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Resonant Dynamics of Anthe

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Abstract

In this work, the short-term, resonant and long-term dynamics of Anthe (S/2007 S4) [1], is investigated with the most recent published ephemeris of the Saturnian system constructed in the *Cassini*'s spacecraft era [2]. We identify and explain many components in the time variations of the elements of Anthe as being caused by the joined effects of the corotation resonance, the long-term precessions of the orbit due to the effects of the oblateness of Saturn (J_2), and the short-term fluctuations also due to J_2 perturbations. Our analyses are performed using both, the osculating orbits and the transformed geometric elements. Firstly, it is shown that the *current resonant state* of the pair Mimas-Anthe is characterized *uniquely* by the stable libration of the angle $\phi_1 \equiv 11\lambda_A - 10\lambda_M - \varpi_M$ around zero, where A, M, λ, ϖ refer to Anthe, Mimas, mean longitude and longitude of the pericenter, respectively. The component ϕ_1 is identified in the time variations of the orbital elements and in the other arguments of the disturbing function. In particular, we show that the libration of the angle $\phi_{10} \equiv 11\lambda_A - 10\lambda_M - \varpi_A - \Omega_A + \Omega_M$ only occurs with when the geometric elements are computed and for relatively short time intervals, $< 80,000$ day approximately; after that it circulates in prograde sense. The episodic libration of ϕ_{10} is therefore a direct manifestation of the corotation resonance, and not implies in a physical simultaneous libration of two critical angles. In a short-term time scale, the ephemeris of Anthe [2] shows a short-term circulation of the *osculating* argument of pericenter, ω_A, with period of the order of one day. We give numerical evidences that the J_2 perturbations are the cause of the fast component of ω_A, which only occurs for very small initial osculating eccentricity (e_0), as is the case of Anthe ($e_A < 0.0044$). These variations are negligible when the *geometric* ω_A is computed, since the geometric elements just attenuate the amplitude of the perturbations of J_2. These results lead us to discuss the relevance of the often calculation of the geometric orbits for small satellites of Saturn like Anthe, and also to propose a review of the osculating orbit of the satellite.

In the second part of this work, we accurately determine the main structures of the 11:10 Mimas-Anthe resonance in the eccentricity versus semi-major axis (a_A, e_A) phase space. The resonance mapping has been constructed in the frequency domain of numerical integrated osculating orbits with initial conditions taken in dense grids around the current orbit of Anthe. The thin domain of the current corotation resonance is determined in the (a_A, e_A) plane, and the orbit of Anthe is located deeply inside the stable regions of corotation zone, in good agreement with the analyses of the first part of this work.

The domains of the Lindblad resonance, defined by the regions of the phase space where the critical argument $\phi_2 \equiv 11\lambda_A - 10\lambda_M - \varpi_A$ oscillates about π, are also mapped. The limits of the Lindblad zone are well separated from the corotation zone by chaotic layers. In the Lindblad zone of resonance, the eccentricity of test satellites are always larger than the eccentricity of Mimas, and since ϕ_2 stably librates around π, the resonance protects the particles and Mimas of potential close approaches in the case of crossing orbits.

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References

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[2] https://ssd.jpl.nasa.gov/horizons.cgi