Radial structures and nonlinear excitation of Geodesic Acoustic Modes*

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Abstract

Geodesic Acoustic Modes [1] (GAM) are toroidally symmetric normal modes unique to toroidal plasmas, whose mode structure is nearly poloidally symmetric. They exist since the charge separation effect, due to ion radial magnetic drifts associated with geodesic curvature, causes a finite parallel a.c. electric field ($\propto T_e/T_i$) and a perturbed ion diamagnetic current to ensure quasi-neutrality via electron and ion dynamic responses, respectively. In this paper, we show that GAMs constitute a continuous spectrum due to radial inhomogeneities. The existence of singular layer, thus, suggests linear mode conversion to short-wavelength kinetic GAM (KGAM) via finite ion Larmor radii. This result is demonstrated by derivations of the GAM mode structure and dispersion relation in the singular layer. At the lowest order in $k_r\rho_i$, with k_r the radial wave vector and ρ_i the ion Larmor radius, the well known kinetic dispersion relation of GAM is recovered [2]. At the next relevant order, $\mathrm{O}(k_r^2\rho_i^2)$, we show that KGAM propagates in the low-temperature and/or high safety-factor domain; i.e., typically, radially outward. Our analyses also confirm that GAM and Beta induced Alfvén Eigenmodes (BAE) are degenerate in the long wavelength limit, where diamagnetic effects are ignored, even when finite Larmor radius corrections are accounted for. As reported earlier [3, 4], this is not a coincidence and is due to the fact that, at long wavelengths, shear Alfvén wave compressibility due to geodesic curvature coupling at $k_\parallel = 0$ is identical to the corresponding dynamics of electrostatic waves with $k_\phi = k_\theta = 0$, provided that diamagnetic effects are neglected.

Geodesic Acoustic Modes are important to turbulence transport studies, since their low-frequency radial structures can scatter drift-wave (DW) fluctuations, which are primarily responsible for collisionless transports, to stable short-wavelength domain and, thereby, suppress the DW turbulence transport. In this work, we show that, while KGAM is linearly stable due to ion Landau damping, it can be nonlinearly excited by finite-amplitude DW turbulence via 3-wave parametric interactions. The resultant 3-wave driven-dissipative nonlinear system then exhibits the typical prey-predator self-regulatory dynamics.

References

[1] N. Winsor, J.L. Johnson and J.M. Dawson, Phys. Fluids **11** (1968) 2448
[2] V.B. Lebedev, P.N. Yushmanov, P.H., Diamond, P.H., et al., Phys. Plasmas **3** (1996) 3023
[3] F. Zonca, S. Briguglio, L. Chen, et al., Plasma Phys. Control. Fusion **48** (2006) B15
[4] L. Chen and F. Zonca, Theory of Alfvén waves and energetic particle physics in burning plasmas, Proc. 21st Int. Conf. on Fusion Energy 2006 (Chengdu, 2006) (Vienna: IAEA) CD-ROM file OV/5-3; submitted to Nucl. Fusion

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