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Cratering asymmetry on the Moon: A new insight from the Apollo Passive Seismic Experiment

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Abstract

The synchronous rotation of the Moon can lead to an asymmetry in the cratering rate between the leading and trailing hemispheres of the lunar orbital motion. We examined this possibility with Apollo seismic data which provides us with the information of the current bombardments and small impact events of meter-size craters. The data implies that the number density of impacts on the leading hemisphere is substantially higher than that on the trailing hemisphere. This indicates that the cratering asymmetry predicted from historical cratering records also exists in the current low magnitude impacts.

1. Introduction

The Moon is known to be in rotation-revolution synchronization with the Earth. The motion of the satellite against random impactors causes a relative flow of impactors. The leading side intercepts more impactors than the trailing side. In addition, the mean impact velocity on the leading side becomes higher than that on the trailing side and crater sizes on the leading side, on average, tend to be larger than those on the trailing side accordingly. For these reasons, the synchronous rotation can lead to a slight increase in the cratering rate on the leading side. A recent study of cratering records reveals the existence of cratering asymmetry on the Moon for kilometer-size craters [1]. In this study, we examined whether such an asymmetry is detected with Apollo seismic data. 8 years observation of Apollo passive seismic experiment detected 1744 meteorite impacts [2]. Craters created by such seismically identified impact events were estimated to be meters to tens of meters in diameter [3]. The Apollo seismic data can be regarded as an important source of information on the current lunar bombardments of relatively small impact events.

2. Data Selection

In this study, we used the list of meteorite impacts organized by *Oberst* [1989][3]. *Oberst* [1989][3] estimated locations and magnitudes for the 91 largest impact events from Apollo seismic data. From the original data set, we eliminated events that can bias the spatial distribution of the impact sites; 1) clustered events related with meteorite showers [4], 2) event detected before the complete establishment of the observation network, 3) small magnitude events ($< 10^9$ J) that concentrate around the observation network. Figure 1 shows the original distribution of the impact site and the distribution after the data selection. We can observe that a concentration of the impact sites around the observation network likely to be due to the detectability of the network was cancelled by the data selection.

3. Results and Discussion

The series of the data selections leaves 56 events to be used in the following statistics. Figure 2 shows impact energy-frequency distributions on the leading and trailing sides. The distribution on the leading side is almost parallel to that of the trailing side and has a certain offset toward a larger value. This shows that the leading side has a higher cratering rate than the trailing side. The enhancement on the leading side is estimated to be 1.8 ± 0.4. The error is 1σ of a binomial distribution of an even probability. To examine statistical significance, we carried out a χ^2-test and/or an evaluation of its occurrence probability using the binomial distribution. Consultation of them shows that the probability of observing this difference is approximately 0.03. It is significantly small and allows us a conclusion that the distribution of the impact events observed with the Apollo PSE is asymmetric.

It is pointed out that the difference in sensitivity of the seismometers between the stations and the detection of the seismic events. To evaluate this effect, we carried out two tests. First, we limited our statistics to the events that are close to the network and can be assured to be detected by all the 4 station. Thus their detections are not influenced by the sensitivity difference. This gives us a leading/trailing ratio of ~1.9 which is consistent with our statistics with all 56 events. Next, we estimated asymmetry in detectability of the network. For a given impact site and a magnitude, an amplitude expected to be observed at a seismic station can be empirically estimated based on a relative value of a reference artificial impact. We can judge whether an impact at a certain location can be identified with the current network by counting the number of station that can detect the impact. Impacts observed with 4 stations can be regarded as well-identified impacts. We carried out such calculation globally and found that detectability of the leading side is enhanced by factor of ~1.3 compared to that of the trailing side. This is significantly smaller than the observed asymmetry of ~1.8 and implies that the asymmetry exists even with the asymmetry in detectability of the network. Both tests suggest the existence of the cratering asymmetry but the inconsistency of its quantitative evaluation may derive from the error in location or energy estimation of impacts and/or error in empirical estimation of the relative amplitudes.

4. Summary and Conclusion

We examined the spatial distribution of the impact events identified from the Apollo seismic observation. The results indicate that the number density of impacts on the leading hemisphere is substantially higher than that on the trailing hemisphere by factor of 1.4 - 1.9. Our result may represent some characteristics of source impactors for the meter size craters we observed.

References

[1] Morota, T., and M. Furumoto (2003), Asymmetrical distribution of rayed craters on the Moon, Earth Planet. Sci. Lett., 206, 315–323.

[2] Nakamura, Y. (2003), New identification of deep moonquakes in the Apollo lunar seismic data, Phys. Earth Planet. Inter., 139, 197–205.

[3] Oberst, J. (1989), Meteoroids near the Earth-Moon system as inferred from temporal and spatial distribution of impacts detected by the lunar seismic network, PhD. Thesis,

[4] Oberst, J., and Y. Nakamura (1991), A search for clustering among meteoroid impacts detected by the Apollo Lunar Seismic Network, Icarus, 91, 315–325.

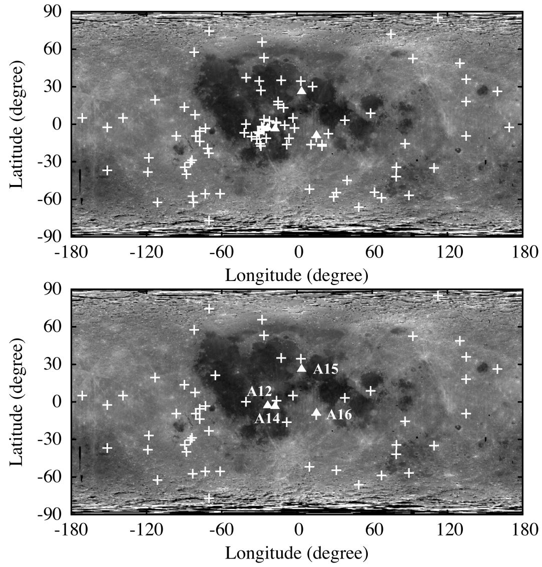

Figure 1. Distribution of the impact sites identified from the Apollo seismic data. Crosses represent the impact sites and solid triangles indicate the Apollo stations. (a) All of the identified impact sites. (b) The selected impact sites used for the statistics in this study. The locations of the impacts are taken from Oberst [1989] [3](The lunar map was taken from http://www.mapaplanet.org/explorer/moon.html).

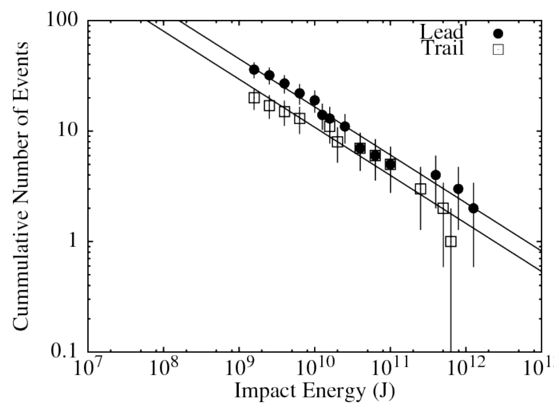

Figure 2. Cumulative energy-frequency distribution of the impact events for the leading side and the trailing side of the Moon. The black circles and the gray squares represent the leading and the trailing sides respectively.