Neutron Star Astrophysics at the Crossroads: Magnetars and the Multimessenger Revolution
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A search for optical and near-infrared counterparts of the compact binary merger GW190814

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Abstract. We report on our observing campaign of the compact binary merger GW190814, detected by the Advanced LIGO and Advanced Virgo detectors on August 14th, 2019. This signal has the best localisation of any observed gravitational wave (GW) source, with a 90% probability area of 18.5 deg^2, and an estimated distance of ≈240 Mpc. We obtained wide-field observations with the Deca-Degree Optical Transient Imager (DDOTI) covering 88% of the probability area down to a limiting magnitude of $w = 19.9$ AB. Nearby galaxies within the high probability region were targeted with the Lowell Discovery Telescope (LDT), whereas promising candidate counterparts were characterized through multi-colour photometry with the Reionization and Transients InfraRed (RATIR) and spectroscopy with the Gran Telescopio de Canarias (GTC). We use our optical and near-infrared limits in conjunction with the upper limits obtained by the community to constrain the possible electromagnetic counterparts associated with the merger. A gamma-ray burst seen along its jet's axis is disfavoured by the multi-wavelength dataset, whereas the presence of a burst seen at larger viewing angles is not well constrained. Although our observations are not sensitive to a kilonova similar to AT2017gfo, we can rule out high-mass (> 0.1 M$_\odot$) fast-moving (mean velocity $\geq 0.3c$) wind ejecta for a possible kilonova associated with this merger.

Keywords. stars: neutron – gravitational waves – gamma rays: bursts

1. Summary

The compact binary merger GW190814 was discovered on the 14th of August 2019 (Abbott et al. (2020)). GW190814 is a merger of a 23 M$_\odot$ black hole (BH) with a 2.6 M$_\odot$ mass gap object. Additionally, it has the best gravitational wave (GW) only localisation of any signal discovered upto Observation Run 3 (O3) of the LIGO-Virgo detectors with a localisation of 18.5 deg^2. This made it an event of interest and it was followed up extensively by the community.

As part of this observation campaign, we performed widefield observations using the Deca-Degree Optical Transient Imager (DDOTI), galaxy-targeted observations of 14 galaxies within the localisation region with the Lowell Discovery Telescope (LDT) for identifying counterparts to this merger. Additionally, we performed multicolour photometry using the Reionization and Transients Infrared (RATIR) camera and spectroscopy with the Gran Telescopio de Canarias (GTC) of identified candidates. A summary of our observation campaign is show in Figure 1. (Thakur et al. (2020))

We could not identify any counterpart for this merger either in widefield imaging ($w = 19.9$ AB mag) or galaxy-targeted observations ($i = 21.4$ AB mag). Furthermore,

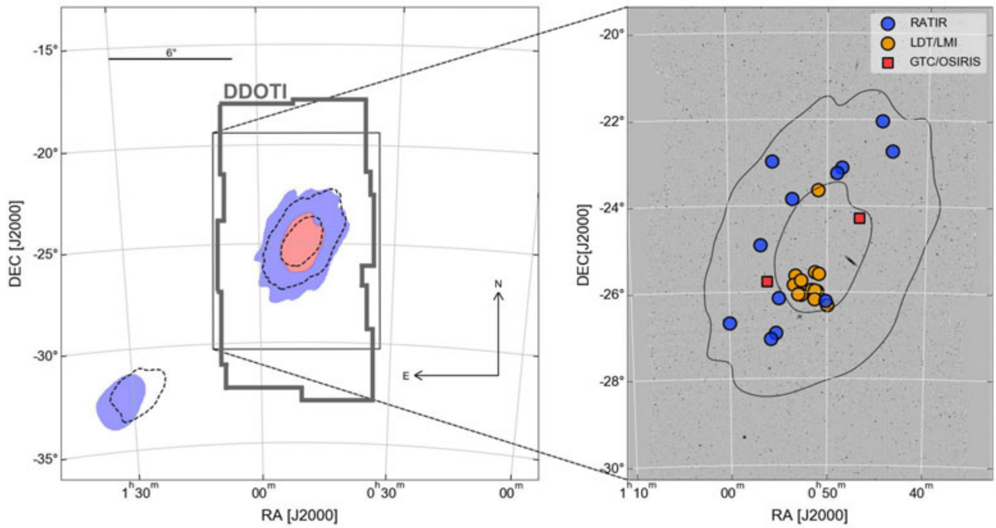

Figure 1. Summary of observation campaign for GW190814. *Left panel*: The initial (coloured) and final (dotted) localisation regions are shown for reference. DDOTI field of view (grey) of GW190814 localisation region. *Right panel*: Targeted observations colour-coded by facility. (Figure 1, Thakur et al. (2020))

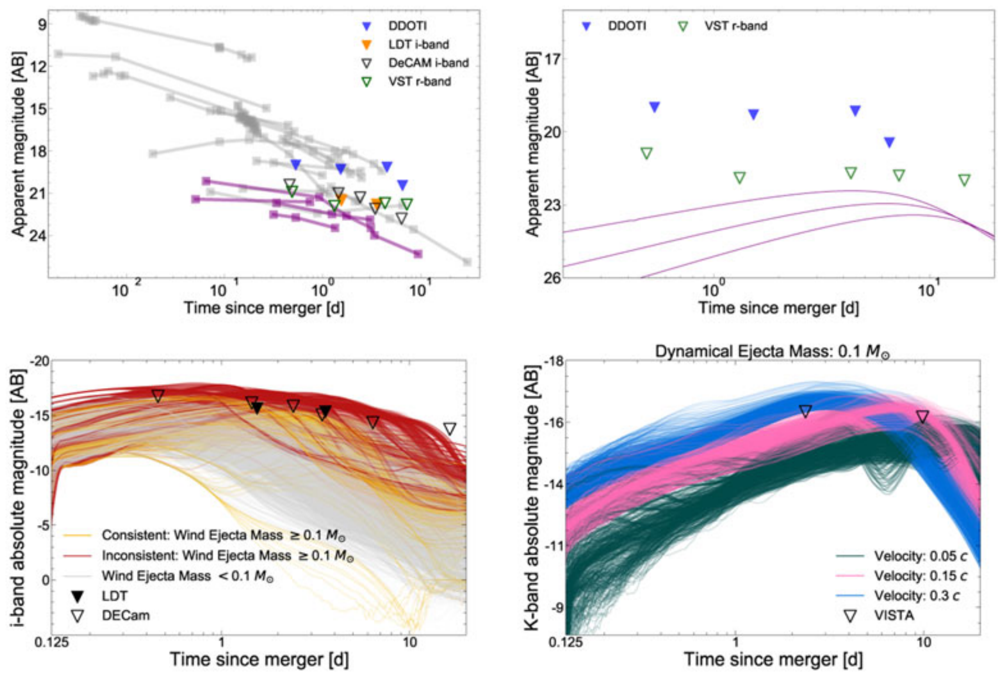

Figure 2. *Top panels*: sGRB lightcurves (LCs) compared to widefield limits. *left*: On-axis LCs, *right*: Off-axis LCs *Bottom panels*: Simulated kilonova LCs compared to limits *left*: *i*-band, *right*: *K*-band. (Figures 8 & 9, Thakur et al. (2020))

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none of the candidates targeted by the multicolour photometry or spectroscopy could be identified as associated with this merger.

We used the upper limits derived from our analysis in combination with the limits from the community-wide campaign to constrain the properties of the possible counterpart of this merger. We used the short gamma-ray burst (sGRB) model from Ryan et al. (2020) and kilonova models from Wollaeger et al. (2021) in our analysis. We find that an on-axis burst is ruled out by our data, whereas the parameters for an off-axis burst are poorly constrained. Additionally, the optical limits rule out kilonova models with a high wind ejecta mass (> 0.1 $M_{\odot}$) and the near-infrared rule out kilonova models with a high velocity ($\geq 0.3c$). (See Figure 2).

References

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