Three types of whistler-mode waves near the Moon observed in the solar wind

Yasunori Tsugawa[1]; Yuto Katoh[1]; Naoki Terada[2]; Takayuki Ono[1]; Hideo Tsunakawa[3]; Futoshi Takahashi[4]; Hidetoshi Shibuya[5]; Hisayoshi Shimizu[6]; Masaki Matsushima[7]
[1] Dept. Geophys., Grad. Sch. Sci., Tohoku Univ.; [2] Dept. Geophys., Grad. Sch. Sci., Tohoku Univ.; [3] Dept. Earth Planet. Sci., Tokyo TECH; [4] TITech; [5] Dep't Earth & Env., Kumamoto Univ.; [6] ERI, University of Tokyo; [7] Dept Earth & Planetary Sciences, Tokyo Tech

Three types of magnetic waves in whistler-mode have been observed near the Moon; (1) narrowband whistler-mode waves which are mostly left-hand polarized because of large Doppler-shift in the frequencies close to 1 Hz [Halekas et al., 2008; Tsugawa et al., 2011]; (2) unpolarized broadband whistler-mode waves in the frequency range from 0.1 to 10 Hz [Nakagawa et al., 2011; Tsugawa et al., 2012]; and (3) right-hand polarized broadband waves with small amplitude in the frequency up to 16 Hz. They are mostly observed near lunar magnetic anomalies in the solar wind and are suggested to be generated by the solar wind interaction with the magnetic anomalies. However, their generation processes have not been understood clearly.

To examine the conditions to observe these whistler-mode waves, we have compared the properties of the waves observed by Kaguya in different altitude and solar wind conditions. At near 100 km altitude, the unpolarized broadband waves are observed only above large-scale magnetic anomalies (South-Pole Aitken basin), while at an altitude lower than 100 km the waves are also observed above smaller-scale magnetic anomalies (e.g., Crisium antipode, Lomonosov-Fleming basin). This indicates that the unpolarizad broadband waves are observed only in the solar wind interaction region or so-called mini-magnetosphere near the magnetic anomalies. On the other hand, the narrowband waves and the right-hand polarized broadband waves are observed in the region surrounding the magnetic anomalies. We have also examined the solar wind dynamic pressure during the observation and have found that these waves are more frequently observed when the solar wind dynamic pressure is higher than 2 nPa.

These results support the idea that these whistler-mode waves originate from the same sources and the narrowband waves are a part of the broadband waves propagating against the solar wind as suggested by Tsugawa et al. [2012]. A part of the broadband waves whose group velocity is close to the solar wind velocity exhibit a large spectral density at a certain frequency in the spacecraft frame to be observed as the narrowband waves. Ions reflected by the magnetic anomalies would be energy source for all of these waves because the broadband waves are associated with them.