

Subaru HSC survey optimized for optical transients (SHOOT)

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Outline

- Transient survey with HSC
- Realtime data analysis system
- Scientific results
- Future plan

Etendue of telescopes/cameras

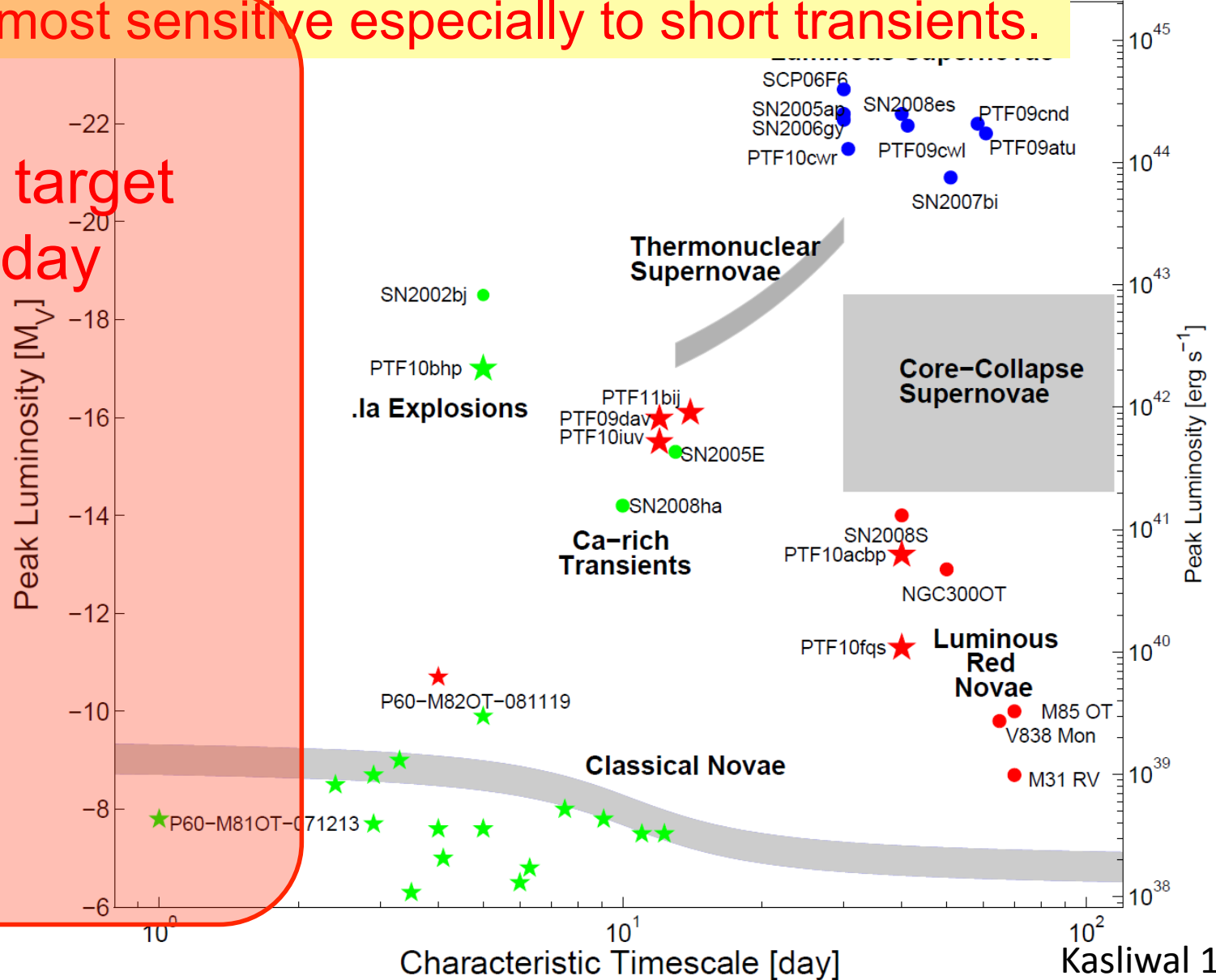
Survey	Diameter [m]	FoV [deg ²]	Etendue (AW, roughly) [m ² deg ²]
ROTSE-III	0.45	3.42	0.54
CRTS	0.7	8	3.1
KISS	1.05	4	3.5
PTF	1.26	7.8	9.7
Subaru/HSC	Subaru/HSC is currently the instrument with the highest etendue.		
SDSS	2.5	1.5	7.4
SNLS	3.6	1	10.2
HST/GOODS	2.5	0.003	0.015
DECam	4	3.0	38
Subaru/HSC	8.2	1.75	92
LSST	8.4	9.62	319

2022-

Timescale of transients

HSC is most efficient per unit time,
i.e., most sensitive especially to short transients.

Our target
 $< \sim 1$ day



Huge data should be reduced in realtime.

- HSC
 - 104 science CCD chips ~ 900M pixels
 - data flow: ~4TB/night
 - 200-300 exposures/nights
 - raw data: ~2GB/exposure
 - processed data: ~26GB/exposure
 - final data: ~36GB/epoch
- KWFC (Kiso Supernova Survey: a pilot survey)
 - Data flow: ~50GB/night
 - 8 CCD chips
 - ~100exposures/nights

Realtime data analysis is challenging.

Real-time transient detection system at Hilo

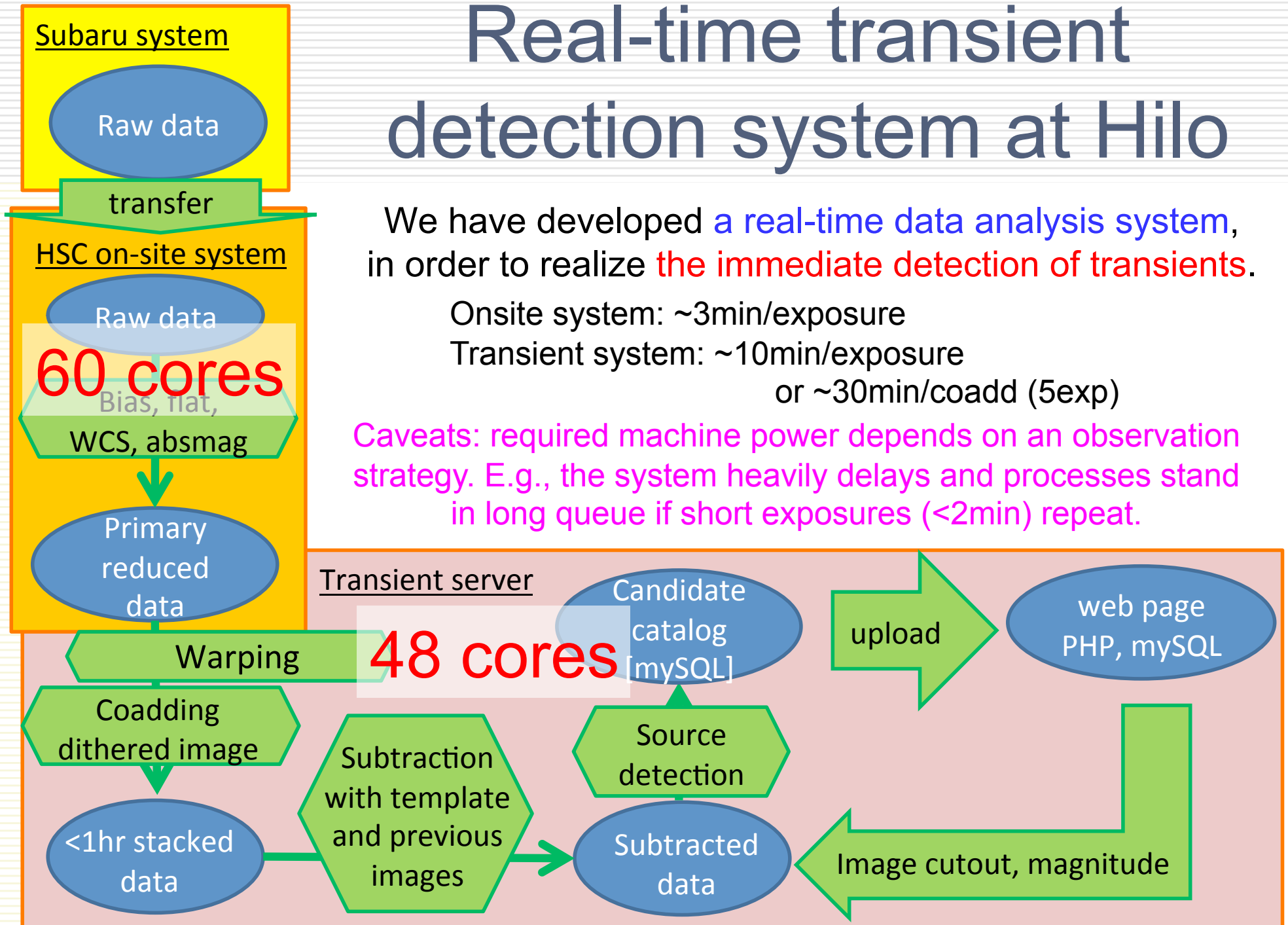
We have developed a real-time data analysis system, in order to realize the immediate detection of transients.

Onsite system: ~3min/exposure

Transient system: ~10min/exposure

or ~30min/coadd (5exp)

Caveats: required machine power depends on an observation strategy. E.g., the system heavily delays and processes stand in long queue if short exposures (<2min) repeat.



Real-time detection and quick alert

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 (Obs.: 02 and 03 Jul 2014)

ATel #6763; *+N. Okabe, T. Futamase* *on 27 Nov 2014; 18:03 UT* (Obs.: 26 and 27 Nov 2014)

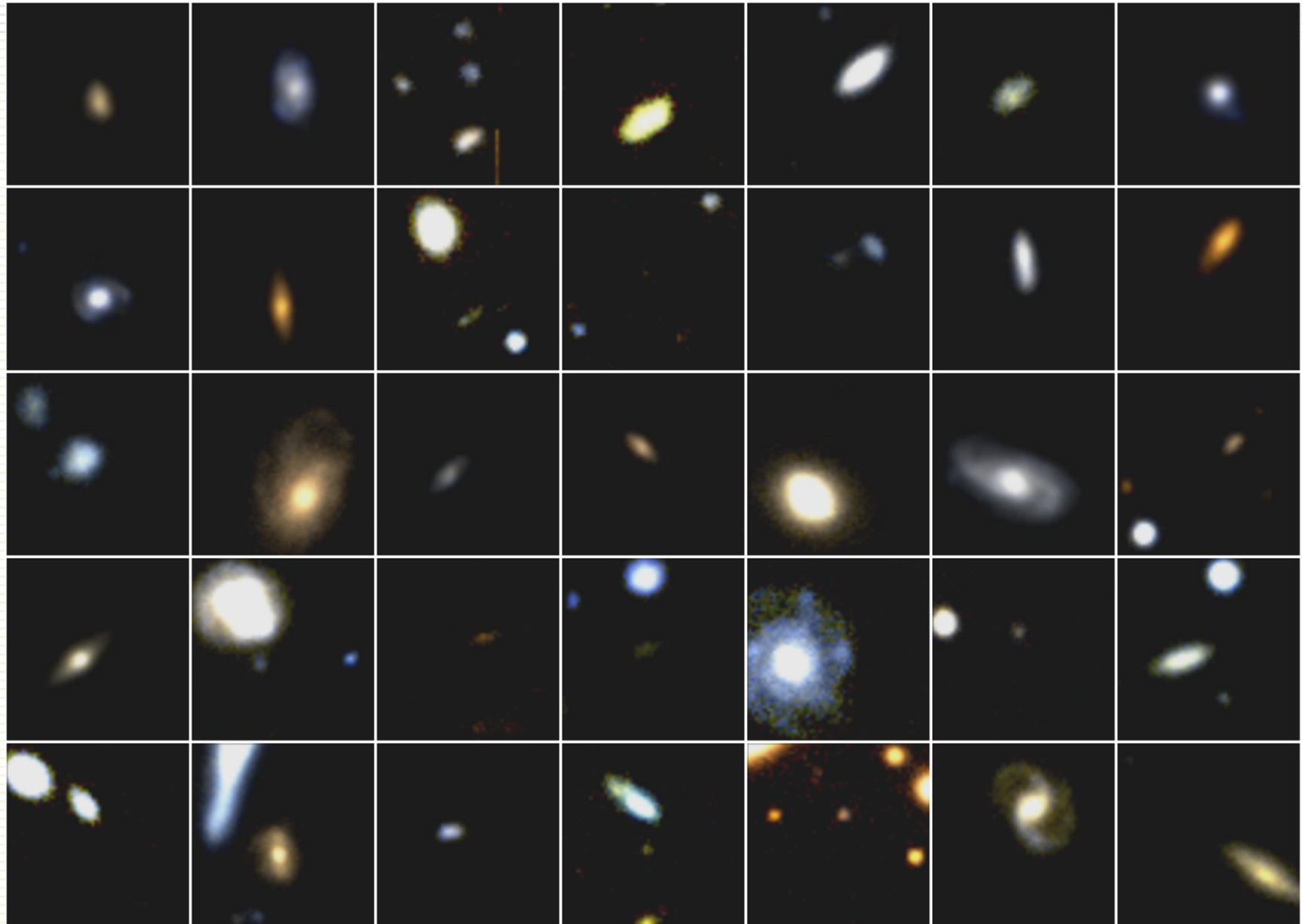
Fifty supernova candidates discovered with Subaru/Hyper Suprime-Cam

ATel #7565 ; *Nozomu Tominaga (Konan U./Kavli IPMU, U. Tokyo), Tomoki Morokuma (IoA, U. Tokyo/Kavli IPMU, U. Tokyo), Masaomi Tanaka (NAOJ/Kavli IPMU, U. Tokyo), Ji-an Jiang (U. Tokyo), Takahiro Kato (U. Tokyo), Yuki Taniguchi (U. Tokyo), Naoki Yasuda (Kavli IPMU, U. Tokyo), Hisanori Furusawa (NAOJ), Nobuhiro Okabe (Hiroshima Univ.), Toshifumi Futamase (Tohoku Univ.), Satoshi Miyazaki (NAOJ), Takashi J. Moriya (AIfA, U. Bonn), Junichi Noumaru (NAOJ), Kiaina Schubert (NAOJ), and Tadafumi Takata (NAOJ)*

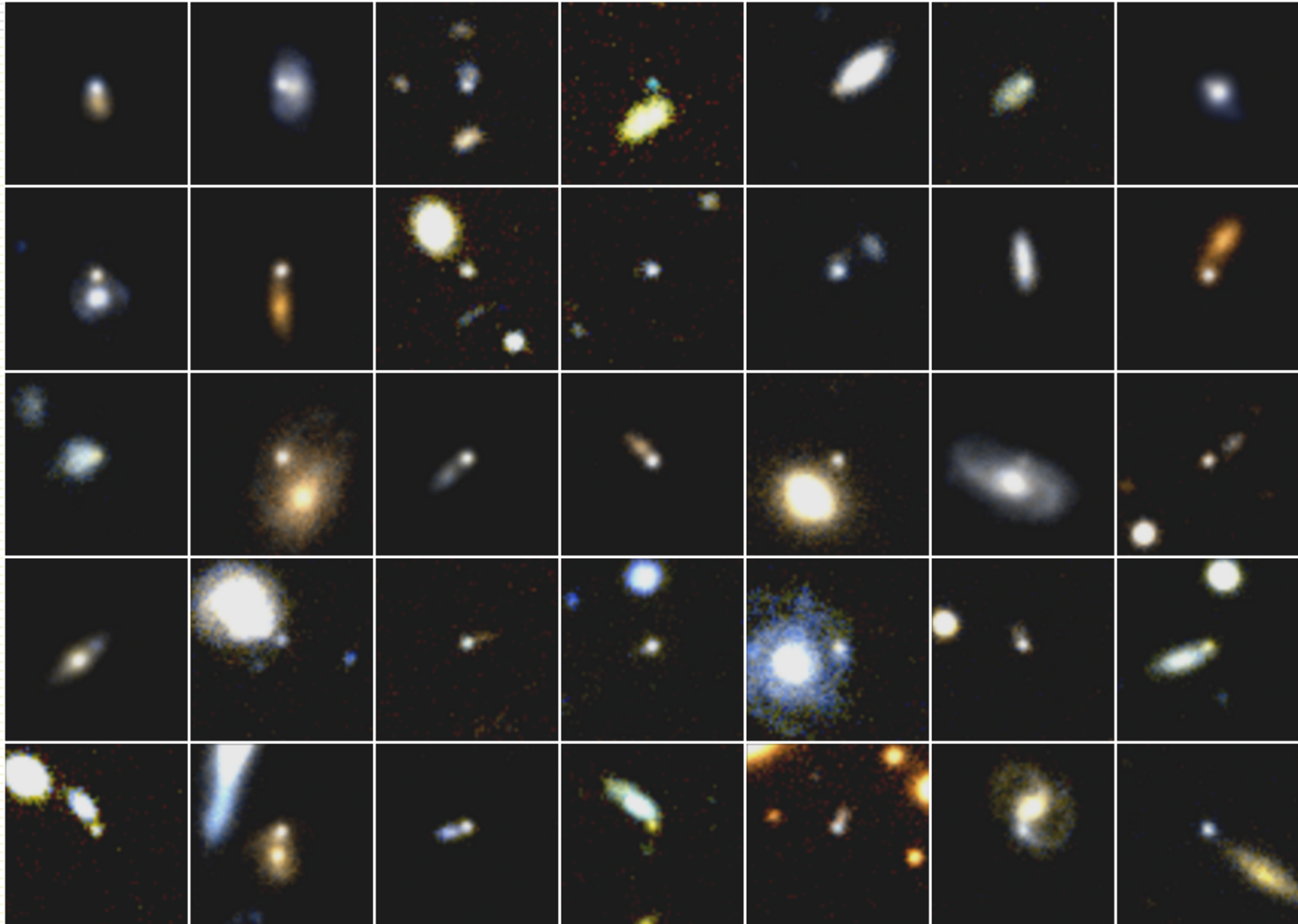
on 26 May 2015; 15:23 UT (Obs.: 24 May 2015)

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

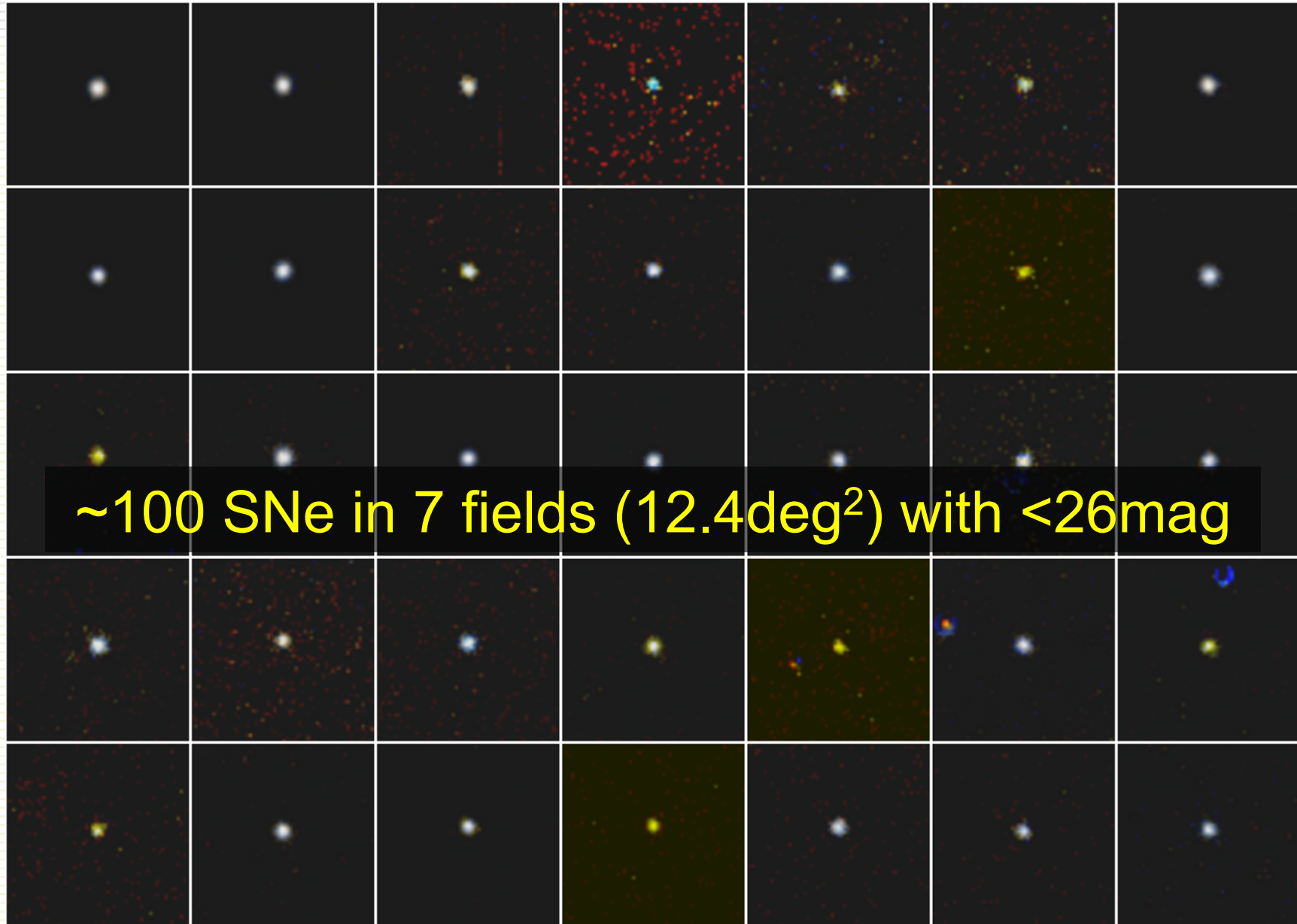
SN candidates -Jul 2014-



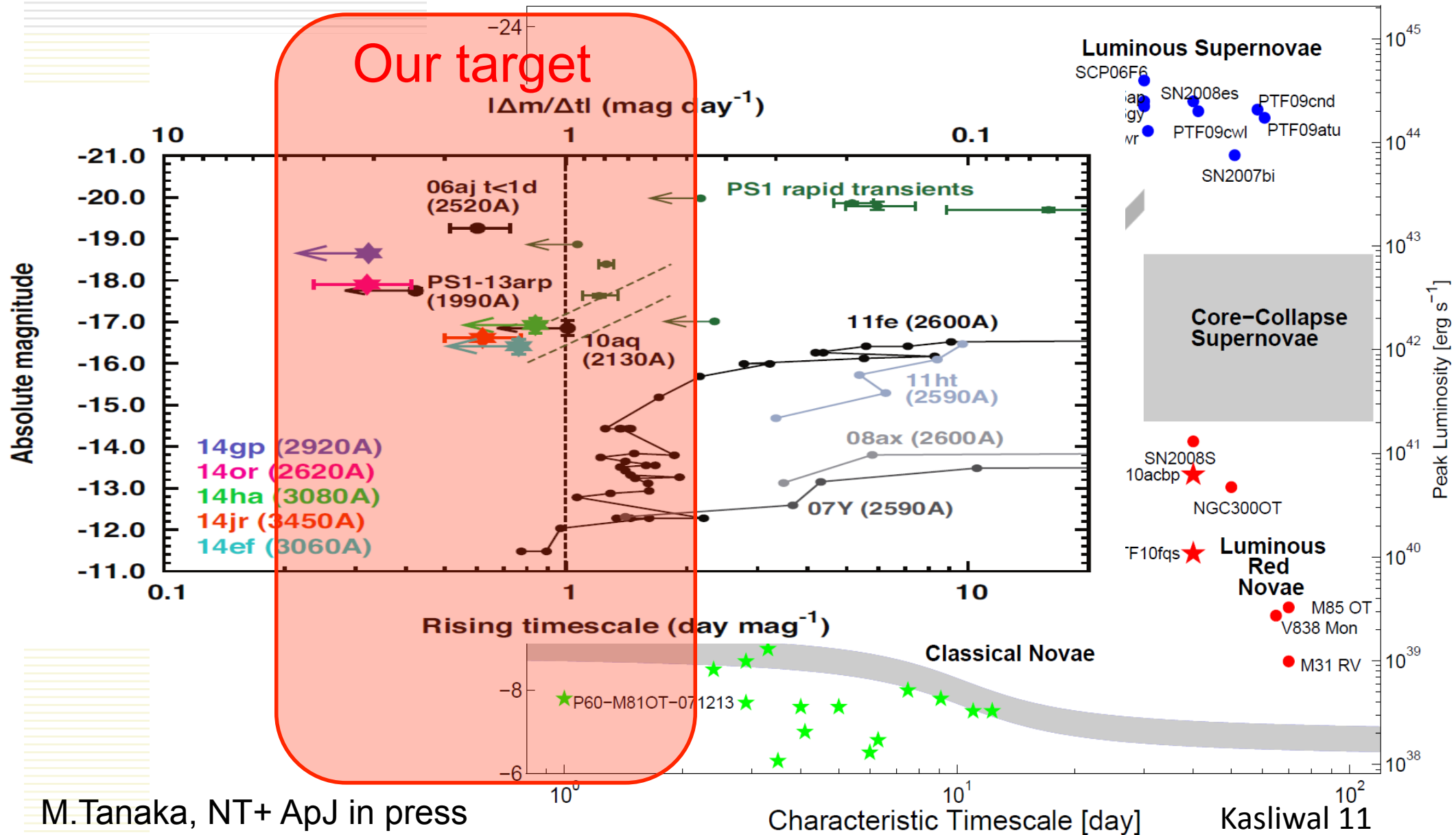
SN candidates -May 2015-



SN candidates -subtracted-



Scientific results



Improvements are ongoing.

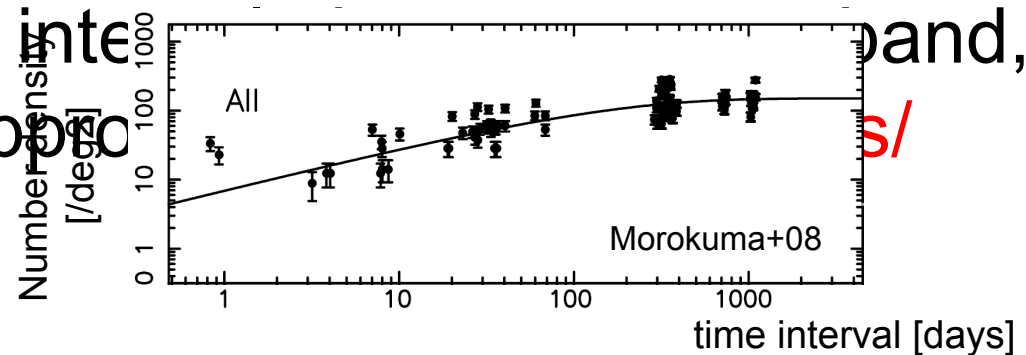
Number of candidates
after the screening.

			3_10	4_10	5_10	6_10	7_10	8_10	9_10	10_10
			3_9 submit 5	4_9 submit 18	5_9 submit 17	6_9 submit 9	7_9 submit 21	8_9 submit 14	9_9	10_9
8	1_8 reducing...	2_8 submit 6	3_8 submit 15	4_8 submit 26	5_8 submit 39	6_8 submit 25	7_8 submit 23	8_8 submit 13	9_8	10_8
7	1_7 reducing...	2_7 submit 22	3_7 submit 40	4_7 submit 20	5_7 submit 38	6_7 submit 18	7_7 submit 22	8_7 submit 28	9_7 submit 2	10_7
6	1_6 submit 5	2_6 submit 59	3_6 submit 36	4_6 submit 20	5_6 submit 30	6_6 submit 14	7_6 submit 25	8_6 submit 29	9_6 submit 8	10_6
5	1_5 submit 15	2_5 submit 34	3_5 submit 40	4_5 submit 33	5_5 submit 44	6_5 submit 23	7_5 submit 36	8_5 submit 37	9_5 submit 18	10_5
4	1_4 submit 15	2_4 submit 38	3_4 submit 38	4_4 submit 56	5_4 submit 43	6_4 submit 31	7_4 submit 58	8_4 submit 42	9_4 submit 15	10_4
3	1_3 submit 10	2_3 submit 20	3_3 submit 26	4_3 submit 40	5_3 submit 36	6_3 submit 41	7_3 submit 52	8_3 submit 27	9_3 submit 5	10_3
2	1_2 submit 1	2_2 submit 3	3_2 submit 19	4_2 submit 26	5_2 submit 29	6_2 submit 26	7_2 submit 32	8_2 submit 395	9_2	10_2
1	1_1	2_1 submit 0	3_1 submit 4	4_1 submit 47	5_1 submit 36	6_1 submit 41	7_1 submit 37	8_1 reducing...	9_1	10_1
0	1_0	2_0	3_0	4_0	5_0	6_0	7_0	8_0	9_0	10_0

Number of candidates in a patch

Number of real transients

- Number of candidates after screening:
 $\sim 10^3$ - 10^4 objs/subtraction (1/100 of w/o screening)
 - The rigorous screening also removes faint real objects.
- The number of real astronomical objects depends on time interval and depth, but approximately field.



Machine learning technique is already implemented

Supernova candidates discovered with Subaru/Hyper Suprime-Cam

ATel #7927; Nozomu Tominaga (Konan U./Kavli IPMU, U. Tokyo), Tomoki Morokuma (IoA, U. Tokyo/Kavli IPMU, U. Tokyo), Masaomi Tanaka (NAOJ/Kavli IPMU, U. Tokyo), Naoki Yasuda (Kavli IPMU, U. Tokyo), Hisanori Furusawa (NAOJ), Mikio Morii (Institute of Statistical Mathematics), Shiro Ikeda (Institute of Statistical Mathematics), Naonori Ueda (NTT Communication Science Laboratories), Junji Yamato (NTT Communication Science Laboratories), Katsuhiko Ishiguro (NTT Communication Science Laboratories), Yoshitaka Nakamura (NTT, Software Innovation Center), Akihiro Yamanaka (NTT, Software Innovation Center), Naoki Yoshida (U. Tokyo/Kavli IPMU, U. Tokyo), Nao Suzuki (Kavli IPMU, U. Tokyo), Ji-an Jiang (U. Tokyo), Takahiro Kato (U. Tokyo), Yuki Taniguchi (U. Tokyo), Takumi Shibata (Konan U.), Satoshi Miyazaki (NAOJ), Takashi J. Moriya (AlfA, U. Bonn), Junichi Noumaru (NAOJ), Kiaina Schubert (NAOJ), and Tadafumi Takata (NAOJ)

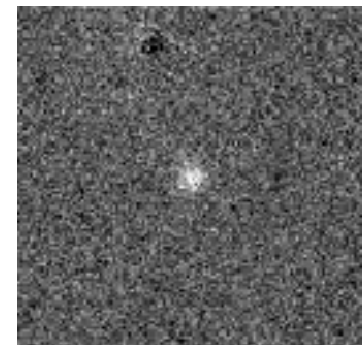
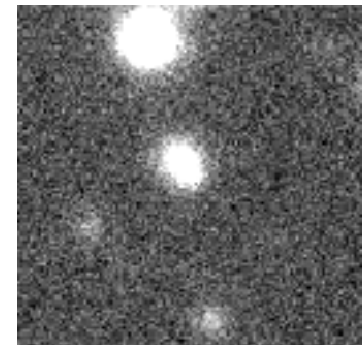
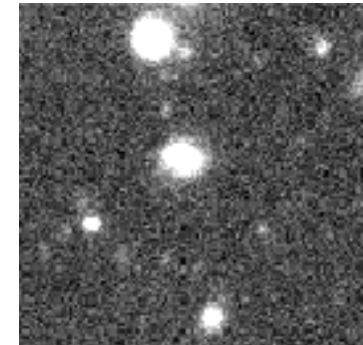
on 19 Aug 2015; 17:52 UT

Credential Certification: Nozomu Tominaga (tominaga@konan-u.ac.jp)

Subjects: Optical, Supernovae, Transient



We report the discovery of 10 supernova candidates from a transient survey with Subaru/Hyper Suprime-Cam (HSC). Our Subaru/HSC open-use observations were performed on 19 Aug 2015 UT, under poor weather condition with 1.1–1.5 arcsec seeing. The candidates were detected in real time using a quick image subtraction system (ATel #6291). Candidate screening was performed by incorporating machine learning techniques into the system. The reference images were obtained with HSC on 2 and 3 Jul 2014 UT.



Summary

- **Realtime analysis system** incorporating with machine learning technique is ready and in use.
- The Subaru/HSC opened the new window at the short timescale.
- We report the discovery of new transients immediately after the observations and trigger the follow-up observations with Gemini.
- **A coordinated observation with Subaru/HSC, Gemini/GMOS, and Keck/LRIS** will be realized.
- The follow-up observations for HSC-SSP SN