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Born-Infeld magnetars: larger than classical toroidal magnetic fields and implications for gravitational-wave astronomy

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Magnetars are neutron stars presenting bursts and outbursts of X- and soft-gamma rays that can be understood with the presence of very large magnetic fields. In this setting, nonlinear electrodynamics should be taken into account for a more accurate description of such compact systems. We study that in the context of ideal magnetohydrodynamics and make a realization of our analysis to the case of the well known Born-Infeld (BI) electromagnetism in order to come up with some of its astrophysical consequences. We focus here on toroidal magnetic fields as motivated by already known magnetars with low dipolar magnetic fields and their expected relevance in highly magnetized stars. We show that BI electrodynamics leads to larger toroidal magnetic fields when compared to Maxwell's electrodynamics. Hence, one should expect higher production of gravitational waves (GWs) and even more energetic giant flares from nonlinear stars. Given current constraints on BI's scale field, giant flare energetics and magnetic fields in magnetars, we also find that the maximum magnitude of magnetar ellipticities should be $10^{-6} - 10^{-5}$. Besides, BI electrodynamics may lead to a maximum increase of order $10\% - 20\%$ of the GW energy radiated from a magnetar when compared to Maxwell's, while much larger percentages may arise for other physically motivated scenarios. Thus, nonlinear theories of the electromagnetism might also be probed in the near future with the improvement of GW detectors.

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