THE GLOBOTOROID

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ABSTRACT:

Mathematical models can give us invaluable insights into natural phenomena, and as such play an important role in science. The intent of this paper is to give a high-level overview of a simple continuous dynamical model that offers an insight into a qualitative behavior seldom reported or discussed. This model has no equilibrium or singular points, yet its phase space unveils four distinct topological features: a limit cycle, a torus, a sphere and a wormhole. Each of these features results from model solutions that can be periodic, quasi-periodic and chaotic, which collectively form a space-time structure referred to as the globotoroid. The model generalizes the energy behavior of many processes of interest, and consequently is reshaping contemporary systems theory to fit more completely with different natural phenomena. Specifically, the globotoroid is the simplest 3-dimensional dynamic model that exposes the concept of the wormhole, which embodies an important energy behavior throughout our universe. The fields of science that may benefit from this modeling approach are many, including physics, cosmology, biology, chemistry, engineering, cognitive sciences, economics, politics, and business and finance. This is demonstrated by reviewing some well-known phenomena in natural and social sciences.

INTRODUCTION:

Over the last century, systems theory has steadily been emerging as the interdisciplinary theory of the abstract organization of scientific phenomena. The origin of the theory dates as far back as the early 1900s with Bogdanov's Tektology thesis (*1,2*), which later was refined by the biologist von Bertalanffy (*3*). Since then, the literature on the subject has exploded with the center stage of this theory being the analysis of continuous and discrete dynamical systems. In this paper, the focus will be on continuous dynamical systems only.

By definition, the system is continuous and dynamic if it can be expressed by a set of differential equations, also referred to as ordinary differential equations (ODE). This is a set of mathematical expressions that relate functions in one or more variables with their derivatives, usually the time derivative. The ODE system is symbolically written as

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$$\frac{dx_1}{dt} = f_1(x_1, x_2, ..., x_N)$$
$$.$$
$$\frac{dx_N}{dt} = f_N(x_1, x_2, ..., x_N)$$

eq. (1)

where x_i , i=1,..,N are variables, dx_i/dt is the derivative of variable x_i w.r.t. time t, $f_1,..,f_N$ are the defining functions, and the integer N is the dimension of space, usually Euclidean space. An ODE system is a mathematical equation which defines a point in space that travels with time according to some prescribed rule, often determined by reasoning from first principles.

Throughout the 1960s and 1970s, research in dynamical systems theory was mainly focused on system stability, and that is where the concept of equilibrium points becomes useful. The equilibrium points are all the points of dimension N≥1 that are solutions to the equations

$$f_1(x_1, x_2, ..., x_N) = 0$$
$$. \qquad .$$
$$f_N(x_1, x_2, ..., x_N) = 0$$

eq. (2)

These points are also referred to as singular or steady-state points and their significance is that they are associated with topological surfaces known as manifolds that manipulate the system's stability. Depending on these manifolds an equilibrium point may be globally or locally stable or unstable. For N≥2, this further implies that the stable and unstable manifolds may reach a balance which can promote different types of periodic behaviors surrounding the singularities. With the introduction of the chaos theory in the 1980s, this balancing was further fractalized due to the appearance of the strange attractors, and chaos emerged as an alternative qualitative behavior. Chaos behavior in continuous dynamical systems was first observed as early as 1963 in the Lorenz system (*4*), but it was not until the 1980s that the concept was accepted by mainstream science. Since then, chaotic behavior has been reported in different dynamical systems with dimension N≥3 (*5-9*).

It is not the purpose of this article to go into the details of stability theory, especially since there is a great deal of literature on the subject already available, for example (*10-13*). At this point, however, it suffices to remember that the minimal dimension for equilibrium points is N=1; for periodic solutions it is N=2; and for chaos N=3. Clearly, from the dimensionality point of view, the behavior of equilibrium or singular points is the most fundamental, implying that the way in which classical systems theory organizes energy is governed by these points. For systems where these points are globally (locally) stable, the energy dissipates globally (locally) and the points are simply referred to as sinks. In contrast, if the points are unstable, then energy expands globally (locally) and the points are referred to as sources.

Furthermore, for periodic or chaotic systems, the two energy behaviors are in balance, and they form predictable or unpredictable orbits surrounding singularities. Thus, since contemporary stability theory is based on the existence of equilibrium points, the energy behavior is either locked by these points, or by the periodic or chaotic orbits surrounding them. In either case, energy is trapped and has no ability to change, which is contrary to its behavior in nature. This energy scenario is being replicated in almost all present-day modeling methods of any dimension N≥1. What is missing is the ability for energy to “refresh” itself.

To address this modeling deficiency, we begin by introducing the globotoroid model and its solutions. It is shown that the globotoroid is the 3-dimensional Euclidian space object that results from a dynamic blend of the globe, or sphere, topology, and the torus topology. This blend is accomplished through the assistance of the slow manifold, which has the natural appearance and characteristics of a wormhole. We demonstrate that this system has no singular points, and that the wormhole can liberate energy behavior.

In the second part of the presentation, examples exhibiting globotoroidal behavior in different areas of science are presented and discussed. The paper concludes by summarizing the results, and by offering a perspective on the future of this novel modeling method.

RESULTS -

A) *The Globotoroid Model and Its Solutions:*

The globotoroid model is defined by a simple 3-dimensional ODE

$$\begin{aligned}\frac{dx}{dt}&=-\omega y-Az(x+1)\\ \frac{dy}{dt}&=\omega x \qquad , \qquad \text{eq. (3)}\\ \frac{dz}{dt}&=-B+A(x+1)^2\end{aligned}$$

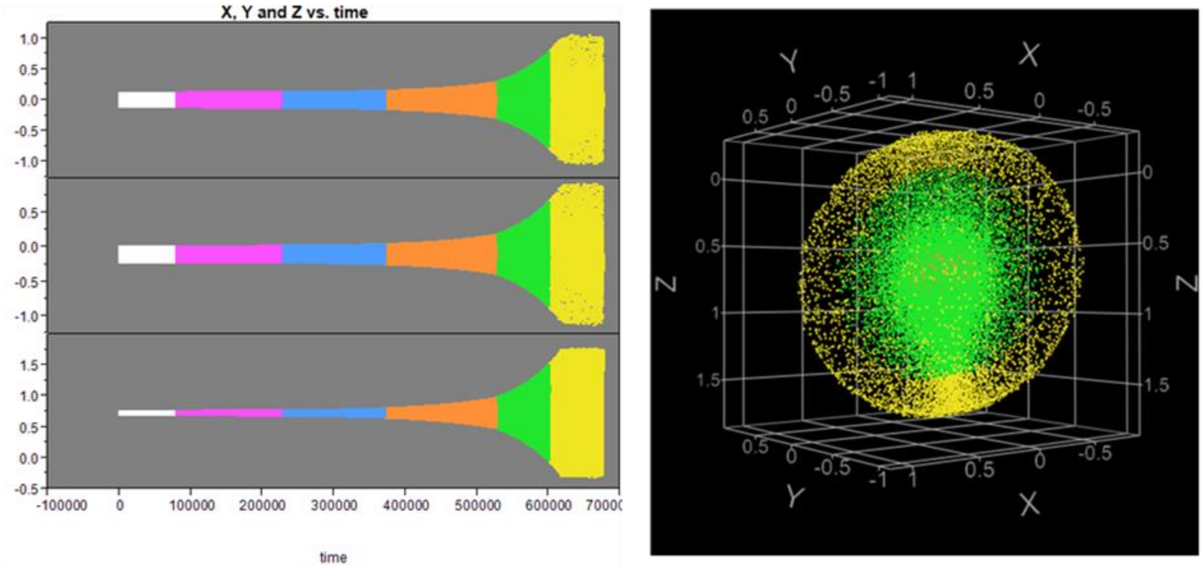
where x,y and z are variables, t is the time defined, $\omega=2\pi f_o$ with $f_o>0$ being the frequency of orbits, $T_o=1/f_o$ the orbit period, and A and B are the stimulus coefficients > 0. The variables are functions of t, and they will be referred to as z(t) the growth variable, and x(t) and y(t) the action or orbital variables, with the understanding that x(t) is also the host variable. There exist different forms of eq. (3), and they may require renaming of the variables; for our purposes, however, this is the simplest version to consider.

Next, we apply the systems theory approach to evaluate singular solutions. From eq. (2) it follows that these solutions must satisfy the expressions

$$\begin{aligned} -\omega y - Az(x+1) &= 0 \\ \omega x &= 0 \\ -B + A(x+1)^2 &= 0 \end{aligned} \quad , \qquad \text{eq. (4)}$$

which is only possible if x=0, B=A, and y=-zA/ω. The last condition further implies that within the 3-dimensional Euclidean space there is not only a singular point at x=0, but there is the line L which goes through it, and is defined by y=-zA/ω. This line is mathematically referred to as the singular manifold, and in reference (*14*) the complete analysis of this manifold is presented. It is shown that for B=A, the line L contains singular solutions which support the nest of concentric spheres. The analysis also shows that for B<A, all singularities along the line disappear, and L forms the slow manifold, or the wormhole, that deflates the spheroid nest. In this case the wormhole is passive and takes off along the line L to infinity. However, for B>A all singularities disappear again, but now L forms the stimulated wormhole that drills through the antipodal points of the spheroid nest and forms the globotoroid. This process of drilling was recently treated by using topological surgery (*15, 16*, 17). It is also useful to note that as B/A>1 increases, the wormhole opening enlarges, and when B/A->1, the wormhole "shrink wraps" the line L.

The idea of the globotoroidal nest was first introduced in 1992 (*18*), where it was shown that the attracting bead, now the globotoroidal shell, reminiscent of a sphere or globe, is a strange attractor. It was further demonstrated that the solutions generating this attractor were "choked" while passing through the slow manifold, now the wormhole. The report also reveals that the interior of the strange attractor is a nest compactly packed with the concentrically folded spherical and toroidal shells, hence the name globotoroid, and that the nest contains a limit cycle core. These results are now illustrated more colorfully by solving eq. (3) for the following model parameters: A=0.144, B=0.145 and ω=1. The solutions of eq. (3) are obtained by using the Euler method for solving ODE with the integration step Δt=0.1, and the initial conditions x_0=0.1, y_0=-0.17 and z_0=0.704. They are periodic and are color-coded in Fig. 1A to distinguish between different time segments. The periodic solutions grow with time t and are used to create the globotoroid in the 3-dimensional phase space illustrated in Fig. 1B. In Fig. 2, the anatomy of the globotoroid nest is presented according to the color scheme given in Fig. 1A; the components of the anatomy collectively constitute the globotoroidal universe. Deep inside the globotoroid is a core that contains the unstable limit cycle, Fig. 2A, which with time inflates into the ring torus 1, Fig. 2B. We can already identify the presence of the wormhole in the ring torus 2 in Fig. 2C, and as the wormhole tightens, the ring opening continues to shrink. The ring torus gradually becomes a horn torus, which eventually morphs into a sphere that emerges as a strange attractor Fig. 2F.



A) x(t), y(t) and z(t) solutions

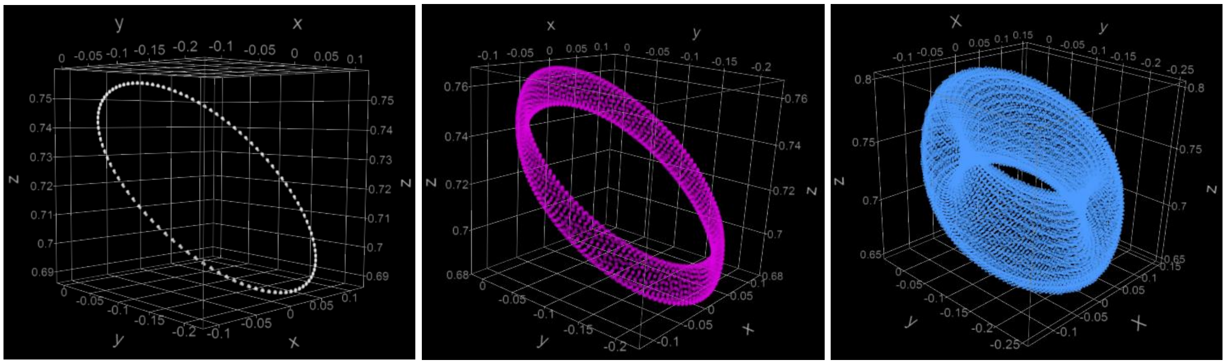
B) Phase space portrait

Fig. 1: The globotoroid solutions.

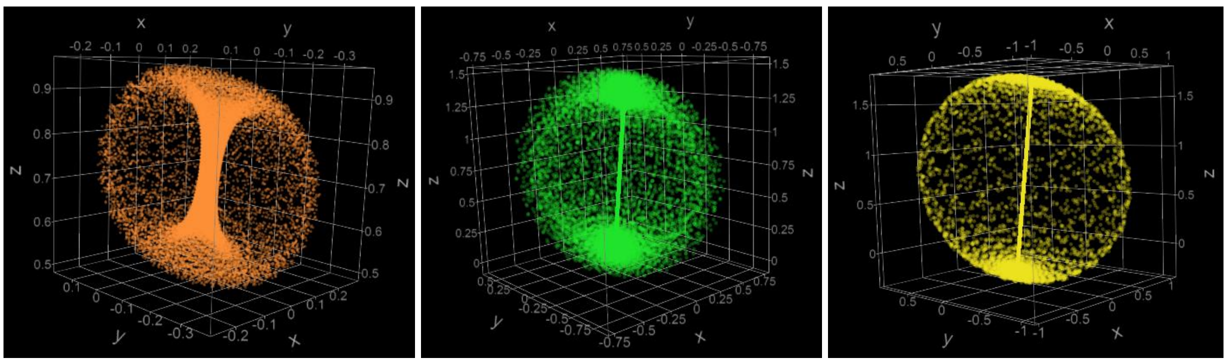
The periodic solutions evolving on the strange attractor are next depicted in Fig. 3. They define the attractor period T_g, as well as the type of solutions covering the fractal globe. From Fig. 3B it is now apparent why z(t) is the growth variable, and why x(t) and y(t) are action, orbital, variables. The last two are analogous to wavelet-type solutions that for the present case are activated on the sphere by the orbital frequency $f_o=1/(2\pi)\approx0.16$Hz. Similarly, for the growth variable we let T_g to be the growth period, and with it the corresponding frequency of growth $f_g=1/T_g$. Note, in contrast to f_o, f_g is not constant because it changes with time as the globotoroid passes through different stages of its anatomy.

The presence of f_g and f_o now explains why the globotoroid contains the phase portraits given in Fig.2. The two frequencies can be viewed as frequencies of two harmonic oscillators having circular phase portraits C_g and C_o, which is precisely what topology requires for the Cartesian product C_gXC_o, or a torus. By inspecting the solutions in Figs. 1 through 3, it is evident that $f_o>f_g$, or $T_o<T_g$. This further implies that we can now calculate the number of orbits solutions exercise while travelling around the geometries in Fig. 2. The calculated result is the toroid winding number $n=f_o/f_g=T_g/T_o$, and for the anatomies in Fig. 2 the following representative values are evaluated: $n_{(white)}\approx0$, $n_{(purple)}\approx84$, $n_{(blue)}\approx91$, $n_{(brown)}120$, $n_{(green)}\approx218$ and $n_{(yellow)}\approx335$. The values are representative because n continuously changes with f_g. In the case of $n_{(yellow)}$, T_g also exhibits indeterminism induced by the fractal nature of the strange attractor.

These observations are further summarized by providing a more detailed view of the globotoroid interior. Fig. 4 illustrates the interior organization of the unstable limit cycle core. The dense green region piercing through the core is where the wormhole activity is most intense, and it contains the highly energetic yellow solutions. The Poincaré section in Fig. 4c also shows how expanding scrolls emerge from the unstable interior core, and how they surround the wormhole. It needs to be noted



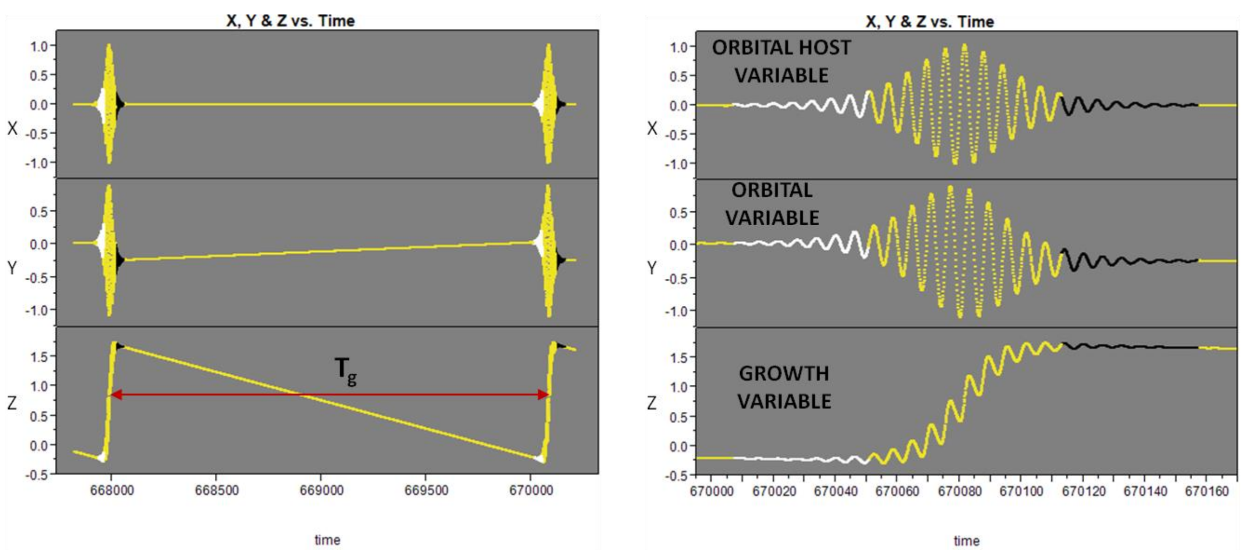
A) Unstable Limit Cycle B) Ring Torus 1 C) Ring Torus 2



D) Horn Torus E) Pierced Spheroids F) Strange Attractor

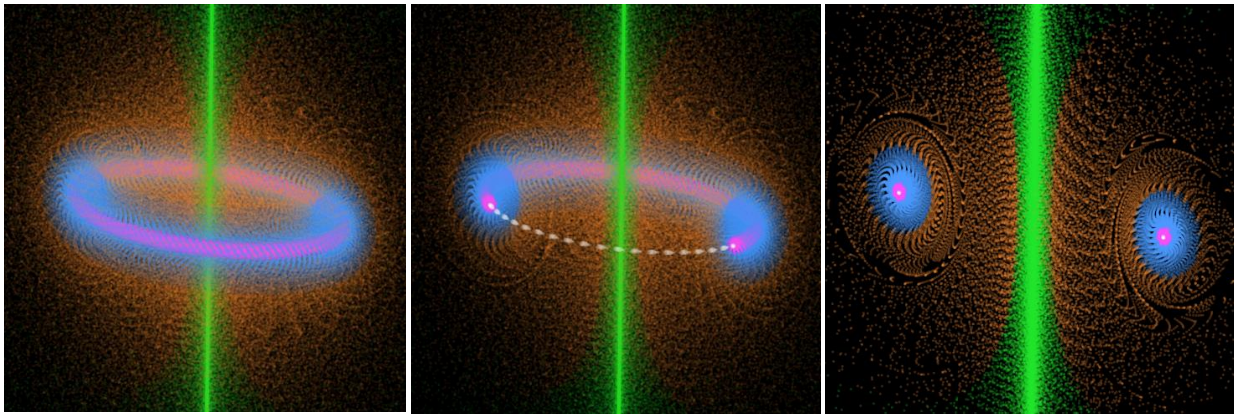
Fig. 2: Typical topologies found in the globotoroidal universe.

that for different model parameters A, B and ω, the globotoroid can have solutions that are contracting with time (*18*). In this case the interior limit cycle is stable, and the Poincaré section will exhibit contracting scrolls.



A) The strange attractor solutions and period T_g. B) Solutions over the attracting globe.

Fig. 3: The strange attractor solutions.



A) Core Bundle B) Unstable Limit Cycle C) Poincaré Section

Fig. 4: Organization of the globotoroid core.

The question now is what happens to solutions initiated in the exterior of the globotoroidal universe? These solutions, like the fractal globe solutions, will ultimately have to pass through the wormhole where they will be choked, and subsequently will end on the globe attractor. This choking process is a very effective way of attracting all the points from the globe exterior.

It is also important to note that because of the wormhole, the globotoroid solutions are hypersensitive to the integration step used in computations. The tighter the wormhole region, the greater the sensitivity to the integration step implemented. Inevitably, this sensitivity will choke the solutions, and the strange attractor may appear even when the solutions are attracted by the stable limit cycle core (*18*). Moreover, the wormhole presence makes the globotoridal universe an irreversible system. This is because when dynamics through the wormhole are reversed, the wormhole characteristic changes. Generally, these observations do not apply to the equilibrium-type system, which brings us to the next section.

B) *The Wormhole:*

Contrary to the popular opinion that wormholes are some hypothetical openings in space which provide passages to other dimensions, the real purpose of a wormhole is to manage the system's energy. How is this achieved? Before we look into this, let's take a look at the history of the wormhole.

The origin of this concept dates back to 1935, and it was named after its founders as the Einstein-Rosen bridge. This bridge, derived from general relativity, was presented as a tubular connection between widely separated exteriors of curved space. In 1957, the bridge was renamed by Misner and Wheeler as the wormhole (*18*). While coining the phrase, the authors observed that a wormhole is a space-time structure free of singularity, which together with the curved space hypothesis fits with the globotoroid description.

Fig. 5 illustrates how the yellow periodic solutions in Fig. 1A create the wormhole outlined in green. This wormhole is tube-like and connects the widest curved separation on the strange attractor, or the antipodal points on the sphere. In this case, the tubular region is narrow and is represented by a line, meaning that the tube opening shrinks around the 1-dimensional manifold L as solutions approach the strange attractor. From a practical point of view, this implies that the entire 3-dimensional curved space is collapsing and cramming through an almost 1-dimensional geometry, which makes the dynamics of solutions hypersensitive and prone to turbulence.

In nature, these dynamical conditions can generate tremendous energies that may be sustainable by some physical systems, but not by biological systems. Luckily for us, not all wormholes behave in this manner. In Fig. 6, the strong wormhole effect is relaxed by the torus, which supports much milder dynamics that are likely to be more sustainable in biological systems.

Theoretically, if the system's resolution were infinite, the radius of the attracting globe would be infinite as well, while the wormhole would become the 1-dimensional manifold L. This under any natural circumstances is not possible, and the radius of the attracting globe in nature must remain finite, implying that the wormhole must be tube-like.

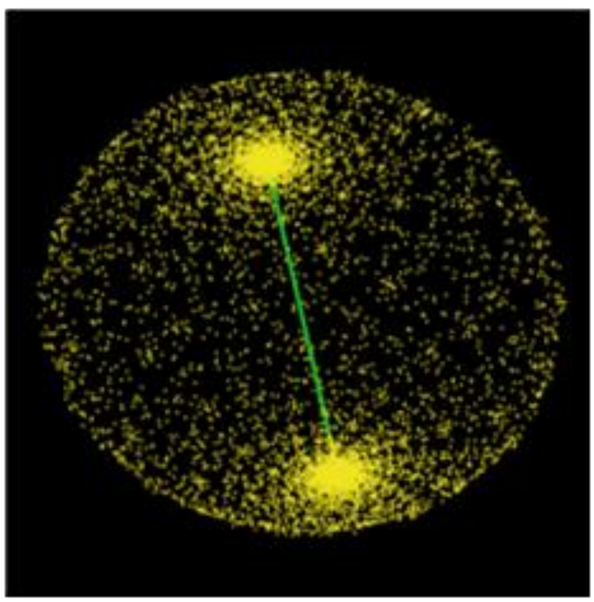


Fig. 5: The strange attractor with wormhole displayed in green.

With the 1-dimensional manifold L establishing the wormhole path, the question now is where does the wormhole begin and where does it end? It was already mentioned that the stimulus coefficients A and B regulate the singular manifold behavior responsible for creating the wormhole. For the case B<A, the

wormhole is passive and it has no finite ending. However, for B>A, the wormhole stimulates a globotoroid by creating the entry and the exit points, which are color coded respectively in Fig. 6 in black

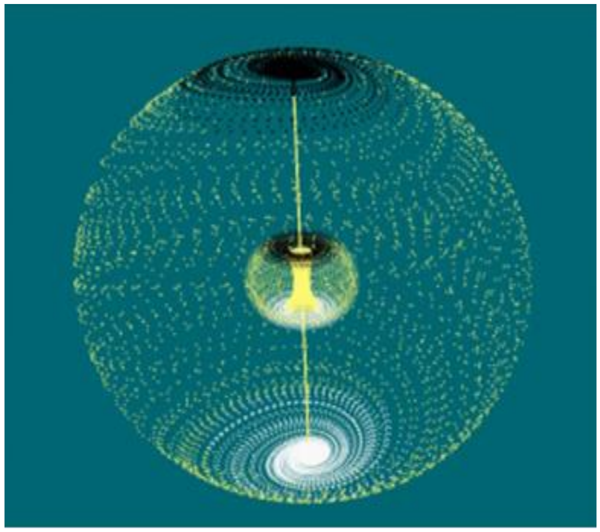


Fig. 6: The wormhole resolutions indicating the locations of the black and white holes.

and white. The color scheme was selected deliberately to suggest the locations of the black and white holes. These two holes play an important energy role and are also depicted in the time domain in Fig. 3B. The black hole acts like an attracting singularity, or a sink, that draws in all of the system's energy. However, since the black hole is not a singularity, but rather an entry point into the wormhole, this energy is redirected to the white hole. While passing through the wormhole, the energy is squeezed out of the globotoroid, with the degree of squeezing determined by the winding number n. This energy does not dissipate like in the equilibrium processes; instead it aggregates at the white hole exit, which now serves as a source that injects energy back into the fatigued system. Through this cycling, the system re-energizes and continues to function. In reference (*19*), the energy cycling was referred to as the explosive route to chaos; however, at that time relevance of wormholes was not fully understood.

It is also interesting to comment about the relationship between the growth phase and the wormhole phase. From Fig. 3B it follows that growth is initiated with the inception of the white hole and ends with the entry into the black hole. Once the black hole is entered, the long transition through the wormhole begins, see Fig. 3A. For this particular system, the ratio of the travelling time through the wormhole to the growth time is approximately 22. In other words, aggregating energy to revitalize the globotoroid appears to be a longer process than using up the energy for growth. This ratio is significantly reduced when the system resolves itself at the level of torus like in Fig. 6, but at the same time the solutions are not as energetic. For more on wormholes take a look at https://youtu.be/5zIfn5zgHqE.

EXPLORING THE GLOBOTOROIDAL UNIVERSE IN SCIENCE:

More can be said about the theory of globotoroids, but for the purpose of this white paper we have covered enough ground to explore the present results in phenomena occurring in nature. Examples of qualitative behaviors encountered by the globotoroidal signatures can cover a broad range of natural and social processes; the model is suitable for processes with long and short time durations. As biology seems to be the science hub for systems theory, we begin here.

In biology there is an overabundance of examples of wormholes. The primary reason for this is that biological processes are continuously reviving without exhibiting any evidences of singular solutions. In fact, all living things resent the state of equilibrium, and speaking thermodynamically, they prefer far-from-equilibrium dynamics. Let's take a look at some examples.

The population behavior between two biological species in competition is commonly modeled by the Lotka-Volterra model (*21*). For instance, the model can capture prey-predator relations between foxes and rabbits. In the 2-dimensional phase space, this model typically depicts a singularity surrounded by periodic solutions that describe the population growth of the two species.

To study the population behavior among three or more species, the same Lotka-Volterra model interactions are replicated in higher dimensions. The resulting model solutions remain very similar to the 2-dimensional case, but now the added possibility of chaotic solutions also exists (*22*). Such pattern of solutions will not change until the order of interactions among species increases and wipes out singularities in the interaction phase space. This was demonstrated in (*19*), where a stimulated wormhole was introduced into the Lotka-Volterra model for three species in competition.

Globotoroids can model different types of biological growth processes, including the life cycles that include a dormant phase. In the latter case, a dormant state corresponds to the passive wormhole, which when stimulated will activate a globotoroid. For instance, the notion that DNA is a wormhole is not entirely new (*23*), and when appropriately stimulated will pack energy by growing a protein clamp in the shape of a torus. Take a look at https://youtu.be/y4aAtUNwPMU.

As a follow up to biology, let's look at some examples in neuroscience. Most brain functions exhibit wormhole-type behavior; how we learn, memorize and recall information is often accomplished through a wormhole-type activity. Also, the state of sleep, which repeatedly reenergizes us, may also be considered as a passage through a wormhole.

Also, globotoroids support two types of duality relations. The wormhole conflict of the black and white holes is the Type 1 duality, whereas the Type 2 duality is responsible for intensifying and relaxing this conflict. The Type 2 duality reflects dynamics of anatomy in Fig. 2, and for this reason is also referred to as the inflation-deflation conflict. Here the limit-cycle orbit corresponds to the deflated state, while the strange attractor is the inflation limit. Clearly both duality relations coexist; the tighter the Type 1 conflict is, the more inflated the Type 2 conflict becomes, and vice versa. The two duality relations appear frequently in philosophy. The Type 1 duality represents a wormhole that connects a pair of philosophical opposites, while the Type 2 intensifies or relaxes the pair's relation. This is quite evident in teachings of Taoism (*24-26*), which are very much influenced by the concept of Yin and Yang.

The subject of wormholes originates from cosmology and physics, where it is still a topic of great interest. Many processes, on all scales of the universe, seem to exhibit globotoroid-type behavior. Some of these phenomena are presently hypothesized in the literature, and some are not. We will cover both. Let's begin with possibly the largest wormhole known to us.

Until recently, cosmology treated the black holes in our universe as if they were massive singularities that devour stars and galaxies. Recently, however, a theory is proposed which suggests that black holes may turn into white holes that explosively pour all the material the black holes swallowed back into space (*26*). If this is the case, then there is a connection between white and black holes: the wormhole. This wormhole would be the giant that reenergizes our universe.

Another interesting observation about celestial objects is that most of them exhibit some form of globotoroidal signature. Galaxies are spirals, and stars have spherical appearances. Even a quasar and a gamma-ray burst exhibit globotoroidal characteristics illustrated in Fig. 4. In both cases a huge amount of energy is packaged and released through a wormhole-type structure referred to as a ray.

The phenomenon closer to home, and very important to us, is the geomagnetic field. This is the globotoroid that shields us from the solar wind and cosmic rays. The Earth's magnetic field is generated by the currents in Earth's core that form a wormhole which energizes the protective globotoroid-type shield. This behavior also occurs on a smaller scale when a current loop becomes energized. In this case, the magnetic field creates a structure similar to that depicted in Fig. 3. Here, the limit cycle core is generated by the current loop, and the magnetic wormhole runs by convention from the North to the South pole. These poles correspond to the black and white holes shown in Fig. 6, and they define the dualistic nature of electromagnetism, with both Type 1 and 2 dualities being clearly evident.

When we get to Earth, there are two types of weather events that exhibit the globotoroidal behavior: tornadoes and hurricanes, or cyclones. Both are generally caused by the atmospheric instability that occurs when the cold air in the upper atmosphere meets the moist and warm air in the lower atmosphere. The fuel for tornadoes is usually found over the land; however, tornadoes can also be spotted over a body of water in which case they are called waterspouts. In either case, the atmospheric conditions pack a significant amount of energy in the form of a funnel cloud, which is a wormhole that becomes destructive when it touches the ground or the water surface. In contrast, hurricanes are fueled by an ocean, and they are characterized by the eye and the eyewall at the center of the storm. The eye, which is a low barometric pressure wormhole with light winds and clear skies, packs a large amount of energy into the eyewall where the greatest wind speeds occur in hurricanes. In both of these events, the Type 1 duality is visibly present, while the Type 2 is harder to detect.

A similar behavior occurs on a much smaller scale in the physical phenomenon known as the Rayleigh–Bénard convection, which exists when a fluid is heated from below (*28*). The wormhole packs heat from below and blends it with a colder fluid at the top. This is especially visible in a low Prandtl number

Rayleigh–Bénard convection, where a thin layer of fluid exposes scrolls called the spiral defect chaos. These scrolls are very similar to the scrolls observed in the Poincaré sections derived from globotoroids. Moreover, the 3-dimensional simulations of the Rayleigh–Bénard cell further expose the presence of the globotorid-type structure (*29*). Similar scroll structures are also visible in a nonlinear chemical oscillator known as the Belousov-Zhabotinsky reaction (*30, 31*), and for globotoroids this has been previously reported (*18, 20*).

In fluid dynamics, instances of globotoroidal behavior are also plentiful. An example given by the swirling flows with vortex breakdown (*32*) clearly shows evidence of the globotoroidal signatures. Also, the flow known as Taylor–Couette (*33)* deserves attention. This flow occurs when a viscous fluid is confined in the gap between two rotating cylinders; usually the outer cylinder is stationary while the inner cylinder rotates. When observed through the outside cylinder wall, this flow at low frequency of rotation is stable and exhibits a uniform fluid column, or the laminar Couette flow. This implies that the energy delivered by the rotating inner cylinder is uniformly distributed along the column. Now as the frequency of rotation increases, the flow along the column forms stacked toroid-type vortices, or the Taylor vortices. This is an indication that energy is no longer uniformly distributed, and the Taylor vortices form distinct packets of energy along the liquid column. In the space of the globotoroidal anatomy, these observations correspond to the deflated core when the flow is laminar, while the Taylor vortices correspond to the inflated anatomy states. In the latter case, each excursion around any member of the inflated anatomies corresponds to one Taylor vortex in the column, or one energy packet. These concepts were clearly exposed by Mullin and Price (*34*), who used empirical data to create a globotoroid-type attractor that shows the Type 1 duality, or the wormhole. Thus, by regulating the frequency of cylinder rotation, the inflation-deflation duality is invoked within the flow, while the wormhole is responsible for packing energy into the Taylor vortices.

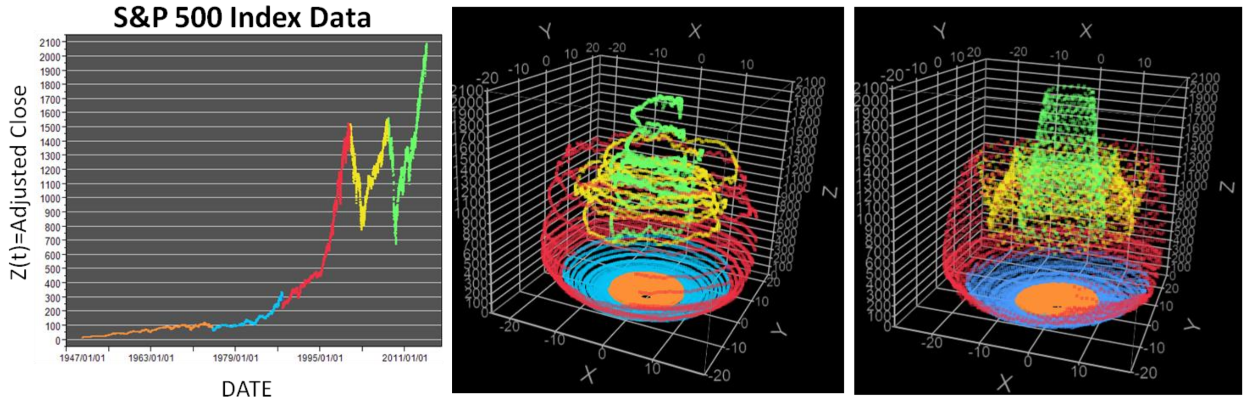
Moreover, there is probably not a simpler model that captures the essential features of quantum mechanics than the globotoroid model given in eq. (3). We explore these observations by connecting some basic quantum mechanics concepts with the globotoroid properties.

As mentioned, the model offers two duality features that also happen to be the backbone of quantum mechanics. To begin, recall that Louis de Broglie postulated in his 1924 doctorate thesis that matter has a wave nature (*35*). From this premise, the wave particle duality concept emerged, which here is analogous to the inflation-deflation duality idea. To see this, let λ_o be the wave wavelength and λ_g be the wavelength that defines the periodicity of energy packets. Next, define the winding number as $n= \lambda_g/ \lambda_o$ and use the wave frequency relation $f=c/ \lambda$, where c is the speed of light, to set the globotoroid winding number in terms of frequencies. Then by keeping λ_o constant and n small, the energy states reside inside the globotoroid core, where the limit cycle represents the pure wave state. However, as λ_g increases so does n, and the energy squeezed out of the wave inflates the anatomy of the globotoroid, or particles, for example photons. Now, as λ_g is the changing wavelength, while both the wave and the particle states remain defined by the same wavelength λ_o, or the orbital frequency f_o, then the de Broglie hypothesis is satisfied. Finally, it is up to the wormhole, or the Type 1 duality, to determine if the energy packed deflates or inflates the particles.

It is also interesting to observe that the energy packets resulting from solutions of the globotoroid equation are, in quantum mechanics, analogous to the wave packets obtained from solutions to the Schrodinger wave equation. This further implies that both the inflation-deflation and the wormhole dualities are present within the domain of Schrodinger's wave functions. The evidence of this is clearly visible in the 3-dimensional visualizations of the hydrogen atom wave functions (*35*). The similar observations also apply to the theory of particles that include gravity, or the string theory, from where the concept of the wormhole originates (*19*), and which today is slowly emerging as the theory of everything (*37-39*). The interesting takeaway from all this is that a simple ODE is capable of modeling phenomena that are otherwise modeled by complex partial differential equations. In some instances the present model may be more useful, because it allows us to be intimate with the dynamics of these phenomena.

The final topic covered is that of social sciences. Ordinarily when we think of dynamical modeling applications in social sciences, we do not find many success stories. Sciences like economics, politics, business and finance seem to be isolated from the world of dynamical modeling and are surrendered to the world of statistics, algebra and geometry (*40*). The primary reasons for this are that social science processes, like biological processes, are not equilibrium-type systems and, in addition, they almost always exhibit a lack of understanding of the process time scales, as well as a lack of meaningful observations or data. Thus, it is not surprising that the dynamic models which made inroads in social sciences came from biology. For instance, the Loka-Volterra model was applied in economics by Richard Goodwin in the 1960s (*41, 42*), and ever since, the prey-predator paradigm has been used in social sciences with moderate successes. As stated earlier, one of the limitations of this model is that it does not include higher-order interactions. This was recently also observed by Jakimowicz (*43*), who commented that dynamic models utilizing the wormhole concept are likely to be beneficial in economics. The observation seems to be further supported by the idea of the economic black hole, which has been slowly emerging in business literature for the past two decades (*44*). These remarks and trends can now be explored further by using the globotoroid model.

Additionally, when social sciences data is available, the proposed model can also be applied as a tool for data analysis. This is because the collected data in social sciences frequently exhibits growth patterns, which is particularly true of business and financial data. Such data can be introduced into the model by assigning them to the growth variable $z(t)$, and the rest is up to a modeler, or analyst, to figure the coefficients in eq. (3). For example, if we consider the market data provided by the S&P 500 Index as a growth curve, then one can obtain the globotoroid-like representation illustrated in Fig. 7. The raw market data in Fig. 7A is color-coded for clarity of date stamps imbedded in Fig. 7B. As we see, the data corresponding to the orange, blue and red date stamps are wrapped around a growth sphere, while the yellow and green data are forming a wormhole. In the model, the coefficient ω is selected so that one orbit corresponds to one year of market activity, while A regulates the wormhole opening. In Fig. 7C, the model was slightly modified to produce orbits that correspond to one month of market activity, and with it expose details of the wormhole structure with more clarity. Now it is up to business or financial analysts to interpret the meaning of the solutions. Take a look at https://youtu.be/gbPaG9AHZfg.



A) Raw Market Data B) Yearly Orbits C) Monthly Orbits

Fig. 7: The globotoroid model for S&P 500 Index data with model parameters ω=25, A=2.25 and Δt=0.001.

CONCLUSIONS:

A simple 3-dimensional ODE model is used to create a blend between the toroid and the globe topologies, here referred to as the globotoroid. It is revealed how this 3-dimensional periodic structure is free from equilibrium points and, instead, supports a qualitative behavior known as the wormhole. This qualitative behavior keeps the blended topologies together by continuously re-energizing the compactly packed globotoroid nest. In the past, these types of dynamic models were unknown. These models generally exhibit behaviors that are more natural and useful than the behaviors found in the equilibrium type models, even in the instances when the dynamics considered are far-from-equilibrium. With the introduction of wormholes into systems theory, scientists can now explore dynamics within the framework of a complete energy cycling process, which happens to be one of the most fundamental properties of our universe.

Although the globotoroid solutions are governed by a simple ODE, their interpretations are far reaching. This was demonstrated by providing and discussing examples from different scientific disciplines. Being in its infancy, the globotoroid model offers a variety of challenges that should be of interest to both theorists and practitioners.

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SUPLEMENTARY MATERIALS:

Additional information with 3-dimensional animations of globotoroids are presented on the website; http://www.globotoroid.com