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Formation of binaries at the stage of rarefied preplanetesimals

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Last years, new arguments in favor of the model of rarefied preplanetesimals - clumps have been found. There are several hypotheses of formation of binaries for a model of solid objects (see references in [1]). Ipatov [2] supposed that a considerable fraction of trans-Neptunian binaries could be formed at the stage of compression of rarefied preplanetesimals moved in almost circular orbits. For circular heliocentric orbits, two objects that entered inside the Hill sphere could move there for a longer time than those entered the sphere from eccentric heliocentric orbits. The diameters of preplanetesimals were greater than the diameters of solid planetesimals of the same masses. Therefore the models of binary formation due to the gravitational interactions or collisions of future binary components with an object (or objects) that were inside their Hill sphere, which were considered by several authors for solid objects, are more effective for rarefied preplanetesimals.

Formulas for the angular momentum of two collided rarefied preplanetesimals - Hill spheres (with radii r_1 and r_2 and masses m_1 and m_2) moved in circular heliocentric orbits are presented in [3]. At a difference in their semimajor axes a equaled to Θ•$(r_1 + r_2)$, the tangential velocity of collision is $v_\tau = k_\Theta$•$(G$•$M_S)^{1/2}$•$(r_1 + r_2)$•$a^{-3/2}$ and the angular momentum $K_s = k_\Theta$•$(G$•$M_S)^{1/2}$•$(r_1 + r_2)^2$•m_1•m_2•$(m_1 + m_2)^{-1}$•$a^{-3/2}$, where $G$is the gravitational constant, and M_S is the mass of the Sun. At r_a=$(r_1 + r_2)/a$«Θ and r_a«1, one can obtain k_Θ ≈(1-1.5•Θ^2). The mean value of $|k_\Theta|$ equals to 0.6. It is equal to 2/3 for mean positive values of k_Θ and to 0.24 for mean negative values of k_Θ. The resulting momentum is positive at 0< Θ <(2/3)$^{1/2}$ ≈0.8165 and is negative at 0.8165< Θ <1.

We suppose that formation of some binaries could be caused by that the angular momentum that they obtained at the stage of rarefied preplanetesimals was greater than that could exist for solid bodies. During contraction of a rotating rarefied preplanetesimal, some material with $v_s > v_{cf}$ (where v_s is the velocity of a particle on a surface of a rotating object at the equator and v_{cf} is the minimum velocity at which a particle can leave the surface) could form a cloud (that transformed into a disk) of material moving around the contracting primary. One or several satellites of the primary could be formed from this cloud. Some collided rarefied preplanetesimals had a greater density at distances closer to their centers. Therefore it might be also possible that sometimes there were two centers of contraction inside the rotating preplanetesimal formed as a result of a collision of two rarefied preplanetesimals. Such formation of binaries could result in binaries with close masses separated by a large distance. In such cases, the values of the eccentricity of the orbit of the secondary component can be different. Most of rarefied preasteroids could turn into solid asteroids before they collided with other preasteroids.

For several observed trans-Neptunian binaries, we calculated the angular momentum K_{scm} of the present primary and secondary components (with observed masses and radii), the momentum K_{s06ps} of two collided preplanetesimals with masses of the binary components moved in circular heliocentric orbits at k_Θ=0.6, and the momentum K_{s06eq} of two identical collided preplanetesimals with masses equal to a half of the total mass of the binary components at k_Θ=0.6. All these three momenta are considered relative to the center of mass of the system. K_{spin} is the spin momentum of the primary. For the binaries considered [1], the ratio r_K=$(K_{scm}+K_{spin})/K_{s06eq}$ is smaller than 1. For most of observed binaries, this ratio is smaller than that for the trans-Neptunian binaries considered (Pluto, (90842) Orcus, 2000 CF105, and 2001 QW$_{322}$). Small values of r_K for most discovered binaries can be due to that preplanetesimals had already partly compressed at the moment of collision (could be smaller than their Hill spheres and/or could be denser for distances closer to the center of a preplanetesimal).

Conclusions: Some trans-Neptunian objects and asteroids could get their axial rotation and/or satellites at the stage when they were rarefied preplanetesimals. The momentum of two collided identical rarefied Hill spheres moved in circular orbits exceeded the momentum of a corresponding present binary of the same total mass.

References: [1] Ipatov S.I. (2009) *LPS* XL, Abstract #1021. [2] Ipatov S.I. (2004) *AIP Conf. Proc.,* v. 713, 277-280. Also http://planetquest1.jpl.nasa.gov/TPFDarwinConf/proceedings/posters/p045.pdf). [3] Ipatov S.I. 1981. Several aspects of the formation of spins of planets, *Inst. of Applied Mathematics Preprint N 102*, Moscow, 28 P, in Russian.