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Bright broad-band afterglows of gravitational wave bursts from binary neutron star mergers as a probe of millisecond magnetars

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If double neutron star mergers leave behind a massive magnetar rather than a black hole, a bright early afterglow can follow the gravitational wave burst (GWB) even if there is no short gamma-ray burst (SGRB) - GWB association or there is an association but the SGRB does not beam towards earth (Zhang 2012). Besides directly dissipating the proto-magnetar wind, we here suggest that the magnetar wind could push the ejecta launched during the merger process, and under certain conditions, would reach a relativistic speed. Such a magnetar-powered ejecta, when interacting with the ambient medium, would develop a bright broad-band afterglow due to synchrotron radiation. We study this physical scenario in detail, and present the predicted X-ray, optical and radio light curves for a range of magnetar and ejecta parameters. We show that the X-ray and optical lightcurves usually peak around the magnetar spindown time scale (~ 10ˆ3 – 10ˆ5 s), reaching brightness readily detectable by wide-field X-ray and optical telescopes, and remain detectable for an extended period. The radio afterglow peaks later, but is much brighter than the case without a magnetar energy injection. Therefore, such bright broad-band afterglows, if detected and combined with GWBs in the future, would be a probe of massive millisecond magnetars and stiff equation-of-state for nuclear matter.

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Summary

Detecting these bright signals associated with GWB triggers would unambiguously confirm the astrophysical origin of GWBs. Equally importantly, it would suggest that NS-NS mergers leave behind a hyper-massive neutron star, which gives an important constraint on
the neutron star equation of state. With the GWB data, one can infer the information of the two NSs involved in the merger. Modeling afterglow emission can give useful constraints on the ejected mass Mej and the properties of the post-merger compact objects. The combination of GWB and afterglow information would shed light into the detailed merger physics.

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