

*The Tomo-e Gozen  
is named after  
Tomo-e Gozen  
(Lady Tomo-e), who  
is a woman warrior  
born in the Kiso  
region, Japan in the  
12th century.*

# Tomo-e Gozen

## Masaomi Tanaka (Tohoku University)

### Instrument

Shigeyuki Sako (PI, U. Tokyo), Rhou Ohsawa (U. Tokyo)

### Transient science (survey/software/follow-up)

Tomoki Morokuma (PI, U. Tokyo), Nozomu Tominaga (Konan U.)

Masaomi Tanaka (Tohoku U.), Jian Jiang (U. Tokyo),

Keiichi Maeda (Kyoto U.), ...



Image: TNM Image Archives

# Tomo-e Gozen: summary

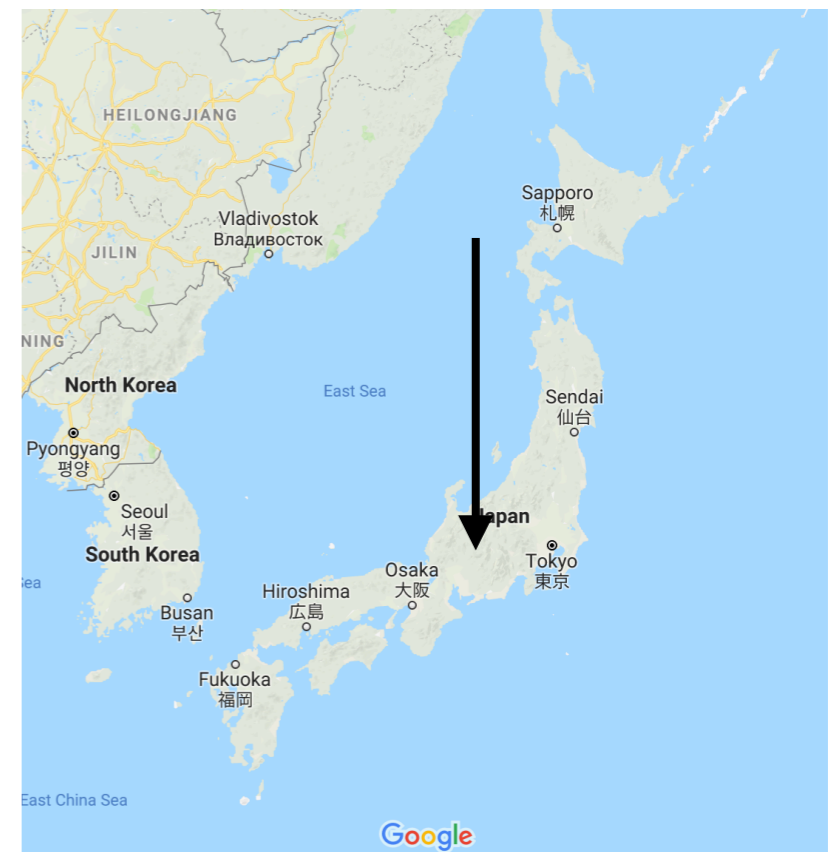
- **Instrument (PI: Shigeyuki Sako, U. Tokyo)**
  - 1m Kiso Schmidt telescope
  - 84 CMOS chips (1k x 2k)
  - 20 deg<sup>2</sup> FOV
  - Imaging with 2 Hz (2 fps)
  - ~17 mag in 0.5 sec exposure
  - 30 TB/night (raw data are deleted in 1 week)
- **Survey (PI: Tomoki Morokuma, U. Tokyo)**
  - 7000 deg<sup>2</sup> - 2 hr cadence - 18 mag (6 sec exposure)
  - No filter
  - 2018 November - (FOV 5 deg<sup>2</sup>), 2019 April - (FOV 20 deg<sup>2</sup>)

# Telescope

[http://www.ioa.s.u-tokyo.ac.jp/kisohp/top\\_e.html](http://www.ioa.s.u-tokyo.ac.jp/kisohp/top_e.html)

- 1m Kiso Schmidt telescope
  - Operated by U. Tokyo since 1974
  - 9 deg diameter FOV

137.6283,+35.7940 (EL=1130 m)



# Camera

<http://www.ioa.s.u-tokyo.ac.jp/tomoe/about.html>



Sako et al. 2018, SPIE

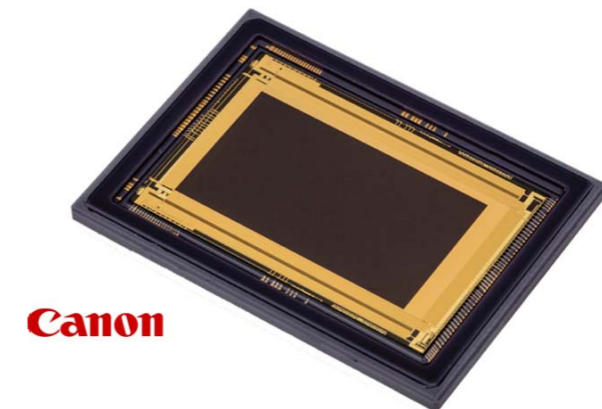
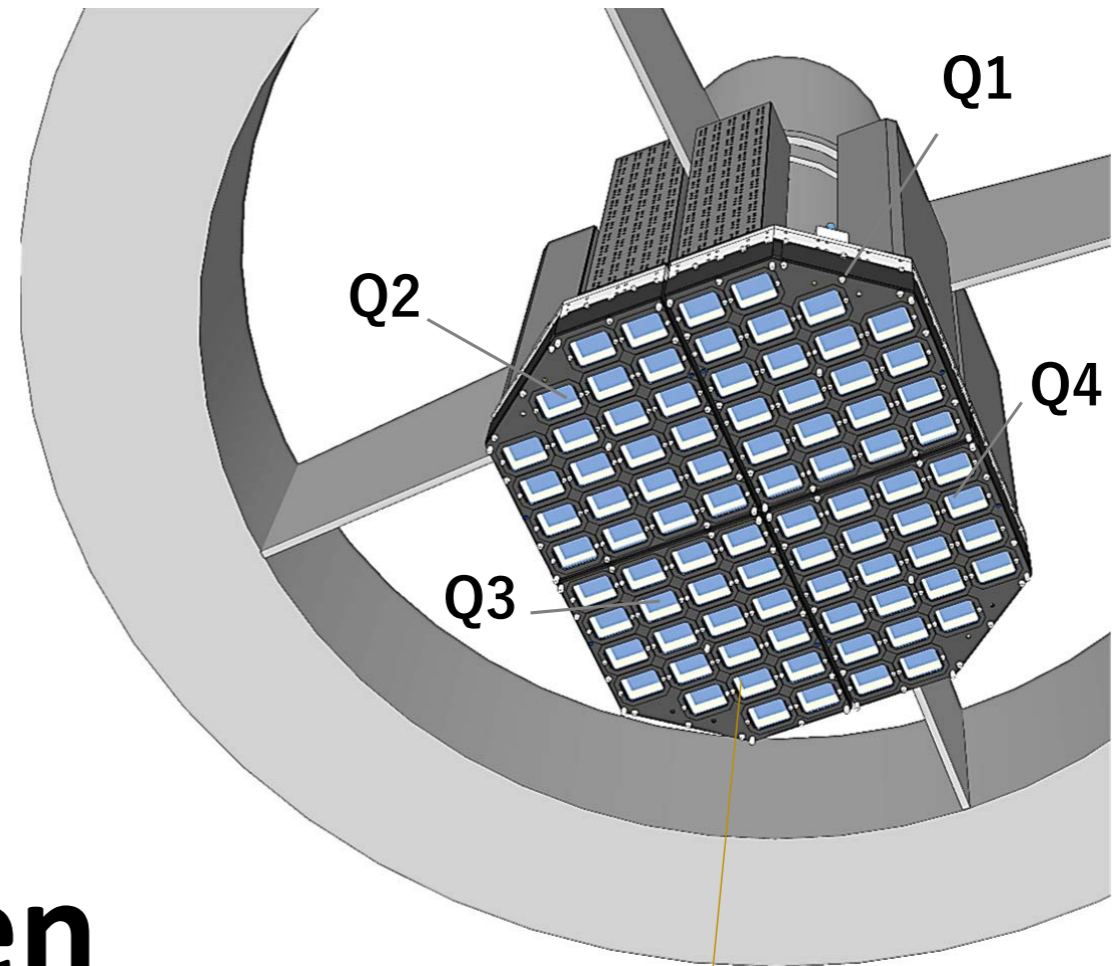
Kojima et al. 2018, SPIE

Osawa et al. 2016, SPIE

**the first wide-field CMOS camera**

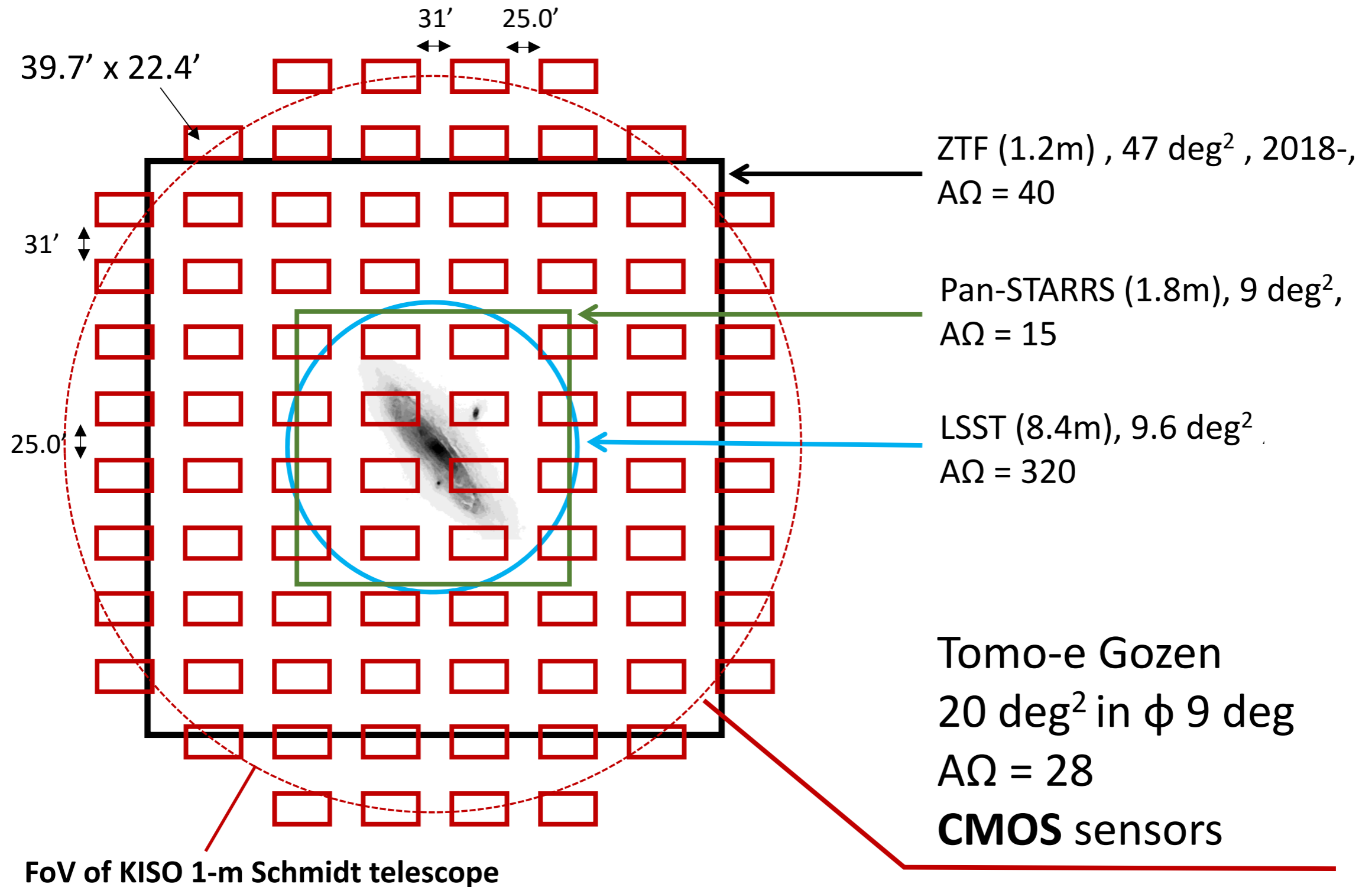
## The Tomo-e Gozen

- FoV of 20 deg<sup>2</sup> in  $\phi$  9 deg
- 84 chips of CMOS, 1k x 2k pixels
- Consecutive frames in 2 fps (max)
- Big movie data of 30 TB/night (max)



Slide courtesy of Shigeyuki Sako

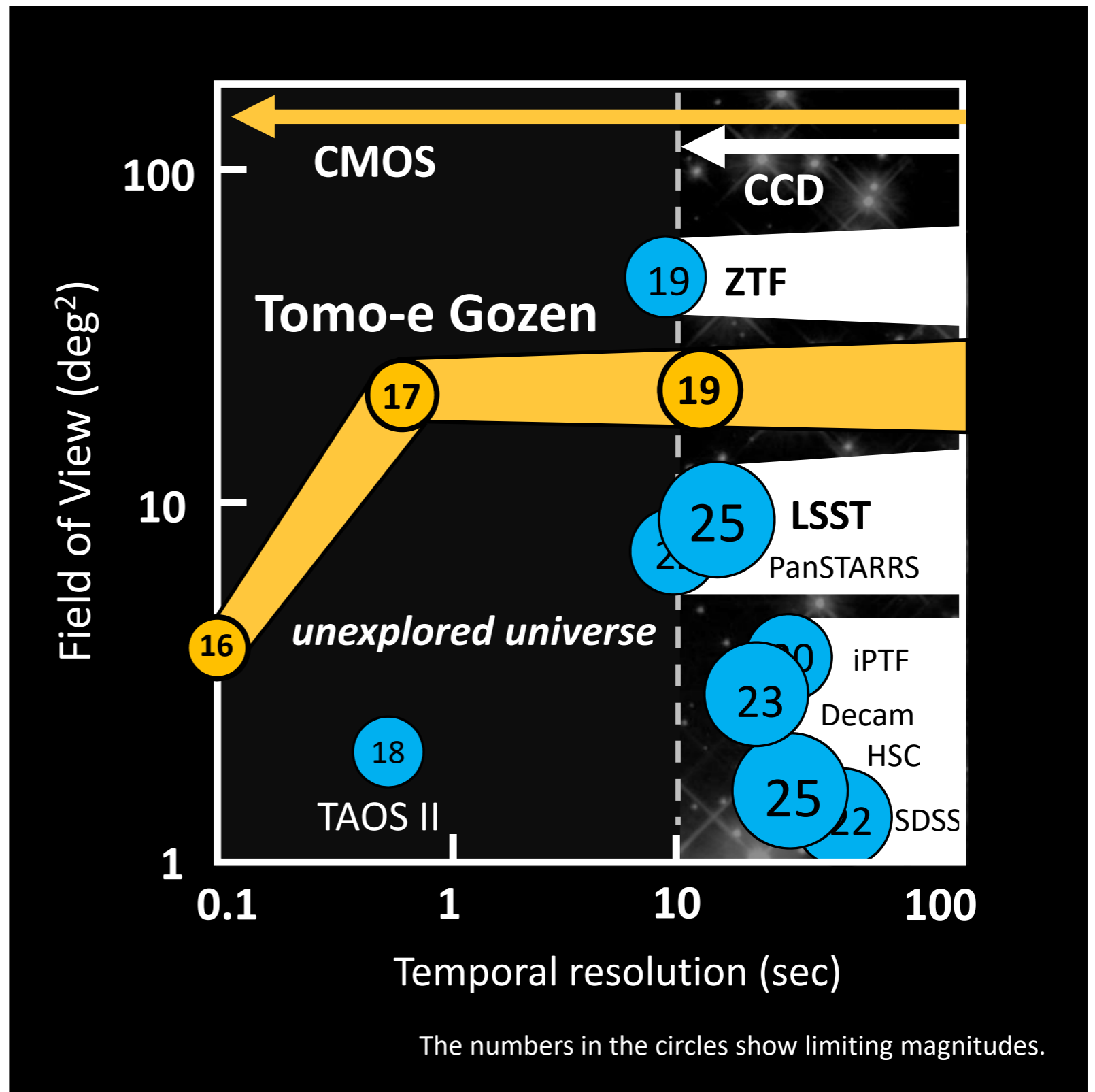
# Field of view



# Transient sky in second timescale

Default observing mode:  
imaging with 2 Hz (2fps)

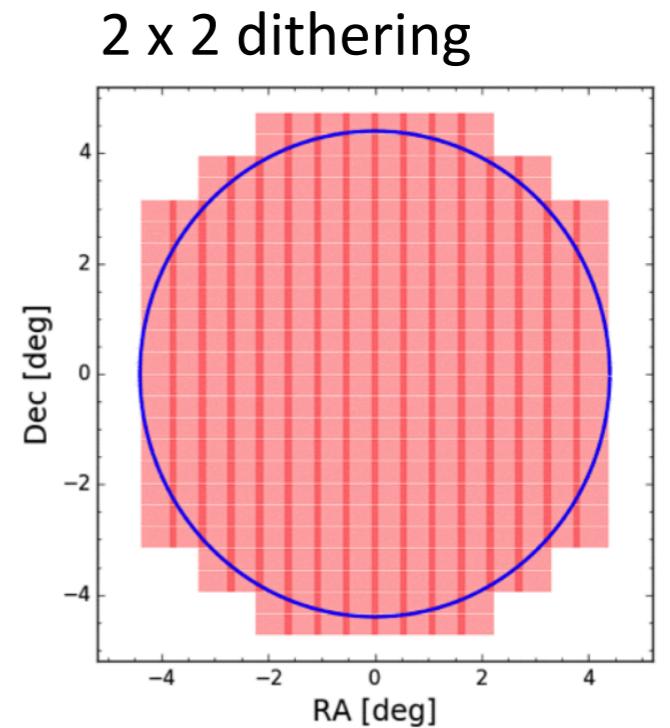
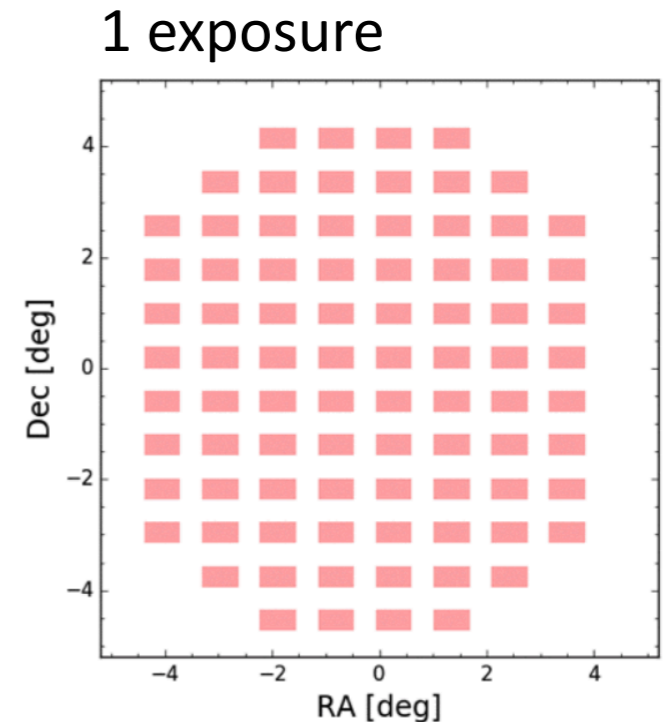
- ~17 mag in 0.5 sec
- ~30 TB/night



# Northern sky transient survey

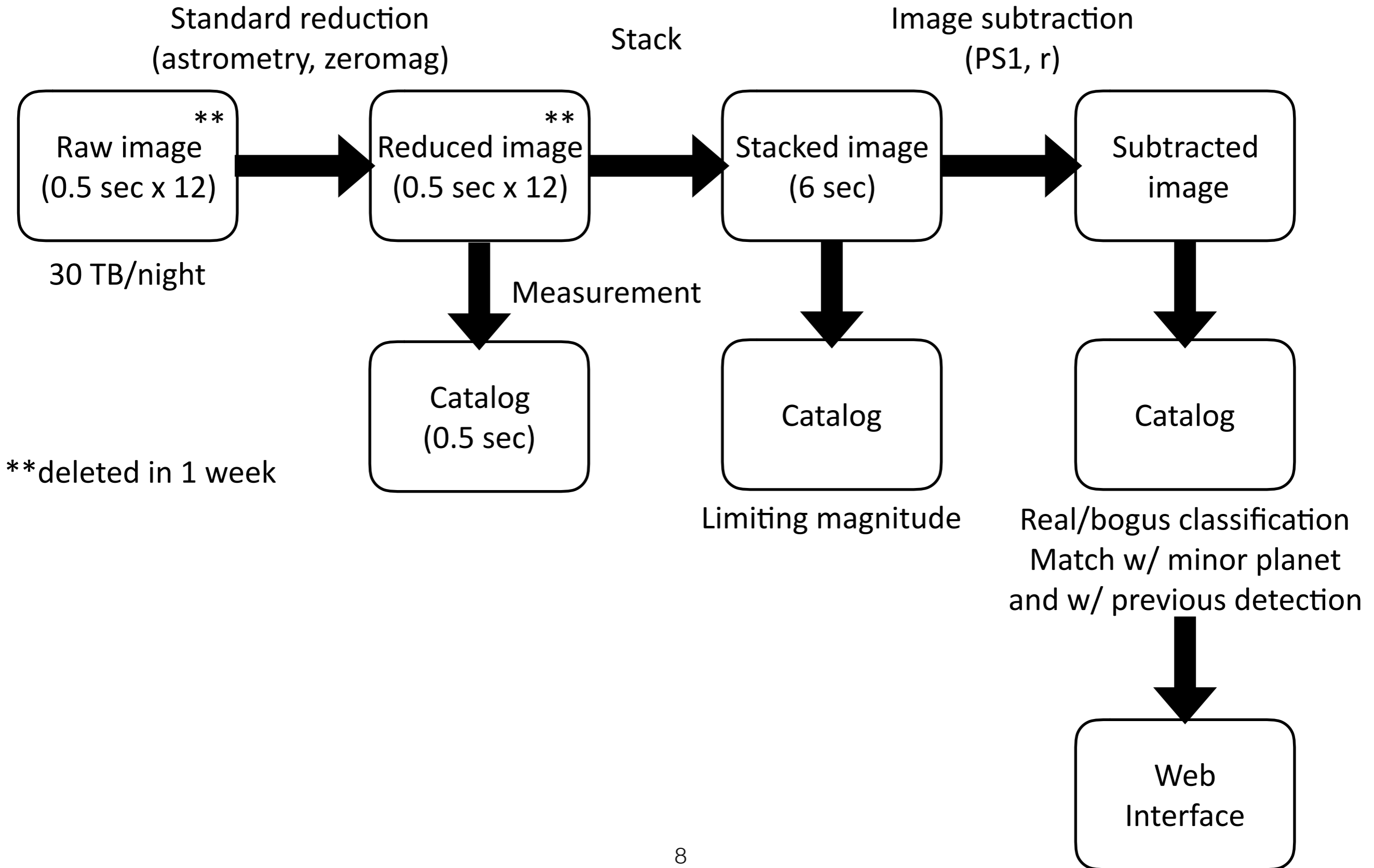
PI: Tomoki Morokuma

- **Survey plan: 7000 deg<sup>2</sup> - 2hr cadence - 18 mag**
  - 1 “visit” = 60 deg<sup>2</sup> in 1 min
    - 12 x 0.5 sec = 6 sec (~18 mag depth)
    - 2 x 2 dithering (to fill the gap)
  - 2 hr cadence (= 120 visits)  
=> ~7000 deg<sup>2</sup> in total (elevation > 40 deg)
  - No filter (effectively g + r)
  - Keep detection information of 2 Hz images
- **Schedule**
  - 2018 November - (Q1, FOV 5 deg<sup>2</sup>)
  - 2019 April - (Q1-4, FOV 20 deg<sup>2</sup>)



By Tomoki Morokuma

# Data flow





# Transient detection in the test run

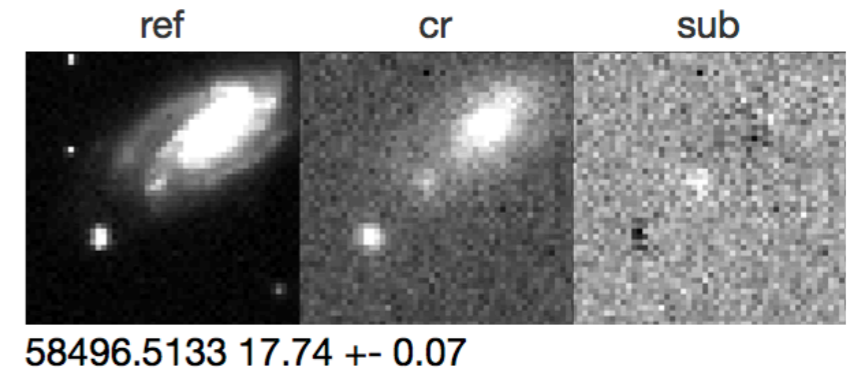
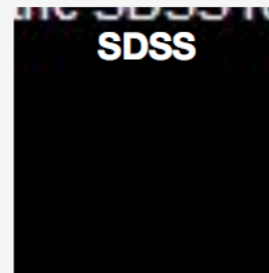
= AT 2018leh (2018-12-31)  
 = ZTF18adbmrug (2018-12-30)

[previous](#)

## 19monv

Transient ID: 220736 Variable\_id: 1021301

Number of detections: **3** (paramcand)



2019-01-11

**Tags** Click a tag for removal

Insert tags

No tag assigned.

or

Ra, Dec (Decimal)	Ra, Dec	Detector ID	x,y
61.26379 , 25.26215	04:05:03.31, +25:15:43.8	134	0.00 , 0.00 0.00 , 0.00

<b>Relavant links</b>	<a href="#">SDSS</a>	<a href="#">PS1</a>	<a href="#">TNS</a>	<a href="#">MPChecker</a>	<a href="#">Visibility (local site: 137.6283 35.7942 1130 +9)</a>
<b>fits files</b>	<a href="#">Ref</a>	<a href="#">Sub</a>			

# Tomo-e Gozen: summary

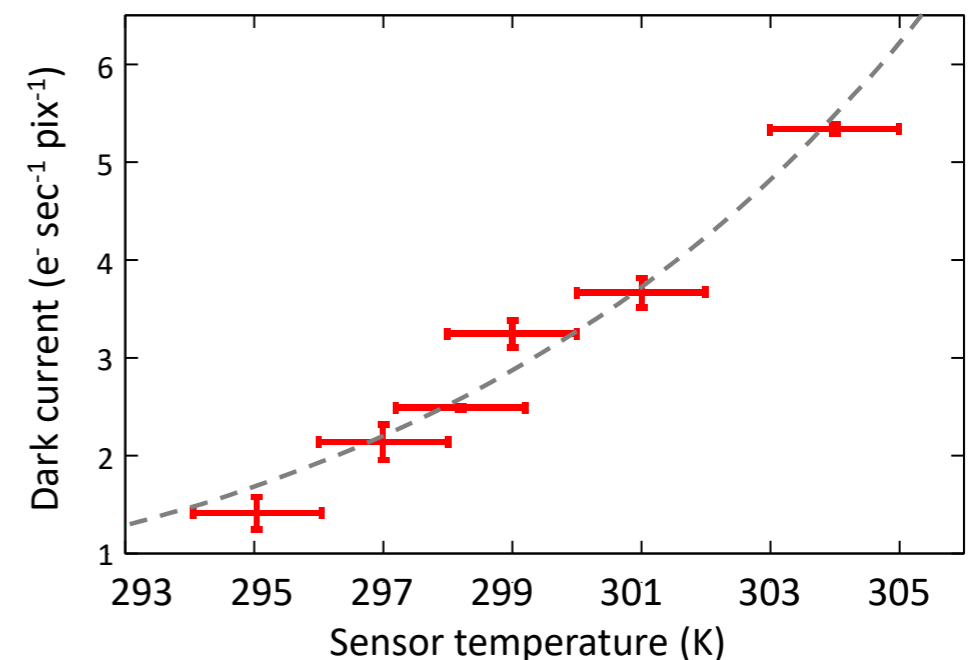
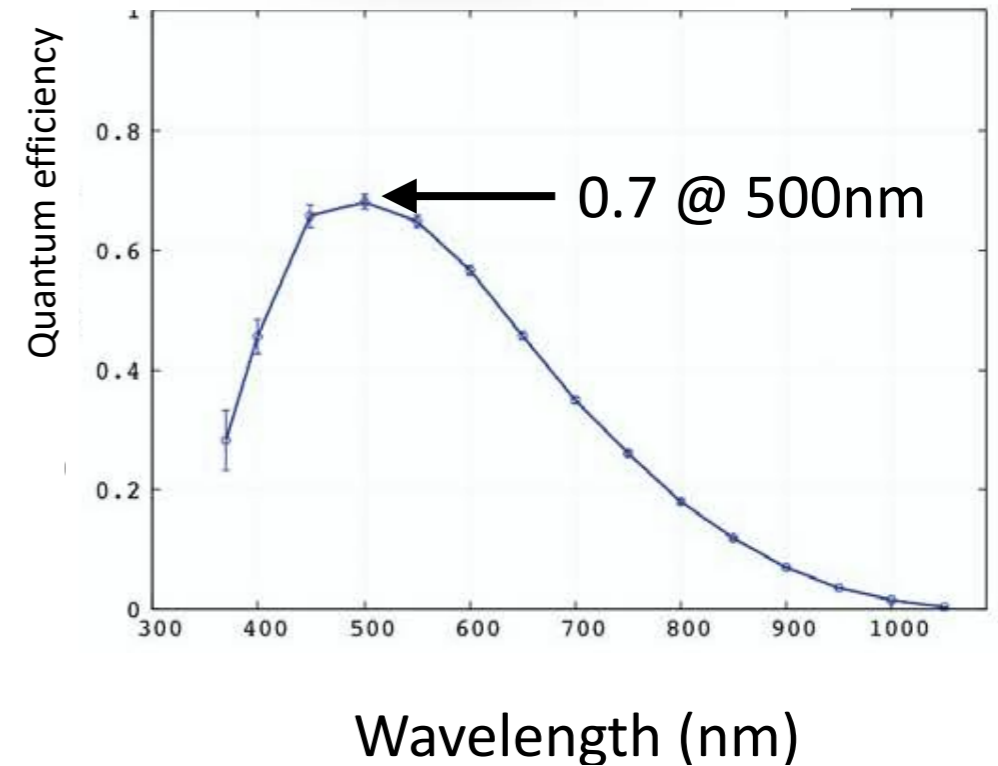
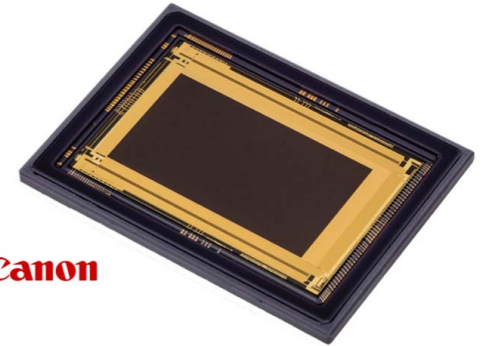
- **Instrument (PI: Shigeyuki Sako, U. Tokyo)**
  - 1m Kiso Schmidt telescope
  - 84 CMOS chips (1k x 2k)
  - 20 deg<sup>2</sup> FOV
  - Imaging with 2 Hz (2 fps)
  - ~17 mag in 0.5 sec exposure
  - 30 TB/night (raw data are deleted in 1 week)
  
- **Survey (PI: Tomoki Morokuma, U. Tokyo)**
  - 7000 deg<sup>2</sup> - 2 hr cadence - 18 mag (6 sec exposure)
  - No filter
  - 2018 November - (FOV 5 deg<sup>2</sup>), 2019 April - (FOV 20 deg<sup>2</sup>)

# Appendix

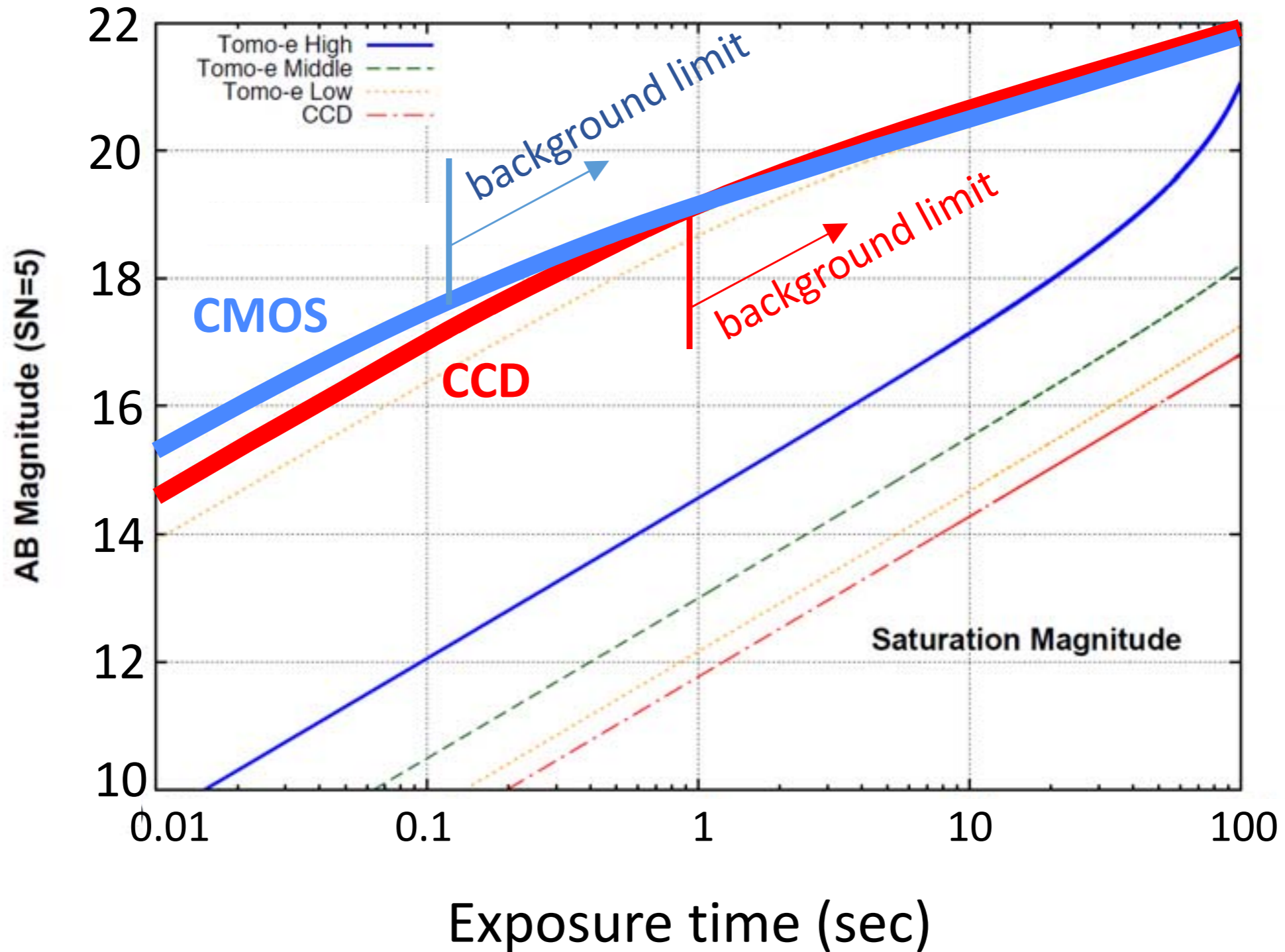
# Sensor

- Large pixel CMOS sensor by Canon
  - 2000 x 1128 pixels, front side illuminated
  - 19  $\mu\text{m}/\text{pix}$  (= 1.198 arcsec/pix)
- Sensitive at 370-730 nm
- Readout noise: 2.0  $e^-$
- Dark current:  $6e^- \text{ sec}^{-1}$  @ 305K  
(sky  $50 e^- \text{ sec}^{-1} \text{ pix}^{-1}$  at Kiso)

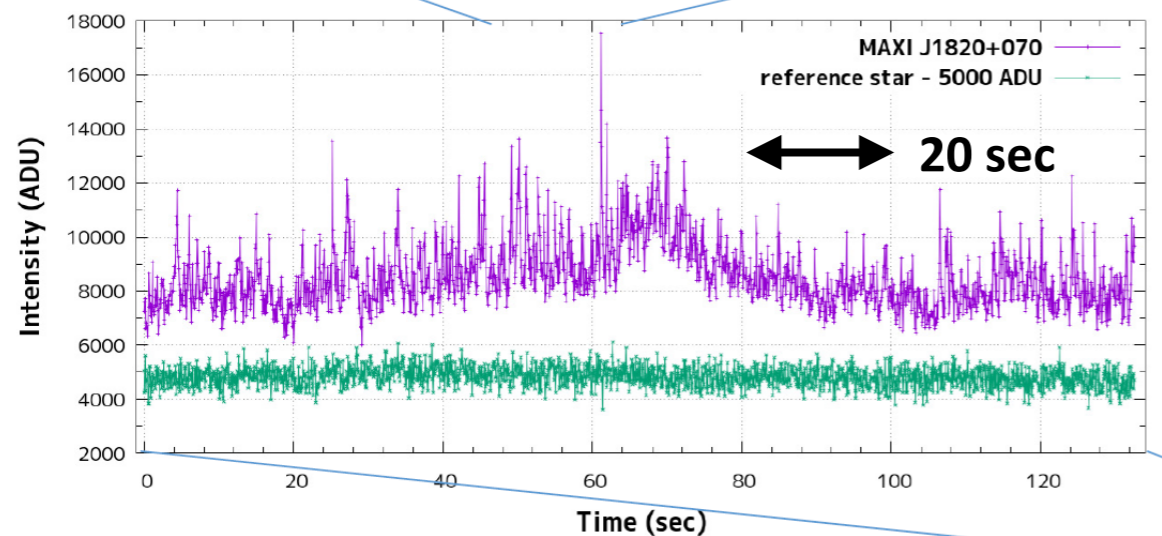
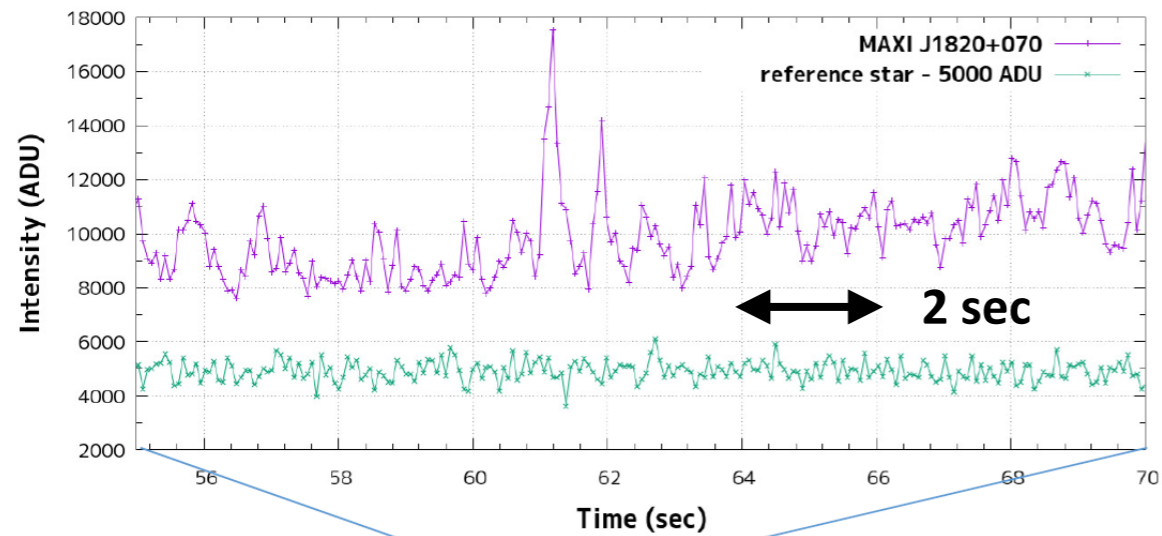
Kojima, Sako, Ohsawa et al. 2018, SPIE



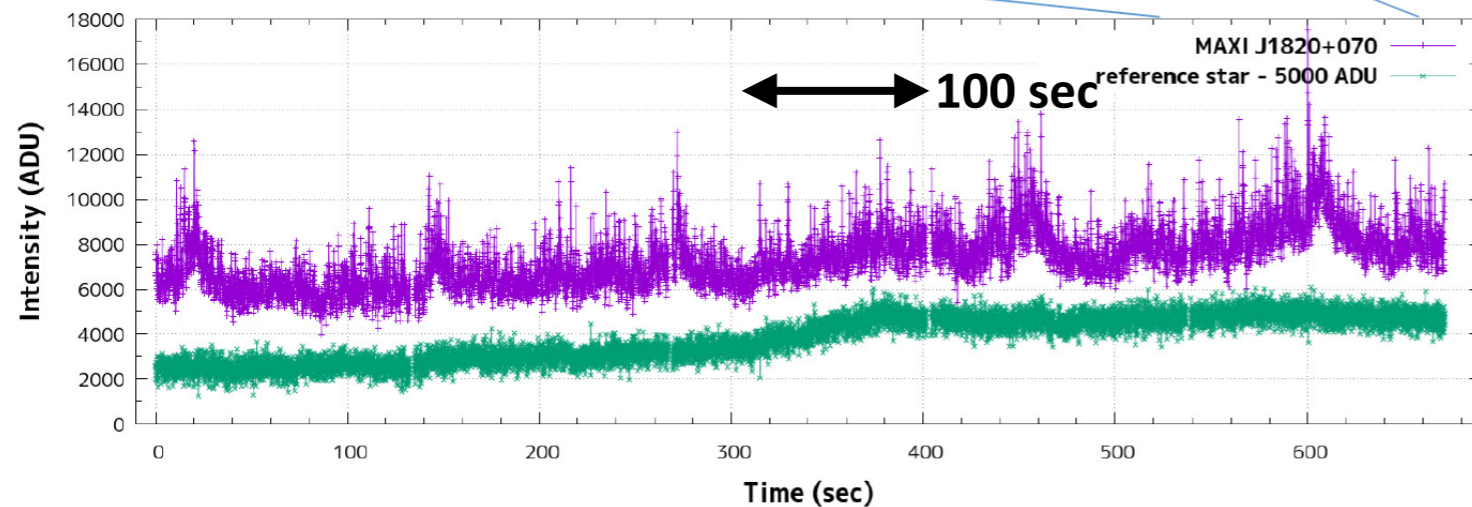
# Limiting magnitudes



# Rapid variability of X-ray transient (MAXI J1820+070)



MAXI J1820+070  
Reference star



Sako et al. 2018, ATel, 11426

<http://www.ioa.s.u-tokyo.ac.jp/tomoe/MAXIJ1820+070/MAXIJ1820+070.html>

# Very rapid transient in 2Hz imaging mode

