Geophysical Research Abstracts
Vol. 13, EGU2011-1492, 2011
EGU General Assembly 2011

Magnetohydrodynamic waves in partially ionized astrophysical plasmas: Application to oscillations in solar prominences

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The study of waves and oscillations in astrophysical and solar system plasmas is one of the most important applications of the magnetohydrodynamic (MHD) theory. In the interplanetary space, as well as in the coldest regions of the solar atmosphere, the plasma is only partially ionized. In such a case, MHD waves are affected by a number of physical processes due to the interaction and collisions of the different species composing the plasma. In this work, the general MHD equations for a partially ionized plasma in the single fluid approximation are derived. The equations contain different terms accounting for nonideal effects, which are related to collisions between the plasma species. As an application, we use these equations to study linear MHD waves in the fine structure of solar prominences, i.e. magnetic flux tubes filled with partially ionized cool and dense plasma threads, which are embedded in the hotter and fully ionized environment of the solar corona. We obtain analytical dispersion relations for the waves in simple cases, while the linear MHD equations are numerically integrated in the full case. We find that MHD waves in prominence threads are damped due to Cowling's diffusion, which is caused by ion-neutral collisions and is the dominant effect in prominence plasmas. Other mechanisms as, e.g., Ohm's and Hall's diffusion are of minor importance. The damping rate is different for the various waves, namely fast and slow magnetoacoustic waves and Alfven waves, and depends on the value of the wavelength and the ionization degree. However, only in the case of slow waves, Cowling's diffusion is efficient enough to produce damping times consistent with those reported in the observations of prominence oscillations. In addition, wave propagation is constrained by the presence of cut-off values of the wavelength. The general results of this investigation may be also applied to waves in chromospheric fibrils and in flux tubes of sunspot penumbrae.