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Ion Cyclotron Harmonic Waves: Theoretical studies related to Cluster observations in the PSBL

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Low-frequency electromagnetic waves in the vicinity of the harmonics (up to the fifth) of the proton cyclotron frequency have been observed by the magnetometers aboard of the Cluster spacecraft during crossings of the plasma sheet boundary layer (PSBL), see Broughton et al. (2008). Using the wave telescope technique Broughton et al. found that the waves propagate nearly perpendicular to the ambient magnetic field. It seems that they are excited by proton beams in the 15keV range which have simultaneously been detected. These observations have stimulated theoretical studies of beam-excited Ion Cyclotron Harmonic Waves (ICHWs) presented here. The full apparatus of Vlasov dispersion theory is used to calculate the growth rates of the ICHWs as a function of the propagation angle, density and velocity of the proton beam, and the temperature of both populations. Assuming reasonable beam densities (about 1% of the background density), the dispersion analysis shows that only a limited range of plasma parameters exists in which ICHWs can be excited. In particular, the propagation angle can only vary within a small range between about 80 and 85 degrees in order for the ICHWs to grow. This requires a beam velocity of at least ten times the Alfven speed. This theoretical parameter space for ICHW growth is consistent with the parameters measured by Cluster during the ICHW emission.