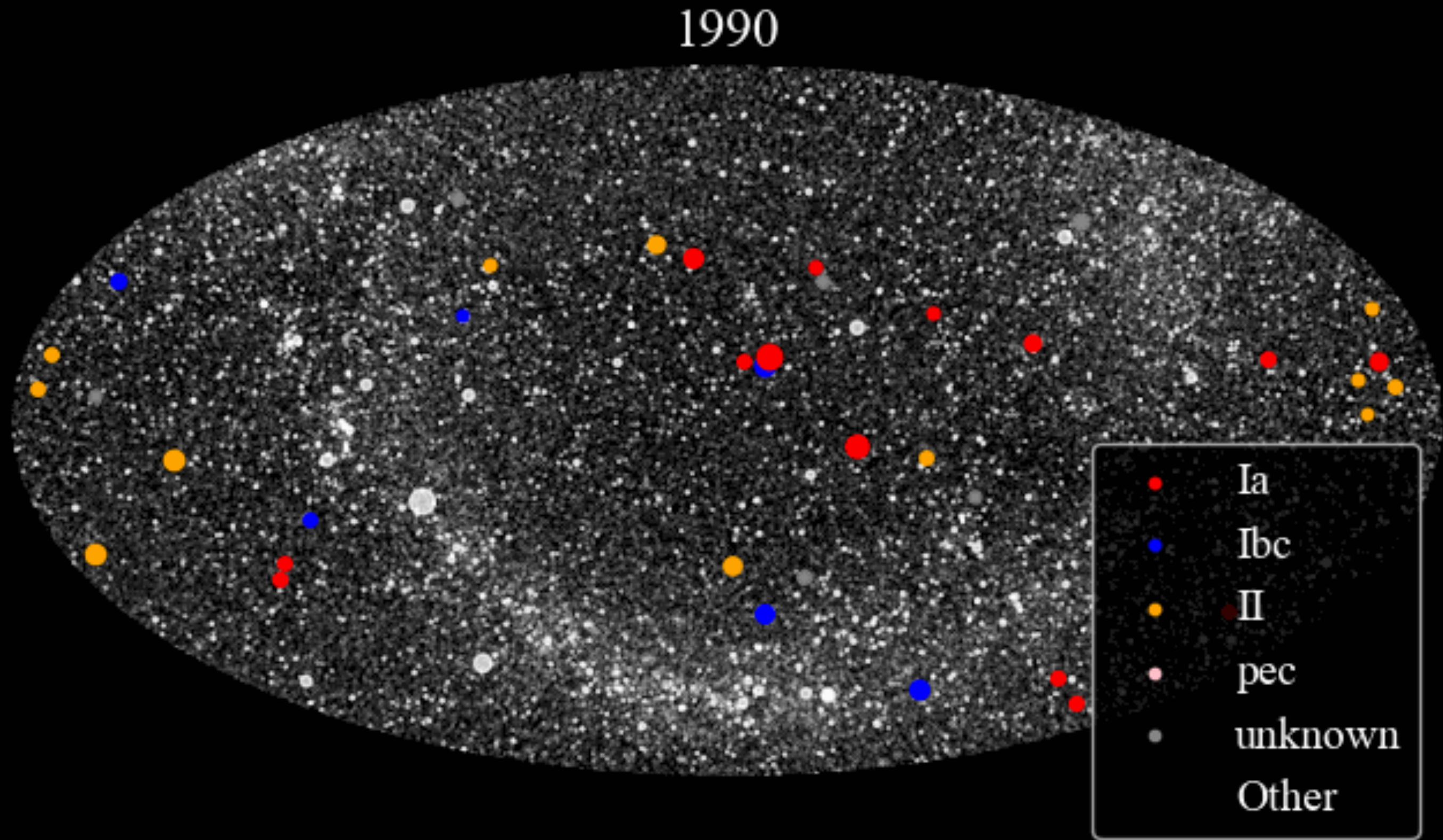


A systematic search for rapid transients in the Subaru HSC-SSP transient survey

Toshikage et al. 2024

Seiji TOSHIKAGE (Tohoku University),
in collaboration with Masaomi Tanaka, Naoki Yasuda, Takashi J. Moriya,
Ichiro Takahashi, Ji-an Jiang, Mitsuru Kokubo, Naoki Matsumoto,
Keiichi Maeda, Tomoki Morokuma, Nao Suzuki, and Nozomu Tominaga

Discovered supernovae



Made with data from open supernovae catalogue

2010 - PS1, ATLAS, ZTF, ...

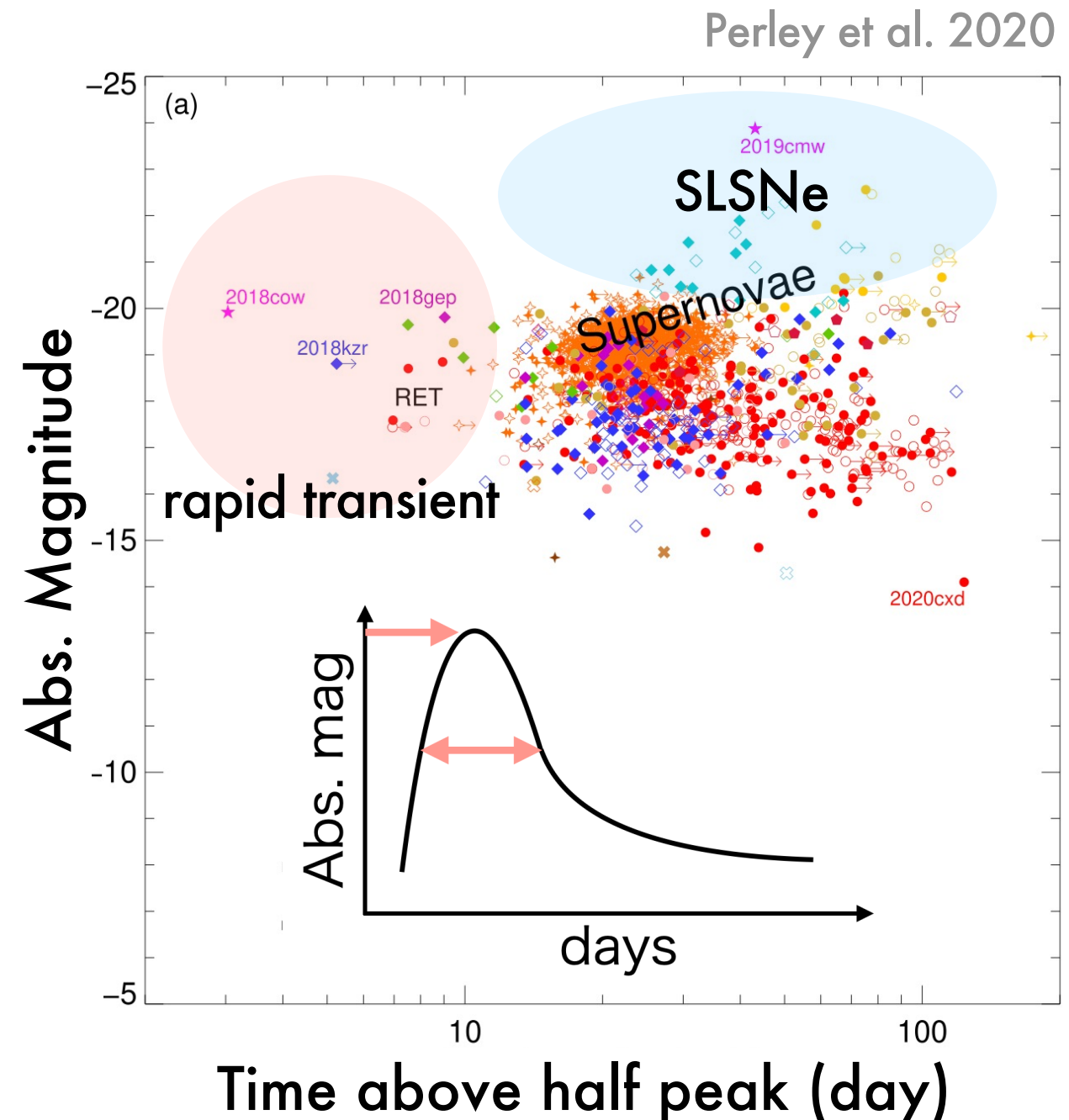
~ 1,000 - 10,000 SNe/year

+ new types of transient

- Super Luminous SNe (SLSNe)
- rapid transient (FBOT, FOT...)
- Type Ibn, Icn ...

2025 - Rubin/LSST, WFST

~ 100,000 SNe/year



For selecting follow-up targets or utilizing light-curve data, photometric classification of transient is needed

What is rapid transient? (in 2010s)

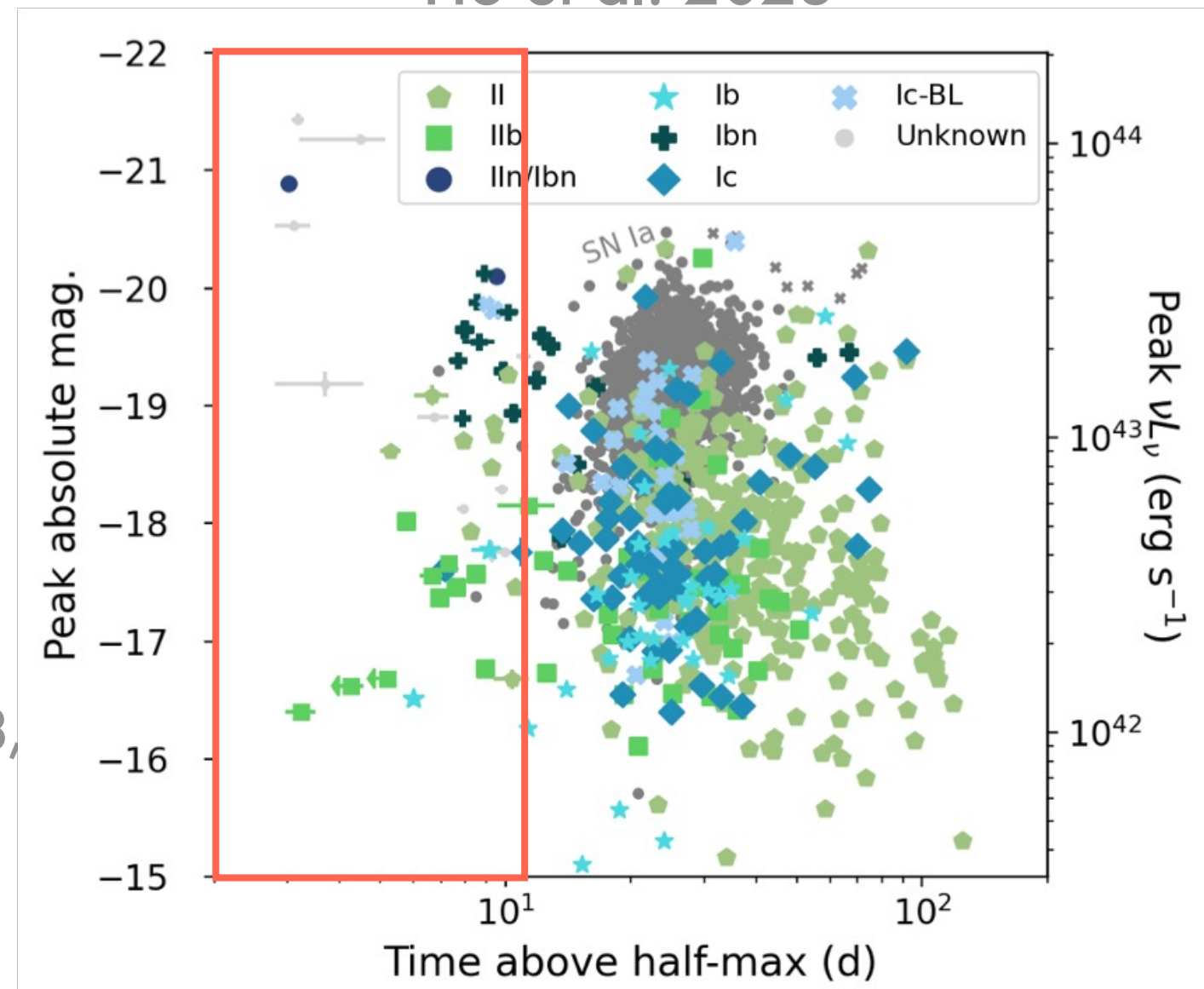
4

**time scale is shorter than
typical supernovae**

$$\Delta t \leq 12\text{day}$$

Drout et al. 2014, Pursiainen et al. 2018,
Tampo et al. 2020

Ho et al. 2023



What is rapid transient? (in 2020s)

5

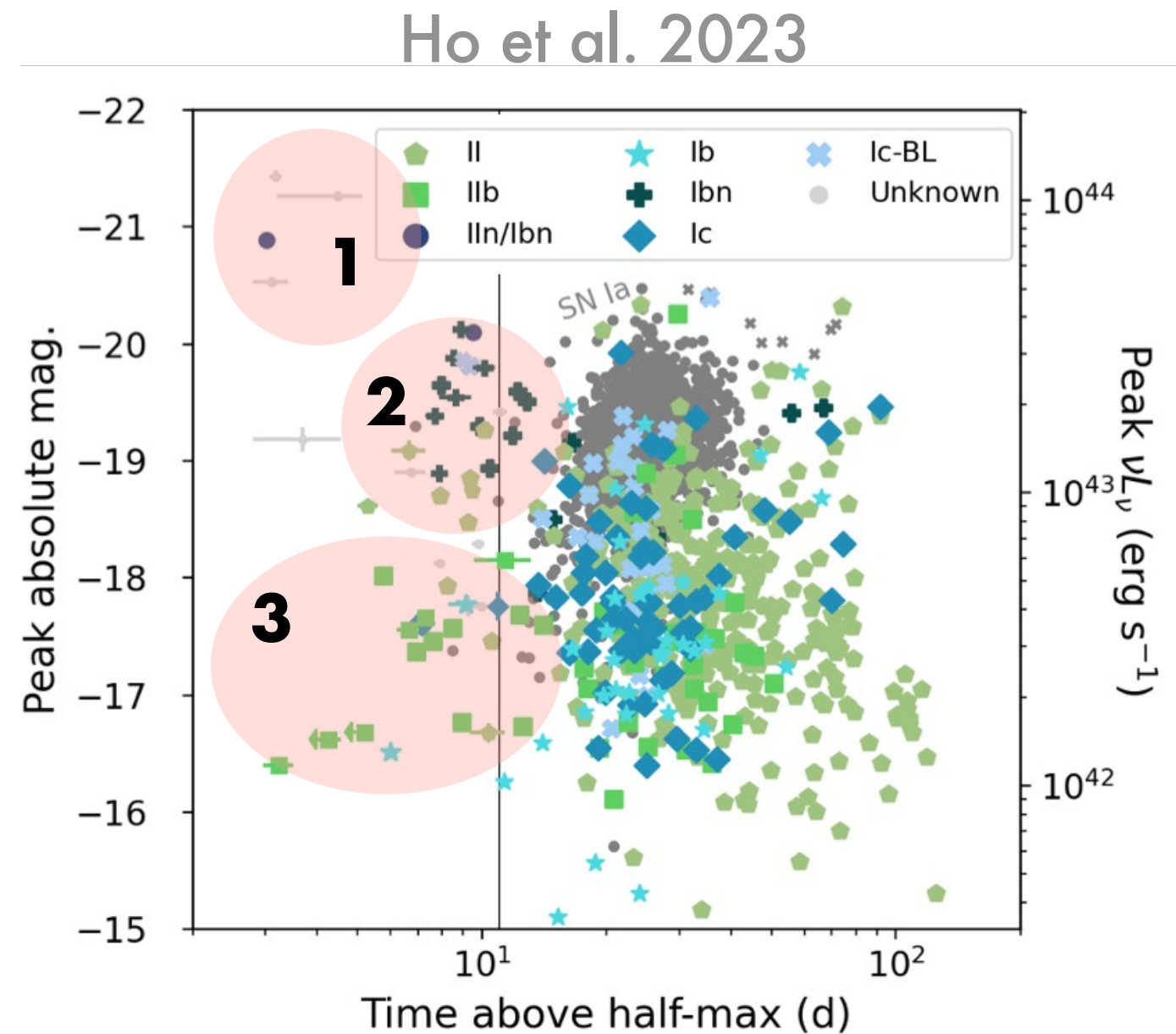
short timescale

$$\Delta t \leq 12 \text{ day}$$

Drout et al. 2014, Pursiainen et al. 2018,
Tampo et al. 2020

subgroup Ho et al. 2023

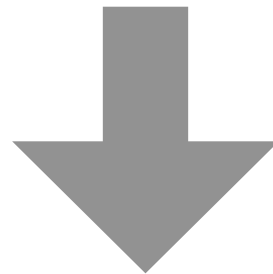
1. Unknown (2018cow-like)
2. CSM interaction (mainly Ibn)
3. first peak of type IIb



**the number of rapid transients is not enough,
and limited in the local universe ($z \leq 0.5$)**

Current issues

- development of the photometric classification method
- the number of Rapid Transient is not enough, especially in mid to high- z
for discussing event rate, luminosity function, host galaxy ...



Exploration of rapid transient in HSC-SSP transient survey

- development of the ML classifier based on photometric data
- statistical analysis of rapid transient with big data

Subaru HSC-SSP transient survey

7

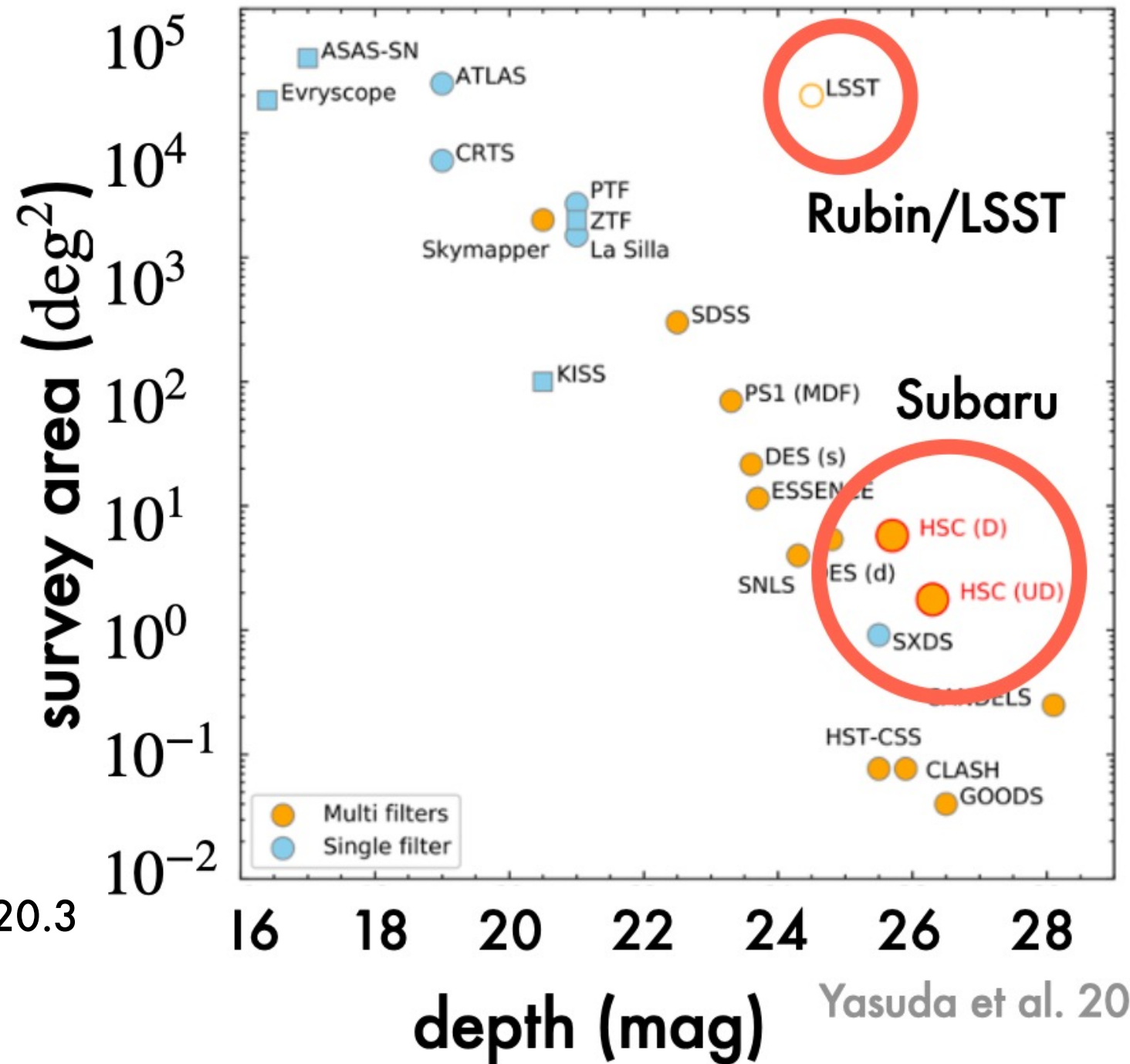
depth ~ 26 mag

filter g, r, i, z band

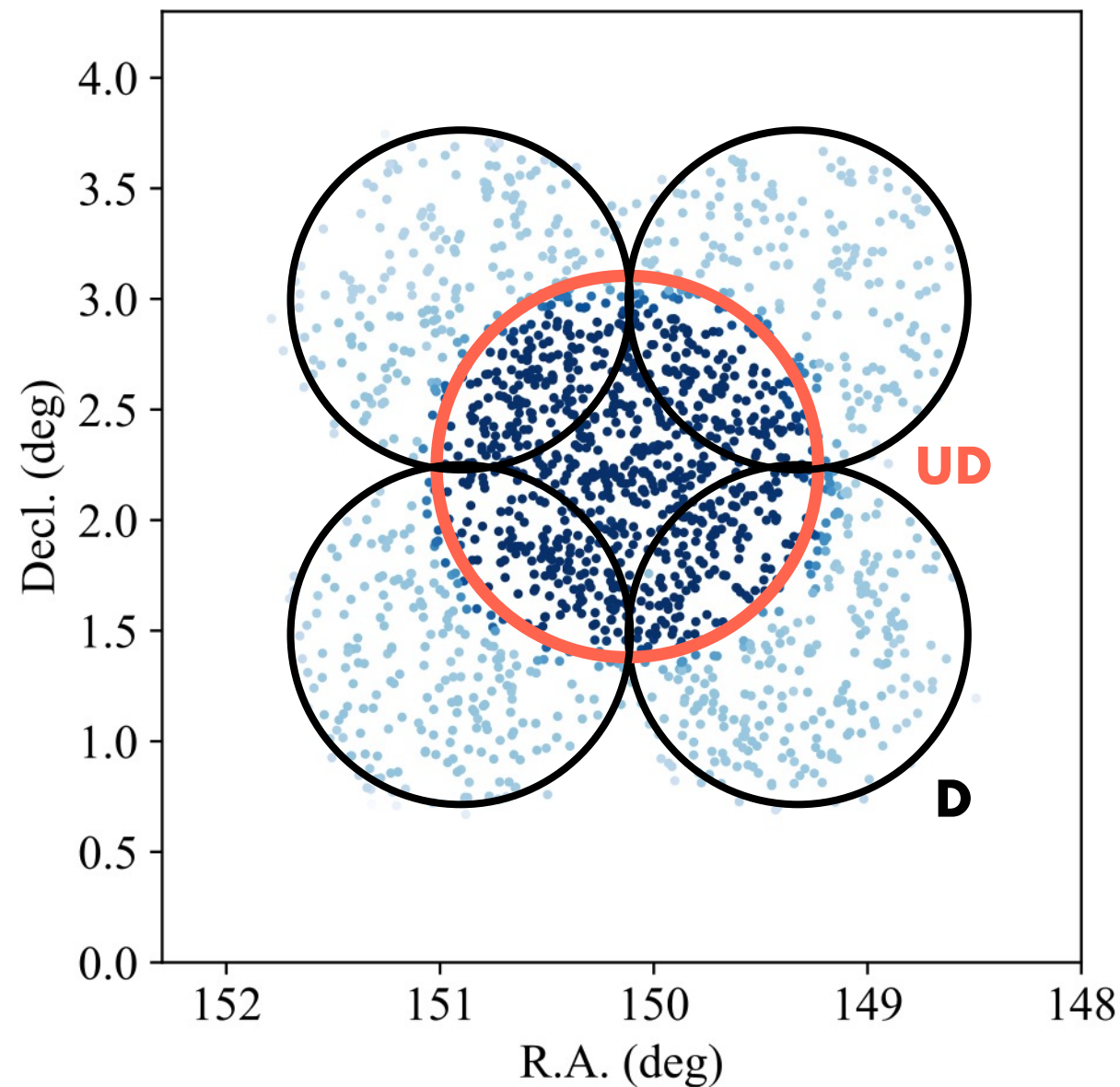
cadence 7 – 10 days

Field of View ~ 1.8 deg²

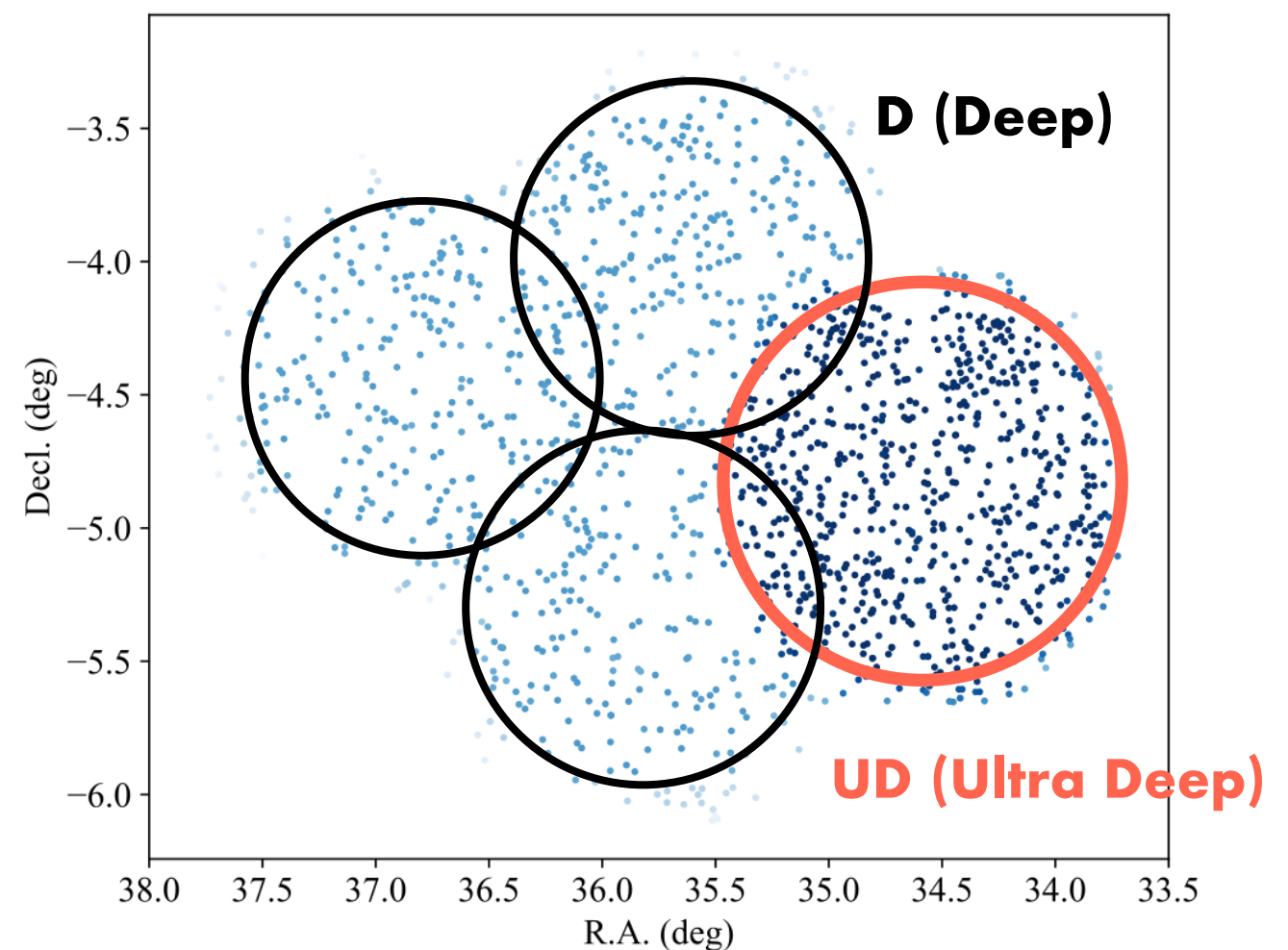
field	COSMOS	SXDS
period	2016.11 – 2017.4	2019.11 – 2020.3
SNe	1824	1557



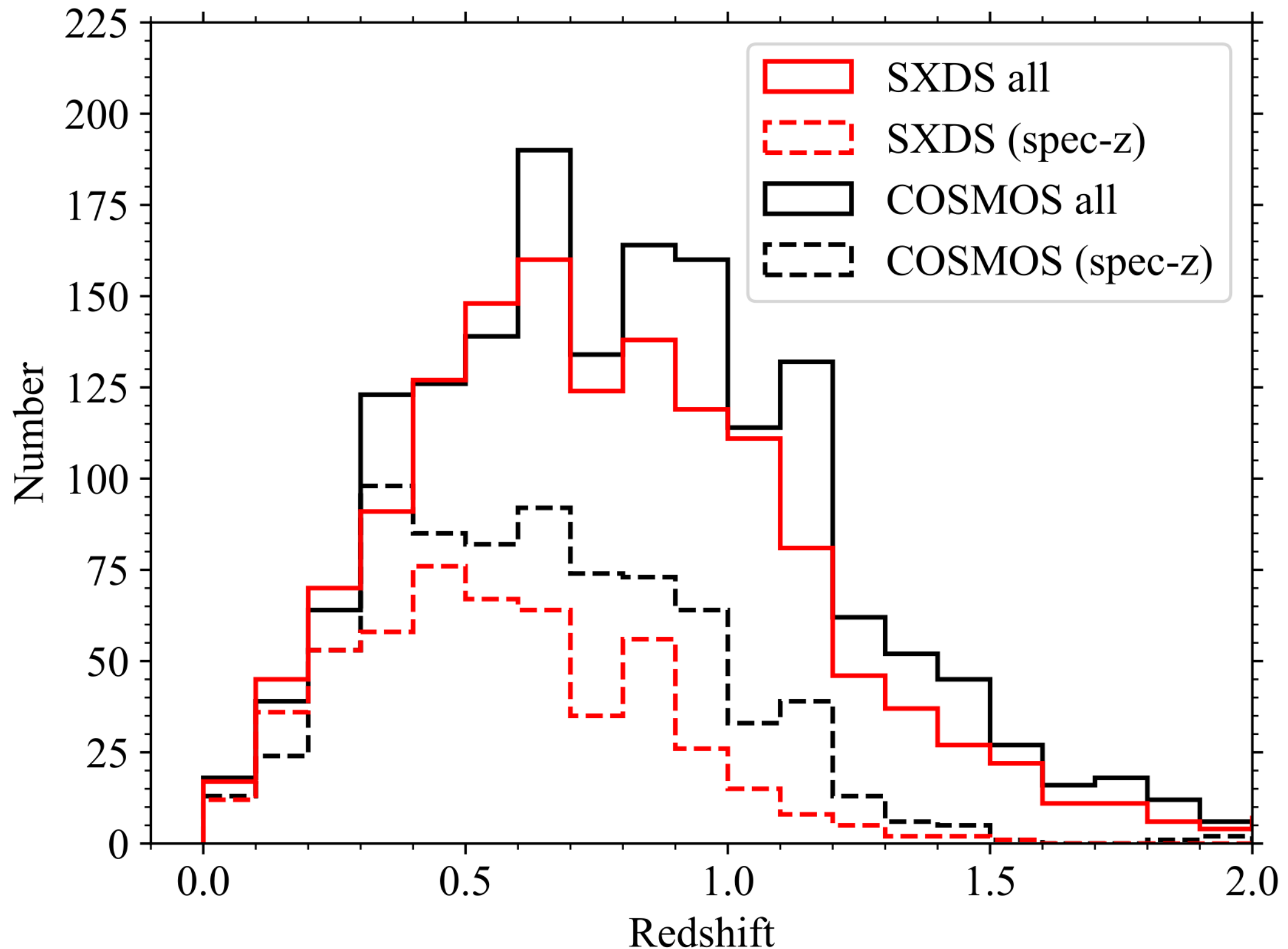
COSMOS (Cosmic Evolution Survey) **1824 SNe**



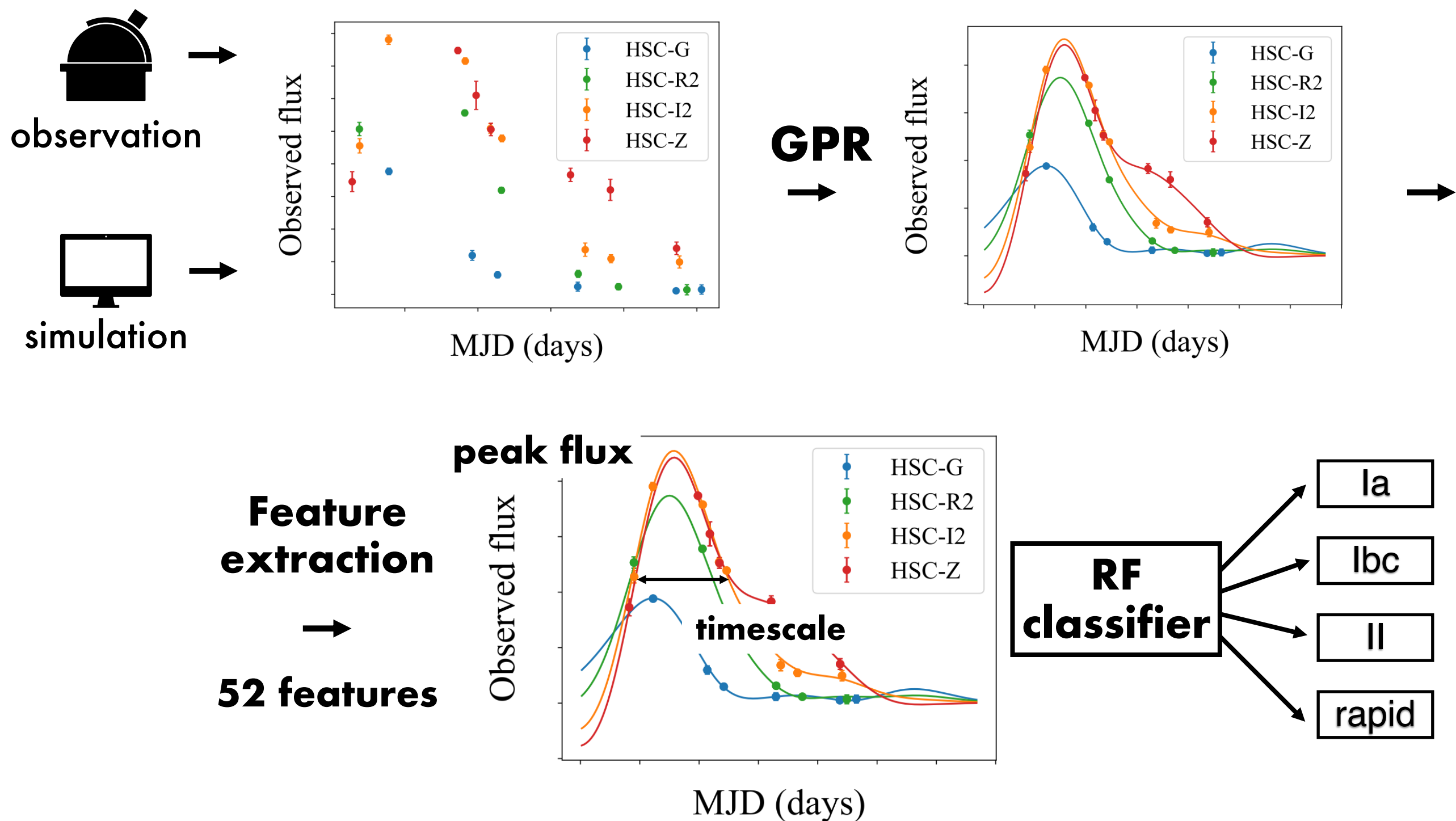
SXDS (Suparu/XMM Deep Survey) **1557 SNe**



Exploration of rapid transients in big data ~ 3000 SNe



Subaru can detect supernovae around $z=1.5$



Random Forest (supervised learning method)

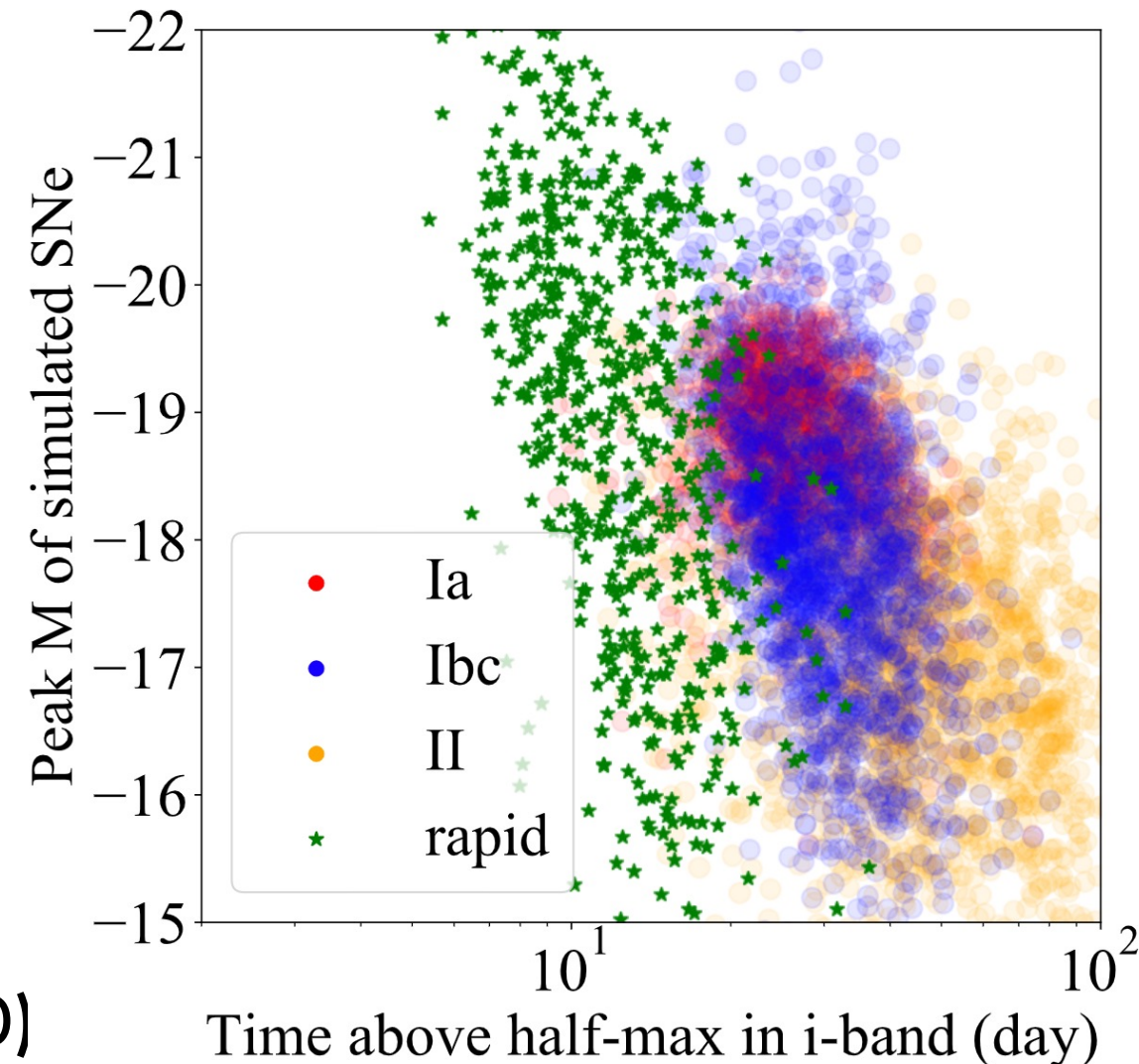
Breiman 2001, Pedregosa et al. 2011

Ia	model template (SALT II)
Ibc	observational template
II	Kessler+ 2009, Sako+ 2011

Arnett 1982

rapid **one zone** approx. model
cover reported objects in phase space

based on these templates simulate LCs
→ training data set (Ia, Ibc, II: 10000, rapid:3000)



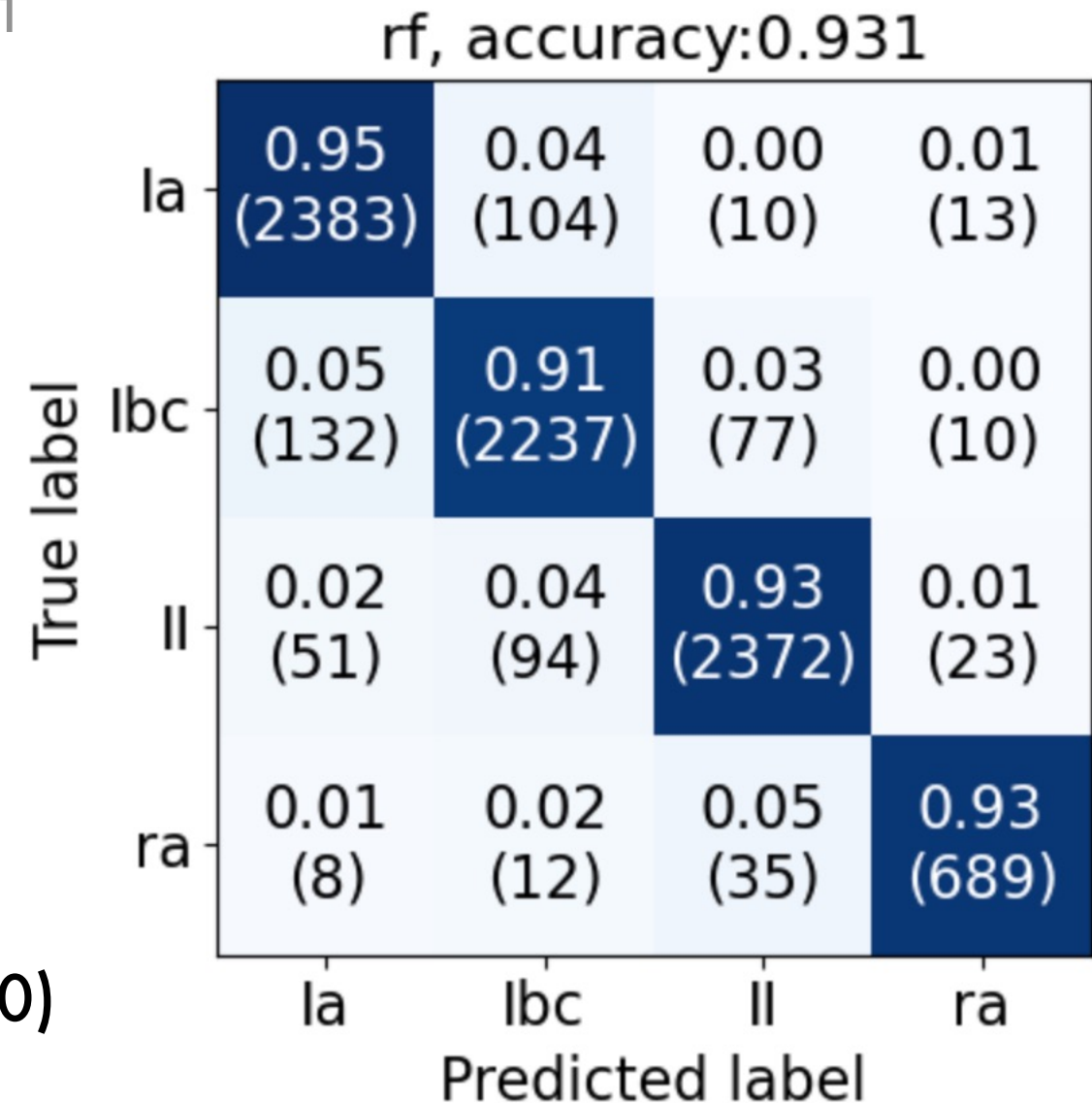
Random Forest (supervised learning method)

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rapid	one zone approx. model cover reported objects in phase space

Arnett 1982

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ML model archive high accuracy more than 90%

HSC transient survey 3381 SNe

ML classification
supervised model : random forest

rapid transient candidates 315 SNe

selection with data quality

- ✓ LC peak was observed
- ✓ No unphysical data point
- ✓ redshift is identified

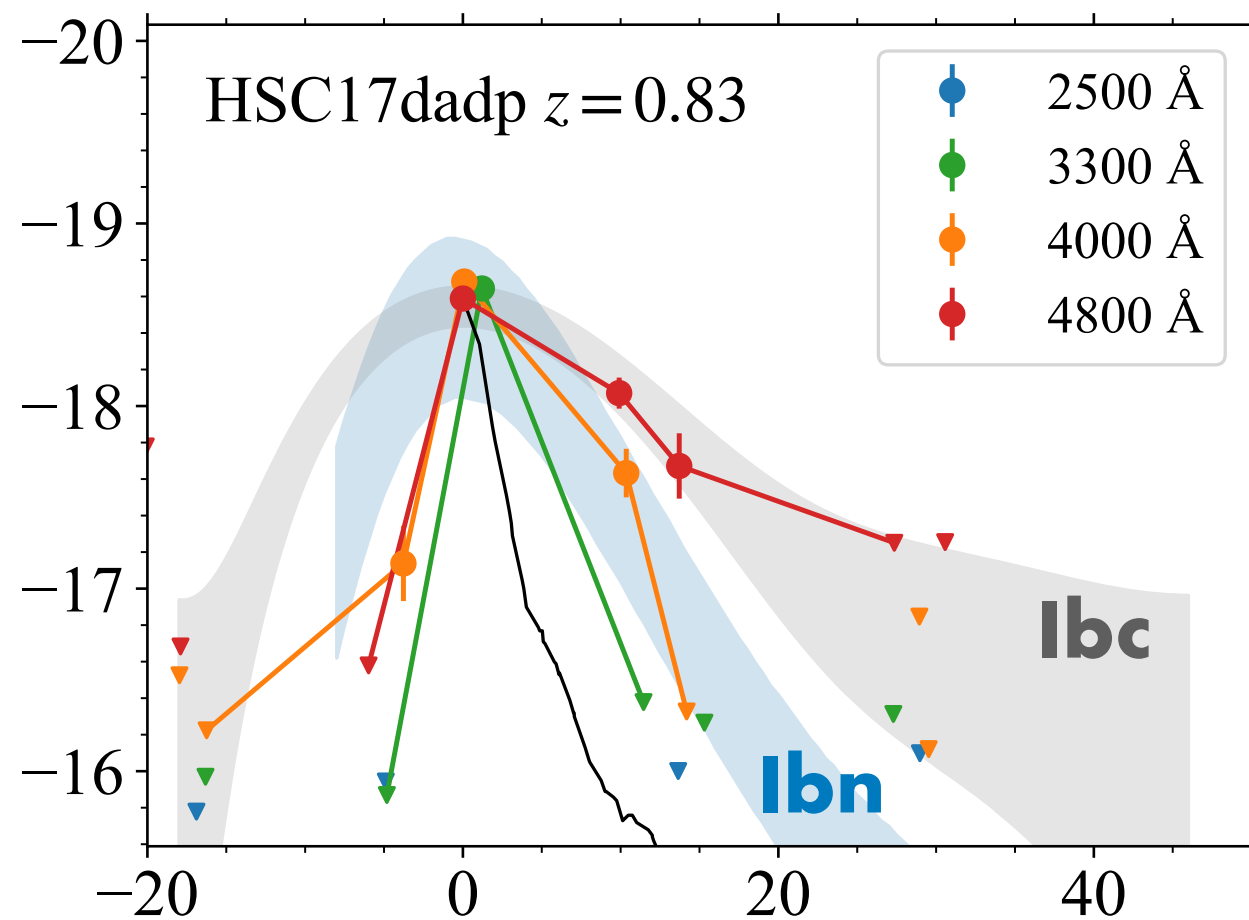
final candidates 76 SNe

Visual inspection with literal samples

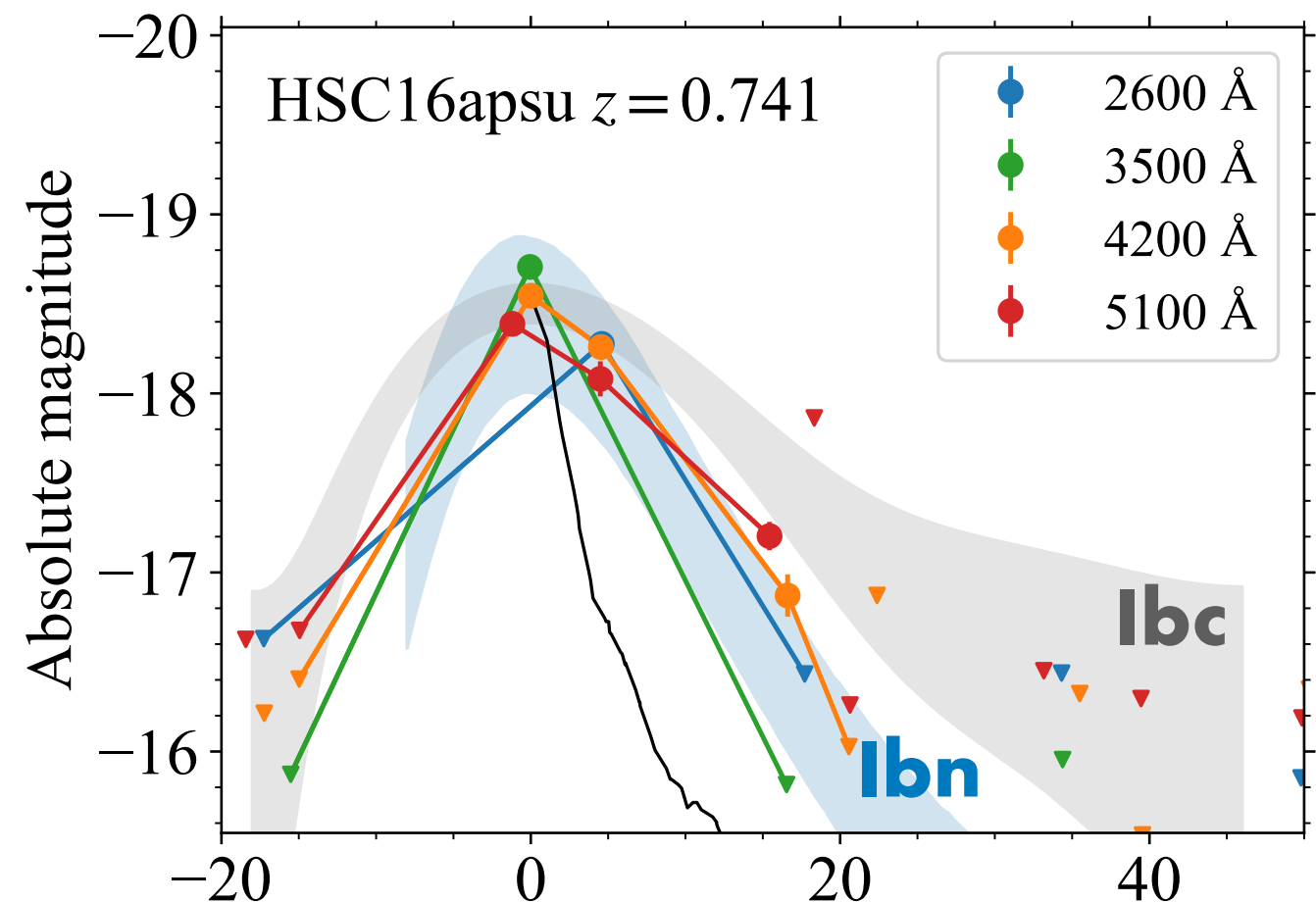
- ✓ GPR miss interpolation?

14 objects

Tampo et al. 2020



New!



14 rapid transients were identified
(including 4 objects already reported by Tampo et al. 2020)

Event rate

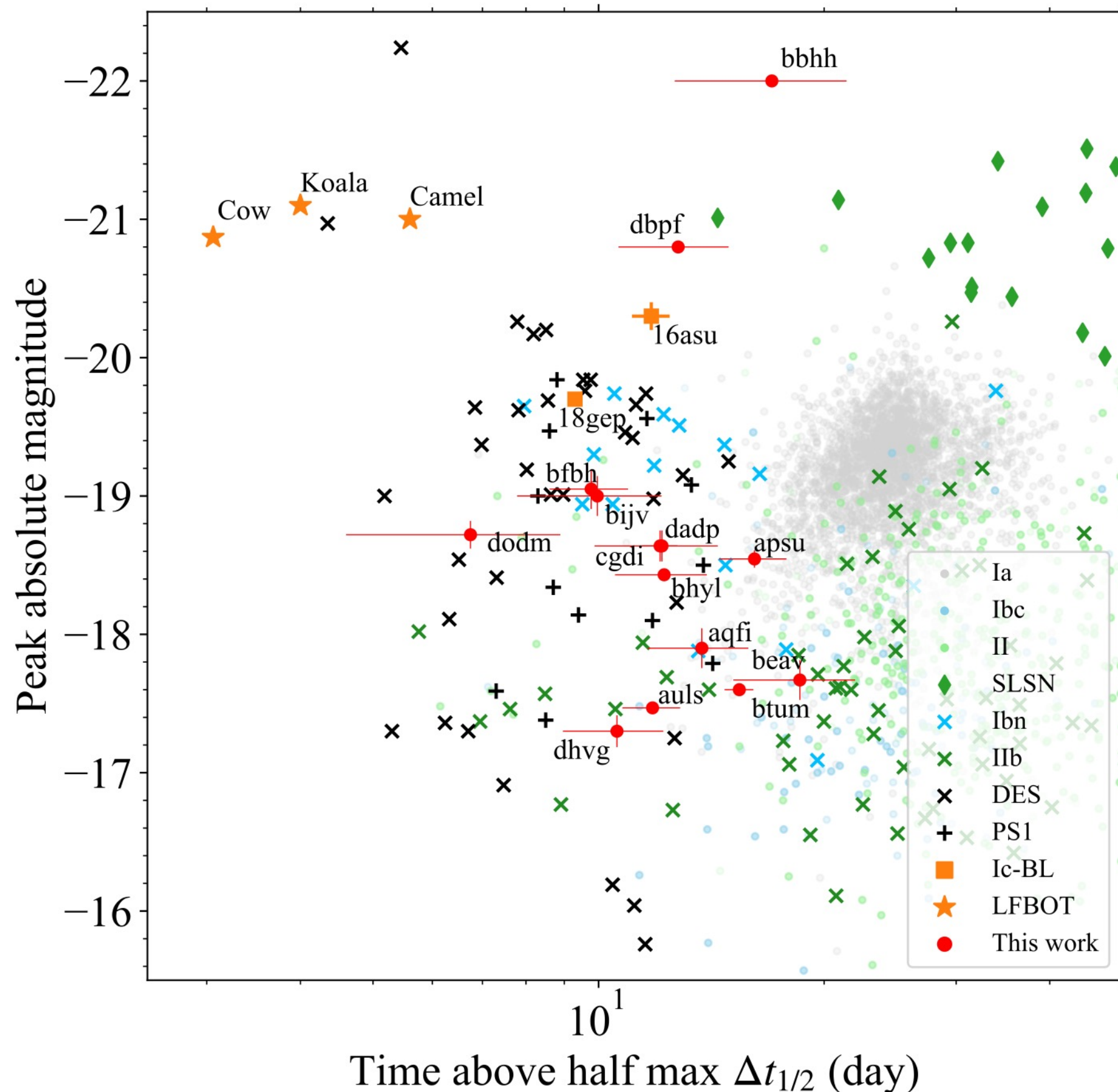
$$r = \sum_i^N \frac{(1 + z_i)}{\epsilon T_i V_{max,i}}$$

$$\sim 4 \times 10^3 \text{ yr}^{-1} \text{ Gpc}^{-3}$$

$$\sim 1\% \text{ of CCSNe @ } z \sim 0.75$$

$\sim$ Drout et al. 2014,

$\sim$ Pirsainen et al. 2018



rapid end of SLSNe

$$\sim 1 \times 10^2 \text{ yr}^{-1} \text{ Gpc}^{-3}$$

$$\geq 10\% \text{ of SLSNe @ } z \sim 1.5$$

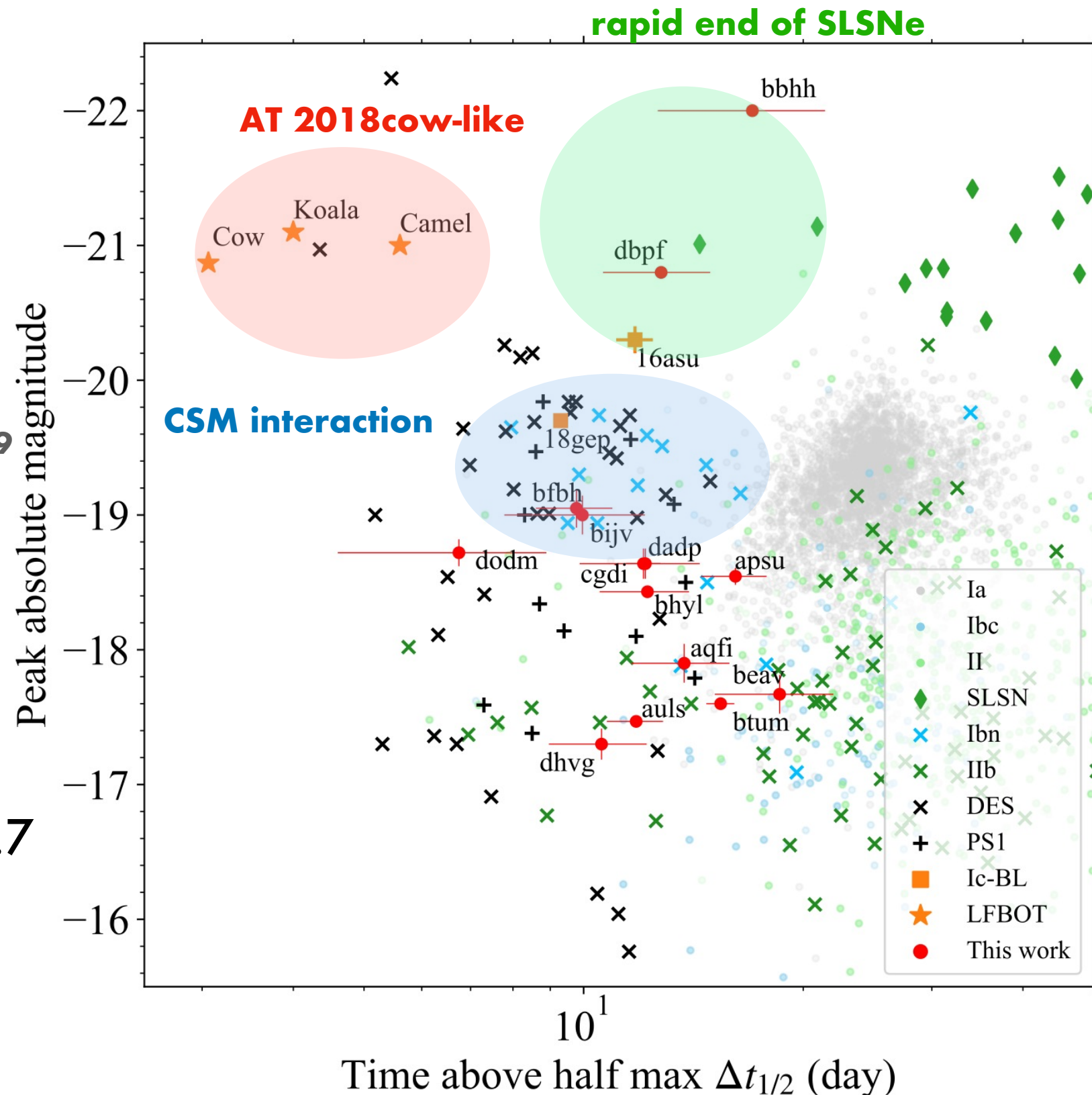
Cook et al. 2012, Moriya et al. 2019

CSM interaction (Ibn-like)

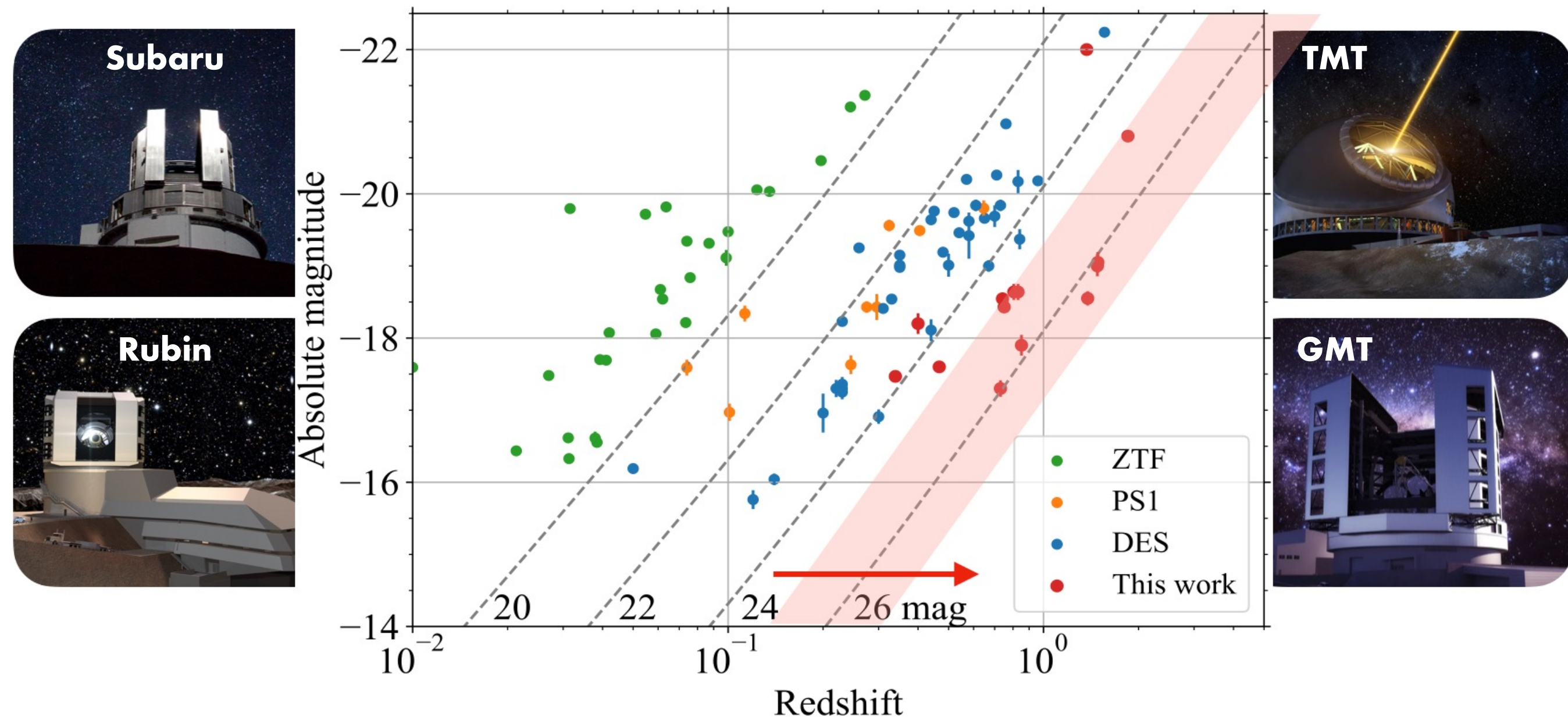
$$\sim 5 \times 10^2 \text{ yr}^{-1} \text{ Gpc}^{-3}$$

$$\geq 1\% \text{ of Type Ib SNe @ } z \sim 0.7$$

Strolger et al. 2015



Photometric search by Rubin, Subaru



→ **Spectroscopic confirmation by Subaru/PFS + ELTs**

Exploration of Rapid Transient in HSC-SSP transient survey

1. selection of rapid transient

development of classification method with ML

identified 14 rapid transients

2. analysis of the rapid transient

rapid transient $\sim 1\%$ of CCSNe

Ibn-like supernova $\geq 1\%$ of Ibc SNe @ $z = 0.7$

rapid and luminous SNe $\geq 10\%$ of SLSNe @ $z = 1.5$