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## Lepton asymmetry from Q-balls and enhancement of second-order gravitational waves

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The recent observation of  $^4\text{He}$  favors a large lepton asymmetry at the big bang nucleosynthesis. If Q-balls with a lepton charge decay after the electroweak phase transition, such a large lepton asymmetry can be generated without producing too large baryon asymmetry. In this scenario, Q-balls dominate the universe before the decay and induce the sharp transition from the early matter-dominated era to the radiation-dominated era, which enhances the gravitational waves produced through a second-order effect of the scalar perturbations. We evaluate the density of the produced GWs and show that pulsar timing array observations can probe this scenario.

**Primary author:** Prof. KAWASAKI, Masahiro (ICRR, University of Tokyo)

**Presenter:** Prof. KAWASAKI, Masahiro (ICRR, University of Tokyo)

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