Lecture Eighteen

New Outer Realms—Kuiper Belt and Oort Cloud

Scope: There is something new under the Sun. Ideas about outer solar system objects have been around for a long time, but the discoveries of the Kuiper Belt have taken place only in the last couple of decades. Kuiper Belt objects, including Pluto, are small icy worlds beyond Neptune. In fact, several families of outer solar system bodies exist, defined by their orbits and their gravitational interactions with the giant planets. Gravitational scattering sends these objects toward the inner solar system to become short-period comets. The source of the long-period comets, the Oort Cloud, can not be directly observed yet, but it can be deduced from the statistics of comet orbits. Calculations indicate that the Oort Cloud extends nearly one-fifth of the way to the nearest star. The size of the solar system, which doubles with the Kuiper Belt, grows again by a factor of a thousand with the Oort Cloud.

Outline

I. We are currently in the midst of discovering and exploring a new region of the outer solar system called the Kuiper Belt.

A. Ideas about outer solar system bodies have been around since the discovery of Pluto.

1. In 1930, Frederick Leonard mentioned the possibility that Pluto was just the first of many objects.
2. In 1943, Kenneth Edgeworth discussed the idea that large numbers of small bodies could have formed in the outer solar system.
3. In 1951, Gerard Kuiper noted that a massive Pluto would scatter objects outward into a belt.
4. Kuiper's idea was incorrect, as it was based on the then-current notion that Pluto was as massive as Earth.
5. It was not until 1980 that Julio Fernández predicted a belt of comet nuclei that matches what was eventually discovered.
6. I would prefer to call it the "comet belt," which is how Fernández referred to it.

B. The discovery of Kuiper Belt objects (KBOs).

1. Pluto is technically the first KBO discovered (in 1930), with an orbit that ranges between 30 and 50 AU.
2. The discovery of 1992 QB1 (the name indicates the date of its discovery) at a distance of 42 AU signaled the existence of the Kuiper Belt.

C. The technique for discovering KBOs is essentially a digital version of the blink comparator Tombaugh used to find Pluto.

1. Images of the same spot on the sky are taken every few hours.
2. Computer programs can efficiently search for points of light that move, which indicate objects within our solar system.
3. Using techniques like this, within years, hundreds of other KBOs had been found.
4. The search programs required lots of time on large telescopes and were most effective from ground-based observatories. Space telescopes provided follow-up observations.

D. KBOs contain mostly ice, with some rock, and range in size up to a couple thousand kilometers.

E. The KBO 2003 UB313, now called Eris, created a stir when it was found to be 10% larger than Pluto. Eris is at a distance of 97 AU on a highly elliptical orbit and has a large moon named Dysnomia.

II. Over a thousand small icy objects exist in the outer solar system, and they make up more than just the Kuiper Belt.

A. The objects can be grouped into several families.

1. The approximate boundaries of the Kuiper Belt are between 30 and 50 AU, but some objects are found closer and some much farther from the Sun.
2. The Trojan Asteroids are located near gravitationally stable points of Jupiter's orbit, and they resemble comets more than asteroids.
3. The Centaurs are icy worlds whose more elliptical orbits are inside the orbit of Neptune.
4. Pluto is the prime example of the Resonant KBOs, those whose orbital periods are in a 3:2 resonance with Neptune.
5. The Classical KBOs are the main part of the Kuiper Belt and have more circular orbits.
6. Eris is one of the Scattered KBOs, whose sometimes highly elliptical orbits can extend to large distances.

1. Tails can stretch for tens of millions of kilometers and always point away from the Sun.
2. The dust particles follow orbital trajectories and produce a curved dust tail.
3. The ionized gases are carried along by the solar magnetic field to form a straight ion tail.
4. Changes in the solar wind magnetic field can produce disconnection events in which the ion tail breaks off and then re-forms.

III. Comets are classified by their orbits into short-period and long-period classes.

- **A.** The short-period comets orbit the Sun in less than 200 years.
- **B.** Their orbits are generally inside Jupiter's orbit and mostly in the plane of the ecliptic.
- **C.** The long-period comets have orbital periods greater than 200 years, with some measured in tens of thousands of years.
- **D.** Their orbit shapes are extremely elongated ellipses and are oriented at all angles.
- **E.** Most long-period comets are seen once and never seen again, while short-period comets are seen over and over until they are destroyed.

IV. Short-period comets have limited lifetimes.

- **A.** Comets lose a small percentage of their mass each passage by the Sun, giving them a rough lifetime of a few thousand orbits.
- **B.** Earth continually passes through ejected comet material, and some of it shows up in our skies as meteor showers.
- **C.** Comets can "die" by breaking apart into many fragments and fading away.
- **D.** Comets have also been observed to crash into planets and the Sun.

V. The destruction of short-period comets indicates the existence of some sort of resupply reservoir.

Suggested Readings:

Beatty, Petersen, and Chaikin, *The New Solar System*, chap. 24.

Bennett, Donahue, Schneider, and Voit, *The Cosmic Perspective*, chap. 12.

De Pater and Lissauer, *Planetary Sciences*, chap. 10.

Lewis, *Rain of Iron and Ice*.

McFadden, Weissman, and Johnson, *Encyclopedia of the Solar System*, chap. 20.

Verschuur, *Impact!*

Questions to Consider:

1. Comet Halley has a 76-year orbit, of which only about a year is spent near the Sun. For the rest of that time, what does it look like? Could we observe it?
2. Without the solar wind, would a comet have a tail?
3. Do you think the puzzling mix of materials inside a comet indicates that they started forming in one region and finished forming in another? Or, might it be that material formed in several places got mixed throughout?