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Plasma Waves around Comets

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Plasma waves are omnipresent in space and are observed in solar system objects such as planets, planetary satellites [1], Sun [2], and interplanetary medium and are predicted to exist in stellar space such as interstellar medium and massive stars [3]. Plasma waves have the capability to propagate the energy across different space regions and can also provide particle transport in systems where the collisions are absent.

Comet is a universal body, primarily made of dust, ice and gaseous matter. A comet can have a large elliptical orbit so that it become visible at Earth periodically (Halley) or it can have a parabolic orbit where it passes the solar system once and then get immersed in the interstellar space. When the solar radiation interacts with the neutral particle medium it results in the formation of localized plasma or ionization in that region. In cometary environment, this plasma medium extends from the coma around the cometary nucleus to the tail of the comet which is at times a magnetotail. The low density, low temperature plasma around a comet is capable of sustaining plasma waves. A number of such plasma waves are observed in comets Giacobini-Zinner (G-Z), Halley, Grigg-Skjellerup (G-S) and Borrelly.

The cometary tail is the extension of comet in a direction opposite to its movement and has a different plasma environment than that of its coma. The activity of comet and the solar wind conditions decides the overall macroscopic structure of the interaction region as well as the plasma environment around the comet including the magnetic field which has a maximum value between 60 – 80 nT for a comet [4].

International Cometary Explorer (ICE) was the first spacecraft to encounter G-Z in 1985 and later comet Halley in 1986. ICE was equipped with Plasma Wave Investigation (PWI) having electric field sensors and magnetometers onboard to detect plasma waves. The erstwhile USSR launched identical spacecrafts Vega-1 and Vega-2 in 1984 to reach comet Halley. ESA launched Giotto in 1985 to meet comet Halley and G-S with magnetometer onboard to measure the time variation of magnetic field due to cometary plasma processes. In 1998 NASA launched Deep Space-1 (DS-1) for comet Borrelly.

ICE detected ion acoustic waves in comet G-Z and EM whistlers and low-level electron plasma oscillations (EPOs) were also observed [5]. The plasma wave observation in comet Halley was carried out by Vega 2 using the high frequency plasma wave analyser (APV-V) [6] and low-frequency plasma wave detector (APV-N) onboard Vega 1 and 2 [7]. The Giotto magnetic field and plasma observations established the low frequency EM waves near comet G-S [8]. DS-1 encountered comet Borrelly in 2001 and observed 1 kHz electron cyclotron waves, predicted to be generated due to plasma instabilities, were observed by DS-1 [9].

The commonly observed plasma waves in the comets are the electron plasma oscillations, ion cyclotron and lower hybrid waves. However, there are some unresolved plasma wave issues in comets such as not all the plasma waves are observed in all the comets and plasma wave observations in other comets such as Wirtanen, Hyakutake, 67P/Churyumov-Gerasimenko, etc. which have plasma wave supportive environment.

In this paper, plasma waves in four comets - Halley, G-Z, G-S and Borrelly shall be discussed along with the plasma wave observations in a future mission.

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