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Dynamic Interaction: A New Concept of Confinement

By Gabriel Barceló

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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

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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]

Author: Advanced Dynamics CB, Madrid, Spain.
e-mail: gestor@advanceddynamics.net

[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.

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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.

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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

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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]

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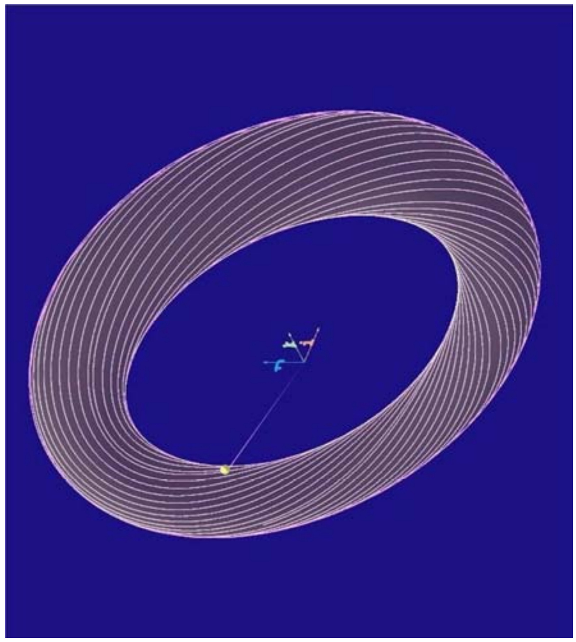

Illustration with the image of the trajectory of the plasma according to the criteria of the TDI. (by Al. Pérez)

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.

[38] R. E. Waltz, G.M. Staebler and J. Candy: Gyrokinetic theory and simulation of momentum transport and energy exchange. General Atomics PPPL Theory/NSTX. Seminar October 22, 2007

[39] 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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[40] 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
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http://dx.doi.org/10.4236/wjnst.2014.44031