# Resolved study of strongly lensed high-redshift galaxies using JWST and HST

APL 1

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Under supervision of

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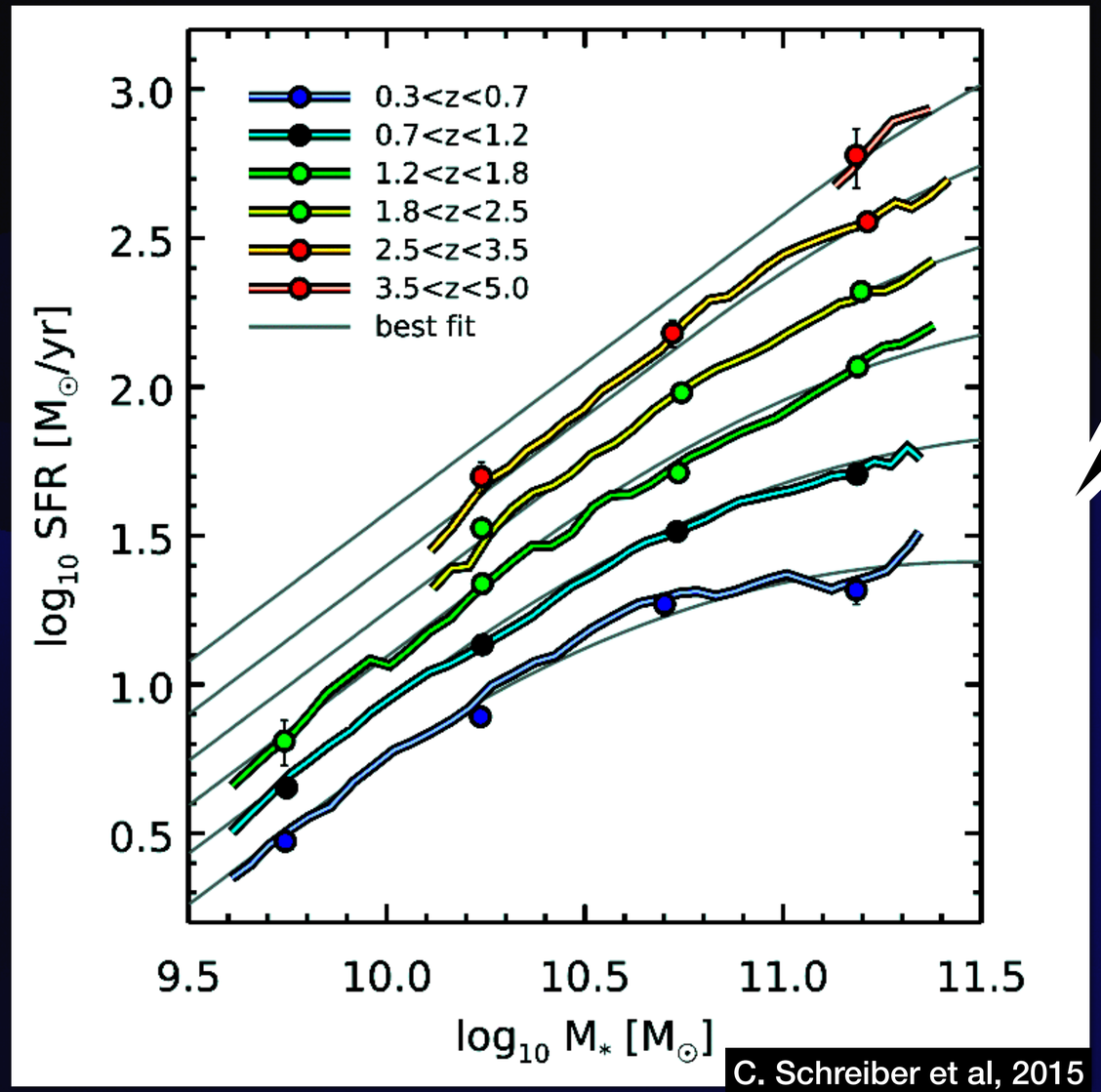
# SFMS?
## (Star Formation Main Sequence)

STAR FORMATION RATE ⟷ STELLAR MASS

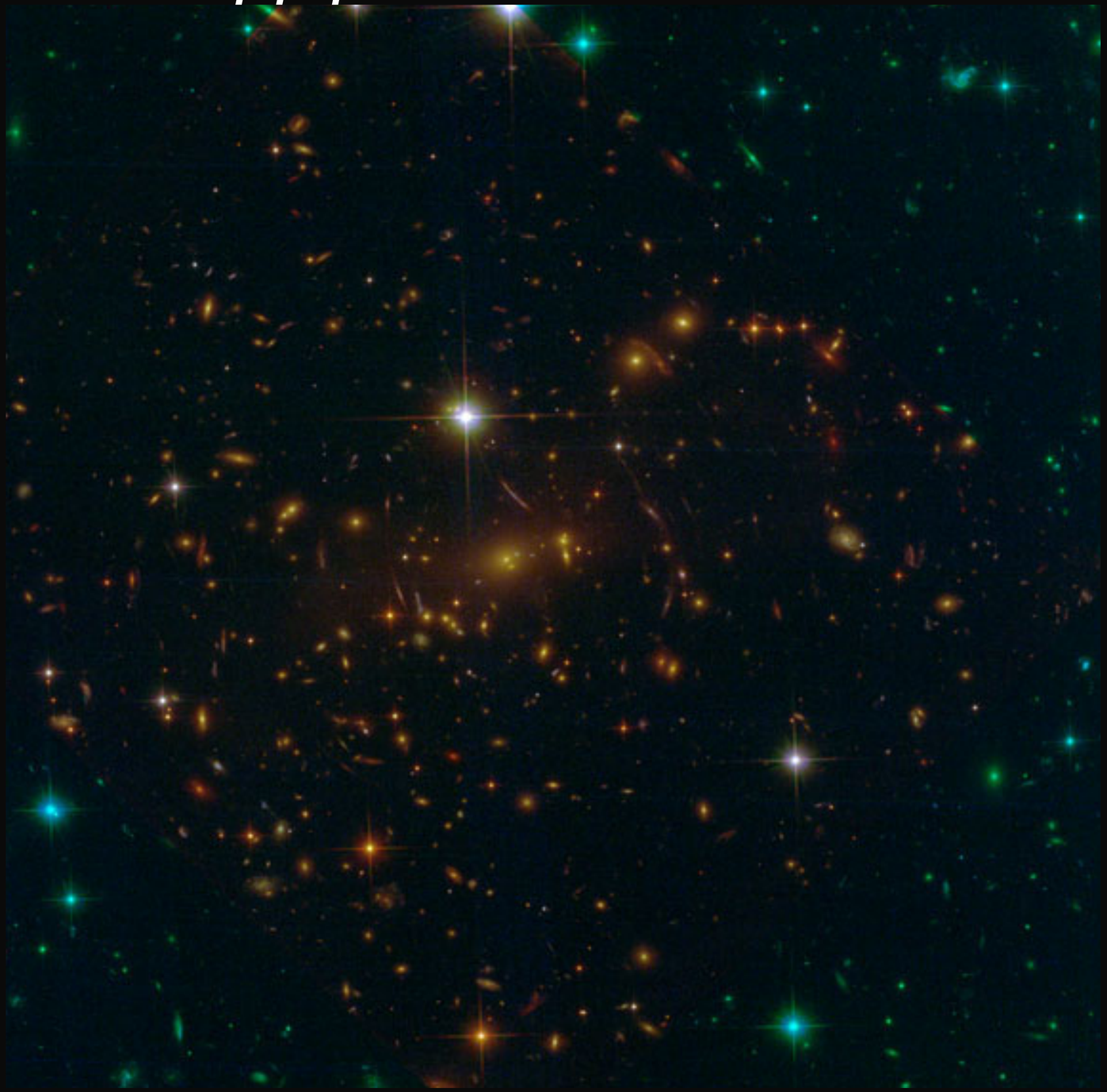



C. Schreiber et al, 2015

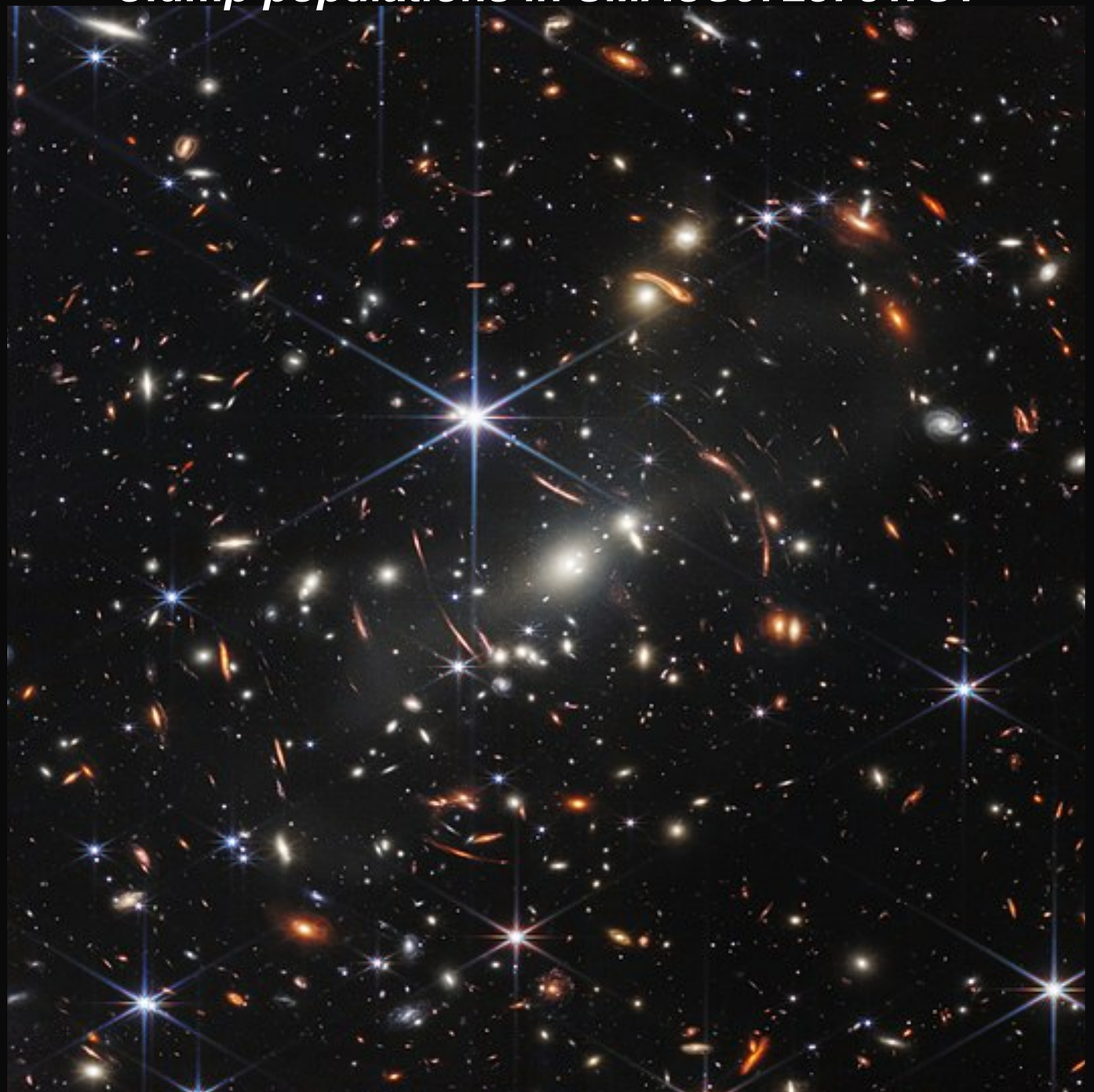
At higher redshift, we see the SFR is higher for the SAME stellar mass!!

# REDSHIFT EVOLUTION OF THE MAIN SEQUENCE

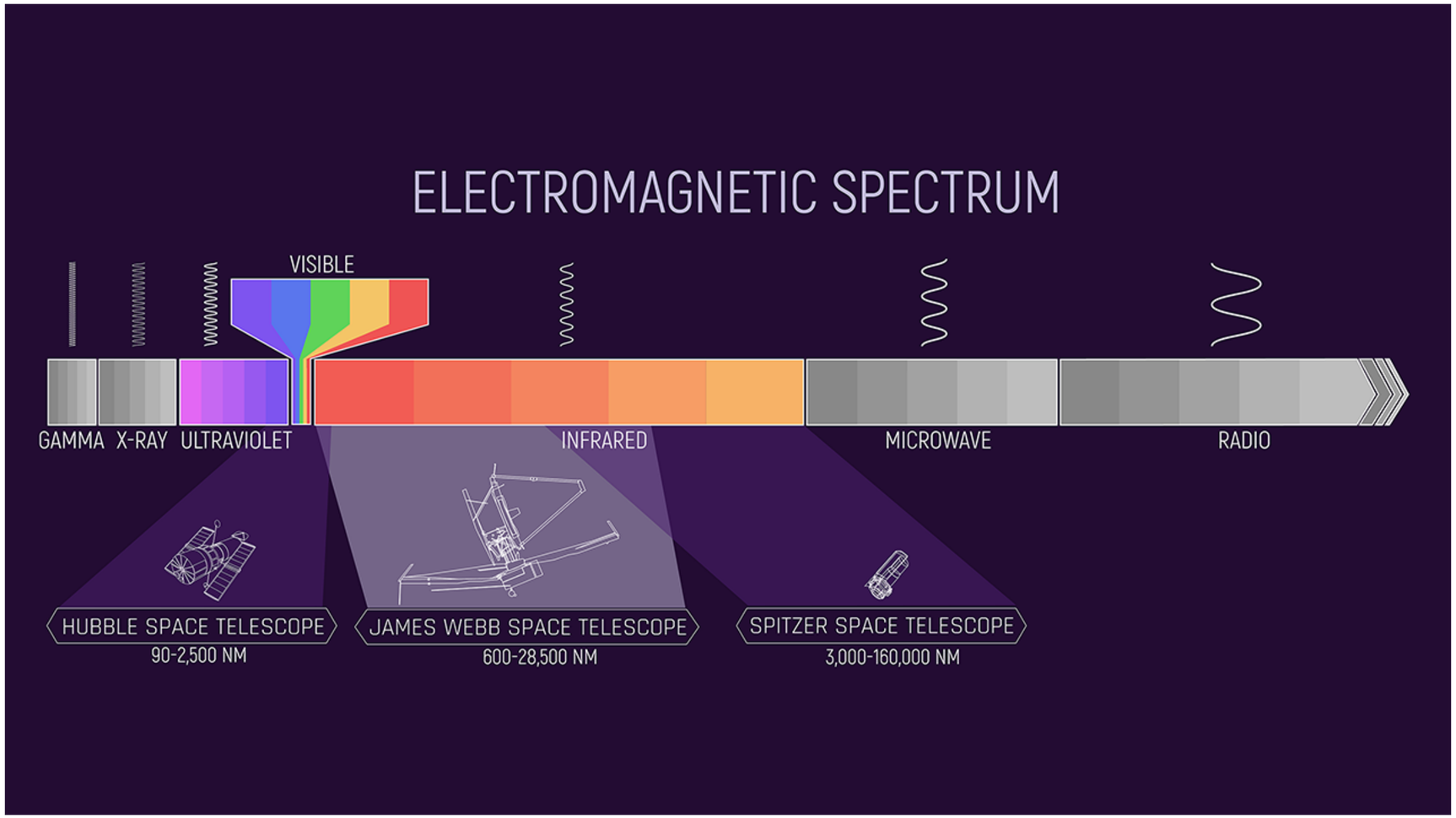
# *Clump populations in SMACS0723: HST*



# *Clump populations in SMACS0723: JWST*



# HST Vs JWST


ELECTROMAGNETIC SPECTRUM
VISIBLE
GAMMA
X-RAY
ULTRAVIOLET
INFRARED
MICROWAVE
RADIO
HUBBLE SPACE TELESCOPE
90-2,500 NM
JAMES WEBB SPACE TELESCOPE
600-28,500 NM
SPITZER SPACE TELESCOPE
3,000-160,000 NM

# PHOTOMETRY

*"Photometry is a technique used in astronomy that is concerned with measuring the flux or intensity of light radiated by astronomical objects."*

Multi-band photometry over 13 wavelengths

| Filter | Exp Time [s] | Det Lim AB mag | ZP corr AB mag | $E(B-V)_{gal}$ | PSF FWHM [arcsec] |
|---|---|---|---|---|---|
| HST F435W | 2,233 | 27 | | 0.776 | 0.120 |
| HST F606W | 2,289 | 27.5 | | 0.502 | 0.120 |
| HST F814W | 2,529 | 27.2 | | 0.315 | 0.120 |
| JWST F090W | 7,537 | 29.1 | -0.174 | 0.265 | 0.050 |
| HST F105W | 6,058 | 26.7 | | 0.203 | 0.160 |
| HST F125W | 3,248 | 26.0 | | 0.151 | 0.180 |
| HST F140W | 5,233 | 26.2 | | 0.125 | 0.190 |
| JWST F150W | 7,537 | 29.3 | -0.047 | 0.112 | 0.060 |
| HST F160W | 4,523 | 26.4 | | 0.102 | 0.190 |
| JWST F200W | 7,537 | 29.1 | -0.114 | 0.074 | 0.068 |
| JWST F277W | 7,537 | 29.1 | +0.223 | 0.048 | 0.110 |
| JWST F356W | 7,537 | 29.2 | +0.163 | 0.034 | 0.130 |
| JWST F444W | 7,537 | 29.0 | +0.162 | 0.027 | 0.140 |

*Claeyssens et al.,2022*

# GRAVITATIONAL LENSING??
# MASS BENDS LIGHT!

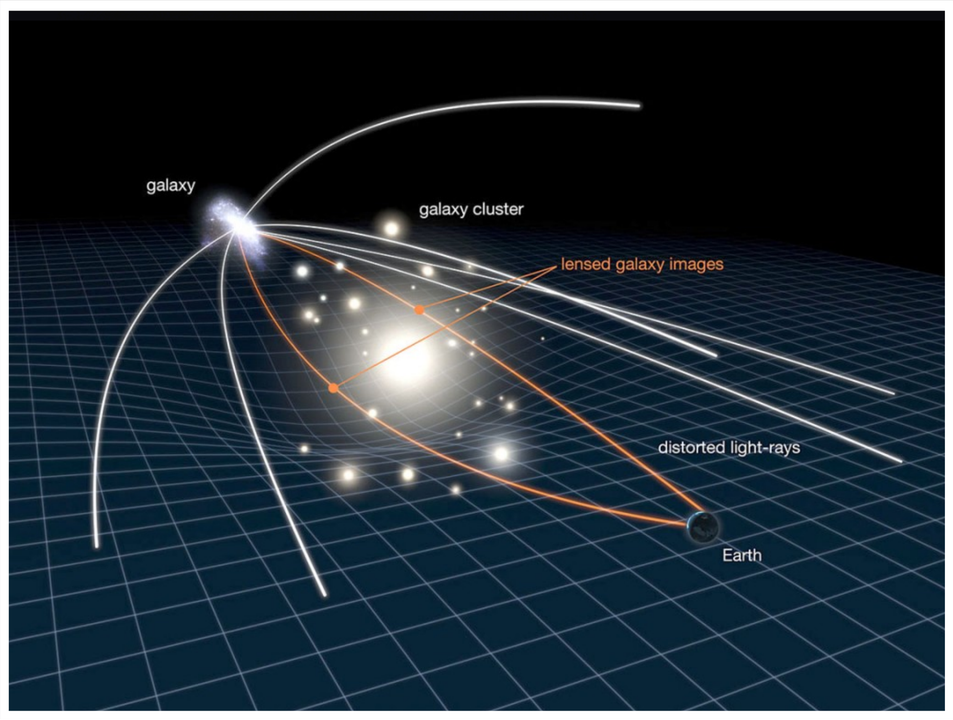



Image: NASA/ESA

Image: https://www.youtube.com/@NASAWebbTelescope

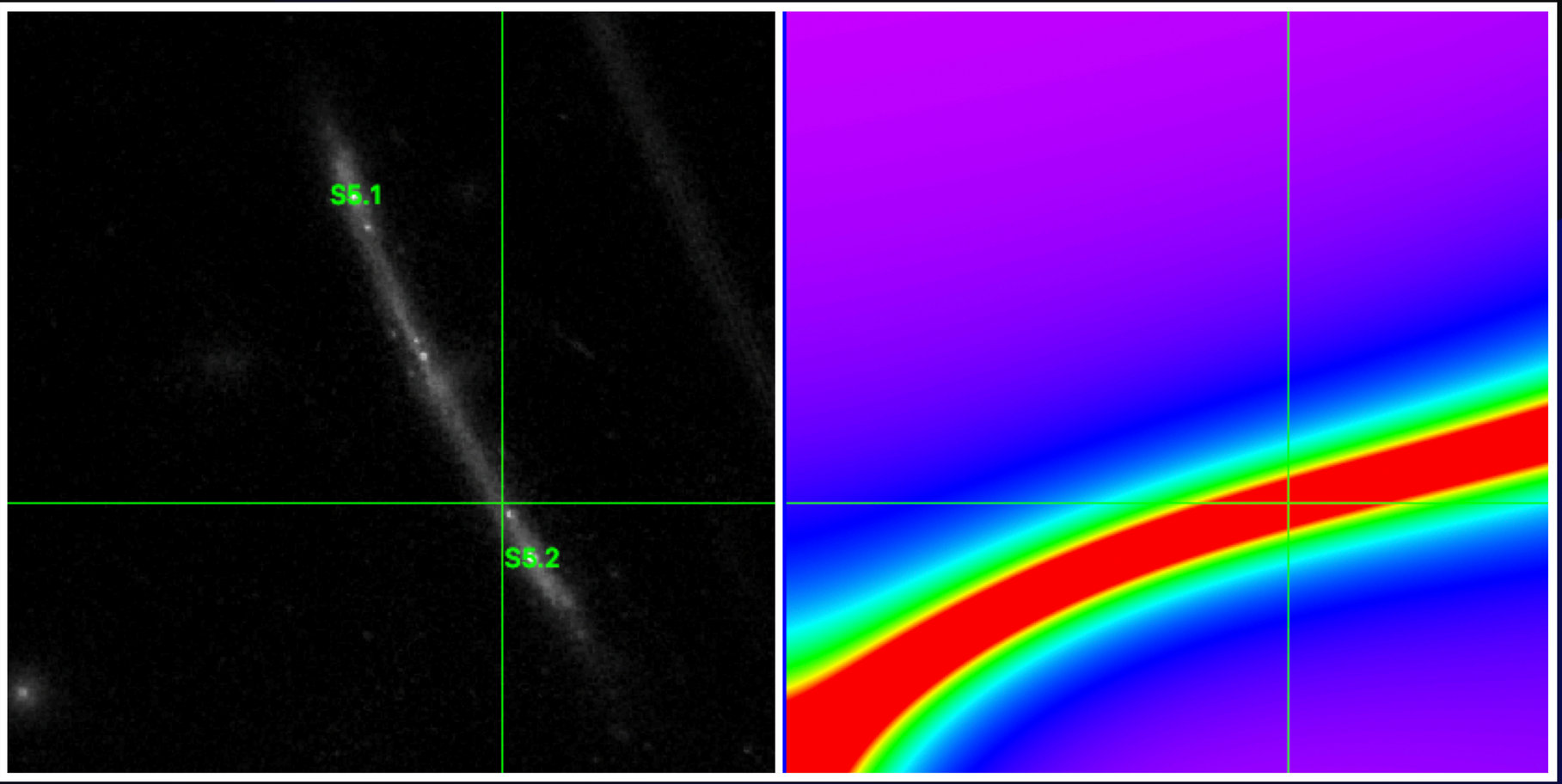
Distorts images! Creates multiple images ! Amplifies light and also spatially amplifies the image!

18 lensed galaxies at redshifts 1 to 8 within the lensing cluster field SMACS0723 were selected with a robust redshift measurement and/or a high lensing magnification

# Image inversion beyond critical line

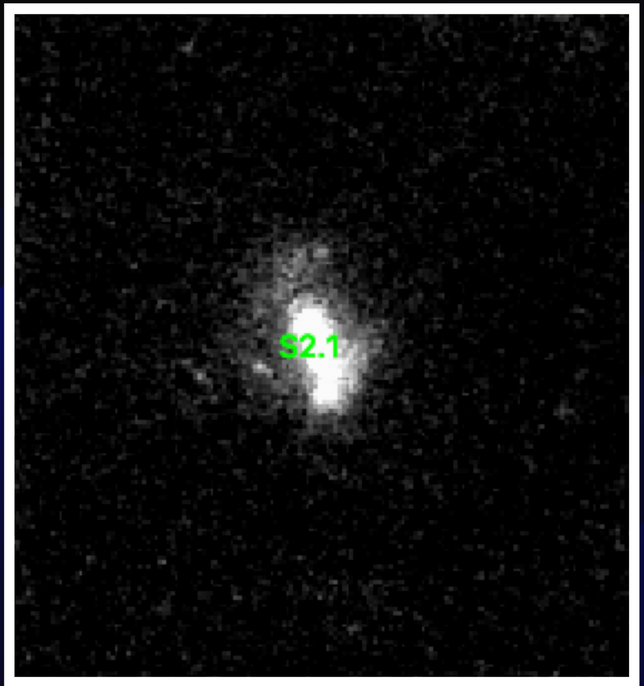
**Amplification values**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| S5.1 | 07:23:17.73 | -73:27:06.77 | 1.425 | MUSE - [OII] | 7.1 ± 0.2 | (Mahler et al. 2022) | 10 |
| S5.2 | 07:23:17.36 | -73:27:10.01 | 1.425 | MUSE - [OII] | 35.0 ± 3.2 | (Mahler et al. 2022) | 10 |

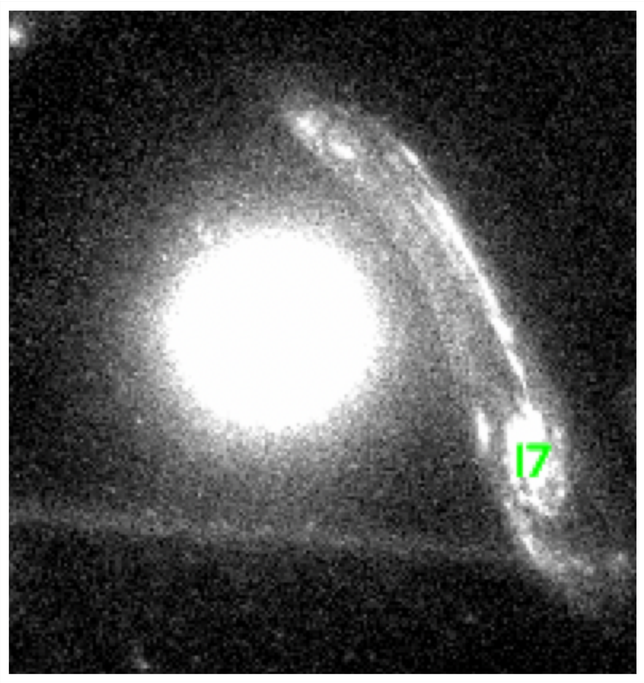


# METHODS :

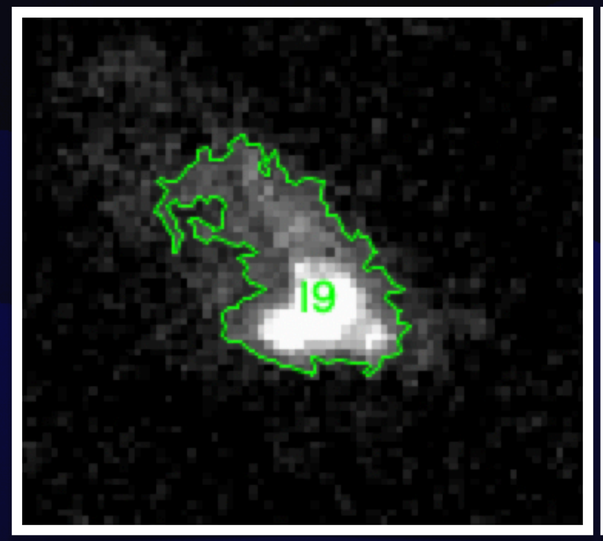
## IMAGES :



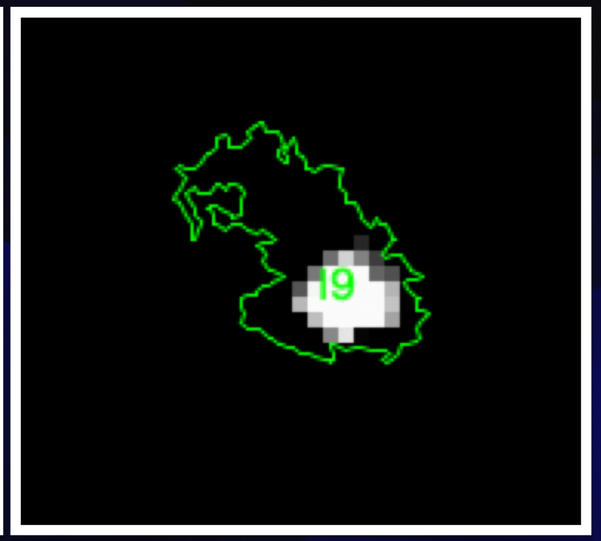

“Normal” image of a galaxy



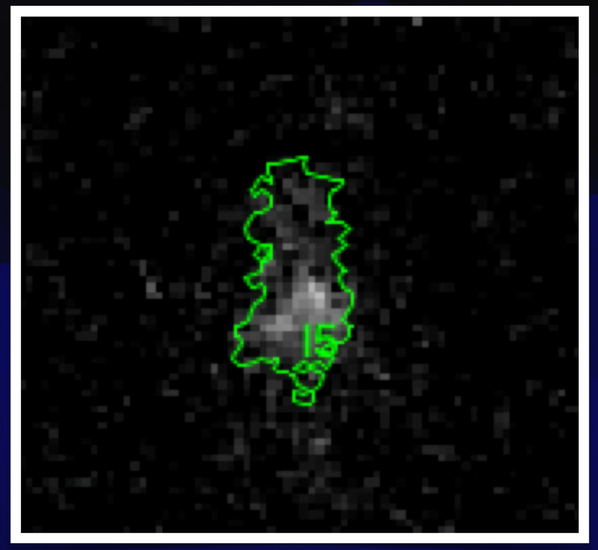

Strongly lensed image of a galaxy



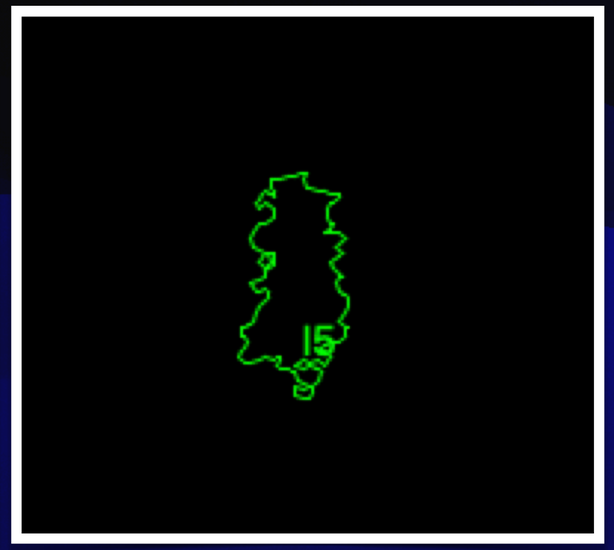

F090JWST




F125HST

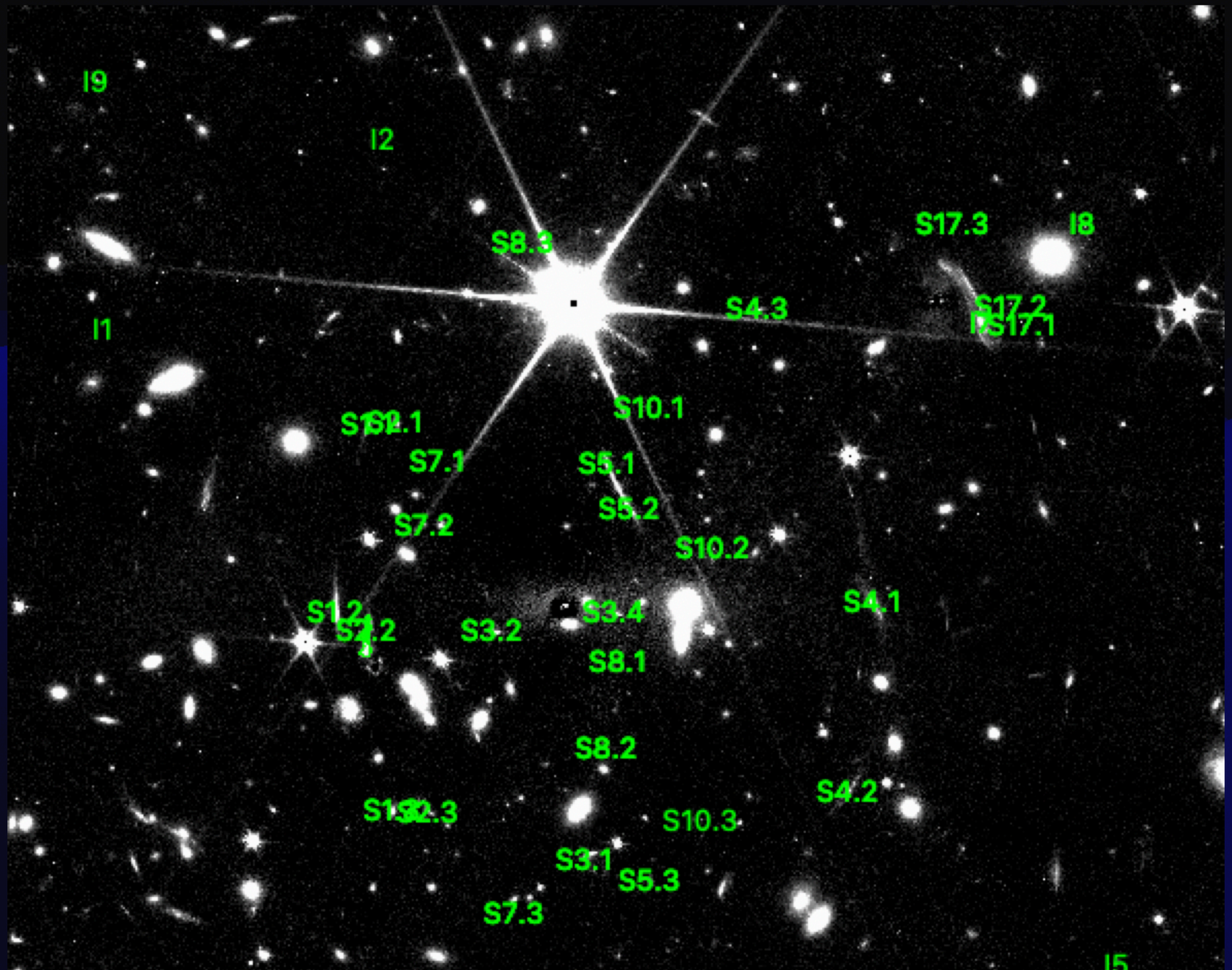



F090JWST



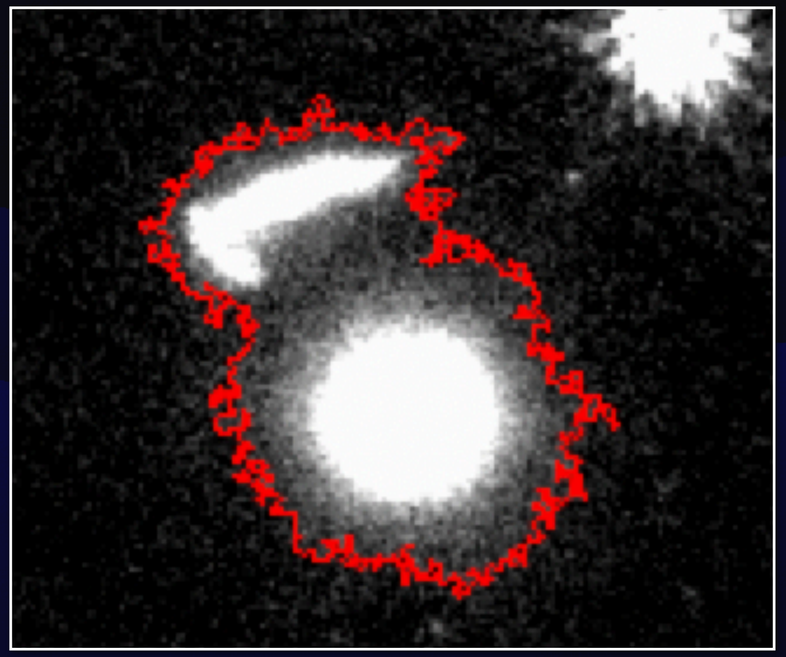

F125HST

# MARKING ALL TARGET GALAXIES

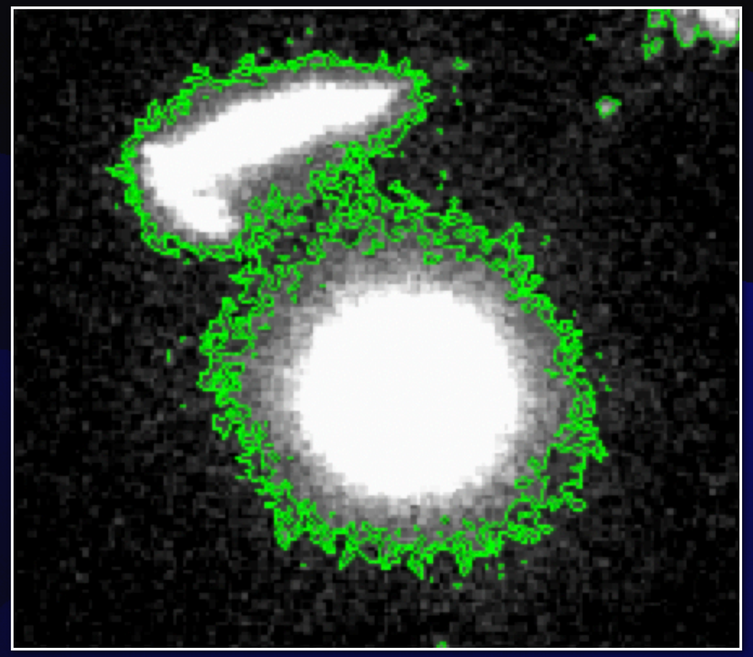


# OPTIMAL DETECTION THRESHOLD CHOSEN BY TRIAL AND ERROR

Detection threshold : 2σ



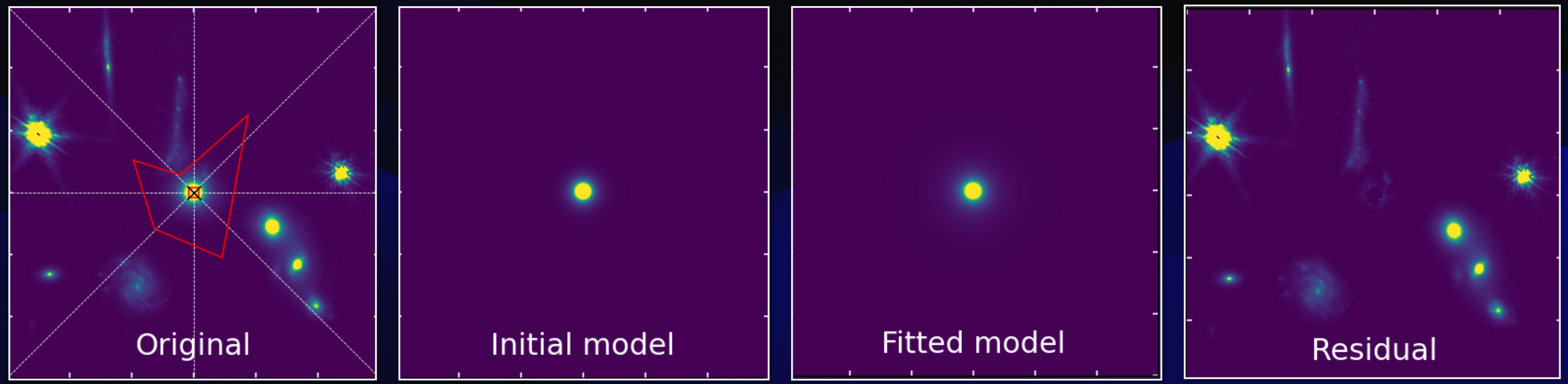
Detection threshold : 3σ



**MUCH BETTER BACKGROUND ELIMINATION FOR 3σ !**

Selection of regions using DS9 contours

# CONTAMINATION AND ITS REMOVAL




**Fitting parameters in the sersic profile to find the correct sersic index fit for a given bright object**

# LENSING CORRECTION

IMPORT DS9 CONTOURS AND .fits FILES

↓

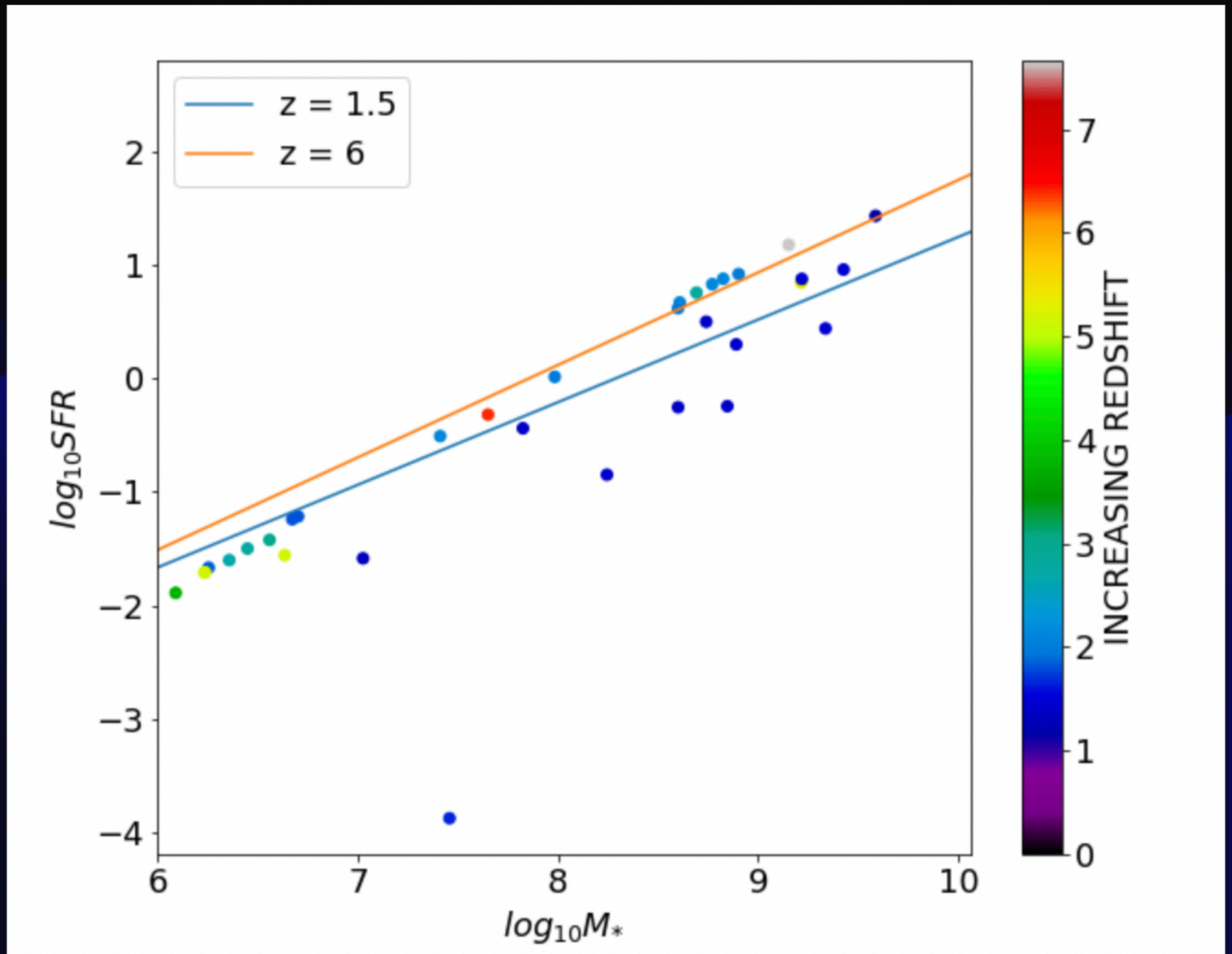
REFER TO AMPLIFICATION MAP

↓

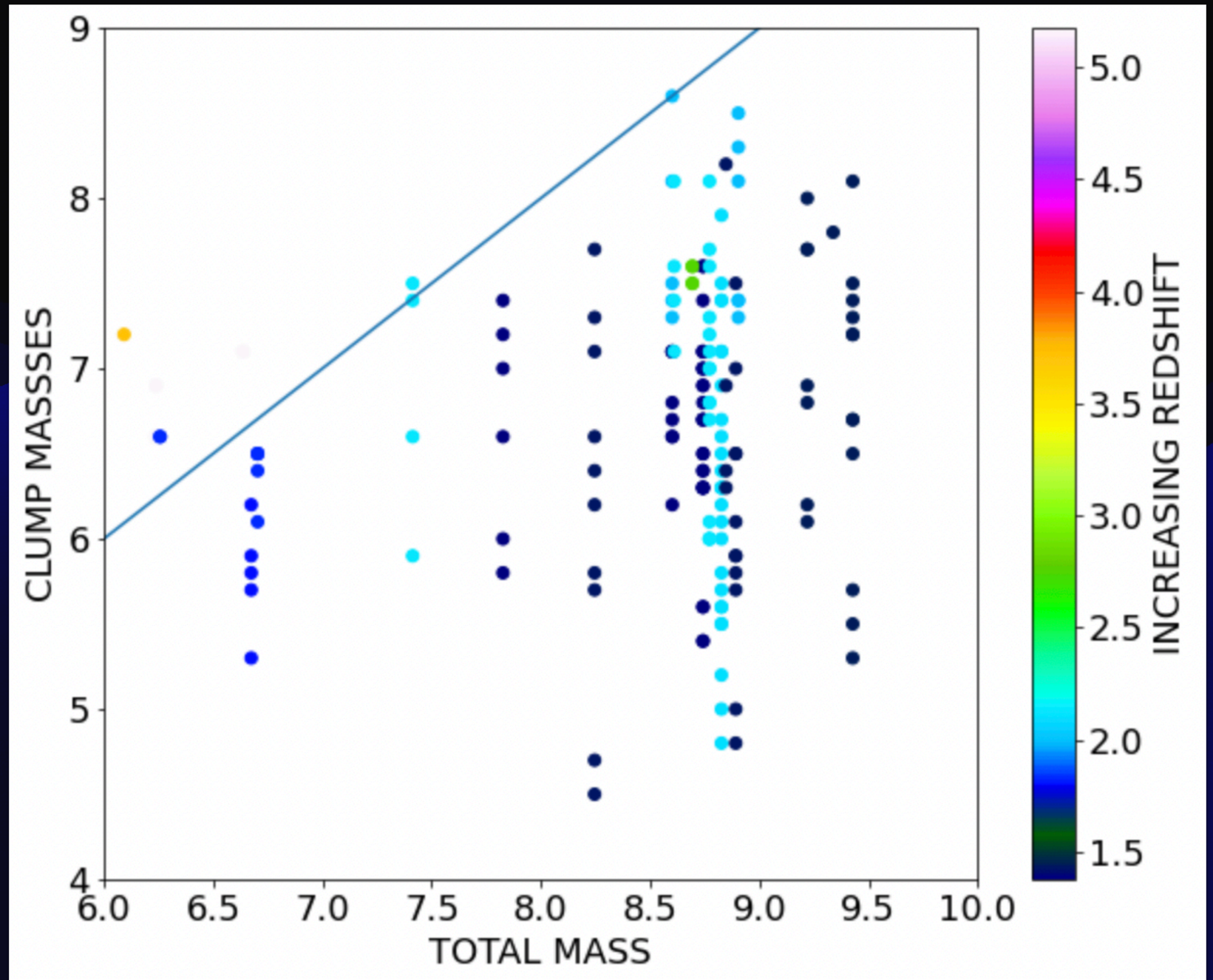
Differential amplification was considered instead of uniform amplification values

RUN PYTHON CODE TO FORM A CATALOG CONTAINING ORIGINAL DATA, LENS CORRECTED DATA, RESIDUAL DATA, LENS CORRECTED RESIDUAL DATA AND CORRESPONDING ERRORS

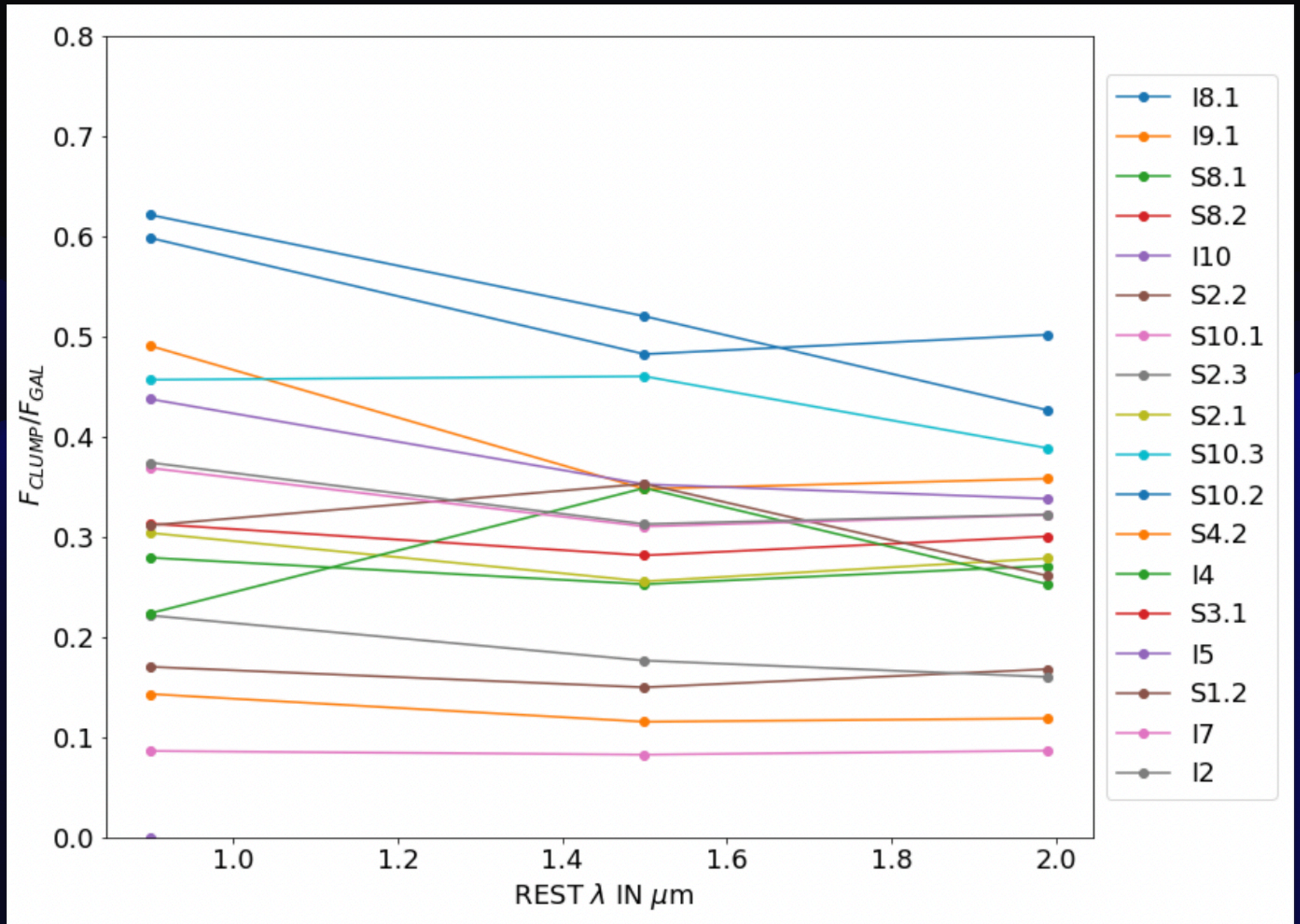
# PLOTS : SFR Vs STELLAR MASS



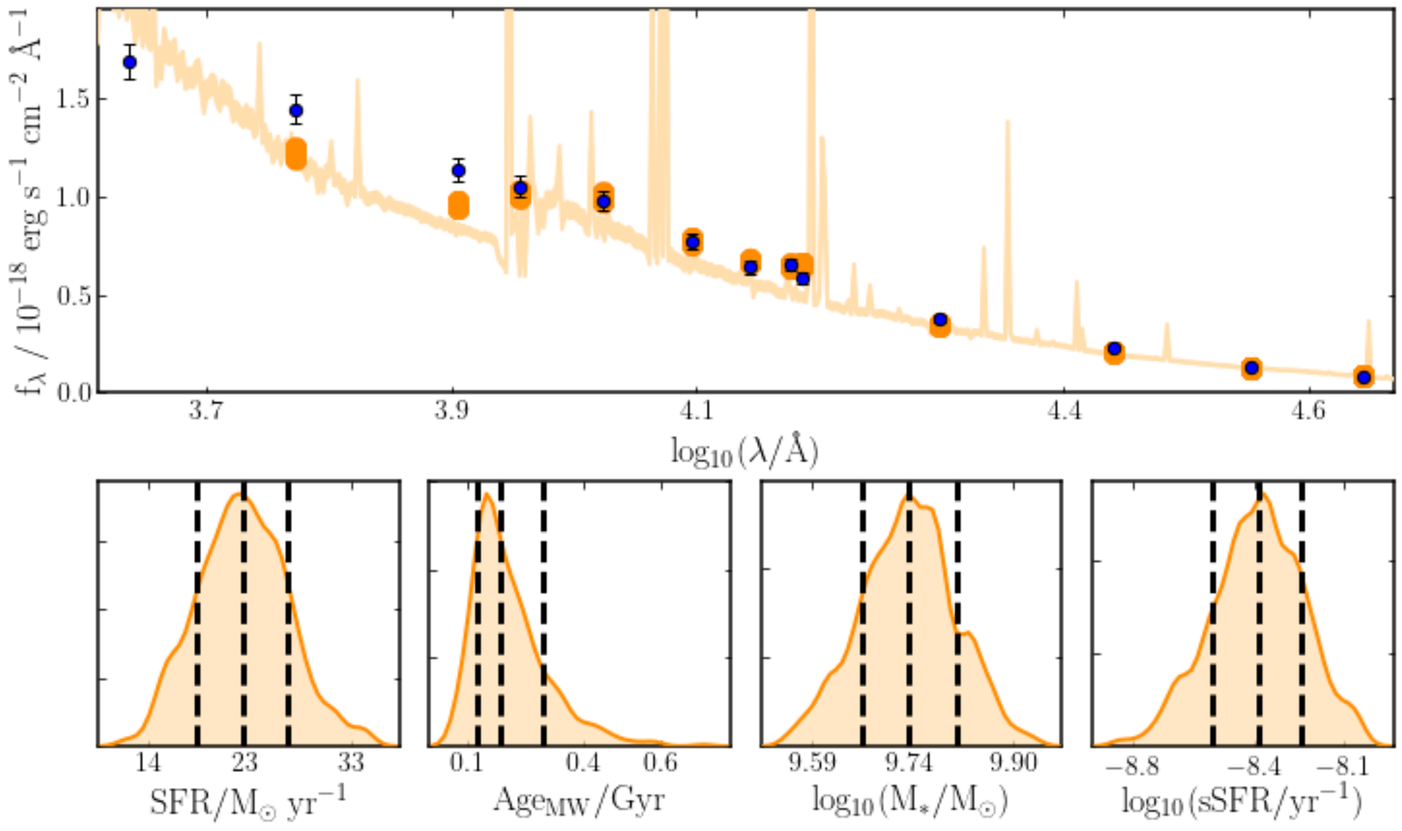
# PLOTS : INDIVIDUAL CLUMP MASS VS TOTAL MASS

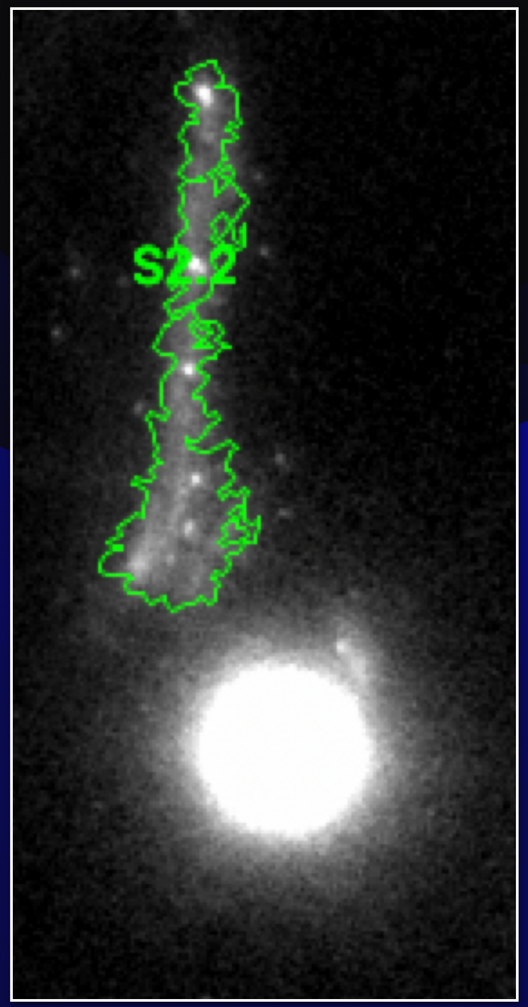


# PLOTS : $F_{clump}/F_{galaxy}$ VS REST WAVELENGTH

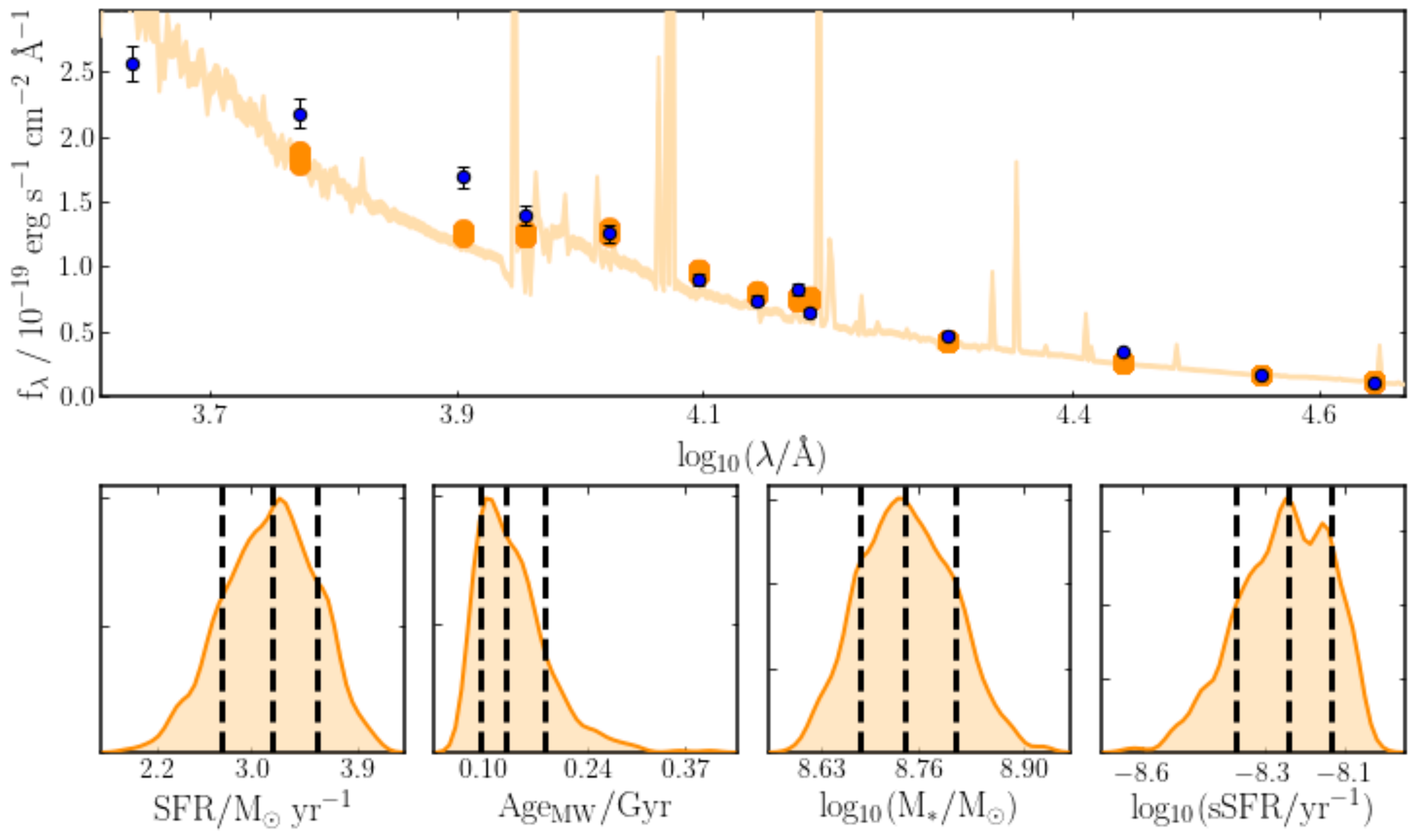


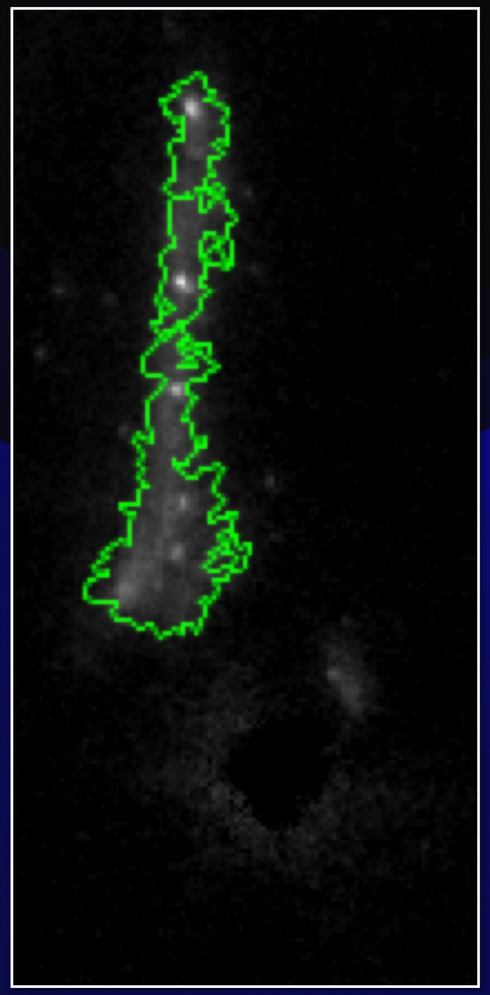
# SED CURVES FOR THE SPARKLER GALAXY(ORIGINAL)



# SED CURVES FOR THE SPARKLER GALAXY(RESIDUAL LENSED)



# CONCLUSION

- The SFR indeed increases for the same stellar mass at higher redshift.

- Clumpiness of galaxies is higher in the the blue wavelengths as they trace the star forming regions while the redder wavelengths trace the older stellar population within a galaxy.

- Inferred clump masses in high-redshift galaxies are, on average, significantly higher than those in local low redshift galaxies

- Removal of contamination and Lensing correction are extremely important while analysing images as otherwise we overestimate physical properties of galaxies drastically and produce erroneous results.