Variety of Planets from the Outer Edge of the Inner Hole

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Planets are very common objects in the Universe. This is already evident from recent discoveries of thousands of exoplanets. However, the standard theory of their formation encounters many notorious difficulties, such as the dust/planet fall and the disk lifetime problems. We do not try to avoid each problem but accept and use all of them positively to find a natural scenario that all these problems indicate.

All the falling problems indicate that dust falls, by the dissipation with gas, toward the central star. All the time scale problems indicate that the relevant processes of planet formation should be rapid. Therefore, **there must be a void of gas very inside**, say at radius 0.04 AU, and the falling dust must stop there at the outer edge of this inner hole. This is our first assumption, without specifying any Physical processes such as MRI, co-rotation instability, photoevaporation, or whatever. Then the following processes, 1 to 5, take place in the sequence, which naturally yields the variety of planets we observe today(Fig.1).

Dust and dust clusters fall toward the center but stops at the edge of the inner hole and accumulate there. We analytically estimate the size-dependent falling time scales. They may be very short such as several hundred years. Turbulence and frequent destructive collision, with dissipation, on the common Kepler orbit, promote their coalescence. **The dense and coherent motion of dust at the edge of the inner hole induces the runaway growth of several huge planets of size Jupiter.** This species is the Hot-Jupiters. This orbit is too close to the center and Hot-Jupiters may not be stable. However, this runaway time scale is short and several hundred years based on the standard disk model parameters. **These massive planets at the outer edge slingshot dust clusters inward and outward.** This stage of evolution is essential to yield a variety of planet species. Small dust clusters of size less than 10 Earth-mass are shot in and out, but cannot effectively accrete gas, and the size of them cannot grow. This species is the Rockey-Planets. They can be shot widely to 0.01AU to 1000 AU. On the other hand, dust clusters of size more than 10 Earth-mass can be shot up to 0.4AU by one Jupiter (pure three-body system) and 1 to 100 AU by two Jupiters (pure four-body system). These shot planets would migrate toward the center but shot again outward; the migration problem does not arise since the planets are always dynamical objects regulated by the outer edge of the inner hole. **Large dust clusters of size more than 10 Earth-mass shut outside can effectively accrete gas**, and the size of them can grow while the gas exists there. In this process, their initially large eccentricity dramatically reduces by acquiring the angular momentum of the gas. This species is the Cold-Gas-Giants or Ice-Giants, depending on the distance blown. They form gap and spiral structures on the planetary disk. **Much smaller dust clusters can be shot very far and become the seeds of `Trans-Neptunian Objects`,** including `Kuiper Best` of exoplanet systems. The dust cluster of 10^{12}Kg, for example, can be shot 100 to 1000AU within a time scale of 5000 years. Their orbital inclination can easily exceed 30 degrees. Furthermore, the eccentricity of them sometimes exceeds one. Therefore, a vast number of stray objects in the interstellar space can be produced.

We verify our model based on the basic predictions of the model.
a) All the cores of the planets, as well as small diffuse objects, are made from a common ratio of materials. This is because all the planet cores are formed at the outer edge of the inner hole as a mixture of falling

dust.

b) These core materials had experienced a thermal metamorphosis in the past. This is because all the planet cores are formed at the outer edge of the inner hole near to the central star. The temperature can easily rise to 2000 K there, which is enough to yield thermal metamorphosis.

These properties also apply to the `Trans-Neptunian Objects`. The study on comets and meteorites of our solar system may provide some information for our model.

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