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New Concept of Confinement

Planckeon Origin of Dark Energy

Highlights

EPR Correlation in Cosmology

Analytical Determination of Subsurface

Discovering Thoughts, Inventing Future

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Dynamic Interaction: A New Concept of Confinement

By Gabriel Barceló

Abstract- We propose new dynamic hypotheses to enhance our understanding of the behavior of the plasma in the reactor. In doing so, we put forward a profound revision of classical dynamics. After over thirty years studying rotational dynamics, we propose a new theory of dynamic interactions to better interpret nature in rotation. This new theory has been tested experimentally returning positive results, including by third parties.

Plasma rotation is an essential factor in the analysis of the turbulent transport of momentum in axisymmetric systems. In magnetic confinement fusion systems, the plasma circulates in the container at a constant movement, which we could define as rotation with respect to its walls. Notwithstanding, it has been shown that the plasma in the reactor can initiate spontaneous circular movement or rotation, without the need for any external dynamic momentum input. The theoretical development of this behavior is still under study, and the origin of this spontaneous intrinsic rotation is still unclear.

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Dynamic Interaction: A New Concept of Confinement

Gabriel Barceló

Abstract- We propose new dynamic hypotheses to enhance our understanding of the behavior of the plasma in the reactor. In doing so, we put forward a profound revision of classical dynamics. After over thirty years studying rotational dynamics, we propose a new theory of dynamic interactions to better interpret nature in rotation. This new theory has been tested experimentally returning positive results, including by third parties.

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We suggest the exploring of a new type of dynamic confinement based on the Theory of Dynamic Interactions (TDI) and one that is compatible with magnetic confinement. Applying this criterion we are proposing would enable a twin physical-theoretical principle to isolate plasma and try to minimize its turbulence.

We suggest that these new dynamic hypotheses, which we hold applicable to particle systems accelerated by rotation, be used in the interpretation and design of fusion reactors. We believe that this proposal could, in addition to magnetic confinement, achieve confinement by simultaneous and compatible dynamic interaction.

I. Magnetic Confinement

On magneto hydrodynamic, the study of nonlinear physics associated with tokamak plasma turbulence and transport, allows us to infer the behavior of the reactor. For this goal, it is possible to use Gyrokinetics plasma turbulence simulation. The rotational nature of astrophysical plasmas has been also taken into account in its development [12], the goal is to have a reactor with a continuous process, which is what is required for its industrial development.

Current developments in our knowledge concerning the magnetic confinement of plasma for fusion defines a toroidal design of magnetic field force lines, which in successive toroidal transits travel over a surface topologically equivalent, in geometrical terms, to a torus. Indeed, this is the basis of the JET tokamak design and that of later reactors.[1]

On these reactors, magnetic confinement consists of containing material in a state of plasma inside an enclosure in which, in turn, a magnetic field has been created. The particles constituting the plasma do not enter into contact with the inner walls of the enclosure.

This method is based on the *Lorentz force*, which acts on any charged particle in motion in a magnetic field, by virtue of which it experiences a force perpendicular to the magnetic field vector and the displacement vector.

Fusion reactions are caused in this plasma that release energy, while at the same time a quantity of movement and angular momentum is moved or "rotated" and transported.

it has been confirmed that circulation in the experimental reactors is more turbulent than that which is supposed in stellar dynamic systems and, as we have pointed out above, this reduction of fluid uniformity can cause undesired losses in the system's power of confinement, or even, the possible cavitation of the physical container.

The speed of the plasma is an important physical field in the study of current laboratory systems, and particularly, in the improvement of its material isolation. The rotation profile can exercise considerable influence in the confinement time of the magnetically confined fluid. Profiles with a sharp radial velocity variation can cause a reduction of the turbulent transport and, therefore, could lead to improved confinement.

The study of plasma micro turbulence caused by the electromagnetic interactions of its particles is one of the current goals in an attempt to improve the performance of these reactors. Understanding this micro turbulence in plasma would enable its control and thus have a direct favorable impact on the building of more efficient fusion reactors.[2]

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[1] Barceló, G.: Dynamic Interaction Confinement. World Journal of Nuclear Science and Technology Vol.4 No.4, October 29, 2014, DOI: 10.4236/wjnst.2014.44031.

[2] Barceló, G.: *Dynamic Interaction Confinement.* World Journal of Nuclear Science and Technology Vol.4 No.4, October 29, 2014DOI: 10.4236/wjnst.2014.44031.

II. Gyrokinetics Theory and Simulations

The Gyrokinetics theory is also applied to determine the behavior of the plasma in the to kamak fusion reactors.

Nonlinear Gyrokinetics equations play a fundamental role in our understanding of the long-time behavior of strongly magnetized plasmas. The foundations of modern nonlinear Gyrokinetics theory are based on three pillars:

1) *A Gyrokinetics Vlasov equation written in terms of a gyro center Hamiltonian,*
2) *With quadratic low-frequency ponderomotive like terms, a set of Gyrokinetics Maxwell Poisson-Ampère equations written in terms of the gyro center Vlasov distribution that contain low-frequency polarization Poisson and magnetization Ampère terms, and*
3) *An exact energy conservation law for the Gyrokinetics Vlasov-Maxwell equations that includes all the relevant linear and nonlinear coupling terms. The foundations of nonlinear Gyrokinetics theory are reviewed with an emphasis on rigorous application of Lagrangian and Hamiltonian Lie-transform perturbation methods in the variational derivation of nonlinear Gyrokinetics Vlasov-Maxwell equations. The physical motivations and applications of the nonlinear Gyrokinetics equations that describe the turbulent evolution of low-frequency electromagnetic fluctuations in a non-uniform magnetized plasmas with arbitrary magnetic geometry are discussed.*[3]

The nonlinear Gyrokinetics system of equations for the arbitrary fluctuation frequencies are also derived from the generalized Lagrangian formulation and the variational principle. They are recommended for simulations and analytic applications in laboratory.

The Lagrangian formulation of the Gyrokinetics theory is generalized in order to describe the particles' dynamics as well as the self-consistent behavior of the electromagnetic fields. The Gyrokinetics equation for the particle distribution function and the Gyrokinetics Maxwell's equations for the electromagnetic fields are both derived from the variational principle for the Lagrangian consisting of the parts of particles, fields, and their interaction. In this generalized Lagrangian formulation, the energy conservation property for the total nonlinear Gyrokinetics system of equations is directly shown from the Noether's theorem. This formulation can be utilized in order to derive the nonlinear Gyrokinetics system of equations and the rigorously conserved total energy for fluctuations with arbitrary frequencies.[4]

From these formulations it is possible to perform computer simulations: *Simulations conducted for numerous situations, and their comparison, It has been confirmed that the existing Gyrokinetics models are sufficiently valid for shorter times than the real time scales of the evolution of the reactor's dynamic profiles, thus it is thought that the effect of turbulence on the electric field and plasma velocity provide incorrect values for the electric field. Consequently more precise mathematical models are needed to represent the real behaviour of plasma at a longer time scale, called the transport scale.*[5]

And also simulations for specific reactor designs: *Simulations of toroidal angular momentum transport have been carried out using global toroidal Gyrokinetics particlein-cell code. The significant redistribution of toroidal momentum is observed, driven by the ion temperature gradient turbulence with adiabatic electrons, resulting in a peaked momentum profile in the central region of the radial domain. Cases with rigid and sheared plasma rotation are considered. Diffusive and off-diagonal pinch like fluxes are identified. Toroidal momentum diffusivity is calculated by subtracting pinch contribution from the total momentum flux, and compared to quasilinear estimates. It is found that the ratio of momentum to heat conductivity is smaller than unity even after subtracting pinch contribution when wave-particle resonance energy is larger than thermal energy.*[6]

III. Transport Physics

New concepts of physical transport toroidal plasmas are studied. The transport of plasma in the reactor is generally externally provided by the momentum input from neutral beam injection in the current generation of tokamaks, which causes its rotation.

The transport characteristics of non-diffusion and non-locality of transport has been recognized to be important in determining radial structures of density, rotation, and temperature, as well as non-linearity in the flux-gradient relation. The non-diffusive term of momentum transport appears as a 'spontaneous rotation and intrinsic torque', while the non-diffusive term of particle transport appears as a 'particle pinch and particle exhaust'. The sign and magnitude of these non-diffusive terms have been found to be sensitive to the turbulence state, which causes reversal phenomena. In the momentum transport, the spontaneous flow reversal from the co- (parallel to plasma current) direction to the counter- (anti-parallel to plasma current) direction and

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[6] I. Holoda and Z. Lin: Gyrokinetic particle simulations of toroidal momentum transport Department of Physics and Astronomy, University of California, Irvine, California 92697, USA, © 2008, American Institute of Physics. DOI: 10.1063/1.2977769.

vice versa have been commonly observed even when the plasma parameter changes slightly. In the particle transport, especially in the impurity transport, reversals of convective radial flux from inward to outward are also observed in toroidal plasmas as phenomena of density peaking/flattening and impurity accumulation/exhaust. (…)

The non-diffusive term of momentum transport appears as a 'spontaneous rotation and intrinsic torque', while the non-diffusive term of particle transport appears as a 'particle pinch and particle exhaust'. [7]

The Toroidal angular momentum (TAM) is a conserved quantity.[8] *Plasma rotation plays important role in turbulence stabilization and in suppression of resistive wall modes, therefore affecting tokamak performance. In present day machines, rotation is usually driven by external sources, such as neutral beam injection; however, it might be unavailable in a future devices such as ITER, due to the large machine size and high densities. Possible solution of this problem could be generation of spontaneous intrinsic rotation and on-axis peaking of momentum profile by inward pinch like flux. Thus, it becomes crucial to understand the nature of intrinsic rotation phenomena, together with momentum transport mechanisms.*[9]

Poloidal and toroidal rotation has been recognized to play an important role in heat transport and magneto hydrodynamic (MHD) stability in tokamaks and helical systems. It is well known that the E × B shear due to poloidal and toroidal flow suppresses turbulence in the plasma and contributes to the improvement of heat and particle transport, while toroidal rotation helps one to stabilize MHD instabilities such as resistive wall modes and neoclassical tearing mode. Therefore, understanding the role of momentum transport in determining plasma rotation is crucial in toroidal discharges, both in tokamaks and helical systems.[10]

IV. Heuristic Description of *Intrinsic Toroidal Rotation*

Plasma rotation is an essential factor in this analysis of the turbulent transport of momentum. In magnetic confinement fusion systems such as on the ITER[11], the plasma circulates in the container at a constant movement, which we could define as rotation with respect to its walls. An intrinsic spontaneous toroidal rotation, with no external momentum input, have been observed on tokamaks: *it has been shown*[12] *that the plasma in the reactor can initiate* ***spontaneous circular movement or rotation****, without the need for any external dynamic momentum input. The theoretical development of this behaviour is still under study.*[13]

According to Parra: *Experimental observations have shown that tokamak plasmas rotate spontaneously without momentum input. This intrinsic rotation has been the object of recent work because of its relevance for ITER, where the projected momentum input from neutral beams is small, and the rotation is expected to be mostly intrinsic. The origin of the intrinsic rotation is still unclear.* (…)

The intrinsic rotation profile depends on the density and temperature profiles and on the up-down asymmetry.[14]

Changes in turbulence accompany the changes in spontaneous intrinsic rotation and they are studied in several successive radial regions, using a variety of diagnostics.

There has been some theoretical work in turbulent transport of momentum using Gyrokinetics simulations[15] [16] [17] [18] [19] *and different mechanisms have been proposed as candidates to explain intrinsic rotation*[20].

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The presence of an external magnetic field introduces a source of plasma anisotropy. Variations or fluctuations in the thermodynamic fields are much greater perpendicularly to the field than parallel to it. (…)

The ion toroidal rotation in a tokamak consists of an E×B flow due to the radial electric field and a diamagnetic flow due to the radial pressure gradient… the momentum pinch for the rotation generated by the radial pressure gradient is calculated and is compared with the Coriolis pinch. This distinction is important for subsonic flows or the flow in the pedestal where the two types of flows are similar in size and opposite in direction. At the edge, the different pinches due to the opposite rotations[21] *can result in intrinsic momentum transport that gives significant rotation peaking.*[22]

We assume that heating induced spontaneous toroidal rotation and other consequences of anomalous momentum transport, it has been observed toroidal rotation during heating, without external torque.

Parametric scaling of the intrinsic (spontaneous, with no external momentum input) toroidal rotation observed on a large number of tokamaks have been combined with an eye towards revealing the underlying mechanism(s) and extrapolation to future devices. The intrinsic rotation velocity has been found to increase with plasma stored energy or pressure in JET, Alcator C-Mod, Tore Supra, DIII-D, JT-60U and TCV, and to decrease with increasing plasma current in some of these cases. Use of dimensionless parameters has led to a roughly unified scaling with MA ∝ βN, although a variety of Mach numbers works fairly well; scaling of the intrinsic rotation velocity with normalized gyro-radius or collisionality show no correlation. Whether this suggests the predominant role of MHD phenomena such as ballooning transport over turbulent processes in driving the rotation remains an open question. For an ITER discharge with βN = 2.6, an intrinsic rotation Alfven Mach number of MA sime 0.02 may be expected from the above deduced scaling, possibly high enough to stabilize resistive wall modes without external momentum input.[23]

V. Phenomenology

Intrinsic spontaneous toroidal rotation driven by pressure and ion temperature gradients has been long predicted, studied and analyzed.

Spontaneous toroidal rotation, self-generated in the absence of an external momentum input, exhibits a rich phenomenology. In L-mode plasmas, the rotation varies in a complicated fashion with electron density, magnetic configuration and plasma current and is predominantly in the counter-current direction. The rotation depends sensitively on the balance between the upper and lower null and plays a crucial role in the H-mode power threshold. Rotation inversion between the counter- and co-current directions has been observed following small changes in the electron density and plasma current, with very distinct thresholds. In contrast, the intrinsic rotation in H-mode plasmas has a relatively simple parameter dependence, with the rotation velocity, proportional to the plasma stored energy normalized to the plasma current, and is nearly always directed co-current. In plasmas with internal transport barriers, formed either with off-axis ICRF heating or LHCD, the core rotation velocity increments in the counter-current direction as the barrier evolves.[24]

The experimental results of investigations of the mechanisms behind the momentum transport, and predictions of intrinsic rotation allow evolving in these investigations.

Regarding momentum transport, the radial flux of momentum has diffusive and nondiffusive (ND)terms, and experimental investigations of these are discussed. The magnitude of the diffusive term of momentum transport is expressed as a coefficient of viscous diffusivity. The ratio of the viscous diffusivity to the thermal diffusivity (Prandtl number) is one of the interesting parameters in plasma physics. It is typically close to unity, but sometimes can deviate significantly depending on the turbulent state. The ND terms have two categories: one is the so-called momentum pinch, whose magnitude is proportional to (or at least depends on) the velocity itself, and the other is an offdiagonal term in which the magnitude is proportional to (or at least depends on) the temperature or/and pressure gradient, independent of the velocity or its gradient. The former has no sign dependence; rotation due to the momentum pinch does not depend on the sign of the rotation itself, whether it is parallel to the plasma current (codirection) or anti-parallel to the plasma current (counter-direction). In contrast, the latter has a sign dependence; the rotation due to the off-diagonal residual term is either in the co- or counter-direction depending on the turbulence state, but not on the sign of the rotation itself. This residual term

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can also act as a momentum source for intrinsic rotation. [25]

VI. Predictions for Intrinsic Rotation

It is important to make predictions for the intrinsic rotation for future reactors: *There are many unresolved problems regarding intrinsic rotation. One of the important issues is the sign of the rotation. As seen in the reversal phenomenon, the direction of the intrinsic rotation changes its sign, even with slight changes in plasma parameters, which cannot be expressed by a global parameter scaling. The other issue is that the intrinsic rotation is very sensitive to the change in turbulence type, and also to the confinement mode, such as LOC/SOC, L-mode/H-mode or L-mode/ITB. Although the magnitude of intrinsic rotation may be sufficient in ITER, the flip in rotation is of concern, so an understanding of rotation reversals is crucial. In order to achieve stable operation in ITER, a better understanding based on the physics mechanisms of intrinsic rotation is necessary.*

There are several physics issues which should be understood in order to predict the intrinsic rotation in future devices. The physics mechanism determining the direction and magnitude of intrinsic torque is still not well enough understood to give a precise prediction, although there are many experimental observations and simulations. Since the intrinsic torque is related to the symmetry breaking of turbulence, it should be correlated with the confinement regime, as well as to heat and particle transport. At the moment, the understanding of the connection among the particle pinch, intrinsic torque and non-local response of the heat transport is still phenomenological. The other remaining issue is how the angular momentum is released when the intrinsic rotation appears. It is not clear whether angular momentum is conserved by the kinetic momentum escaping from the last closed flux surface or by a change in the magnetic vector potential. [26]

There are several others outstanding issues, such as how the angular momentum is released when the intrinsic rotation appears.

Regression analysis has been performed on the intrinsic rotation data set:

Extrapolation to ITER predicts rotation velocities in some of the scatter may be due to the large variety in magnetic field ripple, error fields and/or wall conditioning in the various devices. Extrapolation to ITER predicts rotation velocities in excess of 300km/s. (…) There are several physics issues which should be understood in order to predict the intrinsic rotation in future devices. The physics mechanism determining the direction and magnitude of intrinsic torque is still not well enough understood to give a precise prediction, although there are many experimental observations and simulations. Since the intrinsic torque is related to the symmetry breaking of regime, as well as to heat and particle transport. [27]

Recently there has been widespread attention paid to rotation and momentum transport in tokamak plasmas. Of particular interest is spontaneous (intrinsic) toroidal rotation in plasmas without external momentum input. The strong co-current spontaneous rotation in enhanced confinement regimes, with ion thermal Mach numbers up to 0.3, may allow for resistive wall mode suppression in high-pressure ITER discharges, without requiring the use of neutral beam injection. Spontaneous rotation in L-mode discharges exhibits a complex dependence on plasma parameters and magnetic configuration compared to the relatively simple scaling of Alfven Mach number (MA = VΦ/CA, where CA is the Alfven speed) MA∼βN observed in enhanced confinement plasmas. There is currently no comprehensive, quantitative explanation of this phenomenon. An accurate prediction of the expected rotation velocity profile from whatever neutral beam injection is available on ITER requires a detailed understanding of momentum transport. There have been extensive investigations into correlations between energy and momentum diffusivities, and whether there are systematic trends of the Prandtl number with plasma parameters. Of late, there has been vigorous theoretical activity regarding a possible momentum pinch that could help enhance the rotation in the plasma interior. There has been a renewed interest in poloidal rotation, especially in ITB discharges, which is generally found to be at odds with the predictions of neo-classical theory. (…)

Spontaneous rotation (in the absence of external momentum input) in low confinement mode (L- mode) Ohmic plasmas is often directed counter-current, and depends very sensitively on the magnetic configuration and in a complicated fashion on other parameters, such as the plasma current, electron density and ion temperature. While the study of spontaneous rotation in L-mode discharges is of interest in its own right (e.g. for its relation to the H-mode power threshold), these plasmas will not be considered here, since most ignition scenarii in future devices require H- mode confinement. The spontaneous toroidal rotation in H-mode (and in enhanced confinement regimes in Tore Supra) is generally in the co-current direction and has been observed on many devices and produced with a wide

[26] K. Ida and J.E. Rice: Rotation and momentum transport in tokamaks and helical systems. Published 10 March 2014, 2014 IAEA, Vienna. Nuclear Fusion, Volume 54, Number 4. doi:10.1088/0029-5515/54/4/045001.

[27] *K. Ida and J.E. Rice: Rotation and momentum transport in tokamaks and helical systems. Published 10 March 2014, 2014 IAEA, Vienna. Nuclear Fusion, Volume 54, Number 4. doi:10.1088/0029-5515/54/4/045001.*

variety of techniques (ICRF, Ohmic, ECH), demonstrating its fundamental nature. (…)

Spontaneous (in the absence of external momentum input) co-current toroidal rotation has been observed on many tokamaks in H-mode (and in enhanced confinement regimes in Tore Supra), produced by a variety of different methods: ICRH, ECH, Ohmic heating, ECH with lower hybrid heating and balanced neutral beam injection. A common feature of these observations is that the rotation velocity increases with the plasma pressure or stored energy. (…) At present there is no comprehensive, quantitative explanation for spontaneous rotation. Some recent observations of poloidal rotation are inconsistent with the predictions of neo-classical theory. Momentum transport has been found to be closely coupled to energy transport, and with momentum diffusivities much higher than neo-classical values. These results are consistent with diffusive momentum transport driven by ITG turbulence. Evidence for an inward momentum pinch has also been observed, which could be due to the Coriolis drift effect or from symmetry breaking due to magnetic field curvature.[28]

The theory of turbulent transport of toroidal momentum is discussed in the context of the phenomenon of spontaneous/intrinsic rotation. We review the basic phenomenology and survey the fundamental theoretical concepts. We then proceed to an in-depth discussion of the radial flux of toroidal momentum, with special emphasis on the off-diagonal elements, namely the residual stress (the portion independent of V) and the pinch. A simple model is developed which unifies these effects in a single framework and which recovers many of the features of the Rice scaling trends for intrinsic rotation. We also discuss extensions to finite beta and the effect of SOL boundary conditions. Several issues for future consideration are identified.[29]

Spontaneous spin-up in intrinsic toroidal and poloidal rotation of impurity ions (C and He) was observed at the edge of ohmic plasmas during L-H mode transitions in NSTX. The rotation was reduced again after the H-L back transition. The changes in rotation were accompanied by changes in plasma fluctuations and turbulence observed over the plasma minor radius from the far SOL too deep in the core using diagnostics such as fast reflectometry and Langmuir probes near the chamber walls, gas puff imaging (GPI), and microwave reflectometry and high-k scattering in the plasma core. Intrinsic rotation increases of 10s of km/s were observed using an edge rotation diagnostic and reflectometry showed the long wavelength correlation length in the plasma core to drop sharply at the L-H transition. GPI and a fast radial (midplane) scanning probe showed a strong decrease in plasma turbulence (…) at the plasma edge. The observed intrinsic velocity scalings are consistent with a variety of toroidal devices.[30]

VII. Dynamic Model for Confined Plasma

Against this background of study and constant advancement in unravelling the physical behaviour of tokamak-type nuclear reactors, we suggest a revision of the dynamic criteria being applied, given that we believe there may well be inappropriate interpretations in the principles of classical rotational dynamics at play.[31]

We propose a dynamic new model for confined plasma based on the theory of dynamics interactions (TDI), to allow, a natural dynamic confinement. We advise the study of rotational dynamics, given that it would afford us a better understanding of the dynamics of confined plasma by dynamic interaction, along with an improved reactor result.

In accordance with the theory of dynamics interactions, we suggest that each particle, instead of following a linear path, as would be expected from the classical mechanics equations of Newton-Euler, it would follow a closed path owing to the coupling of the velocities' fields that are caused on every point of each particle.

The issue can be summed up as follows: If we apply this dynamic theory to a tokamak reactor, every plasma particle with intrinsic rotation will follow a closed path like that of the boomerang when it is subjected to a non-coaxial momentum in addition to its intrinsic angular momentum. Consequently, there are different authors[32]

[28] *J E Rice: Spontaneous rotation and momentum transport in tokamak plasmas. Plasma Science and Fusion Center Massachusetts Institute of Technology Cambridge MA 02139 USA, 2007, U.S. Department of Energy, Grant DE DE-FC02- 99ER54512, and IOP Publishing Ltd. Journal of Physics: Conference Series, Volume 123, Number 1, 2008.*

[29] *P. H. Diamond and C. Mcdevitt and O. D. Gurcan and K. Miki and T. S. Hahm and W. Wang and G. Rewoldt and I. Holod and Z. Lin and V. Naulin and R. Singh: Physics of Non-Diffusive Turbulent Transport of Momentum and the Origins of Spontaneous Rotation in Tokamaks. The College of Information Sciences and Technology, 2015. The Pennsylvania State University.*

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[31] Barceló, G.: Dynamic Interaction Confinement. World Journal of Nuclear Science and Technology Vol.4 No.4, October 29, 2014DOI: 10.4236/wjnst.2014.44031 http://www.scirp.org/journal/PaperInformation.aspx?paperID=51026&
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[32] Pérez, L. New Evidence on Rotational Dynamics. World Journal of Mechanics, Vol. 3, No. 3,2013, pp. 174-177, doi: 0.4236/wjm.2013.33016. http://www.scirp.org/ journal/wjm
http://dx.doi.org/10.4236/wjm.2013.33016

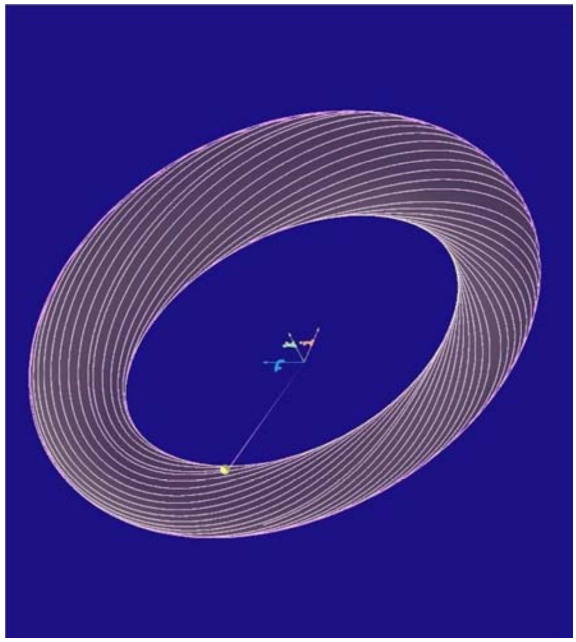

Illustration with the image of the trajectory of the plasma according to the criteria of the TDI. (by Al. Pérez)

who share these same hypotheses[33] *with a view to understanding the dynamic behaviour of bodies or particles in those circumstances in which they have translational velocity, intrinsic rotation and are simultaneously subjected to a non-coaxial momentum with its own rotation.*[34] *Notwithstanding, in our hypothesis, based on a possible analogy, we are extrapolating the observed behaviour in macroscopic moving bodies to the reactor's plasma particles.*

In our opinion, this dynamic model also coincides with the behaviour of hurricanes on the Earth and also resembles atmospheric toroidal vortex rings.

It must be pointed out that in our investigations we have come to a rational deduction to the effect that in such circumstances, the kinetic translational energy can be transformed into kinetic rotational energy, and vice versa, and in general, energy transfers can occur at the core of particles endowed with intrinsic angular momentum: […] kinetic energy can be transferred, increasing its rotation velocity, its linear velocity or modifying its state of potential.[35]

We suggest that the spontaneous/intrinsic rotation can be explained by this dynamic theory: the plasma particles with intrinsic rotation, undergo to a not coaxial torque, initiated the orbiting movement, in the same way that spontaneously initiates a top. By the effect of the external torque, the travel speed of the particle changes its direction but not its magnitude, initiating a closed-orbiting movement, as expressed by the TID. The goal, in this case for better efficiency, it will match the radius of this spontaneous movement with the radius of the reactor. Thus we conceive the plasma as a whole on a closed orbit, inside the reactor, which defines the proposed dynamic inertial confinement, and justified by the TDI.

Thus, the plasma has a repetitive motion equivalent to the boomerang, returning to his place of origin. Both dynamic behaviors, the top and the boomerang are, in our opinion, clear examples of the rotational dynamics justified by the Theory of Dynamic Interactions, TDI, that we propose.

VIII. Lorentz Force

At the beginning of this paper we stated that magnetic confinement is based on the Lorentz force. This force manifests itself when an electric charge in movement moves in a magnetic field. We have stated in other works that, in our opinion, the origin of this force is analogous to that of the inertial forces that manifest themselves in TDI circumstances, and which oblige particles to follow a closed path. Therefore, and in accordance with our hypothesis, the same dynamic effect and the same effective confinement could be obtained doubly, by the magnetic effect and by the dynamic effect.

The Lorentz force is an electromagnetic interaction manifestation, discovered by Hendrik Lorentz, with multiple technological applications. It is the total combination of electric and magnetic force on a point charge due to electromagnetic fields.

[33] Dorado González, M. Dinámica de sistemas con spin: un nuevo enfoque. Fundamentos y aplicaciones. ADI Ser, Ed.: Madrid, 2013.
[34] Dorado González, M. Equation of motion of systems with internal angular momentum – II. arXiv: physics/ 0603207.
[35] Barceló, G. A rotating world (Un mundo en rotación). Editorial Marcombo: Barcelona, 2008. http://www. dinamicafundacion.com/

For a particle of charge subjected to an electric field combined with a magnetic field, the total electromagnetic force or Lorentz force on the particle is given by:

$$\mathbf{f} = q(\mathbf{E} + \mathbf{V} \times \mathbf{B}),$$

Where:

q= particle charge

v= velocity in the presence of an electric field

E= electric field intensity

B= external magnetic field

If we look carefully at the effects a **B** field exerts on an electrical charge q, it holds that:

- When the particle is at rest, the field **B** exerts no force on it.
- The force is maximum when the load speed **v** and the field **B** are orthogonal and is zero when they are parallel.
- The force is perpendicular to the plane formed by **v** and **B**.
- The force is proportional to the charge q, and to de speed **v.**
- If the load changes sign, the force changes direction

Therefore, the force exerted by a field **B** on electric charge q moving with velocity **v** is perpendicular to the field lines **B**, causes a normal acceleration and change the path charge. Accordingly, a circular movement starts, in which the magnetic force acts as normal force or centripetal, and wherein the modulus of the speed remains constant, there being no tangential force.

This is the same behavior justified by the TDI, to the bodies with intrinsic rotation, when subjected to non-coaxial torque. In these cases, a new curved path also circular is generated, when maintained constants the parameters.

If we simply refer to the magnetic moment generated by a magnet, this determines the force that the magnet can exert on electric currents and magnetic field torque exerted on them. Its formulation is:

$$\boldsymbol{\tau} = \boldsymbol{\mu} \times \mathbf{B}$$

Where:

$\boldsymbol{\tau}$ = is the torque acting on the dipole

$\boldsymbol{\mu}$ = is the magnetic moment.

$\boldsymbol{\tau}$ It is always normal to both, both $\boldsymbol{\mu}$ as **B**. When **B** is orthogonal to $\boldsymbol{\mu}$, then it is maximum. Note that this dynamic relationship between two quantities, is analogous to the dynamic equation of the TDI, also the dynamic phenomena occurring in both cases are also similar.

It is assumed, in the case of magnetic materials, that the cause of the magnetic torque are the spin and orbital angular momentum states of the electrons, and whether atoms in one region are aligned with atoms in another.

Magnetic torque and angular momentum have a close connection. It is expressed on a macroscopic scale in the Einstein-de Haas effect, or "rotation by magnetization," and otherwise with its inverse, the Barnett effect, or "magnetization by rotation." Both can be defined as gyromagnetic effects. This applies, for example, when a magnetic moment is subject to a torque in a magnetic field that tends to align it with the applied magnetic field, the moment precesses (rotates about the axis of the applied field).

In these phenomena we can imagine a magnetic dipole as a rotating charged particle. In this case both, the magnetic moment and the angular momentum, increase with the rate of rotation.

Electrons and many atomic nuclei, have intrinsic magnetic moments, which relates to the angular momentum of the particles. This way you can justify the behavior of the plasma. The intrinsic angular momentum (spin) of each type of particle of the plasma is a constant.

The spin magnetic moment is an intrinsic or essential property of particles, such as mass or electrical charge. These intrinsic magnetic moments are what give rise to macroscopic effects of magnetism, and other phenomena such as nuclear magnetic resonance.

In addition, certain orbital distributions, implies an additional magnetic moment, by the movement of electrons as charged particles.

Both ideas being proposed should, we feel, be further explored and, where appropriate, confirmed experimentally; on the one hand, that the Lorentz force is analogous to an inertial dynamic force, similar to TDI ones, and on the other hand, that this theory be applied to the reactor's plasma.[36]

IX. Conclusions

Nuclear fusion is a necessary energy into which countries are researching and in which we trust. Although, to some authors: *At present there is no comprehensive, quantitative explanation for spontaneous rotation,*[37] but in this text we have proposed a dynamic justification of such expontanea plasma rotation.

[36] Barceló, G.: Dynamic Interaction Confinement. World Journal of Nuclear Science and Technology Vol.4 No.4, October 29, 2014DOI: 10.4236/wjnst.2014.44031 http://www.scirp.org/journal/PaperInformation.aspx?paperID=51026& http://dx.doi.org/10.4236/wjnst.2014.44031

[37] J E Rice: Spontaneous rotation and momentum transport in tokamak plasmas. Plasma Science and Fusion Center Massachusetts Institute of Technology Cambridge MA 02139 USA, 2007, U.S. Department of Energy, Grant DE DE-FC02- 99ER54512, and IOP Publishing Ltd. Journal of Physics: Conference Series, Volume 123, Number 1, 2008.

The focus however is on new theory and simulation of the ExB shear and coriolis angular momentum pinch effects needed to understand the intrinsic toroidal rotation in tokamaks without external torque in the core.[38]

We also understand that should be explored a new theory and simulation, but that's not exactly a Coriolis effect, or the ExB shear where the solution must be found, if not in the TID we propose.

As far as magnetic confinement reactors are concerned, plasma dynamics is still a work in progress. We are as yet ignorant of the exact dynamic behaviour of plasma and, moreover, when designing these generators it is still necessary to reduce their turbulent tendency and improve their momentum transport capacity.

We propose a profound revision of the principles of classical rotational mechanics, especially as regards particles subjected to accelerations by simultaneous and noncoaxial rotations. After conducting our research, we put forward certain specific, alternative dynamic hypotheses.

In addition to the plasma's material container, we can envisage another simultaneous, non-material container, along with the use of magnetic confinement techniques. We suggest the exploring of a new type of dynamic confinement based on the TDI and one that is compatible with magnetic confinement.

Gyrokinetics is the workhorse for modern research on low-frequency micro turbulence in magnetized plasmas. It is a very powerful tool that has been used successfully in many different applications in both fusion and astrophysics.[39]

We recognize that the issue is still unresolved. We understand that it is not correct to speak of the Coriolis effect. The problem lies in the design of the equations of motion applied. We propose the implementation of a new rotational dynamics based on the theory suggested in this text.

Moreover, in our opinion, the TDI could also be employed as a complementary theoretical instrument that would lead to greater reactor efficiency. Consequently, its dynamic hypotheses ought to be studied in the field of Gyrokinetics theory.

The equation for movement that we are proposing in the Theory of Dynamic Interactions for these non-inertial situations is very simple […] it becomes possible to determine the path of plasma particles in translation, when these particles are endowed with intrinsic rotation and are subjected to rotation actions on another, different axis. […]

These new dynamic hypotheses we are putting forward and which we hold applicable to particle systems accelerated by rotation can, we suggest, be used in the interpretation and design of fusion reactors. Accordingly, we persist in our belief that magnetic confinement in a reactor can be likened to confinement by dynamic interactions based on the Theory of Dynamic Interactions. Applying this criterion we are proposing would enable a twin physical-theoretical principle to isolate plasma and try to minimize its turbulence: each plasma particle should have spin and be subjected to a non-coaxial magnetic momentum from without and another gravimetric one. Accordingly, plasma confinement will be based on two different, albeit analogous, physical principles, generating double intransigence in its path. [40]

We understand that the variational analysis used in the applied formulation is currently insufficient, if not accompanied by the dynamic hypothesis that we propose. It is necessary to incorporate on the mathematical formulation, the coupling of the fields of the dynamics magnitudes that are generated in the plasma, because this dynamic coupling defines its true behavior: the plasma circulating along the reactor, in a closed path, generating an additional dynamic confinement, besides already magnetic known. The dynamic model based on a new rotational concept, may represent more correctly the real behavior of the plasma in the rector, even could improve the performance of these energy power plants, minimize turbulence and improve momentum transport.

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Bi-Directional EPR Correlation in Cosmology and Planckeon Origin of Dark Energy

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Abstract- A solution of nonlocal EPR correlation between counter-propagating pair of polarization-entangled photons emitted from a common source at S and detected at points P and Q is sought outside the EPR's reality criterion of local causality but within the framework of time-symmetric quantum electrodynamics allowing the bi-directional signal transmission P↔S↔Q on the double-light cone where the future and the past cones share common light paths connecting the photon source S and the detection points P and Q. A cosmlogical implication of the bi-directional signal transmission P↔Q without common source S in the inflationary cosmology and possible Planckeon orgin of dark energy in the upper hemisphere of semiclosed Friedman uiverse, joined on to an asymptotically flat outer space, are also discussed.

Keywords: *quantum theory, relativity, causality, locality, correlation cosmology, dark energy.*

GJSFR-A Classification : *FOR Code: 020109*

BIDIRECTIONALEPRCORRELATIONINCOSMOLOGYANDPLANCKEONORIGINOFDARKENERGY

Strictly as per the compliance and regulations of :

Bi-Directional EPR Correlation in Cosmology and Planckeon Origin of Dark Energy

Noboru Hokkyo

Abstract- A solution of nonlocal EPR correlation between counter-propagating pair of polarization-entangled photons emitted from a common source at S and detected at points P and Q is sought outside the EPR's reality criterion of local causality but within the framework of time-symmetric quantum electrodynamics allowing the bi-directional signal transmission P↔S↔Q on the double-light cone where the future and the past cones share common light paths connecting the photon source S and the detection points P and Q. A cosmlogical implication of the bi-directional signal transmission P↔Q without common source S in the inflationary cosmology and possible Planckeon orgin of dark energy in the upper hemisphere of semiclosed Friedman uiverse, joined on to an asymptotically flat outer space, are also discussed.

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I. Introduction

Since the advent of quantum mechanics in the mid-1920s there have benn continued interpretational controversies surrounding its counter-intuitive nature such as the wave-particle duality and the instantaneous collapse of the particle wave function at the detection point. But the paradox of nonlocal EPR[1] correlation between distant events without nonlocal interactions has been more problematic in recent times by Bell's experimental nonlocality test[2,3] proposed in 1964, though the paradox was first noticed by Schrödinger[4] and discussed in the dialogue between Einstein and Bohr[5] at 1935 Solvay Council. In emphasis of the signal transmission in EPR correlation Cavaicanti and Wiseman[6] asked: "What Bohr could have told Einstein at Solvay had he known about Bell experiments ?" In his recollection in 1990 Bell[7] wrote: "Suppose quantum mechanics were found to *resist* precise formulation. Suppose that when formulation beyond FAPP (For All Practical Purposes)[8] is attempted, we find an unmovable finger obstinately pointing outside the subject....to the Mind of the Observer..., or only Gravitation ?" We here show that the solution of quantum paradoxes can be found outside the EPR's reality criterion of local cauality[9] but within the framework of time-symmetric quantum electrodynamics for finite spacetme.[10] A cosmlogical implication of the bi-directional signal transmission P↔Q without common source S in the inflationary cosmology and a possible orgin of dark energy are also discussed.

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II. EPR Correlation in EPR Loophole

At the Solvay council EPR asked: "Are there spooky actions at a distance in quantum dmechanics ?" Recently, Yin et al.[11] led by Q. Zhang measured a superluminal speed of spooky acions between counter-propagating pair of photons emitted from an opticaly pumped atom in spin 0 state. During the measurement the locality and the freedom-of-choice loopholes of previous expriments were maximally closed by observing a 12-hour continuous violation of Bell's numerical expression (inequality) to EPR's reality criterion of local causality and separability of distant events. Let the spacetime positions of the photon source and the detection points be $S(x_S, t_S)$, $P(x_P, t_P)$ and $Q(x_Q, t_Q)$. Then the lower bound of the speed c_S of the spooky actions

$$c_S = |x_Q - x_P|/|t_Q - t_P| \qquad (1)$$

can be superluminal as $|t_Q - t_P| \to 0$. Here we can see a local and causal link P←S→Q ($t_S < t_P \approx t_Q$) and the nonlocal and acausal (spooky) link P→Q ($t_P < t_Q$). Let ε_P and ε_Q be the unit polarization vectors of photons measured at P and Q. The experiments verified the quantum expectations of the correlation function $C_{QM}(\boldsymbol{\varepsilon}_P,\boldsymbol{\varepsilon}_Q) = \boldsymbol{\varepsilon}_P\boldsymbol{\varepsilon}_Q = \cos\theta$, where θ is the Hilbert space angle between $\boldsymbol{\varepsilon}_P$ and $\boldsymbol{\varepsilon}_Q$, and showed a clear rejection of classical theories obeying Bell's inequlities. The experiments also confirmed the insenstivty of C_{QM} to observer's delayed decision as to which direction to measure each photon's polarization at P and Q after the photon left the source at S—too late for a message to reach the opposite photon,[8] making the causal link P←S→Q improbable and the bi-directional link P↔S↔Q probable in the loophole of EPR's reality criterion of local causlity between P and Q,

III. EPR Correlation on Double-Light Cone

Dirac[12] defined the two-point corrlation function or propagator $\Delta(x, t)$ between S(0,0) and P(x, t), and visualized the signal transmission S↔P on the light cone with the origin S as vertex:

$$(\partial^2/c^2\partial^2 t^2 - \partial^2/^2\partial^2 x^2)\Delta(x,t) = 0, \qquad (2)$$

$$\Delta(x,t) = \alpha(t)\delta(c^2t^2 - x^2)$$

$$= [\delta(ct - x) - \delta(ct - x)]$$

$$= \Delta_{future} - \Delta_{past} = \Delta_{ret} - \Delta_{advt} , \quad (3)$$

where $\alpha(t) = t/|t| = 1$ $(t > 0)$; $= -1$ $(t < 0)$. There an electron at S(0, 0) moves under the retarded (causal) action Δ_{ret} of a charged partcle at P on the past light cone $\delta(ct + x)$ of S as well as the advanced (retrocausal) action Δ_{adv} of a charged particle at Q on the future light cone $\delta(ct - x)$ of S, giving a divergence-free radiation damping of the electron at S. The bi-directional EPR link, $P(x_P, t_P) \leftrightarrow S(x_S, t_S) \leftrightarrow Q(x_Q, t_Q)$, can be visualized on the future light cone of the optically pumped metastble atom at S(0, 0) by replacing the step function $\alpha(t)$ by the square (step-up and down) function $\beta(t) = 0$ $(t < t_S)$; $= 1$ $(t_S < t < t_{P/Q})$; $= 1$ $(t > t_{P/Q})$

$$(t_S < t < t_{P/Q}); = 1 \ (t > t_{P/Q})$$

$$\Delta(|x_{P/Q} - x_S|, |t_{P/Q} - t_S|)$$

$$= [\delta(c|t_{P/Q} - t_S| - |x_{P/Q} - x_{S|}|)$$

$$- \delta[(c|t_{P/Q} - t_S| - |x_{P/Q} - x_{S|}|]/|x_{P/Q} - x_S| . \quad (4)$$

The double-light cone[13] $[\delta_{ret} - \delta_{adv}]$ in Eq.(5) tells that the detection point P/Q on the left/right arms of the future light cone of S is reached by retarded wave $\exp i(\omega t - kt)$ from S while advanced wave $\exp i(\omega t + kx)$ from P/Q reaches S on the right/left arms of the past light cone of P/Q, forming a bi-directional sinusoidal wave, $\exp i\omega t \sin kx$, standing in phase between S and P/Q with nodes fixed in space at $x = n\pi/k$ (n = integer).

IV. Bi-Directional Microscope

"Is the star (moon) there when nobody looks" asked Tetrode (Mermin).[14] At the 1947 Solvay Council Heisenberg proposed a thought experiment measuring the electron position on microscope's object plane. There the photon wave collapsing at S in the retinaof the oberver entails the retrocollapse (appearance) of an elecon at P scattering the photon to be observed at S. That is, the electron is not at P when nobody looks. at S. This point was emphasized by Weizäcker[15] in his delayed-choice thought experiment measuring the transverse photon momentum on the focal plane of Heisenberg's microscope. If the microscope is very long, the observer at S can make choice as to which property of the electron, position or momentum, to measure after the scattering process has taken place at P. To see the bi-directional signal transmission S↔P where $M = \rho_\Lambda V = 4\pi\rho_\Lambda R^3/3$ is the Newtonian mass. in microscope we write Eq.(5) in momentum space[14]

$$\Delta_{\omega,k}(|x_P - x_S|, |t_P - t_S|)$$

$$= [\exp ikc|t_P - t_S| \ |\sin k|x_P - x_S|]/|k|, \quad (5)$$

getting an uncertainty relation between photon momentum $p = \hbar k$ and the microscope length

$$p|x_P - x_S| = nh/2, \quad (6)$$

where n is the number of nodes of the sinusoidal wave standing between S and P.

V. Cosmological EPR Correlation

In his aether hypothesis Dirac[17,18] considered a nonlocal EPR connection without common source S between distant events P and Q on the 4-dimensional hyperboloid $(ct)^2 - r^2 = l_{pl}^2$, or the Lorenz sphere of radius l_{pl}, crossing the light cone at $ct = l_{pl}$ at $r = 0$ with spacelike velocity:

$$dr/dt = ct/r = c(1 + l_{pl}^2/r^2)^{1/2}. \quad (7)$$

Hawking[19] considered a cyclic cosmology where an expanding and contracting Lorenz-de Sitter universe starts and ends on the Lorenz sphere embedded into 4-dimensional Euclidean space $\tau^2 + r^2 \sim l_{pl}^2$ with imaginary time $\tau = it$. There the observable Hubble consant $H = v/d$ relating the relative velocity $v \sim c$ of extragalactic objects at a distance d receding from the Earth, is related to the cycle $C = 2\pi H^{-1}$, temperature $T = H/2\pi$ and entropy $S = \pi H^{-2}$. In high dimensional string theory,[20] the parallel orbifold branes collide periodically in cycle, expanding and contracting with dark energy.

We here consider the embedding of the Planck length l_{pl} in the radial line element ds of the Lorenz-de Sitter-Reissner-Nordstroem universe:

$$ds^2 = c^2 g_{tt} dt^2 - g_{rr} dr^2,$$

$$g_{tt} = g_{rr}^{-1} = c(1 - \Lambda r^2/c^2 + l_{pl}^2/r^2)^{1/2}. \quad (8)$$

Here Λ is the cosmolgical constant interpreted as the timelike vacuum energy density. Note that the light velocity $dr/dt = c(g_{tt}/g_{rr})^{1/2} = c(1 - \Lambda r^2/c^2 + l_{pl}^2/r^2)$ is spacelike at $r \sim l_{pl}$ but decreases with the increase of r towards $dr/dt = c$ at $r = (cl_{pl})\Lambda^{-1/2} \sim 10^{-23}\Lambda^{-1/2}$cm. In the inflationary cosmology starting from quantum fluctuations of preexisting spacetime metric, the radius of the causally related small region extends from $l_p \sim 10^{-33}$cm to $r \sim 10^{-25}$cm during electroweak and grand unification period followed by a brief interlude of reheating, returning to the pre-inflationary temperature of the universe. After the inflationary period, further evolution of the universe is described by the standard Friedman model universe starting the radiation dominated phase of Hubble's expansion history.

VI. Time-Symmetric and Inflationary Friedman .....Universe

Consider a Friedman universe filled with the uniform disrtribution of constant dark energy density ρ_Λ described by the Lorenz-Reissner-Nordstroem metric:

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$$g_{tt} = g_{rr}^{-1} = (1 - r^2/r_g^2)^{1/2} + r_{pl}^2/r^2$$
$$= (1 - r/r_g)^{1/2} (1 + r/r_g)^{1/2} + r_{pl}^2/r^2, \quad (9)$$

where $r_g = 3c^2/8\pi G\rho_\Lambda$ is the gravitational radius of the universe determinig the cosmological event horizon. We find superlminal signal trasmission $dr/dt = c(g_{tt}/g_{rr})^{1/2} >> c$ and causally related small regions at radii $r = r_c$ and $r = r_g - r_c$ where $r_c = (r_{pl}/r_g) \sim 10^{-2}$cm for $r_g = R \sim 10^{28}$cm, that is, the inflationary epochs of expanding and contracting almost closed Friedmanan universe, joined onto asymetrically flat Euclidean spaces through double-valued Schwarzschild bottle-neck.

VII. Mass Defect of Semiclosed Friedman Universe

For $r >> r_{pl}$ the evolutinary history of Friedman universe is determined by the Hubble constant $H = 8\pi G/\rho_\Lambda$ where ρ_Λ is the dark energy density. The dimensionless density parameter Ω_Λ is defined by $\Omega_\Lambda = \rho_\Lambda/\rho_{c\Lambda}$ where $\rho_{c\Lambda}$ is the critical density to make the univese flat. For $r >> r_{pl}$ we have

$$ds^2 = c^2 g_{tt} dt^2 - g_{rr} dr^2,$$
$$g_{tt} = g_{rr}^{-1} = (1 - r^2/r_g^2)^{1/2}. \quad (10)$$

Using the integral $\int dx(1 - x^2)^{1/2} = \sin^{-1}x$ the proper mass M_p and volume V_p of the universe of radius R are calculated ss

$$M_p = \rho_\Lambda V_p = 2\pi\rho_\Lambda \int^R r^2 g_{rr} dr = (3/2)(R/r_g)^3[\sin^{-1}(R/r_g)$$
$$\ldots - (R/r_g)(1 - (R^2/r_g^2)^{1/2})]M, \quad (11)$$

where $M = 4\pi R^3\rho_\Lambda/3$ is the Newtonian mass and $M - M_p$ the mass defect. Equation (11) tells that the proper radius $R_p = \int^R g_{rr} r dr$ increases with the increase of the world radius from $r \sim l_{pl}$, where $\sin^{-1}(l_{pl}/r_g) \sim 1$, until V_p fills the lower hemisphere of the closed Friedman universe, where $\sin^{-1}(l_{pl}/r_g) = \pi/4$. With further increase of r, R_p decreases towards $R_p \sim l_{pl}$, where $\sin^{-1}(l_{pl}/r_g) \sim \pi/2$, forming a gravitational semiclosure with $V_p \sim M_p \sim 0$ in the evolutionarily earlier upper hemisphere, creating Planck scale black holes[19] outside the event horizon of almost closed Friedman universe joined onto asymptoticlly flat space through Schwarzschil bottle-neck pulsating with Planck scale period.[21]

VIII. Source of Dark Energy

We note that the negative equation of state $\rho_\Lambda + p_\Lambda c^2 < 0$, where $p_\Lambda c^2 << \rho_\Lambda$ is the pressure, required by the dark energy, is satisfied in the upper hemisphere of the closed Friedman universe where the gravitationally bound pairs of quantized metric fluctuations or Planckeons of mass m_{pl}, or graviational Bohr atoms, creating negative attractive potential $Gm_{pl}^2/l_{pl} = \hbar c/l_{pl} = m_{pl}c^2$ dominate, forming Bose-Einstein condensate, while the single Planckeon excitations with positive rest mass energy $m_{pl}c^2$ prevail in the lower hemisphere where the positive equation of state $\rho_\Lambda + p\ c^2 > 0$ is satisfied by the dark matter. The evolutionarily earlier upper hemishere is chracterized by the density parameter $0.5 < \Omega_\Lambda = (R/r_g)^2 = 1$ and the less earlier lower hemisphere by $0 < \Omega_m < 0.5$, The recently updated density parameters[21] fall into these ranges: $\Omega_\Lambda \sim 0.685$, $\Omega_m \sim 0.266$, $\Omega_{atom} \sim 0.049$ where Ω_{atom} is the density parameter of the evolutionarily recent atomic matter. The fact that $\Omega_\Lambda + \Omega_m + \Omega_{atom} = 0.965 \sim 1$ can be taken an indication of the asymptotical flatness of the outer space detecting asymptotic solutions of Einstein equations.

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The Dance of the Spinning Top

By Álvarez Martínez, Alejandro & Martín Gutiérrez, Almudena

Abstract- An interpretation of the spinning top movement, the so-called "dance of the spinning top" is proposed. It is based on a mechanical model without a central force, owing to the absence of the same, in spite of the fact that there is curvilinear movement. The path can be interpreted by means of the *Theory of Dynamic Interactions.* This interpretation is valid regardless of the way in which the spinning top has been activated and the manner in which it is bound by the environment.

Following on from the foregoing, we suggest that planetary movement around the sun or that of artificial satellites around the Earth and, in general, all objects endowed with angular momentum on one of their rotating axes in translation and subject to non-coaxial external momenta, could also be interpreted in this way.

Keywords: Theory of Dynamic Interactions, interaction, inertial field, velocity field, torque, orbiting, angular momentum, angular speed, spinning top, planets, satellites.

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The Dance of the Spinning Top

Álvarez Martínez, Alejandro [α] & Martín Gutiérrez, Almudena [σ]

Summary- An interpretation of the spinning top movement, the so-called "dance of the spinning top" is proposed. It is based on a mechanical model without a central force, owing to the absence of the same, in spite of the fact that there is curvilinear movement. The path can be interpreted by means of the *Theory of Dynamic Interactions.* This interpretation is valid regardless of the way in which the spinning top has been activated and the manner in which it is bound by the environment.

Following on from the foregoing, we suggest that planetary movement around the sun or that of artificial satellites around the Earth and, in general, all objects endowed with angular momentum on one of their rotating axes in translation and subject to non-coaxial external momenta, could also be interpreted in this way.

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I. Introduction and Grounds

The rotary movement of bodies is a phenomenon that has hitherto been studied insufficiently. Interest in this area dropped in 20th century only to focus on other aspects of physics that were considered to be of greater import at the time.

Notwithstanding, for some years now, the lecturer Gabriel Barceló Rico-Avello, Doctor in Industrial Engineering and Physics Graduate has been proposing a rotational mechanics that we believe better responds to the behaviour of bodies with intrinsic rotation. We refer to the *Theory of Dynamic Interactions* (TDI), which explains that the rotary movement of a body endowed with intrinsic rotation interacts with the translation of the same. *Dynamic interactions are understood as those inertial reactions that appear when a body is subject to accelerations* [1].

There is a host of rotating bodies that could serve as a subject of study. Nonetheless, this paper restricts its scope to that of the spinning top and, more exactly, to the *dance of the spinning top*, which consists of the curvilinear translation movement made by this body when rotating on its symmetrical axis, which in turn, forms a certain angle with the vertical axis perpendicular to the supporting plane. Moreover, we propose to show that the aforementioned *dance of the spinning top*, is in keeping with the basis of the *Theory of Dynamic Interactions* (TDI).

Intuition would suggest a similarity between this *dance of the spinning top* and the movement of any planet around the sun or that of any artificial satellite orbiting the Earth. Consequently, the conclusions to be gleaned from this behaviour will also be extrapolated to these cases of scientific interest.

Furthermore, other particular instances of the spinning top will be analysed to justify the generalisation of this theory and to show that the interaction is independent of the type of effect that provokes the movement, as long as there is rotation and translation.

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II. Background

As stated by Dr. Barceló Rico-Avello [2], the peculiarity of a rotating body also warranted the attention of some 20th century scientists. Accordingly, G. Bruhat [3] defined it as the *apparently paradoxicalgyroscopic effect*. Likewise, Paul Appell [4] on referring to rotating bodies also frequently insisted on its paradoxical behaviour. Nonetheless, the principles of classical mechanics failed to delve into this aspect.

We believe the original error in the formulation of the theory of the scientific community as regards rotating bodies could lie in the studies of the scientist Louis Poinsot (1777-1859) from two perspectives.

Firstly, he studied the rotation movement with a fixed point (the case of the spinning top were translation not caused on its point of support on the surface) [5].

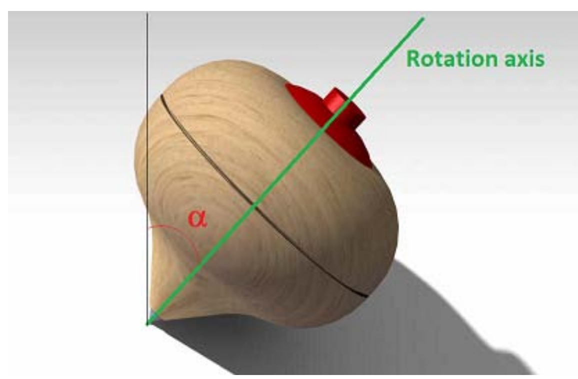

Figure 1 : Spinning top rotation axis and the angle it forms with the vertical

In this analysis he proposed that the *Instantaneous Axis of Rotation* defined by D'Alembert (1717-1783) [6] varied at each moment owing to the movement of the body, forming a cone with a fixed point vertex. However, he further claimed that the axis of rotation also varied inside the body itself. We hold that this starting point is erroneous. From experiments on the rotation movement of spinning top it can be observed that, by taking certain fixed axes on it, its axis of rotation does not shift or rotate in any way with respect to them.

That is to say, as can be seen in figure 1, angle α remains constant.

Secondly, it must be pointed out that Poinsot shows that forces and momenta act on a solid body. However, he further states that "*each one of these dynamic elements produce their forces separately; force determines the translation movement of the body while torque generates rotation around its centre of gravity, without the force exercising any influence*" [7]. Such a reading had already been put forward by Lagrange [8].

This idea, which comes from Classical Mechanics, is the one that has established the method to calculate paths that is still used today. Notwithstanding, we suggest that dissociating translation and rotation in a body where both phenomena occur jointly is mistaken and that the *Theory of Dynamic Interactions* [9] better reflects what really happens, as indicated by Julio Cano in his paper on the pendulum of dynamic interactions. [10]

Other antecedents are known to have questioned the idea of separation. Such is the case of Dr. Shipov, who claims in the context of dynamic energy transfer:

> *Consequently, the law of conservation establishes a connection between translational and rotational forms of movement and makes it possible to transform the translation momentum in a rotational one and vice versa. This means that the law of conservation of momentum in Newtonian mechanics is limited and cannot be generalised to the case of the torsion interactions of colliding bodies.* [11]

Classical Mechanics uses differential equations to calculate paths, the well known "Euler Equations" [12]. Nevertheless, these expressions cannot be integrated even for the case of the movement of the spinning top and, therefore, from this limitation, the need to propose other new ones to provide results for this case arises. Moreover, it must be borne in mind that Newtonian Classical Mechanics is limited to inertial cases. Accordingly, to be able to apply its formula, Coriolis found it necessary to introduce the *Coriolis force* and the *centrifugal force* as fabricated forces for non-inertial cases [13]. Nonetheless, in the *Theory of Dynamic Interactions* we are proposing, there is no need to incorporate fabricated or apparent forces, as the dynamic behaviour of bodies is defined by the coupling of the dynamic fields generated.

Lagrange managed to express the components of angular velocity along the main axes and in function of Euler angles, but he only solved equations for a particular case and was unable to obtain a generalisation or to resolve the case of the spinning top, which is the one that concerns us here. [14].

Subsequently, Sofía Kovalévskaya in her paper entitled *On the rotation of a solid body about a fixed point* [15] attempted to resolve the Euler equations. However, the equations generated four algebraic integrals that it proved impossible to resolve by integration, so she proceeded to resolve them numerically by means of an approximation procedure, thus leaving the general resolution of the equations unresolved.

Some recent studies have been found on the *dance of the spinning top* which in our opinion fall short. Christopher G. Provativis of the Technical University of Athens, published a paper that studies this movement based on the Euler equations and Lagrange's Analytical Mechanics from which he obtained equation systems that cannot be integrated analytically and which he resolved by means of numerical integration, thus arriving at mere approximations. [16]

We came across another thesis in which, on the basis of Lagrange equations and by means of variation calculation, the path of a spinning top in its dance is obtained and visualised. This work compares the different results obtained by different discretizations, but always from the starting point of Lagrangian mechanics [17].

Given the impossibility of resolving the movement equations with the mathematical tools at our disposal and which prevent the confirming of their truthfulness and the relationship between rotation and orbiting, Dr. Barceló proposed the Theory of Dynamic Interactions and a mathematical formula that explains the behaviour of rotating bodies [18].

Indeed, on studying the reactions of a solid rigid body subject to non-coaxial torques, M. Hirn had already concluded in the 19^{th} century that these torques were generating non-homogeneous velocity fields [19]. The *Theory of Dynamic Interactions* also covers the distribution of non-homogeneous fields.

Lastly, it is noteworthy that the Spanish physicist, Miguel A. Catalán, also interested himself in the movement of rotating bodies in the middle of the 20th century, comparing the rotating of an electron around the atom nucleus to spinning top movement [20]. Indeed, he is the lecturer that inspired Dr. Barceló Rico-Avello to develop the theory set forth in this paper.

III. "The Dance of the Spinning Top" and the Theory of Dynamic Interactions

When a spinning top starts to move, it does so owing to a torque acting on it that provokes its rotation.

If the axis of rotation of the spinning top remains perpendicular to the support surface this body stays spinning on a fixed point without shifting. However, what happens when this perpendicularity no longer holds?

By observation, it can be deduced that the spinning top will continue its rotating movement with respect to its rotation axis, which coincides with its symmetrical axis, and will move on the surface tracing a curved path. In this case, it is possible to speak in terms of displacement physics, given that the spinning top point is not fixed on the surface, i.e., it does not have zero speed but rather shifts position.

This curved path, under surface support and smooth displacement conditions (uniform friction coefficient) will be closed and, the more ideal the conditions in which the experiment is being conducted (absence of air) the closer it will come to tracing a circular path.

We have come across historical descriptions of this so-called *spinning top dance* behaviour accompanied by illustrations reflecting this movement (figure 2), as well as descriptions that explain that the spinning top would rest on the support surface if it was not for its rotation (figure 3). [21].

According to Classical Mechanics, a body in movement traces a curved path if there is a force that modifies its straight movement towards its inside at each point of movement (centripetal force). However, the forces acting on the spinning top are weight and the normal reaction with the surface, both of which are perpendicular to the support plane. Neither of them are, therefore, central forces.

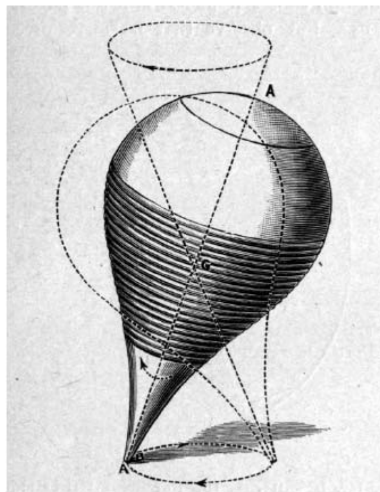

Figure 2 : Dance of the spinning top.

Source: Perry, J. (2010). Spinning Tops. (pg. 21)

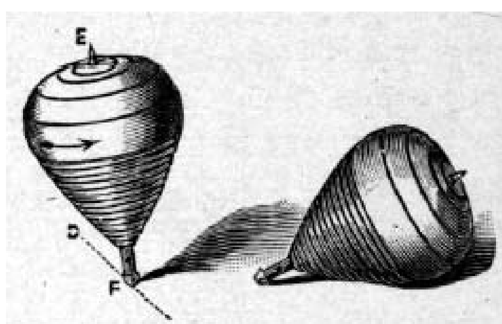

Figure 3 : Spinning top with and without rotation

Source: Perry, J. (2010). Spinning Tops. (pg. 21)

What, therefore, causes this path? We suggest that the reason for it is to be found in the momentum generated by the weight of the spinning top with respect to the point of support, which will provoke the overturning of the spinning top but this, instead of falling, if its support point allows it to slide, will start this dance. (See video: www.advanceddynamics.net/spinning-top-video/). [22] This idea can be seen in figure 4. It is the same effect as produced on the flight of the boomerang, the rotational and orbital movements of which have also been studied. Dr. Barceló suggests in this case:

The weight, a force applied at the boomerang's centre of mass, will not coincide with the resulting lift force, determining a couple that acts at the same time with the rotation, but without being coaxial with it. […] The couple will generate a rotation momentum that tends to tilt the boomerang around its flight direction axis. […] The weight couple and that resulting from the lift forces, which is non-coaxial with the intrinsic rotation of the boomerang, will be the dynamic interaction couple that generates the new path. [23]

This situation (see video) is possible owing to the intrinsic rotation of the body, given that were there no rotation, the spinning top would fall onto the surface.

Accordingly, the interaction between the rotation movement and the translation of a body has been explained.

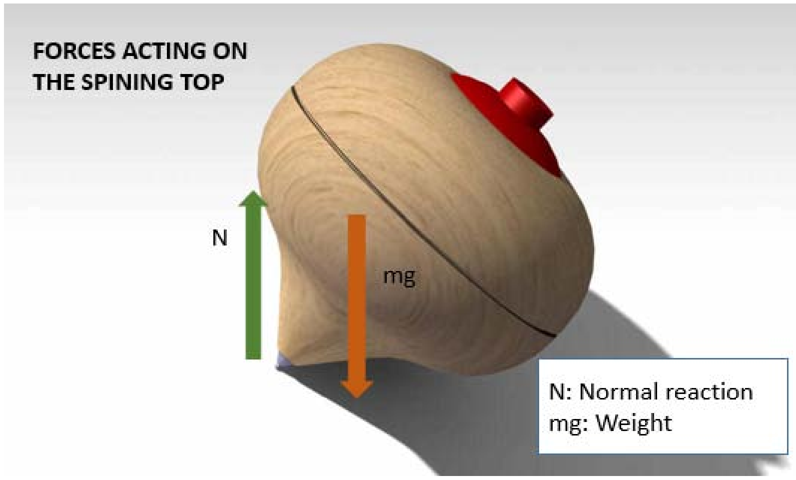

Figure 4 : Forces acting on the spinning top

IV. Similarity with the Planets Orbiting the Sun

Euler [24] was the first to announce the similarity between the Earths' movement around the sun and that of the spinning top. What we intend to do in this paper is not solely to reaffirm this similarity, but rather to explain that the reason behind the Earth's orbit resembles that of the "dance of the spinning top".

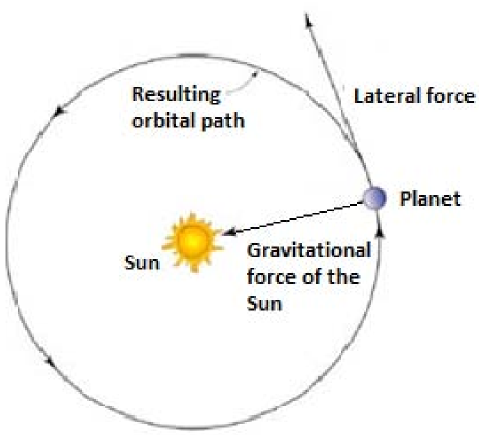

Figure 5 : Forces acting on the Earth according to Newton

Source: http://spaceplace.nasa.gov/review/dr-marc-solar-system/planet-orbits.sp.html

Isaac Newton [25] explained that the Earth's orbit around the sun was caused, on the one hand, by a tangential acceleration and, on the other, by a central force, the sun's force of attraction that acts as a centripetal force and which causes the body to deviate from its straight path, thus converting it into a curved one. In this way, Newton also explained why the Earth, or any of the planets, is at a certain distance from the sun and not stuck to it by virtue of its gravitational force. This idea can be seen in figure 5.

However, Newton's explanation of this orbit is brought into question by the *Theory of Dynamic Interactions*. This theory holds that, as is the case with the spinning top, the orbit of any planet around the sun is not necessarily caused by a central force, but rather by the momenta of forces. This is so based on the first corollary of the tenth law that underpins this theory: "*It is possible to infer the existence of inertial dynamic interactions in rotation and orbital phenomena from the momenta of forces.*"[1]and[26]

Obviously the dance of the spinning top is not caused by any central force, owing to the inexistence of the same, as has been explained in the previous section. However, this idea is not as obvious in the case of a solar system planet because the existence of the force of attraction of the sun is a reality. What follows is an attempt to explain and justify it.

The Earth or any planet is, as are the majority of bodies in space, rotating while at the same time moving in translation. As indicated in the principle of inertia formulated in Newton's laws [27], if there is no effect to impede it, such bodies would continue to move in a straight line. The planets orbit around the sun, thus obviously there must be something that provokes the curved path. Accordingly, the *Theory of Dynamic Interactions* is being proposed as a conceptual framework within which to explain the mechanics of celestial bodies understood as rigid solids subjected to successive non-coaxial rotations. [28]

The *Theory of Dynamic Interactions* holds that the orbit is not caused by the gravitational force of the sun, given that, were this the case, the planets would be stuck to it, but rather by the torque exerted by the sun on the centre of the mass of planets, as a result of its position not coinciding with the centre of the same.

On account of the non-homogeneous constitution of planets, the centre of mass of these is displaced as regards their geometrical centre. Accordingly, the force of the sun's attraction, which will have the direction of a vector that passes through the centre of mass of the sun and that of any planet, will provoke a momentum on the geometrical centre in such a way that the planet, with intrinsic rotation, is subjected to a new non-coaxial momentum. The TDI accepts that the velocity field generated by this new, non-coaxial momentum couples with the translation velocity field thus causing the new orbital path around the sun.

Hitherto, the resemblances have been shown between the spinning top movements and that of the planets. An important difference must now be highlighted: the rotation axis of the dance of the spinning top is inclined with respect to the path. This means that, owing to the effect of the weight, the rotation axis of the spinning top varies with respect to the inertial reference system by tracing a cone. In the case of the Earth, its axis of rotation maintains practically the same inclination with respect to the inertial system along any point of its orbital path. Of course, there will be variations, but much slower and imperceptible, taking some 25,800 years to trace a complete cone. This idea can be seen in figures 6 and 7.

We claim that the oscillation of the Earth's axis, a phenomenon known as *Chandler wobble*, is caused by gravitational forces, as in the case of the spinning top. It must basically be the gravitational force of the moon that makes the axis of rotation of the Earth so stable and showing such extremely slow variations.

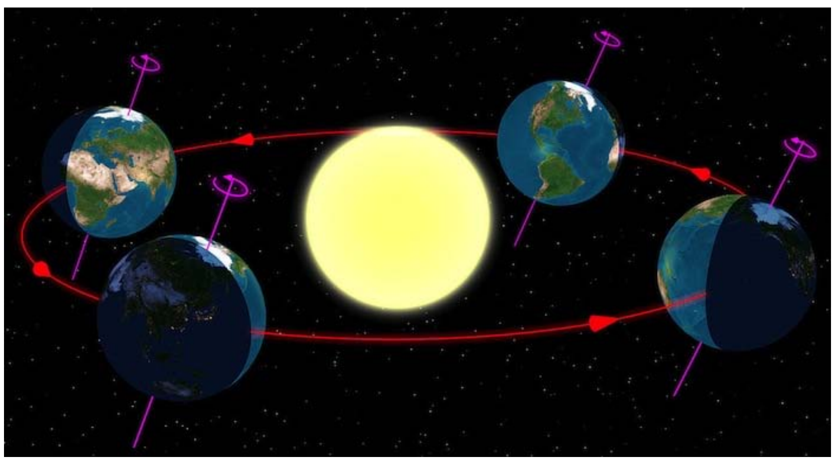

Figure 6 : Situation of the Earth in orbit at several positions.

Source: www.geoenciclopedia.com/movimientos-de-la-tierra/

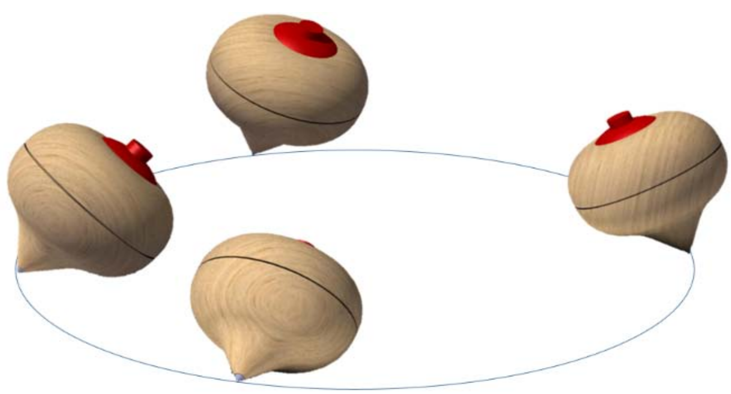

Figure 7 : Situation of the spinning top during its "dance" at several positions

V. Similarity with Artificial Satellites Round the Earth

Even though the case of an artificial satellite orbiting around the Earth resembles that of the Earth around the sun and, therefore, that of the spinning top dance, there will be differences as regards the mechanism that keeps the satellite orbiting around the Earth.

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Dr. Barceló Rico-Avello already expounded his intention to extend the Theory of Dynamic Interactions in *Un mundo en rotación* (A Rotating World) [18] to communication satellites which, having an initial speed and endowed with intrinsic rotation if subject to a non-coaxial torque, will assume an orbiting movement.

Obviously, for a satellite to orbit around the Earth at a certain height over its surface, a launch vehicle is required to generate the thrust that will position it at that height. Moreover, it is also clear that, if at that height the thrust no longer exists, the satellite will return to the surface of the Earth, impacting against it, owing to the Earth's force of gravity. Consequently, some type of propellant is needed to generate a force parallel to the Earth's surface that will be sufficient not to represent a simple launch that eventually "spends itself" and returns to the Earth's surface on account of the gravitational action. This force is called thrust.

The thrust will suffice if it provides the satellite with the required orbital speed at that height to orbit the Earth and will be determined by the energy equation. This speed will depend on the Earth's mass [29].

The thrust can be exerted in two different ways, depending on whether it is produced by a motor located on the axis of symmetry of the satellite or from several situated around the same and structurally attached to it. In both cases, a non-coaxial momentum will be caused with respect to the axis of symmetry of the satellite, given that its centre of mass is not going to be located exactly on this axis owing to the heterogeneity peculiar to all satellites, which is inevitable. This will make the satellite rotate owing to the momentum caused and, in turn, endow it with a translation movement on account of the thrust, thus generating a path that will be curved; once again accounting for the *Theory of Dynamic Interactions* and clearly showing that, as is the case with the dance of the spinning top, the movements are not caused by a central force, even though in this case the Earth is indeed the centre of the movement.

Lastly, it must be pointed out that satellites are stabilised by different mechanisms to undertake the mission for which they have been launched and thus are not orbiting with the described characteristics.

VI. Interaction of Fields on the Spinning Top

In all movements there is another physical vectorial magnitude that acts about which no mention has yet been made, namely, translation velocity. In this section, the velocity fields are analysed that are present in the "dance" movement of the spinning top along with inertial fields and, with them, it will be explained how the moving spinning top maintains its position as it does. (See video).

The foregoing is based on the following idea: *"orbital movement is an inertial reaction caused by the distribution of speeds and accelerations that are generated by the action of the second external torque that is acting."* [18]

This idea is based on the four axioms [1] that were announced after long years of research and on which the later field analysis is based:

1. The rotation of space determines the generation of fields.
2. Result of the action of non-coaxial momenta.
3. Inertial fields cause dynamic interactions.
4. The resulting action of the different successive, non-coaxial torques that act on a rigid body cannot be determined by an algebraic sum or be calculated by means of an alleged resulting torque.

The *Theory of Dynamic Interactions* holds that when a rigid solid is subjected to the successive couplings of forces, the first momentum will cause its intrinsic rotation (in this case the rotation of the spinning top on its axis of symmetry) while the subsequent momenta will generate the non-homogenous velocity fields [23].

If the spinning top is placed vertically on its axis and it is endowed with a rotary movement, it will be left rotating on its axis of symmetry and will take longer to fall the faster it rotates. When the spinning top starts to rotate it will also start its dance, even though it has not been endowed with a thrust that provides it with a quantity of movement. It can be understood that at the initial moment, the axis of symmetry undertakes a falling movement endowing the centre of mass with an initial linear velocity, and finally, the spinning top will rotate and orbit at the same time. It can also be supposed that the spinning top's (or those of any rotating body) angular momenta do not add up algebraically or vectorially, resulting in a final momentum and therefore, no general law of the composition of momenta is obtained [18].

Firstly, (see video), a study is made of the fields to which the spinning top is subject at a particular instant of its movement, that is to say, on certain fixed axes to the same, without considering translation.

Figure 8 shows in blue the instantaneous inertial field generated initially on a spinning top that is tilted owing to the effect of the torque action of the forces present on the spinning top: the weight and reaction of the ground on the spinning top. This field will be perpendicular to the radius of the tilt and tangential to the tilt path.

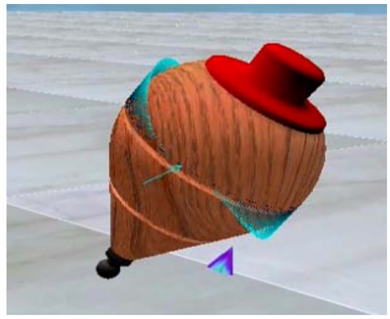

Figure 8 : Inertial fields on the spinning top (without considering its translation movement).

Nevertheless, were only this inertial field to exist, the spinning top would fall and impact against the ground. Therefore, the velocity and inertial fields are coupled thus causing its new path. This has also been observed and mentioned in other studies on bodies in which dynamic interactions are to be found [18] [30].

The body is endowed with intrinsic rotation on its axis of symmetry, which is going to cause a linear velocity on each point of the spinning top. As we are dealing with a rigid solid, this linear velocity value will be constant at each one of its points on the same disc at the same time.

Moreover, the tilt velocity generates a velocity that makes the spinning top fall onto its support surface. The velocity field in yellow in figure 9 that is tilted 90º with respect to the instantaneous tilt velocity is precisely the one that is going to prevent the overturning of the spinning top.

The maximum tilting velocity in the downward direction will correspond to the closest point to the surface (red point in figure 10). The maximum upward tilting velocity will be at 180º from this. Nevertheless, in the first revolution of the spinning top, the amounts of movement will be summed up in successive instants at each point on it. Accordingly, the initial maximum tilting velocity at the following instant will have been shifted by the rotation of the spinning top and the tilting velocity corresponding to its new position will be added to this tilting velocity leading to a change in velocity value. Therefore, on completing the first revolution, the tilt velocity field will have been displaced 90º thus giving rise the situation in figure 9. This situation will hold as long as the spinning top is in a state of dynamic stability. This succession of states until attaining stability (figure 9) can be seen in figure 10.

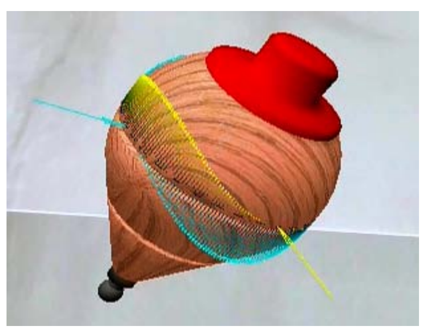

Figure 9 : Resulting velocities fields (yellow) and tilt velocities fields (blue) on the spinning top (without considering its translation movement)

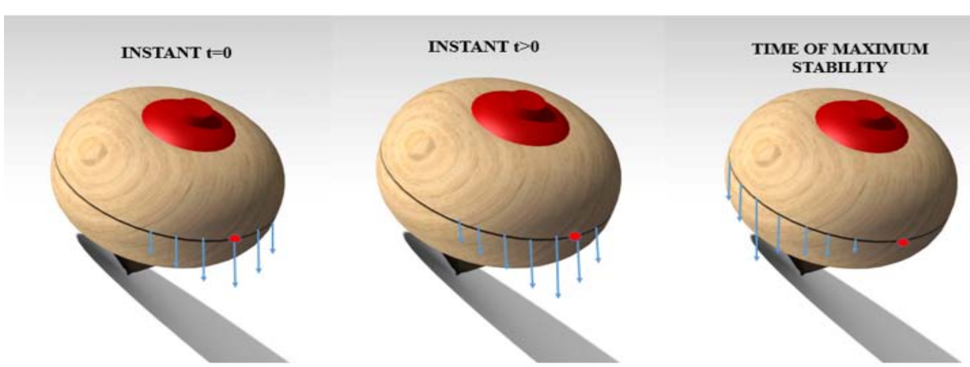

Figure 10 : Spinning top tilt velocities from the initial instant to maximum stability

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It must be pointed out that, owing to friction with the surface and the Magnus effect, the linear velocity that caused rotation will begin to fall. The translation of the velocities field will, then, be contrary to that which was seen when it was increasing, reaching a moment in time in which it coincides with the situation at the initial instant and which causes, therefore, the spinning top to overturn.

In the light of the foregoing, it is understood that the spinning top movement passes from a transitory state in which the linear velocity of rotation of the spinning top increases to a dynamic stability in which this linear velocity is constant, until this speed falls entering once again in a transitory state until it comes to nothing and the spinning top is left overturned on the surface. The states of equilibrium correspond to states of spinning top stability, on the understanding that the concept of equilibrium is not restricted to "static equilibrium". According, Gabriel Barceló claims as follows: "*In accordance with the Theory of Dynamic Interactions proposed, we conceive a universe in dynamic equilibrium in which a constant orbit movement acts inside a closed path.*" [1]

However, it must not be overlooked that the linear translation velocity acts at the same time as the tilting velocity. The yellow velocities field couples with the system's translation velocities field thus generating the movement that is observed. The variation in the time of the two velocities fields gives rise to acceleration fields that serve to generate a force field. The force of these two fields is the effective force produced on the system.

Take the following axes (see video): the green triad symbolises the translation reference system of the solid, where the vector T indicates the direction of translation from the centre of mass of the solid, while R indicates the radial direction that points towards the centre of the curve traced by the dancing spinning top. The yellow triad symbolises the reference system without translation with respect to the foregoing, but tilted in accordance with the inclination of the body to the vertical plane of the Earth. These systems of axes are represented in figure 11.

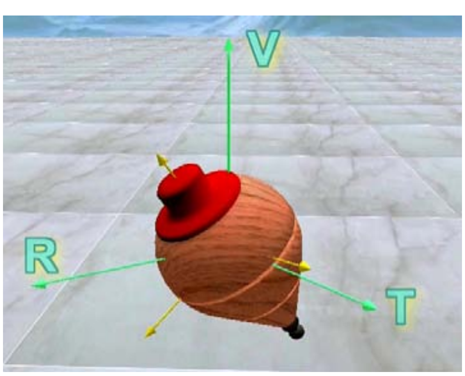

Figure 11 : Systems of axes on the spinning top

Based on the analysis conducted and the observation of the rotary and translation movement of the spinning top, (see video) the proposed axioms are duly corroborated and in the light of the coupling of the fields of velocities it can be concluded that: "*the body will keep to a closed path (e.g., a an orbital movement), without any need for a central force, and will simultaneously intrinsically rotate around its initial axis.*"[31].

VII. Magnetic Spinning Top

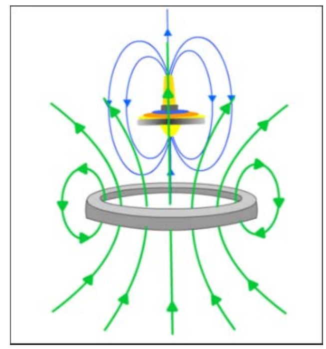

Figure 12 : Magnetic spinning tops

Source: *http://cienceandoenelsulayr.blogspot.com.es/2014/09/inicio-del-curso-2014-2015.html*

The magnetic spinning top, save for those that can levitate on account of the magnetic repulsion effect, behaves similarly to the conventional spinning top in terms of movement and, therefore, can only be distinguished from it because of the way in which it is activated and in the variations of angular velocity to which its rotation may be subject, owing to the variations in the magnetic forces applied. The spinning top must be magnetised to apply the external forces. These ideas about the magnetic spinning top have already been expounded by Gabriel Barceló in his book *Un mundo en rotación*(A Rotating World) [18]:

> *The disc would be activated remotely by a magnet. Magnetic spinning tops subjected to different external magnetic forces confirm the action of external magnetic torques in the variation of the rotating and orbiting velocity owing to the magnetic induction effect. This is also the case of a magnetic spinning top that keeps a constant rotating movement owing to the effect of an electromagnet acting by impulses, or which levitates in a magnetic field. In these cases, the orbital path generated has been confirmed for different rotating velocities and different levels of friction with the support surface.*

The foregoing, therefore, leads to the following conclusion: it is possible to propose a generalisation of the *Theory of Dynamic Interactions* for any body endowed with intrinsic rotation, regardless of the way in which this rotation is activated or the type of the external forces and momenta acting on it. We have now seen several cases: the conventional spinning top, planets, satellites and magnetic spinning top in which this theory is confirmed and in different circumstances the reason why the intrinsic rotation was different.

VIII. TDI Equations on the Spinning Top

The paths of several, different sized spinning tops with different masses have been traced to check compliance with the mathematical formula for the *Theory of Dynamic Interactions* in the case of the spinning top; paths that have been calculated applying the TDI. The results obtained are shown below.

The mathematical formula for the *Theory of Dynamic Interactions* is as follows[30]:

$$\vec{v} = \Psi \vec{V_0}$$

Where Ψ is a rotation matrix defined as follows:

$$\Psi = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha \\ 0 & \sin\alpha & \cos\alpha \end{bmatrix}$$

Where $\alpha = t\frac{M'}{I\omega}$, M' is the external momentum, I the body's inertial momentum, in this case of the spinning top and ω the angular velocity of the rotating body [18].

Figure 13 shows two images of the first experiment. The image on the left shows the real path followed by the spinning top, while the one on the right, the path calculated according to TDI, considering the deceleration caused by dissipative forces (surface friction). This first experiment was done as follows: a spinning top was activated on a wooden table surface by means of a torsion spring. A video was recorded of the spinning top in movement and later images were captured at intervals of a second. Accordingly, the different positions of the spinning top were located during movement, which are the points plotted on the graph to the left of figure 13.

It can be seen that both paths are similar though the second one will be more perfect on having considered the dissipative forces causing an homogenous deceleration, when in reality this will depend on the friction coefficient at each surface point, which may not be homogenous.

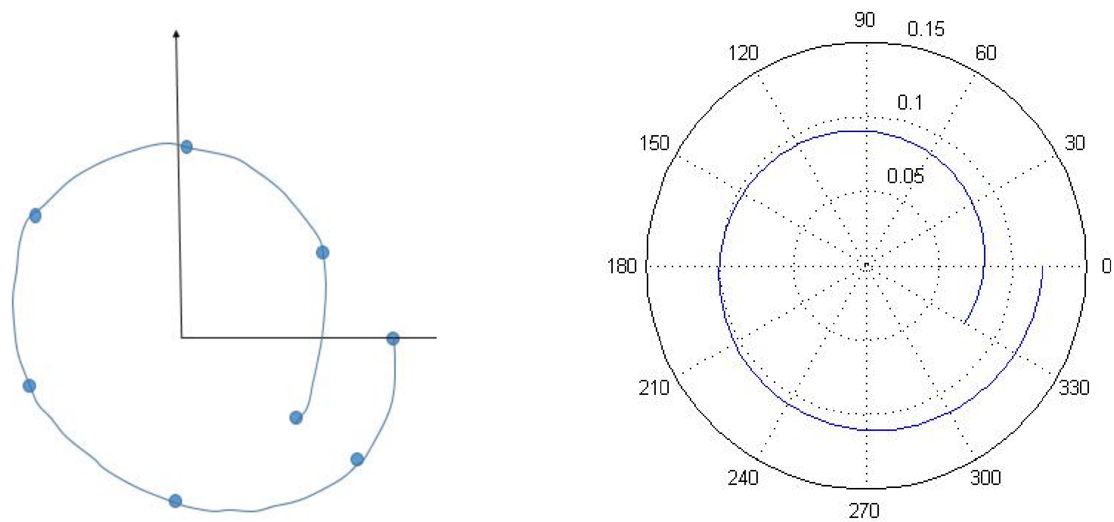

Figure 13 : Real path of the spinning top and the path calculated by TDI

Another experiment was conducted to assess the TDI results. In this experiment it was possible to obtain a high number of path points at halfway along the revolution of the dancing spinning top. These points were used to produce a graph that was superimposed on the one obtained by using the TDI. The result of this can be seen in figure 14.A second experiment was designed to obtain a greater number of points. This time, the spinning was activated as before, but it was placed on a sheet covered with powder to trace the path taken.

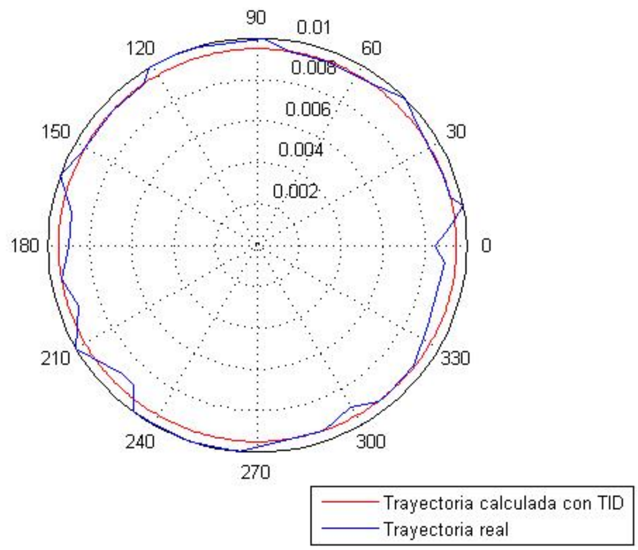

Figure 14 : Superimposition of real spinning top path graphs and the one calculated in accordance with the TDI (I)

Figure 14 shows the real movement of the spinning top at the start of the same. At this moment in time, the linear velocity begins increasing, which is reflected in the increase of the radius until such time as the dissipative effects cause it to diminish as can be seen in the graph. The difference between the real path and the calculated one arises from the difference in the coefficient of friction on the support surface, because as stated above, this was a sheet covered in powder. Moreover, this gap between the real path and the calculated one came about because the surface had a slight inclination that caused the increase of the radius.

A third experiment was done to reduce the difference among friction coefficients throughout the surface. This obtained the path of a complete revolution owing to the spinning top being able to paint on the surface travelled. However, this spinning top was of greater mass than the previous one so its path radius was smaller. This explains why less points were obtained and greater accuracy attained as regards the tracing of the path. Consequently, in figure 15, a path can be perceived that resembles the one calculated by the TDI, but which has gaps owing to the paucity of the data sample.

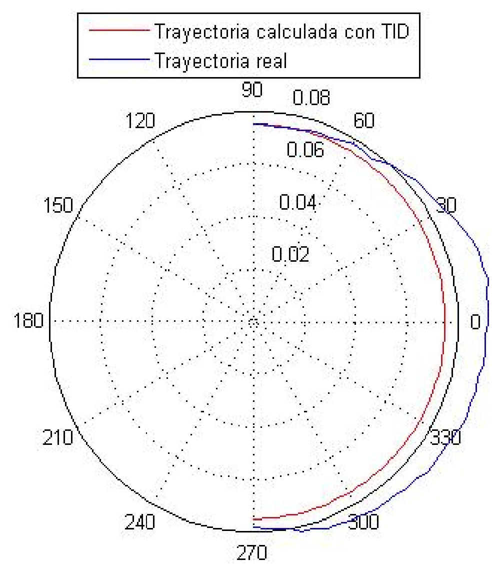

Figure 15 : Superimposition of real spinning top path graphs and the one calculated in accordance with the TDI (II)

In the light of the foregoing, it has been seen that the *Theory of Dynamic Interactions* manages to closely approximate the path of the spinning top and surpasses that of the Euler equations that did not allow for integration with respect to the case of the spinning top.

IX. Angular Momentum on the Dance of the Spinning Top

We also analyse the conservation of angular momentum on the movement of the spinning top. The angular momentum is transferred to the spinning top by means of a thrust that is generated on applying a torque in several ways [32].

As regards this issue, the following reflection by Dr. Barceló Rico-Avello must be mentioned:

*This behaviour of nature can also be interpreted in the field of physics by the fact that, under such circumstances, **angular momenta are not added up**, so if a body is subject to an angular momentum **L**, its variation ΔL, due to the effects of external forces, will not necessarily be added to the already existing **L**, but rather can generate a new movement, different and simultaneous to the existing one, which we have called **precession movement** or, where appropriate, **orbital movement.** This would be the case of the spinning top, and in the case of a body in space without any restraint, like a boomerang, or numerous other like objects, the body will begin to orbit without the necessary existence of a central force.* [18]

In the case of the spinning top it is possible to differentiate three rotations (figure 16).

The inertial momentum of the spinning top does not vary given that we are dealing with a rigid body and, therefore, it will always have the same mass and be distributed in the same way. Consequently, the variation in the angular momentum is going to be determined by the angular velocity and will be constant in each axis system if the angular velocity in these is also constant.

The conservation of the angular momentum in the rotating of a spinning top (with respect to 0 axes) has already been expounded by A. Fernández-Rañada:

*When the aforementioned angular velocity is high, the inertia of the spinning top due to its spinning on its own axis is very high and the external torque does not suffice to appreciably change I ω (…). Therefore, the **L** value of the angular momentum remains constant. As must be the conclusion that the angle formed by the axis of rotation and the Z axis must also be constant. In order for these two conditions to be met in the presence of the M torque, the axis of rotation of the spinning top has to trace a cone solid of revolution thus causing a precession movement around the Z axis.* [33]

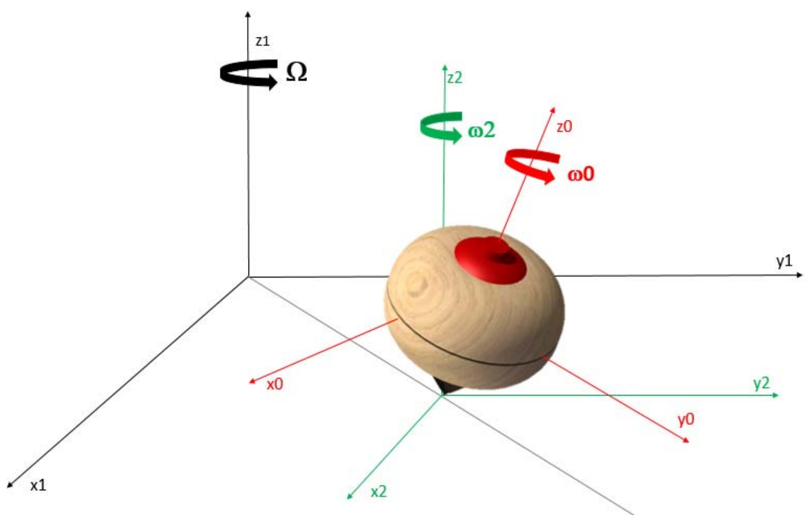

Figure 16 : Illustration of rotations in the "dance of the spinning top"

X. Future Lines of Research

The most important issues have been dealt with throughout this paper that are considered essential to showing how the *Theory of Dynamic Interactions* explains the dance of the spinning top and other bodies that behave similarly in reality and that may be of interest to the reader. We now deal with other issues related to the subject matter discussed, albeit outside the scope of this paper, but which point to future lines of research.

We know that the Earth makes the following movements: rotation on its own axis, orbiting around the sun, equinoctial precession, along with another we have had cause to mention: the Chandler wobble [34]. It would be interesting were future research to study the latter movement in relation to the others. In the "*El vuelo del bumerán*" (The Flight of the Boomerang) [2], Gabriel Barceló has already hinted at this subject:

In 1758, Euler predicted that the axis of rotation of the Earth also had a further movement with respect to a fixed frame of reference. In 1891, Chandler determined the time interval of this free polar movement. The oscillation radius of the Chandler wobble on the Earth's rotation axis is around 6 m.

It is also proposed that research be done to confirm or refute Poisont's [5] claim that there is an instantaneous axis of rotation that is different at every instant of the movement, both on inertial axes, as well as on those axes bound up with the solid. This seems to coincide in the first case, but not in the latter, given that this would mean having a different axis of rotation to the axis of symmetry at every moment of rotation, whereas observation seems to reflect otherwise.

We also suggest research be done into the technological applications that could be developed on the basis of the *Theory of Dynamic Interactions* proposed by Dr. Barceló in previous papers. [35].

Lastly, we suggest that the reader have another look at the video to better understand the behaviour of the spinning top: www.advanceddynamics.net/spinning-top-video/

You can consult the following links for further information on the *Theory of Dynamic Interactions:*

http://advanceddynamics.net/
http://dinamicafundacion.com/

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Analytical Determination of Subsurface Temperature using Two Layers Model in Part of Niger Delta Sedimentary Basin, Nigeria

By Emujakporue, Godwin Omokenu
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Abstract- The solution of Fourier's one-dimensional steady state conduction heat flow equation for two layers-model has been solved using the analytical techniques and applied to part of Niger Delta sedimentary basin. The temperature-depth profile obtained shows a linear increase in temperature with depth. The internal properties affecting the thermal structures are the thermal conductivity and heat production. Comparison of measured and computed temperatures for some wells showed good agreement with minor variation ranging between -4.0 to 5.0 oC. This model can be used to determine thermal properties of other parts of the basin with little adjustment of the rock properties values.

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I. Introduction

Geothermal heat flow is a natural process by which heat is transferred from the earth interior to the surface. Heat can be transferred by three different ways, namely conduction, convection, and radiation (Cacace et al., 2010; Beardemore and Cull, 2001).Conduction is the major process by which heat is transfer through the solid part of the earth (crust) while in the fluid part (mantle) heat is usually transfer by convectional method. Geothermal heat flow variation is dependent on subsurface temperature variation and distribution, rock thermal conductivity and depths to heat sources.

Some researchers have worked on the geothermal gradient and heat flow of different parts of the Niger Delta sedimentary basin using bottom-hole or continuous temperatures. Two of the researchers (Odumodu and Ayonma, 2014) calculated the geothermal gradient and heat flow in parts of the eastern Niger delta from bottom hole temperature in 71 wells and obtained geothermal gradient varying between 12 to 24°C/Km with an average of 17.6°C/Km in the coastal swamp, 14°C /Km to 26°C/Km with an average of 20.4 °C/Km in the shallow offshore. They obtained average heat flow value of 42.5mWm^{-2}. Another group (Chukwueke et al., 1992) discovered that the geothermal gradients and heat flow values in the distal part of the Niger delta varies between 19-32°C/Km and 45-85mWm^{-2} respectively.

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The major source of information about subsurface temperature is from continuous or bottom hole temperatures measured in oil wells(Rider, 2002). Unfortunately, as a result of high cost and limited depth of drilling, current drilling campaigns in the Niger delta are limited to depths of only a few kilometres and at certain places, rendering direct and complete characterization of the entire subsurface thermal regime impossible to be carried out. Therefore, it is imperative to predict subsurface thermal conditions using alternative means. One method, is by solving Fourier's 1-D steady- state conduction heat flow equation for various layer models and applying it to a given basin.

A steady-state heat flow occurs when the amount of heat arriving and leaving a column of substance is equal over long period of time. Heat conduction across unit area, is a function of thermal property of the material and thermal conductivity. The ability of a substance to transfer its internal heat from one point to another depends on its thermal conductivity(Turcotte and Schubber, 2002; Safanda, 1985; Rudnick et al., 1998). The basin model is based on an extensional sedimentary basin where heat transfer by conduction dominates and the effect of advective transfer of heat by circulating groundwater is negligible due to flat surface topography. The spatial variation of temperature of a sedimentary basin is dependent on thermal conductivity, boundary conditions, water flow, rate of sedimentation and erosion and radiogenicheat production.

The objective of this research is to perform analytical modelling of 1-D conductive steady state temperature distribution of part of the Niger Delta by using two layer techniques and to characterize the geothermal features of the subsurface. The analytical solution of the 1-D Fourier heat flow for two layers model will be used to compute the subsurface temperature of the study area which will be compared with measured temperature from some oil wells.

II. Summary of the Geology of the Niger Delta

Figure 1 shows the location of the study area within the Niger Delta sedimentary basin. The Niger Delta is the youngest sedimentary basin in the Benue

Trough system and it started developing after the Eocene tectonic phase (Ekweozor and Daukoru, 1994; Doust and Omatsola, 1990). The Niger and Benue Rivers is the main supplier of sediments. The thickness of the sediment is approximately 12.0 Km.

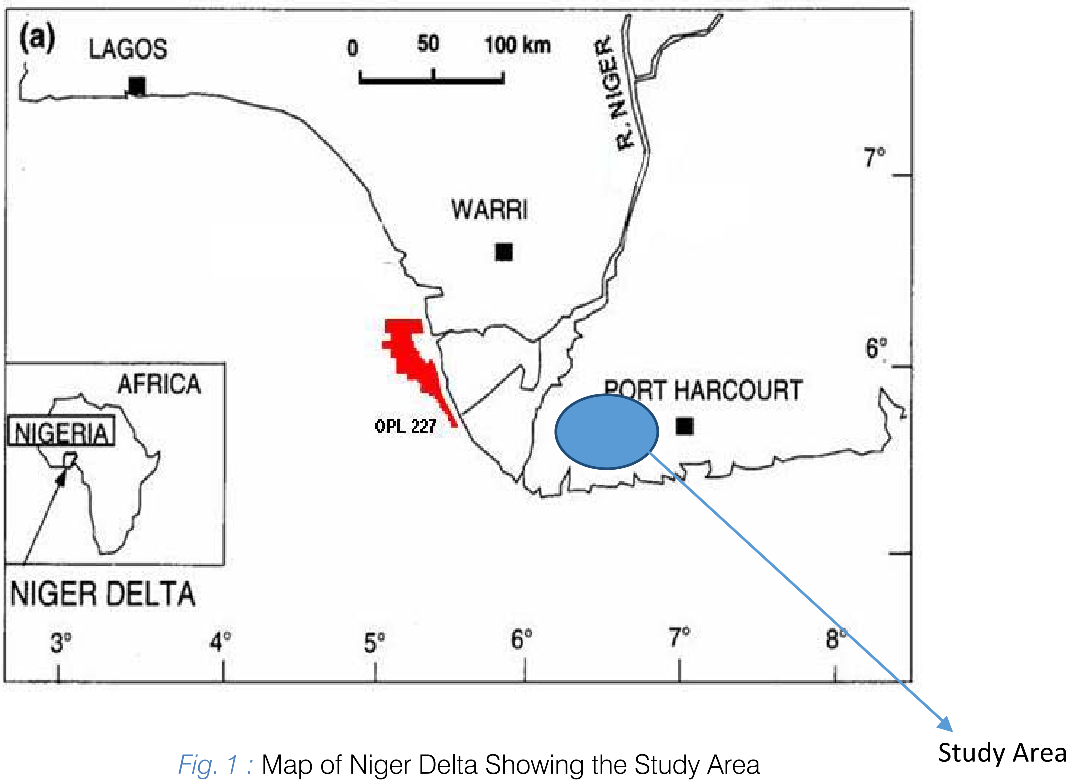

Fig. 1 : Map of Niger Delta Showing the Study Area

The Tertiary portion of Niger Delta is divided into three lithostratigraphy (Figure 2.) representing prograding depositional facies that are distinguished based on sand – shale ratios. The lithostratigraphyare Benin, Agbada and Akata Formations(Ekweozor and Omatsola, 1994; Kulke, 1995). The Benin Formation is the youngest of the Delta sequence and it consists mainly of sand and gravels with thickness ranging from 0 - 2100m. The sands and sandstones in this Formation are coarse – fine and commonly granular in texture and partly unconsolidated. Very little oil has been found in the Benin formation, and it is the major source of portable water in the area.

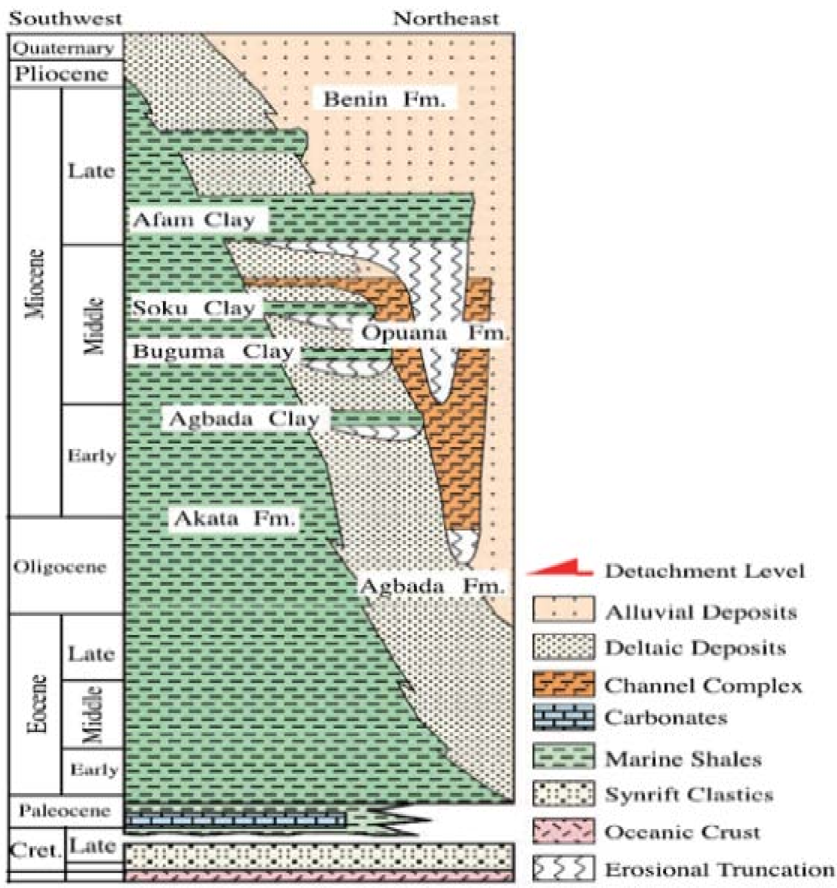

Fig. 2 : Stratigraphic setting of Niger Delta showing the three formations of Niger Delta (modified after [1])

The Agbada Formation consists of alternation of sandstones and shale. The deposition of Agbada Formation began in Eocene and continues into Pleistocene. Shale and sandstone beds were deposited in equal proportions in the lower portion. The upper portion consists of minor shale interbed. The thickness of the Agbada Formation ranges from 300m – 4500m. Most reservoir in the Niger Delta are found in the Agbada Formation.

The Akata Formation forms the basal part of the Delta complex. It is of marine origin and it is made up of thick shale sequence (potential source rock), turbidite sand (potential reservoir in deep water) and minor amount of clay and silt(Avbovbo, 1978). Beginning in the Paleocene and through the recent, the Akata Formation was formed when terrestrial organic matter and clays were transported to deep water areas characterized by low energy conditions and oxygen deficiency. The thickness of the Akata Formation ranges from 0 – 6000m. The formation out lies the entire Delta, and is typically over pressured. It is the major source rock in the basin.

III. Materials and Methods

In order to characterize the process of heat transfer in the subsurface, it is necessary to understand the underlying physical principle. The general conduction equation governing heat transfer in the Earth is the Fourier heat equation (Mussett and Khand, 2000; Lowrie, 2007). The one-dimensional steady state heat conduction equation in vertical direction in a sedimentary column for a two layers model(Fowler, 2005) is given as;

$$\frac{d2T}{dz2} = -\frac{A1}{K} \quad (1)$$

And

$$\frac{d2T}{dz2} = -\frac{A2}{K} \quad (2)$$

Where

T = temperature (°C)

$A\ (1)$ = radioactive heat production for layer 1

$A\ (2)$ = radioactive heat production for layer 2

K = thermal conductivity (Wm^{-1} °C)

z = depth (m).

The radioactive heat production is as expressed as source (mWm^{-3}). The assumed two layers are the Benin and Agbada Formations of Niger Delta sedimentary basin. Assuming the heat production in the Benin and Agbada Formations are A1 and A2

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respectively and the boundary between the two lithostratigraphy is Z1, then the ordinary differential equations 1 and 2 can be solved by applying the following assumptions and boundary conditions:

Assumptions

A = A1 for $0 \leq z < z1$ (Benin Formation) (3)

A = A2 for $z1 \leq z < z2$ (Agbada Formation) (4)

Boundary Conditions

T = 27°C on z = 0 (5)

Q = −Q2 on z = z2. (6)

Where

Q2 = heat flow from the base of the Agbada Formation.

The average surface temperature in the Niger Delta is 27°C. The basal heat flow Q=-Q2 is negative because heat flow upwards out of the earth, which is in the negative z direction. It is straightforward to solve the second order temperature differential equations (1 and 2) with two integrations. Integrating the differential equations two times results in two integration constants. The constants can be obtained by applying the two boundary conditions(Stein, 1995; Gibson, 2008). Integrating equations (1 and 2) once, we obtained

$$\frac{dT}{dz} = -\frac{A1}{K}z + C1 \quad (7)$$

And

$$\frac{dT}{dz} = -\frac{A2}{K}z + c2 \quad (8)$$

Integrating equations 7 and 8, then

$$T1 = -\frac{A1Z2}{K} + C1Z + C3 \quad (9)$$

And

$$T2 = -\frac{A2Z2}{K} + C2Z + C4 \quad (10)$$

Where T1 and T2 are the temperature regimes of Benin and Agbada Formations respectively. Applying the first boundary condition (equation 5) to equation 9, at the earth surface, then

$$C3 = 27 \quad (11)$$

Equation 7 is equal to equation 8 at the boundary between the two layers (Z1), therefore

$$-\frac{A1}{K}z1 + C1 = -\frac{A2}{K}z1 + c2 \quad (12)$$

Solving for C1 in terms of C2, then

$$C1 = -\frac{A2}{K}z1 + \frac{A1}{K}z1 + c2 \quad (13)$$

Putting equation 13 into equation 9, we have

$$T1 = -\frac{A1Z2}{K} + \left(-\frac{A2}{K}z1 + \frac{A1}{K}z1 + c2\right)Z + C3 \quad (14)$$

Substituting equation 11 into equation 14, we obtained

$$T1 = -\frac{A1Z2}{K} + \left(-\frac{A2}{K}z1 + \frac{A1}{K}z1 + c2\right)Z + 27 \quad (15)$$

At the base of the Agbada Formation (Z= Z2), applying second boundary condition (equation 5);

$$\frac{dT}{dZ} = \frac{Q2}{K} \quad (16)$$

Comparing equations 8 and 16, then

$$\frac{Q2}{K} = -\frac{A2}{K}z2 + c2 \quad (17)$$

Solving for C2 in equation 17, we obtained

$$c2 = \frac{A2}{K}z2 + \frac{Q2}{K} \quad (18)$$

Substituting equation 18 for C2 in equation 15, we obtained

$$T1 = -\frac{A1Z2}{K} + (-\frac{A2}{K}z1 + \frac{A1}{K}z\,1 + \frac{A2}{K}z2 + \frac{Q2}{K})Z + 27 \quad (19)$$

Similarly, putting equation 18 into 10, we obtained

$$T2 = -\frac{A2Z2}{K} + (\frac{A2}{K}z2 + \frac{Q2}{K})Z + C4 \quad (20)$$

At z1, equation 19 is equal to equation 20, therefore

$$-\frac{A2Z2}{K} + \left(\frac{A2}{K}z2 + \frac{Q2}{K}\right)Z1 + C4 = \frac{A1Z2}{K} + \left(-\frac{A2}{K}z1 + \frac{A1}{K}z1 + \frac{A2}{K}z2 + \frac{Q2}{K}\right)Z1 + 27 \quad (21)$$

Solving for C4, we have

$$C4 = \frac{A1Z2}{K} + \frac{A2Z2}{K} + \left(-\frac{A2}{K}z1 + \frac{A1}{K}z1\right)Z1 + 27 \quad (22)$$

Putting equation 22 into equation 20, we have

$$T2 = -\frac{A2Z2}{K} + \left(\frac{A2}{K}z2 + \frac{Q2}{K}\right)Z + \frac{A1Z2}{K} - \frac{A2Z2}{K} + \left(-\frac{A2}{K}z1 + \frac{A1}{K}z1\right)Z1 + 27 \quad (23)$$

The solutions 19 and 23 give the temperature at any position in the depth interval 0 to z1 and z1 to z2.

IV. Result and Discussion

The equilibrium geotherm for the Benin and Agbada Formations was calculated by considering each layer separately. Figure 3depictsa 1-D model for the two layers with its associated boundary conditions (surface temperature and basal heat flow). Thermal conductivity and heat production are the internal properties that influence the temperature structure in the column. The thermal conductivity and heat production were obtained from well logs (Emujakporue, 2009; Emujakporue, 2016).

The model is made up of sediment column with two layers of thickness 1.8 and 4.5 Km respectively. The thermal boundary conditions are surface temperature To = 27°C and basal heat flow of 50.0mWm^{-2} and thermal conductivity. Temperature and temperature gradient were matched across the boundary between the two layers.

Using the above model properties the equilibrium geotherm was calculated for the two lithostratigraphy from equations 21 and 23. The equilibrium geotherms was calculated by assuming heat production and thermal conductivity for layer 1 to be 1.8*10^{-6} and 2.0 Wm^{-1} °C^{-1}respectively. Similarly, for the second layer, basal heat flow, heat production and thermal conductivity were 50 mWm^{-2}, 2.1*10^{-6}, and 2.2 Wm^{-1}°C^{-1}.

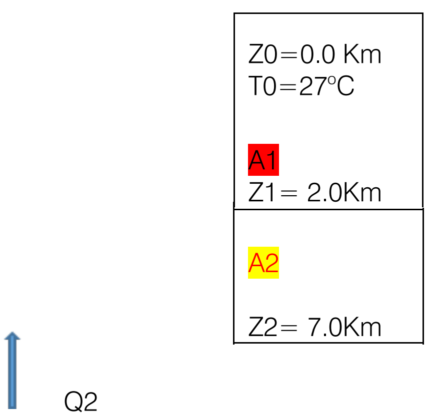

Fig. 3 : A two-layer model for the Benin and Agbada Formations

The computed temperature depth distribution is shown in Figure 4. The geotherm increases linearly with depth which is normal. The linear relationship between computed temperature and depth from the graph is given as;

$$T = 22.407x + 27.0 \quad (24)$$

The regression coefficient for the equation is 0.9992. The high regression coefficient is an indication of the significant and confidence imposed on the relationship. The equilibrium geotherm for the model rock column changes when the conductivity, radioactive heat generation and basal heat flow are varied.

Equation 24 was applied to part of the Niger Delta and compare with measured bottom hole temperature from some oil wells in the Niger Delta and the result is shown in Table 1.The difference between measured and computed temperature ranges between -4.0 to 5. 0°C.The difference between the measured and computed values are minimum and within tolerance level. The computed average geotherm provides an interesting useful information on the thermal state of the sedimentary basin.

As a result of lateral variation of heat flow due to changes in lithology, thermal conductivity, heat production and groundwater flow, it is necessary to carry out accurate determination of the above parameters in order to use the model equations. The results of the geothermal modelling can be used as an aid to interpreting heat flow patterns in the study area, thermal and hydrocarbon modelling. The surface heat flow can be calculated by multiplying the temperature gradient (slope of the graph) with the thermal conductivity values at a particular depth. Therefore, accurate geothermal heat flow is dependent on accurate determination of subsurface lithology distribution and their corresponding thermal conductivity values.

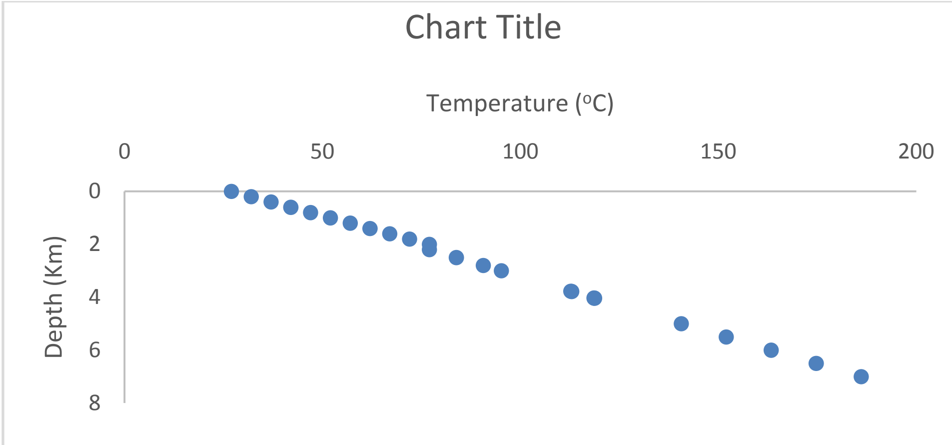

Fig. 4 : Computed equilibrium geotherm of the studied area

Table 1 : Measured and computed temperatures at some depths for three wells

Well	Depth (Km)	Measured Temp(oC)	Comp. Temp (Oc)	Difference
	3.218	98.89	102.323	-3.43373
	3.21716	98.89	102.304	-3.41406
Well1	3.21564	98.89	102.268	-3.37849
	3.80634	117.22	116.095	1.125
	3.80665	117.22	116.102	1.11774
	3.80695	116.67	116.109	0.56072
	3.80875	117.22	116.151	1.06858
well2	3.039	97.78	98.1338	-0.35387
	3.051	97.78	98.4147	-0.63476
	3.206	107.22	102.042	5.17715
	3.3395	107.22	105.167	2.05232
	3.205	107.22	102.019	5.20056
	3.38	111.11	106.115	4.99434
	3.394	111.11	106.443	4.66664
	3.39	111.11	106.349	4.76027
well3	2.9852	92.78	96.8745	-4.09458
	2.981	92.78	96.7762	-3.99627
	2.985	92.78	96.8699	-4.0899
	2.98	92.78	96.7528	-3.97286
	3.041	101.67	98.1806	3.48931
	3.044	101.67	98.2509	3.41909
	3.176	101.67	101.340	0.32936
	3.1766	101.67	101.354	0.31532

V. Conclusion

In this study the analytical solution of the 1-D steady state heat conduction equation based on two layers model was obtained and applied to the study area. Two equations obtained for the two layers were used to generate the temperature structure. The accuracy of the model depends on the accuracy of thermal conductivity, heat production in the sediment and the basal heat flow. Comparison of the computed and measured temperature shows that the difference is minimal and the model is dependable and can be applied for thermal and hydrocarbon modelling in the Niger Delta. Therefore, it is possible to predict subsurface thermal properties without drilling expensive hole and also carrying out temperature logging.

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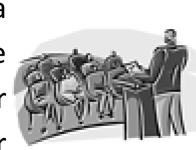

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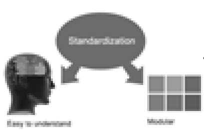

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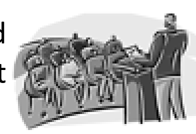

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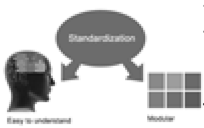

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5.STRUCTURE AND FORMAT OF MANUSCRIPT

The recommended size of original research paper is less than seven thousand words, review papers fewer than seven thousands words also.Preparation of research paper or how to write research paper, are major hurdle, while writing manuscript. The research articles and research letters should be fewer than three thousand words, the structure original research paper; sometime review paper should be as follows:

Papers: These are reports of significant research (typically less than 7000 words equivalent, including tables, figures, references), and comprise:

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(b) A brief Summary, "Abstract" (less than 150 words) containing the major results and conclusions.

(c) Up to ten keywords, that precisely identifies the paper's subject, purpose, and focus.

(d) An Introduction, giving necessary background excluding subheadings; objectives must be clearly declared.

(e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition; sources of information must be given and numerical methods must be specified by reference, unless non-standard.

(f) Results should be presented concisely, by well-designed tables and/or figures; the same data may not be used in both; suitable statistical data should be given. All data must be obtained with attention to numerical detail in the planning stage. As reproduced design has been recognized to be important to experiments for a considerable time, the Editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned un-refereed;

(g) Discussion should cover the implications and consequences, not just recapitulating the results; conclusions should be summarizing.

(h) Brief Acknowledgements.

(i) References in the proper form.

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References

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27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

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30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

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The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

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- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

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References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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