#### Tomo-e Gozen High-Cadence Transient Survey

Tomoki Morokuma (Univ. of Tokyo, IoA; <u>tmorokuma@ioa.s.u-tokyo.ac.jp</u>), Nozomu Tominaga (Konan Univ.), Masaomi Tanaka, Ichiro Takahashi (Tohoku Univ.), Keiichi Maeda (Kyoto Univ.), Shigeyuki Sako, Ryou Ohsawa, Satoshi Takita (Univ. of Tokyo, IoA), Tomo-e Gozen Supernova WG members

#### Related talks

- Day 1 大澤亮(東京大学):東京大学・木曽観測所の活動報告
- □ Day 2 紅山仁(東京大学): 微小地球接近小惑星の即時動画/多色測光観測
- ロ Day 2 吉田二美(産業医科大学): Tomo-e Gozenデータを用いた既知小惑星の位相角曲線の研究

### Kiso Schmidt Telescope

- 🗆 @Nagano, Kiso
- IO5 cm Schmidt telescope
- Ohsawa-san's talk@Day 1





#### Tomo-e Gozen

- B4 CMOS sensors
- □ effective area: 20 deg2 (9 deg in diameter)
  - □ 1k x 2k ~ 22.4 x 39.7 arcmin2
- no filter
- □ 2 fps readout (nominal): up to ~200 Hz

ansient Survey

#### almost unexplored log (Characteristic Timescale [sec])



## Very Early Phases of Core-Collapse Supernovae



□ (^) SN 2016gkg@NGC 613: Discovered by Victor Buso@Argentine, 16-inch telescope possible detection with Gaia (Garnavich+2016, Rubin+2016)

serendipitous detections (SN 2008D): Swift/XRT (Soderberg+2008), GALEX (Schawinski+2008)

□ no early excess for individual TESS SNe, but some excess for stacked LCs (Vallely+2020) almost no detailed follow-ups for previous detections because of low S/N (high-z), discovery latency, insufficient follow-up time (large telescopes) <== overcome by Tomo-e + OISTER 11th OISTER WS

# Northern Sky Transient Survey w/ Tomo-e Gozen 7,000 deg2 - 2 hr cadence - 18 mag depth 2019 (initial phase) 7,000 deg2 - one visit - 18 mag depth 2020-==> 2,000 deg2 - 0.5 hr cadence - 18 mag depth (now) ==> 7,000 deg2 - one visit - 18 mag depth Tomo-e footprint@last night

#### Northern Sky Transient Survey w/ Tomo-e Gozen

7,000 deg2 - 2 hr cadence - 18 mag depth 2019 (initial phase)

7,000 deg2 - one visit - 18 mag depth ==> 2,000 deg2 - 0.5 hr cadence - 18 mag depth ==> 7,000 deg2 - one visit - 18 mag depth (now)

- no filter: effectively g+r bands
- I visit: 6 sec exposure = [0.5 sec exposure] x 12 (~18-19 mag)
- ~60 deg2 w/ 2x2 (or 2x3) dithering to fill the gaps between sensors
   cadence: ~2 hours ==> ~0.5 hours (around midnight)
- Survey area:

~7,000 deg<sup>2</sup>/2hrs ==> ~2,000 deg<sup>2</sup>/0.5hrs ==> ~7,000 deg<sup>2</sup>/2hrs

- □ survey planning: Pedroso, Ikeda, TM+ et al. in prep.
- recent (FY2019 winter) changes:
  - 2020/01: cadence change (see above)
  - □ 2020/10: 24 contiguous frames instead of 12 @ 1st round
- <u>near-future changes</u>:
  - reference for image subtraction: [PS1/r] ==> [Tomo-e]
    - achieve better subtraction around bright nearby galaxies

# Transients in Transient Name Server (TNS)

Dec > -3 deg & 2019/01/01 - 2020/3/31 (discovery date@TNS)
Detected before TNS discovery date : 86 transients
Deeper than discovery magnitude : 29 transients

# Target Handling System: web I/F

#### CNN (Hamasaki 2020, master thesis/Konan U.) will be open in a few months ==> automatic alert for bright transients Transient ID: Variable\_id: Number of detections: (paramcand) link to SDSS (if available) Ra, Dec (Decimal) Ra, Dec SDSS Phot-z Detector ID SDSS Spec-z x,y I, b (Galactic) link to SDSS, PS1, TNS, MPChecker Visibility (local site: 137.6283 35.7942 1130 +9) link to visibility plot (IAC) SDSS Archive MPChecker Relavant links PS1 TNS fits files Ref Sub link to Tomo-e Gozen fits Light Curves Images Comments 2020-04-03 58942.7169 (11210440) 19.03 +-0.42 (limmag = 18.10) 🕂 🕑 IOPI Ə 💾 🖍 🥆 I 🗏 🙆 submit ref cr sub 14 No comments posted yet. 16 2020-04-03 58942.7171 (11210332) 17.50 +-Apparent magnitude 8 0.14 (limmag = 17.87) sub ref cr light curve in magnitude unit image cutout (light curve in linear scale below) 2020-04-03 58942 7177 (11210087) 17 58 +

Photometry for images before image subtraction will be also available.

### **OISTER Follow-Up Observations**

Discoveries, identification, & characterization of a few rapidly evolving transients # expectation: ~15 candidates per semester w/ ~> 1 mag day-1

- □ "flash" follow-up (<1 hour) w/ MITSuME (automated), ...
- □ "flash" spectroscopy (<1 day) w/ Seimei/KOOLS-IFU(, TriCCS), ...
- □ daily follow-up: multi-band imaging, spectroscopy(, polarization, radio, ...)



#### Summary

Let's find young supernovae in early-phase (right after explosions).

- Northern Sky Transient Survey from Nov. 2018 w/ (partial) Tomo-e Gozen.
   full operation w/ completed Tomo-e Gozen started in Oct. 2019.
- 7,000 deg / 2 hours, 18 mag ==> 2,000 deg2 / 0.5 hours, 18 mag
   ~10,000 deg2 area is observed at least once during a night.
- survey planning w/ statistical approach (Joao, Ikeda, TM, et al. in prep.)
   +consider weather conditions (avoid cloudy region/choose clear region)
- Development of automatic data reduction pipeline+web I/F: almost done.
   Machine-learning technique (CNN) to pick up only real sources
- **quick follow-up observations in OISTER** 
  - □ imaging w/ MITSuME etc.
  - spectroscopy w/ Seimei, Kanata, etc. (OISTER), Gemini, etc.
- Collaborative transient surveys with UV wide-field satellite (Yatsu-san)
- □ fully utilize "2 Hz" data (see our pilot study in Richmond+2020)
- Contact us (Morokuma, Ohsawa, Sako) if you are interested in survey.