

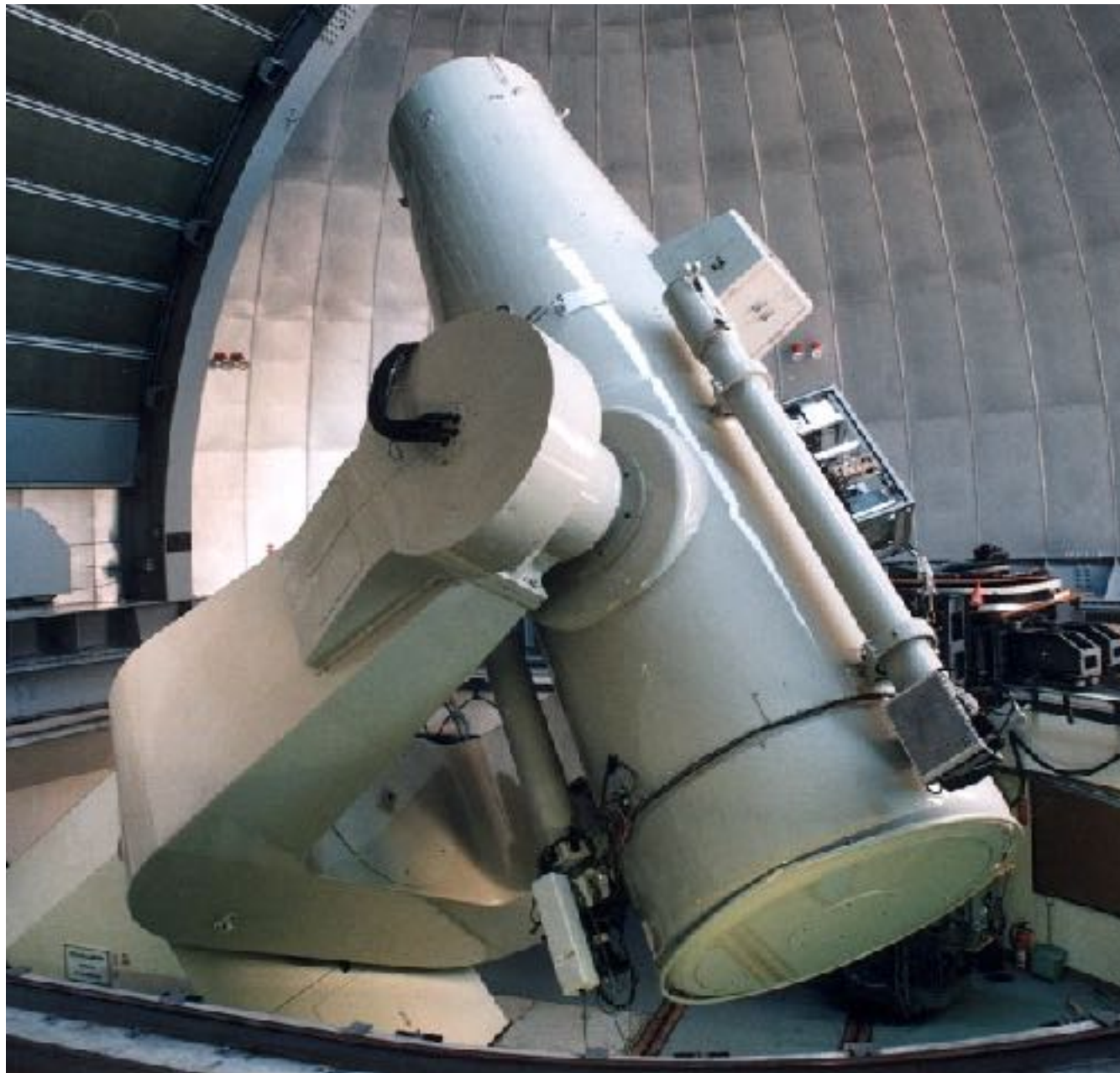
Tomo-e Gozen High-Cadence Transient Survey

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Tomo-e Gozen SN WG members

- ❑ New Parameter Space: High Cadence Transient Surveys
- ❑ Northern Sky Transient Survey w/ Tomo-e Gozen
- ❑ Survey Design
- ❑ Survey Statistics
- ❑ Summary

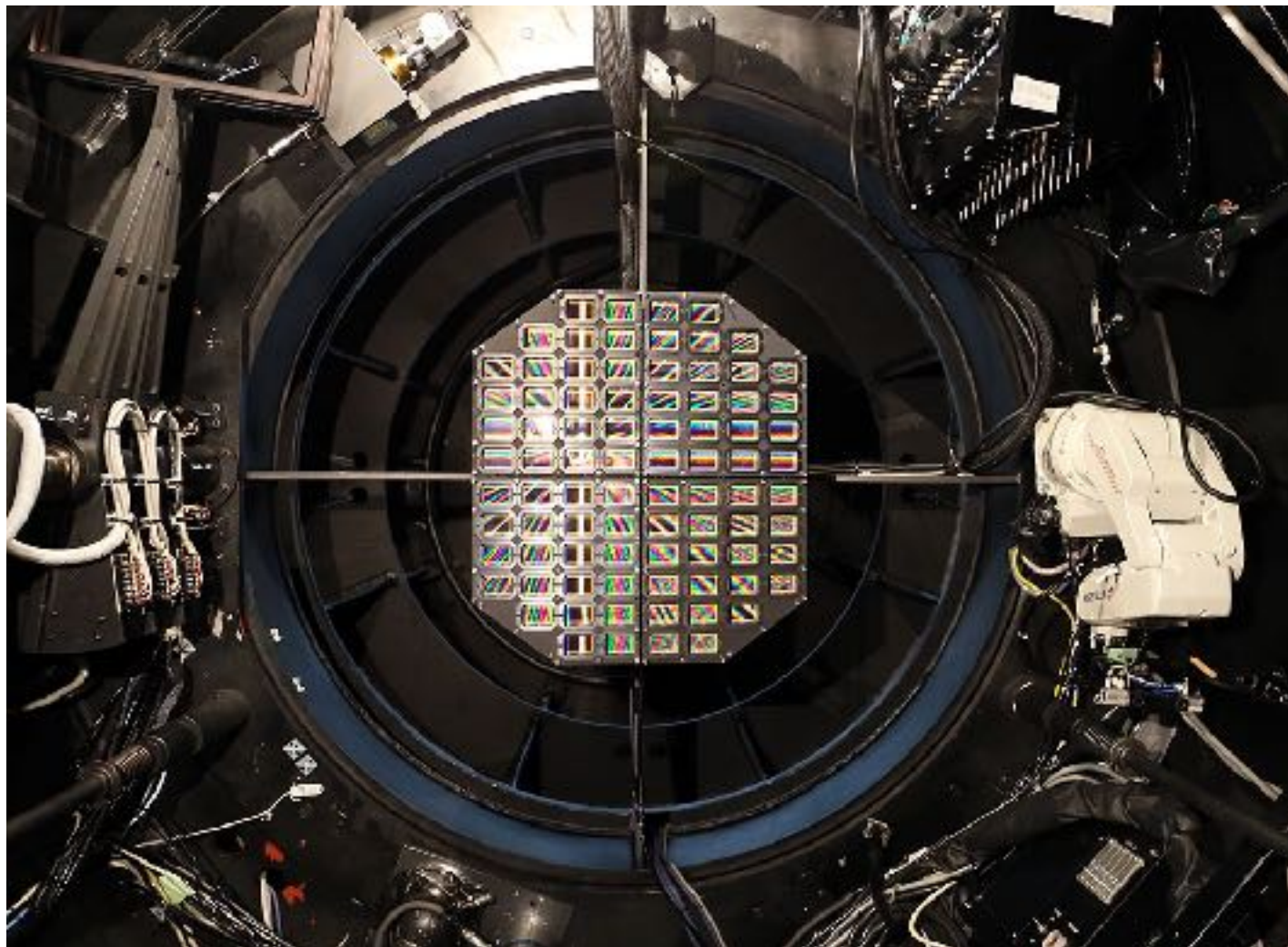
105cm Kiso Schmidt Telescope

- ❑ @Nagano, Kiso
- ❑ 105 cm Schmidt telescope (4th largest Schmidt in the world)
- ❑ since 1974
- ❑ open-use ==> collaboration basis (2018-)



Tomo-e Gozen April 2019 completed

- 84 CMOS sensors
- low dark current, readout noise
 - operated in room temp. (no cooler)
- effective area: 20 deg² (9 deg in diameter)
 - 1k x 2k ~ 22.4 x 39.7 arcmin²
- no filter (gri, Ha, ... sometimes)
- 2 fps readout (nominal): up to ~200 Hz

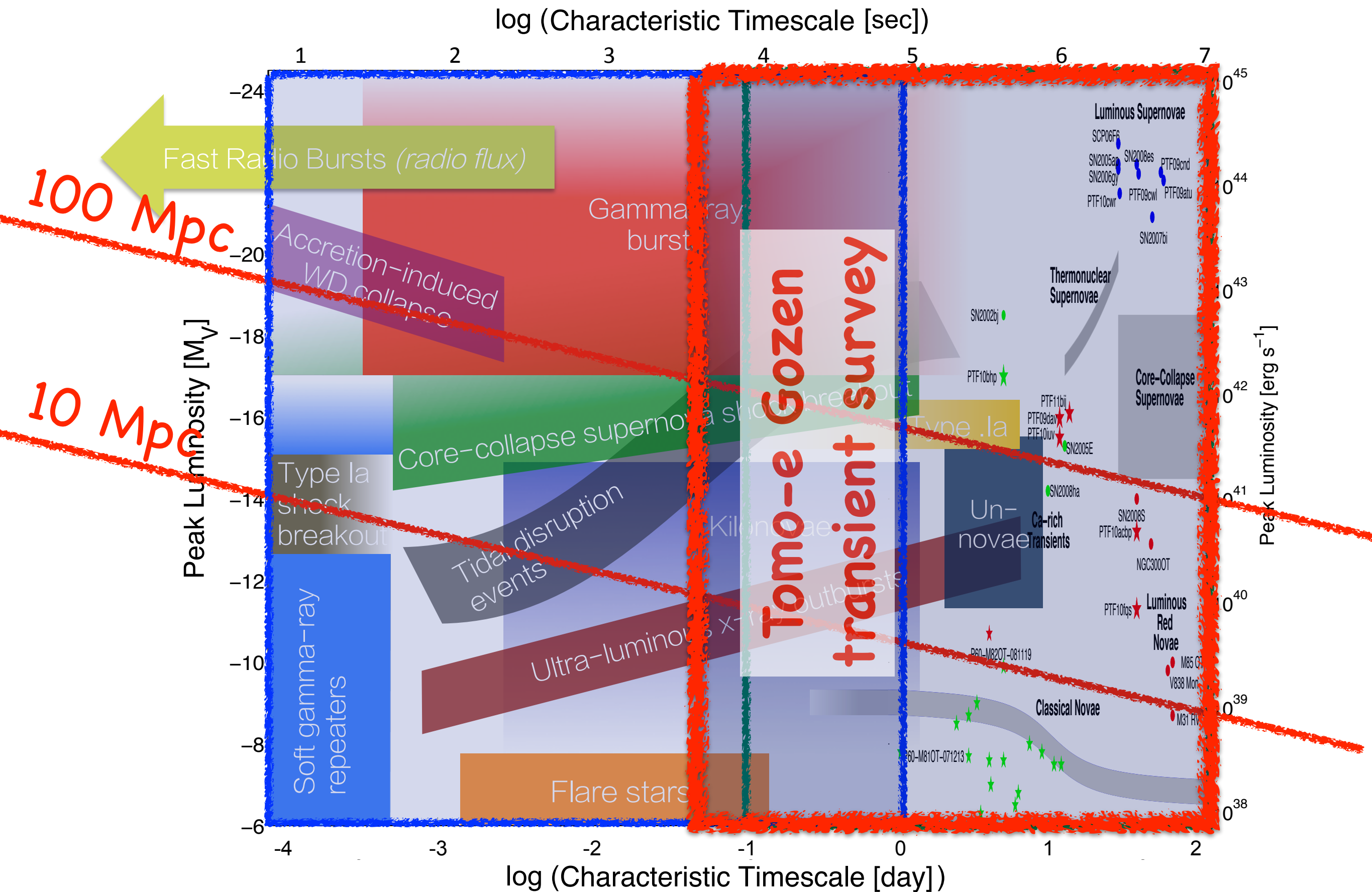


Tomo-e Gozen High-Cadence Transient Survey

薮関月作, 「巴御前出陣図」,
東京国立博物館,
©Image: TNM Image Archives



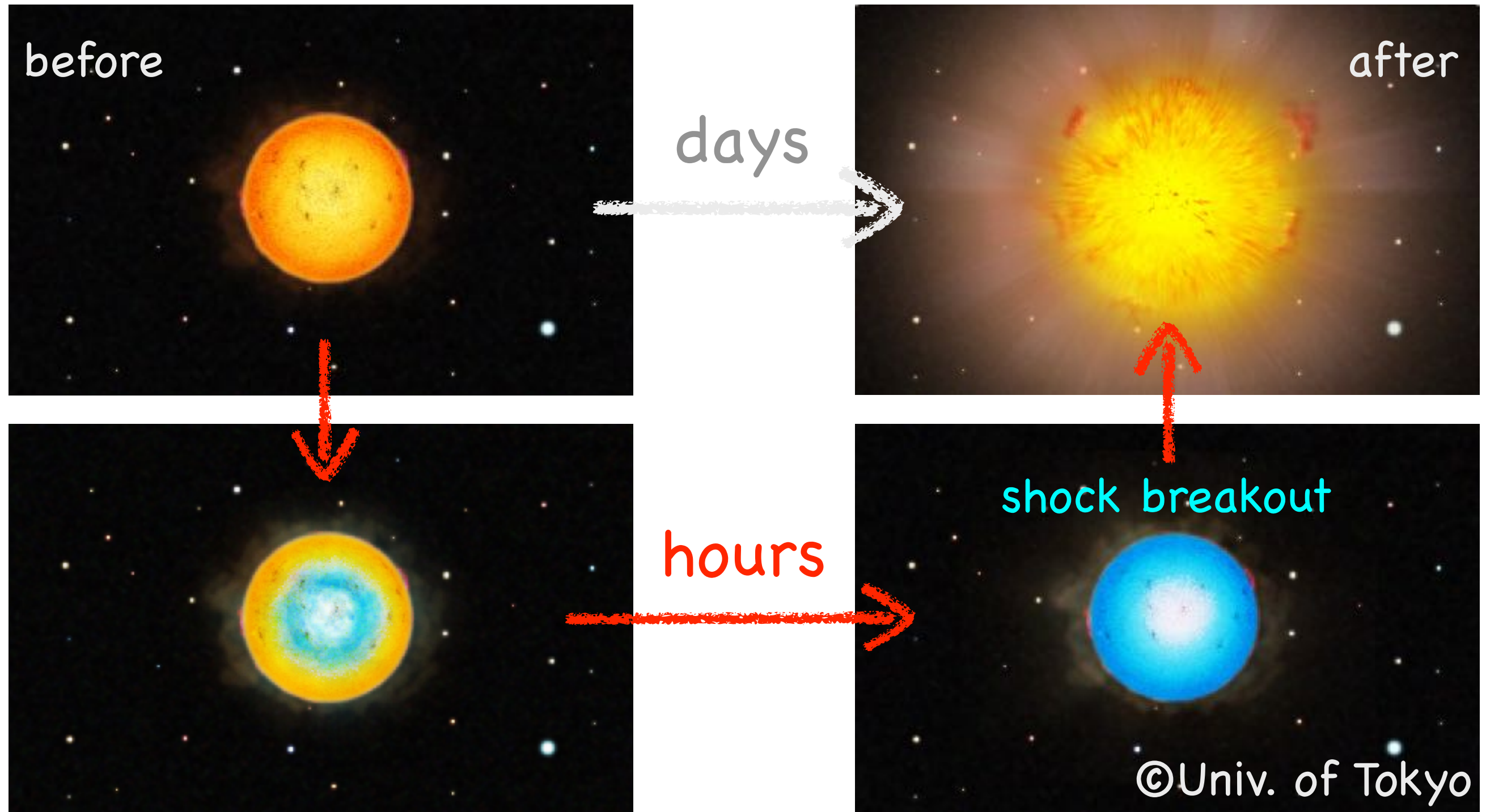
Seimei U



Kasliwal 2011, Cooke (http://www.astro.caltech.edu/~ycao/B&ETalks/B&E_FRBs_Cooke.pdf)

"Moment" of Supernova Explosion

Supernova Shock Breakout



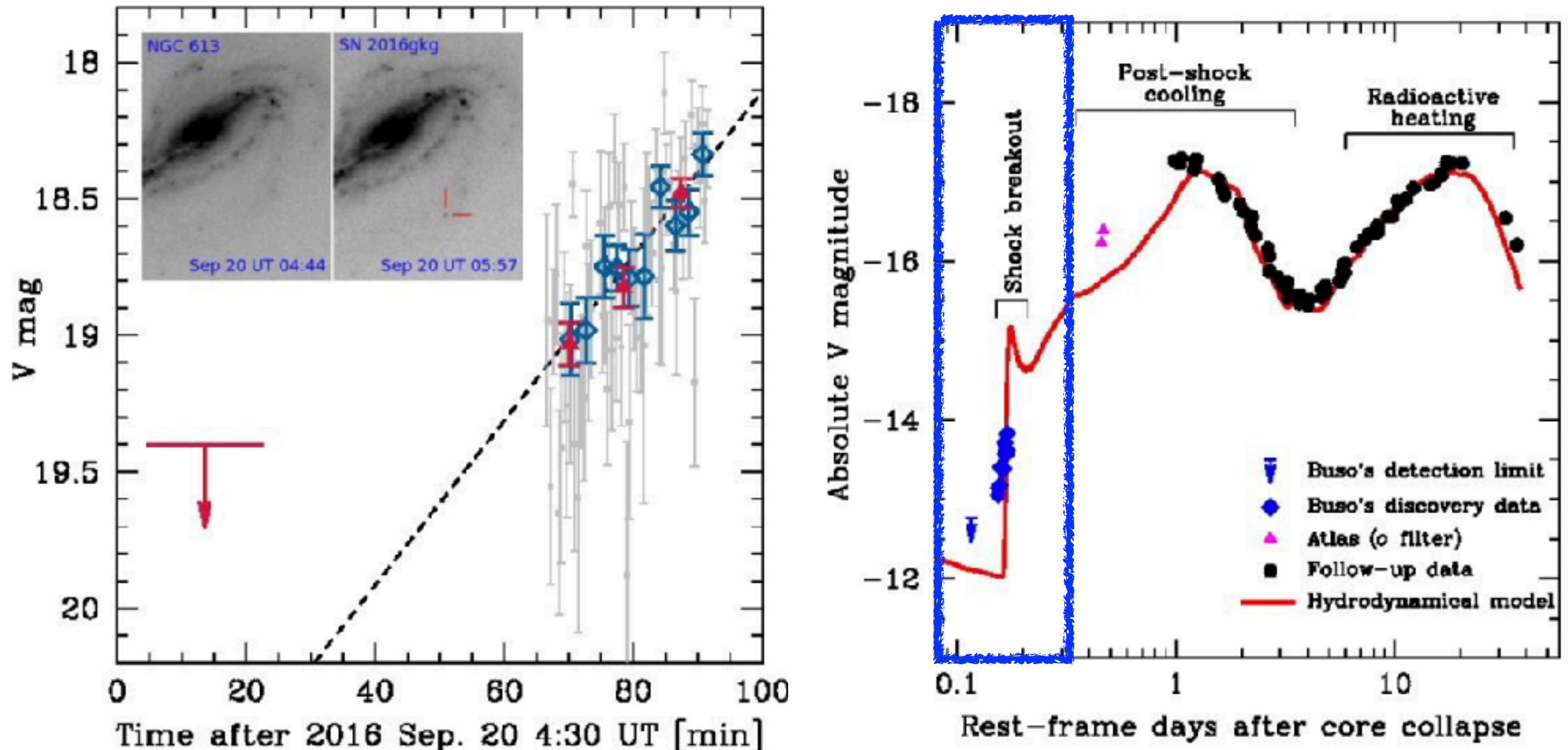
Very Early Phases of Core-Collapse Supernovae

Discovered by Victor Buso@Argentine, 16-inch telescope

SN 2016gkg@NGC 613

Bersten+2018, Nature

Figure 1



- possible detection with Gaia (Garnavich+2016, Rubin+2016)
- serendipitous detections with Swift/XRT (SN 2008D; Soderberg+2008), GALEX (Schawinski+2008)
- **almost no detailed follow-ups** for previous detections because of low S/N (high-z), discovery latency, insufficient follow-up time (large telescopes) <== **overcome by Tomo-e + Seimei obs.**

Northern Sky Transient Survey w/ Tomo-e Gozen

7,000 deg² – 2 hr cadence – 18 mag depth 2019 (initial phase)

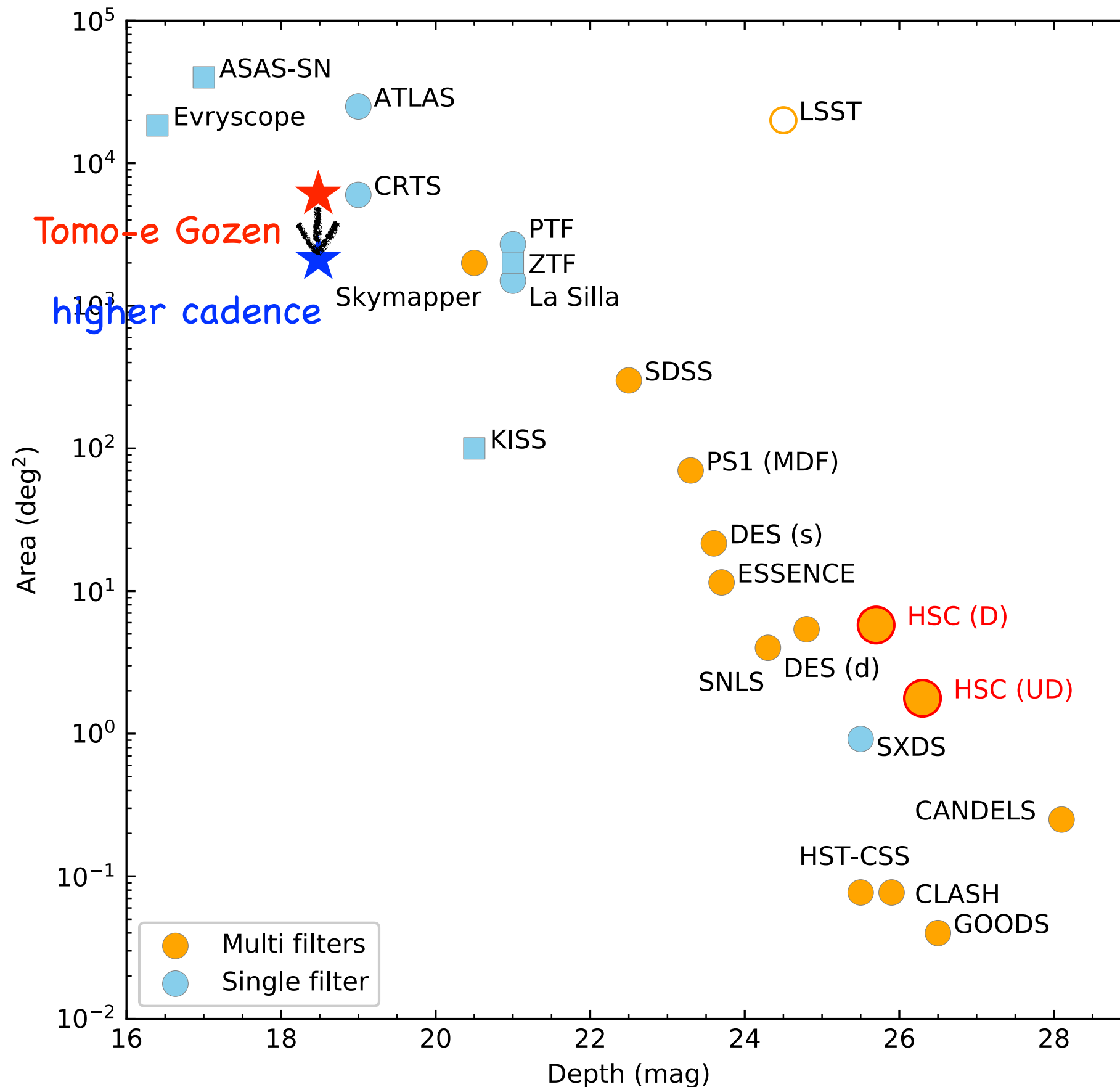


7,000 deg² – one visit – 18 mag depth
==> 2,000 deg² – 0.5 hr cadence – 18 mag depth 2020– (now)

- no filter: effectively g+r bands
- 1 visit
 - 6 sec exposure: [0.5 sec exposure] x 12 ==> ~18–19 mag
 - ~60 deg² w/ 2x2 (or 2x3) dithering to fill the gaps between sensors
- cadence: ~2 hours ==> ~0.5 hours (around midnight)
- survey area: ~7,000 deg² / 2 hrs ==> ~2,000 deg² / 0.5 hrs
- survey planning: Pedroso, Ikeda, TM+ et al. in prep.
- recent (2020 winter) changes:
 - 2-hour cadence in a night ==> one-visit all-sky, then 0.5-hour cadence
- near-future changes:
 - reference for image subtraction: [PS1/r] ==> [Tomo-e]
 - achieve better subtraction around bright nearby galaxies
 - 24 contiguous frames instead of 12?

Transient Survey Power

Yasuda+2019



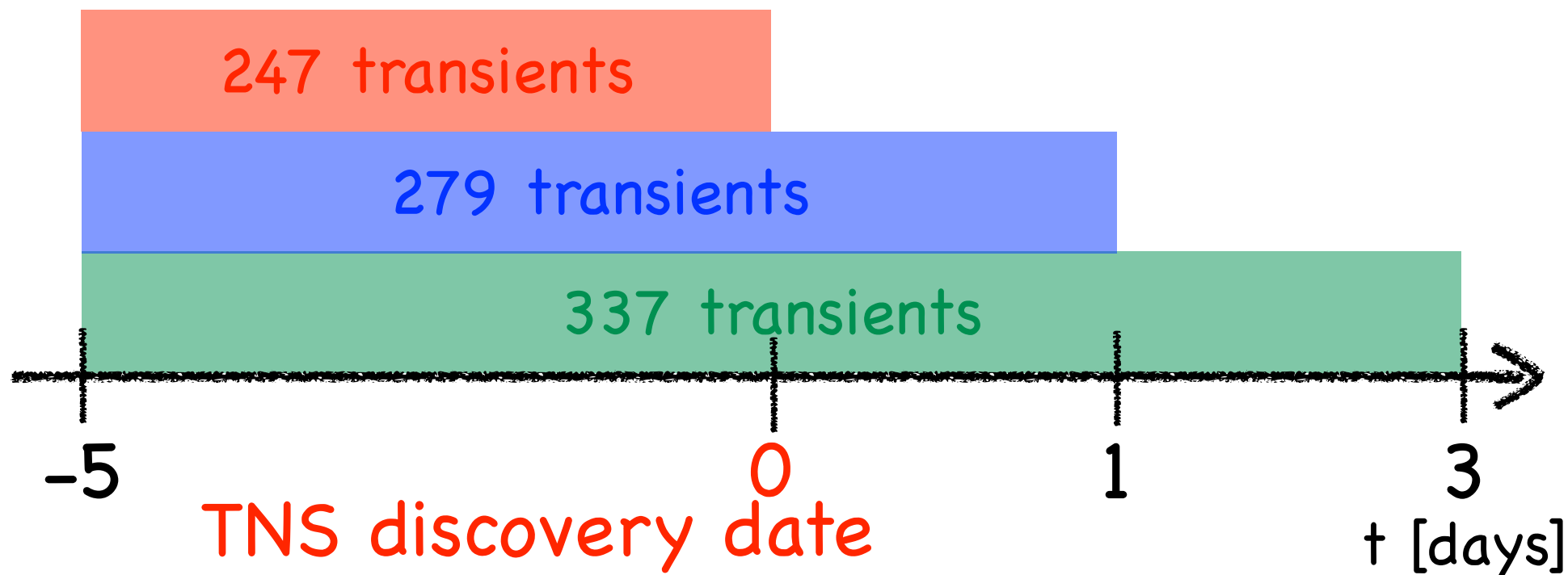
Data Products

- after image subtraction:
 - Subtracted images relative to PS1 r-band
 - CNN (Hamasaki 2020, master thesis/Konan U.)
==> automatic alert for bright transients
 - Coadded good-seeing Tomo-e data will be used in a few months.
 - better subtraction
 - photometry@subtracted images
 - photometry of Tomo-e-detected transients
 - photometry of other known (reported to TNS) transients
 - almost the same search for GW EM counterparts (Niino+ in prep.)
- before image subtraction for variable stars etc.
 - Photometry for all the detected sources, calibrated relative to PS1
 - light curves for all the sources will be available.
 - blazar variability study (Morita, 2020, master thesis/U. of Tokyo)
- motion detection
 - NEO search
 - Discovery of 8 NEOs incl. 2019 FA
 - size: ~8m (<http://www.ioa.s.u-tokyo.ac.jp/kisohp/NEWS/2019FA/2019FA.html>)

We are preparing a dedicated server to store the products and release them with limited access. Contact us if you are interested in it.

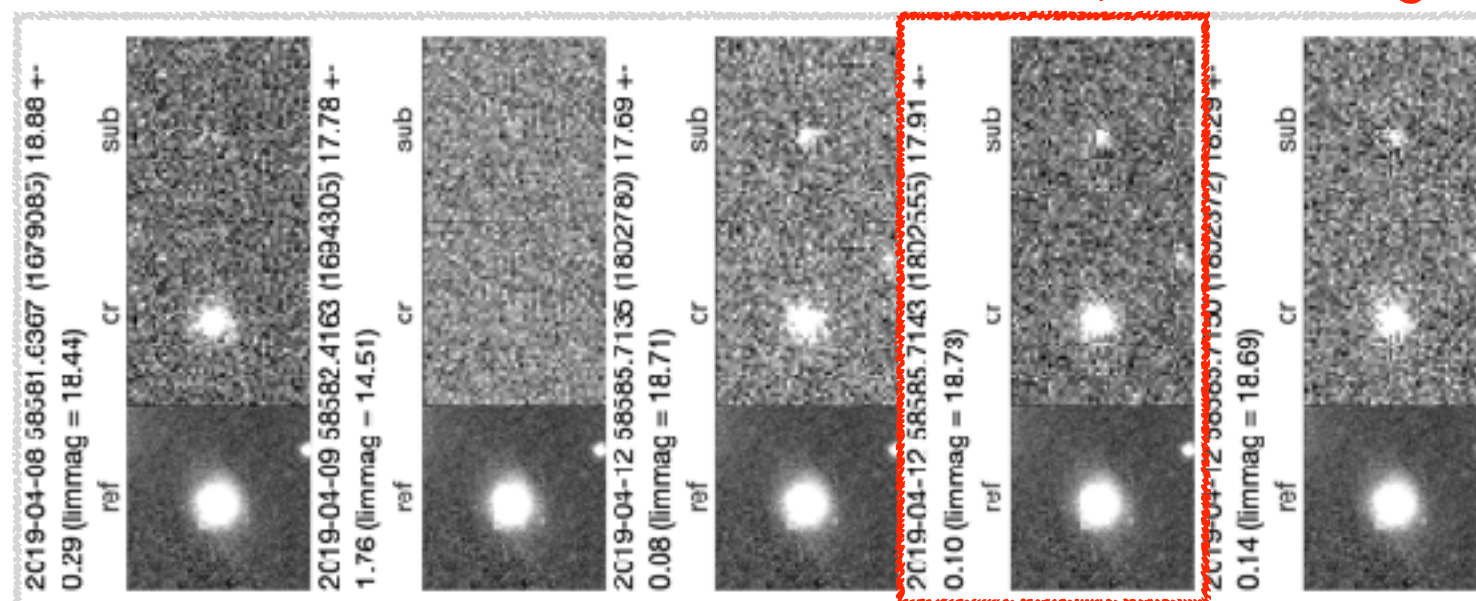
Transients in Transient Name Server (TNS)

- Dec > -3 deg & 2019/04/06 - 2019/12/31 (discovery date@TNS)
 - ~1,600 transients reported to TNS
- #(Tomo-e Obs, deeper than discovery magnitude) > 0



Example: SN 2019dwy (SN Ic)

Tomo-e discovery
(2nd detection), MJD=58585.71 (12 days before TNS
discovery), ~18 mag



TNS discovery
MJD=58597.41
17.2 mag (ASAS-SN)

Target Handling System: web I/F

AT 2020ftl

Transient ID: Variable_id:

Number of detections: (paramcand)

[AT 2020ftl](#)



link to SDSS (if available)

Ra, Dec (Decimal) l, b (Galactic)	Ra, Dec	SDSS Phot-z	SDSS Spec-z	Detector ID	x,y
185.01560 , 5.34320	12:20:03.74, +05:20:35.5				,
					,

link to SDSS, PS1, TNS, MPCChecker

Relavant links	SDSS Archive	PS1	TNS	MPCChecker	Visibility (local site: 137.6283 35.7942 1130 +9)	link to visibility plot (IAC)
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fits files

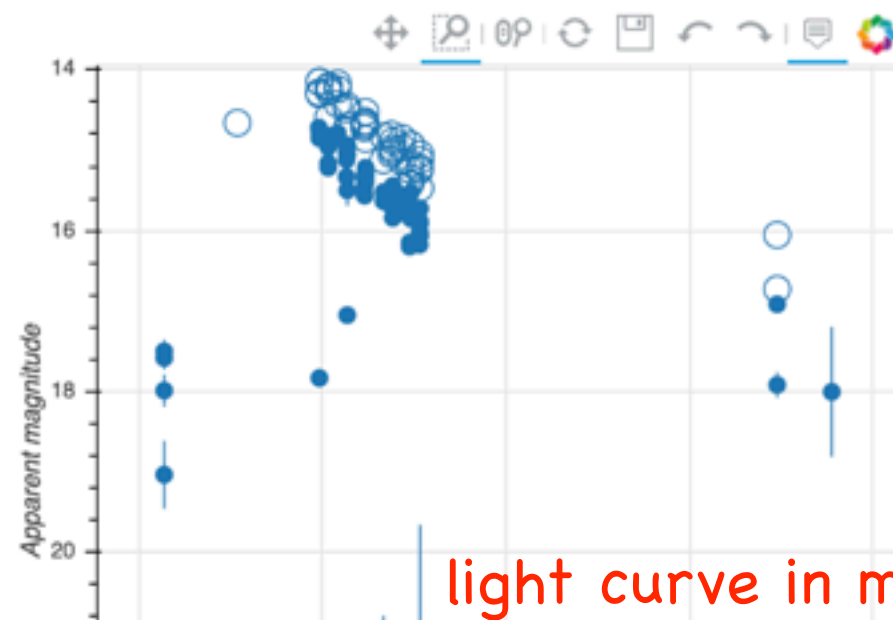
[Ref](#)

[Sub](#)

link to Tomo-e Gozen fits

Light Curves

58941.2665046

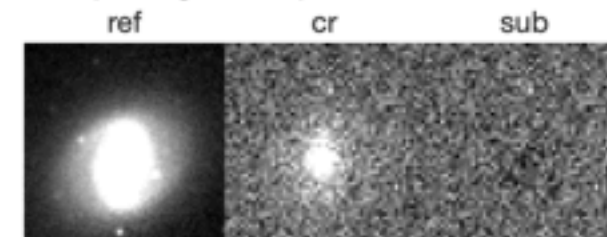


light curve in magnitude unit
(light curve in linear scale below)

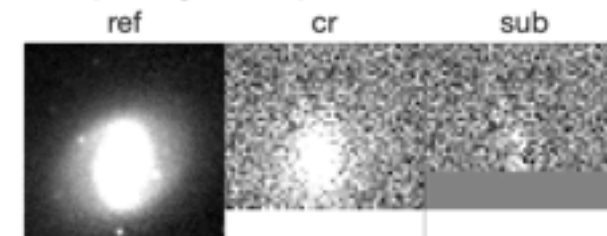
Images

Comments

2020-04-03 58942.7169 (11210440) 19.03 +- 0.42 (limmag = 18.10)



2020-04-03 58942.7171 (11210332) 17.50 +- 0.14 (limmag = 17.87)



2020-04-03 58942.7177 (11210087) 17.58 +-

submit

No comments posted yet.

image cutout

Proposed Observations for Seimei/KOOLS-IFU

- expectation: ~ 15 candidates per semester w/ $\sim > 1$ mag day⁻¹
 - (up to 150 Mpc)
 - “flash spectroscopy” (<1 day after Tomo-e discovery)
 - ~ 4 objects (among ~ 15) per semester
 - more (~ 4 more times) follow-up w/ Seimei/KOOLS-IFU
- Discoveries, identification, & characterization of a few rapidly evolving transients

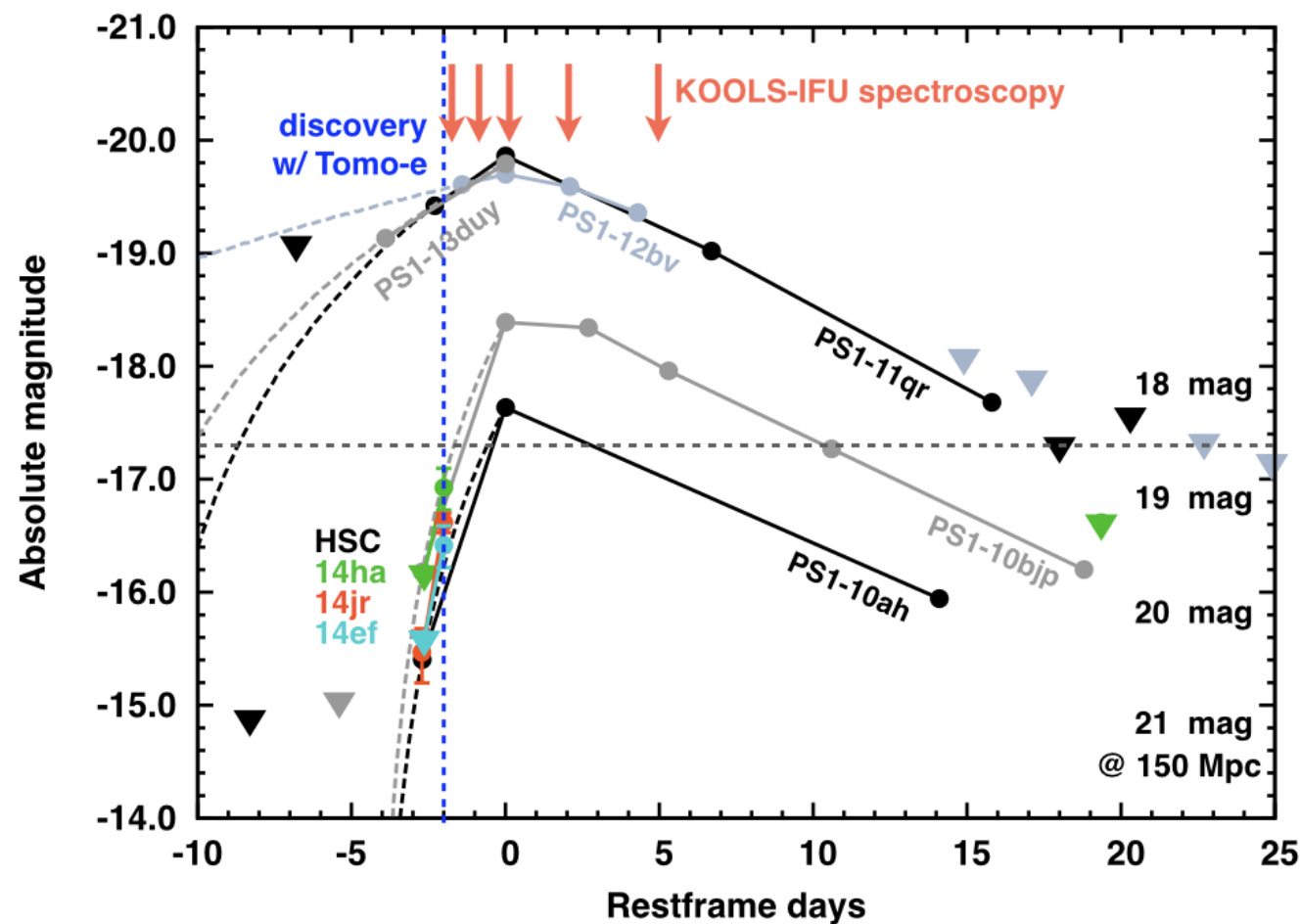


Figure 3 Light curves of rapid transients with planned epochs of KOOLS-IFU spectroscopy. @Our Seimei proposal (from Tanaka+2016)

Other Follow-ups

- multi-band light curves
 - automated follow-up w/ MITSuME (w/ K. Murata et al.)
- Tomo-e Gozen survey: bright enough for OISTER domestic telescopes
 - discovery ==> follow-up within the same night

Summary

- ❑ Let's catch **supernovae (and other transient phenomena) in early-phase (right after explosions)**.
- ❑ Tomo-e Gozen was completed in April 2019.
- ❑ Northern Sky Transient Survey has been started since Nov. 2018 w/ partially completed Tomo-e Gozen.
 - ❑ full operation w/ completed Tomo-e Gozen started in Oct. 2019.
- ❑ 7,000 deg / 2 hours, 18 mag depth ==> **2,000 deg² / 0.5 hours, 18 mag depth**
 - ❑ almost all-sky data are taken at least once during a night.
 - ❑ All the northern sky regions (Dec>0) have been observed at least once.
- ❑ **survey planning w/ statistical approach (Joao, Ikeda, TM, et al. in prep.)**
 - ❑ additionally consider weather conditions (avoid cloudy region and choose clear sky region)
- ❑ Development of **automatic data reduction pipeline & website I/F** are almost done.
 - ❑ **Machine-learning technique (CNN) to pick up only real sources** developed.
 - ❑ **Automatic alerts** (to MITSuME & Seimei) in near-future?
- ❑ quick follow-up observations w/ Seimei, Kanata, etc. (OISTER), Gemini, etc.
 - ❑ **"flash" spectroscopy w/ KOOLS-IFU**
- ❑ **fully utilize "2 Hz" data** to search for more rapid transients in future
 - ❑ see our pilot study in Richmond+2020
- ❑ Please contact us (Morokuma, Ohsawa, or Sako) if you are interested in the survey, data, etc.