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Formation and Evolution of Pluto and Kuiper Belt

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Abstract: Despite Pluto's demotion to dwarf planet status, people are still attached to it. Scientists combined observations of Pluto from NASA's New Horizons probe with observations of comet Churyumov-Gerasimenko from the European Space Agency's Rosetta probe and found that Pluto's nitrogen abundance matched the pattern of about a billion comets, which led to the theory that Pluto is made of about a billion comets. Yet they don't know exactly when or where these comets originated. By studying the origin and orbit of comets, the author of this paper found that the material that condensed Pluto was mainly comets and dust ejected by Neptune, and the Kuiper Belt objects were condensed by material ejected by Neptune toward the outer side of its orbit.

Keywords: Neptune, comet, Pluto, Kuiper Belt.

1. Introduction

Pluto has been listed as one of the "nine planets of the solar system" since it was discovered by American astronomer Clyde William Tombaugh in 1930 at the distant edge of the solar system. But Pluto's status as a planet was disputed when astronomers discovered a degree of difference between it and the other planets in our solar system. According to the International Astronomical Union's definition of a planet, it must have a roughly circular orbit around its star, and it must have enough gravity to clear out other objects approaching its orbit — leaving no larger objects in the orbit. However, in 1978, when Charon was discovered, scientists correctly calculated Pluto's mass for the first time by using the gravitational pull between Pluto and Charon. In the end, it was found that Pluto's mass was only 0.24 percent of the mass of Earth. That's 7 percent of the mass of all the other objects in its orbit combined, not enough to clear its orbit. In addition, Pluto's orbit is oblong, with a 17 degree inclination to the ecliptic plane of the solar system. When Pluto reaches perihelion, it has actually entered the orbit of Neptune. As a result, Pluto was demoted to dwarf planet status and removed from the group of nine planets in the solar system [1], but people did not completely abandon their attachment to Pluto. On January 19, 2006, NASA launched its New Horizons probe, whose main purpose was to explore Kuiper Belt objects such as Pluto and Charon. As a result, it got a lot of useful data. Before that, the European Space Agency carried out its first unmanned mission to a comet in 2014, successfully landing on Comet 67P's icy surface to take samples for analysis. Scientists at the Southwest Research Institute (SwRI) combined Pluto data from NASA's New Horizons mission with observations of comet 67P from the Rosetta probe and found consistency in the estimates of nitrogen content in the comet and Pluto's glaciers [2], which led to a new theory to explain how Pluto was formed. They speculate that Pluto was formed from about a billion comets or other Kuiper Belt objects [3, 4]. But they don't know exactly when or where these comets or Kuiper Belt objects originated [5, 6]. Therefore, by studying the origin and orbit of comets, the author found that the materials that condensed Pluto were mainly cometesimals and dust ejected from Neptune in the solar system and other interstellar materials near Pluto's orbit.

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2 The Origin of Comets and the Formation and Evolution of Pluto

Since the study of comet orbits has shown that any comet found so far does not come from outside the solar system, it must be a product of the sun or its planets. So there are only two possibilities:

1) If the comet is a planetesimal emitted by the Sun, since the mass of the sun is much greater than that of Jupiter, the escape velocity of the sun is greater than that of Jupiter. It’s known that the escape velocity of Jupiter is 60 km/s, hence the escape velocity of the sun is much higher than the explosion velocity of the most explosive metal hydrogen, 24 km/s, so the probability of the comet being ejected from the sun is very small.
2) It is more likely if comets are planetesimals ejected from some planets in the solar system. Some planets in the solar system are relatively active bodies in the solar system because of their large mass and their rotation speed is higher than that of the sun [7]. For example, Neptune, near the Kuiper Belt, has 17 times the mass of Earth and spins 0.7 km/s faster than the Sun. Because of its mass, it can draw a lot of hydrogen and helium into its atmosphere, so the amount of hydrogen and helium in its atmosphere is high. In addition, Neptune has an attractive azure color, which suggests a lot of methane in its atmosphere. Although Neptune was discovered in the mid-19th century, it was little studied until NASA’s Voyager 2 probe, launched in 1977, made an epic flyby of the planet in August 1989, which yielded a valuable set of observations. From these observations, it is inferred that Neptune's outermost layer is a high-altitude cloud; its lower layer is an atmosphere of hydrogen, helium, and methane, ranging between 2,500 and 5,000 kilometers below the top layer; its inner layer is a frozen layer of water, ammonia, and methane , then a hot mantle; and its innermost layer is a hard core of iron, nickel, and silicate material, as shown in Fig. 1 below. In fact, Neptune’s hot mantle is a molten asthenosphere, where high temperatures and pressures cause alkanes to break down into hydrogen and carbon, which in turn crystallizes into dense diamonds, so there is a diamond layer between Neptune’s permafrost and hot mantle.

Fig. 1 The hierarchy of Neptune.

When Neptune moves near perihelion, a large amount of water, hydrogen and other gases are evaporated into Neptune's atmosphere. Therefore, with the rapid rotation of Neptune, its poles can form a series of strong polar vortices. When a Neptune’s satellite gets close to a polar vortex, the polar vortex will be cut or destroyed, even producing some new cyclones, which will move to multiple regions. Among them, the Great Dark Spot is a relatively large cyclone [8], which can absorb a lot of clouds and make the clouds descend rapidly, and then be cooled or compressed. In this case, a large number of hailstones will be formed. When some large hailstones fall into Neptune’s permafrost, they punch a series of deep holes, even through the diamond layer, allowing large amounts of molten icy water to seep into the hot mantle layer and come into contact with hot molten material, causing violent explosions and magma eruptions, as shown in Fig. 1. These eruptions not only ejected a great deal of mantle material, but also some diamonds, some of which, traveling slower than Neptune’s escape velocity, would have to rain down as diamonds, while some of the broken rocks would have to fly at more than 18.13 kilometers per second. When they are flying in the same direction as Neptune’s revolution (Neptune’s revolution speed is 5.43 km/s), the probability of their escape from Neptune is greatly increased. When their escape speeds are greater than or equal to Neptune’s escape velocity of 23.56 km/s, they can escape smoothly from Neptune and become comets. In particular, comets may enter Pluto’s orbit if they are ejected at the intersection of Neptune’s and Pluto’s orbits, as shown in Fig. 2. As a result, there are a lot of comets in Pluto’s orbit, and it is the aggregation of many comets in this orbit that formed Pluto.

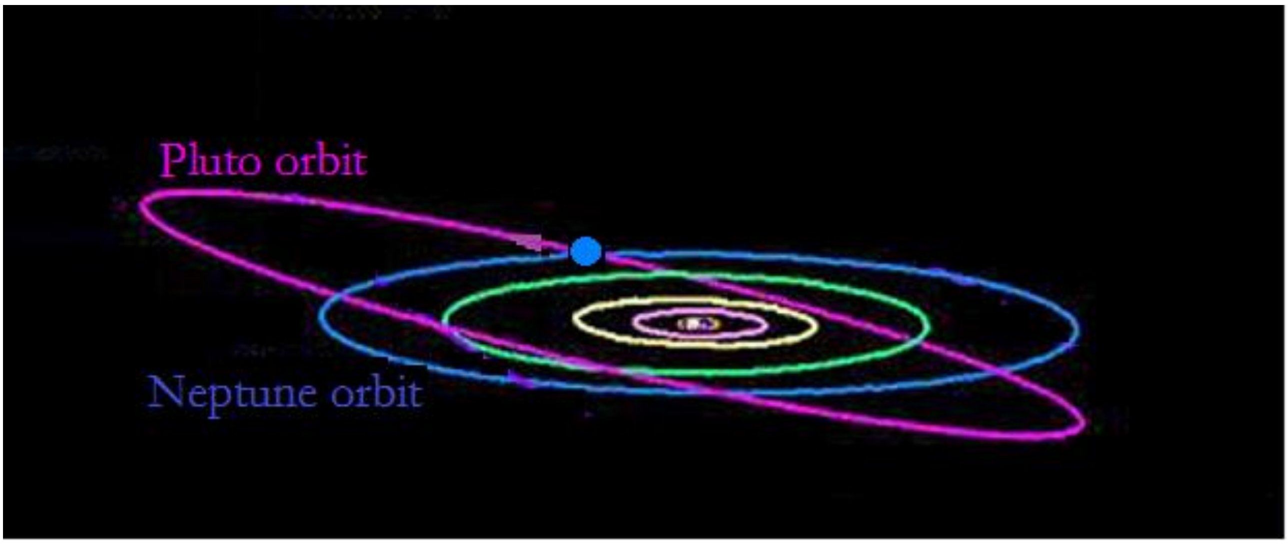

Fig. 2 Pluto orbit marked by pink

Although Pluto is a relatively small object compared to the other planets in the solar system, it is composed of hundreds of millions of comets, and as it goes through its long orbit, it continues to absorb the interstellar material around its orbit, increasing its size and mass. Because its various components will constantly be affected by the uneven solar gravity, its components rub against each other to produce heat energy; adding the heat generated by the friction of air currents caused by Pluto’s long-distance revolution, the heat generated by Pluto’s own gravitational contraction process and the heat generated by Pluto’s internal chemical reaction, its internal materials melt and differentiate, forming hot spheres and inner magma. When the ice covering Pluto is melted by the hot sphere, a large amount of ice water will be produced, and the long-term erosion of the ice water on Pluto's shell will cause the shell to break. When the ice water enters the mantle layer and contacts with the hot magma, the water will be vaporized immediately, resulting in a violent volcanic eruption, which ejects many rocks at a high speed exceeding the first cosmic speed into an orbit around Pluto. These planetesimals are then combined into several moons such as Charon [9].

3. Formation of the Kuiper Belt

In general, if Neptune shoots planetesimals outward of its orbit, a collection of objects of varying sizes formed from these planetesimals, including Pluto, Eris, and Ornithus, would be members of the Kuiper Belt [10], thus the Kuiper Belt is the result of Neptune's constant ejection outward of its orbit, as shown in Fig. 3.

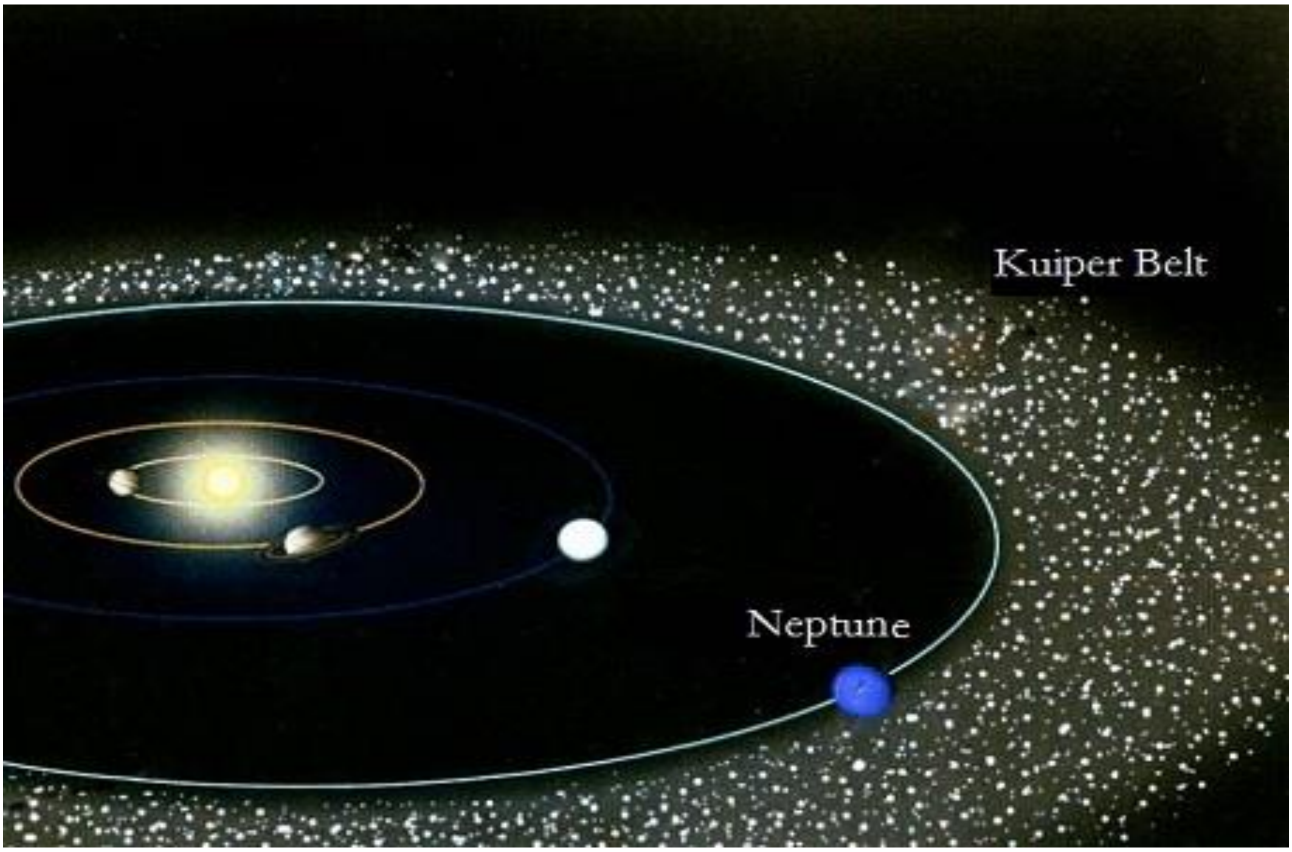

Fig. 3 Kuiper Belt.

4. Conclusion

After Pluto's demotion from planet to dwarf planet, scientists have made a series of discussions about its true status. One of the more influential is the work of Christopher Glein, PhD, of the Southwest Research Institute in the United States. In his reconstruction of the Pluto model, he found a consistency between the nitrogen content of the comet and Pluto's glaciers, which suggests that Pluto is composed of about a billion comets, but has less carbon monoxide and less water on its surface. They also don't know much about the origin of comets or Kuiper Belt objects. For this purpose, the authors reexamined the origin of comets and Pluto's orbit, and found that Pluto was formed by the condensation of cometesimals and dust that were ejected from Neptune. As the comet nears the sun, water, carbon monoxide and so on are heated and volatilized, so Pluto, made of many heated comets, must lack some water, carbon monoxide and so on.

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