SPECULATIVE SCIENCE ("FAIRY TALE SCIENCE") IN PHYSICS, COSMOLOGY, AND ECONOMICS[1]

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ABSTRACT:

The paper juxtaposes two recent books dealing with reality issues in a broad sense. The first of these, by Baggott (2013,) examines and criticizes the historically increasing trend to base scientific conclusions on mathematical hypotheses and logical consistency rather than on empirical evidence -- Bagott calls this trend "fairy tale science". The second book, Tegmark (2014),i defends the opposite view – it considers Mathematics as identical to Reality and promotes increasing reliance of modern physics and cosmology on mathematical assumptions and logical consistencies rather than empirical evidence -- defending such controversial conclusions that we live in one of infinitely many parallel universes with numerous alter egos of each of us. But this is not a book review of Baggott (2013) and Tegmark (2014); its aim is to draw attention to the fact that social scientists are not the only scholars blamed for paying too much attention to model building and too little to empirical confirmation. This, ought to be of enormous interest to financial scholars; it may even be a consolation to some of them for emphasizing mathematical consistency rather than empirical confirmation. But our examples (from "speculative science" in finance) illustrate that such a trend caused staggering losses during the financial crisis of 1997-1998 (of Japan and Russia) and serious threats to the entire World Economic System during the crisis of 2007-2008.

KEY WORDS:
Reality, mathematical consistency vs. empirical evidence in physics, cosmology, economics and finance.

[1] a. Enviado/Submitted: 30-04-16
b. Aceptado/Accepted: 21-10-16

1. Introduction

It seems that such disciplines as quantum theory and cosmology are in the process of having exhausted a good deal of their vast empirical potential, and -- in order to explore a host of exciting “theoretical” questions – their scholars increasingly rely on mathematical consistencies and dubious assumptions rather than factual confirmation. The resulting conclusions may seriously affect our view of what is to be considered Science, or even Reality. This attitude seems to be supported by the fact that today such highly reputable scientists as Brian Greene (2003, 2004, 2011), AlanGuth (1997), Hugh Everett (1957), Andrei Linde (1990), Max Tegmark (2014a, 2014b), Leonard Susskind (2005), Alexander Vilenkin (2006), Steven Weinberg (1992, 1993) and others, do not hesitate to accept ideas that are *not* based on empirical evidence. They accept the existence of infinitely many parallel universes and, above all, the outlandish notion that some of them are populated with alter egos of each of us. Or as Tegmark (2014a, p. 119-120) says:

> This proposition [about alter egos] doesn’t even assume speculative modern physics, but merely that space is infinite and rather uniformly filled with matter. Your alter ego is simply a prediction of eternal [cosmic] inflation, which, as we’ve seen in the last chapter, agrees with all current observational evidence [but how can the attributes of something “infinite” and “eternal” be observational evidence?] and is implicitly used as the basis for most calculations and simulations presented at cosmology conferences.

As to Baggott (2013, cf. p. 24), he admits that reality is a metaphysical concept, and science – as a human endeavour -- is more ambiguous than many of its disciples like to concede. Yet, he believes it is possible to draw a line between science, in the rigorous sense, and speculative science, which he calls “fairy tale science.” To distinguish genuine science, he outlines six Principles most of which are here concisely reformulated:

1. While *Reality* (things-in-themselves) is a metaphysical concept, science deals with *empirical reality* (things-as-they-appear or are measured), which is assumed to be rational, predictable and accessible to reason.

2. Verified *Facts* (rooted in observation and experiment) are the basis of science. Yet, facts are not theory-neutral and require a supporting theory.

3. A physical *Theory* describes empirical facts, but is "founded on abstract mathematical (we could even say metaphysical) concepts. The process of abstraction from facts to theories is highly complex, intuitive and not subject to simple, universal rules applicable to all science for all time" (Baggott 2013, p. 17).

4. *Testability* (whether by verifying or falsifying) is the founding criterion of a theory (cf. Baggott, 2013, p. 20).

5. *Veracity*. A theory is accepted as possessing a high truth-likeness (verisimilitude) as the degree of belief in the theory grows. It finally becomes (for the time being) the 'authorized' version of empirical reality (cf. Baggott, 2013, pp. 22-3).

6. *The Copernican Principle* (a misnomer, as it was not defended by Copernicus, as Baggott admits): "The universe is not organized for our benefit and we are not uniquely privileged observers. Science strives to remove 'us' from the centre of the picture, making our existence a natural consequence of reality rather than the reason for it." (Baggott, 2013, p. 23).

In contrast to this, Tegmark distinguishes between *three* concepts of reality: External Reality (approximately Baggott's "empirical reality"), Internal Reality (Baggott's metaphysical concept of "reality") and Consensus Reality. The latter stands between the first two, and serves as a common basis among living beings. Or as Tegmark (2014, p.238) says: "The world for which we have a shared description in terms of familiar concepts from classical physics."

Both books (Baggott's and Tegmark's) deal in their early parts with fairly well-established concepts and theories from standard physics and cosmology. These passages are not merely an excellent recapitulation for the lay-person, they also introduce her to many new aspects of those fields – with the distinction that Tegmark's book is profusely sprinkled with auto-biographical details. However, the later parts of both of these books are the ones of interest to us. It is there where the opinions divide sharply; where we find Baggott's harsh criticism of recent scientific conclusions, while Tegmark plunges deeper into such daring assumptions that mathematics is not merely describing reality, but is reality itself -- quite apart from his defence of other radical views, as the existence of four levels of infinite multiverses with their abundance of doppelgangers of each of us. Such extreme conclusions may reveal the Achilles heel of present-day physics and cosmology. What will be the reaction from scholars of other disciplines? What will be the future confidence of lay-persons in science? Will this open a wider trend of prioritizing mathematical consistency but neglecting empirical evidence?

2. Is Mathematics Playing a Trick on us, or is Reality, indeed, Unbelievably Weird?

The notion of infinity has engendered much anxiety in mathematics and science, and often forced scholars to take refuge in the “inelegant” solutions of renormalization. Hence, one explanation of the present dilemma is that the highly disputed notion of infinity is playing havoc with our reasoning process. Even Tegmark, the “champion of mathematics” as the essence of Reality is, at times, critical of the notion of infinity. He writes:

> Thefailures of classical mechanics required switching to quantum mechanics, and I think that today’s best theories similarly need a major shakeup. Nobody knows for sure where the root of the problem lies, but I have my suspicions. Here’s my primary suspicion: infinity.
>
> In fact, I have two suspects: “infinitely big” and “infinitely small.” By *infinitely big,* I mean that space can have infinite volume, that time can continue forever, and that there can be infinitely many physical objects. By *infinitely small,* I mean the continuum: the idea that even a liter of space contains an infinite number of points, that space can be stretched out indefinitely without anything bad happening, and that there are quantities in nature that can vary continuously. (Tegmark 2014, p. 316).

And in the next paragraphs, Tegmark admits that “We have no direct observational evidence for either the infinitely big or infinitely small.” Tegmark also affirms that already as a youth he had suspicions against infinity. And such suspicion he considers rare among physicists but not among mathematicians. He points out that the famous mathematician, Carl FriederichGauss,”protested” against this concept. Gauss considered infinity as a way of speaking about a limit which certain ratios approach indefinitely close, while others are allowed to expand without limitation.

Indeed, most of the speculative aspects in modern cosmology could be avoided by banishing the notion of infinity. But why, then, do so many physicists continue with theories based on infinity? Tegmark’s answer: “because infinity is an extremely convenient approximation, and we haven’t discovered good alternatives” (Tegmark, 2014, p. 317). Thus, as things stand presently, to eliminate this concept is unlikely to occur. The concept of infinity is too well entrenched, not only in mathematics but also in cosmology. After all, when you think of it, the concepts of “beginning” and “end” are intimately tied to that of infinity. And when you contemplate the nature of the cosmos; it is just as logical or illogical to assume a beginning and an end instead of assuming neither. Because then the question arises: “what happened before the beginning and after the end?” And these questions are no less puzzling to answer.

Furthermore,if the leaders in some of the most successful empirical sciences defend such "outrageous" views, there must be good reasons for them to do so. And these reasons force us to reflect whether mathematics with its mysterious notions of infinities plays a trick on us. If not, Reality may, indeed, be so weird that many of us have difficulty accepting the resulting conclusions. Among these, are, for example, that each of us has infinitely many doppelgangers in infinitely many universes and that, under such conditions, "whatever can happen will happen."

Hence, the scepticism that arises in many social scientists when learning about parallel universes and alter egos (populating them) may have to be mitigated. That does not necessarily mean we have to embrace such extreme conclusions whole-heartedly; it rather means that we should recognize the limitations of our own reasoning process. As much as this may hurt our pride, we have to admit that notions such as infinitely small, infinitely large, various mathematical infinities, and eternity are all beyond our full comprehension and may easily lead us astray when relying too much on them.

One potential counter-argument against the criticism that theories predicting unobservable entities are unscientific, is this: "*For a theory to be falsifiable, we need not be able to observe and test all its predictions, merely at least one of them* (Tegmark, p. 124). But that hardly solves the repeated reliance on infinity -- which in our view is neither a testable nor falsifiable notion.

The most famous argument in favour of speculative science is the postulation and ultimate confirmation of the Higgs boson. The empirical discovery of this particle by the Large Hadron Collider of CERN (near Geneva) in July 2012 (ATLAS and CMS experiments – see CERN n.d.: http://home.web.cern.ch/topics/higgs-boson) was one of the major events of modern experimental physics. It confirmed that "mass" is not an inherent property of things (as previously believed) but is the result of the Higgs field that creates resistance in most particles and things (but not in all of them – e.g. not in photons that have no mass). This resistance appears to us as mass or weight. This particular boson was postulated mathematically by Peter Higgs, François Englert (both receiving the Nobel Prize in Physics of 2013) and others, almost 40 years before its experimental confirmation. The major reason for the long delay between mathematical and empirical discovery is the fact that the latter requires a hadron collider of enormous energies (some 126 GeV), not available in earlier years. This story may illustrate that a mathematical hypothesis, as daring as it might be, should not be dismissed just because it has not yet been confirmed.

3. Baggott's assertion that "modern physics betray the search for scientific truth."

Baggott (2013) lists and discusses seven *assumptions* and one *conjecture* that have, so far, *not* been empirically confirmed (hence his expression: "fairy tale physics"). These are:

1. The supersymmetry assumption (pp. 163-65, 188).
2. The string assumption (pp. 185-86).
3. The compactification assumption (pp. 192-93).
4. The brane [membrane] assumption (pp. 198-202).
5. The many worlds assumption (pp. 216-19).
6. The [cosmic] inflationary multiverse assumption (pp. 221-24).
7. The landscape assumption (pp. 224-26).
8. The M-theory conjecture (pp. 196-98).

Hence, the main targets of Baggott's criticism (in Part 2: "The Grand Delusion") are: supersymmetry theory (where esoteric and mainly unconfirmed particles maintain the symmetry), string and superstring theories, brane theory (where membranes replace strings), M-theory, the theory of parallel universes and multiverses. It is not possible here to explain these theories in detail. But let it suffice to say, these are parts of a complicated conglomerate of bits and pieces of recent physical and cosmological theories -- sometimes competing with each other, sometimes supplementing each other. But, according to Baggott, none of them can claim empirical verification. Let us offer some samples and passages from his book:

Baggott (2014, p. 202):

> My problem is that branes and braneworld physics appear to be informed not by the practical necessities of empirical reality, but by imagination constrained only by the internal rules of an esoteric mathematics and an often rather vague connection with problems that theoretical physics beyond the standard model is supposed to be addressing. No amount of window-dressing can hide the simple fact that this is all *metaphysics*, not physics.

Or Baggott (2014, p. 288):

> SUSY [Supersymmetry] has made some predictions, of a sort, but these are not so far supported by data emerging from the LHC [Large Hadron Collider]. SUSY is failing the test. Superstrings/M-theory and the various multiverse theories have made no really testable predictions at all.

> At what point do we recognize that the mathematical structures we're wrestling to come to terms with might actually represent a wrong turn…?

Baggott (2013, p. 205) also points out that the renowned Richard Feynman (and Nobel Laureate) was complaining about these problems already many decades ago, in the 1980s, by saying:

> I don't like that they're not calculating anything. I don't like that they don't check their ideas. I don't like that for anything that disagrees with an experiment, they cook up an explanation — a fix up to say 'Well, it still might be true.' [see also Baggott's Chapter 8, p. 309, note 16].

But the "measurement problem" of quantum physics – with its superpositions, its probabilities and collapsing wave functions, multiple universes, etc. – is considered by Baggott (2013, p. 209) the most unwieldy of all of those problems. He says:

> The problems that SUSY, superstring theories and M-theory seek to address pale almost into insignificance compared with one of the most fundamental problems inherent in contemporary physical theory – the quantum measurement problem.
>
> Seeking to resolve this problem has produced metaphysics on the very grandest of scales.

And in regard of Tegmark's Mathematical Universe Hypothesis, Baggott (2013, p. 238) says:

> Despite his claims of testability, Tegmark himself seems to acknowledge that it is really all philosophical speculation. In an apparent throwaway remark towards the end of the interview with Discover,[ii] he comments that his wife, a respected cosmologist, 'makes fun of me for my philosophical "bananas stuff", but we try not to talk about it too much'.
>
> Now that sounds like good advice.

4. Why an increasing number of physicists and cosmologists believe there actually exist an infinite number of parallel universes, with alter egos of each of us.

The root causes for the widespread acceptance of an infinite number of parallel universes seem to be two. On the one side is the "theory of eternal inflation" (i.e. that big-bang-like events occur eternally in some parts of our multiverse). On the other side is the need to create a connection between the micro-world of quantum theory and the macro-world of classical physics.[iii] The basic disconnect between the two is the "measurement problem" of quantum physics. According to this, sub-atomic entities have particle characteristics as well as wave characteristics. One solution is the process of "measurement" (observation) that determines the position of the particle with the simultaneous collapse of the wave-function (the Copenhagen interpretation). One alternative is maintaining the wave function by assuming the existence of multiple universes that enable the realization of each of the possible super-positions of the wave function (in one universe or the other). In other words, according to the Copenhagen interpretation we can observe whether Schrödinger's legendary cat (subject to a random device that may kill the cat or may not kill it) is either alive or dead by opening the box containing the cat. In the alternative, the multiverse interpretation (in which the wave function does not collapse), Schrödinger's cat may be alive in some of the parallel universes but dead in others.

The example, discussed above, is a highly simplified version of the two major interpretations of quantum mechanics – as we, as laypersons, understand them. But while the Copenhagen interpretation was originally the dominant one, the multiple universe hypothesis has recently greatly increased in popularity among physicists and cosmologists. This preference may be difficult to fathom for the layperson. But, it *maintains* the wave function (instead of letting it collapse). This assuresgreater consistency with quantum physics and does not even require any infinity assumption. Above all, it *avoids the subjective interference of an observeras a requirement* to measure the position of the particle (or the observation whether the cat is alive or dead) -- thus relinquishing the collapse of the wave function and avoiding a subjective element in science. In other words it preserves the Copernican Principle, that gets lost under the Copenhagen interpretation.

Baggott (2013, p. 238-241, 258) also deals with the problem of quantum information: i.e. its scientific vs. metaphysical interpretation. The latter (i.e. the non-physical notion of information) he obviously relegates to "fairy tale science." Thus, Baggott questions the notion that Reality is nothing but information (i.e. the holographic and the anthropic principles).

5. Is Reality Nothing but Mathematics?

And how about Tegmark's hypothesis that Reality is nothing but mathematics? Traditionally, a structure expressed in mathematical terms is as different from the real thing as is sheet-music compared to the music played on the piano or in a concert hall with real instruments. It is, of course, true that nature manifests itself in a great number of mathematical ways directly to us. From the hexagonal shape of the numerous cells in a bee hive to the elliptical orbit of planets around the sun. But in all those cases there is a clear distinction between the abstract structure of representation and the real thing that possess such a structure.

Or take another example: the architect's plan of a house. Such a design may reveal the structure of the house. But this is not the same as the house itself, in which you will live and entertain your guests. We agree with Tegmark that nowadays computerization and simulation employ more and more mathematical devices that dominate our daily lives. However, digitalized music, for example, still needs to be translated by some mechanical device into sound waves, and although those waves can be expressed in mathematical terms, they are not the sound itself. In other words, one has to breathe "life" (or "fire", as Hawking would say) into the structure to become the music you can listen to. A genius like Beethoven may have been able to "hear" the music when writing or reading the notes from a music sheet. But few people have such a gift – apart from the fact that, in the case of Beethoven we may have been dealing with what Tegmark calls "personal reality" (see above) in contrast to his "physical reality" or his "conventional reality."

6. Is the Passage of Time an Illusion?

Another question connected with the problems of eternity and infinity is the issue of time. Philosophers distinguish between Presentism (the conventional or every-day view of time) with its distinction between past, present, and future, on one side, and Eternalism (rooted in Special Relativity Theory), on the other side -- (see Wikipedia (2015a) "Eternalism (philosophy of time)". In the latter case, one also speaks of the "block universe", considering the four dimensions of spacetime as a block in which the time dimension is inseparable from the space dimension, and the notion of simultaneity for different space-time frames becomes illusionary. Or as Tegmark (2014: pp. 272-73), referring to Einstein, points out that he:

> taught us that there are two equivalent ways of thinking about our physical reality: either as a three-dimensional place called *space*, where things change over time, or as a four-dimensional place called *spacetime* that simply exists, unchanging, never created and never destroyed [note omitted].These two perspectives correspond to the frog and bird perspectives on reality that we discussed in Chapter 9: the latter is the outside overview of a physicist studying its mathematical structure, like a bird surveying a landscape from high above; the former is the inside view of an observer living in this structure, like a frog living in the landscape surveyed by the bird.

In general one regards the first alternative (of three space dimensions plus a separate time dimension) as one where time is flowing, whereas in the second alternative (the four-dimensional spacetime), time is standing still. However, would it not be more accurate to regard the second case as one in which time *leaps* from one time-slice to another? In this case time would not stand still at all; it would be digitalized rather than continuous, but nevertheless it moves – a picture that seems to us more in accord with common sense.

In consequence one may considers time as digitalized (instead of continuous). Thus the Present becomes a time-slice and the only real time-dimension while the "flow of time" (though not the existence of time itself) is regarded as an illusion. In this view the passage of time is questioned. But if time is no longer flowing, is it not at least *jumping* (from one frame or moment to the next)? And jumping is still a mode of passing. Hence, we ask ourselves whether it would not be more reasonable to consider the "passage of time" as a legitimate form of speech, even if we can no longer speak of a smooth flow of time like that of water.

And as to the *digitalization or quantification of time* (and even possibly of *space*), it seems to be a reasonable suggestion. Is not digitalization the essence of quantum theory? If such a basic element of reality as energy is quantized (as modern physics has demonstrated) why should time and space (or spacetime) not also occur in quanta? After all, for us space and time are basic and interdependent elements of reality, as is energy (see Mattessich and Galassi, 2015).

However, there is one major problem. The quantum leap of a sub-atomic particle in the transition from one energy level to another (be it upwards when absorbing a particle, or downwards when emitting one) amounts to a specific quantity and can be measured. But such measurement seems to be more problematic in the quantification of space and time. Although we may assume time quanta (and/or space quanta) we have, in contrast to energy quanta, no clue about the size of time and space quanta – if they should exist. How can we measure them? How large are they? Is this the reason why such kinds of quanta are rarely considered by scientists?

7. Speculative Science in Economics and Finance.

The problem of excessive reliance on mathematics combined with insufficient empirical backing is by no means limited to the physical sciences. On the contrary, traditionally this very problem has been plaguing the soft sciences. This gives reason to suspect that economists and other social scientists might derive some satisfaction from the fact that even such hard sciences as physics and cosmology are afflicted by the same, or a similar, phenomenon.

Baggott (2013, pp. 289-91) suggests that a typical example of speculative science in financial economics is the application of the "Gaussian copula function" to financial markets (introduced by the Chinese-American actuary David X. Lee). This application is claimed by Baggott to have triggered the financial crisis of 2008, the biggest breakdown in the American financial market since the crash of 1929. Although this might be too simplistic a picture (since many more factors were involved in the 2008 crisis), the Gaussian copula function is an excellent example for the role in which speculative economics played havoc with the American economy. At first, this new technology proved to be an immense success, enabling traders to sell huge amounts of financial securities, often by distorting the real risk involved. It helped to expand the pertinent markets to unimaginably large levels. But after five years or so, it turned to disaster. Or as Salmon (2009, p. 1) describes it:

> His [Li's] method was adopted by everybody from bond investors and Wall Street banks to ratings agencies and regulators. And it became so deeply entrenched—and was making people so much money—that warnings about its limitations were largely ignored… Then the model fell apart… The cracks became full-fledged canyons in 2008—when ruptures in the financial system's foundation swallowed up trillions of dollars and put the survival of the global banking system in serious peril.

However, the major factor causing this disaster was the re-packaging of low-rated mortgages but selling these packages as high-rated bonds – in other words fraudulent intentcombined with a major failure of American securities rating agencies.

An earlier and equally notorious example of the application of mathematics and speculative science in finance is the paper by Black and Scholes on "The Pricing of Options and Corporate Liabilities" (1973). The underlying Black-Scholes formula estimates the price of options when hedging such options by either buying or not buying (or selling vs. not selling) a specific asset. Doing this at the right time is supposed to minimize (or even eliminate portions of) the risk of trading financial options. Indeed, the formula – particularly with the improvements made by Merton (1973) was hailed as the Holy Grail of modern Finance ("investing without risk!"). Scholes and Merton both received the Nobel Memorial Prize in Economics of 1997 (Fisher Black, the coauthor of Scholes, had died by the time the prize was awarded). However, the model had its limitations as the following story vividly illustrates.

In 1994 Merton, Scholes and a group of high-powered financial expert from practice and academia founded an exclusive hedge-fund under the name of Long-Term Capital Management (LTCM). Based on their mathematical formulas the fund undertook fixed income arbitrage in government bonds (mainly of the USA, Japan, and some European countries – with a splinter-fund investing in Latin American countries). The fund was highly successful in the first three years (net returns in percent were 21%, 43%, and 41%, respectively) but in1998 the fund lost no less than 4.6 billion dollars, and had to be liquidated in the year 2000.

> At the beginning of 1998, the firm had equity of $4.72 billion and had borrowed over $124.5 billion with assets of around $129 billion, for a debt-to-equity ratio of over 25 to 1 [note omitted]. It had off-balance sheet derivative positions with a notional value of approximately $1.25 trillion, most of which were in interest rate derivatives such as interest rate swaps. The fund also invested in other derivatives such as equity options (Wikipedia, 2015b).

Whereas initially the fund was highly successful, it collapsed during the financial crises of Japan in 1997 and Russia in 1998 due to an insufficient empirical data base. The aftermath of this catastrophe was a bailout of LTCM in the amount of 3.6 billion dollars by some sixteen major financial institutions (under supervision of the Federal Reserve Bank of New York, whose officers feared this immense failure might trigger a general financial collapse).

8. Summary and Conclusion.

This paper has tried to illustrate the trend of various scientific disciplines to rely increasingly on mathematical consistency than on empirical verification. According to Jim Baggott (2013) examples of this trend are abundantly found in modern physics (including quantum theory) and cosmology. This may come as a surprise (perhaps even a pleasant one) to social scientists (particularly economists) who may have deemed themselves to be the major group of scholars traditionally afflicted by this trend.

However, as Baggott shows, such immensely successful empirical sciences as physics and cosmology bear the same stigma of relying (in relatively recent times) to an exceedingly large extent on mathematical consistency rather than empirical evidence. The major reason for this trend and its criticism seems to be the excessive reliance on the concept of infinity. This notion is beyond human comprehension, though it is abundantly used in physics, and particularly in cosmology. Nevertheless, it should be a warning that the concept of infinity might easily lead us astray. In other words, Baggott (2013, p. 294) sees a danger for science in general:

> If scientists can set themselves up as the high priests of a new metaphysics, and continue to preach their gospel unchallenged through popular books and television, then the credibility of all scientists starts inexorably to be eroded. Why should we take any of them seriously?
>
> The really worrying thing is that the scientific community seems caught in two minds about all this. While there are many physicists prepared to take the tellers of fairy tales to task, this is extremely sensitive ground. It is hard to criticize fairy-tale physics without being perceived to be criticizing science as a whole.

Perhaps, this paper and the entire context of speculative science deserves greater attention from philosophers -- and Baggott (2013, p. 297) agrees with this in expressing the following words:

> I think it's high time we heard a bit more from the philosophers. I'd be interested in their interpretation of the status of M-theory, the multiverse and the anthropic principle. A hostile reception can be pretty much guaranteed, but I believe it is vitally important that the guardianship of science and the scientific method should not be left solely in the hands of scientists, particularly those scientists with intellectual agendas of their own.

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ENDNOTES

• Financial support from the Social Sciences Research Council of Canada is gratefully acknowledged.

[i] Jim Baggott is a British physical chemist and successful science writer (2005, 2011, 2012, 2013), and Max Tegmark is a Swedish Cosmologist and Professor at the Massachusetts Institute of Technology. He is well-known for his daring book, *Our mathematical universe* (2014a) and other publications, e.g. Tegmark (2014b).

[ii] This interview took place before Temark's (2014a) book appeared.

[iii] See Mattessich (2014, pp. 164-5, 225, 247 n.11).

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