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THREE CURRENT TOPICS ON MATHEMATICS AND THEOLOGY*

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To Prof. Liliana Restuccia, who has always been attracted by these perennial questions

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Abstract

In this paper, we briefly deal with some aspects of three active topics in mathematics and theology, namely: the deep mathematical structure of the universe and the creator's mind; chaos theory and mathematical metaphors of the Trinity; and mathematical undecidability of the existence of God. These are classical aspects of conceptual research where natural theology and the philosophy of mathematics meet and discuss. New findings in cosmology, in mathematical physics and in mathematical logics, as well as updated theological questions drive the impetus of the conceptual aspects beyond pure mathematical research.

Keywords: philosophy, theology, cosmology, chaos theory, undecidability.

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1 Introduction

Since the time of Pythagoras, mathematics has gone beyond the mere practice of accounting and measurement and, for many, has offered an almost religious dimension of reality, at least in three senses. It seems essential to

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the order of the world, as if it were a true foundation; it is an intellectual exercise that disciplines, structures, and illuminates the mind beyond our subjectivity; and it binds us to truths outside time, which transcend us. Physics, in its mathematical dialogue with the world, brings into contact an immaterial, abstract, timeless reality, outside space, with a mutable and concrete material reality - something that calls to mind natural theology, in its effort to reflect on the relationship between a God outside space and time and the material and historical reality in which we are immersed.

The role of mathematics in natural theology is well known and has changed and been enriched over the centuries: the ideals of clarity and proof of Euclidean geometry; the surprises of non-Euclidean geometries; the appeal and fascination of numbers and numerical relations (natural, rational, irrational, imaginary); the theme of infinity; the subtleties of mathematical logic; the variational principles of physics; the mathematical algorithms of computing, robotics, artificial intelligence, and so on.

Cardinal Nicholas of Cusa, in *De docta ignorantia* (1460), set forth the aspiration for a theology that would be sober and rigorous like mathematics; Pascal, by contrast, warned in the *Pensées* (1670) of the differences between the *esprit de géométrie* and the *esprit de finesse* and of the need to employ, in the analysis of each question, the appropriate cast of mind. In any case, in an age like ours, which gives such prominence to the emotional, individual, and interior aspects of religion, calling attention to its rational, collective, and cosmic aspects may help to achieve a reasonable balance between the emotional and rational sides of religiosity.

Here I will address three aspects of the relationship between mathematics and theology: the profound dependence of the universe on the value of the physical constants and on the mathematical structure of reality; some metaphors of the Trinity within the framework of nonlinear dynamics; and the undecidability of certain mathematical statements as an analogy for a possible undecidability of the existence of God.

2 The deep mathematical structure of the Universe and the Creator's mind

In theology, the universe depends on a reality that transcends it, surpasses it qualitatively, and is a necessary condition for its existence and order - a reality identified or posited as God. Is the idea that the universe depends on some reality that transcends it acceptable in physical cosmology?

An immaterial and timeless reality that would transcend the universe

could be mathematics. The mode of existence of mathematics is a topic debated in the philosophy of science. For some, following Pythagoras and Plato, mathematics has a timeless reality independent of us. For others, mathematics is a construction of the human mind. This discussion has certain analogies with debates about the existence of God: is there a timeless, immaterial God who transcends the universe and on whom the universe depends, or is the idea of God merely a human construction?

If mathematics served only to describe efficiently and compactly many aspects of the reality we observe, we could regard it as a human construction - an effort to systematize and compress the numerical properties of our observations. But, current cosmology indicates that life would not exist without a cosmic mathematical order prior to any star, to any galaxy, long before the beginning of life. In this respect, then, it seems plausible to think of a mathematical reality prior to humans, to life, and to the stars.

Indeed, physical cosmology relates the contents of the universe and the possibilities for the existence of life to the values of the universal physical constants-numerical constants that appear in the basic physical laws and whose values are not explained by any physical theory so far, such as the speed of light, Planck's constant of quantum physics, the mass and electric charge of the electron and the proton, the gravitational constant, and so on.

The explanation of this relationship between universal physical constants and the possibility of the existence of life - or, more concretely, of the existence of carbon and other elements necessary for life - is as follows. According to the Big Bang model, when the universe was three minutes old it consisted of hydrogen and helium. Yet the life we know is composed largely of molecules made of hydrogen, carbon, oxygen, nitrogen, and phosphorus atoms, and the Earth is made mostly of silicon oxide and iron, in addition to the water of the oceans and seas and the oxygen and nitrogen of the atmosphere. How were these atoms produced?

Nuclei heavier than helium were formed by successive nuclear fusions in massive stars, which are structured in concentric layers that, the deeper they are, the higher their temperature and pressure, and are composed of heavier atomic nuclei synthesized by nuclear fusion of the lighter nuclei in the adjacent layers: hydrogen, helium, carbon, oxygen, and so on, up to silicon and iron. The fusion of silicon yielding iron is very rapid and produces the explosion of the star as a supernova, dispersing into its surroundings the nuclei it contained.

The formation then begins of a second generation of stars and planetary systems, with more diverse atoms, which in some solid planets may include matter capable of a prebiotic molecular evolution that will, in some cases,

lead to life. Life, therefore, has a cosmic dimension already at its material foundation.

But the situation is subtler still. The rates of the various nuclear reactions depend strongly on pressure, temperature, and the values of the fundamental physical constants. When the synthesis of heavy nuclei is studied mathematically, one concludes that the abundance of carbon depends crucially on a fine-tuning among the values of the fundamental physical constants, such that if any of them were to vary by more than four percent from its value, the universe would contain no carbon and could not harbor life.

Why do the physical constants of our universe have the values needed to support life? May we regard this (in principle, highly improbable) coincidence as a sign that our universe was created so that it could contain life? Will we one day know a more general and deeper physical theory that explains the values of these constants? Is there a great multitude of universes, each with its own values for its physical constants, and are we in a universe whose values permit the existence of life - because otherwise we could never have come to exist?

In fact, reflecting on the necessity of things can be very radical and unsettling. "Is God necessary?" some ask. "Am I necessary? Are human beings necessary? Is the Earth necessary? Are galaxies necessary? Is the Universe necessary?" we might also ask. And we would see, within the framework of physics and biology, that none of this is necessary. . . In a certain sense, realizing that your existence is not necessary at all can be interpreted existentially as liberating, anxiety-inducing, or cynical, depending on the sensibility of the person who becomes aware of their condition of absolute contingency.

For the universe to be able to contain life, the values of its physical constants must be finely tuned to one another. We shall go further than this observation, to point out just how much the way the universe is depends on subtle details of a fundamental mathematical order.

Indeed, the compatibility of quantum physics with special relativity requires the existence of matter and antimatter in equal quantities. But if that were so, matter and antimatter would have turned into electromagnetic radiation in the first millionths of a second of the universe, and the universe would contain only light. The matter we observe, which forms about one hundred billion galaxies, is the survivor of a cosmic cataclysm in which every one hundred million antiparticles came into contact with one hundred million plus one particles. In this process, one hundred million antiparticles and one hundred million particles disappeared, and a single particle and two hundred million photons were left over.

Although we now observe only matter and antimatter is produced only in

certain high-energy reactions, matter and antimatter were present in almost the same amounts when the universe was millionths of a second old. The small asymmetry mentioned between matter and antimatter - on the order of one in one hundred million - would arise from a spontaneous breaking of the symmetry between matter and antimatter. The known processes capable of breaking this symmetry are not sufficient to explain the amount of matter we observe. The origin of the abundance of matter in the universe is one of the great open questions in physics.

To break the symmetry between matter and antimatter, there must be more than two generations of elementary particles - quarks and leptons. When we speak of generations of particles, we are not referring to generations in time but to differences in mass. The first generation (made up of the u and d quarks, the electron, and the electron neutrino) is the lightest and forms all the matter we know, since the u and d quarks make up protons (uud) and neutrons (udd), which constitute atomic nuclei. The other two generations of elementary particles (formed by the s and c quarks, the muon and the muon neutrino, and by the b and t quarks, the tau and the tau neutrino, respectively) are like the first generation but with heavier and very unstable particles that decay in millionths or ten-millionths of a second, respectively. Thus, it might seem that the first generation of elementary particles (stable and light) would be sufficient to give rise to all known matter, but this is not the case. Without the other two generations, the mathematical structure of the universe would not have been compatible with the breaking of symmetry between matter and antimatter, and these would have annihilated each other, leaving only light.

Perhaps God is not psychologically necessary for some, but the question of what is required for the existence of life, of planets, and of matter is far subtler and deeper than our psychology. Few people know that, for the matter that constitutes them - and the landscape around them - to exist, there must also exist two generations of highly unstable particles that disappeared from the universe in the first ten-millionths of a second of its history and that, at first glance, seem to play no role in the current universe. We depend not only on what is near and immediate, but also on what is subtle, invisible, unknown, and barely imaginable. We thus find that the universe depends on a mathematical structure that transcends it. In multiverse-type cosmologies, in which the same physical laws but with different values of their constants govern a multitude of universes, the general laws would transcend the particular universes. Mathematics, in this sense, is not a human invention but something much deeper and prior to us - something that transcends us, that goes beyond life and galaxies.

3 Chaos theory and mathematical metaphors of the Trinity

Mathematics puts us in contact with what we might call "eternal truths." In an age like ours, in which the very idea of truth - and even more, of objective and eternal truth - is viewed with such suspicion, or even scorned with such vehemence and contempt, this contact with a form of truth provided by mathematics is stimulating and suggestive. These are not truths that present themselves immediately and trivially, emotionally and capriciously; rather, they are attained through effort and work - though their pursuit is by no means devoid of relevant intuitive and emotional elements. Once proved, mathematical results are so forever and for everyone - even if the vast majority of people do not understand them, take no interest in them, and are not even aware of their existence.

The timeless character of these truths can give mathematics a certain detachment from our ever-changing world. But there are other aspects of mathematics that bring it closer to the dynamism of reality. One of these is computation, which - with computers and supercomputers - has reached such high degrees of power, providing accurate simulations of so many different kinds of systems, or creating virtual realities or large-scale uses of language in which we can immerse ourselves with a sense of admiration, surprise, and distrust. In this dynamic sense, we can imagine computation as a particular yet powerfully metaphorical gust of the Spirit acting in the world, stirring images of leaves and ears of grain, of waves or clouds, of volcanoes and earthquakes.

In this complementary contrast between eternal truths and immediate gusts, we may also ask what kinds of dynamisms God might have - a God who is at once timeless and dynamic in time. A God outside time, beyond time - what dynamism can such a God have? Love, compassion, wrath, justice, vengeance? Is it not a contradiction to speak of dynamism without time? Is it dynamism in potency?

In Christian theology, the idea of the Trinity presents a God who is at once static Being and dynamic Relation. Theologians reflect on what God's inner dynamism would be - if God is love, what kind of love is it? If God is cause, what kind of cause is it? - and on God's dynamism with respect to the world - creation, providence, miracles, salvation, judgment, incarnation, resurrection.

The dynamism of the Trinity has stirred theological and political passions. In 1054 the great schism occurred between the Catholic Church and

the Eastern Orthodox Church, which involved, among other far more earthly motives, the issue of the procession of the Holy Spirit - that is, whether the Holy Spirit proceeds from the Father and the Son (Catholic Church) or from the Father alone (Eastern Orthodox Church). Closer to us than these subtleties, one of the most lyrical and inspiring metaphors of the Trinity is the one that considers the lover, the beloved, and the love between them. This image suggests a placid, reciprocal, intense, circular dynamic. From a scientific perspective, however, there is a theorem of nonlinear dynamics that says, among other subtler points, that if a system has a periodic dynamism of period 3 - that is, the periodic repetition of three states A, B, and C - then that system contains all possible dynamics: periodic, nonperiodic, and chaotic. The idea is striking mathematically and also in its theological metaphor: the dynamism of the Trinity might not be merely a cyclic, reciprocal, periodic dynamism - an internal contemplation that is more or less regular and placid - but could contain all possible dynamisms, including chaotic, strange, and conflictual ones. The unfathomable character of God could thus also manifest itself in the divine dynamics, which would encompass all possibilities.

4 Mathematical undecidability of the existence of God

A powerful intellectual element of mathematics is the rigorous proof of its results. We might therefore feel tempted to ask to what extent we can scientifically prove the existence of God, starting from scientific observations and using the scientific method.

Science provides a provisional picture of the universe and of life - one that will be modified by future science - and therefore it is not advisable to base definitive conclusions on it or to ground a religious outlook in it, nor is it particularly useful for deriving ethical criteria. Moreover, the scientific method does not answer the question of the existence of God, nor how we ought to behave.

The question thus arises as to the extent to which the existence of God is demonstrable by pure reason, and what kinds of revelations and traditions shape the way we imagine God. This has been much discussed and debated throughout the history of theology, with many attempts at rational reflection on the existence of God - efforts that are respectable and ambitious attempts to clarify an important question about the essence of the world.

It may be that, from the standpoint of strict reason, the existence of

God is undecidable, but this does not mean that it cannot be an essential question, nor that it falls into the nebulous and turbulent realm of the irrational. Since Gödel's undecidability theorem, formulated in 1926, we know that in any sufficiently complex axiomatic system, questions eventually arise that are undecidable - that is, it cannot be concluded within that system of axioms whether they are true or false. This does not detract from the value of mathematics or reason, nor from the results and discoveries that the application of axioms may yield, but it does point to limits of reason and prevents us from confusing it with a totalizing Absolute.

What can we do when we reach such limits? Suppose an undecidable question has two possible answers: yes or no. We then have three possibilities: to step away from the question, or to adopt as a new axiom - additional to the previous ones - either the answer yes or the answer no, and begin to explore where the axiomatic system extended with yes or with no leads. In the long run, we may see which of the two options proves more fruitful in results or better suited to describing the world.

If the existence of God were an undecidable question from the standpoint of pure reason, it could combine creative Reason with human freedom. Creative Reason would not be deterministic and imperative, but would leave room for a free choice. Faith would thus be a foundational freedom, which, like any freedom, would have to be accompanied by responsibility, respect for others, inner consistency, and life commitment. What would incline us toward one choice or the other - believing or not in the existence of a certain form of God - would not be strictly rational; it would spring from a different source that would tilt us toward one of the two options, or toward abandoning the question. This would not imply a disdain for reason nor a praise of irrationality, but a work that is at once rational, emotional, and practical, seeking to see which option - does a personal God exist or not? - offers greater fullness and prospects for the existential questions of the individual and of society.

It is worth noting, since we are speaking of Gödel, that this author - around 1940, though publicized years later - offered a proof of the existence of God by means of mathematical logic. To do so, he defined God in a specific and complicated way that probably no religion would recognize as its own. Now, what "existence" means in the context of mathematical logic is a subtle question, and, moreover, proving the existence of a mathematical solution does not mean knowing what the solution is. From a proof of existence to actually finding the solution, centuries may pass and the efforts of generations may be required.

Gödel's undecidability sets a limit to mathematical reason, reminding us

that reason is not absolute. But there is another limit to reason related to physics. Physics constructs mathematical theories about the world. Some of these theories possess extraordinary internal consistency and elegance, but their predictions are not always compatible with experimental observations, in which case the theory must be modified. In other words, mathematical reason by itself does not describe the world - not because it cannot reach it, but because it can describe so many worlds alternative to our own that we must complement it with observation. Through the senses and the results of experiments, the physical world reveals itself to reason and constrains its many possibilities. As in the realm of religion, aspiring to a deep scientific knowledge of reality requires not only the use of reason but also experiments that must complement reason, bringing it into contact with observation.

The debate over whether God is demonstrable by reason takes on different nuances depending on whether we think in terms of a natural religion - which asks about very general properties of God - or concrete religions, which try to specify in greater detail God's manner of being and acting. In natural religion, the only accepted revelation is that of observation and experiment, which disclose the order of the world and guide an unbounded reason - which could imagine so many worlds. In concrete religions, other elements of revelation are accepted: inspired texts, crucial figures, exemplary witnesses. When it is sometimes said that it is not God who created man - understood inclusively of man and woman, of course - but man who created God, the reference is more to the revealed aspects of religions than to their rational elements. Rationally speaking, it seems clear that the universe existed long before human beings, that there were cosmic laws long before humans, and that life and human beings have been the result of these cosmic laws and not the other way around.

In the decision to accept or not the existence of God, both conditioning or accidental factors and underlying questions play a role. The conditioning or accidental factors may include the family and its opinions, the educational system, the way culture presents religion, the opinions and arguments of friends and close circles. These are circumstances given from without, but they influence us greatly. The underlying questions, more unfathomably personal, concern above all emotion, reason, and action - the personal experiences of joy, serenity, anguish, pain, and protest that we have felt. All these factors admit various nuances: emotion may be aesthetic experience, fear, or protest against injustice; reason may be philosophical or practical; action may be charitable, juridical, or cultural. A repertoire of reasons for believing in God has recently been published in this same series. Rather than irrefutable demonstrations, these are reasonable motives for opting to

believe in God, such as ontological, cosmological, probabilistic, and moral arguments, and life experiences.

5 Conclusions

Here we have outlined three aspects of a very rich field of reflection: the parallels and differences between mathematics and theology. Specifically, we have seen the fundamental role that mathematics plays in the constitution of the material world, such that it appears to be an entity that transcends the universe and upon which our universe depends. The ideas of the universe's contingency and of its dependence on an abstract, timeless, non-spatial framework that transcends it find a valuable illustration in today's physico-mathematical cosmology.

Secondly, we have raised the theme of a truth that is eternal and yet acts dynamically in the world; within the framework of mathematics, we have considered the timelessness of its results in contrast with the temporality - indeed, at times exasperated in its speed and power - of computation, and we have asked, by analogy, about possible divine dynamisms within the framework of the Christian Trinity.

Finally, we have highlighted Gödel's undecidability, in the sense that in any finite axiomatic system there are statements whose truth or falsity is unprovable. We have suggested that perhaps the question of God's existence has a cognitive status analogous to undecidability, without this diminishing either the logical quality or the vital interest of the question.

When reason confronts an undecidable question, it need not stop. If it has sufficient curiosity about the matter, it can broaden its frame and continue its exploration, adopting as a new axiom one of the possible answers to the undecidable question. It can also seek to argue why it takes that path and not the alternative one - indeed, in a "quantum" reason, it might attempt to take all paths at once. What then presents itself is a rational labor, aware that its basis is not secure, yet recognizing the need to keep reasoning - examining with a critical spirit, with reflective emotion, with restrained feeling - dialoguing with those who have chosen our same path and, as far as possible, with those who have chosen other paths.

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