ISSN 2176-5480

22nd International Congress of Mechanical Engineering (COBEM 2013)
November 3-7, 2013, Ribeirão Preto, SP, Brazil

ON THE RELEVANCE OF THE SAILBOAT ISLAND FOR THE NEW HORIZONS MISSION

Othon Cabo Winter
Grupo de Dinâmica Orbital & Planetologia - UNESP
Av. Ariberto Pereira da Cunha 333
CEP 12516-410 - Guaratinguetá - SP
ocwinter@feg.unesp.br

Silvia M. Giuliatti Winter
Grupo de Dinâmica Orbital & Planetologia - UNESP
Av. Ariberto Pereira da Cunha 333
CEP 12516-410 - Guaratinguetá - SP
silvia@feg.unesp.br

Ernesto Vieira Neto
Grupo de Dinâmica Orbital & Planetologia - UNESP
Av. Ariberto Pereira da Cunha 333
CEP 12516-410 - Guaratinguetá - SP
Ernesto@feg.unesp.br

Rafael Sfair
Grupo de Dinâmica Orbital & Planetologia - UNESP
Av. Ariberto Pereira da Cunha 333
CEP 12516-410 - Guaratinguetá - SP
sfair@feg.unesp.br

***Abstract**. In previous works we have studied the location of stable regions in the Pluto-Charon system. Among the findings, we discovered an island of stability, named Sailboat Island. On the other hand, in 2006 it was launched the spacecraft of the New Horizons mission. The main goal of this NASA mission is to have a flyby close to the Pluto-Charon system. In the present work we analyze the relevance of the Sailboat island for the New Horizons mission. First we identified the location and extent of the stable trajectories in physical space around Pluto. They go beyond the trajectory of Charon in a way that Charon never crosses such trajectories. However, we verify that the planned trajectory of the New Horizons spacecraft passes through the region of the Sailboat island trajectories. The existence of particles (small boulders) in such region might result in a collision with the spacecraft, what would be catastrophic for the whole mission. Then, we explore the relative density of probability of having particles in such region compared to well known stable circular trajectories close to Pluto. The preliminary results indicate that the risk may not be negligible, needing further studies.*

***Keywords**: Pluto-Charon system, New Horizons mission, periodic orbits, stable trajectories.*

1. INTRODUCTION

In an exploration of the planar S-type orbits of the Pluto-Charon binary system, Giuliatti Winter et al. (2010) identified an island of stable trajectories in the semi-major axis (a) versus eccentricity (e) diagram of initial conditions (Fig. 1). A curious feature of this stable trajectories is that they might have initial eccentricity up to 0.9. Due to its shape, this island has been called "sailboat island".

In order to better understand the reason for this stable island, Giuliatti Winter et al. (2013b) analyzed the family of periodic orbits responsible for such stability. The inclusion or not of an eccentricity for Charon does not make a significant change in the stable island. Therefore, the analysis is made considering the planar circular restricted three-body problem. Using Poincaré surfaces of section was possible to find the initial conditions for the periodic orbits.

In another study (Giuliatti Winter et al., 2013a), we have shown that this island of stability exists even in the three-dimensional space of the Pluto-Charon system.

ISSN 2176-5480

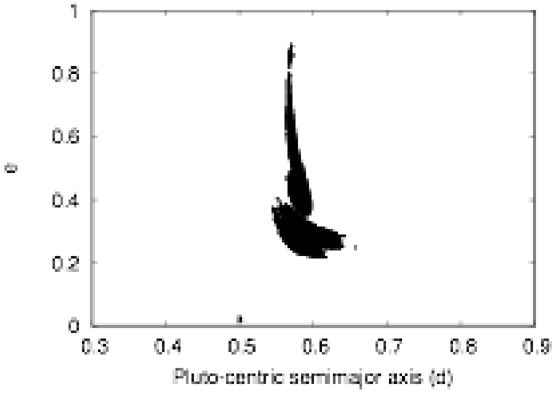


Figure 1. Island of stable trajectories in the Pluto-Charon system, called *sailboat island*. This plot indicates in black the values of *a* and *e* for the initial conditions of particles that are stable. This corresponds to the planar case with the particle initially in conjunction at pericenter. (reproduced from Giuliatti Winter et al. 2013b).

2. LOCATION AND SIZE OF STABLE PERIODIC ORBITS

The location and extent of the trajectories associated with the stable sailboat island can be visualized in Fig. 2, where is shown a representative set of trajectories corresponding to periodic orbits for different values of orbital inclination, one periodic orbit for each inclination. In this plot is also shown the planned trajectory of the New Horizon spacecraft (straight line in red). Note that none of the trajectories get close to the path of the spacecraft.

However, in fact, the trajectories that cover a wider area of the physical space are the quasi-periodic orbits that are further from the periodic orbits. In Fig. 3 we present the excursions due to the largest quasi-periodic orbits for different values of orbital inclination. Projections of Fig. 3 in the Cartesian planes are presented in Fig. 4. Note that now the spacecraft gets closer to some of the trajectories associated to the sailboat island. The closest distance to the New Horizons spacecraft trajectory is about 1,650km.

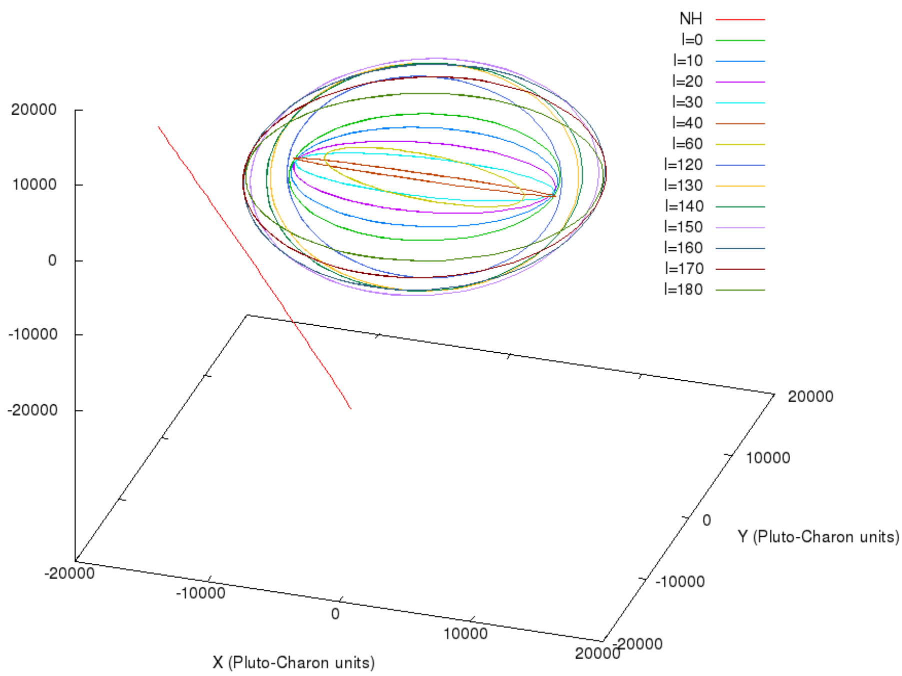


Figure 2. A set of trajectories corresponding to periodic orbits for different values of orbital inclination (one periodic orbit for each inclination) and the trajectory of the New Horizon spacecraft (straight line in red).

ISSN 2176-5480

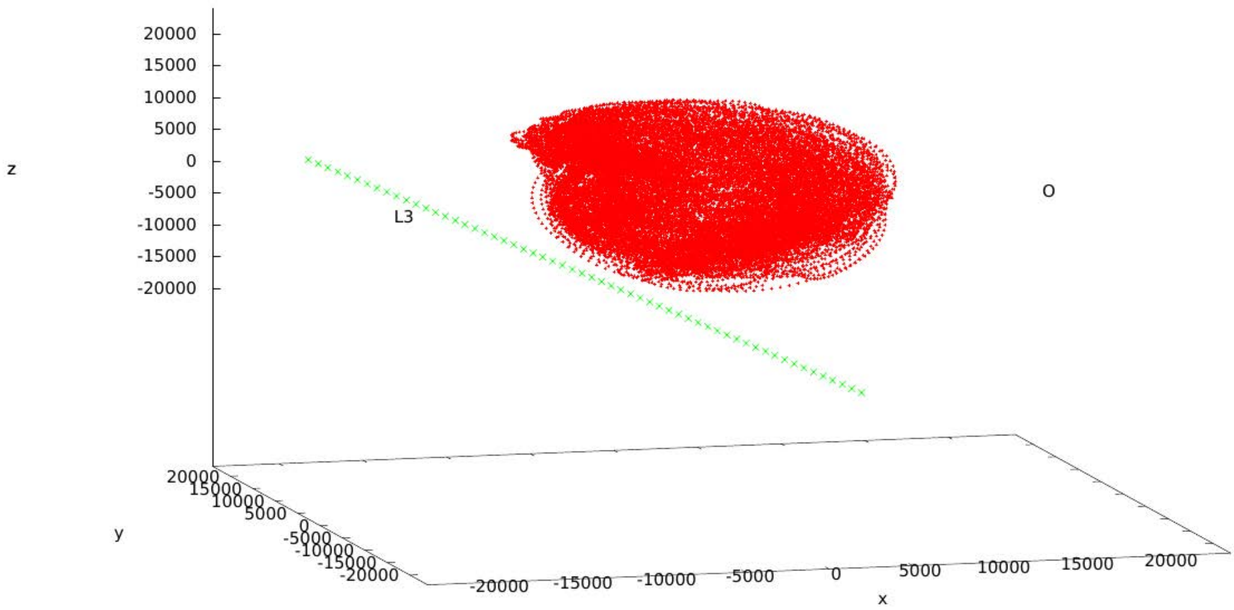
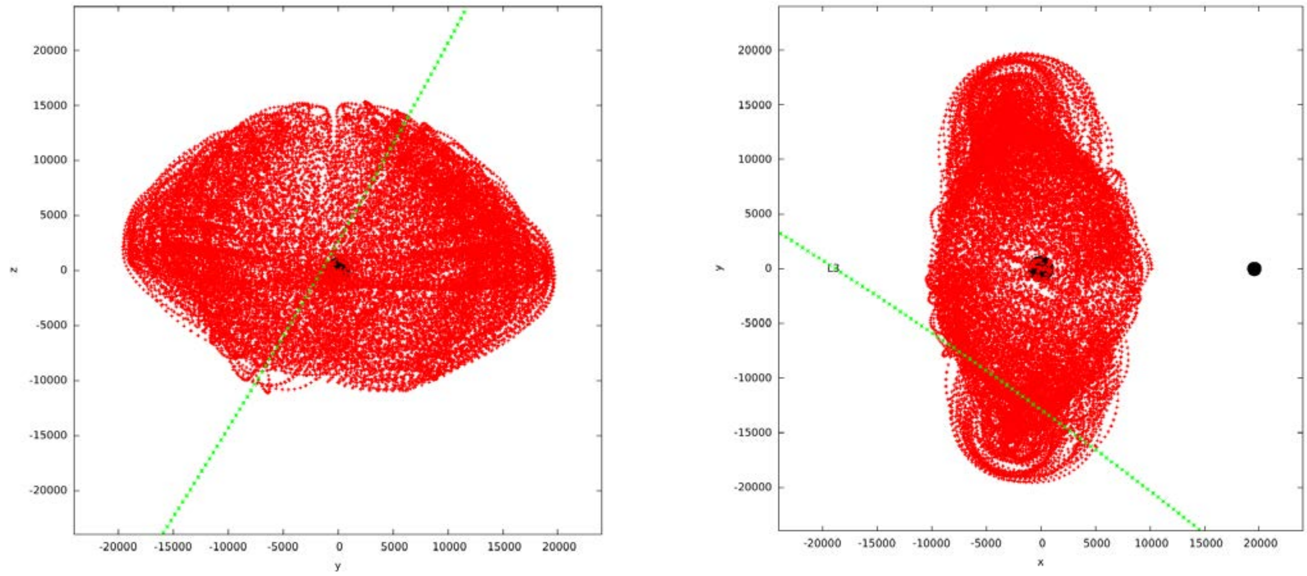


Figure 3. A set of trajectories corresponding to some of the largest quasi-periodic orbits for different values of orbital inclination (several quasi-periodic orbits for each inclination) and the trajectory of the New Horizon spacecraft (straight line in green). The open circle on the right indicates the position of Charon.

ISSN 2176-5480



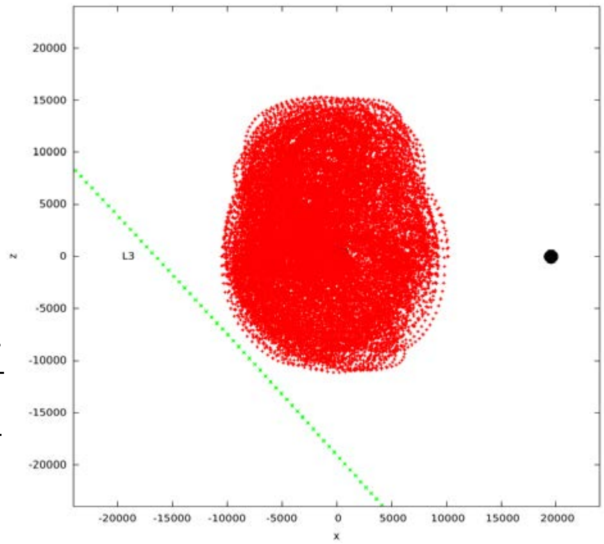


Figure 4. Projections of Fig. 3 in the Cartesian planes. A set of trajectories corresponding to some of the largest quasi-periodic orbits for different values of orbital inclination (several quasi-periodic orbits for each inclination) and the trajectory of the New Horizon spacecraft (straight line in green). The black dot indicates the position of Charon.

3. DENSITY OF TRAJECTORIES

In order to explore the relevance of the *sailboat island* particles for the New Horizons mission we estimate the density of particles per area in the equatorial region around Pluto. By following the trajectories of particles from the *sailboat island,* we stored the location of the particles at equal time intervals. For sake of comparison, we considered another well known stable region of circular orbits close to Pluto, here called *standard region*. The results, presented in Fig. 7, show the density of particles along the physical space in terms of a color code. The darker blue color indicates the areas with the highest density of particles. There are only two areas with such color. One ring close to Pluto, with orbital radius smaller than four thousand kilometers, which is occupied by particles from the *standard region*. And other area at much larger orbital radius, beyond seven thousand kilometers, which is occupied by particles from the *sailboat island*. The projection of the spacecraft trajectory gets closer to this dense region.

4. FINAL COMMENTS

In the present work we make some exploration of the trajectories associated to the stable sailboat island. We show their excursion in the three-dimensional space around Pluto and how close to them the New Horizons spacecraft can get. We also estimate the density of particles in comparison with that due to a well known region of stable circular orbits close to Pluto. Nevertheless, this subject still deserves further studies.

ISSN 2176-5480

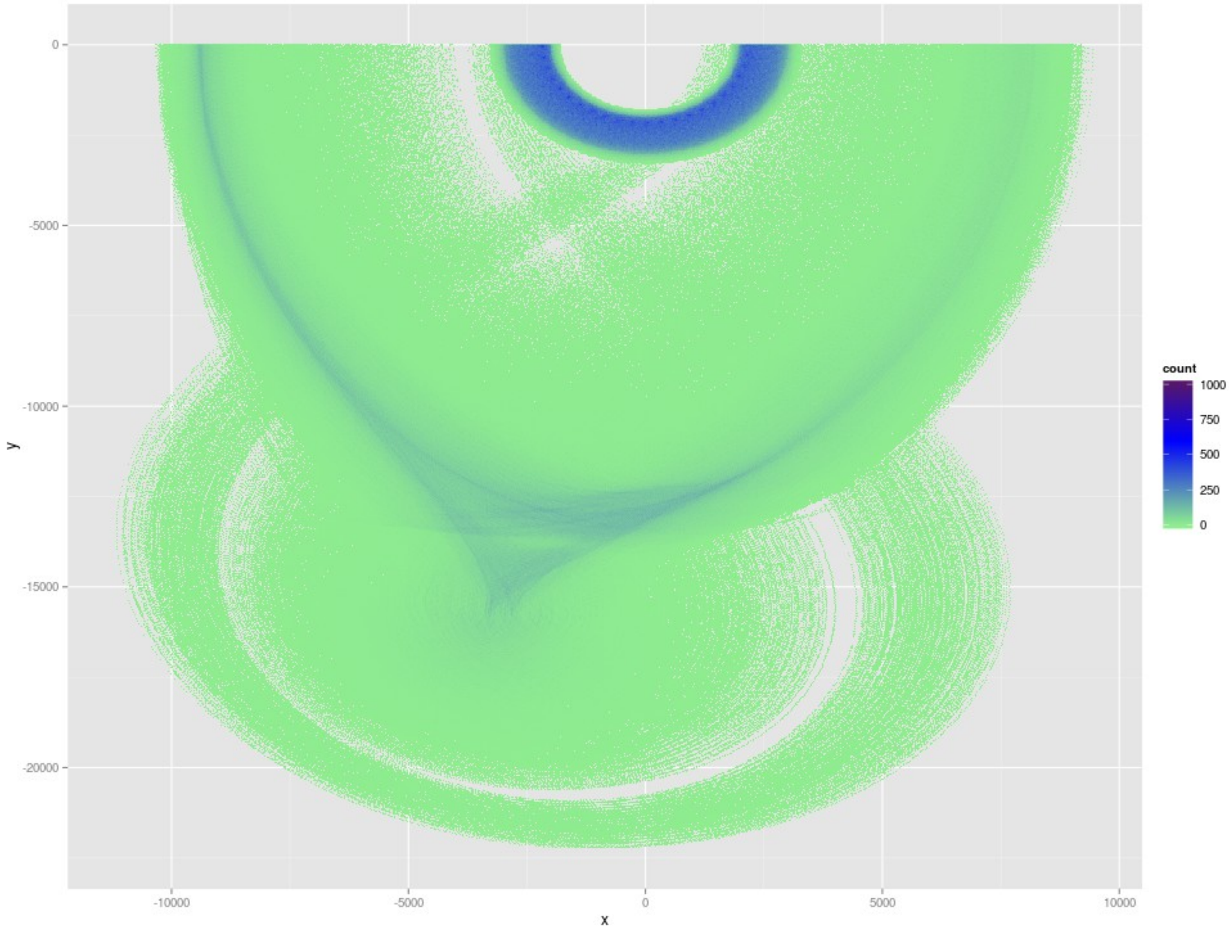


Figure 5. Density of trajectories. The regions in red correspond to locations where the probability of finding particles is higher. This plot shows half of the physical space. The other half is symmetric, as a mirror.

5. ACKNOWLEDGEMENTS

The authors acknowledge the financial support of the state agencies FAPESP and CNPq.

6. REFERENCES

Murray, C.D.; Dermott, S.F., 1999. *Solar System Dynamics*. Cambridge University Press, London.

Giuliatti Winter, S.M.; Winter, O.C.; Fernandes Guimarães, A.H.; Silva, M.R., 2010. “Exploring S-type orbits in the Pluto-Charon binary system”, *Monthly Notices of the Royal Astronomical Society*, 404, 442-450.

Giuliatti Winter, S.M.; Winter, O.C.; Vieira Neto, E.; Sfair, R., 2013a. Stable regions around Pluto, *Monthly Notices of the Royal Astronomical Society* , 430, 1892-1900.

Giuliatti Winter, S.M.; Winter, O.C.; Vieira Neto, E.; Sfair, R., 2013b. A peculiar stable region around Pluto, *Monthly Notices of the Royal Astronomical Society* (submitted).

7. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.