WFIRSTとすばる望遠鏡を使った宇宙再電離期の超新星探査

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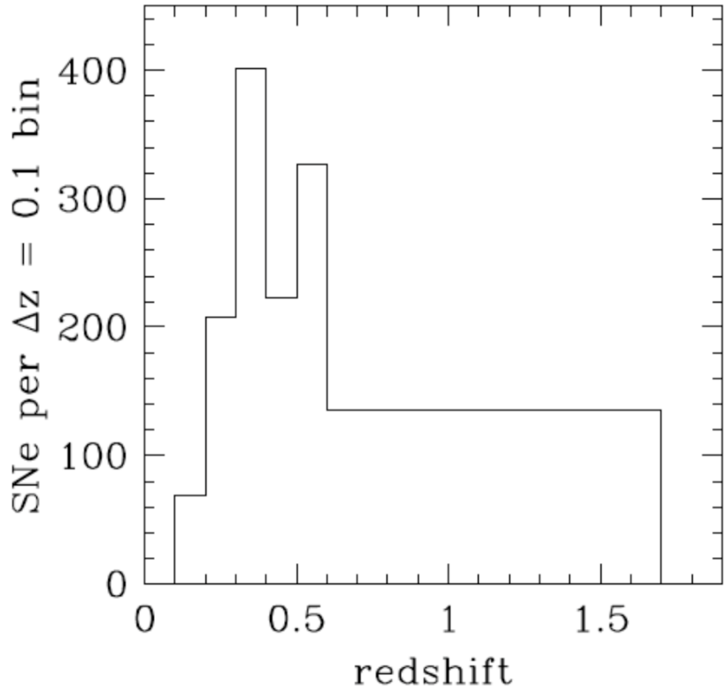
Transient survey in WFIRST

- Main science driver: Type Ia SN cosmology
  - every 5 day for 2 years
  - 30 hours/visit (imaging + IFU spectra)
  - 2700 SNe Ia in total

layer	area (deg2)	filters	depth / visit	targeted SN Ia
wide	27.44	Y, J	24.5 mag	z < 0.4
medium	8.96	J, H	25.5 mag	z < 0.8
deep	5.04	J, H	26.5 mag	z < 1.7

Spergel et al. (2015)

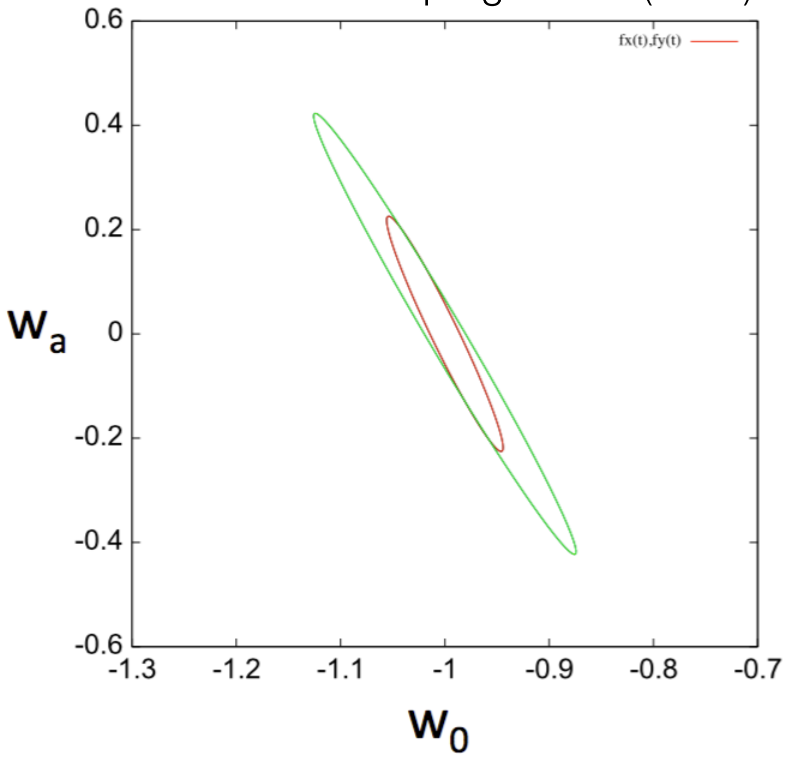


What WFIRST wants from ground telescopes

- low-redshift SNe Ia (pre-survey)
  - 800 SNe Ia at z<0.1
- photo-z for candidate selection

- coordinated observations not required
  - IFU for spectroscopy
  - better to have them
    - color selection
    - LSST field?

Spergel et al. (2015)



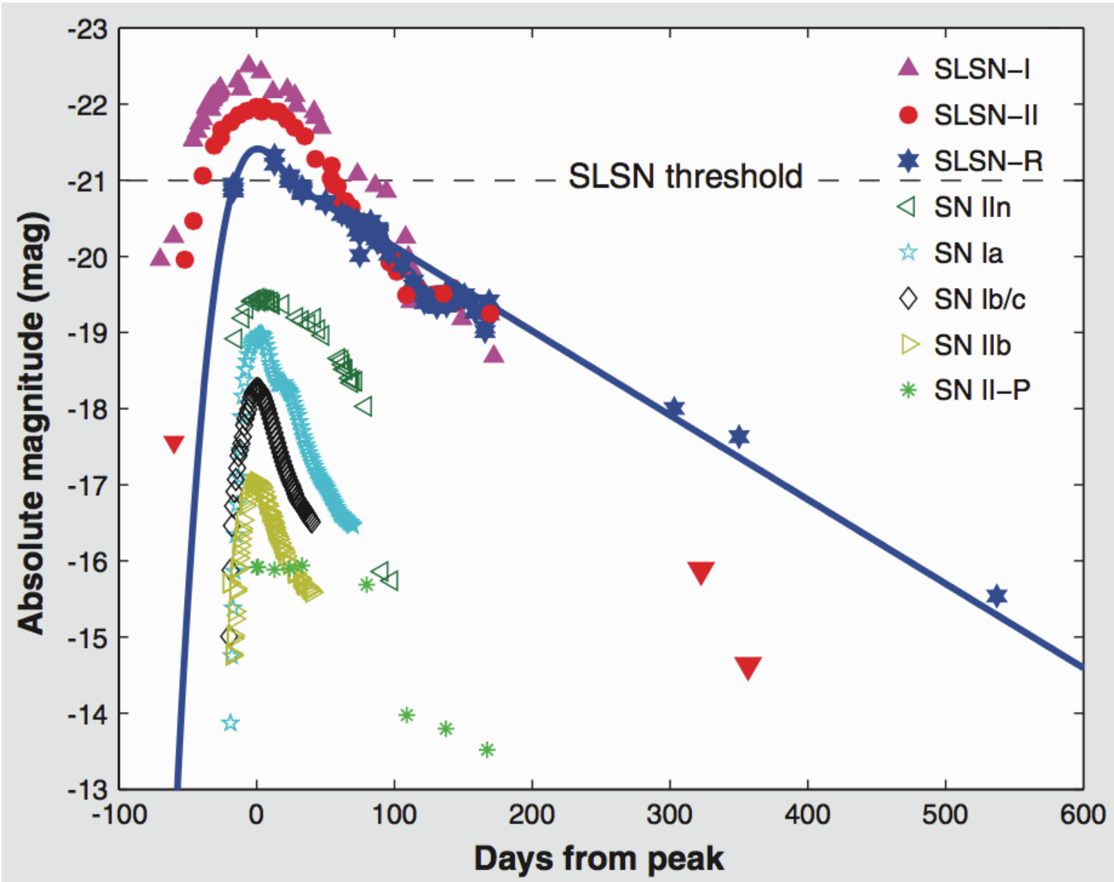
Science with Subaru

Supernovae at the reionization era and beyond with Subaru/HSC

Superluminous supernovae (SLSNe)

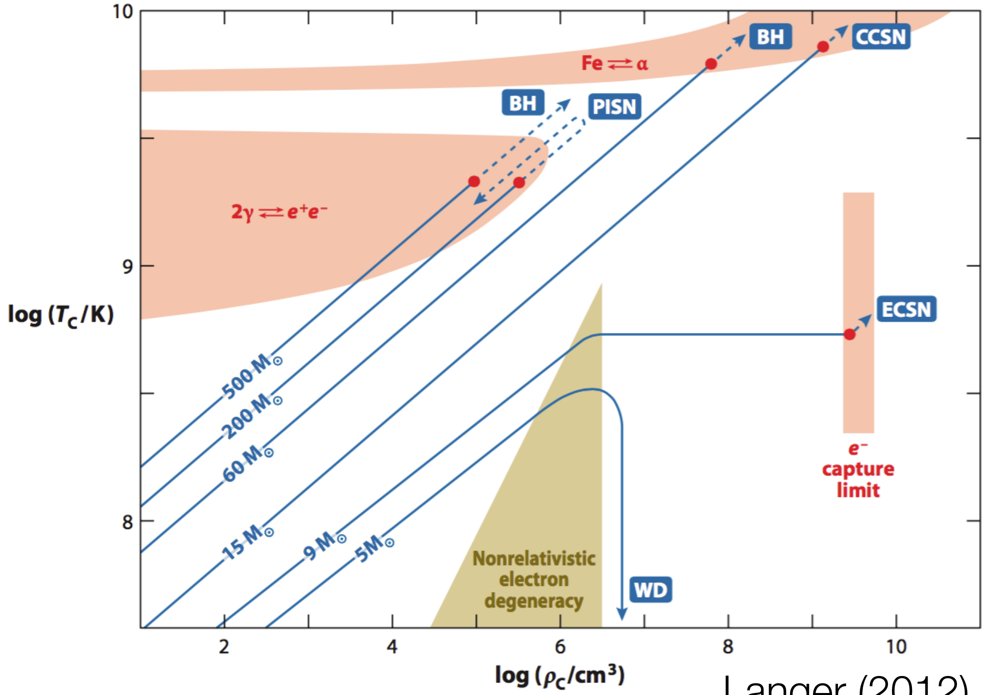
- a new member of SN family
  - started to be discovered from ca. 2005
  - bright and blue

Gal-Yam (2012)



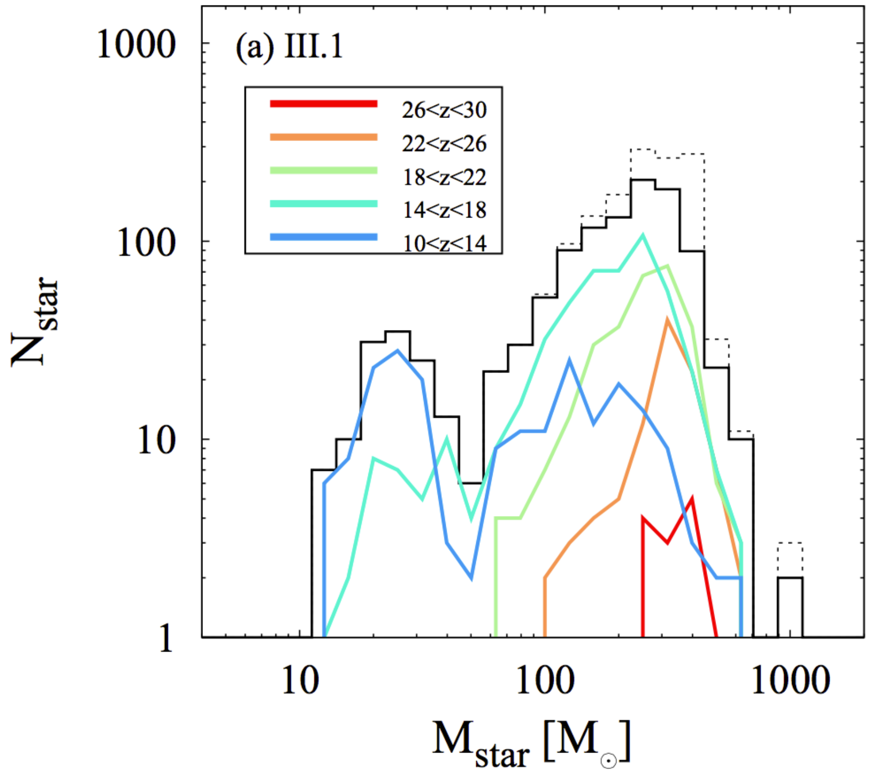
How can SNe become superluminous?

- large production of 56Ni (more than 5 Msun)
  - pair-instability supernovae (PISNe)
    - explosions of stars between ~150 Msun and ~250 Msun
    - only exist in metal-poor environment (Z < ~ Zsun/3)
    - first massive stars!



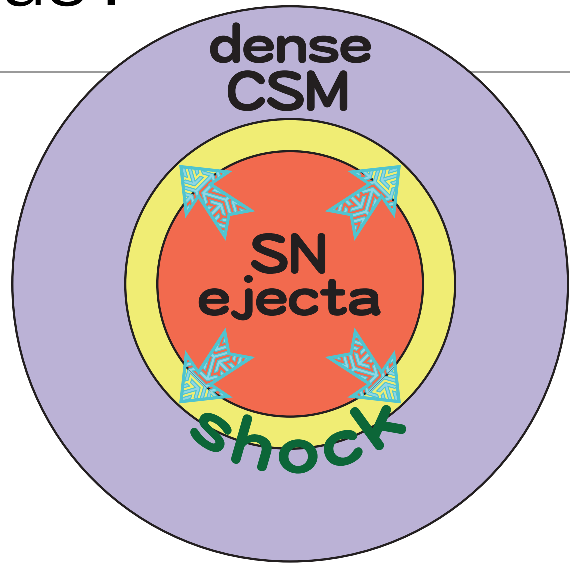
Langer (2012)

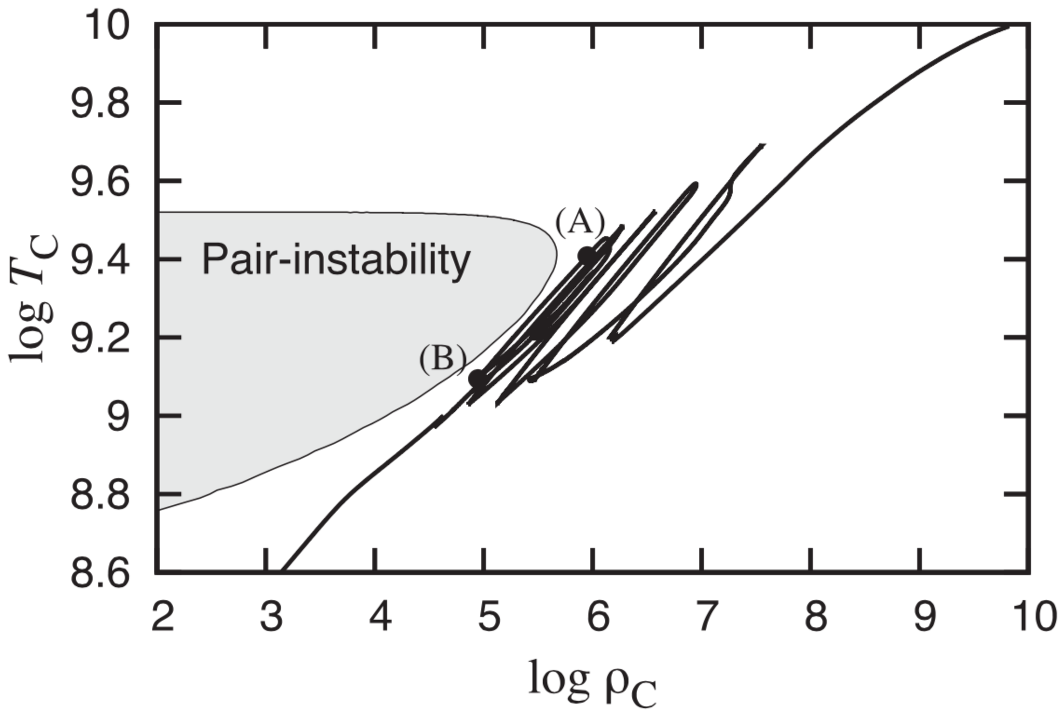
Hirano et al. (2014)



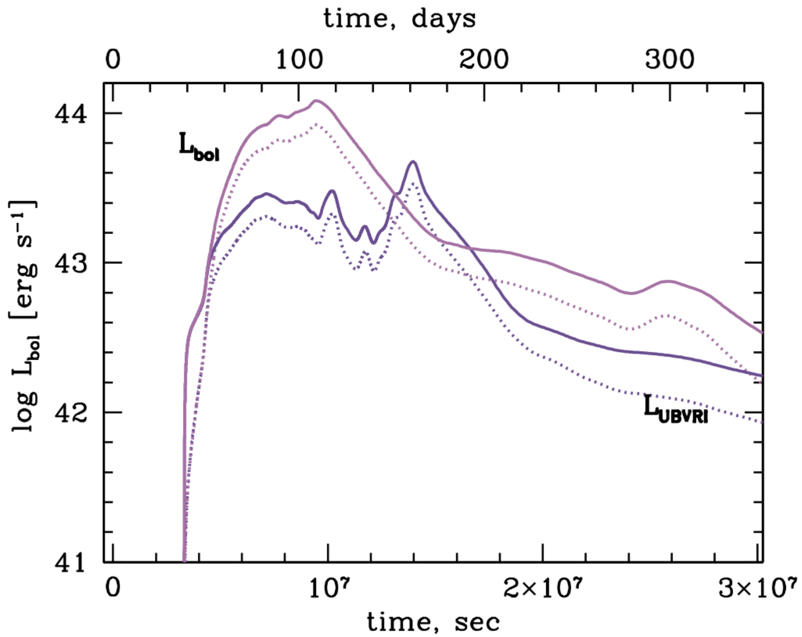
How can SNe become superluminous?

- interaction between SN ejecta and dense CSM
  - ~ 10 Msun CSM required
    - pulsational pair-instability
    - or other mechanisms





Yoshida et al. (2016)



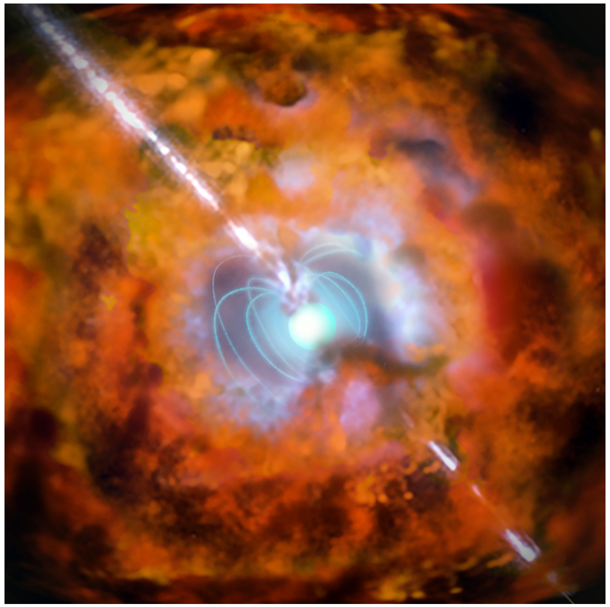
Woosley et al. (2007)

How can SNe become superluminous?

- magnetars
  - rapidly-rotating strongly-magnetized neutron stars
  - huge rotational energy can be emitted with a timescale of ~ 10 days

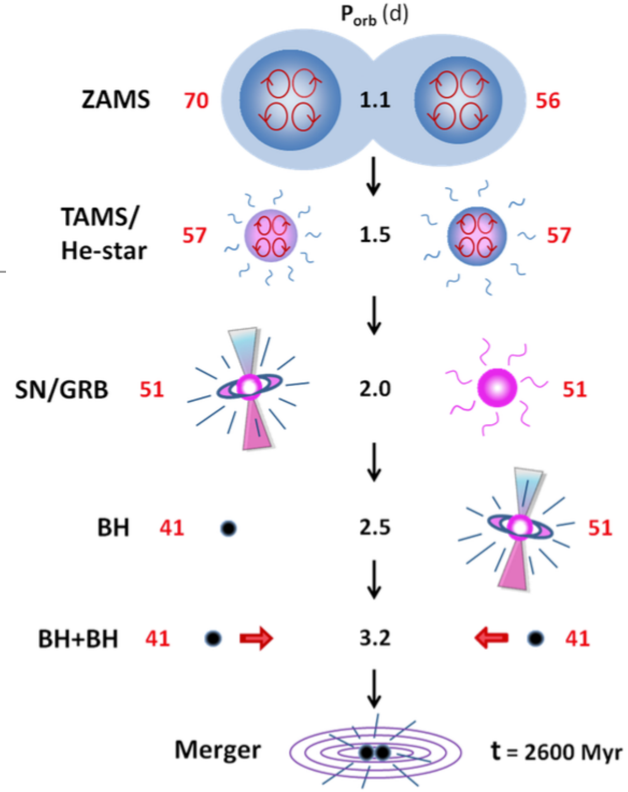
$$E_p = \frac{1}{2} I_{\mathrm{NS}} \Omega_i^2 \simeq 2 \times 10^{52} P_{\mathrm{ms}}^{-2} \ \mathrm{erg}$$

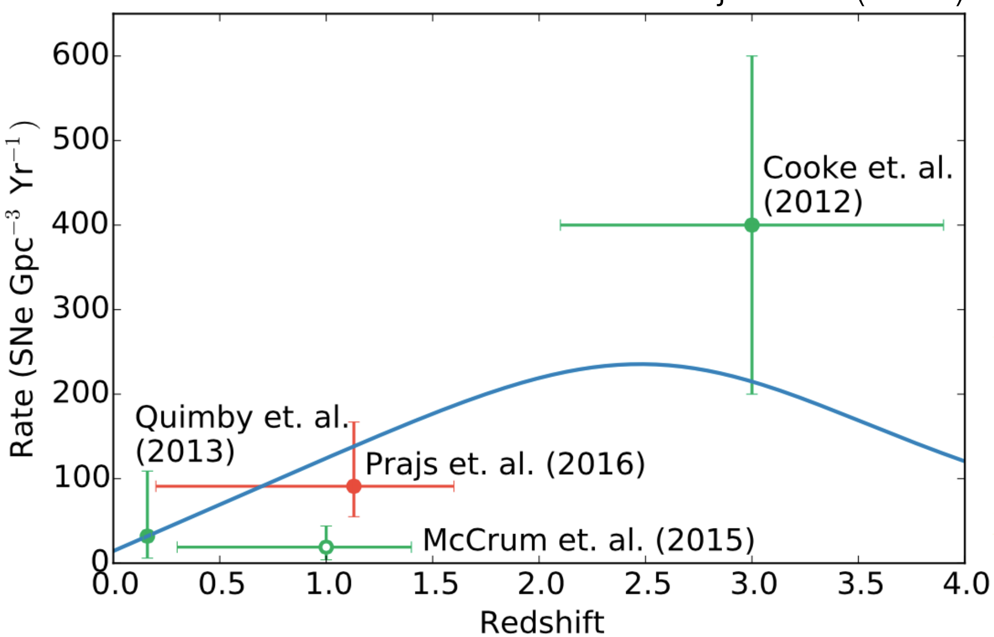
$$t_p = \frac{6 I_{\mathrm{NS}} c^3}{B^2 R_{\mathrm{NS}}^6 \Omega_i^2} \simeq 4.1 \times 10^5 B_{14}^{-2} P_{\mathrm{ms}}^2 \ \mathrm{sec}$$

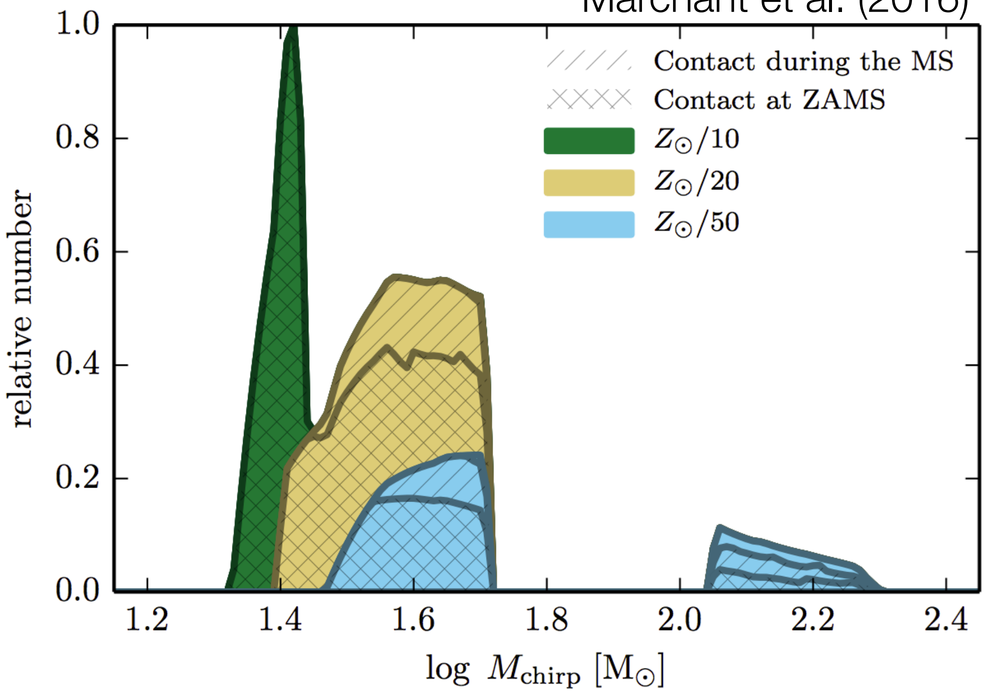


What SLSNe tell us?

- massive star population
  - SLSNe are from massive stars
- massive stars preferentially formed at high-z?
  - reionization
  - are there PISNe?
    - synergy with GW astronomy



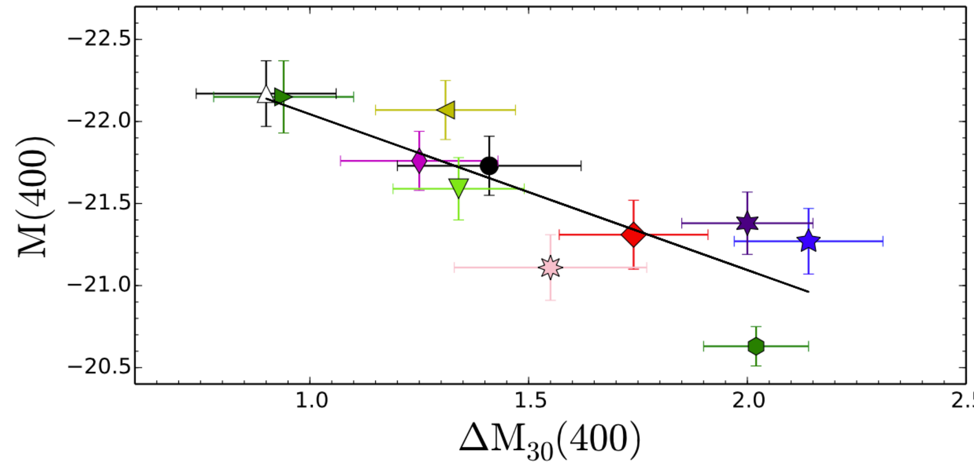




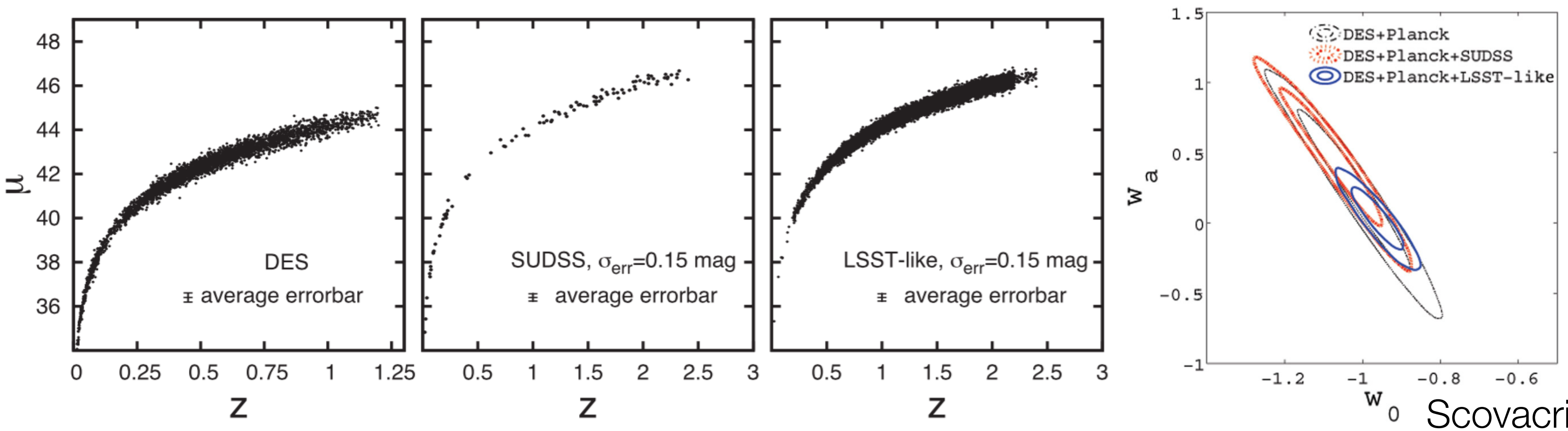
Cosmology with SLSNe

- possible relation between peak luminosity and decline rate
    - like in Type Ia SNe

Inserra & Smartt (2014)



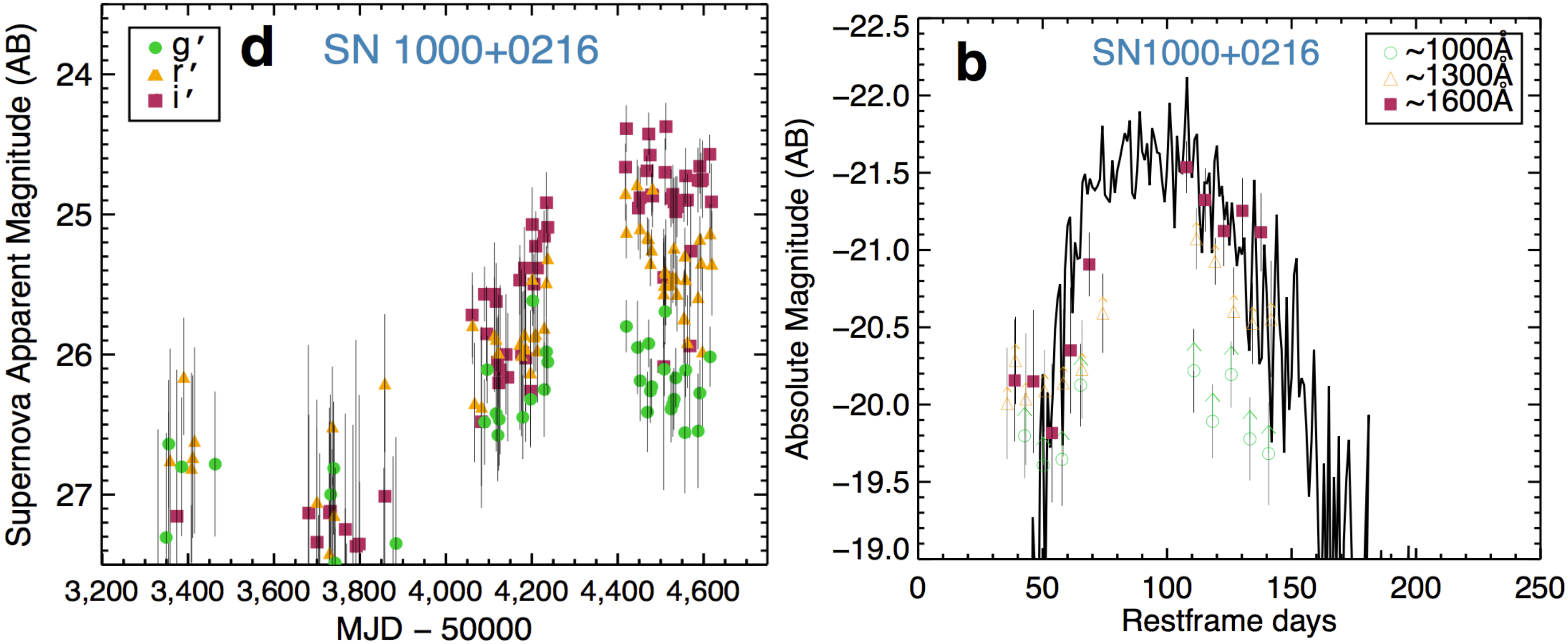
- Hubble diagram and constraint on the dark energy equation of state



Scovacricchi et al. (2016)

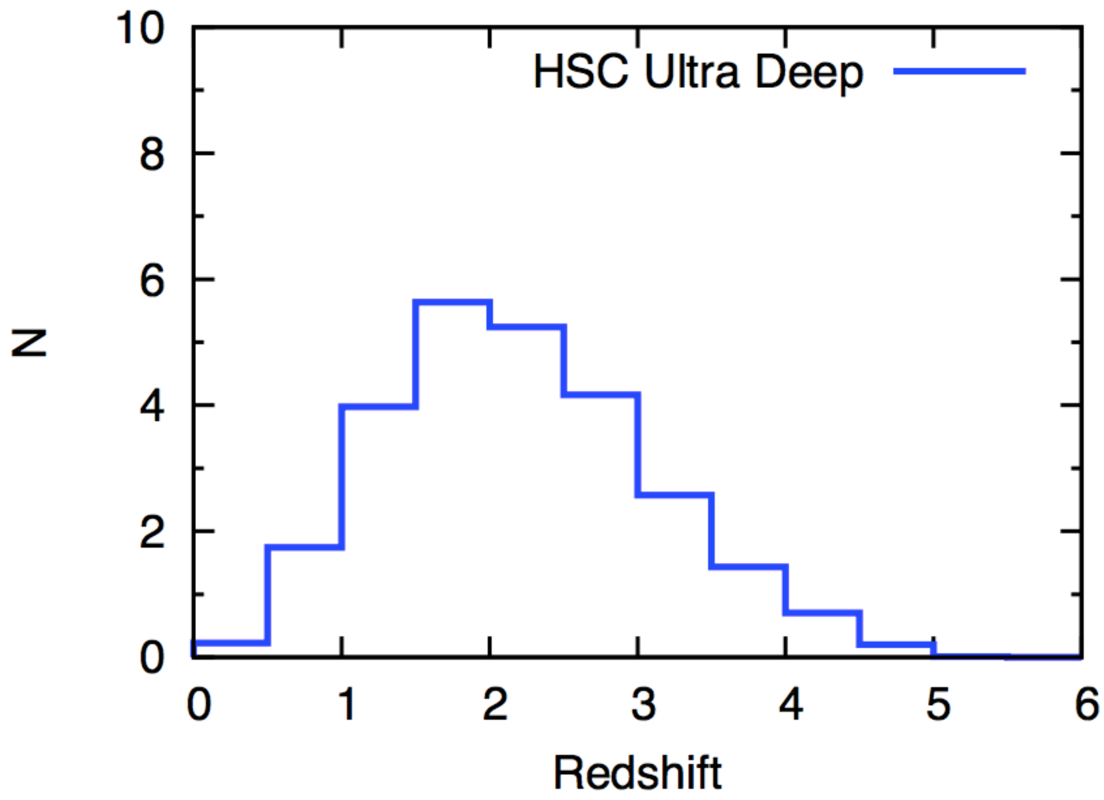
Current highest-redshift SLSN

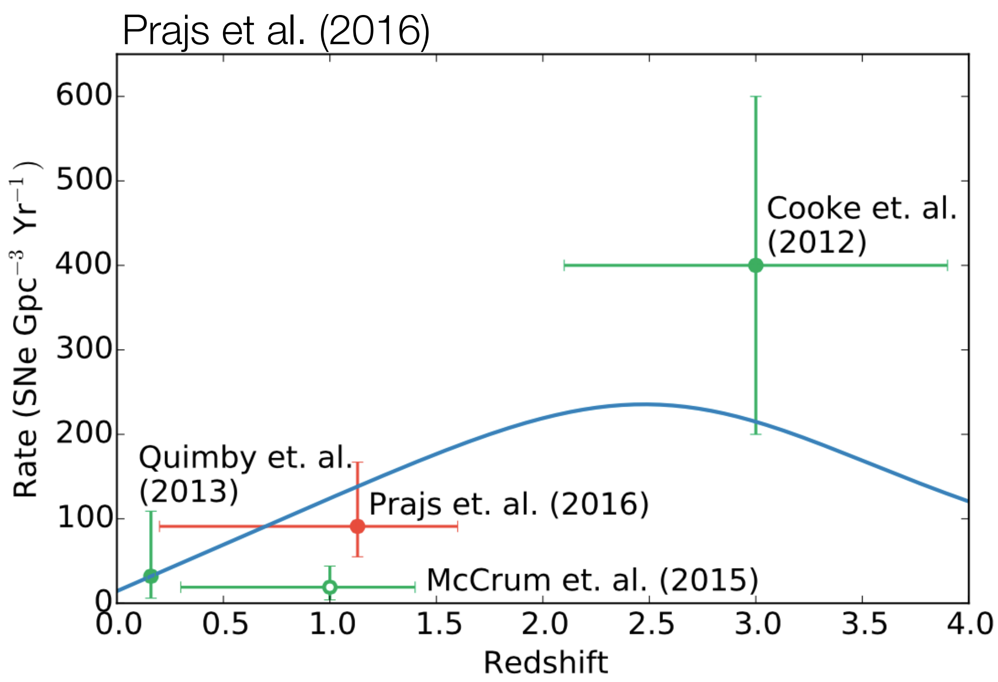
- z = 3.9 (Cooke et al. 2012)
    - with CFHT/MegaCam
    - redshift from the host galaxy



z<6 with Subaru (optical)

- HSC SSP can reach z~4
  - from this November
  - only two SLSN (candidates) at z>2 are currently known
  - first SNe at z>2 with spectroscopic confirmation





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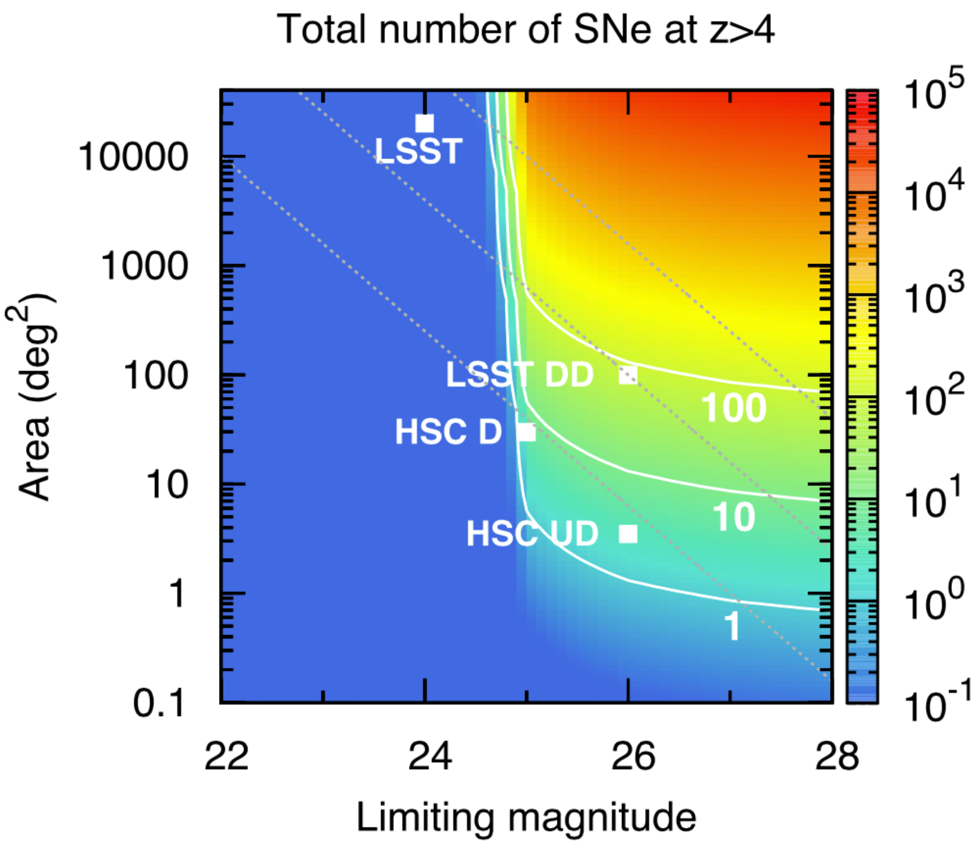
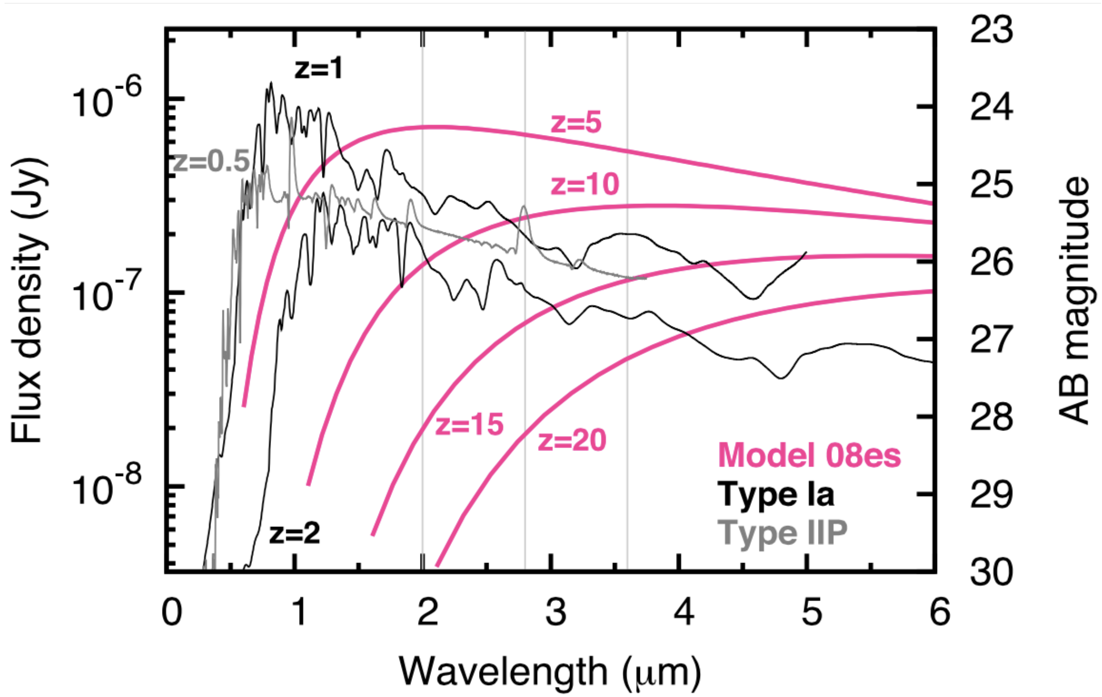
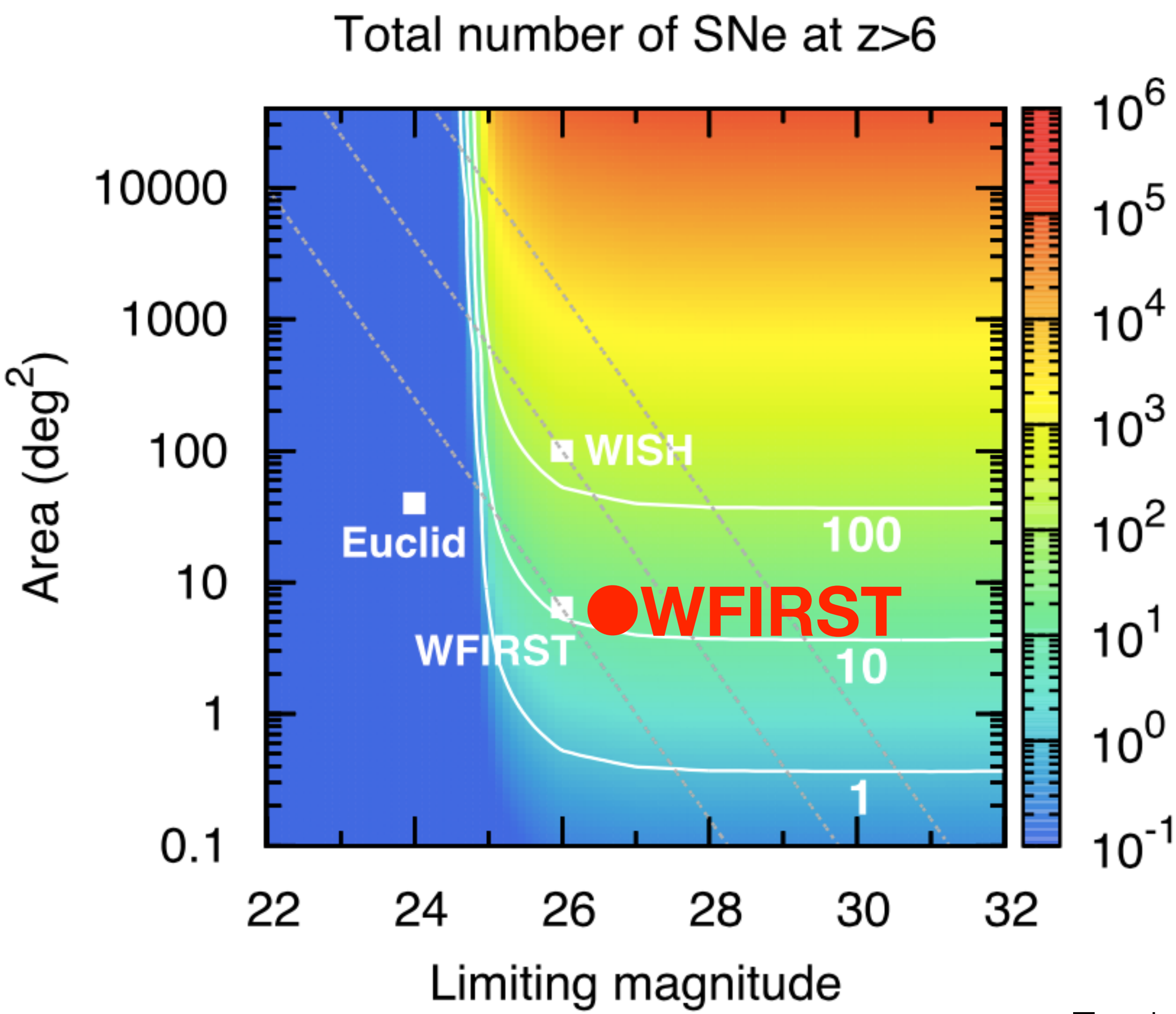




Tanaka, Moriya, & Yoshida (2013)

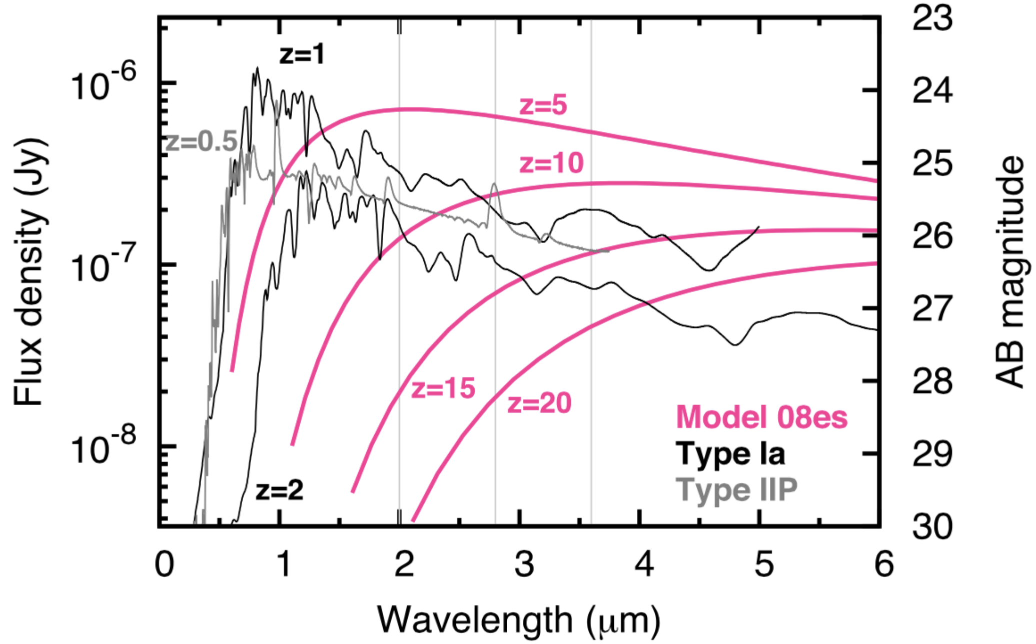
NIR transient survey



Tanaka, Moriya, & Yoshida (2013)

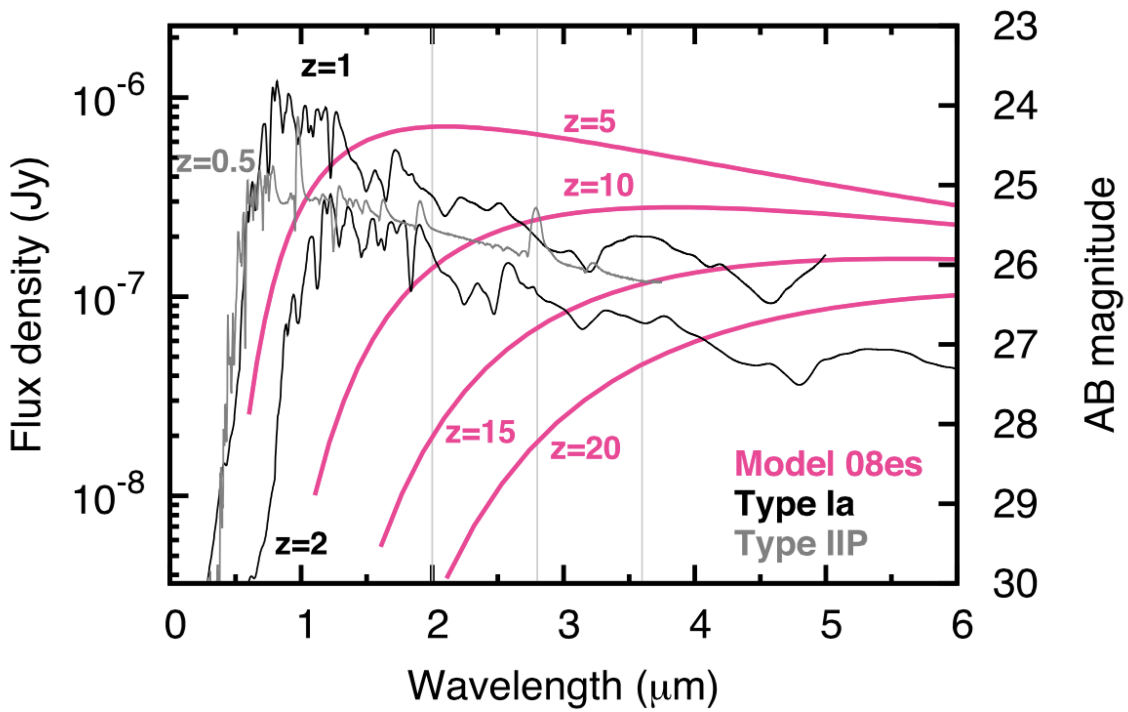
How to confirm the SNe at the reionization era

- spectral observations for all candidates are difficult
  - faint (~26 mag in NIR)
- host galaxies are too faint - they will be “hostless”
  - no photo-z

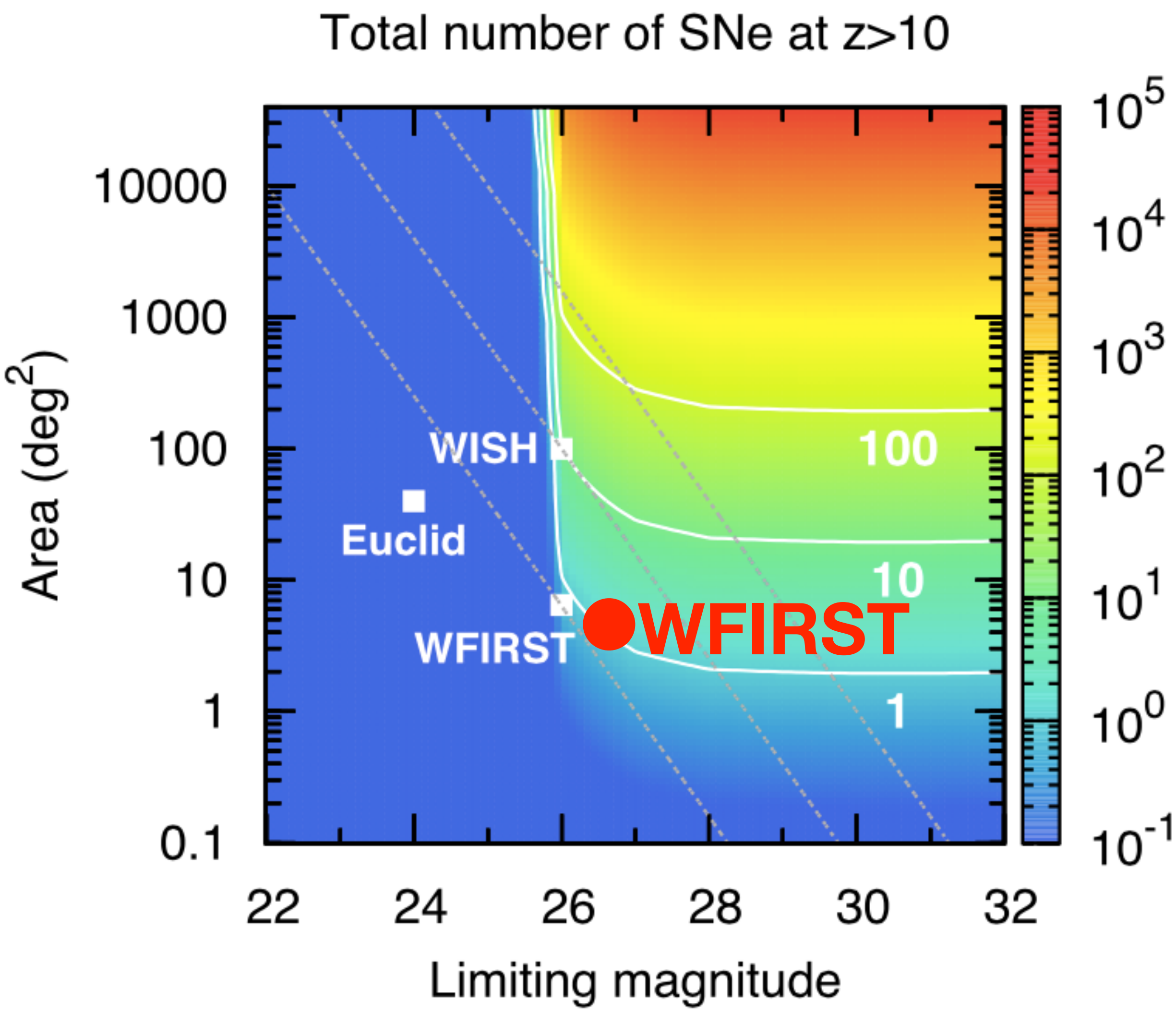


How to confirm the SNe at the reionization era

- if we have very deep z band from HSC at the same time
  - high-z SNe will not be detected in z band
    - high-z SNe will be detected as “z-drop” hostless SNe
  - observe the same field as the NIR survey to find “z-drop” SNe
- 27 mag in z band (~ 11 hours for S/N = 5)
  - ~55 hours for 5 deg2 (deep field)
  - x a few epochs
  - hard for LSST?
- Y band is too shallow



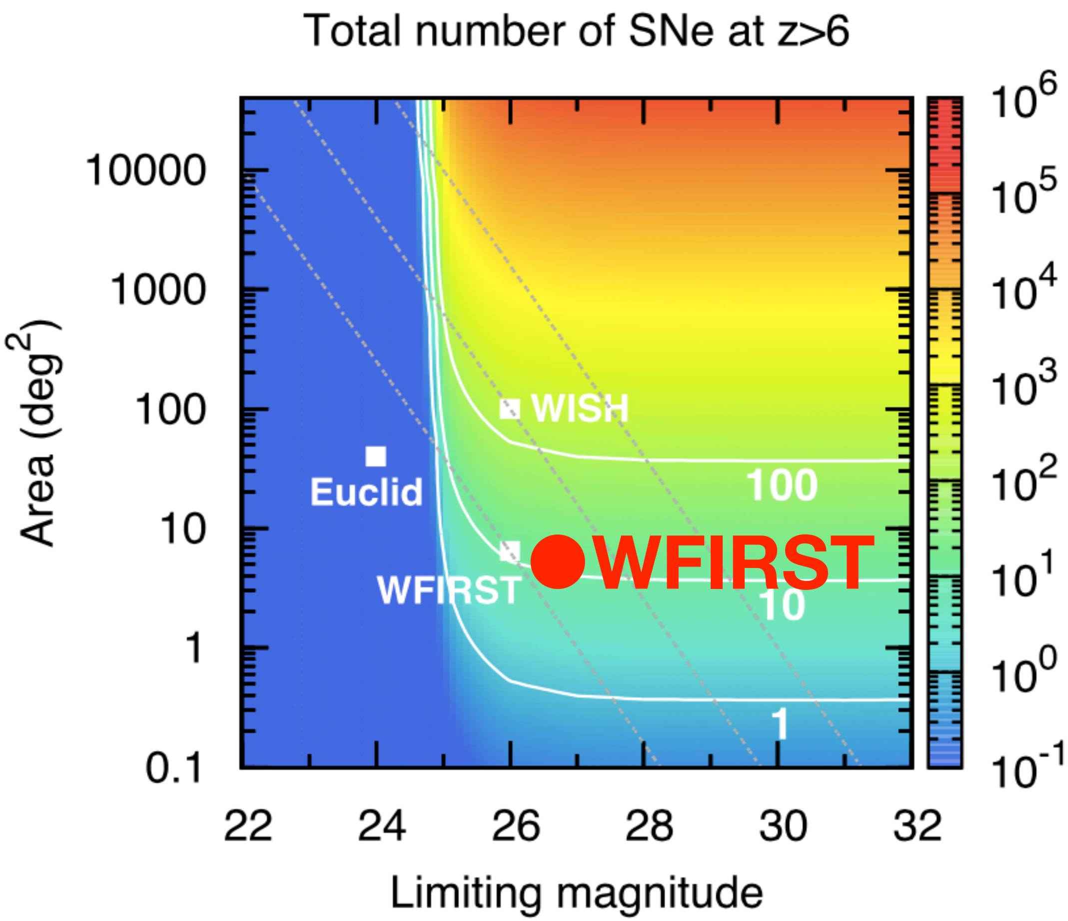
z>10: towards the first explosions



Tanaka, Moriya, & Yoshida (2013)

WFIRST

- Depth
  - 26.5 mag
- Area
  - 5 deg2
- Duration
  - 2 years
  - 50 days at z~6 = 1 year
- Time
  - 2024 or later
  - JWST is from 2018
    - for ~5+ years
  - TMT from 2028



Summary

- supernovae with WFIRST
  - main goal is SN Ia cosmology
    - low-z SNe Ia from ground-based optical survey
    - photo-z
  - SLSNe at the reionization era will be discovered with Subaru
    - coordinated deep observations in z band
    - look for “z-drop” SNe
      - ~ 100 - 200 hours/epoch in z band for several epochs
      - deep z band images will be obtained as well
      - difficult with LSST?
    - long survey period of WFIRST is good for high-z SNe
    - can be coordinated with TMT (2028 -) and JWST (2018 - ?)
  - optical observations coordinated with space are interesting!