Saturn's magnetosphere after the Cassini
~ Works related to the RPWS/LP ~

M. W. Morooka, J. -E. Wahlund, M. K. G. Holmberg, O. Shebanits, and E. Odanaka

Cassini-Huygens is the NASA/ESA/ASI joint spacecraft mission to Saturn. It has been launched in 1997 and after the flybys of the Earth, Venus, and Jupiter, inserted into Saturn orbit in 2004. Since then Cassini has been continuing its exploration of Kronian magnetosphere and making amazing discoveries. We reviewed a part of Cassini's findings in terms of the RPWS (Radio and Plasma Wave Science) /Langmuir Probe (LP) observations.
The Cassini RPWS/LP is a 5 cm diameter titanium sphere mounted with a hinged boom at 0.8 m out from the spacecraft. It samples the total electrical current from the plasma by applying 512 points bias voltages (±32 V), and its methods give estimates of several thermal plasma parameters that are important for characterizing the properties of the Kronian magnetosphere [Wahlund et al., 2005].

In the condition of the tenuous plasma in the outer magnetosphere (usually beyond $9R_S$, Saturn radii) the floating potential of the probe (U_{float}) can be used as a proxy to evaluate the electron number density (Ne). The obtained electron densities were used to investigate the special and temporal structures of the Kronian magnetosphere. The statistical result of the electron densities by the RPWS/LP shows disc like structure with a periodic density enhancement in the planet's spin [Morooka et al., 2009]. Since Cassini had arrived at Saturn in 2004, the periodic structure of the Kronian magnetosphere has been recognized by many *in-situ* and remote sensing instruments onboard Cassini [see Carbary and Mitchell, 2013 and references therein]. The enigma of Saturn's periodicity became even more complicated after the dual periodicity of Saturnian Kilometric Radiation (SKR) has discovered [Gurnett et al., 2009] and the discussion is still ongoing within the Kronian magnetosphere scientists.

In the cold plasma the Langmuir Probe technique can be used to determine the density (N_e) and temperature (T_e), the ion densities (N_i) and thermal speed (v_i), and spacecraft potential (U_{SC}) [Wahlund et al., 2005]. Those parameters are important to determine the characteristics of the atmosphere of Titan, the largest moon of Saturn. Titan has a substantial atmosphere that resembles the early atmosphere of the Earth. The LP data obtained at Titan, together with many other instruments data revealed the existence of the complex chemistry with heavy molecules ongoing at the lower altitudes of Titan [e.g., Coates et al., 2007,2010; Waite et al., 2007; Ågren et al., 2012; Shebanits et al., submitted]. Cassini data also revealed the interaction between the atmosphere of Titan and the magnetospheric plasma of Saturn.

An individual estimate of the electrons and ion density by the LP has lead to the detection of a new type of the plasma state around the moon Enceladus. A large ion and electron density difference (N_e/N_i < 0.01-0.5) associated to the micrometer-sized dust grains have been observed near the Enceladus plume and surrounding E ring. This is because more than 99 % of electrons are attached to the dust grains and the plasma and the charged grains are strongly coupled by dust-plasma interactions, i.e., a dusty plasma [Morooka et al., 2011]. The Enceladus expels water vapor and ice grains from its south pole and forms a plume that becomes the major source for the E ring and the surrounding neutral gas [Dougherty et al., 2007; Porco et al., 2007], and after the ionization by the EUV radiation results a dominant plasma source for Saturn's magnetosphere. The dusty plasma of the Enceladus plume is therefore important to the Kronian magnetosphere dynamics.

The Cassini mission is planed to continue at least until September 2017, and the extending observations would give keys to answer the questions listed above.