CHAOTIC ALFVÉN WAVES IN SOLAR AND COMETARY PLASMAS

SUMMARY

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The recent observations, of energetic heavy ions in the vicinity of Comet Halley and Comet Giacobini-Zinner, are rather intriguing. Moreover the solar coronal heating is still not well understood and is somewhat puzzling. Since both these observations can not be properly explained by means of classical processes, we have to invoke anomalous heating and acceleration effects due to chaotic and turbulent plasma processes.

Large amplitude Alfvén waves as well as Alfvénic turbulence has been observed in the solar wind and in the cometary environment. It is well known that a chaotic system is essentially turbulent and a turbulent system is essentially nonlinear. In order to understand and properly interpret the above mentioned observations, we have applied the tools of nonlinear dynamical systems to study the evolution of Alfvén Waves (A.W).

On using the two-fluid equations with the generalized Ohm's law, we have shown [1,2] that the nonlinear Alfvén waves are governed by the Vector Derivative Nonlinear Schrödinger (VDNLS) equation which for parallel or quasiparallel propagation reduces to the Derivative Nonlinear Schrödinger (DNLS) equation for circularly polarized waves. For propagation in an arbitrary direction, VDNLS can be shown to reduce to the KdV equation. The latter describes the nonlinear behaviour of both the fast and the slow MHD solitary waves. The intermediate waves are, however, governed by the Modified KdV equation.

Pseudo-potential formulation, of the DNLS, leads to a rich variety of nonlinear Alfvén waves and solitons e.g., bright, dark and mixed solitons. In homogeneous plasmas, these solitons propagate with constant speeds. In an inhomogeneous plasma, however, the solitons get accelerated or decelerated depending upon whether wave propagation is along the increasing or the decreasing densities [3]. On the other hand, the streaming plasmas e.g., the solar wind exhibits the phenomena of flipping [4] of accelerating solitons into decelerating ones and vice-versa. In the presence of an external source, e.g., a plane wave, the nonlinear Alfvén waves can even lead to chaos provided the external source is strong enough. In a dissipative system, we will demonstrate that the chaos can occur through two channels:

1. through a sequence of bifurcations
2. sudden transition to chaos due to strange attractor.

Both the solar as well as the cometary plasmas consist of heavy ions besides electrons and protons. Through Poincare map analysis, we have shown that the presence of heavy ions makes the system less chaotic. The latter is a consequence of the inertial stabilization due to heavy ions [5].

S. Ferraz-Mello (ed.), Chaos, Resonance and Collective Dynamical Phenomena in the Solar System, 297–298.

References

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[3] B. Buti, *Geophys. Res. Lett.* **18**, 309 (1991).
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Discussion

A.M.Fridman – I have several questions: 1. Let we have infinite conductivity and Larmor radius equal to zero. Have you the cube nonlinearity in this case? 2. The scalar nonlinearity is not general nonlinearity for the Alfvén waves. There is also so call the vector nonlinearity. When may you neglect the latter? 3. When did you derived this equation with the cube nonlinearity? Jointly with Drs. Mikhailovskii and Petviaskvili, we had derived the nonlinear equation for the Alfvén waves in 1976.

B.Buti – 1. Yes, in that case also, we would have the cubic nonlinearity. It is the dispersion term which would be different. 2. The nonlinearity that we have in our VDNLS equation is the vector nonlinearity and not the scalar one. 3. The results for 2-species were published in *Phys Fluids*, 1989, but the ones for multispecies are in press. The nonlinear Schrödinger(NLS) equation derived earlier is a special case of VDNLS. For long wavelength perturbations, VDNLS reduces to NLS. In any case chaotic Alfvén waves have been discussed for the first time by us.