

# Electrostatic electron cyclotron harmonic waves observed by the ARTEMIS satellite in the vicinity of the Moon

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Electrostatic electron cyclotron harmonic (ECH) waves are electrostatic emissions observed in the frequency bands between the integer multiples of electron cyclotron frequency,  $f_{ce}$ . These emissions have electric field oscillations almost perpendicular to the ambient magnetic field. ECH waves are observed in the magnetosphere of planets such as Earth, Jupiter, and Saturn. Previous studies have shown that the waves are excited by a loss cone distribution of hot electrons with cold core electrons. ECH waves are observed near the Moon, and was analyzed using data from KAGUYA, which orbits at an altitude of about 100 km above the Moon's surface. However, research on the ECH waves at higher altitudes has not been performed. This study aims to elucidate the relationship between ECH wave excitation and the plasma environment around the Moon using data from the ARTEMIS satellite, which orbits around the Moon in an elliptical orbit and observes a higher altitude range compared with the KAGUYA observation. We found that the ECH waves observed at the altitude of the ARTEMIS satellites are categorized into three types of spectral structures: those with a peak near the UHR frequency (Type1), those with multiple spectral peaks between integer multiples of  $f_{ce}$  well below the UHR frequency (Type2), and those with spectral peaks between integer multiples of  $f_{ce}$  from  $\sim f_{ce}$  up to the UHR frequency (Type3). We found that Type 2 emissions were rarely observed, and the Type 1 emissions were mainly observed on the lunar dayside in the lobe. The Type 3 emissions were mainly observed on the lunar nightside in the plasma sheet. The analysis of the electron velocity distribution reveals that the Type1 emissions are related to the observation of the electron deficiency and low-energy electrons from the Moon, while the Type3 emissions are accompanied by the energy-dependent electron deficiency and electron beam from the Moon. The dependence of ECH wave intensity on the distance from the Moon shows that the ECH wave intensity tends to be smaller as the distance from the Moon becomes larger. This may be due to the fact that the unstable electron velocity distribution of lunar origin becomes less unstable as the distance from the Moon increases. We analyzed the relationship between the ECH wave intensity and several deformations of the electron velocity distribution that results from the Moon-plasma interactions, and discuss the free energy source for the excitation of the ECH waves at the ARTEMIS altitude.

Keywords: Moon, Plasma, Electrostatic Electron Cyclotron Harmonic waves, ARTEMIS