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Editorial

Universe: An International Multidisciplinary Open Access Journal

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There is an unescapable connection between mathematics and the Universe [1–4]. It has been so since the dawn of the rationalist view of approaching to the natural world superseding the mythological eras when its various aspects were nothing but manifestations of this or that godhead. This thread never got broken up over the centuries, surviving to vast and profounds changes in the nature of mathematics itself and our concept of Universe, and in the relation of mathematics with the natural world as well. At the times of the Pythagoreans, the Universe was essentially a mathematical construct in the sense that the integer numbers were thought as building blocks of the natural world whose constituents could be put in numerical relationships in terms of ratios of integer numbers. The Pythagoreans were serious with mathematics; when they discovered that the square root of 2 could not be expressed as a rational number, they decided not to divulge such a terrifying discovery, and a strict secret was posed on it. Later, at the time of Ptolemy, the Universe was essentially limited to a part of our Solar System. In Ἡ Μεγάλη Σύνταξις ("The Great Composition"), known as *Almagest* [5] from the Arabic translation *al-Majisṭī* of the emphasized version Ἡ Μεγίστη ("The Greatest") of the original title, a mathematical picture of it was given in terms of epicycles, deferents and equants. It was a mere phenomenological description able to "save the appearances" as they were provided by the observations collected over the past centuries. It was not intended as an attempt to put forth a coherent model of some physical mechanisms underlying the phenomena observed in the skies; it was not a theory in the modern sense. Incidentally, it may be interesting to know that, according to R.R. Newton [6], Ptolemy would have systematically faked alleged celestial observations by computing them indoors.

Things changed with the revolutionary, brave and bold work by titans like Copernicus, Kepler, Galilei, Newton and Leibniz who, among other things, were convinced that mathematics does not just limit itself to offer mere interchangeable descriptions of observations, lying instead at the deepest level of the reality of the world. Indeed, in the *Giornata prima* of his *Dialogo* [7], Galilei let Salviati unambiguously proclaim: "…quanto alla verità di che ci danno cognizione le dimostrazioni matematiche, ella è l'istessa che conosce la sapienza divina…" ("As far as the truth provided to us by the mathematical demonstrations, it is the same held by the God's knowledge"). In the Preface to the first edition of his *Principia* [8], Newton writes: "Cum…Recentiores…Phænomena Naturæ ad leges Mathematicas revocare aggressi sint: Visum est in hoc Tractatu Mathesin excolere, quatenus ea ad Philosophiam spectat" ("Since…the moderns …have endeavoured to subject the phenomena of nature to the laws of mathematics, I have in this treatise cultivated mathematics so far as it regards philosophy"). Moreover, some of them invented entirely new mathematical concepts to capture the nonstatic aspects of the Universe. Mathematics became the major way to express physical mechanisms at work in shaping the world as it was getting revealed by observations and dedicated laboratory experiments. Superb mathematical theories were proposed not only to order in coherent frameworks the increasing wealth of data at disposal of the scientists but also to predict new phenomena and suggest new experiments and observational surveys to put such predictions on the test. Paradigmatic is the case of the discovery of the planet Neptune [10], never seen before or, at least, never recognized before as a planet [9], on the basis of purely mathematical reasonings pertaining the use of the Newtonian law of universal gravitation following a mathematical analysis of long observational records of the motion of Uranus [11].

A steady flow of discoveries in the micro and macro realms over the centuries revolutionized our picture of Universe, ranging from atoms and subnuclear particles to galaxies and beyond. Only new mathematical languages of increasing refinement have been able so far to fully account for such a fascinating trend throwing bridges between different areas and fostering the opening of new ones. Nowadays, mathematical tools of ever increasing sophistication [12] are required to have a coherent picture of the Universe, to make predictions of observable effects getting more and more subtle and to properly analyze and interpret data gathered with instrumentation of increasing accuracy [13]. The advent of the General Theory of Relativity by Einstein, for the first time after centuries of more or less sound speculations, sometimes farsighted and precursory, sometimes visionary, allowed to make Cosmology a testable science [14]. Extreme regimes, in which physical conditions far beyond the possibilities offered by our laboratories take place, point towards the need of profound and radical modifications of our current best physical theories describing either the extremely small and the extremely large domains. Suffice it to say that the General Theory of Relativity, if extrapolated back in time, encounters singularities [15] in which several key quantities of it become infinite: an unambiguous sign that, as physical theory, it is not anymore valid in those conditions. Indeed, the beautiful creature by Einstein is, in its essence, a classical field theory; the physical conditions at which it ceases to be valid require the use of a quantum mechanical description. Within the framework of quantum field theories [16–18], progresses have been so far towards a unified description of the other three fundamental interactions shaping the natural world, *i.e.*, electromagnetism and the weak and strong nuclear interactions [19]. Nonetheless, it has not been possible so far to straightforwardly extend the mathematical methods of the quantum field theory to general relativity; the quest for a coherent quantum theory of gravitation remains one of the grandest challenges we are faced with [20–23]. Such a re-foundation will necessarily have an impact on the required mathematics which, to a large extent, is not even yet available to us, contrary to the fortunate situation faced by Einstein when he conceived his theory of gravitation. Such deep changes will likely lead to modifications in our ways of philosophically interpreting either fundamental physical frameworks and the associated mathematical schemes themselves [24,25]. On the other hand, in the latest decades our picture of the Universe has been enriched with new actors on the cosmic scene: Dark Matter and Dark Energy [26]. To date, we have no direct knowledge of them, being their existence indirectly inferred from observations at different scales ranging from galaxies and clusters of galaxies to the entire fabric of spacetime. Perhaps, only a new, unified mathematical framework may properly account for their action. Some of the big questions that such developments should try to address are:

- What did induce the Big Bang? What did exist before the Big Bang, if any?
- Is there really a singularity to be associated with the Big Bang?
- Is Inflation just an ad-hoc phenomenological mechanism to put some patches on known problems of relativistic cosmogonies, or is it possible to find more fundamental and physically coherent explanations of it? If so, are they testable?
- Are multiverses mere speculative concepts, or have they connections with experimantally/observationally accessible phenomenology?
- What will be the final destiny of the Universe?
- What are Dark Matter and Dark Energy?
- Are they really new physical ingredients of the "stuff" of which the Universe is made, or are they somewhat mirages being, instead, manifestations of still undiscovered new physical laws modifying the currently known ones at certain scales?
- How many dimensions has the spacetime?
- How to combine Quantum Mechanics and the General Theory of Relativity in a quantum theory of gravitation?
- Is our place in space and time really insignificant?

The multidisciplinary *Universe* Journal is devoted to those fascinating intermixed areas, aiming to follow and, hopefully, to lead to the largest extent as possible the ever-self renovating threads which weave mathematical theories with our understanding of the magnificent natural world. On behalf of all the distinguished members of the editorial board, I extend my welcome to this new journal and look forward to hearing from the interested contributors and learning about their valuable research.

References

1. Wigner, E.P. The unreasonable effectiveness of mathematics in the natural sciences. *Commun. Pure Appl. Math.* **1960**, *13*, 1–14.
2. Hamming, R.W. The Unreasonable Effectiveness of Mathematics. *Am. Math. Mon.* **1980**, *87*, 81–90.
3. Barrow, J.D. *Perché il Mondo è Matematico? (1991 Sigma-Tau-Laterza Lectures)*; Laterza: Rome, Italy, 1992.
4. Tegmark, M. The Mathematical Universe. *Found. Phys.* **2008**, *38*, 101–150.
5. Cl. Ptolemei pheludiensis alexandrini astronomorum principis. In *Almagestum*; Petrus Lichtenstein: Venice, Italy, 1515. (In Italian)

6. Newton, R.R. *The Crime of Claudius Ptolemy*; Johns Hopkins University Press: Baltimore, MD, USA, 1977.
7. Galilei, G. *Dialogo di Galileo Galilei Matematico Straordinario dello Studio di Pisa e Filosofo e Matematico Primario del Serenissimo Gr. Duca di Toscana, dove ne i congressi di quattro giornate si discorre sopra i due Massimi Sistemi del Mondo, Tolemaico e Copernicano, proponendo indeterminatamente le ragioni filosofiche e naturali tanto per l'una, quanto per l'altra parte*; Gio. Batista Landini: Florence, Italy, 1632. (In Italian)
8. Newton, IS. *Philosophiæ Naturalis Principia Mathematica*; for the Royal Society by Joseph Streater: London, UK, 1687.
9. Standish, E.M.; Nobili, A.M. Galileo's observations of Neptune. *Balt. Astron.* **1997**, *6*, 97–104.
10. Galle, J.G. Account of the discovery of Le Verrier's planet Neptune, at Berlin. *Mon. Not. R. Astron. Soc.* **1846**, *7*, 153.
11. Le Verrier, U. Sur la planète qui produit les anomalies observées dans le mouvement d'Uranus & Détermination de sa masse, de son orbite et de sa position actuelle. *Comptes Rendus Hebdomadaires des Séances de l'academie des Sciences* **1846**, *9*, 428–438. (In French)
12. Islam, J.N. *An Introduction to Mathematical Cosmology*, 2nd ed.; Cambridge University Press: Cambridge, UK, 2001.
13. Martinez, V.J.; Saar, E.; Gonzales, E.M.; Pons-Borderia, M.J., Eds. *Data Analysis in Cosmology*; Springer: Berlin, Germany, 2009.
14. Einstein, A. Kosmologische Betrachtungen zur allgemeinen Relativitätstheorie. *Sitzungsberichte der Königlich Preußischen Akademie der Wissenschaften zu Berlin* **1917**, 142–152. (In German)
15. Hawking, S.W.; Penrose, R. The Singularities of Gravitational Collapse and Cosmology. *Proc. R. Soc. Lond. A* **1970**, *314*, 529–548.
16. Weinberg, S. *The Quantum Theory of Fields I–III*; Cambridge University Press: Cambridge, UK, 1995–2000.
17. Wilczek, F. Quantum field theory. *Rev. Mod. Phys.* **1999** *71*, S83–S95.
18. 't Hooft, G. The Conceptual Basis of Quantum Field Theory. In *Philosophy of Physics, Part A*; Butterfield, J., Earman, J., Eds.; Elsevier: North-Holland, The Netherlands, 2007; pp. 661–730.
19. Langacker, P. Grand unification. *Scholarpedia* **2012**, *7*, 11419.
20. Rovelli, C. *Quantum Gravity*; Cambridge University Press: Cambridge, UK, 2004.
21. Ashtekar, A. The winding road to quantum gravity. *Curr. Sci.* **2005**, *89*, 2064–2074.
22. Kiefer, C. Quantum Gravity: General Introduction and Recent Developments. *Ann. Phys.* **2005**, *15*, 129–148.
23. Weinstein, S.; Rickles, D. Quantum Gravity. In *The Stanford Encyclopedia of Philosophy*; Zalta, E.N., Ed.; Spring: Berlin, Germany, 2011. Available online: http://plato.stanford.edu/archives/spr2011/entries/quantum-gravity/ (accessed on 6 November 2014).
24. Callender, C.; Huggett, N., Eds. *Physics Meets Philosophy at the Planck Scale*; Cambridge University Press: Cambridge, UK, 2001.
25. Batterman, R., Ed. *The Oxford Handbook of Philosophy of Physics*; Oxford University Press: Oxford, UK, 2013.

26. Amendola, L.; Bertone, G.; Profumo, S.; Tait, T., Eds. Next Decade in Dark Matter and Dark Energy— Next Decade in Dark Matter and Dark Energy. *Phys. Dark Universe* **2012**, *1*, 1–218.