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# Development of the near-ultraviolet imager *SCUID* on the 1.5m Kanata Telescope

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## [1] Introduction

- We are developing an imager, ***SCUID***, with a high throughput at near-ultraviolet (NUV) wavelengths (300-400 nm; ~u-band), for a ground-based telescope (1.5-m Kanata telescope at Higashi-Hiroshima Observatory, Japan; Fig. 1).
- The optical design and detector selection are optimized for the NUV range, at the expense of efficiency at longer wavelengths. The peak efficiency we are expecting at u-band is ~32 percent, including atmosphere and telescope optics.
- At u-band, the limiting magnitude with a singal-to-noise (S/N) ratio of 5 corresponds to ~20.2 ABmag for 100 seconds of exposure.

This allows us to detect NUV emission from nearby transient objects, for example, a kilonova from a neutron star merger (as GW170817) closer than 130 Mpc within a day after its collapse (Fig. 2).

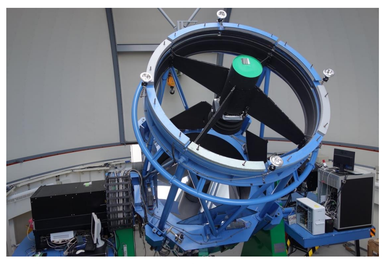


Fig. 1: Kanata telescope.

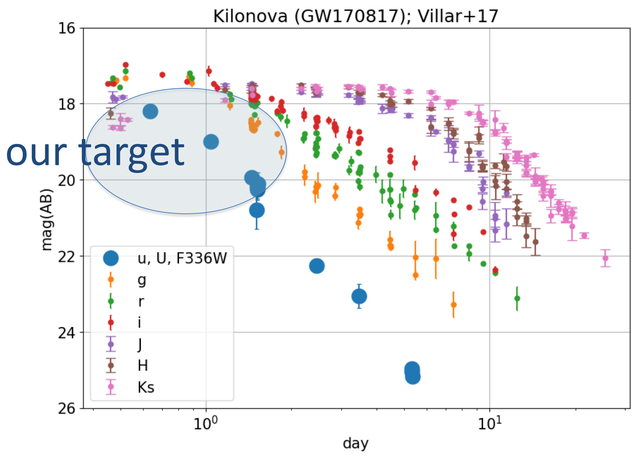



Fig. 2: Kilonova (GW170817 associated) light curve.


## [2] Design and specifications

**Components**

- **Telescope:** Kanata Telescope; Higashi-Hiroshima Observatory (HHO) (1.5-m diameter; f/12.2; Ritchey-Chretien; 2nd Nasmyth focus; elevation of 511.2 m.)
- **Filters:** (Fig. 3)
  - ✓ SDSS u-band filter: A specially designed interference filter (Asahi-spectra Co., Ltd.) .
  - ✓ Medium-band pass filters u-short (300-350nm) and u-long (350-410nm) (Edmund Optics), and SDSS g’, r’ filters (Baader Planetarium).
  - ✓ A transmission grating (400 gr/mm) with a BG38 colored glass filter for objective spectroscopy.
- **Optics:** a corrector lens unit. (Fig. 4)
  - ✓ A corrector lens unit, consisting of a pair of $CaF_2$ and fused silica lenses, is designed to achieve a good image quality (>80 % encircled energy in a pixel) over the FOV. AR coating design is also optimized for NUV wavelengths. Design and manufacture are by Photocross, Co. Ltd.
- **Detector:** a CMOS image sensor Gpixel GSENSE400 BSI UV (2048 x 2048 pixels; 11 μm/pix, QE: 45-70% at NUV) on FLI KL400 cooled camera module.
- (**Polarimetry unit** with a half-wave plate and a wire-grid polarizer will be installed.)

**Specifications**

- Imaging with 5’ x 5’ FOV (0.14 arcsec/pixel), objective spectroscopy, (and linear polarimetry in the future).
- Total throughput at u-band including telescope mirrors, atmosphere, and the filter : ~32% at the peak (Fig. 5)

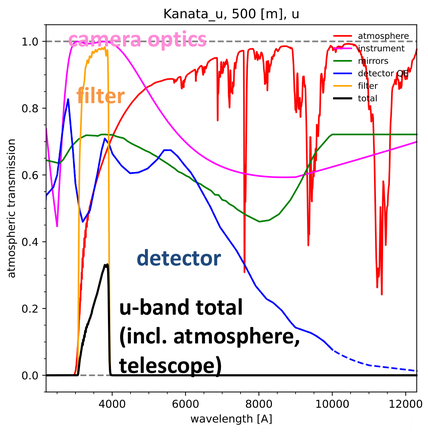



Fig. 5: Throughput estimation of the imager. Total efficiency of the imager through the u-band filter (black) and efficiency of the fore-optical components (other lines).

- Expected limiting magnitudes for a point source (Fig. 6):

S/N=20: ~17.2 magAB (10sec) / ~18.6 magAB (100sec)
S/N=5: ~18.6 magAB (10sec) / ~20.2 magAB (100sec)

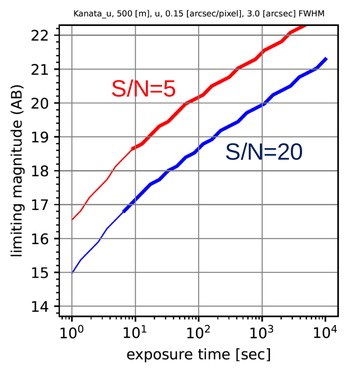



Fig. 6: Expected limiting magnitudes (at Kanata, airmass=1.2, and 3.0” seeing)

(a)

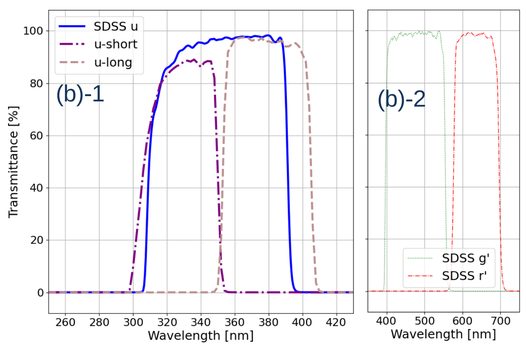
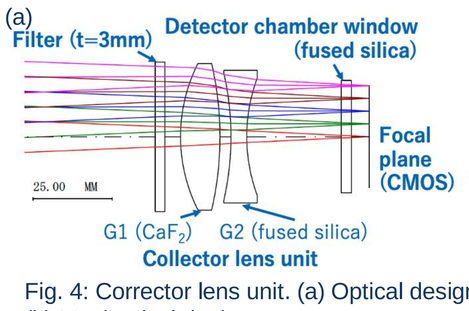



Fig. 3: (a) The u-band filter and (b) transmittance curves of the filters.



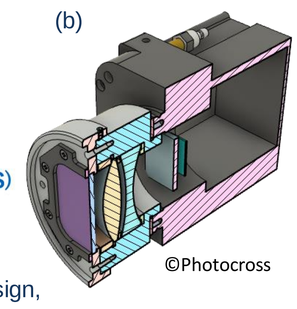




Fig. 4: Corrector lens unit. (a) Optical design, (b) Mechanical design

## [3] On-sky observation

- We performed the first on-sky observation of the imager at the Kanata telescope in March 2024.
- The observational data has preliminarily confirmed the targeted performances of the imager. The analysis is still ongoing.

### (1) Quality and detection limit of the first light images

Images of the open cluster NGC 2355 were obtained at u-band with a 60-second exposure.
- The faint sources excepted from the S/N calculations have been well detected (Fig. 7).
- Images with seeing limited point sources over the FOV have been obtained as designed.

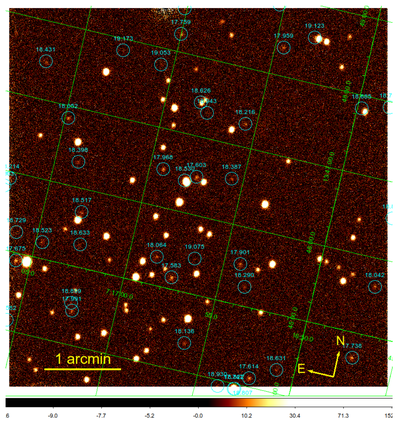



Fig. 7: NGC 2355 (u-band, 60 sec) with magnitudes from SDSS DR7.

### (2) Atmospheric extinction at u-band

Atmospheric extinction at u-band during clear nights on March 9 and 10, 2024, was measured to be 0.75 mag/airmass (= transmittance of 50 %) on average by observing stars with U-band magnitudes in the literature, which is in accordance with the estimation from the LOWTRAN7 atmospheric model (Kneizys88) assuming an elevation of HHO (511 m). (Fig. 8)

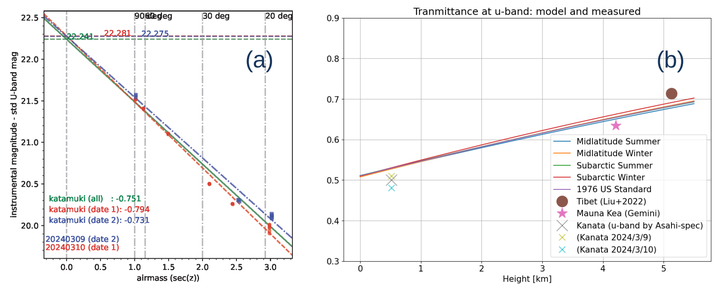



Fig. 8: (a) Atmospheric extinction measurements at u-band by observing stars with various airmasses. (b) Measured atmospheric transmittance (cross marks) and those of existing observatories (filled markers) with LOWTRAN7 model calculations (solid lines).

### (3) Sky-brightness measurement

Actual u-band sky-brightness at HHO, which is crucial to estimate the limiting magnitude, was measured on dark, clear nights.
→ ~21-22 mag/arcsec$^2$ (cf. Mauna Kea 22.2 mag/arcsec$^2$)

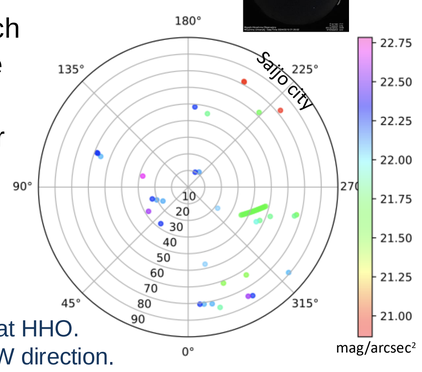


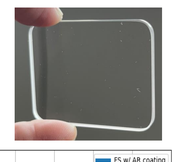

Fig. 9: u-band Sky-brightness at HHO. Nearby city is located in the NW direction.

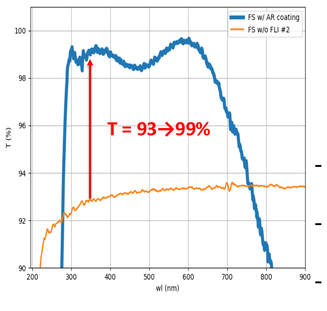
## [4] Recent improvements and Future prospects

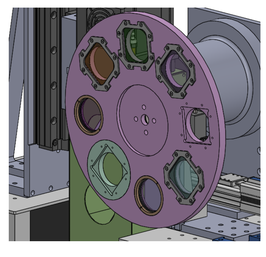
- Transmittance of the chamber window of the CMOS module has been improved by UV AR-coating.
- A remote filter exchange unit and a remote instrument exchange unit will be installed. (Manual filter exchange operation is necessary in the current state.)

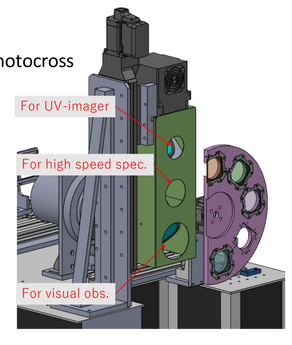
→ The imager will be available on the Kanata telescope as one of the resident instruments.

- Polarimetry unit development.
- Next on-sky observation will be conducted in late 2024.





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