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ROTATIONAL BEHAVIOR OF COMET NUCLEI UNDER GRAVITATIONAL PERTURBATIONS

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Abstract. A dynamical qualitative study of the rotational motion for cometary-type bodies submitted to gravitational perturbations has been performed by numerical simulations, including the Sun and Jupiter's disturbing torques in the model. Results show small gravitational disturbing effects from the Sun on Halley-type orbits, as well as from Jupiter on most close-approach configurations. Only a *very* close-approach induces notable effects, presenting then some interesting sensitivity to initial conditions.

INTRODUCTION

Nucleus rotation is assumed to greatly influence solar exposure and thus gas ejection, or more generally non-gravitational forces. Some preliminary works investigating gravitational effects on the rotational motion of cometary-type bodies are required to figure out the basic mechanisms. They are developed in Bois *et al.* (1991), including solar and jovian gravitational disturbing torques in the numerical simulations.

Two different angular sequences are used to locate a body-fixed rotating frame (O, x, y, z) relative to a fixed reference frame (O, X, Y, Z), both with the origin at the center of mass: 3-1-3, and 1-2-3. Numbers 1, 2, and 3 refer respectively to the axes x or X, y or Y, z or Z. Shifting rules can be found in Bois (1986). The two sequences are of different types, and the singularities occur for different configurations. However, after the integration has been carried out, the motion is only described in the classical 3-1-3 sequence (precession ψ, nutation θ, *proper* rotation φ), making it easier to interpret the results. Throughout the paper, the comet nucleus is modeled by an ellipsoid, its three axes of inertia being chosen with the following order: $a > b > c$. The rotation of greatest energy is applied around c. For every figure, the angle φ is plotted without its mean rotation.

SOLAR GRAVITATIONAL PERTURBATION

In the following, the solar gravitational torque acts on an assymmetric comet nucleus. Tests are performed for the following initial orientation: $\psi = 0, \theta = 60, \varphi = 0$ deg, with only one initial period: $P_\varphi = 2.2$ days. The shape is given by: $a = 10$, $b = 5$, and $c = 1$ km, and the orbit is Halley's one. The curves present the differences between non-perturbed and perturbed cases, plotted at perihelion, with identical initial conditions. Figure 1 shows the variations of the angular momentum. Librations shown on figure 2 are then due to the solar disturbing action. They are of order several hundreds of arc seconds on this 20-day simulation. The solar gravitational perturbation changes a little bit the rotational pattern at each perihelion passage. Its action remains to be compared with non-gravitational effects (Peale and Lissauer, 1989).

JOVIAN CLOSE-APPROACH

The comet is moving on an inner orbit in Jupiter's mean plane. Comet parameters are chosen in such a way that the close encounter occur near the aphelion of both the comet and Jupiter, for different minimum distances between the two bodies. The eccentricity is Halley's one.
For an encounter distance of 1 AU, Jupiter's influence is almost negligible. When the encounter occurs for 0.1 AU, only small effects can be detected on the rotational motion, in contrast to the great changes on the orbital motion.
When the encounter distance is planned to occur at 0.01 AU, the comet is ejected from an almost

keplerian orbit two days before the anticipated aphelion. The osculating semi-major axis and eccentricity undergo a brief but strong impulse before decreasing. Their initial values were 2.77 AU and 0.965. For the last three figures, angular initial values are: $\psi = 0, \theta = 60, \varphi = 0$ deg, and initial periods are: $P_\psi = 7.4$, $P_\varphi = 2.2$ days. Because the close-approach happens far from the Sun, the angular momentum is almost constant until 2 or 3 days before the encounter (fig. 3). After the encounter, an almost constant pattern returns, and libration amplitudes for the angles have strongly increased (fig. 4). Figure 5 shows the pulse shape of Jupiter's torque. The motion is greatly sensitive to particular sets of initial conditions, then depending on the particular comet orientation at the encounter moment. With almost identical initial conditions, the global behavior can be opposite to the previous one, with largely decreased libration amplitudes.

CONCLUSION

Physical librations due to gravitational solar perturbations have small amplitudes relative to simple oscillations obtained without perturbations. A close-approach with Jupiter leads to a limited change on the rotational motion compared to the orbital one. However, the motion is greatly sensitive to particular sets of initial conditions. This could be a hint for a possible zone of non-predictible motions in the phase space. This preliminary but necessary study of gravitational effects on a rotational pattern has to be extended by modeling non-gravitational forces, investigating that way other possible motions in the Sun's vicinity.

References

Bois, E. (1986) First-order theory of satellite attitude motion - Application to Hipparcos. Celestial Mech., 39, 309-327.

Bois, E., Oberti, P., Frœschlé, C. (1991) Gravitational Model of Comet Nucleus Rotation. Celestial Mech., submitted.

Peale, S.J., Lissauer, J.J. (1989) Rotation of Halley's comet. Icarus, 79, 396-430.

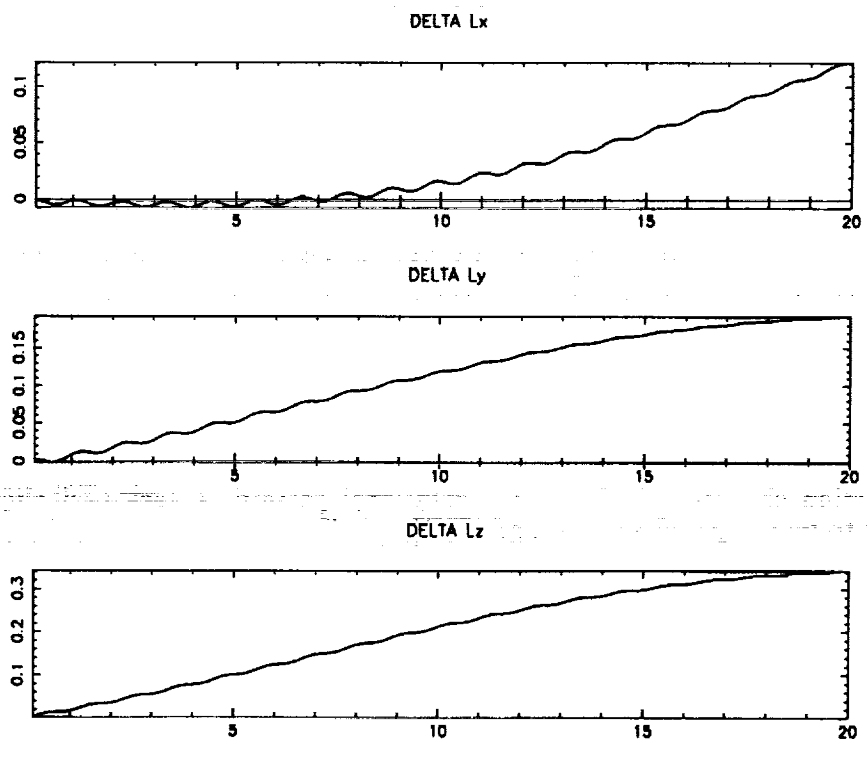

Fig. 1. Solar perturbation on the angular momentum

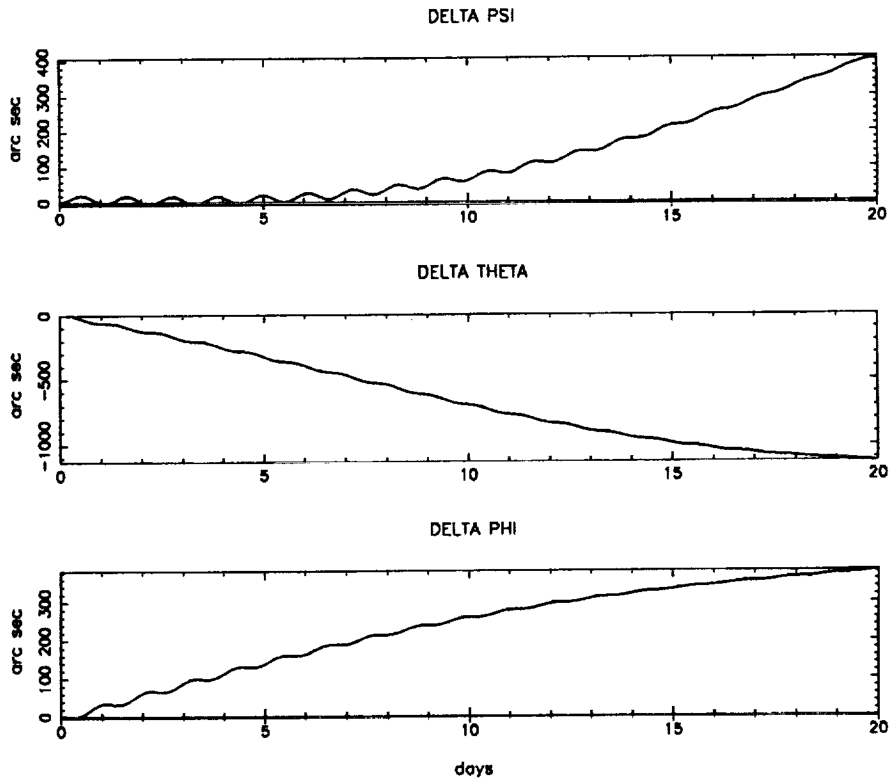

Fig. 2. Physical librations due to solar torque

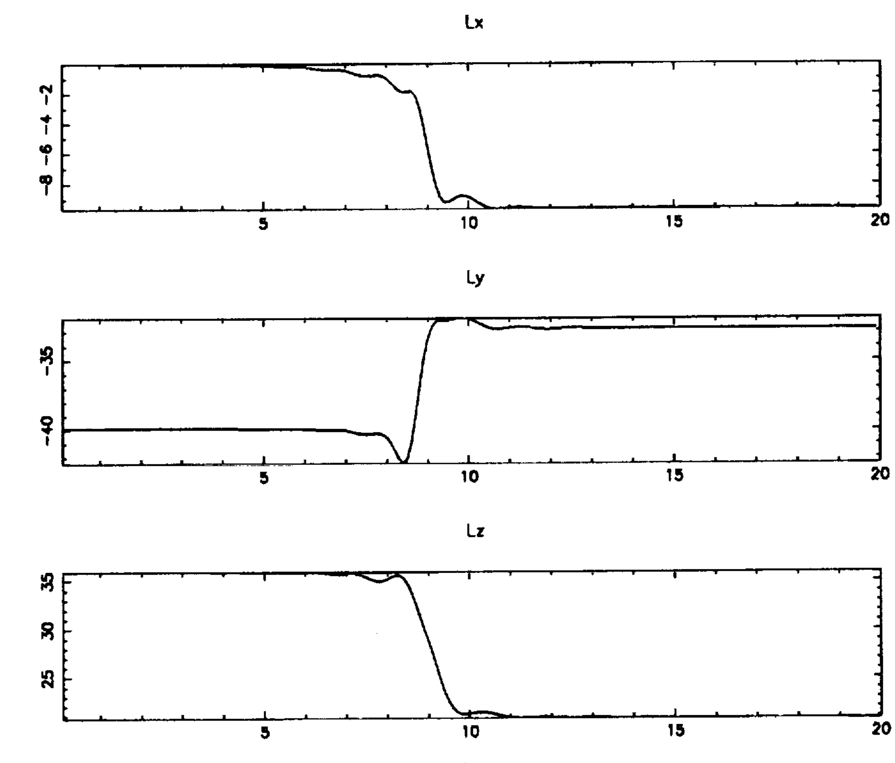

Fig. 3. Jovian perturbation on the angular momentum

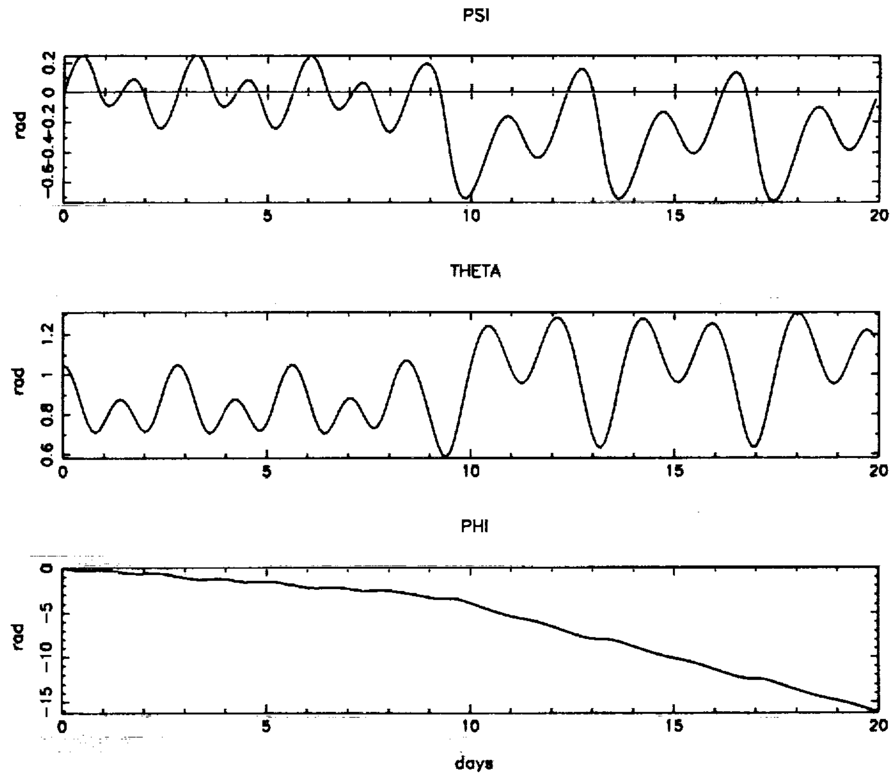

Fig. 4. Jovian close-approach effect

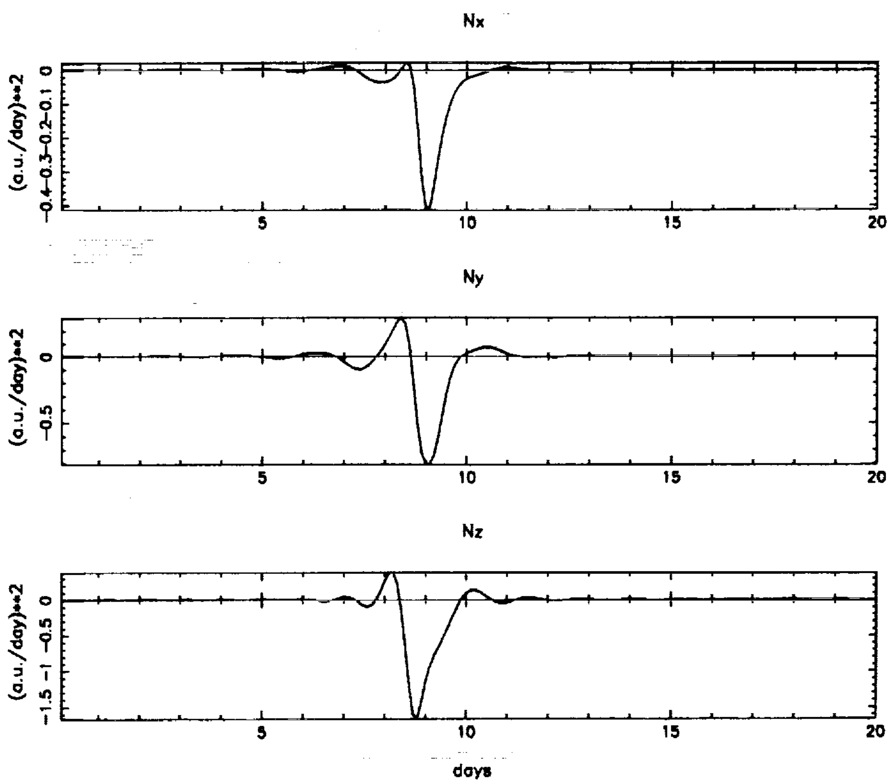

Fig. 5. Pulse shape of jovian torque