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Assessment of Spatial Distribution of Basin Scale Crater on the Lunar Surface

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Abstract

In generally, lunar surface is expected to have a bias of spatial distribution of crater because the Moon has same rotation and revolution periods. Morota et al. (2005) showed that rayed crater density of leading side tends to be high compared to that of trailing side. On the other hand, Werner and Medvedev (2010) showed that the peak of high crater density (5 km – 50 km in diameter) was observed at a distance of about 60˚ away from the apex and low latitude. A purpose of our research is to develop an algorithm to assess spatial distribution of craters on spherical lunar surface by using Voronoi area method. Our result of applying this algorithm to the craters more than 200 km in diameter shows that the large number of craters which have small Voronoi area is found to be on the trailing side.

1. Introduction

Bodies in the solar system that have the same rotation and revolution periods, such as the Moon, are expected to have a bias of spatial distribution of craters. These bodies always keep the same side toward the orbital-motion. The orbital-motion side of the Moon is called as the leading side, on the other hand, opposite side is called as the trailing side. As a result of lending-trailing effect, the cratering rate on the lunar surface at the apex (0˚N, -90˚E) becomes larger than that of the antapex (0˚N, +90˚E) [1].

The effect of apex-antapex asymmetry was supported by lunar image observation. Morota et al. (2005) [2] focused on rayed craters and compared crater size-frequency distributions of the leading and trailing sides. They found that there is a bias of spatial distribution on the Moon, especially; the rayed crater density at the apex is higher than that of the antapex. However, Werner and Medvedev (2010) [3] revealed that the peak of frequency of rayed craters (5 - 50 km in diameter) is observed at the distance of about 60˚ away from apex, and low latitude.

Purpose of our research is to develop an algorithm to assess the spatial distribution of craters by using Voronoi area method. The Voronoi area of each crater relates to the crater spatial density. The advantage of the Voronoi area method over the crater size-frequency distribution is possible to evaluate of spatial density of each crater. In this paper, we assess spatial distribution of basin scale craters (≥ 200 km in diameter). We have exploited an algorithm of spatial distribution evaluation of three-dimensional cratered surface of the whole Moon.

2. Method

2.1 Numerical simulation for ideal crater spatial distribution

In our algorithm, the Voronoi area of observed craters was compared to that of ideally random spatial distribution of craters. So, the first step is to generate an ideal lunar-cratered surface that shows random spatial distribution of craters on a virtual spherical surface. The number of generated craters and its size range in virtual space are determined to be same as that of observed crater set. In the virtual lunar surface, one selected crater was fixed at same site, and other craters except for one selected crater are spatially distributed to the virtual lunar surface at random. In our calculation, we generated 50 patterns of each crater for the average and standard deviation of the Voronoi area.

2.2 Voronoi tessellation on the Moon

The second step is to apply the Voronoi tessellation to observe and virtual crater spatial distribution. The Voronoi tessellation is a method of dividing into a number of regions on the sphere [4]. In our calculation, the lunar surface is split up into 1˚ x 1˚ region (64800 regions). For determination of belonging each region to certain crater, we calculated a distance between each region and rim of all craters by spherical trigonometry, and closest crater possess each region. The sum of possessing the regions equals to the Voronoi area.

2.3 Comparison of Voronoi area

Finally, we compare the Voronoi area of observed and virtual craters. The Voronoi area of observed craters, average of virtual craters, and its standard deviation are defined as V, A, and S, respectively. The difference from Voronoi area average normalized to standard deviation, Δ, is calculated by following formula [4].

$$\Delta = (V - A)/S$$

If $\Delta > 1.0$, the Voronoi area of observed crater is low, and if $\Delta < -1.0$, the Voronoi area of observed crater is high.

3. Result

We adopted “The Lunar Orbitar Laser Altimeter (LOLA) Large Lunar Crater Catalog” [5]. This crater catalogue includes the positions and sizes of 5185 crater more than 20 km in diameter (Fig. 1). In this research, we evaluated 59 craters more than 200 km in diameter. However, for simplicity, South Pole – Aitken basin was omitted from our evaluation.

Fig. 2 shows the results of the Voronoi area method applied to lunar surface. The red, blue, and yellow circles reveal $\Delta < -1.0$, $\Delta > 1.0$, $-1.0 \leq \Delta \leq 1.0$, respectively. In this result, some craters with small Voronoi area are concentrated in at the trailing side rather than the leading side.

4. Summary

In this research, we assessed spatial distribution of craters more than 200 km in diameter on the lunar surface by Voronoi area method. The result of this analysis showed that some craters, which have small Voronoi area, exist on the trailing side. This result is inconsistent with the expected spatial pattern of the apex-antapex cratering asymmetry [6], suggesting a 180° reorientation of the Moon after basin scale craters formation.

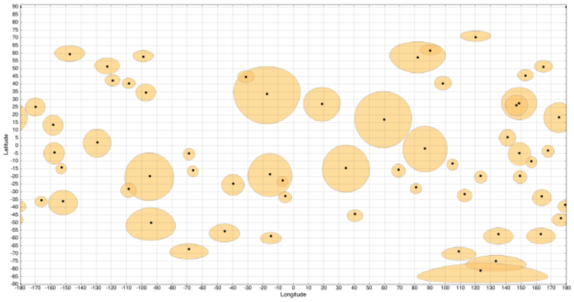

Fig. 1. Distribution of crater ≥ 200 km in diameter. Black points are center of crater. Yellow patched circles or ellipses reveal evaluated craters.

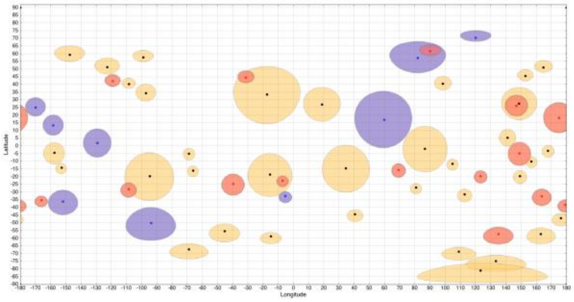

Fig. 2. Result of Voronoi area method applied to 59 craters.

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