Thermal anisotropy and magnetospheric ESW

Madhurjya P Bora
Physics Department, Gauhati University, Guwahati 781014, India

Electrostatic Solitary Waves (ESW) are pretty common in the magnetosphere. They form an important part of our understanding of space weather phenomena and also provide an excellent platform for studying fundamental plasma processes.

In this work, we have considered a two-fluid plasma model immersed in an external magnetic field (the geomagnetic field) which leads to both electron and ion pressure anisotropies. In view of the relevant time scale of interest being the ion-acoustic time scale, we have assumed a CGL (Chew-Goldberger-Low) double adiabatic law for the ions, whereas the electrons are described with an anisotropic bi-Maxwellian distribution.

The bi-Maxwellian electron distribution results in an electron anisotropy factor $\gamma(\phi)$,

$$\gamma(\phi)=\left[\frac{T_{e\perp}}{T_{e\|}}+\left(1-\frac{T_{e\perp}}{T_{e\|}}\right)\frac{B_0}{B_s(\phi)}\right]^{-1}, \tag{1}$$

where the symbols have their usual meanings. The effect of electron thermal anisotropy is related to the magnetic field line variation within the soliton through the anisotropy factor $\gamma(\phi)$, which is parameterised by the field line ratio$B_0/B_s(\phi)$.

The plasma approximation that we have used in this work essentially means that the Debye shielding length is at least a few orders of magnitude smaller than the size of the nonlinear structures, which is found to be correct for the parameter regime of magnetospheric plasmas. This also ignores the small scale variation of the ambient magnetic field within the soliton width. In order to model the magnetic field variation within the soliton width, we consider a state *far away* from a relaxed plasma state i.e. the state of Taylor relaxation, so that in the moving frame of the soliton

$$\boldsymbol{E}\simeq\eta\boldsymbol{j}, \tag{2}$$

which helps us in estimating the electrostatic potential ϕ

$$\phi\sim-\eta\int j_\|\,dl\sim-\eta\frac{BL}{\mu_0 l}+\text{const.}, \tag{3}$$

where the plasma resistivity can be thought to be a result of field line stochasticity within the solitary structure. The scale length l is the width of the electric current structure and L is the length over which the integration is carried out. Though we have chosen to parameterise the dependence of magnetic field line B_s on the plasma potential as per the above relation, we note that the resultant equation for n_e becomes analytically non-invertible in terms of ϕ. So, we approximate the above equation for small ϕ as

$$\frac{B_s}{B_0}\sim e^{-\phi} \tag{4}$$

which also reduces to the correct asymptotic value at the limit $\phi\to 0$ in conformation with above relation. The plasma potential is now given by

$$\phi=-\ln\left(\frac{n\alpha}{1-n+n\alpha}\right), \tag{5}$$

where $\alpha=T_{e\perp}/T_{e||}$ is a measure of electron temperature anisotropy.