A coupling of the origin of Asteroid belt (planetary ring) and comets

Yongfeng Yang

Bureau of Water Resources of Shandong Province, Jinan, Shandong Province, China,

Mailing address: Shandong Water Resources Department, No. 127 Lishan Road, Jinan, Shandong Province, China, 250014

Tel. and fax: +86-531-8697-4362

E-mail: roufengyang@gmail.com

It is a popular feature in the solar system that there are an asteroid belt and four planetary ring systems, various scenarios [1, 2, 3, 4, 5, 6,7] have been presented to account for their origins, but none of them is satisfactory. Asteroid belt that is located between planetary orbits (Mars and Jupiter) is thin, circular, and parallel to the ecliptic, relatively, planetary rings that are located between satellite's orbits are also thin, circular, and approximately parallel to their father planetary equatorial plane. This similarity in distribution and shape implies that asteroid belt and planetary ring is likely to derive from the same physical process. Here we show, the two bodies of a binary planetary system (satellite system) due to their orbital shrinkages occur a powerful collision, which shatters them into fragments to all around. But due to the effect of hierarchical two-body gravitation (a non-Newton's gravitation proposed by Yang) that is responsible for the association of celestial objects in space, the barycenter of the initial binary planetary system (satellite system) is survived in the collision and continues to orbit, which brings the barycenters of a series of subordinate hierarchical two-body associations of fragments to move. This successive hierarchical drag trends to constrain these separated fragments to form a circular belt (ring), and subsequently dynamical evolution confines the belt (ring) to become thin. The farther fragments are dragged by the belt (ring) to run across the solar system back and forth, which gives rise to the advent of comets when close enough to the Sun.

In the past various theories had been presented to account for the origins of asteroid belt, planetary ring, and comet. The previous story of the origin of asteroid belt believes that asteroids are fragment of a destroyed planet [1], the currently accepted scenario believes that asteroids are rocks that in primordial solar nebula never accumulate to form a genuine planet due to a strong Jupiter's gravitational perturbation [2]. The origin theories of planetary ring are plentiful. Especially for Saturn's ring, they include tidal disruption of a small moon [3], unaccreted remnants from the satellite-formation era [4], collisional disruption of a small moon [5], and tidal disruption of a comet [6]. Canup recently viewed the disabilities of these scenarios and developed a model to propose that planetary tidal forces strip ice material from a Titan-sized satellite to form a pure ice ring and icy moons are subsequently spawned from the ring [7]. Saturn's satellites have various inclinations to both its equatorial plane and ring, if they are spawned from identical ice ring, it is necessary for them to keep parallel to the ice ring. On the other hand, these satellites are also not fully composed of ice. Saturn's ring is observed to be very thin and there are countless gaps within it, and various spectral features indicate that it is composed of different materials. It is thus impossible for Canup's model to account for such significant features. The origin of comet mainly includes Oort cloud hypothesis [8] and Kuiper belt hypothesis [9], but the orbital features of short period comets do not agree to an origination from Oort cloud, and the mechanism by which the comets are supplied from Kuiper belt to planet-crossing orbits is still unclear [10]. In the last 20 years, a lot of Trans-Neptunian objects were found from Kuiper belt, but there is no evidence to indicate that these Trans-Neptunian objects are directly relative to comets. The recent discovery of a population of comets in the main asteroid belt [11] suggests that comets are likely to derive from various origins. Roughly speaking, all the scenarios are commonly based on both Newton's gravitation and solar nebula hypothesis [12]. However, high resolution photographs of well-regulated movement of asteroid family (group) [13], integrity of Saturn's narrow F ring [14], unique spokes in Saturn's B ring [15], and twisted arc in Neptune's Adams ring [16] indicate that Newton's gravitation cannot work well. Solar nebula hypothesis still are still surrounded by a series of problems [17-21]. All these discrepancies indicate that the current understanding of the origins of asteroid belt, planetary ring, and comet are still incomplete. Asteroid belt and planetary ring in appearance are flat, circular, and parallel to respectively the ecliptic and planetary equatorial plane; they in distribution are embedded between planet's orbits and between satellites' orbits, respectively; in material asteroid belt consists primarily of three categories of asteroids: C-type or carbonaceous asteroids, S-type or silicate asteroids, and M-type or metallic asteroids, this compound is very similar to the material in the Earth and Mars.

Relatively planetary ring consists primarily of ice and dust, which is also very similar to the material in the icy satellites. On large scale, the Sun has a lot of planets around it, relatively each giant planet (Jupiter, Saturn, Uranus, and Neptune) also has a lot of satellites around it, which makes it look like a little solar system. The similarity in these aspects suggests that the formation of both asteroid belt and planetary ring should share the same physics. Yang recently proposed that all objects in the universe are orderly organized in a series of hierarchical two-body systems with gravitation, and that under the effect of gravitation the two components of a two-body system will finally take place a collision due to their orbital shrinkages (see http://vixra.org/abs/1010.0042). A coupling of hierarchical two-body association and collision may thus responsible for the formation of asteroid belt, planetary ring, and comet.

In the frame of hierarchical two-body association all bodies are indirectly fixed together with gravitation, this indicates that if a moving body is shattered into small fragments, these fragments are still constrained by gravitation to form a series of hierarchical two-body associations, and the barycenter of the initial body is survived in the smash and may bring these associations of fragments to continue to orbit. As shown in Figure 1 that a moving body is shattered into some fragments that are still constrained by gravitation to form a series of hierarchical two-body associations, some of these fragments are further shattered into smaller fragments that are also constrained by gravitation to form a series of subordinate hierarchical two-body associations. All the associations of fragments are still being brought by the barycenter of the initial body (point 1) to continue to orbit.

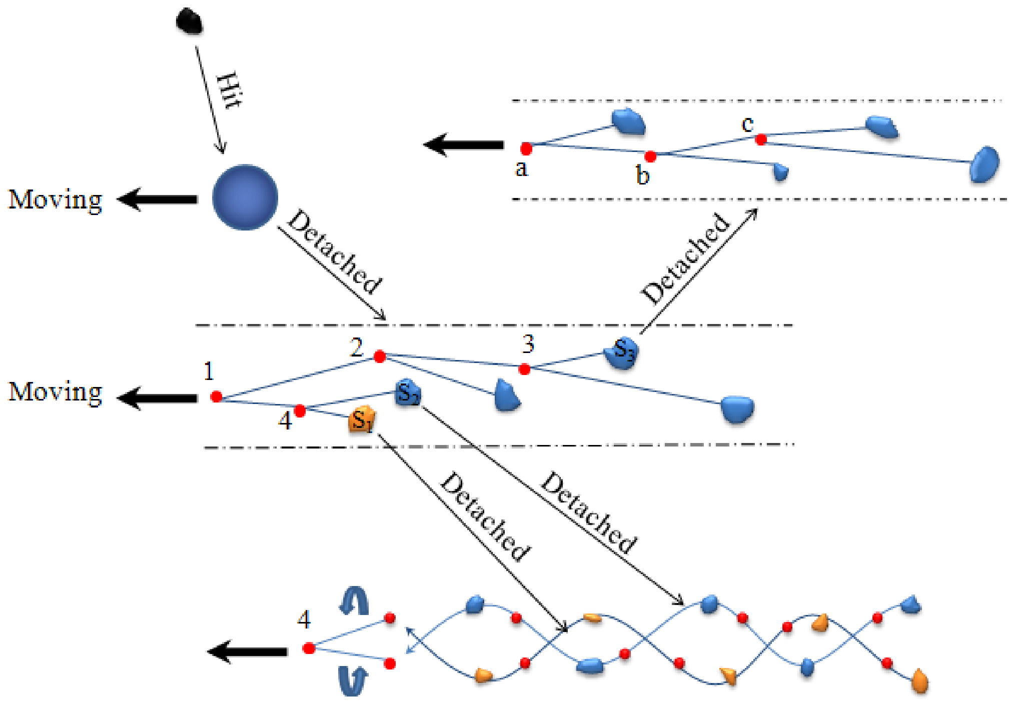

Figure 1: Simulation of the motions of detached fragments based on hierarchical two-body association. Fragments S_1, S_2, and S_3 are further detached to form a series of subordinate hierarchical two-body associations of fragments. In particular, S_1 and S_2 before a second detachment have obtained additional motions, which make their son associations enlace with each other orderly. Red dot represents the position of the barycenter of related two-body system in hierarchical two-body association. Large black arrow represents uniform movement of the associations of fragments along the direction of initial body.

Based on this physics, a theoretical model is here developed to demonstrate the formation of asteroid belt (planetary ring) and comet: A binary planetary system (satellite system) is orbiting the Sun (or a giant planet). With the passage of time, the two components of the two-body system due to their orbital shrinkages occurs a powerful collision to eject fragments in all directions. But due to the constraint of two-body gravitation, these fragments form a series of hierarchical two-body associations in space. As the barycenter of the binary planetary system (satellite system) is survived in the collision, it thus continues to bring these associations of fragments to orbit the Sun (or the planet). A successive hierarchical drag via the barycenter of related two-body system automatically confines these fragments to form an asteroid belt (planetary ring) (Fig.2). For instance, Point O_1 is dragging two components: point *a* and 1, while point *a* is also dragging point *b* and *d*, point *b* is also dragging point *c* and one fragment, point *c* is also dragging two fragments. At the same time, point 1 is also dragging a series of hierarchical two-body associations. It is such a hierarchical dragging relation to confine all the fragments into a circular belt (ring) around the center body. Some of the farther fragments are dragged by the asteroid belt (planetary ring) to run across the solar system back and forth, this gives rise to the bombardment to planet and satellite. Once some of the fragments approach the Sun's body, comets are created. Because of orbital shrinkage, the barycenter of the binary planetary system (satellite system) is also ever-increasing approaching the Sun (the planet), this further brings the barycenter of related two-body system to move towards the Sun (the planet), the asteroid belt (planetary ring) thus becomes thin gradually.

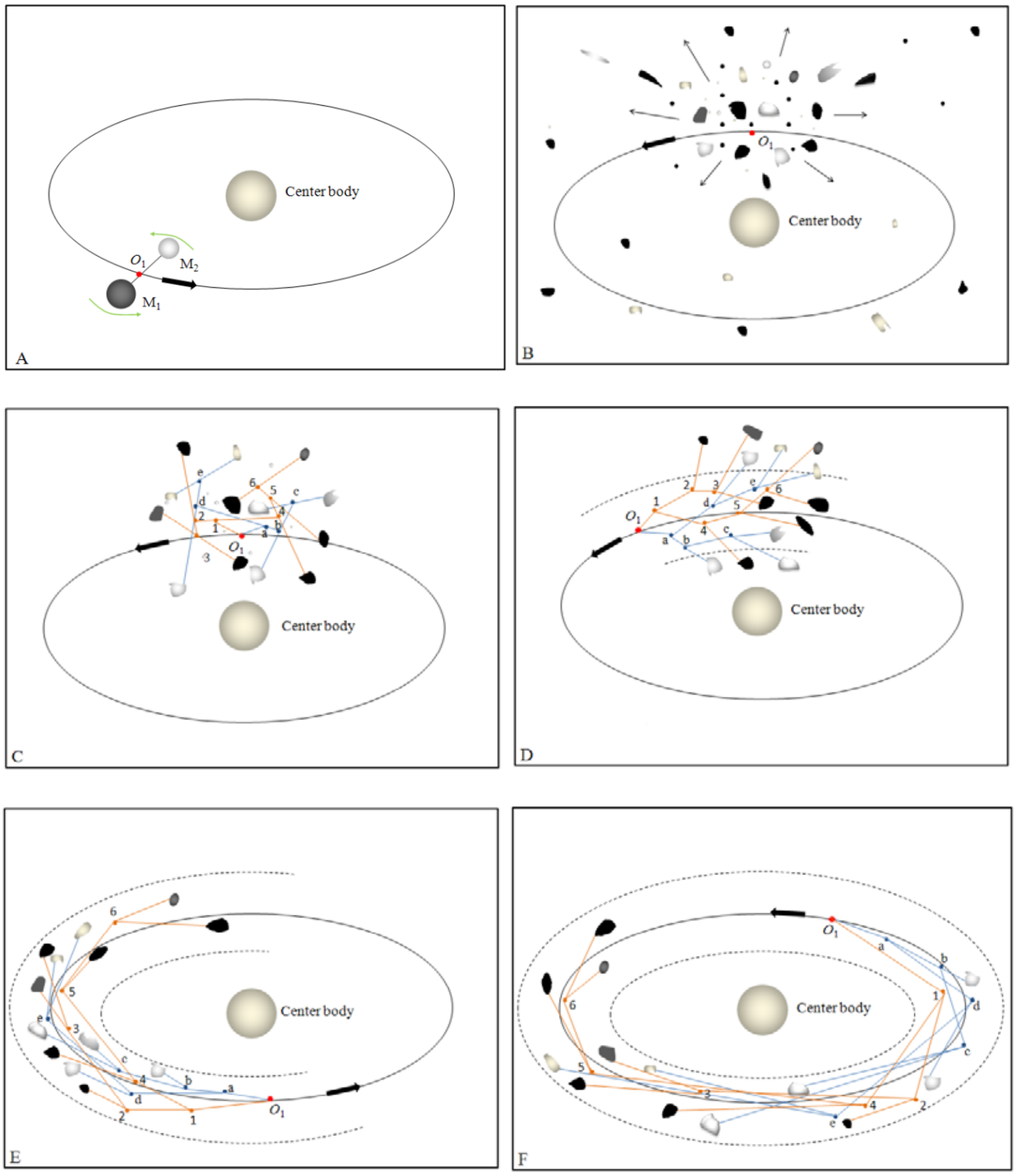

Figure 2: Simulation of the formation of a belt (ring) based on hierarchical two-body associations. A: a two-body system is orbiting a center body; B: the two bodies of the two-body system occur a powerful collision due to their orbital shrinkages, which shatters them into small fragments in all directions; C: the separated fragments are still gravitationally constrained in a series of hierarchical two-body associations in space; D, E, F: the barycenter of the initial two-body system continues to orbit the center body, which brings these fragments by means of the barycenters of all related two-body systems to move along a circular path. Point O_1 is the barycenter of the initial two-body system. Red dot (marked with letter a, b, c, etc., and number 1, 2, 3, etc.) represents the position of the

barycenter of related two-body system in the association. Blue (orange) line represents gravitation. Large black arrow represents the movement of the association of fragments.

It is important to note that a two-body system is always brought by the barycenter of a superior two-body system to orbit, this determines all the fragments in the hierarchical two-body associations to hold some same orbital elements (excluding the difference in time if they orderly pass a special position). As the fragments in a subordinate hierarchical two-body association are originally derived from the disruption of a parent body, this determines them to hold identical composition. As shown in Figure 3(it is the dynamical evolution from Figure 2(F) that some of fragments are further detached into smaller fragments to form a family, gravitation here is hided in the diagram), the fragments in a family share the same orbital elements such as semimajor axis, eccentricity, period, and inclination, and their composition is also identical. Similarly, if a fragment is further detached into smaller fragments, they may thus form a group, in which these smaller fragments also share the same orbital elements and identical composition. It is clear that there may have gaps between families (groups) because each family (group) in space is a separated hierarchical two-body association.

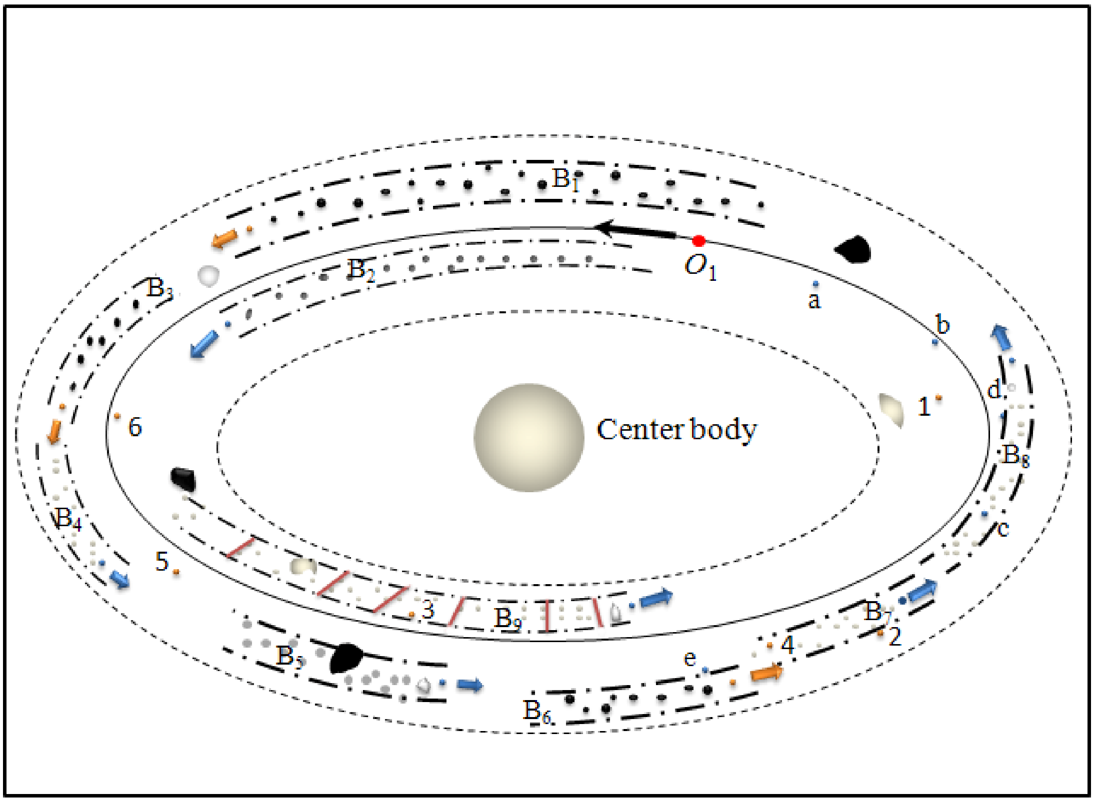

Figure 3: Simulation of the evolution of a belt (ring) based on hierarchical two-body association. Some of the fragments are further detached to form a family (marked with B_1, B_2, etc.). Point O_1 is the barycenter of the initial two-body system (see Figure 2). Blue (orange) dot (marked with letter a, b, c, etc., and number 1, 2, 3, etc.)

represents the position of the barycenter of related two-body system in the association. All the families and separated fragments are hierarchically constrained by these barycenters. There are gaps between families (for instance, there is a gap between family B_1 and B_2). Large black arrow represents the motion of the barycenter of integral belt (ring), while short blue arrow represents the motion of each family.

It is now necessary to specify that the center body in the model is replaced with the Sun, the initial binary planetary system in both physical element and chemical composition is similar to the Earth-Moon system (especially it is rich in the composition of carbonaceous, silicate, and metallic material), and it is just placed between the Mars' and Jupiter's orbits. It is no doubt that a collision between the two bodies of the binary planetary system due to their orbital shrinkages is powerful enough to shatter them into fragments in all directions, subsequently these ejected fragments due to hierarchical two-body gravitational constraint are brought by the barycenter of the initial binary planetary system to form the asteroid belt. We also specify that the center body in the model is replaced with a giant planet (Jupiter, Saturn, Uranus, and Neptune), the initial binary satellite system in chemical composition is similar to the giant planet's satellite that is rich in icy material, and it is just placed more near to the planet than other satellites. The powerful collision between the two bodies of the binary satellite system due to their orbital shrinkages thus shatters them into fragments to form a series of hierarchical two-body associations, these fragments are further detatched into smaller fragments to form a series of subordinate hierarchical two-body associations, the barycenter of the initial binary satellite system continues to bring these associations of fragments to orbit, which results in the formation of a planetary ring. As each association of fragment is separated from one another in space, a planetary ring system is thus composed of some larger rings that are divided with gaps, each ring is also composed of many smaller rings that are divided with smaller gapes.

Some of the farther fragments that are ejected in the collision are dragged by the asteroid belt (planetary ring) by means of the barycenter of related two-body system to run across the solar system back and forth. As the orbits of four giant planets generally have inclinations to the ecliptic, in the movement the angle between planetary ring plane and the ecliptic is variable, this determines the orbits of fragments to be with various inclinations to the ecliptic. Because of different distance from the Sun, the fragments that are dragged by asteroid belt, Jupiter's and Saturn's ring tend to have shorter orbit than those are dragged by Uranus's and Neptune's ring. Among of four giant planet ring planes and asteroid belt, Uranus's ring plane has a high inclination of around 97 degrees to the ecliptic, while the remaining are generally low-inclination or parallel to the ecliptic, this determines short orbital fragments to be mainly low-inclination while long orbital ones to be mainly high-inclination. Once these fragments approach the Sun's body close enough, comets may be created, while some of them that approach the Earth's body may become meteorite. As shown in Figure 4 that fragment C_1 under the drag from a gravitational point in the asteroid belt runs an elongated rotational orbit, and thus has chance to become a comet when close enough to the Sun's body. Once the Earth encounters the orbit of fragment C_3 (C_5) that is an association of smaller fragments, meteor shower may be created. In Figure 5, each of the four giant planets by means of its ring drags some fragments to orbit, the different distance of each fragment to its father ring determines various amplitude in trajectory. It is safe to infer that a large body of fragments in such a crossed frame can yield a lot of comets in all directions of the sky.

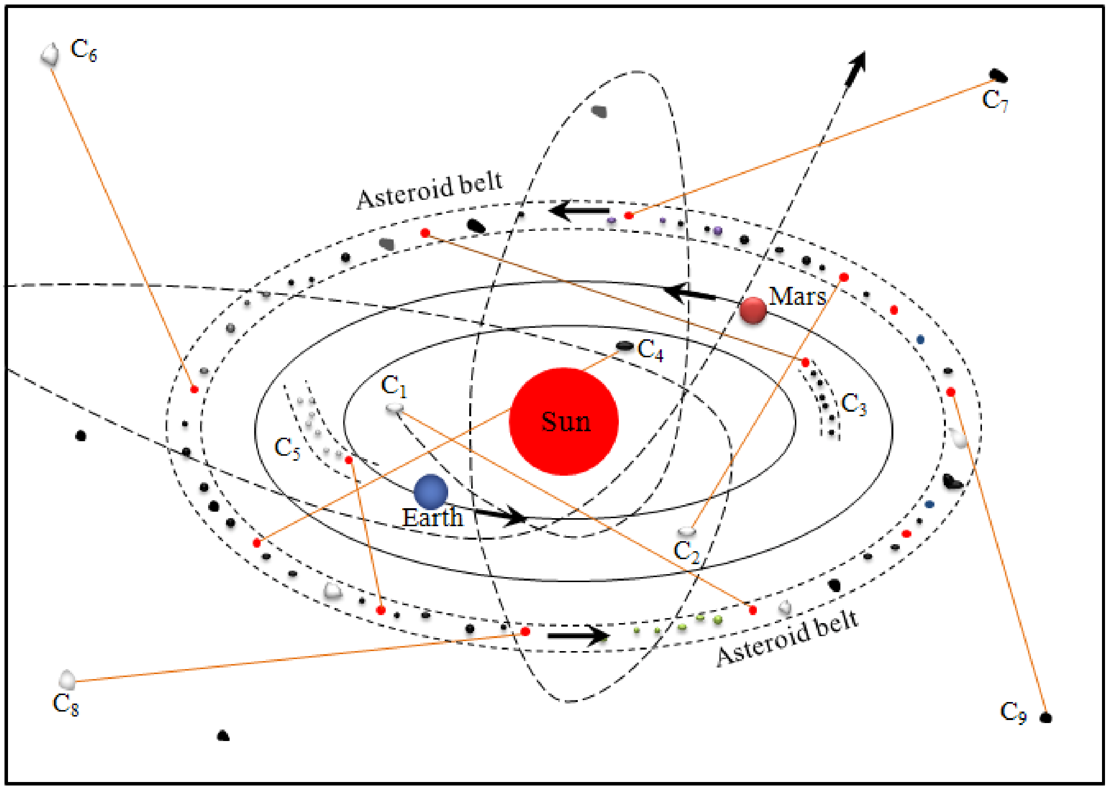

Figure 4: Simulation of the formation of comet in the asteroid belt. Some fragments that are beyond the belt are being dragged by some gravitational points (they are the barycenters of some two-body systems in the belt) to orbit. The positions of these barycenters are marked with red dot. The elongated trajectory represents an ideal path for fragment C_1 during this movement. Orange line represents the gravitation form gravitational point to fragment.

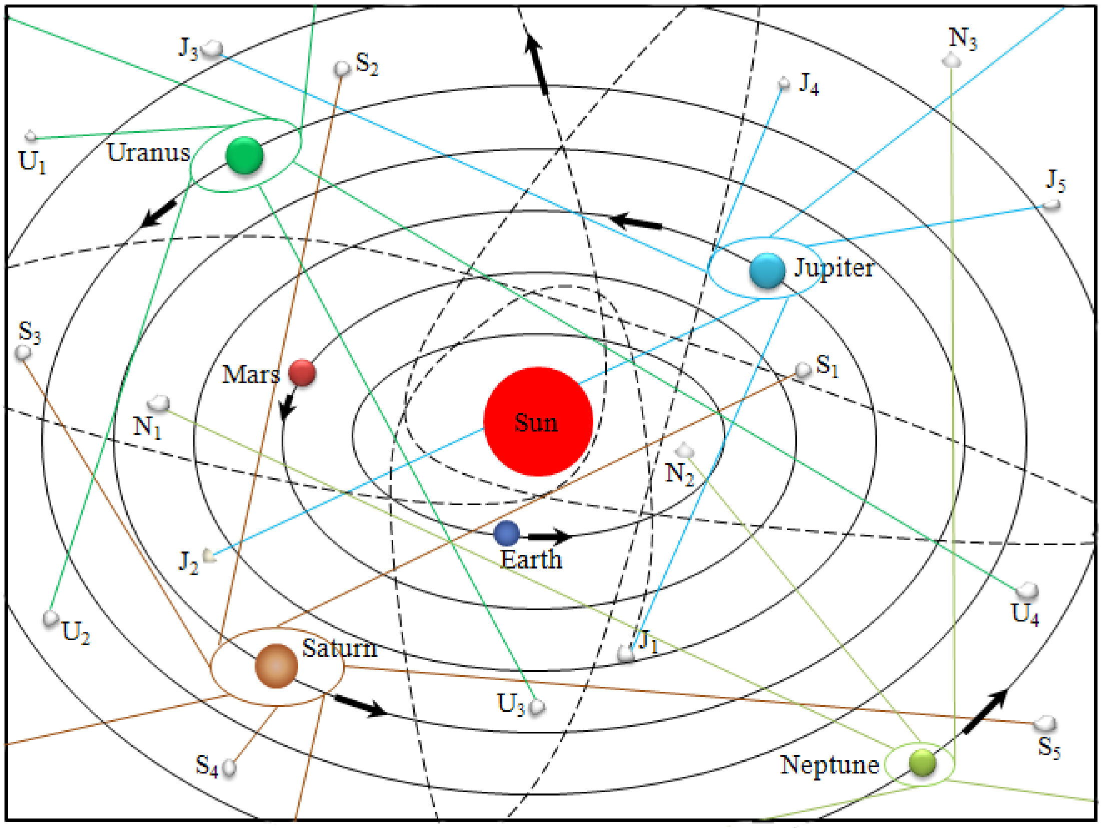

Figure 5: Simulation of the comet's formation from the drag of planetary ring. Each giant planet by means of its ring brings a lot of fragments to orbit a very elongated orbit that looks like a highly eccentric ellipse. For instance, fragment J_1 under the drag of the Jovian ring performs an elongated rotational orbit (marked with dashed line). $J_{1,2,3,\text{ etc}}$ ($S_{1,2,3,}$ etc, $U_{1,2,3,\text{ etc}}$, $N_{1,2,3,\text{ etc}}$) respectively represent the fragments controlled by their planetary ring.

Fits to observation: (1) Asteroid belt. It has been proved that many asteroids belong to some independent families or groups, in which these asteroids share nearly identical orbital elements [13, 22]. Although the current asteroid belt is believed to contain only a small fraction of the mass of the primordial belt, numerical simulations suggest that the original asteroid belt may have contained mass equivalent to the Earth [2]. There are gaps like Kirkwood gaps in the belt. Chemical composition mainly includes carbonaceous, silicate, and metallic materials. All these aspects are fully consistent with the expectation from this model; (2) Planetary ring. The composition arranged in the model is feasible to fit to the observation. Most of the giant planet's satellites are icy, which is nearly identical with the ring's composition that is mainly composed of water ice and dust; Some of the rings like Saturn's B ring include countless smaller rings that are separated with gaps. The propeller-shaped and ringlet structures in Saturn's ring and the twisted Fraternity arc in Neptune's ring fit to the model in Figure (1): as the two bodies of a two-body system are originally derived from the detachment of a common parent body, in the detachment each of the two bodies can obtain additional movement, as the barycenter of the two-body system continues to orbit, the two bodies due to their additional movements make them look like a propeller in space. If each body is further shattered to form an association of particles, and then the two associations may perform some kind of rotation, which makes them look like a twisted strap or rope in space. If one body is shattered to form an association of particles while another is survived, the survived body will accompany the association to orbit, which makes it look like a shepherd. Because of additional rotation, a separated association of particles looks like a long ringlet. The most prominent feature in Saturn's B ring is radial spoke. Spokes were first observed by the Voyagers in 1981, and the recently frequent appearance captured by Cassini was between 2008~ 2009, they are therefore thought to be a seasonal phenomenon, which corresponds to a coupling of solar radiation and spokes [23]. The leading theory regarding the spokes' composition is that they consist of microscopic dust particles suspended away from the main ring by electrostatic repulsion that relates to the magnetosphere of Saturn [24, 25], but a recent analysis of the spectrum of a Saturn ring spoke from Cassini/VIMS suggests that spokes are composed of water ice [26]. In Saturn's ring spokes are rare but water ice is rich, this significant difference is impossible to fit that spokes are composed of water ice. Although most of the Saturn's satellites are icy, their chemical composition is various, for example, Titan has a lot of hydrocarbons and other gases such as cyanoacetylene, carbon dioxide, carbon monoxide, and so on. Image from NASA/ESA/ASI Cassini-Huygens spacecraft shows that Saturn's ring has a temperature generally below -163 degrees Celsius. Our model here thinks that Saturn's ring is originally derived from the collision of a binary satellite system, thus the majority of materials at such a low level of temperature are probably freezed in the ring after the two bodies of the binary satellite system are shattered. But if solar radiation is properly supplied, some volatile materials which have higher freezing point may vaporize. For instance, dry carbon dioxide has a freezing point of -78.5 degrees Celsius. If a large number of volatile materials are efficiently vaporized by solar radiation, it may form a clump of gas across the ring plane. Also note a fact that spokes were darker than the rings in backscattered light but brighter than the rings in forward scattered light. This suggests that the vaporized materials above the ring plane may partly shade the ring plane from the Sunlight. Thus, when the ring plane brings the shadows of vaporized materials to orbit, spokes are created. D'Aversa et al employed Cassini/VIMS spectrometer to detect the composition of a spoke [26], it is very possible that they detect the material just below the spoke rather than the spoke itself. Saturn's ring is composed of mainly water ice, the rapid spoke looks like very thin, both of them easily deceives Cassini/VIMS spectrometer. A comparison of video between Voyager and Cassini may find that spokes are commonly light-footed, which really looks like some kind of shadow in the ring plane; (3) Comet. It is established that comets are composed of water ice, rock, dust, and frozen gases [27], planetary ring also consists of mainly water ice and dust, some of them like Saturn's ring has its atmosphere, this suggests that both comet and planetary ring may derive from the same origin. A population of comets in the main asteroid belt had been observed [11]. Most comets have elongated orbits that take them close to the Sun and then out into the further reaches of the solar system. Some of comets have orbits located between the Sun and outer planet. For instance, the aphelion of Halley's Comet is a little beyond Neptune's orbit, while Encke's Comet has an orbit which never puts it farther away from the Sun than Jupiter. There are also Centaurs that orbits the Sun between Jupiter and Neptune and crosses the orbits of one or more of the giant planets [28]. Statistical result indicates that comets have various inclination of orbit [8], and long period comets are generally on high-inclination orbits while short period one are mostly on low-inclination prograde orbits [29]. All these observations fit to the expectation from the model. Halley's Comet (or 1P/Halley) has a period of around 75-76 years around the Sun, and its perihelion is around 0.586 AU while aphelion is 35.1 AU (reference to Horizon Online Ephemeris System). Uranus has a semi-major axis of 19.23 AU and a period of around 84 years. The orbit of Halley's Comet appears to be averagely cut by Uranus's orbit, I therefore speculate that 1P/Halley is very likely to be dragged by Uranus's ring to orbit (Fig.6). As Uranus's equatorial plane is highly tilt to the ecliptic, this means that its satellites are clockwise with aspect to the planets around the Sun. As a result, the fragments from the collision between the two bodies of proposed binary satellite system are likely to be clockwise around the planet. Another comet 2P/Encke based on its orbital features is likely to derive from the control of the asteroid belt.

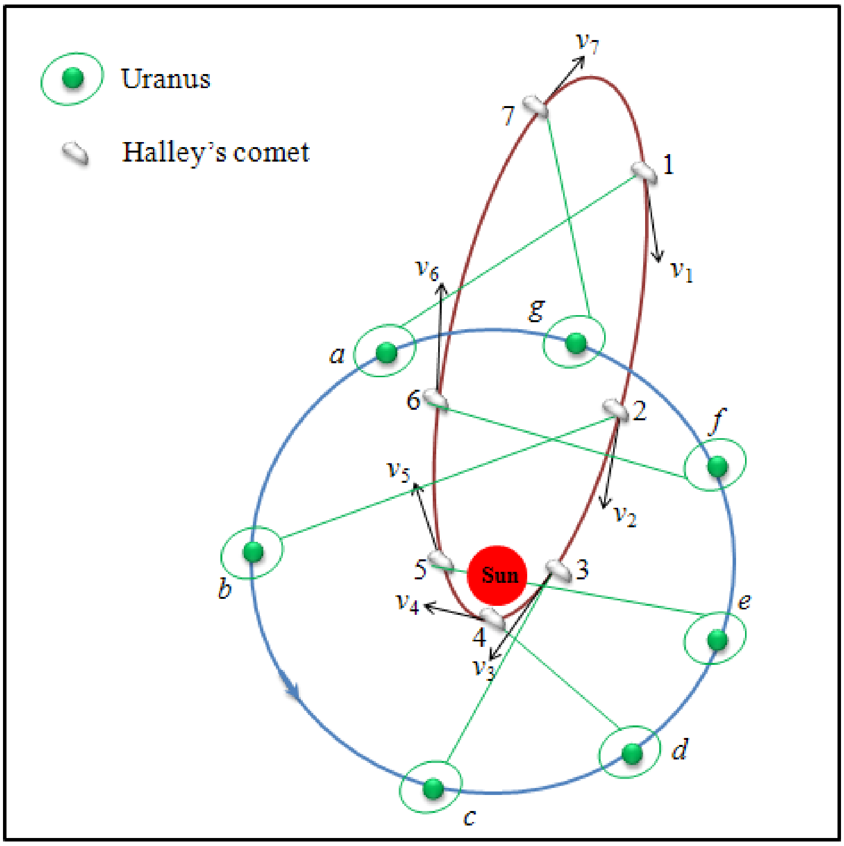

Figure 6: Simulation of the coupling of the Uranus and Halley's Comet. We assumed that when Halley is at position 1 with velocity v_1, the Uranus is at position *a* where its ring exerts a gravitation to drag Halley. When the Uranus continues to orbit the Sun along a path of *a*, *b*, *c*, *d*, *e*, *f*, and *g*, Halley is dragged by the ring to run an elongated path along position 1, 2, 3, 4, 5, 6, and 7. Note that from position 3 to 5, Halley is dragged by the ring to turn a large turn, this is determined by Halley's momentum. Blue line represents gravitation from the ring to Halley.

A large number of craters that are observed on the planets and satellites indicate that planets and satellites had been significantly bombarded after their births, this requires a special event to fit. The orderliness of the asteroids in a family (group) indicates that they are self-control. The identical spectral feature indicates that the members of a family are likely to derive from the disruption of a common parent body. The fragments from the disruption of a parent body are necessarily separated by distance in space, but under the frame of Newton's gravitation they are mutually entangled, which is very difficult for them to form a well-regulated association. In addition to this, the Sun's strong attraction will not allow these isolated fragments to form a self-gravity system, unless each fragment has a massive mass and the distance between any two fragments are very small. Instead, a hierarchical two-body gravitation may competent for this task. Yang speculated that due to the orbital shrinkage, the Earth and Moon will collide with one another within the following 1 billion years (see http://vixra.org/abs/1010.0042), if possible, the collision will have to yield another asteroid belt around the Sun.

Reference:

1. Herschel, W. Observations on the Nature of the New Celestial Body Discovered by Dr. Olbers, and of the Comet Which Was Expected to Appear Last January in Its Return from the Sun. Philosophical Transactions of the Royal Society of London **97**, 271–272 (1807).

2. Petit, J.-M., Morbidelli, A., Chambers, J. The Primordial Excitation and Clearing of the Asteroid Belt. Icarus **153**, 338–347 (2001).

3. Roche, E. A. Acad. Sci. Lett. Montpelier. Mem. Section Sci. **1**, 243-262 (1847).

4. Pollack, J. B., Grossman, A. S., Moore, R., Graboske, H. C. Jr. The formation of Saturn's satellites and rings as influenced by Saturn's contraction history. Icarus **29**, 35-48 (1976).

5. Charnoz, S., Morbidelli, A., Dones, L., Salmon, J. Did Saturn's rings form during the Late Heavy Bombardment? Icarus **199**, 413-428 (2009).

6. Dones, L. A recent cometary origin for Saturn's rings? Icarus **92**, 194–203 (1991).

7. Canup, R. M. Origin of Saturn's rings and inner moons by mass removal from a lost Titan-sized satellite. Nature **000**,1-4 (2010).

8. Oort, J. H. The structure of the cloud of comets surrounding the Solar System and a hypothesis concerning its origin. Bull. Astron. Inst. Neth.**11**, 91-110 (1950).

9. Kuiper, G. P. In Astrophysics: A Tropical Symposium, edited by J. A. Hynek. Mcgraw-Hill, New York, 357 (1951).

10. Duncan, M., Quinn, T., Tremaine, S. The origin of short-period comets. ApJ, Part 2 -Letters **328**, L69-L73 (1988).

11. Hsieh, H.H., Jewitt, D. A Population of Comets in the Main Asteroid Belt. Science **312**, 561-563 (2006).

12. Woolfson, M. M. Solar System – its origin and evolution. Q. J. R. Astr. Soc. **34**, 1-20 (1993).

13. Hirayama, K. Groups of asteroids probably of common origin, AJ. **31**, 185-188 (1918).

14. Murray, C. D. The determination of the structure of Saturn's F ring by nearby moonlets. Nature **453**, 739-744 (2008).

15. McGhee, C. A. *et al*. HST observations of spokes in Saturn's B ring. Icarus **173**, 508–521 (2005).

16. Hammel, H. The Ice Giant Systems of Uranus and Neptune. Solar System Update. Springer Praxis Books. 251-265 (2006).

17.Wurchterl, G. Planet Formation Towards Estimating Galactic Habitability. In P. Ehrenfreund et al.. Astrobiology: Future Perspectives. Kluwer Academic Publishers, 67–96 (2004).

18. Klahr, H. H., Bodenheimer, P. Turbulence in accretion disks: vorticity generation and angular momentum transport via the global baroclinic instability. ApJ. **582**, 869–892 (2003).

19. Taishi, N., Yushitsugu, Nakagawa. Formation, early evolution, and gravitational stability of protoplanetary disks. ApJ. **421**, 640–650 (1994).

20. Andrew N, Youdin., Shu, F. N. Planetesimal formation by gravitational instability. ApJ. **580**, 494-505 (2002).

21. Inaba, S., Wetherill, G.W., Ikoma, M. Formation of gas giant planets: core accretion models with fragmentation and planetary envelope. Icarus **166**, 46–62 (2003).

22. Anne, Lemaitre. Asteroid family classification from very large catalogues. Proceedings Dynamics of Populations of Planetary Systems. Belgrade, Serbia and Montenegro: Cambridge University Press, 135–144 (2004).

23. Mitchell, C.J., Horanyi, M., Havnes, O., Porco, C.C. Saturn's Spokes: Lost and Found. Science **311**,1587-1589(2006).

24. Goertza, C. K., Morfill, G. A model for the formation of spokes in Saturn's ring. Icarus **53**, 219-229 (1983).

25. Tagger, M., Henriksen, R. N., Pellat, R. On the nature of the spokes in Saturn's rings. Icarus **91**, 297-314(1991).

26. D'Aversa, E. *et al*. The spectrum of a Saturn ring spoke from Cassini/VIMS. Geophys. Res. Lett. 37, L**01203** (2010).

27. Huebner, W. F. Composition of Comets: Observations and Models. Earth, Moon, and Planets. **89**,179-195(2000).

28. Horner, J., Evans, N.W., Bailey, Simulations of the Population of Centaurs I: The Bulk Statistics. Mon. Not. R. Astron. Soc. **000**, 1–15 (2008).

29. Duncan, M., Quinn, T., Tremaine, Scott. The origin of short-period comets. ApJ. **328**,L69-L73 (1988).