

Tomo-e Gozen Supernova Survey Plan

Tomoki Morokuma

(University of Tokyo, Institute of Astronomy)

Nozomu Tominaga (Konan Univ.), Masaomi Tanaka (NAOJ),
Keiichi Maeda (Kyoto Univ.), Shigeyuki Sako, Ryou Ohsawa
(Univ. of Tokyo), Kazuya Matsubayashi (NAOJ), Kouji Ohta
(Kyoto Univ.), Tomo-e Gozen SN Survey Team

Supernova Survey Plan w/ Tomo-e Gozen

10,000 deg² – 2 hr cadence – 18 mag depth
10,000 deg² – 1 day cadence – 19 mag depth

- no filter: effectively g+r bands
- 1 visit
 - 3 sec exposure: [0.5 sec exposure] x 6
 - ~18 mag
 - 2x3 or 2x2 dithering to fill the gaps
 - ~60 deg² (partially vignetted by ~30%)
- time interval for the same field: 2 hours
- survey area (per 2 hours): ~10,000 deg² (EL>30 deg)
- 3–5 times visits per night
 - ~19 mag for daily stacked data
- weather factor: usable (half), photometric (30%)

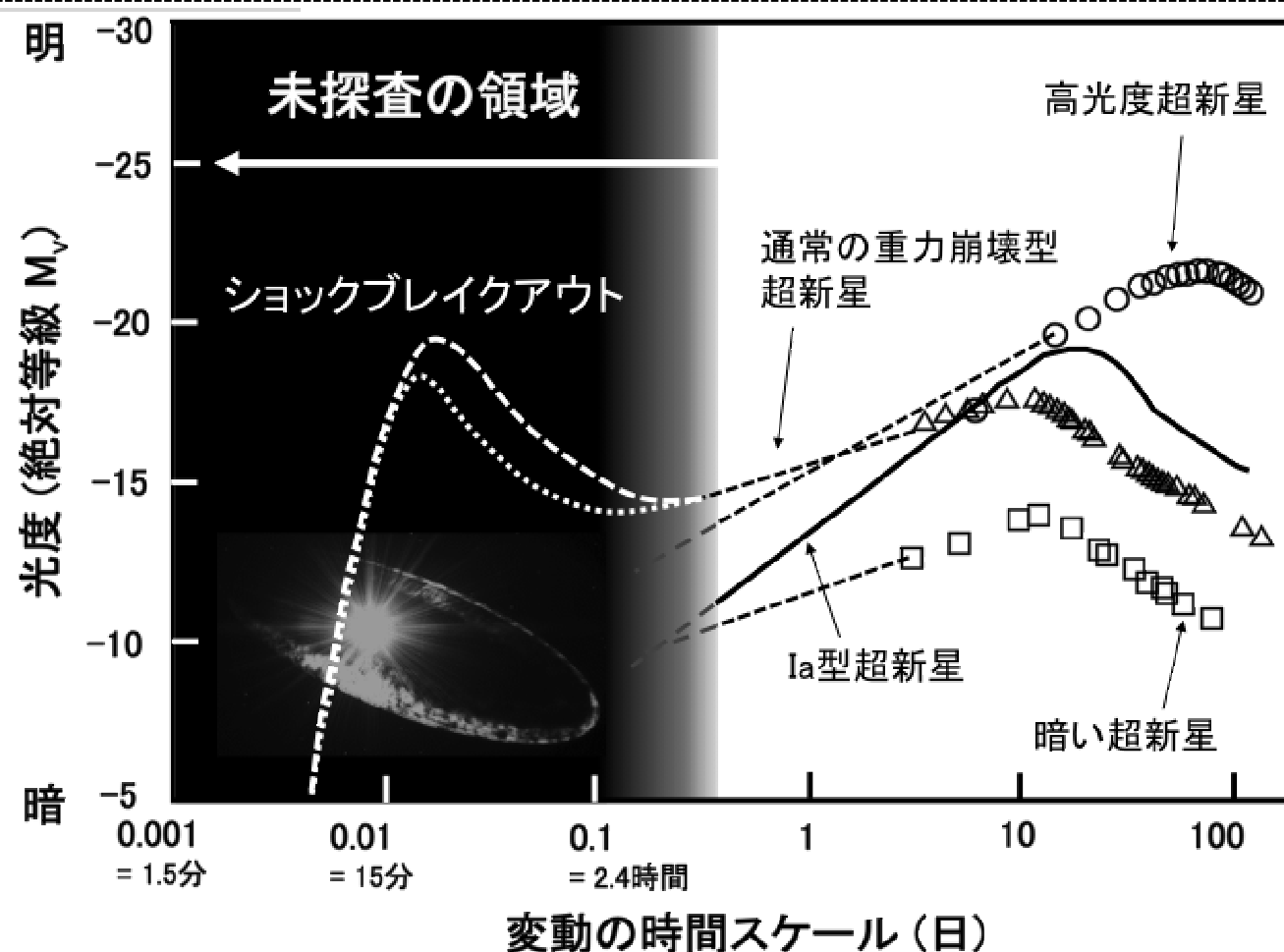
Contents

- Purpose
- Tomo-e SN Survey Plan
- Follow-Up Observations
- Summary

Purpose

研究目的(概要) ※ 当該研究計画の目的について、簡潔にまとめて記述してください。

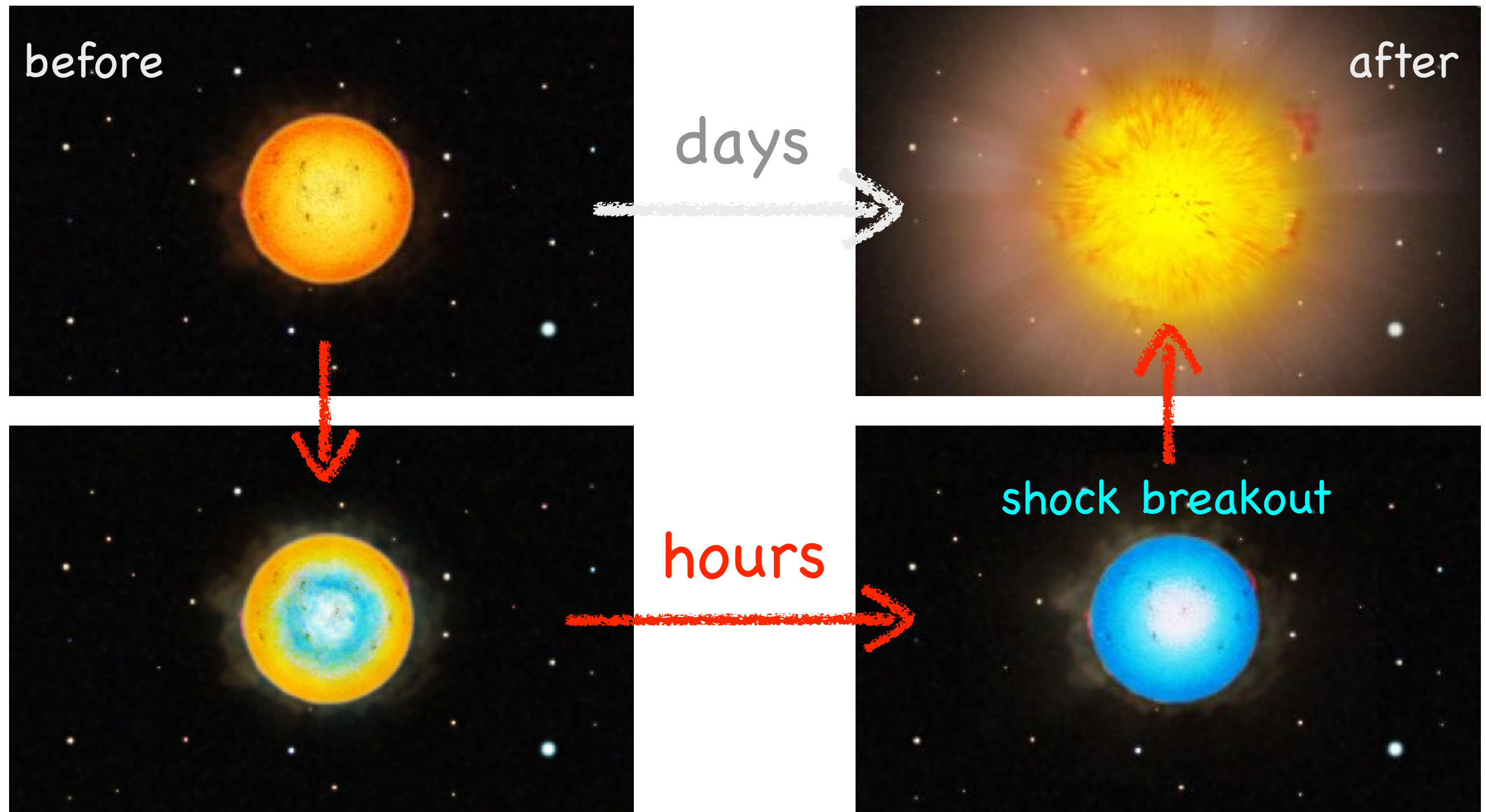
本研究では、(1) **84** 台の高感度 CMOS センサを用いて **20** 平方度を覆う超広視野カメラ *Tomoe Gozen*(以後 *Tomoe*) を開発し、(2) **10,000** 平方度を **2時間** 間隔でモニターするという過去に無い高頻度の広域観測を、東京大学木曽観測所口径 1m シュミット望遠鏡を用いて 400 夜実施する。これにより、近傍宇宙において、**超新星ショックブレイクアウト(約 10 天体)**を含めた約 50 天体の超新星爆発最初期の高精度データを取得し、精密な理論モデルを構築することで、質量放出を含めた重力崩壊型超新星爆発直前の大質量星の最期の姿を明らかにする。加えて、超新星を含む多種多様な短時間変動現象を検出し、動的宇宙の未探査の時間パラメータ領域を開拓する。



expected #(SN) / yr

- ~1,000 SNe
- ~a few tens young SNe
- a few shock breakouts

"Moment" of Supernova Explosion



Supernova Shock Breakout

e.g., Klein & Chevalier 1978

After core-collapse...

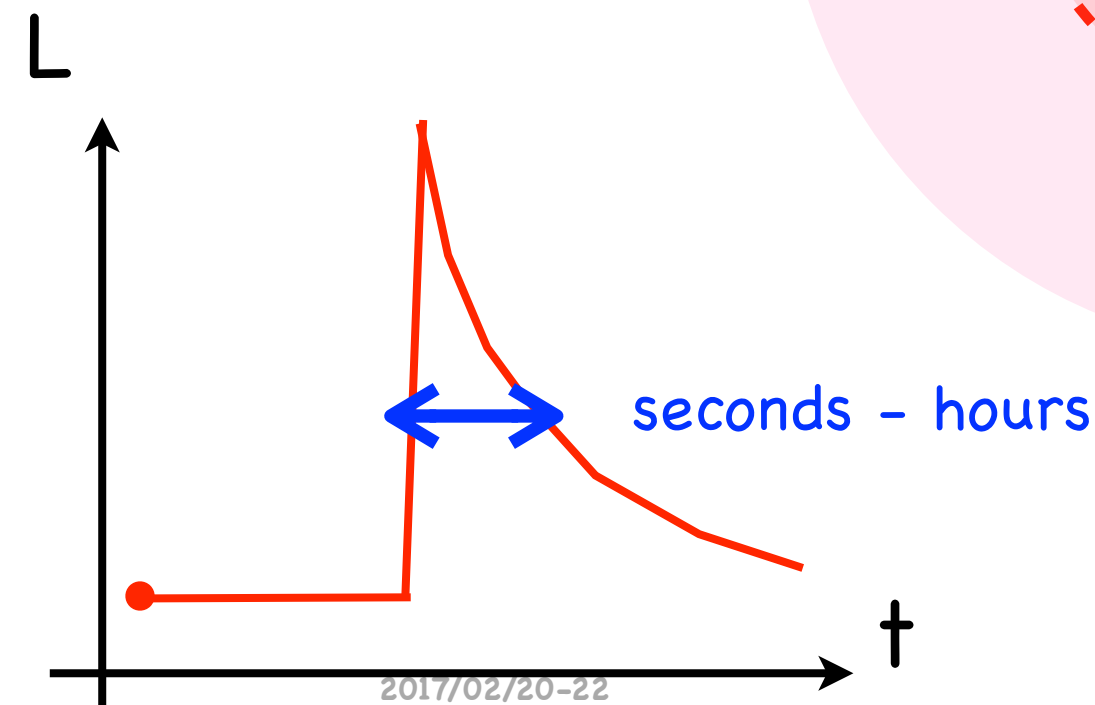
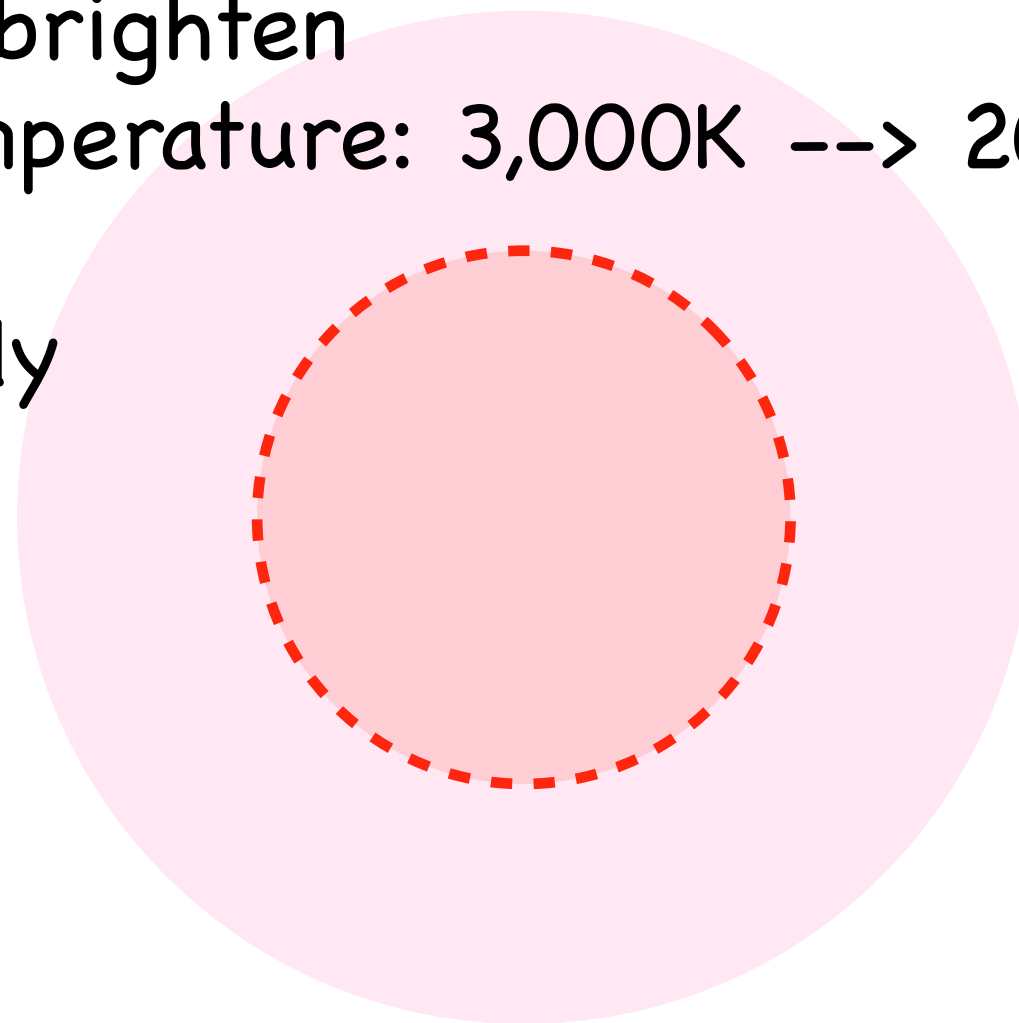
=> shock wave propagates outside

=> passes the stellar surface

=> suddenly brighten

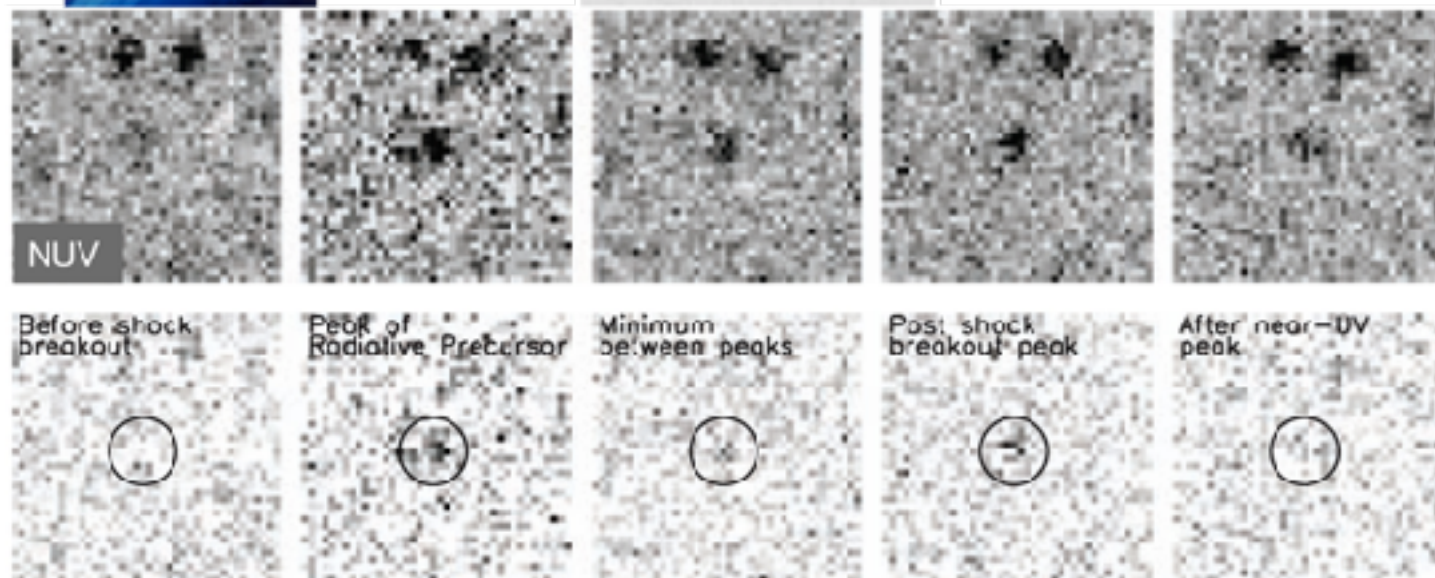
(color temperature: 3,000K --> 200,000K!!!)

semi-blackbody





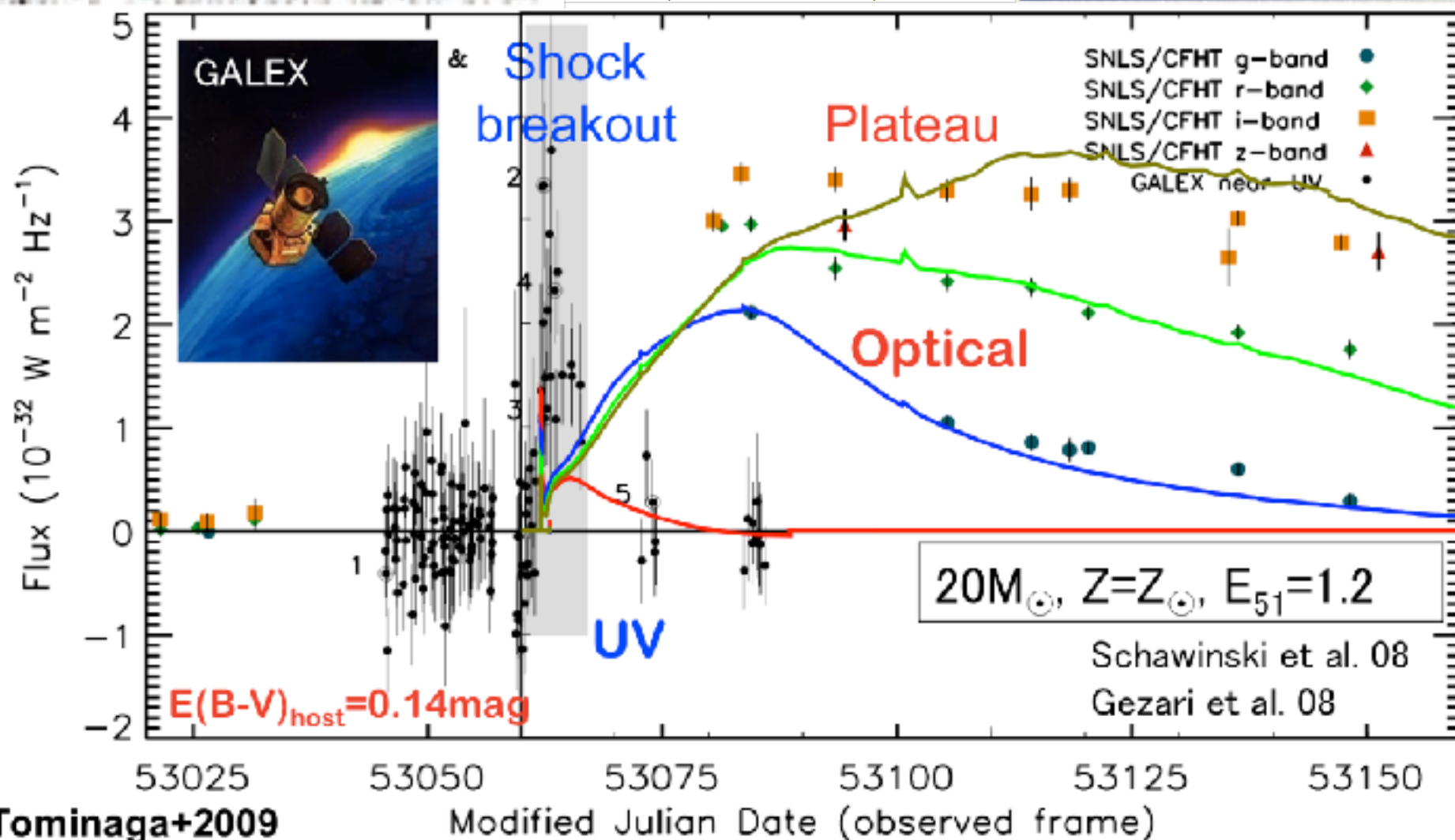
shock breakout detection@UV



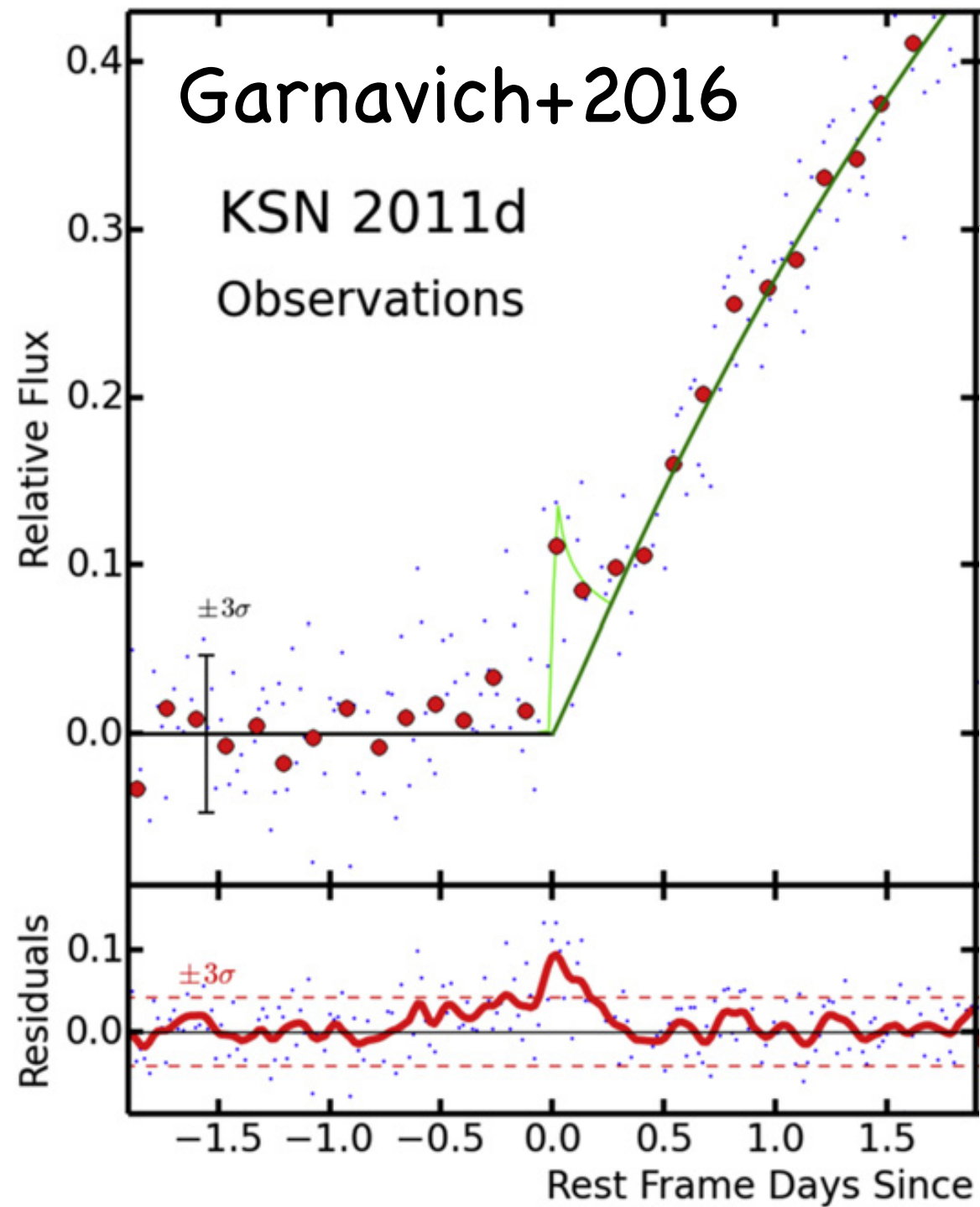
Multigroup radiation
hydrodynamics code
STELLA (Blinnikov + 98)
LC reproduced

SNLS-04D2dc@z=0.19

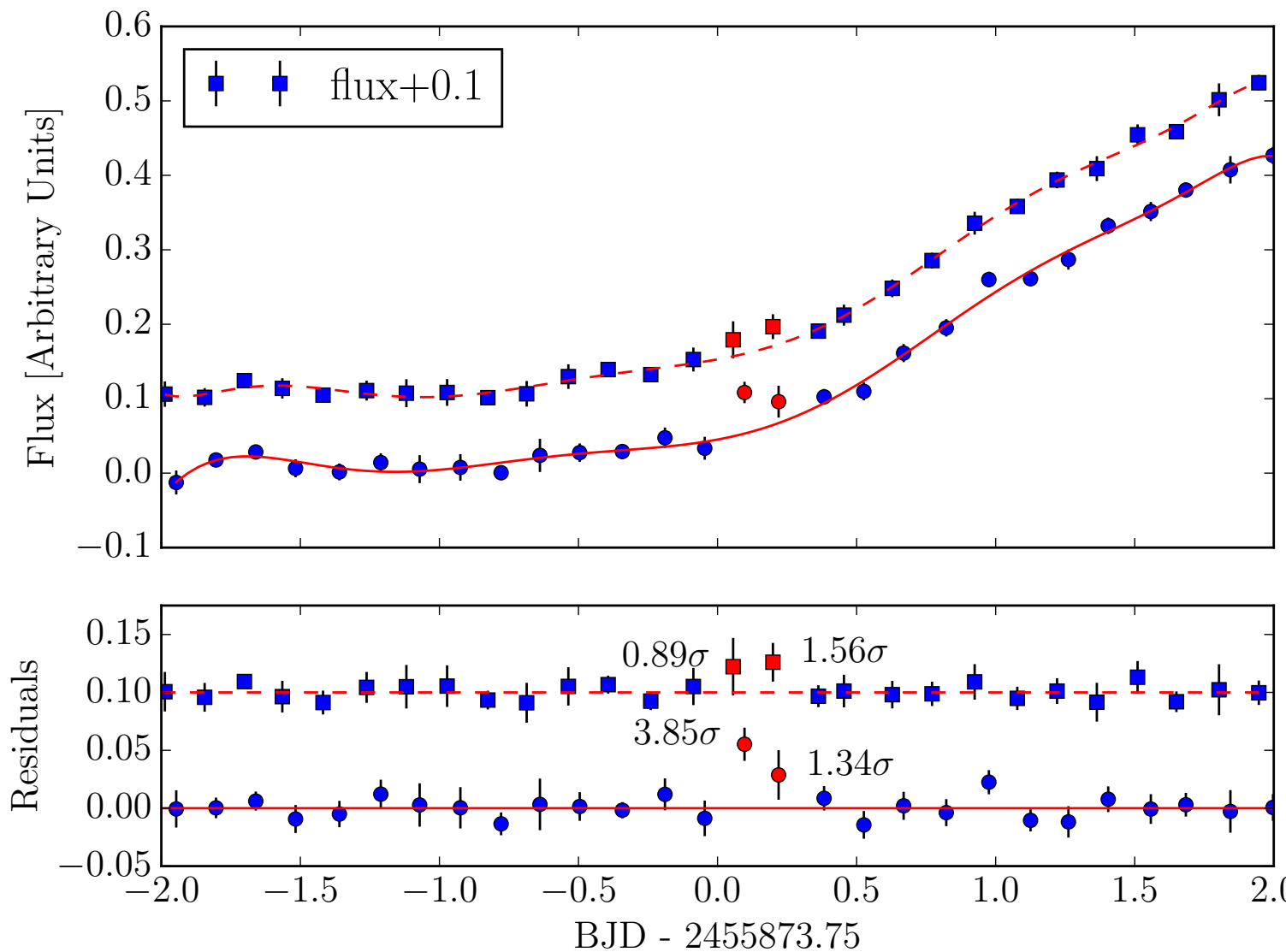
GALEX discovery



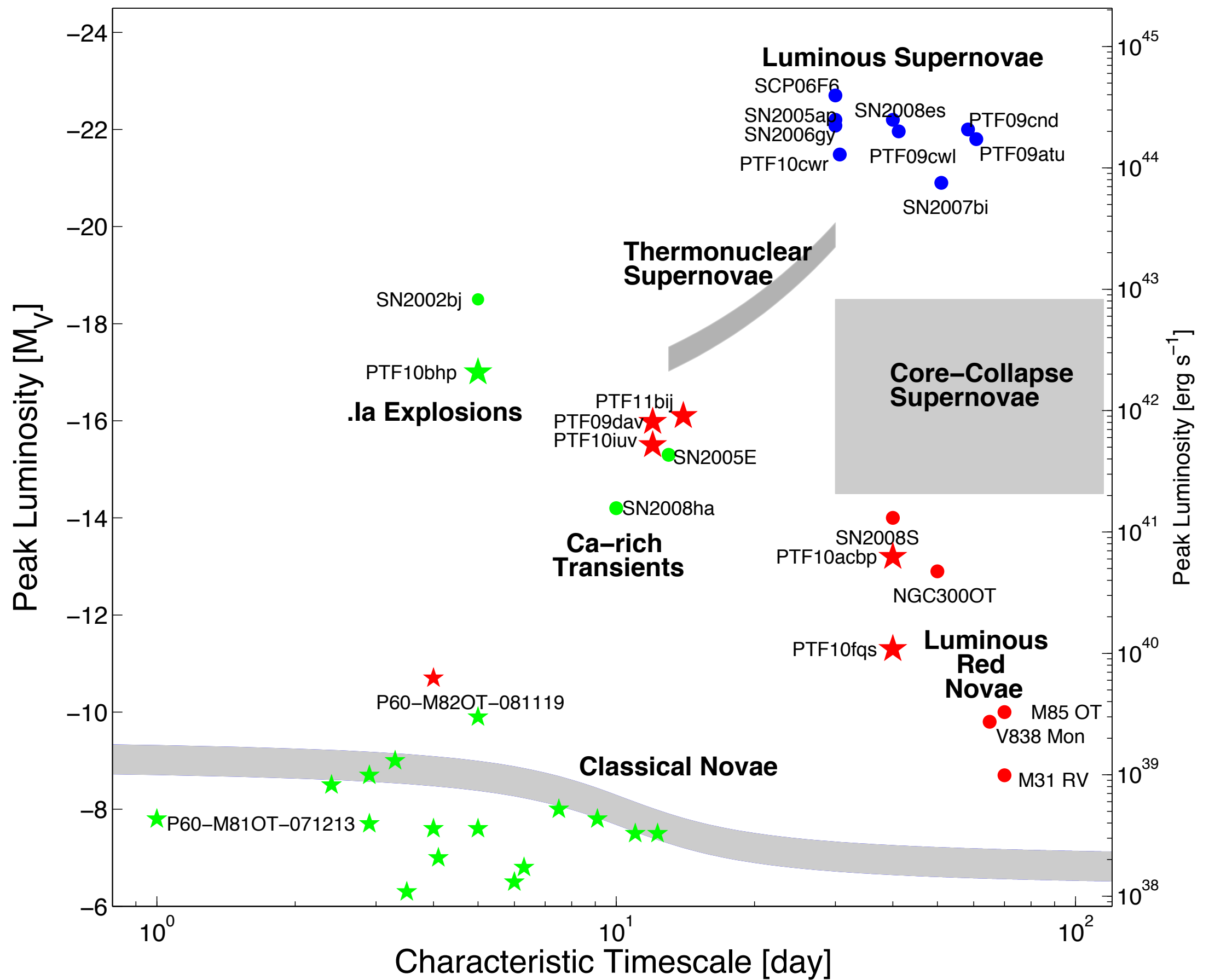
“Kepler” Shock Breakouts ???



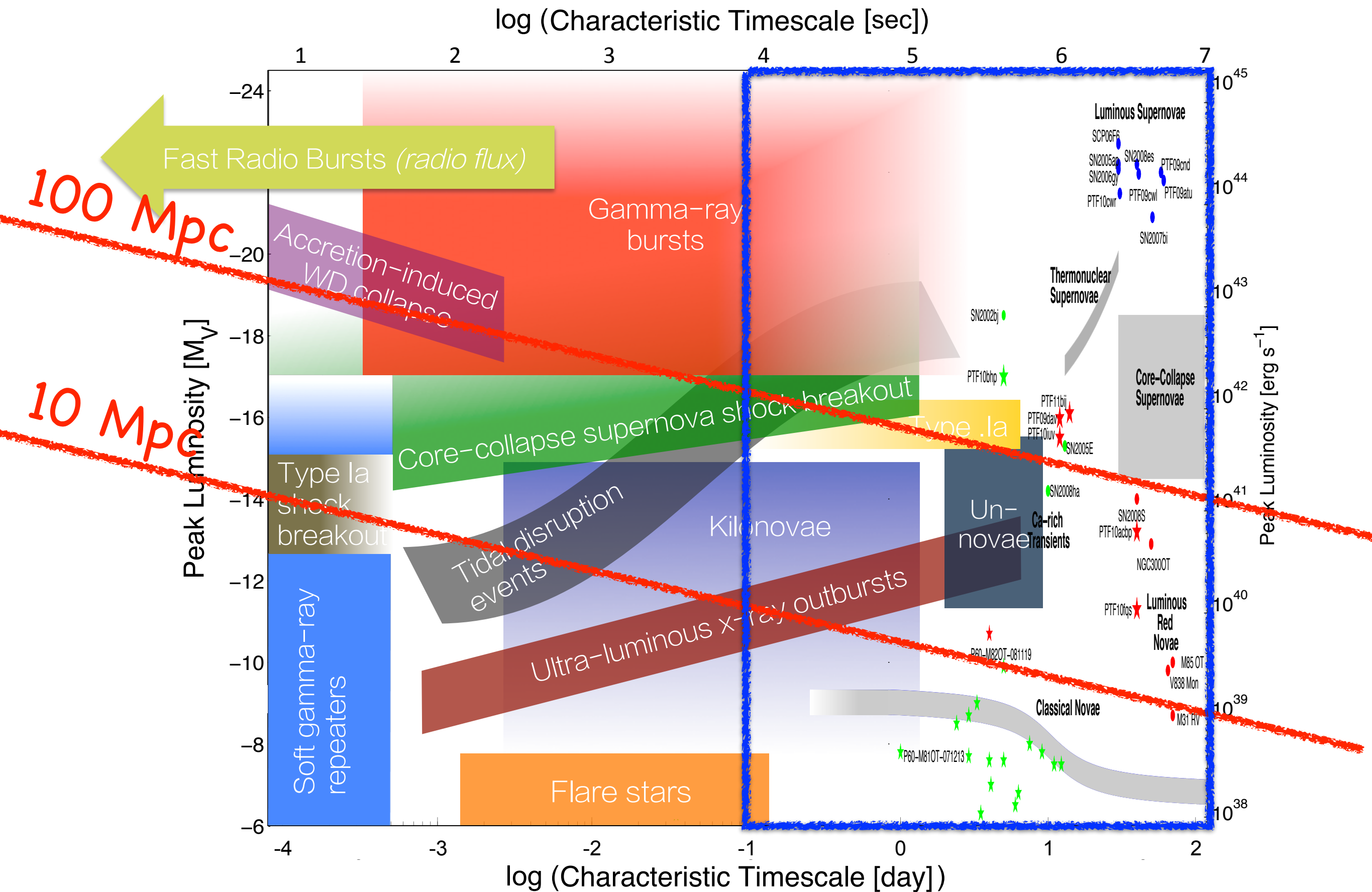
- first **optical** detection?
- not significant?



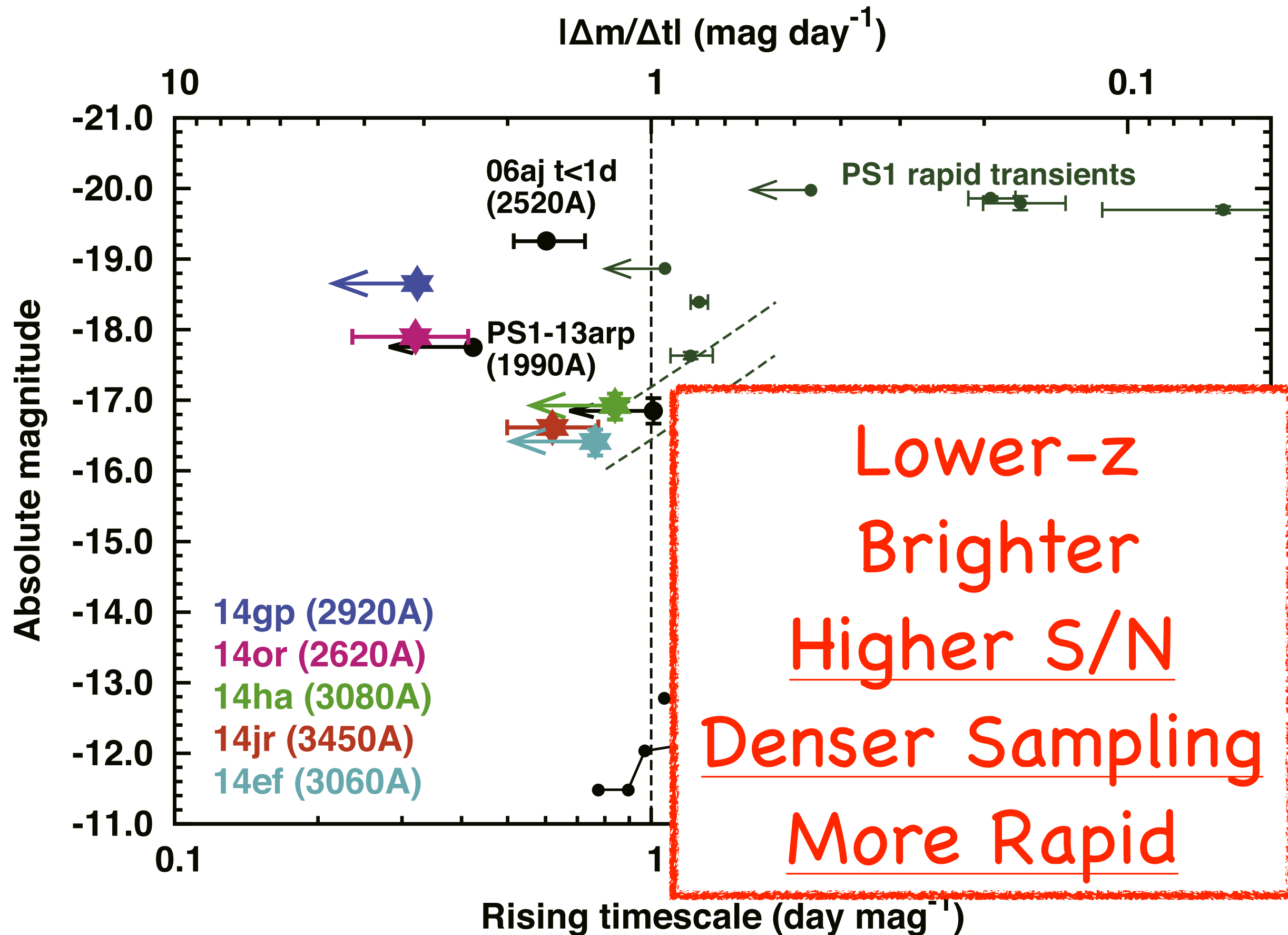
Rubin & Gal-Yam 2016 (arXiv:1612.02805)



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



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



Tanaka+2016, Subaru/HSC (e.g, Drout+2014, PS1)

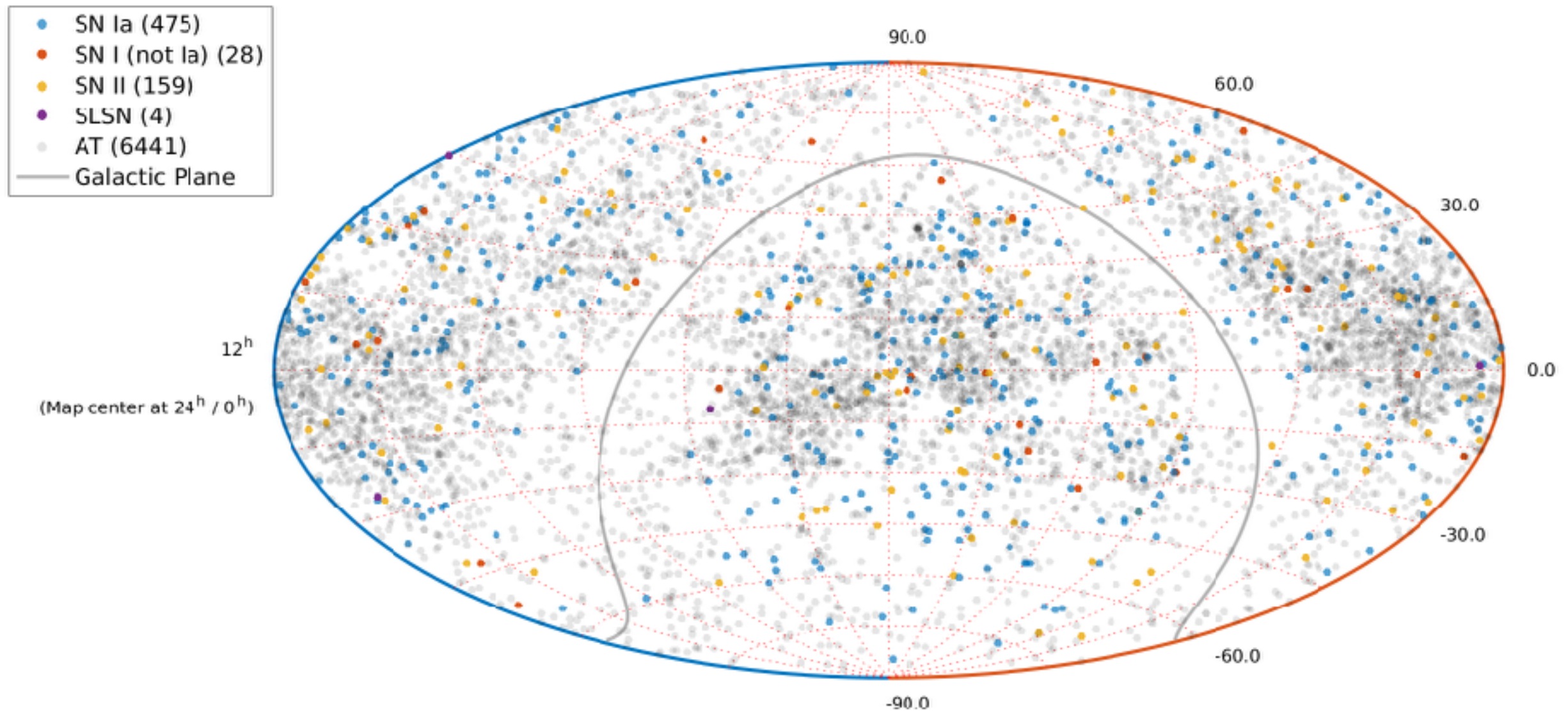
Supernova Survey Plan w/ Tomo-e Gozen

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TNS Full-Sky Map by Type

> 600 spectroscopically classified SNe



2016/01/01–2017/02/19

<https://wis-tns.weizmann.ac.il/stats-maps/maps>

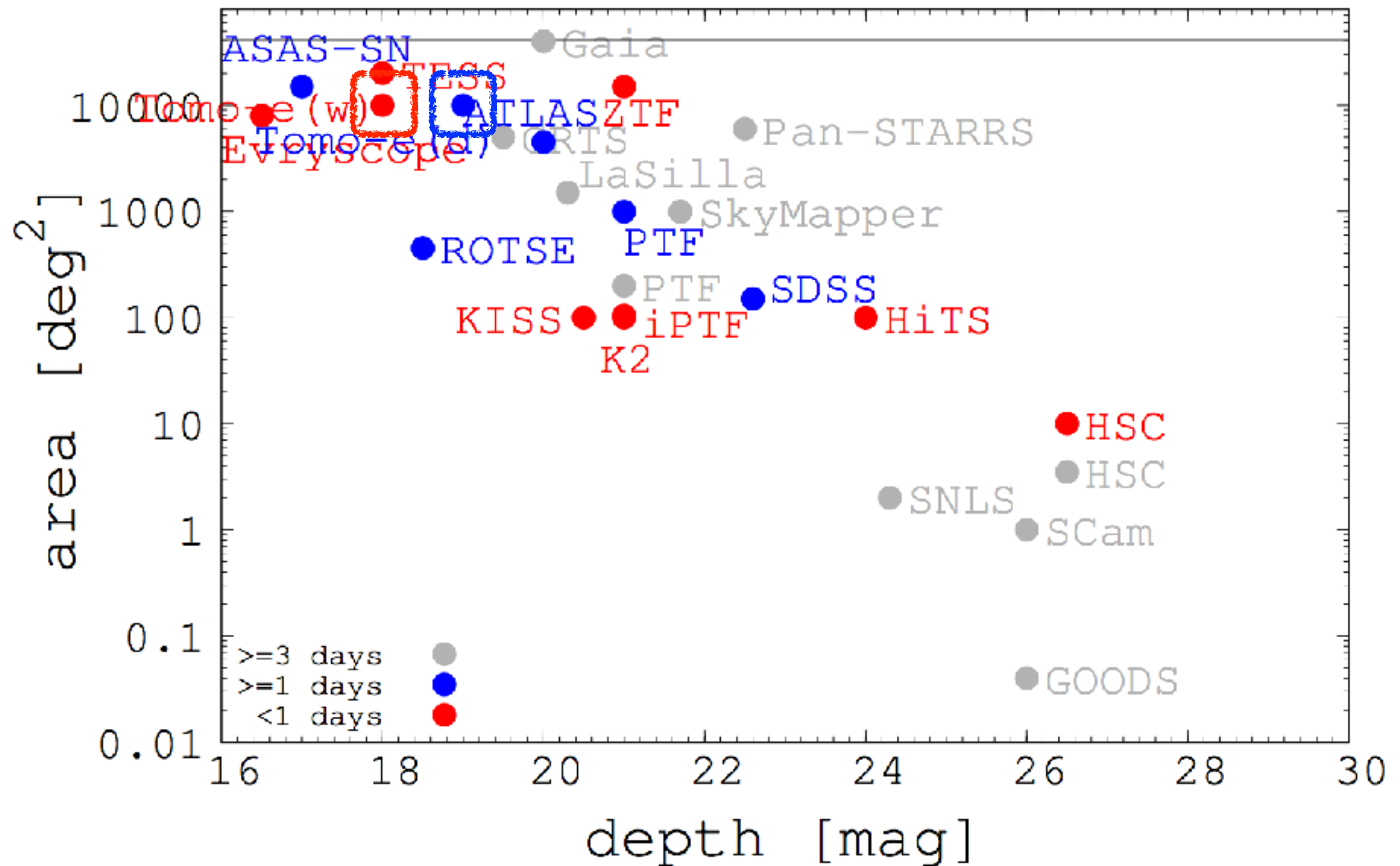
Tomo-e Gozen SN Survey

vs Kiso Supernova Survey (KISS) w/ KWFC

	Tomo-e SN Survey	KISS
instrument	Tomo-e Gozen	KWFC
sensor	CMOS	CCD
readout time	~0 sec	120 sec
period	2018/9-	2012/4-2015/9 (3.5 yrs)
survey area [deg ²]	10,000	50-100
cadence	2 hours / 1 day	1 hour
exposure time / visit	3 sec	180 sec
depth	18 mag / 19 mag	20-21 mag
filter	no (~g+r)	g
#(SBOs), #(SNe) / yr	5, 1000	O(0.1)-O(1), 100
data storage	daily-stacked image SN cutout images	all data saved
reference	-	TM, Tominaga, Tanaka+2014

Tomo-e Gozen SN Survey vs other SN surveys

year 2018

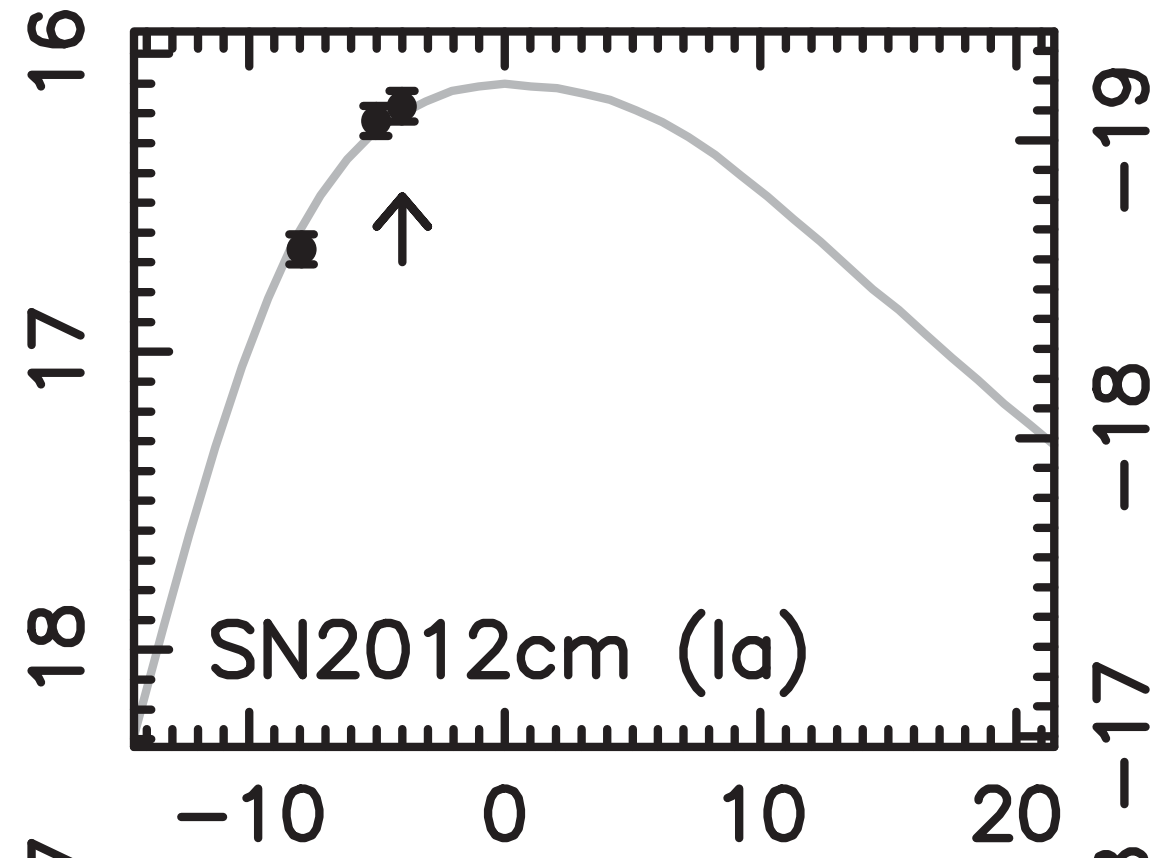
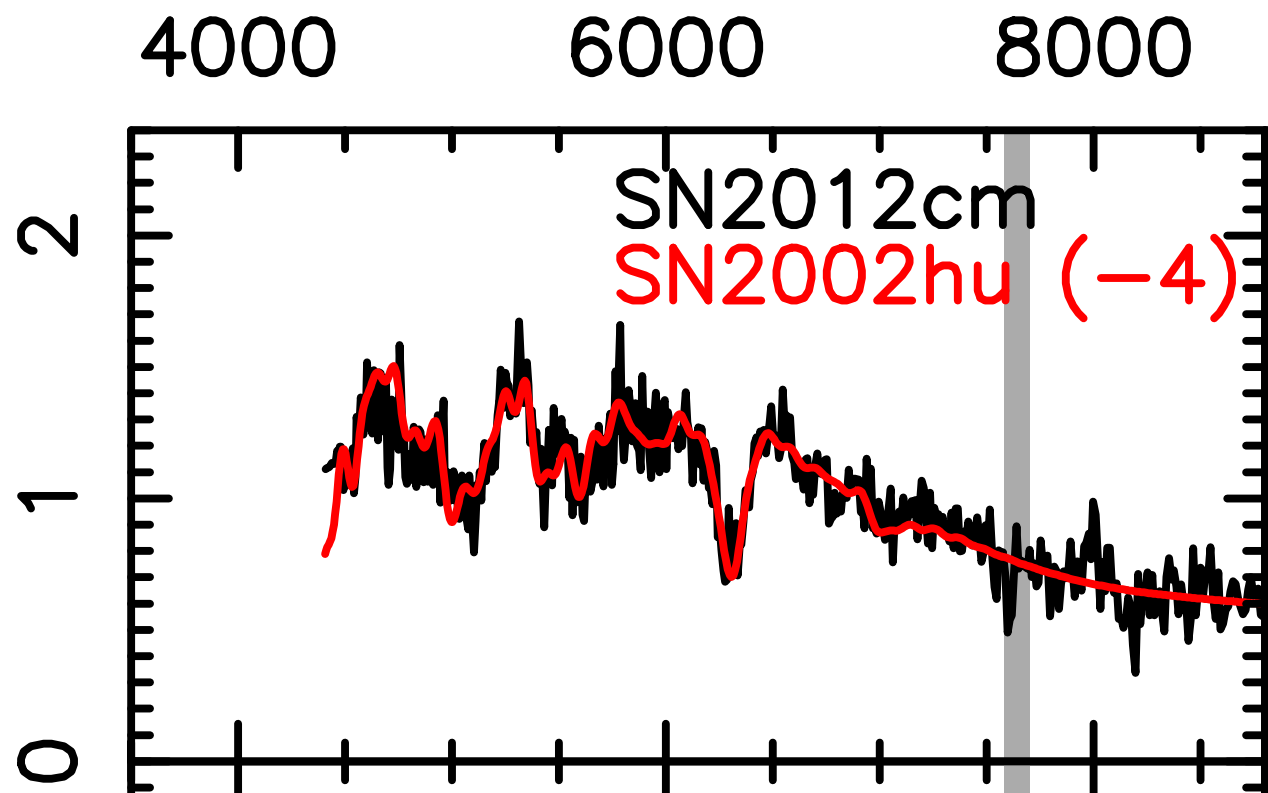
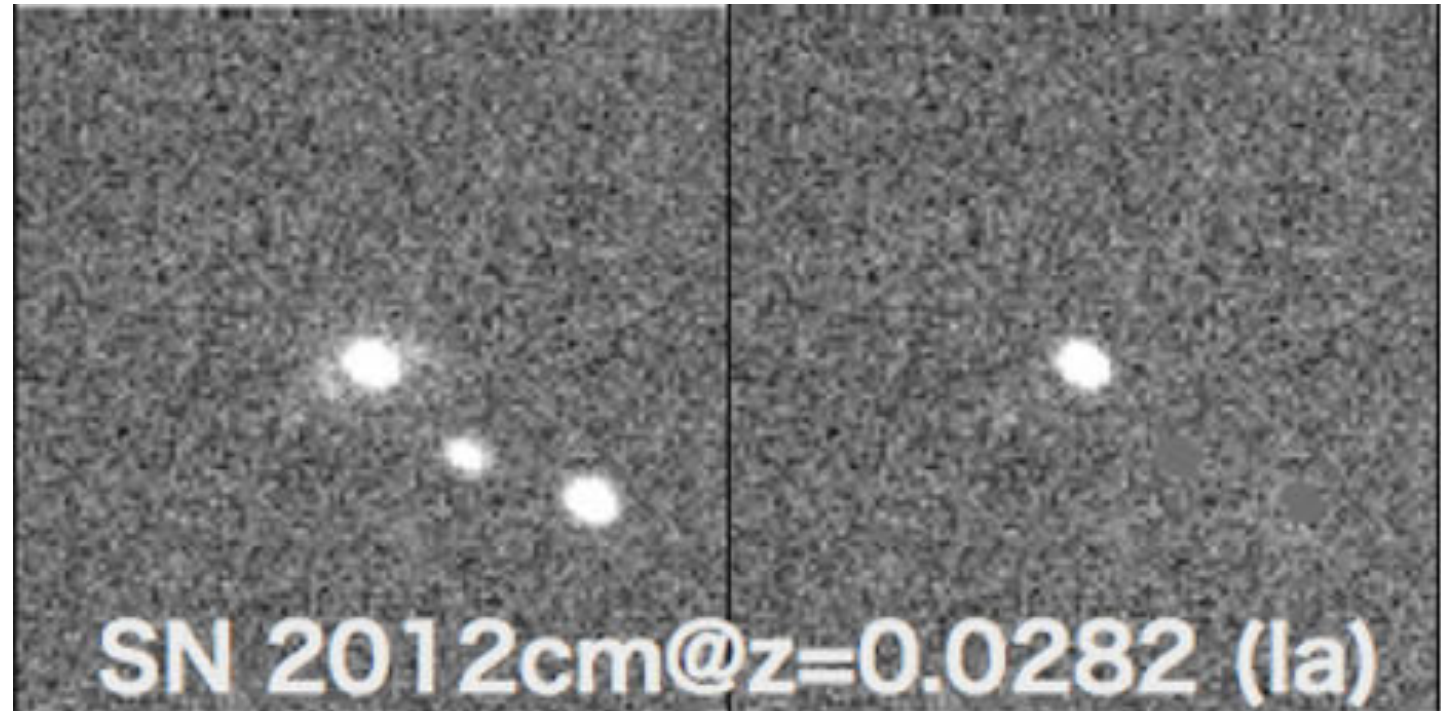


!!! Follow-Up Observations !!!

- After discovering SN candidates...
 - spectroscopic identification
 - multi-band light curves
- most successful recent SN projects
 - PTF, iPTF (Palomar 1.2m)
 - “550 nights of spectroscopy in 4.5 years” (M. Kasliwal)
 - ASAS-SN (0.14m x 8 x 2)
 - bright, <17 mag. Easily observed w/ 1m tel.
- KISS + KISS collaboration + OISTER
 - # of spectroscopic observations (29 spec-ID+) limited.
 - because most of the candidates (1.05 m, 3-minute exposure, 1-hour cadence) were as faint as $g > 19$...
 - brightest spec-ID: $g=16.8$, SN 2012cm
 - faintest spec-ID: $g=20.6$, SN 2015aa

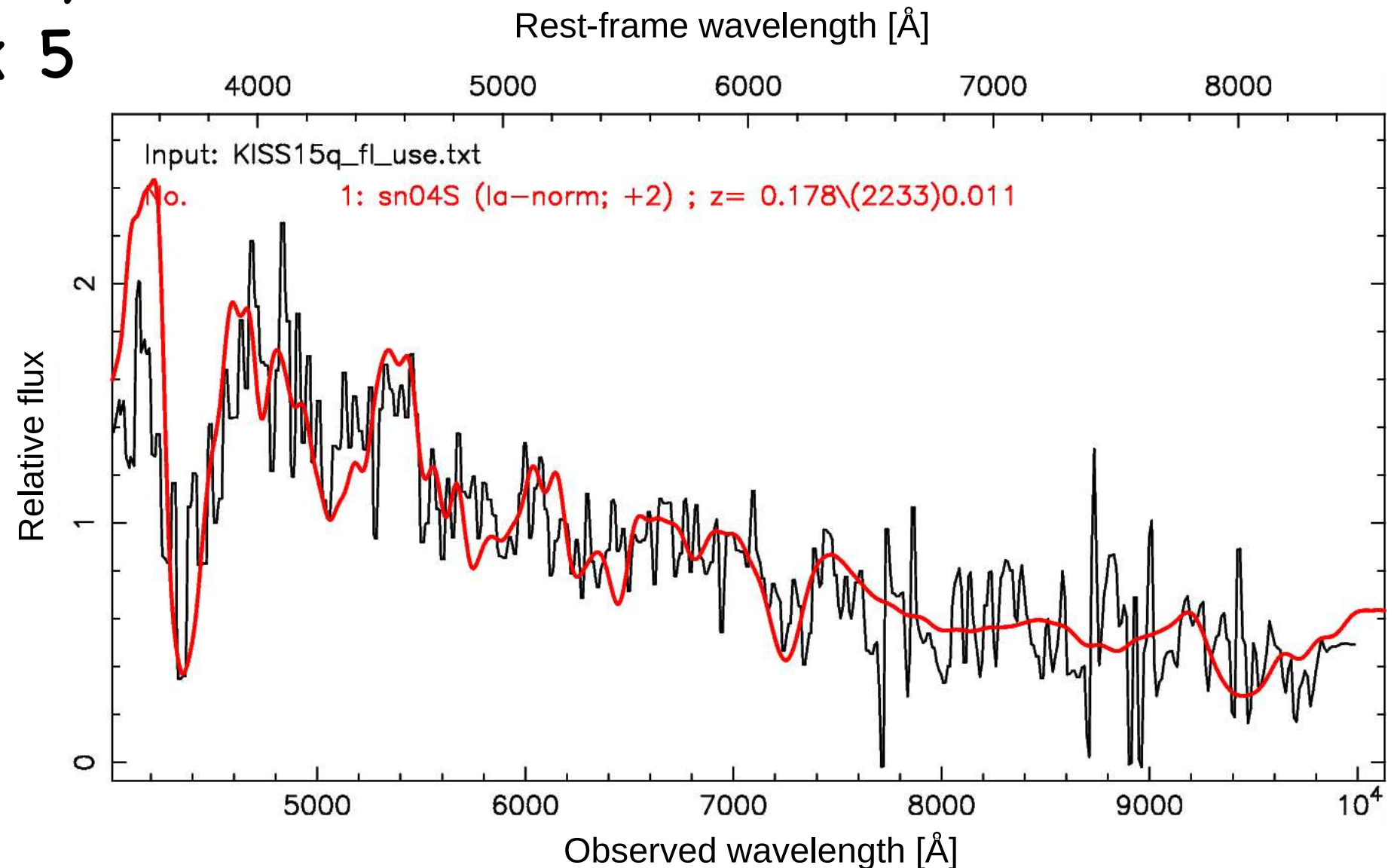
First KISS SN was the brightest.

- May 2012
- $g=16.8$
- SN 2012cm
- identified w/ Kanata/
HOWPol (Itoh+2012)

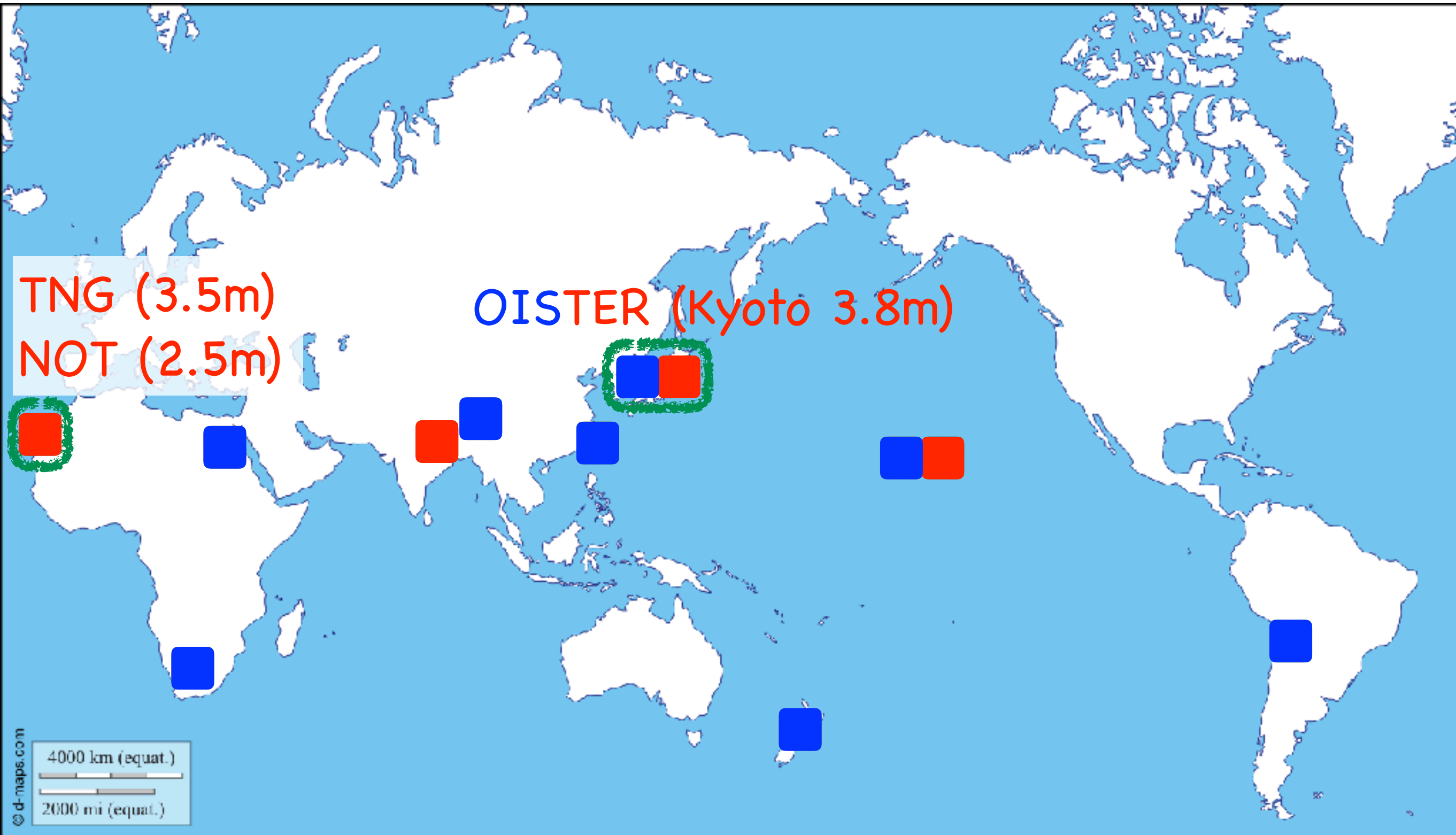


Faintest spec-ID. KISS SN

- May 2015
- $g=20.6$
- SN 2015aa
- identified w/ Nayuta/LISS (TM+2015)
 - 10 minutes x 5

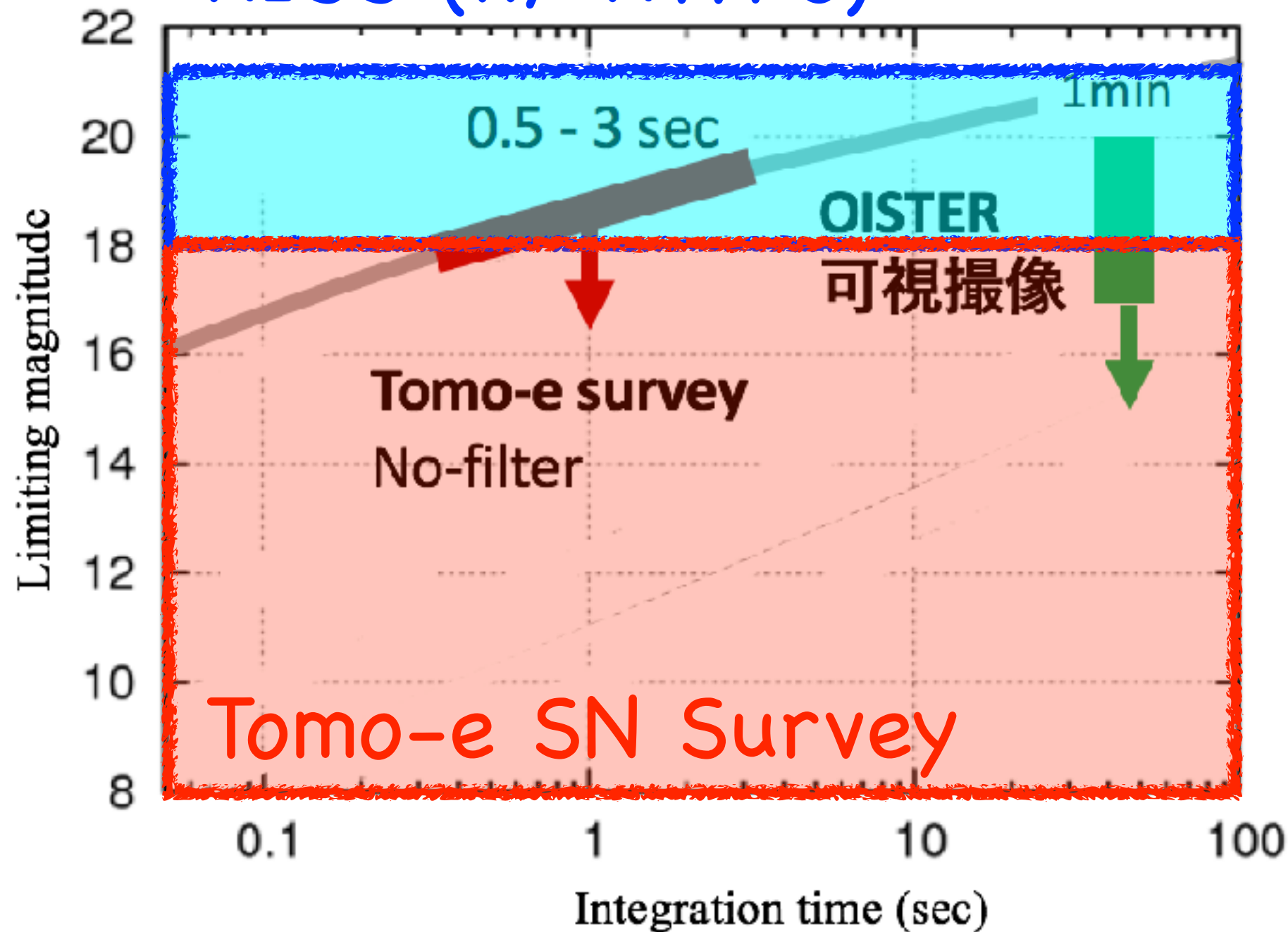


Follow-Up Facilities



imaging spectroscopy

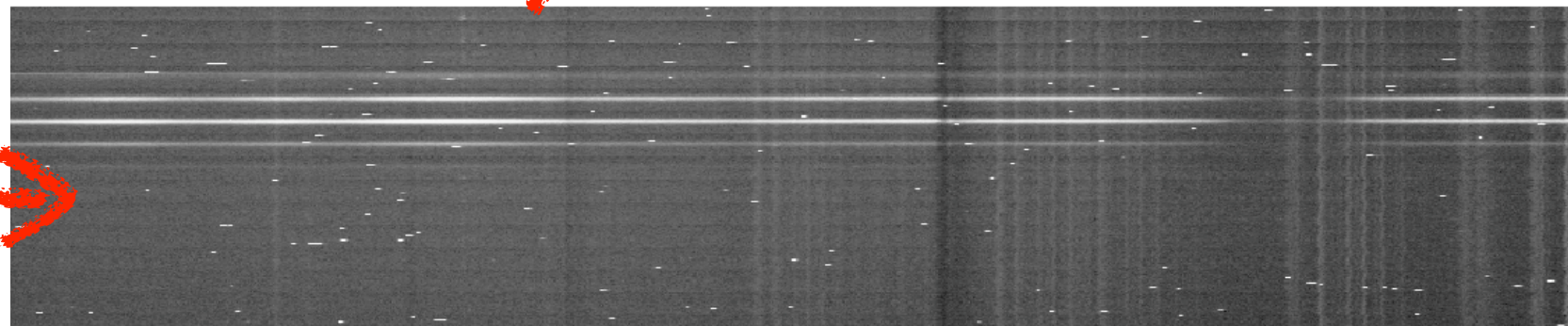
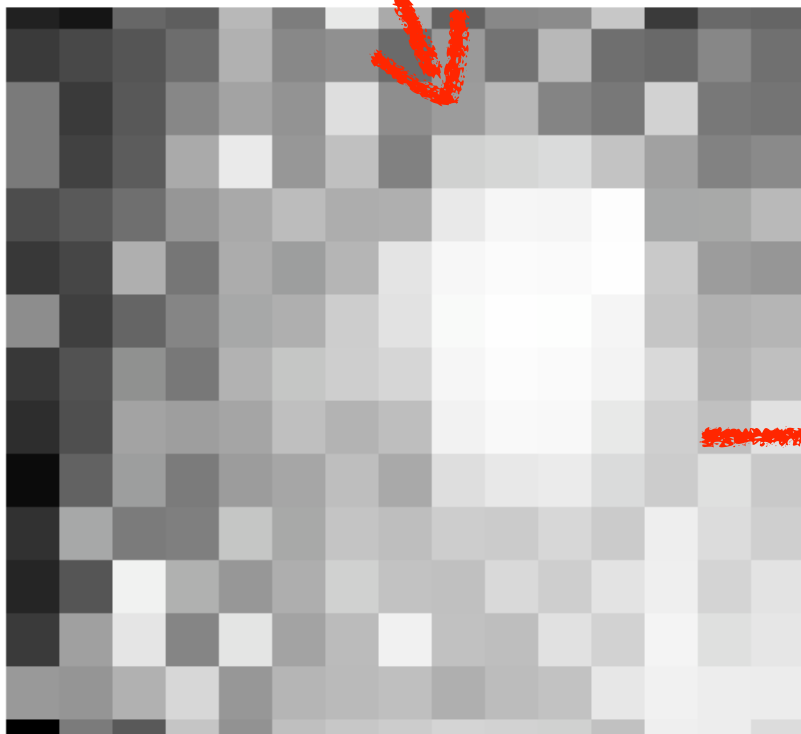
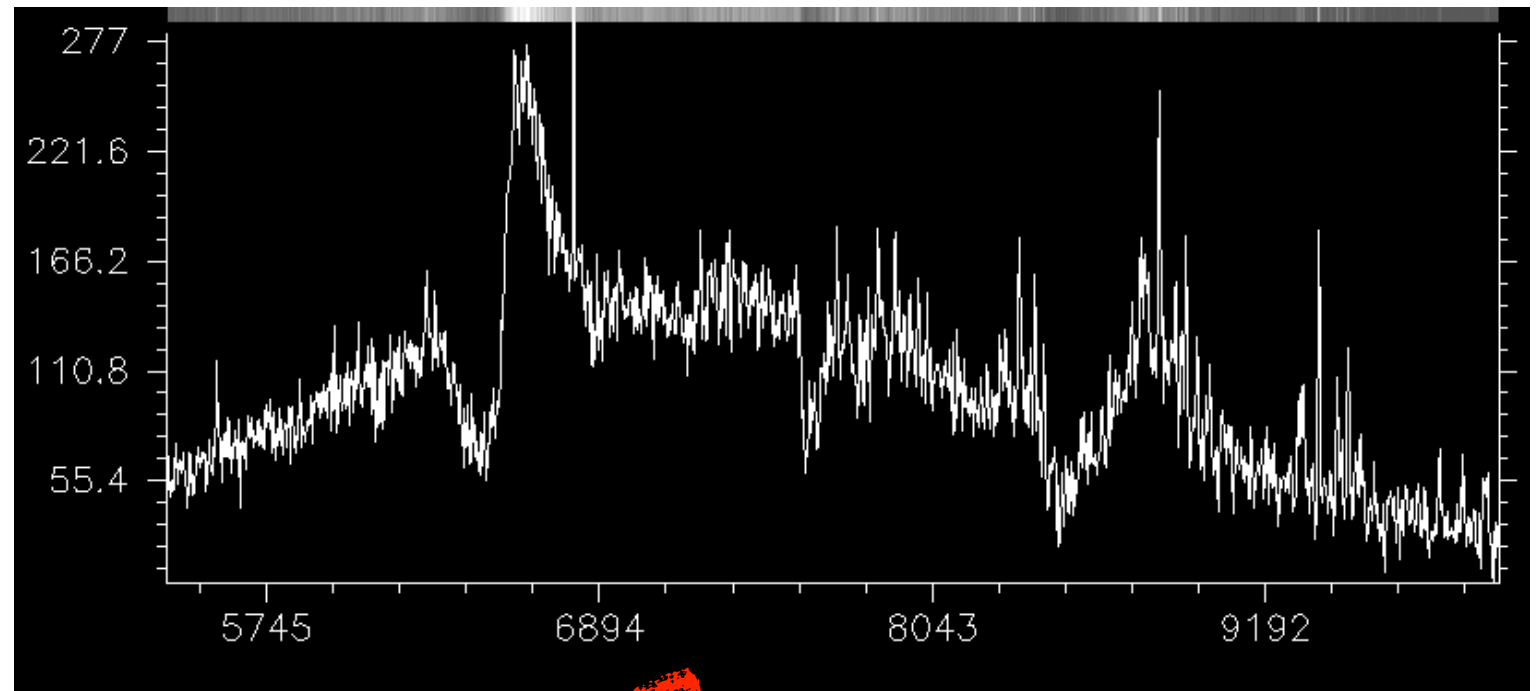
KISS (w/ KWFC)



©Sako

“flash” spectroscopy w/ Kyoto 3.8-m/KOOLS-IFU

- IFU is an ideal instrument for SN quick follow-up
- no accurate slit alignment necessary



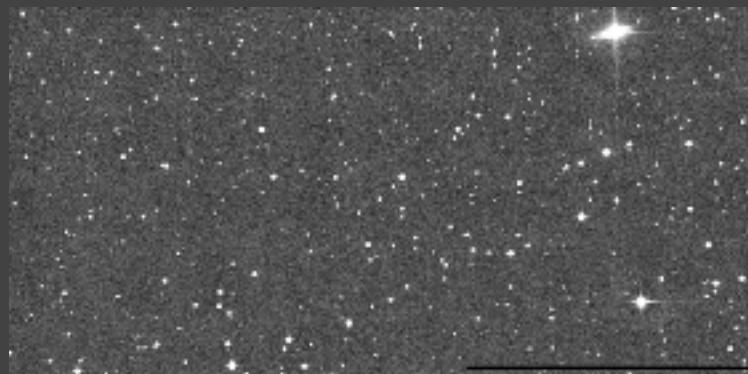
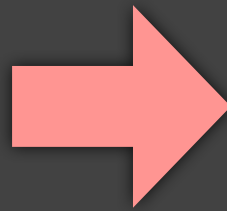
“flash” spectroscopy w/ Kyoto 3.8-m/KOOLS-IFU

- IFU is an ideal instrument for SN quick follow-up
 - no accurate slit alignment necessary
- Tomo-e Gozen SN Survey starts from summer 2018.
 - Kyoto 3.8m tel. operation starts from summer 2018.
- ToO / queue observations
- sensitivity: 19.0 mag (S/N=10)
 - 30-minute exposure, $R \sim 600-800$
- 10-minute exposure is enough for Tomo-e Gozen SNe.
- total observing time (KOOLS-IFU)
 - 1000 SNe x 1 epoch (identification) $\Rightarrow \sim 40$ clear nights
 - + 100 SNe x 10 epochs $\Rightarrow \sim 80$ clear nights

Kiso observatory



KISS pipeline



standard reduction

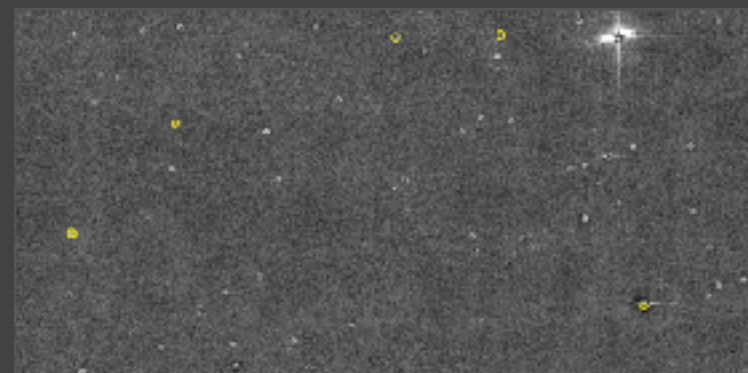


image subtraction

source detection

< 10 min
~ 50GB/day

cut-out images



2017/02/20-22

KISS database

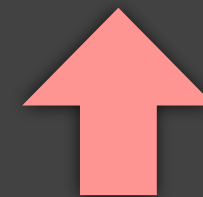


Tokyo

cut-out images



KISS



KISS interface



facebook

Realtime check

Amateur astronomers@anywhere

©Masaomi Tanaka

木曾広視野サーベイと京都3.8m即時分光によるタイムドメイン天文学

Target Handling System (KISS)

developed by M. Tanaka et al.

KISS

KISO Supernova Survey

[MyPage](#) [Candidate](#) [TopPage](#)
Hello morokuma san! (userid = 4)
[LogOut](#)

List of Reduced Data

Selected date
2012-11-18

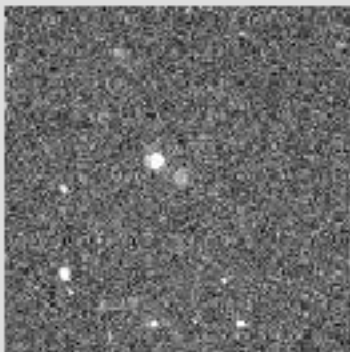
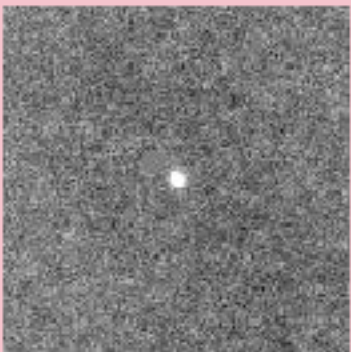
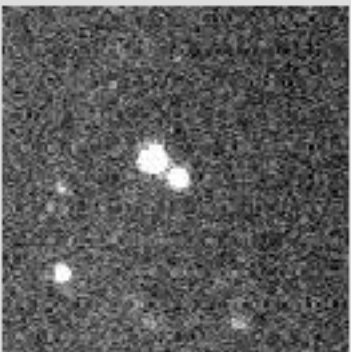
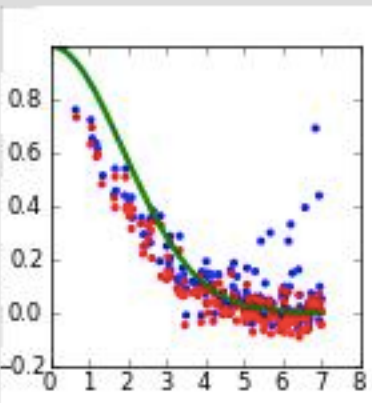
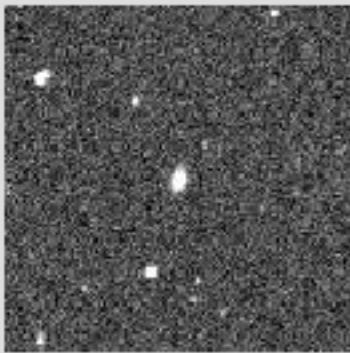
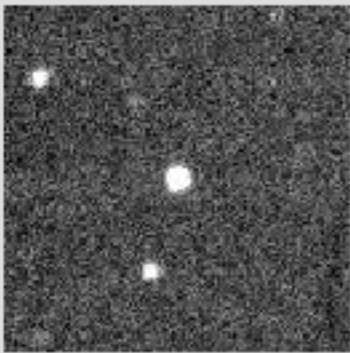
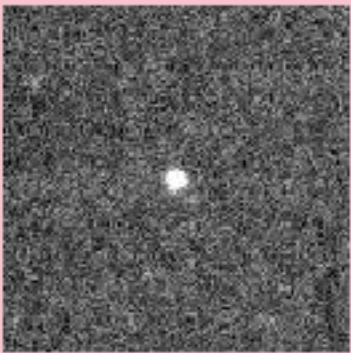
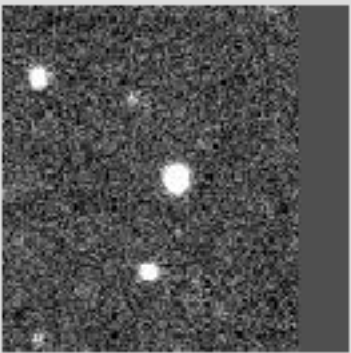
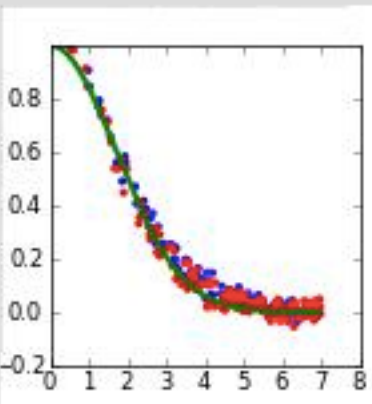
Selected object
%%

Total number selected: 53

No	Request	Date	UT	Object	ExpID	Filter	Limit Mag	Reduced date (newest)
1	submit	2012-11-18	18:29:39	KSFJ0745+2025	0022414	g	17.85	2012-11-19 04:00:02
2	submit	2012-11-18	18:23:06	KSFJ0753+3116	0022413	g	20.19	2012-11-19 03:50:12
3	submit	2012-11-18	18:16:39	KSFJ0800+3604	0022412	g	20.15	2012-11-19 03:42:30
4	submit	2012-11-18	18:10:12	KSFJ0804+4030	0022411	g	0.00	2012-11-19 03:31:51
5	submit	2012-11-18	18:03:54	KSFJ0744+3925	0022410	g	20.69	2012-11-19 03:26:00
6	submit	2012-11-18	17:57:01	KSFJ0948+5300	0022409	g	0.00	2012-11-19 03:17:27
7	submit	2012-11-18	17:50:20	KSFJ0826+2800	0022408	g	0.00	2012-11-19 03:12:05

Target Handling System (KISS)

developed by M. Tanaka et al.

No	Request	FitsID	Reference (2' x 2')	New (2' x 2')	Subtracted (2' x 2')	Previous (2' x 2')	Profile 7pix
1	source ID 669371 submit	2012-11-18 KSFJ0753+3116 0022406_0					
	unbookmark	score 0 1 2					
2	source ID 669258 submit	2012-11-18 KSFJ0804+4030 0022404_0 KISS12r					
	bookmark	score 0 1 2					

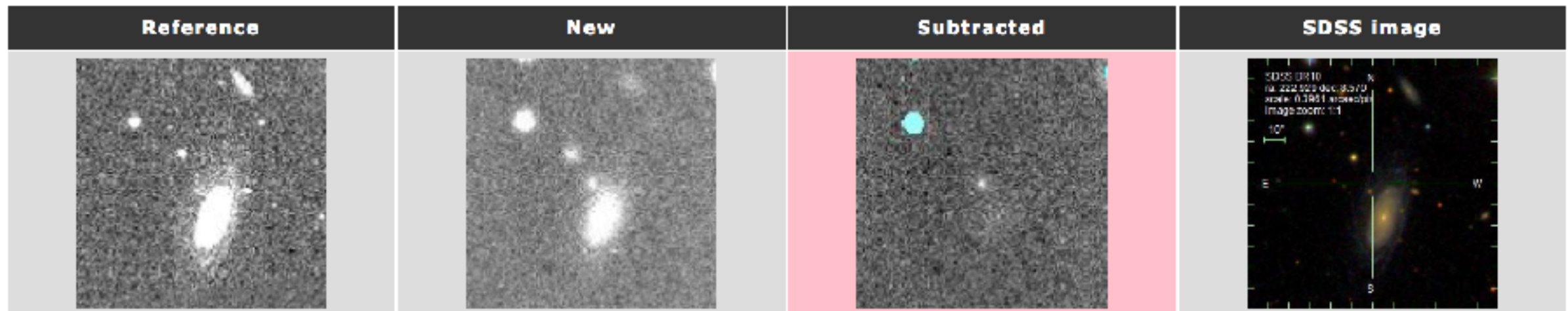
↑
SDSS
KWFC
KWFC

realtime check "by human" = KISS member & amateur astronomers

Target Handling System (KISS)

developed by M. Tanaka et al.

KISS14n



source ID: **1313597**

SDSS

Navigation tool

Explore

NED

near position search (1' radius)

Offset Calculation in altair

```
bash /raid/kiss/pipeline/calcoffset.sh 222.9288689 8.5701321
```

Please Add the SDSS possible Host coordinates in degree. You do not need to remove ',' and just copy RA/Dec Decimal.

Position		Position (decimal degree)		Field
14:51:42.93	+08:34:12.5	222.9288689	8.5701321	KSFJ1451+0945

Discovery date	Discovery magnitude (prelim)	Limiting magnitude	Filter
2014-03-31.68	13.1475	19.77	g

Redshift	Type	Alias
0.06	Type Ia	SN2014an

Target Handling System (KISS)

developed by M. Tanaka et al.

Original source page (admin)

[submit](#)

For admin

Please upload fits file with this command at Altair (if you have not done yet)

```
scp /raid/kiss/subtracted/KSFJ1451+0945/20140331/0073501/cr_1.fits kiss:~/www/fits/0073501_cr_1.fits
```

Update (admin)

Redshift	Type	Alias
0.06	Type Ia	SN2014an

Coordinator:

Last non-detection:

Link:

Request:

Disc. note:

Urgent? (2=red, 1=blue, 0=no, -1=hide from the list)

[Update](#)

Image history

```
/home/kwfc/kiss_history/kiss_history.py KSFJ1451+0945 14:51:42.93 +08:34:12.5 20140231 20140331
./tmp/KSFJ1451+0945_145142.93_+083412.5_20130101_20140331.gif
./tmp/KSFJ1451+0945_145142.93_+083412.5_20140231_20140331.gif
./tmp/KSFJ1451+0945_145142.93_+083412.5_20140231_20140401.gif
```

Light curve (admin)

```
/home/kwfc/kiss_lightcurve/light_curve.py KSFJ1451+0945 14:51:42.93 +08:34:12.5 20140231 20140331
./lightcurve/14:51:42.93+08:34:12.5.png
```

Target Handling System (Subaru/HSC)

developed by M. Tanaka et al.

HSC transient server

List

Object

Account

Logout

Transient ID: 23368 Variable_id: 758213
Number of detections: 8 (NY's selection, paramcand)

Reference

2017-01-21

Difference

HSC-Z

Tags

Click a tag for removal

rising_2017-01-30_HSC-I2

rapidAny_2017-01-25

rising_2017-01-30_HSC-Z

SN

rapidAny_2017-02-01

rapidAny_2016-12-26

hostless

moriya

rising_2017-02-02_H

tominaga(2017-02-13)

tominaga(2017-02-13)

tominaga(2017-02-13)

suzuki(2017-tominaga(2017-02-13)
01-24)

tominaga(2017-02-13)

suzuki(2017- moriya(2017-tominaga(2017-02-13)
01-24) 02-06)

Ra, Dec (Decimal)	Ra, Dec	tract	patch	x,y

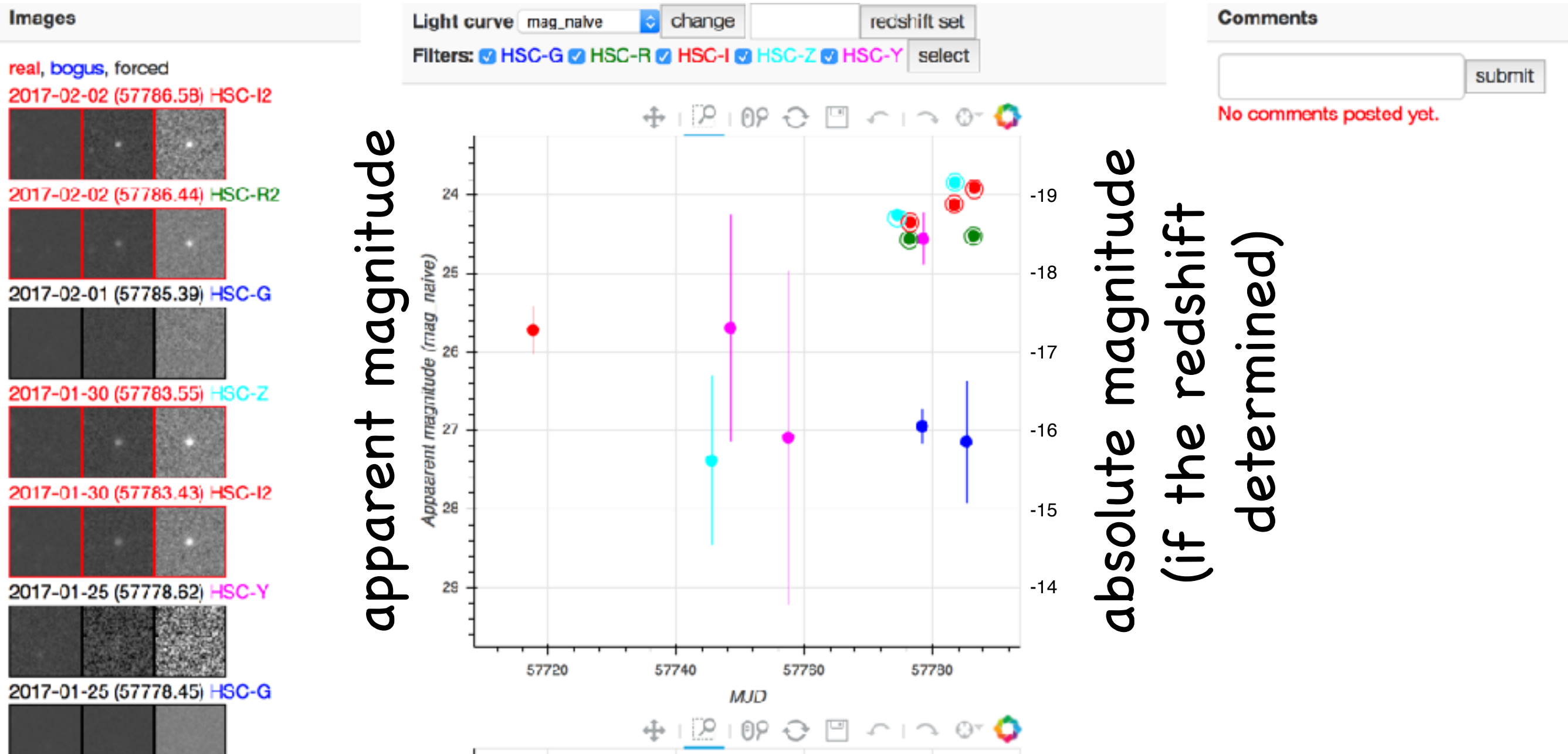
Host Ra, Dec (Decimal)	Extend	Spec-z	Type_COSMOS	Distance	Photo-z	Cosmos id	Host id

Image links	hscMap	SDSS	Finding Chart
fits files	9813 0.5	9813 1.5	9813 2.5
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Hyper Suprime-Cam (on 8.2m Subaru telescope)
Transient Survey for COSMOS field (2016/11-2017/4)

Target Handling System (Subaru/HSC)

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Hyper Suprime-Cam (on 8.2m Subaru telescope)
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Target Handling System (Tomo-e SN)

HSC transient serverListObjectAccountLogout

18mrq

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2017-01-21

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HSC-Z

Tags Click a tag for removal

rising_2017-01-30_HSC-I2

rapidAny_2017-01-25

rising_2017-01-30_HSC-Z

SN

rapidAny_2017-02-01

rapidAny_2016-12-26

hostless

moriya

rising_2017-02-02_H

tominaga(2017-02-13)

tominaga(2017-02-13)

tominaga(2017-02-13)

suzuki(2017-tominaga(2017-02-13)
01-24)

tominaga(2017-02-13)

suzuki(2017- moriya(2017-tominaga(2017-02-13)
01-24) 02-06)

Ra, Dec (Decimal)	Ra, Dec	tract	patch	x,y

Host Ra, Dec (Decimal)	Extend	Spec-z	Type_COSMOS	Distance	Photo-z	Cosmos id	Host id

Image links	hscMap	SDSS	Finding Chart
fits files	9813 0,5	9813 1,5	9813 2,5
-----	-----	-----	-----

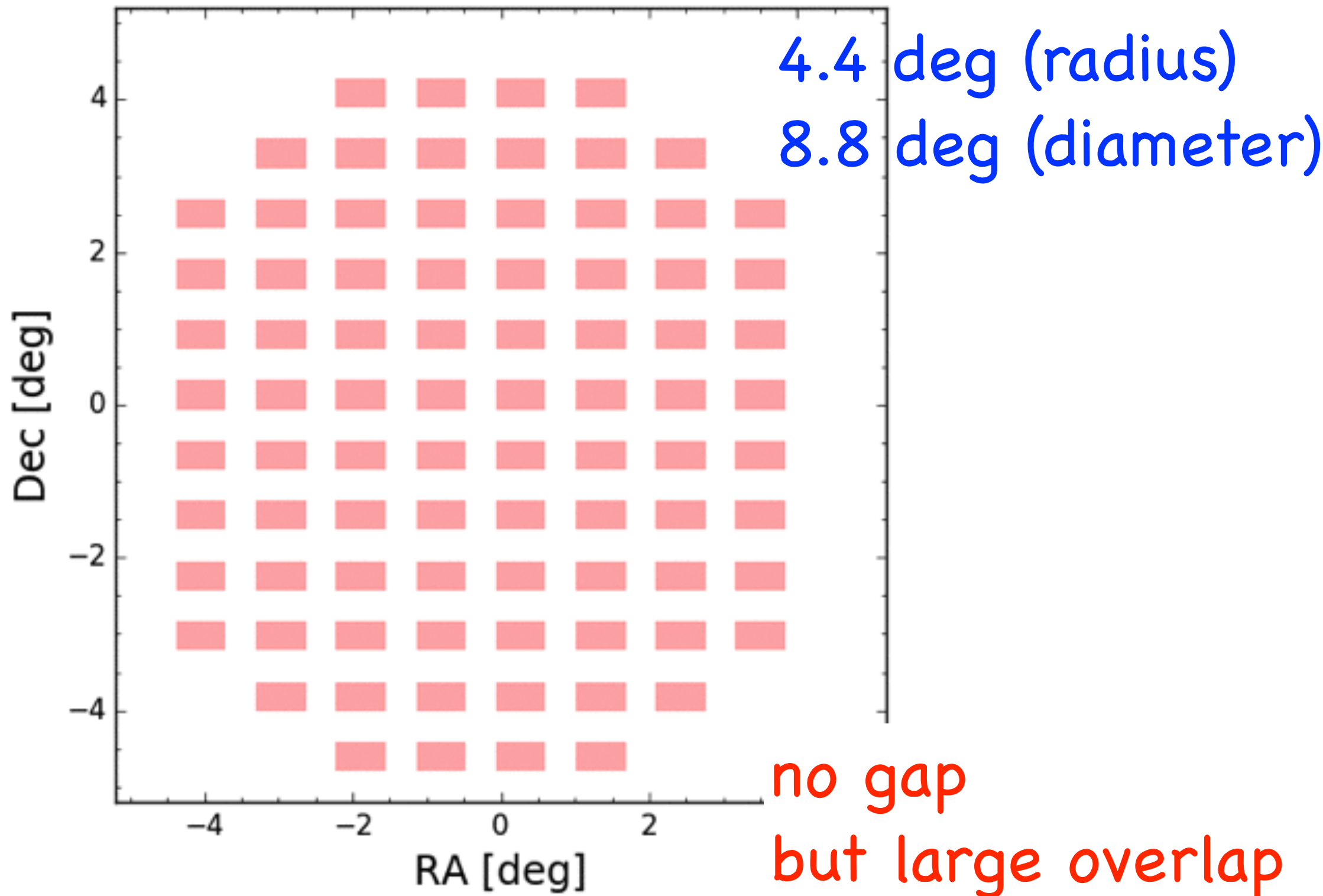
“no-human” alerts for bright candidates

Supernova Survey Plan w/ Tomo-e Gozen

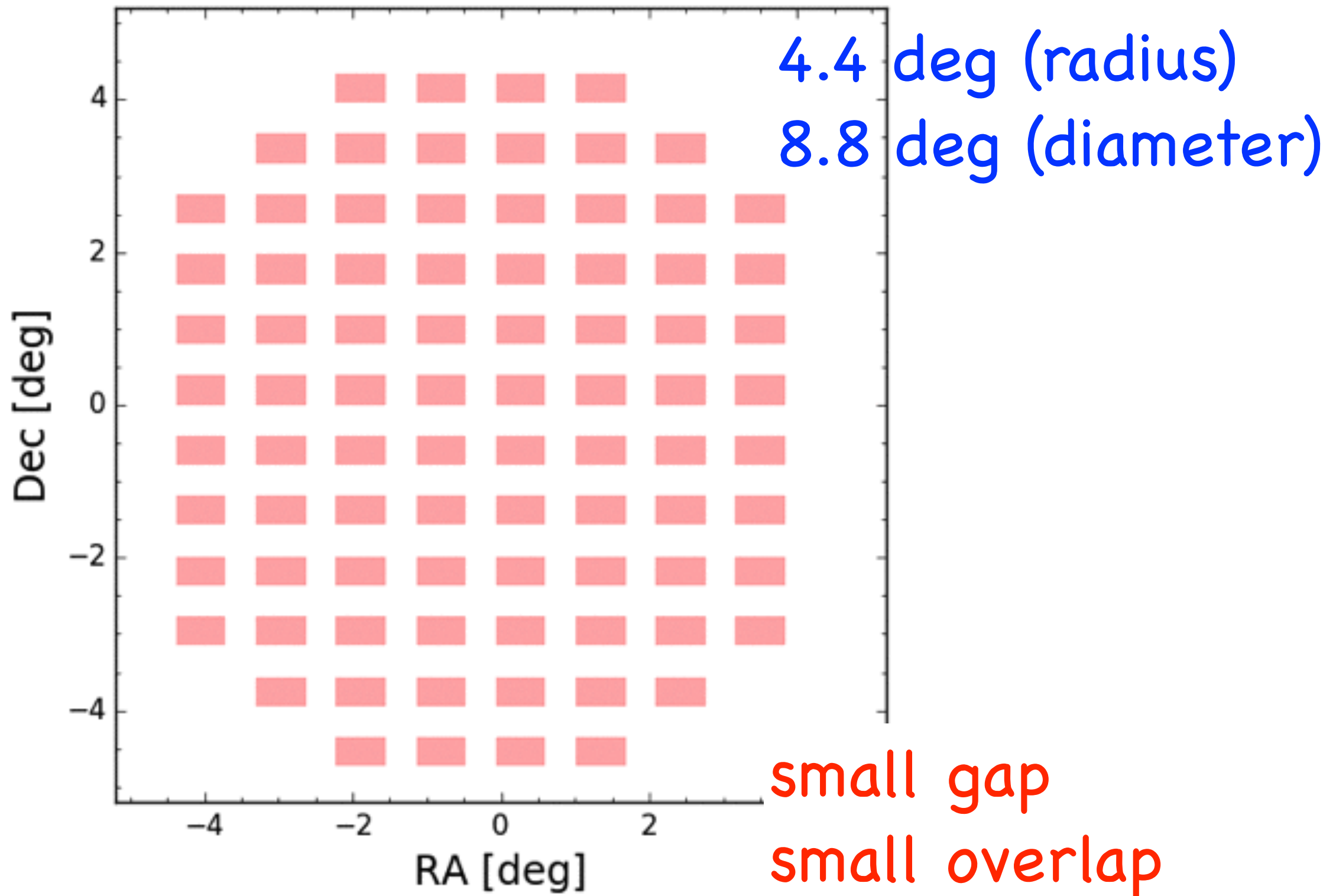
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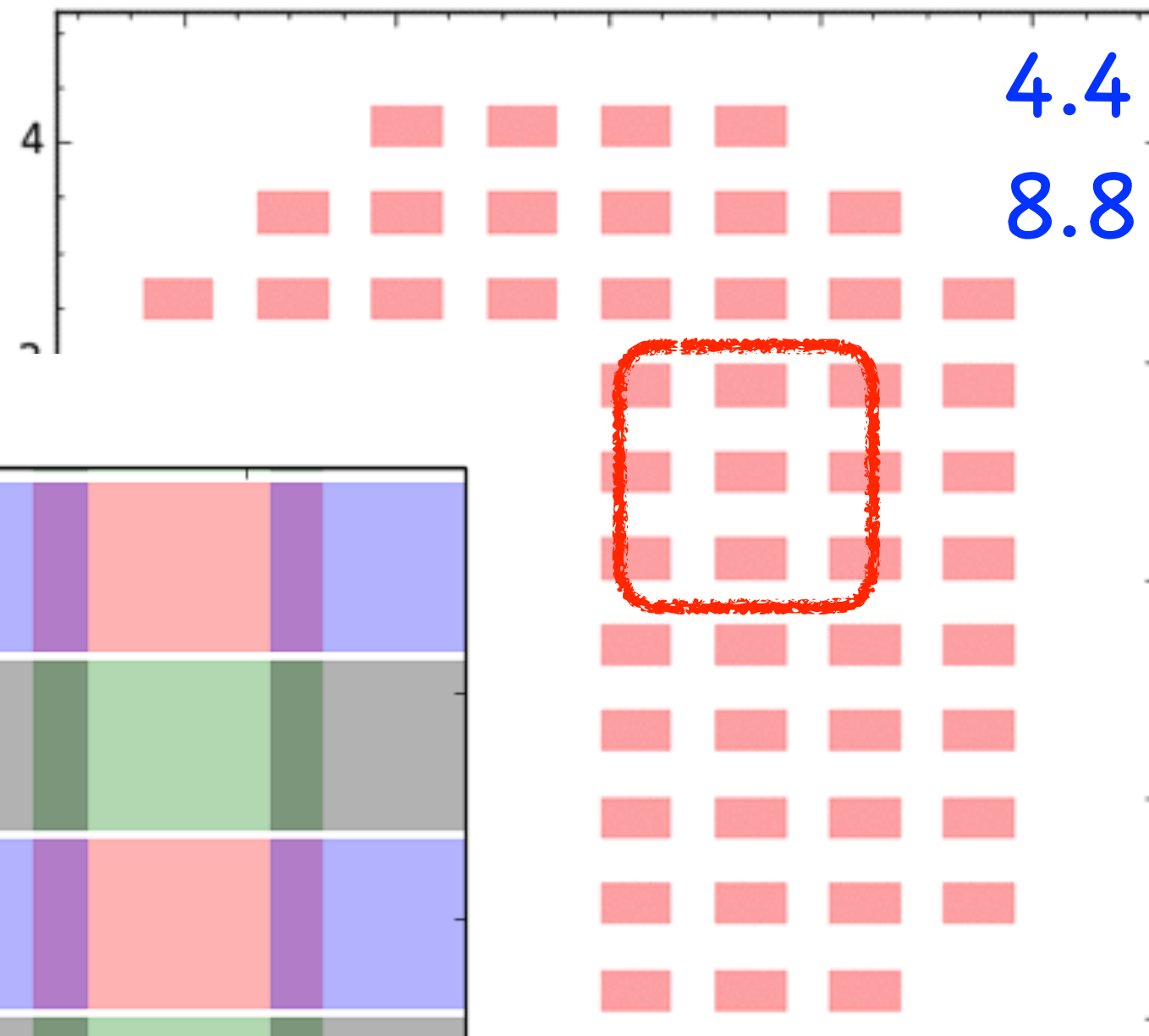
2x3 dithering



2x2 dithering

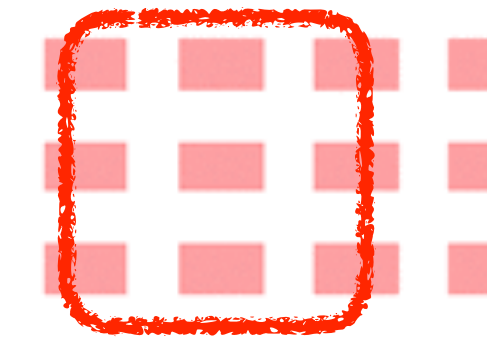
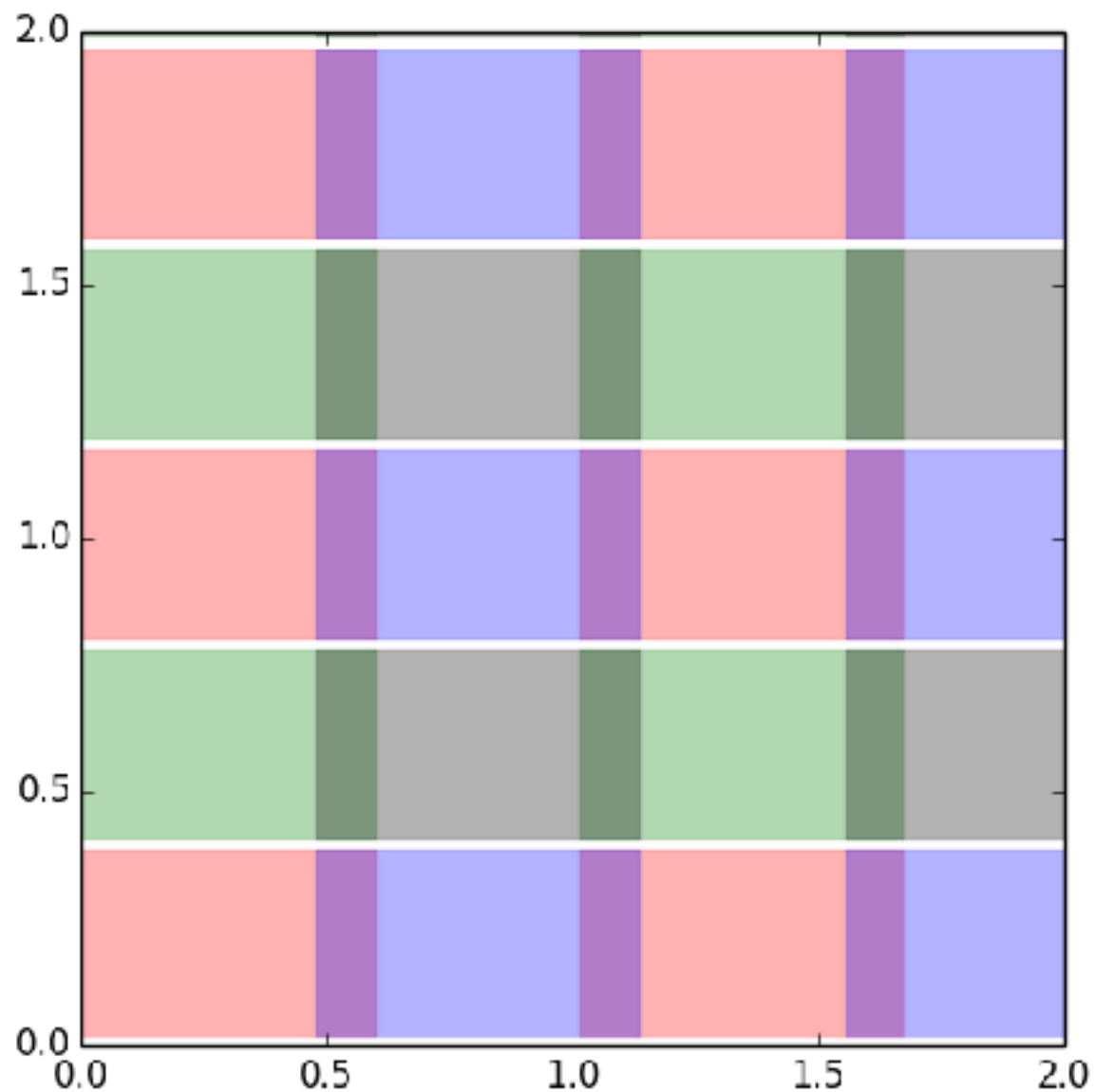


2x2 dithering



4.4 deg (radius)

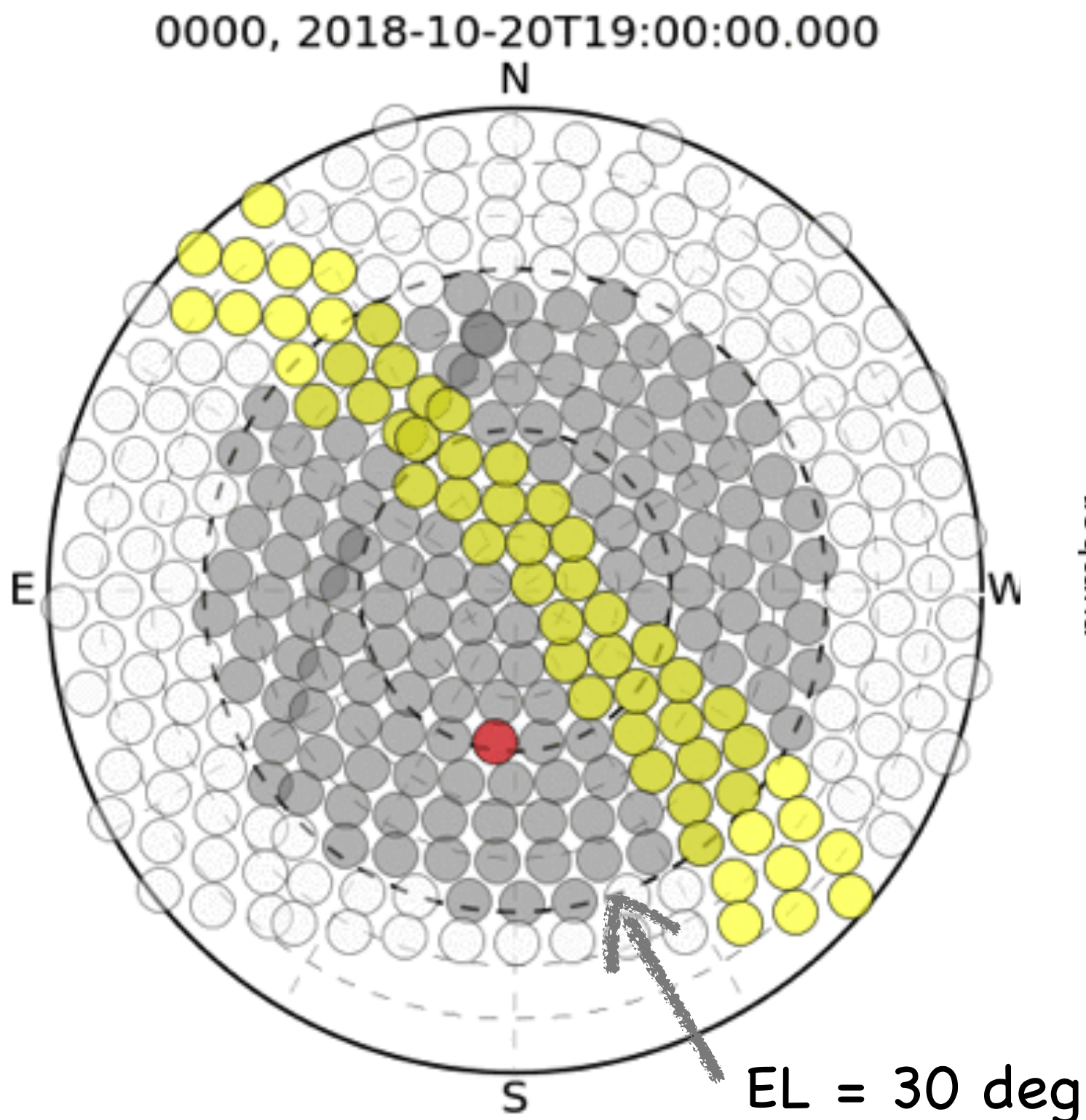
8.8 deg (diameter)



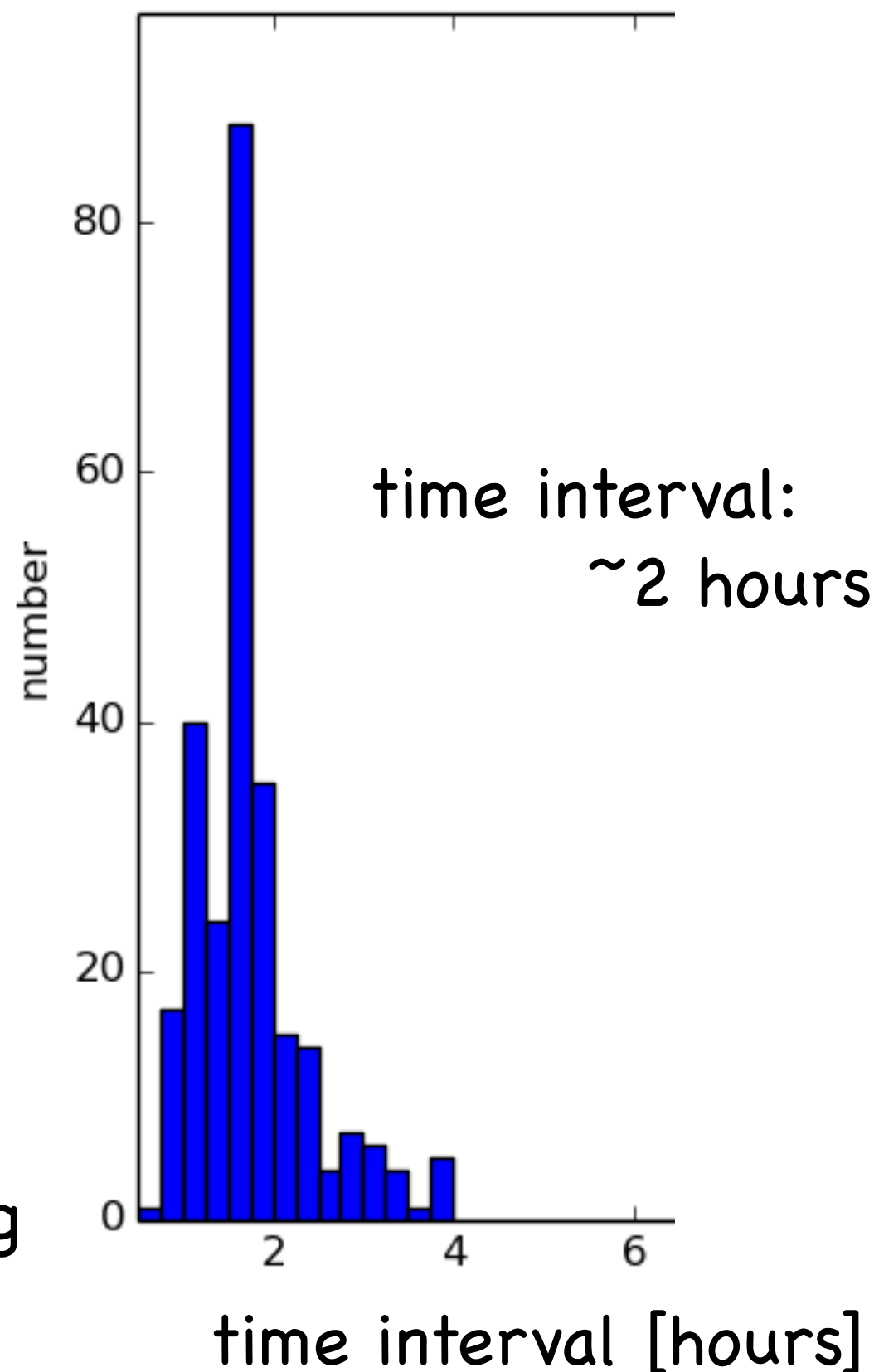
[deg]

small gap
small overlap

Survey Simulation (ongoing...)



Galactic Plane ($< \pm 10$ deg)



Tomo-e Gozen = All-Sky Monitoring Survey

- Supernovae (Maeda, Suzuki, Yamanaka, Nagao, **Jiang**): **KISS, SKYS**
- GRBs, high energy phenomena (Ioka, **Serino**, Yatsu, **Y.Tanaka**):
MAXI, IceCube follow-up
- radio transients (Niino)
- stars (Notsu, Niinuma, Ichiki, Nogami, Imada, **Maehara**): **KISOGP, M31 monitoring**
- search for gravitational wave sources (Tagoshi, **M.Tanaka**): **J-GEM**
- quasar / nearby AGN monitoring (Iwamuro, **Horiuchi**): **accretion miniBAL/NAL monitoring, accretion disk (Kokubo+), low-mass BHs (Taniguchi+)**
- Solar System / Near-Earth (**Ishiguro**, Abe, Yanagisawa, Okumura)
- stacking all data (> 1 hr): stellar population in galaxy outskirts
- synergy with other surveys? (Itoh, Kawabata)

Summary: Tomo-e Gozen SN Survey

10,000 deg² - 2 hr cadence - 18 mag depth

10,000 deg² - 1 day cadence - 19 mag depth

- no filter: effectively g+r bands
- 3 sec exposure: ~18 mag, ~60 deg²
- 2-hour cadence
- survey area (per 2 hours): ~10,000 deg² (EL>30 deg)
- 3-5 times visits per night (~19 mag for daily)
- search for supernova shock breakouts
 - more SN-related science
 - many other sciences cases
- Systematic quick follow-up spectroscopy is critical.
 - Kyoto 3.8-m/KOOLS-IFU is the best (40 nights/yr?).
 - collaborative follow-up obs w/ other facilities
 - Late-phase obs. w/ larger telescopes (Subaru, TAO, ...)
- Join us & Let's discuss in more detail.