Biotic patterns in the Schrödinger equation and the evolution of the universe

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1. Introduction

The evolving universe displays structure at multiple scales and levels of organization. Galaxies and clusters of galaxies are clustered together in a rich topological structure that has come to be called the “cosmic web” [Springel et al. 2006], which at multiple points displays spatial hierarchical lattice-like organization. Its formation from a single origin likewise represents lattice organization. The physical universe likewise displays group properties at multiple levels, beginning with the well-known symmetries exhibited by the organization of elementary particles and including the rotational movements of macroscopic objects.

Notwithstanding, equilibrium and randomness are regarded as natural. It is often assumed that at its origin, the universe was uniform [Springel et al. 2006] and in thermal equilibrium, and yet, contradictorily, also in a state of extremely low entropy [Carroll 2006]. The standard cosmological model assumes homogenous and isotropic mass distribution (Einstein’s cosmological principle), and a random stationary origin for the distribution of matter [see Peebles 1993], although the observation of large macroscopic heterogeneity in the distribution of galaxies and microscopic heterogeneity in the cosmic background radiation have led to the weaker notion that homogeneity is only statistical and at large scales. To account for large scale homogeneity, several inflation models have been advanced, beginning with those of Starobinsky and Landau. Inflation models predict that the large-scale structure derive from Gaussian random-phase distribution of quantum noise. It is proposed that the heterogeneous distribution of galaxies has been determined by random initial deviations from uniformity such as those detected in studies of the cosmic background radiation. However WMAP temperature maps show anomalies that are not expected from Gaussian fluctuations and show large-scale asymmetries unexpected in an isotropic and homogeneous space [Springel et al. 2006]. How does this heterogeneity come about? The origin of the initial quantum non-homogeneity and the mechanism for inflation are unknown. There is also no explanation [Bennett 2006] for the new epoch of accelerated expansion that only recently begun.

In contrast to random stationary models, we propose to regard the evolution of the universe as similar to the development of a biological organism that creates a unique individual starting from a set of structures (the genes) that determine its overall features largely independently from external inputs. In a similar manner, the evolution of the universe would be a creative development from a "cosmic gene", which is now embodied in the four basic physical forces, rather than as the product of chance and selection. In particular, we propose that physical processes embody logically necessary relations, lattice order, group symmetry, and topological form [Sabelli 1989]. At the quantum level, action, charge, and color are exemplary of these generic processes [Sabelli 2005]. Lattice, group and topology are fundamental components of all other mathematical structures (Bourbaki, [see Beth and Piaget 1968]), and are evident at multiple levels of organization.

Concretely, we propose that cosmological structure originated with quantum processes that generate an expansive pattern characterized by novelty, diversification, non-random complexity, asymmetric statistical distribution, and non-uniform recurrence plots. These features characterize bios, as contrasted to random, periodic, chaotic, or random walk patterns. Biotic patterns are generated mathematically with bipolar feedback models such as $A(t+1) = kt\sin(A(t)) + A(t)$ that combine action (recursion), bipolar opposition (trigonometric function) and connection with previous state ($+A(t)$ term), that is to say conservation. Biotic patterns are ubiquitous in natural and human processes (heartbeat intervals, respiration, sequences of bases in DNA, meteorological data, shape of rivers and shorelines, economic series [Kauffman and Sabelli 1998; Sabelli et al. 1997; Sabelli 2005; Levy et al. 2006] but they have often been described as noise or chaos.

Recently, Sabelli and Kovacevic observed biotic patterns in a discrete approximation to the Schrödinger equation [Sabelli and Kovacevic 2006] and in the temporal distribution of galaxies (Sabelli and Kovacevic 2003]. (The finite velocity of light convolutes time and space in the direction away from of our point of observation when considering galactic scales.) They thus proposed that biotic processes contribute to cosmological evolution.

Here we confirm, expand and consolidate these results by studying the exact continuous Schrodinger equation, its relativistic equivalent the Klein-Gordon equation, and three different distance scales: atomic, nuclear and Planck (time and distance scale obtaining shortly after the big bang). We also examine the distribution of galaxies as recorded by a more recent and extensive survey [Springel et al. 2006]. We highlight the importance of conservation through the examination of the process and the Klein-Gordon equations.

2. Biotic recursions

Recursions of bipolar feedback with a conserved term such as the process equation $A(t+1) = kt\sin(A(t)) + A(t)$) offer a model for creative development. Independently of the initial conditions, these recursions generate a series of increasingly complex patterns: steady state, periods, chaos, and bios. Chaotic and biotic trajectories are sensitive to initial conditions, but the sequence of patterns generated by the recursion, and the values of the parameter at which they emerge, are totally independent of the initial conditions. The generation of bios requires large enough gain $k \cdot t$ (representing the energy of the feedback), bipolar feedback (unipolar feedback, as in the logistic equation, produces only chaos) and the conserved term $+A(t)$.). Instead of converging to an attractor, biotic series (figure 1) expand, remaining only temporarily within a given boundary.

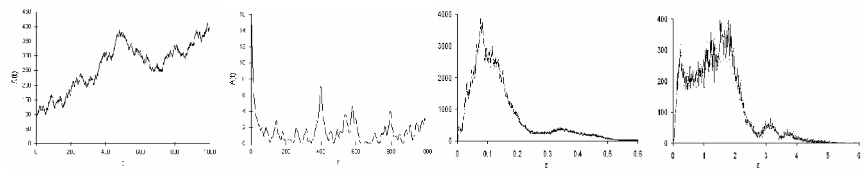

Figure 1. Time series from left to right: Mathematical bios generated with the process equation $A(t+1)=6\sin\left(A(t)\right)+A(t), \quad A(1)=100$; Schrödinger wave equation; Distribution of galaxies along the time-space z-axis; and distribution of quasars along the time-space z-axis.

3. Schrödinger Equation

We start with the equations for a particularly simple one-dimensional Schrödinger equation for a *particle* in an infinite well, making some useful scale changes to help focus but keep the discussion general. At atomic scales the well corresponds to an idealized hydrogen atom with one proton and one electron. The electron is trapped in the well by its electric charge. For reference, in three dimensions the Schrödinger equation has the following form for a general potential V :

$$i\hbar\frac{\partial\psi}{\partial t}=-\frac{\hbar^2}{2m}\nabla^2\psi+V\psi \ .$$

At nuclear scales, the well represents quarks confined inside the nucleon, and at Planck scales, the well corresponds to the size of the Universe. For the latter two cases the above is replaced with an appropriate relativistic version.

We express the exact solution of the Schrödinger equation in one-dimension where the potential is replaced by an infinite well:

$$\psi\left(\overline{x},\overline{t}\right)=\sum_{n=1}^{\infty}a_n e^{-i\frac{1}{2}\pi^2 n^2\overline{t}}\sin\left(\pi n\overline{x}\right).$$

To explore the behavior of this solution, we use new variables to define distance and time coordinates that are dimensionless:

$$x=a\overline{x}$$

$$t=\frac{ma^2}{\hbar}\overline{t} \ .$$

This captures the essence of the solution for all distance scales. The time dépendance is a function of the dimensionless energy $\overline{E}_n=\frac{1}{2}\pi^2n^2$. The solution can be characterized in momentum space $k_n=\pi n$ by specifying the coefficients in the above summation.

We analyze the possible behaviors of the system given an initial normalized packet for the wave function at the initial time $\overline{t}=0$. Given the exact form of the solution, and the above set of coefficients, we compute the time series for the Schrödinger equation by taking a fixed point in space and the wave function for successive points in time.

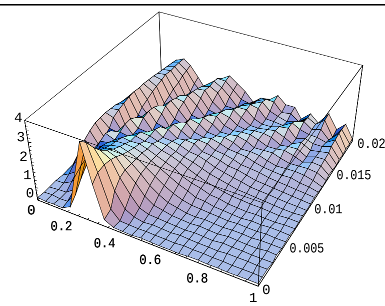

Figure. 2. Evolution in time and space of wave packet generated with Schrödinger wave equation.

The result (Figure 2) shows that the packet is at rest, and its center does not move, though the wave form spreads out in time; the area does not change and the height decreases with time. As the wave packet encounters the sides of the well, it is reflected back and like a wave, interferes with waves still coming toward the wall. The time series can be provided for the wave function's real part, imaginary part, and absolute value or phase. In this article we present only the series of absolute value of the wave function as representative.

4. Bios Analyses

Bios is characterized by features of creativity that can be demonstrated by mathematical analysis of the time series [Sabelli et al. 2005]. Many processes commonly regarded as chaotic or stochastic can be demonstrated to be biotic with these analytic methods.

We measure diversification as the increase in standard deviation (SD) with embedding. The SD is computed for sets ("embeddings") of $2, 3, \ldots, N$ consecutive terms of the time series, starting with each term in the series. The values obtained for each embedding are averaged for the entire series, and these averages are plotted as a function of the number of embeddings. Biotic series, random walks and many creative natural processes show diversification [Sabelli et al. 2005]. Random distributions and chaotic attractors maintain a stable variance after the first few embeddings. The Schrödinger series shows diversification (figure 3).

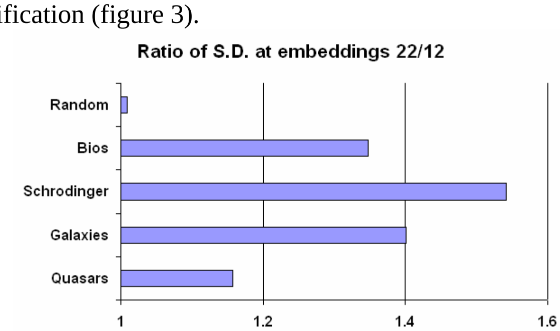

Figure 3. Diversification of time series: Increase in Standard Deviation with increase in embedding is the characteristic of bios, and is evident in both mathematical and empirical series analyzed, while it is absent in the shuffled copy of bios (random series).

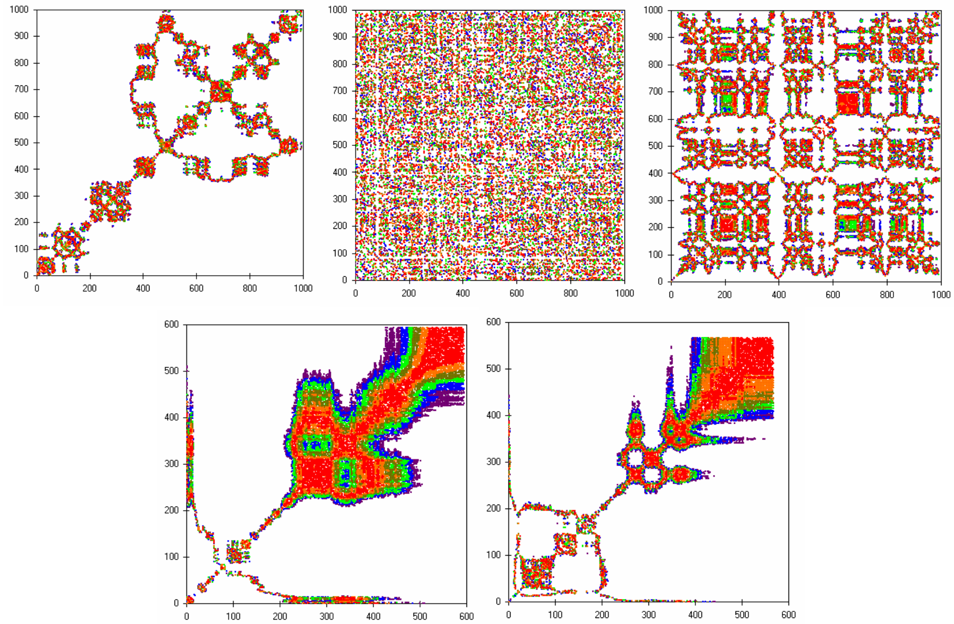

Figure 4. Recurrence plots at 5 embeddings. Top left: mathematical bios. Top middle: randomized (shuffled) copy of mathematical bios. Shuffling eliminates complexes. Top right: Schrodinger wave equation. Bottom left: Galaxies. Bottom right: Quasars.

The pattern of the biotic series changes in time, as observed in many natural processes and in random walks [Sabelli et al. 1997]. Distinct phases with different pattern can be detected in **wavelet plots**, and indicate the episodic character of the process. Shuffling erases this structure. Random data shows no structure. Episodic patterns are most evident in recurrence plots (figure 4). To construct a recurrence plot, the Euclidean norms of vectors of $1, 2, \ldots, N$ consecutive terms are calculated and compared. When their difference is less than a given radius of tolerance, an isometry is counted and plotted (recurrence isometry). Distinct clusters of recurrences with different patterns (complexes) separated by recurrence-free intervals are evident in biotic series and in brown noise. Shuffling erases these complexes. Random and chaotic series show uniform recurrence plots, without clustering. The pattern of the Schrödinger series changes in time, as observed in wavelet and in recurrence plots.

Shuffling the data increases the number of isometries in biotic series, as illustrated in figure 4 for mathematical bios. Novelty is the essential feature of bios, which differentiates it from chaos and from random series. In random data, recurrence can increase or decrease with shuffling, as expected. Since a recurrence is a repetition of pattern, a lower than random recurrence rate indicates that the process under consideration innovates more than chance events. Novelty is thus defined as the increase in recurrence isometry produced by shuffling the data [Sabelli et al. 2005]. Novelty can be quantified at multiple embeddings (figure 5). Novelty is evident in the Schrödinger series.

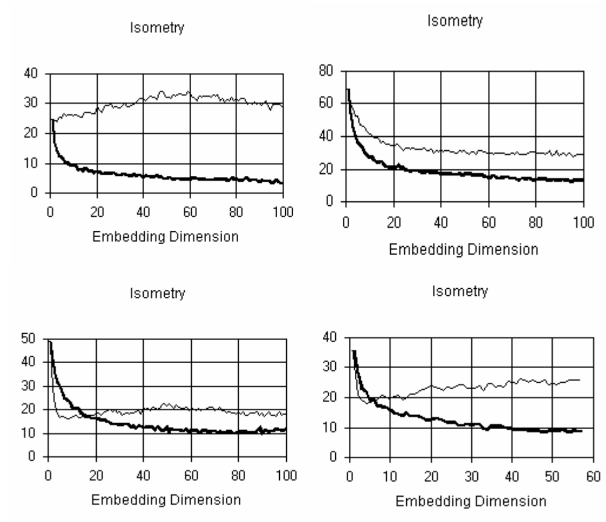

Figure 5. Embedding plots of isometry of the time series (bold lines) and their shuffled copies (thin lines). The increase in isometries with shuffling is defined as novelty. Top left: mathematical bios. Top right: Schrodinger wave equation. Bottom left: Galaxies. Bottom right: Quasars.

In summary, the Schrödinger series shows the characteristic features of mathematical bios namely diversification, episodic pattern, and novelty.

5. Klein-Gordon equation

At relativistic energies, the Schrödinger equation is replaced with its relativistic counterparts. We illustrate this with the Klein-Gordon equation for spin 0 particles, which is representative of all relativistic particles with spin since we are concerned primarily with the effects due to the mass:

$$\frac{\partial^2 \phi}{\partial t^2} - \frac{\partial^2 \phi}{\partial x^2} + m^2 \phi = 0 .$$

The form of the Schrödinger equation changes in such a way that the mass and momentum are now covariant with respect to reference frame:

$$\phi\left(\overline{x},\overline{t}\right) = \sum_{n=1}^{\infty} a_n e^{-i\overline{t}\sqrt{\pi^2 n^2 + m^2}} \sin\left(\pi n \overline{x}\right) .$$

We make the important observation that in the relativistic regime where the mass contribution can be ignored, the solution can be expressed in terms of the initial packet $f\left(\overline{x}\right)$. The solution is proportional to $f\left(\overline{x}-\overline{t}\right) - f\left(\overline{x}+\overline{t}\right)$. At a fixed point in space, the time series is two packets offset from each other. The time series has no biotic behavior. If mass is sufficiently large then it can't be ignored and the solution is well approximated by the Schrödinger case above with biotic behavior. Therefore the presence of mass is a necessary requirement for bios in physical processes. For strictly massless particles such as photons, there is no bios. In this regard we note that biotic behavior has not been observed in the cosmic background radiation [Sabelli, 2005].

6. Galaxies

We analyzed the temporal distribution of 462,879 galaxies and 61,966 quasars from the Sloan Digital Sky Survey (SDSS) [Springel et al. 2006]. As the velocity of light is finite, and distances between galaxies and quasars are enormous, their distribution along the z-axis that represents space-time allows one to observe directly cosmological evolution. The series analyzed are the number of galaxies in 10^{-3} red shift bins or quasars in 10^{-2} red shift bins and series were compared with shuffled copies.

Analyses of the series show local diversification, separate complexes, and novelty. These properties can be observed in biotic series generated deterministically or in stochastic processes. To distinguish between these two cases, we also studied the series of the differences between consecutive terms in these series. The difference between consecutive terms in a random walk series is of course random. In the simple biotic series generated by the process equation, the time series of the difference is chaotic, but in more complex computer models of bios, the time series of the differences is biotic. For both galaxies and quasars, these series of differences showed diversification, novelty and complexes. This demonstrates that these series are generated deterministically, not stochastically.

In summary, the data, which reflect the evolution of the Universe, show diversification, novelty and determinism, confirming the finding of biotic pattern in the two smaller galaxy surveys (LCRS and 2DFGRS) analyzed previously.

7. Discussion

In conclusion, both continuum and discrete models of the Schrödinger equation generate biotic patterns. Bios appears at three different distance scales: atomic, nuclear and Planck (time and distance scale obtaining shortly after the big bang). Quantum processes can generate biotic patterns with creative features. We also observed that biotic patterns are observed in the temporal distribution of galaxies described by the most extensive survey carried to this day.

We thus propose that quantum processes shaped the very early evolution of the universe, and that these organized processes would be reflected in an organized distribution of matter in the tridimensional cone of our observations of the 3 + 1 dimensional spacetime. To assume that quantum processes play a major role shortly after the big bang is consistent with accepted physical knowledge.

More generally, we propose that logically necessary mathematical relations such as those abstracted by lattice, group and topological theory may shape cosmological evolution; that they represent the original heterogeneity that caused the heterogeneous distribution of energy and matter in the universe; and that they continue to generate structure. The expansion of the universe is accelerating in our times, and the cold dark matter model implies that galaxy formation is a process extending from early times to the present, not an event in the distant past.

While some physicists regard thermal equilibrium as a more “elegant” portrait for the initial universe, it seems difficult to imagine how equilibrium becomes evolution. Pasteur proposed that the most rational account for the widespread asymmetry of biological entities is to assume that the most basic physical entities also are asymmetric, and one can interpreted the unidirectionality of time and causality as Pasteur’s cosmic asymmetry [Sabelli, 1989; 2005]. Asymmetry is the central feature of lattices.

The embodiment of lattice order, group closure and opposition, and topological connectivity by quantum processes may generate biotic processes that play a significant role in cosmic evolution. Biotic diversification, novelty and expansion may explain how the universe evolved from an asymmetric (non-equilibrium) state and continues becoming more asymmetric, diverse, and complex. Cosmologists speculate that certain regions of the early universe expanded, became huge, and account for most of the volume of the universe. One may further speculate that the regions that expanded were those in which the pattern was biotic, while those regions that remained in steady, periodic or chaotic states did not inflate, and thus became insignificant. Biotic expansion thus creates organization out of quantum physical processes that embody the asymmetry of action, the bipolarity of electrical charge, and topological connectivity and conservation of mass.

We thus propose that the universe evolves **from order to bios** (complex, biological-like organization) rather than from random chaos to order. In other words, we propose that cosmological processes are, as biological development, deterministic in their origin, but creative in their development. In any case, static, crystal-like order is not a convincing model for the current physical organization of the universe, which, if physics is indeed fundamental, must also account for the generation of life (Dirac, 1931). Also, mathematical order is arguably more "natural" than randomness. Leading physicists such as Carroll [2006] and others have pointed out that our notions of what is natural are historically determined. That in recent centuries physicists have come to regard equilibrium, time reversibility, and high entropy states as "natural" do not make them so. In fact it forces us to regard the early universe as being in an extremely delicately specified state, and to consider the evident directionality of time as a problem. Why should we regard randomness as natural and organization as requiring explanation, when everything we see is organized and we cannot even produce a truly random series in a computer? It seems to us that, on the contrary, mathematical order is logically necessary, and therefore anything that exists physically by necessity must be organized mathematically.

As lattice order, group symmetry, and topological form are logically necessary regardless of the existence of physical processes, these generic forms may be regarded as the "cosmic gene" that molded the physical processes that embody them. Diversity, novelty and complexity are generated by recursions involving lattice order, group symmetry, and topological form. Physical processes embody these logically necessary relations. Causation in unidirectional time embodies lattice order; charge embodies opposition, and color and other physical symmetries embody higher group symmetries; topological forms, their continuity and conservation are embodied in pattern and material structures. Physical processes such as portrayed by Schrodinger equation are sufficient to generate novel and complex patterns such as the bios, and therefore they could contribute to cosmological evolution.

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