P225-003 **Room: 302** **Time: May 21 9:24-9:36**

Understanding the Outer Solar System by Observation

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The truth is always one— Even how much the science improves or how much our knowledge deepens; the nature of the solar system has already been decided. In order to approach the solution, we use two methods: (A) ‘Prediction by theory’ - ‘Confirmation by observation’, or (B) ‘Discovery by observation’ - ‘Verification by theory.’ We should focus on the fact that ‘observation’ and ‘theory’ have correlation even though the order is different. In both case A and B, the physical parameters that can be obtained by observation are positions on the celestial sphere and brightness (apparent magnitude). In contrast to stars or galaxies in the deep space, celestial objects in the solar system are constantly changing its positions; therefore, we usually calculate the orbital elements from the their positions. Three positional data (longitude and latitude) generally are converted into the six orbital elements such as the semi-major axis, eccentricity, inclination, argument of perihelion, longitude of ascending note, and mean anomaly or time of perihelion passage. The brightness is also changing due to the relative positions of the sun, earth and object, so we may calculate the absolute magnitude. There are two types of the absolute magnitude; the definition for a solar system object is, apparent magnitude observed at the sun when the object is at 1 AU from the sun. On the other hand, the rotation of an object itself makes variation to the brightness, and the amplitude or period of the light curve are the important factors to discuss the shape or the surface characteristics of the object. We can start to discuss the classification and concepts of the objects after the common parameters such as the orbital elements and absolute magnitude are obtained.

The existence of the objects in the outer solar system had been predicted around 1950, and we now know the existence of more than 1,000 Trans-Neptunian objects (TNOs or Edgeworth-Kuiper Belt Objects = EKBOs). The total number of objects discovered including Centaurs, which are thought to have evolved from TNOs, and scattered TNOs by planets or other objects is more than 1,200. The figure plots each semi-major axis and eccentricity of the above objects (the semi-major axis is omitted over 60 AU). The closed circle represents the first 200 objects and open circle is the total 1,224 objects. The objects above the curve from the bottom left to the upper right means that they should cross the orbit of Neptune. ‘4:5’ and other numbers show the positions of the mean motion resonance with Neptune. Pluto (closed squares) is at (39.8, 0.25) that is hard to distinguish from other marks. We can easily see that there is a little difference between the first 2000 objects and the total objects; it may indicate that we could predict the 1,224 distribution by only knowing the first 200 objects, which is only 1/6 of the current number. If we further extend the this consideration, the real figure of the solar system has already been derived.

On the other hand, the relation between the semi-major axis and absolute magnitude seems to be random. However, a selection effect must be taken into the account; we can see only bright objects. In other words, brighter objects at the observation time than the limiting magnitude of the observation could be discovered. Considering these facts, we notice an unusual situation; that is there are few objects that have small eccentricity farther than 50 AU. Large telescopes such as the Subaru Telescope can detect the similar size objects to current discovered TNOs at 100 AU from the sun. Why are there few small-eccentricity objects over 50 AU? The history of the outer solar system has passed through phase (A) of ‘the prediction of the existence - Discovery of the first TNOs 1992 QB1’ and reached phase (B) of ‘Few objects farther than 50 AU - Why?’ We will discuss how much we approach the true figure of the solar system.