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Development of the extending probe for lunar and planetary heat flow measurement

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The heat flow measurement in the lunar and planetary surface layers is an important method which constrains their internal activity, thermal history and material composition. In the case of the Moon, the internal heat source would be mostly radioisotopes, which are also refractory elements and elements concentrated in melt. Therefore the heat flow measurement constrains bulk quantity and distribution of radioisotopes, and they are essential for the verification of the giant impact theory and the magma ocean theory. The in-situ measurements were conducted in the Apollo 15 and 17 missions. But because a part of the heat flow probe was exposed on the lunar surface, and the measurements are also influenced by the thermal difference during day and night on the surface, the correct heat flow values could not have been measured. Penetrating probes including penetrators would not be exposed on the surface, but because the thermometers and heaters on the penetrating probe are exposed on the regolith, and influenced by the regolith consolidated by penetrating and the thermal distribution of the regolith varies from the heat conduction of the penetrating probe, it is difficult to determine the primary heat flow value of the planet precisely.

In this study, we propose that after the thin extending probes including a thermometer and heater are extended from both sides of the penetrating probe, they measure temperature and thermal conductivities at a point distant from the penetrating probe. By this new method, we do not have to correct the heat flow values with the physical state variation of regolith by penetration. Moreover the extending probes can measure the absolute value of thermal conductivities, and greatly enhance the accuracy to decide the heat flow values. Additionally the extending probes can explore geology and life under the surface layer if fiberglass rods are extended from the penetration probe, open at the end, and do spectral analysis.

Developing the extending probe, we especially discuss its length, diameter, and material.

We determine the shortest distance from a side of the penetrating probe to the area of the primary thermal gradient as the length of the extending probe by estimating the thermal variation of regolith after penetrating and analyzing the numerical simulations based on a thermal mathematical model of the penetrating probe. Of course the extending probes are stored inside the penetrating probe before measurement, so it can be difficult to emplace and extend the extending probes depending on their length. We discuss not only each length of extending probes but also the way to emplace and extend them.

The diameter of the extending probe should be as small as possible. This is because the error of thermal conductivities of the extending probe is reduced preferably when measuring the thermal conductivities with the line heat source method. It is also important because the extending force is reduced. But if the extending probe is made too thin, it can bend due to variation in the physical properties of regolith. We conduct penetration tests with a consolidated regolith simulant, and set out a minimum diameter required to avoid bending.

The material of the extending probes is generally stainless. But if it can not be put in the penetrating probe, we use hyperelastic material or memory metal as the material of the extending probes which can be transformed and emplaced. Additionally we have to measure the mass and thermal conductivity of the material, and choose one whose mass and thermal conductivity are as small as possible.

On this presentation, we report the current progress of analysis, experiment, and development of the extending probe.

Keywords: heat flow, moon, planet, regolith