月探査かぐやの観測した月周辺で観測される電子領域プラズマ波動

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Plasma Waves generated in the relation to electron dynamics around the Moon: KAGUYA observations

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We have analyzed plasma electrostatic wave around the Moon observed by KAGUYA spacecraft which is the Japanese mission to the moon. It observed plasma wave, plasma particle, magnetic field when it was in both the solar wind and the Earth's magnetosphere at the distance of 60Re from the Earth. The plasma wave data show that Electron Cyclotron Harmonic (ECH) waves, Langmuir waves and upper hybrid waves are observed around the Moon.

Plasma wave data of Wave Form Capture receiver (WFC) on KAGUYA revealed that ECH waves are observed around the moon. ECH waves do not appear when the moon in solar wind but in the magnetosphere. In addition they are often observed on the night side, and near the magnetic anomaly.

ECH wave is one of static wave. The frequency peaks are a little higher than integral multiple of cyclotron frequency, and it is polarized almost vertically. The ECH waves have been widely studied in the relation to the electron precipitation in the magnetic anomaly due to the loss cone instability. However, that does not directly link to the observation of the ECH around the moon orbit at the distance of 60RE from the Earth.

We examine the particle data to know what particle velocity distribution cause to generate ECH waves under the circumstance around the moon. They show that the combination of loss cone distribution and low energy beam aligned are observed in electron velocity distribution when ECH waves are excited. Loss cone distribution is caused by mirror force at the magnetic anomaly on the surface of the moon, and low energy electron beams are accelerated by the negative potential of the moon surface on the night side. These phenomena were already found by Lunar Prospector in 2002. So we assumed these two kinds of electron distribution is necessary to excite ECH waves, but loss cone distribution and low energy beam are observed not only in the magnetosphere but also in the wake, where ECH waves are not observed, so we assumed ECH waves are generated only under the parametric condition in the magnetosphere.

In order to study the generation of the ECH waves, we calculated the linear growth rate by solving the kinetic plasma dispersion relation using the realistic plasma parameters, density, thermal velocity of particles and magnetic field, of electromagnetic environment of lobe, plasma sheet and wake based on the KAGUYA observation. We assumed two components, hot electrons and cold electrons, and the former have loss cone distribution and the latter has drift velocity which equivalent electron beams.

As a result ECH waves should be excited in as long as there exist both loss cone distribution and electron beam. We also found cold electron need not drift velocity. The result also shows the growth rate of ECH depends on the parameter of temperature ratio of cold electrons and hot ones T_c / T_h and density ratio of n_c / n_h, and growth rate is highest in the region of environment of plasma sheet and it is lowest in that of wake. This result of calculation correspond to observation data that ECH waves are often observed in plasma sheet while they not at all.

We also focus on electron plasma waves. They are observed in the frequency close to local electron plasma frequency. The electron plasma waves can be observed in the dayside of the Moon and in the edge of the wake region. Since the electron cyclotron frequency is much lower than the electron plasma frequency in space along the moon orbit, the upper hybrid frequency is almost equal to the electron plasma frequency. I t is difficult to distinguish these waves only using spectrum features. The polarization analyses, then, are helpful for identifying the wave mode of electron plasma waves. Our preliminary analyses show both these waves can be observed around the moon. We discuss the generation model of these two kinds of electron plasma waves based on the parametric dependence of the observations.