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Cyclic Tilt Spin Vector Variations of Main Belt Asteroids due to the Solar Gyro-Gravitation.

described by using
the Maxwell Analogy for gravitation.

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Abstract

In the paper "*The Gyro-Gravitational Spin Vector Torque Dynamics of Main Belt Asteroids in relationship with their Tilt and their Orbital Inclination*" I found the excellent compliance between the observations and the extrapolations of E. Skoglöv and A. Erikson, 2002, and the theoretical deductions according the Maxwell Analogy for Gravitation. This implies namely the existence of the second gravitational field : Gyrotation (Co-gravitation). Six of the seven observations are directly explained by the theory. The seventh observation : "there is a significant majority of asteroids with a prograde spin vector compared to retrograde ones" is explainable by supposing that the asteroids are created, like most of the planets are, prograde. The theory found that the asteroids' spins are expected to end-up as retrograde. Two factors play a role : the speed of change of tilt due to gyrotation, and the other influences like the perturbations by Jupiter and Saturn or the gravitational librations. Here, mainly the gyrotation part is studied analytically and graphically, and commented.

Keywords: Main Belt Asteroids – gravitation – gyrotation – prograde – retrograde – orbit – precession – nutation.
Method: Analytical.

1. Introduction.

This paper is an extension of "*The Gyro-Gravitational Spin Vector Torque Dynamics of Main Belt Asteroids in relationship with their Tilt and their Orbital Inclination*" wherein the following observations could be confirmed theoretically.

- the spin oscillations' amplitude increases with increasing orbital inclination of the asteroid.
- the largest spin oscillations' amplitudes are found if the initial spin vector lays in the orbital plane.
- the spin obliquity differences are generally insensitive to the shape, composition and spin rate of the asteroids.
- the spin vectors of prograde asteroids are more chaotic than the spin vectors of retrograde asteroids.
- there are very few asteroids having a spin vector that lays in the vicinity of the orbital plane.
- the heliocentric distance is relevant for the spin vector behaviour.
- there is a significant majority of asteroids with a prograde spin vector compared to retrograde ones.

The last observation however is only valid, according the theory, if at the origin, the asteroids were created with a prograde spin, like the majority of the planets. In "*Are Venus' and Uranus' tilt of natural origin?* " and in "*The Titius-Bode law shows a modified proto- gas-planets' sequence.*" are explained how the planets are probably created from a solar eruption.

If the asteroids' spins are really created prograde, and if a number of asteroids might have changed polarity of spin by collisions, there might also be some of them that just obey the theory, wherein is found that the tilt changes from prograde to retrograde continuously du to the gyrotation force that works on it.

In this paper, we look for the interpretation of the quantitative results of the former paper: "*The Gyro-Gravitational Spin Vector Torque Dynamics of Main Belt Asteroids in relationship with their Tilt and their Orbital Inclination*".

Especially, we look for the net velocity of the asteroid's tilt change due to the solar gyrotation, for prograde and for retrograde orbits.

2. The tilt change and its interpretation.

2.1 The equations.

In the former paper, I have found the velocity with which the tilt of the asteroid will change. This is given by the equation (B.6) of that paper.

$$\dot{\theta} = \omega_0 \frac{\mathrm{d}\theta}{\mathrm{d}\alpha} \approx \omega_0 \frac{\left(2I_0 - I\right)^2}{I_0 I^2 \omega_1^2} \frac{\mathrm{d}\mathcal{T}_{xy}}{\mathrm{d}\alpha} \tag{2.1}$$

wherein

- $\dot{\theta}$ is the time-derivate of the angle θ , which is the deviation of the tilt spin vector;
- we define a cylinder-symmetric asteroid with the inertia moments : $I_0 = I_x = I_y$ and $I = I_1 = I_z$; whereby the Z axis is the spin axis;
- the spinning velocity is ω_1 and the orbital velocity ω_0 ;
- $\mathcal{T}_{xy} \equiv \sqrt{\mathcal{T}_x^2 + \mathcal{T}_y^2}$ is the effective torque on the asteroid;
- α is the position angle of the asteroid in the orbital path (see fig. 2.1);

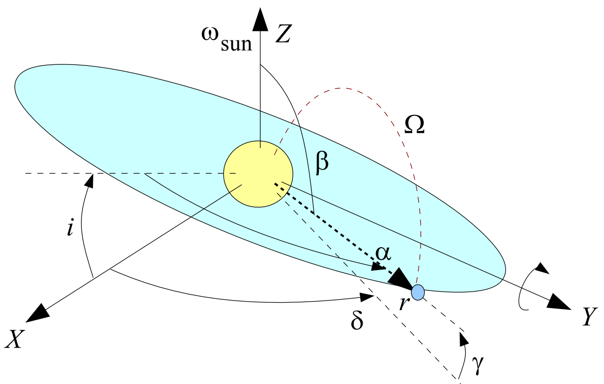

Fig. 2.1 : Definition of the angles α and i . The orbital plane is defined by the orbital inclination i in relation to the axis X . The location of the asteroid inside the orbit is defined by the angle α . The equipotential line of the gyrotation $\boldsymbol{\Omega}$ through the asteroid has been shown as well.

The torque $\mathcal{T}$ is given by $\mathcal{T}_{xy} \equiv \sqrt{\mathcal{T}_x^2 + \mathcal{T}_y^2}$ the equation (B.7) in the former paper: (2.2)

"*The Gyro-Gravitational Spin Vector Torque Dynamics of Main Belt Asteroids in relationship with their Tilt and their Orbital Inclination*"

wherein :

$$\mathcal{T}_x = \frac{G\,m\,R^2\,\omega\,I_1\,\omega_1}{5\,r^3\,c^2}\left(\left(1 - \frac{3}{4}\sin^2 2\alpha\right)\sin\eta - \frac{3}{2}\,\sin 2\alpha\,\sin i\,\cos\eta\right) \tag{2.3}$$

and :

$$\mathcal{T}_y = -\frac{3\,G\,m\,R^2\,\omega\,I_1\,\omega_1}{10\,r^3\,c^2}\cos^2\alpha\,\sin 2i \tag{2.4}$$

In these equations, we have called $\omega_{\text{sun}} = \omega$. The derivate to α is given by the equations (B.8) , (B.9) and (B.10) of the former paper.

Working out (2.1) will need us to find the result of $\frac{\mathrm{d}\mathcal{T}_{xy}}{\mathrm{d}\alpha}=\frac{\mathcal{T}_x\frac{\mathrm{d}\mathcal{T}_x}{\mathrm{d}\alpha}+\mathcal{T}_y\frac{\mathrm{d}\mathcal{T}_y}{\mathrm{d}\alpha}}{\sqrt{\mathcal{T}_x^2+\mathcal{T}_y^2}}$. (2.5)

The derivatives are :

$$\frac{\mathrm{d}\mathcal{T}_x}{\mathrm{d}\alpha}=\frac{3\,G\,m\,R^2\,\omega\,I_1\,\omega_1}{5\,r^3\,c^2}\cos 2\alpha\left(\sin 2\alpha\sin\eta-\sin i\cos\eta\right) \tag{2.6}$$

And

$$\frac{\mathrm{d}\mathcal{T}_y}{\mathrm{d}\alpha}=\frac{3\,G\,m\,R^2\,\omega\,I_1\,\omega_1}{10\,r^3\,c^2}\sin 2\alpha\sin 2i \tag{2.7}$$

Partially, the value of $\dot{\theta}$ will vary cyclically with the orbital cycle, but it will also progress steadily until θ reaches π, as found in the former paper *"Analytic Description of Cosmic Phenomena Using the Heaviside Field"*.

2.2 The special case of $\alpha=\pi/2$.

But, what is much more interesting is that for $\alpha=\pi/2$ the value of $\dot{\theta}$ in (2.1) becomes strongly dependent from ($\cos\eta$).

$$\left.\frac{\mathrm{d}\mathcal{T}_{xy}}{\mathrm{d}\alpha}\right|_{\alpha=\pi/2}=\frac{3\,G\,m\,R^2\,\omega\,I_1\,\omega_1}{5\,r^3\,c^2}\sin i\cos\eta \tag{2.8}$$

$$\left.\dot{\theta}\right|_{\alpha=\pi/2}=\frac{3\,G\,m\,R^2\,\omega}{5\,r^3\,c^2}\frac{\left(2\,I_0-I_1\right)^2\omega_0}{I_0\,I_1\,\omega_1}\sin i\cos\eta \tag{2.9}$$

This equation suggest that there is a velocity shock at that place : the smaller η, the larger $\dot{\theta}$ when the asteroid crosses the sun's equator. When $\eta=\pi/2$, $\dot{\theta}$ falls to zero at the place where $\alpha=\pi/2$ (orbit nodes).

2.3 The special case of $\alpha=0$.

This case of course happen only once during each orbital cycle.

$$\left.\frac{\mathrm{d}\mathcal{T}_{xy}}{\mathrm{d}\alpha}\right|_{\alpha=0}=-\frac{3\,G\,m\,R^2\,\omega\,I_1\,\omega_1}{5\,r^3\,c^2}\sin i\cos\eta \tag{2.10}$$

and

$$\left.\dot{\theta}\right|_{\alpha=0}=-\frac{3\,G\,m\,R^2\,\omega}{5\,r^3\,c^2}\frac{\left(2\,I_0-I_1\right)^2\omega_0}{I_0\,I_1\,\omega_1}\sin i\cos\eta \tag{2.11}$$

Also here, the smaller η, the larger $\dot{\theta}$.

2.4 The special cases of $\eta=0$ and $\eta=\pi$.

For analysing these cases, I prefer plotting the results for $0<i<\pi$ and for $0<\alpha<2\pi$. The result contains only the trigonometric factors, not the gravitational nor the shape-related nor the motion-related constants of the equations.

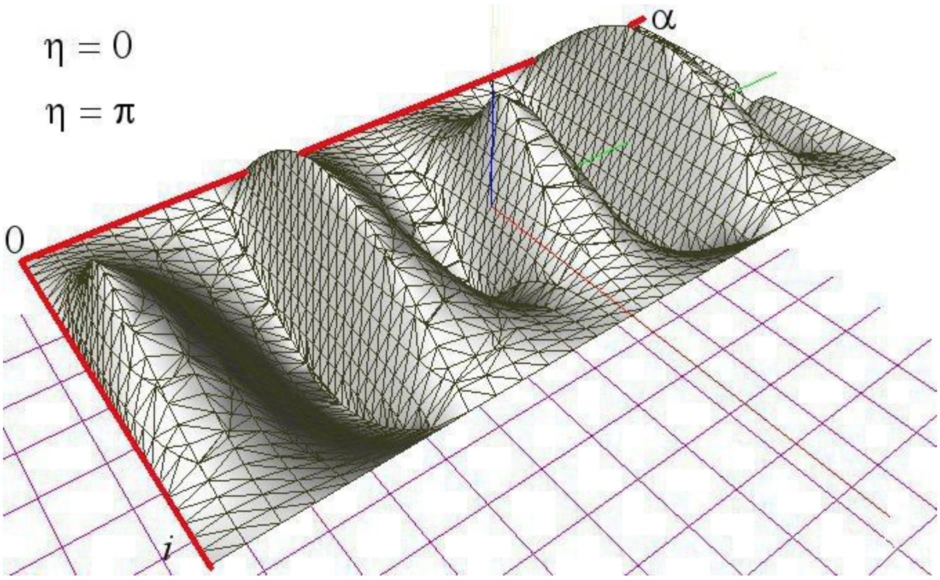

Fig. 2.1: Indicative values of the tilt change $\dot{\theta}$ at $\eta = 0$ and $\eta = \pi$. The thick red line shows $i = 0$ and $\alpha = 0$. The graph is plotted for $0 < \alpha < 2\pi$ and $0 < i < \pi$.

A strong positive velocity shock occurs when α is just over $\pi/2$ and 3 $\pi/2$. A weaker positive velocity shock occurs just over $\alpha = 0$ and $\alpha = \pi$. A strong negative velocity shock occurs when α is just before $\pi/2$ and 3 $\pi/2$. A weaker negative velocity shock occurs just before $\alpha = 0$ and $\alpha = \pi$. The strongest velocity shocks occur at $i = \pi/2$.
This result is important to understand some chaotic motions of spin vectors in general, for planets as well.

2.5 The special cases for other values of η.

Below are plotted several cases of tilts. The thick red line shows $i = 0$ and $\alpha = 0$. The graphs are plotted for $0 < \alpha < 2\pi$ and $0 < i < \pi$.

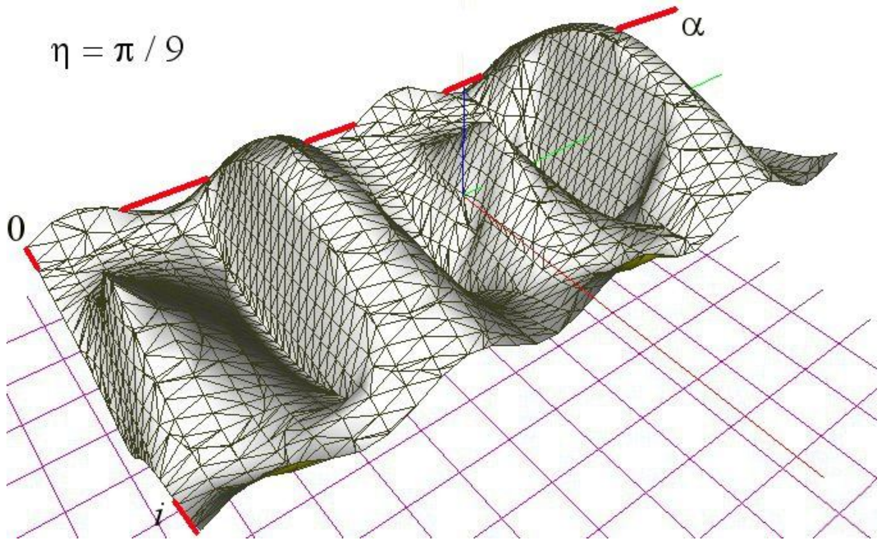

Fig. 2.2: Indicative values of the tilt change $\dot{\theta}$ at $\eta = \pi/9$.

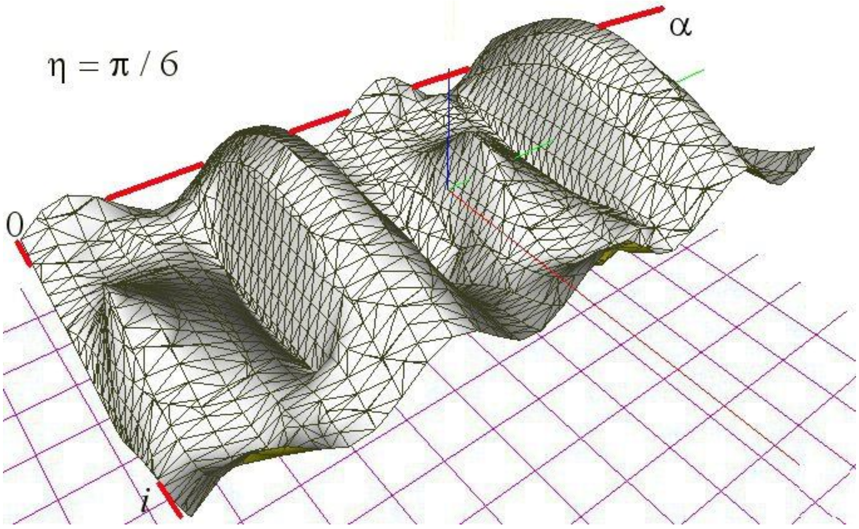

Fig. 2.3: Indicative values of the tilt change $\dot{\theta}$ at $\eta = \pi/6$.

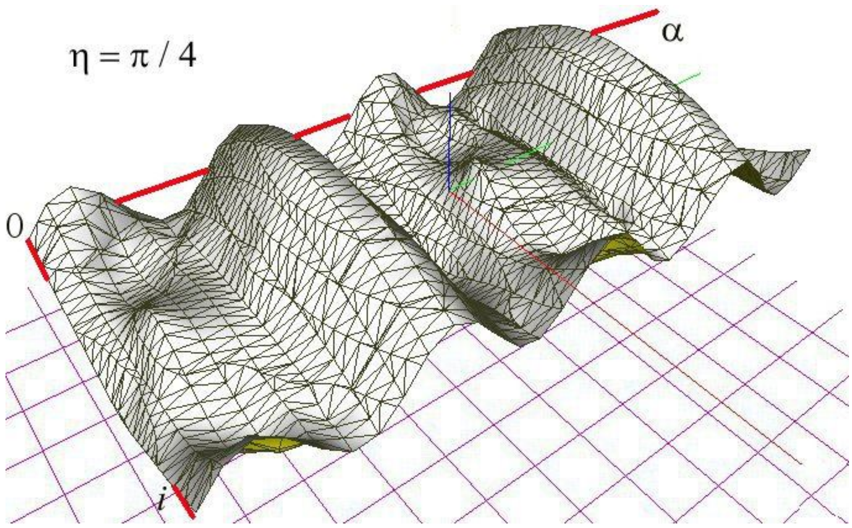

Fig. 2.4: Indicative values of the tilt change $\dot{\theta}$ at $\eta = \pi/4$.

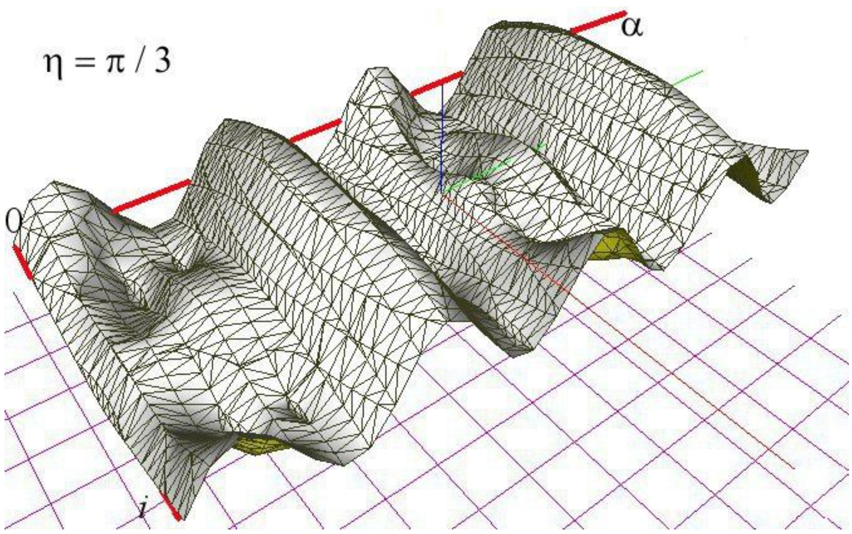

Fig. 2.5: Indicative values of the tilt change $\dot{\theta}$ at $\eta = \pi/3$.

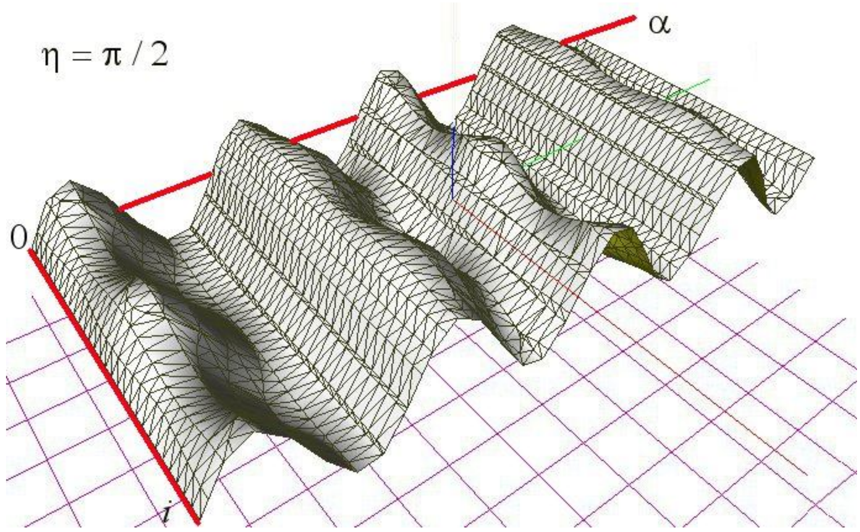

Fig. 2.6: Indicative values of the tilt change $\dot{\theta}$ at $\eta = \pi/2$.

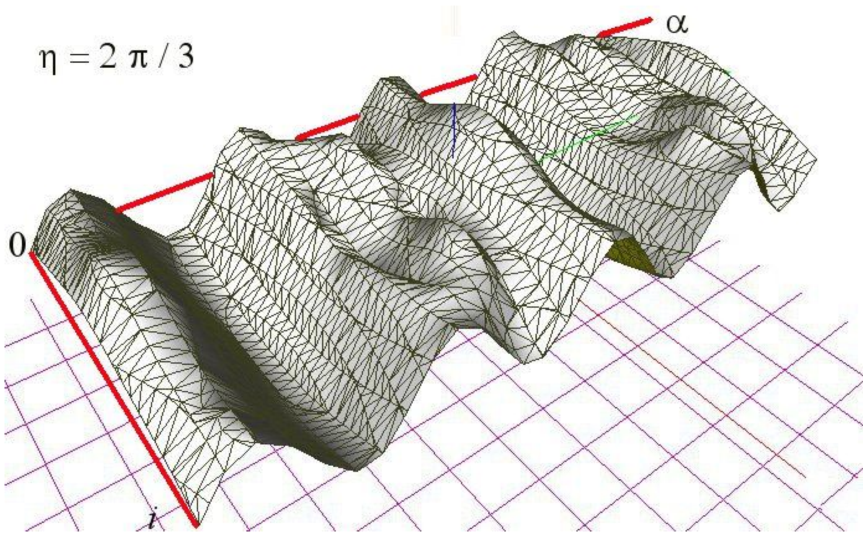

Fig. 2.7: Indicative values of the tilt change $\dot{\theta}$ at $\eta = 2\pi/3$ (η = -$\pi/3$).

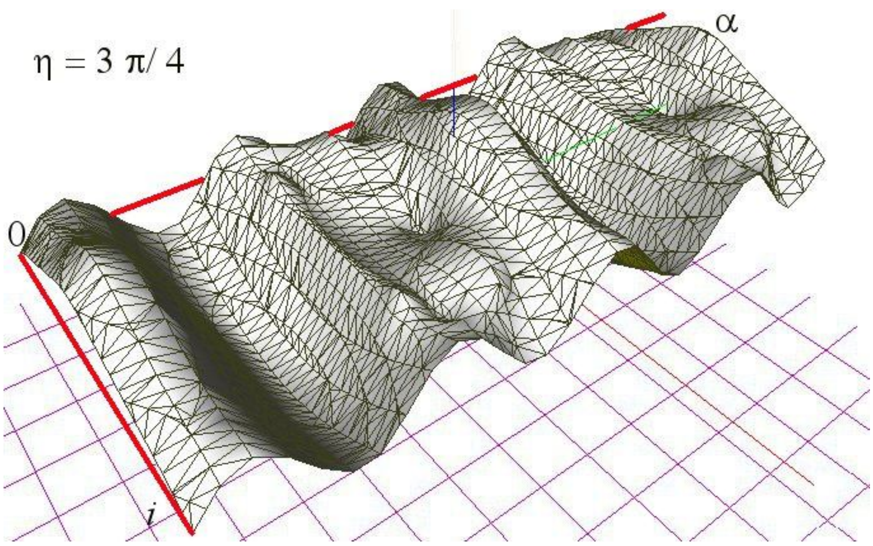

Fig. 2.8: Indicative values of the tilt change at $\eta = 3\pi/4$ (η = -$\pi/4$).

Here, the velocity variations are smaller and less precise than in the case of small values of η. Remark how different this graph is from the one of $\eta = \pi/4$.

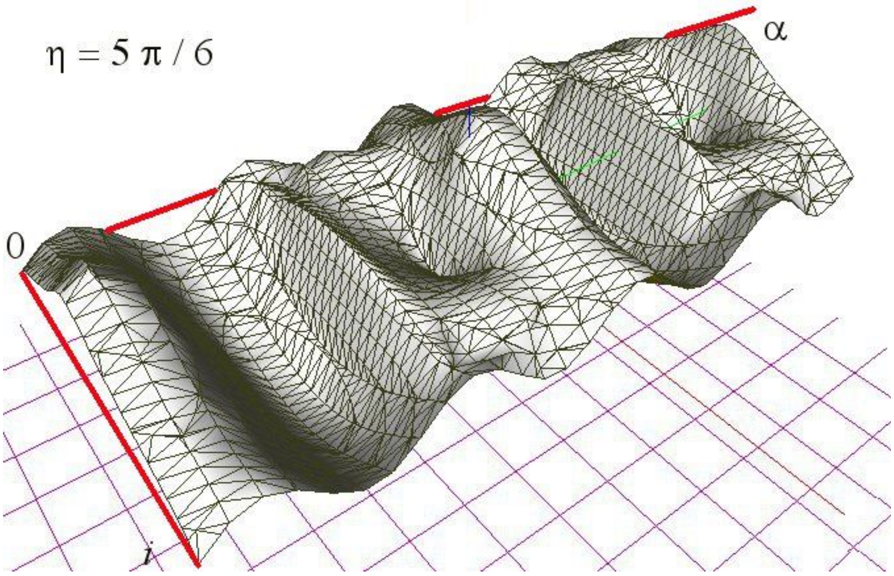

Fig. 2.9: Indicative values of the tilt change $\dot{\theta}$ at $\eta = 5\pi/6$ ($\eta = -\pi/6$).

3. Discussion and conclusions.

The velocity of the nutation is indicative for the small motions and even for chaos of the spin vector of some asteroids. There is no tilt position where no tilt velocity effect would occur. Even for orbits with a zero inclination, the tilt velocity effect occurs four times per orbit cycle.
For $\eta = \pi/2$, the tilt velocity variations are almost identical for any orbit inclination, and their magnitudes are not much lower than the maxima of, say, the tilt velocity variations for $\eta = 0$.
For a spin vector that is directed prograde and parallel to the Sun's spin vector, or opposite to it, retrograde, there is a sudden jump of the velocity for every quarter of its orbit.
From a former paper we know that the prograde tilt is labile and the retrograde tilt is stable. We know also that, for all tilts, there is a tendency to move the tilt towards the tilt position of π, in order to have an alignment of the tilt with the local gyrotation vector. See my paper: *"Analytic Description of Cosmic Phenomena Using the Heaviside Field"*.

The shape of the tilt variations becomes sharper when the tilt vector becomes prograde $\eta = 0$ or retrograde $\eta = \pi$ and the maximal values increase significantly. The maxima are again obtained at the orbital position where the asteroid passes the Sun's equator.
The same effects of sudden tilt orientation changes should occur with artificial satellites that orbit about the Earth, and should be very noticeable.

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