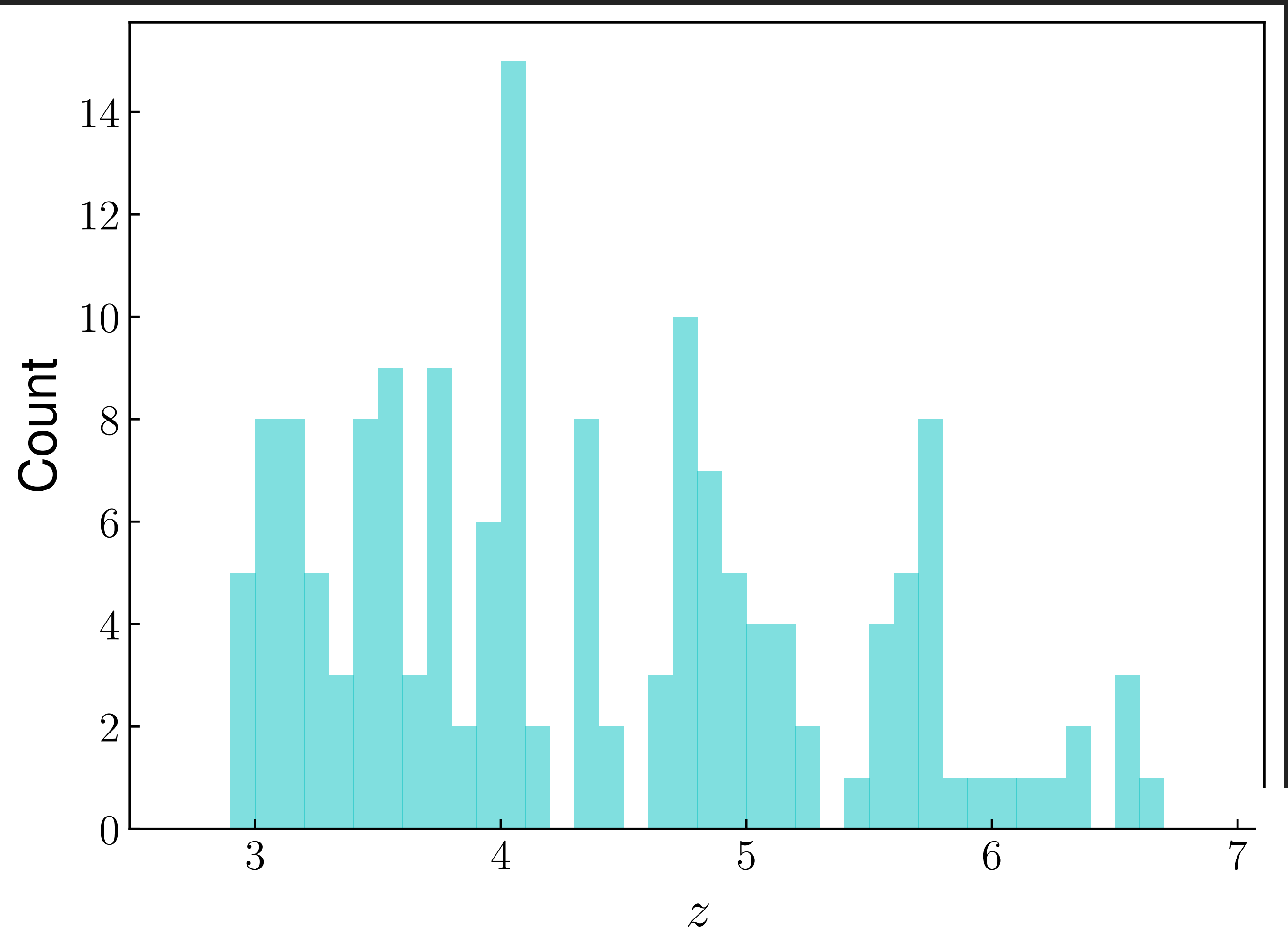


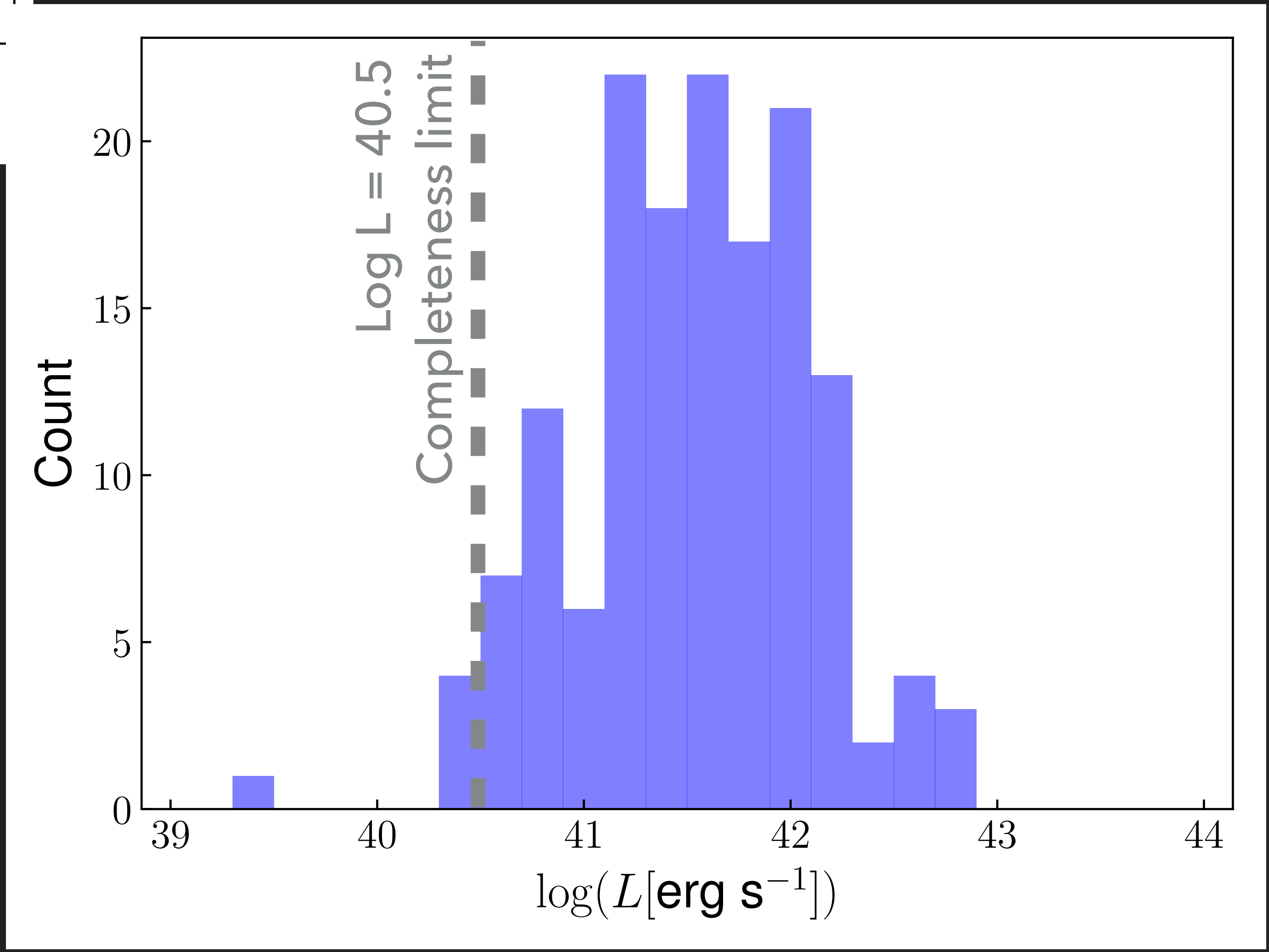
Amplification map overlaid over HFF observations of A2744

Mass model of **Mahler+2018**

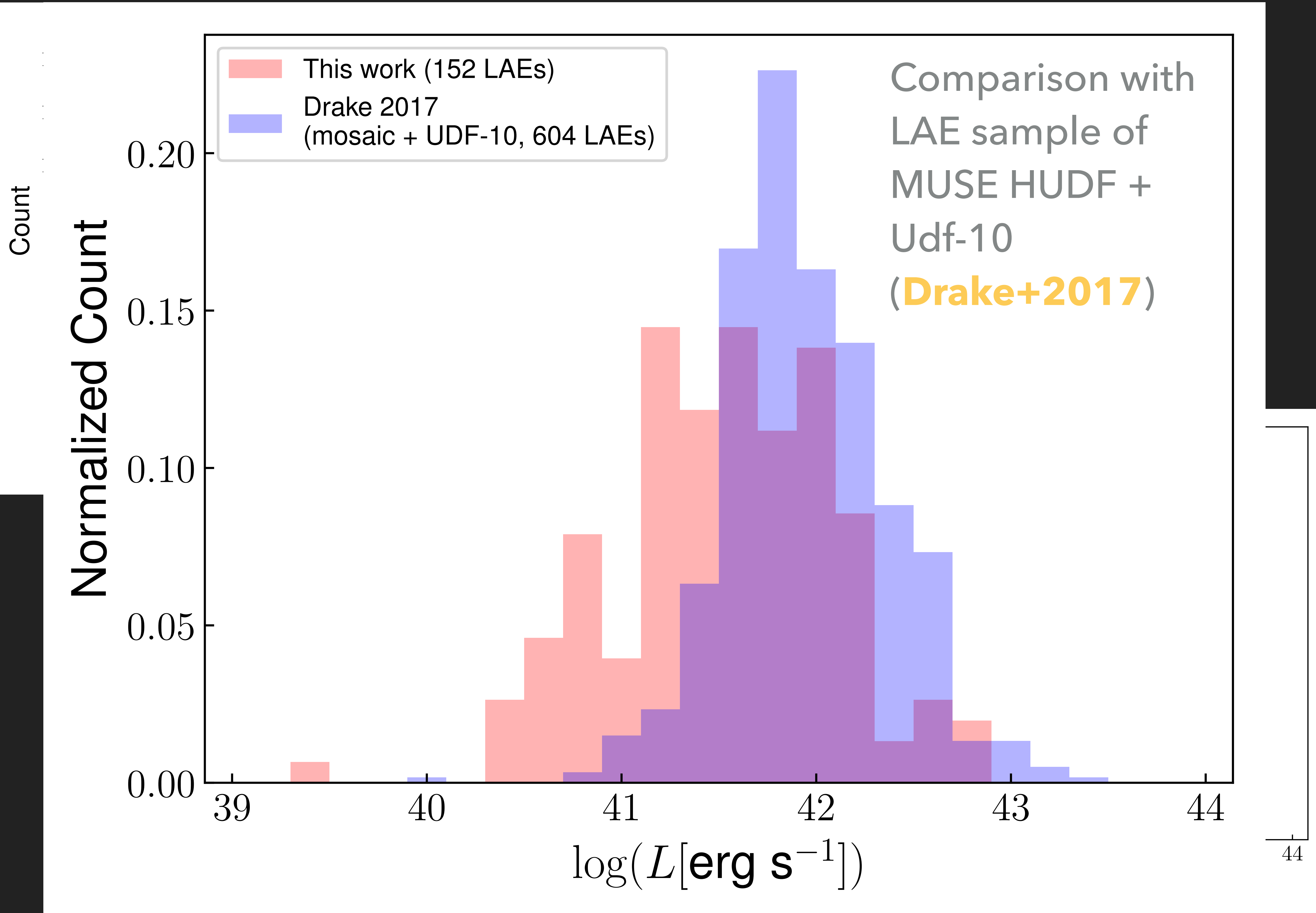
Mass models improved by MUSE observations for 3 other clusters

LAE LENSED SAMPLE





LAE LENSED SAMPLE

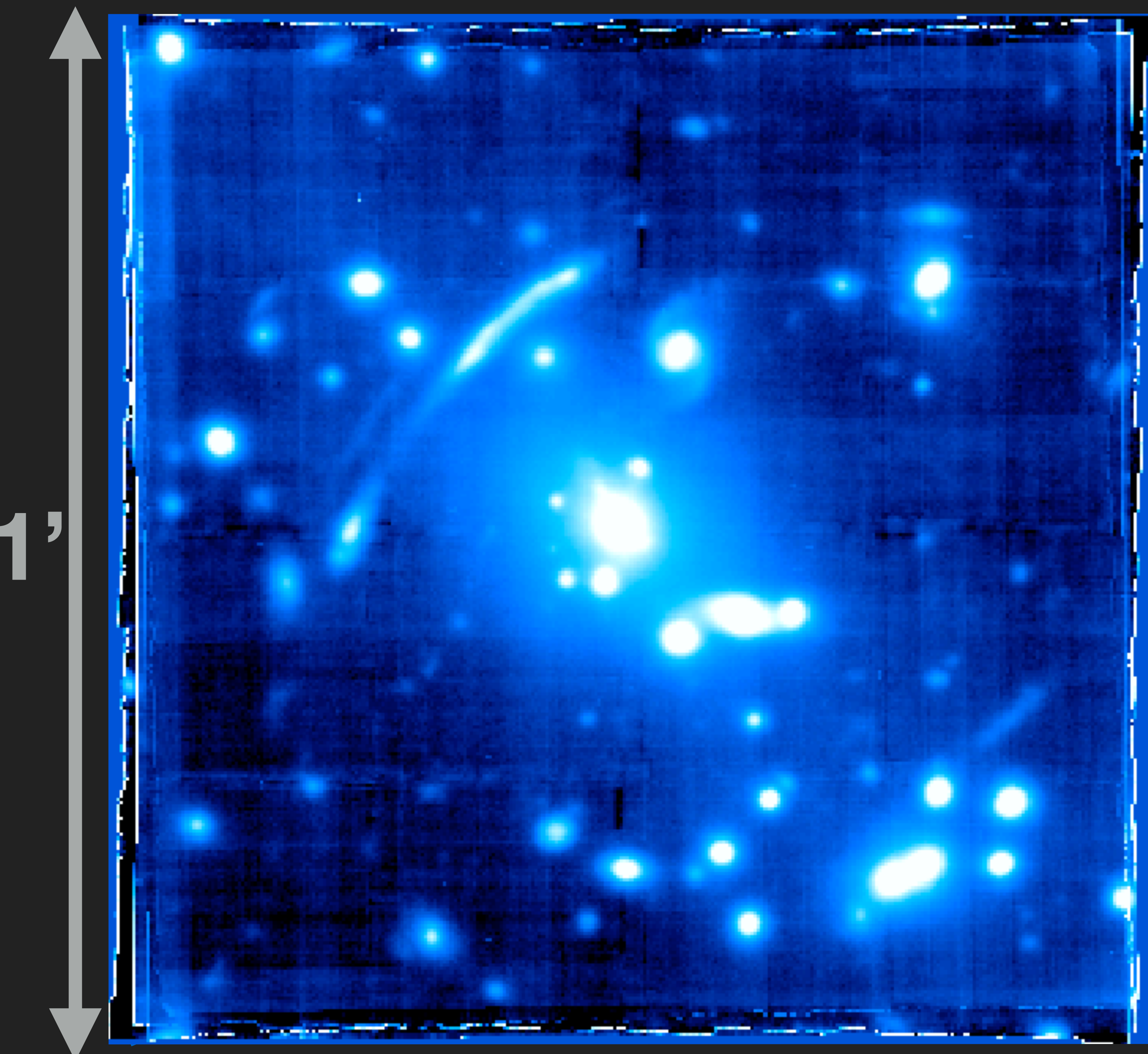


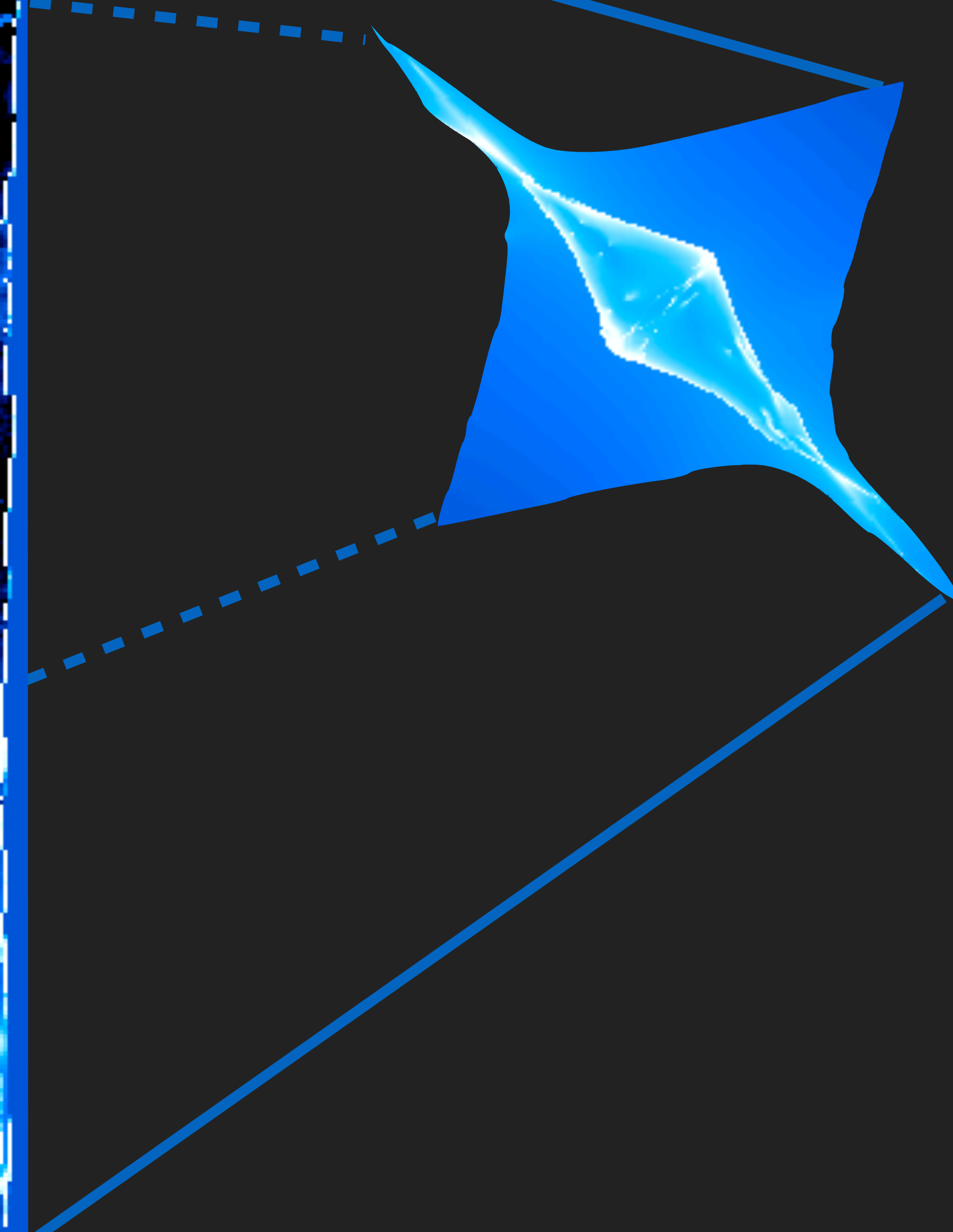
Comparison with LAE sample of MUSE HUDF + Udf-10 (**Drake+2017**)

EFFECTIVE VOLUME IN LENSING CLUSTERS

All lensing computations are done with Lenstool
(Kneib+1996, Jullo+2007, Jullo & Kneib 2009)

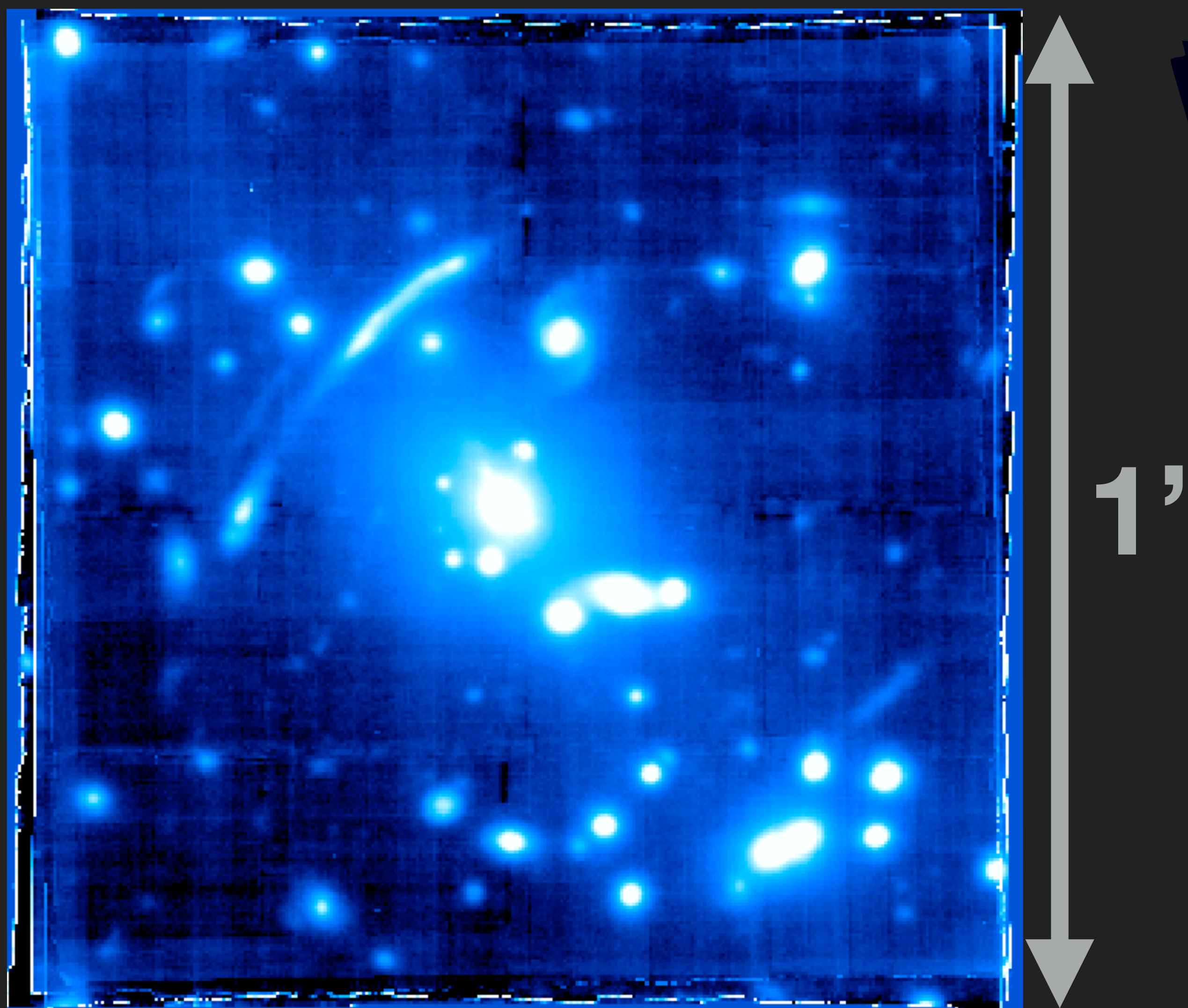
Source plane projection of the FoV **combined with amplification map** at z = 3.5



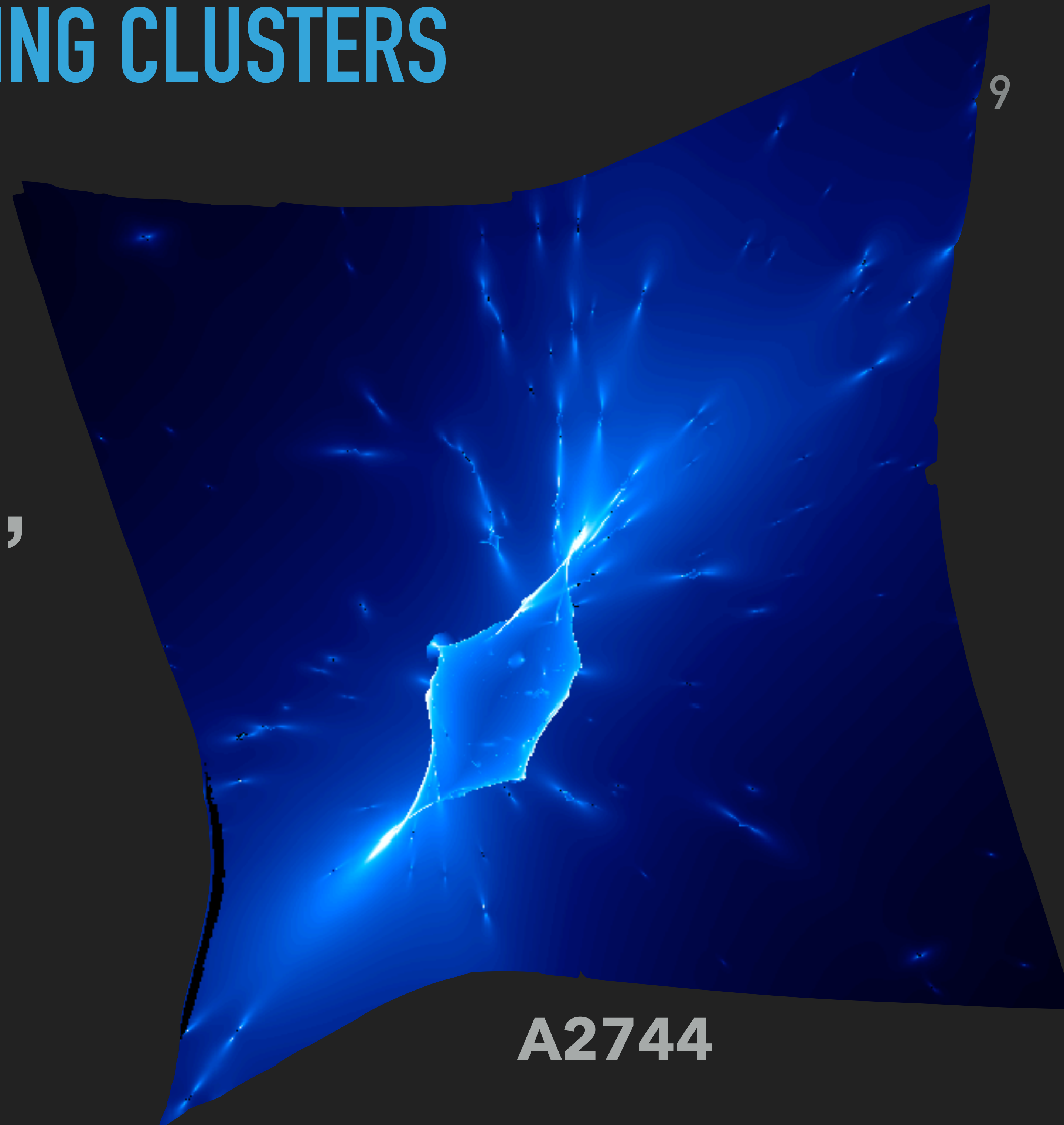


A2667 MUSE white light image

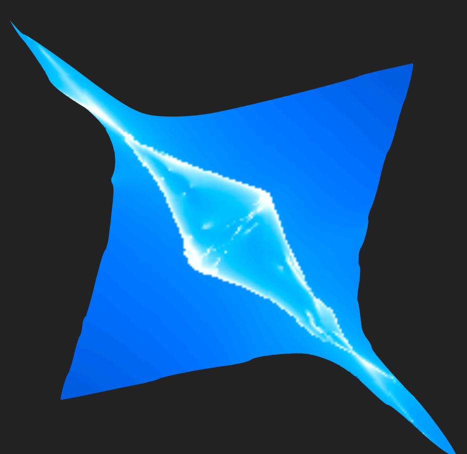
EFFECTIVE VOLUME IN LENSING CLUSTERS



A2667 MUSE white light image



A2744



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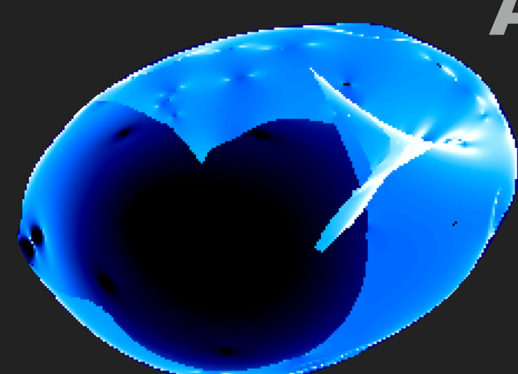
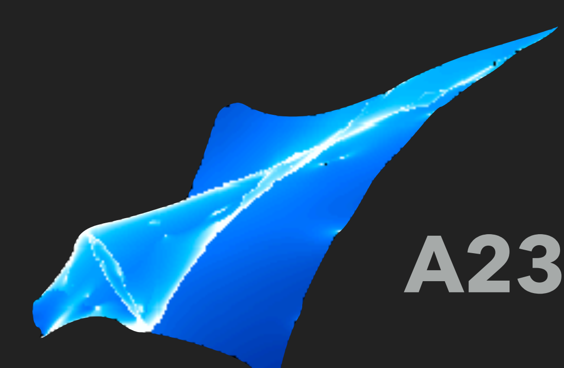
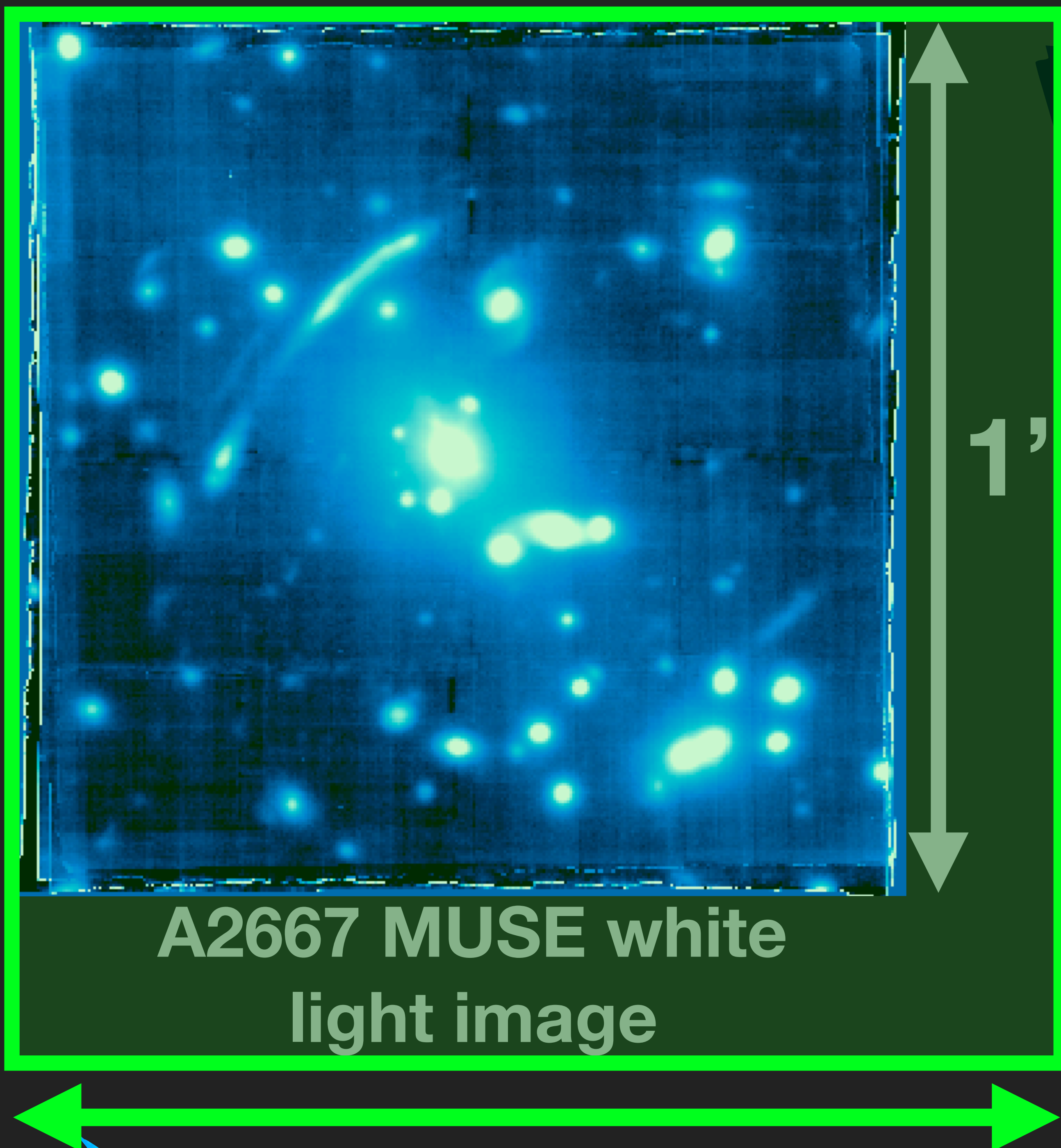


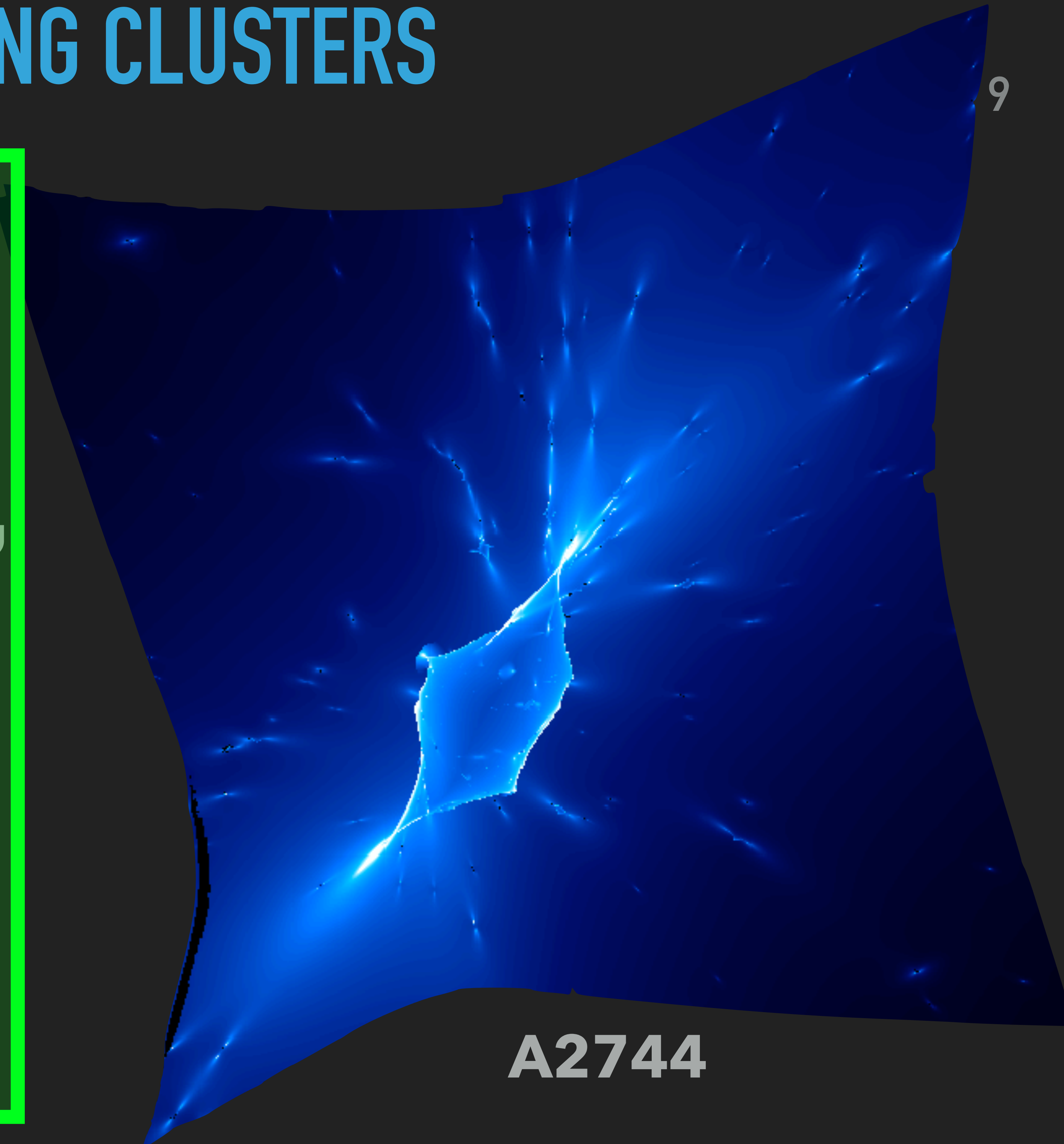
A1689



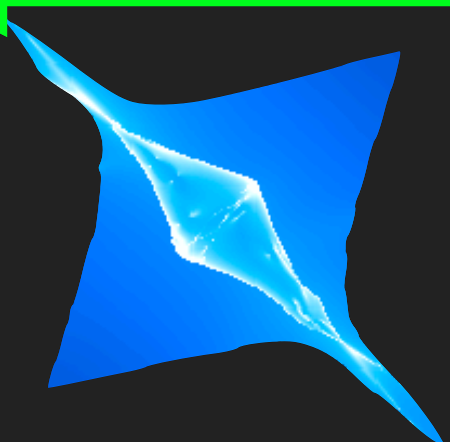
A2390

EFFECTIVE VOLUME IN LENSING CLUSTERS





A2744



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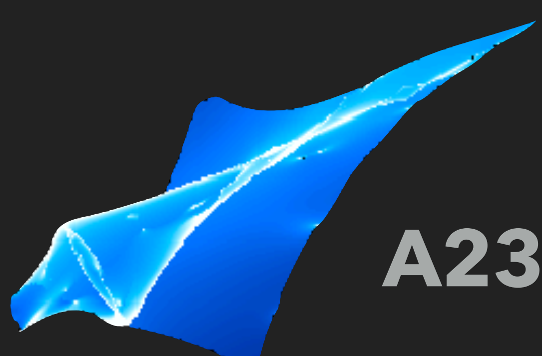


A2390

HOW TO COMPUTE THE LAE LF

The Lf computation is about volume computation, but …

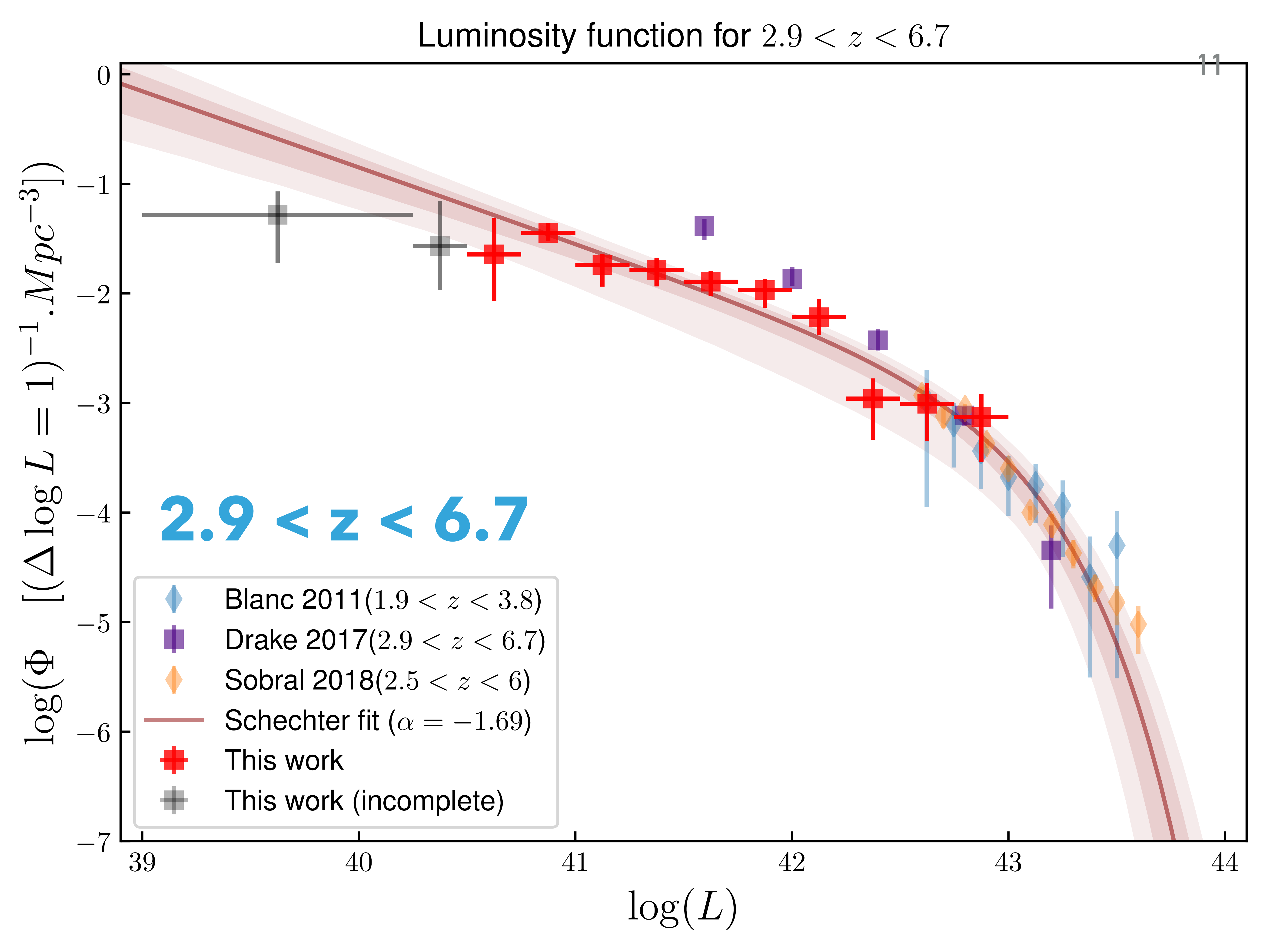
- Necessity to work in the **source plane** (CPU time consuming)
- Strong **variations of volume** depending on luminosity/amplification regime considered
    - low luminosity LAEs can only be detected in the highly magnified regions
- Effect of **sky lines** on detectability of sources within the cubes
- Large variety of **LAE surface brightness profiles, shape, amplification …**

Vmax : Volume of the survey where an individual LAE could have been detected

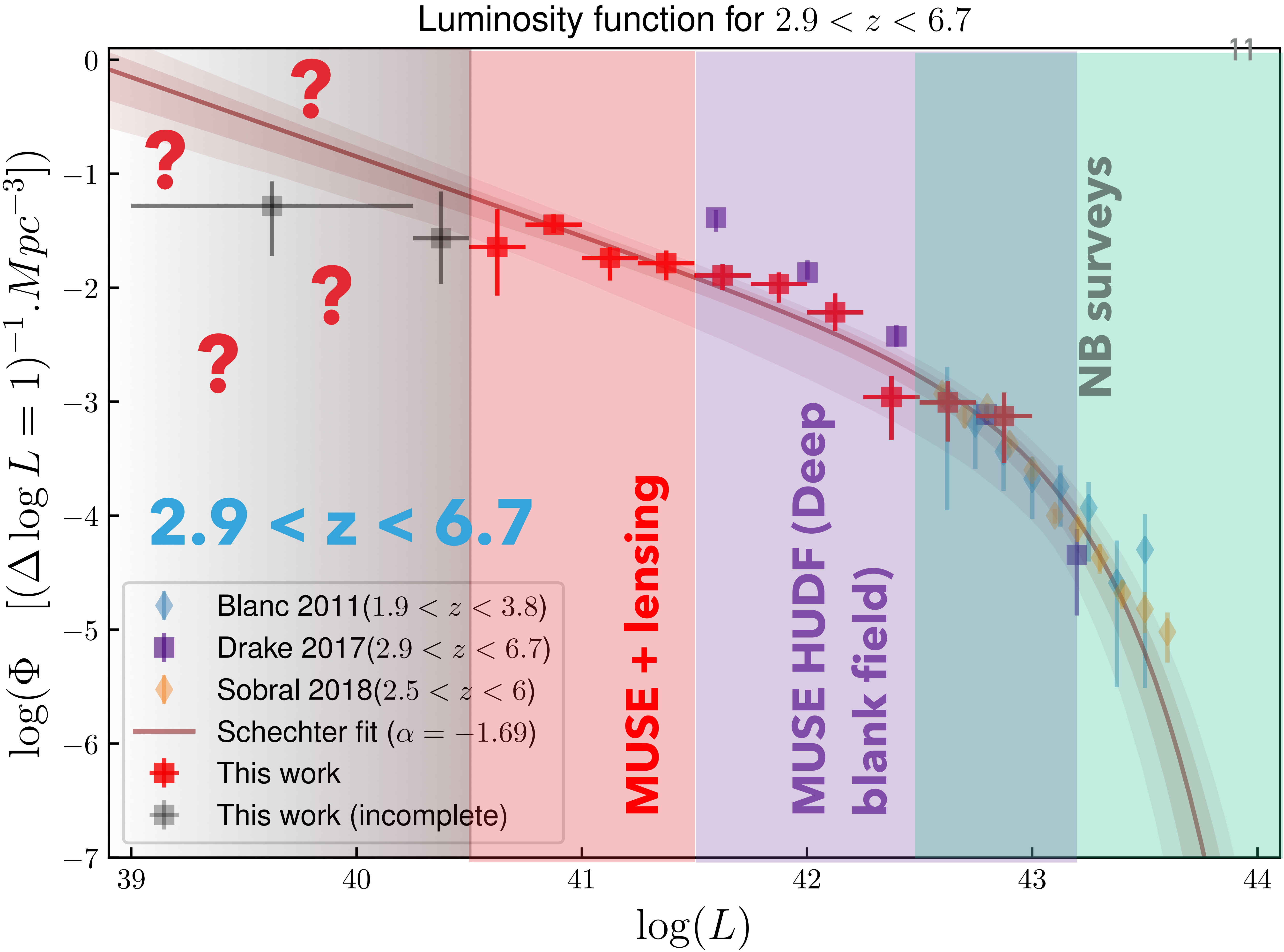
1/Vmax : contribution of 1 LAE to numerical density

Simulation of the detection process of individual LAEs through the 4 cubes of the survey and in the source plane to have **the best completeness determination possible** (see **G. de La Vieuville et al. 2019**)

Heavy MC process when building the LFs



Luminosity function for $2.9 < z < 6.7$
11
2.9 < z < 6.7
Blanc 2011($1.9 < z < 3.8$)
Drake 2017($2.9 < z < 6.7$)
Sobral 2018($2.5 < z < 6$)
Schechter fit ($\alpha = -1.69$)
This work
This work (incomplete)
$\log(\Phi \quad [(\Delta \log L = 1)^{-1}.Mpc^{-3}])$
$\log(L)$
0
−1
−2
−3
−4
−5
−6
−7
39
40
41
42
43
44


Luminosity function for $2.9 < z < 6.7$
$\log(\Phi \quad [(\Delta \log L = 1)^{-1}.Mpc^{-3}])$
$\log(L)$
2.9 < z < 6.7
MUSE + lensing
MUSE HUDF (Deep blank field)
NB surveys
Blanc 2011($1.9 < z < 3.8$)
Drake 2017($2.9 < z < 6.7$)
Sobral 2018($2.5 < z < 6$)
Schechter fit ($\alpha = -1.69$)
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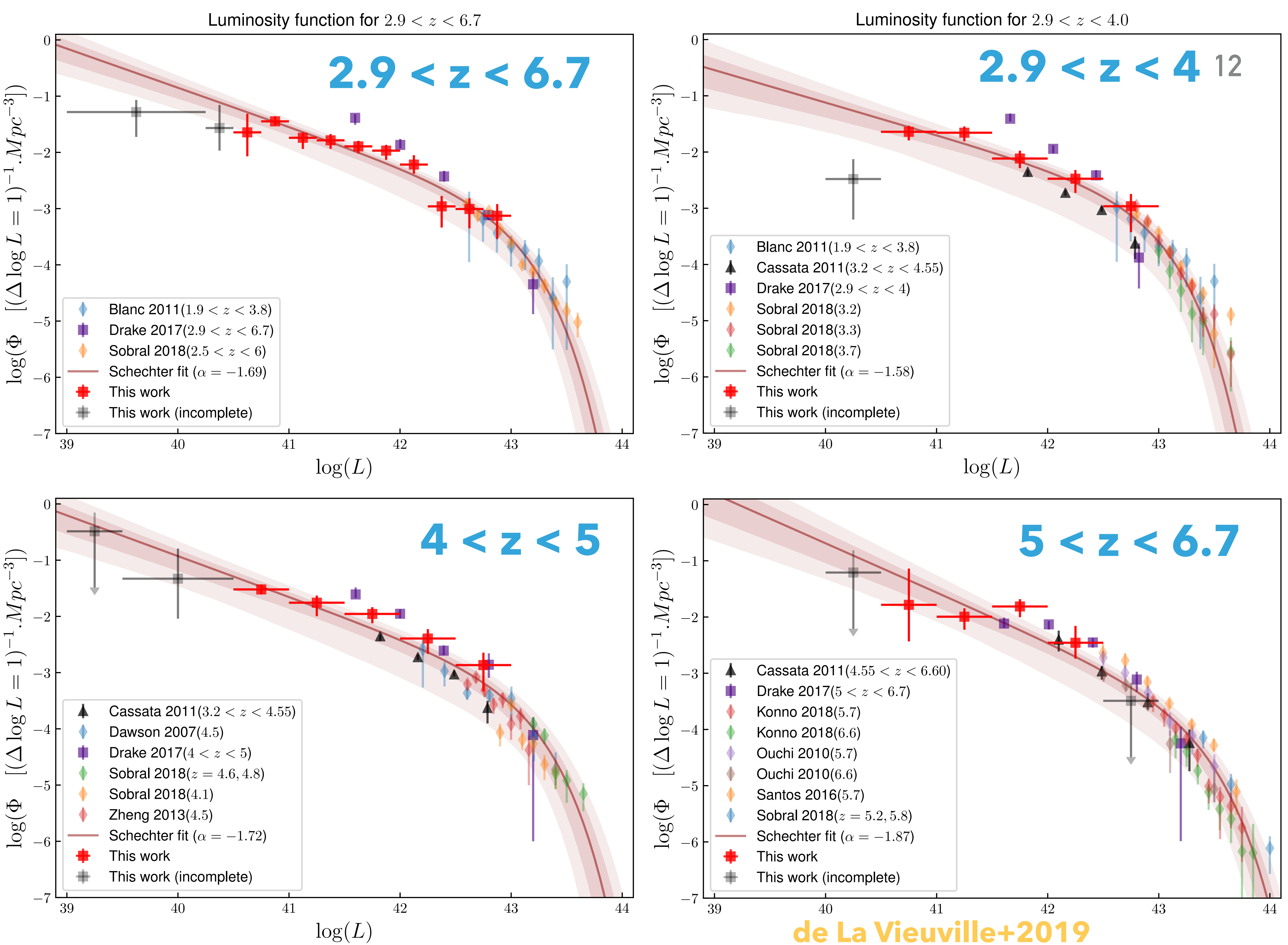
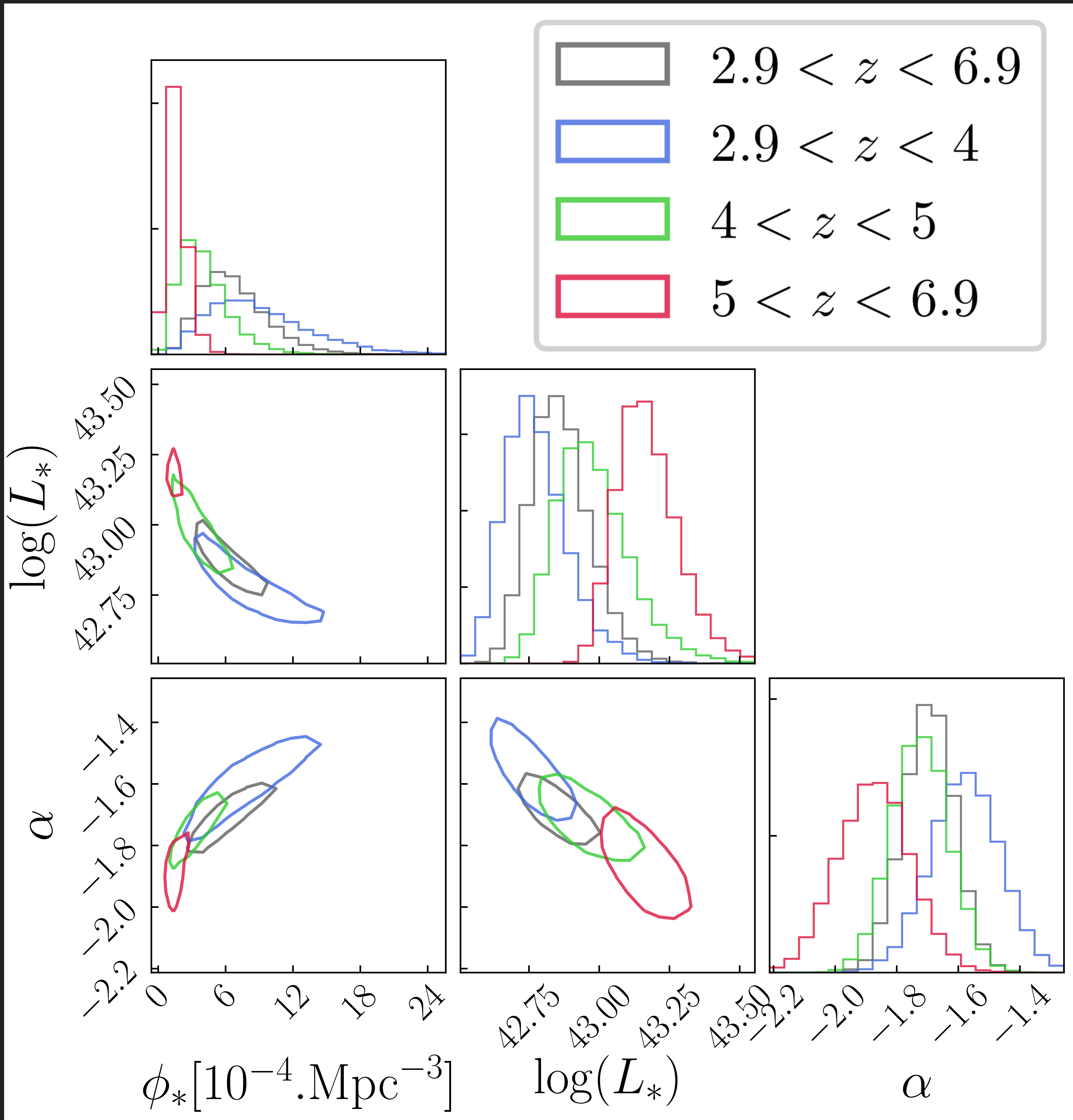

Luminosity function for $2.9 < z < 6.7$
2.9 < z < 6.7
Blanc 2011$(1.9 < z < 3.8)$
Drake 2017$(2.9 < z < 6.7)$
Sobral 2018$(2.5 < z < 6)$
Schechter fit $(\alpha = -1.69)$
This work
This work (incomplete)
Luminosity function for $2.9 < z < 4.0$
2.9 < z < 4
Blanc 2011$(1.9 < z < 3.8)$
Cassata 2011$(3.2 < z < 4.55)$
Drake 2017$(2.9 < z < 4)$
Sobral 2018(3.2)
Sobral 2018(3.3)
Sobral 2018(3.7)
Schechter fit $(\alpha = -1.58)$
This work
This work (incomplete)
4 < z < 5
Cassata 2011$(3.2 < z < 4.55)$
Dawson 2007(4.5)
Drake 2017$(4 < z < 5)$
Sobral 2018$(z = 4.6, 4.8)$
Sobral 2018(4.1)
Zheng 2013(4.5)
Schechter fit $(\alpha = -1.72)$
This work
This work (incomplete)
5 < z < 6.7
Cassata 2011$(4.55 < z < 6.60)$
Drake 2017$(5 < z < 6.7)$
Konno 2018(5.7)
Konno 2018(6.6)
Ouchi 2010(5.7)
Ouchi 2010(6.6)
Santos 2016(5.7)
Sobral 2018$(z = 5.2, 5.8)$
Schechter fit $(\alpha = -1.87)$
This work
This work (incomplete)
$\log(\Phi \quad [(\Delta \log L = 1)^{-1}.Mpc^{-3}])$
$\log(L)$
de La Vieuville+2019

EVOLUTION OF THE LAE LF WITH REDSHIFT



Schechter fit: **combination wiht NB data** to constrain the bright end

Slight steepening of the faint end slope with increasing redshift :

$\alpha = -1.58 \pm 0.08$

at 2.9 < z < 4.0

$\alpha = -1.87 \pm 0.12$

at 5.0 < z < 6.7

increase in the relative proportion of low luminosity LAEs at higher redshift

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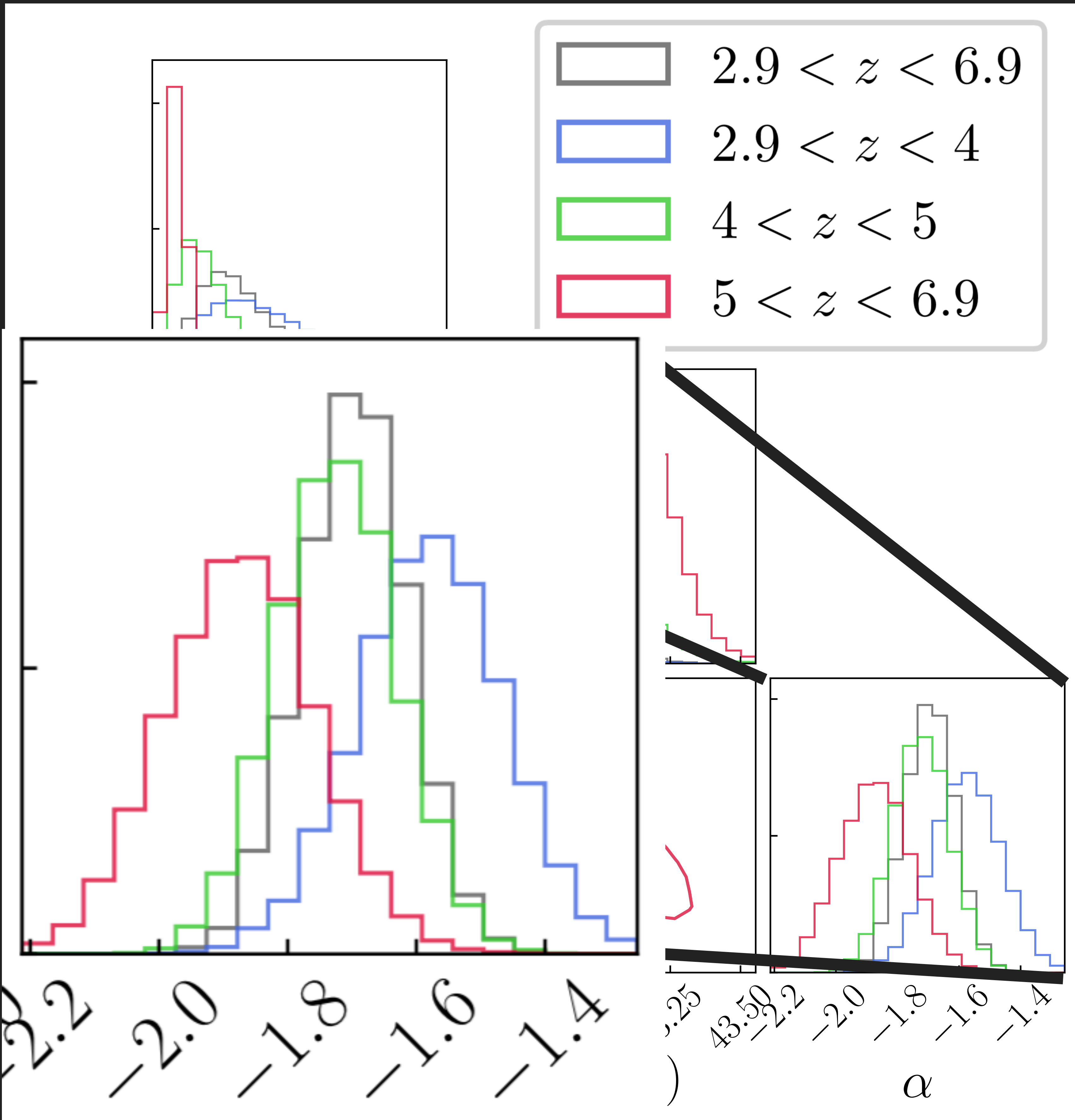

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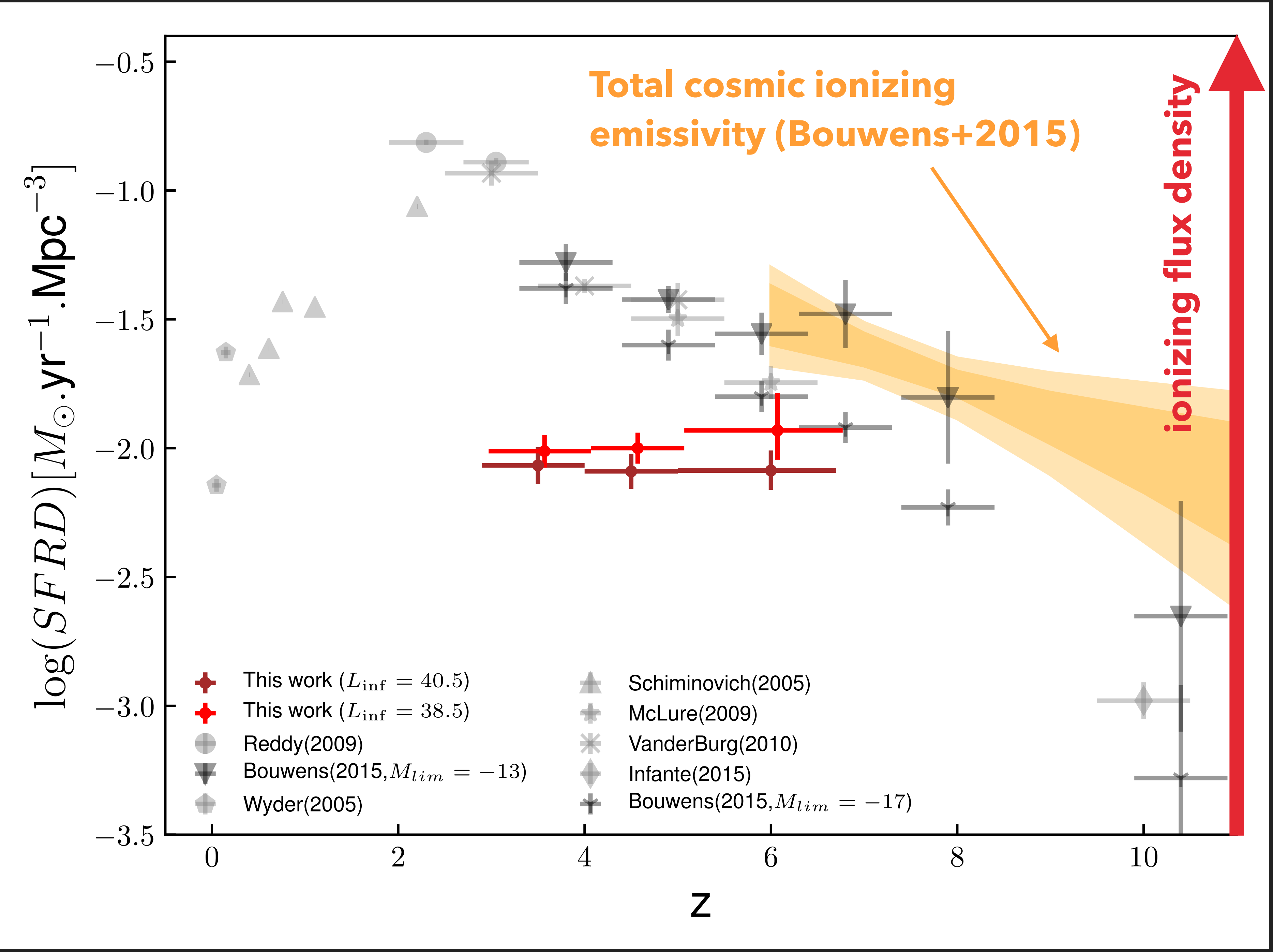
EVOLUTION OF SFRD



SFRD ~ Ionizing flux density

SFRD computed from **integration of the LFs**

- Down to Log L = 40.5 (Completeness limit)
- Down to Log L = 38.5 (2 dex extrapolation)

No correction for escape fraction of Lya photons

Significant contribution of the LAE population to reionization at z ~ 6

Similar level of contribution as the LBG (UV selected population)

What about the intersection of the LAE and LBG populations ?

LAE AND LBG POPULATION IN THE SAME VOLUME

See work of **Maseda+2018, Arrabal Haro+2018**

Comparison of the two populations **behind A2744**:

- Large and deep MUSE coverage
- Large and deep photometric coverage as part of HFF

LAE selection : MUSE LAE catalog from **Mahler+2018**

LBG selection : Astrodeep collaboration photometry catalog (**Merlin+2016, Castellano+2016**)

- **SED fitting with HyperZ** (**Bolzonella+2000**)
  - Starburst 99 (Leitherer+1999), synthetic SEDs from Bruzual&Charlot+2003, empirical SEDs from Coleman+1980, starburst SEDs from Kinney+1996
- **LBG if $P(z > 2.9) > 60\%$**

Comparison within the MUSE FoV in the range $2.9 < z < 6.9$

Multiple object removal ensuring that not LAE with no LBG counterpart was on top of brigth foreground galaxy

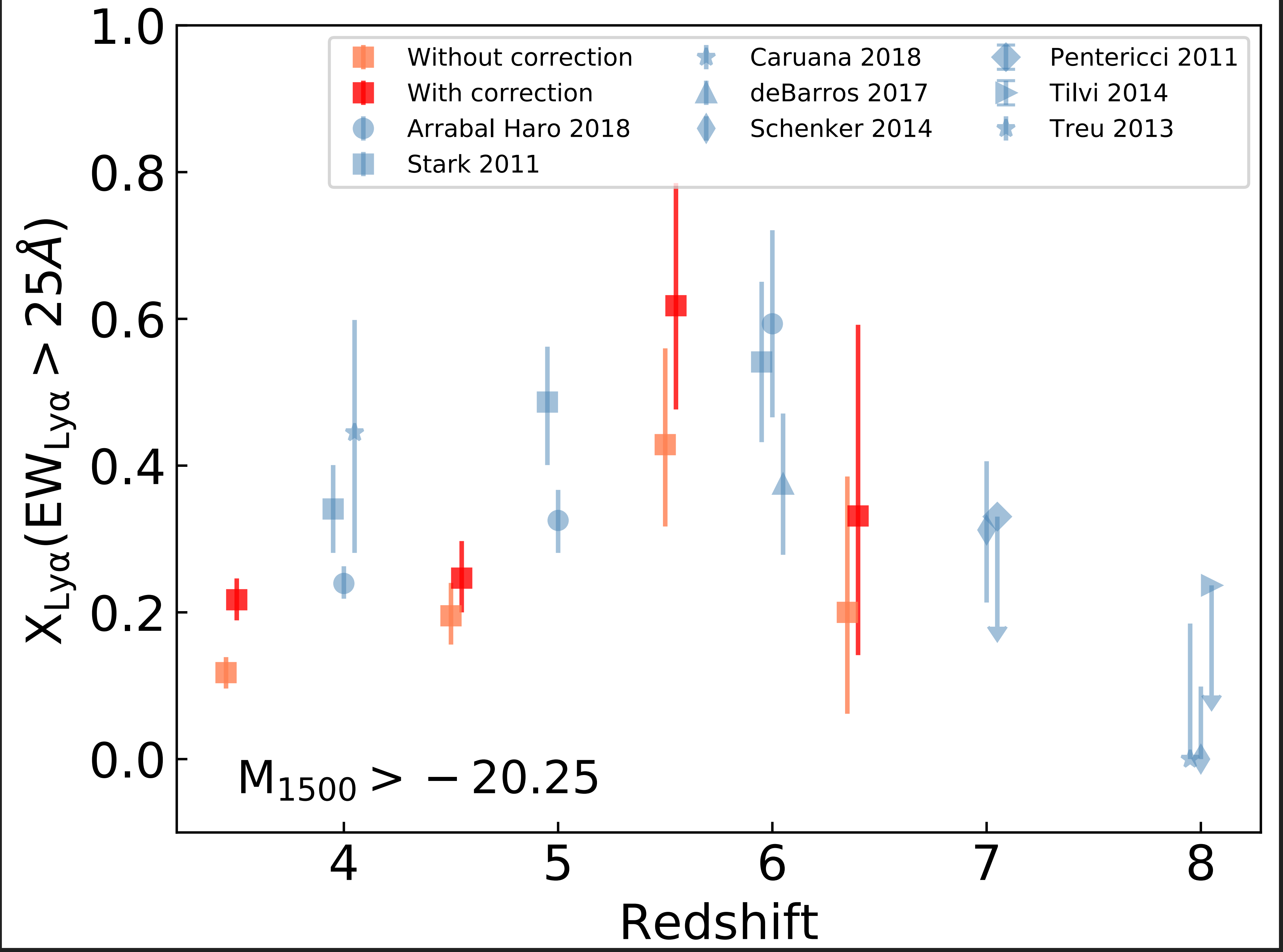
Using mass modesl of **Mahler+2018** for all lensing corrections

LBG with LAE : 92

LBG only : 408

LAE only : 46

Evolution of the three sample with Lya luminosity / absolute magnitude / redshift ?



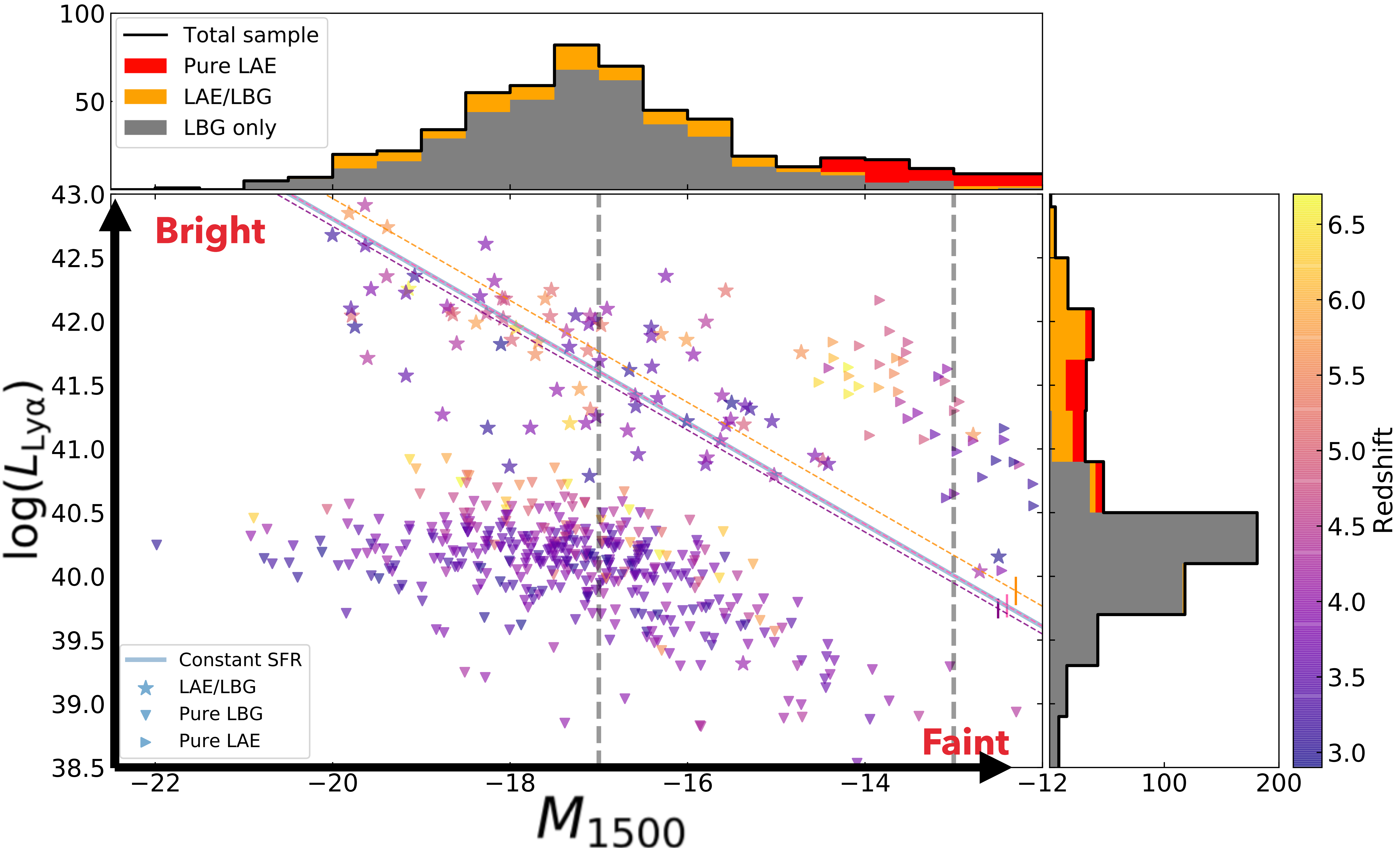
Fraction of LAEs with EW > 25 among LBGs with M1500 > -20.25

Correction for completeness of the LAE selection (work in progress)

Observed drop at z ~ 6 due to an increase of HI content

Most coherent with the results of Arrabal Haro+2018

EVOLUTION WITH LUMINOSITY/MAGNITUDE



CONCLUSIONS

de La Vieuville+2019

- **New and complex method to study the LAE LF from MUSE data**
- **Exploring new luminosity domain down to Log L = 40.5**
- **Solid constraints on the shape of the LF** at very low luminosity
- Steepening of faint end slope
- LAE provide a significant amount of ionizing flux at z ~ 6

de La Vieuville+ in prep.

- Observed decrease in X(LAE) for z > 6
- The LAE selection is more effective to select intrinsically UV fainter galaxies (as found in **Maseda+2018**)
- **Up to M_{1500} = -15** the LBG selection seems to provide a good representation of the total SFGs population