

Supernova shock breakout and HSC transient survey

Nozomu Tominaga
(Konan University)



27th Aug 2014

長瀧天体ビッグバン研究室主催
超新星・ガンマ線バースト研究会 2014

Outline

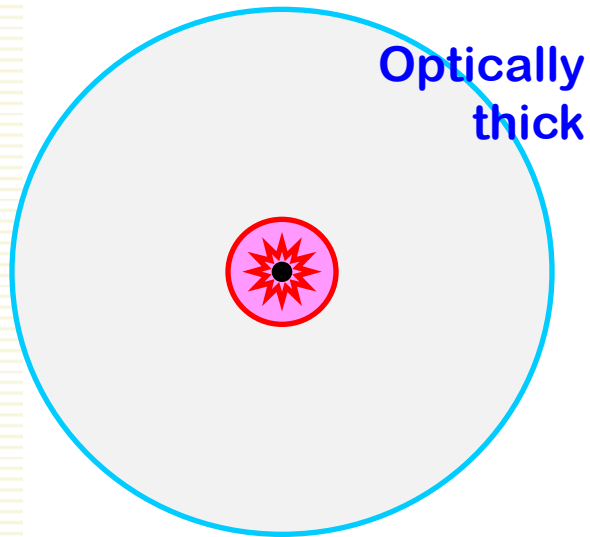
- **Shock breakout**
 - Observations of shock breakout
 - Theoretical model of shock breakout
- **Supernova surveys**
 - Shock breakout survey with Hyper Suprime-Cam
 - Transient survey in strategic survey program

Shock breakout

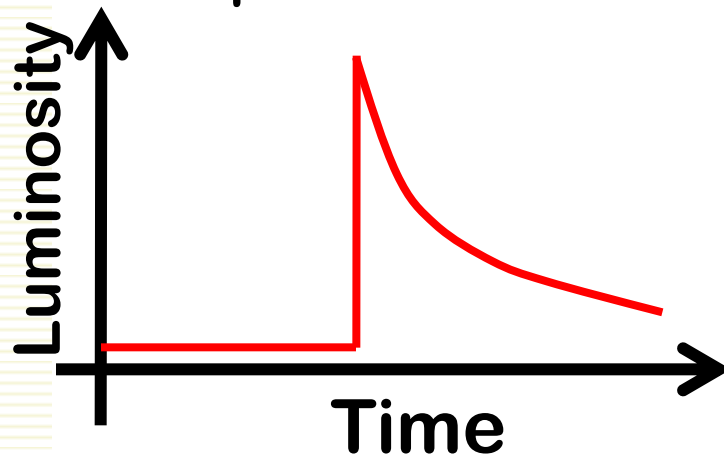
NT, Blinnikov, Baklanov, + 2009 ApJ 705 L10

NT, Morokuma, Blinnikov, + 2011 ApJS 193 20

What is shock breakout?



Core collapse



Massive Star ($>10M_{\odot}$)

e⁻-capture SNe ($8-10M_{\odot}$)

Core collapse

Shock formation



At the shock emergence,
a stored energy is released
as **radiation**.

Spectra are quasi-blackbody

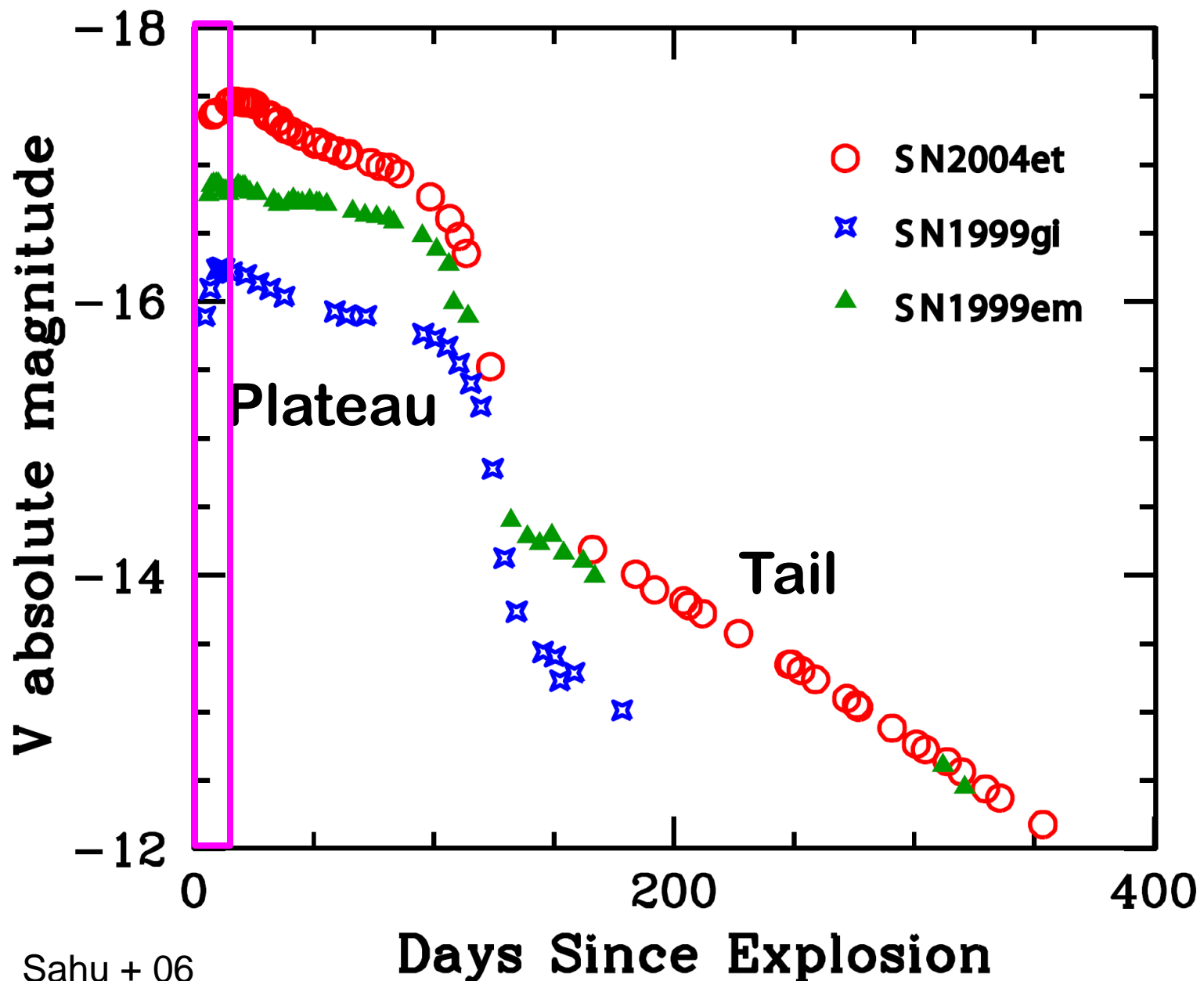
$$T \sim R^{-3/4} E^{1/4}$$

Typical properties

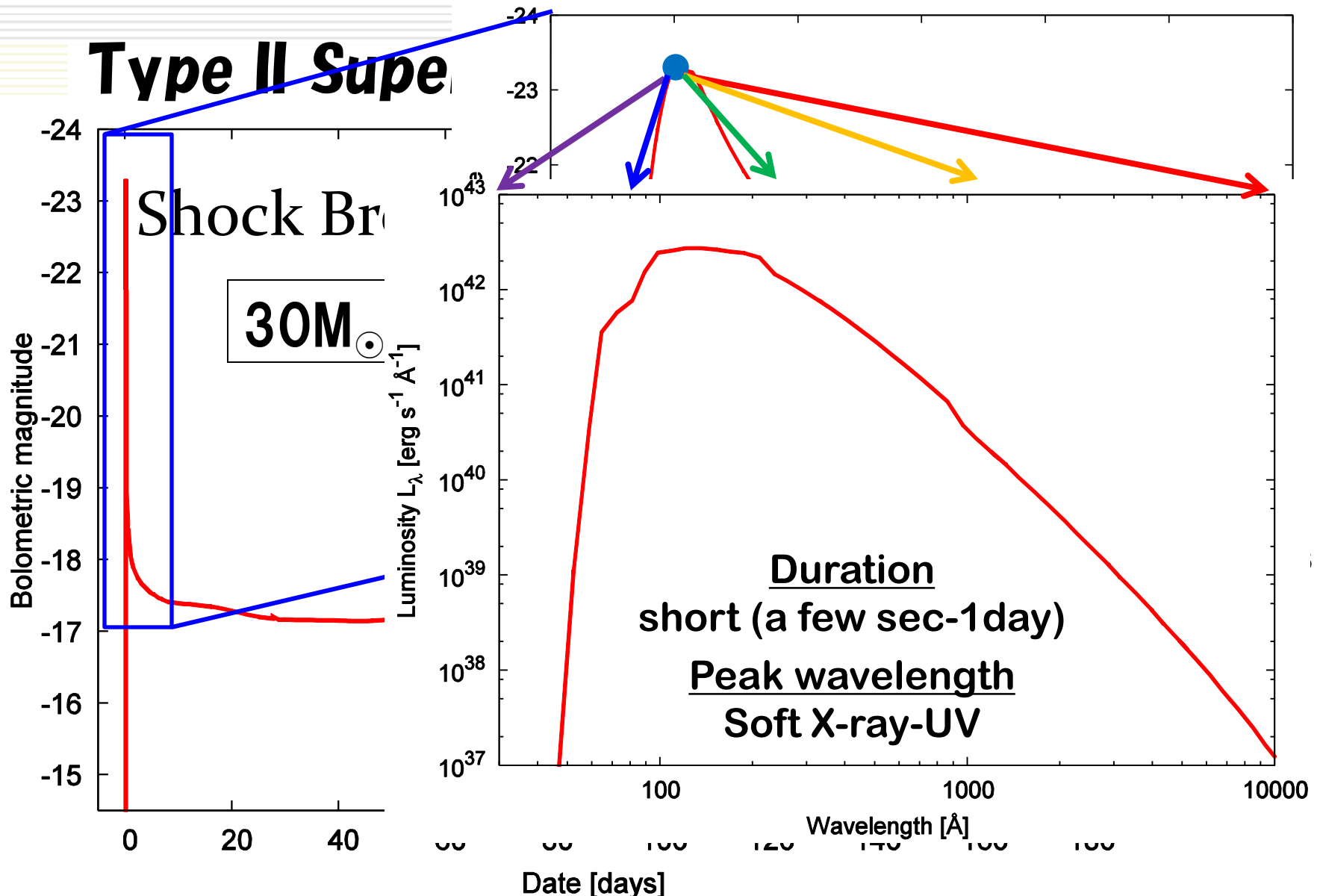
timescale: 100sec ~ 1day

peak wavelength: X-ray ~ UV

V-band LCs of Type IIP SNe



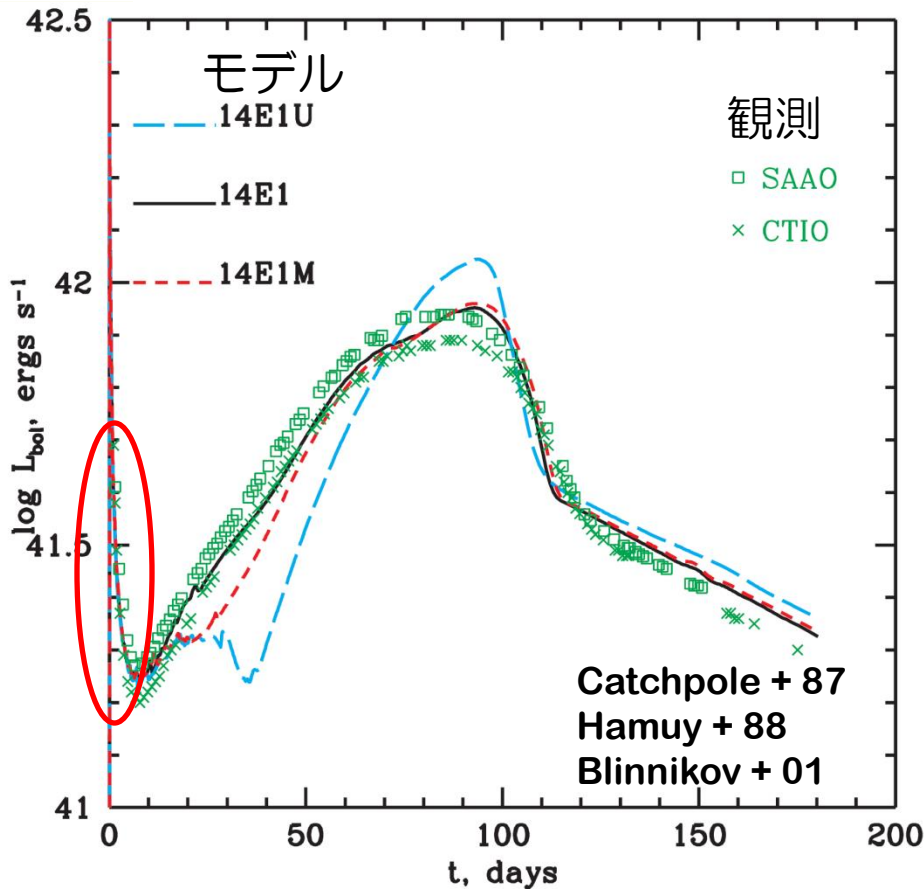
Light curve of a Type II SN



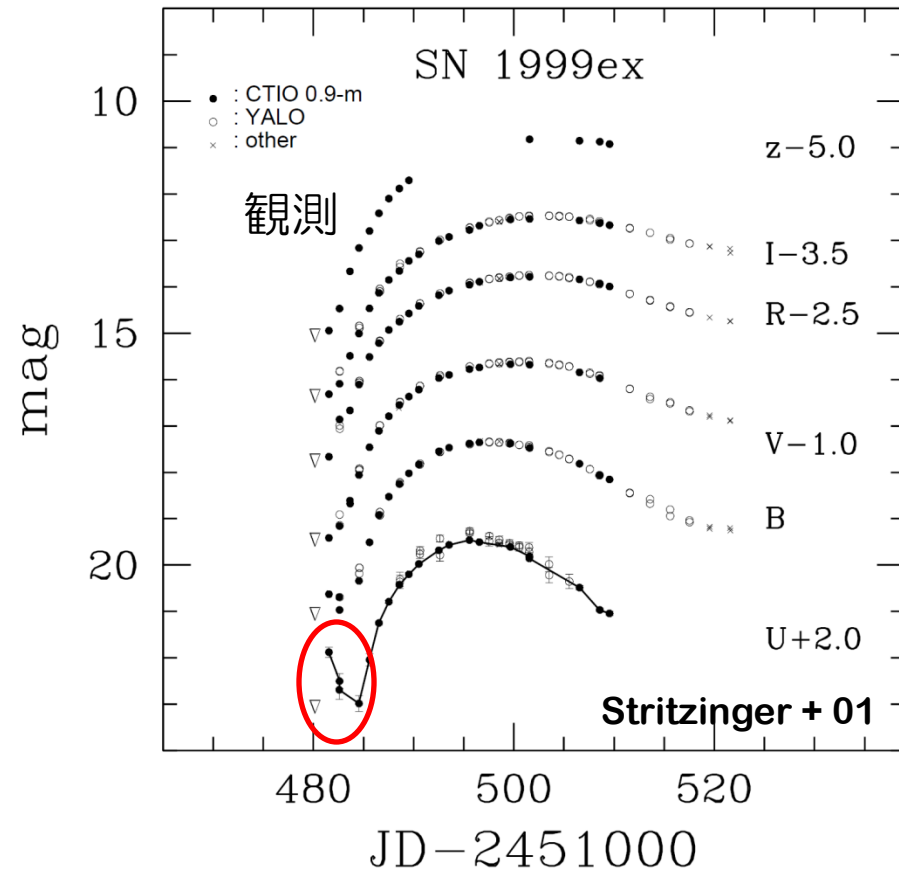
Shock breakout tail

—Observations before 2008—

Type II-peculiar SN1987A

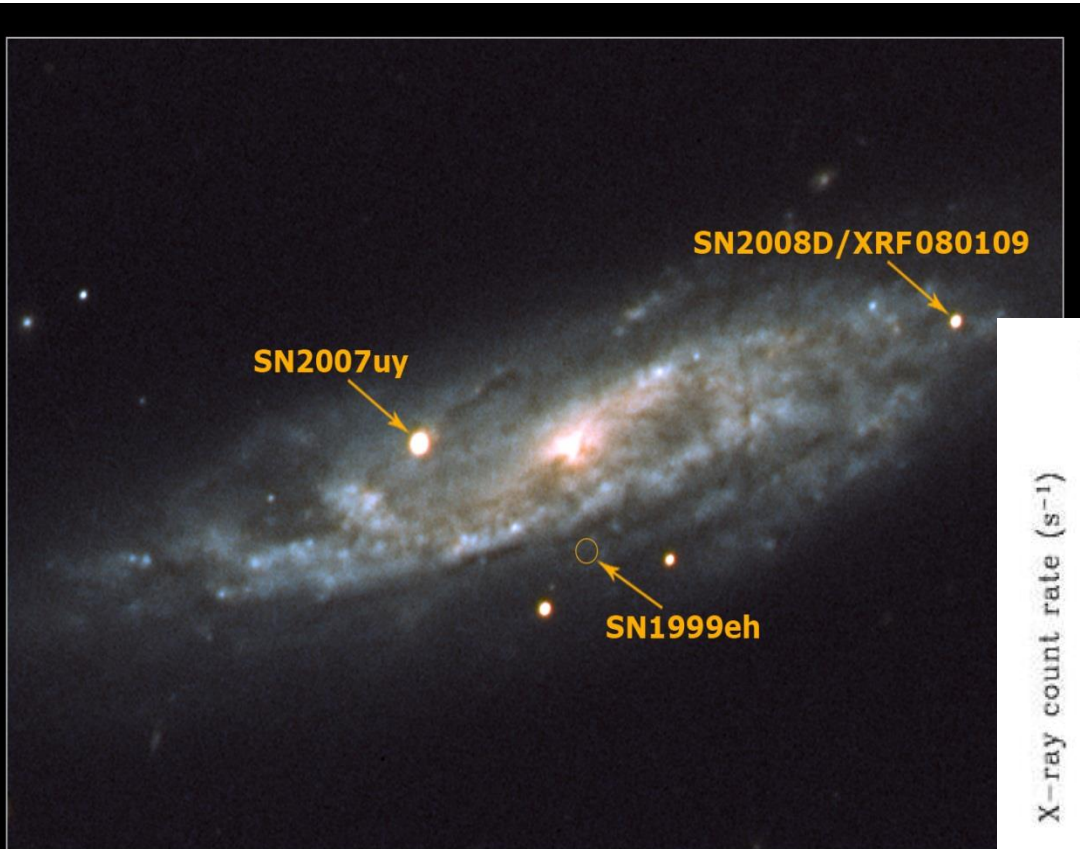
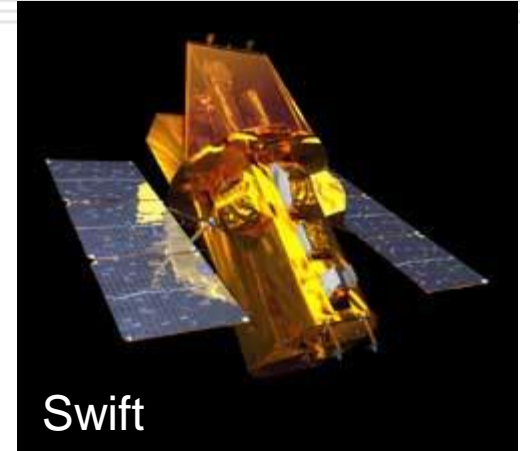


Type Ib SN1999ex

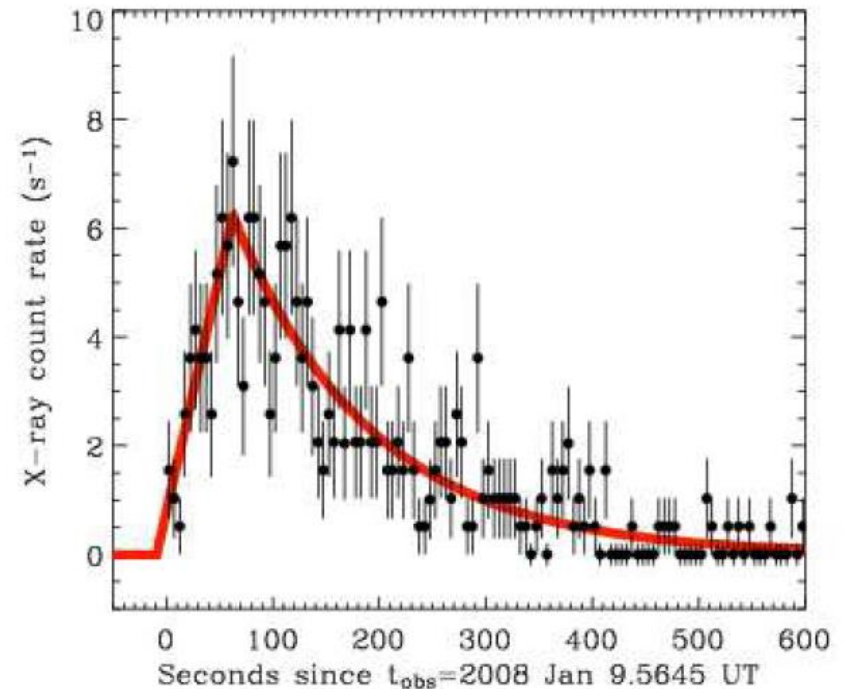


Serendipitous detection of shock breakout -Type Ib SN2008D/XRF080109-

Soderberg + 08; Modjaz + 09



NGC 2770
Supernova factory



Shock breakout of Type IIP SNe

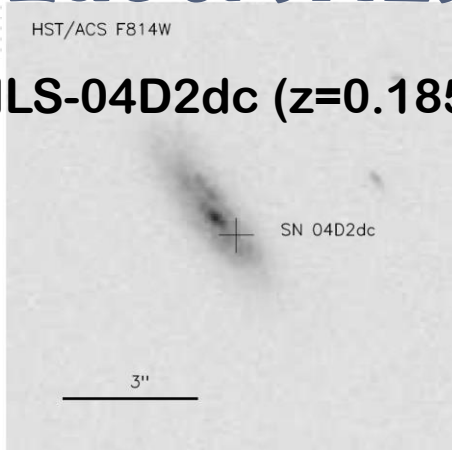
-SNLS-04D2dc & SNLS-06D1jd-

SNLS SuperNova Legacy Survey



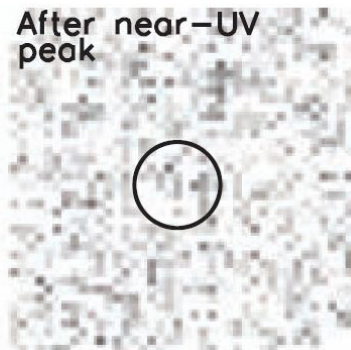
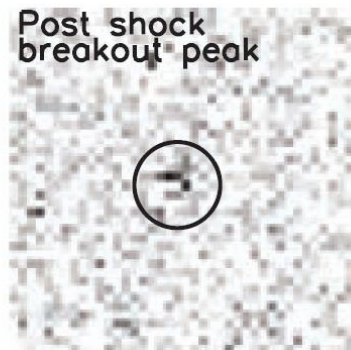
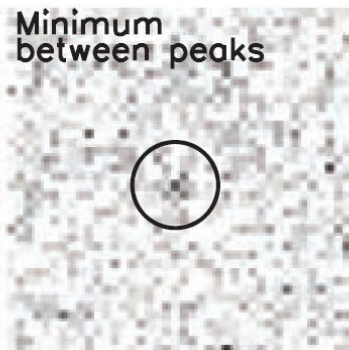
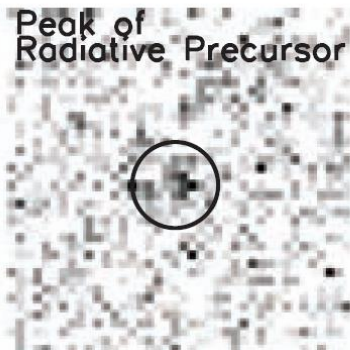
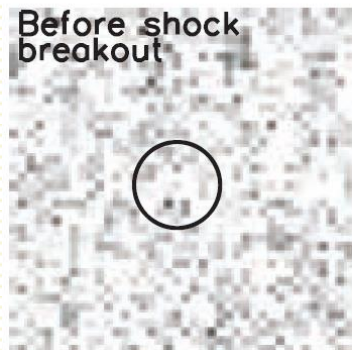
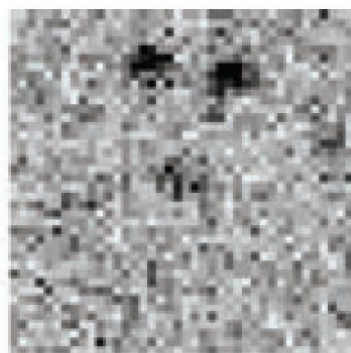
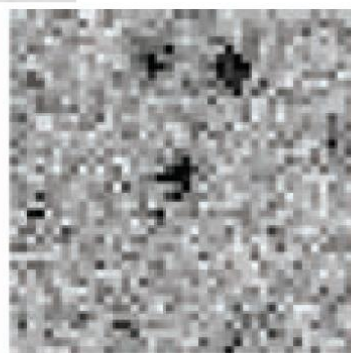
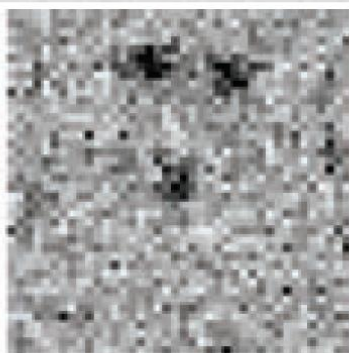
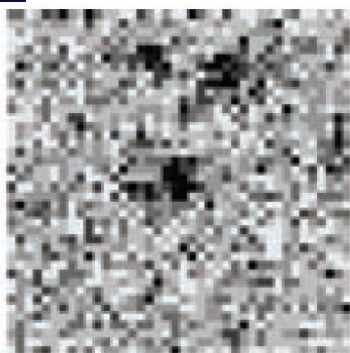
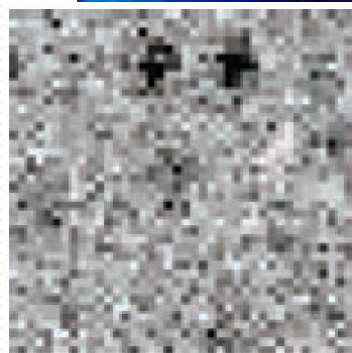
HST/ACS F814W

SNLS-04D2dc ($z=0.1854$)



Schawinski et al. 08

Gezari et al. 08



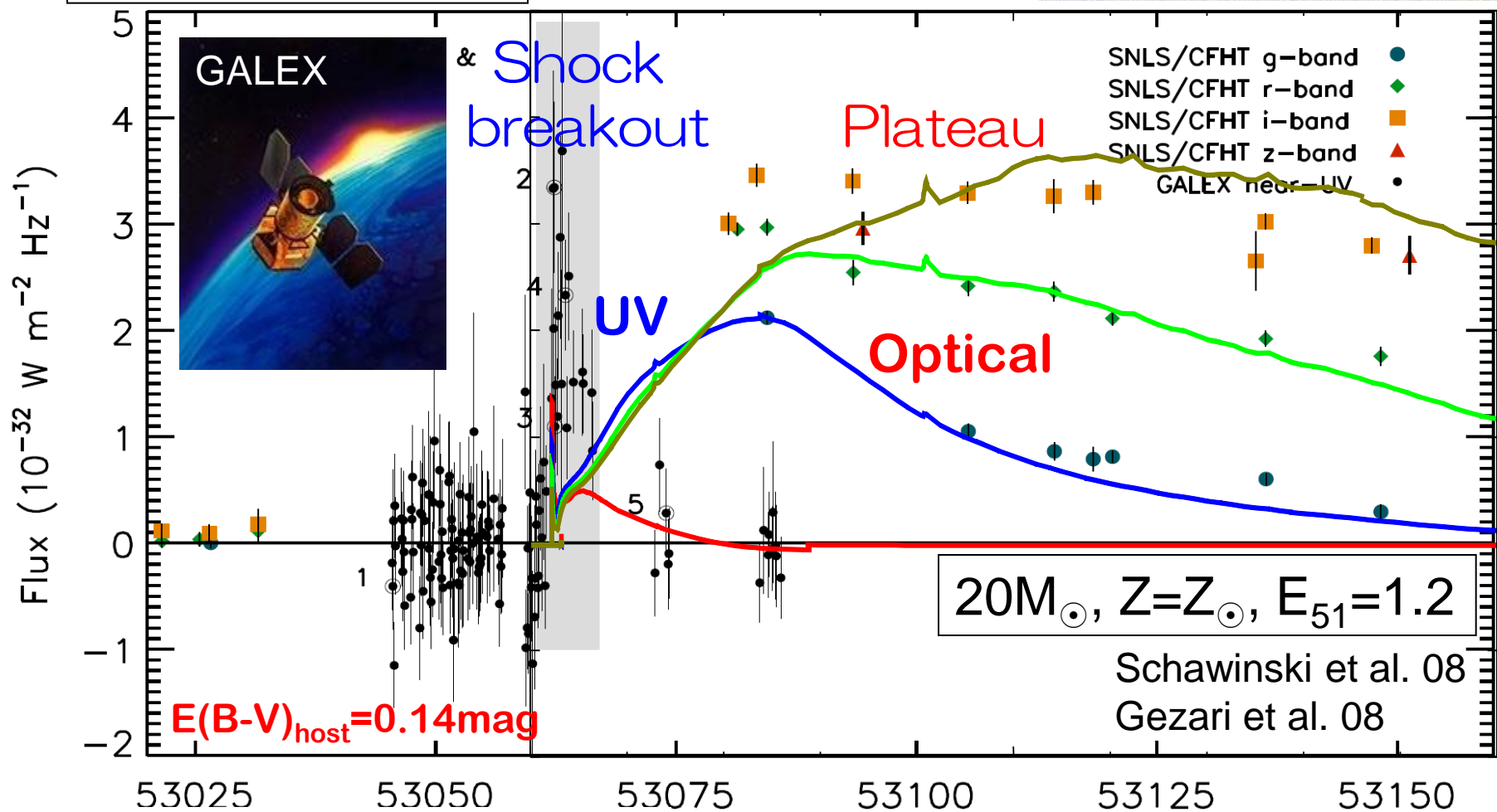
Shock breakout of Type IIP SN

— Observations and model —

SNLS-04D2dc

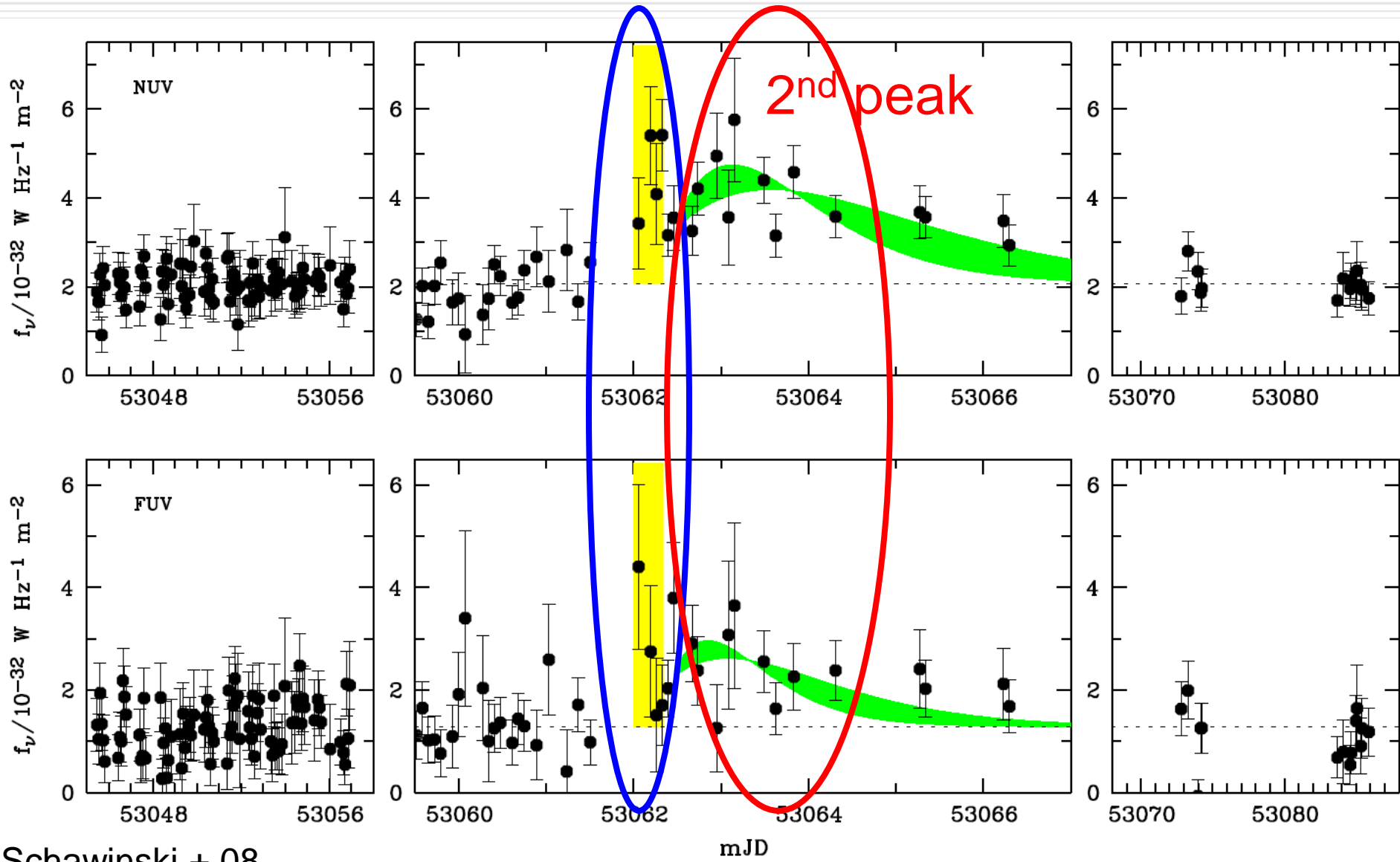
SNLS

SuperNova Legacy Survey

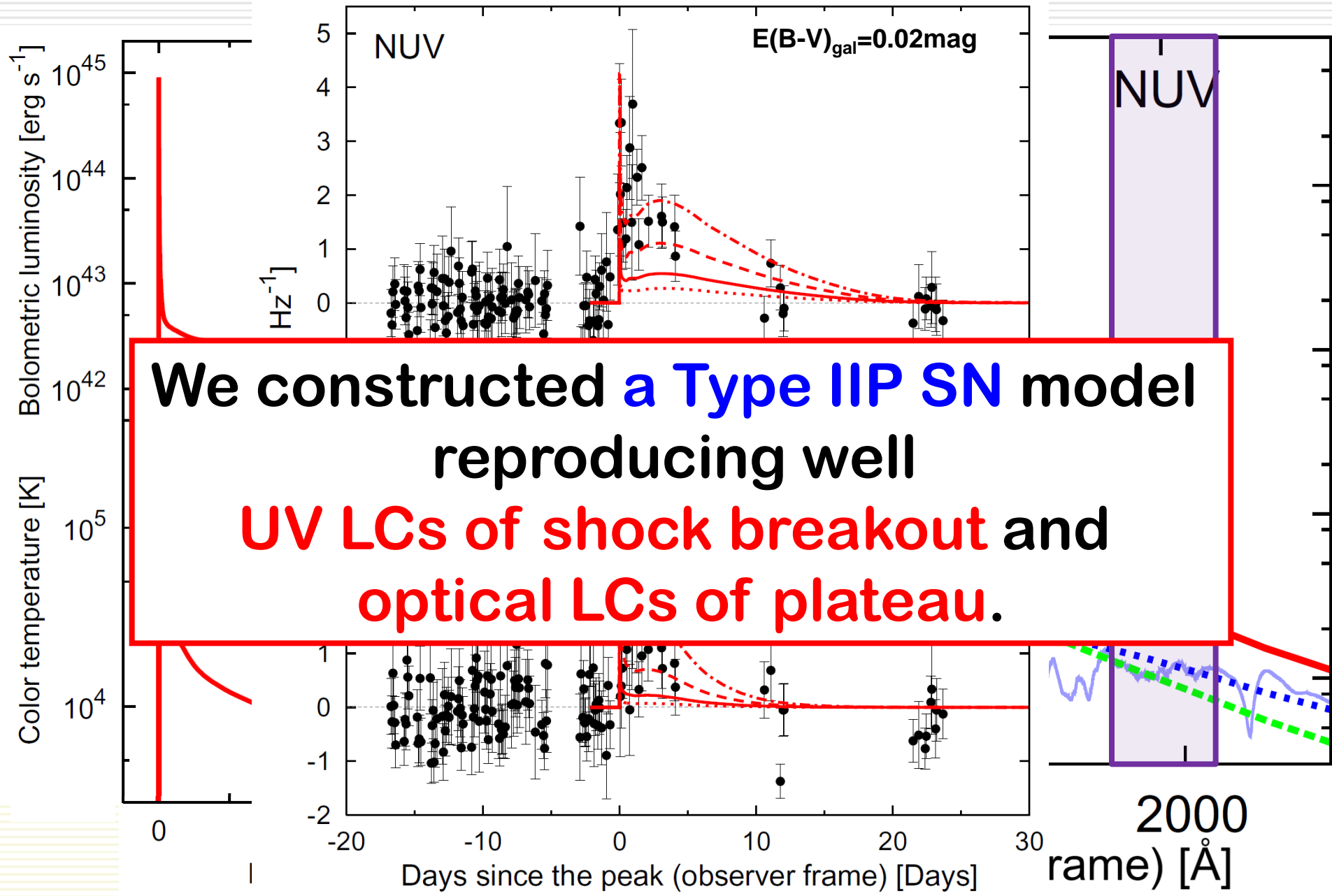


NT + 09 (STELLA: Blinnikov+98) Iian Date (observed frame)

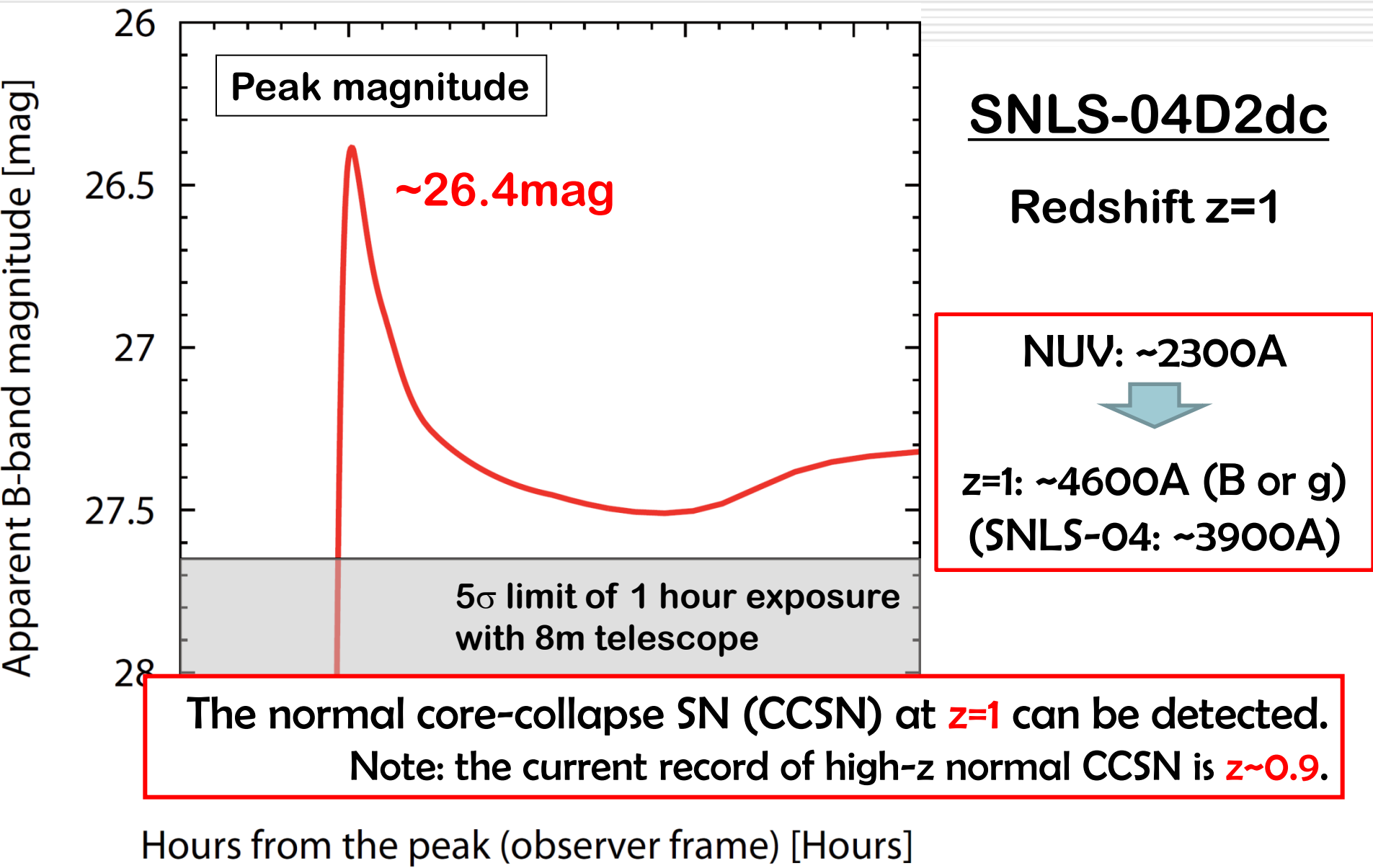
UV LCs of Shock breakouts



Model: light curve & color evolution



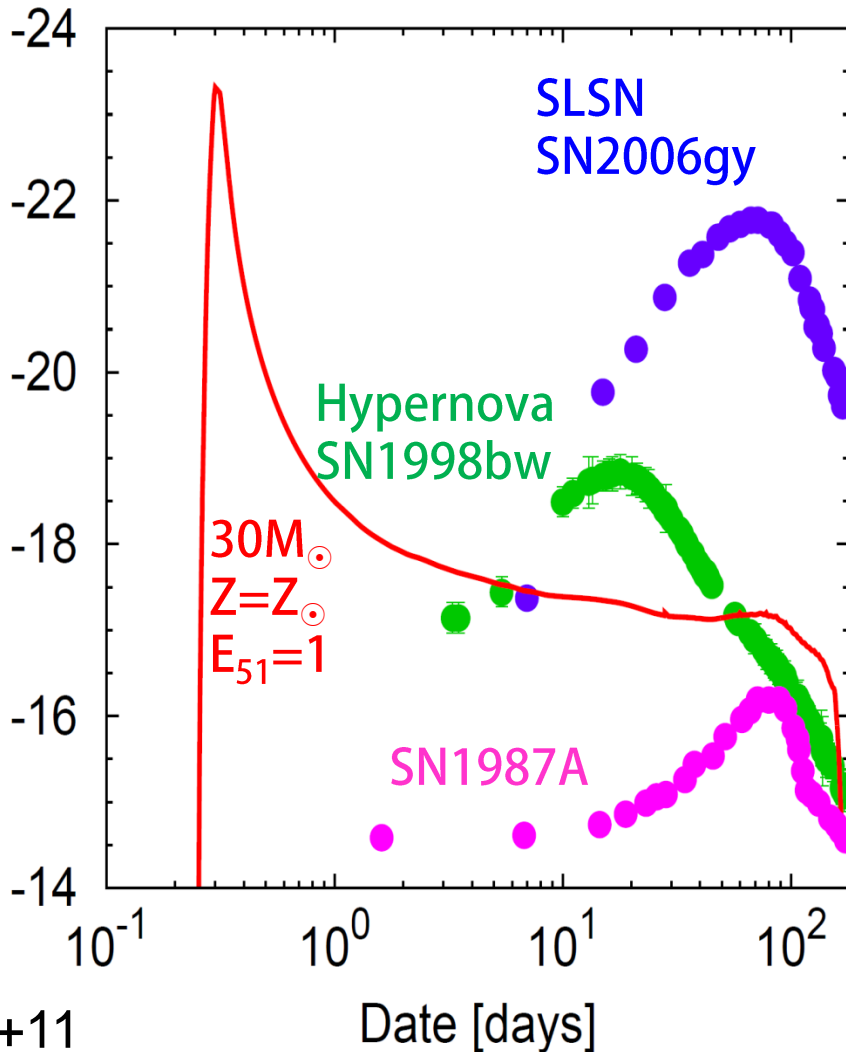
When the same SN takes place at $z=1$,



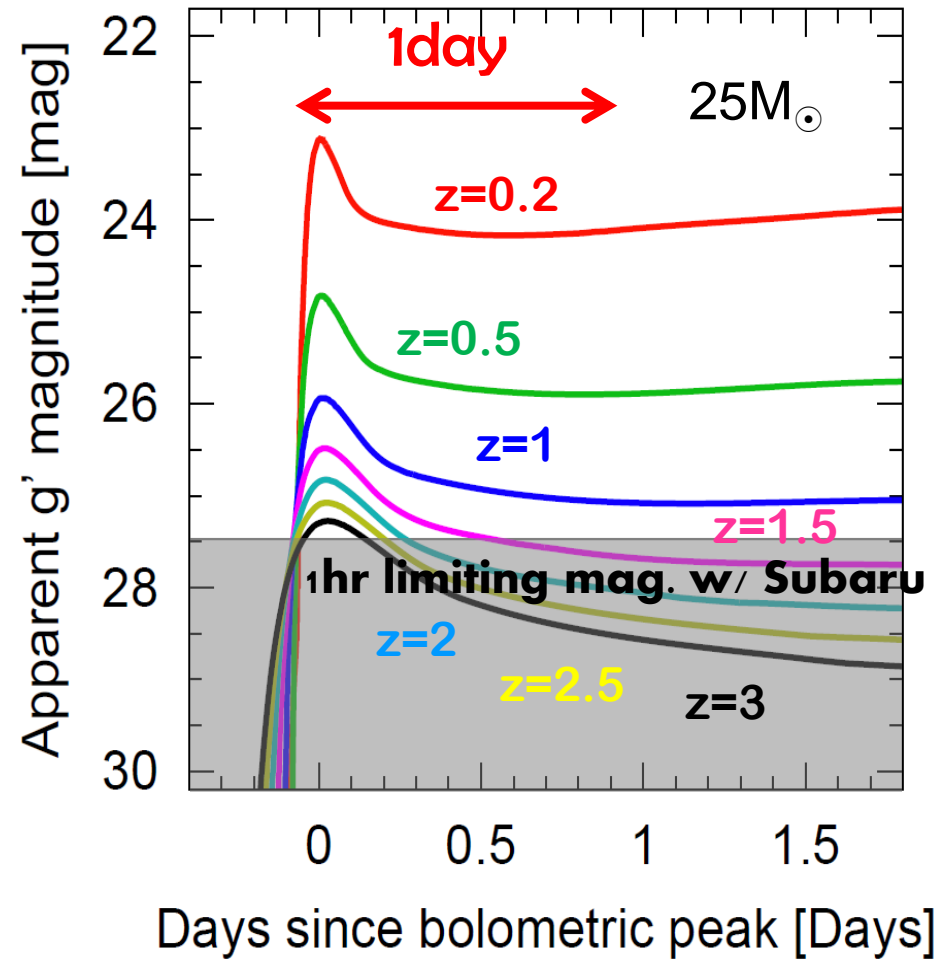
Supernova surveys

Shock breakout is **bright!**

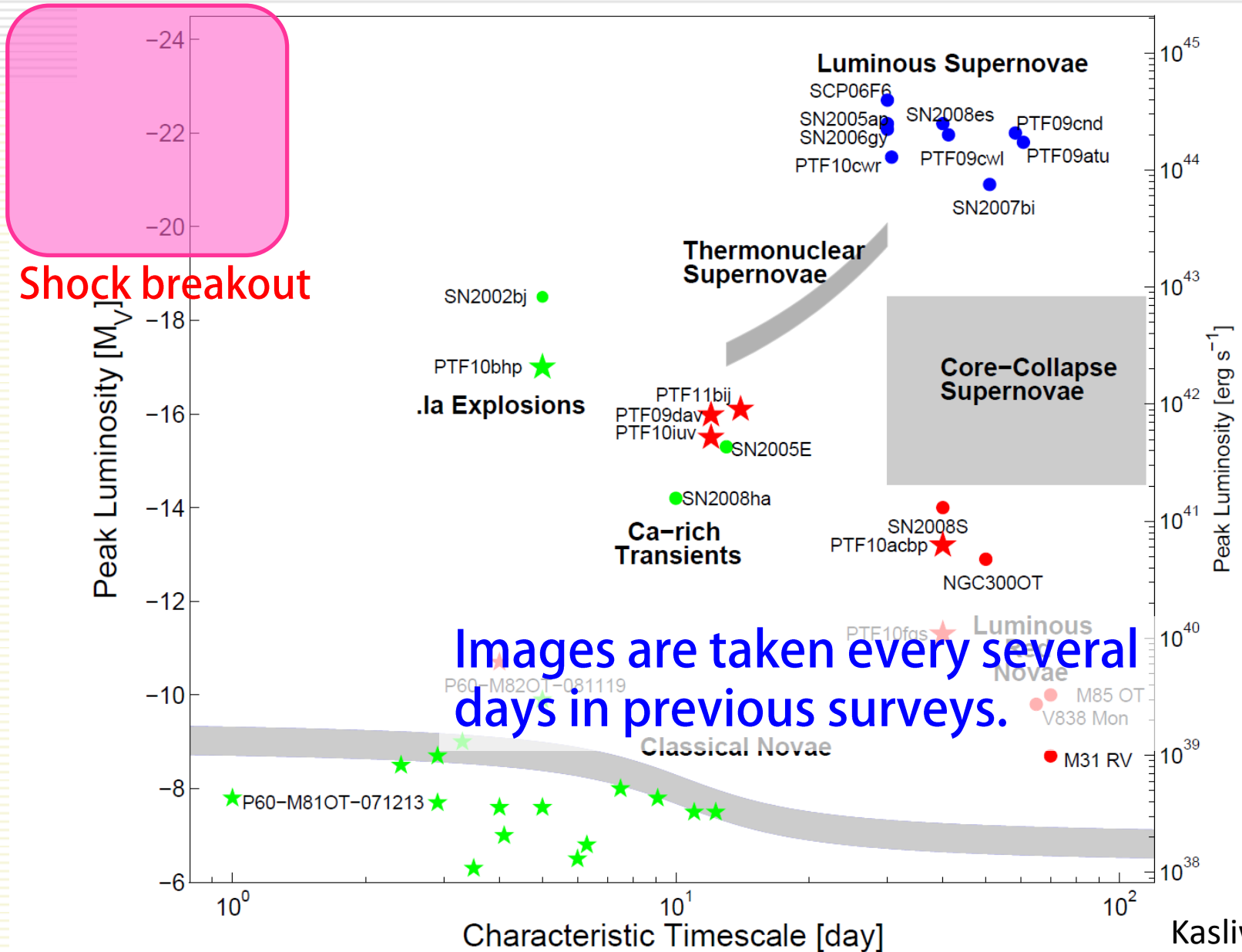
- Brighter than SLSN



- Detectable up to $z \sim 3$



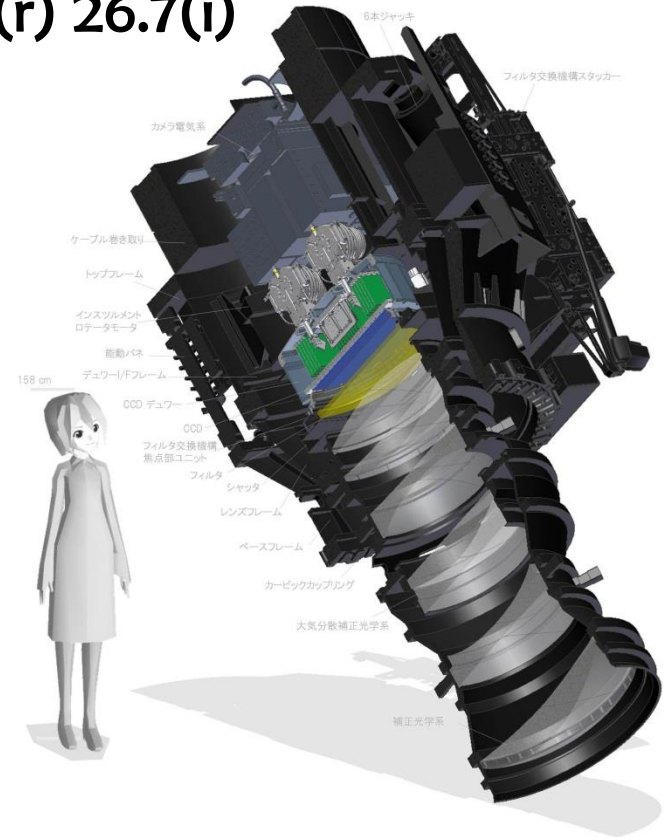
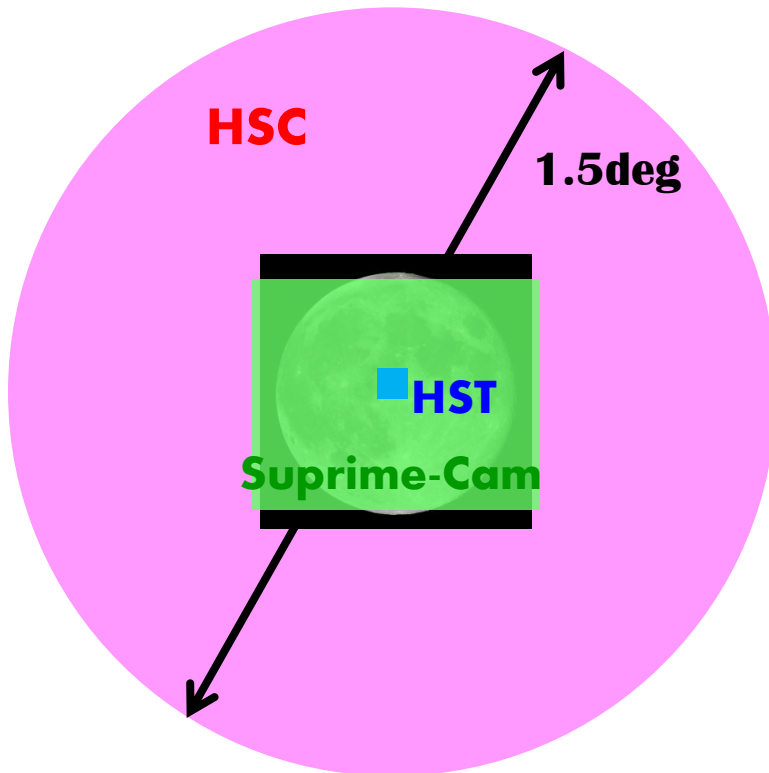
Time scale and brightness of transients



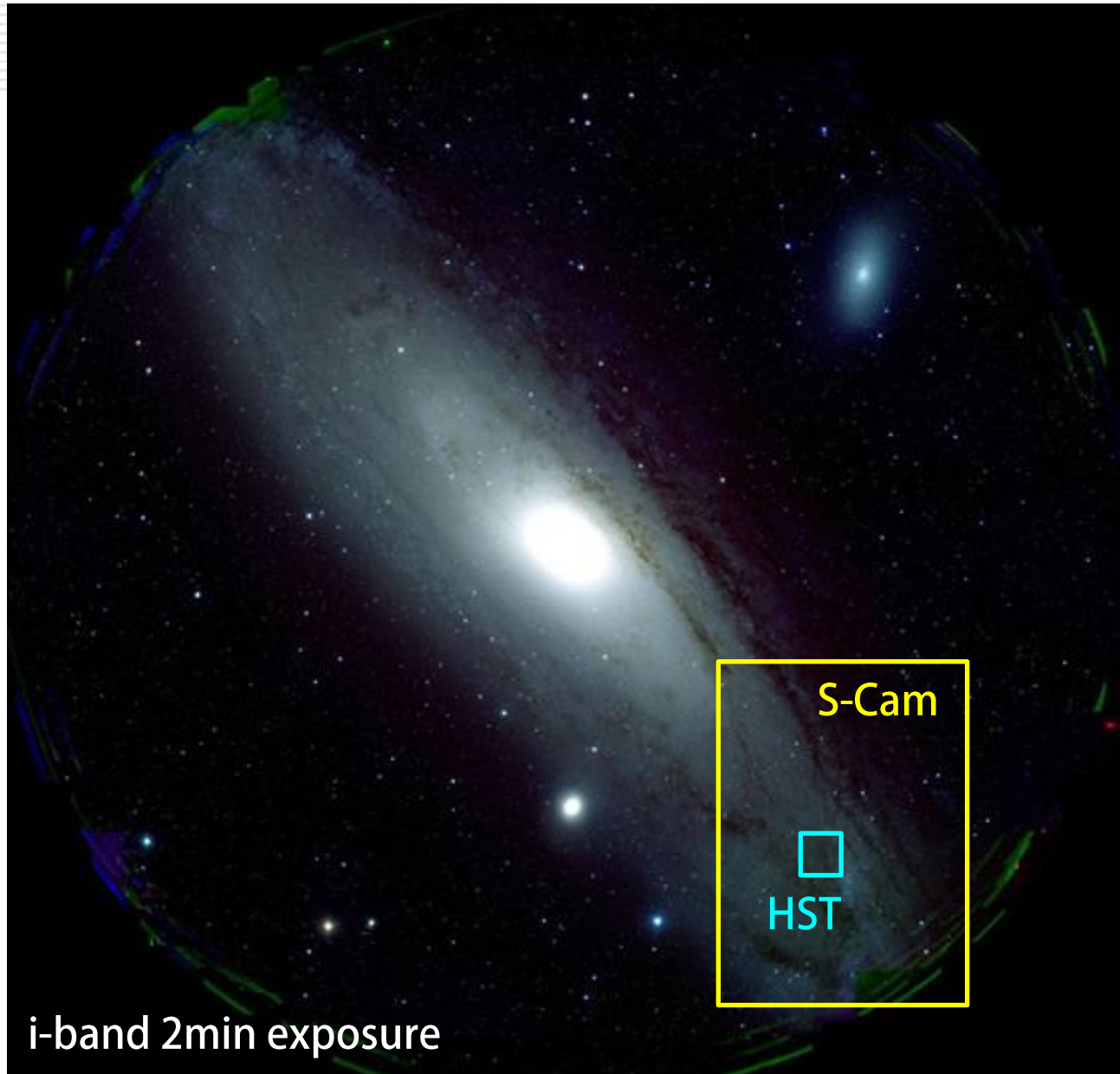
Hyper Suprime Cam on Subaru telescope

- Hyper Suprime-Cam (HSC)
 - Diameter: 8.2m, FoV: **1.77deg²**
 - m_{lim} (5σ) w/ 1hr: 27.5(g) 27.2(r) 26.7(i)

from Feb 2014



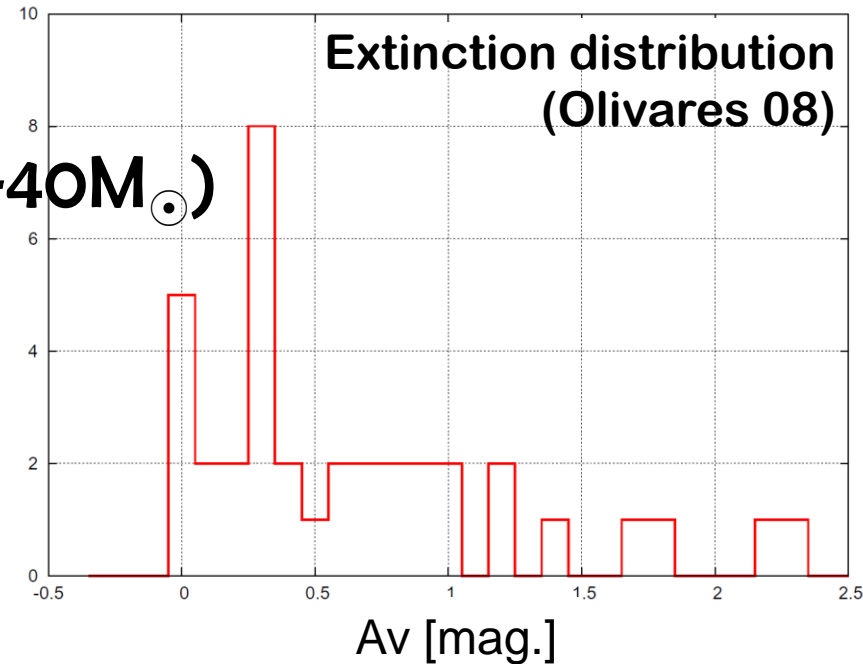
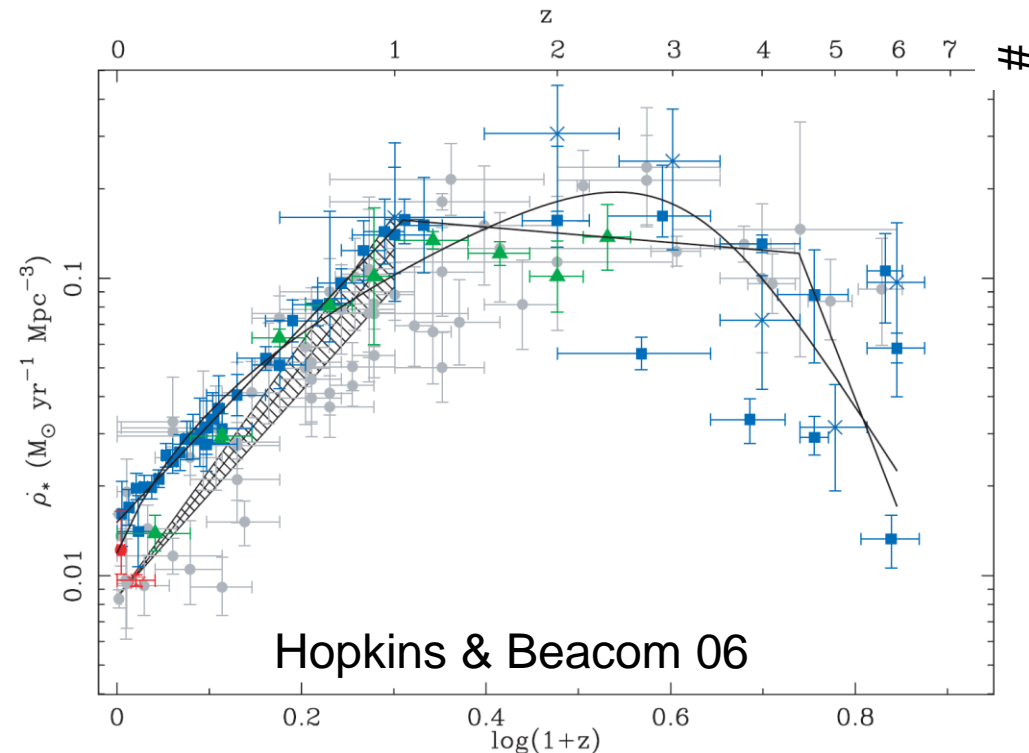
First image (M31) -Feb 2013-



i-band 2min exposure

Expected number of detections

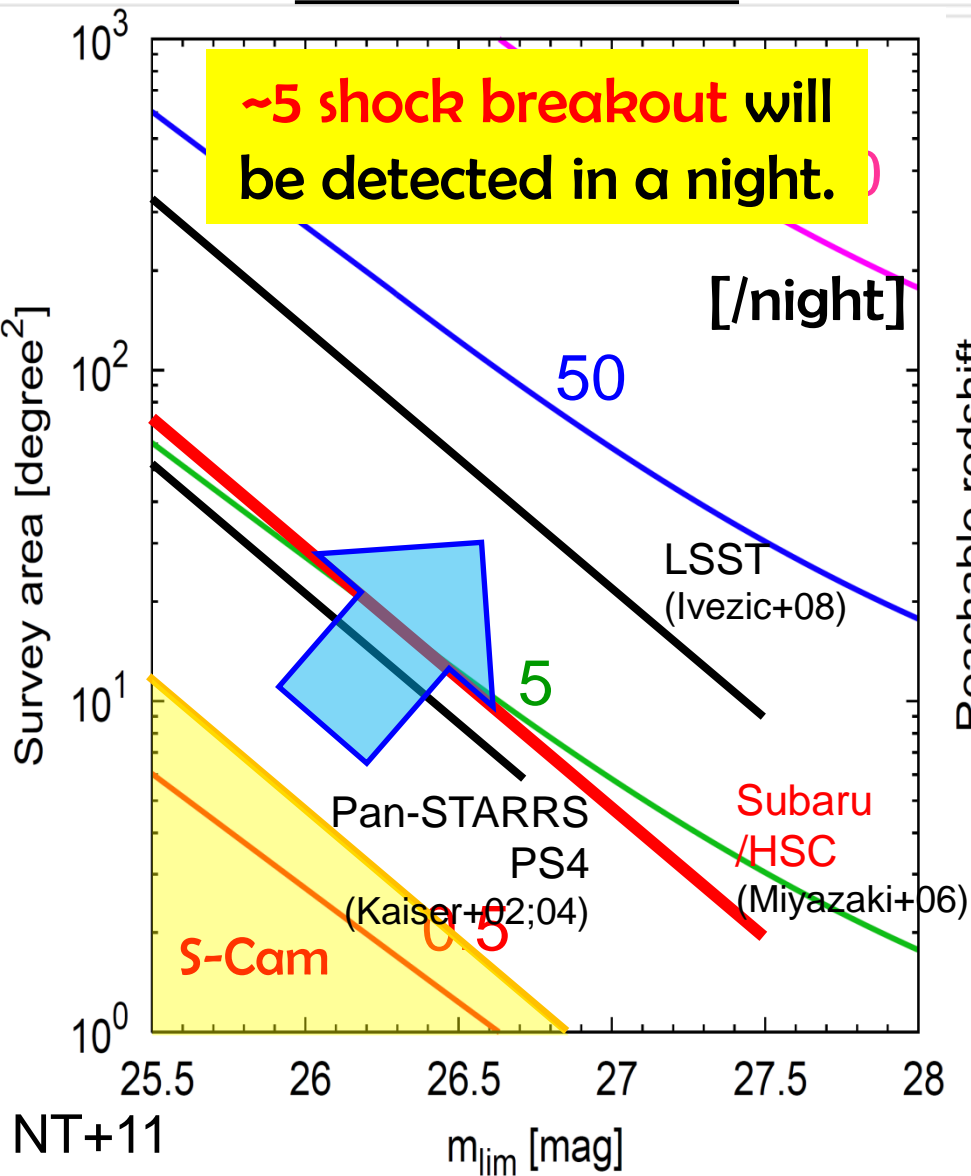
- Cosmic star formation rate (Hopkins & Beacom 2006)
- Distribution of hosts extinction (Olivares 08)
- Salpeter's IMF
- Shock breakout models (1-40M_⊙)



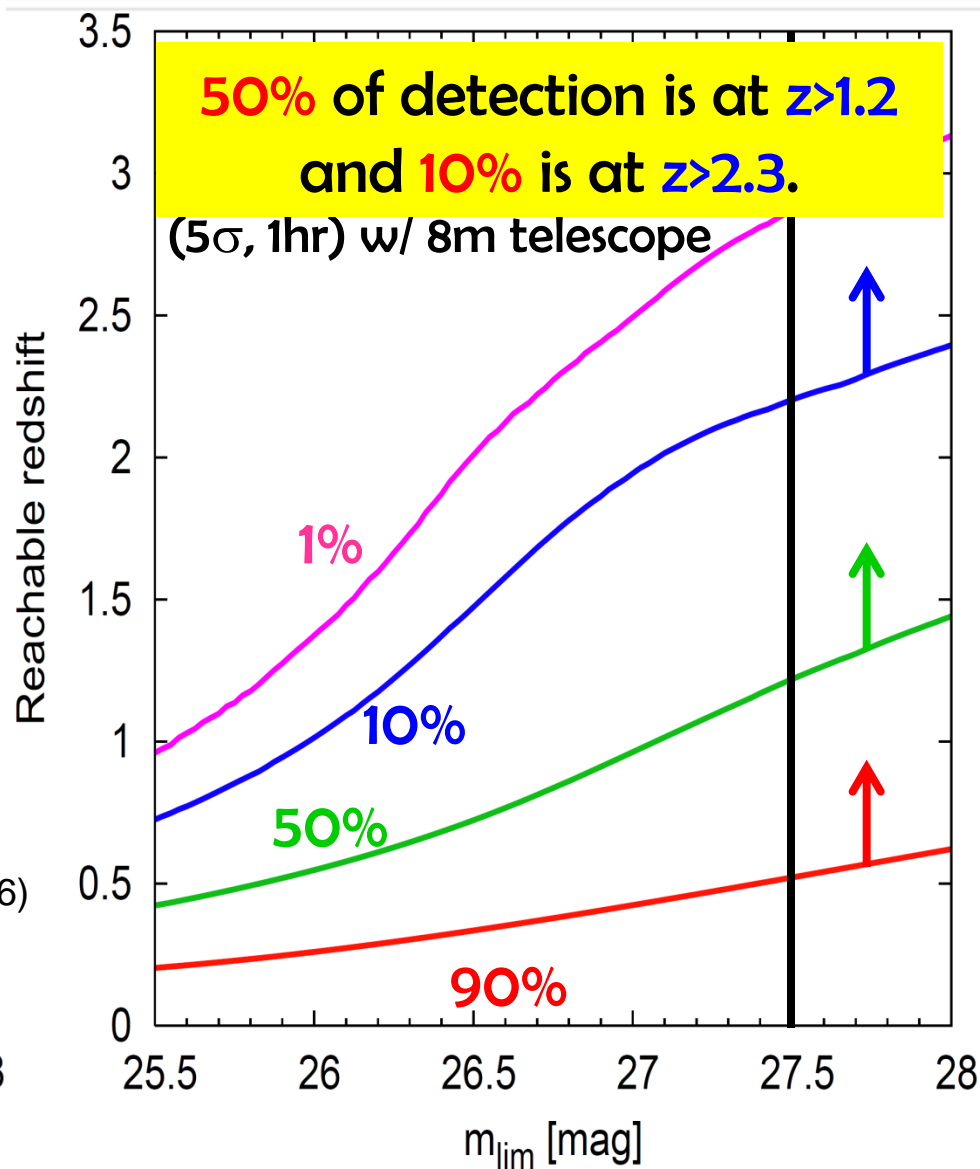
gray: Hopkins (2004)
Hatched region & green: FIR (24 mm)
red: radio (1.4 GHz) & H estimate
blue: UV & UDF

Shock breakout by HSC

Detection rate



Redshift distribution



HSC strategic program

- **300nights/5yrs**
- **Primary science**
 - Weak lensing
 - Galaxy evolution
- **3 layers**
 - Wide, Deep, Ultradeep

Transient science is free!!

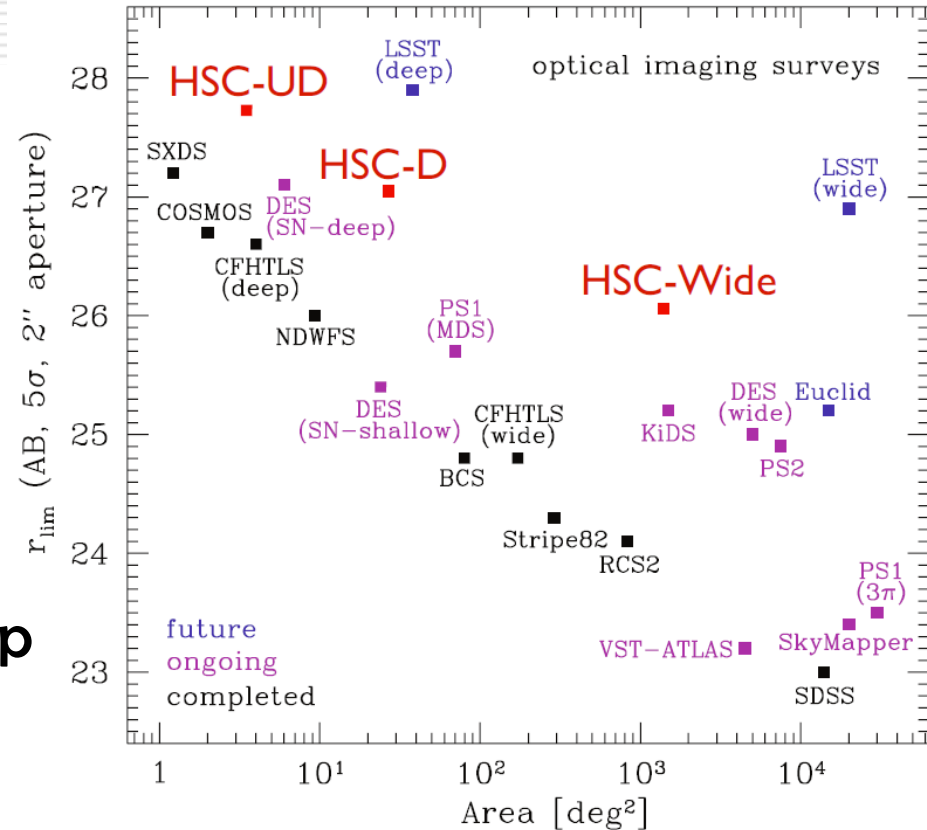
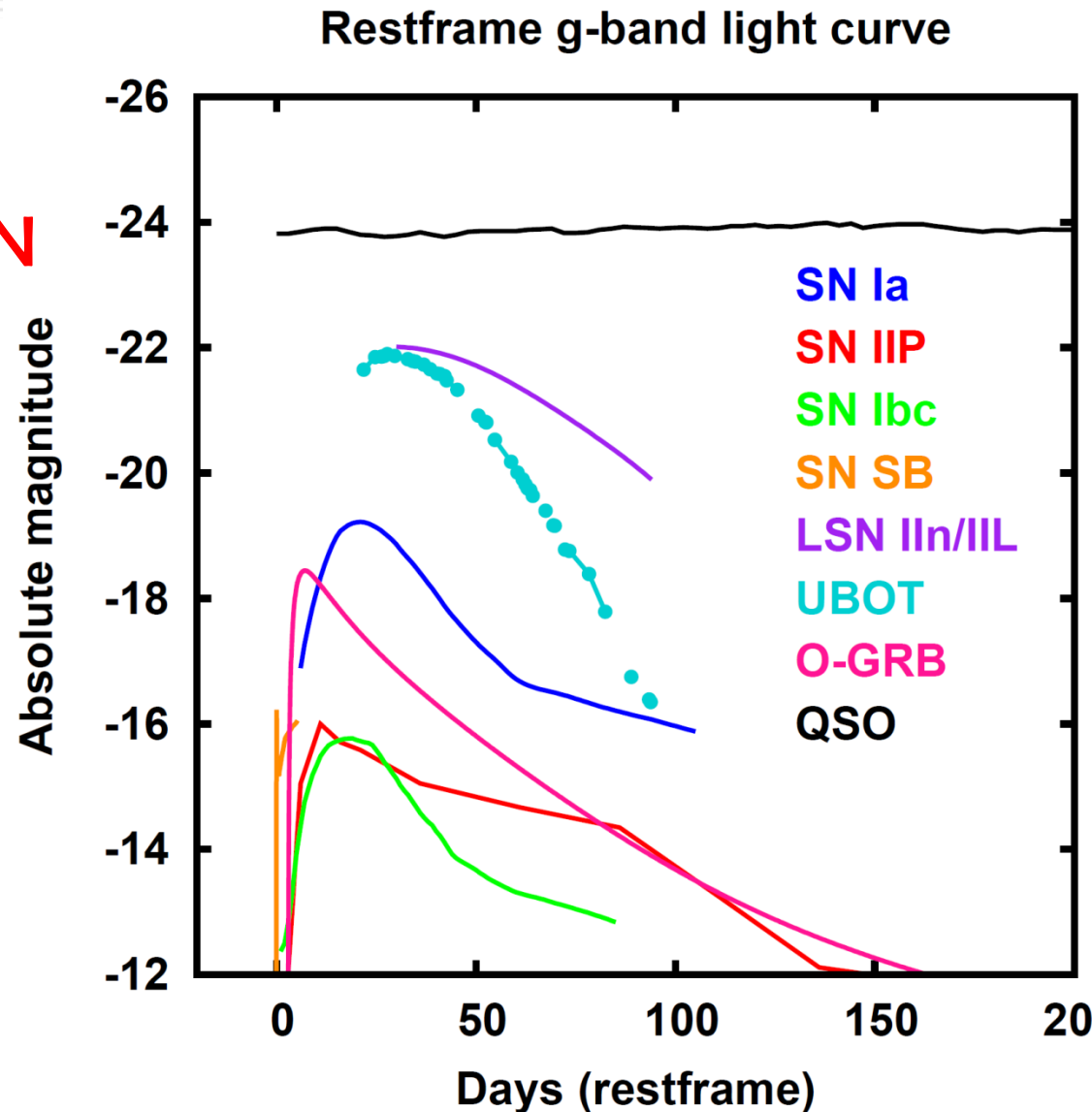


Table 1: Summary of HSC-Wide, Deep and Ultradeep layers

Layer	Area [deg^2]	# of HSC fields	Filters & Depth	Comoving volume [$h^{-3}\text{Gpc}^3$]	Key Science
Wide	1400	916	<i>grizy</i> ($r \simeq 26$)	~ 4.4 ($z < 2$)	WL cosmology, $z \sim 1$ gals, clusters
Deep	27	15	<i>grizy</i> +3NBs ($r \simeq 27$)	~ 0.5 ($1 < z < 5$)	$z \lesssim 2$ gals, reionization, WL calib.
Ultradeep	3.5	2	<i>grizy</i> +3NBs ($r \simeq 28$)	~ 0.07 ($2 < z < 7$)	$z \gtrsim 2$ gals, reionization, SNeIa

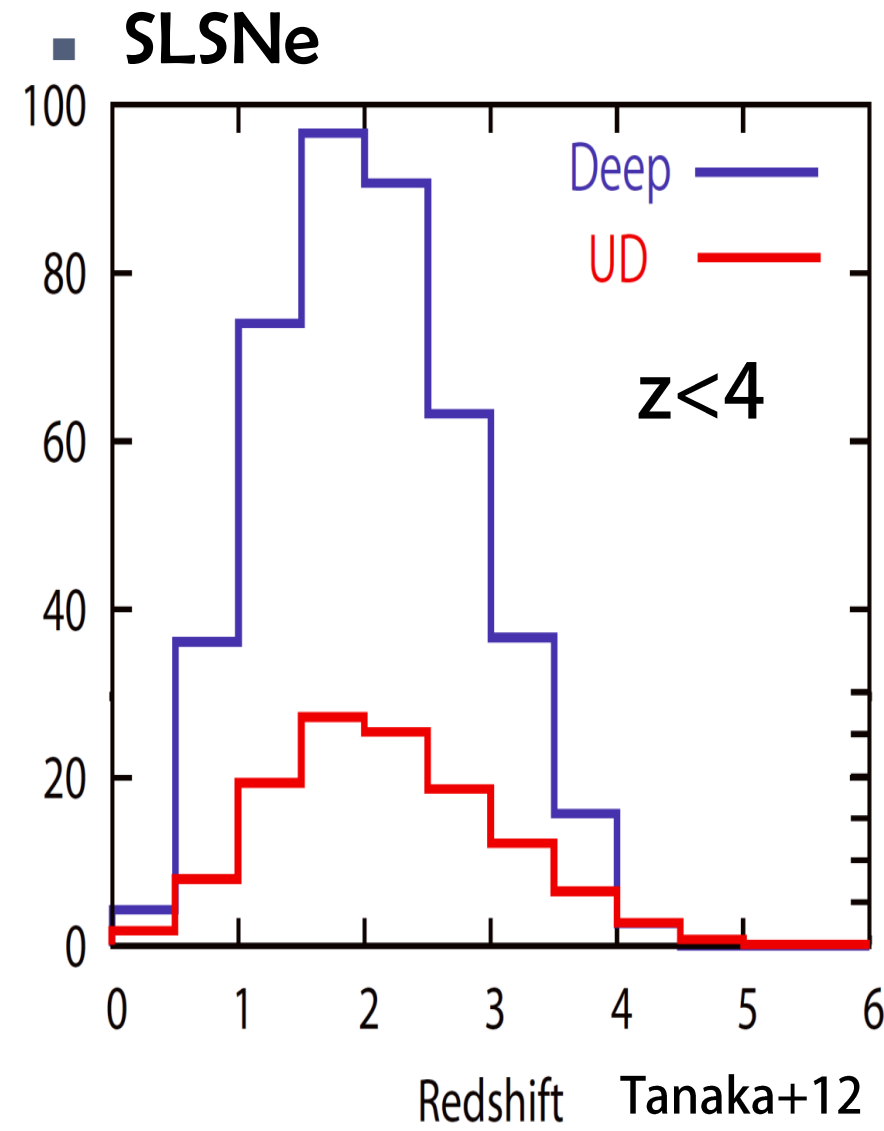
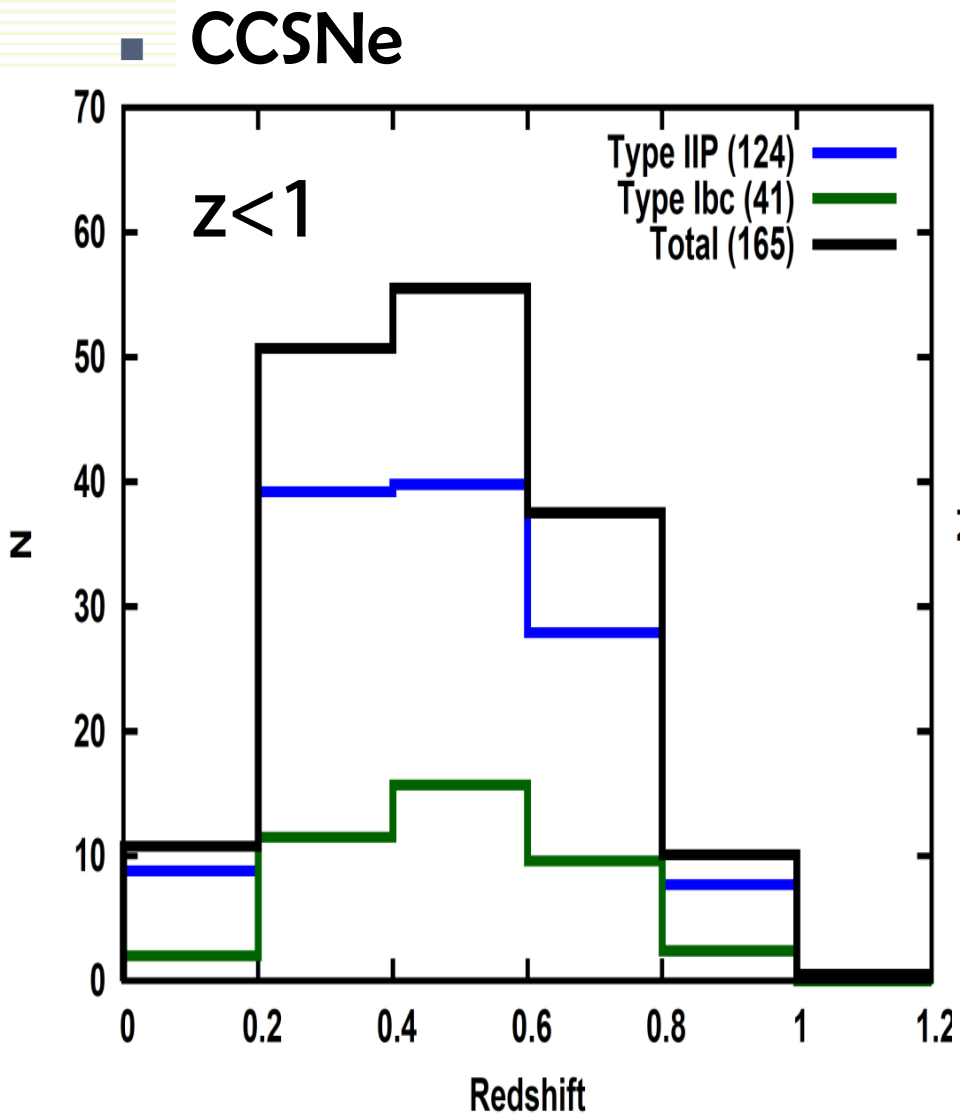
Objectives

- Type Ia SN
- Core-Collapse SN
- Shock Breakout
- Type II_n/II_L LSN
- Type Ic LSN
- GRB Orphan Afterglow
- QSO

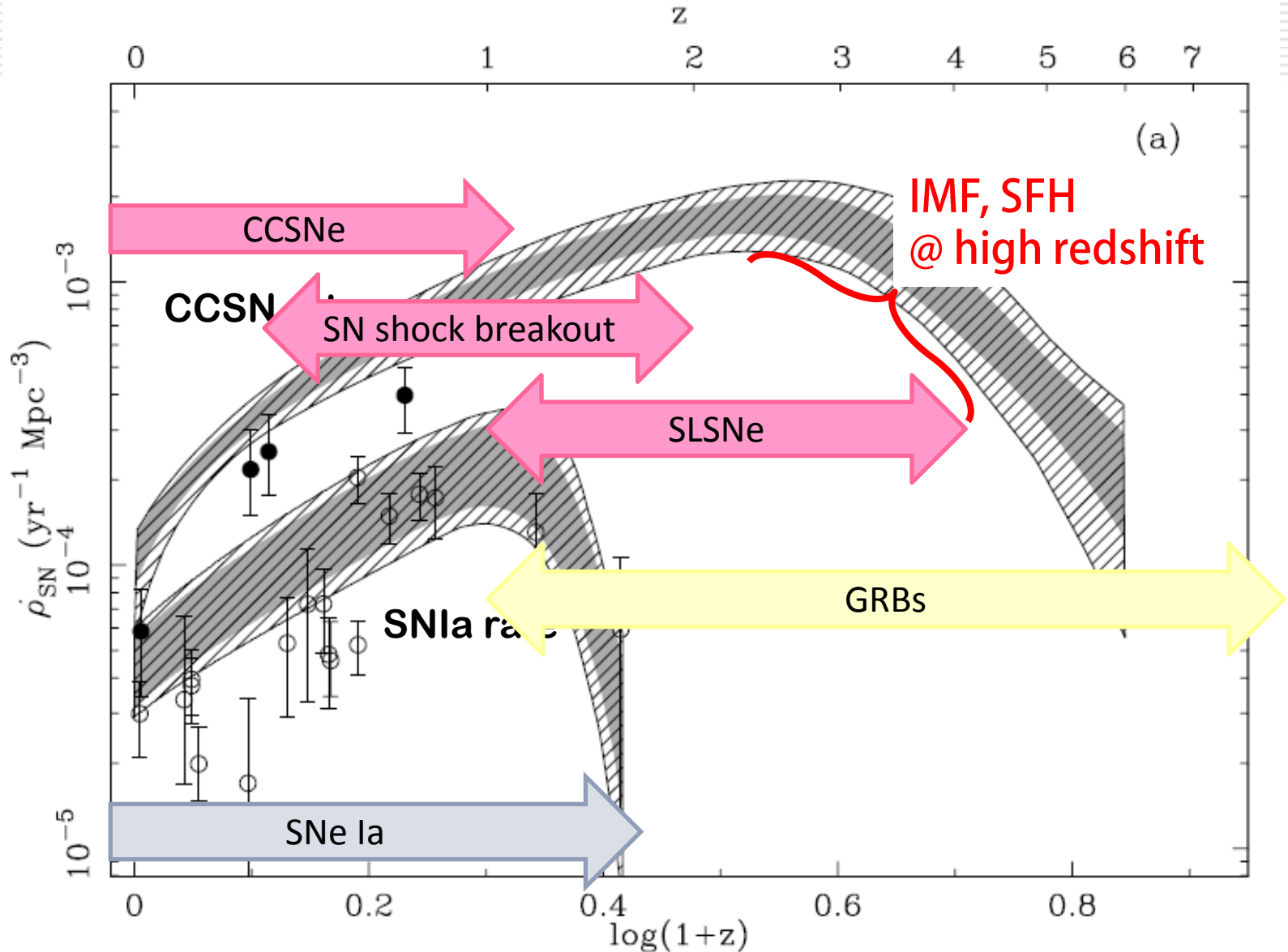


CCSNe and SLSNe by HSC

-Redshift distribution-

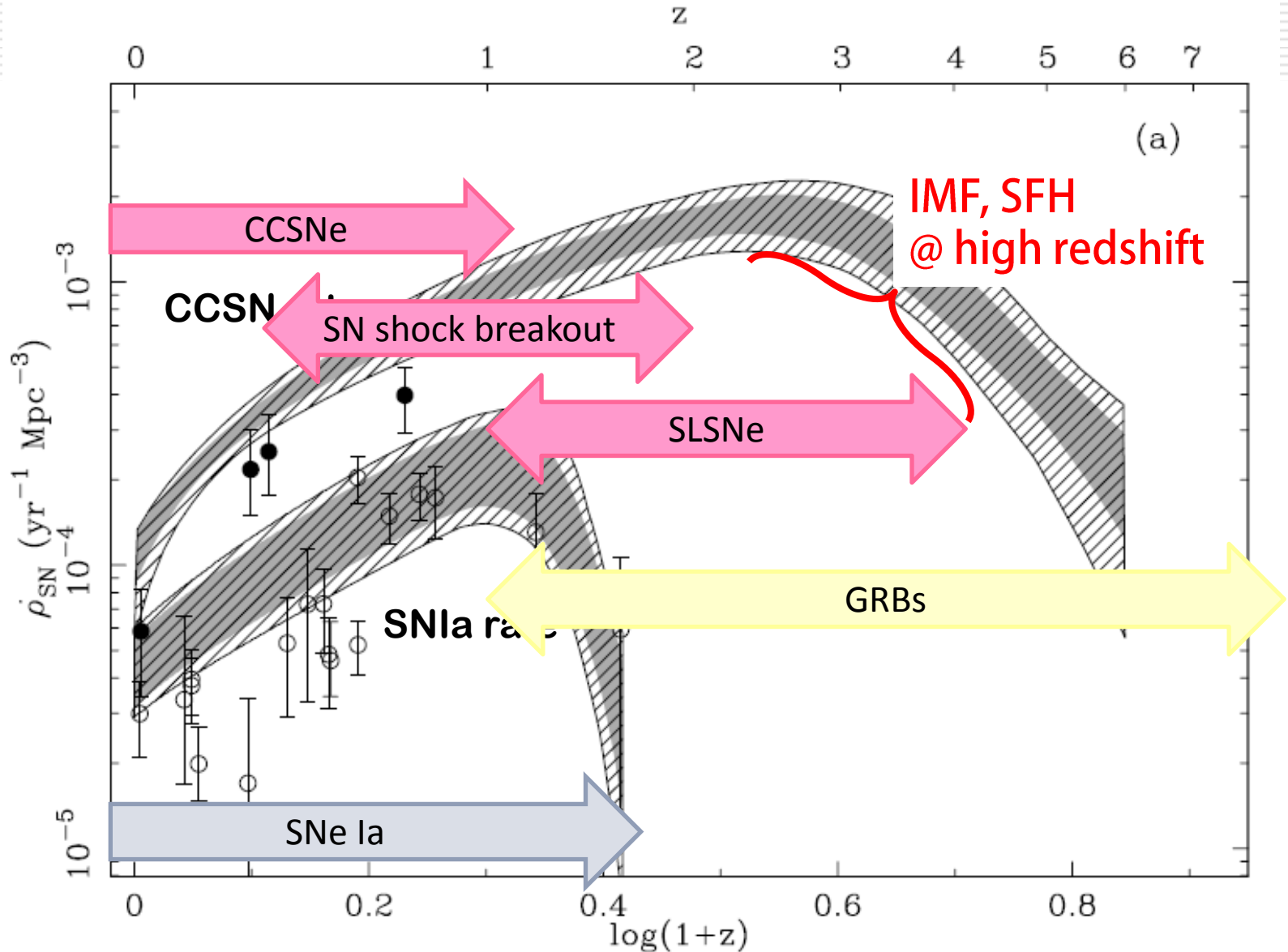


SN rate history



Hopkins & Beacom 06 and references therein

Ladder with SNe



Hopkins & Beacom 06 and references therein

Summary

- Shock breakout is the **brightest** phenomenon in a supernova. A theoretical model reproducing the UV light curve can be observed even if it takes place at high redshift ($z > 1$).
- We have started **a shock breakout survey with Hyper Suprime-Cam** and detect candidates of shock breakout.
- The strategic survey program (SSP) started from Feb 2014. The realtime transient finding works well. We expect many transient objects.