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Estimates of lunar crustal magnetic field distributions using plasma sheet electrons

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Lunar crustal magnetic anomalies have been observed by surface magnetometers at the Apollo landing sites, magnetometers onboard orbiting satellites, or the electron reflection method with the use of the electron's magnetic mirror effect. The spatial scale length of the lunar magnetic anomaly ranges from less than a few km up to several hundred kilometers. However, the measurement of lunar magnetic anomalies by satellite-borne magnetometer is limited by orbital altitudes, and further, the electron reflection method underestimates the strength of surface magnetic fields with wavelengths smaller than the electron gyrodiameter. Therefore, it is difficult to perform a precise measurement of weak and small-scale magnetic anomalies from the orbiting satellite. On the other hand, surface magnetometers can measure actual magnetic fields on the lunar surface but the observations were made at only a few points so far. The small-wavelength component may provide important information on the origins of lunar magnetic anomalies, which have been debated for a long time.

In this study, we estimate the lunar crustal magnetic field distributions using electrons observed by Kaguya when the Moon was located in the terrestrial plasma sheet. Electron velocity distribution functions obtained at low altitudes (~10-30 km) sometimes indicate relatively high-energy electrons ($>$ 1 keV) thought to strike the lunar surface within one gyromotion from our reversed particle trace calculations, which suggests that these electrons were nonadiabatically scattered by local surface magnetic fields. If we assume that these surface magnetic fields have vertical scale lengths much smaller than Kaguya's orbital altitude, we can infer their surface distributions from the observed electron velocity distribution functions. Electrons will be scattered upward from the lunar surface depending on the strength of the parallel magnetic field component with respect to the lunar surface. Therefore, a minimum value of the product of the strength and the horizontal scale length of the horizontal magnetic field component can be derived from the electron's scattered velocity obtained by the particle trace calculation. Thus, it is possible to infer small structures of the surface magnetic fields by using the high-angular resolution data of electrons obtained by Kaguya.

Keywords: Moon, magnetic anomaly, plasma, Kaguya