Northern Sky Transient Survey w/ Tomo-e Gozen

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Contents

- New Parameter Space: High Cadence Transient Surveys
- Northern Sky Transient Survey w/ Tomo-e Gozen
- Survey Design
- Follow-up Scheme
- Survey So Far
- Summary
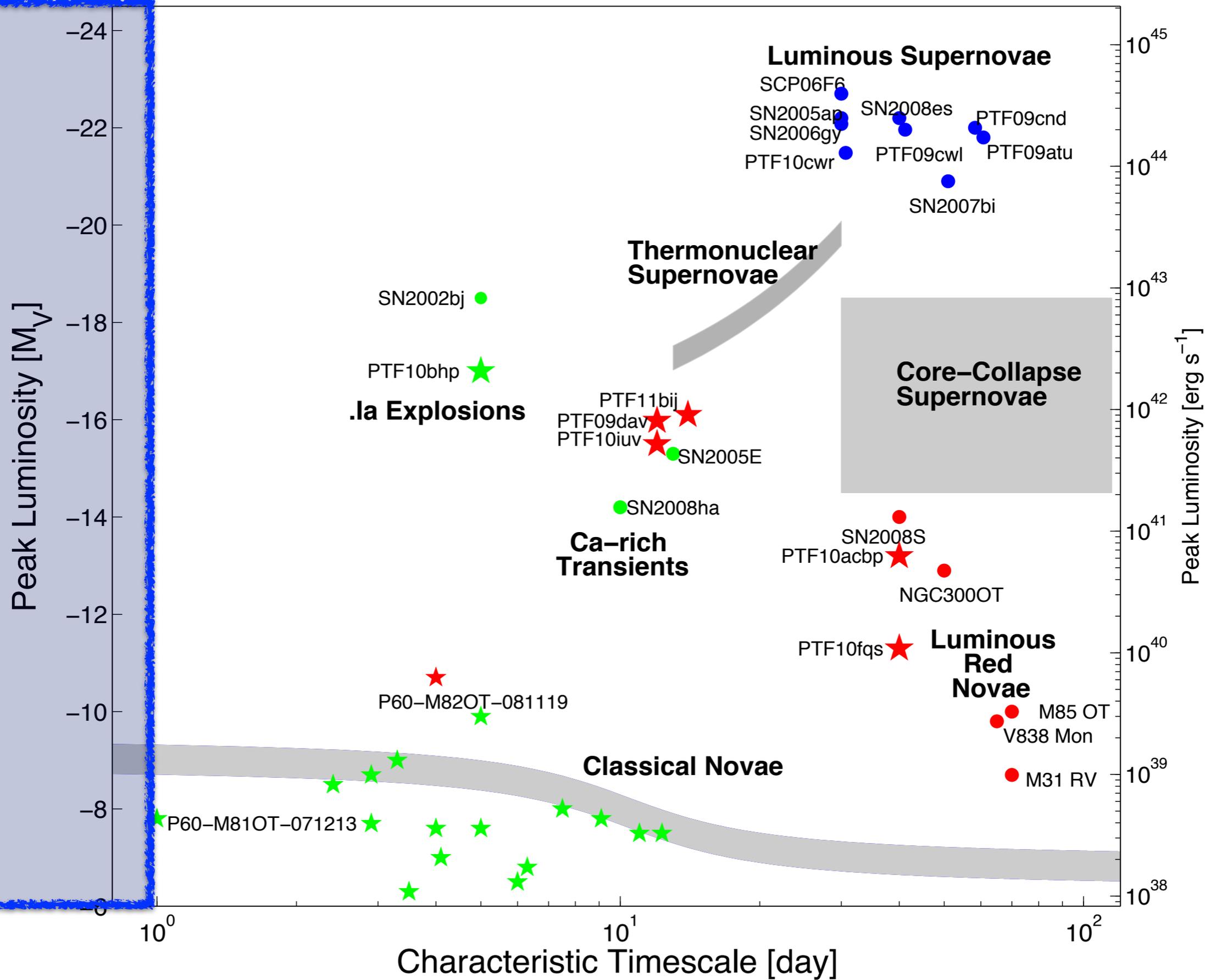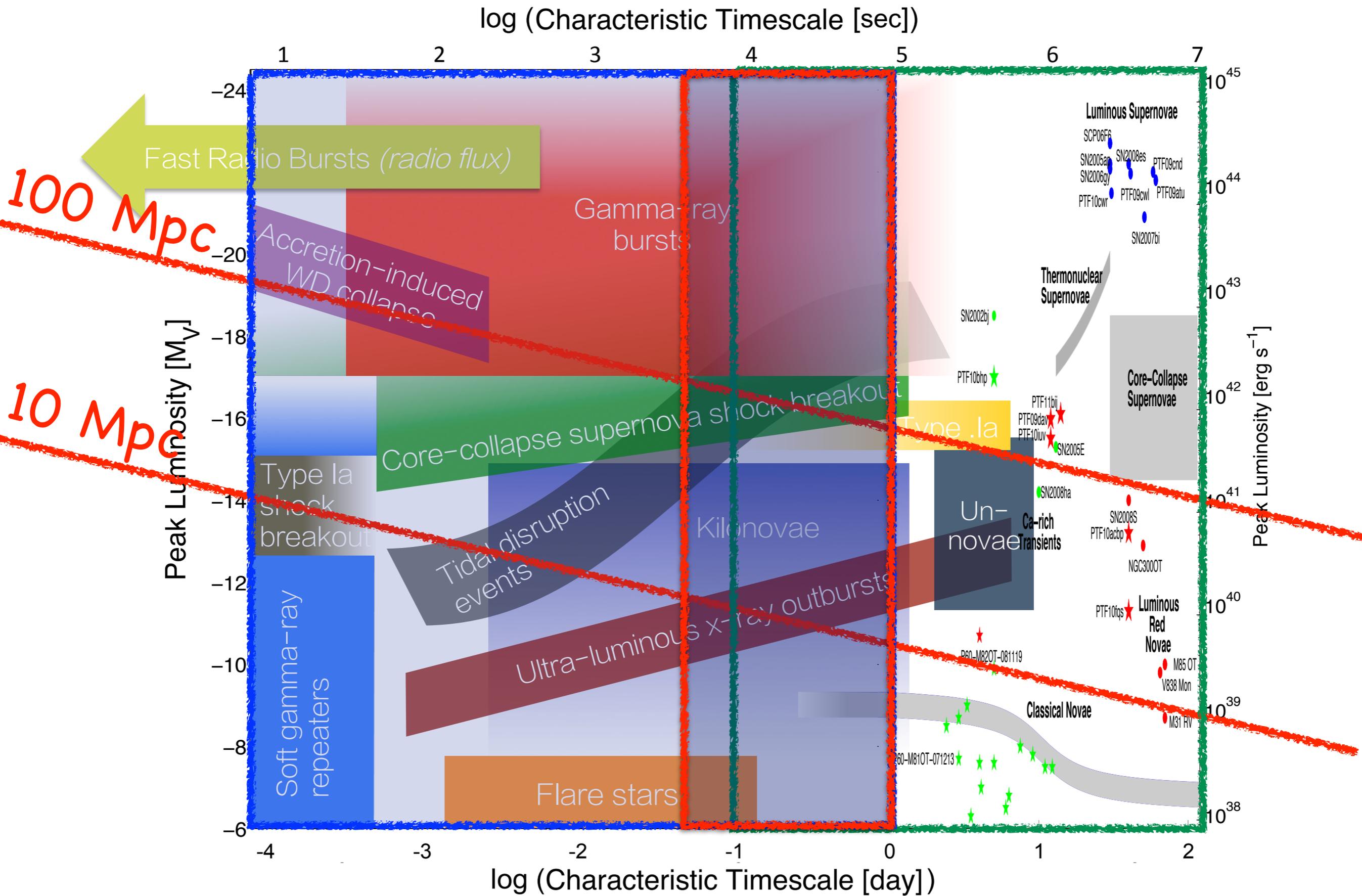
Kasliwal 2011

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

"Moment" of Supernova Explosion

Supernova Shock Breakout

before

after

days

hours

shock breakout
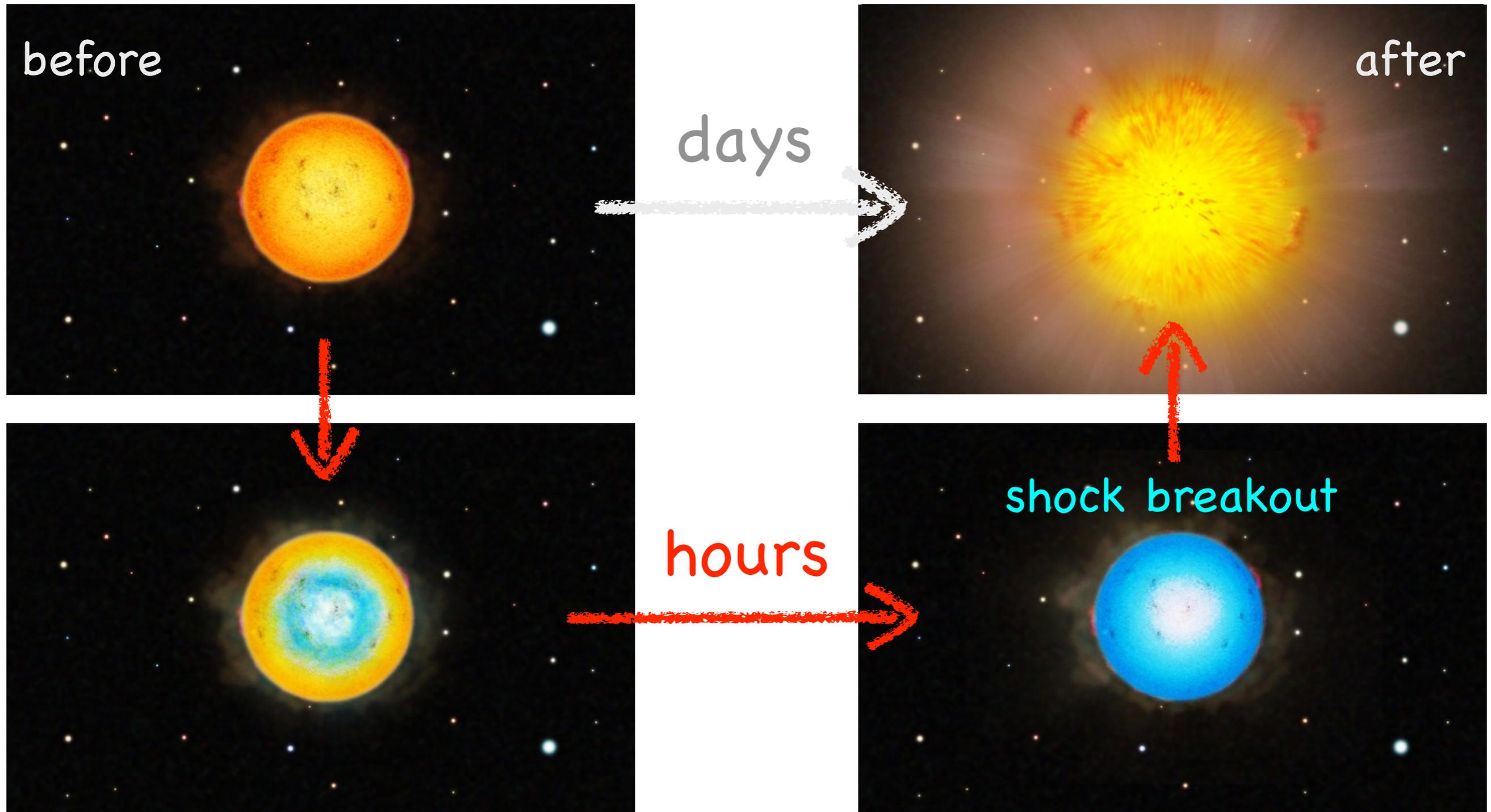
Very Early Phases of Core-Collapse Supernovae

Discovered by Victor Buso@Argentine, 16-inch telescope

SN 2016gkg@NGC 613   Bersten+2018, Nature

Figure 1
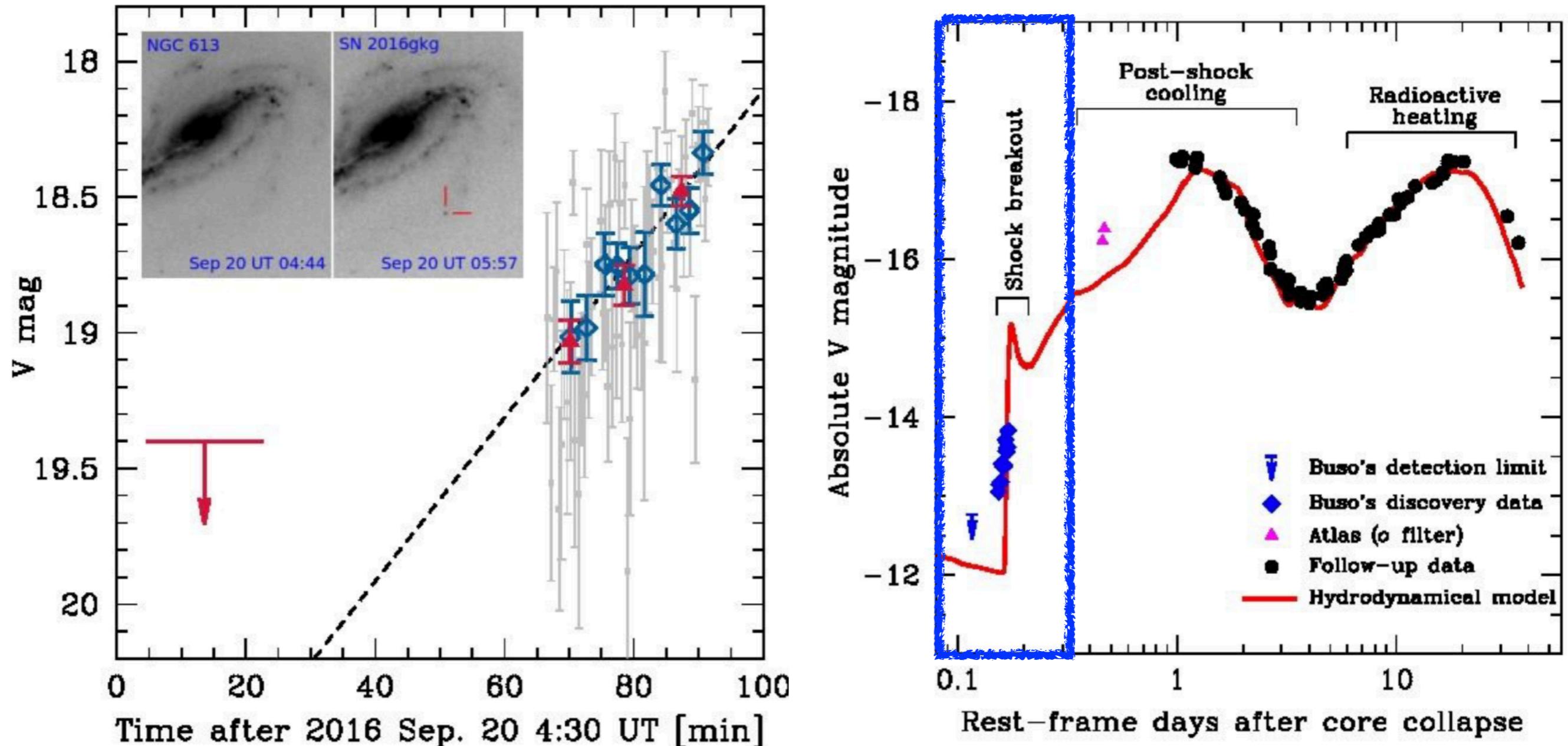
- possible detection with Gaia (Garnavich+2016, Rubin+2016)
- serendipitous detections with Swift/XRT (SN 2008D; Soderberg+2008), GALEX (Schawinski+2008)

Northern Sky Transient Survey w/ Tomo-e Gozen

7,000 deg2 - 2 hr cadence - 18 mag depth
7,000 deg2 - 1 day cadence - 19 mag depth

- no filter: effectively g+r bands
- 1 visit
  - 6 sec exposure: [0.5 sec exposure] x 12
    - ~18-19 mag
  - 2x3 or 2x2 dithering
    - ~8% missed
  - ~60 deg2 (partially vignetted by ~30%)
- cadence: ~2 hours
- survey area / 2 hrs: ~7,000 deg2, EL>40 deg
- 2-4 times visits per night
  - ~19 mag for daily stacked data (not yet implemented)
  - more needed for NEO search?
- survey simulation: being improved by Pedro-san, Ikeda-san
- weather factor: usable (half), photometric (30%)
- reference: PS1 r-band

0000, 2018-11-21T19:00:00.000

Az: 349.4213280(
Alt: 26.71285032
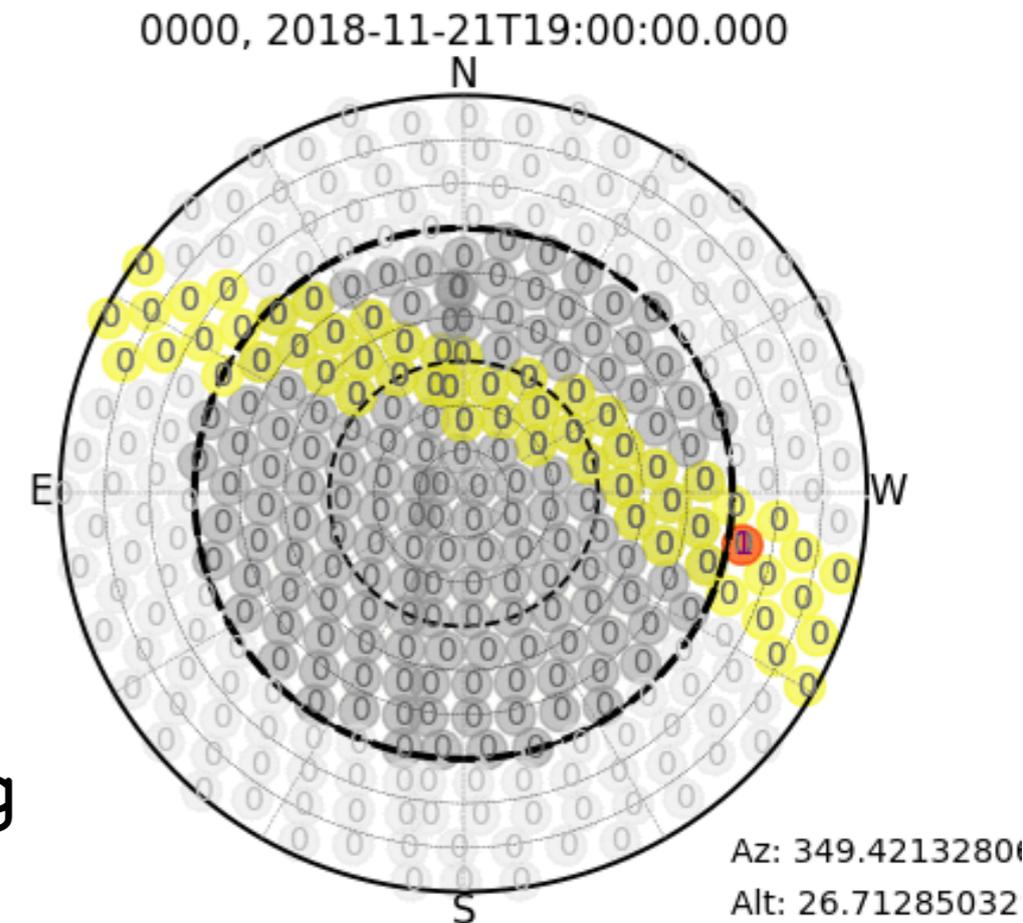
Tomo-e Gozen Survey Power

Yasuda+2019, in press
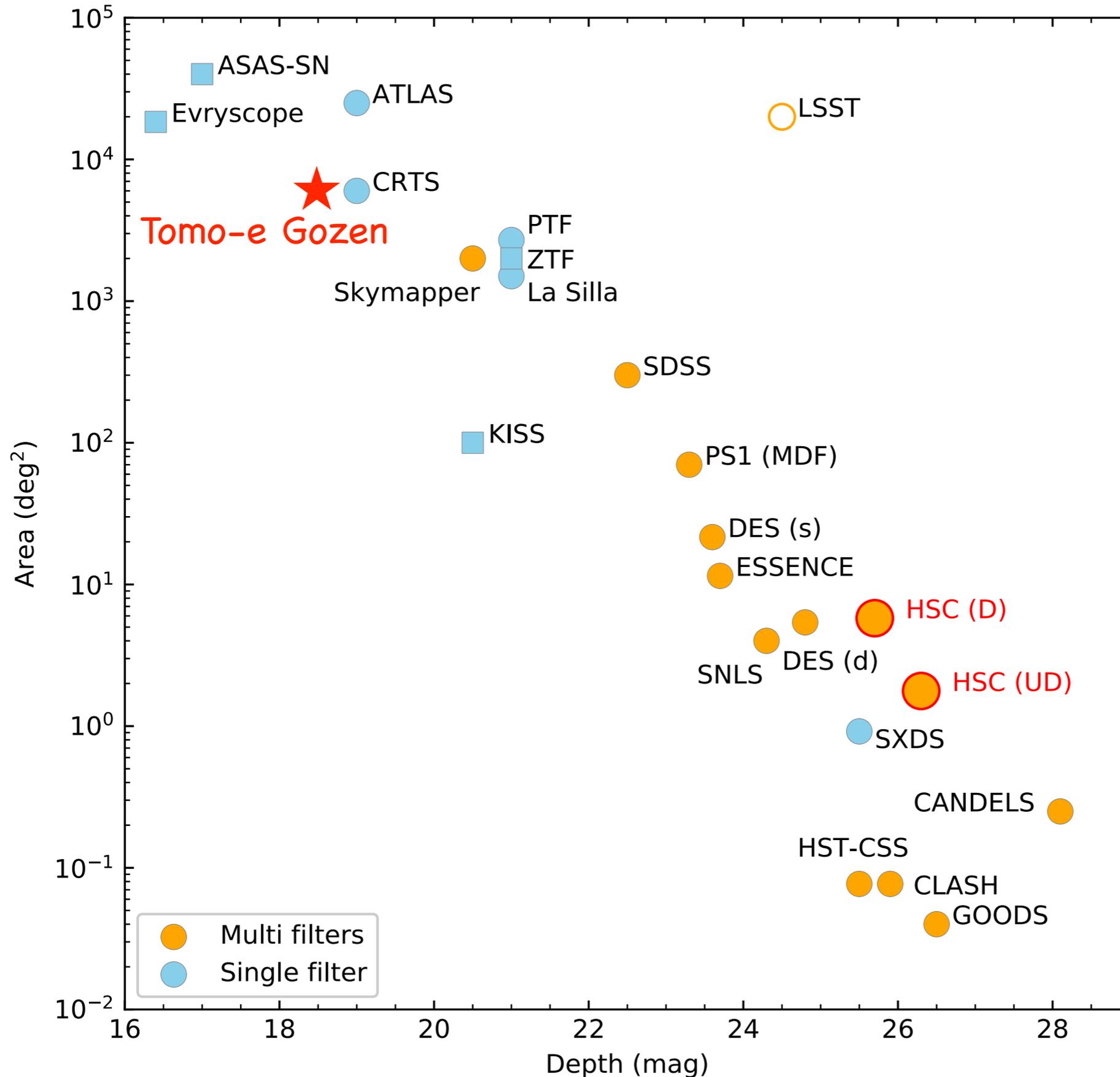
Powerful Competitors

Zwicky Transient Facility
(ZTF; 1.2m, 47 deg2)

All-Sky Automated Survey for Supernovae
(ASAS-SN; 24x0.14m, 20 deg2 each)
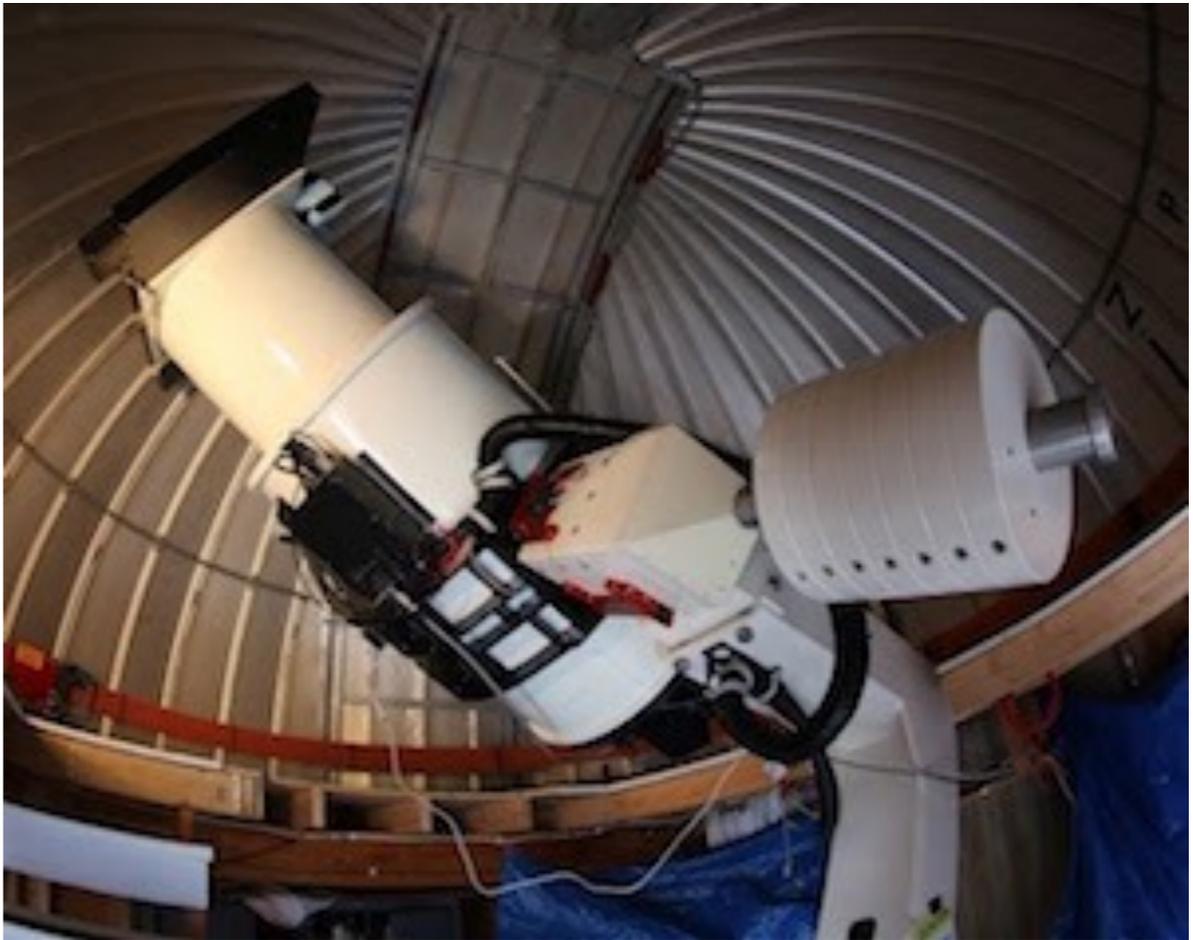
Asteroid Terrestrial-impact Last Alert System
(ATLAS; 2x0.5m, 30 deg2 each)

Survey Statistics (as of 2019/07/05)

Q1   Q3   Q2   Q4

17.0 (bright) – 18.4 (dark)

4.2 arcsec seeing

Survey Statistics (as of 2019/07/05)

equatorial

Q1xxx, MJD=58426.0-58427.0 (0 deg2, 0 chips)

ecliptic
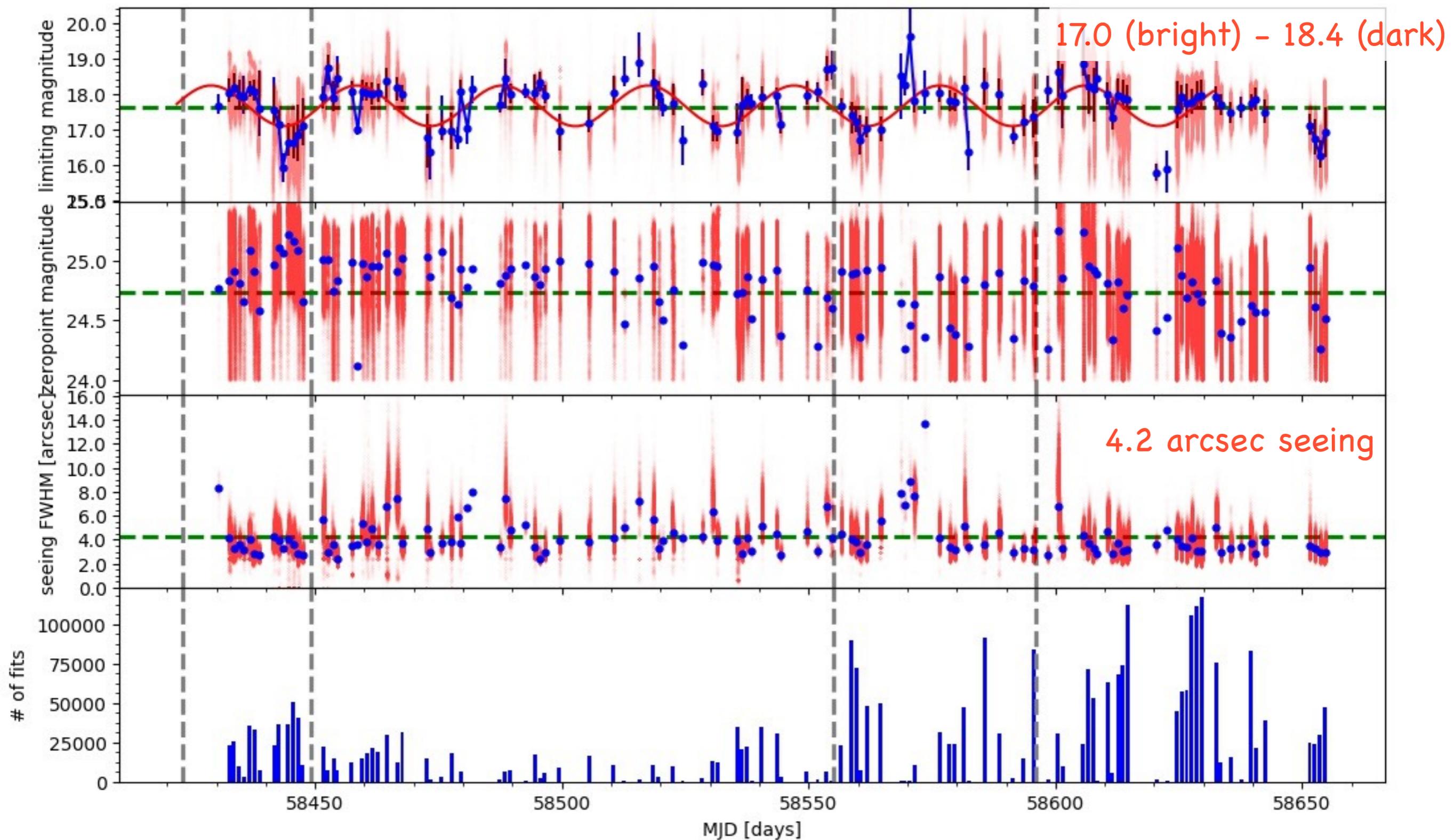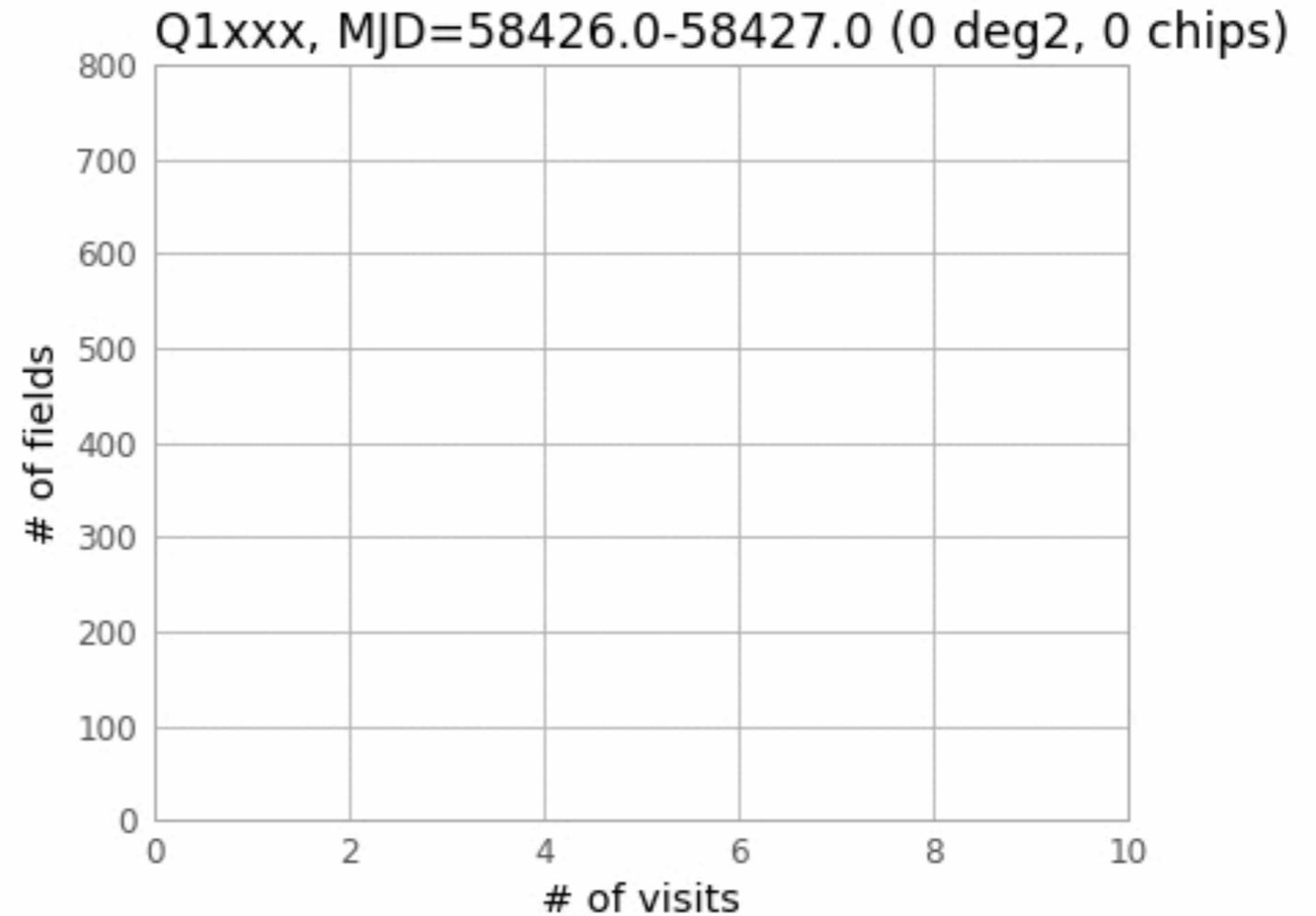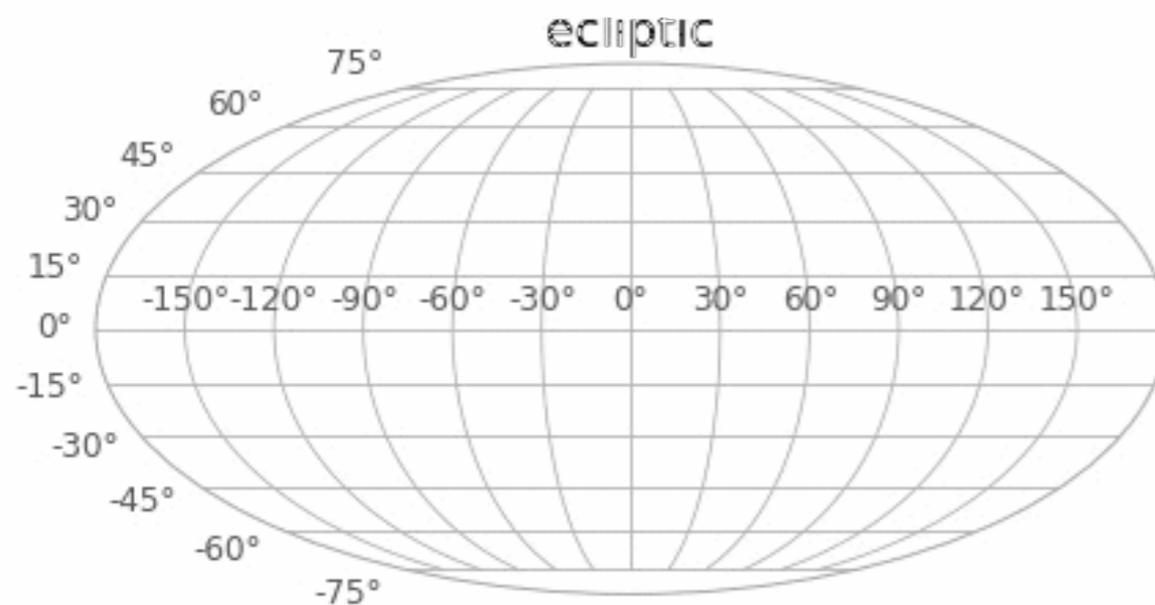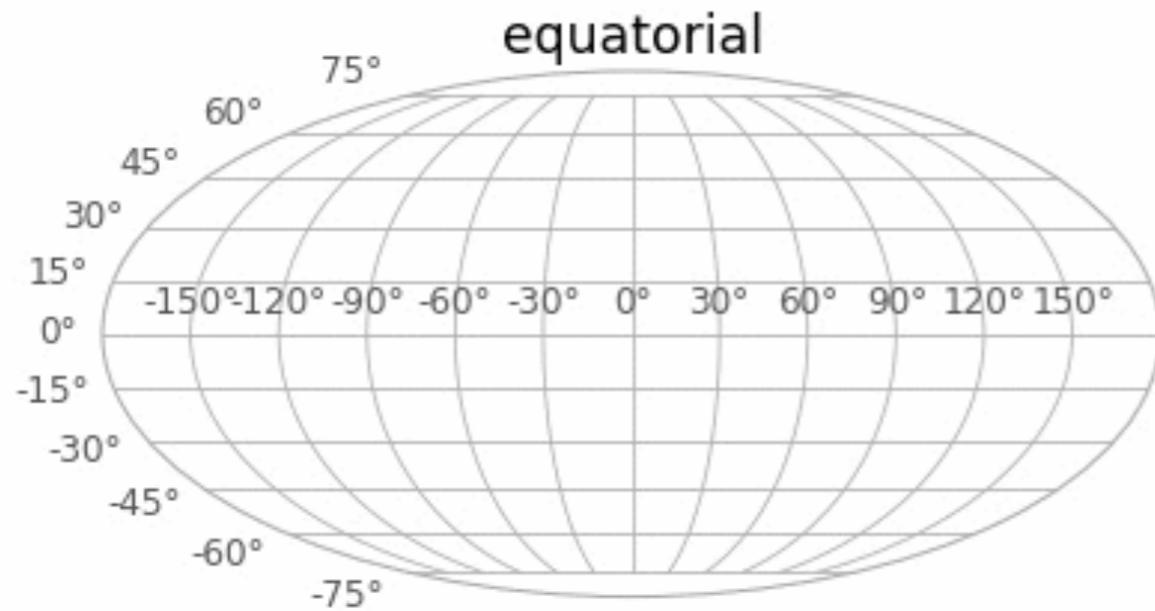
red: tonight
blue: previously observed
(thicker, more visits)

First Discovery of A Supernova (SN 2019cxx)

- Type Ia supernova@z=0.025
- follow-up observations
  - Spectroscopy
    - Gemini-N/GMOS (Tanaka+)
    - Seimei/KOOLS-IFU (Maeda+)
    - Kanata/HOWPol
  - Imaging
    - Kanata/HOWPol
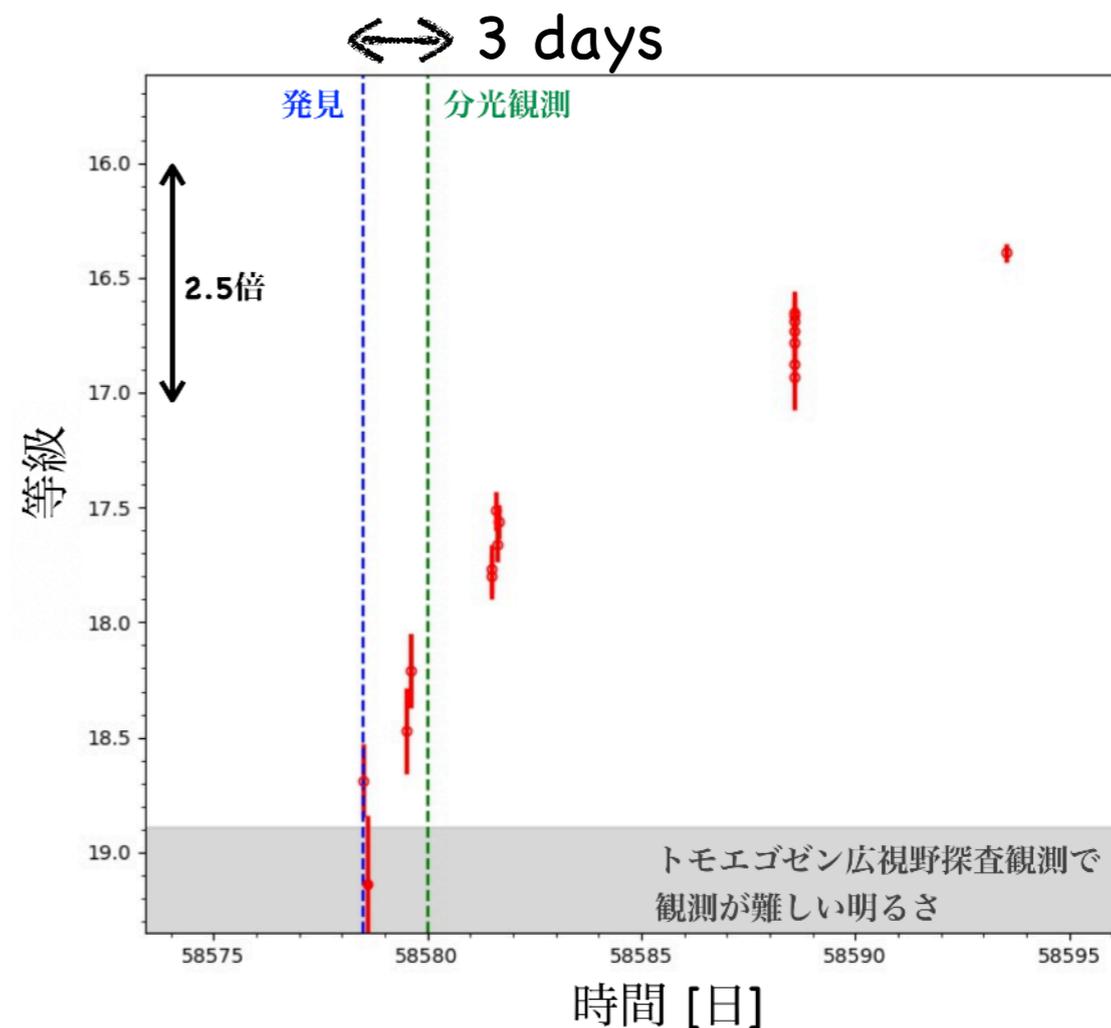
Tomo-e　　　PS1　　　[Tomo-e] - [PS1]　　　Kanata/HONIR

http://www.ioa.s.u-tokyo.ac.jp/kisohp/NEWS/SN2019cxx/index.html
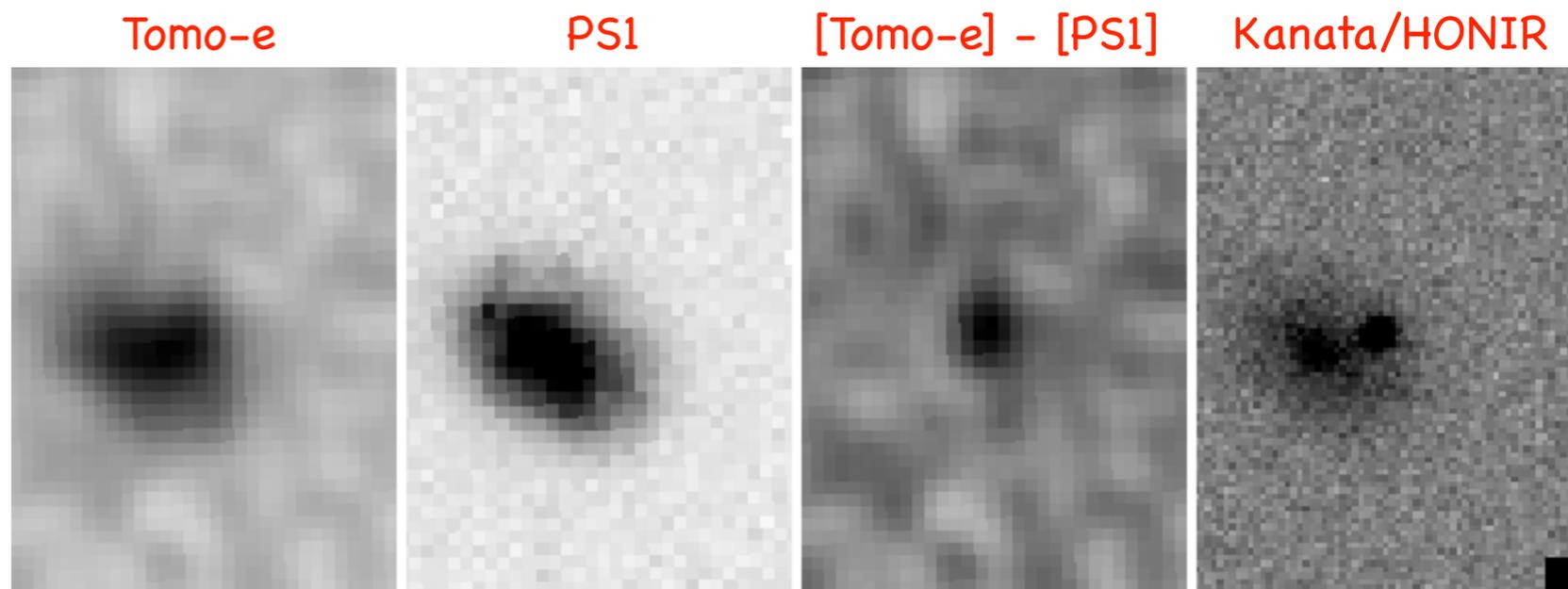
Transient Name Server (TNS)

- ☐ Dec > -30 deg, April 2019
- ☐ #(Tomo-e Obs) > 0
- ☐ several transients discovered w/ Tomo-e Gozen

  before TNS registration

- ☐ **t(Tomo-e) < t(TNS)**, t(Tomo-e) > t(TNS)

#TNS	name	RA	Dec	Other Name	DiscDate	Disc Mag	DiscFilter	transId	#(TG)	MJD (get transient ID) MJD (Tomo-e detection) MJD (Tomo-e data)	mag max mag min
39	AT 2019hzl	157.37296	70.52804	Gaia19cnz	2019-05-25 18:23:02 (58628.766)	17.43	G-Gaia	39428	17(10)	58614.694 (-14.072) 58613.657-58642.515 (58613.657- 58651.539)	17.67(0.06) -18.08(0.18)
44	AT 2019fyw	196.82692	2.00321	ASASSN-19nm	2019-05-25 07:40:48 (58628.320)	17.70	g-Sloan	38051	5(5)	58640.550 (12.230) 58635.498-58642.556 (58635.498- 58642.556)	17.06(0.06) -16.99(0.15)
45	SN 2019fyw	196.82692	2.00321	ASASSN-19nm	2019-05-25 07:40:48 (58628.320)	17.70	g-Sloan	38051	5(5)	58640.550 (12.230) 58635.498-58642.556 (58635.498- 58642.556)	17.06(0.06) -16.99(0.15)
55	AT 2019fun	277.42483	26.47833	ATLAS19lgv	2019-05-22 11:51:21 (58625.494)	16.44	orange-ATLAS	37938	1(0)	58632.744 (7.250) 99999.999--99999.999 (58653.641- 58653.641)	99.99(9.99) -16.99(0.15)
64	AT 2019fsz	248.77821	34.98120	Gaia19bwq	2019-05-20 15:05:45 (58623.629)	16.59	G-Gaia	37897	12(4)	58607.767 (-15.862) 58607.767-58614.627 (58607.767- 58658.638)	17.41(0.05) -18.28(0.10)
103	AT 2019ghx	267.80586	76.24397	ZTF18abokkfh	2019-05-14 08:19:50 (58617.347)	17.81	g-ZTF	38290	2(2)	58639.649 (22.302) 58639.649-58640.613 (58639.649- 58640.613)	16.67(0.05) -16.77(0.04)
112	AT 2019fll	235.19776	68.53095	ZTF19aauptux	2019-05-13 06:53:16 (58616.287)	15.98	g-ZTF	37698	7(4)	58625.590 (9.303) 58627.560-58627.562 (58627.560- 58654.732)	18.11(0.09) -18.24(0.13)
114	SN 2019fck	204.05423	38.35506	ZTF18aaqkcso	2019-05-13 04:23:32 (58616.183)	16.76	g-ZTF	37460	1(1)	58651.524 (35.341) 58635.493-58635.493 (58635.493- 58635.493)	14.78(0.00) -14.78(0.00)
115	AT 2019fck	204.05423	38.35506	ZTF18aaqkcso	2019-05-13 04:23:32 (58616.183)	16.76	g-ZTF	37460	1(1)	58651.524 (35.341) 58635.493-58635.493 (58635.493- 58635.493)	14.78(0.00) -14.78(0.00)
118	AT 2019fjf	274.02587	15.60989	Gaia19btz	2019-05-12 13:45:07 (58615.573)	15.73	G-Gaia	37640	2(0)	58612.633 (-2.940) 99999.999--99999.999 (58654.710- 58658.622)	99.99(9.99) -14.78(0.00)
136	AT 2019ffe	296.90817	14.29320	Gaia19bsy	2019-05-10 08:00:57 (58613.334)	14.69	G-Gaia	37535	6(4)	58639.655 (26.321) 58639.630-58653.633 (58639.630- 58654.704)	16.07(0.03) -16.35(0.19)
141	AT 2019fda	266.95435	18.68696	ZTF19aaumtxz	2019-05-09 10:34:20 (58612.441)	16.26	r-ZTF	37473	39(15)	58613.718 (1.277) 58613.622-58629.765 (58607.734- 58658.625)	15.82(0.02) -17.58(0.13)
143	AT 2019evz	218.12848	8.54073	ZTF19aaujiwc	2019-05-09 06:32:25 (58612.273)	17.86	g-ZTF	37293	9(5)	58625.525 (13.252) 58639.538-58642.550 (58639.538- 58642.550)	17.62(0.06) -18.33(0.15)
154	AT 2019evp	296.99887	24.99620	Gaia19bsi	2019-05-07 19:53:45 (58610.829)	15.22	G-Gaia	37283	5(1)	58626.636 (15.807) 58637.589-58637.589 (58637.589- 58654.703)	16.65(0.10) -16.65(0.10)
180	AT 2019eku	287.64536	25.97231	ZTF19aaticbv	2019-05-02 10:40:48 (58605.445)	16.58	r-ZTF	37000	20(5)	58614.765 (9.320) 58613.726-58614.765 (58613.616- 58658.612)	17.44(0.13) -17.36(0.13)
189	AT 2019ejy	297.61021	51.08673	Gaia19bqu	2019-05-01 19:35:02 (58604.816)	17.21	G-Gaia	36974	11(2)	58607.751 (2.935) 58612.757-58613.741 (58612.757- 58654.739)	18.29(0.17) -18.56(0.19)
191	SN 2019eix	280.67870	40.36883	ATLAS19ify	2019-05-01 14:09:36 (58604.590)	17.00	cyan-ATLAS	36947	8(5)	58606.627 (2.037) 58613.594-58640.598 (58613.594- 58654.740)	17.13(0.05) -18.71(0.15)
192	AT 2019eix	280.67870	40.36883	ATLAS19ify	2019-05-01 14:09:36 (58604.590)	17.00	cyan-ATLAS	36947	8(5)	58606.627 (2.037) 58613.594-58640.598 (58613.594- 58654.740)	17.13(0.05) -18.71(0.15)
194	AT 2019ekj	244.37817	50.71628	ATLAS19igg	2019-05-01 12:38:52 (58604.527)	17.47	cyan-ATLAS	36985	9(5)	58607.773 (3.246) 58607.773-58614.634 (58607.773- 58654.729)	17.49(0.07) -17.74(0.06)
213	AT 2019ehu	259.05808	68.61077	Gaia19bpo	2019-04-28 19:10:33 (58601.799)	16.72	G-Gaia	36918	1(0)	58625.483 (23.684) 99999.999--99999.999 (58635.467- 58635.467)	99.99(9.99) -17.74(0.06)
222	SN 2019edo	182.96463	24.13669	ASASSN-19kx	2019-04-27 07:26:24 (58600.310)	16.70	g-Sloan	36807	8(7)	58606.711 (6.401) 58613.683-58642.489 (58613.559- 58642.489)	16.70(0.05) -16.69(0.10)
223	AT 2019edo	182.96463	24.13669	ASASSN-19kx	2019-04-27 07:26:24 (58600.310)	16.70	g-Sloan	36807	8(7)	58606.711 (6.401) 58613.683-58642.489 (58613.559- 58642.489)	16.70(0.05) -16.69(0.10)
243	SN 2019dwy	168.54410	70.76804	ASASSN-19ku	2019-04-24 09:50:24 (58597.410)	17.20	g-Sloan	36633	55(30)	58585.724 (-11.686) 58585.714-58595.787 (58578.541- 58651.539)	17.65(0.08) -17.81(0.13)
244	AT 2019dwy	168.54410	70.76804	ASASSN-19ku	2019-04-24 09:50:24 (58597.410)	17.20	g-Sloan	36633	55(30)	58585.724 (-11.686) 58585.714-58595.787 (58578.541- 58651.539)	17.65(0.08) -17.81(0.13)
246	AT 2019dwq	223.56508	4.79299	ZTF19aarnqzw	2019-04-24 07:07:12 (58597.297)	17.99	r-ZTF	36625	33(30)	58600.540 (3.244) 58600.540-58642.549 (58600.540- 58642.549)	16.90(0.09) -17.88(0.17)
247	SN 2019dwq	223.56508	4.79299	ZTF19aarnqzw	2019-04-24 07:07:12 (58597.297)	17.99	r-ZTF	36625	33(30)	58600.540 (3.244) 58600.540-58642.549 (58600.540- 58642.549)	16.90(0.09) -17.88(0.17)
251	AT 2019due	240.40661	16.43601	ATLAS19hsk	2019-04-22 11:58:33 (58595.499)	17.87	orange-ATLAS	36559	23(17)	58606.615 (11.116) 58606.735-58658.581 (58606.735- 58658.648)	16.90(0.02) -19.34(0.19)
252	SN 2019due	240.40661	16.43601	ATLAS19hsk	2019-04-22 11:58:33 (58595.499)	17.87	orange-ATLAS	36559	23(17)	58606.615 (11.116) 58606.735-58658.581 (58606.735- 58658.648)	16.90(0.02) -19.34(0.19)
257	AT 2019dxm	217.76979	28.28726	ZTF18aakqsre	2019-04-21 06:58:52 (58594.291)	17.31	g-ZTF	36648	30(27)	58559.713 (-34.578) 58558.659-58658.644 (58558.659- 58658.644)	16.21(0.03) -16.19(0.02)
355	AT 2019cwv	121.87384	15.57832	ZTF18aaablok	2019-04-08 03:41:31 (58581.154)	16.82	r-ZTF	35937	5(3)	58581.571 (0.417) 58578.578-58581.571 (58578.578- 58600.515)	18.64(0.16) -16.81(0.16)
367	AT 2019dcu	89.37442	11.45399	Gaia19bfy	2019-04-05 18:01:26 (58578.751)	16.08	G-Gaia	36098	14(1)	0.000 (-58578.751) 58499.547-58499.547 (58488.518- 58540.486)	16.90(0.09) -16.90(0.09)
394	AT 2019cvt	80.96571	1.00852	Gaia19bfo	2019-04-02 11:54:14 (58575.496)	14.23	G-Gaia	35908	29(13)	0.000 (-58575.496) 58489.570-58544.439 (58488.571- 58544.439)	17.89(0.11) -15.87(0.06)

Follow-up Scheme

- After discovering transient candidates...
  - <u>spectroscopic identification</u>
  - multi-band light curves
- KISS w/ KWFC: KISS international collaboration + OISTER
  - # of spectroscopic observations (29 spec-ID+) limited: too faint
    - TM+2014, Tanaka+2014, TM+2017, Gabanyi+2018, Kokubo+2019
- Tomo-e Gozen survey: bright enough for OISTER domestic telescopes
  - discovery ==> follow-up within the same night
- Approved programs
  - Seimei/KOOLS-IFU
  - Gemini-N/GMOS
  - (Kanata, MITSuME)

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5σ検出限界
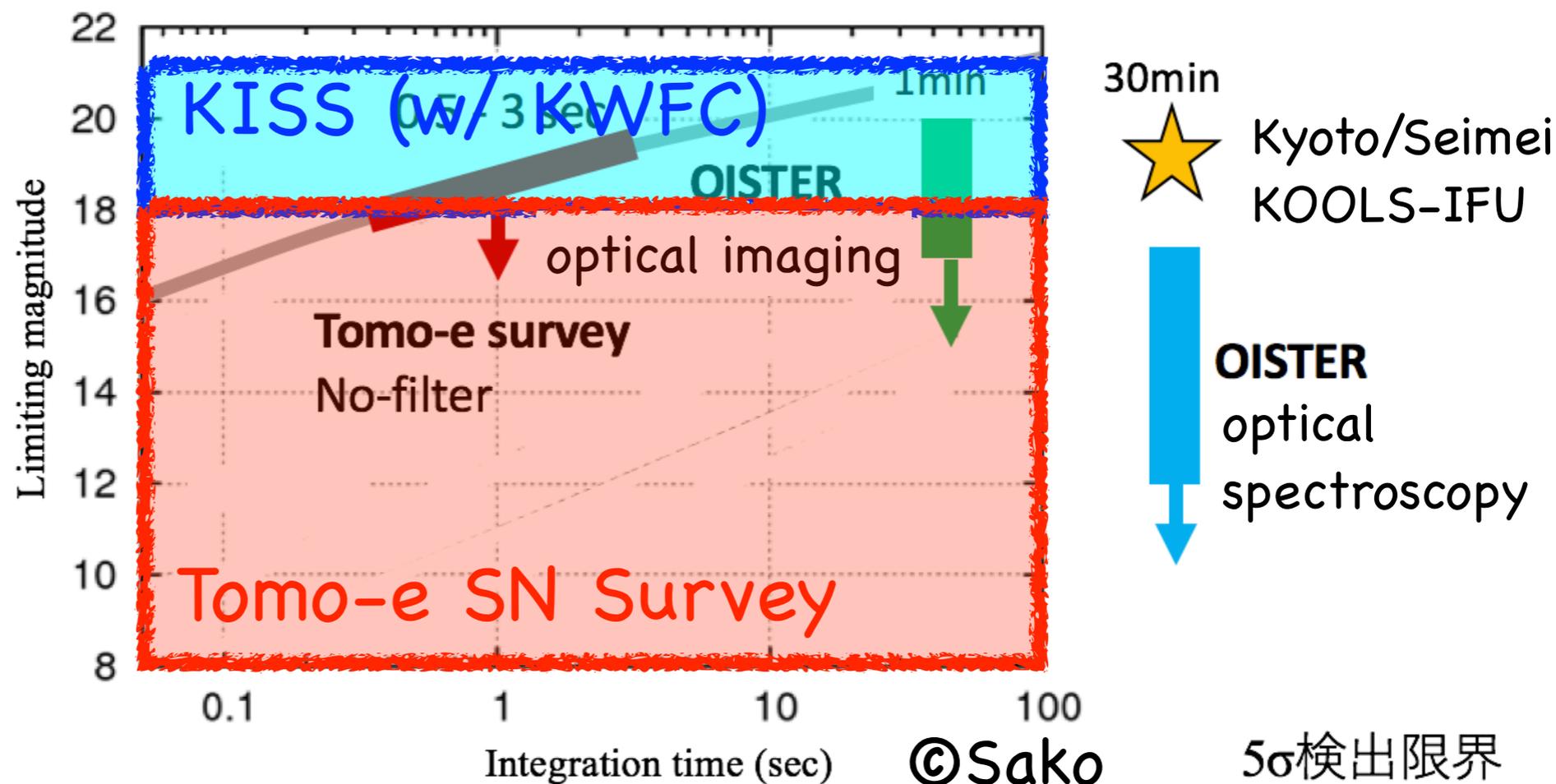
Data Products

- **after image subtraction**: developed by Tomo-e SN group
  - Subtracted images relative to PS1 r-band (reference)
  - Photometry for all the subtracted images of the transients
    - transient detection
    - CNN applied (Hamasaki+)
  - almost the same: search for GW EM counterparts (Niino-kun's talk)
- **before image subtraction**: (please help us...)
  - Photometry for all the detected sources
    - calibrated relative to PS1 r-band
    - light curves for all the sources: not yet
- **motion detection**
  - NEO search: developed by Kojima-kun & Beniyama-kun

Summary

- Let's catch supernovae (and other transient phenomena) in early-phase (right after explosions).
- Northern Sky Transient Survey has been started since Nov. 2019 (w/ Q1).
- 2x2 dithering, 7,000 deg / 2 hours, 18 mag depth
- 2-4 visits / night
    - Survey simulation by Pedro-san ==> Ikeda-san's talk
        - additionally consider weather conditions (avoid cloudy region and choose clear sky region) <== ongoing
- Development of automatic data reduction pipeline & website I/F are almost done. ==> Tominaga-kun's talk
    - Machine-learning technique (CNN) to pick up only real sources is being developed and adopted. Automatic alerts in near-future? (Hamasaki-kun's talk)
- quick follow-up observations w/ Seimei, Kanata, Gemini, …
- fully utilize "2 Hz" data to search for more rapid transients
- need to name the survey (after Tomo-e? Tomo-e Shinohara?)
    - Supernova HIgh-CadeNce Optical searcH for eARly phAses (SHINOHARA)
    - PREPREPRETTY, ULTRA RELUX
    - TOmoe gozeN high CAdence Transient Survey (TONCATS)