EPSC Abstracts
Vol. 7 EPSC2012-542-1 2012
European Planetary Science Congress 2012

1996 FG3, MarcoPolo-R mission target: Living on the edge

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Abstract

199FG3 is a binary asteroid, the nominal target of the MarcoPolo-R mission [1]. Its mass, size, spin rate and satellite orbital period are well estimated. Radar observations (from Arecibo and Goldstone) have also provided estimates of the primary shape and maximum separation of the secondary. The fast spin rate of the primary make it an extremely interesting object from a mechanical point of view as it is at the limit of rotational stability against reshaping and/or mass loss. This rare circumstance gives an outstanding added value to the mission because it may provide constraints on the internal structure of the primary and the mechanisms of formation of binary asteroids. The working group on mechanical properties of the MP-R mission has analysed 1996FG3's peculiar characteristics from a theoretical standpoint and through analysis of numerical experiments. Our conclusions may have consequences on the design and landing site choice of this unique mission.

1. Introduction

According to the observations of the binary orbit of 1996 FG3, through asteroid thermophysical models and the Arecibo and Goldstone radar images, the mass of the primary is 3.3×10^{12} kg, its diameter $1.9^{+0.55}_{-0.42}$ km and it has a fast rotation period of 3.6 h. The orbit of the secondary is 16.1 h, its diameter about 500 m and a maximum separation from the primary of 2.55 km. The mass ratio is estimated to be 0.02. Radar observations suggest that the secondary rotation is compatible with being synchronous with its revolution period around the primary, and that the primary seems to have a characteristic equatorial bulge. The density of the primary is estimated to be around 0.9 g/cm^3.

2. Motivation

The observables of 1996 FG3 make this system extremely interesting to study, and a unique target for a space mission. Were MarcoPolo-R selected to visit this binary asteroid, it would give a major contribution to the understanding of important features of asteroid science.

2.1 Binary formation

Observations of binary asteroids and asteroid pairs [5] and theoretical studies on fission processes [4] agree on the minimum size ratio for binary systems to have stable orbits. This ratio is at least 0.2, 10 times larger than in the case of 1996 FG3. Was this system formed by fission, or gradual mass loss, or by another mechanism such as tidal perturbation during a close encounter with a terrestrial planet? Was it formed during its original stay in the asteroid belt as the result of a collision? Is the equatorial bulge related to the formation of the binary [6]?

2.2 Internal structure

The rapid rotation of the primary, well beyond stability for fluid bodies with 1996 FG3's density [2] suggests that this body is mostly held together by internal friction between components preventing failure [3]. Therefore, the primary has internal sheer stresses that may accumulate tensile energy. Is part of that energy released at some point due to the interaction with the secondary? What are the effects of that release of energy on the surface regolith motion and morphology and how could that be detected by the MarcoPolo-R mission? Can that be used as a free diagnostic of the primary's interior structure?

3. Summary

The working group on mechanical properties of the MarcoPolo-R mission is studying in detail the characteristics of the 1996 FG3 binary system. The primary appears to have close to zero gravity around equatorial latitudes due to high centrifugal forces. Gravity could even be positive (that is directed outwards the object) if the highest values for its equatorial radius are confirmed, implying potential loss of regolith coming from regions at higher latitudes. In the case of negative gravity, the value would be extremely small ($\sim 10^{-6}$ m/s^2) such that vibration caused by energy release of internal stress or the perturbation induced by the secondary on regolith particles may deliver enough energy to lift dust from the surface that would levitate during tens of minutes. The role of cohesion due to electrostatic and/or Van der Waals forces between mm to cm-size particles may be non-negligible in this environment. The mentioned effects have been evaluated analytically and performance of numerical simulations is ongoing to understand those effects on the surface regolith. We present our results and we comment about how they may affect the choice of the landing/sampling site of the MarcoPolo-R mission.

Acknowledgements

ACB and PGB acknowledge funding from the Spanish program on Astronomy and Astrophysics by the Ministerio de Ciencia e Innovación. Grant AYA2011-30106-C02-02.

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