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Theoretical study of the spectral formation of monochromatic whistler waves near the Moon detected by Kaguya

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We study the spectral formation mechanism of monochromatic whistler waves observed by the Lunar Magnetometer aboard the Kaguya spacecraft orbiting at 100 km altitude above the Moon. The waves are observed as narrowband magnetic fluctuations with frequencies close to 1 Hz and are mostly left-hand polarized in the spacecraft frame.

Assuming whistler-mode waves in the solar wind frame propagating in the sunward direction with the group velocity comparable to the solar wind velocity, we find that, in the spacecraft frame, the Doppler-shifted frequency spectra of the waves are considerably modified making a peak at a certain frequency. The similar discussions have been made on the characteristics of upstream whistler waves observed near planetary bow shocks [e.g., Russell, 2007]. We suggest that the characteristics of the spectra of monochromatic whistler waves are determined by the relation between the group velocity vector of the waves and the solar wind velocity vector. By using the dispersion relation of whistler-mode waves in a cold plasma, we show that the factors controlling the solution are the wave vector, the magnetic field directions, and the solar wind parameters. We investigate these parameter spaces and find that the wave vector angles with respect to the sunward and to the magnetic field directions change the solution considerably than the solar wind parameters do.

To confirm the theory described above, we compare the peak frequency distribution predicted by the theory with the observed wave distribution. The consistency between the theoretical and observed wave distributions indicates that the frequency shift of the waves is well explained by the theory and that the most important controlling factor is the angle between the group velocity and solar wind velocity vectors.

Keywords: whistler-mode, Moon, monochromatic, group velocity, upstream, bow shock