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Low frequency view of the first binary neutron star merger GW 170817/GRB 170817A with the Giant Metrewave Radio Telescope

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On 17th August 2017, Gravitational Wave (GW) detector network AdvLIGO/VIRGO reported the first ever detection of a merging neutron star binary, GW170817 [1]. A spatially and temporally coincident gamma-ray signal, short Gamma Ray Burst (GRB) 170817A, was observed by the Fermi space telescope, kickstarting the era of multi-messenger astronomy [2]. Further electromagnetic follow-up observations revealed associated emission in X-ray, UV/Optical/IR, and radio wavelengths [3]. Our collaboration has used the Atacama Large Millimeter Array (ALMA) and the Giant Metrewave Radio Telescope (GMRT) to follow-up the event and made several successful detections of the low-frequency radio transient with the GMRT [4,5]. Multi-wavelength electromagnetic observations of the GW event corroborated the hypothesis that short GRBs originate from neutron star mergers. Yet some puzzles remained. The prompt gamma-ray signal was exceptionally under-luminous compared to the classical short GRB population. In addition, the non-thermal X-ray and radio emission had a distinctly unique time evolution in comparison to typical short GRB afterglows. Currently there are two competing models capable of explaining all the electromagnetic observations: (i) a relativistic jet viewed away from its axis (off-axis jet) or (ii) a quasi-spherical cocoon of sub-relativistically moving material. Both models are motivated from numerical general relativistic hydrodynamical simulations of neutron star mergers.

Here, we present low radio-frequency (610 and 1390MHz) observations of the electromagnetic counterpart obtained with the GMRT. Our observations start ~7 days and continue beyond an year since the GW trigger. The afterglow started to emerge above the detection threshold of the upgraded GMRT at these low frequencies about 60 days after the burst. We model the GMRT radio data along with the archival X-ray, Optical and high-frequency radio data within the ambit of relativistic jet models. We find that a jet with a Gaussian angular profile in energy and velocity can very well explain the multi-wavelength flux evolution [5,6]. Posterior bounds of the viewing angle from our MCMC analysis (12.6 +/- 2.7 deg) is consistent with that inferred from the gravitational wave signal (< 27 deg) [7]. Posterior of the bulk Lorentz factor at the jet axis is $215.4^{+60.3}_{-85.9}$, indicating that neutron star mergers can launch jets with a broad range of Lorentz factors, as high as what is expected in classical GRBs. The large viewing angle has brought the mildly relativistic wings of a GRB jet in view for the first time. Our calculations show that the low isotropic gamma-ray energy and the unique temporal evolution of X-ray/Radio afterglow are consequences of the off-axis viewing angle. GW triggered GRBs in the upcoming AdVLIGO/VIRGO cycles are going to further enrich our understanding of these explosions and the jets thereby launched.

References

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