Deep Multi-Band Early-Phase Type Ia Supernova Survey with Subaru/Hyper Suprime-Cam

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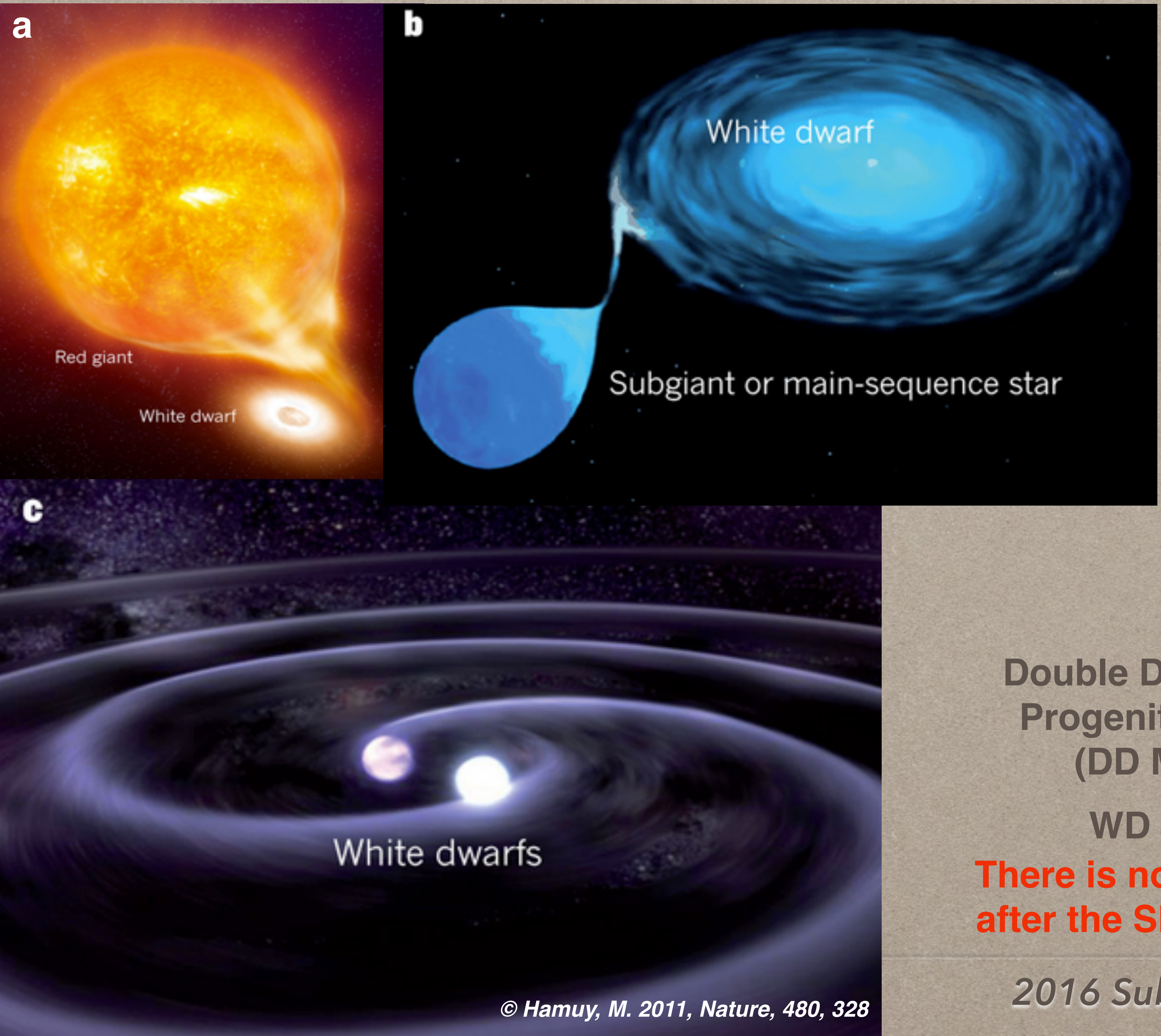
➤ Basics of Type Ia supernovae—the progenitor system



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Single Degenerate Progenitor Model (SD Model)

WD + MS/RG

The companion should be survived.

Double Degenerate Progenitor Model (DD Model)

WD + WD

There is no companion after the SN explosion.

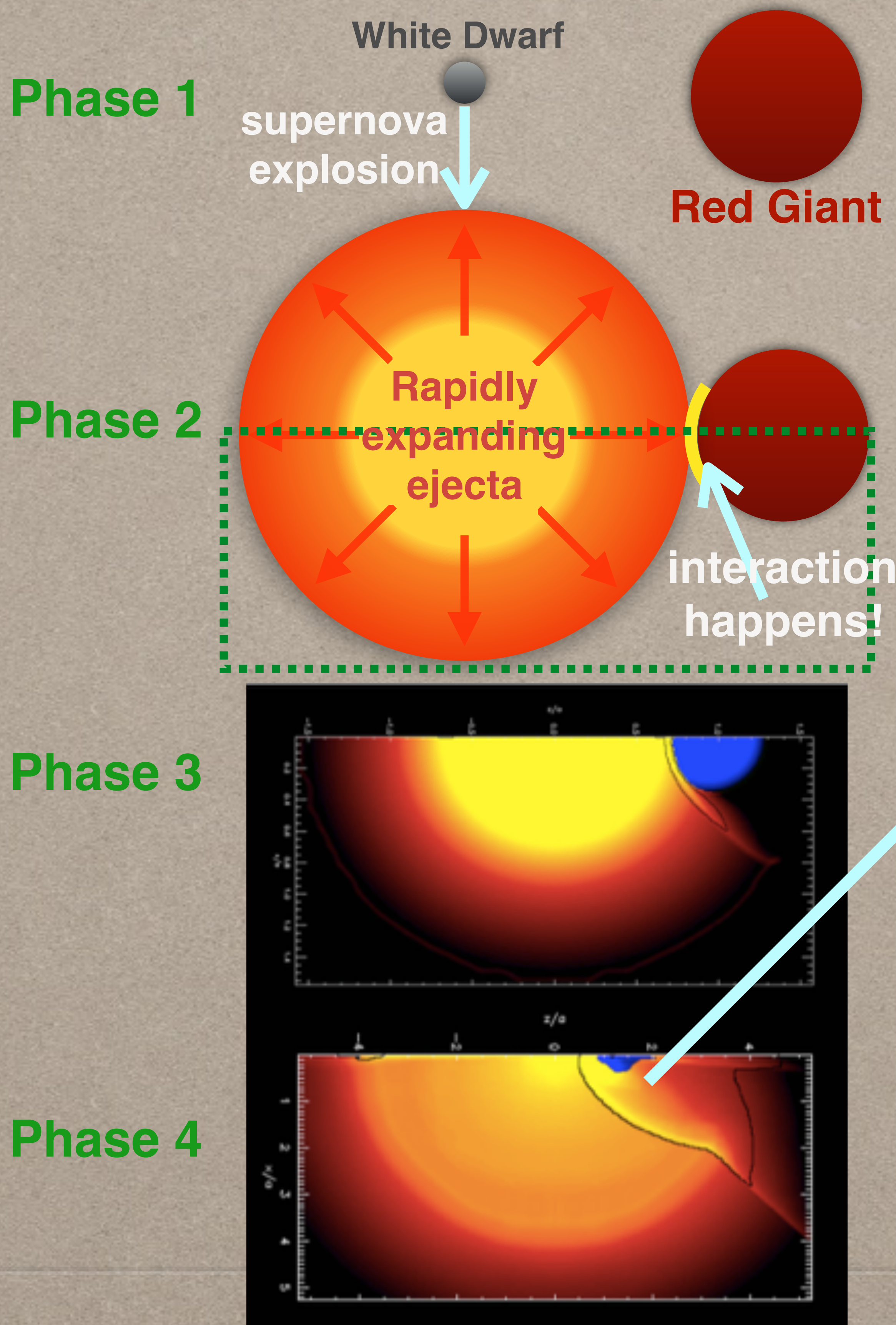
➤ Why early-phase Type Ia supernovae?

"early-phase": within about 3 days after the supernova explosion.

- ✧ Providing a unique diagnostic for the progenitor system.
  - ✦ Finding out the footprint of the companion star;
- ✧ Testifying the SN Ia explosion mechanism.
  - ✦ The early-phase light curve/color diversity;
  - ✦ The carbon footprint in early SN Ia spectra;
  - ✦ Velocity evolution for specific absorption lines;
  - ✦ Spectropolarimetry in the early epoch;

✧ Providing unique diagnostic for the progenitor system

✦ Finding out the footprint of the companion star



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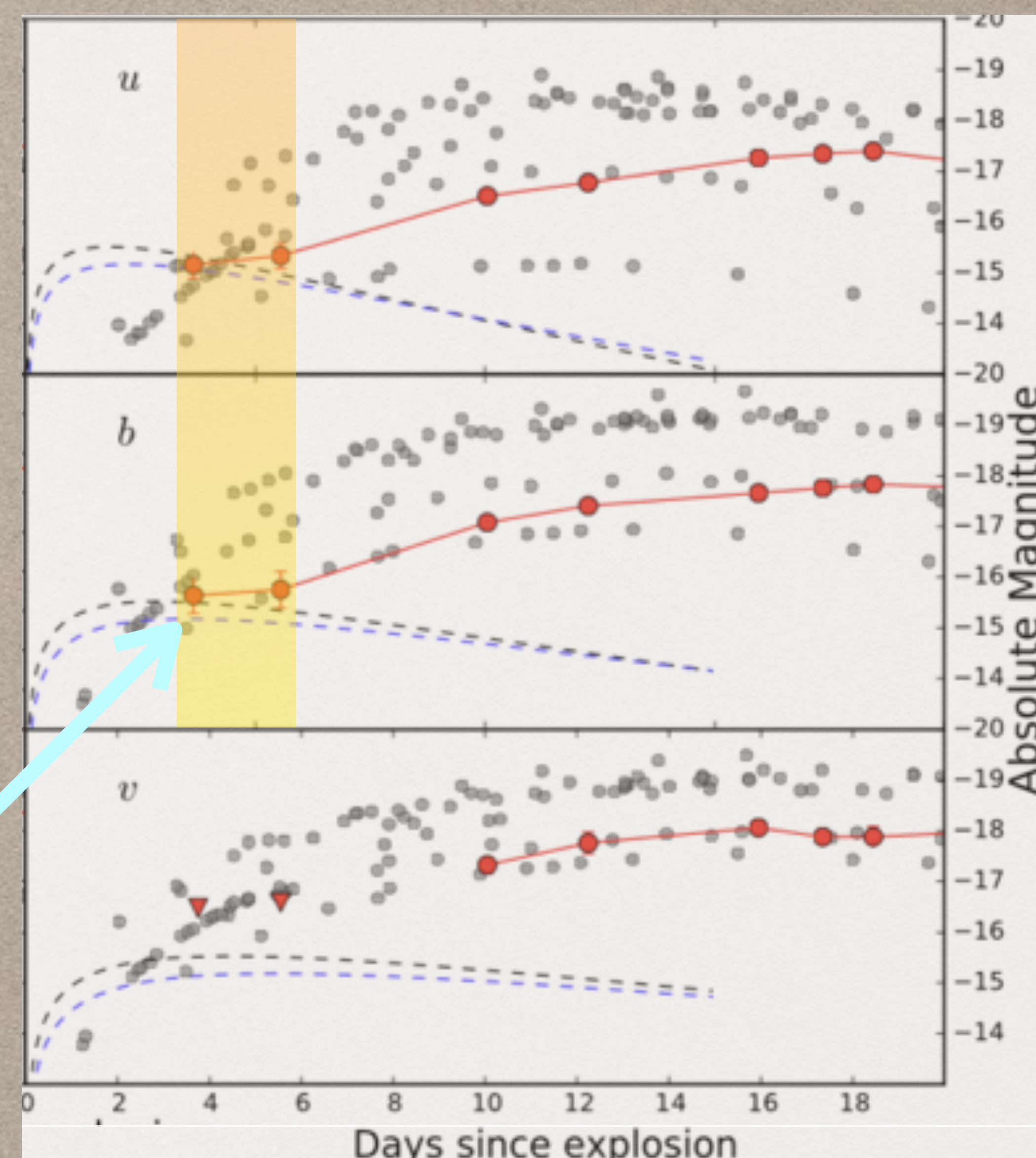

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Extra radiation can be produced from the heated interaction region (Companion-Ejecta Interaction, CEI)

➤ Why Subaru/HSC?

Project	All-Sky Automated Survey for Supernovae (ASSA-SN)
Telescope	Eight 0.14-m robotic telescopes (two Units)
Survey Area	~20,000 sq. deg per night
Observing Depth	≲17 mag in V-band
ESNe Ia*	ASASSN-14lp in 3 years

Project	intermediate Paloma Transient Factory (iPTF)
Telescope	1.2-m Samuel Oschin Telescope
Camera	7.8 sq. deg Camera (11 2k x 4k CCDs)
Observing Depth	< ~20.5 mag in R-band
ESNe Ia*	ptf11kly, iptf13asv, iptf13ebh, iptf14atg, iptf14bdn in 4 years

Project	Dark Energy (time-domain) Survey
Telescope	4-m Blanco Telescope
Camera	Dark Energy Camera (62 2k x 4k CCDs, 3 sq. deg)
Observing Depth	< ~25 mag in V-band
ESNe Ia*	No report

****The statistics is based on published papers.***

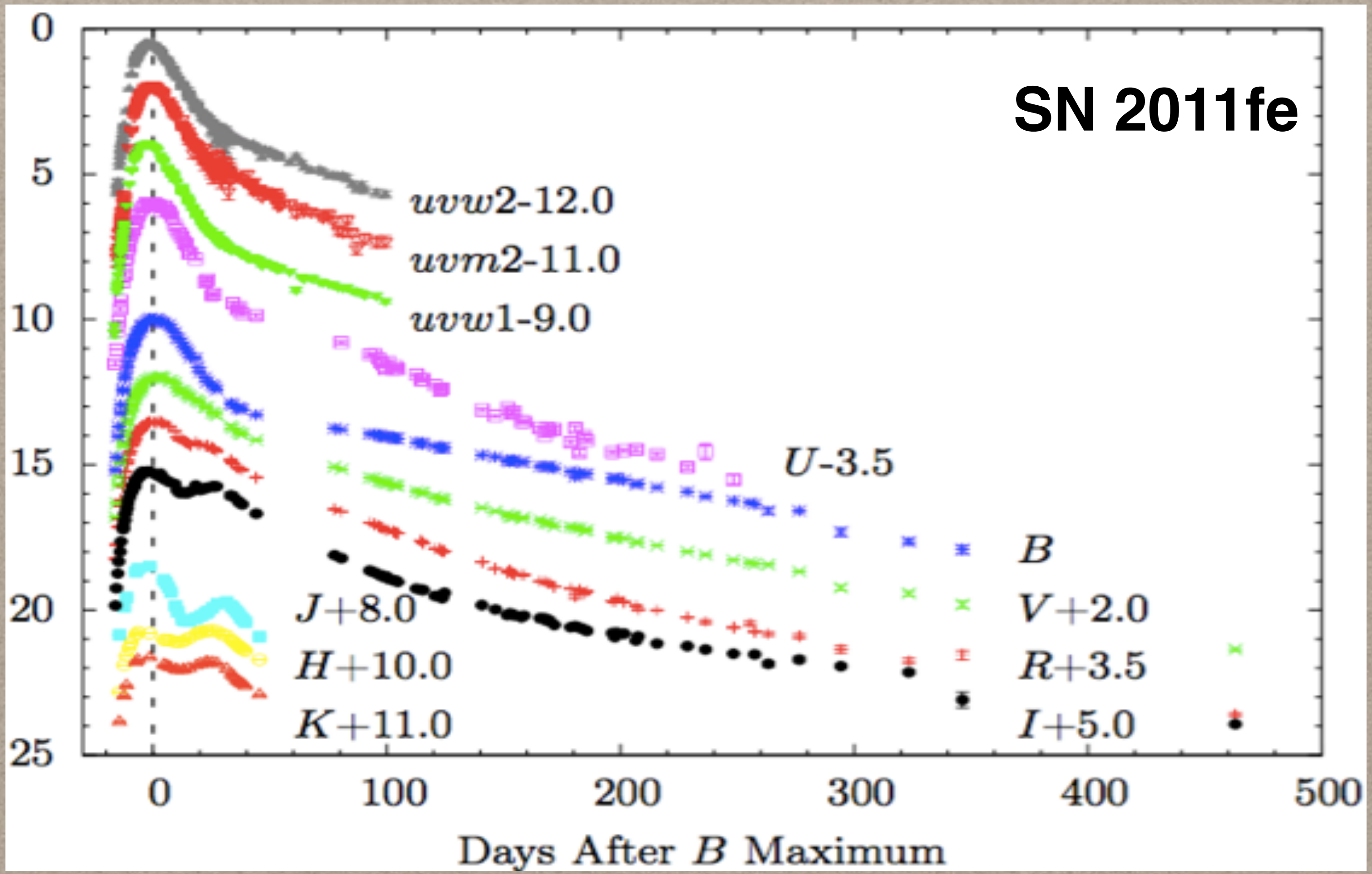
➤ Why Subaru/HSC?

1) High ESNe Ia detection efficiency.

- The largest etendue of Subaru/HSC
- Higher SN Ia rate as the redshift increases

2) Ultra-large magnitude dynamic range for hunting extremely early SNe Ia.

3) Blue-band information can be obtained thanks to the redshift effect.



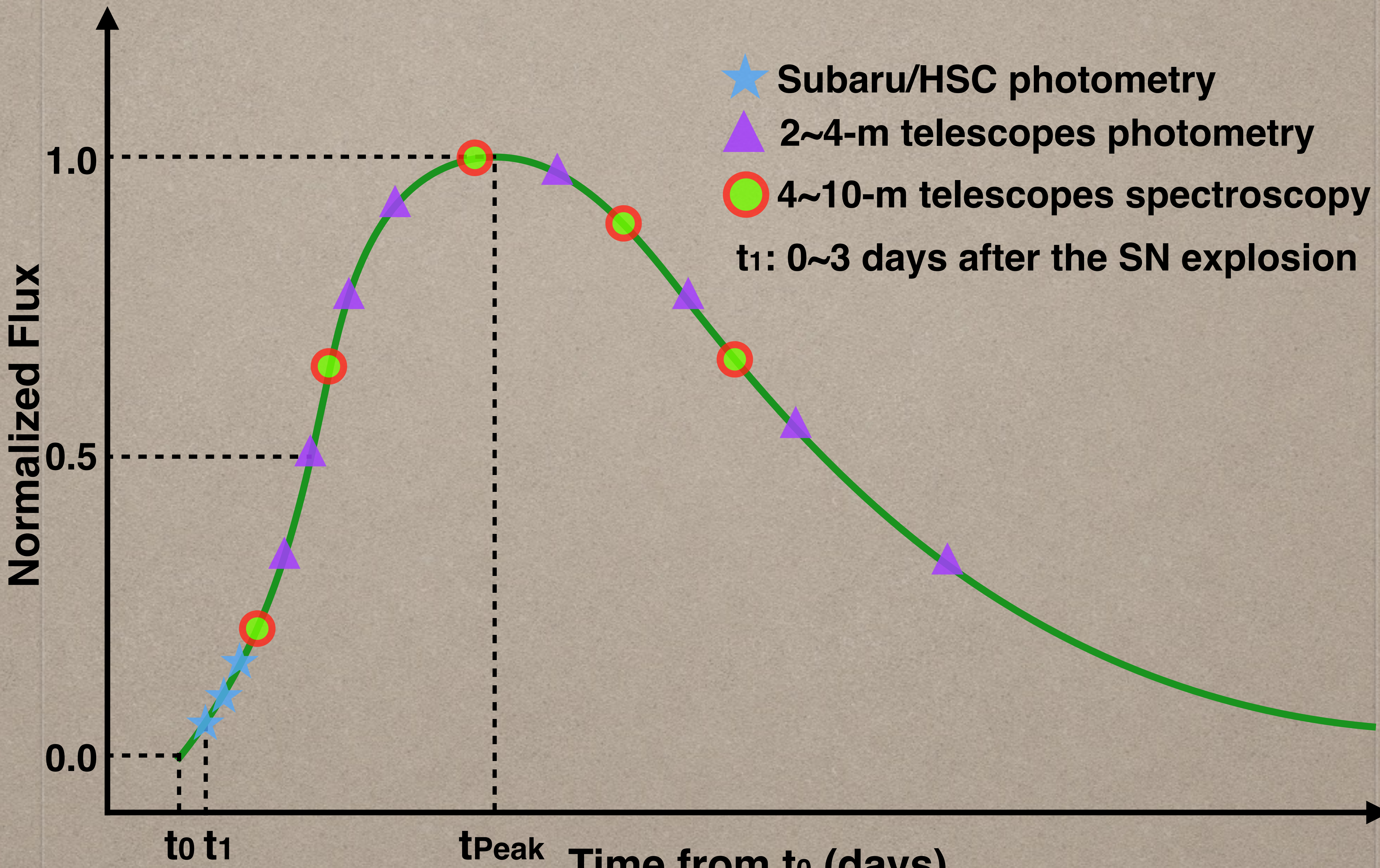
Zhang, K. et al. 2016, MNRAS

The MUlti-band Survey with Subaru for Early-phase SNe Ia (MUSSES)

Ji-an Jiang, Mamoru Doi, Keiichi Maeda, Toshikazu Shigeyama, Naoki Yasuda, Tomoki Morokuma, Masaomi Tanaka, Nozomu Tominaga, Hisanori Furusawa, Nao Suzuki, Ken'ichi Nomoto, Saurabh W. Jha, Zeljko Ivezic, Andrew Connolly, Peter Yoachim, Pilar Ruiz-Lapuente, Maximilian Stritzinger, Paolo Mazzali, Christopher Ashall, David Jones, Lifan Wang, Ferdinando Patat, Jeremy Mould

- Period: Started from April 04, 2016
- Objectives: Investigating the photometric/spectroscopic behavior of ESNe Ia
- Observational Mode: Subaru/HSC survey+ follow-up observations
- Time Allocation: 2 nights Subaru/HSC observation for each observing run
- Filters: g- and r-band for the Subaru/HSC observation
- **Limiting Magnitude (S/N = 5): ~26 mag in g-band**
- **Cadence: 1 day**
- **Survey Area: ~60 deg^2 for each observing run (40 deg^2 for the first run)**
- **Expected Number of ESNe Ia: ~6 per observing run**
- **Follow-up Network:** 10.4-m GTC, 9.2-m SALT, 9.2-m HET, 8.2-m VLT, 8.1-m Gemini, 3.5-m ARC, 2.5-m NOT, 2.5-m INT, 2-m LT & 1-m Kiso

Observational Strategy of MUSSES



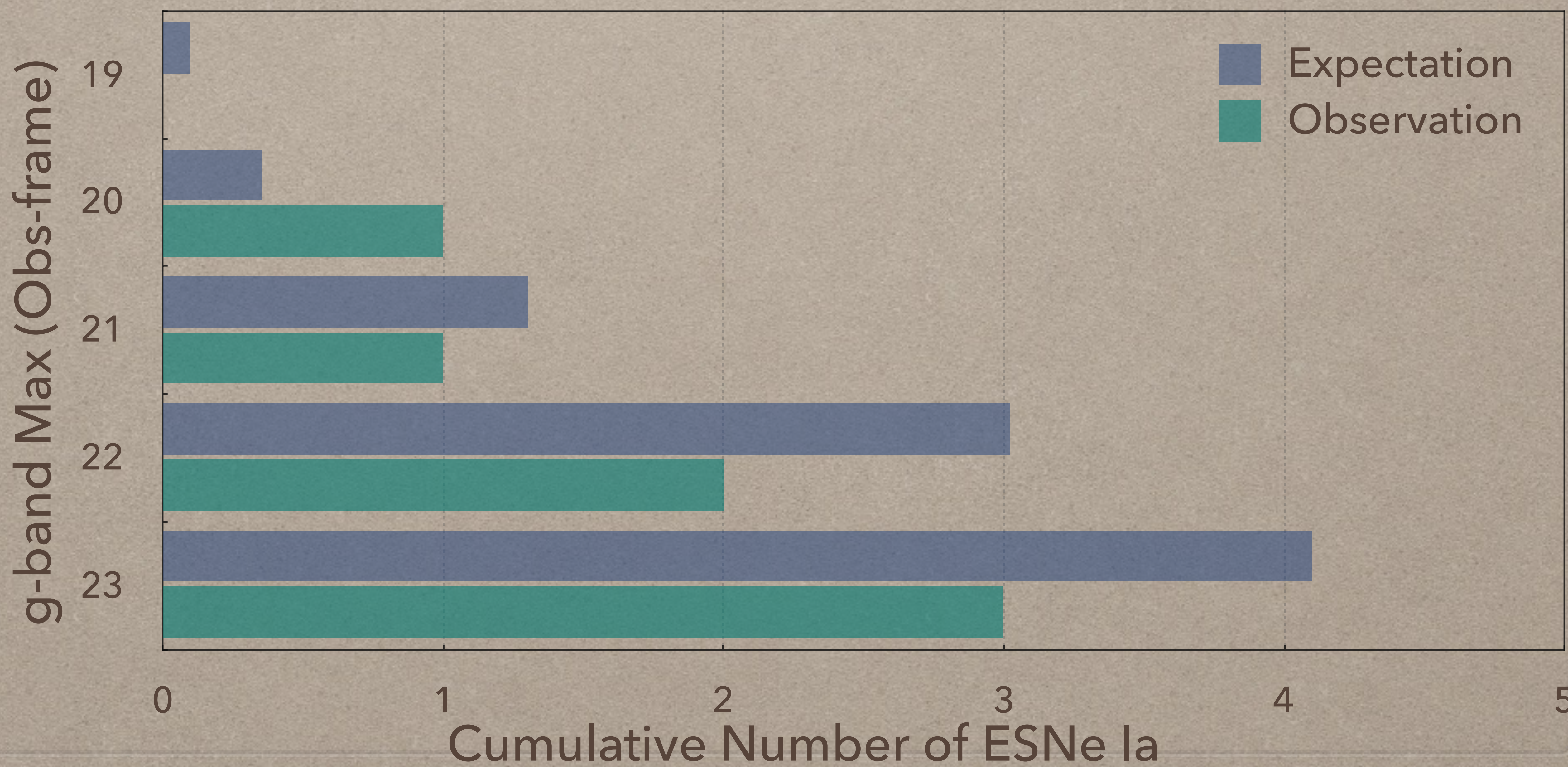
Review of the 1st MUSSES run (1604-1606)

➤ Review of the first observing run of MUSSES

Expected ESNe Ia number: ~4.1 @ $z \lesssim 0.5$;

Identified ESNe Ia: 3 @ $z \lesssim 0.5$;

Note that no transient at the center of the host has been selected as possible candidates. In general, the total ESNe Ia found from the first MUSSES observation is well in line with our expectation.



➤ Prospects for the ESNe Ia study with Subaru/HSC

Early-phase observation is the most promising approach for figuring out the progenitor system and explosion mechanism of SNe Ia. There is no doubt that Subaru/HSC has an incomparable performance for ESNe Ia hunting at present.

In order to maintain the advantage of Subaru/HSC ESNe Ia study, it is necessary to carry out subsequent MUSSES observations ASAP. Based on the success of the first observing run, we plan to carry out the second MUSSES observing run in ~~S16B~~, ~~S17A~~, S17B,? which mainly aims to:

I) Keep enlarging the ESN Ia samples size for the statistical analysis;

II) Carrying out early-phase spectroscopic follow-up observations with the upgraded follow-up network;

III) Hunting for unexpected transients.

➤ Summary

✧ The early-phase SN Ia plays an irreplaceable role in addressing the progenitor and explosion mechanism issue of SNe Ia.

✧ The large magnitude dynamic range and high SNe Ia survey efficiency can be realized simultaneously with Subaru/HSC, which is the key for hunting ESNe Ia.

✧ In order to maintain the advantage of ESNe Ia study with Subaru/HSC, it is imperative to carry out systematical investigation of the early-phase photometric/spectroscopic behavior of SNe Ia in subsequent MUSSES observing runs as soon as possible.