A Review on Self-Organized Criticality as a Model of the Scientific Development

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Abstract

According to a conventional belief held by most science communities, sciences can advance by two ways: (a) incremental approach by virtue of scientific methods, (b) paradigm shift. The latter term has been advocated by a notorious science historian, Thomas Kuhn. Despite such widespread acceptance, such a term of paradigm shift is not often tested empirically. Therefore, in this paper we review a recent work which uses citation analysis of journal-journal for the past recent years. This analysis reveals that scientific progress seems to follow Self-Organized Criticality. In the last section, we compare this citation analysis result with our model of the origin of the Universe.

Keywords: paradigm shift, realism interpretation, scientific progress, Self-Organized Criticality.

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Introduction

In its simplest form and According to a conventional belief held by most science communities, sciences can advance by two ways: (a) incremental approach by virtue of scientific methods, (b) paradigm shift. The latter term has been advocated by a notorious science historian, Thomas Kuhn. According to his proponents, one of the most interesting features of Thomas Kuhn's work in The Structure of Scientific Revolutions is its naturalism. But naturalism is just another philosophical strand which may or may not agree with empirical data itself. Despite such

widespread acceptance, the fact is that such a term of paradigm shift is not often tested empirically.

There are other ways to describe innovation changes, namely: (c) Christensen's disruptive change, (d) Self-organized criticality. But they are rarely employed for describing scientific progress.

Therefore, in this paper we review a recent work which uses citation analysis of journal-journal for the past recent years. This analysis reveals that scientific progress seems to follow Self-Organized Criticality.

A review of 4 methods of human knowledge progress

There are some papers in literature which indicate those 4 methods, we will review briefly as follows:

a. Incremental approach: by virtue of scientific methods, science advances by small steps. Until the 1950s, the hegemony of logical empiricism reached to its highest level- by the representatives of the logistic approach such as R. B. Braithwaite, Rudolf Carnap, Herbert Feigl, Carl G. Hempel, and Hans Reichenbach. Prior to Kuhn's SSR, historians and philosophers of science considered the scientific enterprise to be a rational endeavor in which progress and knowledge are achieved through the steady, daily, rigorous accumulation of experimental data accredited facts and new discoveries.[4]
b. Paradigm shift:
   Thomas Kuhn's *Structure of Scientific Revolutions* (SSR) is believed to be one of the most important books in the 20th century. The book conceived a whole industry of commentary, interpretation, and exegesis. The growth of a new academic discipline – the sociology of science- came into existence around a shared paradigm following Kuhn's emphasis on the importance of communities of scientists. After the book was published researchers began to examine scientific disciplines much as sociologists studied social/cultural groups, and in which science was regarded not as the most esteemed, untouchable product of the Enlightenment but as just another subculture. Yet, as Kuhn claimed "the philosophy and sociology of science cannot be practiced independently of

each other". However, Kuhn saw the communities (not individuals) as the basic agents of science and he thought that communities must be characterized by the specific cognitive values to which they are committed.[4]

After the 1960s and 70s, following Kuhn's historiography, and philosophers such as Paul Feyerabend, Imre Lakatos, Larry Laudan and Michael Polanyi have greatly contributed to the creation of an anti-positivistic philosophy of science as a new tradition. History of science after Kuhn has frequently taken a more consciously externalist line, in looking outside science for the causes of the content of science. [4]

c. Disruptive change:

In his article in Harvard Business Review, Clayton Christensen, differentiate between: Sustaining innovations and disruptive innovations.[6] This seems to follow Schumpeterian view of creative destruction. But this paper will not focus on disruptive innovation. See also his more recent article in HBR 2015.[6a]

d. Self-Organized Criticality:

Self-organized criticality is a rich phenomenon as it combines self-organization and criticality to describe complexity. This concept was first introduced by P. Bak and the collaborators in the seminal paper in 1987, and also in his book [5]. SOC is a property of dynamical systems to organize its microscopic behavior to be spatial (and/or temporal) scale independent. That resembles of the critical behavior of the critical point of phase transitions. However, in contrast to the usual phase transitions, the systems displaying SOC do not require external tuning of the control parameters, i.e. the system evolutions, i.e. organizes itself into the critical behavior. Thus, the dynamical system organizes itself into a state with complex, but rather general structure. Complexity arises in the sense that no single characteristic event size exists, i.e. no scale present to guide the system's evolution. Despite the complexity, system exhibits simple statistical properties governed by power laws.[7]

Results of citation analysis

Bolijka Tadic et al. have reported self-organized criticality pattern in online social behavior especially in knowledge creation process.[2] But the first convincing citation analysis to prove this pattern has been made by Loet Leydesdorff, Caroline S. Wagner, and Lutz Bornman. [1]

As we know, journals play a crucial and institutionalized role in the validation of knowledge claims and in the incorporation of new knowledge into the archive of science. Given their role in the codification of knowledge, journals can be considered as an organizing layer of the scientific literature. Not incidentally, the Science Citation Index (SCI) and its derivates (the Social Sciences Citation Index (SSCI) and the Arts & Humanities Citation Index (AHCI)) were defined in terms of specific journal selections (Garfield, 1972; 1979b), as is Scopus, the main competitor of the SCI since 2004. [1]

Method:

In their study, Leydesdorff et al. use aggregated journal-journal citation relations as units of analysis instead of journals. Each relation specifically combines two journals. The journal-journal citation relation is a link in the networks of which journals are the nodes. The citation relations among the 10,000+ journals contained in the Journal Citation Reports (JCR) of the Science Citation Index and the Social Sciences Citation Index can be organized as a matrix of (10,000+) cells, each representing a unique relation between a citing and a cited journal. These (valued) relations can change over time to the extent that they can disappear or emerge; that is, turn from a zero into a positive value larger than or equal to one. [1]

Result:

According to Leydesdorff et al. [1]:

> "The fit with a power-law in Figure 7 suggests self-organized criticality (SoC) in the system of journal-journal citation relations. New knowledge claims in manuscripts continuously generate journal-journal citation relations potentially leading to an equivalent of "avalanches" of reconstructed inter-journal relations. These avalanches can occur anywhere; their effects may be very different; but the consequences are local, that is, within the discipline or specialty. The self organized criticality remains globally available for new critical transitions in the full range from minor, but more frequently

occurring changes, to rare but disruptive ones. The comparison with earthquakes provides another metaphor.

… This model of self-organized criticality differs from the Kuhnian model of normal science versus revolutionary science as phases in paradigm transitions (Kuhn, 1962; Marx & Bornmann, 2013; van den Daele & Weingart, 1975). The flux of manuscripts with knowledge claims contain references to other journals which can be compared with the grains of sand that hit the sand pile or, in this case, the knowledge base as a construct. The effect can be an avalanche of any size depending on the state of the system at that specific place and time."

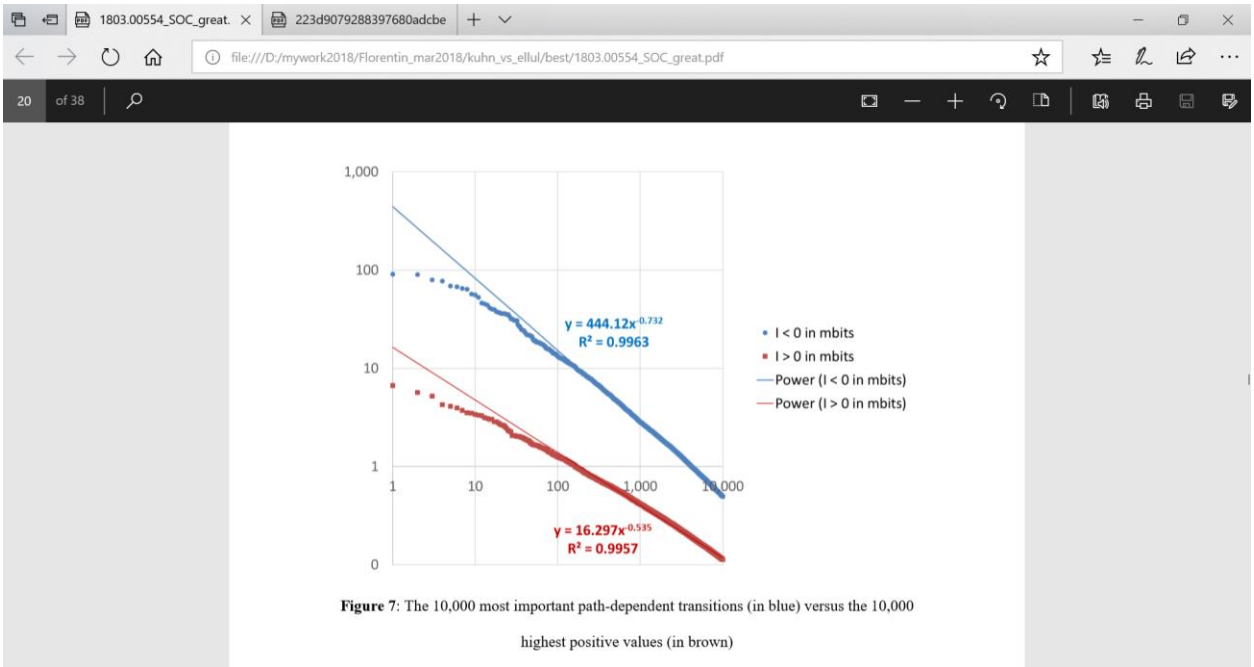

Diagram 2: Source: Leydesdorff et al. [1]

Comparison with our model of abrupt origin of the Universe

Now we will compare this citation analysis result with our proposed model of the origin of the Universe.

It has been known for long time that most of the existing cosmology models have singularity problem. Cosmological singularity has been a consequence of excessive symmetry of flow, such as "Hubble's law". More realistic one is suggested, based on Newtonian cosmology model but here we include the vortical-rotational effect of the whole Universe.

In other paper, we obtained an Ermakov-type equation following Nurgaliev [8]. Then we solve it numerically using Mathematica 11. An interesting result from that simple computational simulation is shown in the following diagram:[9]

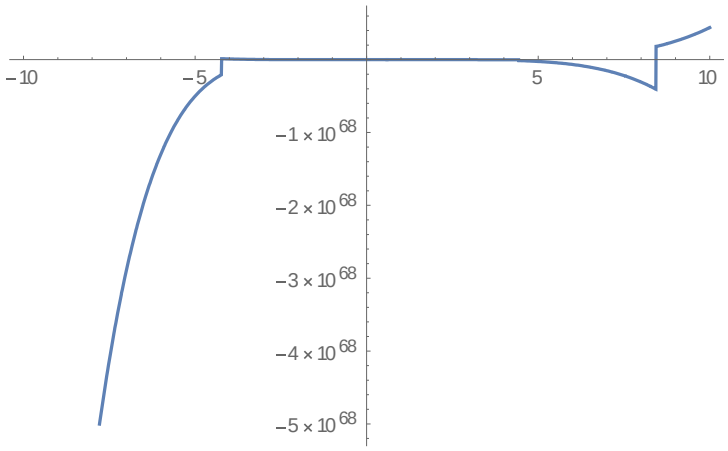

Diagram 2. Plot of Ermakov-type solution for A=1, B=-10 (from [9])

From the above computational experiment, we conclude that the evolution of the Universe depends on the constants involved, especially on the rotational-vortex structure of the Universe. This needs to be investigated in more detailed for sure.

One conclusion that we may derive especially from Diagram 2, is that our computational simulation suggests that it is possible to consider that the Universe has existed for long time in prolonged stagnation period, then suddenly it burst out from *empty and formless* (Gen. 1:2), to take its current shape with observed "accelerated expansion."

Comparing our model of abrupt origin of the Universe with the above citation analysis, it seems both reveal similarities. But whether such abrupt origin of the Universe also indicates SOC feature, remains open for further study.

Concluding remarks

Despite its enormous popularity in the past 5-6 decades, paradigm shift view of scientific progress has not been tested quite often. Therefore, in this paper we review a recent work which

uses citation analysis of journal-journal for the past recent years. This analysis reveals that scientific progress seems to follow Self-Organized Criticality pattern.

Comparing our model of abrupt origin of the Universe with the above citation analysis, it seems both reveal similarities. But whether such abrupt origin of the Universe also indicates SOC feature, remains open for further study.

It can be expected that the above discussions will shed some lights on such an old problem especially in the context of modelling scientific progress based on empirical data (evidence based). This is reserved for further investigations.

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