ショックブレイクアウト探査観測

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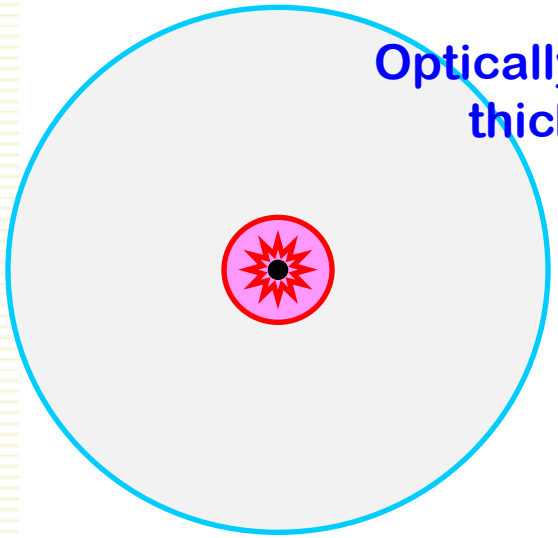
Outline

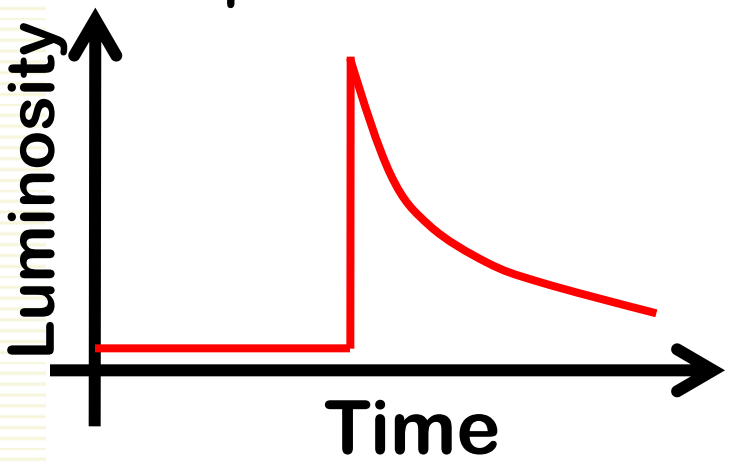
- Supernova shock breakouts
- Initial results of the HSC shock breakout survey

Supernova shock breakouts

What is the shock breakout? -theoretically predicted in 1970s-



Core collapse



Massive Star (>10$M_\odot$)

e^--capture SNe (8-10$M_\odot$)

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

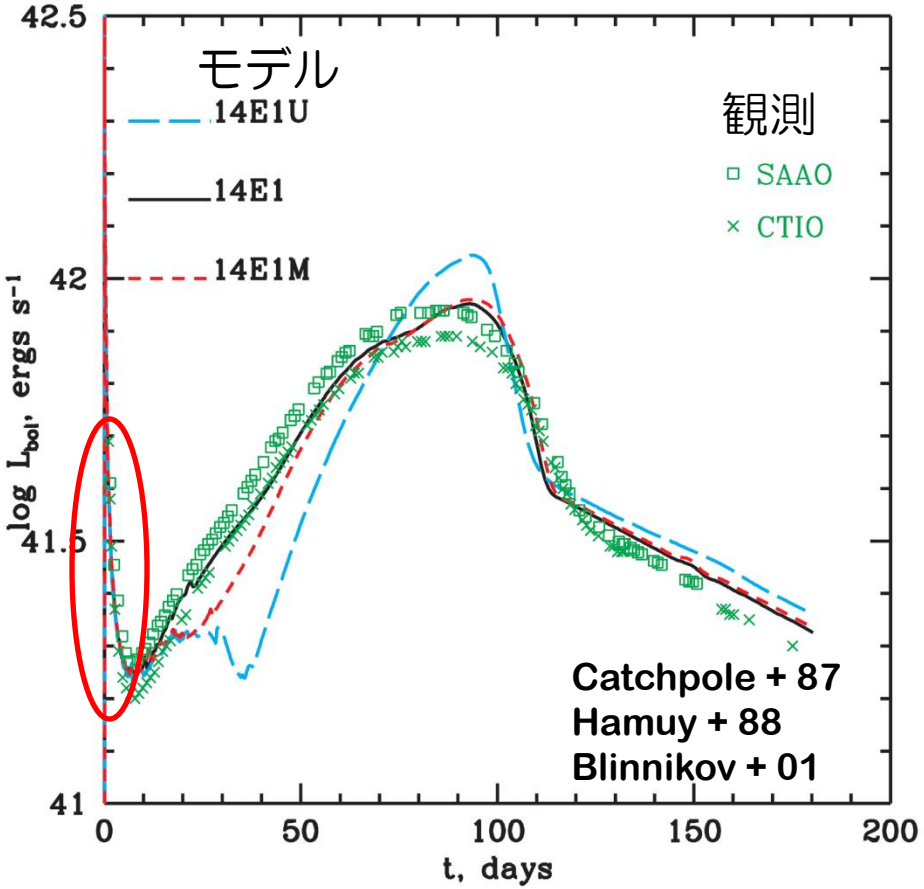
timescale: 1sec ~ 1day

peak wavelength: X-ray ~ UV

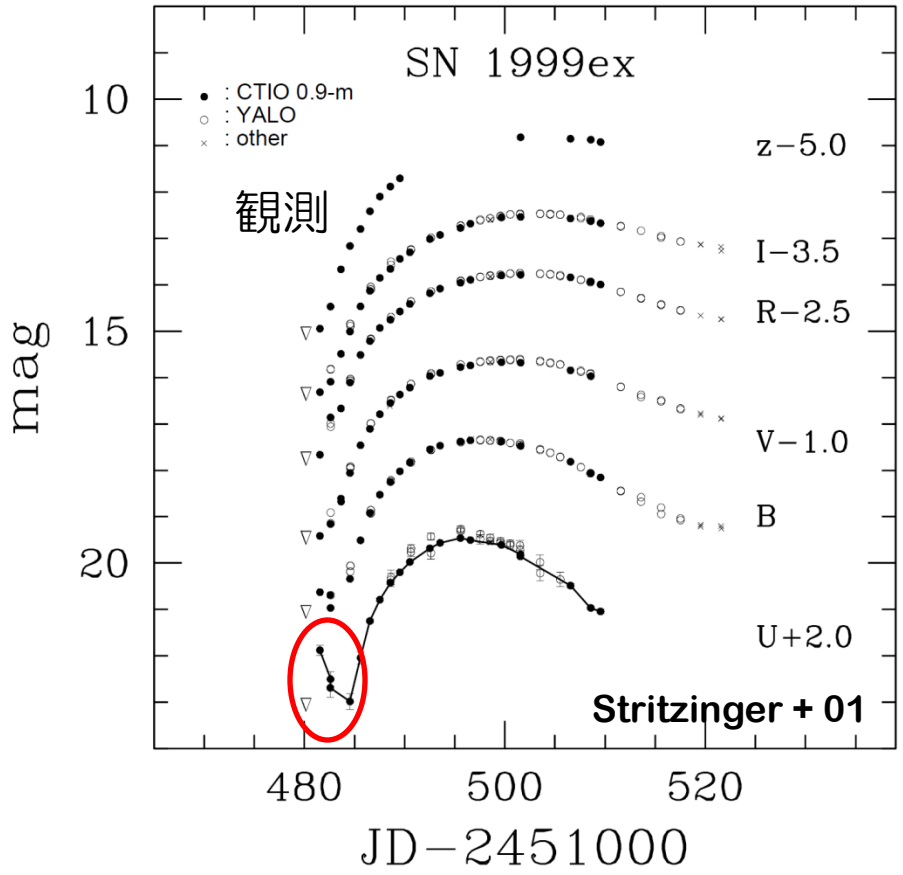
Observations before 2008

-Tail of shock breakout-

Type II-peculiar SN1987A

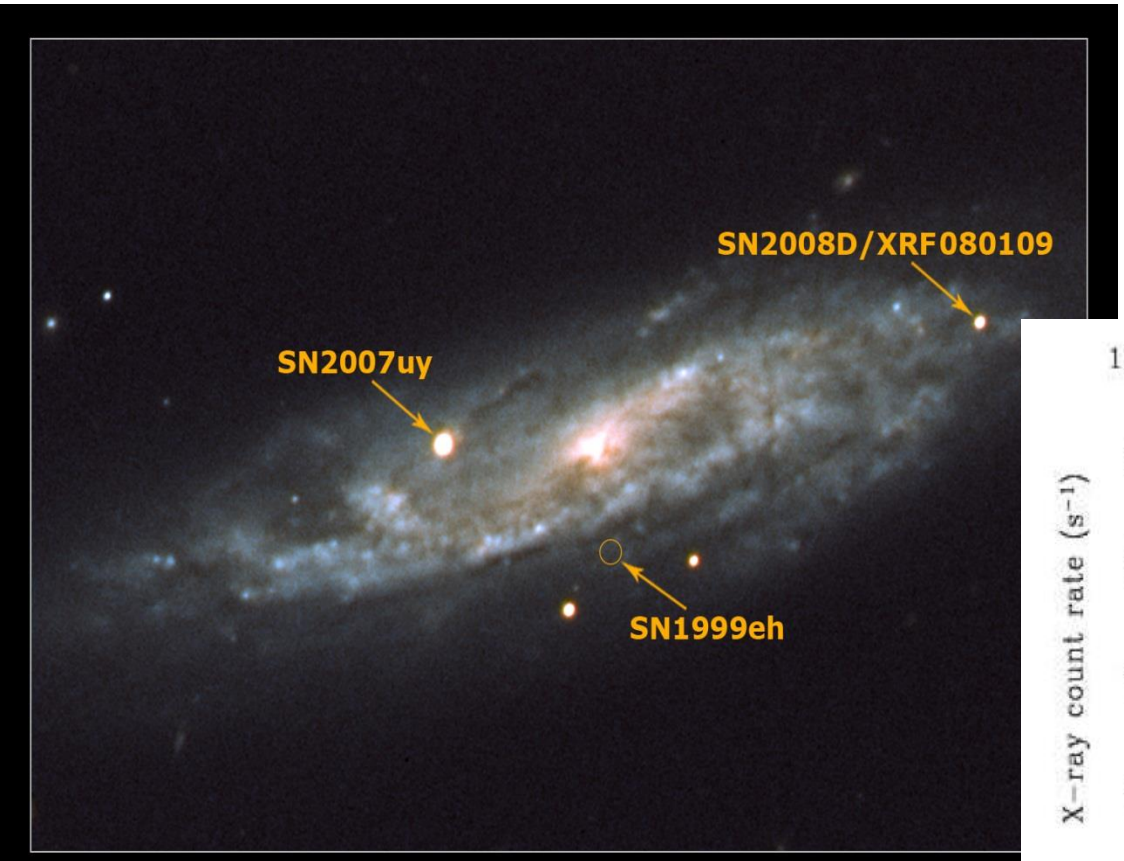


Type Ib SN1999ex

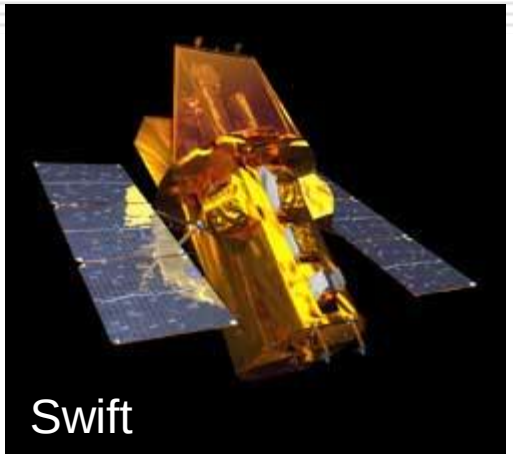


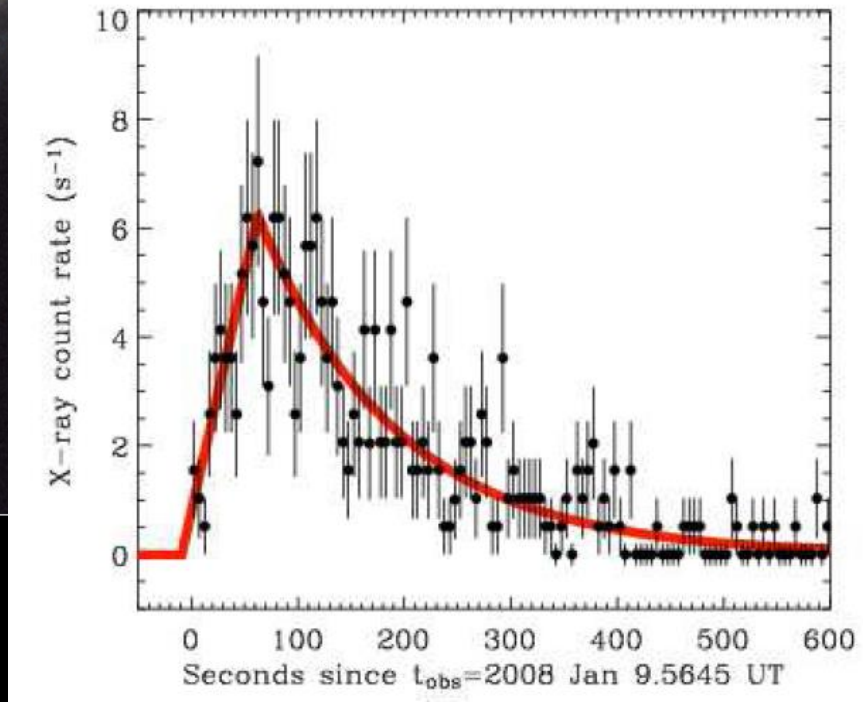
Serendipitous detection of shock breakout -Type Ib SN2008D/XRO080109-

Soderberg + 08; Modjaz + 09



NGC 2770
Supernova factory



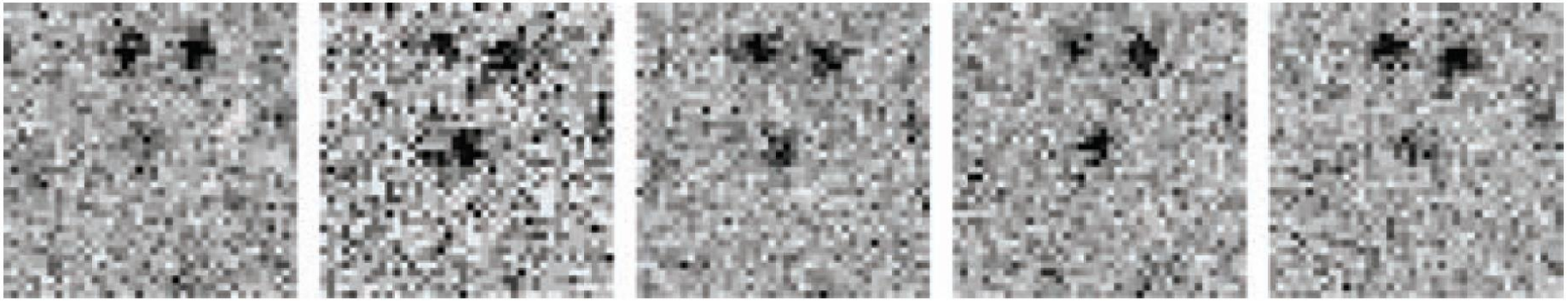


Shock breakouts of Type IIP SNe
-SNLS-04D2dc & SNLS-06D1jd-

SNLS SuperNova Legacy Survey

SNLS-04D2dc (z=0.1854)

Schawinski et al. 08
Gezari et al. 08



Before shock breakout | Peak of Radiative Precursor | Minimum between peaks | Post shock breakout peak | After near-UV peak

Shock breakouts of Type IIP SN -Observations and model-

SNLS-04D2dc (z=0.1854)

SNLS SuperNova Legacy Survey

& Shock breakout

Plateau

UV

Optical

SNLS/CFHT g−band
SNLS/CFHT r−band
SNLS/CFHT i−band
SNLS/CFHT z−band
GALEX near−UV

$E(B-V)_{host}$=0.14mag

$20M_{\odot}$, $Z=Z_{\odot}$, E_{51}=1.2

Schawinski et al. 08
Gezari et al. 08

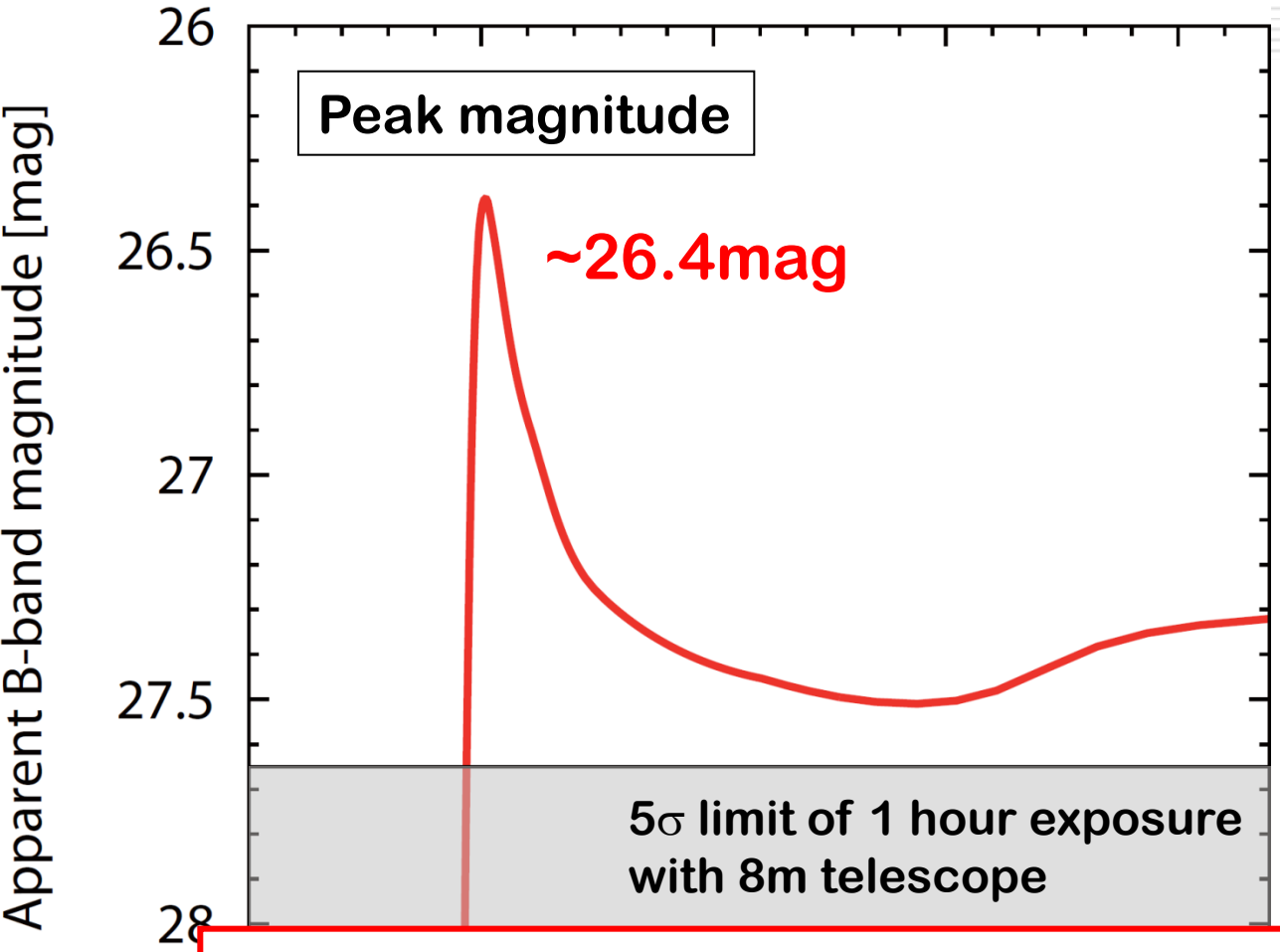
Flux (10^{-32} W m^{-2} Hz^{-1})

5 4 3 2 1 0 −1 −2

53025 53050 53075 53100 53125 53150

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

When the same SN takes place at z=1,



SNLS-04D2dc

Redshift z=1

The normal core-collapse SN (CCSN) at z=1 can be detected.
Note: the current record of high-z normal CCSN is z~0.9.

HSC shock breakout survey

Aims of the survey

1. Detecting shock breakouts first in optical bands with an intended strategy
2. Studying stellar structures at a presupernova stage in the high-z Universe
3. Probing the evolution of the high-z Universe, like SFR and IMF, with the shock breakouts
4. Realizing a real-time spectroscopic follow-up observation of the shock breakout within the night
5. Providing first observational constraints on radiation hydrodynamics in a high-T moving medium with marginal coupling of radiation and matter

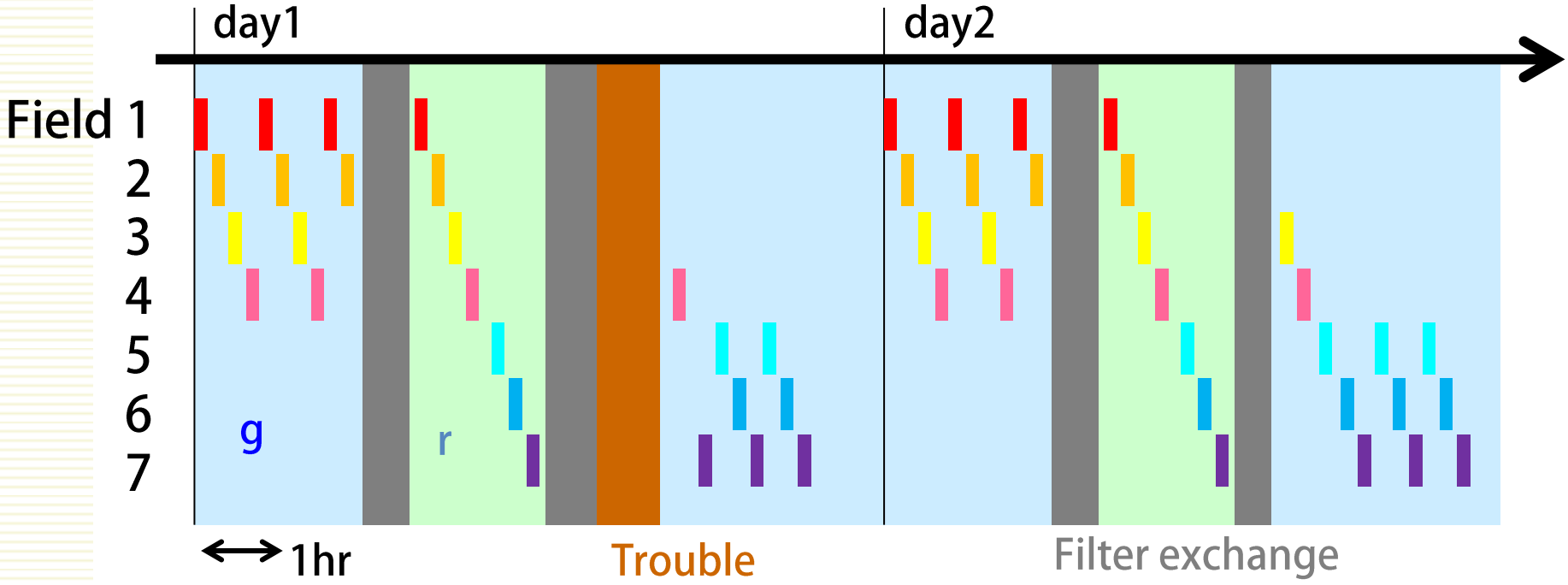
Future

Subaru openuse programs

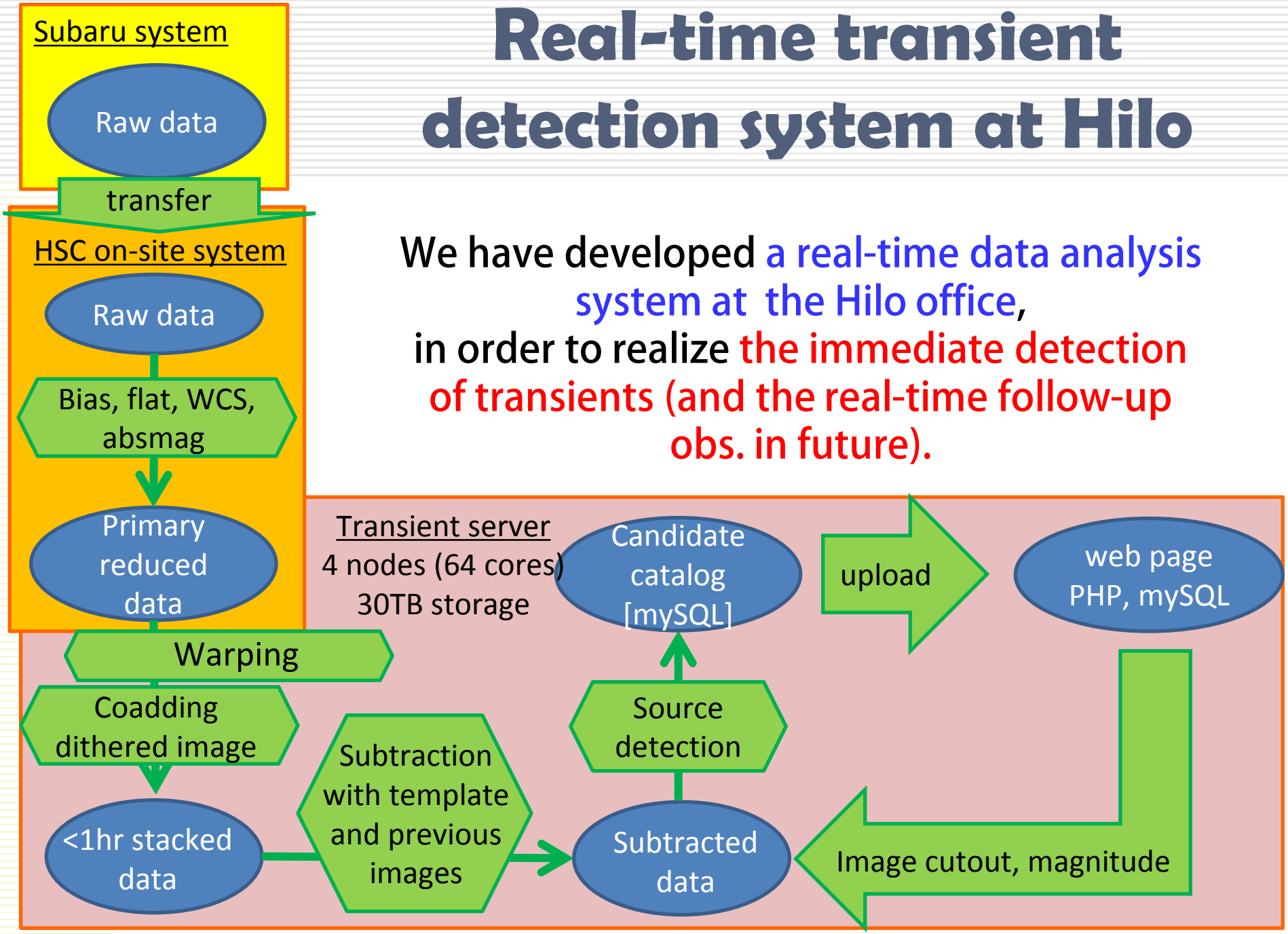
- S14A-191 (HSC, Jul 2014, PI: N. Tominaga)
  - First detection of the shock breakout
  - Fiducial strategy
- S14B-061 (FOCAS, Aug 2014, PI: M. Tanaka)
  - Spectroscopic follow-up observation
  - ~1 month after the HSC observation
- S14B-048 (HSC, Nov 2014, PI: N. Tominaga)
  - Detection of the highest-z shock breakout
  - Increase the number of shock breakout
  - Deep and narrow survey

HSC observation strategy

- 7 fields (~ 12deg^2)
- 2 continuous nights: 2 and 3 July 2014 (UT)
- 3 g and 1 r 10min exposures with ~1 hr interval



Real-time transient detection system at Hilo



We have developed a real-time data analysis system at the Hilo office, in order to realize the immediate detection of transients (and the real-time follow-up obs. in future).

Quick alert of candidates within 1 day after the observation

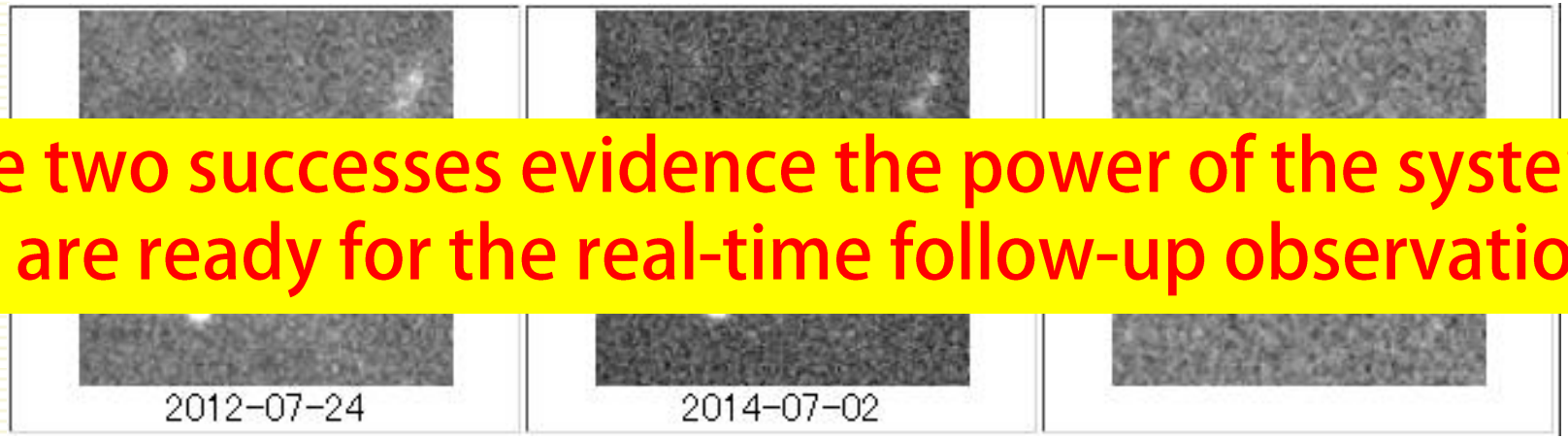
First supernova candidates discovered with Subaru/Hyper Suprime-Cam

The Astronomer's Telegram

ATel #6291; *Nozomu Tominaga (Konan U./Kavli IPMU, U. Tokyo), Tomoki Morokuma (U. Tokyo), Masaomi Tanaka (NAOJ), Naoki Yasuda (Kavli IPMU, U. Tokyo), Hisanori Furusawa (NAOJ), Jian Jiang (U. Tokyo), Satoshi Miyazaki (NAOJ), Takashi J. Moriya (U. Bonn), Junichi Noumaru (NAOJ), Kiaina Schubert (NAOJ), and Tadafumi Takata (NAOJ)*
on 4 Jul 2014; 15:51 UT

ATel #6763; *+N. Okabe, T.Futamase* *on 27 Nov 2014; 18:03 UT*

HSC observation
2-3 Jul 2014
26-27 Nov 2014



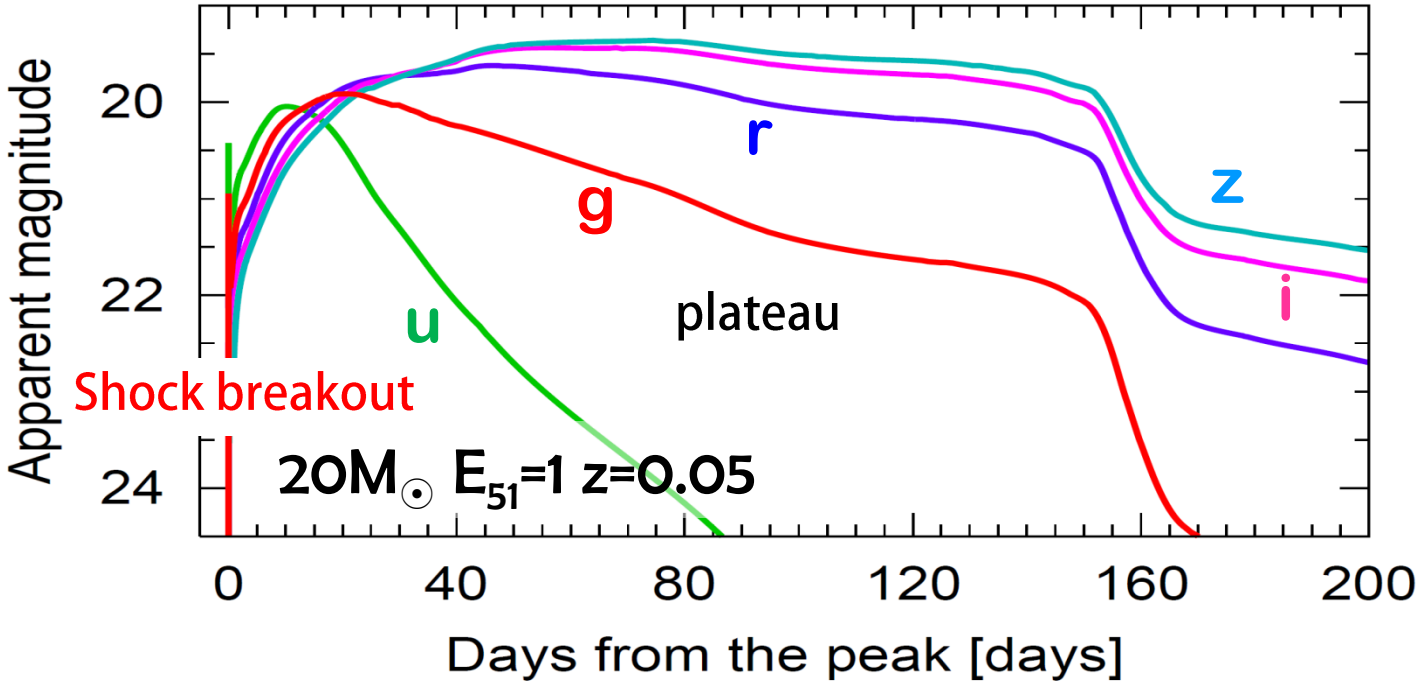
The two successes evidence the power of the system. We are ready for the real-time follow-up observations.

http://tpweb2.phys.konan-u.ac.jp/~tominaga/HSC-SN/

Nearby shock breakout survey -Kiso Supernova Survey (KISS)-

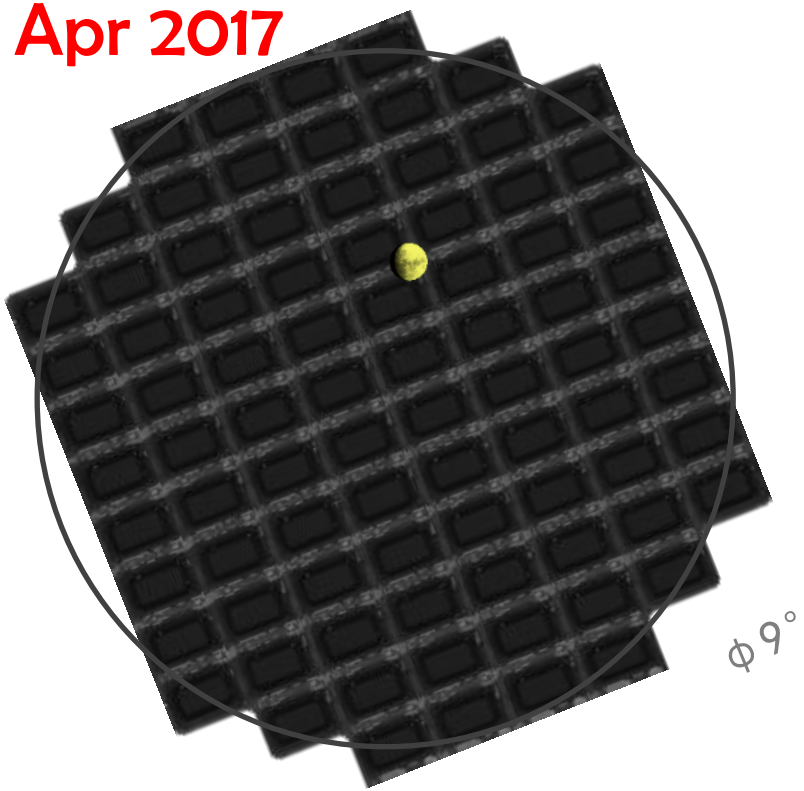
Kiso Wide Field Camera (FoV: 4deg^2, PI: T.Morokuma)

- Complementary to the HSC high-z survey
- $m_{plateau}$~20mag, m_{tail}~22mag
  - Plateau and spectra are easily followed up.

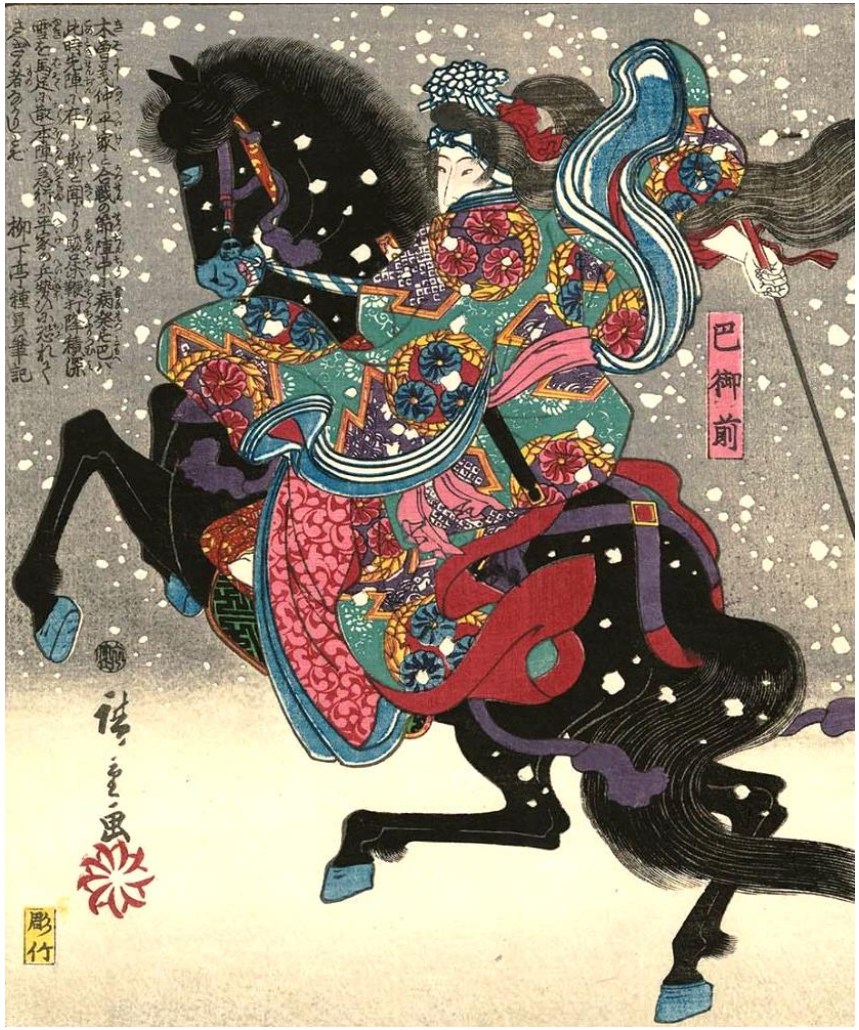


Tomo-e Gozen Project
Next nearby high-cadence (2Hz) survey

From Apr 2017



- 20deg^2 in ϕ9deg
- 84 CMOS chips
- 2Hz readout



Summary

- High-z shock breakout survey with HSC has been started.
- We successfully announced the discoveries immediately after the run with the real-time transient detection system.
- We found 4 high-z (z>0.5) shock breakout candidates with the HSC and FOCAS runs. This demonstrates that the shock breakout is the good probe of the high-z supernova.
- Deep and narrow (Nov 2014, HSC) and nearby (KISS) shock breakout surveys have been performed as well.
- We are leading studies of shock breakouts and initiate studies with shock breakouts. These will be achieved ultimately with the real-time spectroscopic follow-up observation and the large sample of shock breakouts.