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Enhancements in the lunar exosphere seen in LACE data

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Abstract

Apollo 17 carried a miniature mass spectrometer, called the Lunar Atmospheric Composition Experiment (LACE), to the Moon as part of the Apollo Lunar Surface Experiments Package (ALSEP) to study the composition and variations in the lunar atmosphere [4]. Although our initial task was to archive the LACE data in the Planetary Data System, during this analysis a sudden increase in many, but not all, of the atomic species was discovered during the 5th lunation. The solar wind plasma flux was elevated during the entire 10 hour period preceding the enhancements in exospheric density observed by LACE. The maximum in the solar wind plasma flux during this time period was measured by the IMP-6 spacecraft in Earth orbit at 20:00 hours on May 6, about four hours prior to the observed density enhancement on the nightside. Our Monte Carlo models cannot reproduce the observed sudden increase with the increase in the solar wind flux at the Moon. Alternative explanations may involve a small meteoroid impact.

1. Introduction

The LACE data were available for mass/charge (M/Q) 1 to 100, but the usable data are in the range 16 - 45 AMU/Q. The raw data are in counts per 0.6 second. The first task was therefore to calibrate the data. There is no available calibration for the LACE mass spectrometer data, however, a similar instrument was constructed and flown on the Pioneer Venus mission [3] and we used their calibration. Looking closely at the variation of the Mass 22 peak over the 9 available lunations, a sudden increase of peak in the later part of 5th lunation was seen. Although the second half of 5th lunation was mostly noise, a mass 22 peak suddenly appeared at 00.38 UT on May 7th, 1973. We then saw that the other masses were increased, but by varying amounts (Figure 1). We show in Table 1 the ^{20}Ne densities estimated from the Pioneer Venus neutral mass spectrometer calibration curve.

1.1 Solar Wind Data

We saw an enhancement in ^{20}Ne of a factor of 18.4 on May 7, 1973, from 00 UT to 01 UT, then decreasing for 8 - 10 hours. Solar wind data for this time period obtained by the IMP-6 spacecraft, which was in Earth orbit during years 1971-1974, were retrieved from the NASA OMNIWeb [5, 7] for IMF (B (nT)), proton density, n (cm^{-3}), solar wind velocity, v (km/s), and alpha/proton ratio. The solar wind plasma flux was elevated during the entire 10 hour period preceding the enhancements in exospheric density observed by LACE. The increase in exospheric densities began about 00 UT on May 7, 1973 after the proton flux had been elevated for the 10 hour period preceding this observation. Although the solar wind speed increased to 600 km/s 12 hours later, the proton density decreased to about 3 cm^{-3}, and the proton flux would have been reduced by an order of magnitude below that seen just before our observation of elevated exospheric density. The maximum flux was 1.76 x10^{9} protons cm^{-2} s^{-1}, and it remained high throughout the period leading up to our observations on May 7, 00 hours UT, when the plasma flux was 7.58 x10^{8} protons cm^{-2} s^{-1}.

2. Figure and Table

Figure 1: Increase ratio for M/Q 15 - 50

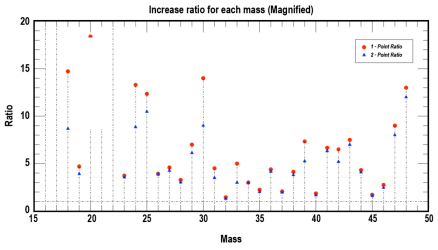

Table 1: ^{20}Ne densities estimated for lunations 2 - 5

Lunation	^{20}Ne Density atoms/cm^3
2nd	1.5 - 3.5 x 10^3
3rd	2.0-4.5 x 10^3
4th	2.0- 4.0 x 10^3
5th before &after	2.0 - 4.0 x10^3
5th increased	2.74 x10^4

3. Summary and Conclusions

We have observed a measured increase in ^{20}Ne at the Moon observed on May 7, 1973, at 00 Hr UT after an elevated solar wind flux observed by the IMP6 spacecraft. The measured ^{20}Ne densities before and after the solar wind increase were consistent with the ^{20}Ne column densities reported by Cook et al. (2013) [2] for normal solar wind conditions and by Benna et al. (2015) [1] for CME conditions, respectively. The Benna et al. (2015) value was measured during the CME of 7-27 Feb. 2014. For CME conditions, the solar wind would have an enhanced abundance of heavy ions such that Ne/O =0.32 and O/H=3x10^{-4} [6]. If v_{sw}=800 km/s and N_{sw}=10 cm^{-3} as expected for the CME, then the solar wind Ne flux to the lunar surface would be Ne = 7.7x10^4 cm^{-2} s^{-1}. If we assume CME conditions persisted for 4.5 days, the column abundance at the subsolar point would be N(Ne)=3x10^{10} cm^{-2}. We have not been able to reproduce the measured rapid increase and rapid decline in ^{20}Ne seen in the LACE data with our Monte Carlo model [8] using the measured solar wind flux. It is possible that the increased density was the result of an impact on the lunar nightside. We believe that the increase in surface number density at mass 22 at sunrise is not ^{22}Ne but rather CO_2^{++}. If Ne were evaporating at dawn the surface number density would decrease, not increase since the scale height would be increasing. Ne is a non-condensable gas. Thus the increased counts at dawn are not Ne but a contaminant, most likely CO_2^{++}. A dawn increase at Mass 20 could be MgO^{++}, Ar^{++}or Ca^{++} as well as ^{20}Ne. We also see an increase in oxygen and hydroxyl at the same time as the increase in Ne. These values will be considered in a subsequent paper.

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