Tomo-e Gozen突発天体サーベイと連携した
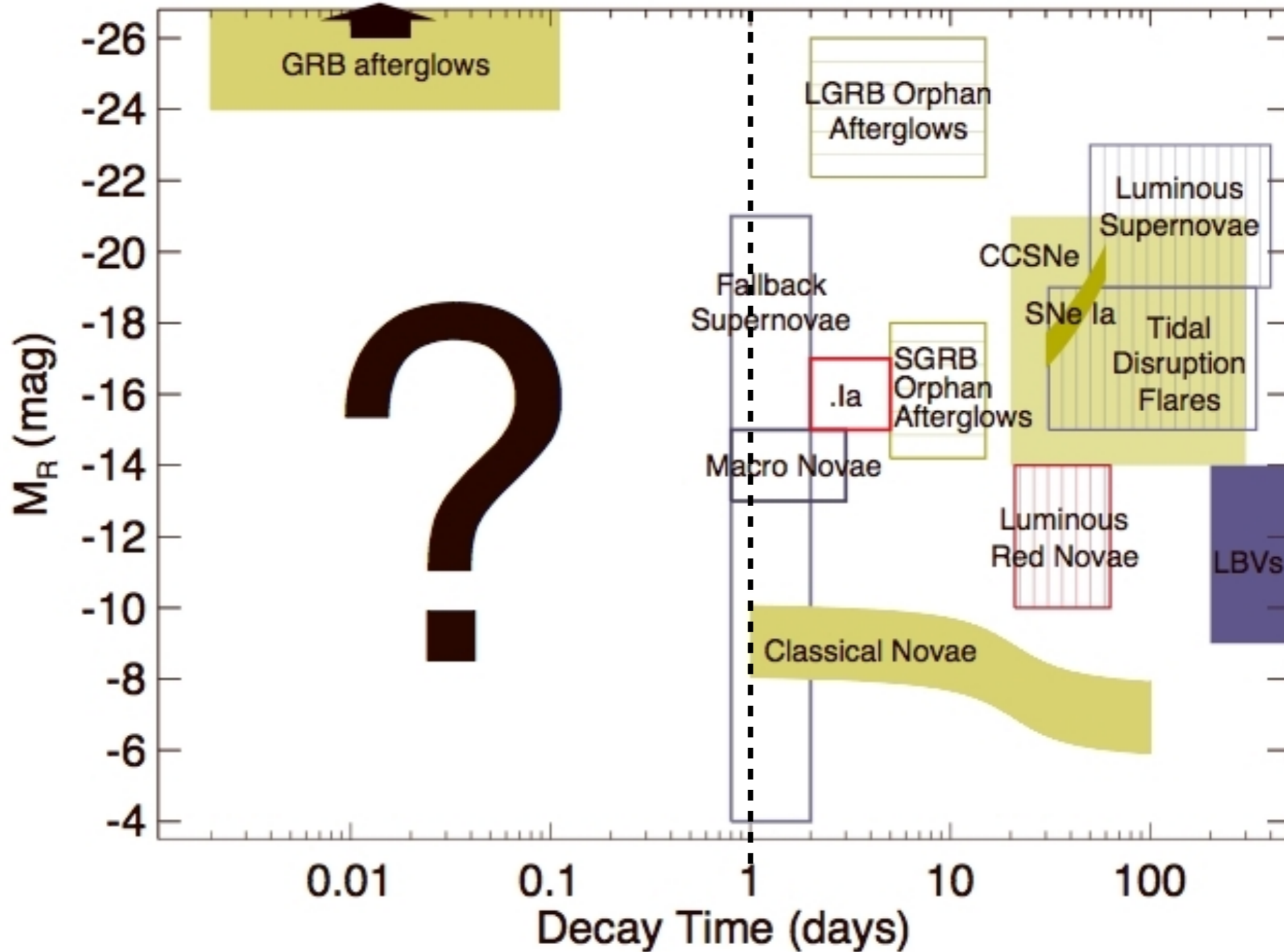
Rapid Transientの観測

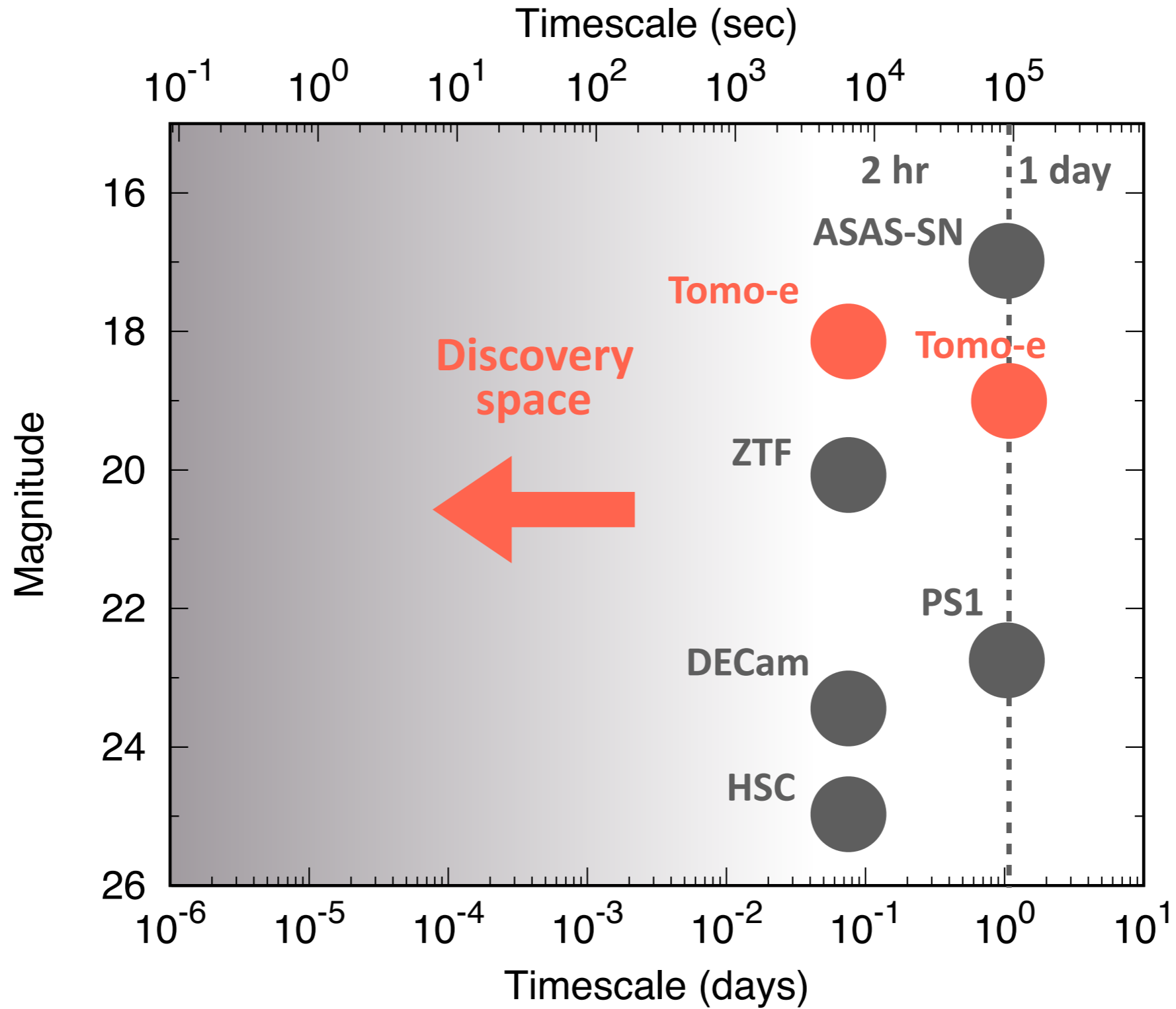田中 雅臣 (東北大学)
on behalf of Tomo-e Gozen Transient Survey Team

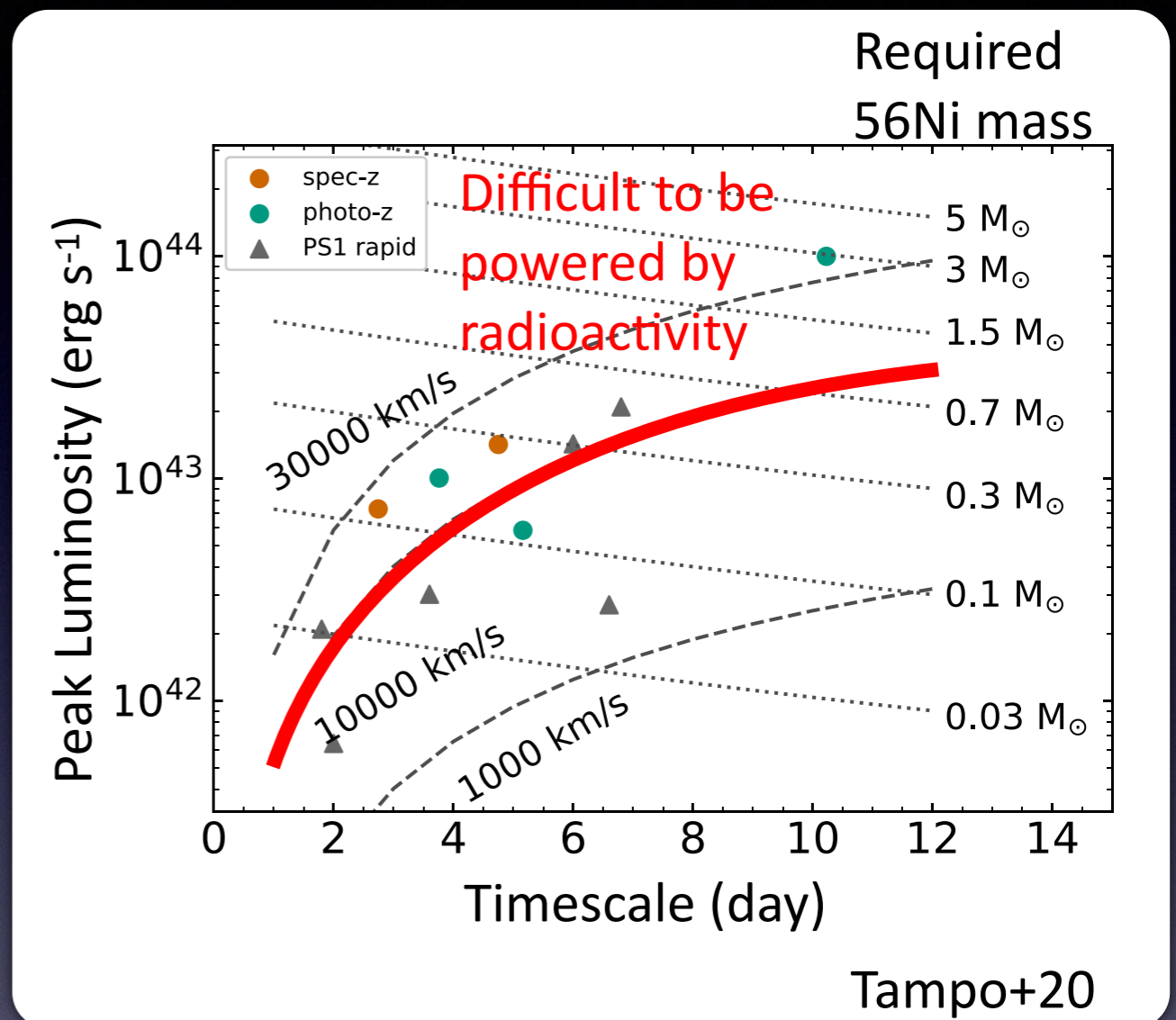# Frontier of transient sky

LSST Science Book (after Rau+09, Kasliwal+,Kulkarni+)

Transient survey

Discovery of rapid transients
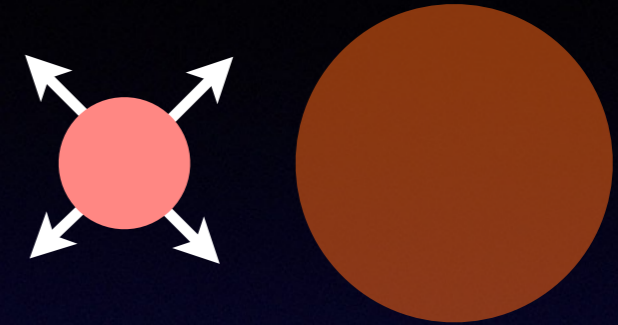

Drout+14

Tampo+20
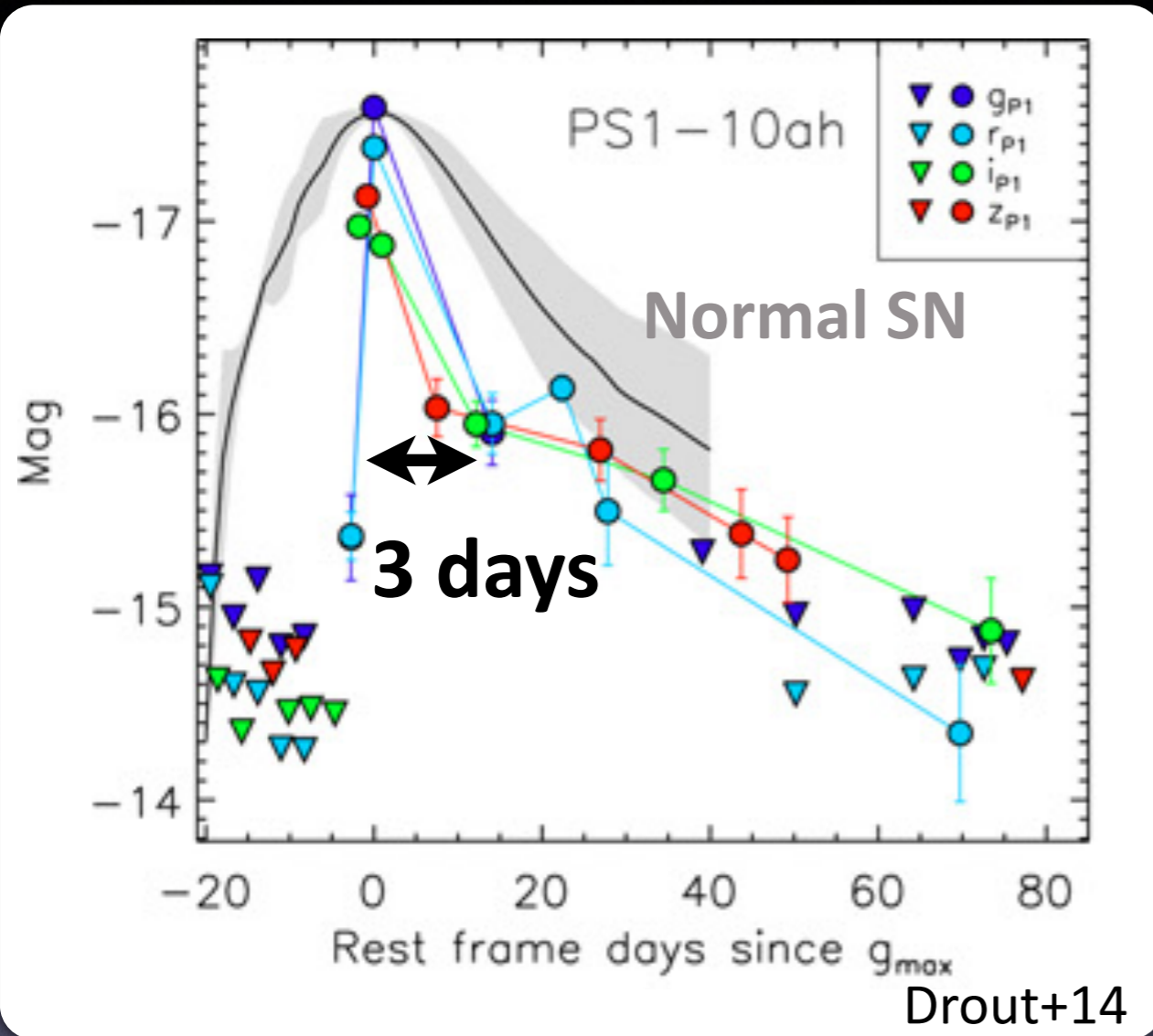
Compared with supernovae:
- Similar luminosity (w/ large diversity)
- Shorter time scale (= small mass involved)
- ~5 % event rate

Origin of rapid transients?

- **Ultra-stripped envelope SN?**

  - Mej ~0.1 Msun by binary interaction
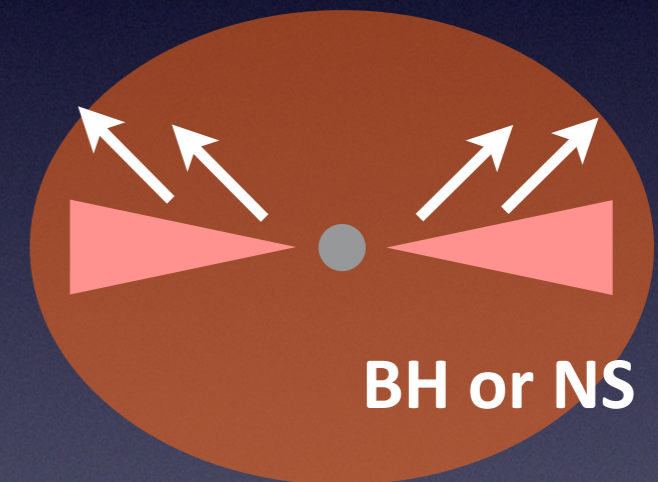   (e.g., Tauris+13, Moriya+17)
    a route to neutron star merger?

- **BH-forming supernovae?**

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

- **...?**

  Moderate samples so far
  Drout+14 (PS1, 2m), Pursiainen+18 (DES, 4m), Tampo+20 (Subaru, 8m)

  => Difficult to perform spectroscopy
  Need nearby, bright objects for spectroscopy

Mej ~ 0.1 Msun

Mej ~ 0.01 Msun

BH or NS

Tomo-e Gozen Transient Survey (2019/4-)
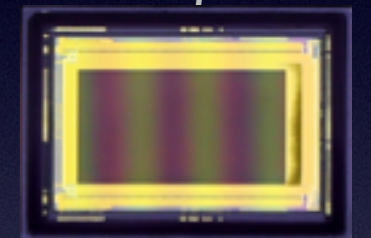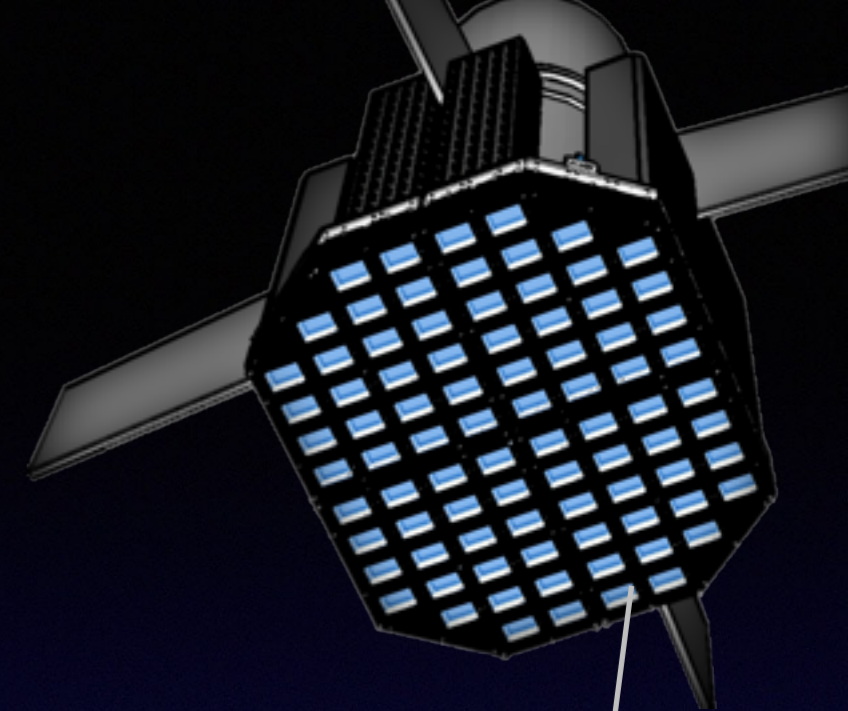
- **Tomo-e Gozen @ Kiso Schmidt**
  - 84 CMOS sensors, no filter
  - 20 deg² FOV
    => Multi-messenger follow-up
    (Gravitational wave, IceCube neutrino)

- **Survey strategy**
  - 7000 deg2
  - 2 hour cadence
  - 0.5 sec x 12 = 6 sec exposure
    => 18 mag (5 sigma)
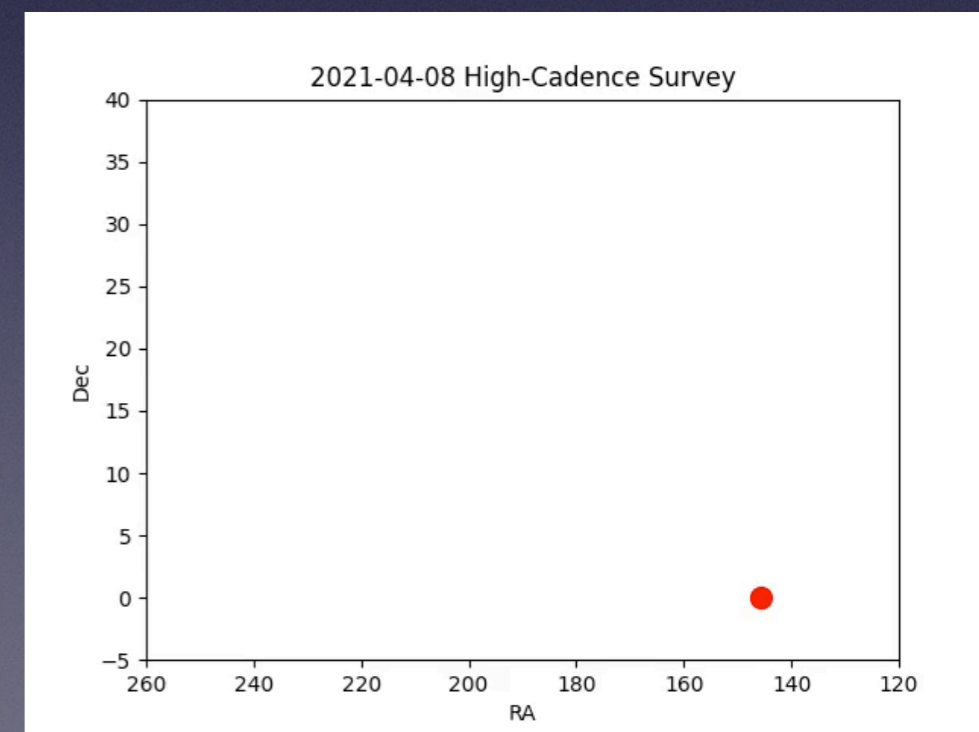 - ~ a few rapid transients / 0.5 yr (< 200 Mpc)

- **Follow-up with Seimei**
  - 19A-21A (PI: Morokuma) KOOLS-IFU
  - 21B (PI: Tanaka) KOOLS-IFU + TriCCS

High-sensitivity CMOS video sensors

Pointing pattern

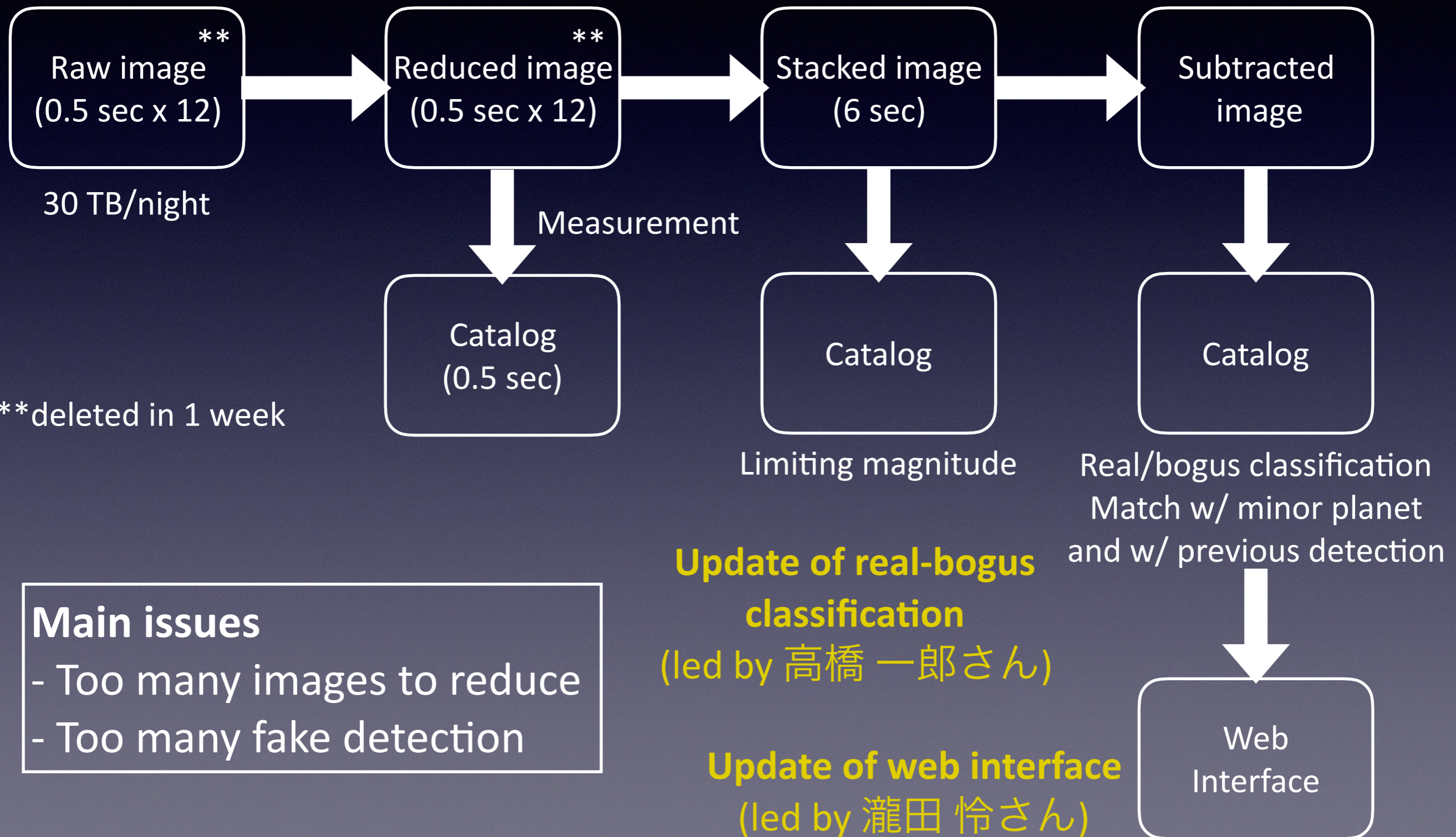

Pedroso, Ikeda, et al. in prep.

Data flow

Standard reduction
(+ astrometry)

Stack

Image subtraction
(PS1, r-band)

Raw image
(0.5 sec x 12)

Reduced image
(0.5 sec x 12)

Stacked image
(6 sec)

Subtracted
image

30 TB/night

Measurement

**deleted in 1 week

Catalog
(0.5 sec)

Catalog

Catalog

Limiting magnitude

Real/bogus classification
Match w/ minor planet
and w/ previous detection

**Update of real-bogus
classification**
(led by 高橋 一郎さん)

Main issues
- Too many images to reduce
- Too many fake detection

Update of web interface
(led by 瀧田 怜さん)

Web
Interface

Challenges in transient detection

New — Old = Difference

Examples of difference images

Fake — Cosmic ray

Real

Fake — Imperfect convolution

Fake — Saturation

Fake — Cosmic ray

Fake — Imperfect alignment
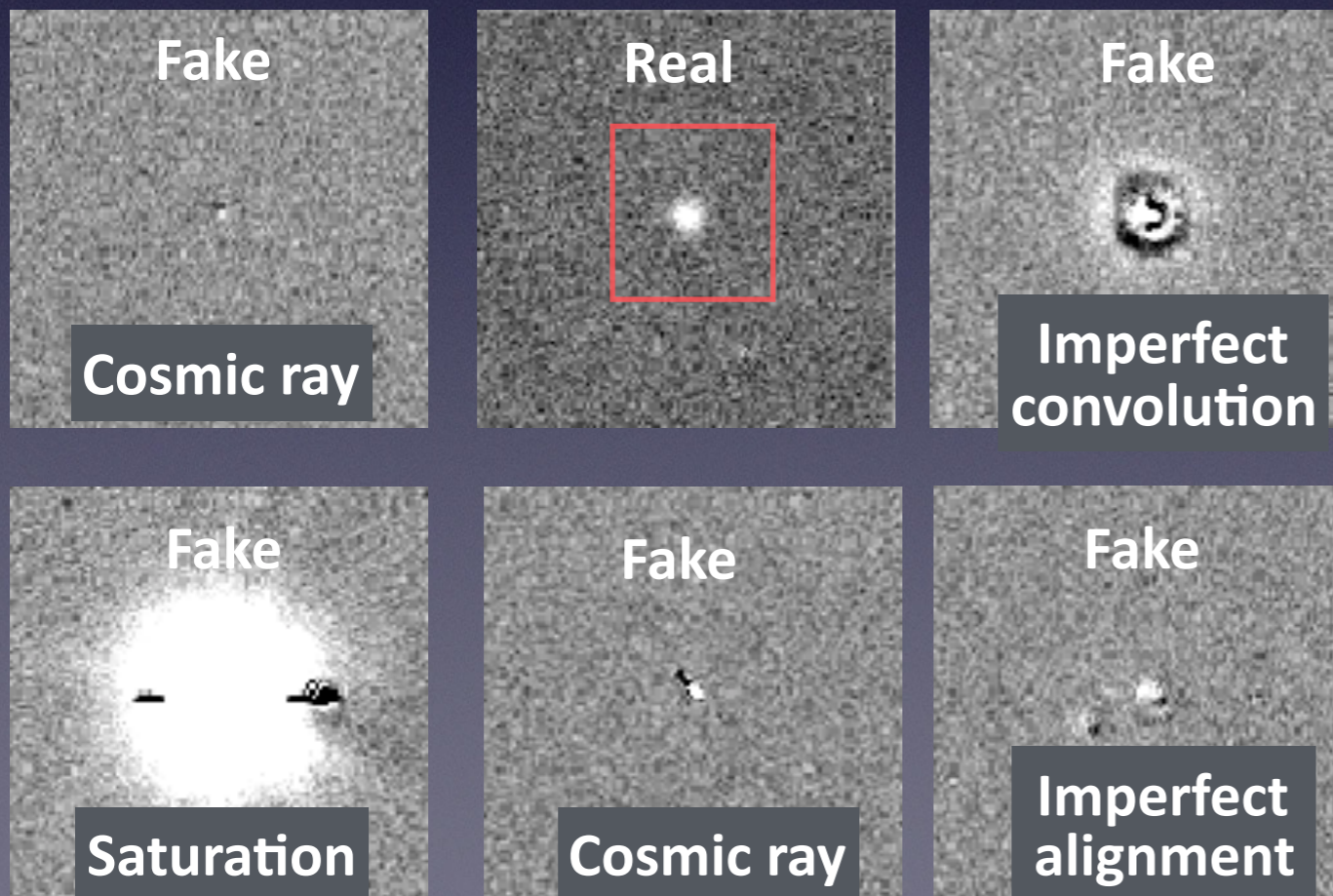
**Fake/Real >> 1000
=> 1% false positive rate
is not good enough**

Classification with Convolutional Neutral Network (CNN)

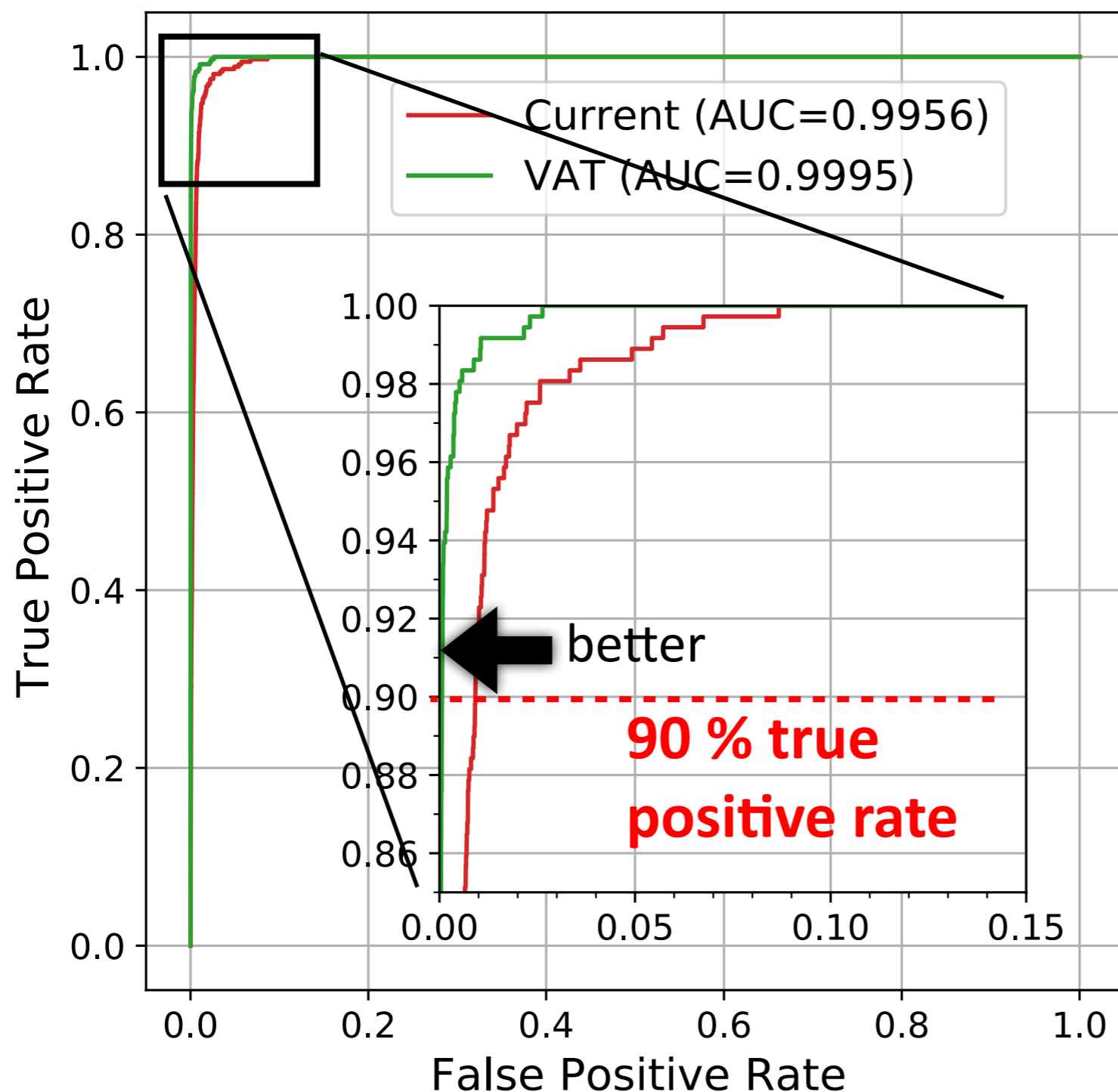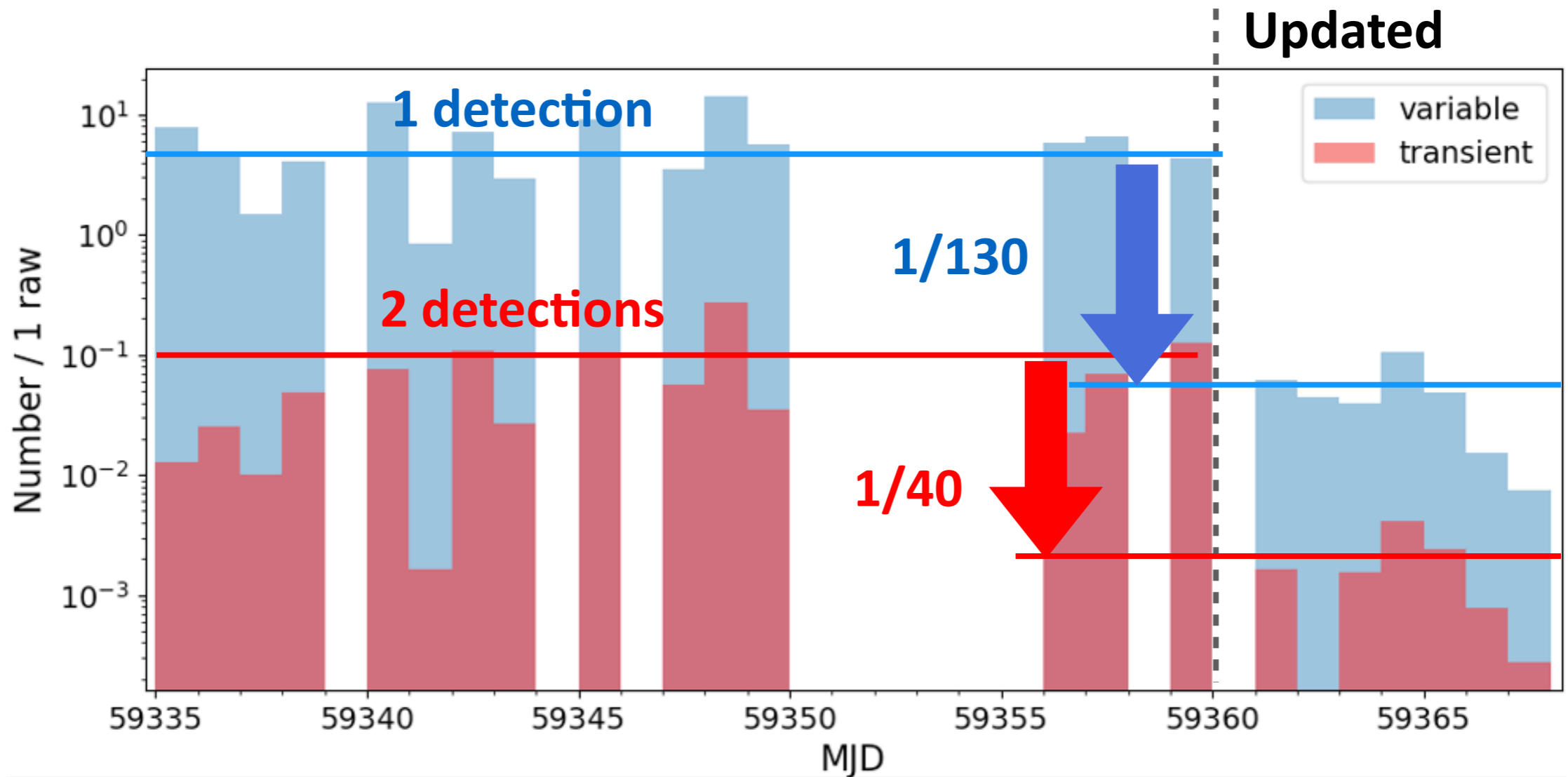Initial development: 浜崎 凌さん (甲南大)
Performance update: 高橋 一郎さん (東北大)

Figure by Ichiro Takahashi

False positive rate = 0.0006 (at 90 % true positive rate)

Performance of new machine

Figure by Ichiro Takahashi

Updated

1 detection

2 detections

1/130

1/40

variable

transient

Number / 1 raw

10^1

10^0

10^{-1}

10^{-2}

10^{-3}

59335   59340   59345   59350   59355   59360   59365

MJD

~100,000 images /day

=> ~150 transient candidates / day = manageable number!

Deep coadd reference for 20,000 deg² sky (PS1 => Tomo-e)

Led by 新納 悠さん (東京大)
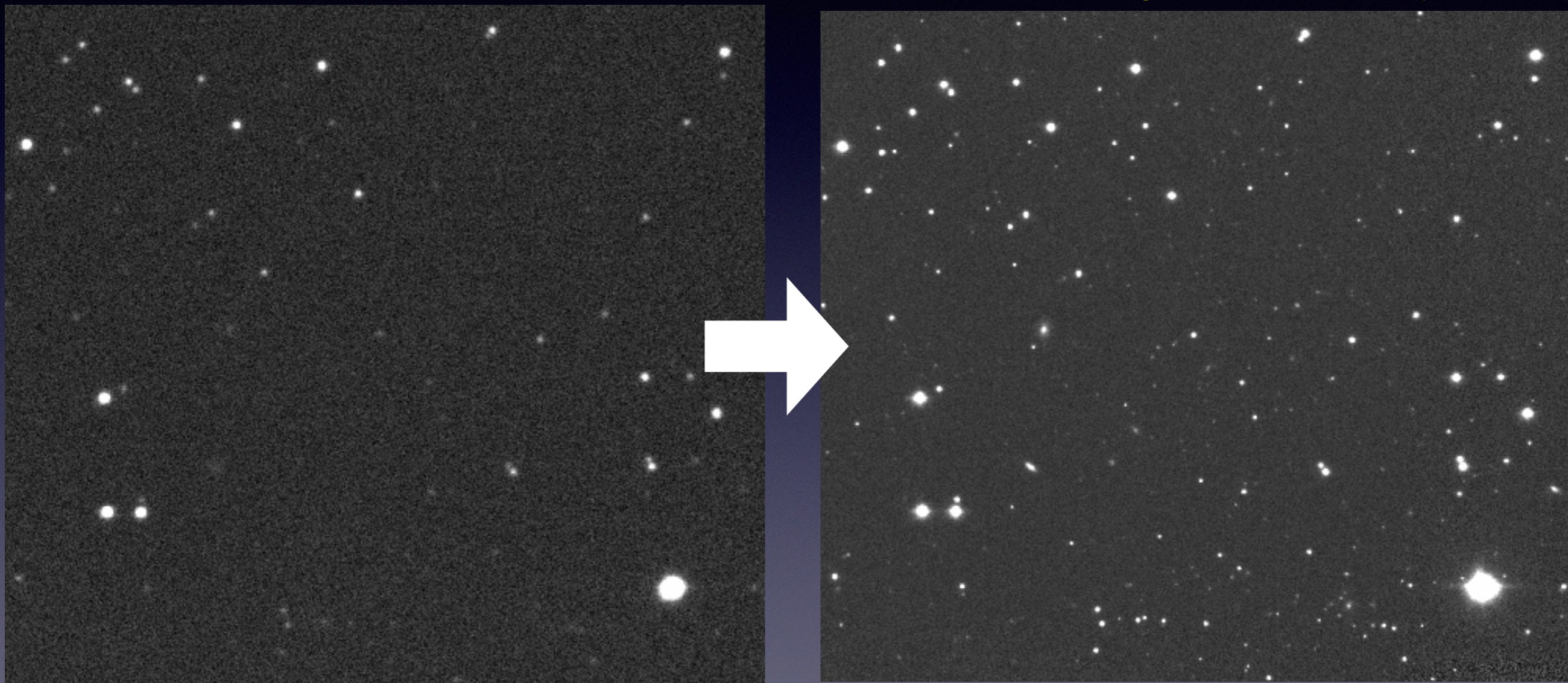
Further improvement in real-bogus classification (identical response) => automatic alert for high-confidence candidates 前田さん講演

Web interface

Toward higher time resolution
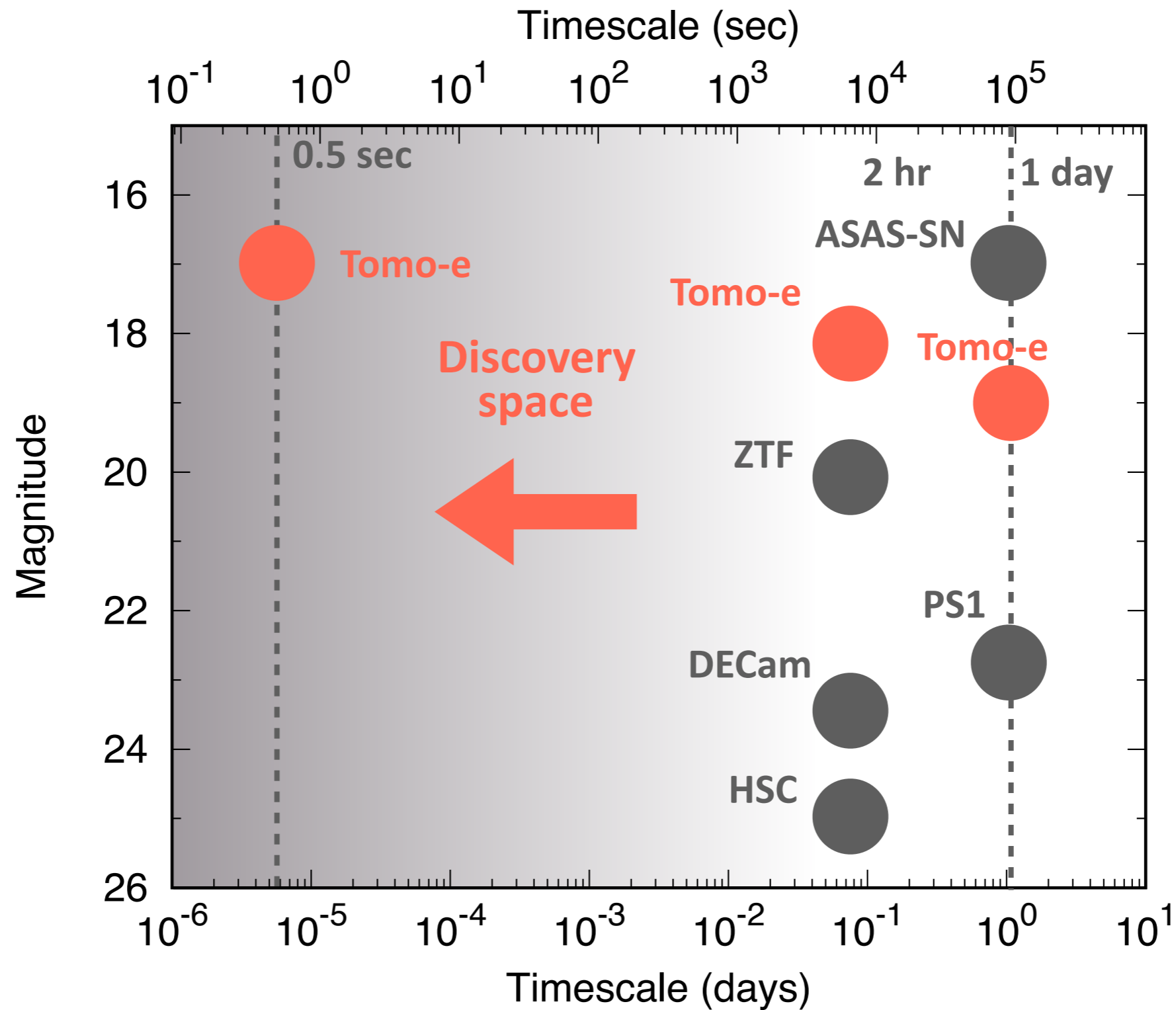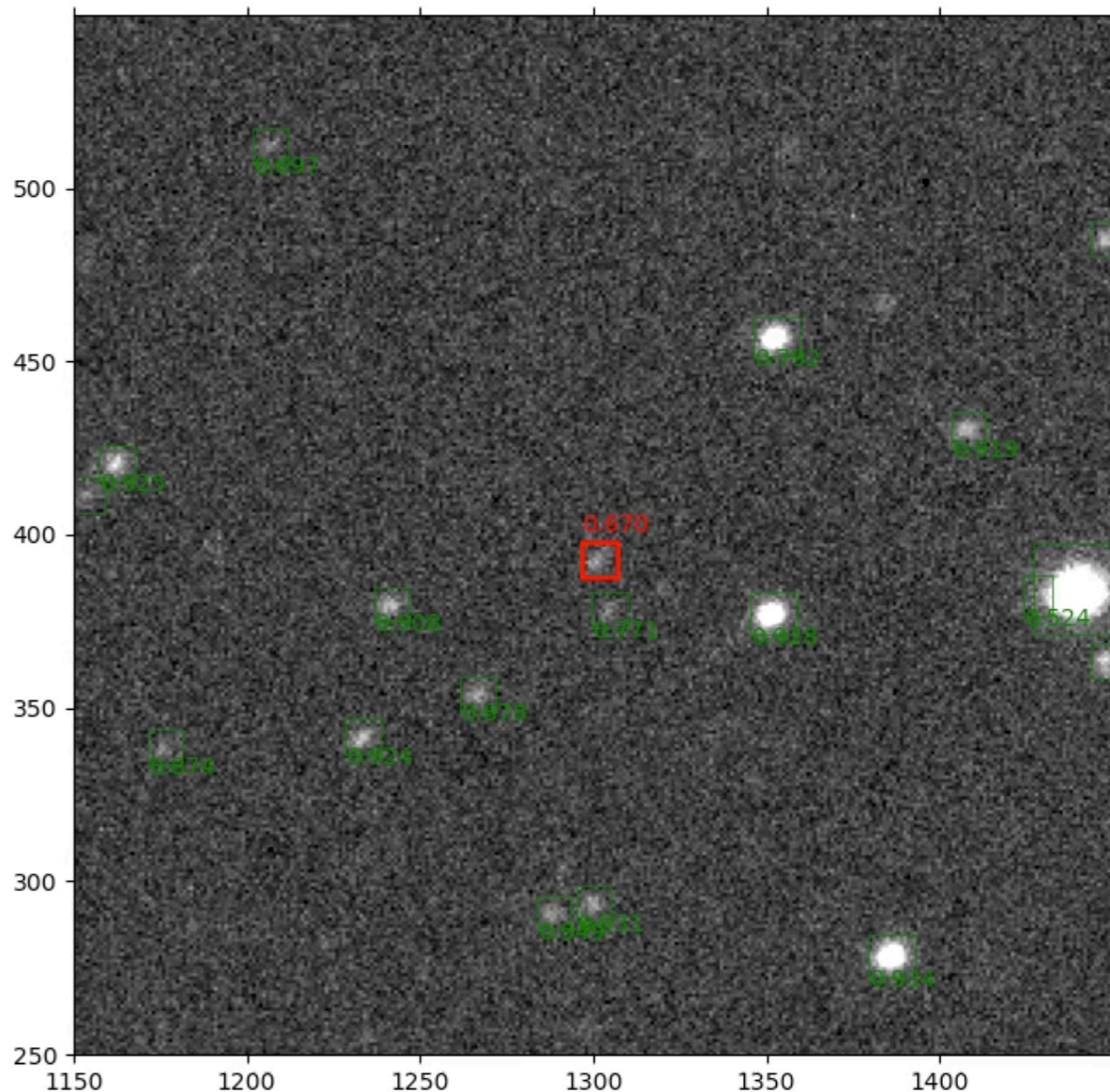
Realtime analysis of "movie"

Application of
object recognition technique
(Single Shot Multibox detector
 = SSD, arXiv:1512.02325)
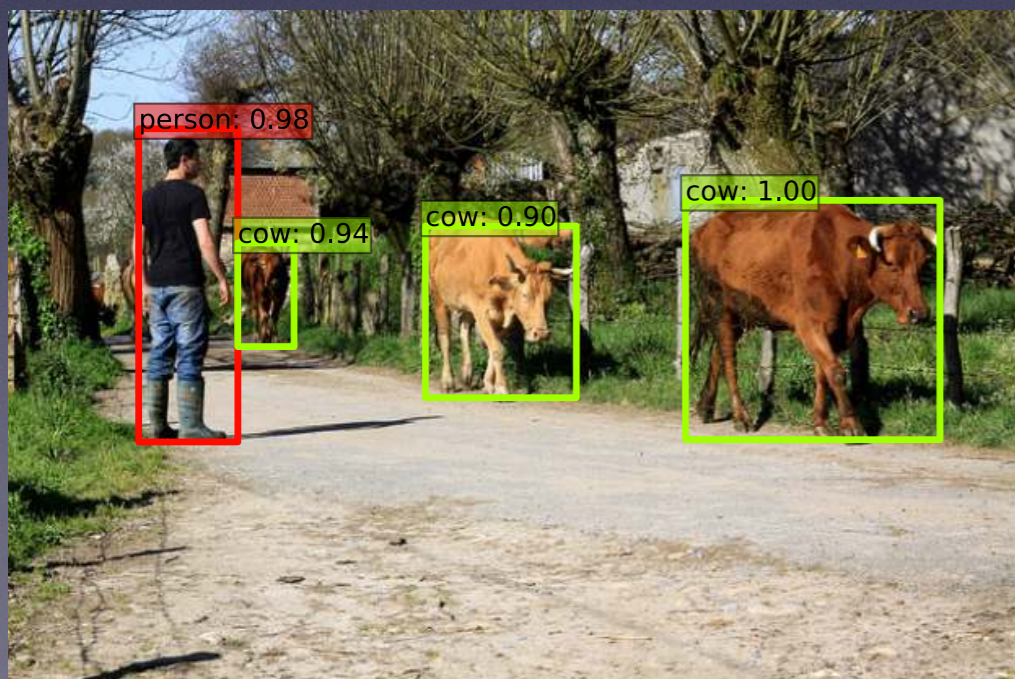
Watch out 16th frame

Summary

- **Frontier of transient sky**

  - Rapid transients: new kind of astronomical explosion

  - Need rapid spectroscopic follow-up

- **Tomo-e Gozen transient survey**

  - 7000 deg^2 - 2 hr - 18 mag

  - A number of development work in the past years

    - Data reduction pipeline, Real-bogus classifier, Coadded reference images, Web interface, Reduction of movie data

  - Feed good targets for Seimei

  - Toward automatic alert for high-confidence candidates

    昨日からの議論：「自動ToO観測」は非常にありがたいです
    = 当日観測者に負担をかけない/依存しない、迅速な分光観測の実現