INVESTIGATION OF IONIZED VOLATILES AND INTERIOR STRUCTURE OF THE MOON: IMPLICATIONS FROM RESTORED APOLLO MAGNETIC FIELD DATA.
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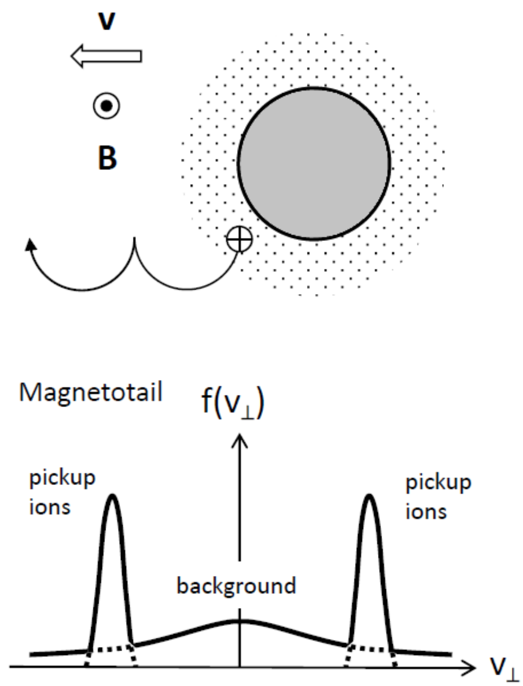
Introduction: Magnetic field fluctuations may reveal the state of ambient plasma or the interior of solar system bodies. As the Moon is surrounded by plasma in the solar wind, the Earth's magnetosheath, or the magnetotail, characteristics of magnetic fluctuations or waves may infer the presence of ionized lunar volatiles. On the other hand, if saline ice exists inside the Moon, it induces magnetic variations on and above the lunar surface, which can be used to infer the electrical conductivity of the lunar interior.

Restoration of Apollo Magnetic Field Data: Among the series of lunar missions that carried magnetometers since the 1960s, the Apollo missions made earliest yet unique contributions to the measurements of the lunar magnetic field. After the conclusion of the Apollo Program, the format in which the Apollo magnetic field data were stored gradually became obsolete, and for several decades the data could not easily be understood. In 2008, an effort began to restore the Apollo magnetic field data with the help by NSSDC and support from the NASA LASER Program. The digital data include the 0.3-s samples from Apollo 12, 15 and 16 Lunar Surface Magnetometers (LSM) and the 24-s samples from Apollo 15 and 16 Sub-satellite Biaxial Magnetometers (SBM). After a lengthy process of identifying legitimate data structures in the binary data stream [1], all the SBM data archived at NSSDC have now been restored. The restoration of the LSM data has been slower due to the irregular pattern of time words, but the data during April-July 1972 when both Apollo 15 and 16 LSMs were operational have been recovered.

Ionized Volatiles near the Moon: An unexpected discovery in the restored Apollo LSM data is the ion cyclotron waves on the lunar surface [2]. A class of narrowband waves with frequencies ranging from 0.04 to 0.17 Hz were found only when the Moon was in the terrestrial magnetotail, including regions in and near the current sheet as implied from magnetic field directions. The wave properties are consistent with those of ion cyclotron waves: A wave frequency at or slightly lower than the local proton gyrofrequency, a dominant transverse component, and left-hand polarization. When the plasma convection is present and perpendicular to the ambient magnetic field, the pickup ions originating from the lunar exosphere can travel along cycloid trajectories resulting in a ring distribution in the velocity space (see Figure). This is how ion cyclotron waves are generated near comets, Venus, and Mars, in the Io torus, or in the Saturn E-ring. Because the lunar exosphere is tenuous, pickup ions from the Moon may not constitute a significant amount of particles in the solar wind plasma where a typical density is 5 cm^{-3}. When the Moon is in the terrestrial magnetotail, however, the ambient plasma density is at the order of 0.1 cm^{-3} or less, and pickup ions can be much more noticeable and form an unstable ring-type distribution.



More studies are needed to confirm the generation mechanism of ion cyclotron waves at the Moon and where these waves are present. An ongoing study using the Apollo Suprathermal Ion Detector Experiment (SIDE) data suggests that many events of ion cyclotron waves were seen in the tail lobes rather than in the plasma sheet [3], favoring the generation by pickup ions associated with lunar volatiles.

Magnetic Sounding of Lunar Interior: One of the important uses of the lunar magnetic field measurements is detecting the electrical conductvitiy and the metallic core in the lunar interior. During the Apollo era, the electrical conductivity of the Moon has been inferred from examining the transfer function between external and surface magnetic field fluctuations [4], the decay of magnetic impulses on the lunar surface [5], and the deflection of the magnetic field above the lunar surface when the Moon was in the magnetotail tail lobes [6]. Most magnetic sounding studies using surface magnetic field measurements are based on the Apollo 12 LSM data, but the Apollo 15, 16 LSM data with larger quantity and higher quality have not been fully explored. We have examined the transfer function using the restored Apollo 15 LSM data and Explorer 35 magnetometer and found that the responses in both radial and transverse components at high frequencies ($f > 10^{-4}$ Hz) are consistent with modeled results. For the data during the short interval when these two datasets overlap, the statistical uncertainty for frequencies below 10^{-4} Hz is too large to resolve the size of the conducting core. We will report the ongoing effort in recovering the orbit data of Apollo sub-satellites and the SBM data in the full three components in order to improve the precision of magnetic sounding analysis with Apollo magnetic field data.

References:

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