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Theory of Dynamic Interactions: The Flight of the Boomerang II

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Abstract

On Volume 2, Number 7, June 2014 of this Journal of Applied Mathematics and Physics, I proposed a new interpretation of the dynamic behavior of the boomerang and, in general, of the rigid bodies exposed to simultaneous non-coaxial rotations. I proposed the boomerang as a paradigmatic example of bodies in rotation. Accordingly, I propose a new *Theory of Dynamic Interactions*. The aim of this paper is to present an audiovisual of the Theory of Dynamic Interactions, and the dynamic behavior of the boomerang, as an extension of the referred paper, asserting that the boomerang is a clear example of the application of this theory.

Keywords

Dynamic Systems Theory, Dynamic Fields, Intrinsic Angular Momentum, Speed Coupling, Celestial Mechanics, Boomerang

1. Introduction

On Volume 2, Number 7, June 2014 of this Journal of Applied Mathematics and Physics [1], I proposed a new interpretation of the dynamic behavior of the boomerang and, in general, of the rigid bodies exposed to simultaneous non-coaxial rotations. I proposed a new rotational non-inertial dynamics hypothesis, which I called *Theory of Dynamic Interactions*, which could be applied to understand the flight of the boomerang as well as patterns of behavior found in celestial mechanics. It is found applicable in general to all bodies subject to simultaneous no-coaxial rotations.

The Theory of Dynamic Interactions (TDI) claims that the boomerang returns to its origin as a result of being a body that is subject to two simultaneous rotations on different axes, and that a new interpretation of the behavior of the rotational dynamics is required.

Therefore, this paper is an audiovisual presentation of an already published article on June 2014, of the same

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title, in the Journal of Applied Mathematics and Physics.

2. Display

The aforementioned article was accompanied by a slide show, in order to facilitate understanding of the conducted research project. We believe that this video presentation on the behavior of the boomerang is an improvement in the explanation and understanding the dynamic hypothesis exposed in the TDI. The video is displayed at the following address:
https://www.dropbox.com/s/stng5b2co1441hk/Boomerang_ENG_mini.mp4?dl=0 [2].

In Annex I of this paper, the script of the video is incorporated. The video explains and justifies the TDI, and addresses many issues: the boomerang's path, why do boomerangs not fall, why do boomerangs return, lift forces, physico-mathematical TDI model, the boomerang tilt, velocity field coupling, and experimental tests.

3. About the Theory of Dynamic Interactions

Following the publication referred, we have carried out further investigation on rotating bodies under the TDI. On the paper entitled *On Motion*, *Its Relativity and the Equivalence Principle* [3], this author suggests that an observer can identify the prior situation of absolute rest or absolute non-rotation of a body, thus leading to the conclusion that movement does not necessarily have to be a relative concept.

But we also gather that the potential technological applications of the theory are of great interest. In addition to possible applications already expressed in previous articles [4], on *Dynamic Interaction Confinement* [5] I propose new dynamic hypotheses to enhance our understanding of the behaviour of the plasma in the fusion reactor.

This author suggests 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. This proposal could, in addition to magnetic confinement, achieve confinement by simultaneous and compatible dynamic interaction. Accordingly, we are of the opinion that it would be possible to get better performance and results in the design of fusion reactors by way of simultaneous magnetic and dynamic interaction confinement.These hypothesis are supported in the observed plasma spontaneousrotation phenomenon, which is not totally yet explained by the complex gyro kinetic theory.

The paper *Dynamic Interactions in the Atmosphere* [6] explains why the criteria of classical dynamics that are applied to vortex systems in the atmosphere should be rigorously reviewed; and proposes to establish the new hypotheses in the field of dynamics, in order to better interpret rotation in nature. This author proposes to use the TDI to interpret the behaviour of systems undergoing successive rotations around different axes; for example, to interpret the behavior of air masses and groups of particles in suspension that are accelerated by rotations. Accordingly, the theory might be used to interpretthe behaviour of tornadoes, cyclones and hurricanes. This proposal could enhance our understanding of these atmospheric phenomena and improve predictions about them.

Therefore, our interest in showing the behavior of the boomerang, according to the dynamic hypothesis of TDI, is based on it being a clear example of rotational dynamics.This dynamic model for accelerated non-inertial systems, has been verified experimentally. Moreover, numerical simulations have been successfully conducted.

Thus, in addition to explaining the behaviour of the boomerang, this model allows us to conceive a different rotational mechanics, which we have defined as Theory of Dynamic Interactions, and which we believe has numerous technological and dynamic applications.

Anyone interested in submitting opinions or views on this independent research project is invited to request additional information from Advanced Dynamics C.B. or check out our site at www.advanceddynamics.net.

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Annex I

Video Script

The Flight of the Boomerang II

1) The boomerang's path

The boomerang is a particularly significant, intriguing and widely known example of a rotating body. Numerous texts have been written to try and explain the flight of the boomerang. Indeed, there are more than a few Internet portals given over to this topic. Nonetheless, the reason behind its path and for its behaviour in flight are questions which to date remain unanswered in the context of Classical Mechanics.

The boomerang, on being thrown, is endowed with an initial rotation on its vertical axis of symmetry, perpendicular to its plane. This rotation is maintained on that same axis throughout its flight, as it travels along its orbit, in accordance with a closed path, thus returning to its point of origin.

It must be understood that boomerang dynamics, like that of all flying objects with intrinsic rotation, are not explained by the laws of Classical Mechanics, but rather form part of the dynamics of non-inertial systems and, more exactly, that of systems accelerated by rotation, in which the moving object is subject, at one and the same time, to numerous non-coaxial rotations.

The author states in his book *The Flight of the Boomerang* that after its launch: "*The boomerang begins to rise practically vertically and rotate like a disk. It then drops gradually travelling in a circular path, doing a complete turn, without ever ceasing to rotate on itself. It is this peculiar closed path that some experts find more complicated to explain than how a rocket is put into orbit.*"

The illustration shows the theoretical, closed path of the boomerang, which is completed without stopping rotating around itself (**Figure A1**).

In the 1970s, Felix Hess conducted an in-depth theoretical and experimental study at the University of Groningen in the Netherlands, which has come to be regarded as the benchmark study in this field. He revealed that the flight of the boomerang is somewhat more complex than the theory holds. The video shows a real flight as studied by Hess.

The typical, real flight path of a wooden boomerang seen from the top and side, according to Hess.

Nevertheless, in our study we will analyse that theoretical, circular path in which the boomerang is always at a tangent to the flight path and which results from the proposed mathematical formula; albeit aware that, in reality, the boomerang flight is more complex, given that it would be subject to more variables.

2) Why does it not fall?

In the June edition (Volume 2, Number 7, 2014) of the scientific magazine: Journal of Applied Mathematics and Physics (**Figure A2**), the author's article entitled: *Theory of dynamic interactions*: *The flight of the boomerang*, is published which reveals to us the key elements of its dynamic behaviour.

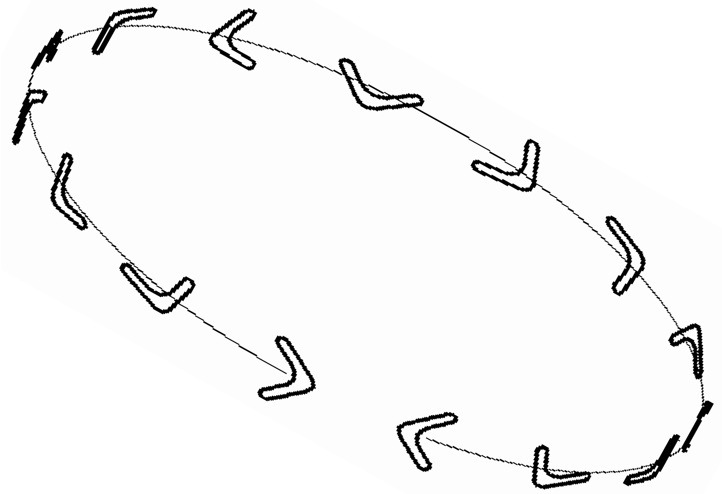

Figure A1. Theoretical, closed path of the boomerang under the assumption that all variables are constant and there is no initial momentum.

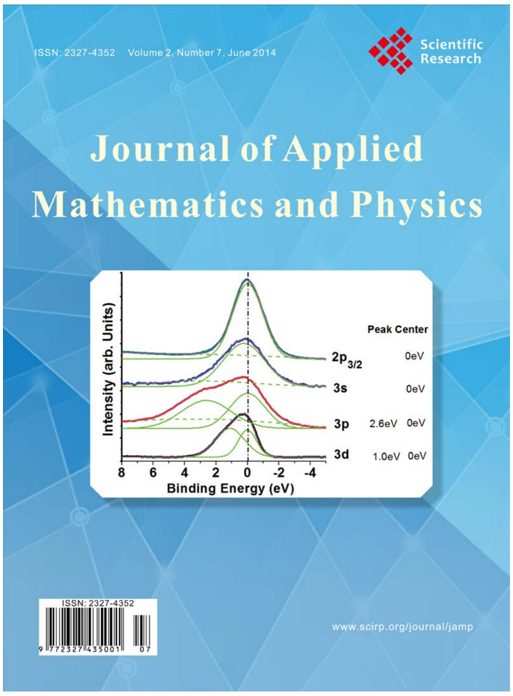

Figure A2. Volume 2, Number 7, 2014, of the Journal of Applied Mathematics and Physics.

On being thrown, the boomerang does not follow the path of any other weighted body that rises while still subject to the thrust of the throwing action, then quickly falling to the ground owing to its weight. It rises at the start of its flight, not only because of the impulse received, but also because of another force that makes it rise. The reason for this behaviour lies in the peculiar characteristics of its construction, which enable it to glide in the air.

A boomerang must be made of two or more blades, each with an appropriate shape, to which the author adds in his book: "*The blades of a boomerang are lift surfaces, just like an aeroplane's wings. Their shape generates a lifting force on moving through the air*".

It is precisely the shape of the blades, like the aeroplane's wings when gliding in the air, that causes the aerodynamic phenomenon that enables their lifting. This animation highlights the different sections of the boomerang according to its relative position.

By looking at the different boomerang sections, we can see how these vary in accordance with its relative position. The central section is symmetrical, thus no lift is generated there. However, along the length of each blade the section is the same as that of a glider wing. Notwithstanding, the section is different and asymmetric on each blade, in keeping with its translational velocity.

These construction characteristics are the key to the peculiar flight of the boomerang and explain its lift, but they fail to explain its closed path; the fact that it can return to its place of origin.

Its characteristic closed path is due to another dynamic phenomenon, which does not occur in bodies thrown without their own rotation, which is why it differs from them: the secret lies in its peculiar initial rotation.

The *Theory of Dynamic Interactions* holds that the boomerang returns to its origin because it is a body that is subject to two simultaneous rotations on different axes.

3) Different speeds

If we analyse the speeds that affect a boomerang's path that moves its centre of mass at a velocity of V, and rotates at the same time around a hypothetical axis perpendicular to its plane at a velocity of ω, we will see how each blade moves at a different relative velocity (**Figure A3**).

The blade at point A will have a total velocity of $V + \alpha\omega$, whereas the blade at point B will have a velocity of $V - \alpha\omega$. Given that the blade in the top position is moving faster with respect to the air, the lift effect will be greater at this point: The blade rotating forwards experiences a faster relative wind speed and a correspondingly

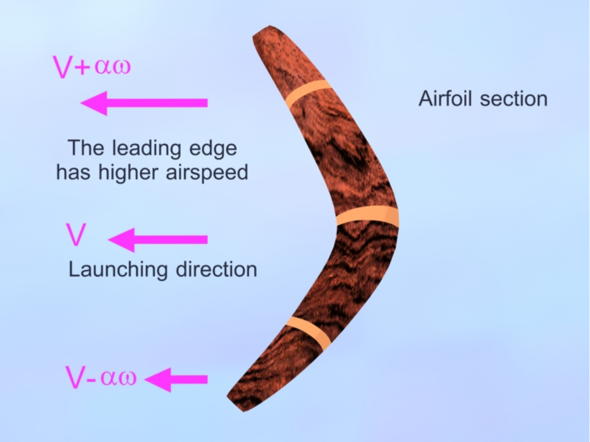

Figure A3. Each blade moves at a different relative velocity.

greater lift force than the blade that is moving backwards.

The different relative velocity of each blade causes an imbalance in the lift forces generated, a phenomenon that does not occur in the cases of aeroplanes or gliders. The two blades receive a lift force that causes the boomerang to glide, or even rise, but each blade is driven by different, never equal forces (**Figure A4**).

4) Lift forces

Because the speeds of the blades are not equal, and as the lift forces are proportional to their speed, as we have seen, these will be very different for each blade. Consequently, we can imagine two imbalanced, lift forces F_A and $F_{B,}$ which would oblige the boomerang to rotate on a new axis.

The illustration shows a side view of the lift forces generated on the boomerang's blades.

This imbalance of forces increases with the weight of the boomerang itself, which will also tend to tilt it onto a new axis in the direction of its flight.

The illustration shows the acting torques and forces. These imbalanced lift forces are equivalent to a lifting force at its centre and a torque (**Figure A5**).

Nevertheless, the most startling fact is that, despite lift forces causing a new rotation of the boomerang on a new axis, and that its own weight further increases this imbalance, the boomerang does not tilt or rotate during flight on account of this new torque, nor does it appreciably modify its plane with respect to the ground (**Figure A6**).

Moreover, the lift forces are not constant; they fluctuate in accordance with the different air variables. Consequently, the boomerang will tend to oscillate in the face of the changes caused by them. Notwithstanding, the weight strengthens the torque that will tend to right the boomerang plane.

Whatever the case, these forces generate a non-uniform velocity field in the boomerang itself. This velocity field plays a leading role in the boomerang's new path.

The illustration shows a velocity field generated by the imbalance of the weight and the lift forces.

In accordance with the Theory of Dynamic Interactions: The anisotropic distribution of the velocities generated by the torque, that is to say, the velocity field V_c shall be compounded with the initial velocity field V_T, thus enabling the curved path of the boomerang.

The V_T translational velocities are added to the non-homogenous V_c velocities created by the weight and imbalanced lift forces at each point of the boomerang's mass, thus creating the new V_R path.

5) Rotations

Once again, different section views of the boomerang where you can see how they vary depending on their relative position. We have seen above how, after the initial impulse that projects it and obliges it to turn, the boomerang rises due to the aerodynamic lift effect that is generated by its own blades. We stated that, as a force opposing the weight, the lift is generated by the shape of its blades, as is the case with aeroplanes wings, and that while it moves through the air, it maintains its rotation on its axis, blue in our illustration.

However, we have emphasised how, at the same time, it is being excited by the imbalance of lift and weight forces, on making it rotate on a new axis that is other than the previous one—in red in the illustration—and which we will call non-coaxial with the initial rotation.

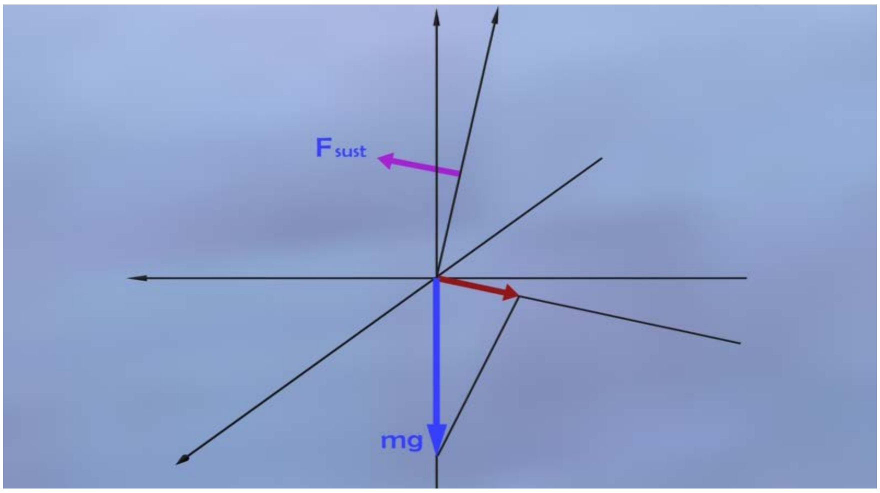

Figure A4. Resulting lift and weight forces.

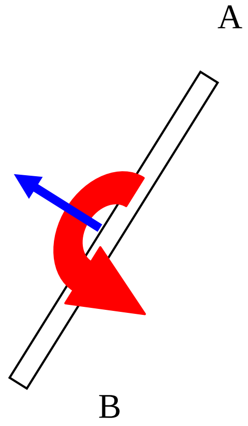

Figure A5. The imbalance of the lift and weight forces determines the appearance of a resulting lift force and a non-coaxial torque.

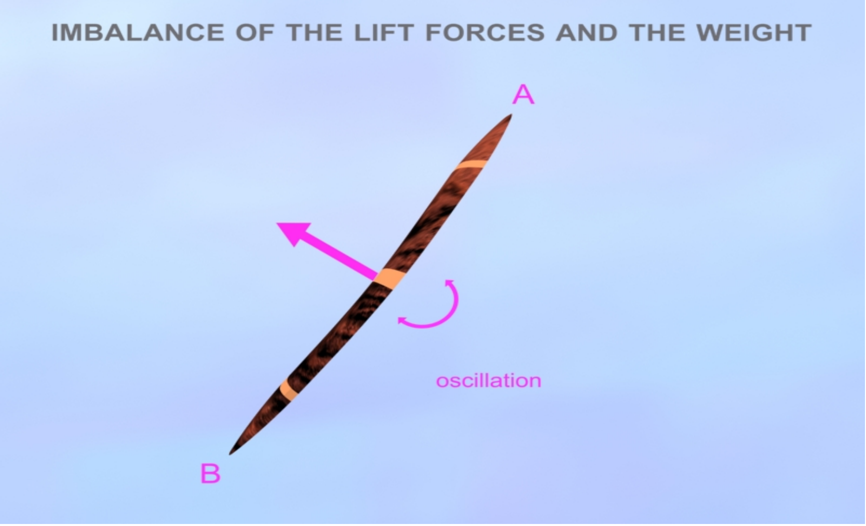

Figure A6. Subject to the torque generated by the weight and the resulting lift forces, which is non-coaxial with its intrinsic rotation, the boomerang will oscillate on a new axis.

As we can see, the boomerang is being subject to two simultaneous rotations on different axes. Indeed, it is its dynamic response to these excitations that determines its characteristic path.

According to the Theory of Dynamic Interactions, the boomerang returns in free flight to the place from where it was thrown because it is a body subject to two simultaneous rotations on different axes (**Figure A7**).

It is important to bear in mind that a characteristic of the flight of the boomerang is that its plane always maintains the same tilt throughout its path. This is a constant feature in these dynamic phenomena, as was already pointed out in the 19th century, on observing the behaviour of the first, scientific precursor, to the gyroscope.

The figure illustrates the recommended throwing angle to the vertical plane. This tilt on its plane is essential to understanding boomerang dynamics. The boomerang must be thrown with this particular tilt, otherwise there would be no torque or sufficient lift: if it is thrown vertically, it will fall due to a lack of lift force.

6) Velocity field coupling

In the book that we mentioned earlier, *The Flight of the Boomerang*, a new dynamic hypothesis is put forward for non-inertial systems that can explain the true nature of the dynamics of boomerang flight.

The author carefully studied the dynamic phenomena of rotation in bodies when subject to new, non-coaxial rotations, thus identifying the existence of *dynamic interactions*. He did tests with imbalanced aluminium cylinders floating on water and conducted experiments with moving objects in rotation in water, which were subjected to the new rotations that did not coincide with the initial rotation.

His experimental tests led to his putting forward the *Theory of Dynamic Interactions*, described in the text: *A Rotating World*, where it can be seen how this theory has a far-reaching effect not only on the basic principles of dynamics, but on numerous other branches of physics.

The theory holds that when a rigid body is subject to different rotations on different rotating axes, the first will cause rotation on an axis, but the subsequent excitations, if non-coaxial ones, will generate a non-homogenous velocity field. This velocity field conditions the behaviour of the body, while its variations generate, in turn, an acceleration field, the distribution of which is also not homogenous. Thus it can be interpreted as an inertial force field.

The boomerang is launched, as we have seen, with its own rotation, which is later subject to a torque created by the imbalance between lift and weight forces. It is therefore, a body subject to simultaneous, non-coaxial rotations. The illustration shows the rotations generated by the change of the boomerang's path as a result of the coupling of the velocity fields that act on its centre of mass.

The key to the theory is that, if the body is also endowed with translational velocity, the author holds that this will lead to the coupling between the translational velocity field and the non-homogenous velocity field generated by these forces, thus obliging it to perform a new rotation on another axis.

Figure A7. The boomerang maintains the same tilt throughout its path. This is a constant feature in these dynamic phenomena.

Instead of performing this new rotation on a new axis, on adding both velocity fields together, what happens is that the boomerang changes its flight, following a new one: namely, that characteristic closed orbit path that enables it to return to its original point. The ideal path when not subject to any motive force is a circle.

Consequently, because the lift forces are not the same on each blade, and also due to the effect of its weight, which would apparently oblige the boomerang to start a new rotation on a new axis, the coupling, or adding together of the velocity fields, modifies the path of the moving centre of mass, without having applied any external force in that direction. Accordingly, the action of these tilt forces modifies the path of the centre of mass, the boomerang maintains the tilt of its plane throughout the flight, without this new rotation coming about.

The key to the flight of the boomerang lies, according to the author, in the adding of the translational velocity fields to the non-homogenous velocity fields created by the weight and the unbalanced lift forces.

This coupling of fields, and therefore, this behaviour, will hold as long as the initial rotation of the boomerang lasts.

Even though, as we have said, the real path of the boomerang is somewhat more complex, owing to the variability of other factors that also comes into play. The illustration shows a typical, real boomerang path as described by Walker in 1897.

Furthermore, there will be a transfer of kinetic rotation energy to translation energy, and *vice versa*, in dynamic phenomena dealt with under this hypothesis.

7) Mathematical formula

It is easy to understand the behaviour of the boomerang if we accept the true inertial behaviour of bodies in which rotation on an axis of symmetry prevents the compounding of rotations that are not on the same axis (**Figure A8**).

In addition to the translational inertia, rotational inertia has to be accepted, which would correspond to the inertia of a body when subject to an inertial rotational movement on its main axis, by virtue of which it will tend to maintain this rotation even if the forces acting on it were to cease.

However, the rotational inertia is such that it prevents any new, non-coaxial rotation being added to the movement of the particles, thus maintaining both rotations without vectorial addition.

This behaviour is therefore explained by that inertial reaction of the mass we call: rotational inertia.

The equation for movement proposed by the author in his theory of dynamic interactions for these non-inertial situations is very simple. It is based on the application of an operator Ψ that stands for a rotation in space, in such a way that the end speed of the boomerang is defined by the matrix multiplication of this operator by the initial translational velocity:

By means of this simple formula it becomes possible to determine the path of the boomerang, or indeed, of any rigid body, in translation when it is simultaneously subject to two rotations on different axes.

8) Physico-mathematical model

The physico-mathematical model developed in the *Theory of Dynamic Interactions* for non-inertial accelerated systems, has been proven by experiment, reflecting the expected behaviour, and by computer simulation. The illustration compares a representation of the boomerang path with that obtained by computer simulation (**Figure A9** and **Figure A10**).

The fact is we can easily interpret the flight of the boomerang with the *Theory of Dynamic Interactions*. This dynamic model is even valid to represent any other moving object in space with translational velocity, intrinsic rotation and subject to other forces obliging it to new rotations on new axes.

This has led the author state in his book, *A Rotating World*, that: "*A lot of texts claim that the boomerang is as much a glider as it is a gyroscope, but they fail to understand or fully explain the physical phenomena that are generated during its flight. Gliders and paper planes work to overcome air resistance. On their downward flight, both one and the other convert gravity's potential energy into kinetic energy and, therefore, glide until ending up on the ground. Boomerangs are clearly like aeroplanes and gliders, their arms are wings that experience a lift force when in movement, but the boomerang rotates in the air at the same time, thus its lift force will be perpendicular to its wing, no matter what the latter's position be.*"

He further adds: "*The curved path of balls, bowls, disks and other elements, when endowed with rotation on their axis, the so-called "ping-pong or tennis ball effect", were also for us undeniable indications of dynamic interactions. As indeed, was the resistance of radial saws to any rotational movement, which is described in numerous textbooks on physics.*

$$\vec{v} = \vec{\Psi}\,\vec{V}_0$$

Figure A8. The operator Ψ acts on the initial (travelling) speed in such a way, that the end speed will be defined by the matrix multiplication of the operator and the initial speed.

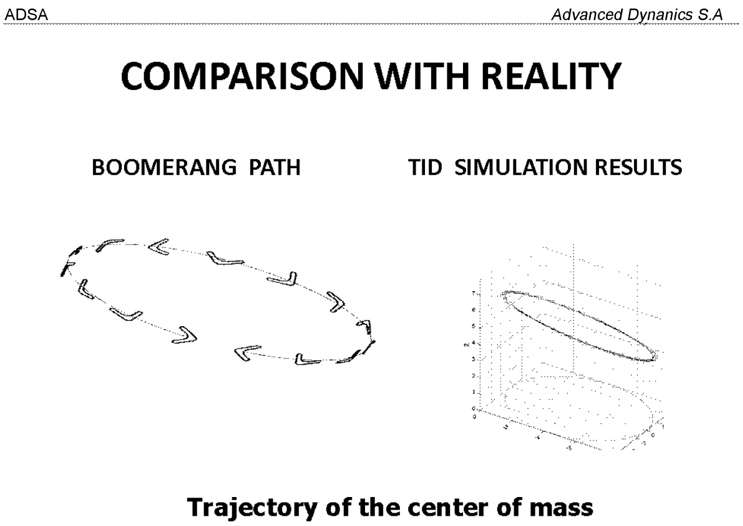

Figure A9. Representation of the boomerang path with that obtained by computer simulation.

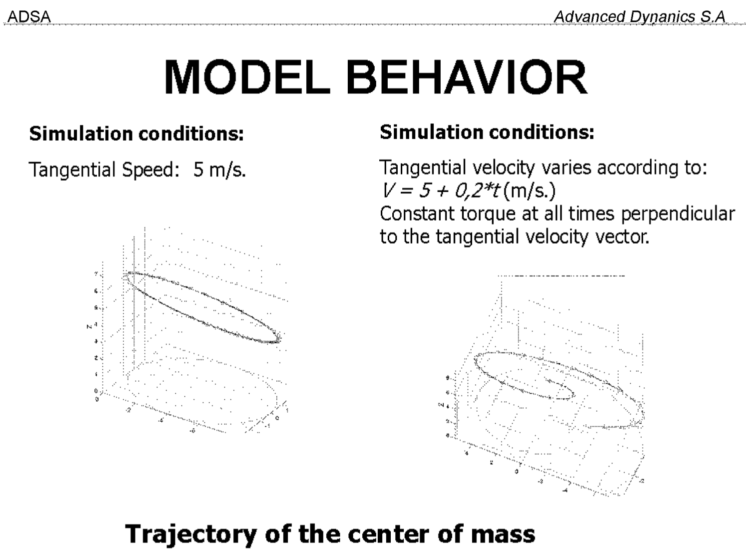

Figure A10. Representation of two paths with computer simulation.

There have been examples of this peculiar behaviour in more specialised areas, such as that of the gyroscope and laboratory instruments which, since the 19th *century, have been designed to conduct rotational mechanics experiments. Not to mention magnetic, electromagnetic or simply mechanical experimental physics divertissement revealing a clear divergence from the laws of classical mechanics.*"

9) The Theory of Dynamic Interactions

The author goes on: "*The interpretation of the dynamic behaviour of the boomerang, the spinning top, and of a host of other rotating objects, based on the re-interpretation of compound movements in accordance with the*

Theory of Dynamic Interactions can, in our opinion, be generalised to include any free body in space. This way of understanding the movement of rotating bodies can be applied to other free bodies, or ones with support points, in space, whenever these are subject to new non-coaxial rotations."

The flight of the boomerang is a clear example of the dynamics of accelerated systems caused by rotation (**Figure A11**). The *Theory of Dynamic Interactions* generalises the idea of the gyroscopic torque, along with that of other inertial phenomena, bringing them together in a unified structure of a new, non-inertial rotational dynamics. Notwithstanding, the *Theory of Dynamic Interactions*, which is simple in structure and easily applicable to, as yet, numerous, unexplained physical phenomena, calls for a new understanding of mechanics, proposing new inertial hypotheses for matter.

The theory can also be used to explain other secrets of the universe, such as the why of the ecliptic plane and the wherefore of Saturn's rings. The treatise entitled *Imago Universi* tells the fascinating history of human knowledge of the universe, while also proposing, developing and explaining the application of the *Theory of Dynamic Interactions* to afford us a better understanding, not only of the flight of the boomerang, but also of the dynamic enigmas that surround us.

For all those wishing to learn more about the flight of the boomerang or the theory of dynamics that can explain it, or who would like to collaborate in this private research project, more information is to be had from Dinamica Fundacion or Advanced Dynamics C.B. by consulting: www.dinamicafundacion.com and www.advanceddynamics.net.

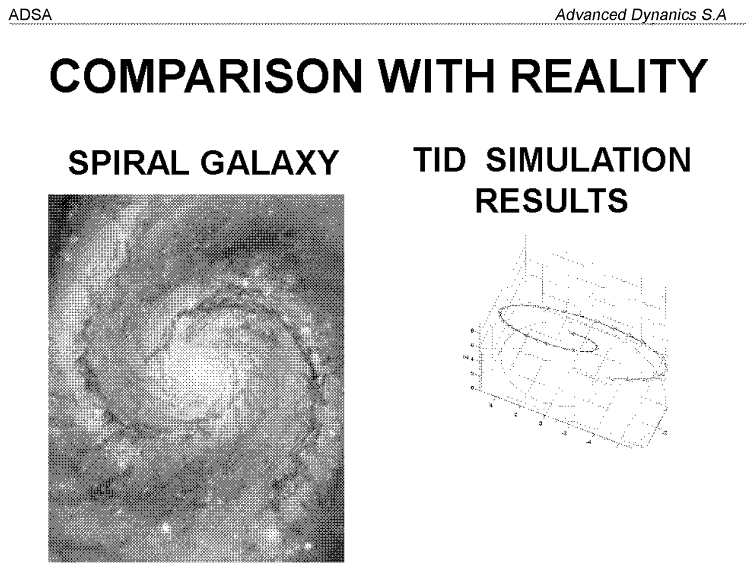

Figure A11. Representation of the arms of a spiral galaxy and the TID simulations results.