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How poloidal Alfven waves persist without particle sources?

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Standing poloidal Alfven waves, radial oscillations with ultra-low frequency of 5-20mHz, are excited by wave-particle interaction in the magnetosphere. It has been a question over several decades why poloidal oscillations often persist and are not quickly converted into toroidal waves even when there is no corresponding particle source. By adopting magnetohydrodynamic simulations in the dipole model, we first show that long-lasting poloidal waves are available if the local Alfven frequency gradient becomes negligible. Assuming that initial poloidal modes are excited by driving particles, we investigate two loss mechanisms into either toroidal modes[1] or compressional modes. Both mechanisms enable us to derive two necessary conditions for the existence of persistent poloidal modes. It is found that these conditions are very consistent with statistical feature of observations. Our results will be useful in identifying the persistent poloidal mode in terms of the corresponding particle energy and wavenumbers.

Ultra-low frequency poloidal Alfven waves in the Earth's magnetosphere are of great interest since they are capable of interacting with the high-energy ring current particles despite of their low frequency ranges[2]. Poloidal mode arises when azimuthal wave number becomes very large in the MHD wave equations, and thus observed poloidal mode wave typically has high azimuthal wave number (m >> 1). Observations of poloidal mode from satellites and ground stations over half a century shows a discrepancy in terms of their lifetime that sometimes the waves decay rapidly within a few wave cycles but they could also remain for tens of wave periods. It has not been understood under which circumstances the waves persist for hours. We begin with dividing two potential loss mechanisms; one by the mode conversion into the toroidal mode, and the other by scattering via compressional mode. We conduct numerical tests and confirm that the poloidal mode keeps its polarity when gradient of local Alfven frequency is negligible. From the numerical results, where the poloidal mode could avoid mode conversion within a flattened Alfven frequency region, we derive the two necessary conditions for persistent poloidal mode[3].

The results are summarized as follows[3]:

We have performed theoretical and numerical studies on the long-lasting poloidal Alfven waves. It is found in the MHD dipole model that the locally constant Alfven frequency allows persistence of poloidal modes.

For the formation of such flattened f_A, that prevents mode conversion, we have derived a necessary condition with Alfven speed distribution and local flux tube, which gives the upper limit of particle energy.

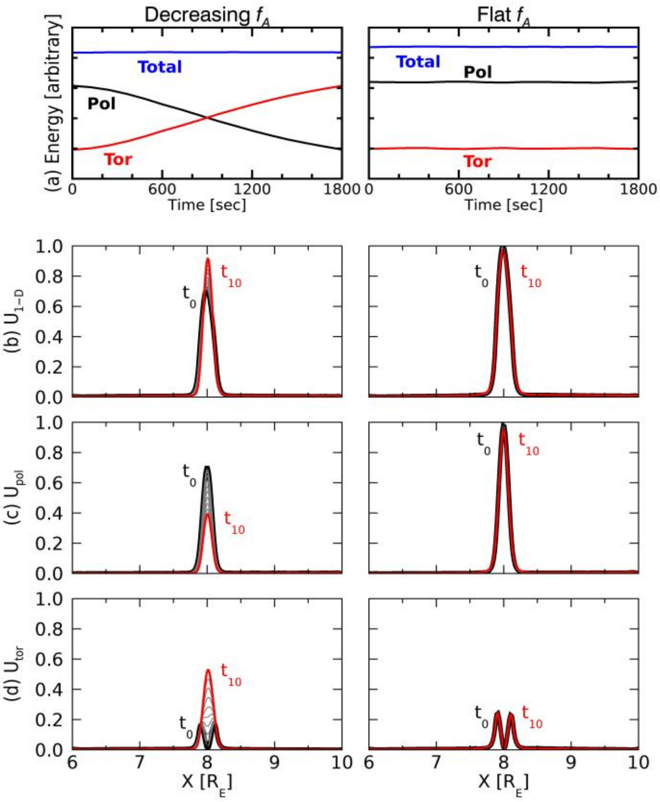

Figure 1. The wave energy in each case of monotonically decreasing Alfven frequency (left column) and locally constant frequency (right). (a) Time histories of wave energy, (b-d) spatial distribution of one-dimensional, poloidal, and toroidal modes at each magnetic shell, respectively. Initial (black), after 10 wave cycles (red), and intermediate (gray).

For the highly evanescent compressional wave, that preserves one-dimensional energy along the field lines, we have obtained another necessary condition, which provides the upper limit of azimuthal wavenumber.

It is found that a statistical study of observations is consistent with the conditions above. The results show that our new criterions will be useful in identifying the conditions of persistent poloidal mode in terms of the corresponding particle energy, wave numbers and the source characteristics.

References

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