KOOLS-IFU Workshop

東京大学木曽観測所 Tomo-e Gozen と KOOLS-IFU のシナジー

大澤 亮 (東京大学)

Kyoto University, 2018.02.05-6

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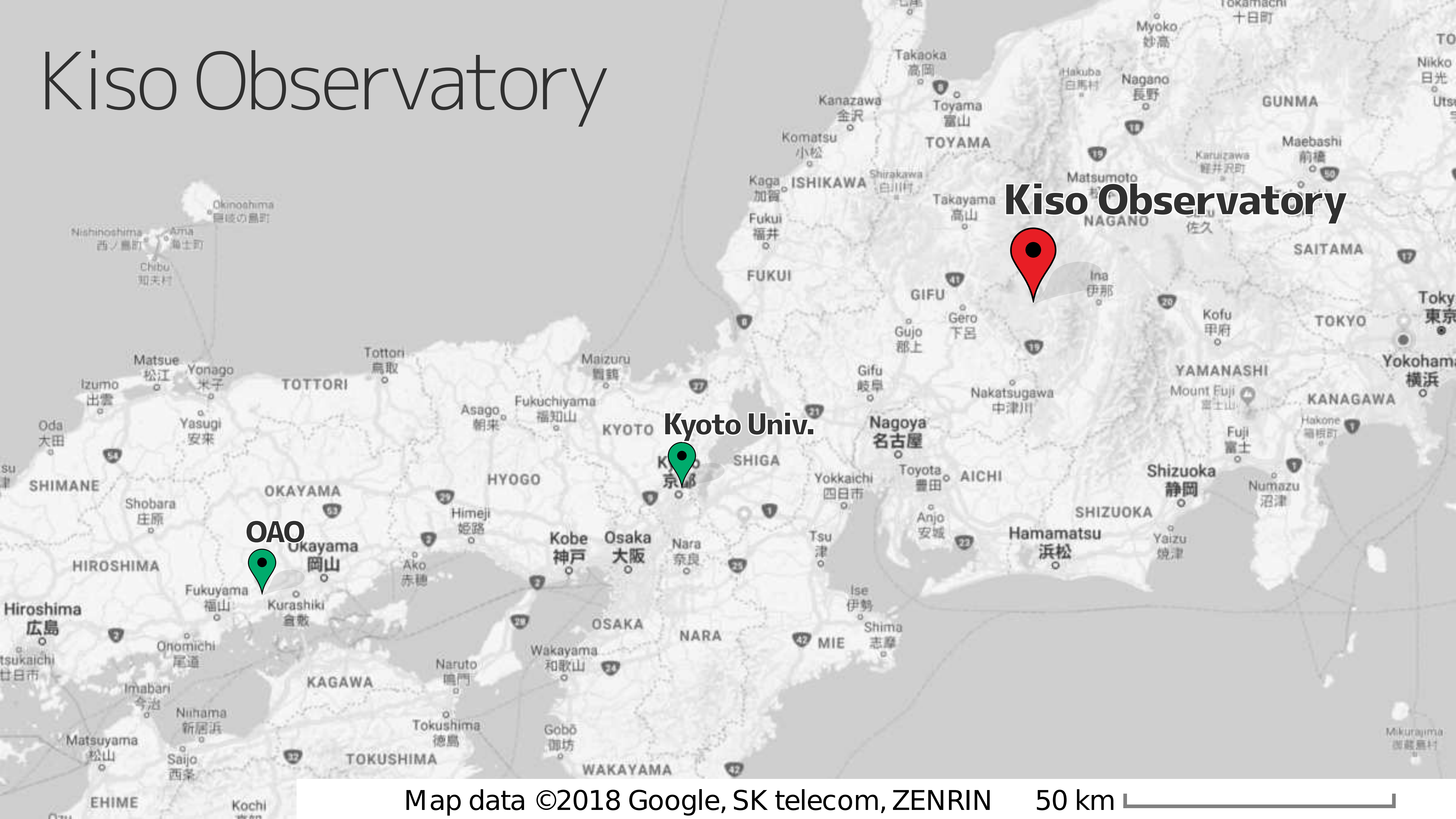
A ultra wide-field mosaic CMOS camera

Kiso Observatory



Kiso Observatory

Map data ©2018 Google, SK telecom, ZENRIN 50 km

1.05m Schmidt Telescope

originally designed for observations with photographic plates

extremely wide-field of view (~ ø9° without distortion)

Era of photographic plates

A leading facility in the wide-field obs. astronomy in Japan

~ 8000 photographic plates are going to be archived.

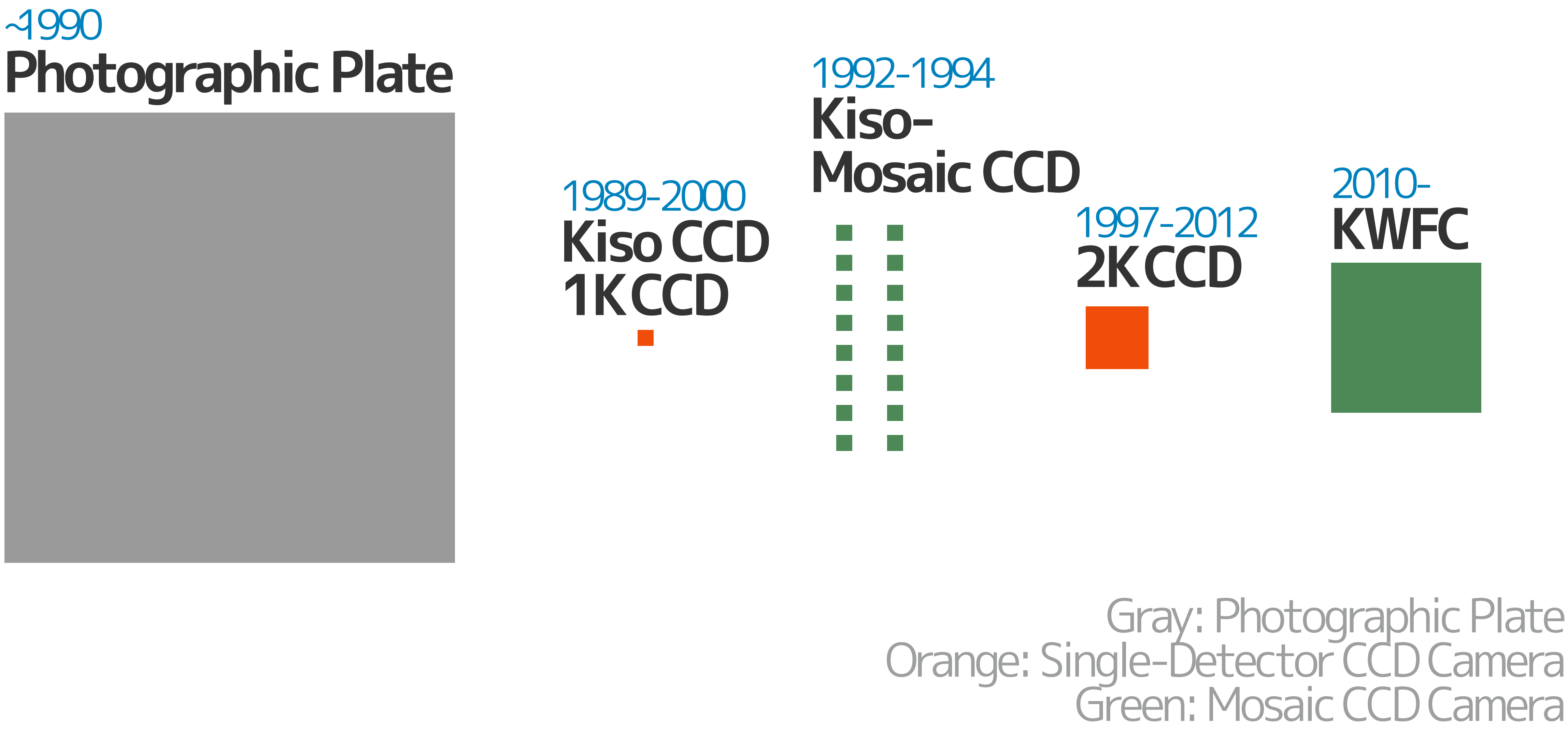
Era of semicondactor/CCD image sensor

A birthplace of the first CCD/mosaic CCD cameras in Japan

A pathfinder to the Hyper Suprime-Cam in Subaru

Large survey programs by Kiso Wide Field Camera (KWFC)

Cameras in Kiso Observatory



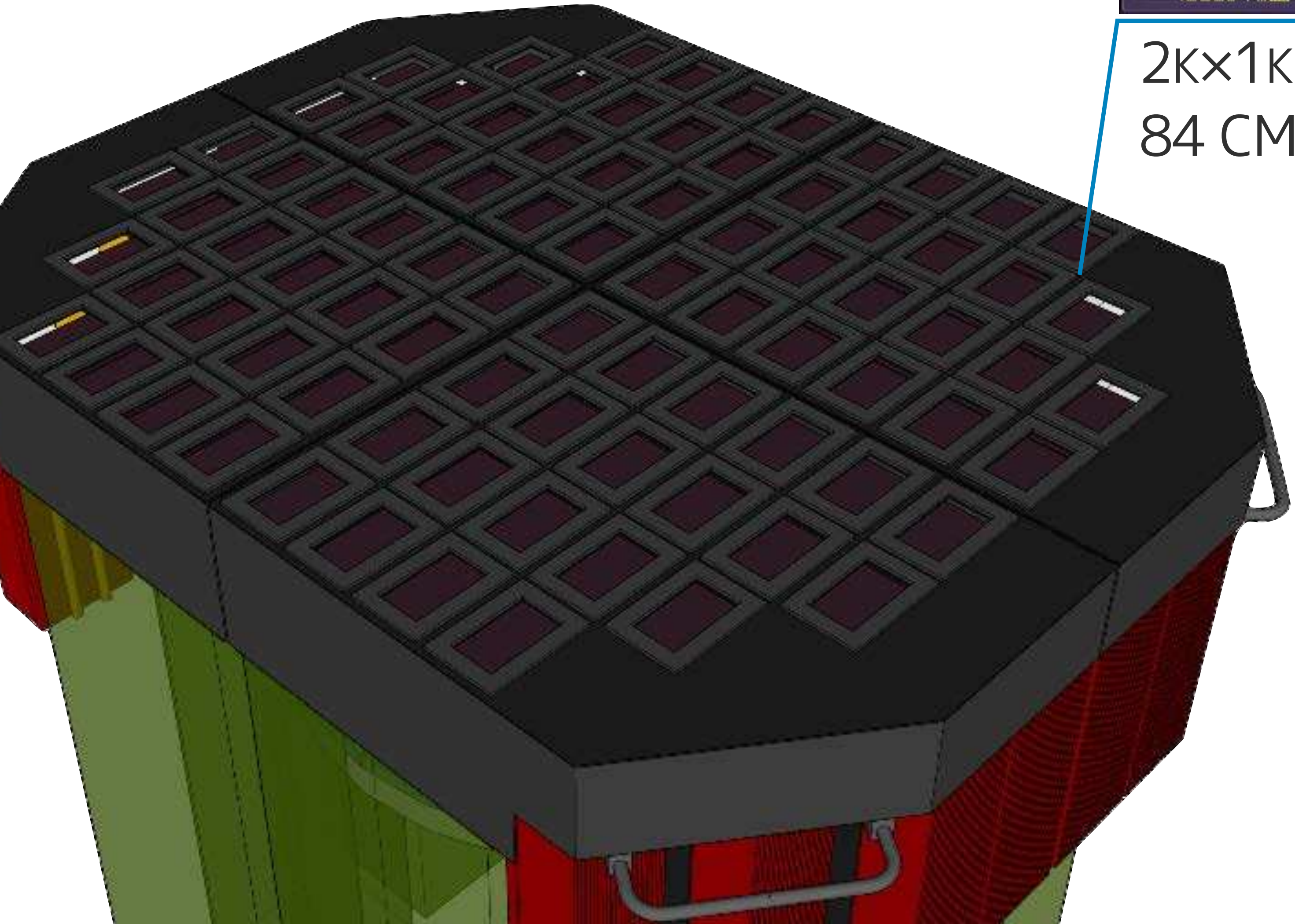
Next-generation Camera

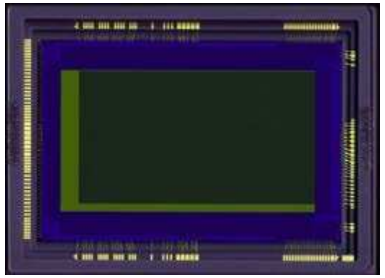
Concepts:

Surveys for **extremely rare** transient events

- Field-of-View ⇢ **as large as photographic plates**
- Quick readout ⇢ **High survey efficiency**
- Movie observation ⇢ **explore a new parameter space**

Tomo-e Gozen



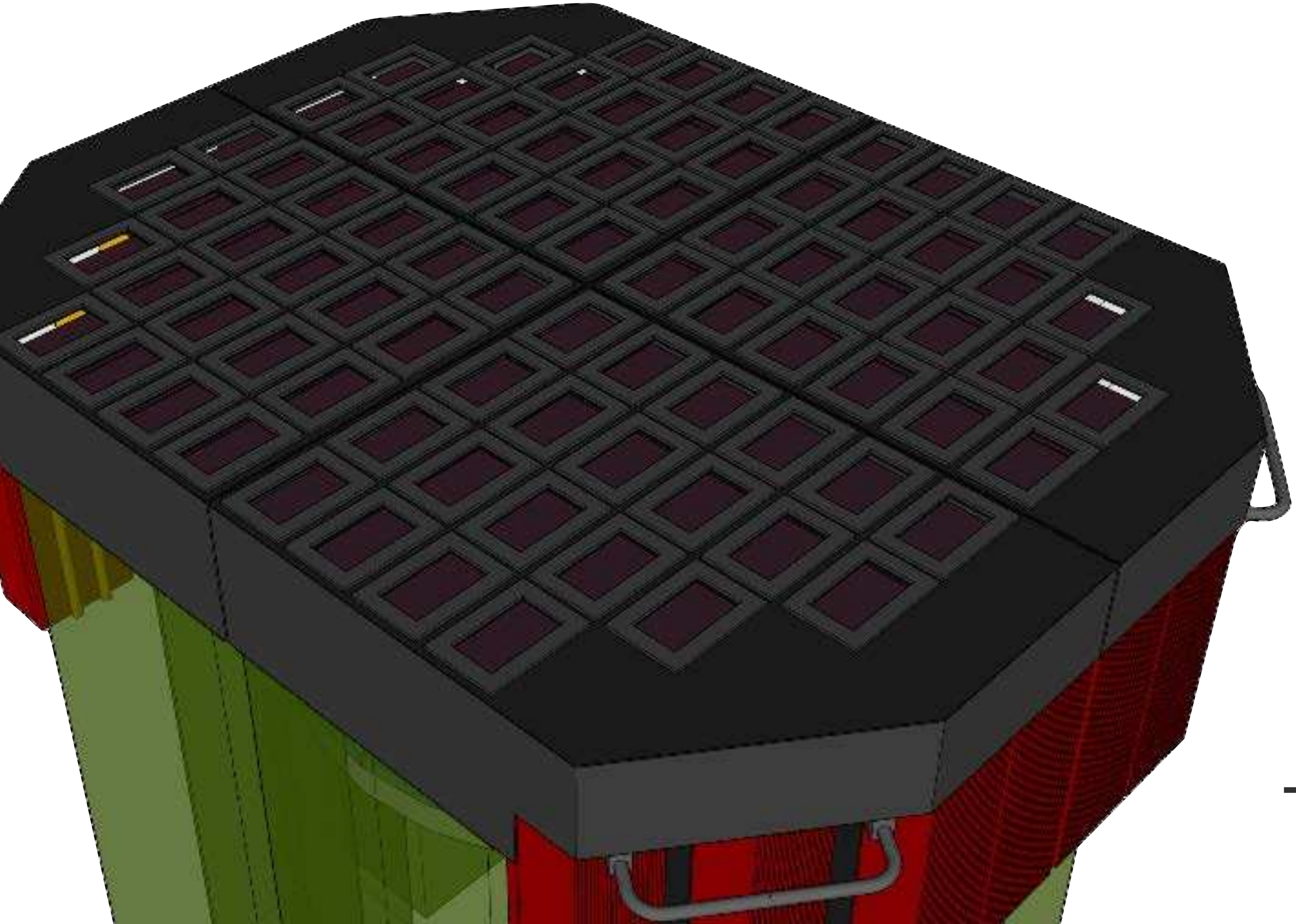


2K×1K CMOS image sensor by **Canon**

84 CMOS sensors are tiled to cover ~20□°

An overview of the Tomo-e Gozen camera

Tomo-e Gozen

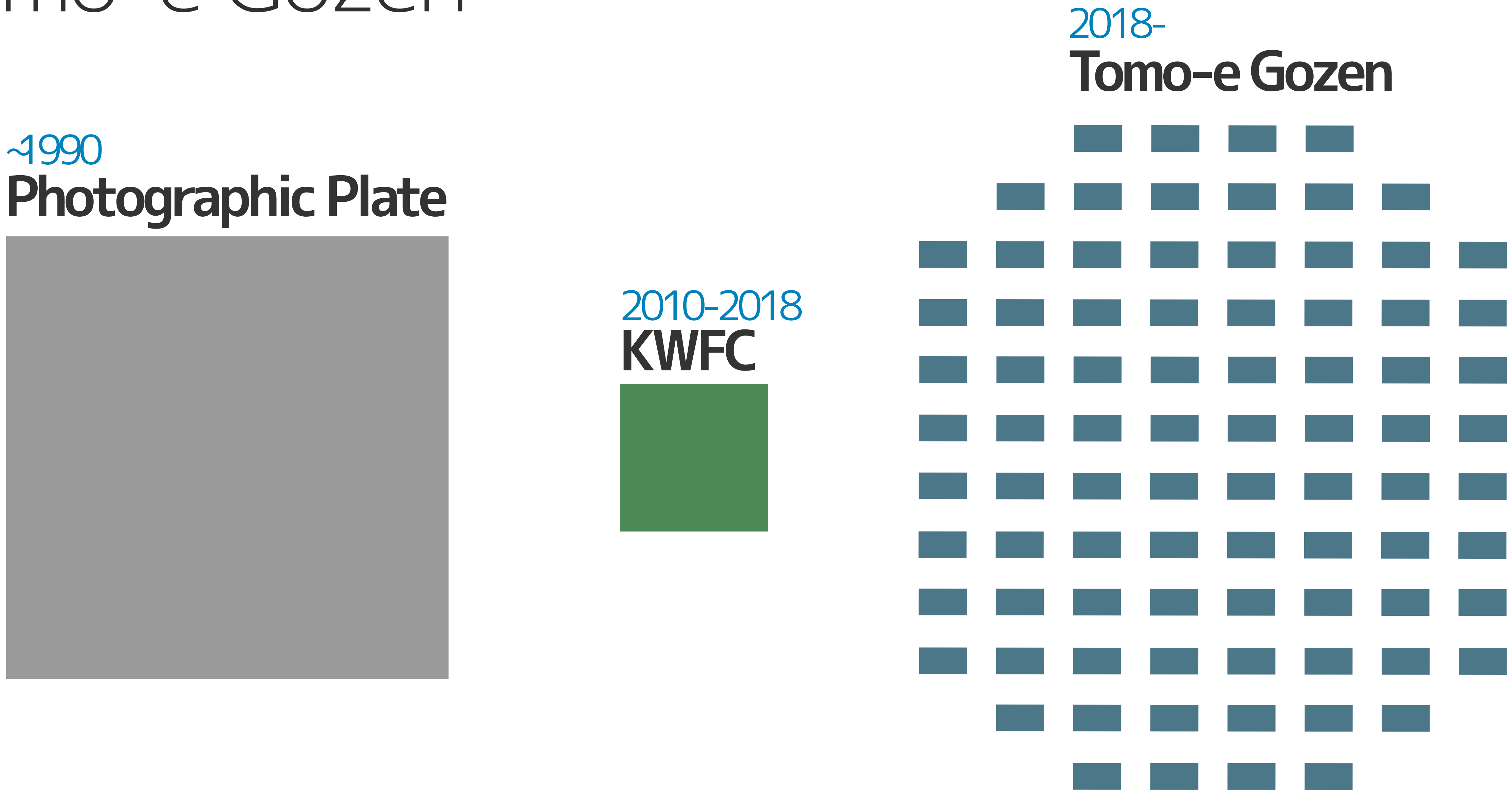


Specifications

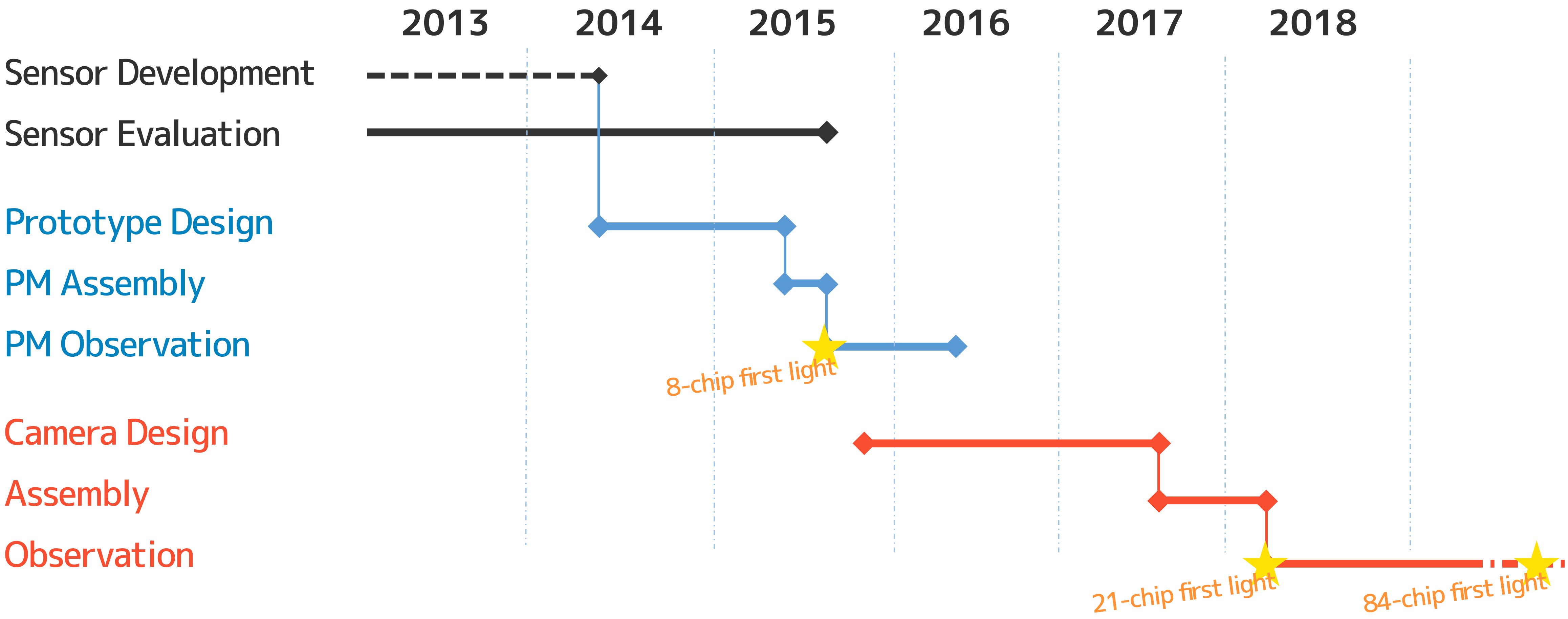
Observatory	Kiso Observatory
Telescope	1.0-m f/3.1 Schmidt telescope
Sensor format	2160×1200 pix chip^{-1}
Field of view	$39'.7\times22'.4\times84$ chips
Pixel scale	19 μm, $1''.189$ pix^{-1}
Wavelength	350–700 nm (peak at 500 nm)
Filters	optical broadband (transparent)
Frame rate	2 Hz (max, continuous, full frame)
Read noise	~ 1.9 e^- at 2 Hz
Dark current	~ 0.1 e^- sec^{-1} pix^{-1} at 277 K
Well depth	~ 6,400 e^-
5σ lim. mag.	~ 18.5 mag. in 0.5 sec exposure

An overview of the Tomo-e Gozen camera

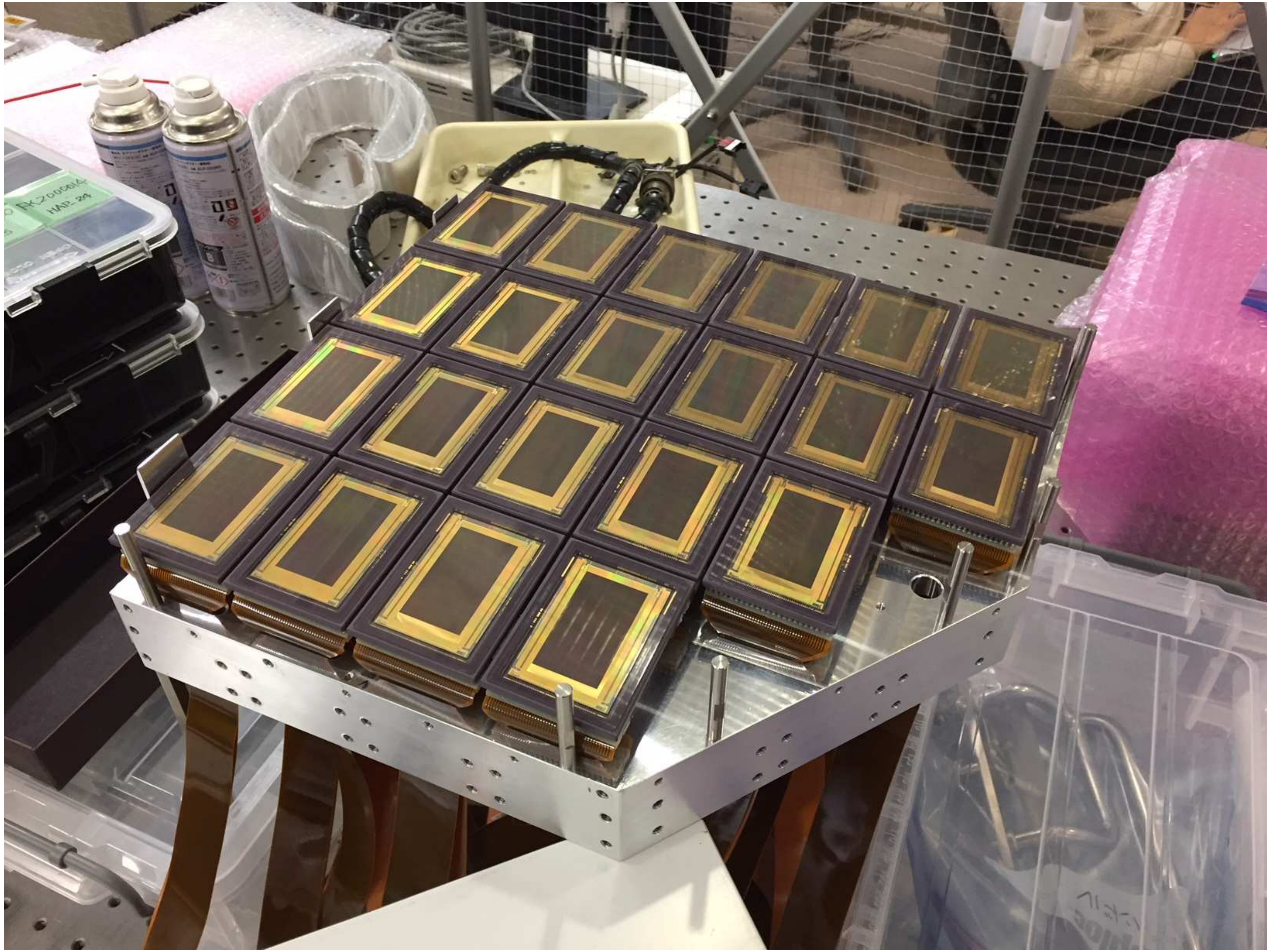
Tomo-e Gozen

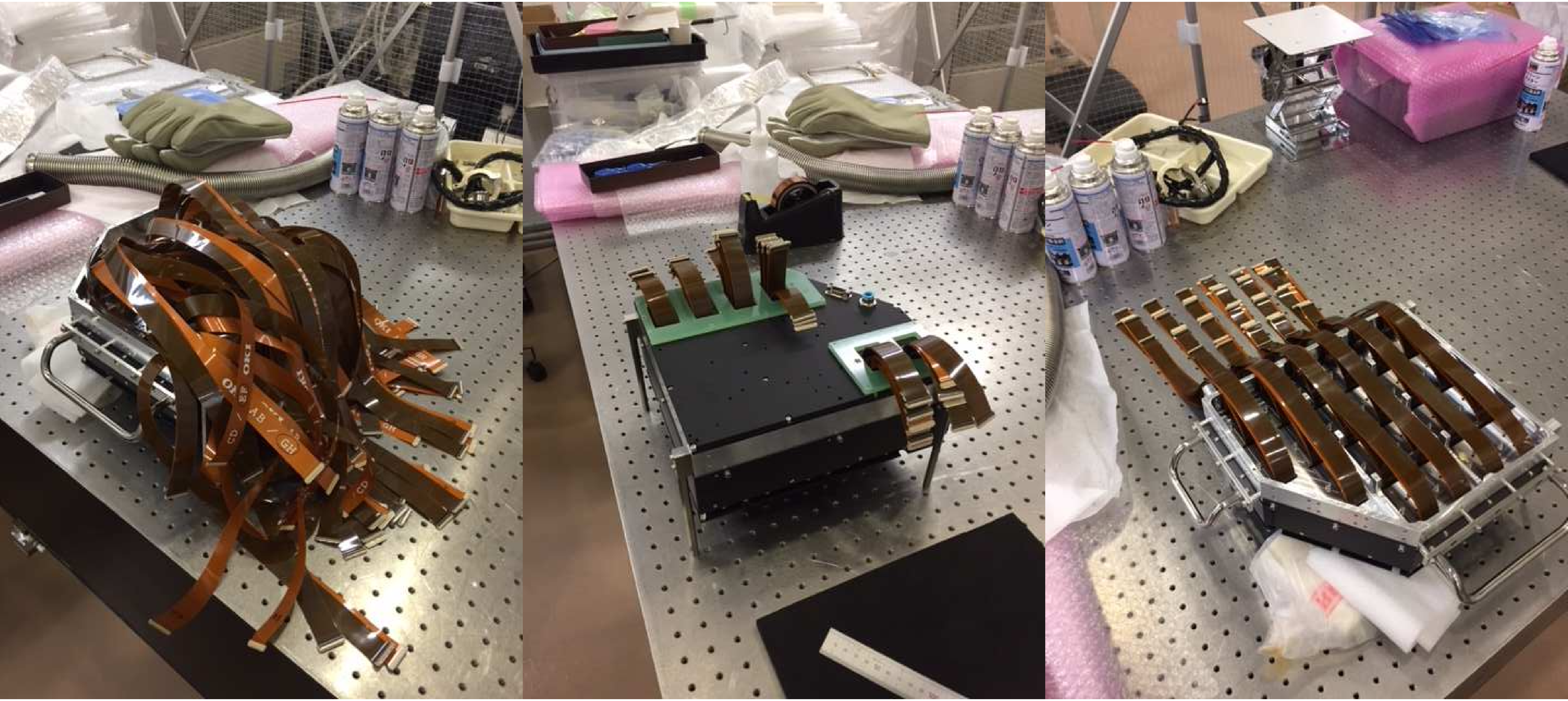


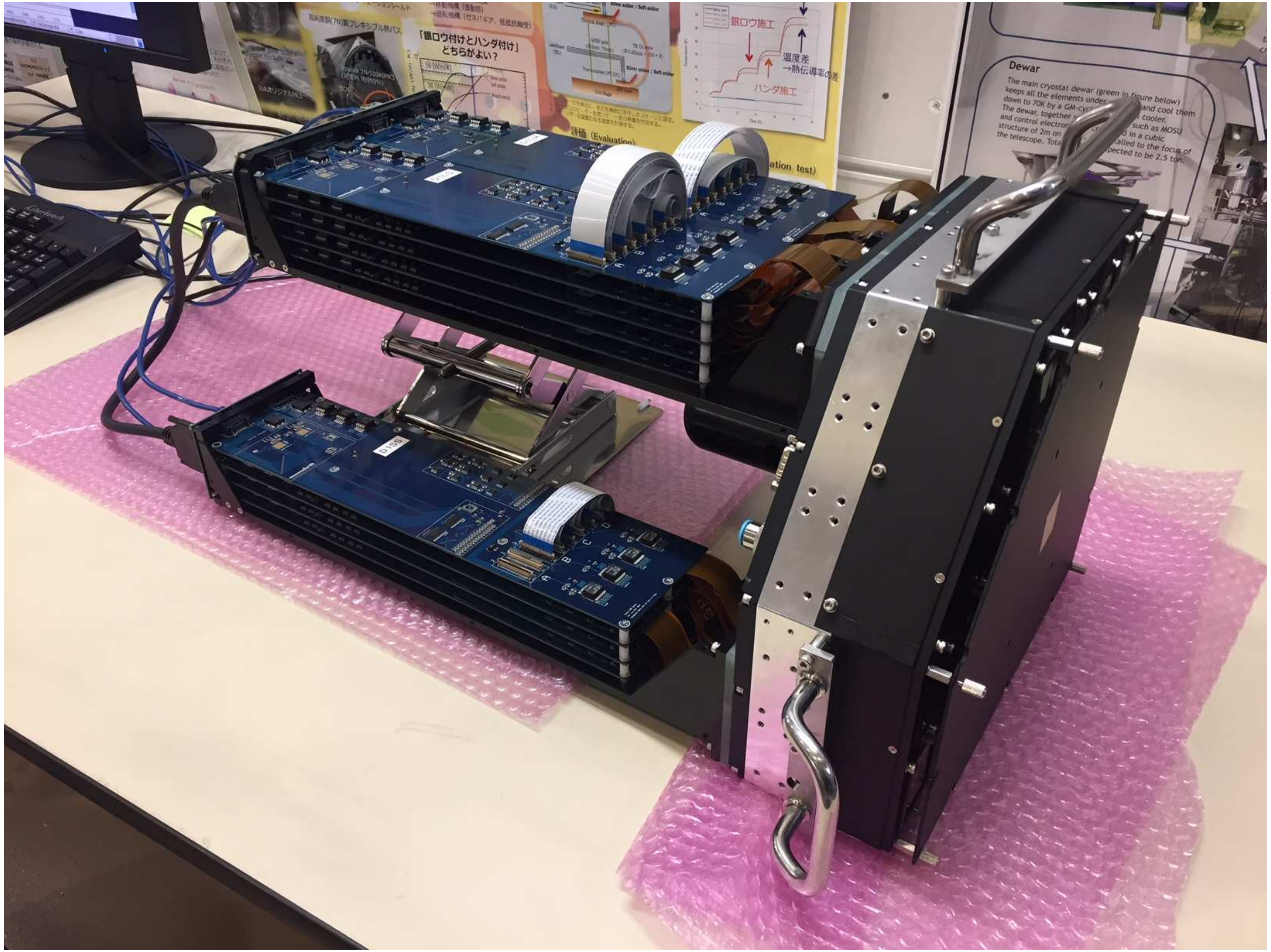
Timeline



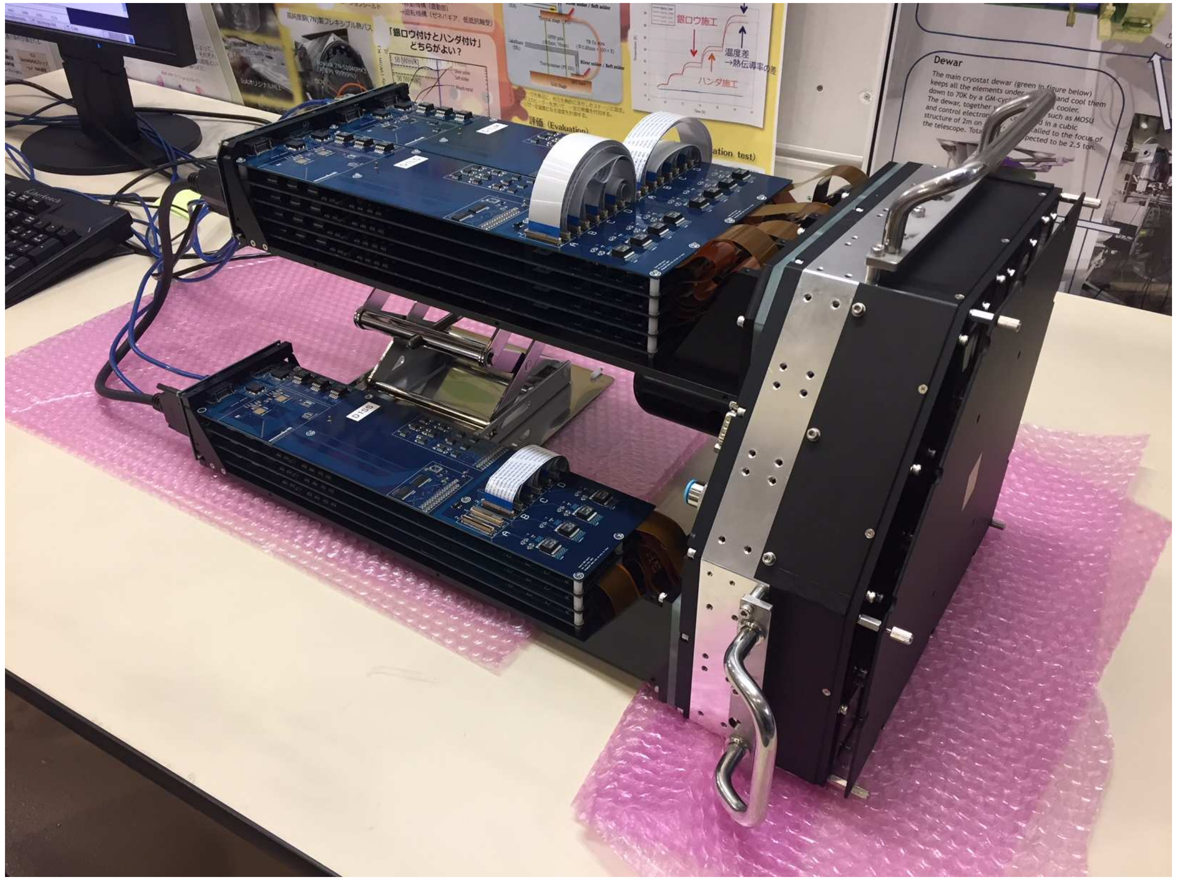
2013
2014
2015
2016
2017
2018
Sensor Development
Sensor Evaluation
Prototype Design
PM Assembly
PM Observation
8-chip first light
Camera Design
Assembly
Observation
21-chip first light
84-chip first light






「銀ロウ付けとハンダ付け」
どちらがよい？
銀ロウ施工
温度差
→熱伝導率の差
ハンダ施工
評価 (Evaluation)
Dewar

Current Status



Specifications

# of sensors	21 sensors
total FOV area	~ 5 sq-degree
readout noise	~ 2 e^- at 2 Hz
sim. operation	confirmed
sensor alignment	to be confirmed
GPS sync.	implemented
partial readout	implemented
control software	on going
data reduction	on going

First light with 21 sensors is scheduled on Feb. 19, 2018

Data Release Plan

Data release plan is now under discussion.

Possible schedule:

- development of the observation management system **~early-2018**
- two-dimensional FITS files available **early-2018~**
- all sky photometric catalog available **mid- or late-2018~**
- other products available **2019~**

People in collaborations will be allowed to acccess the data.

- VPN accounts will be issuued for the collaborators (under discussion).

KOOLS-IFU & Tomo-e Gozen

Quick spectroscopic follow-up observations

Possible Observations

1. All-Sky Transient Survey (c.f. Morokuma-san's talk)
   monitoring a 10,000 sq-deg sky in a 2 hours, to detect ~18-19 mag. transients
   about 1,000 typical SNe and 5 SN Shock Breakout detected per year

2. High-cadence monitoring to detect fast transients
   survey of Trans Neptunian Objects; monitoring of active star-forming region
   survey of disintegrating planets wround WDs; extremely short-timescale transients

3. Follow-up observations to localize transient events
   localization of gravitational wave EM counterparts, fast radio bursts, and others

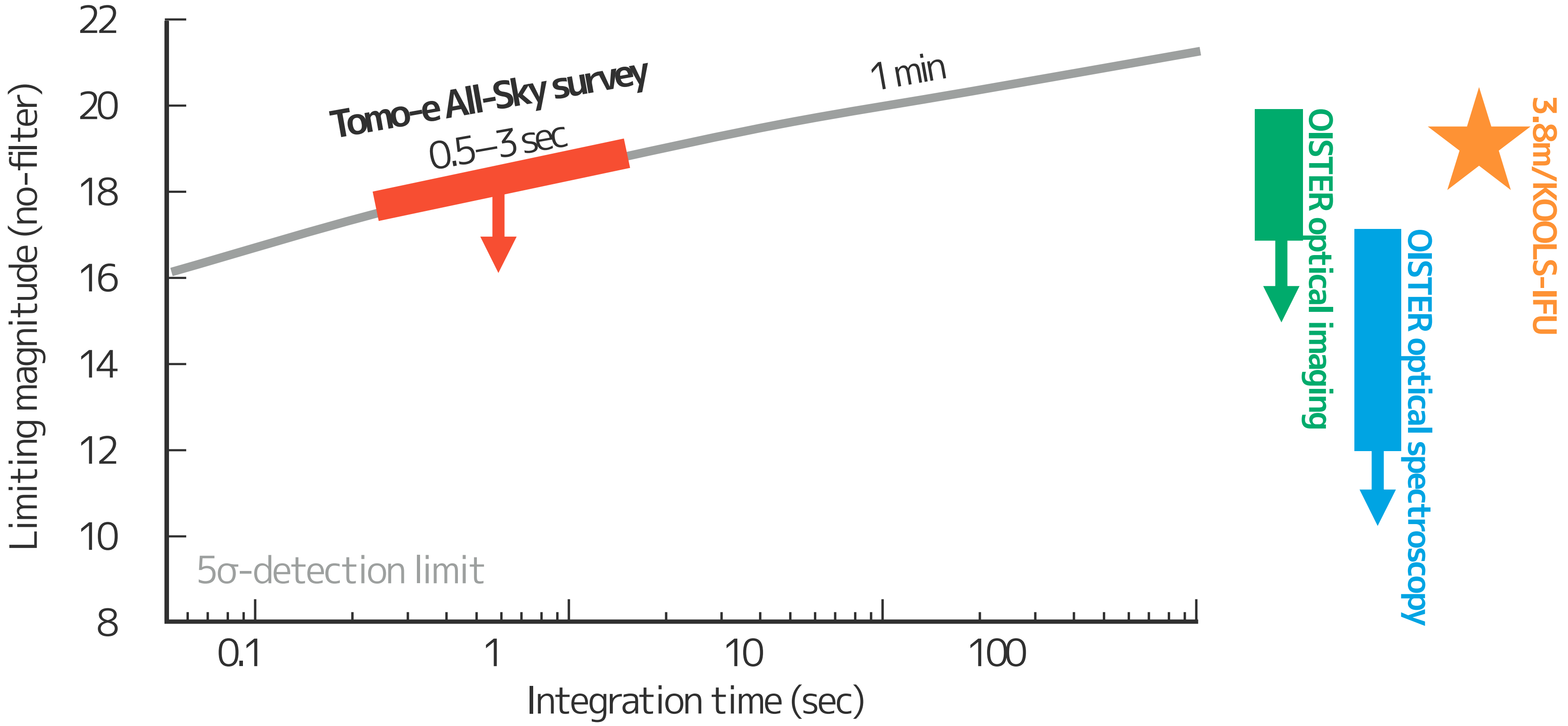
4. Coordinated observations with other facilities
   meteor obs. with Kyoto Univ. MU-radar; pulsar obs. with radio telescopes

from Sako-san's presentation in the OISTER meeting in 2016

Possible Observations

Tomo-e Gozen is specialized to **detect** transients.

Facilities to **characterize** the detected transients are required.



Topics: GW counterparts

EM localization still required for spectroscopy in LIGO O3.

GW170817 (SSS17a) was identified by a 1-m telescope.

- Small but wide-field telescopes have chances to detect counterparts.

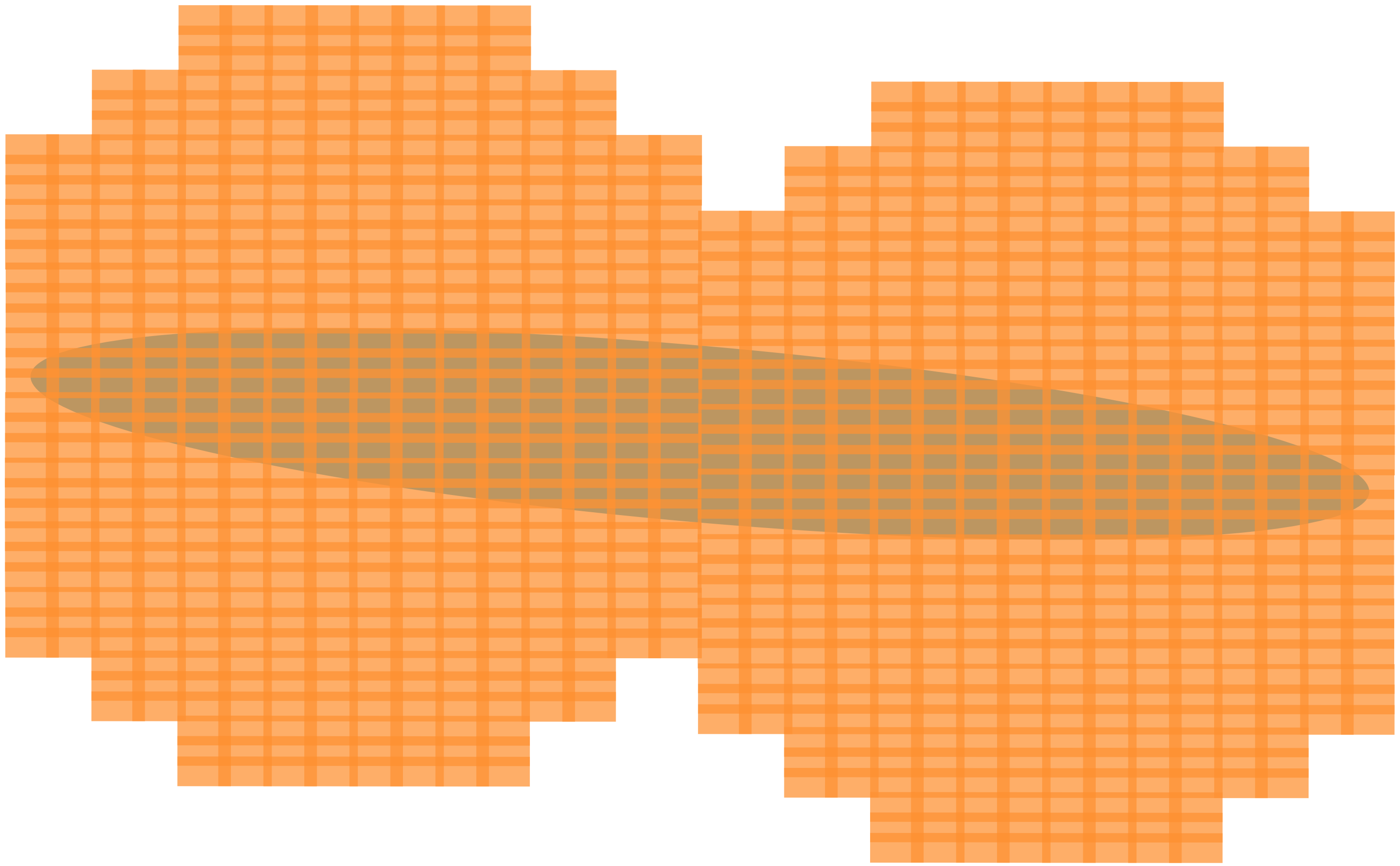
Other facilities: LSST, DeCam, Pan-STARRS, ZTF, etc...

- Quick (within the same night) follow-up observations are required.
- How many candidates will we have?

Topics: GW counterparts

Error circle of GW170817: **~2×15 deg** **≒ 12 Tomo-e Gozen**

decision-making timescale ~ 1 hour (5 min x 12 position)

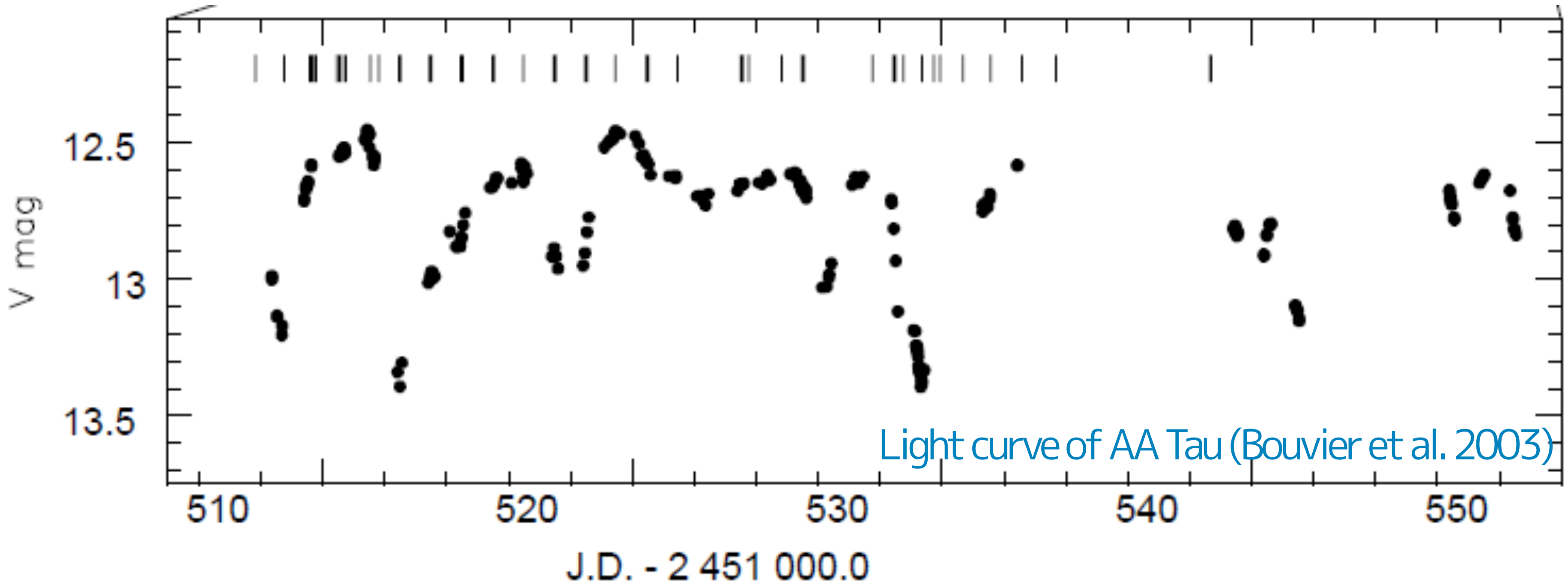


Topics: Yound Stellar Objects

High cadence observation

↳ physics of the innermost region of accretion disks

AA Tau-type stars: accretion along with magnetic fields

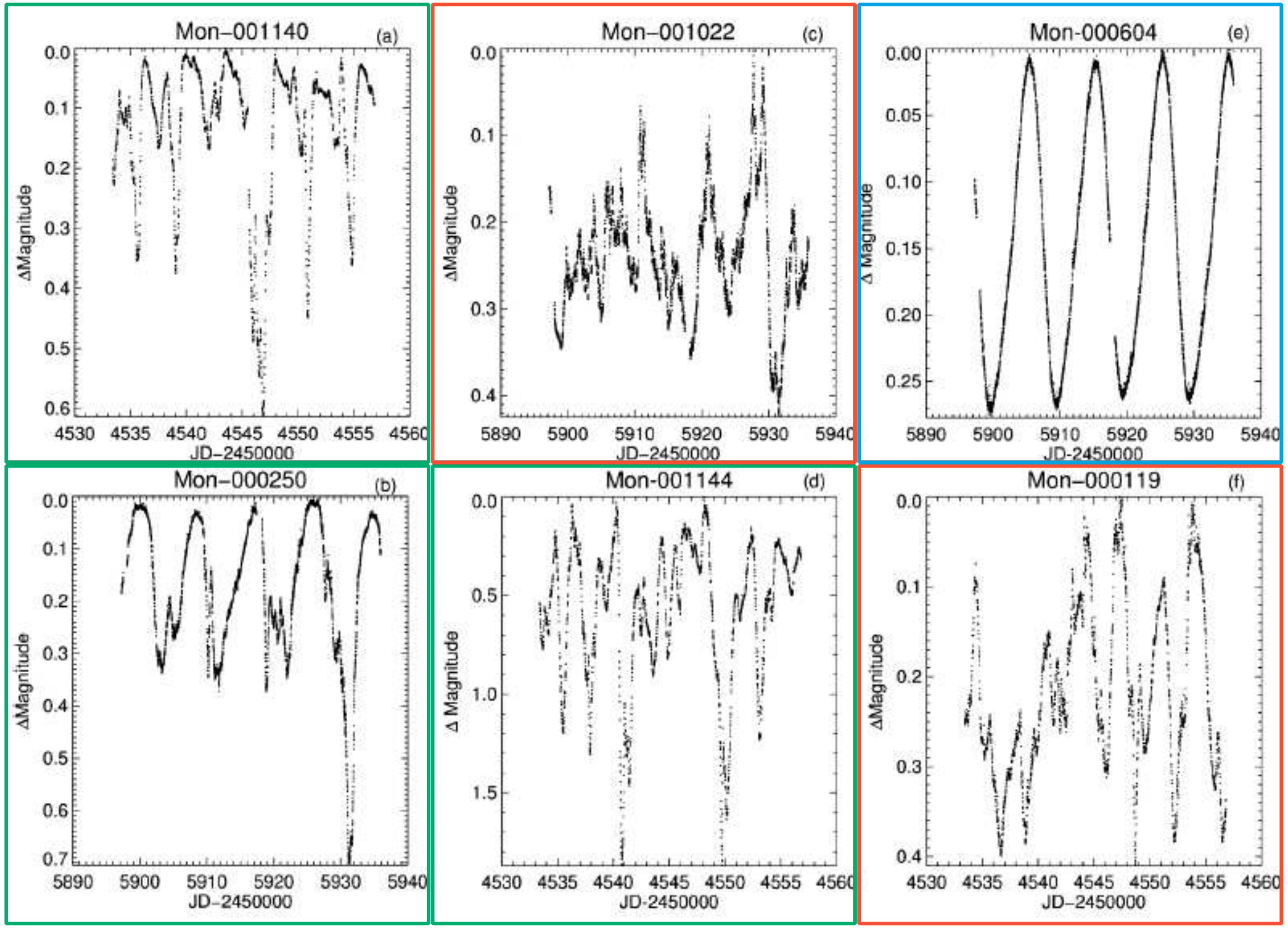


Light curve of AA Tau (Bouvier et al. 2003)

c.f. the presentation by T. Mori in Kiso Schmidt Symposium

Topics: Yound Stellar Objects

Monitoring observations by Corot (Mcginnis et al., 2015)



Typical timescale: **hours – days**
Typical variation: **0.1 – 1 mag.**

Blue: periodic (stellar spots)
Green: quasi-periodic (AA Tau-like)
Red: ramdom (non-static accretion)

c.f. the presentation by T. Mori in Kiso Schmidt Symposium

Topics: Yound Stellar Objects

AA Tau-type stars: 0.1–1 mag. in a timescale of few hours–days

Monitoring observations by Corot (Mcginnis et al., 2015)

Simultaneous spectroscopic observations

↳ accretion geometry can be investigated by **"veiling" effect**

Spectroscopic follow-up of **accretion burst** objects

c.f. the presentation by T. Mori in Kiso Schmidt Symposium

Topics: Debris around WDs

dirty WDs (~50%): accretion of debris

WD 1145+017

- transits detected by Kepler, follow-up by ground-based telescopes
- asteroid at the distance of tidal disruption

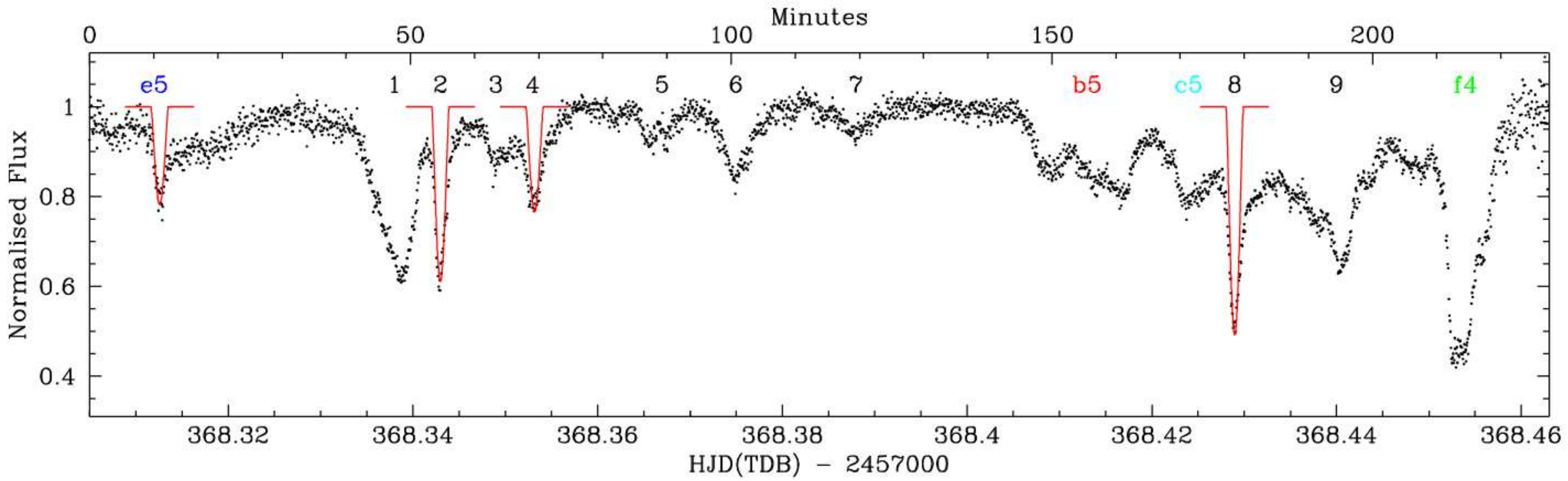


Figure 1. TNT/ULTRASPEC high-speed (5 s) photometry of WD 1145+017, obtained over 3.9 hr on 2015 December 11, illustrating the varied and complex nature of the multiple transit events. Many of the broader transits display sub-structure that appears to be the superposition of several shorter events, e.g., #4 and b5. Transits labeled in color can be tracked in phase across multiple nights (see Figure 2). Simple transit models are overlaid in red, see Section 4 for details.

Topics: Debris around WDs

monitorings of Galactic Plane by Tomo-e Gozen

↳ identify WDs showing short-time variations

↳ coordinated spectroscopic follow-up by KOOLS-IFU

Cataloged WD ~ 13,000 obj. (McCook & Sion, ApJS, 1999)

note that these WD are heavily biased in SDSS regions
Gaia will provide a more complete catalog of Galactic WDs

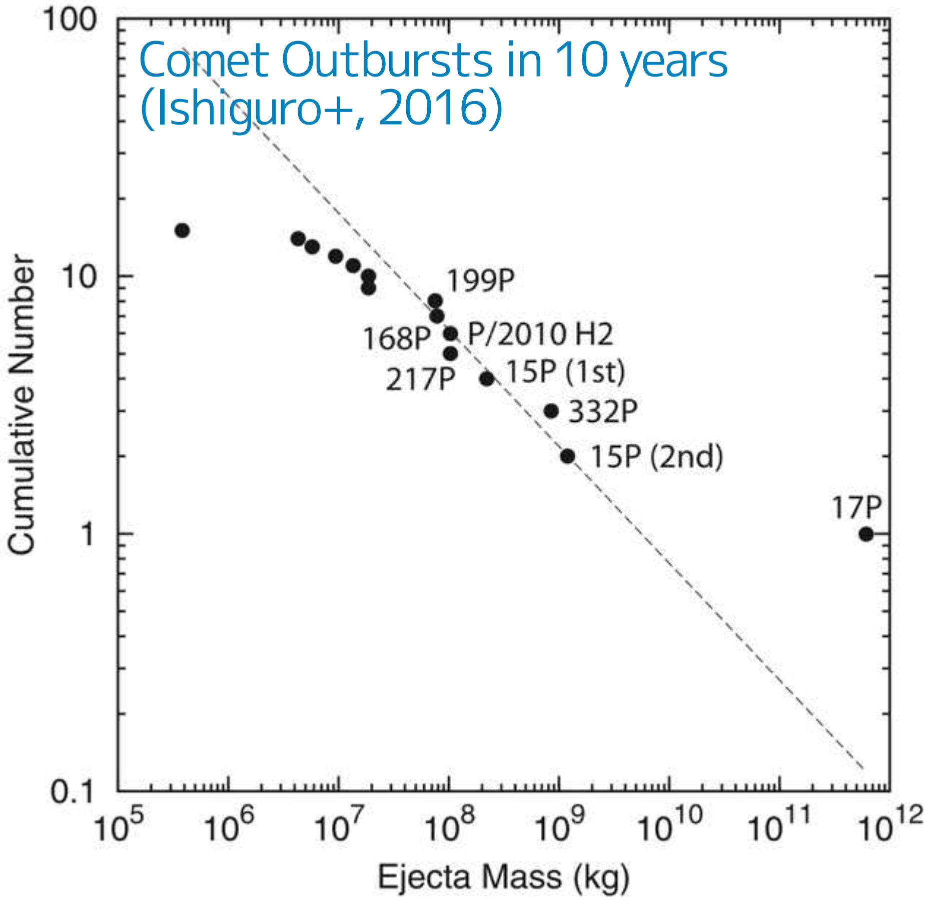
more than 100 WD should be monitored

$13{,}000 \times (\underbrace{20}_{\text{tomoe}} \ / \ \underbrace{41{,}000}_{\text{all-sky}}) \sim 6.3$ WDs in Tomo-e's FOV

Topics: Outbursts in Solar System

Outbursts of comets and asteroids

most plausible way to investigate primordial materials in Solar System



Comet outbursts: **~1.5 yr^{-1}**

Asteroid impact events: **a few yr^{-1}**

Asteroid rotational breakups: **~10 yr^{-1}**

↳ can be detected in Tomo-e SN survey

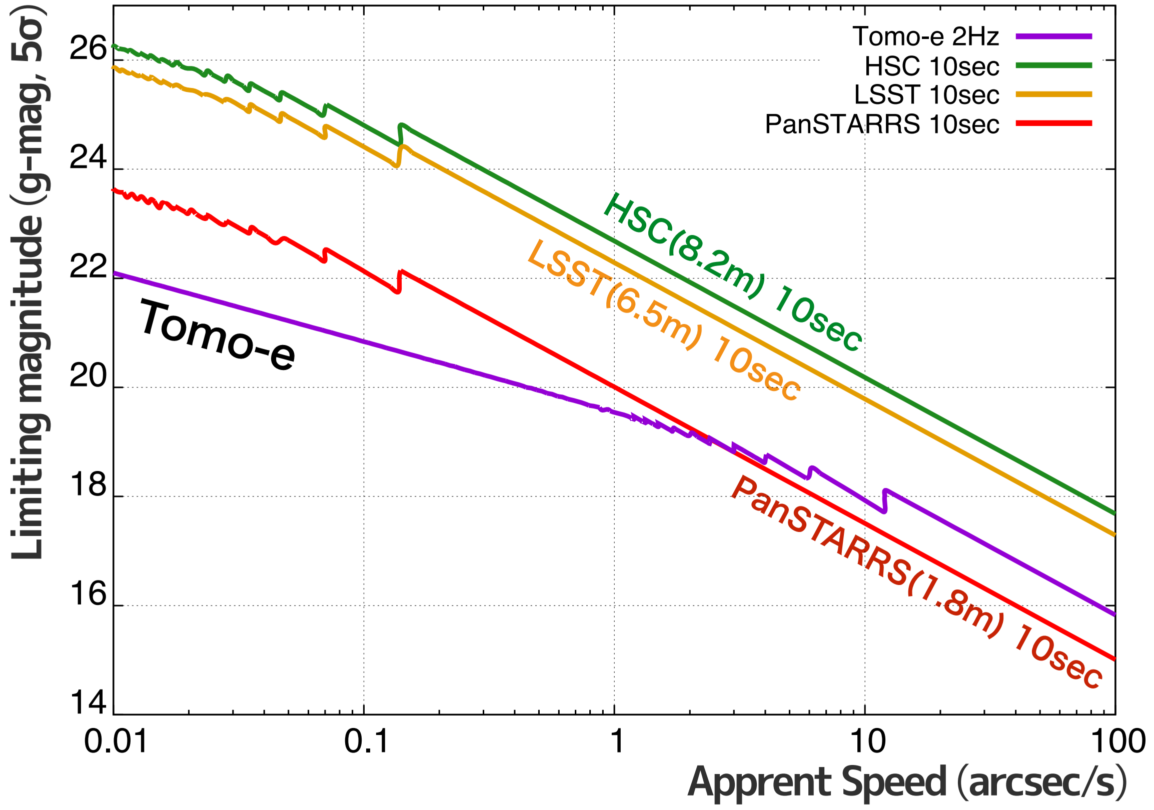
↳ as frequent as SN shock breakouts

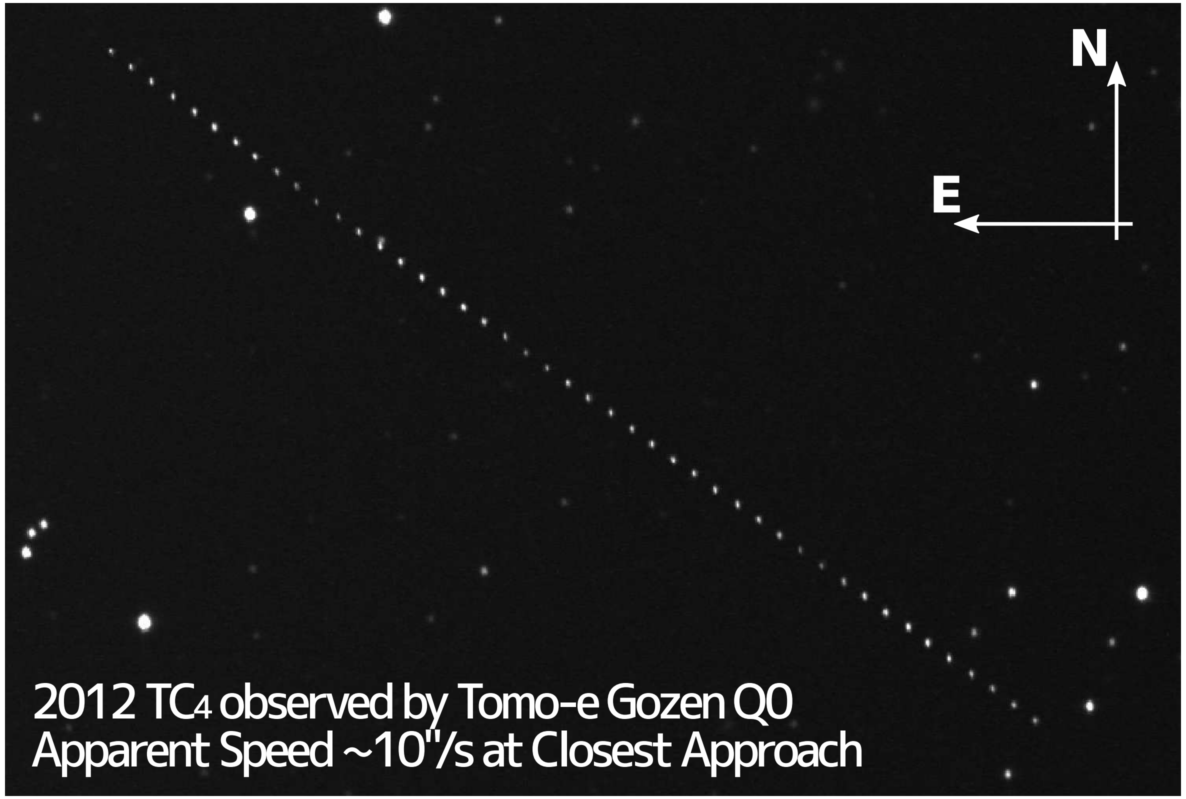
c.f. the presentation by M. Ishiguro in KOOLS-Tomoe WS

Topics: Near-Earth Asteroids+α

2Hz observations ⇉ efficient in detecting fast moving objects

no trail loss, high position accuracy, self follow-up observation





c.f. the presentation by Y. Kojima in Kiso Schmidt Symposium

Topics: Near-Earth Asteroids+α

Flash spectroscopy of Near-Earth Asteroids

determine the asteroid types of the near-earth asteroids

moving & large positional uncertainty ⇉ a potential advantage in IFU

Don't miss the next 1I/´Oumuamua

the first interstellar asteroid detected in 2017

extremely rare chances to investigate small bodies outside of Solar System

c.f. the presentation by Y. Kojima in Kiso Schmidt Symposium

Summary

1. Tomo-e Gozen's first-light in **2018**

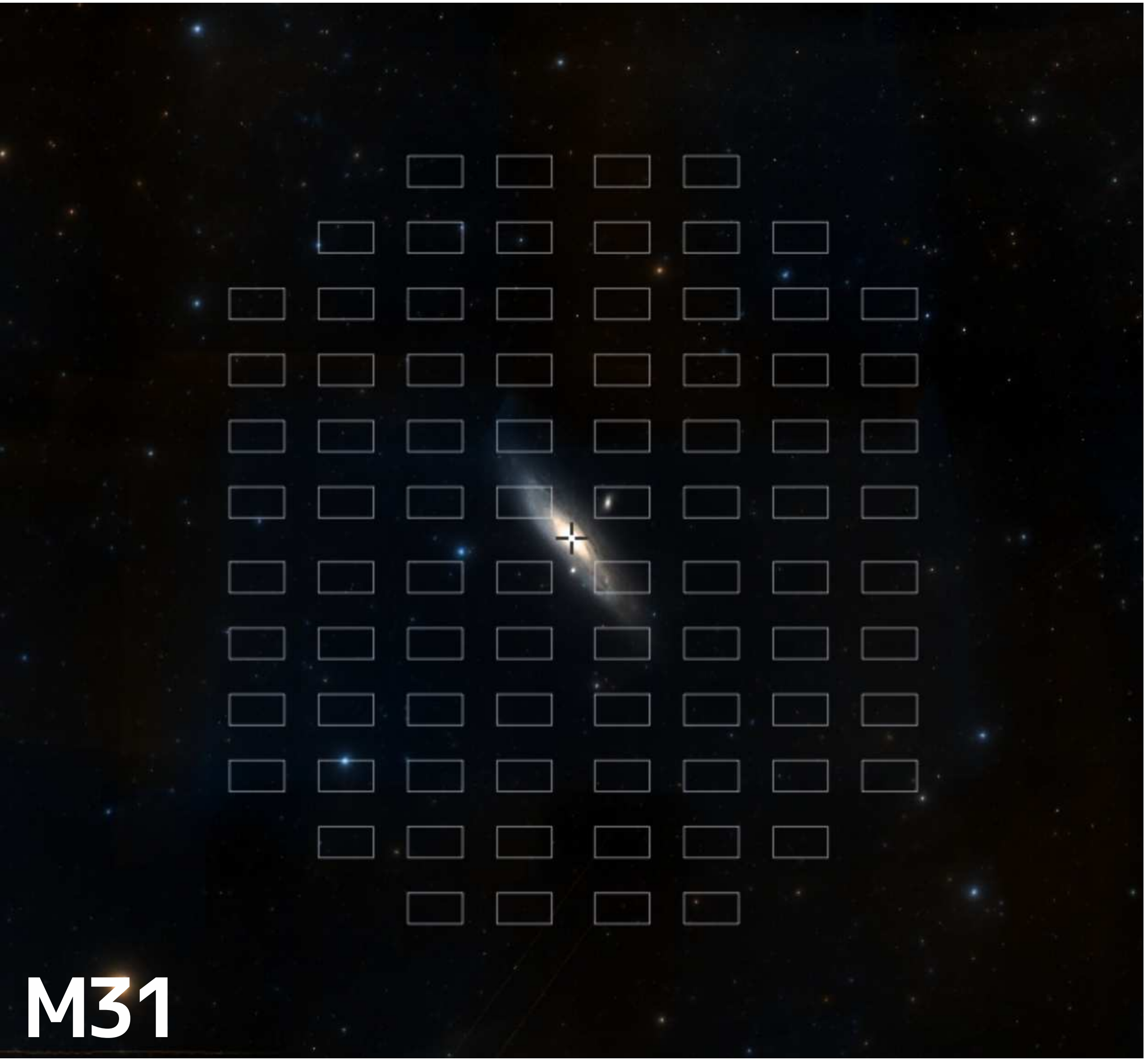
Commissioning observation with 21 image sensors in Feb. 2018
The second module will be ready in late 2018.

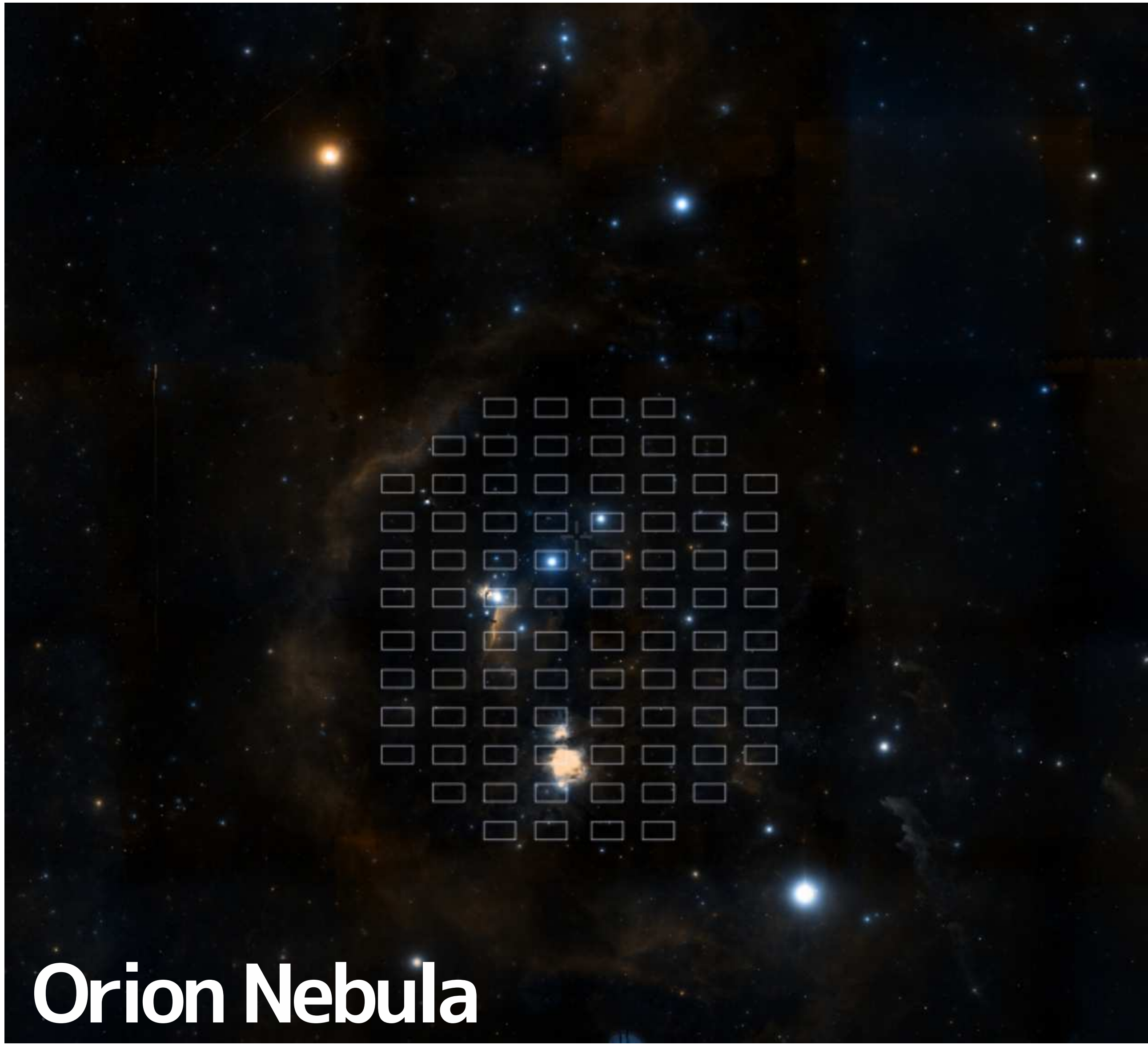
Sensor format	2160×1200 pix chip^{-1}	Field of view	$39'.7 \times 22'.4 \times 84$ chips
Pixel scale	19 μm, $1''.189$ pix^{-1}	Wavelength	350–700 nm (peak at 500 nm)
Frame rate	2 Hz (max, continuous, full frame)	Filters	optical broadband (transparent)
Read noise	~ 1.9 e^- at 2 Hz	5σ lim. mag.	~ 18.5 mag. in 0.5 sec exposure

2. ToO or Coordinated observations with KOOLS-IFU

Tomo-e Gozen needs KOOLS-IFU to characterize transient objects.

ToO follow-up: GW counterparts, YSOs, Near-Earth Asteroids, Outbursts
Coordinated observation: debris around WDs


M31


Orion Nebula


Galactic Center