The Helios Theory: The Sun as a Self-Regulating System and as a Cosmic Living Organism

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Abstract: I summarize here the recent scientific achievements exploring the causal chain of solar activity. Following the causal chain has led to a novel, comprehensive picture, including system-level regulation of local processes, such as the mass flows in the solar interior. I call attention to some crucial aspects of solar activity and present a series of facts that demand a revision of the old picture, according to which the Sun is a mere "hot ball of gas." For example, the magnetic changes of solar activity are accelerated more than a billion times faster in comparison to theoretical expectations. The closer aspects of the comprehensive picture show that the mass flows accelerating magnetic changes deviate significantly from their physically prescribed behavior corresponding to the given physical conditions of the solar interior. I argue that they must be orchestrated in a highly sophisticated manner. Another novel aspect that has been found is that the dynamo process is not enough to give an account of the magnetic cycle, since a regulative factor is needed to make the dynamo a machine. I show that the existence of a machine within the Sun introduces novel conceptual issues transcending the conceptual framework of physics. The novel problems have guided my search for the ultimate causes of solar activity toward biology. I present arguments showing the difference between the thermodynamic behavior of far-from-equilibrium open systems and the non-physical behavior of solar activity initiated by biological causes determining and organizing quantum uncertainties. Remarkably, the results fit adequately with the Whiteheadean view of organizational duality and show that the Sun can be regarded as a compound individual.

> "The creative activity of the World as a whole
> must be operating in the stars
> just as in our solar system."
>
> Sir Francis Younghusband

1. The Sun's Place in the Cosmic Hierarchy

The question of whether the Sun is completely inanimate has never been debated in the history of modern science. The modern view simply claims that the Sun is a mere "hot ball of gas" (Kiepenhauer 78; Ridpath 450). Accordingly, Griffin formulated that "rock or star is devoid of spontaneity" and "the spontaneities of their various members cancel each other out" (*Panentheism* 123; also see Whitehead 102). Systematic research in the last decades has led me as a solar physicist to remarkable evidences that require a revision of this old view. Actually, the Sun manifests a systematic kind of spontaneity, including extremely complex and energetic phenomena on a large variety of temporal and spatial scales. Although the standard solar model is successful in describing the structure of the Sun (Figs. 1, 2), it is unable to give an account of these spontaneous phenomena that are collectively called "solar activity" (see Carpenter et al.; Parker, "Solar"; Spruit; Judge; and several of my own publications).

Charles Hartshorne claims that complexity increases as one goes up the hierarchy (112ff) from atoms toward the Universe as a whole. One would think it plausible to consider that the complexity of the Sun corresponds to its place in the Universe. If so, the Sun's complexity should

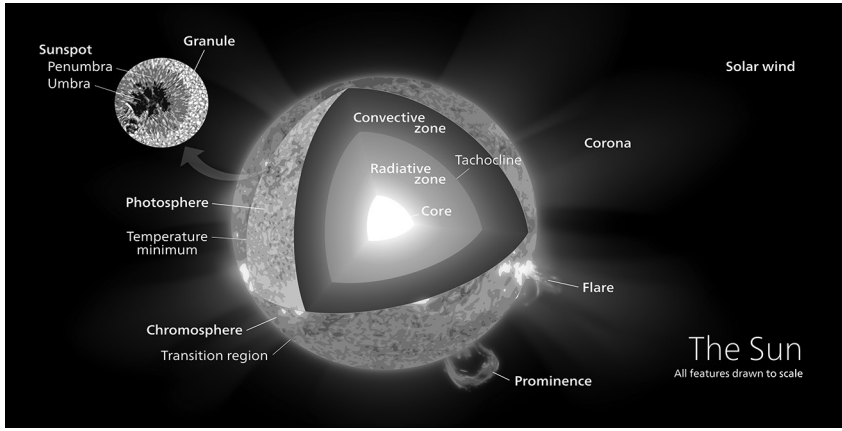

Figure 1: The structure of the Sun. Behind its 6,000-degrees-hot surface called the photosphere lies the convective zone having a depth around 200,000 kilometers. Behind the convective zone lies the radiative zone. The innermost region of the radiative zone is the Sun's energy-producing core. The core inside 0.20 of the solar radius extends only to 0.8 percent of the Sun's volume but generates 98 percent of the Sun's total fusion power.

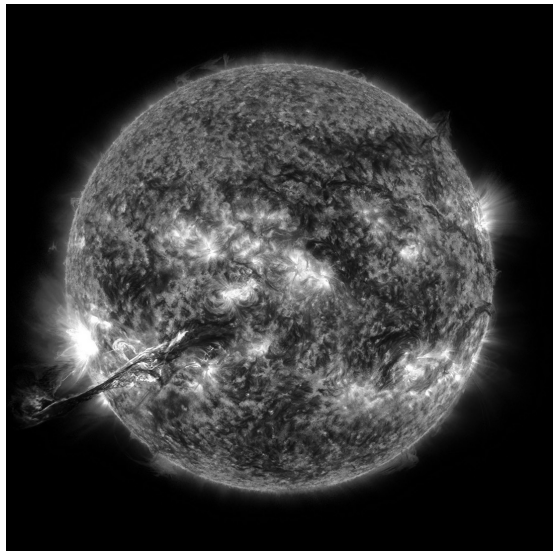

Figure 2: Solar activity is a highly spectacular phenomenon involving dark sunspots, violent solar eruptions like flares, hot active regions, and strong dynamism of Sun's matter.

be seen as in between that of humans and the Universe, both involving extremely high levels of spontaneity, complexity, and creativity.

2. How to Understand Our Star, the Sun

Modern science is based on observations. The *usual approach* in solar physics is to obtain observations and study their most immediate aspects. For example, solar flares are treated in their most immediate contexts, such as the structural changes in the nearby magnetic fields (Fig. 3). This is the *observational approach*.

The *theoretical approach* considers solar activity in its somewhat larger contexts. In space, this approach involves the convective zone extending down 200,000 kilometers below the photosphere. On these broader scales unified, global phenomena show up in a solar activity cycle. Remarkably, the local phenomena, such as sunspots and flares, are also involved in this global cycle, having an average period of around eleven years. Each cycle shows a minimum phase with practically no field and no or few sunspots that are observable. After usually four to five years, the activity reaches its maximum phase, characterized by a large number of big sunspots, sometimes reaching one hundred to two hundred in number.

If our aim is to understand solar activity, we have to obtain a comprehensive picture of the causes of its changes. This task requires us to explore the causal chain of events backward from the observed manifestations of

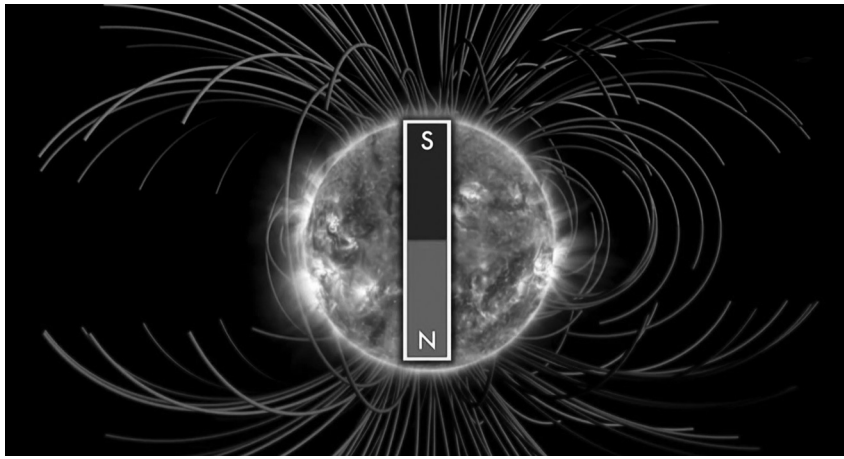

Figure 3: The global magnetic field of the Sun is similar to that of a bar magnet having a northern (N) and a southern (S) pole.

solar activity to the more primary causes. Actually, the most important causal factors determining solar activity do not necessarily fall in the range of the two above approaches. As a solar physicist, in the first years it was highly disturbing for me to realize that some aspects of solar activity seem to be inconsistent with the usual picture in which solar activity was determined by local physical conditions plus random factors. Due to decades of systematic work, this *comprehensive causal approach* has led to a more inclusive picture that extends from solar system-level interactions throughout the solar interior down to the energy-producing solar core.

3. The Comprehensive Causal Scheme of Solar Activity

In this comprehensive picture, magnetic braking is at the origin of causal scheme (Grandpierre, "The Origin"). Magnetic braking of the Sun arises because it is connected to the solar system by its magnetic field, and this interaction decelerates the rotation of the Sun. It is magnetic braking that is responsible for the fact that *the slower a star rotates, the lower the level of its activity is* (Skumanich).

The global magnetic field constrains the hot ionized plasma of the solar interior to co-rotate. The solar energy-producing core is theoretically expected to rotate four to fifteen times faster than the surface of the Sun. In contrast, observations confirm that the solar core rotates as slowly as the solar surface. The co-rotation of the solar core indicates that magnetic braking extends down to the solar core. If so, the huge rotational energy

of the Sun must be liberated, in transient events, in the solar core (Grandpierre, "The Origin").

Moreover, it has become known that the strength of surface magnetic activity is determined solely by the star's rotation rate and is independent of other stellar parameters, such as the depth of the convective zone (Reiners, Schuessler, and Passegger). This fact also confirms that *solar activity must be rooted, ultimately, below the convective zone, namely in the solar core*.

In an inhomogeneous body permeated by a magnetic field, rotational energy dissipation is generally manifested in transient local, point-like events somewhat similar to earthquakes. During the last 4.6 billion years, the solar core has spun down from a fifty-times higher value at the zero-age main sequence to the present one. The enormous difference in the Sun's earlier and present rotational energy must be liberated in the solar interior. The present rate of solar spin-down indicates that the rate of rotational energy liberation within the solar core in a year corresponds to the energy of a hundred large solar flare eruptions occurring in the solar atmosphere.

Realizing that the liberation of rotational energy occurs in a point-like region, we arrive at the conclusion that this small region must become extremely hot. Since the energy production in the solar core goes with a high power of temperature, the rate of nuclear energy production proceeds faster in this hotter region. The faster energy production leads to even higher temperatures that accelerate the nuclear energy production in the hot volume to an increasingly higher rate (Grandpierre, "How"). A positive *feedback cycle* develops almost explosively, a "thermonuclear runaway in the solar core." The developing "hot bubble" becomes hotter and hotter and expands more and more into its environment. The arising buoyant force acting upon the bubble will be able to move it away from the solar core and accelerate it toward the solar surface (Grandpierre, "A Pulsating-Ejecting").

Detailed numerical calculations indicate that within suitable conditions these hot bubbles might reach the solar surface regions (Grandpierre, "Dynamism"). Since these hot bubbles are accelerated upward, they become faster and faster on the way toward the solar surface and arrive there approximating the local sound speed. At this threshold, a sonic boom develops, transforming the energy of the fast hot bubble into the generation of high-energy particle beams injected upward into the solar atmosphere. The high-speed particle beam usually hits the top of the magnetic loop connecting a pair of bipolar sunspots, transported and

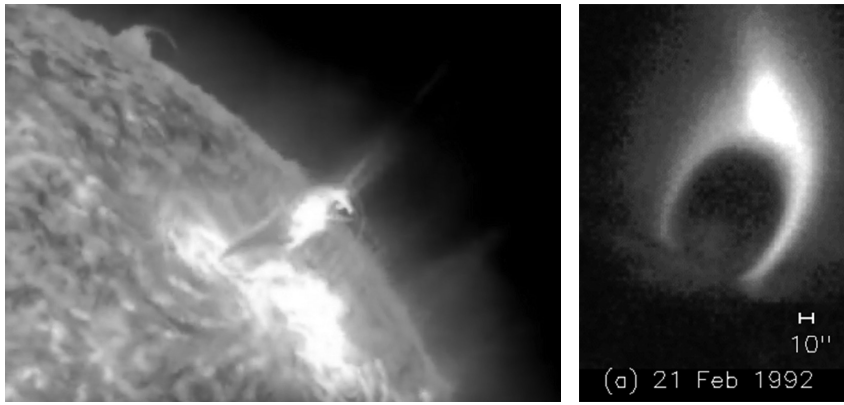

Figure 4: On the basis of the atmospheric theory, the primary explosion is assumed to occur above the loop top and directed downward. If so, it should produce downward concave intrusions at the top of the magnetic loop interconnecting sunspots. Remarkably, observations show the contrary: the eruptions explode from below upward (see also the video www.youtube.com/watch?v=SeSKSmEVwz8) and produce upward elongating cusp-like structures at the loop tops.

compressed by the uprising hot bubble. The high-energy particle beam injected into the magnetic loop becomes suddenly decelerated (Grandpierre, "A Mechanism"). A significant part of its energy will be radiated in the flare phenomenon. At the same time, it elongates the magnetic field lines *upward* from below (Fig. 4).

Although the usual picture about solar activity is that it is basically a discharge of the electromagnetic energy in the solar atmosphere similar to the lightning in the atmosphere of the Earth, it is more similar to terrestrial volcanism.

The comprehensive causal scheme calls attention to the systematic study of system-level relations. In James Lovelock's words, this new branch of solar science can be termed *solar system science*. Among the main tasks of this new science could be the study of the relations between such global parameters like rotation, global magnetism, luminosity, planetary influences, and local activities like emergence of sunspots, mass flows, magnetic configurations, and other manifestations of the complexity of solar activity. Remarkably, some predictions of the comprehensive solar model already have been confirmed (Ehrlich; Clark; Wolff and O'Donovan; Wolff; Scafetta).

4. Three Questions Regarding the Causal Chain of Solar Activity

4.1. Question 1: What Is the Cause of the Changes in the Global Magnetic Field?

It is a popular view that solar activity, both locally and globally, is dominantly a magnetic phenomenon (Charbonneau, "Solar Dynamo"). In case we want to understand solar activity, the question arises: what is the cause of these magnetic changes? Considering that the magnetism of solar activity is manifested locally and globally, our first question is: *what is the cause of the changes in the global magnetic field?*

The Problem of the Acceleration of Magnetic Changes in a Rate of Billions

As one of the most eminent solar physicists suggested (Parker, "The Origin"), one would expect that a massive, sluggish, gently heated globe of gas like the Sun would be entirely placid: the epitome of celestial tranquility. On a physical basis, the global magnetic field of the Sun is theoretically expected to become weaker, losing half of its energy during a billion years by magnetic diffusion (Shore 178). In this way, the magnetic field decays asymptotically and would never decrease to zero. In contrast, observations show that the global solar magnetic field changes more than a billion times faster than expected and its changes have a different character: after the maximum of solar activity, it disappears completely to zero within five to six years. Solar activity is practically missing in the minimum phase for one to two years, and the next maximum of solar activity is usually reached within four to five years. Definitely, a non-magnetic factor must be responsible for the observed change of solar global magnetism. The only factor that could accelerate the rate of magnetic changes is mass flows in the solar interior generating, transporting, and modifying the magnetic fields quickly.

Since the hot, highly ionized gas of the mass flows have extremely high conductivity, the magnetic field is "frozen" into their matter, which means that mass flows transport the magnetic field lines with them. Their accelerating effect *must be permanent in one respect, namely, preserving their highly special quality suitable to accelerate the changes of magnetic field in a rate more than a billion times faster*. Magnetic fields and mass flows change fast in many respects, but one thing remains: the mass flows preserve their unique ability to accelerate magnetic changes in a rate of billions. The

next step in exploring the causes of solar activity arises in the following form: what is the cause of the mass flows that are causally responsible for the changes of global magnetism on the Sun?

The Problem of Organization of Internal Mass Flows in the Solar Interior

We have now two global fields to take into account: that of magnetic fields and that of velocity fields of the mass flows in the solar interior. My point here is that in the old picture, the mass flows are assumed to be heat flows determined by the *local physical conditions* in the solar interior. These local physical conditions determining the origin and dynamics of mass flows seem to be essentially *independent* from the strength and direction of the global magnetic field. This fact seems to lead to insurmountable difficulties in obtaining a causal explanation of solar activity. The difficulty arises because throughout the immense volume of the solar interior, the changes of mass flows and of magnetic fields must be in *a highly sophisticated and permanent relation* suitable to produce the cyclic changes in the global level of solar activity. We are led to think that the causal power of solar activity relies in *a special permanent relation of two continuously changing fields*, the magnetic and the velocity field. This special relation is a subtle and extremely sophisticated, apparently highly fragile but *invariant relation between two continuously varying, extremely complex and independent fields that are expected on physical grounds to be related randomly*.

Let me illustrate the strength of a solar magnetic field with the height of a sand hill in a desert. The hill of sand will lose its height as time passes by, since the grains of sand slowly roll down on the hillside. On a long timeline of a billion years, the sand hill would slowly shrink to half of its original height. In contrast, observations show that the magnetic field strength of the Sun actually disappears within a few years, and the Sun remains spotless for a year or two. Correspondingly, the sand hill exemplifying the Sun should shrink its height to zero within a few years and become "lowland" in a year or two. This strange behavior is due to internal mass motions within the sand hill. These internal mass motions should produce such whirlwinds that by their whirling motion suck in the material of the hill in all directions simultaneously, manifesting *strikingly strict correlations, highly effective and coordinated activities*. Such behavior of this strange sand hill, which is like solar activity, could not occur as a result of random internal changes or due to the wind blowing around.

This example calls our attention to the fact that the mass flows within the solar interior must be organized in a highly orchestrated manner in order to drive the magnetic cycle. Outer factors like planetary influences and internal factors like thermal fluctuations are not suitable to couple the magnetic and velocity fields in such a highly complex and special manner that they destroy and reproduce both fields from cycle to cycle. Local physical conditions are not suitable to produce causes responsible for the globally cyclic solar activity. After three decades of thinking about this tantalizing problem, I am led to realize that if local determinations could not work, the only possibility left is global determination. Unexpectedly, we are led to think about solar activity as initiated by the Sun itself. Yet before taking such a radical idea seriously, we have to be careful to conduct systematic research in order to obtain a broader and deeper picture about related problems.

4.2. Question 2: What Is the Cause of the Changes in the Local Magnetic Field?

The cyclic destruction and regeneration of the magnetic field locally requires magnetic reconnection or annihilation that is possible when compressive inflows push antiparallel field lines of equal strength to each other (Fig. 5).

Destroying the magnetic field in a point requires extremely special, oppositely directed mass inflows compressing oppositely directed magnetic fields of equal strength. The disappearance of the global magnetic field requires the destruction of the magnetic field in each and every point

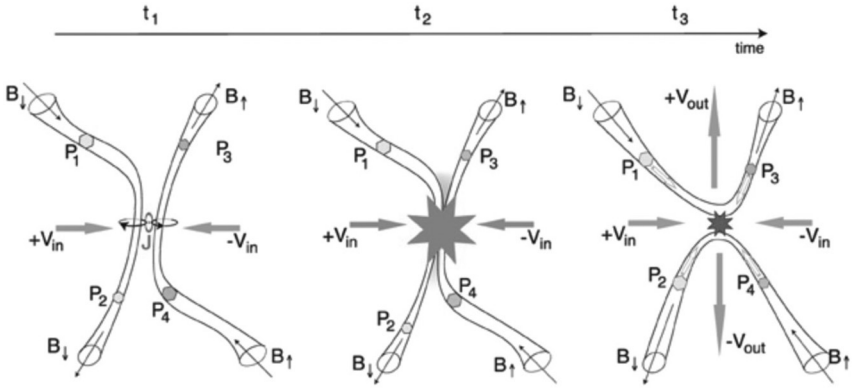

Figure 5: The annihilation of field lines requires compressive inflows pushing antiparallel field lines to each other (Treumann and Baumjohann).

in an orchestrated manner. The mass flows should arrive at the right place and at the right time and at the right velocities and at the right magnetic fields. These mass flows must maintain very strict relations, both structural and dynamic, between them. Such striking, strict relations both at the production of such special mass motions and at the development of their trajectories could not be expected on the basis of the locally given physical conditions. This is because the development of these internal mass flows is highly coordinated not only relatively to each other, but also relative to the strength, direction, structure, and future evolution of the magnetic field the mass flows meet on their trajectories to the site of reconnection. If the development of mass flows in the solar interior was determined by local physical conditions, they could not be expected to produce any pairs of compressive inflows of opposite direction. The only physical force that could deteriorate heat flows from their "vertical" (radial) pathways is the Coriolis force, but this acts uniformly and cannot turn the mass flows against each other. Moreover, the local physical conditions do not seem suitable to generate additional magnetic fields of equal strength and opposite direction transportable at the front of the mass flows. Therefore, the local physical conditions seem to be extremely unsuitable to be responsible for the disappearance and regeneration of the magnetic fields in the solar interior, especially simultaneously and preserving the magnetic field's global character. It seems that if the apparent cooperation of the individual mass flows cannot arise from local determinations, then it must be the result of governance from the global level of the Sun.

4.3. Question 3: What Is the Cause of the Cyclic Nature of the Magnetic Changes?

This question leads us to the *dynamo problem*. The only known process that could produce, destroy, and reproduce the global magnetic field is the *dynamo process*. The dynamo process is the generation of the magnetic field from material flow. In the case of the Sun, the assumption that a dynamo process is producing the magnetic field seems to be inevitable. It is inevitable because the magnetic field is observed to change cyclically, and no other process is known that could achieve that feat. It is plausible theoretically since it would require, by hypothesis, merely two simple processes.

The global solar magnetic field is basically similar to that of a bar magnet (Fig. 3); the magnetic field lines run from the northern to the southern pole along the longitudinal lines. The idea behind the solar dynamo is

that the rotation is faster at the solar equator (one rotational period at the equator is around twenty-six days) than at higher latitudes (one rotational period around the poles is almost thirty-eight days); therefore, the longitudinal magnetic field lines will become distorted and form an omega-shaped line instead. The differential rotation of the solar convective zone generates a latitudinal component from the longitudinal one. This is the assumed first step of the dynamo, and it is called the *omega effect*. It is speculated that if a second step would produce a longitudinal one from the latitudinal magnetic field produced by the omega effect, then the cycle could be completed and accounted for. This assumed second process is called the *alpha effect*. This elegant and plausible idea of the solar dynamo was introduced by Eugene Parker ("Hydrodynamic"). Unfortunately, it turned out that this idea does not seem to meet reality.

After more than fifty years of intensive research, it seems that the alpha effect does not work (Spruit; Werne). But even if it did, my point is that the omega effect should transform approximately all the pole-connecting fields of the given activity cycle into the latitudinal component of the next cycle, and the alpha effect should transform approximately all of them into the longitudinal component of the next cycle. Actually, the alpha effect could produce either a positive or a negative effect, adding to or diminishing the basic global magnetic field of the Sun. In either case, it may act only at some regions and at a certain rate. Considering that an enormous number of such local processes would be needed at many subsequent stages of the solar activity cycle, and both their directionality and the strength of the dynamo-produced field components should be suitable to destroy the complete global field practically at all points at the vast volume of the solar interior, the crux of the dynamo lies at the requirement that all the changes together should be suitable and sufficient to destroy and regenerate the field cyclically. The idea of the dynamo implicitly assumes a *regulating or organizing factor* that would make the dynamo work well as a *machine* (Fig. 6).

The point is that such a tailoring of each of the assumed effects as well as their fitting would require *a sophisticated regulation* which would make the dynamo process functioning regularly as a dynamo machine. *We have to distinguish the dynamo process and the dynamo machine*. It is useful to keep in mind that the solar dynamo as a machine has to produce the magnetic field regularly from the kinetic energy of the hot, highly ionized gas of the mass flows driving it. The dynamo as a process

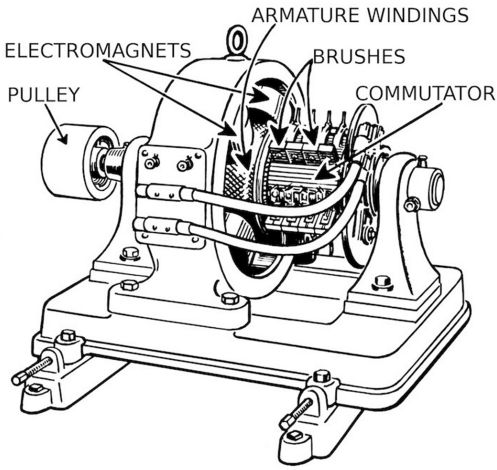

Figure 6: The dynamo is a complicated machine producing electromagnetic fields and currents by mechanical motions. It must be constructed in an extremely special manner harnessing the physical laws.

can be partial and contingent. The dynamo as a machine requires the maintenance of all the conditions necessary for the dynamo process to generate, destroy, and regenerate the solar magnetic fields more than a half billion times during the lifetime of our Sun. The difference between the non-regulating dynamo process and the regulating dynamo machine is remarkable and invites more attention. We have arrived at an unexpected, insurmountable, and inevitable conceptual difficulty. How could a *machine* be produced by the Sun?

Would it be possible to avoid such conceptual difficulties? Yes, but as the history of solar physics explicitly shows, the result is frustrating. Although astrophysical dynamos are at the heart of cosmic magnetic fields (Charbonneau, "Solar and Stellar"), *the generally assumed mechanism supplying the alpha effect*, namely the cyclonic turbulence of convection, *cannot lie at the heart of the solar dynamo* (Spruit). "Proper capture of important solar cycle elements—most notably the formation, emergence and surface decay sunspots and active regions—is certainly not forthcoming" (Charbonneau, "Dynamo" 73). Faced with such issues, it is no wonder that the dynamo is one of the truly largest mysteries in astrophysics (Carpenter et al.). At present, there is not even a generally accepted approximate dynamo model. In fact, the *experts do not agree which are the key processes that are involved* (Carpenter et al.). In other words, dynamo theorists cannot identify the essential ingredients of the dynamo. *The standard view, which treats the solar cycle as a manifestation of the interaction*

between convection and magnetic fields, is shown to be misplaced (Spruit). It is no wonder that in this situation the present state of the dynamo theory can be characterized with the title of a recent summarizing essay "Solar Magnetic Fields: History, Tragedy, or Comedy?" (Judge). In the conclusion of this paper, the frustration is formulated explicitly: "I leave it to the reader to decide if the history of dynamo theory, as related by Parker (2009) and Spruit (2011), is a tragedy, or perhaps a comedy" (Judge).

It is easy to spend a lifetime in the usual framework, exploring the extremely complex magnetic fields and mass flows and their relations observationally and theoretically. The hard thing to do is to find the causes of these phenomena in trying to understand solar activity. In the effort to understand the origin of solar activity, we cannot avoid the conceptual issues that arise. The working of a dynamo machine in the Sun involves conceptually unusual, more inclusive, regulating, and engineering principles. Michael Polanyi has pointed out that *the machine as a whole works under the control of two distinct principles. The higher one is the principle of the machine's design*, and this *harnesses* the lower one, which consists in the physical-chemical processes on which the machine relies. But where is the designer in the case of the solar dynamo machine?

It seems that the production of mass flow pairs developing into compressive inflows at the site of magnetic reconnection requires a *global-level regulation*. Considering that the generation and development of mass flows and the magnetic fields they transport in the solar interior as well as the special configuration required for the annihilation of the field lines are all necessary ingredients for the operation of the solar dynamo, it seems that the local physical conditions prevailing in the solar interior are highly insufficient tools. Another unexpected conceptual difficulty arises: *the insufficiency of local or effective causes*. Could it be that the problem is that we are accustomed to such restricting expectations that make the problems of solar activity unsolvable?

It is timely to take a step back and reconsider our basic knowledge from a distance of an unbiased scientist.

5. On the Complexity of Solar Activity

Recently it has become established that the Earth as a whole is a self-regulating complex entity called Gaia (Lovelock). Considering that the Earth is a planet of the solar system, its complexity indicates that creative powers act on cosmic scales. But could any creative cosmic power do anything with such an apparently simple "ball of gas" like the Sun?

Remarkably, gas is the state of matter that has no fixed shape and no fixed volume, consisting of free particles, each particle having minimally three degrees of freedom. Since the mass of the Sun is 2×10^{33} grams, the total number of these free particles is enormous, more than 10^{56}. From this point of view, the Sun involves enormous possibilities that exceed anything we know on Earth, including the human mind. In comparison, the number of magnitudes regarding the population of particles on the Sun is double the magnitudes involved in a human body involving a mere twenty-eight magnitudes. What can our Sun do with such a huge number of possibilities exceeding the potential of a human organism's complexity at the same rate that is found between atoms and human beings? Accepting that Nature involves "natura naturans," or creativity, the question arises: What can Nature's first generation offspring, the Sun as the manifestation of cosmic creativity, do with its cosmically vast potential of possibilities? Does the Sun have any suitable tools to act with on such a tremendous storehouse of possibilities?

It is important to realize that the Sun has access to the full arsenal of all cosmic powers simultaneously at the same place. All four fundamental physical interactions (gravitation, electromagnetism, weak and strong nuclear interactions) are present in the Sun, including their quantum fields permeating each other and containing vast energies that are not merely given properties, but possibilities to live by. Indeed, the Sun lives with all these energies and continuously mobilizes them, producing its light and all the remarkable forms of its activities. Changes occur at all its levels simultaneously, from the level of quantum fields and elementary particles through a variety of scales of organized microscopic and macroscopic motions and energies, including their couplings. The number of the possible couplings have combinatorial perspectives. We have found that the most spontaneous, autonomous, and self-determined form of solar activity is present in its internal mass flows. Solar activity represents a vast level of complexity that is suitable to store an immense amount of information. Indeed, solar activity has been shown to manifest a significant amount of information (Consolini et al.). Let us mention here only one of these factors: electromagnetism. In stars like the Sun, highly complex features like current filaments, current sheets, and plasmoids can be spontaneously produced in a large number due to a variety of instabilities (Grandpierre, "Conceptual"; Grandpierre and Ágoston).

It would be important to know whether organized, algorithmic complexity (Grandpierre, "Fundamental") is present on the Sun or not.

Remarkably, the construction principle of machines can be characterized by algorithmic complexity. It seems inevitable to admit that a dynamo machine exists on the Sun. Consequently, the algorithmic complexity of the solar dynamo's construction principle should be created *in situ*. It seems unavoidable to allow that this algorithmic complexity is created by the Sun itself, since the solar dynamo must be created by the Sun. Let us try to explore what this task requires.

We must admit that the construction of a machine requires the suitable arrangements of its components. Actually, in the case of the Sun, the dynamo consists not of solid but of gaseous, liquid, or plasma "components." In the case of the solar dynamo, it is not possible to make a "ready" machine because all its elements are in a continuous state of change. Therefore, the only possibility to make the dynamo operational is to prepare and maintain all the initial and boundary conditions necessary for the working of the dynamo. We are led to allow that a regulating process exists on the Sun that arranges the necessary input conditions for the solar dynamo. Systematic regulation of the input elements of a physical system that leads to a permanent output is called "control" in science. We are led to assume that the Sun creates its own dynamo and controls the processes necessary for it.

The following three aspects of solar activity are remarkable:

1. Local physical conditions are unable to produce the highly sophisticated relation that must exist between continuously changing mass flows and magnetic fields. The mass flows preserve their unique ability to accelerate magnetic changes despite all other changes. Acceleration of magnetic changes at a rate of billions requires extremely efficient regulation of physical processes.
2. Local physical conditions seem to be unable to produce mass flows and magnetic fields suitable for systematic reconnection. It requires systematic deviation of the pairs of mass flows from their buoyant pathways. These systematic deviations are physically impossible; therefore such a regulation seems to be physically impossible. The factor organizing the relation of mass flows and magnetic fields is present all the time at every point of the solar interior. It governs mass flows everywhere at the right place and at the right time and at the right velocities and at the right magnetic fields. Local physical determinations seem to be highly insufficient.

3. The dynamo process is not enough. Instead, a dynamo machine is needed. A machine as a whole involves higher-level control above the physical level (Polanyi) and assumes outer purpose (Nicholson). It requires a tailoring, regulating, or organizing factor involving design principles for which local physical conditions are insufficient. The solar dynamo is controlled by a regulative factor organizing its conditions permanently. The control over physical processes arguably involves the Sun. Solar activity can be, indeed, the genuine activity of the Sun.

In sum, the observed stable character of the global activity cycle indicates that while both magnetic fields and velocity fields change completely, there is something that remains invariant, and this something is the extremely special way they interact. Within the framework of physics there is no room for such an extraneous regulation. At the same time, the deviations from pathways determined by local physical conditions are significant, systematic, and preserved among the varying physical conditions. Such deviations from physical pathways require a significant amount of freedom and causal power in order to produce the sophisticated, subtle, orchestrated changes of mass flows and magnetic fields.

I can add that, besides these problems of solar activity, even larger problems are included as well. For example, the energetics of solar activity seem to involve a significant part of total solar luminosity. All these energy forms are regulated invariantly in a highly unique and orchestrated manner despite the permanent changes in the local physical conditions. Perhaps the biggest problem of all is that *solar activity, besides being governed by physical laws, regulates the input conditions of these laws by regularly creating and regenerating the potential differences that are consumed in solar activity*. We need a suitable tool of science to solve these problems and conceptual issues simultaneously.

If physics seems to be unsuitable to answer them and we prefer to remain within the framework of science, the next thing we can do is to turn toward biology. This move requires one to formulate the nature of life in a context suitable to solve the above problems of solar activity. There exists only one way for a promising approach to identify the nature of life, and this is to find the *general scientific theory of life* (Cleland). Fortunately, such a theory does exist, even if, due to historical reasons, it is not well known; it is the theoretical biology of Ervin Bauer (Bauer; Grandpierre et al.).

7. Life as Control over Matter

The theoretical biology of Ervin Bauer states that living systems are living because they unceasingly invest work on the debit of their free energy to increase as much as possible their deviation from the physical behavior that should occur on the basis of physical laws within the given conditions (43–55). Bauer has formulated the biological principle also in a mathematical form. Living organisms continuously invest work on the very conditions within which the physical laws prevail. The work invested by living organisms is a highly special and unusual kind of work. It is a biological work on the physical conditions of physical laws. This biological work is not controlled by physical laws because it occurs on the quantum level (Grandpierre, "Genuine"; Grandpierre, Chopra, and Kafatos). There is a large enough room for biological self-determination below the quantum level. The uncertainty relation allows the spontaneous creation of virtual particle pairs within quantum limits. The physically undetermined quantum of action could be determined by biological causes. No physical laws are violated. Instead, all physical laws are governed by their input elements that are controlled biologically. Biological control is harnessing the physical laws. *Biology is the control science of physics.*

The biological work is a pre-physical work since it acts on the input elements of physical laws, preparing these input conditions in such a way so to become suitable to realize biological aims, namely, to increase the biological potential differences prevailing within the living organism. More precisely, this biological work regenerates the biological structures and their potential differences, making them able to do their job.

According to popular views, living organisms are open systems in "dynamic equilibrium" or "far from equilibrium." For example, living organisms are frequently compared to a waterfall. There are some similarities between a waterfall and living organisms: both are in a long-term quasi-static state preserving form, both require matter and energy input from their environment for their maintenance, and both are capable of doing work. Similarly, many people consider that living organisms are nothing but open thermodynamic systems, obtaining energy and matter from their environment that maintain their work, like that of a waterfall. But let us now consider their differences. Living organisms are capable of doing work even in the relatively long-term absence of external energy sources. In contrast, the waterfall ceases to exist immediately in the absence of water coming into it from above. Moreover, and even more importantly, living organisms do a highly special kind of work. The

chemical energy of the food intake is first transformed by biological work *regenerating the potential differences* that makes it possible to maintain life and do physical work. On the basis of Bauer's principle, a waterfall would be qualified as living only if it could itself initiate work by creating the level differences between the incoming and outgoing flow of water by systematic deviations from the physically prescribed pathways of its own behavior. This is a principal difference that cannot be bridged by any physical ways.

The distinguishing characteristic of living organisms is that they utilize the incoming flux of matter and energy directly for biological work invested in the level of the quantum vacuum. They are fundamentally different from the far-from-equilibrium open systems studied in non-equilibrium thermodynamics. Living organisms generate the biologically useful potential differences by *biological causes generating virtual particle pairs*. The energy required for generating virtual particle pairs is supplied by *biologically governed energies* (Grandpierre, "Genuine"; Grandpierre and Kafatos, "Biological," "Genuine"). Living organisms utilize the incoming physico-chemical energies for creating potential differences on the basis of their own laws that distinguish them from machines and open thermodynamic systems. This theory repairs, simultaneously, two fundamental insufficiencies of quantum theory. At present, quantum theory assumes the *violation of the law of energy conservation* in case of virtual particle pair production as well as *acausality*, rejecting the universal validity of the causality principle. Now if biological causes would elicit quantum fluctuations, as I suggest here, then biological energies could supply the necessary energy and the necessary causes, achieving two fundamental improvements over quantum theory.

Bauer's principle prescribes that in each time step the boundary conditions change ("jump") quantum mechanically from the one that would be the output of the previous time step on the basis of the physical laws (Grandpierre, "Biological Principle," "On the First," "Genuine"). *In each time step a self-determining biological change occurs*, increasing the biological potentials to larger values further away from physical equilibrium. This is the way biological organization becomes possible: the elementary deviations from physical pathways are the elementary "actions" that arise due to biological causes that become increasingly significant, organized, amplified, and integrated into observable amplitudes that deviate characteristically and lawfully from the physical behavior. It is the integral form of the biological principle (Grandpierre, "Biological Extension")

that realizes the cumulative summing up of all the elementary biological interventions from the quantum level to macroscopic levels.

8. The Sun and the Organizational Duality of Nature

It is a remarkable fact that our idea of biologically organized subquantum determinations is practically identical with the Whiteheadean idea of "organizational duality" (Griffin, *Reenchantment* 22; *Panentheism* 30). A crucial part of this doctrine is that there are two ways in which low-grade individuals, such as photons, quarks, or gluons, can be combined. The first way to combine these elementary quantum units is what leads to a nonindividuated object, in which no unifying subjectivity is found. Instead of being combined randomly, as it is usual in physics, the elementary quantum units can be combined systematically so as to form compound individuals. It is this way of combination that is found in solar activity and in biological organization governed by Bauer's principle, as indicated above.

Whitehead notes (100) that *the growth of complex structured society exemplifies the general purpose pervading Nature*. If so, the task exploring the complexity of our Sun can be regarded as highly timely.

Exact theoretical biology states that *the most essential aspect of living organisms is that they utilize the energy sources available to them to regenerate the potential differences necessary to maintain their internal system of activities*. We have obtained strong evidence in accordance with a whole set of scientific indications to claim that our Sun is a cosmic life form indeed—of course not protein-based, but a generalized, plasma-based life form (Dyson; Rothstein; Grandpierre, "Fundamental Complexity").

Unexpectedly, our scientific research has resulted in a picture of the Sun being an extremely sophisticated, complex and creative, self-regulating living organism, similar to the ancient idea that considered the Sun as a Sun god named Helios. In this way, our *Helios theory* can be regarded as the companion of Lovelock's famous *Gaia theory*. James Lovelock, the author of *Gaia: A New Look at Life on Earth* recommends the book *The Helios Theory* (Grandpierre) with the following words: "A shining book illuminated by the effulgence of our own star, the Sun. For the serious scientist a primer on solar system science."

Conclusions

By following the causal chain of solar activity we have found that the physical causes form a unified system connecting the global and local

levels of solar activity in a regulative manner. We have found that solar activity involves primary causes regulating and controlling the physical ones, manifesting a kind of biological activity. The Helios theory could become a part of constructive postmodern cosmology and a pioneer in developing a well-grounded comprehensive scientific worldview pointing toward the general theory of the living Universe.

Works Cited

Bauer, Ervin. *Elméleti biológia*. Budapest, Akadémiai Kiadó, 1967.

Carpenter, K. G., et al. "Stellar Imager Vision Mission Report." *Vision Mission Study Report*, 15 Sept. 2005, https://hires.gsfc.nasa.gov/si/documents/Exec_Summary_SI_Report_final_091505_ebook.pdf.

Charbonneau, P. "Dynamo Models of the Solar Cycle." *Living Reviews in Solar Physics*, vol. 7, 2010, p. 3.

---. "Solar and Stellar Dynamos." *Saas-Fee Advanced Course: Swiss Society for Astrophysics & Astronomy*, vol. 39, 2013.

---. "Solar Dynamo Theory." *Annual Review of Astronomy and Astrophysics*, vol. 52, 2014, pp. 251–90.

Clark, Stuart. "Sun's Fickle Heart May Leave Us Cold." *New Scientist*, 25 Jan. 2007, p. 12.

Cleland, C. E. "Understanding the Nature of Life: A Matter of Definition or Theory?" *Life as We Know It*, edited by J. Seckbach, Dordrecht, Springer, 2006, pp. 591–600.

Consolini, G., et al. "Information Entropy in Solar Atmospheric Fields: I. Intensity Photospheric Structures." *Astronomy and Astrophysics*, vol. 402, 2003, pp. 1115–27.

Dyson, F. "Time Without End: Physics and Biology in an Open Universe." *Reviews of Modern Physics*, vol. 51, 1979, p. 3, www.aleph.se/Trans/Global/Omega/dyson.txt.

Ehrlich, Robert. "Solar Resonant Diffusion Waves as a Driver of Terrestrial Climate Change." *Journal of Atmospheric and Solar-Terrestrial Physics*, vol. 69, 2007, pp. 759–66.

Grandpierre, Attila. "Biological Extension of the Action Principle: Endpoint Determination Beyond the Quantum Level and the Ultimate Physical Roots of Consciousness." *Neuroquantology*, vol. 5, 2007, pp. 346–62.

---. "The Biological Principle of Natural Sciences and the Logos of Life of Natural Philosophy: A Comparison and the Perspectives of Unifying the Science and Philosophy of Life." *Analecta Husserliana*, vol. 110, 2011. pp. 711–27.

---. "Conceptual Steps Towards Exploring the Fundamental Lifelike Nature of the Sun." *Interdisciplinary Description of Complex Systems*, vol. 2, 2004, pp. 12–28.

---. "Dynamism in the Solar Core." *Proceedings of the Third UN/ESA/NASA Workshop on the International Heliophysical Year 2007*, edited by Hans Haubold and A. M. Mathai, New York, Springer, 2010, pp. 103–39.

---. *Az Élő Világegyetem könyve* [*The Book of the Living Universe*]. Budapest, Valasz Konyvkiado, 2002.

---. *Az Élő Világegyetem könyve 2012* [*The Book of the Living Universe 2012, thoroughly revised edition*]. Budapest, Titokfejto Konyvkiado, 2012.

---. "Fundamental Complexity Measures of Life." *Divine Action and Natural Selection: Questions of Science and Faith in Biological Evolution*, edited by J. Seckbach and R. Gordon, Singapore, World Scientific, 2008, pp. 566–615.

---. "Genuine Biological Autonomy: How Can the Spooky Finger of Mind Play on the Physical Keyboard of the Brain?" *Anthology of Philosophical Studies*, vol. 7, 2013, pp. 83–98.

---. *The Helios Theory. A New Look at the Sun and Life*. Submitted.

---. "How Is the Sun Working?" *Solar Physics*, vol. 128, 1990, pp. 3–6.

---. *Living Universe through the Eyes of a Solar Astronomer*. Submitted.

---. "A Mechanism Driving Solar Flares." In *Proceedings of YOYOGI Symposium in Observational Plasma Astrophysics*, edited by T. Watanabe, et al., Berlin, Springer, 1998, 83–84.

---. "On the First Principle of Biology and the Foundation of the Universal Science." *Analecta Husserliana*, vol. 107, 2011, pp. 19–36.

---. "The Origin of Solar Activity: Local Thermonuclear Runaways in Hot Bubbles and Their Triggers." *Planetary Influence on the Sun and the Earth and a Modern Book-Burning*, edited by N. Morner, Hauppauge, NY, Nova Science Publishers, 2015, pp. 97–113.

---. "A Pulsating-Ejecting Solar Core Model and the Solar Neutrino Problem." *Astronomy and Astrophysics*, vol. 308, 1996, pp. 199–214.

Grandpierre, Attila, and Gabor Ágoston. "On the Onset of Thermal Metastabilities in the Solar Core." *Astrophysics and Space Science*, vol. 298, 2005, pp. 537–52.

Grandpierre, Attila, Deepak Chopra, and Menas Kafatos. "The Universal Principle of Biology: Determinism, Quantum Physics and Spontaneity." *NeuroQuantology*, vol. 12, 2014, pp. 364–73.

Grandpierre, Attila, and Menas Kafatos. "Biological Autonomy." *Philosophy Study*, vol. 2, 2012, pp. 631–49.

Griffin, D. R. *The Reenchantment of Science*. Albany, SUNY P, 1998.

---. *Panentheism and Scientific Naturalism*. Claremont, CA, Process Century P, 2014.

Hartshorne, C. *Beyond Humanism*. Chicago, Willett, Clark, & Co., 1937.

Judge, P. "Solar Magnetic Fields: History, Tragedy, or Comedy?" *School of Astrophysics: Cosmic Magnetic Fields*, vol. 25, Winter 2014, http://people.hao.ucar.edu/judge/homepage/wsbook.pdf.

Kiepenhauer, K. O. *Die Sonne*. New York, Springer, 1953.

Lovelock, James E. *Gaia. A New Look at Life on Earth*. New York, Oxford U P, 1987.

Nicholson, D. J. "Organisms ≠ Machines." *Studies in History and Philosophy of Biological and Biomedical Sciences*, vol. 44, 2013, pp. 669–78.

Parker, E. N. "Hydrodynamic Dynamo Models." *Astrophysical Journal*, vol. 122, 1955, pp. 293–314.

---. "The Origin of Solar Activity." *Annual Review of Astronomy and Astrophysics*, vol. 15, 1977, pp. 45–68.

---. "Solar Magnetism: The State of Our Knowledge and Ignorance." *Space Science Reviews*, 144, 2009, pp. 15–24.

Polanyi, M. "Life's Irreducible Structure." *Science*, vol. 160, 1968, pp. 1308–12.

Reiners, A., M. Schuessler, and V. M. Passegger. "Generalized Investigation of the Rotation-Activity Relation: Favoring Rotation Period Instead of Rossby Number." *Astrophysical Journal*, vol. 794, 2014, article number 144.

Ridpath, I., editor. *A Dictionary of Astronomy*. New York, Oxford U P, 1997.

Rothstein, J. "Generalized Life." *Cosmic Search*, vol. 1, no. 2, 1979, http://www.bigear.org/vol1no2/life.htm.

Scafetta, N. "Does the Sun Work as a Nuclear Fusion Amplifier of Planetary Tidal Forcing?" *Journal of Atmospheric and Solar-Terrestrial Physics*, vol. 81, 2012, pp. 27–40.

Shore, S. N. *An Introduction to Astrophysical Hydrodynamics*. San Diego, Academic P, 1992.

Skumanich, A. P. "Time Scales for CA II Emission Decay, Rotational Braking, and Lithium Depletion." *Astrophysical Journal*, vol. 171, 1972, pp. 565–67.

Spruit, H. C. "Theories of the Solar Cycle: A Critical View." *The Sun, the Solar Wind, and the Heliosphere*, edited by M. P. Miralles and J. Sanchez Almeida, Berlin, Springer, 2011, 39–49.

Treumann, R. A., and W. Baumjohann. "Collisionless Magnetic Reconnection in Space Plasmas." *Frontiers in Physics*, vol. 1, 2013, ID 31, doi:10.3389/fphys.2013.00031.

Werne, J. "The Solar Dynamo." *NorthWest Research Associates*, 2014, http://www.cora.nwra.com/~werne/eos/text/dynamo.html.

Whitehead, Alfred North. 1929, *Process and Reality*. Corrected ed., edited by David Ray Griffin and Donald Sherburne, New York, Free P, 1978.

Wolff, Charles L. "Effects of a Deep Mixed Shell on Solar g-Modes, p-Modes, and Neutrino Flux." *Astrophysical Journal*, vol. 701, 2009, pp. 686–97.

Wolff, Charles L., and A. E. O'Donovan. "Coupled Groups of g-modes in a Sun with a Mixed Core." *Astrophysical Journal*, vol. 661, 2007, pp. 568–85.