Self-Referential Noise and the Synthesis of Three-Dimensional Space

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Abstract

Generalising results from Gödel and Chaitin in mathematics suggests that self-referential systems contain intrinsic randomness. We argue that this is relevant to modelling the universe and show how three-dimensional space may arise from a non-geometric order-disorder model driven by self-referential noise.

Keywords: Self-Referential Noise, Heraclitean Process System, Self-Organised Criticality.

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1 Introduction

General relativity begins the modelling of reality by assuming differentiable manifolds and dynamical equations for a $3 \oplus 1$ metric spacetime. Clearly this amounts to a high level phenomenology which must be accompanied by various meta-rules for interpretation and application. The same situation also occurs in the quantum theory. But how are we to arrive at an understanding of the origin and logical necessity for the form of these laws and their interpretational meta-rules? We argue that the understanding, and therefore also the unification, of these almost fundamental theories actually involves an appreciation of the special features of *end-game* modelling. In essence an *end-game* theory is one which involves the unique situation in which we attempt to model reality without *a priori* notions. Present day theoretical physics is very much based upon the notion of *objects* and their rules, which amounts to *numbers* (of objects) and thus arithmetic, and the generalisation to sets and abstract mathematics. From these rules of objects we also arrived at traditional *object-based logic*. Axiom-based modelling always assumes some starting set of *objects* and their *rules*. This has the apparent defect of requiring an infinite regress of a hierarchy of models; each one yielding a higher level as an emergent phenomenon. Here this profound problem of an infinite regress of nested *objects* and their *rules* is overcome by proposing that a fundamental modelling of reality must invoke self-organised criticality (SOC) to hide the start-up axioms via *universality*. Further we also generalise the results of Gödel and Chaitin in mathematics to argue that a self-referential system, such as the universe, must involve intrinsic randomness, which we name Self-Referential Noise (SRN). Our analysis of *end-game* modelling then results in a sub-quantum non-geometric order-disorder process model driven by SRN from which, the evidence suggests, emerges a fractal 3-space; the fractal character being necessary to achieve *universality*. Self-consistency requires that at higher levels *objects* and their *rules* emerge via an *objectification* process, together with the quantum phenomena. We call this approach a Heraclitean Process System (HPS) after Heraclitus of Ephesus (6 BCE) who, in western science, first emphasised the importance of process over object. We suggest that the SRN provides an important extension to the pregeometric class of modellings of reality[1, 2, 3].

2 Self-Referential Noise

Our proposed solution to the end-game problem is thus to avoid the notion of *objects* and their *rules* as fundamental; for these categories are only appropriate for higher level phenomenological modelling. However the problem is then not merely to construct some model of reality but to do so using the, in principle, inappropriate *language* of objects which themselves are high level emergent phenomena; i.e. we must develop a technique to extend object-based logic and mathematics beyond their proper domains. We propose to achieve this by exploiting the concept of *universality* in self-organising criticality (SOC). SOC describes the ability of many systems (the first studied being the sand-pile[4]) to self-organise in such a way that the system itself moves towards a state characterised by a fractal description, i.e. in which there is no fundamental scale and phenomena of all scales appear (avalanches in the case of the sand-pile model[4]). This fractal or universality property had been much investigated in non-SOC systems in which the universality only appeared at critical points that could be reached by suitably adjusting external parameters such as temperature and pressure. The term *universality* indicating that the behaviour of the system at such a critical point was not uniquely characteristic of individual systems, but that many systems, in the same *universality class*, showed the same behaviour; at criticality the individuality of the system is suppressed. SOC systems display the novel behaviour of always evolving towards such criticality without the need for fine tuning of external parameters. Smolin[5] has discussed the possible relevance of SOC to cosmology.

The notion that a system is self-supporting or *bootstrapped* has always been weakened so that some set of axioms is invoked as a start-up part of the system. In HPS we require that the start-up axioms be suppressed by requiring a SOC system for which many other modellings belong to the same universality class. In this way we attempt to achieve an *axiom-less* model. Hence in the HPS modelling of reality we apply object-based logic and mathematics to an individual realisation of a, hopefully, SOC relational process, but then confirm and extract the *universal* emergent behaviour which will be independent of the realisation used. To be consistent any HPS must not only display SOC but at some high level it must also display an emergent objectification process which will be accompanied by its object-based logic. The key idea is that a truly *bootstrapped* model of reality must self-consistently bootstrap *logic* itself, as well as the *laws of physics*. Further, only by constraining our modelling to such a complete bootstrap do we believe we can arrive at complete comprehension of the nature of reality.

Together with the SOC process we must also take account of the powerful notion that by definition a universe is self-contained, and this also has profound implications for our *ab initio* bootstrap modelling. This means, as we will argue, that the universe is necessarily self-referential, and that this suggests that we must take cognisance of a fundamental and irremovable non-local randomness (SRN). We propose here that SRN is a fundamental process that has been ignored until now in model building in physics and in the general comprehension of reality. Again our SOC proposal is to be invoked in order that the SRN not be understood as a 'thing', but as a realisation-independent characterisation of the self-referencing. Nevertheless we believe that already there are several indicators of the special consequences of this SRN, but not understood as such in present day physics.

The construction of a viable HPS can only be achieved at present by inspired guessing based in part upon the lessons of Quantum Field Theory (QFT) and also the consequences of the self-referential process in mathematics where the precision of analysis by Gödel and others has lead to definitive conclusions. In QFT there are several features that have suggested to us a deeper processing; first, that all practical non-perturbative computations are done most easily and efficaciously in the Euclidean rather than Minkowski metric. In this Euclidean metric it is more natural to think of the QFT as an ensemble average of a zero temperature statistical system. Furthermore, these zero-temperature functional-integral ensemble averages can be obtained as the ensemble averages of Wiener processes via the *stochastic quantisation* construction[6]; a construction which has lacked until now an interpretation. However the key clue is that the *stochastic quantisation* (where the term *quantisation* now appears inappropriate) invokes a random noise process which here we identify with the SRN.

That the modelling of a self-referential system contain SRN we believe follows plausibly as a generalisation from the work of Chaitin[7] who, extending the work of Gödel and Turing, showed that the arithmetic system is sufficiently complex that the self-referential capability of arithmetic results in randomness and unpredictability, and means that in some manner arithmetic should be thought of in a thermodynamic sense. Patton and Wheeler[8] conjectured some time ago that Gödel's self-referencing results in mathematics might be relevant to understanding cosmogony. So, as in QFT, there is the suggestion of some intrinsic randomness. Of course in the case of arithmetic the randomness arises even in a sufficiently complex object-based logic system. We conjecture that in a completely self-referential system the necessity for SRN is even stronger.

A further clue to the fundamental presence of non-local SRN is that of the randomness of the quantum measurement process, and particularly its non-local manifestations as clearly revealed by Bell[9]. We will argue that the peculiarities of the quantum measurement process are manifestations of the non-linear and non-local character of a HPS via its objectification process, which proceeds along the lines of a localising collapse of large-scale non-local configurations, induced by macroscopic objects (detectors in the case of quantum measurements).

3 Heraclitean Process Systems

To construct a complete bootstrap model of the universe we must attempt to take into account these various considerations and arrive at a HPS showing SOC characteristics with a fractal 3-space as the dominant emergent *universal* feature. The general requirements are then randomness, non-linearity, non-locality (this is actually automatic in the sense that we must not build in the notion of geometry and thus of locality; and so our model must by definition be non-geometric), and finally iterative in order to generate fractal structures.

One such realisation is suggested by extending the QFT deconstruction begun in [10]. There we took the bilocal field representation (hence the origin of the notation B below) of Quantum Electrodynamic type field theories and essentially 'removed' the underlying geometrical Euclidean space. All these considerations[10, 11] suggested the following non-linear noisy iterative map as our first HPS realisation:

$$B_{ij} \to B_{ij} - (B + B^{-1})_{ij}\eta + w_{ij}, \quad i, j = 1, 2, ..., 2M; M \to \infty. \tag{1}$$

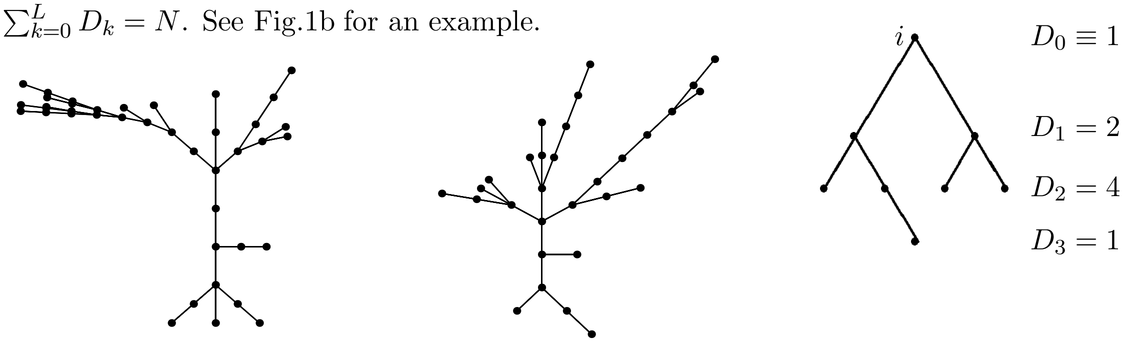
In this modelling we introduce, for convenience only, some terminology: we think of B_{ij} as indicating the connectivity or relational strength between two monads i and j. The monads concept was introduced by Leibniz, who espoused the *relational* mode of thinking in response to and in contrast to Newton's *absolute* space and time. Leibniz's ideas were very much in the *process* mould of thinking. It is important to note that the iterations of the map do not constitute *a priori* the phenomenon of time, since they are to perform the function of producing the needed fractal structure. The monad i acquires its meaning entirely by means of the connections $B_{i1}, B_{i2}, ...,$ where $B_{ij} = -B_{ji}$ avoids self-connection ($B_{ii} = 0$), and real number valued. The map in (1) has the form of a Wiener process, where the $w_{ij} = -w_{ji}$ are independent random variables for each ij and for each iteration, and with variance η. The w_{ij} model the self-referential noise. The 'beginning' of a universe is modelled by starting the iterative map with $B_{ij} \approx 0$, representing the absence of order. Clearly due to the B^{-1} term iterations will rapidly move the B_{ij} away from such starting conditions.

The non-noise part of the map involves B and B^{-1}. Without the non-linear inverse term the map would produce independent and trivial random walks for each B_{ij} - the inverse introduces a linking of all monads. We have chosen B^{-1} because of its indirect connection with quantum field theory[10] and because of its self-organising property. It is the conjunction of the noise and non-noise terms which leads to the emergence of self-organisation. Hence the map models a non-local and noisy relational system from which we extract spatial and time-like behaviour, but we expect residual non-local and random processes characteristic of quantum phenomena including Einstein-Padolsky-Rosenfeld (EPR)/Aspect type effects. There are several other proposals considering noise in spacetime modelling[12, 13].

4 Emergent Space

Here we discuss this HPS iterative map, analysis of which suggests the emergence of a dynamical 3-dimensional fractal spatial structure. Our results follow from a combination of analytical and numerical studies. Under the mapping the noise term will produce rare large value B_{ij}. Because the order term is generally much smaller, for small η, than the disorder term these large valued B_{ij} will persist under the mapping through more iterations than smaller valued B_{ij}. Hence the larger B_{ij} correspond to some temporary background structure which we now identify.

Consider the connectivity from the point of view of one monad, call it monad i. Monad i is connected via these large B_{ij} to a number of other monads, and the whole set of connected monads forms a tree-graph relationship. This is because the large links are very improbable, and a tree-graph relationship is much more probable than a similar graph involving the same monads but with additional links. The set of all large valued B_{ij} then form tree-graphs disconnected from one-another; see Fig.1a. In any one tree-graph the simplest 'distance' measure for any two nodes within a graph is the smallest number of links connecting them. Indeed this distance measure arises naturally using matrix multiplications when the connectivity of a graph is encoded in a connectivity or adjacency matrix. Let $D_1, D_2, ..., D_L$ be the number of nodes of distance $1, 2, ..., L$ from node i (define $D_0 = 1$ for convenience), where L is the largest distance from i in a particular tree-graph, and let N be the total number of nodes in the tree. Then we have the constraint $\sum_{k=0}^{L} D_k = N$. See Fig.1b for an example.



(a) (b)

Figure 1: (a) Rare and large components of B form disconnected tree-graphs, (b) An $N = 8$ tree-graph with $L = 3$ for monad i, with indicated distance distribution D_k.

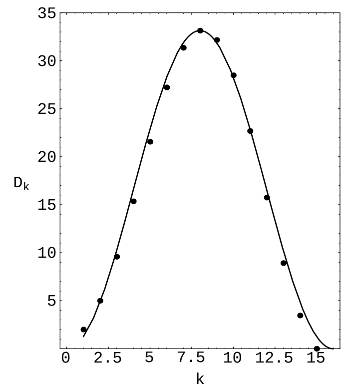


Figure 2: Data points shows numerical solution of eq.(3) for distance distribution D_k for a most probable tree-graph with $L = 16$. Curve shows fit of approximate analytic form $D_k \sim \sin^2(\pi k/L)$ to numerical solution, indicating weak but natural embeddability in an S^3 hypersphere.

Now consider the number $\mathcal{N}(D, N)$ of different N-node trees, with the same distance distribution $\{D_k\}$, to which i can belong. By counting the different linkage patterns, together with permutations of the monads we obtain

$$\mathcal{N}(D, N) = \frac{(M-1)! D_1^{D_2} D_2^{D_3} ... D_{L-1}^{D_L}}{(M-N-2)! D_1! D_2! ... D_L!}, \tag{2}$$

Here $D_k^{D_{k+1}}$ is the number of different possible linkage patterns between level k and level $k+1$, and $(M-1)!/(M-N-2)!$ is the number of different possible choices for the monads, with i fixed. The denominator accounts for those permutations which have already been accounted for by the $D_k^{D_{k+1}}$ factors. We compute the most likely tree-graph structure by maximising $\ln\mathcal{N}(D, N) + \mu(\sum_{k=0}^{L} D_k - N)$ where μ is a Lagrange multiplier for the constraint. Using Stirling's approximation for $D_k!$ we obtain

$$D_{k+1} = D_k \ln\frac{D_k}{D_{k-1}} - \mu D_k + \frac{1}{2}. \tag{3}$$

which can be solved numerically. Fig.2 shows a typical result obtained by starting eq.(3) with $D_1 = 2, D_2 = 5$ and $\mu = 0.9$, and giving $L = 16, N = 253$. Also shown is an approximate analytic solution $D_k \sim \sin^2(\pi k/L)$ found by Nagels[14]. These results imply that the most likely tree-graph structure to which a monad can belong has a distance distribution $\{D_k\}$ which indicates that the tree-graph is embeddable in a 3-dimensional hypersphere, S^3. Most importantly monad i has a 3-dimensional connectivity to its neighbours, since $D_k \sim k^2$ for small $\pi k/L$. We call these tree-graph B-sets *gebits* (geometrical bits). However S^3 embeddability of these gebits is a weaker result than demonstrating the necessary emergence of a 3-space, since extra cross-linking connections would be required for this to produce a strong embeddability. But that also appears to be the case, as we now see.

The monads for which the B_{ij} are large thus form disconnected gebits. These gebits however are in turn linked by smaller and more transient B_{kl}, and so on, until at some low level the remaining B_{mn} are noise only; that is they will not survive an iteration. Under iterations of the map this network undergoes growth and decay at all levels, but with the higher levels (larger $\{B_{ij}\}$ gebits) showing most persistence. It is convenient to relabel the monads so that the current gebits $g_1, g_2, ...$ form matrices block diagonal within B, and embedded amongst the smaller and more common noise entries.

A key dynamical feature is that most gebit matrices g have $\det(g) = 0$, since most tree-graph connectivity matrices are degenerate. For example in the tree in Fig.1b the B matrix has a nullspace (spanned by eigenvectors with eigenvalue zero) of dimension two irrespective of the actual values of the non-zero B_{ij}; for instance the right hand pair ending at the level $D_2 = 4$ are identically connected and this causes two rows (and columns) to be identical up to a multiplicative factor. So the degeneracy of the gebit matrix is entirely structural. For this graph there is also a second set of three monads whose connectivities are linearly dependent. These $\det(g) = 0$ gebits form a *reactive gebits* subclass of all those gebits generated by the SRN. They are the building blocks of the self-organising process, and we define their *reactive monads* as those appearing in the nullspaces. Because of the antisymmetry of B in this model gebits with an odd number of monads automatically have a nullspace of dimension ≥ 1. Monads belonging to the nullspace form the reactive or dynamical components of a reactive gebit under the mapping because of the B^{-1} order term: in the absence of the noise B^{-1} would be singular for reactive gebits, but in the presence of the noise the matrix is invertible but with large entries connecting the reactive monads within B.

Numerical studies show that the outcome from the iterations is that the gebits are seen to interconnect by forming new links between reactive monads and to do so much more often than they self-link as a consequence of links between reactive monads in the same gebit. We also see monads not currently belonging to gebits being linked to reactive monads in existing gebits. Furthermore the new links, in the main, join monads located at the periphery of the gebits, i.e these are the most reactive monads of the gebits. Of course it is the lack of appropriate cross-linkings between these particular monads that results in individual gebits having only a weak S^3-embeddability. Hence the new links preserve the 3-dimensional environment of the inner gebits, with the outer reactive monads participating in new links. Clearly once gebits are sufficiently linked by B^{-1} they cease to be reactive and slowly die via the iterative map. Hence there is a on-going changing population of reactive gebits that arise from the noise, cross-link, and finally decay. Previous generations of active but now decaying cross-linked gebits are thus embedded in the structure formed by the newly emerging reactive gebits.

These numerical studies thus reveal gebits competing in a Darwinian life-cycle. However we must next characterise the global structure formed by this transient population of cross-linking gebits. We suspected that the simplest global structure might correspond to an emergent geometry in that the dominant links defined a structure strongly embeddable in a S^3 hypersphere, but with the weaker links diffusing the embedding. To test this hypothesis we first ran the iterative map with a modest $N = 100$ monads for some 10 iterations, but with our random SRN term biased to produce a greater number of large B_{ij}. To test for embeddability we then minimised with respect to the monad positions an E^n embedding measure defined by

$$V(X) = \sum_{i>j} B_{ij}^2 \left(D(X^i, X^j) - \frac{1}{|B_{ij}|} \right)^2 \tag{4}$$

where $X^i = \{x_1^{(i)}, ..., x_n^{(i)}\}$ is the possible Euclidean position of monad i in E^n, and $D(X^i, X^j) = \sqrt{(\sum_{\alpha=1,n}(x_\alpha^{(i)} - x_\alpha^{(j)})^2)}$ is the Euclidean distance between monad i and monad j in E^n. The measure V corresponds to a *spring* embedding model in which the spring between monad i and j has spring constant $\kappa = B_{ij}^2$, and natural length $1/|B_{ij}|$. The minimisation with respect to the X's then minimises the 'energy' stored in the n-dimensional network of springs in such a manner that strongly linked monads have a strong spring linking them with a short natural length, so that the minimisation attempts to place them at short separation, while the weaker monad links (smaller $|B_{ij}|$) are represented by weaker and longer springs, so that these links have less influence on the embedding, and are allowed to diffuse any E^n embedding. For the same B_{ij} matrix we then performed the minimisation of V *wrt* the $100n$ monad coordinates for spaces of dimension $n = 2, 3, 4$. We then searched the resulting embedding for an S^{n-1} signature, noting that S^{n-1} is embeddable in E^n with all points at the same radius from the 'centre'. Hence for each embedding in E^n we located the 'centre-of-mass' (com) of the located monad set, defined by $x_\alpha^{\text{com}} = \frac{1}{N}\sum_{i=1,N} x_\alpha^i$, and computed the radial distance $R^{(i)}$ of each monad from this centre according to $R^{(i)} = \sqrt{(\sum_{\alpha=1,n}(x_\alpha^{\text{com}} - x_\alpha^{(i)})^2)}$. We then extracted the radial distribution of the monads in each E^n, but with the monad i contributing to this distribution with a weighting $w^{(i)}$ proportional to the maximum value of B_{ij}^2 wrt all j; this ensures that it is the location of the most strongly linked monads which dominate these distribution plots, since they had the greatest influence on the embedding.

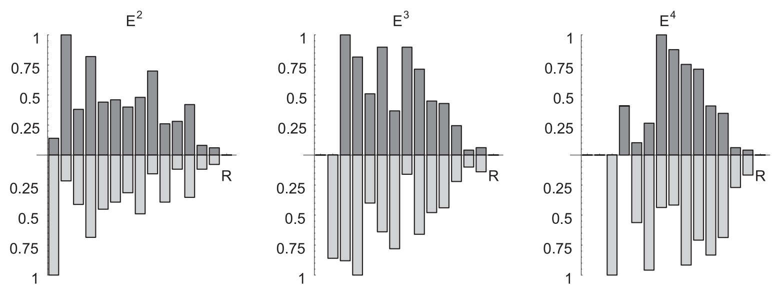


Figure 3: Above axis plots shows density of monads plotted against radial distance after embedding in E^n for $n = 2, 3, 4$. Below axis plots shows randomly generated cases for same number of monads. A peaking for E^4 case indicates a strong embeddability of B in an S^3 hypersphere.

The results are shown in Fig.3 together with the distribution obtained from a purely random embedding: this in the limit of large N would produce a flat distribution, but for $N = 100$ the statistical variations are noticeable. The key result of these studies is that the larger valued entries of the B-matrix show the presence of a S^3 structure as revealed by the peaking of the radial distribution for the case of E^4. For E^2 and E^3 the radial distribution is essentially flat and no different from that generated by a random embedding. For E^5 our analysis would reveal the embeddability already apparent for E^4. The finite width of the peak in the E^4 embedding shows links that are outside of the S^3 geometry, and thus are non-local *wrt* the S^3 geometry. We conjecture that this effect is an indication of *quantum phenomena* attached non-locally to an emergent geometrical 3-space.

Hence we have produced some evidence that a three-dimensional geometry is the dominant emergent structure. First we saw that, of the disconnected randomly produced tree-graphs, the most probable forms have a three-dimensionality potential; these we called gebits. Second that in turn most of these form reactive gebits which cross-link via the iterative map to produce a strong embeddability in S^3 (Of course with only 100 monads any embeddability will be noisy, and not all runs succeeded in producing the S^3 signature in an E^4 embedding, shown in Fig.2). After the HPS has produced an S^3 structure we have the notion of *local* in the sense of having a *position*. As we have previously discussed, it is required that the resultant 3-space be fractal in order that the details of the particular HPS realisation are hidden via *universality*. Clearly the numerical examples above are inadequate to reveal fractal structure, though the decay of older gebits does suggest a fractal structure. A numerical demonstration of a fractal 3-space would require a huge increase in monad numbers, or alternatively the development of analytical techniques.

Hence in combination the order and disorder terms synthesise a dynamical 3-space which is entirely relational; it does not arise within any *a priori* geometrical background structure. By construction it is the most robust structure - however other softer emergent quantum modes of behaviour will be seen attached to this flickering 3-space.

5 Emergent Time

It is important to note that the iterations of the map do not constitute *a priori* the phenomenon of time, since they perform the function of producing the needed fractal structure. However the analysis to reveal the internal experiential time phenomenon is non-trivial, and one would certainly hope to recover the local nature of experiential time as confirmed by special and general relativity experiments. However (experiential) time is only predicted in this model if there is an emergent ordered sequencing of events at the level of *universality*, i.e. above the details which are purely incidental to any particular realisation. As a counter example it could well be the case that the iterative map fails to produce *change* at a high level; in which case there is no emergent time phenomenon.

However in the absence of a *universality* analysis we take our clues from the nature of the iterative map and notice that the modelling of the time phenomenon here is expected to be much richer than that of the historical/geometric modelling. First the map is clearly uni-directional as there is no way to even define an inverse mapping because of the role of the noise term, and this is very unlike the conventional time-symmetric differential equations of traditional physics. In the analysis of the gebits we noted that they show strong persistence, and in that sense the mapping shows a natural partial-memory phenomenon, but the far 'future' detailed structure of even this spatial network is completely unknowable without performing the iterations. Furthermore the sequencing of the spatial and other structures is individualistic in that a re-run of the model will always produce a different outcome. Most important of all is that we also obtain a modelling of the 'present moment' effect, for the outcome of the next iteration is contingent on the noise. So the system shows overall a sense of a recordable past, an unknowable future and a contingent present moment.

The HPS process model is expected to be capable of a better modelling of our experienced reality, and the key to this is the noisy processing the model requires. As well we need the 'internal view', rather than the 'external view' of conventional modelling in physics. Nevertheless we would expect that the internally recordable history could be indexed by the usual real-number/geometrical time coordinate at the level of *universality*.

This new self-referential process modelling requires a new mode of analysis since one cannot use externally imposed meta-rules or interpretations, rather, the internal experiential phenomena and the characterisation of the simpler ones by emergent 'laws' of physics must be carefully determined. There has indeed been one ongoing study of how (unspecified) closed self-referential noisy systems acquire self-knowledge and how the emergent hierarchical structures can 'recognise' the same 'individuals'[15]. We believe that our HQS process model may provide an explicit representation for such studies.

6 Objectification

To demonstrate the viability of the HPS model of reality we must exhibit an extremely important but often ignored process, namely *objectification.* Despite its many successes the quantum theory has one significant failure, namely in not predicting the spatial localisation of macroscopic quantum systems in such a manner that they behave as familiar *objects*. Schrödinger, Einstein and others were quick to identify this failure, which is a direct consequence of the linearity of quantum theory.

The objectification process has largely gone undiscussed simply because the prevailing attitude is that even electrons and protons are small objects (particles) which are localised but whose actual position can only be predicted statistically. There is in fact no experimental evidence for this notion. What is supported by experiment and the quantum theory is that the probability of a localisation in space *by* a detector is probabilistic with the probability given by the usual Born prescription ($\propto |\psi(x)|^2$). The quantum theory itself makes no reference to objects, and indeed the often quoted *radii* of the proton and other quantum states are nothing more than correlation lengths.

In the early stages of constructing Heraclitean Process Systems one can only outline the expected nature of the emergent quantum systems and of the objectification process, which we now briefly discuss. The evidence is that the primary and dominant process is the emergence of a dynamical 3-space, and that this arises from a non-linear noisy map. From this one would expect secondary phenomena corresponding to small deviations from the localisation process inherent in the dominance of the 3-space, that is, the strongly non-linear system will only support small amplitude non-local deviations whose description would be by a linear theory: these we expect to be essentially the well known quantum phenomena. And so the HPS is then best described as sub-quantum. However macroscopic quantum systems (formed by bound states of large numbers of quantum systems) will amount to large amplitude non-local deviations from the 3-space process, and the strong non-linearity of the underlying system would not support the continued persistence of such a non-local deviation, since this deviation is incompatible with the formation of the 3-space. Indeed one would expect the complete system to undergo a sudden restoration of 3-space; amounting to a localisation of the macro-quantum system. This is the objectification process. Penrose[16] has proposed a quantum gravity driven Objective-Reduction process. The HPS appears to amount to an implementation of that suggestion which is, however, sub-quantum since the HPS apparently generates the spatial phenomena without proceeding through a quantum description. Not only would such a mechanism be responsible for the ongoing localisation and consequent emergence of objects, but should a small amplitude non-local (quantum) deviation result in one or more detectors (localised objects) becoming non-local by interacting with that quantum process one would expect the objectification or localisation process again to be strongly manifested but to do so randomly via the non-local SRN. This means that the localisation process must be non-local in character and not to be understandable as the propagation of some signal locally through the 3-space. Such phenomena are seen in EPR/Aspect experiments with their apparent concomitant faster-than-light non-local effects.

The objectification process is also essential to recovering our everyday object-based phenomena and its logic. A demonstration of emergent objectification would then amount to a derivation of logic from a sub-quantum modelling, which itself only used such logic in as much as it could be suppressed by the SOC argument. Omnès[17] has also discussed the derivation of logic but from quantum theory via the decoherence mechanism for objectification. However that mechanism imports objectification by assuming the quantum measurement postulate in an *ad hoc* manner.

There is evidence that the quantum measurement process does indeed involve non-local SRN at the sub-quantum level, for it has been discovered that the individuality of the measurement process - the 'click' of the detector - can be modelled by adding a noise term to the Schrödinger equation[18]. Then by performing an ensemble average over many individual runs of this non-linear and stochastic Schrödinger equation one can derive the ensemble quantum measurement postulate - namely $< A >= (\psi, A\psi)$ for the "expectation value of the operator A".

7 Conclusion

We have addressed here the unique end-game problem which arises when we attempt to model and comprehend the universe as a closed system without assuming high level phenomena such as space, time and objects - nor even object-based logic. To do this we have proposed a bootstrap modelling which invokes self-organised criticality to allow the start-up mechanism of the bootstrap to be hidden. The outcome is the suggestion that the peculiarities of this end-game problem are directly relevant to our everyday experience of space (and time); particularly the phenomena of the three-dimensionality of space (and elsewhere of the contingent present moment). This analysis is based upon the notion that a closed self-referential system, and the universe is *ipso facto* our only true instance, is necessarily noisy. This follows as a conjectured generalisation of the work of Gödel and Chaitin on self-referencing in the abstract and artificial game of mathematics. To explore the implications we have considered a simple *pregeometric non-linear noisy iterative map*. The analysis of this map shows that the first self-organised structure to arise is a dynamical 3-space formed from competing pieces of 3-geometry - the gebits; however the actual details of this level of modelling are necessarily to be hidden via the self-organised criticality of the model. The analysis of experiential time is more difficult, but it will clearly be a contingent and process phenomenon which is more complex and hence richer than the current geometric/historic modelling of time. We suggest that the non-local self-referential noise has been a major missing component of traditional modelling of reality.

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References

[1] J.A. Wheeler, *Pregeometry: Motivations and Prospects*, in *Quantum Theory and Gravitation*, A. R. Marlow, ed. (Academic Press, New York 1980).

[2] P. Gibbs, Int. J. Theor. Phys. **35**(1996)1037.

[3] D.R. Finkelstein, *Quantum Relativity*, (Springer, 1996).

[4] P. Bak, C. Tang, and K. Wiesenfeld, Phys. Rev. Lett. **59**(1987)381; Phys. Rev. A **38**(1988)364.

[5] L. Smolin, *Cosmology as a Problem in Critical Phenomena*, in the proceedings of the Guanajuato Conference on Complex Systems and Binary Networks, (Springer, 1995), eds. R. Lopez-Pena, R. Capovilla, R. Garcia-Pelayo, H. Waalebroeck and F. Zertuche, gr-qc/9505022.

[6] M. Namiki, Prog. Theor. Phys. Suppl. No.111, 1993.

[7] G.J. Chaitin, *Information, Randomness and Incompleteness*, 2nd ed. (World Scientific, 1990).

[8] C.M. Patton and J.A. Wheeler, *Is Physics Legislated by Cosmogony?*, in *Quantum Gravity - an Oxford Symposium*, p539, Eds.: C.J. Isham, R. Penrose and D.W. Sciama, (Clarendon Press - Oxford 1975).

[9] J. Bell, *Speakable and Unspeakable in Quantum Mechanics: Collected Papers on Quantum Mechanics*, (Cambridge Univ. Press 1989).

[10] R.T. Cahill and C.M. Klinger, Phys. Lett. A **223**(1996)313.

[11] R.T. Cahill and C.M. Klinger, *Bootstrap Universe from Self-Referential Noise*, gr-qc/9708013.

[12] I.C. Percival, Proc. R. Soc. Lond. A **453**(1997)431.

[13] F. Calogero, Phys. Lett. A **228**(1997)335.

[14] G. Nagels, Gen. Rel. and Grav. **17**(1985)545.

[15] T. Bastin and C. Kilmister, *Combinatorial Physics*, (World Scientific, 1995).

[16] R. Penrose, *The Large, the Small and the Human Mind*, (Cambridge Univ. Press 1997).

[17] R. Omnès, Il Nuovo Cim. B **110**(1995)723.

[18] N. Gisin and I.C. Percival, *Quantum State Diffusion: From Foundations to Applications*, quant-ph/9701024.