EPSC Abstracts
Vol. 7 EPSC2012-368 2012
European Planetary Science Congress 2012

Haumea and the rotational fission of trans-Neptunian objects

J. L. Ortiz (1), A. Thirouin (1), A. Campo Bagatin (2,3), R. Duffard (1), J. Licandro (4), D. C. Richardson (5), P. Santos-Sanz (1,6), N. Morales (1) and P. G. Benavidez (2,3)
(1) Instituto de Astrofísica de Andalucía - CSIC, Apt 3004, 18008 Granada, Spain
(2) Departamento de Fisica, Ing. de Sistemas y teoria de la Señal, Universidad de Alicante, PO Box 99, 03080 Alicante, Spain
(3) Instituto de Física Aplicada a las Ciencias y la Tecnología, Universidad de Alicante, PO Box 99, 03080 Alicante, Spain
(4) Instituto de Astrofisica de Canarias, C/ Via Lactea sn La Laguna, Tenerife, Spain
(5) Department of Astronomy, University of Maryland, College Park, MD 20742-2421, USA
(6) Observatoire de Paris, LESIA-UMR CNRS 8109, 5 place Jules Janssen, F-92195 Meudon cedex, France

Abstract

We think it is likely that rotational fission has occurred for a fraction of the known trans-Neptunian objects (TNOs). It is also likely that a number of binary or multiple systems have formed from that process in the trans-Neptunian belt. We focus on Haumea, which is a potential example of an object that has suffered rotational fission. Its current fast spin would be a slight evolution of a primordial fast spin, rather than the result of a catastrophic collision. We conclude that based on the specific angular momentum of Haumea and its satellites, and from N-body simulations of rotational fission applied to the case of Haumea. These show that the process is feasible, it might have generated satellites, and it might have even created a 'family' of bodies associated to Haumea's orbit. These associated bodies might come from the direct ejection of fragments, according to our simulations, or through the evolution of a proto-satellite formed during the fission event, or from an escapee that later suffered a disruption. In the future, perhaps TNO pairs may be found (i.e. pairs of bodies sharing very similar orbital elements but not bound together), as is the case in the NEA and Main Belt asteroid populations, where pairs are known to come from rotational fissions.

1. Introduction

Our Solar system contains a large number of icy bodies beyond Neptune's orbit. These objects are collectively referred to as trans-Neptunian objects (TNOs). A topic that has attracted particular interest within the science of TNOs is binarity. Binaries are a powerful means to study the trans-Neptunian belt because they can allow us to derive the masses and densities of their components (by assuming some mean albedo value). Also, TNO binaries appear to be quite common. Several mechanisms of binary formation have been proposed for TNOs, most of which have been reviewed by [1]. There are also newer binary formation scenarios, such as direct collapse [2] and we recently proposed the rotational fission mechanism [3]. Rotational fission had not been particularly investigated in the case of TNOs prior to our work. This mechanism is thought to be an important source of binaries in the near-Earth and main belt asteroid populations (e.g. [4]). Although the preferred formation mechanisms of most of the binaries in the trans-Neptunian belt is the capture scenario (e.g. [1]), rotational fission might also provide a fraction of the observed high-mass-ratio binary systems, and other binaries with small specific angular momentum. It would be useful to know approximately what fraction should be expected. The study of rotational fission is important not only for binarity studies, but also for our general understanding of the trans-Neptunian belt.

2 The case of Haumea

2003 EL61 (Haumea) is a dwarf planet with a mass of 4.006 x10^{21}kg [4] and a short spin period of 3.92 h. Two satellites, Hi'iaka and Namaka, are orbiting Haumea and have mass ratios relative to Haumea of 1/200 and 1/2000, respectively [5]. The scaled spin rate versus the total specific angular momentum of the system is almost identical of that of the high mass ratio binary asteroids (which are known to come from rotational fission or mass shedding episodes). Thus, this is a clue for the origin of the Haumea satellite system from fission.

3 Simulations

We have simulated spontaneous rotational fissions and collisionally induced rotational fissions. The first step of the process is the generation of a fast-spinning object with a total mass of around 4.5x10^{21} kg. Such a gravitationally held object has comparable mass and size to Haumea, with a mass 10% larger in order to account for mass loss as the system is formed. The proto-Haumea body is generated by means of a coagulation method starting from a spinning nebula of 1000 equal-sized particles, which generates a stochastic pile of spheres with no preferential geometrical structure [6].

S1: In the spontaneous rotational fission scenario, twenty one small increments of angular momentum were performed until fission occurred. The object is allowed enough time to adjust itself to the successive increments of angular momentum. This technique is used in order to look for the object's disruption limit in a very smooth way, avoiding sharp accelerations to the body's rotation. **S2:** These simulations are induced rotational fissions, which are equivalent to S1 until the twentieth spin-up step is done. This was done to simulate a situation in which a proto-Haumea is originally rotating fast when, at some point, a low-energy collisional event occurs. The last step is performed by means of a collision that provides enough angular momentum to trigger fission. The relative speed of the collision is 1 km s^{-1}, the average impact speed in most of the main classical belt of TNOs. This simulation is performed in order to answer the straightforward question that can arise after S1: why should a 2000-km-sized body increase its own angular momentum at some point? **S3:**This is a faster collision than in S2, which provides more angular momentum than is strictly needed for fission. The collision is performed at 3 km s^{-1}. The relative speeds that have been tested are close to, or even above, the limit for sound speed in the target body. In a homogeneous body, simulations of hypervelocity collisions must include the damage produced by the propagation of the shock wave into the body structure, as in smoothed particle hydrodynamics (SPH) simulations. Nevertheless, this consideration does not invalidate our technique because we are dealing with bodies that have, at least, a crust of heavily fragmented material. **S4:** This fourth scenario corresponds to simulations in which a different target is impacted by the projectile at 3 km s^{-1}. Except for the target, this scenario is the same as S3. In S4, the target has a different number of particles and rotation period, compared to S2 and S3.

4 Summary and Conclusions

We have presented evidence that indicates that rotational fission of TNOs might be a mechanism that has affected a fraction of the TNO population. Binaries could have formed in this way in the trans-Neptunian region. Also, 'TNO pairs' – and even triple Systems – might exist as a result of rotational fission. Haumea is a particularly good candidate, which might have suffered a rotational fission because of its fast spin rate and other remarkable features. The satellites of Haumea might have been formed as a result of the fission itself. The 'family' of bodies orbitally related to Haumea might derive from the ejected fragments after the fission. But apart from Haumea there are other TNOs that may have suffered fission, like Orcus, as we showed [7]. **A full description of the simulations and other details are in [3]**.

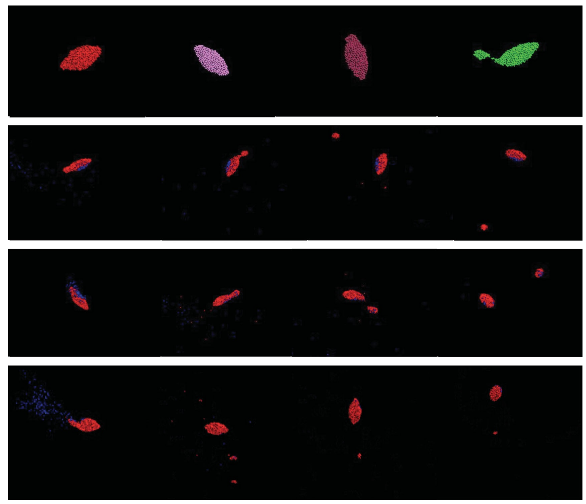

Figure 1: Snapshots of the different simulations, from top to bottom, S1, S2, S3, S4.

References

[1] Noll et al. The Solar System Beyond Neptune. University of Arizona Press, Tucson, AZ, p. 345.

[2] Nesvorny D., et al., 2010, AJ, 140, 785.

[3] Ortiz et al. 2012. MNRAS 418, 2315-2324

[4] Walsh K. J., et al. P., 2008, Nat, 454, 188

[5] Ragozzine D., Brown M. E., 2009, AJ, 137, 4766

[6] Tanga P. et al., 2009, ApJ, 706, L19

[7] Ortiz et al. 2011, Astron. Astrophys. 525, id. A31