Discovering Supernovae at Epoch of Reionization with Nancy Grace Roman Space Telescope

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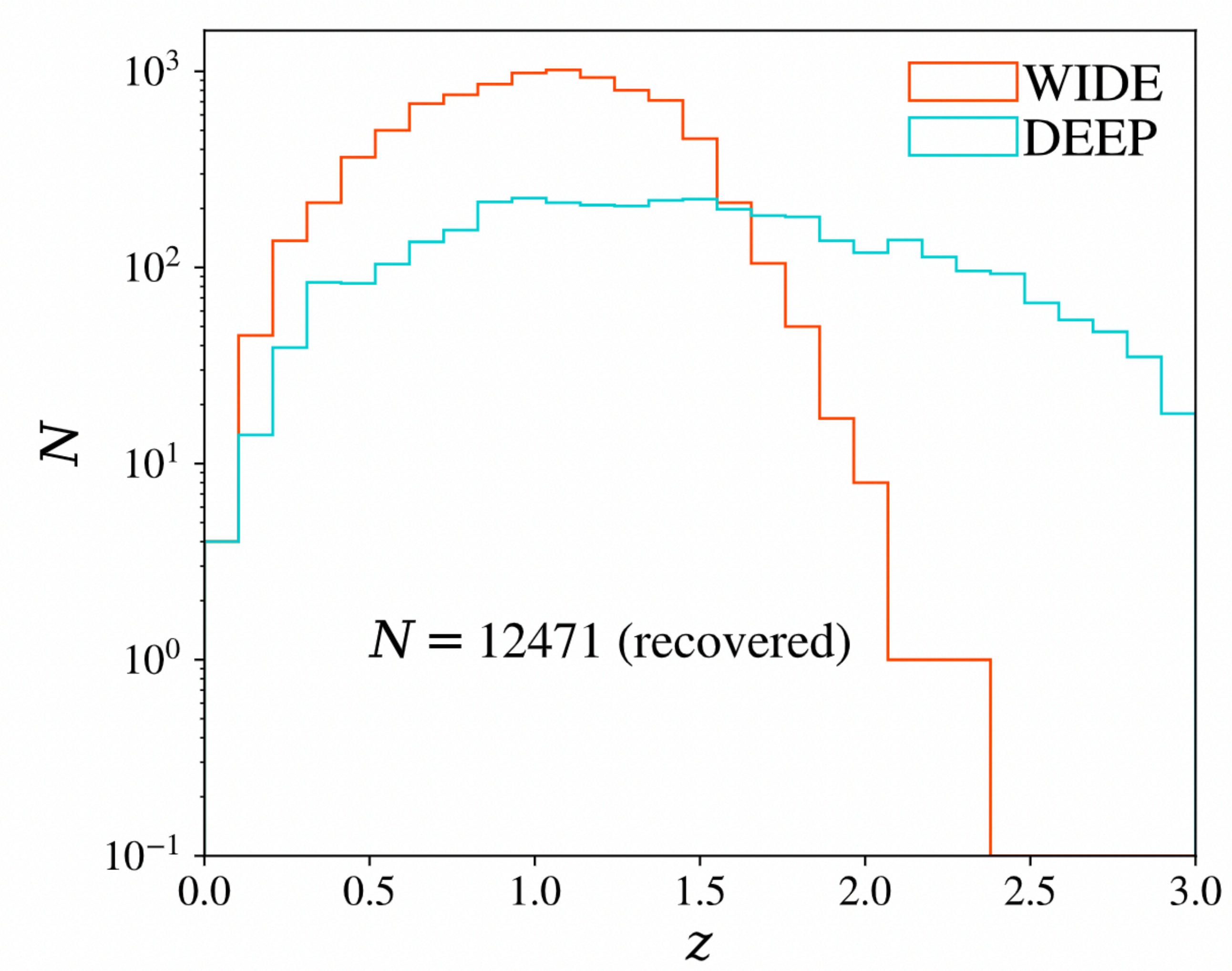
High-redshift supernova survey with Roman

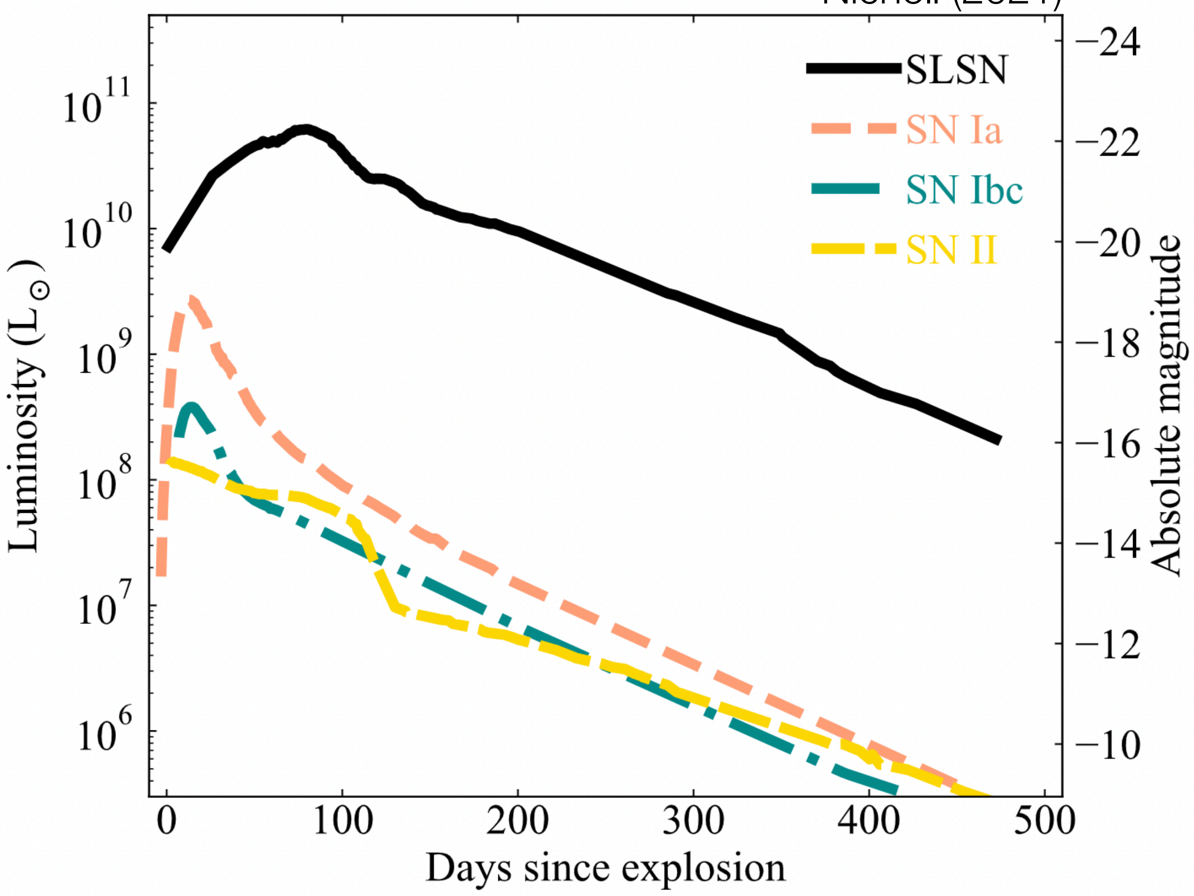
- Type Ia supernovae up to z ~ 3 (Rose et al. 2021)



High-redshift supernova survey with Roman

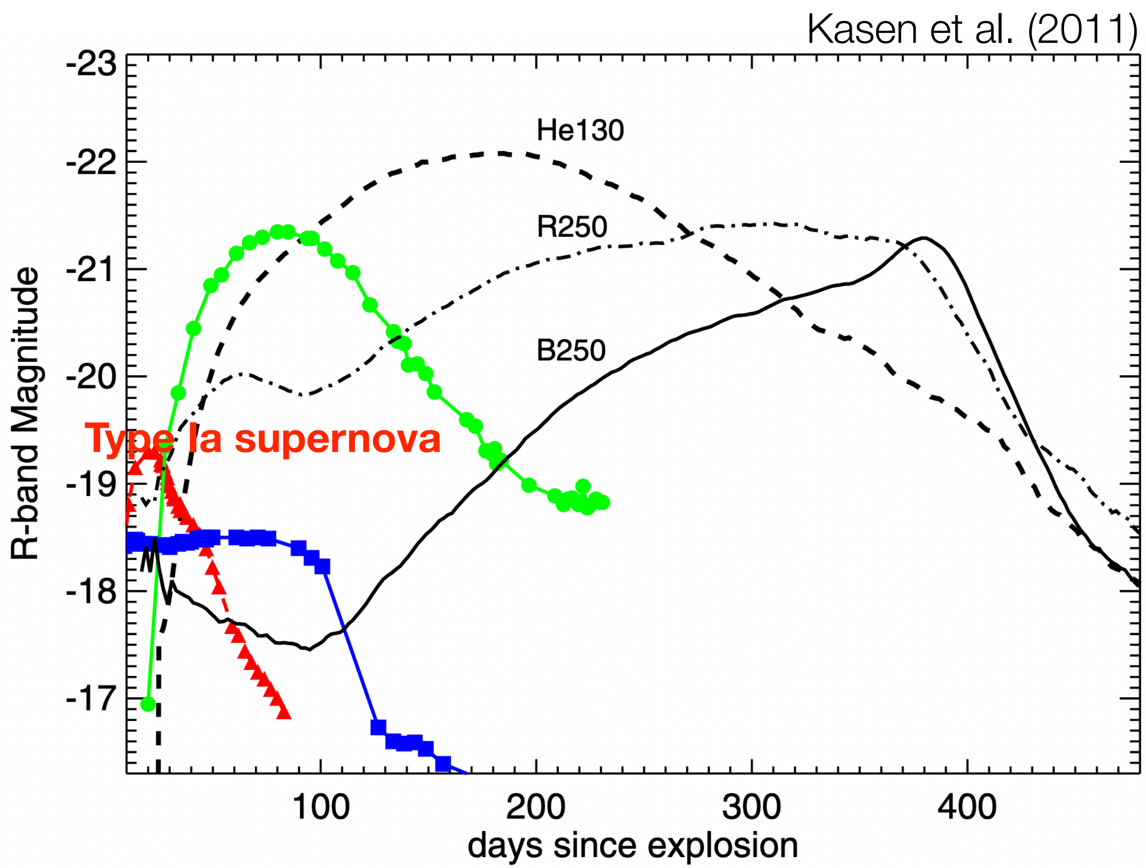
- some supernovae become much brighter than Type Ia supernovae
  - superluminous supernovae (SLSNe)
    - extremely luminous core-collapse supernovae

Nicholl (2021)

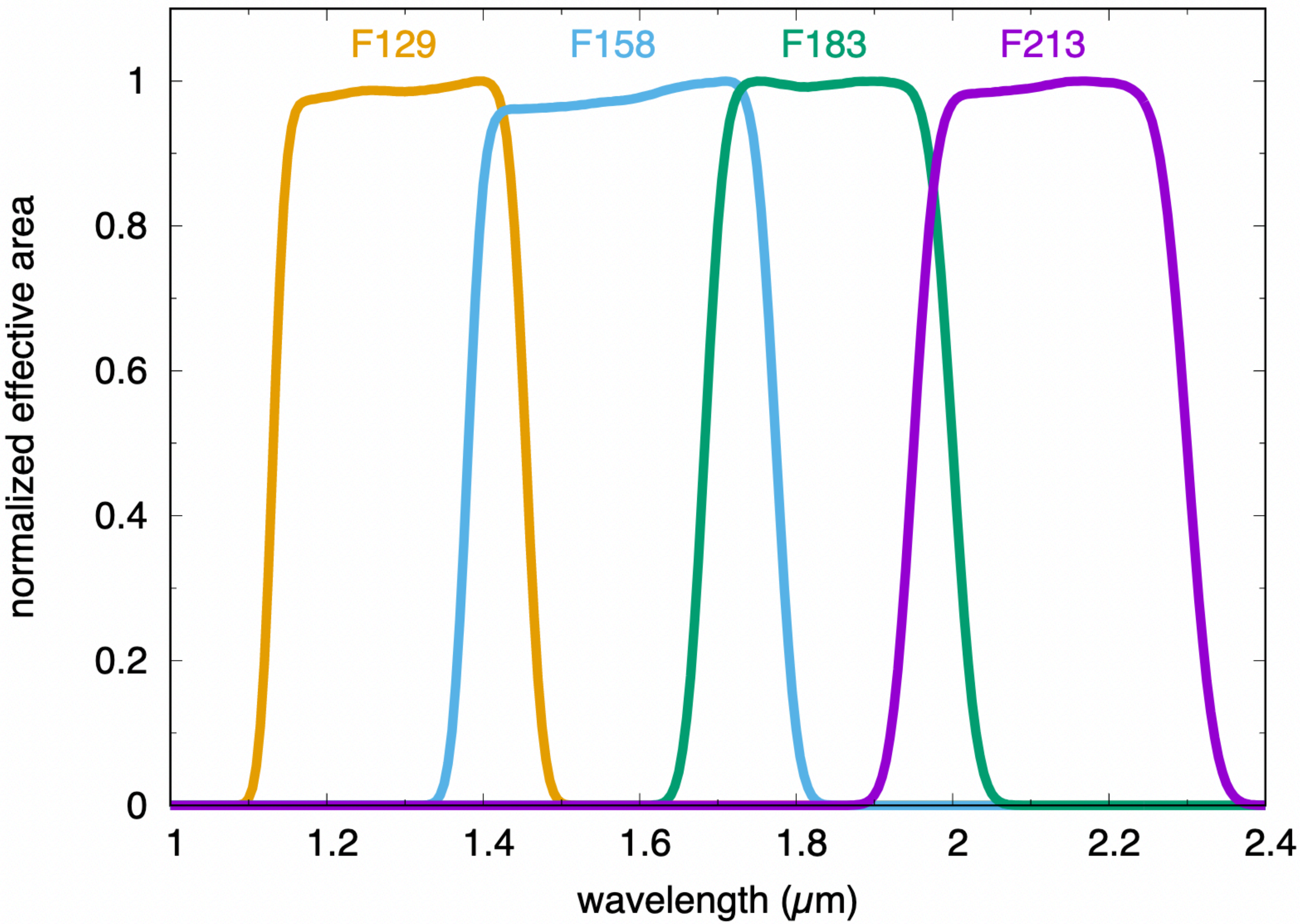


High-redshift supernova survey with Roman

- some supernovae become much brighter than Type Ia supernovae
  - pair-instability supernovae (PISNe)
    - hypothetical thermonuclear explosions of very massive stars with helium core mass between 65 Msun and 130 Msun

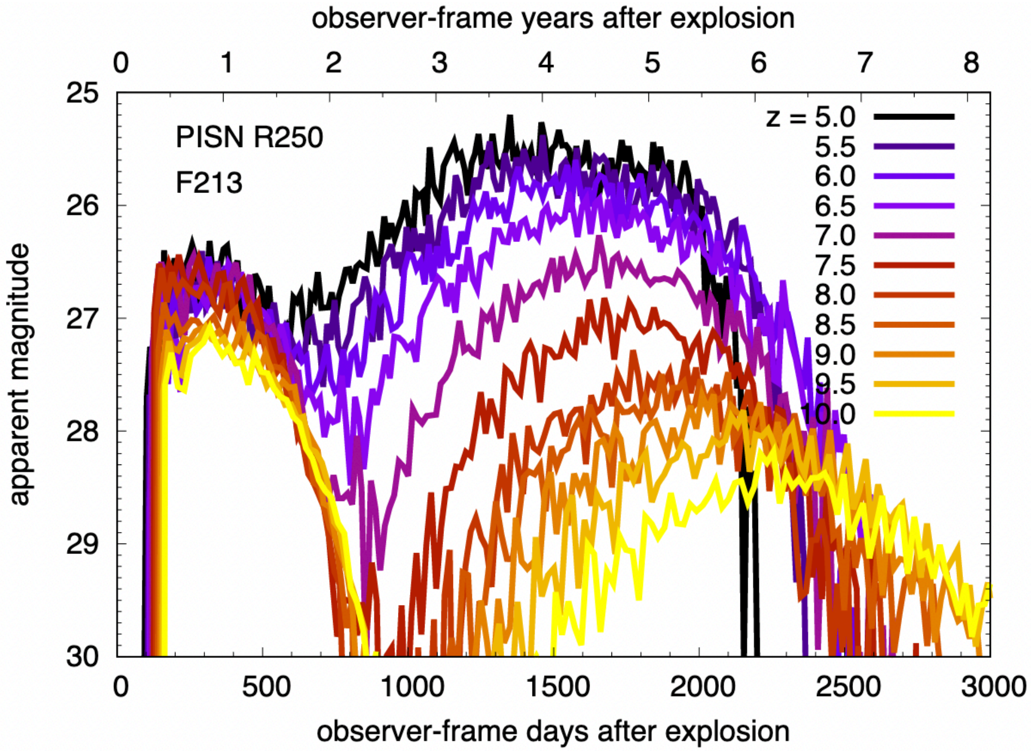


PISN & SLSN light curves with the Roman filters

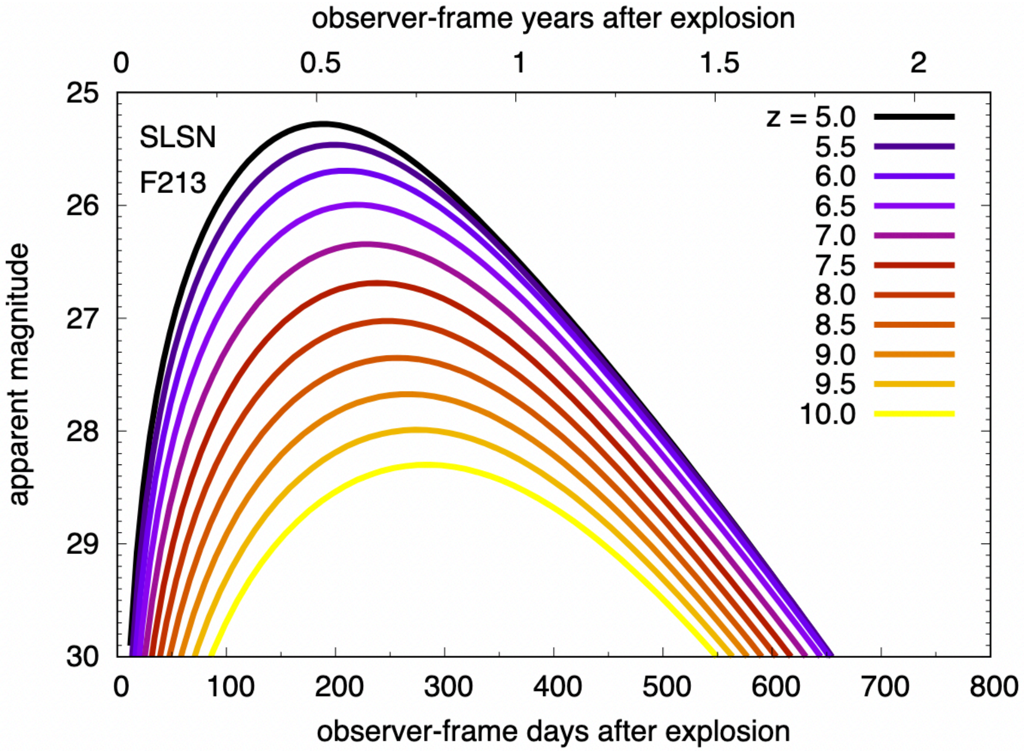


PISN & SLSN light curves with the Roman filters

PISN



SLSN



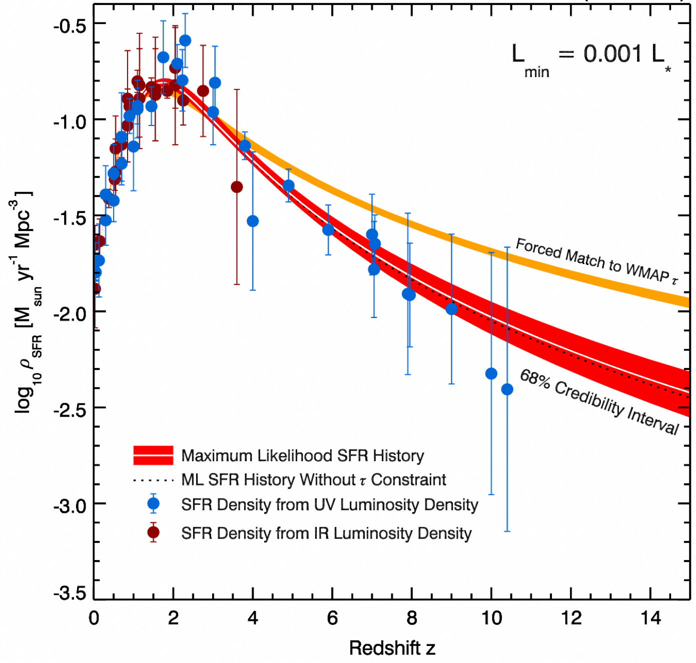
Discovering PISNe/SLSNe at Epoch of Reionization

- PISNe and SLSNe are probes of massive stars
  - direct identification of massive star properties at EoR
    - top-heavy IMF?
  - constrain massive star contribution to reionization

- confident PISNe have not been identified
  - fundamental prediction of stellar evolution
    - BH mass distributions, etc…
  - PISNe preferentially exist at low metallicity
  - high-redshift SN survey is needed to find

- etc!

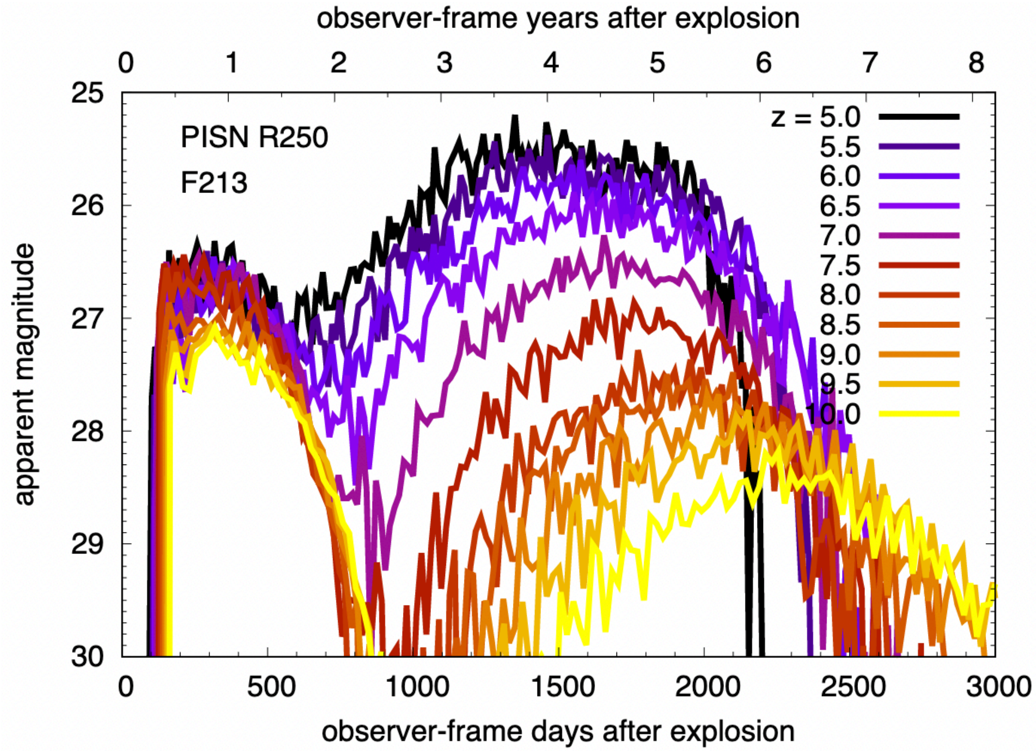
Robertson et al. (2015)



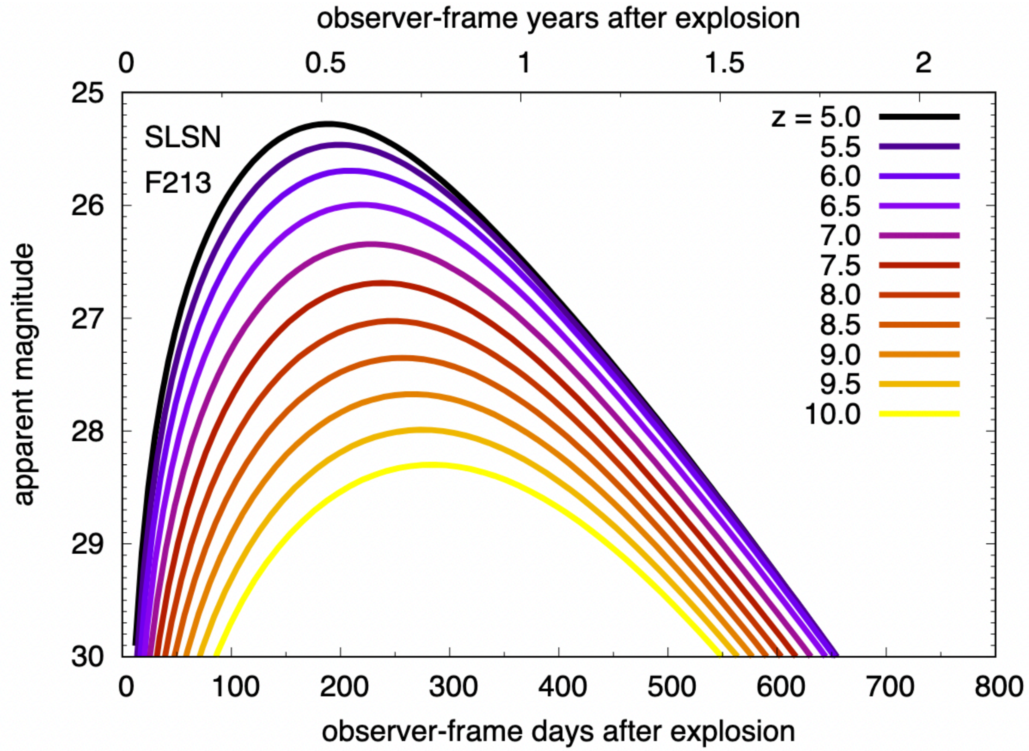
We investigated survey strategy to discover PISNe/SLSNe at z > 6.

Light curves with the Roman filters

PISN



SLSN



no severe requirements for survey cadence!

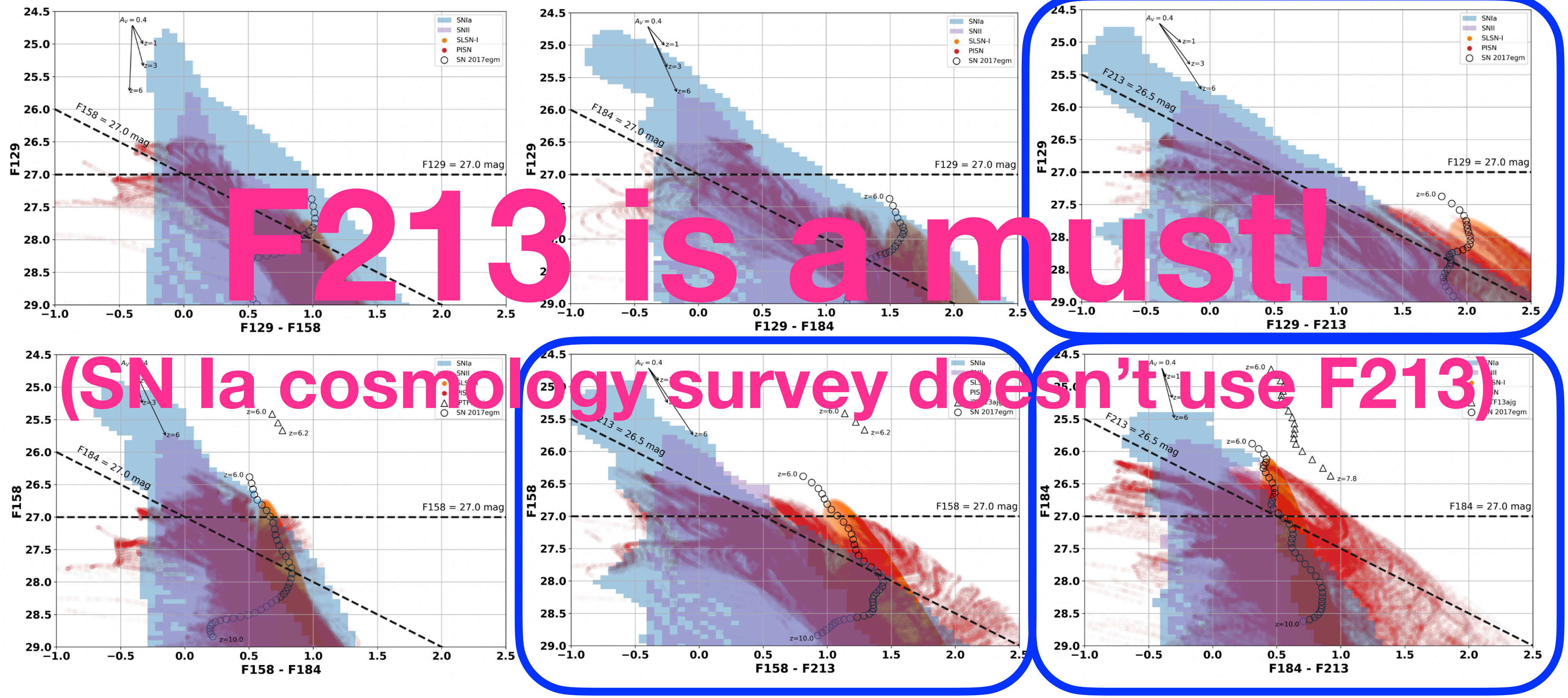
every 0.5 - 1 year observation is OK

Single-epoch candidate screening with CMD

- rare PISN and SLSN candidates need to be identified among other SNe
- color information is essential for the efficient identification

color-magnitude diagram (CMD) of possible filter combinations

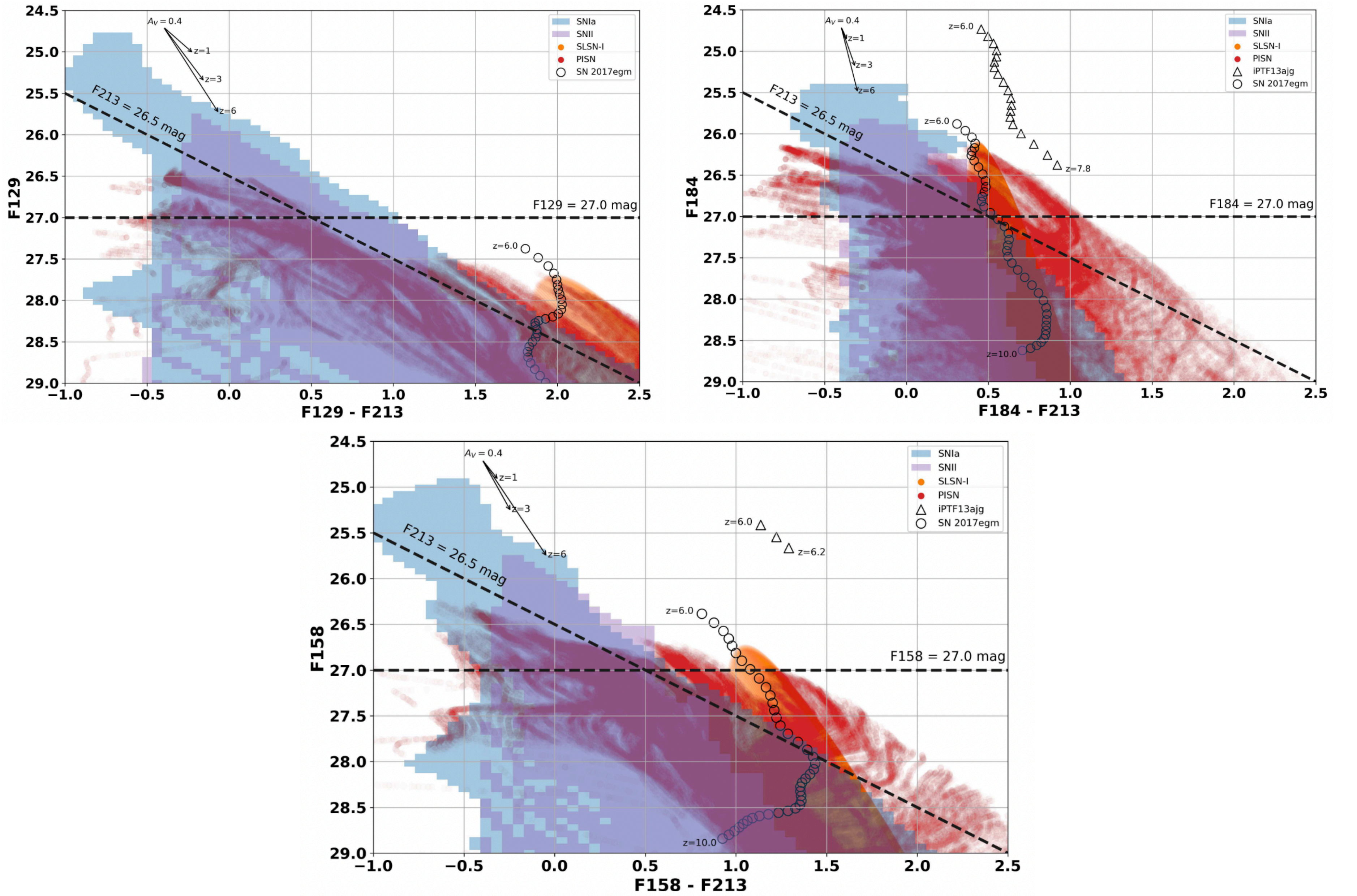
SNe Ia at z > 1.5 **SNe II at z > 1.5** **SLSN at z > 6** **PISN at z > 6**



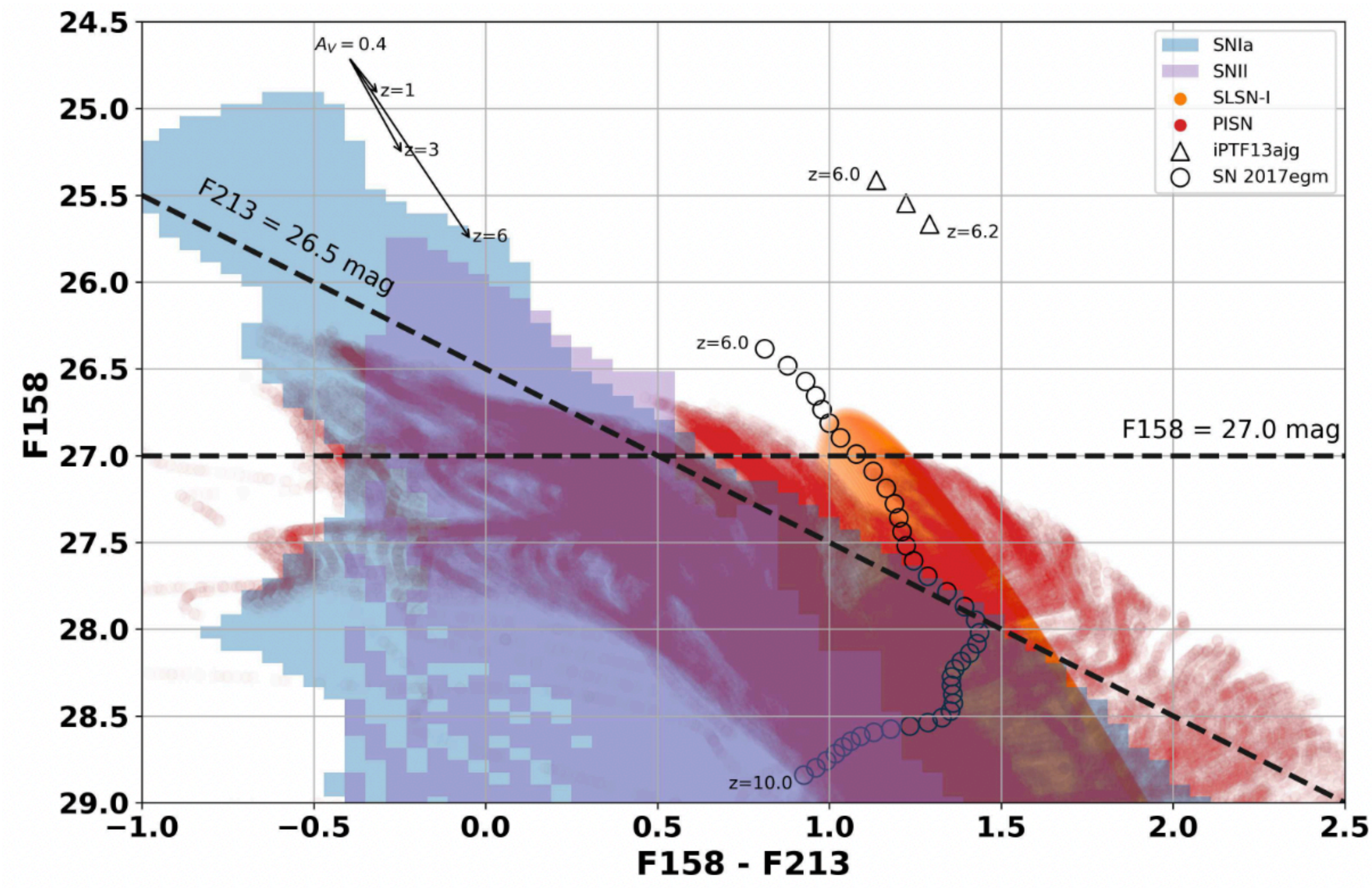
F213 is a must!

(SN Ia cosmology survey doesn't use F213)

Single-epoch candidate screening with CMD

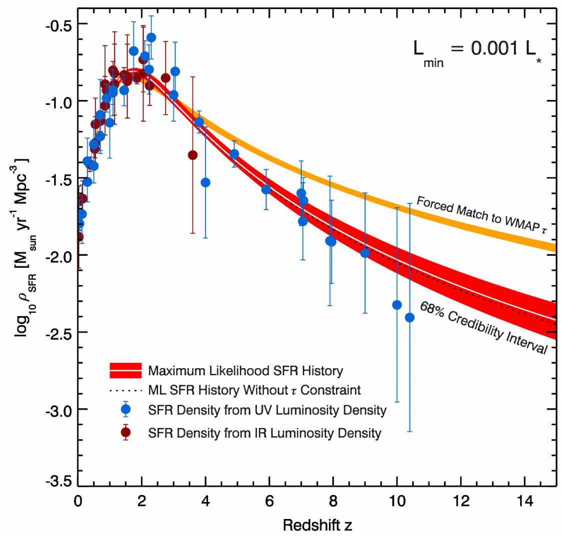


Survey limiting magnitudes



F158 > 27.0 mag & **F213 > 26.5 mag** will identify PISNe/SLSNe

Survey simulations



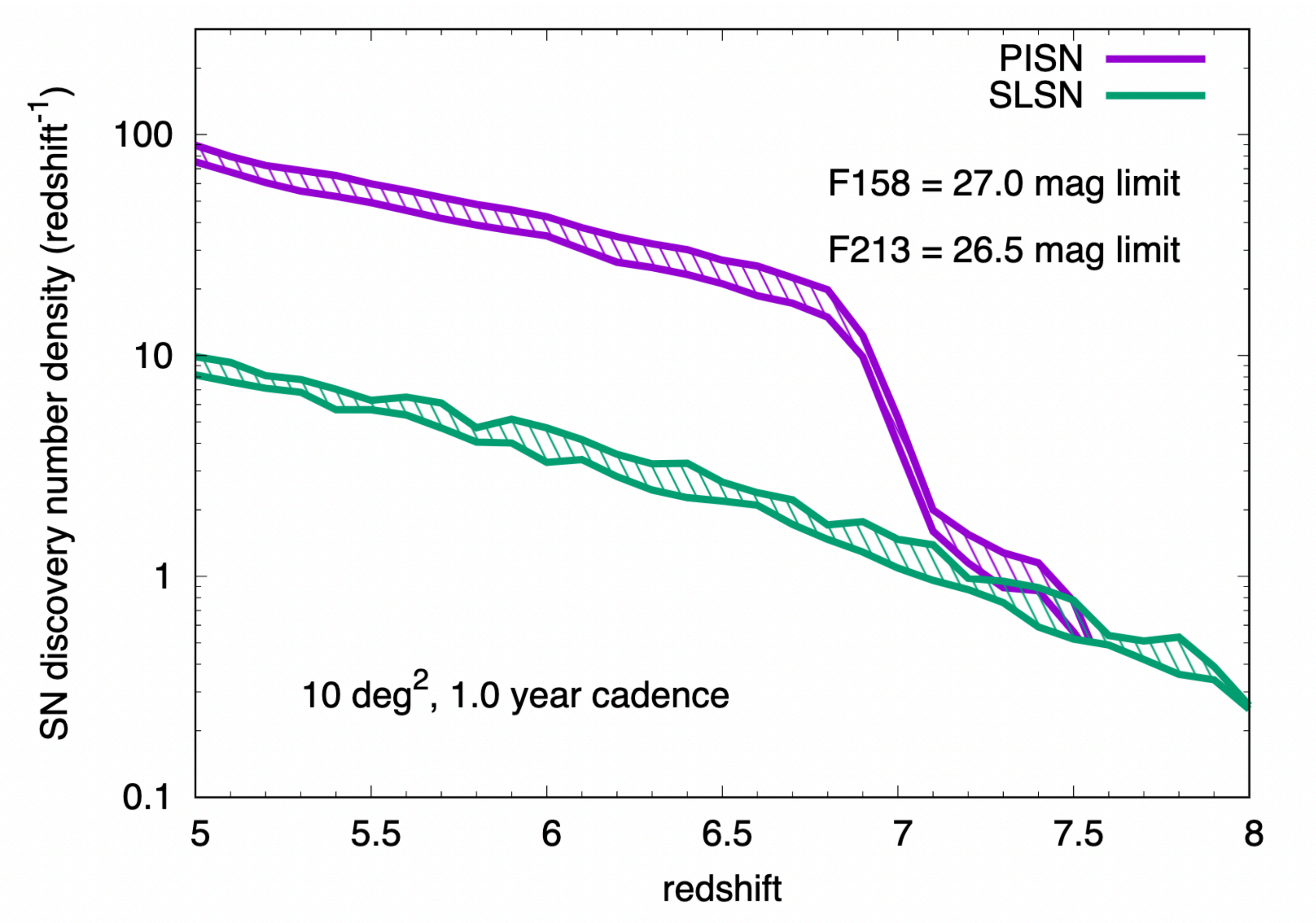
Robertson et al. (2015)

- F158 = 27.0 mag & F213 = 26.5 mag limits
- 10 deg^2, 5 year baseline
- PISN rate based on the SFR density and Saltpeter IMF
- SLSN rate extrapolated based on the local rate and SFR density

Cadence	$t_{\rm total}$	$z > 5.0$	$z > 6.0$	$z > 6.2$	$z > 6.4$	$z > 6.6$	$z > 6.8$	$z > 7.0$
				PISN				
0.5 yr	877 hr	78.9 ± 8.5	24.2 ± 3.3	17.7 ± 2.3	12.1 ± 1.6	7.3 ± 1.0	3.5 ± 0.5	1.2 ± 0.1
1.0 yr	525 hr	76.1 ± 8.2	22.5 ± 2.8	16.0 ± 2.1	10.5 ± 1.4	5.9 ± 0.7	2.1 ± 0.2	0.62 ± 0.08
1.5 yr	385 hr	64.1 ± 6.9	18.4 ± 2.2	13.0 ± 1.7	8.3 ± 1.1	4.5 ± 0.5	1.5 ± 0.1	0.40 ± 0.06
				SLSN				
0.5 yr	877 hr	12.0 ± 1.2	4.4 ± 0.5	3.4 ± 0.4	2.7 ± 0.3	2.0 ± 0.2	1.5 ± 0.1	1.1 ± 0.1
1.0 yr	525 hr	9.1 ± 0.9	3.1 ± 0.3	2.4 ± 0.2	1.8 ± 0.2	1.3 ± 0.1	1.0 ± 0.1	0.76 ± 0.09
1.5 yr	385 hr	5.9 ± 0.6	1.9 ± 0.2	1.5 ± 0.2	1.1 ± 0.1	0.8 ± 0.1	0.6 ± 0.1	0.45 ± 0.09

~ 20 PISNe and ~ 3 SLSNe at z > 6!

Survey simulations



~ 20 PISNe and ~ 3 SLSNe at z > 6!

Summary

- Discovering PISNe & SLSNe at $z > 6$ are essential for understanding reionization and stellar evolution at early Universe

- In order to discover PISNe & SLSNe at $z > 6$, we suggest
    - long-term (5 year) yearly observations of ~ 10 deg2 field
    - with F213 > 26.5 mag and F158 > 27.0 mag per epoch
        - quick and reliable candidate identification to trigger follow-up observations with, e.g., JWST
    - total required time is ~ 525 hours

- ~ 20 PISNe and ~ 3 SLSNe at $z > 6$ will be discovered!

- Roman Early-Definition Astrophysics Survey for high-z PISNe & SLSNe has been proposed by Ori Fox — see his talk on Thursday!