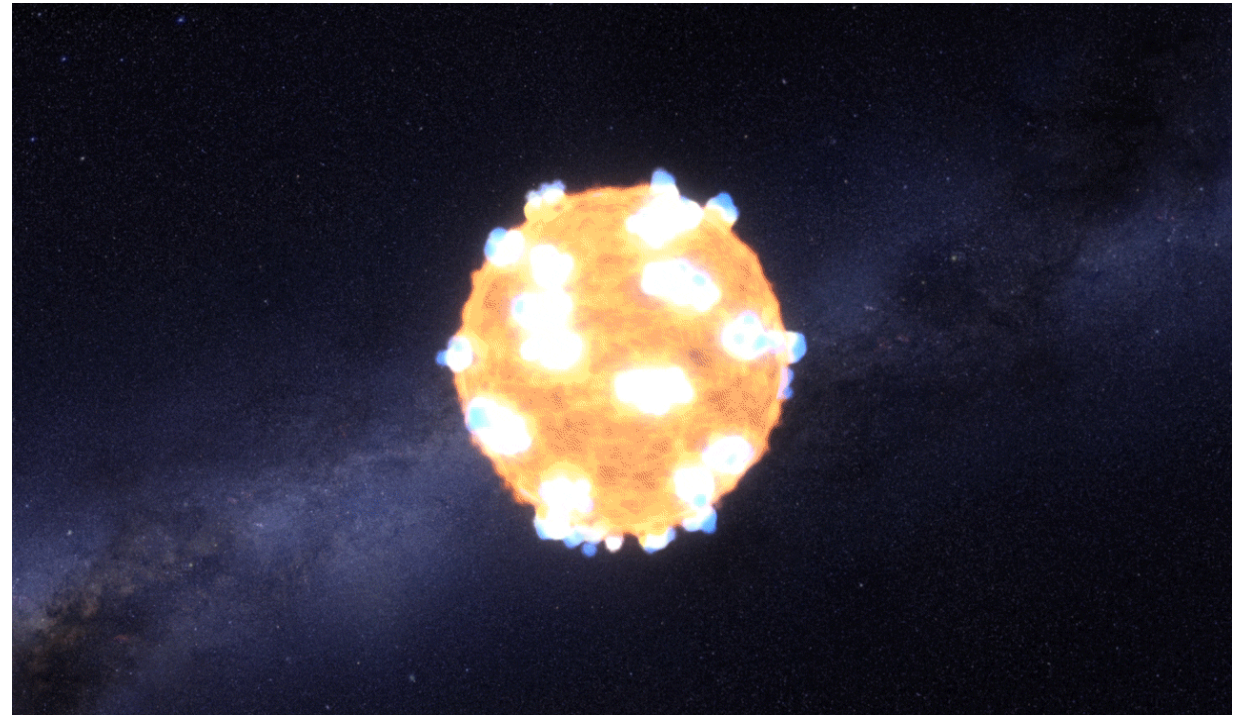
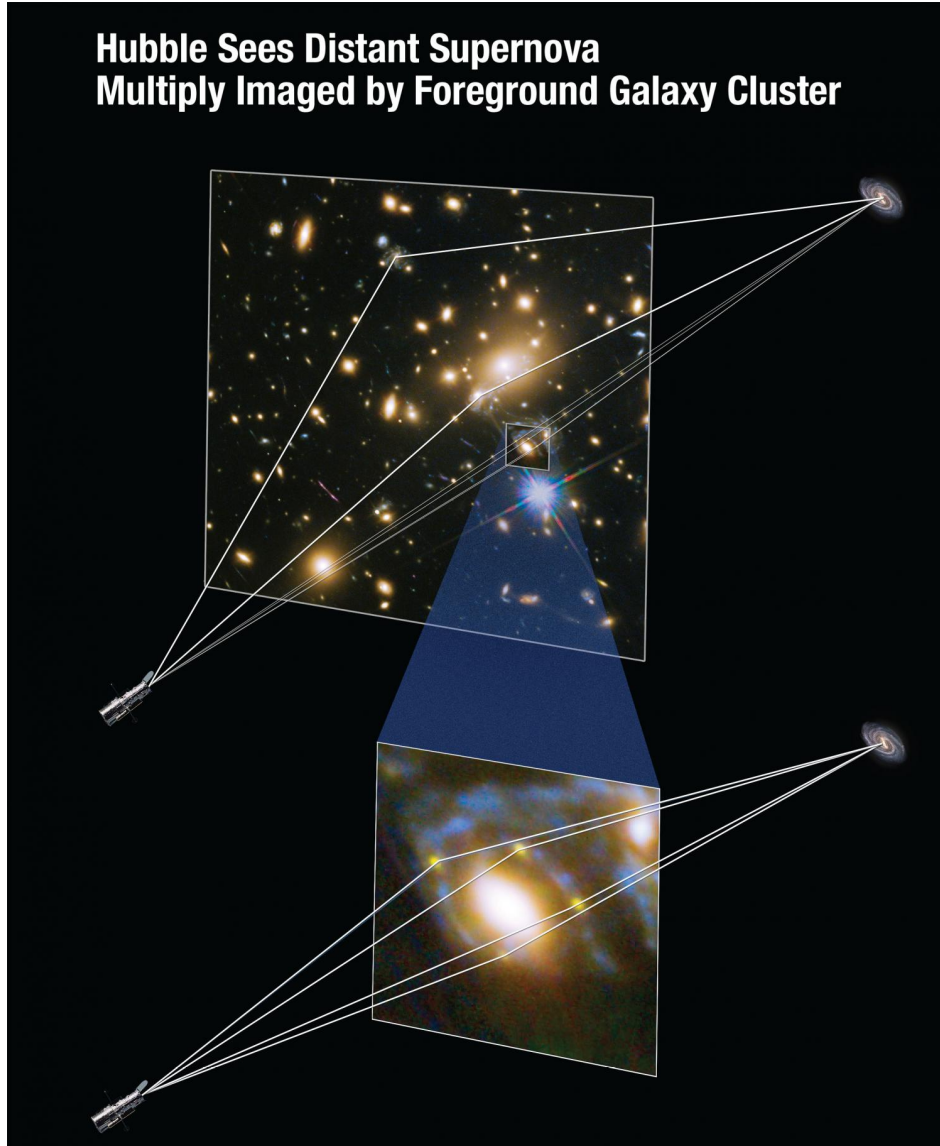
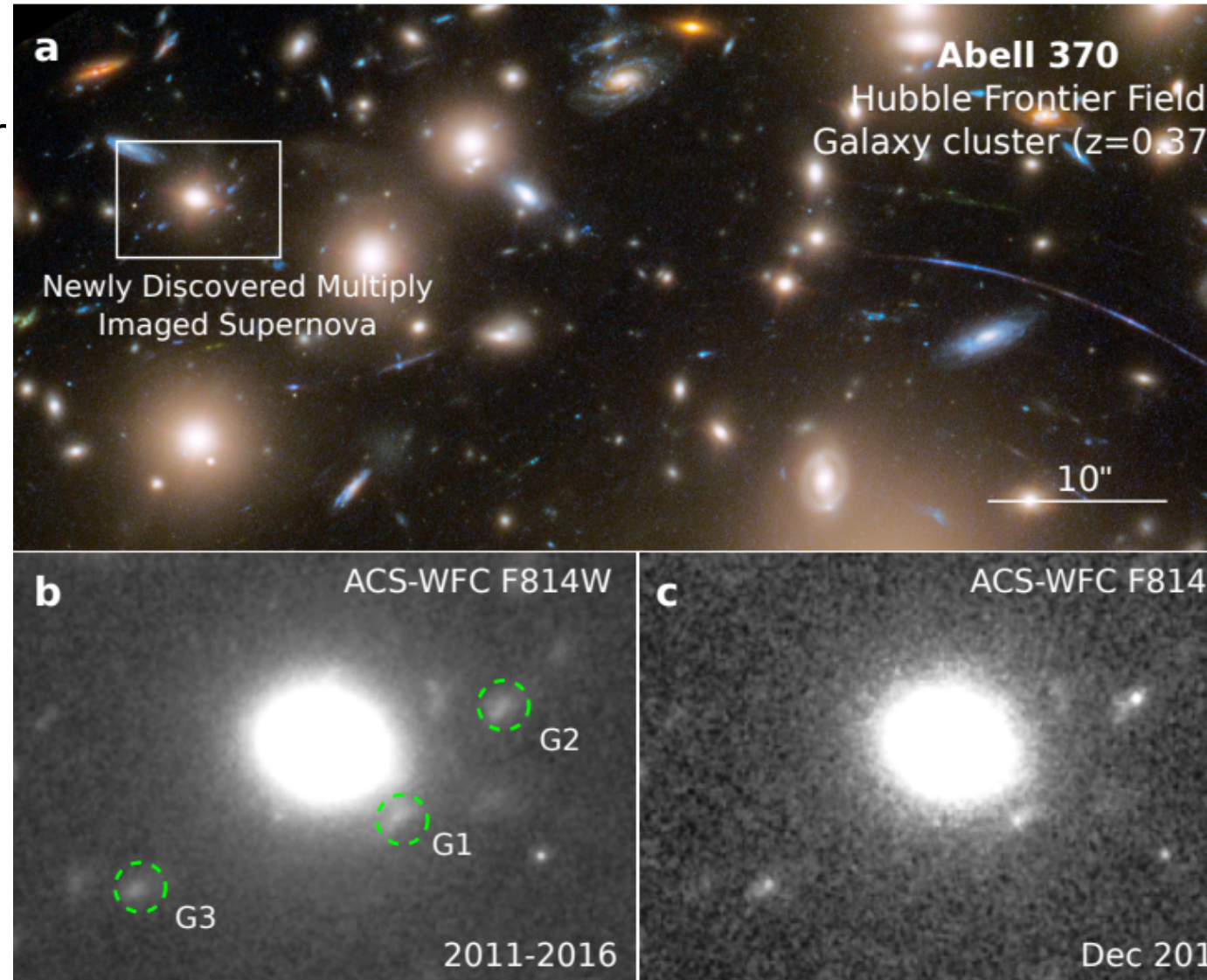


Shock cooling of a red-supergiant supernova at redshift 3 in lensed images



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

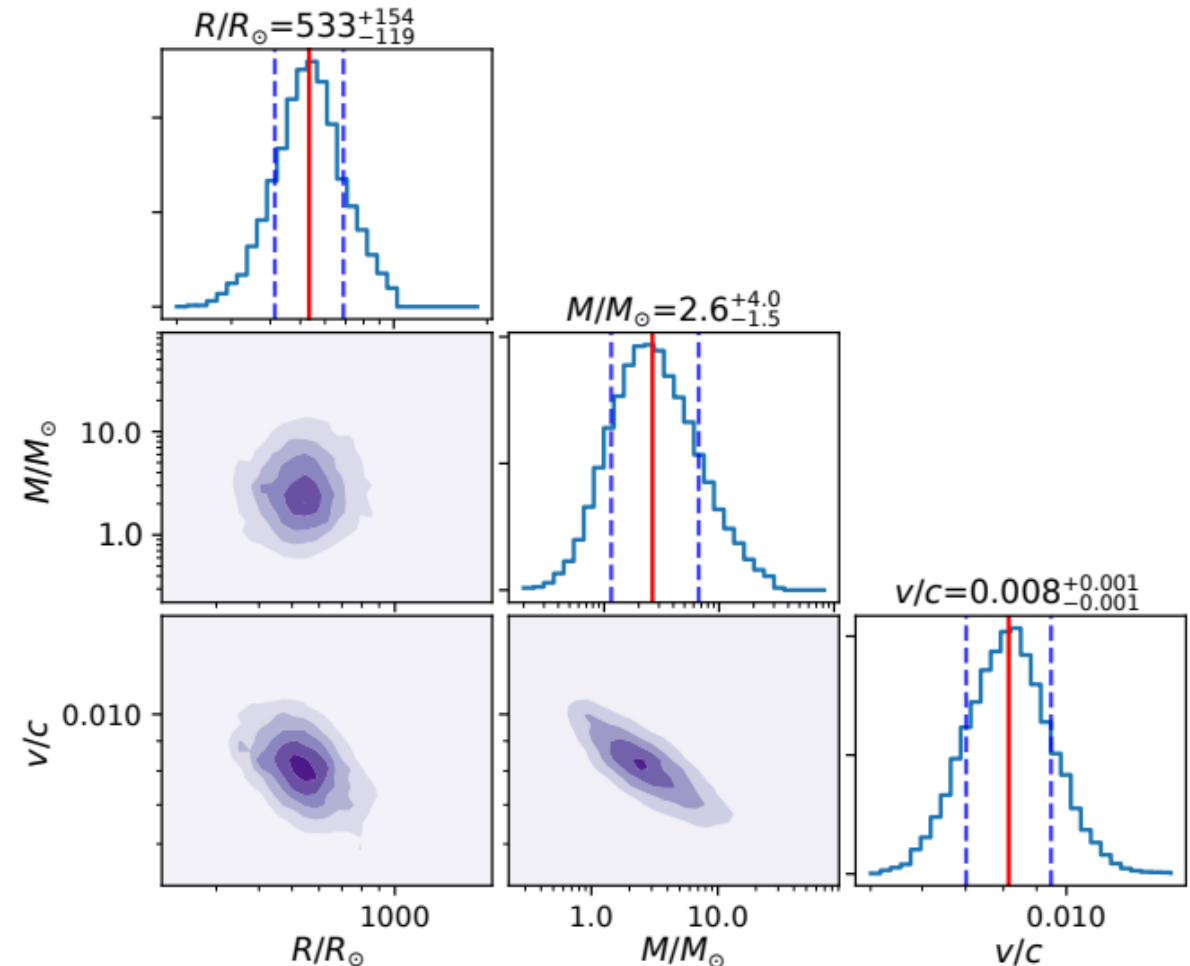
- Lensed cc Sne, from HFF, @ A370($z=0.375$), observed in 2010 Dec
- Images aligned, resampled to 0.03 arcsec
- The lensed host galaxy
1 arcmin from the center of cluster
photo- z 2.94
- F160W, F110W, F814W
- Effective temperature:
 - $5.5e4$ K, $2.0e4$ K, and $1.1e4$ K
- 100,000 to 10,000K in 8 days



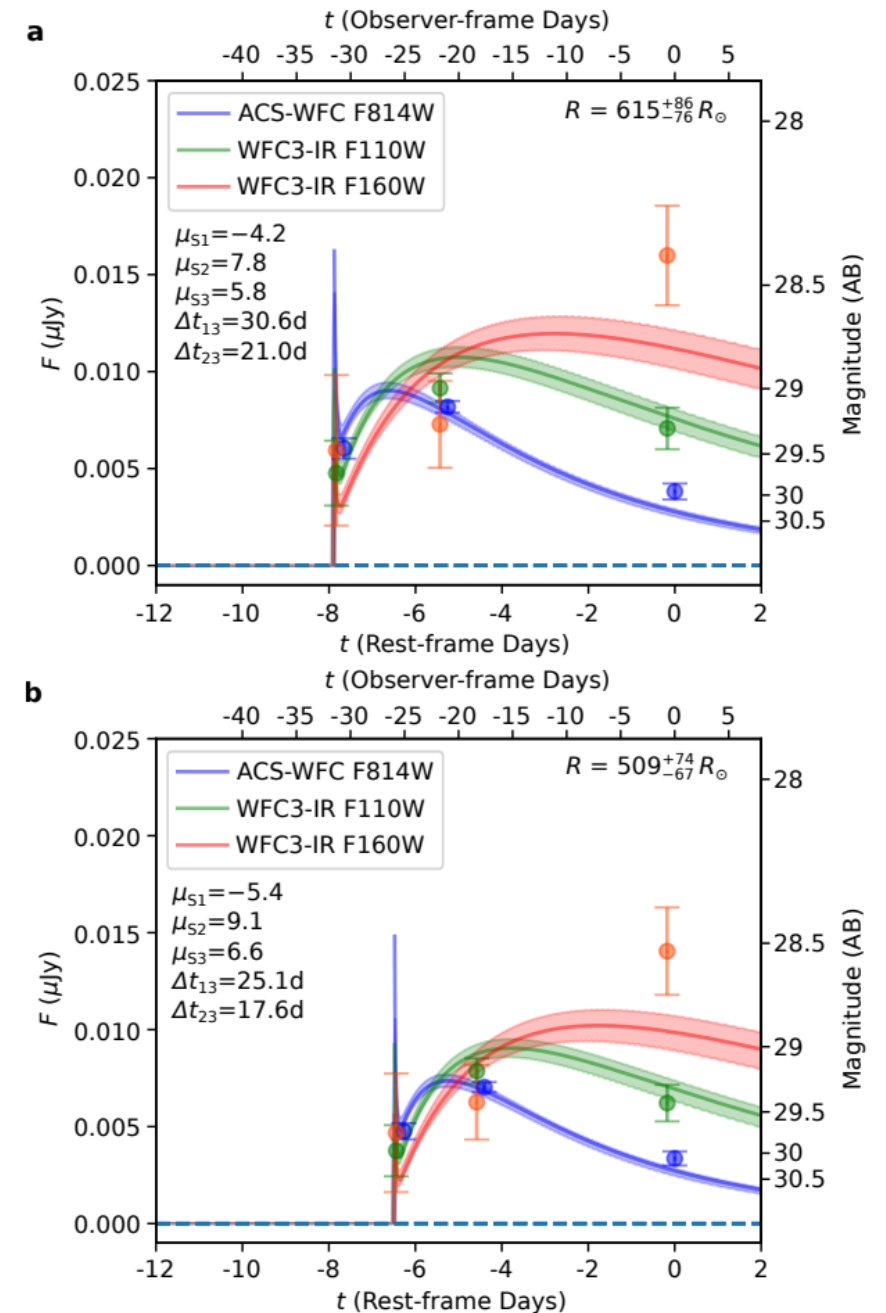
- Lens modelling (GALFIT)
 - Cluster + early type galaxy

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

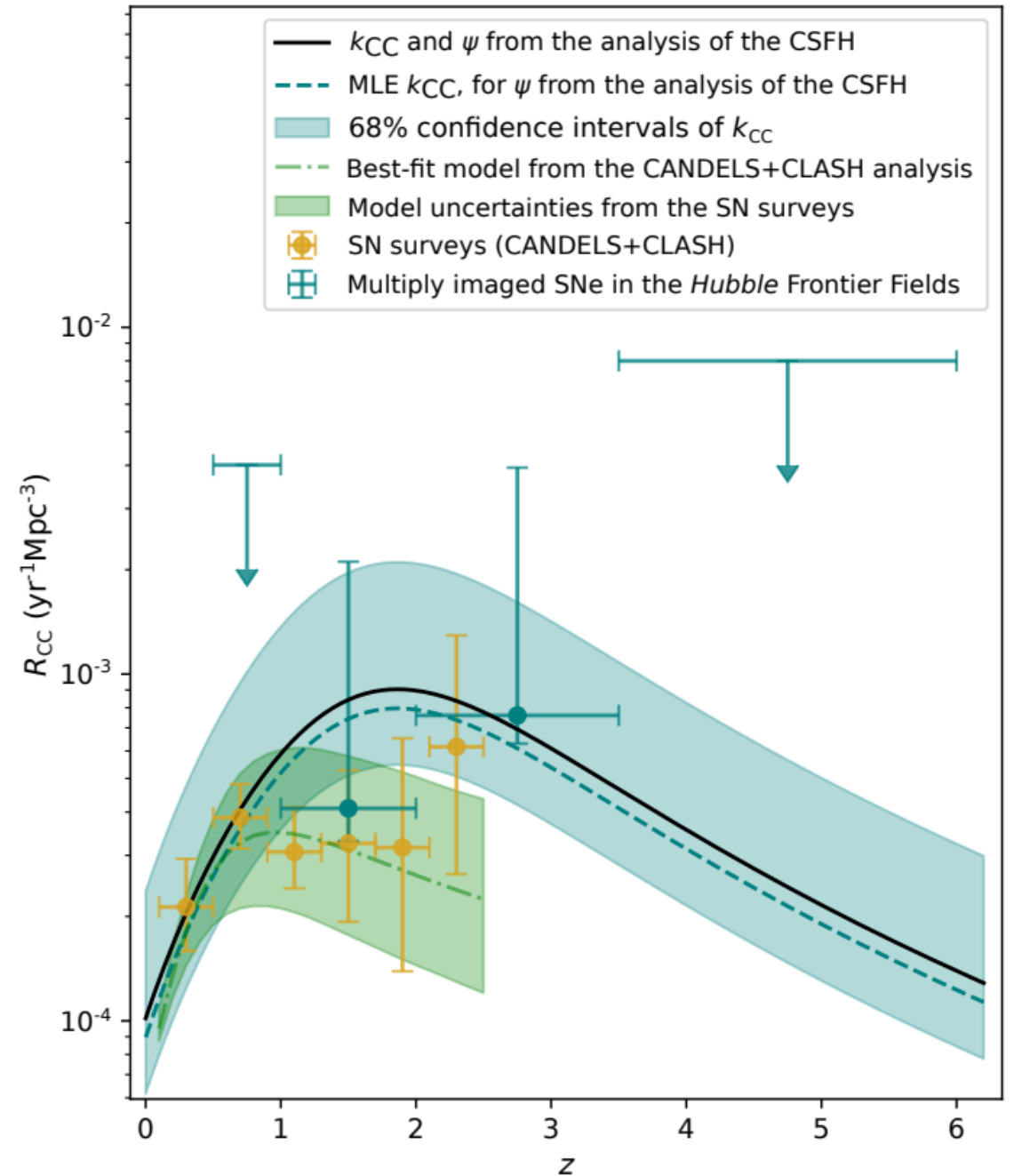


- lensing magnification \rightarrow intrinsic flux
- lensing time delay \rightarrow Light curve
 - Top: best fitting: $R \sim 615 R_{\text{sun}}$,
 - Bottom: $\mu - 1\sigma$ larger, $t_0 - 1\sigma$ smaller $509 R_{\text{sun}}$



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 $M_{\text{sun}}/\text{pc}^2$
 - ML probability: 0.01, 0.013, 0.006
- JWST for better lens modelling and constraint to CSM?