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Paper Title: **FROM THE PRECESSION OF THE EQUINOXES TO THE GYROSCOPE DYNAMICS: A PATH THROUGH HISTORY**

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Abstract: In the works that inaugurated the research on student's alternative conceptions (VIENNOT, 77 and SALTIEL, 78) we have already found similarities and differences between these ideas and some from the conceptions of ancient scientists.

Researches developped by the Brasilian Physics Teaching Group at the Federal Fluminense University (UFF), have taken into account different aspects of History in order to understand the way of the students' thinking. The opposite, concerning to the students, has been used too: from their conception to understand the History of Science. To go through these two ways has been suggesting us some new educational strategies to cause the conceptual changing we have in mind.

In a previous work we have studied the students' conceptions about circular motion dynamics (QUEIROZ and KRAPAS-TEIXEIRA, 1991). Searching the History we have found a track coming from a centrifugal "endeavour to recede from the centre" to the centripetal force, too much similar to the same students' conceptions track.

Taking an analogous way, the present work, concerning to the rigid body dynamics teaching, begins in classroom and goes to History. The results from the research with college students' conceptions about the dynamics of the gyroscope are being presented in a parallel paper in this Seminar (KRAPAS-TEIXEIRA and QUEIROZ, 1993).

Our purpose now is to study the development of this subject in the History of Science, indicating similarities and differences between scientists' and students' conceptions.

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FROM THE PRECESSION OF THE EQUINOXES TO THE GYROSCOPE DYNAMICS: A PATH THROUGH HISTORY

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THE PRECESSION OF THE EQUINOXES

According to RADIX (1978) some properties of the tops were already known in China and Egypt since the Ancient Times. However, Foucault made his famous experience demonstrating the Earth rotation motion using a pendulum first and gyroscopes after, in 1852. The word gyroscope Foucault took from the Greek language and means "a method of viewing or demonstrating rotations".

The history of the gyroscope has its origin in the ancient human interest on astronomical phenomena. The vernal and autumnal equinoxes have been known by the men since the ancient times too. These were days when ambiental changings were festivally commemorated. They have been known by having day and nigth with the same lenght of time. Up today, in Christian countries, the Holy Week is scheduled on the first Full Moon after the vernal equinoxe (Nort Hemisphere) (roughly).

The precession of the equinoxes has been also well known since many centuries. Hiparco (II B.C) calculated as much as 36" the annual difference from one equinoxe to another subsequent. Today the value is 50", 26. The vernal equinoxe happened in Taurus constelation at Babilonic time and shifted place, going to Aries at Hiparco time. Later on it retroacted to Pisces constelation, even more.

According to TATON (1966) "probably when studying the Sun anual motion, Hiparco noted that the Sun used to take a litle more time to appear at the same point of the Zodiac (Sideral year: 365d 6h 10min 46s; exact value: 365d 6h 9 min 10s) than to find again the equator, from one spring to another (Solar year: 365d 5h 55 min 12s; exact value: 365d 5h

46s). He also explained correctly, that phenomenon is due to an annual displacement of the equinoxial points. However, having a geocentric point of view, in which the eclitic plan was supposed to be unchangeable, this displacement was considered as a slow motion of the fixed stars sphere around the axis of the eclitic, opposing to its daily motion. The vernal equinoxial point goes forward in the Zodiac" (our translation).

The word "precession" has its original meaning in this ancient knowledge: one equinoxe preceds another one yearly. Nowadays the current meaning of this word is: rotation motion of the main axis of a rigid body around another axis.

Ptolomeu and his islamic sucessors, as well Hiparco, explained the precession of the equinoxes by an extra motion of the celestial sphere (in addition to the motions in order to explain the days and the nights and another the seasons).

Coming with the changing in the the cosmological view of the Universe, introduced by Copernicus, the phenomenon of precession of the equinoxes became prominent once more.

From a heliocentric point of view and still making use of material orbits to bring the planets, Copernicus has conceived a third Earth motion, in order to explain the precession of the equinoxes. This motion, named by him declination, was "also an annual revolution but one towards the signs which precede (from Aries to Pisces), or westwards, i.e., turning back counter to the movement of the centre (COPERNICUS, 1543).

Copernicus with his new cosmological view apparently didn't introduce any great change in the explanation of the equinoxes, comparing to Ptolomeu. Nevertheless he brought the problem to a general discussion. He probably was pressioned by necessary astronomical reforms at his time. Kuhn says: "In the days of Copernicus a suitable measure of the precession was the main requirement to the most pressing problem of pratical astronomy: the reform of the Julian calendar". (KUHN, 1985)

Finally concluded in 1582 by the pope Gregorio XII, the new calendar reset the vernal equinoxe on March 11 st. It was supressed ten days from the present calendar at the reform year (october, 4 became october 15) (FREDRICK & BAKER, 1976).

Newton did the first calculus explaining the precession of the equinoxes. This fact, with the explanation of the irregular motion of the Moon and the theory of tides, besides many other practical problems, they have established an ensemble of knowledges that has brought a more consistence to the reception of the Newtonian paradigm.

In his Principia Newton said that the rotation of the Earth around its axis is responsible by its oblate shape. In his famous book he mentioned measures done by Jean Richer, in 1672. Richer had measured the period of a pendulum in two places: France and Venezuela. The difference he found was explained by a greater distance from the center of Earth in one of the places in relation to the other, according to Newtonian ideas (NEWTON 1683).

Another form to the Earth was still being supported by Descartes theories: elongated on the poles an flattened in the equator. The two forms, suggested by the first Newton and the other by Descartes cohabited the minds at the beginning of the XVIII century. A controversy between them extended until the Enlightement (HANKINS, 1985). Two expeditions were sent to take measures in order to end the controversy, one in 1735 and another in 1736. "The polar expedition completed this work relatively qickly, its members returning to Paris in 1737... Ten years elapsed before the equatorial expedition arrive back in Paris."(HANKINS, 1985). Then they could compare the results of these expeditions. The measures, taken one near the equator and another near the north pole, were in accord to Newton.

It is impressing how audacious was Newton, in trusting fifty years before, he stating the oblate form of the Earth made the calculus of the precession of the equinoxes. To do that, Newton divided the Earth in two parts: a spheric one and a salience. He considered them as bodies independently under the action of forces of gravitation due to the Sun an to the Moon. Besides he subdivided the Earth in small and similar particles. "Then, the force by which particle F recedes from the plane QR will (by supposition) be as that perpendicular FG; and this force multiplied by the distance CG will represent the power of the particle F to turn the earth round its centre" (Newton, Lemm 1, Proposition 38, Book III, Principia).

In the Proposition 39 Newton presented the calculus that led him to the final result of the yearly precession angle of 9" 7"' 20"" due to the force of the Sun and of 40" 52"' 52"" due to the force of the Moon, giving a total yearly precession of 50" 00"' 12"", asseverating that this value "agrees with the phenomena, for the precession of the equinoxes, by astronomical observations, is about 50" yearly." (NEWTON, 1683)

Despite of the exit of Newton in the calculus of the precession of the equinoxes, Truesdell (1968) says that there wasn't any general rigid body dynamics theory in Newton's book, from what one can extract the relation between the momenta of gravitational forces of the Sun and the Moon and the variation of the angular momentum of the Earth. This can be seen nowadays, for example, in classic mechanics didatic books (NUSSENZWEIG, 1989).

THE DYNAMICS OF RIGID BODIES

D'Alembert gave in 1749 a more rigorous explanation in his book "Les Recherches sur la precession des equinoxes et sur la nutation de l'axe de la terre", than Newton had given in the Principia. But, according to HANKINS (1985): "As usual Euler straightened out d'Alembert's tortuous mathematics, gave a much more elegant statement of the solution and extended the theory to the motion of rigid bodies in general in his famous Theoria motus corporum solidorum seu rigidorum [Theory of the motion of solid and rigid bodies] (1760)."

Once more Physics had then general solutions to solve problems of celestial as terrestrial bodies: the precession of the Earth and of a top could be calculated using the same equation.

The word precession, which since remote times has been used to denote an yearly antecipation of one equinoxe in relation to its subsequent, from this period has begun to be used to the conic motion of the axis of rotating rigid bodies.

From Euler to Foucault almost a hundred years had been spent until the gyroscope began to be used in inertial experiences. Foucault first with the pendulum that took his name and after with gyroscopes gave the first steps to this way.

CONSIDERATIONS

Studying previously the circular motion dynamics having in mind the students behaviour and that of the History we found a great similarity. In this present study, with the dynamics of the gyroscope, the ways the students and ancient scientists went through were not exactly the same.

The original query to ancient scientists was the precession of the equinoxes while to the students this question doesn't make any sense; this query doesn't take any part of the Universe of nowadays questions as it was to the scientists by the time of the changing of the Julian calendar.

Our form to approach the students with the body rigid dynamics was through the precession of the gyroscope, phenomenon that astonish the students with the possibility of sustentation in the air of a body, when precessing. The answers they give are interpreted in details in another palallel work of the same authors (KRAPAS-TEIXEIRA & QUEIROZ, 1993). There one can see traces from explanations given by ancient scientists when studying the circular motion. We believe that this happens with the students because both, circular motion and gyroscope motion are seen by them like balanced situations, instead of be treated by the fundamental equations of the translational and the rotational dynamics, respectively (NUSSENSZWEIG, 1992).

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