# Preparing for Gaia and BlackGEM Searches for Electromagnetic Counterparts during O4

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## Abstract

Motivated by the recent developments in the field of multimessenger astronomy and the expected commencement of LIGO/Virgo's next observing run (O4) later this year, ESA's Gaia satellite and the three dedicated telescopes of BlackGEM (Chile) will be contributing to the electromagnetic (EM) follow-up of gravitational wave (GW) events. A new alerts stream called GaiaX will be operational to help search for the EM counterpart to GW events. The BlackGEM telescopes have been specifically designed to optically follow-up GW events, and will be operational in time for O4. Ahead of O4, an experiment was executed to test the various transient detection pipelines. Since BlackGEM was not yet operational at the time, MeerLICHT (South Africa), an operational prototype of BlackGEM, was used. We then analysed the data to understand and improve the detection algorithms of both, before the start of O4.

## GaiaX-MeerLICHT Contemporaneous Observations

In Sep and Oct 2021, we ran a contemporaneous experiment in which the ground-based telescope MeerLICHT (ML) followed the position of *Gaia* in orbit, as much as possible. During this time, the *GaiaX* alerts were publicly published - there were **11861** *GaiaX* alerts and **7458** ML detections during this time. We then proceeded to compare and investigate these detections.

## List #1: Real Transients

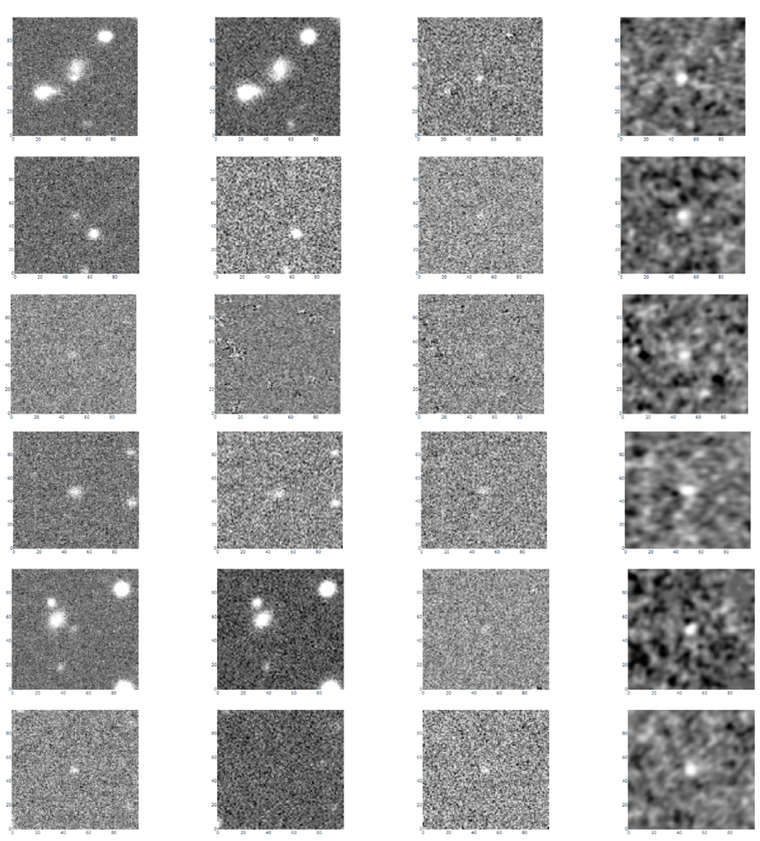

Figure 2: 6 real transient images identified from this experiment in Sep-Oct 2021; *From L to R: reduced, reference, difference and scorr images;*

## Final Remarks

With this experiment, we considered *Gaia*'s contribution to the search for EM counterparts during O4. In the process, we managed to test and improve the *GaiaX* filtering techniques and additionally, BlackGEM's detection algorithms. We now have a clearer idea about what to expect during O4, and are confident about *Gaia* and BlackGEM joining the race for multimessenger observations.

## GaiaX

The ESA-*Gaia* mission allows to serendipitously detect transients. A new detection algorithm, *GaiaX*, that makes use of the GW event localisation and timing to allow it to run at a lower detection threshold [1], will be introduced during O4.

1. *GaiaX* triggers an alert if a source is detected by just one telescope (instead of two);
2. Magnitude limit increased to G∼20.68 mag (from G∼19 mag);

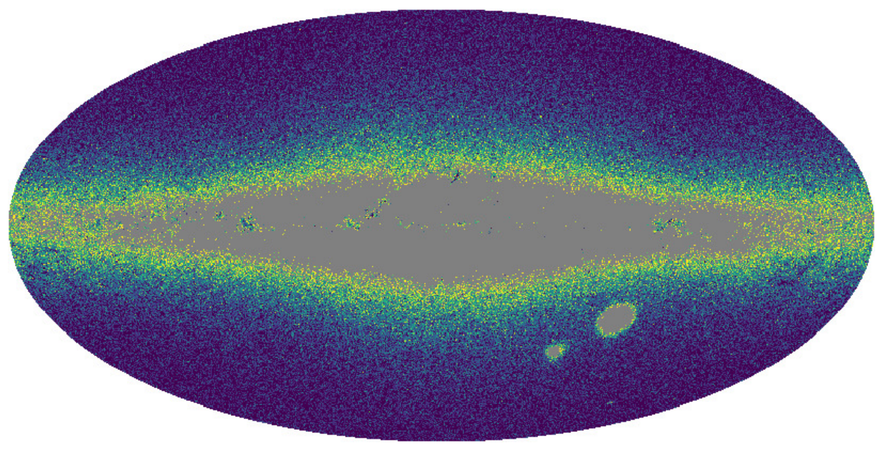

Figure 1: 21% of the sky has been removed *(gray)*

## BlackGEM/MeerLICHT

The BlackGEM (BG) array, situated in ESO La Silia (Chile), consists of 3 telescopes (Phase 1). MeerLICHT (ML) is an operational prototype of BG, near Sutherland (South Africa). The operational status of BG is unfortunately delayed to mid-2022 due to the pandemic, so this work was done with ML instead.

1. BG is designed to optically follow-up GW events: uniquely suited to match the pointing of the telescopes to the shape of the GW error boxes;
2. Entirely robotic, reaction time to GW alerts are ∼1 min;

## Results

| List # | GaiaX Alert? | MeerLICHT Detection? | Outcome | # |
|---|---|---|---|---|
| 1 | Yes | Yes | Real Transients | 8 (6 unique) |
| 2a | Yes | No | *GaiaX* detection can potentially be spurious since the ML detection limit is deeper than the *GaiaX* detection magnitude of the transient | 46 (21 unique) |
| 2b | Yes | No | *GaiaX* transient can be real since the ML detection limit is less deep than the *GaiaX* detection magnitude | 0 |
| 3 | No | Yes | The *GaiaX* transient was too faint to be detected; | *to-fill* |

## Acknowledgements/References

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[1] Z Kostrzewa-Rutkowska, P G Jonker, S T Hodgkin, D Eappachen, D L Harrison, S E Koposov, G Rixon, Ł Wyrzykowski, A Yoldas, E Breedt, A Delgado, M van Leeuwen, T Wevers, P W Burgess, F De Angeli, D W Evans, P J Osborne, and M Riello. Electromagnetic counterparts to gravitational wave events from igaia/i. *Monthly Notices of the Royal Astronomical Society*, 493(3):3264–3273, feb 2020.

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