

# **Tomo-e Gozen Transient Survey**

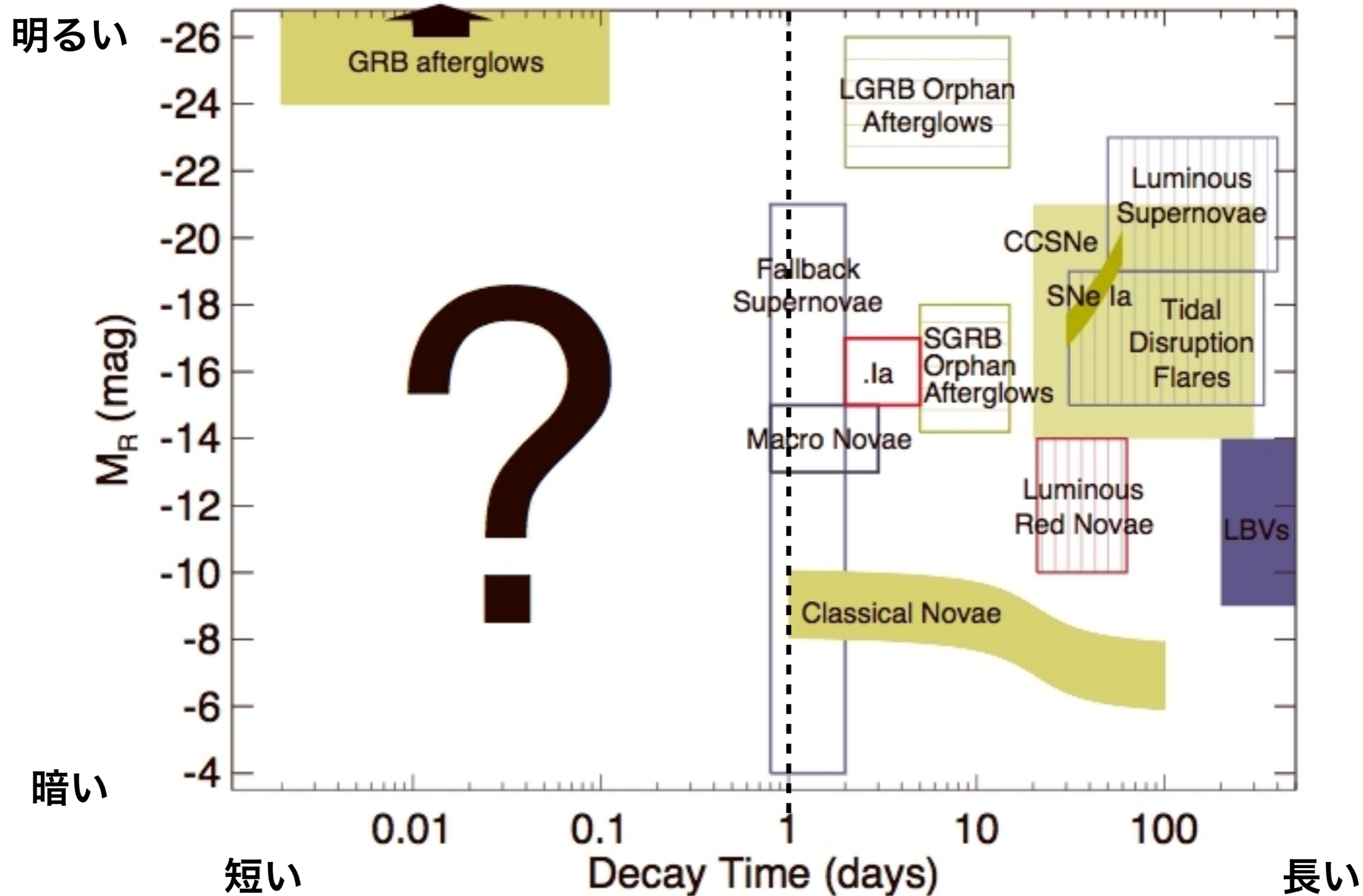
**Masaomi Tanaka (Tohoku U.)**

**on behalf of Tomo-e Gozen Transient Survey Team**

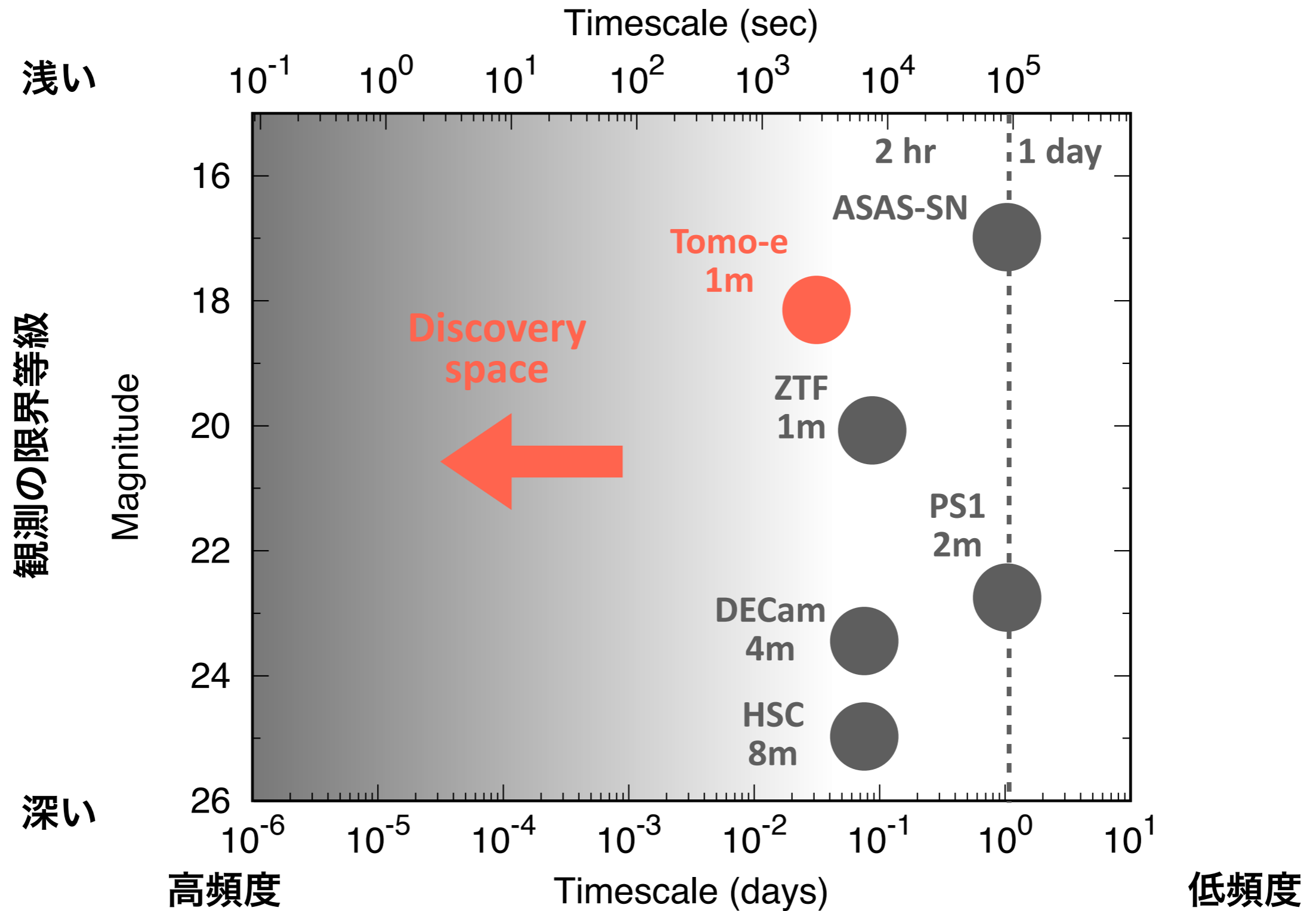
# Tomo-e Gozen Transient Survey

- **Motivation and survey design**
- System, data products, and recent updates
- Wish list

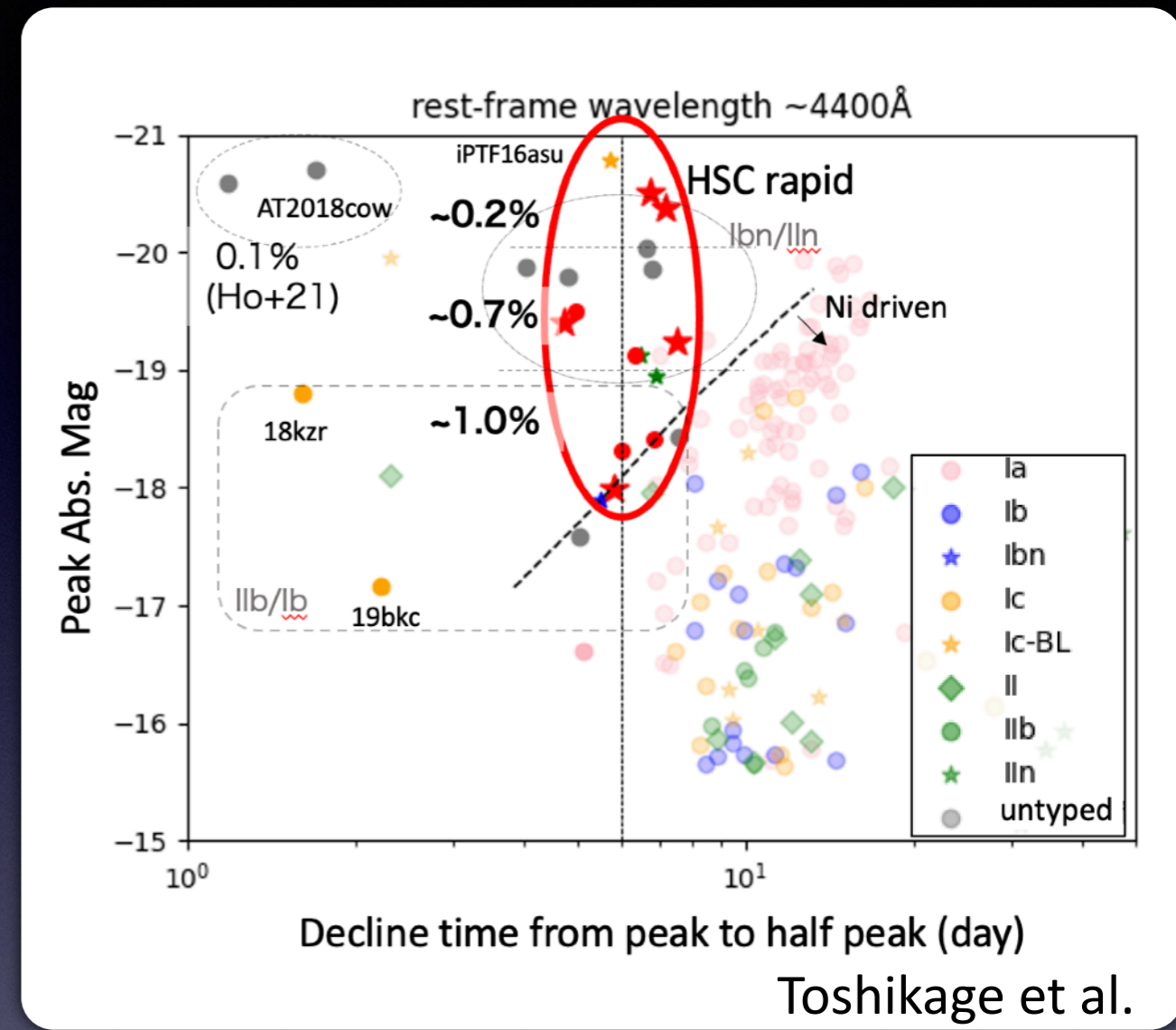
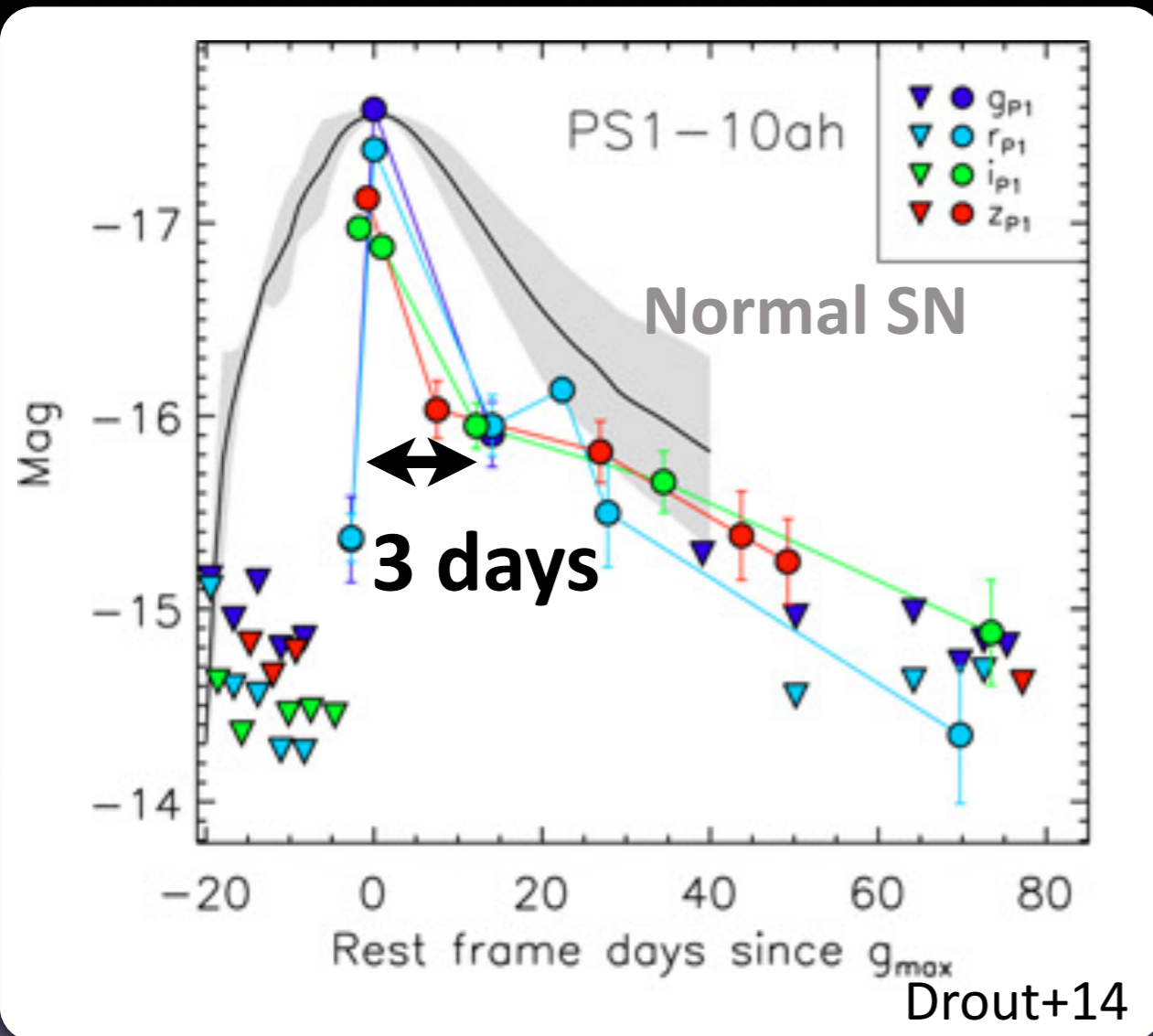
# Frontier of transient sky



# Transient survey



# Discovery of rapid transients



By Seiji Toshikage

Compared with normal supernovae:

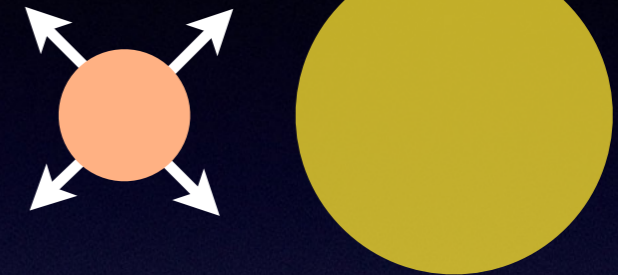
- Similar or higher luminosity (w/ large diversity)
- Shorter time scale (= small mass involved)
- $\sim <$  a few % event rate

# New probes for stellar evolution, compact object formation, and high-energy phenomena

## ● Ultra-stripped envelope supernova?

- $M_{ej} \sim 0.1 M_{\text{sun}}$  by binary interaction (e.g., Tauris+13, Moriya+17) ?

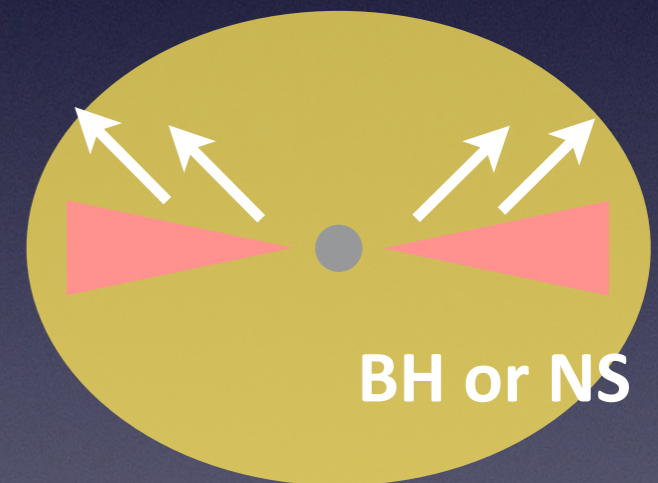
$M_{ej} \sim 0.1 M_{\text{sun}}$



## ● Interaction with circumstellar material?

- Objects with emission line spectra (e.g., Rest+18, Ho+22, Maeda & Moriya 22)

$M_{ej} \sim 0.01 M_{\text{sun}}$



## ● Black hole-forming supernova?

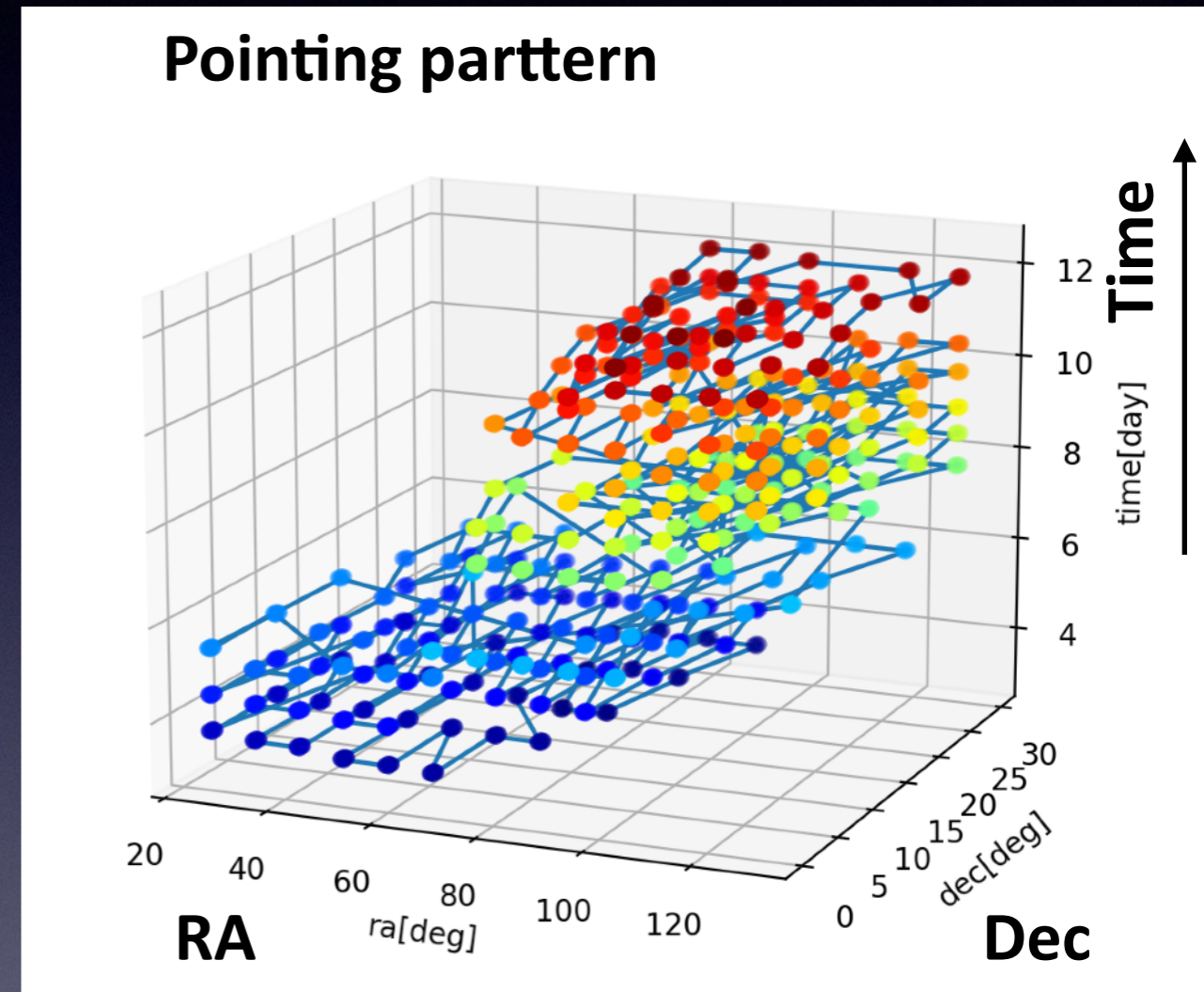
- Accretion-powered transients? (e.g., Dexter & Kasen 13, Kashiyama+15)

Distant objects: difficult to perform spectroscopy

=> **Need to discover nearby (bright) objects for spectroscopy**

# Tomo-e Gozen Transient Survey (2019/4-)

- All sky survey (~12,000 deg<sup>2</sup>)
  - 0.5 sec x 18 = 9 sec exposure
- High cadence (~3,000 deg<sup>2</sup>)
  - 0.5 sec x 12 = 6 sec exposure  
=> ~18 mag (5 sigma)
  - ~0.5-1 hour cadence
  - ~ a few rapid transients / 0.5 yr  
( < 200 Mpc)



By Kakeru Oshikiri

Fast Optical Transientの探査 => 押切さん (東北大)トーク

# Tomo-e Gozen Transient Survey

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# Data flow

**Overall structure**  
(富永 望さん)

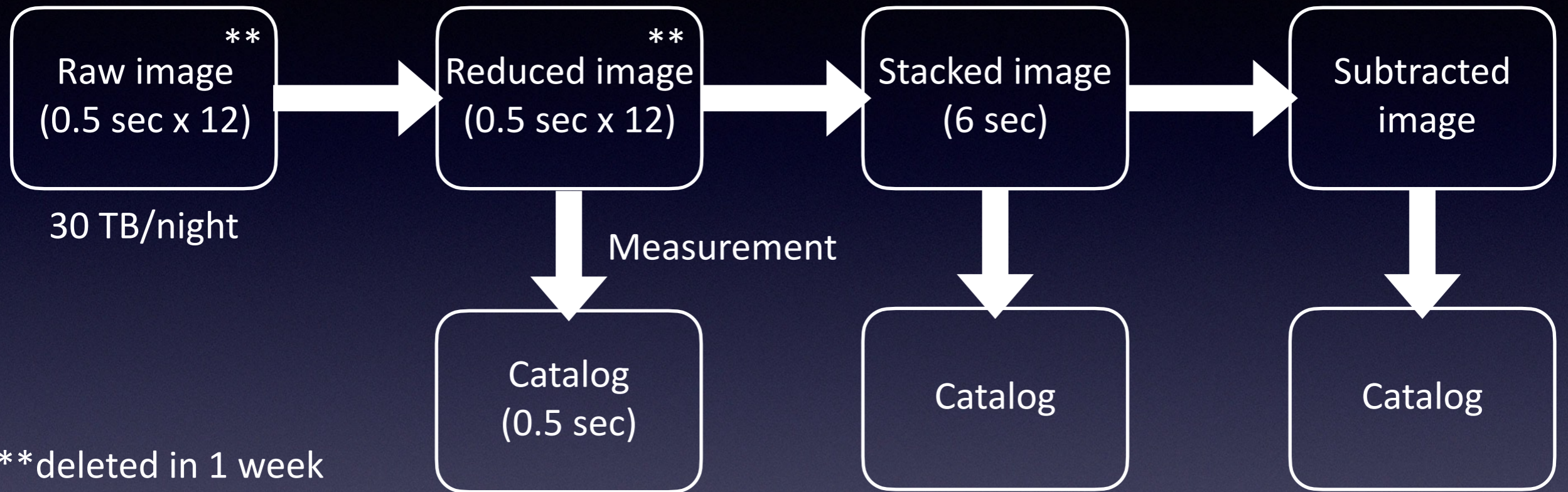
**Measurement**  
(諸隈 智貴さん)

**Reference images**  
(新納 悠さん)

Standard reduction  
(+ astrometry)

Stack

Image subtraction  
(PS1, r-band) => Tomo-e



\*\*deleted in 1 week

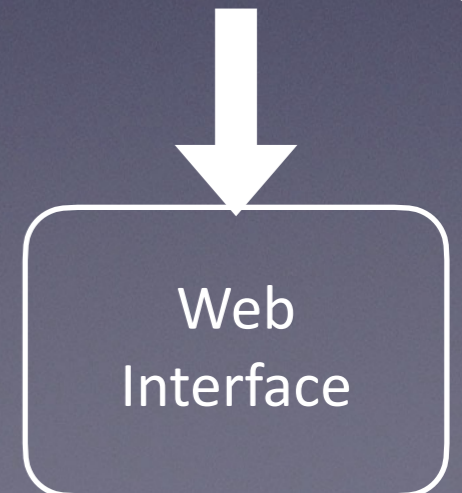
Limiting magnitude

**image subtraction**  
(田中)

**Real-bogus classification**  
(高橋 一郎さん)

**Web interface**  
(瀧田 怜さん)

Real/bogus classification  
Match with internal  
and external catalogs



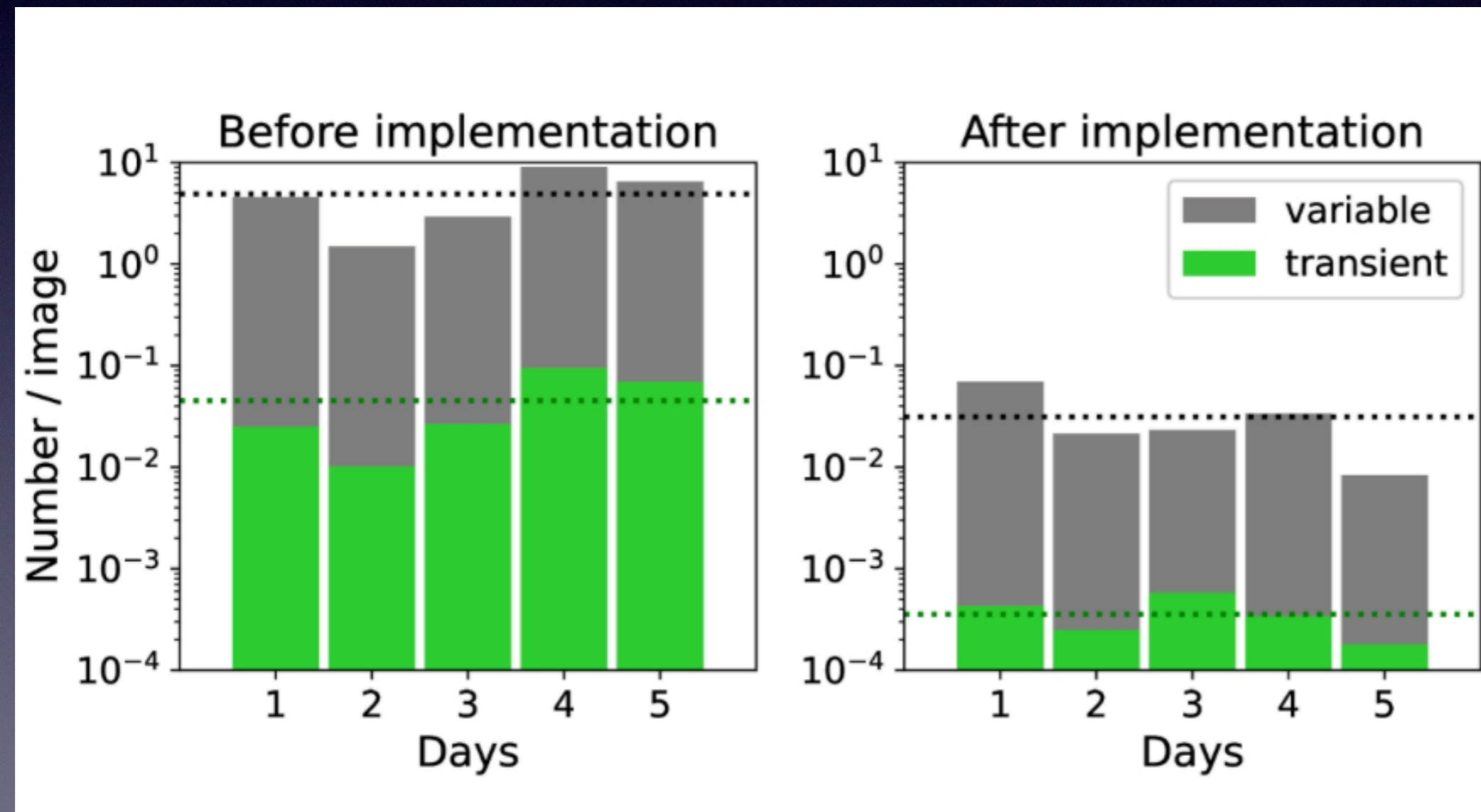
# 突発天体の分類性能が大幅に改善

2022年6月22日

トモエゴゼン突発天体探査のデータから機械学習によって本物の突発天体を分類する高性能な分類器が開発されました。この分類器は自身で学習データに含まれる誤ラベルを検出し、「半教師あり学習」を行います。この新しい分類機によって、実際の観測データに対する分類成績が従来のものに比べて100倍以上向上しました。

– DOI:[10.1093/pasj/psac047](https://doi.org/10.1093/pasj/psac047)

Led by 高橋 一郎さん (東北大)  
Takahashi et al. 2022



# Web interface

Led by 瀧田 怜さん (東京大)

1 2 3 44 Select page:  Jump

<input type="checkbox"/>	transientId	TNS Name	R.A., Dec.	mag	Image			Ref. image		paramcand	mark
	Name	TNS date	project	variableId	ref	new	sub	SDSS DR15	PS1 gri 3-color	cnncand	
	date		event	rawId							
	current tag										
<input type="checkbox"/>	7663084	AT 2021iaw	215.7820207, 50.2220496	19.26						2	<input type="checkbox"/> SN <input type="checkbox"/> AGN <input type="checkbox"/> SN/AGN <input type="checkbox"/> Star <input type="checkbox"/> Unclear <input type="checkbox"/> Bogus <input checked="" type="checkbox"/> Checked
	202105asbsm	2021-04-03 07:52:04	All-Sky Survey	36337384						2	
	2021-05-31	<a href="#">link to TNS</a>	SN	33941178							
<input type="checkbox"/>	7662721	AT 2021njo	241.779068, 47.4434566	18.88						2	<input type="checkbox"/> SN <input type="checkbox"/> AGN <input type="checkbox"/> SN/AGN <input type="checkbox"/> Star <input type="checkbox"/> Unclear <input type="checkbox"/> Bogus <input checked="" type="checkbox"/> Checked
	202105asbff	2021-05-25 07:05:23	All-Sky Survey	75745065						2	
	2021-05-31	<a href="#">link to TNS</a>	SN	33913289							
<input type="checkbox"/>	7662645	AT 2021mvl	248.1849589, 30.0617608	18.45						2	<input type="checkbox"/> SN <input type="checkbox"/> AGN <input type="checkbox"/> SN/AGN <input type="checkbox"/> Star <input type="checkbox"/> Unclear <input type="checkbox"/> Bogus <input checked="" type="checkbox"/> Checked
	202105asbch	2021-05-18 07:17:37	All-Sky Survey	75743697						2	
	2021-05-31	<a href="#">link to TNS</a>	SN	33914303							
<input type="checkbox"/>	7662573	SN 2021mfn	232.4819291, 8.5351936	20.21						5	<input type="checkbox"/> SN <input type="checkbox"/> AGN <input type="checkbox"/> SN/AGN <input type="checkbox"/> Star <input type="checkbox"/> Unclear <input type="checkbox"/> Bogus <input checked="" type="checkbox"/> Checked
	202105asazz	2021-05-13 11:45:36	All-Sky Survey	75747171						5	
	2021-05-31	<a href="#">link to TNS</a>	SN	33921351							
<input type="checkbox"/>	7662405	AT 2018ddw	324.6104024, 28.7729514	18.51						4	<input type="checkbox"/> SN <input type="checkbox"/> AGN <input type="checkbox"/> SN/AGN <input type="checkbox"/> Star <input type="checkbox"/> Unclear <input type="checkbox"/> Bogus <input checked="" type="checkbox"/> Checked
	202105asavh	2018-07-04 08:35:31	All-Sky Survey	75585595						4	
	2021-05-31	<a href="#">link to TNS</a>	SN	33910368							
<input type="checkbox"/>	7663130	AT 2021mnd	185.4441071, 41.7395844	16.50						2	<input type="checkbox"/> SN <input type="checkbox"/> AGN <input type="checkbox"/> SN/AGN <input type="checkbox"/> Star <input type="checkbox"/> Unclear <input type="checkbox"/> Bogus <input checked="" type="checkbox"/> Checked
	202105asbug	2021-05-16 08:03:50	All-Sky Survey	75750725						2	
	2021-05-30	<a href="#">link to TNS</a>	SN	33971784							

# Forced photometry for objects in Transient Name Server

Led by 富永 望さん

Discovery by other surveys  
(ZTF, ATLAS, ...)  
=> Transient Name Server

重力崩壊型超新星

=> 村井さん(東北大)トーク

Ia型超新星

=> 越さん(東京大)

**202011aajep**  
Transient ID: 4366186, Variable ID: 42221605

**Number of detections**  
paramcand: 51, cncand: 51  
psStar: 0  
TNS: [2020aagy](#)

**Current Tag**  
No tags were assigned.  
Insert/Update tag  
To remove classification or keywords, select the same value.  
Classification:    
Keywords:

**Object Info**  
R.A., Dec. [deg] = 14.2895197, 54.7474125  
[hms] = 00:57:09.48, +54:44:50.69  
detId = 416  
[stacked fits](#) (internal network only)  
[subtracted image](#)

**Other Archives**  
[SDSS](#)  
[PS1](#)  
[TNS](#)

**Tomo-e Images**

Date (mjd)	rawId	limmag
2021-01-15 (mjd: 59229.4021)	25286021 (single)	18.14 +- 0.08 (limmag: 19.16)
2021-01-15 (mjd: 59229.4014)	25286155 (single)	18.64 +- 0.11 (limmag: 19.37)
2021-01-15 (mjd: 59229.4010)	25287045 (single)	18.21 +- 0.08 (limmag: 19.25)
2021-01-15 (mjd: 59229.4003)	25287207 (single)	18.07 +- 0.06 (limmag: 19.40)
2020-12-10 (mjd: 59193.4337)	23675748 (single)	17.73 +- 0.06 (limmag: 19.00)
2020-12-10 (mjd: 59193.4329)		


**Light Curve**  
Set redshift:    
Apparent magnitude vs. mjd plot showing data points and error bars.

**Finding Chart**

# Automatic alert

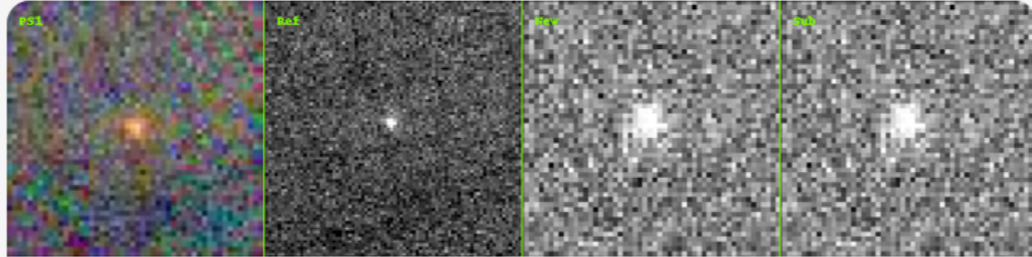
Led by 富永望さん

## Tomo-e Slack

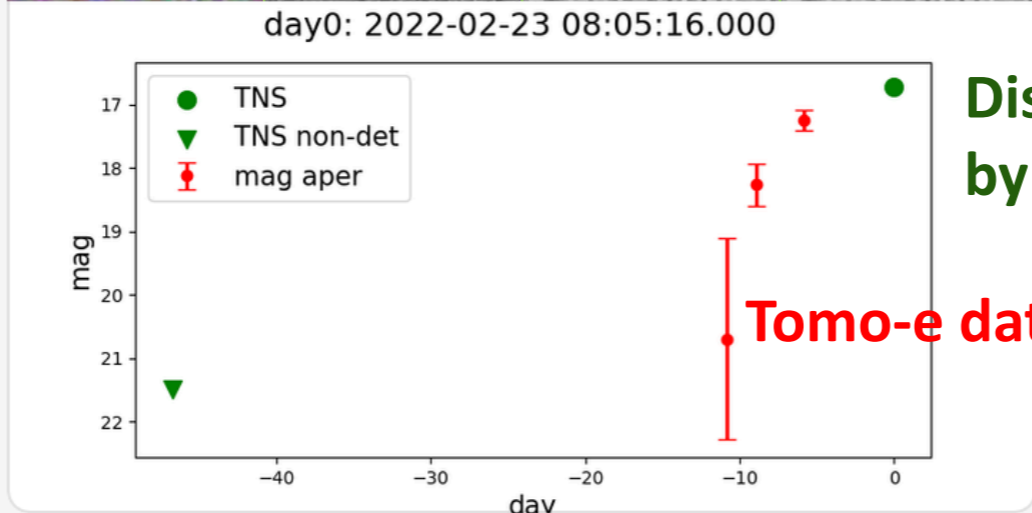
 **SN bot** アプリ 18:34 2月26日 (土) ▾

Positive before TNS discDate

TNS name: AT 2022ddv  
TNS URL: <https://www.wis-tns.org/object/2022ddv>  
TNS DateTime: 2022-02-23 08:05:16  
TNS Mag: 16.71  
Tomo-e URL: <https://tomoe.mtk.ioa.s.u-tokyo.ac.jp/tomoesn/objectTNS.php?tns=2022ddv>  
Num. positive (>5sigma between -30.0-10.0days): 1  
MAG (at max S/N): 17.25 (6.22) (-5.85days)  
coord: (55.93825, 32.06625) (03h43m45.18s +32d03m58.5s)  
New transient: AT 2022ddv ▾



day0: 2022-02-23 08:05:16.000

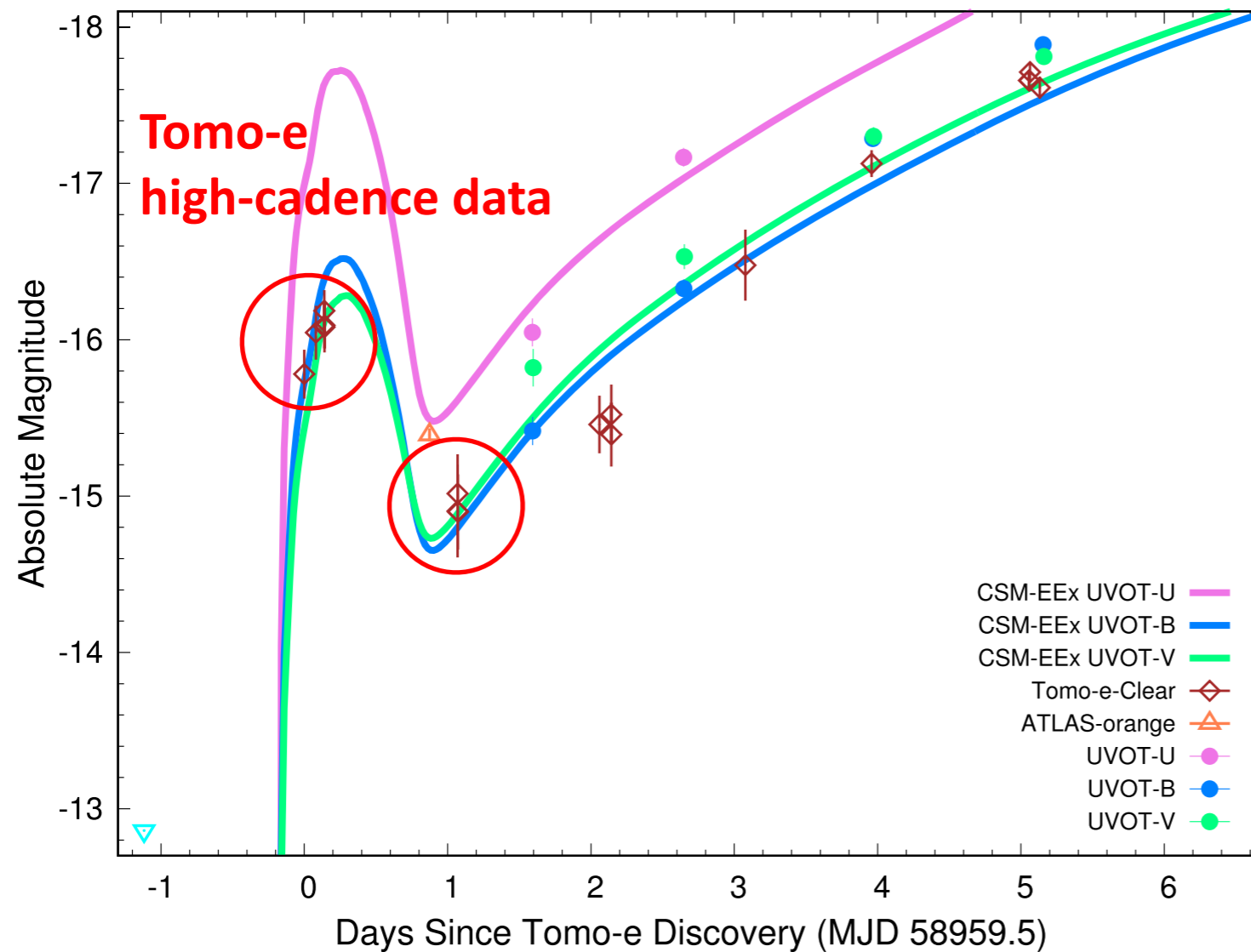


Time (days)	Magnitude (mag)	Source
-45	21.5	TNS non-det
-10	20.5	Tomo-e data
-8	18.5	mag aper
-5	17.5	mag aper
0	17.25	TNS

Automatically create observational scripts for Seimei telescope

# Early detection of Type Ia supernova

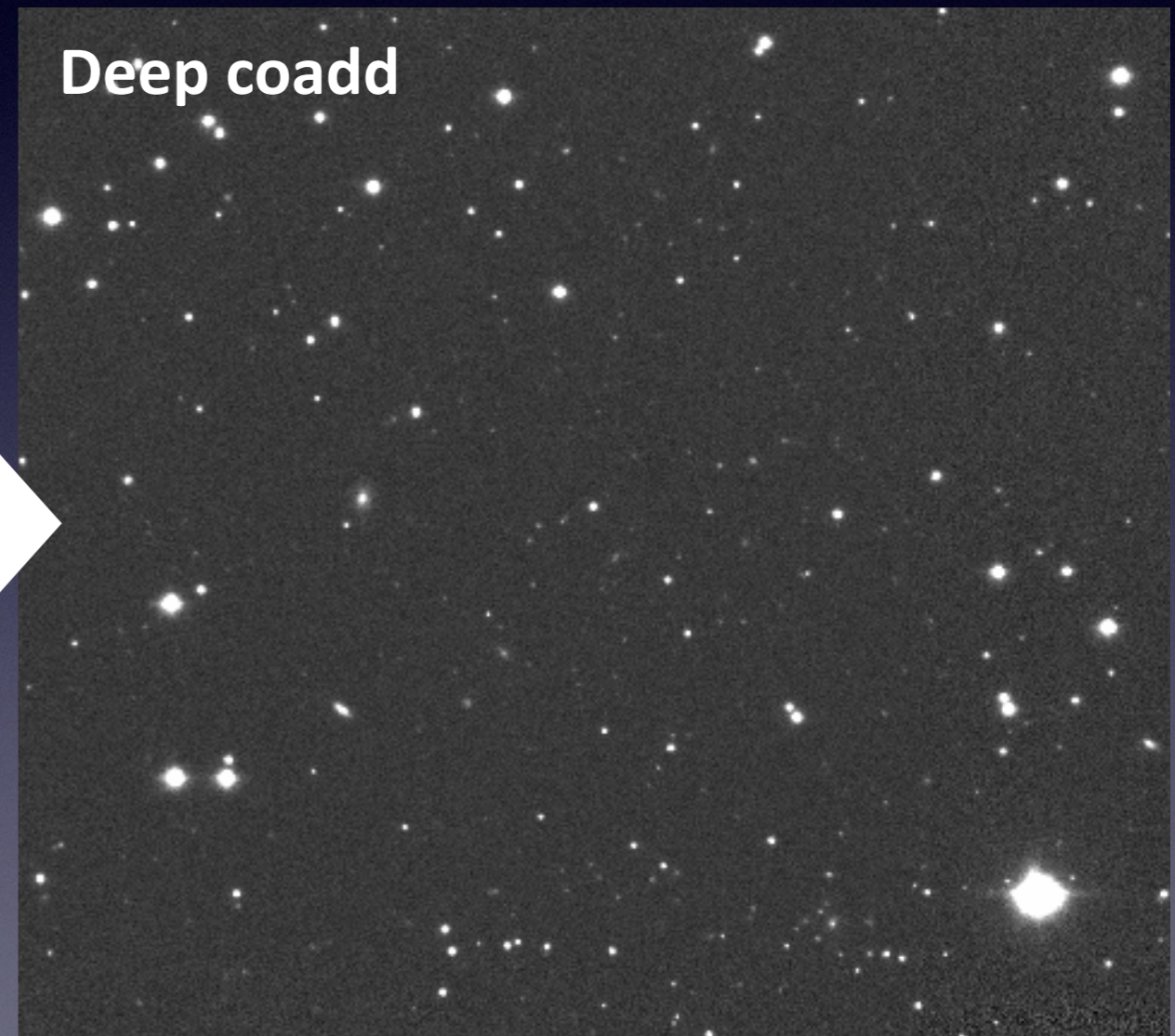
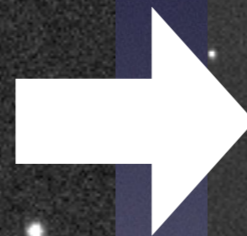
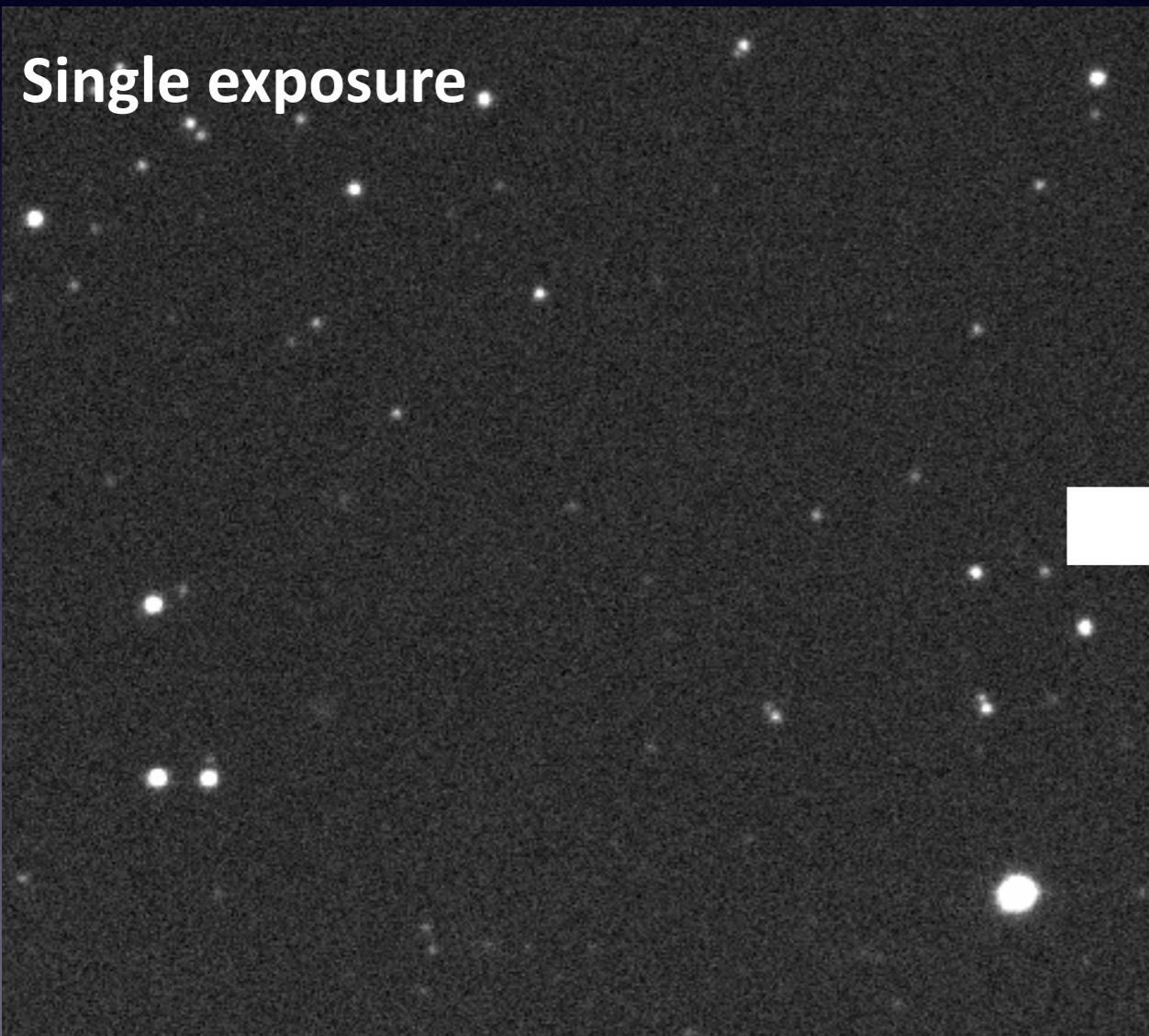
Jiang et al. 2021



Probe of circumstellar environment of Type Ia SN

# Tomo-e deep coadd reference for 20,000 deg<sup>2</sup> sky

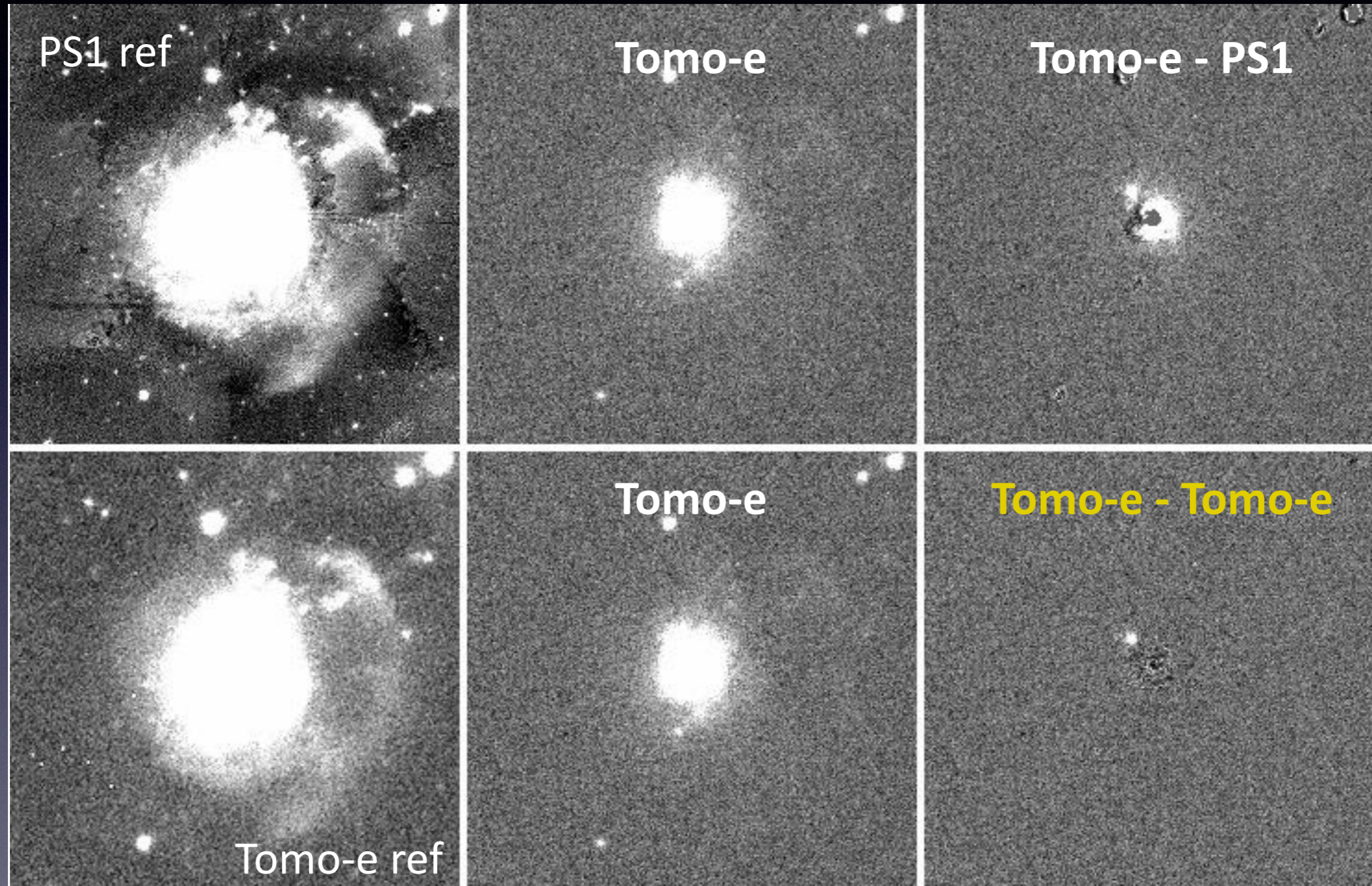
Led by 新納 悠さん (東京大)



# Improvement in image subtraction

Led by 新納 悠さん (東京大)

富永さん2021年 シュミットシンポ資料より

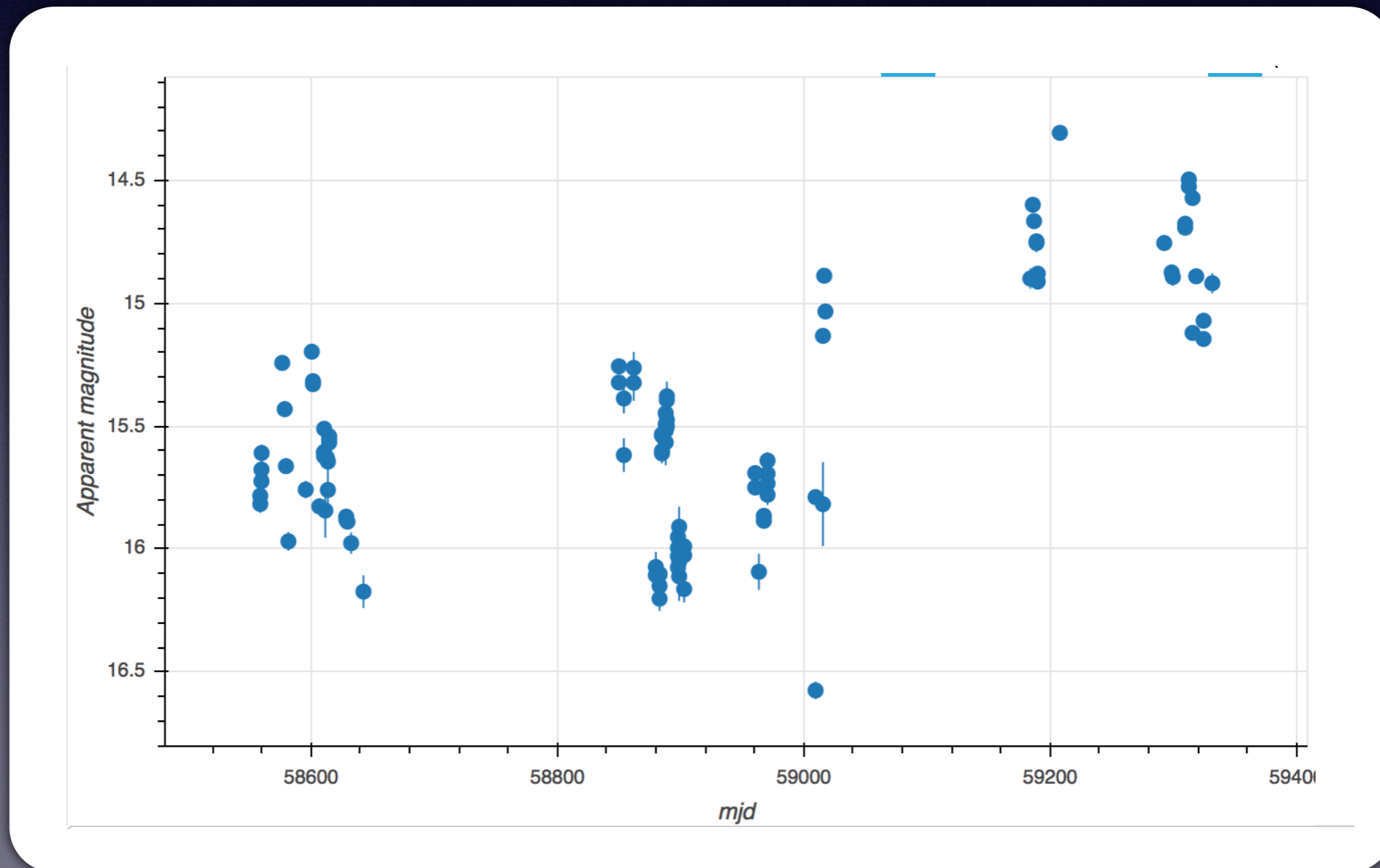


=> Implementation of machine learning (高橋さん)

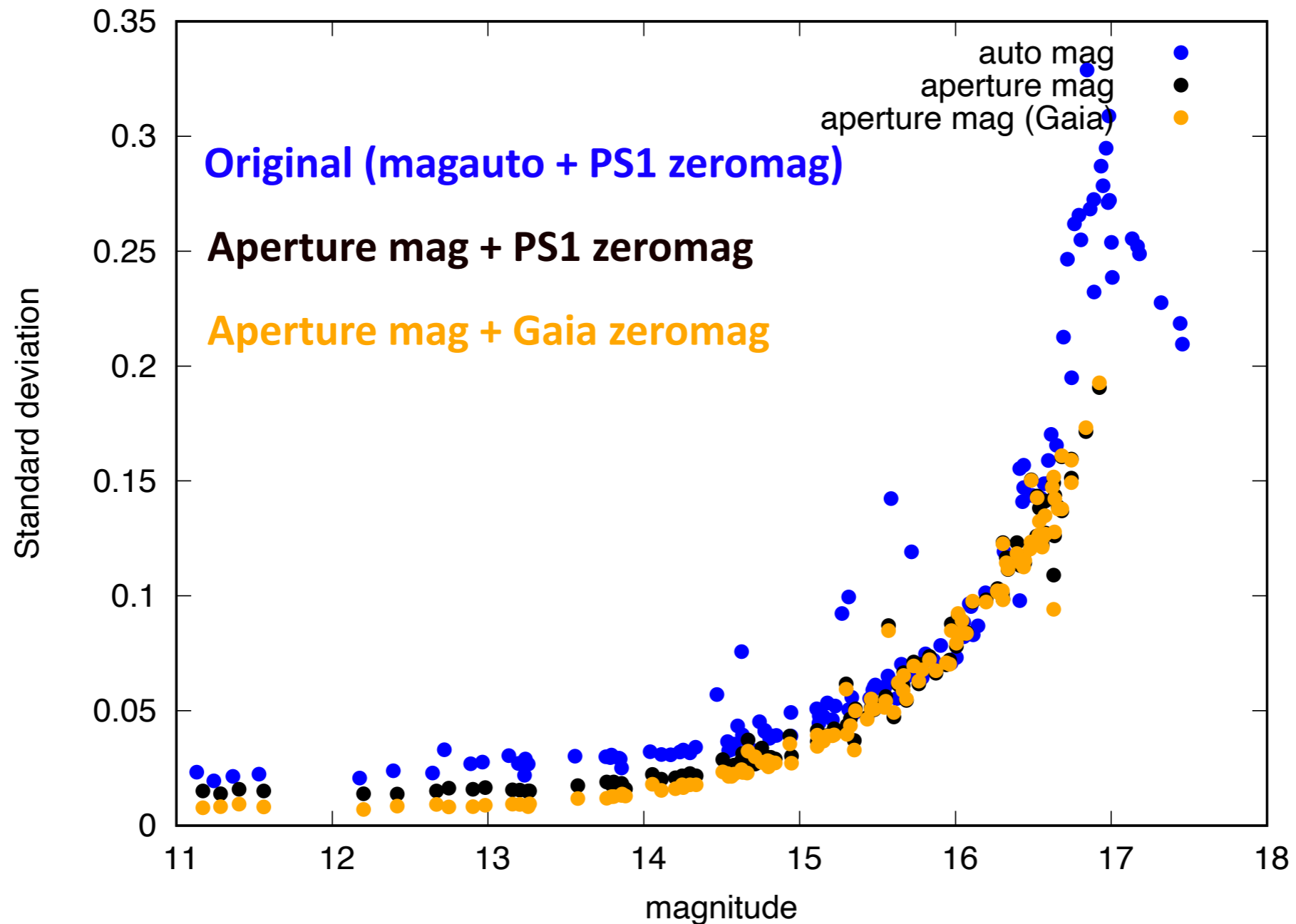


# Photometric catalog (before image subtraction)

銀河系内突発天体 (classical nova, dwarf nova)  
マイクロレンズイベント



# Improvement in photometric stability



=> start to use aperture mag + Gaia zeromag

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# まとめに代えて (今後の予定)

- **System update**
  - Tomo-e reference image + real-bogus classification
  - New measurements (zeromag, aperture photometry)
- **Rapid follow-up observations**
  - Response to multi-messenger/multi-wavelength trigger
  - Check rising/decline rate (to discover early transients)
  - Machine learning classifier
  - Automatic observations at Seimei
- **Exploration for shorter-duration objects**
  - Transient detection in 2 fps data => 高橋さんトーク
- **Anything else?**
  - Your comments are always welcome!

データ利用に興味がある方はご連絡下さい