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Three dimensional magnetohydrodynamic simulation of linearly polarised Alfven wave dynamics in Arnold-Beltrami-Childress magnetic field

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Previous studies (e.g., Malara et al., Astrophys. J. 533, 523 (2000)) considered small-amplitude Alfven wave (AW) packets in Arnold-Beltrami-Childress (ABC) magnetic field using WKB approximation. They draw a distinction between 2D AW dissipation via phase mixing and 3D AW dissipation via exponentially divergent magnetic field lines. In the former case, AW dissipation time scales as S $^{1/3}$ and in the latter as $\log(S)$, where S is the Lundquist number. In this work [1], linearly polarised Alfven wave dynamics in ABC magnetic field via direct 3D magnetohydrodynamic (MHD) numerical simulation is studied for the first time. A Gaussian AW pulse with length-scale much shorter than ABC domain length and a harmonic AW with wavelength equal to ABC domain length are studied for four different resistivities. While it is found that AWs dissipate quickly in the ABC field, contrary to an expectation, it is found the AW perturbation energy increases in time. In the case of the harmonic AW, the perturbation energy growth is transient in time, attaining peaks in both velocity and magnetic perturbation energies within timescales much smaller than the resistive time. In the case of the Gaussian AW pulse, the velocity perturbation energy growth is still transient in time, attaining a peak within few resistive times, while magnetic perturbation energy continues to grow. It is also shown that the total magnetic energy decreases in time and this is governed by the resistive evolution of the background ABC magnetic field rather than AW damping. On contrary, when the background magnetic field is uniform, the total magnetic energy decrease is prescribed by AW damping, because there is no resistive evolution of the background. By considering runs with different amplitudes and by analysing the perturbation spectra, possible dynamo action by AW perturbation-induced peristaltic flow and inverse cascade of magnetic energy have been excluded. Therefore, the perturbation energy growth is attributed to a new instability. The growth rate appears to be dependent on the value of the resistivity and the spatial scale of the AW disturbance. Thus, when going beyond WKB approximation, AW damping, described by full MHD equations, does not guarantee decrease of perturbation energy. This has implications for the MHD wave plasma heating in exponentially divergent magnetic fields.

[1] D. Tsiklauri, Phys. Plasmas 21, 052902 (2014); http://dx.doi.org/10.1063/1.4875920

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