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Nonlinear waves in the terrestrial quasi-parallel foreshock

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Upstream regions of quasiparallel collisionless astrophysical shocks are among the most complex plasma systems. When the magnetic field direction is quasiparallel to the shock normal, a fraction of incoming ions are reflected upstream generating an extended and turbulent foreshock. We provide strongly conclusive evidence that the cubic nonlinearity plays an important part in the evolution of the large amplitude magnetic structures in the terrestrial foreshock. Large amplitude nonlinear wave trains at frequencies above the proton cyclotron frequency are identified after non harmonic slow variations are filtered out by applying the empirical mode decomposition. Numerical solutions of the derivative nonlinear Schrodinger equation, predicted analytically by the use of a pseudo-potential approach, are found to be consistent with the observed wave forms. The approximate phase speed of these nonlinear waves, indicated by the parameters of numerical solutions, is of the order of the local Alfven speed. We suggest that the feedback of the large amplitudec fluctuations on background plasma is reflected in the evolution of the pseudo-potential.