On a Linear Theory of Discrete GAMs

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Both experimental observations and simulations show that there exist geodesic acoustic modes (GAMs) in tokamak plasmas with discrete frequencies that do not vary radially, in contrast to that of the continuum GAMs. To understand this fact from the analytical viewpoints, we developed a linear theory based on directly manipulating the set of ideal MHD equations, especially on the decomposition of the vectorial momentum conservation equation for the plasma fluid element into its component form. The key points of geodesic acoustic modes are: 1) the plasma fluid element has a finite perpendicular compressibility that is attributed to the existence of the geodesic curvature of the equilibrium magnetic field line in a toroidal configuration; 2) the characteristic coupling between the geodesic curvature and the plasma compressibility allows a geodesic displacement, which does not vary with the poloidal angle to the leading order and is of the same order as its parallel counterpart; 3) these two on-flux-surface movements give rise to the dispersion function of the continuum GAM when the perturbations are treated to be electrostatic. However, the geodesic coupling also introduces the second θ-harmonic component, which co-exists with its zeroth θ-harmonic cousin and needs to be balanced by shear magnetic perturbations that involve finite plasma normal displacement and the component of the geodesic flow that varies with θ. As the perturbations become electromagnetic, the plasma perpendicular compressibility also picks up its electromagnetic component, which adds corrections to the GAM continuum. These two facts together lead to the eigen differential equation of second order that allows constant eigen-frequencies to exist for certain types of equilibrium profiles. We will present the approximate solution to the eigen-value problem for a special type of q and the GAM continuum profiles, and the mode existence criterion for the same type of profiles.