

Mass of Asteroid (25143) Itokawa Determined by Hayabusa Spacecraft

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Hayabusa (MUSES-C) is the asteroid sample return mission of Japan. It was launched on May 9, 2003, and it arrived at its destination, Asteroid (25143) Itokawa, on September 12, 2005. For about three months Hayabusa made detailed observations of Itokawa and tried to touch down on its surface twice after several rehearsal approaches. In this mission period, Hayabusa was under the effect of gravity attraction of Itokawa. In this paper, we report about the mass determination of Itokawa.

At first Hayabusa stayed around the position of 20 km from Itokawa and then it moved a little closer about 7 km from Itokawa. Using the range and Doppler data from Sept. 12 to Oct. 2, the mass of Itokawa was estimated as 3.51×10^{10} kg. Since the effect of the solar radiation pressure is much larger than that of the gravitational attraction from Itokawa at this time, the error of this estimation is about 15 %. We expected that we could get more precise value of the mass when Hayabusa approached much closer to Itokawa. However one of the two reaction wheels had a trouble, and after Oct. 3 the attitude control was done by the chemical thrusters. The chemical thrusters generated small orbital acceleration, so it became difficult to carry out the precise mass determination of Itokawa. Therefore, we intentionally stopped the attitude maneuvers on Oct. 21-22, when distance from Itokawa is about 3 km. On this pass we tried to determine the mass of Itokawa, and we got the value of 3.43×10^{10} kg with the error of 5%. Up to this analysis, we assume a point mass model for Itokawa.

In November, Hayabusa closely approached Itokawa several times for the approach rehearsals and the actual touchdowns. For the approach on Nov. 12, the orbit of Hayabusa was determined accurately by using LIDAR (Light Detection and Ranging) and the optical images. At the same time, the mass of Itokawa was estimated as $3.54 - 3.58 \times 10^{10}$ kg with the error of about 5%. The distance from Itokawa was 1500 m to 100 m, so the polyhedron model is used to calculate the gravity potential of Itokawa. On Nov. 19, the first touchdown was executed. At this time Hayabusa was put in the state of the free fall from the height of about 20 m and we are trying to determine the local gravity by using the distance data from LRF.

As the summary, we can say that the mass of Itokawa is most probably around 3.5×10^{10} kg. The volume of Itokawa determined by other groups is $1.74 - 1.84 \times 10^7$ m³, so the bulk density of Itokawa is about 1.9 - 2.0 g/cm³.