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Gravitational wave turbulence in the early Universe

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The non-linear nature of the general relativity equations suggests that space-time can be turbulent. Such a turbulence may happen in the primordial universe (first second). The analytical theory of weak gravitational wave (GW) turbulence [1] was built from a diagonal space-time metric reduced to the variables t, x and y [2]. The theory predicts the existence of a dual cascade driven by 4–wave interactions with a direct cascade of energy and an inverse cascade of wave action. In the latter case the wave action spectrum - an exact solution of the equations - has the power law index -2/3 involving an explosive phenomenon. In this context, we developed a nonlinear diffusion model in spectral space to describe GW turbulence in the approximation of strongly local interactions [3]. We showed analytically that the model equation satisfies the conservation of energy and wave action, and reproduces the power law solutions previously derived from the kinetic equations. We showed numerically that in the non-stationary regime the wave action spectrum presents an anomalous scaling which is understood as a self-similar solution of the second kind.

The regime of weak GW turbulence is actually limited to a narrow wavenumber window and turbulence is expected to become strong at larger scales. Then the phenomenology of critical balance can be used. The formation of a condensate may happen and its rapid growth can be interpreted as an accelerated expansion of the universe that could be at the origin of the cosmic inflation. We can show with this scenario that the fossil spectrum obtained after inflation is compatible with the latest data obtained with the Planck/ESA satellite [4].

[1] Galtier & Nazarenko, Phys. Rev. Lett. **119**, 221101 (2017)
[2] Hadad & Zakharov, J. Geom. Phys. **80**, 37 (2014)
[3] Galtier, Nazarenko, Buchlin & Thalabard, Physica D **390**, 84 (2019)
[4] Galtier, Nazarenko & Laurie (2020)

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