EVIDENCE FOR ACCELERATION OF LUNAR IONS  R. H. Manka,  
F. C. Michel, and J. W. Freeman, Jr., Space Science Dept., Rice 
Univ., Houston, Tex. 77001. P. Dyal, C. W. Parkin, D. S. 
Colburn, and C. P. Sonett, NASA Ames Research Center, Moffett 
Field, Calif. 94035

The dynamics of ions in the lunar atmosphere are related to 
phenomena such as: gas clouds released into the lunar atmosphere 
by lunar venting or man-made impacts, lunar ions detected by sur-
face ion detectors, and the apparent presence of trapped lunar 
atmosphere in the lunar soil samples. A recent model for the 
dynamics of lunar ions describes their energy and flux as a re-
sult of acceleration by fields in the solar wind and at the lunar 
surface (Manka and Michel, 1970). The purpose of this paper is 
to discuss some further characteristics of this model and to pre-
sent, using correlated data from lunar surface and orbital mag-
netometers and surface ion detectors, an analysis of several ion 
events which support the theory.

The model has already been applied to studies of noble gases 
found in lunar samples and to results of ALSEP ion detectors. At 
present it appears that, in addition to the solar wind gases 
trapped in lunar surface samples, there is a significant amount 
of lunar atmosphere which is being ionized and accelerated into 
the moon with sufficient energy to be trapped; furthermore, some 
isotopic fractionation of the trapped atmosphere is likely and 
the magnitudes of these effects have previously been estimated. 
The lunar atmosphere can also be detected in ionized form; the 
Suprathermal Ion Detector (SIDE) sees sporadic bursts of lunar 
ions (Freeman, et al., 1971). Different types of ion events are 
seen, each being characteristic flux, peak energy, and phase of 
the lunar orbit in which they occur. Many of the types of ion 
events, including low energy events (tens to hundreds of elec-
tron volts), occur preferentially around local sunrise and sun-
set, as is predicted by this acceleration model. Special gas 
clouds could be generated by spacecraft impacts or by sudden lu-
nar venting (which could produce an event such as the one recent-
ly attributed to vented water vapor (Freeman et al., 1972). Such
clouds may be detected by an ion detector, provided that field conditions are such that ions formed in the cloud are accelerated into the detector look angle. Such an acceleration mechanism is, then, crucial to the connection between the atmosphere or gas event itself, and its detection in the lunar surface samples or by charged particle experiments.

The proposed mechanism is based on photo- and charge exchange ionization of the gas and subsequent acceleration into the moon by electric ($E_{SW}$) and magnetic ($B_{SW}$) fields associated with the solar wind. This acceleration has several unique characteristics. One expected feature is that the fluxes of heavier ions should be quite directional, approximately along $E_{SW}$, and predominantly at right angles to both $B_{SW}$ and the solar wind velocity ($V_{SW}$). This is because the ion is initially accelerated along the interplanetary electric field, given by $E_{SW} = -V_{SW} \times \vec{B}_{SW}$. Another feature is that the ions should be energetic, compared to the terrestrial ionosphere, with energies of tens of eV to a few keV. These directions and energies could be modified by lunar surface electric and magnetic fields; and the ions might even be used to probe these surface fields. We discuss the application of this model to gas clouds from sudden, localized events; the sporadic detection of ions from the event may be due to the orientation and fluctuation of $E_{SW}$.

The expected ion energy and flux spectra are given and estimates are made of the effects of surface electric and magnetic fields. Lunar ion trajectories are studied by comparing flux measurements from the SIDE, which looks in the ecliptic plane, with magnetic measurements from the Lunar Surface Magnetometer and the Ames Magnetometer on lunar orbiting Explorer 35 (Dyal and Parkin 1971; Colburn et al., 1971). The model predicts that near local lunar sunrise and sunset, ions from the lunar atmosphere could enter the detector when the interplanetary magnetic field is out of the ecliptic in such a way that the $V \times E$ electric field drives ions into the detector; in addition, a source of lunar nighttime particles could be ions from the earth's bow shock traveling up the interplanetary magnetic field. Thus a condition for lunar ions to enter a detector would be that $E_{SW}$ is anti-parallel to the detector look direction, while a condition that bow shock ions enter a detector would be that $B_{SW}$ is approximately parallel or anti-parallel to the detector look direction. Comparison of sunrise - sunset ion events, detected by the SIDE,
LUNAR IONS

R. H. Manka

with the corresponding magnetometer data shows that in most cases $B_{SW}$ was strongly out of the ecliptic and had the proper orientation for $E_{SW}$ to drive lunar ions toward the detector. Analyses of several low energy events are presented for which detailed time correlations between ion flux and $B_{SW}$ are found.

Implications of these findings are discussed with respect to other detected ion events, the assumptions used in calculations of ion trapping, and the interaction of the solar wind with the lunar atmosphere. In particular, some properties of the ion dynamics during the possible "water vapor" event of March 7 are discussed. Using preliminary data from the Ames Explorer 35 Magnetometer and the lunar surface Solar Wind Spectrometer, the strength of the interplanetary electric field is calculated. If the assumption is made that the observed ion energy is derived entirely from $E_{SW}$, then the ions originate at heights of 16 to 32 km, consistent with the scale height for water vapor ($\sim 25$ km).

We thank Drs. H. K. Hills and Conway Snyder for making available preliminary data.

References


