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Proton cyclotron wave conditions upstream of Venus

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Abstract

As a new feature at Venus, proton cyclotron waves (PCW) were recently detected in the upstream region by the Venus Express spacecraft. The waves are characterized by their occurrence at the local proton cyclotron frequency and by their left-hand polarization, both in the spacecraft frame and are observed in and upstream of the foreshock region over a large volume of space, up to large distances from the planet (~ 9 Rv). They are a direct indication of pick up of planetary protons from the exosphere of Venus and loss of hydrogen to interplanetary space.
Long term observations of these waves now raise the question, under which general solar wind conditions these waves are generated and maintained. Magnetometer data of the Venus Express spacecraft for two Venusian years of observations are analyzed before, during and after the occurrence of the waves. The configuration of the upstream magnetic field and the solar wind velocity is investigated, to study if the waves are generated from a ring distribution of pick-up ions in velocity space or from a parallel pick-up ion beam, i.e. for quasi-parallel conditions of solar wind velocity and magnetic field when the solar wind motional electric field is weak. It is found that stable and mainly quasi-parallel magnetic field conditions for up to 20-30 minutes prior to wave observation are present, enabling sufficient ion pick-up and wave growth to obtain observable waves in the magnetometer data. Persistent waves occur mainly under quasi-parallel conditions, only few cases under quasi-perpendicular conditions of the interplanetary magnetic field and the solar wind velocity are detected. This is in agreement with linear theory, which predicts efficient wave growth for instabilities driven by field-aligned planetary ion beams.
Furthermore, the occurrence of highly coherent waves at distances far upstream towards the Sun implies that planetary neutral hydrogen is initially picked up at least 5 Venus radii towards the Sun from a sufficiently dense Venus hydrogen exosphere.

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