5th Asia-Pacific Conference on Plasma Physics, 26 Sept-1Oct, 2021, Remote e-conference

# Transition from MHD to KAW turbulence in solar and space plasmas

Yuriy Voitenko[1]

[1] Solar-Terrestrial Centre of Excellence, BIRA-IASB, Brussels, Belgium

e-mail: voitenko@oma.be

Power-law spectra of Alfvenic turbulence have been observed by spacecraft in situ in the solar wind [e.g. 1, and references therein] and terrestrial magnetosphere [e.g. 2, and references therein]. It has been hypothesized that the similar turbulence can also develop in the solar corona [e.g. 3,12, and references therein]. The spectral slopes of the turbulence are close to Kolmogorov -5/3 at large MHD scales and ~-2.7 at kinetic scales shorter than the ion gyroradius. Such spectra can be formed by the strong turbulence of MHD Alfven waves and kinetic Alfven waves (KAWs), respectively. In between, in a narrow MHD-kinetic transition range at intermediate scales, the spectra often steepen to -3 or even -5, which became a subject of heated debate [e.g. 4, and references therein]. Although there is growing consensus that these spectra are constituted by KAWs, which is supported by observations [5,6], the relative role of dissipative versus dispersive effects in the spectra formation remains unclear.

In the semi-phenomenological theory of imbalanced Alfvénic turbulence [7,9], in addition to traditional counter-collisions (collisions of waves propagating in opposite directions), we take into account also co-collisions (collisions of waves propagating in the same direction along the background magnetic field $B_0$).

Counter-collisions dominate in the MHD inertial range, whereas in the dispersive transition range the turbulence imbalance makes the KAW co-collisions more efficient than counter-collisions. The KAW co-collisions form very steep spectra, ~-3 in the strongly turbulent regime and ~-4 in the weakly turbulent regime [7,8], and thus can be responsible for such spectra observed in the MHD-KAW transition range. Even steeper ~-5 spectra observed by PSP in the inner heliosphere at about 0.17 AU [4] can be formed by intermittent KAW turbulence [12]. We also found [9] that the turbulence cross-helicity (imbalance) should decrease with decreasing scales in the transition range because of the energy exchange between counter-propagating wave fluxes. This last effect is still awaiting experimental verifications.

Our results demonstrate that the turbulence imbalance and related modifications of the Alfvénic nonlinear interactions regulate turbulent transport of energy from MHD to kinetic scales and eventual energy release. Although dissipative effects do not affect much the transition-range spectra, the eventual deposition of the turbulent energy in plasma can be significant producing various observed phenomena, like type I solar radio storms in the solar corona [10], or suprathermal ion beams and tails in the solar wind [11].

References

[1] Bruno, R., & Telloni, D. 2015, ApJL, 811, L17
[2] Chaston, C. C. et al. 2015, JGR, 120, 8603
[3] Zhao, J. S. et al. 2013, ApJ, 767, 109
[4] Huang, S. Y., et al. 2021, ApJL, 909, L7
[5] He, J. S., et al 2012, ApJL, 745, L8
[6] Salem, C. S., et al 2012, ApJL, 745, L9
[7] Voitenko, Y. & De Keyser, J. 2016, ApJL, 832, L20
[8] Voitenko, Y. & De Keyser, J. 2011, NPG, 18, 587
[9] Gogoberidze, G. & Voitenko, Y. 2020, MNRAS, 497, 3472
[10] Lyubchyk, O. et al. 2017, Solar Phys., 292, 117
[11] Y. Voitenko, Y. & Pierrard, V. 2015, Solar Phys., 290, 1231
[12] Zhao, J. S. et al. 2016, JGR, 121, 5