

Dynamical environments of MU69: a state of chaotic clearing

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Abstract. The second (after Pluto) plausible target object for the New Horizons mission is 2014 MU69. It is a classical TNO, a primordial contact binary. Identifying any material in the vicinities of a target object is of an especial concern for planning cosmic fly-byes, as it is hazardous for a space probe. Luckily, no such material has been reported for MU69 up to now. The point of our report is that this lucky absence is just a dynamical consequence of the physical nature of MU69. Spinning gravitating dumbbells create zones of dynamical chaos around them, and this has a *clearing effect*: any material put in orbits around a rotating dumbbell (e.g., any material ejected from its surface) cannot be long-lived in such zones; it either escapes into space, or returns to the parent body's surface. As the orbiting matter is removed in this way, a spinning gravitating dumbbell clears its vicinities. We show that MU69 is able to create such a clearing, making itself a safe and hospitable target for a space mission. Therefore, the guest probe is expected to be safe on arrival.

Keywords. Celestial mechanics, minor planets, asteroids, Kuiper Belt.

1. Introduction

After a number of adventures, including accomplishment of a HST survey, the second (after Pluto) plausible target object for the New Horizons mission was successfully discovered in 2014, named 2014 MU69. Later on, it has turned out to be a classical TNO, a primordial contact binary with lobe sizes of 20 and 18 km (Stern 2017; Parker *et al.* 2017). Such a dumbbell shape is typical for TNOs. Lightcurve observations are under way, aimed to retrieve the rotation period (Benecchi 2016). Identifying any material in the vicinities of a target object is of an especial concern for planning cosmic fly-byes, as it is hazardous for a space probe. Luckily, no such material has been reported for MU69 in a meticulous survey (Kammer *et al.* 2017).

2. Chaotic clearing

The point of our report is that this lucky absence is just a dynamical consequence of the physical nature of MU69. Spinning gravitating dumbbells create zones of dynamical chaos around them (Lages, Shepelyansky & Shevchenko 2017), and this has a *clearing effect*: any material put in orbits around a rotating dumbbell (e.g., any material ejected from the surface) cannot be long-lived in this zone; it either escapes into space, or returns to the parent body's surface (Lages, Shevchenko & Rollin 2018). As the orbiting matter is removed in this way, a spinning gravitating dumbbell clears its vicinities. A well-known example of analogous “cleansing” is the formation of the Wisdom gap in the co-orbital

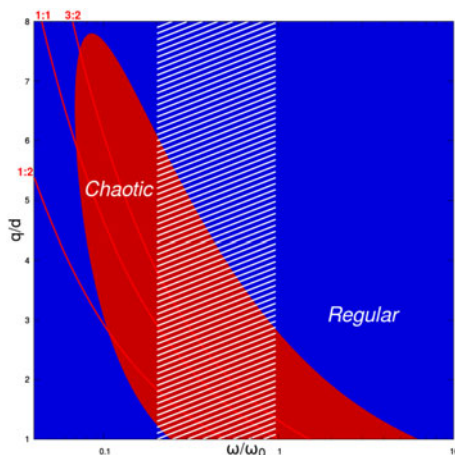


Figure 1. Extents of the chaotic zone around a contact binary as a function of the binary’s rotation rate ω . Red (blue) colour indicates chaos (stability). White shaded area delimits the range of typical rotation rates of the Kuiper belt objects, according to [Thirouin *et al.* \(2014\)](#).

neighbourhood of a planet. One of the conditions in the definition of a planet implies the co-orbital cleansing ([IAU General Assembly 2006](#)).

The Wisdom chaotic gap is formed by the overlap of the accumulating first-order mean-motion resonances in the co-orbital neighbourhood of a planet; whereas the circumdumbbell chaotic zone is formed by the overlap of the accumulating integer and half-integer spin-orbit resonances with the rotating dumbbell ([Lages, Shevchenko & Rollin 2018](#)). In the both cases, any material injected in the chaotic zones is subject to an unlimited chaotic diffusion in the eccentricity, to be removed, finally, out of these areas. In [Figure 1](#), the extents of the chaotic zone, where the clearing takes place, are represented graphically in the “dumbbell rotation rate – particle’s pericentric distance” diagram. The rotation rate is in the units of its critical value, equal to the contact binary’s Keplerian rate of rotation, corresponding to disintegration of the binary. The pericentric distance is in units of the binary’s size, defined as the distance between the mass centers of its components. The form and size of the chaotic domain depends on the binary’s mass ratio only weakly, as shown in [Lages, Shevchenko & Rollin \(2018\)](#); therefore, using the parameters of MU69 obtained in any future observations, the extents of the chaotic clearing can be easily evaluated.

3. Conclusions

Tantalizingly, the chaotic-clearing phenomenon affects both targets of the New Horizons mission, but in different ways: Pluto is not able to cleanse any radial neighbourhood of its orbit, and on this reason it was deprived of the planetary status ([IAU General Assembly 2006](#)); conversely, MU69 is able to create a clearing, but of another (circum-body) kind, making itself a safe and hospitable target for a space mission. The rendezvous will take place on 31 December 2018 or 1 January 2019. The object of destination, as we point out, chaotically cleanses its environments; therefore, the guest probe is expected to be safe on arrival.

Acknowledgements

I.I.S. was supported by the Russian Science Foundation (project No. 19-12-11010).

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