MATHEMATICAL MODELS BEYOND SPACE AND TIME

Michael Heller reflects on the 'big questions' of cosmology

JAVIER MONSERRAT
Universidad Autónoma de Madrid

The winner of the Templeton Prize 2008 was announced during a press conference at the United Nations' Church Centre in New York on 17 March this year. The Prize was awarded to Michael Heller for his work over more than forty years and his shrewd and often surprising insights regarding our concepts of the origin and cause of the universe. Heller is a professor of philosophy, although he trained in the fields of mathematics, physics and cosmology, as well as in philosophy and theology. His contributions pertain, in many senses, strictly to the field of physics, although they are theoretical rather than experimental. Indeed, they are more proposals of speculative mathematical-formal models and have been published in many prestigious international physics journals. But the heart of Heller's concerns always points towards the philosophy or metaphysics of the universe, where the fundaments of reality relate the ontological roots of the universe to the ontology of the Divinity and the act of creation. One may or may not agree with Heller's speculations, may view them as more or less plausible and consider their formal construction to be either laudable or poor, but anyone who reads his work cannot help but gain the impression of following the arguments and affirmations of an extraordinarily well-informed, precise and deep-thinking physicist-philosopher.

One significant circumstance in Heller's life was his relationship with Pope John Paul II, which was established even before Cardinal Karol Wojtyla acceded to the pontificate. In private meetings with Heller and other Polish scientists, John Paul II often reflected on the implications of key scientific questions on theology. It seems (since officially, we can obviously affirm nothing) that Heller is the author of the letter John Paul II sent in 1996 to George Coyne, the then director of the Vatican Observatory. This letter, later published on the STR Chair website, is one of the most explicit and open theological documents ever signed by John Paul II. In it, the Pope echoed the need for a theory inspired in the world of science, just as a theology inspired in Aristotle's teachings was developed during the Middle Ages.

Michael Heller's curriculum vitae

Michael Heller is a professor of philosophy at the Pontifical Academy of Theology in Krakow. He graduated in theology from the Catholic University of Lublin and was ordained in 1959. He returned to university in 1960, earning a Master's degree in philosophy in 1965, with a dissertation on the theory of relativity, followed by a PhD in cosmology with a thesis on relativist cosmology. Although his studies focused on theoretical physics, he nevertheless earned his degree in philosophy because during the communist era, the Catholic university lacked the authority to bestow degrees in physics. In 1969, Heller earned a post-doctorate degree which authorised him to begin lecturing. Again, his thesis focused on Mach's principle in relativist cosmology.

He was not granted a passport until 1977. Once he was free to leave the country, he was appointed visiting professor at the Catholic University of Louvain's Institute of Astrophysics and Geophysics, in Belgium, and also carried out research at the Oxford University Institute of Astrophysics and the physics and astronomy department of the University of Leicester. In 1985 he joined the teaching staff of the Pontifical Academy of Theology in Krakow, where he has engaged in a wide range of teaching activities over the last twenty years.

In 1986 he began collaborating with the Vatican Observatory in Castel Gandolfo, where he worked with the Jesuits George Coyne and William Stoeger, repeatedly mentioned in 'trends of religions'. He also made contact with the Vatican Observatory Research Group at the Steward Observatory at the University of Arizona, Tucson, and is the co-author of a book with Coyne. Some of his other works in English were also published by the Vatican Observatory.

Heller's biography reflects the dramatic nature of the tormented history of 20th century Europe. His father, an engineer by profession, sabotaged the chemical facility in which he worked in order to prevent it from being used by the German troops during the Second World War. Fleeing from repercussions, the family lived in Ukraine, Siberia and Southern Russia, before finally returning to Poland. Heller's decision to devote his life to science was frustrated and severely limited for decades due to the oppression of the communist regime. Only the protection of the Polish Church enabled him to pursue his scientific and philosophical vocation, which recently culminated in his being awarded the Templeton Prize.

Publications

The statement issued by the Templeton Foundation accompanying the announcement of the 2008 prize-winner described Heller's oeuvre as prodigious, encompassing thirty books (some in English, the majority in Polish) and around 400 papers, consisting of both research and, mainly, dissemination. Here, we will refer to the four books in English that, for now at least, provide a feasible point of access for getting to know the work of this great academic.

Theoretical Foundations of Cosmology (World Scientific, 1992) is a technical cosmological work examining the mathematical models which underpin theoretical physics and cosmology. In *Some Mathematical Physics for Philosophers* (Pontifical Council for Culture, Gregorian University, 2005), Heller provides philosophers with a structuralist vision of the theory of relativity and quantum mechanics.

His other two English-language works relate both new physics and cosmology with the question of God, religion and theology. These works are: *The New Physics and a New Theology* (Vatican Observatory Publications, 1996) and also *Creative Tension: Essays on Science and Religion* (Templeton Foundation Press, 2003). We will base our overview of Heller's personality and work on both these two books and the documentation included on the website templetonprize.org, about the author.

A structuralist conception of physics

'People often say that physics is a science of matter or of the material world, but while most books on theoretical physics contain lots of mathematics, few mention anything about matter. This is because physics develops by constructing mathematical models of the world and then by confronting them with empirical results. One may say that the world, as viewed by modern physics, is constructed not out of matter but rather out of mathematics. But mathematics is a science of structures'.

'Of course, mathematics deals also with much more complex structures, for instance, vector spaces, algebras, Euclidean or Riemannian spaces and so on. And physicists take some of these structures and interpret them as structures of the world. For instance, they say that the space-time of our world is a four-dimensional Riemannian space. This is a very powerful method; it sees the world through the glasses of structures. In this sense, physics is not a science of matter but rather a science of structures. This view is called structuralist philosophy of physics. I not only develop it in my philosophical papers, but also try to do science and teach it in the spirit of this philosophy' (Heller, *Reflections on Key Books and Publications,* templetonprize.org).

Here we see with absolute clarity the perspective that enables us to assess the nature and meaning of Heller's physical-philosophical thought: his analysis and understanding of physical theories of matter and the universe is always a reflection on the mathematical models applied to provide an ontological view of reality. This structuralist approach to scientific theories is not something unique to Heller, but rather has a long history in the epistemology of science. We need go no further than empiriocriticism, Pierre Duhem or Poincaré, or Wolfgang Stegmüller in the nineteen-seventies. However, it is an approach that was assimilated by Heller, and which illuminates his way of probing the philosophical problems of physics.

His early studies, focusing mainly on the theory of relativity, provided him with access to an example of structuralism: Einstein's relativity identified using Riemannian geometries which enabled him to make the world 'fit' and describe it. Prompted by the mathematical logic of relativist models, Heller began exploring the issue of singularities (anticipated in the mathematical form of the relativist model). However, when reason reaches the limits of Planck's era and attempts to cross Planck's threshold in time and space (10^{-33} cm), entering the original limits of the singularity in which the big bang occurred, the question arises as to the type of real situation in which all this was possible. And asking about a 'real situation' is, in physics, the same as asking about the mathematical (structural) models which enable us to understand it.

Mathematical models for the origin of the universe

The question is then, what type of physical situation existed in Planck's era, from which our real world emerged. This, as it is accessible to us now, corresponds on the one hand to the classical-relativist mechanics (macrocosmos) encompassed in a Riemannian geometric mathematical model, and on the other to the quantum mechanics (microcosmos) encompassed in a non-geometrical mathematical model (Hilbert space), with primordially statistical and probabilistic traits. In ordinary physics, relativity and quantum mechanics have both become parallel correct explanatory dimensions of the macroscopic and microphysical (respectively) physical reality.

However, when entering Planck's era, both relativist and quantum perspectives necessarily become confused, since there is no physical reality that can be known by either of these approaches. The only physical theory capable then of responding to the situation existing in Planck's era must be quantum-relativist; hence the vital importance of current research into 'quantum gravity'. As Heller observes, the problem of this quantum-relativist merging is that the mathematical model of relativity is geometric, while the quantum model is not. Hence the difficulty in finding a single conception that encompasses mathematical models of different natures (relativist and quantum).

Some relativity theorists have in fact proposed diverse ways of explaining the geometrical nature of the 'singularity' (in physical terms, the big bang) and the birth of the relativist space-time until the end of Planck's era. Heller offers an in-depth analysis of these different theoretical proposals. He does not appear to study the superstring theory here in any great depth (although he doubtless does so in other parts of his extensive oeuvre), but we should remember that Magic Theory is also a formal mathematical speculation designed to explain, based on its eleven dimensions or variables, how our space-time world emerged though Planck's era.

Here is where the fundamental idea provided by Heller fits in. It is an evidently speculative idea (as indeed is the superstring theory) that suggests that in Planck's era, relativist and quantum approaches may coincide and be understood from a higher level of abstraction represented by the mathematical model of a 'non-commutative geometry'. This new geometry, constructed recently by some authors, is not a space-time geometry, but rather a space without points or seconds which would, according to Heller, enable the emergence of both classic-relativist space-time and the special form of quantum space-time.

Metaphysical-theological speculation from the perspective of cosmology

The primordial reality modelled by this 'non-commutative geometry' would therefore be non-local, non-temporal, on the sidelines of the space-time we know and dynamic, rather than static.

There would be different states and operators between one state and another, but no space-time; in other words, there would be a kind of 'superimposed' simultaneity. In some way, in this primordial reality modelled by the 'non-commutative geometry', in which the classical-relativist and quantum worlds could be reconciled, many of the quantum properties to which we now have experimental access though a series of 'observables' would become valid.

It is clear that Heller likes this idea, since as a theologian and someone engaging in a moment of 'second order' speculation, this model seems to suggest certain parallels with the idea of a God existing beyond the space-time which is, nevertheless, dynamic. This God would not be 'eternal' (i.e. with infinite time), but rather simply something different, non-temporal, existing beyond the space-time, where the superimposition of states and simultaneity would prevail.

Furthermore, the idea of God suggested by this 'non-commutative geometry' is used by Heller to discuss some of the principles of process theology (Whitehead), namely, the idea of God as a non-creator Demiurge subjected to the space-time of the real classical world. For Heller, it is erroneous to claim that God should be subject to the space-time in order to be a dynamic, living God, connected to the events of the world. The non-commutative geometry model enables him to conceive a type of reality outside the space-time, which is nevertheless dynamic. In this sense, the model proposed by Heller responds more to the traditional idea of a transcendent God who is also the creative origin, the fundament of being, out of whom the space-time of the created world emerges.

We should not forget that there is also another speculative aspect regarding the ultimate origins and foundations of the physical reality. We talk of a 'singularity' (within the framework of the mathematical model of relativity) which translated into a real big bang that actually occurred as a physical event. But, what existed before the big bang? Today, there is much debate and speculation around the idea that the singularity of our universe is just one of an infinite number of singularities occurring in a meta-space or eternal fundamental universe constituted perhaps by a quantum vacuum, by a sea of energy, by Bohm's 'implicate order' or by a 'primordial ether' (although not in the Newtonian sense) from which infinite 'multiverses' are generated. In each of these scenarios, the emerging universe responds to a set of values in keeping with the structure of variables conceived (also using speculative-mathematical methods) by the superstring theory.

Heller is obviously opposed to these speculations about multiverses and string theory. He proposes instead an alternative speculation which he believes is more realistic and, in his opinion, more in keeping with theology: his speculation deals with a universe which, in moving towards its primordial foundations, transforms into a non-space-time dimension which ends up connecting to the transcendent reality of an atemporal God beyond any possible geometric singularities and the big bang.

Non-commutative geometry for a theist philosophy

According to Heller, we can speculate that, rather than an artificial instrument used in relation to classic singularities in general relativity, non-commutative geometry is, in fact, something which reflects the structure of the era of quantum gravity. The fact that the operators in Hilbert space (the typical mathematical objects of quantum mechanics) respond to the true essence of a non-commutative description of singularities may suggest that said singularities 'have a certain knowledge' of quantum effects. The tempting hypothesis is that the era of quantum gravity exists under Planck's threshold, modelled by a non-commutative geometry and, as a result, absolutely non-local. In this era there is neither space nor time in the usual sense. Only when the universe passes over Planck's threshold is there a 'transition phase' to commutative geometry, and it is during this transition that ordinary space-time emerges, along with its frontiers or singular limits (singularities) (Creative Tension, 92-93).

Singularities are formed during the transition process over Planck's threshold, when space-time emerges from a non-commutative geometry. This process can be explained in the following way. Normally, we think of Planck's era as something hidden in the prehistory of the universe, when its typical scale was around 10^{-33} cm. However, Planck's era can in fact be seen even now if we delve deeper and deeper into the structure of the world, until we reach the 10^{-33} cm threshold. Upon crossing this threshold, we find ourselves in Planck's 'stratum', with its non-commutative regime. At this basic level under Planck's scale, all states exist equally, and there is no difference between singular

and non-singular ones. Only the macroscopic observer, located in space-time (and therefore beyond Planck's threshold), can say that their universe began in a singularity in a finite past, and may possibly finish in a final singularity in a finite future (Creative Tension, 93).

The non-commutative perspective provides a natural explanation for all non-local phenomena. Since the fundamental level is totally non-local, it is hardly surprising that certain quantum phenomena (such as the EPR experiment) that occur at this level have non-local effects; they are like the tip of the iceberg of this 'non-local non-commutativity' which remains present despite the transitional phase to ordinary physics. In order to explain the horizon problem [the astrophysical fact that very distant parts of the universe that have not had any physical contact nevertheless have exactly the same values for certain parameters], Heller believes we should adopt a different approach and regard 'fundamental non-commutativity' as being located 'at the beginning', in the pre-Planck era. This hypothesis supposes that this era was totally global; it would not, therefore, be at all surprising if, when passing over Planck's threshold, the universe preserved certain global characteristics even in those places that never (after Planck's threshold) came into causal contact with each other (Creative Tension, 115).

The 'second order' speculative reflection (the 'first order' one would be scientific only) is for Heller the philosophical-metaphysical-theological one. It is here that the logic of his explanatory hypothesis of the non-commutative geometry prompts him to reinterpret certain classic themes of philosophy-theology, such as: the idea of time, or to be more precise, space-time, in God; the application of this to the traditional idea of 'creation' (continuous creation 'from eternity', as foreseen by Saint Thomas); the concept of causality and the 'first cause'; the way in which chance, probability and statistics can be understood as elements of the creative design of a divinity beyond the space-time; the classic themes of divine omnipotence and omniscience in the debate with process philosophy-theology (Whitehead); and the classic theme of the meaning of the 'actions of God in the world', among others.

Does the universe need a cause?

In his acceptance statement for the Templeton Prize, Heller says:

'When contemplating the universe, the question imposes itself: does the universe need to have a cause? It is clear that causal explanations are a vital part of the scientific method. Various processes in the universe can be displayed as a succession of states in such a way that the preceding state is a cause of the succeeding one. If we look deeper at such processes, we see that there is always a dynamical law prescribing how one state should generate another state. But dynamical laws are expressed in the form of mathematical equations, and if we ask about the cause of the universe we should ask about a cause of mathematical laws. By doing so we are back in the Great Blueprint of God's thinking the universe. The question on ultimate causality is translated into another of Leibniz's questions: 'Why is there something rather than nothing?' (from his *Principles of Nature and Grace*). When asking this question, we are not asking about a cause like all other causes. We are asking about the root of all possible causes'.

Upon reading this text (and other similar ones by Heller), one has the impression that the author admits the approach of classic Thomist metaphysics, i.e. that the explanation of the universe requires a non mundane and necessary first cause, attributable only to God, since the need cannot be attributed to the world. Only God, not the universe, can be understood as the 'root cause', as the fundament of being, or in other words, as a necessary being: only God can be necessary.

Playing devil's advocate, however, we may perhaps dare to make a few observations. 1) Science, and also philosophical reason, base their thinking on a factual empirical world and strive to understand its ability to be real, to be just as we experience it (the expectation of science and reason would be, in principle, for the real system we see to be self-sufficient). 2) The problem with science/reason is precisely that any understanding of this sufficiency is enigmatic: it can be attributed to a pure world without a God (atheism) or to a God understood as a reality which transcends the universe (theism). 3) Regardless of whether we attribute this sufficiency to the universe or to a God, in both cases, it should itself, *eo ipso*, be attributed the need. This would be the specific approach of science.

In other words, the need is something we should postulate, either for the universe or for God, depending on whom we attribute the sufficiency of reality to. However, in neither case do we

understand why its 'ontology' makes it 'necessary'. Returning to Leibniz's question, which Heller mentions in the text quoted above, we cannot know why the universe exists or does not exist, or why God exists or does not exist. The only thing reason and science can do is try to understand the basis of the sufficiency of the universe that does in fact exist and which contains us, and *eo ipso*, attribute the need to it.

This is exactly what Leo Smolin says in reference to Leibniz's question 'why is there something rather than nothing?', in a text cited by Heller himself, in which he says that he does not really understand how science, despite all its progress, can ever help us understand questions of this kind. At the end of the day, perhaps room should be left for mysticism. However, mysticism is not metaphysics, and this, he says, is all he is trying to eliminate (Creative Tension, 160).

Indeed, if reason could only attribute need to God, then the existence of God would be rationally certain (in other words, it would be a 'metaphysical certainty' as the Thomist school would say). Atheism would not be feasible for reason. Is this what Heller thinks? The truth is that he seems somewhat ambivalent. On the one hand, we have texts like the one cited above. But on the other, he also says that science's greatest contribution to theology is the fact that it makes us understand that the universe is a Mystery. And here, we wholeheartedly agree with him.

It is a mystery that some try to clarify with freely assumed atheist hypotheses. But it is also a mystery susceptible to others, such as Heller, suggesting freely assumed possible hypotheses and speculations that demonstrate the verisimilitude of the hypothesis that it was created by a personal divine being, the fundament of being.

[Texto básico publicado en Tendencias21.net,
por la Cátedra CTR, Escuela Técnica Superior de Ingeniería,
Universidad Comillas, Madrid]

JAVIER MONSERRAT