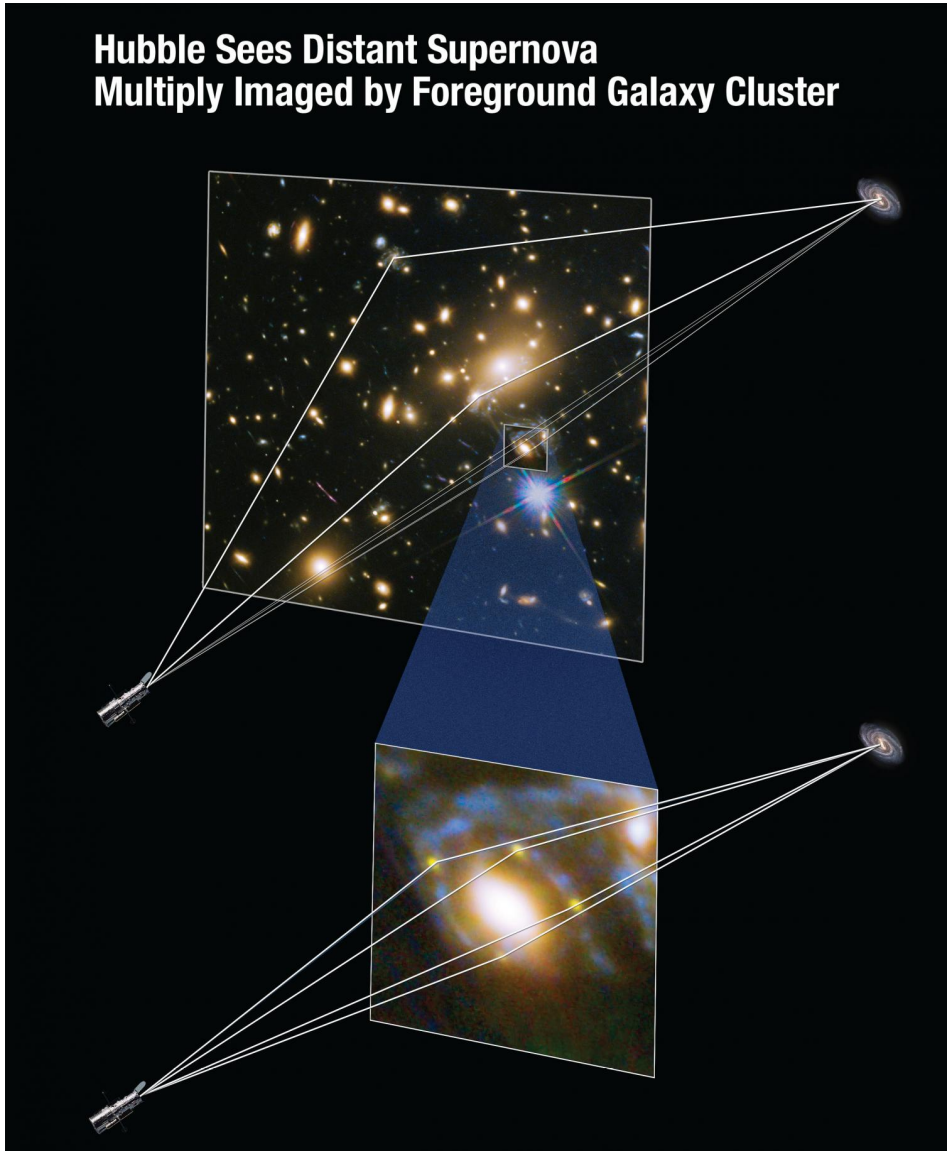
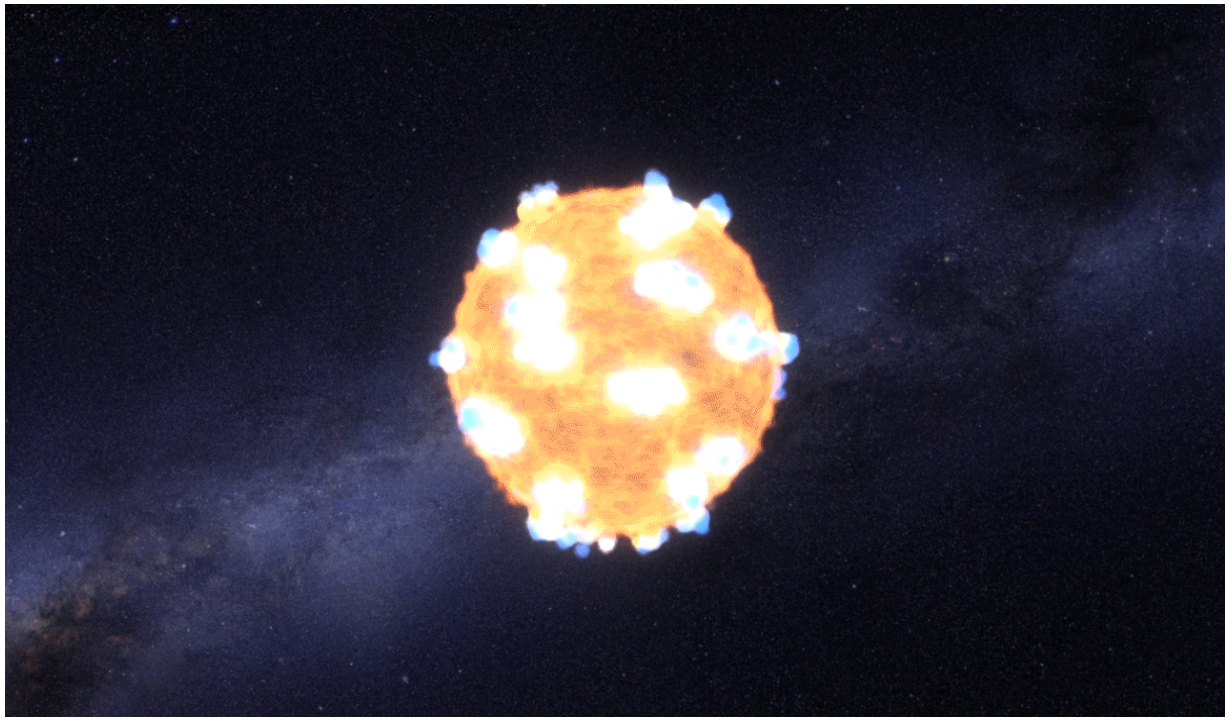
Shock cooling of a red-supergiant supernova at redshift 3 in lensed images





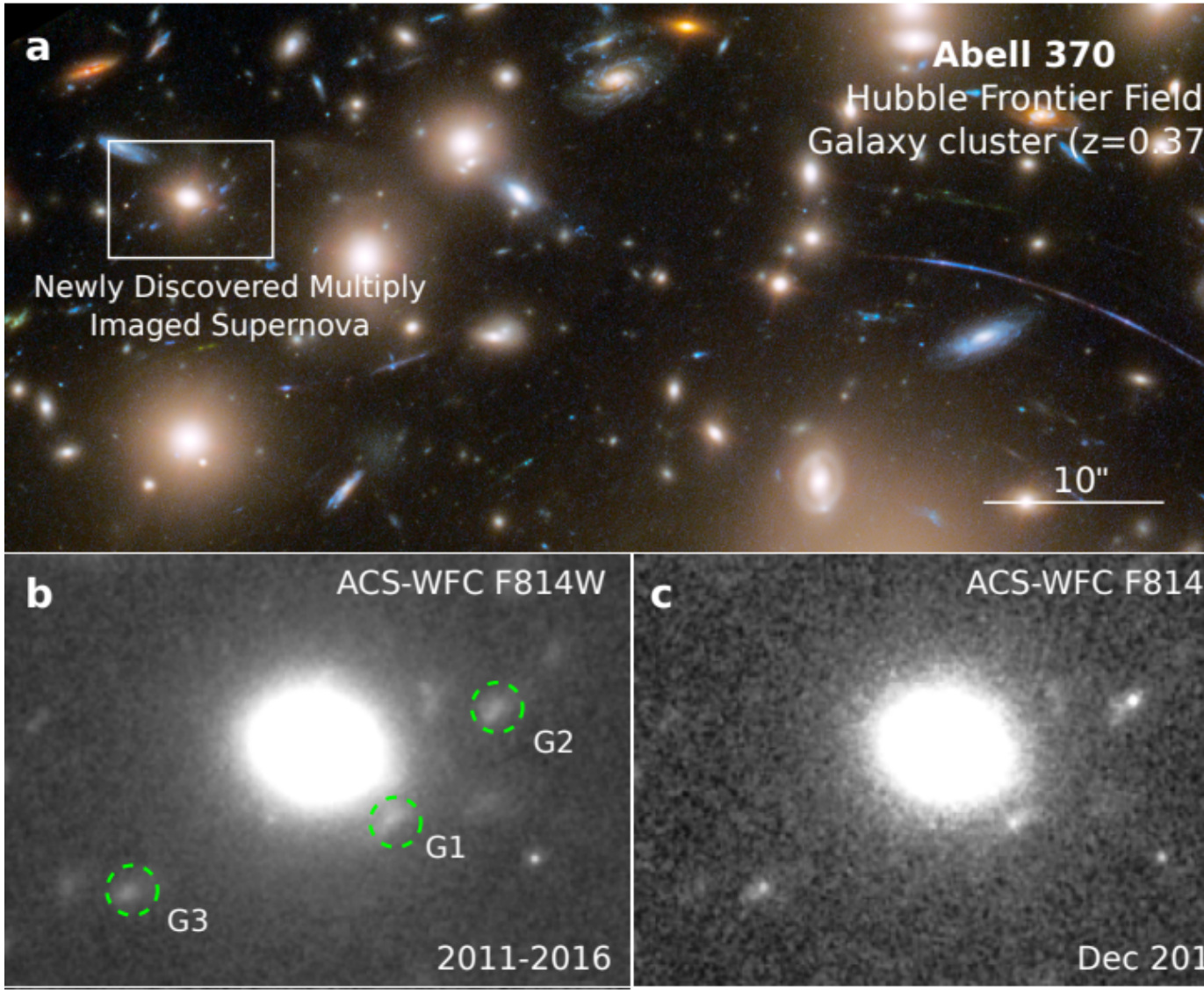
- Lensed Sne, predicted by Refsdal in 1964
- 5 found

- Lensed cc Sne, from HFF, @ A370(z=0.375), observed in 2010 Dec
- Images aligned, resampled to 0.03 arcsec
- The lensed host galaxy

1 arcmin from the center of cluster

photo-z 2.94

- F160W, F110W, F814W
- Effective temperature:
  - 5.5e4 K, 2.0e4 K, and 1.1e4 K
- 100,000 to 10,000K in 8 days



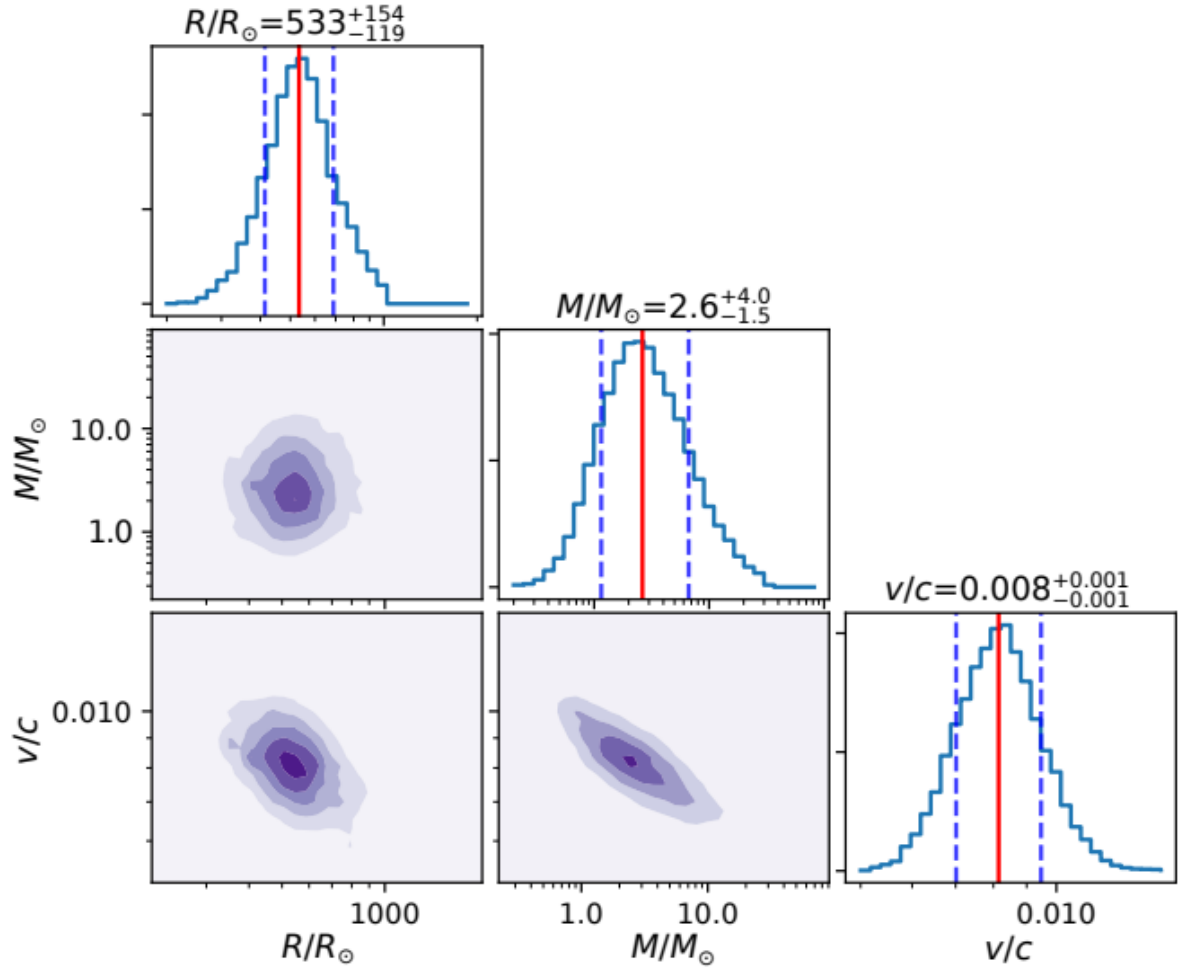
- Lens modelling (GALFIT)
  - Cluster + early type galaxy

Image	S1	S2	S3	S4
μ	-4.24 (1.14)	7.79 (1.27)	5.79 (0.80)	-1.21 (0.47)
Δt / days	30.62 (5.56)	21.03 (3.41)	0 (0)	53.49 (7.17)

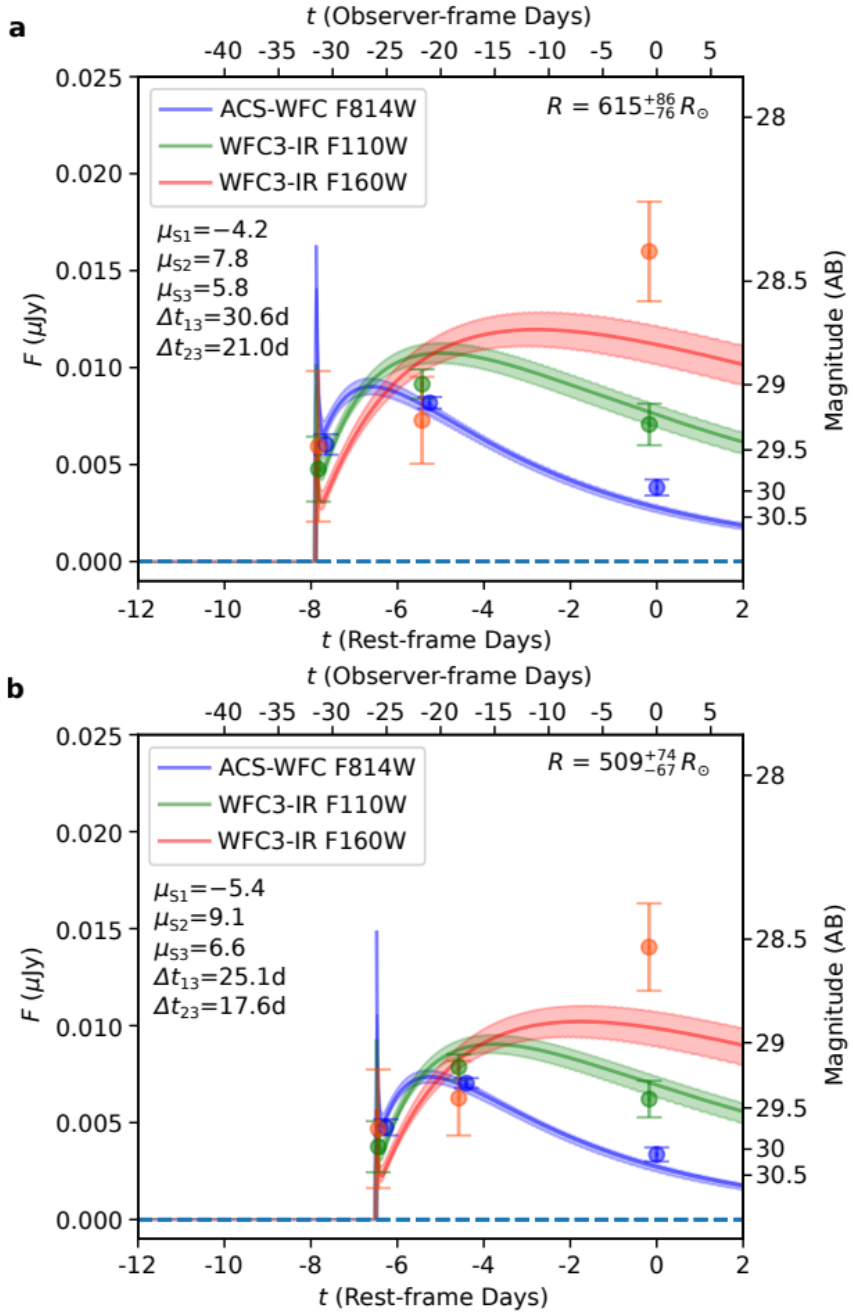
- Fitting 10 parameters (lens and Sn)
  - the evolving of SN is not considered, SN is a blackbody
  - RSG with small CSM (0.001-0.1) is preferred over BSG or CSM (Figure)
  - If larger CSM is allowed:

    SNIIP + homologous CSM (1 Msun)

    481 Rsun



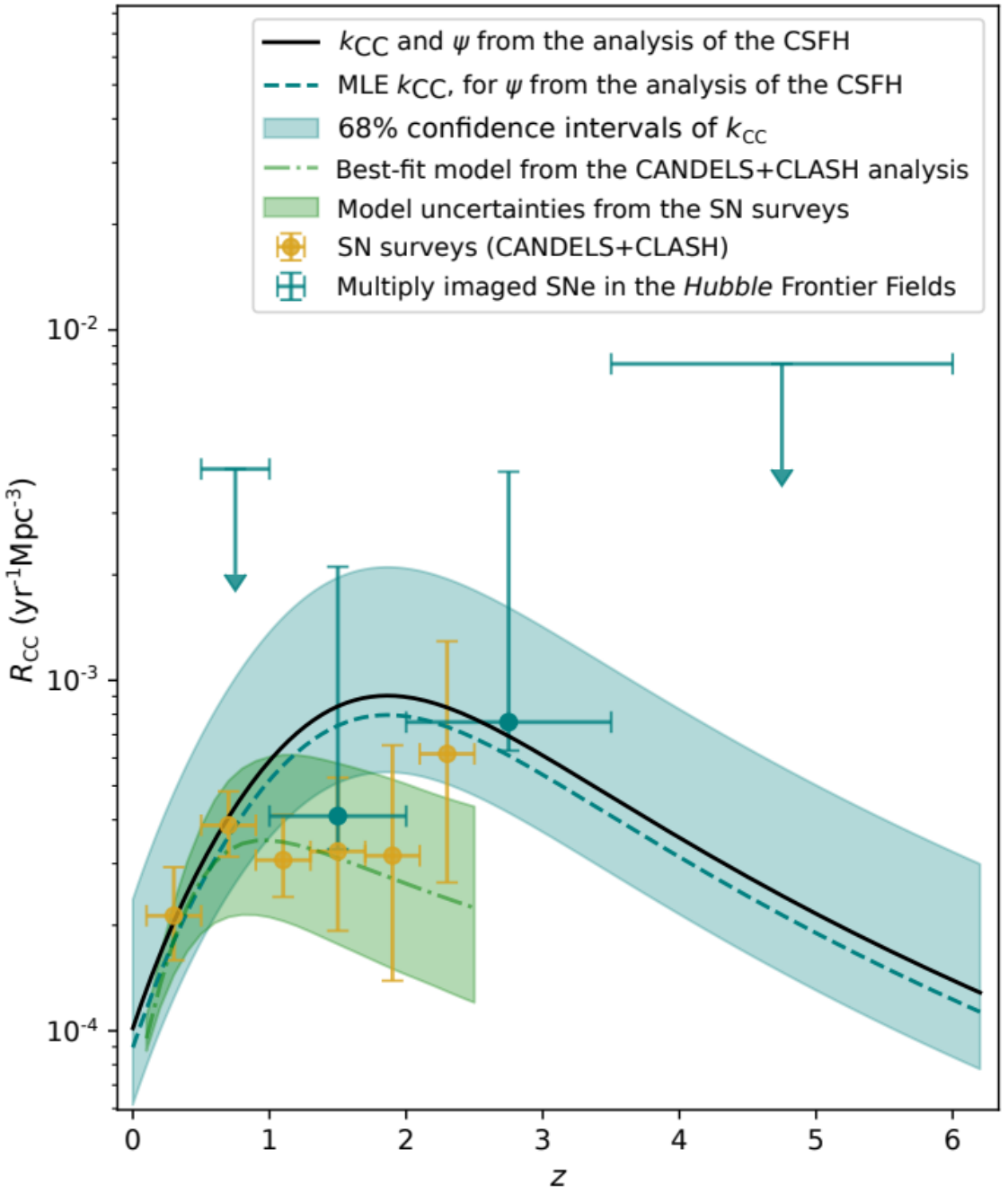
- lensing magnification → intrinsic flux
- lensing time delay → Light curve
  - Top: best fitting: R~615 Rsun,
  - Bottom: mu-1sigma larger,t0-1sigma smaller 509 Rsun
-



CCSN rate at high z

- 2 lensed SNe in 6 HFFs

- Black line: Salpeter IMF star formation rate
- Cyan dots: this work



Other problems

- Lens modelling, with host galaxy
- Microlensing & subhalos
  - Photometry of intracluster light in the vicinity of three images
  - Stellar mass density 3.55, 3.47, 2.09 Msun/pc2
  - ML probability: 0.01, 0.013, 0.006

- JWST for better lens modelling and constraint to CSM?