Causal gravitational waves as a probe of free streaming particles and the expansion of the universe. (English) Zbl 1460.83022

Summary: The low frequency part of the gravitational wave spectrum generated by local physics, such as a phase transition or parametric resonance, is largely fixed by causality, offering a clean window into the early Universe. In this work, this low frequency end of the spectrum is analyzed with an emphasis on a physical understanding, such as the suppressed production of gravitational waves due to the excitation of an over-damped harmonic oscillator and their enhancement due to being frozen out while outside the horizon. Due to the difference between sub-horizon and super-horizon physics, it is inevitable that there will be a distinct spectral feature that could allow for the direct measurement of the conformal Hubble rate at which the phase transition occurred. As an example, free-streaming particles (such as the gravity waves themselves) present during the phase transition affect the production of super-horizon modes. This leads to a steeper decrease in the spectrum at low frequencies as compared to the well-known causal $k^3$ super-horizon scaling of stochastic gravity waves. If a sizable fraction of the energy density is in free-streaming particles, they even lead to the appearance of oscillatory features in the spectrum. If the universe was not radiation dominated when the waves were generated, a similar feature also occurs at the transition between sub-horizon to super-horizon causality. These features are used to show surprising consequences, such as the fact that a period of matter domination following the production of gravity waves actually increases their power spectrum at low frequencies.

MSC:
83C35 Gravitational waves
83D05 Relativistic gravitational theories other than Einstein’s, including asymmetric field theories
85A40 Astrophysical cosmology
62P35 Applications of statistics to physics

Keywords:
cosmology of theories beyond the SM; beyond standard model; classical theories of gravity

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References:


Caprini, C., Detecting gravitational waves from cosmological phase transitions with LISA: an update, JCAP, 03, 024 (2020)


Christensen, N., Stochastic gravitational wave backgrounds, Rept. Prog. Phys., 82 (2019)


Espinosa, JR; Racco, D.; Riotto, A., A cosmological signature of the SM Higgs instability: gravitational waves, JCAP, 09, 012 (2018)


Caprini, C., Science with the space-based interferometer eLISA. II: gravitational waves from cosmological phase transitions, JCAP, 04, 001 (2016)


Cui, Y.; Lewicki, M.; Morrissey, DE; Wells, JD, Probing the pre-BBN universe with gravitational waves from cosmic strings, JHEP, 01, 081 (2019) - Zbl 1410.83040

Caldwell, RR; Smith, TL; Walker, DGE, Using a primordial gravitational wave background to illuminate new physics, Phys. Rev. D, 100 (2019)


Figueroa, DG; Tanin, EH, Ability of LIGO and LISA to probe the equation of state of the early universe, JCAP, 08, 011 (2019)

Auclair, P., Probing the gravitational wave background from cosmic strings with LISA, JCAP, 04, 034 (2020)

Chang, C-F; Cui, Y., Stochastic gravitational wave background from global cosmic strings, Phys. Dark Univ., 29, 100604 (2020)


Gouttenoire, Y.; Servant, G.; Simakchorn, P., Beyond the standard models with cosmic strings, JCAP, 07, 032 (2020)

Gouttenoire, Y.; Servant, G.; Simakchorn, P., BSM with cosmic strings: heavy, up to EeV mass, unstable particles, JCAP, 07, 016 (2020)


Domènech, G.; Pi, S.; Sasaki, M., Induced gravitational waves as a probe of thermal history of the universe, JCAP, 08, 017 (2020)

R. Allahverdi et al., The first three seconds: a review of possible expansion histories of the early universe, Open J. Astrophys.4 (2021) [arXiv:2006.16182] [INSPIRE].


[58] Brust, C.; Cui, Y.; Sigurdson, K., Cosmological constraints on interacting light particles, JCAP, 08, 020 (2017)


[60] Cui, Y.; Lewicki, M.; Morrissey, DE; Wells, JD, Cosmic archaeology with gravitational waves from cosmic strings, Phys. Rev. D, 97, 123505 (2018)

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