EPSC Abstracts
Vol. 6, EPSC-DPS2011-485, 2011
EPSC-DPS Joint Meeting 2011

Orbital evolution of the main Uranian satellites

E. Verheylewegen (1) and B. Noyelles (1,2)
(1) NAmur Center for Complex SYStems (NAXYS), FUNDP-The University of Namur, Belgium
(2) IMCCE-Paris Observatory, France
(emilie.verheylewegen@fundp.ac.be, benoit.noyelles@fundp.ac.be / Fax:+32-81-724914)

Abstract

Since Voyager 2 space mission, we know some properties of the main Uranian satellites (Miranda, Ariel, Umbriel, Titania, Oberon): on the one hand, we observe an important resurfacing of both Miranda and Ariel, and on the other hand some strangenesses in the orbital elements such as the anomalously high inclinaison of Miranda or the anomalously high eccentricity of Ariel. The aim of this study is to use some modern methods including advances in computing resources to revise some studies developed in the last 20 years (see for instance [1], [2], [3], [4]). We therefore consider a model of a n-body problem which takes into account of the mutual perturbations of the five main satellites and of the planet Uranus and meet/improve some previous results.

1. Introduction

As already known, the combination of the observations of some satellite resurfacings and some abnormalities in orbital elements of these satellites are a sign of a resonant configuration between some satellites in the past of the Uranian system. The resurfacings of the satellites are the consequence of a deep energy dissipation. Considered tidal evolution can lead to a resonant configuration because it is the principal source of energy dissipation which can have some geophysical (resurfacing) and dynamical consequences. In a dynamical point of view, the energy dissipation via tidal effects leads to a variation of the semi-major axis and a migration of the satellite in the system. This migration leads to the meetings of resonance zones or chaotic zones.

In the case of the Uranian satellites, the resonance configurations are mean-motion commensurabilities and some of them have already been studied by considering the gravitational interactions by pairs. We can mention in particular the 3:1 commensurability between Miranda and Umbriel suspected to be the origin of the high inclinaison of Miranda or the 5:3 between Miranda and Ariel which can explain the curent eccentricity of Ariel

2. Tidal effects

Tidal effects are the consequence of a gravitational force applied to a system of non-ponctual bodies. The result of this effect is a distorsion of the bodies in ellipsoidal forms and a deep energy dissipation. The consequence on orbital motions is variations on semi-major axes and on eccentricities of the satellites. To modelise these variations, we use the Kaula's formulations (see for instance [5]) :

$$\frac{da_i}{dt} = 3\,\frac{k_2^p n_i m_i R_p^5}{Q_p a_i^4 m_p}\left(1+\frac{51}{4}e_i^2\right) - 21\,\frac{k_2^i n_i m_p R_i^5}{Q_i m_i a_i^4}e_i^2$$

$$\frac{de_i}{dt} = \frac{57}{8}\,\frac{k_2^p n_i m_i}{Q_p m_p}\left(\frac{R_p}{a_i}\right)^5 e_i - \frac{21}{2}\,\frac{k_2^i n_i m_p}{Q_i m_i}\left(\frac{R_i}{a_i}\right)^5 e_i$$

with i, the number of the satellite and p the index for the planet. The variables R is the radius of the body, n the mean motion and m the mass. We observe that these formulations depend on the Love number k_2 and on the dissipation function Q.

3. Numerical simulations

We add the tidal effects on semi-major axes and on eccentricities to the n-body equations of motion and integrate the problem with an Adams-Bashforth-Moulton 10^{th} order predictor-corrector algorithm over 1000 kyr. We have made many simulations depending on the parameter $\left(\frac{k_2}{Q}\right)$ for the planet and the satellites. We obtain the 3:1 mean-motion resonance between Miranda and Umbriel by considering a system with 6 bodies (Uranus+5 satellites): we recognize the resonance in inclination i_M^2 (see Fig. 1) for Miranda wich leads in some case to the rise of the inclination to 4° (see Fig. 2).

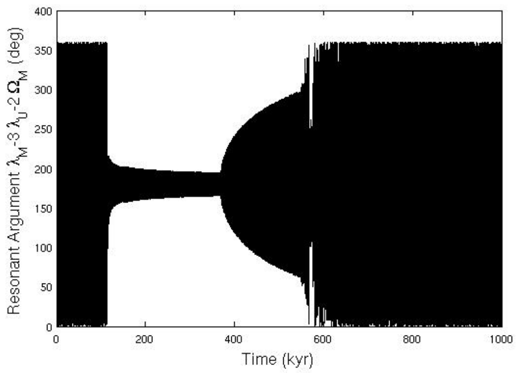

Figure 1: Resonant argument : $\lambda_M - 3\lambda_U + 2\Omega_M$.

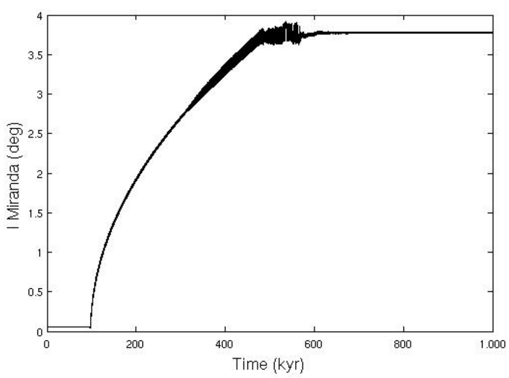

Figure 2: Evolution of Miranda's inclination i_M vs time.

We also observe the break of this resonance by another mean-motion resonance: the 5:3 Ariel-Umbriel whose consequence is a jump in the eccentricity of Ariel.

4. Conclusions

Our first results on orbital evolution of the main Uranian satellites are promising. We meet some previous results and we can improve them with modern methods. We are convinced that a better comprehension of the orbital evolution of the main Uranian satellites can lead to a better knowledge of the dynamics of the inner satellites, which could be helpful.

Acknowledgements

This research used resources of the Interuniversity Scientific Computing Facility located at the University of Namur, Belgium, which is supported by the F.R.S.-FNRS under convention No. 2.4617.07 and also local computing resources (Cluster URBM-SYSDYN) at the University of Namur. E. Verheylewegen is F.R.S-FNRS doctoral research fellow and B. Noyelles is F.R.S-FNRS post-doctoral research fellow.

References

[1] Moons, M. and Henrard, J.: Surfaces of section in the Miranda-Umbriel 3:1 inclination problem, Celestial Mechanics and Dynamical Astronomy 59, pp. 129-148, 1994.

[2] Dermott, S., Malhotra, R. and Murray C.: Dynamics of the Uranian and Saturnian Satellite Systems: A Chaotic Route to Melting Miranda?, Icarus 76, pp. 295-334, 1988.

[3] Tittemore, W.C. and Wisdom, J.: Tidal Evolution of the Uranian Satellites. I. Passage of Ariel and Umbriel through the 5:3 Mean Motion Commensurability, Icarus 74, pp. 172-230, 1988.

[4] Tittemore, W.C. and Wisdom, J.: Tidal Evolution of the Uranian Satellites. II. An Explanation of the Anomalously High Orbital Inclinaison of Miranda, Icarus 78, pp. 63-89, 1989.

[5] Yoder, C.F. and Peale S.J.: The tides of Io, Icarus 47, pp. 1-35, 1981.