

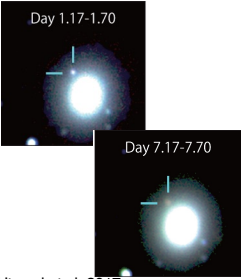
Subaru/MOIRCS Near-Infrared follow-up observation of the gravitational wave event S240422ed

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Introduction

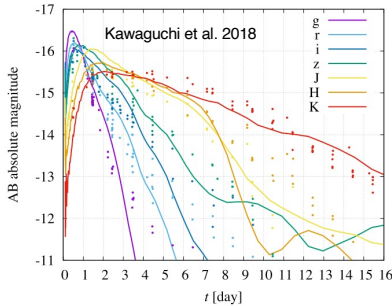
Confirmation of kilonova from a compact binary merger in the gravitational wave (GW) event GW170817

Three-color (z, H, Ks) composite images of AT2017gfo



Utsumi et al. 2017a

Light curve and kilonova models of AT2017gfo



- Further observations of the electromagnetic (EM) counterparts of GW events are needed to understand the diversity of mass ejection and nucleosynthesis in compact binary mergers.
- In the LIGO-Virgo-KAGRA observing run O4b (from April 2024), J-GEM is performing EM counterpart surveys.

GW event S240422ed

The results of the real-time GW data analysis for this event motivated EM follow-up observations by optical/near-infrared telescopes around the world.

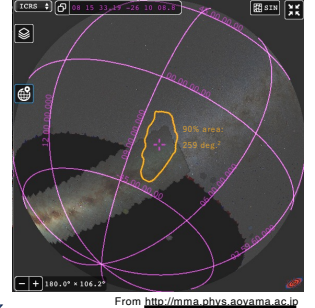
- T0: 2024-04-22 21:35:13 UT
- GW source classification: **NSBH (>99%)**
- HasRemnant: >99%
- Distance: 188 +/- 43 Mpc
- No gamma-ray burst was detected in coincidence with the event.

J-GEM triggered ToO observations with Subaru/MOIRCS to search for the EM counterpart.

GW source classification was updated on July 3.

- Updated: Terrestrial (93%), **BNS (5%), NSBH (2%)**

Sky localization map of S240422ed



From <https://mma.phys.aoyama.ac.jp>

Despite the (likely) non-astrophysical origin of this event, our observations provide a nice test case for deep NIR follow-up observations of GW events.

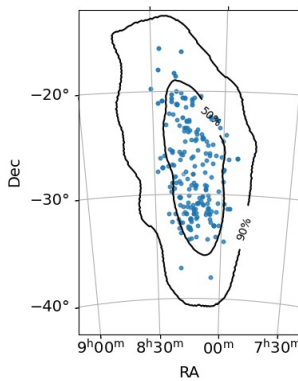
Observations and Data analysis

Subaru/MOIRCS observation

We conducted near-infrared imaging observations of 222 nearby galaxies with Subaru/MOIRCS on 2024-04-22 and 23 (Morokuma et al. 2024a, b; GCNC 36265, 36302).

Observed galaxies were selected from the GLADE+ catalog (Dalya et al. 2022) based on the high probability sky area and estimated distance range of the event.

Sky localization map and observed galaxy positions



Observation Information

Obs. start	7.8 hours after the GW event
Filter	Y, K _s
Limiting magnitude	20-21 mag. (3σ)
Coverage (Total probability of each galaxy)	40.2 %
Coverage (Considering the catalog completeness)	~ 20%

Candidate screening

To find counterpart candidates in the reduced MOIRCS data, we conducted two types of analyses.

1. Catalog matching

We searched for objects not in the reference catalogs or 5-sigma brighter than the catalog magnitude.

Reference catalogs

- Pan-STARRS (PS1)
- 2MASS
- VISTA Hemisphere survey

No new or 5-sigma brighter objects compared to catalogs.

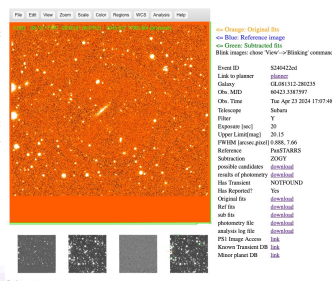
2. Visual inspection

J-GEM provides a candidate object search tool which enables visual comparison of observed images with reference and difference images (Sasada et al. 2021).

Since this event occurred near the Galactic plane in the southern sky (see sky localization map), we used reference data from the Galactic plane surveys (DECamPS2 and VISTA VVVX) as well as PS1.

We have found 5 candidates for the EM counterpart.

J-GEM candidate search tool

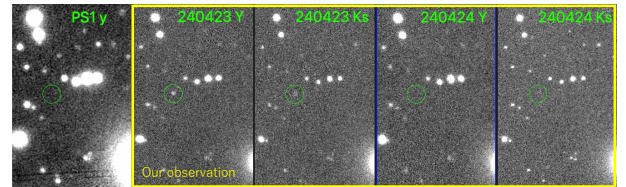


EM counterpart candidates

Candidate: J-GEM24a

(RA, Dec.) = (122.2158 deg., -24.5164 deg.)

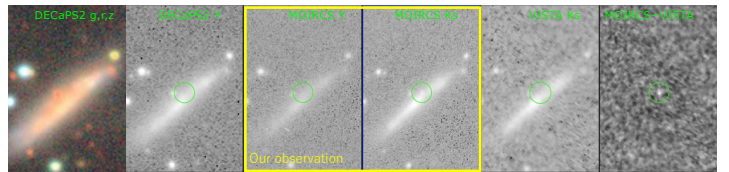
- Found in Y- and K_s-bands on the first day of MOIRCS observations
- We reported this candidate four days after the GW event (Takahashi et al. 2024; GCNC 36333), and it was not detected despite follow-up observations by VLT and Gemini.
- host spec-z = 0.055 (247 Mpc) by VLT/XShooter (GCNC 36341)



Candidate: J-GEM24c

(RA, Dec.) = (123.2977 deg., -28.04254 deg.)

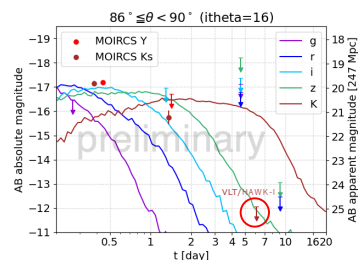
- Found in the galaxy (distance: 199 Mpc) with the highest probability in our list of candidate host galaxies.
- Found on both observing dates and confirmed by K_s-band differential images.
- Only confirmed by MOIRCS due to the delay in discovery.



Note: Other candidates were detected only one night and with only one filter.

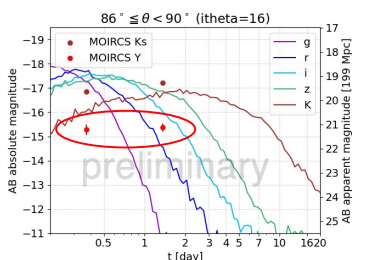
Photometric comparison with kilonova model

J-GEM24a



Model: BNS (Kawaguchi+2022, Shibata+2021) long-lived remnant & MHD dynamo effect, 75a

J-GEM24c



Model: BNS (Kawaguchi+2022, Shibata+2021) long-lived remnant & MHD dynamo effect, 80a

The photometric data are inconsistent with the kilonova models we have adopted.