Supernova survey with the wide-field CMOS camera Tomo-e Gozen

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  ➢ Key words: CMOS sensors, 20 deg² FoV, 2 fps

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**About Tomo-e Gozen**

**Tomo-e Gozen** is a wide-field high-speed CMOS camera

- **Kiso observatory, Nagano, Japan**
  - 137:37:31.5, +35:47:50.0 (Alt = 1132 m)

84 chips of CMOS sensors on the focal plane

- => 20 deg$^2$
- => 2 frames/sec

- Completed on April 23, 2019

Kiso 105 cm Schmidt telescope (f/3.1)
Evaluation of CMOS sensors

- 84 chips of CMOS sensors on the focal plane
- Canon
  - 2k x 1k pixels
  - 19 μm pix\(^{-1}\)
  - Sensitive λ range: 370 – 730 nm
- Dark current: 0.5 e-/sec/pix at 290 K
  - Much lower than sky background flux of Kiso Schmidt (50 e-/sec/pix)
- Readout noise: 2.0 e-
  - Sky background noise limited in 2 fps observations
Evaluation of CMOS sensors

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About Tomo-e Gozen

- 0.68 at a peak of 500 nm
About Tomo-e Gozen

Field-of-view

Comparison of FoV

- ZTF (1.2m), 47 deg$^2$, 2018-, $A\Omega = 40$, $\Delta \tau \sim$ days, CCD
- Pan-STARRS (1.8m), 9 deg$^2$, $A\Omega = 15$, $\Delta \tau \sim$ days, CCD
- LSST (8.4m), 9.6 deg$^2$, 2023-, $A\Omega = 320$, $\Delta \tau \sim$ hours, CCD

Tomo-e Gozen
20 deg$^2$ in $\varphi$ 9 deg
$A\Omega = 28$, $\Delta \tau \sim$ subsec
CMOS sensors
About Tomo-e Gozen

Difference between CCD & CMOS

Observable timescale & limiting magnitude

Timescale (sec)

Magnitude

Timescale (hour)

0.5 sec

CMOS: efficiency = 0.65, $N_{\text{read}} = 2 \text{ e-}$

CCD: efficiency = 0.90, $N_{\text{read}} = 5 \text{ e-}$

assuming same filter-bandwidth and pixel size
Northern transient survey with Tomo-e Gozen
Northern transient survey

Observation programs

1. Northern transient survey
   - Elv > 40 deg (7,000 deg²) every 2
   - 3-5 visits per night
   - SNe, Novae, variables

2. Follow-up / Simultaneous
   - GWs, neutrinos
   - FRBs, NSs, BBHs, meteors, NEOs,

3. Fixed FoV + high-speed
   - 2-fps@ 20 deg² -- 200-fps@ 52” x 38”
   - Occultation of TNOs, YSOs, flares, FRBs, NSs, BBHs, 
     meteors, NEOs

1 exposure
Northern transient survey

Observation programs

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   - $\text{Elv} > 40 \text{ deg} \ (7,000 \text{ deg}^2)$ every 2 hours
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Northern transient survey

Observation programs

1. **Northern transient survey**
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   - 3-5 visits per night
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Web interface for human inspections
Northern transient survey

Observation programs

1. Northern transient survey
   - Elv > 40 deg (7,000 deg²) every 2 hours
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Tomo-e Gozen sky map

April 23, 2019

At each pointing (red region),
- 0.5 sec exposure x 12 frames
- 2 x 2 dithering to fill in sensor gaps
Follow-up collaborations

For spectroscopic/multi-band photometric follow-up observations

- Collaborations with other telescopes in Japan as a framework of OISTER

OSITER: Optical and Infrared Synergetic Telescopes for Education and Research
Scientific targets

Observations for very early phases of type Ia supernovae

- give us important clues to SD and DD scenarios

Light curves of theoretical models

Kutsuna & Shigeyama 2015

Observational results @z=0.117 (Jiang+2017)
Initial results

Detection of an event with duration of < 0.5 sec:

- Detected in only one frame, < 0.5 sec
- Single event (not repeated), 16-mag
- Same PSF as other sources, ~3"

Discovery of Near earth asteroid 2019FA:

- Detected in only one frame, < 0.5 sec
- Single event (not repeated), 16-mag
- Same PSF as other sources, ~3"

Image size: 9’ x 6’

2019/03/16 20:51:29 (JST)
2019/03/16 20:52:13 (JST)
2019/03/17 01:57:48 (JST)
Initial results

Discovery of SN2019cxx

➢ The first supernova discovered by Tomo-e Gozen

- Tomo-e Gozen
- PS1-reference
- Subtracted

- discovery: 21:09, April 5, 2019(JST)
- position: 11h17m48.22s +13d43m42.0s
- discovery mag: 18.7(clear)
Initial results

Discovery of SN2019cxx

- The first supernova discovered by Tomo-e Gozen
- Spectrum taken by 8.1 m Gemini-N/GMOS & Seimei 3.8 m

- SN type: Ia
- host: SDSS J111748.57+134339.5
- redshift: 0.025
- phase: ~5 days before maximum
Summary

- Tomo-e Gozen is a camera
  - covered by 84 chips of CMOS image sensors
  - has a FoV of 20 deg²
  - can take consecutive images at 2 fps

- Northern transient survey optimized for SNe
  - 7,000 deg² every 2 hours down to ~18 mag
  - Aiming at observing very early phases of SNe Ia

- The first discovery of SN2019cxx
  - initial result w/ Tomo-e Gozen
  - Tomo-e Gozen surveys will start from September
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Collaboration welcome

If you got interested and want to use our data, please contact us!