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COSMOLOGICAL THINKING: CULTURAL HERITAGE AND CHALLENGE

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ABSTRACT

The limitations of current technology do not allow one to foresee the expansion of the humankind beyond our planet for at least a few decades. Furthermore, the laws of physics, as for as they are known, preclude any form of traveling beyond the speed of light, as well as any viable and stable space-time shortcuts (wormholes, warp-drives, etc) that would facilitate cosmic traveling. Given the vastness of the Universe these are insurmountable obstacles for any in situ exploration of the cosmos beyond our most immediate cosmic neighbourhood. Nevertheless, the Universe is transparent and contains countless sources of visible light. Actually, in the last decades, technological developments have made possible to observe the cosmos throughout most of the electromagnetic spectrum as well as to perform dynamical studies that allow perceiving the presence of invisible components such as black holes, dark matter and dark energy. In this respect, humankind has then been given the opportunity to unravel the inner workings of the cosmos and through this process be part of the cosmic habitat. In this contribution various forms of cosmological thinking will be discussed, from some myths of creation till some of the latest scientific discoveries.

1. COSMOLOGICAL THINKING: FROM THE MYTHS OF CREATION TO THE BIG BANG

It is somewhat unusual that a theoretical physicist discusses issues that are related with history and the history of ideas given that these matters go beyond his field of expertise. However, this is somewhat inevitable when one's purpose is to discuss the underlying assumptions and the challenges that a physicist faces in analyzing the impact on human culture of most recent discoveries in cosmology, and physics in general. Furthermore, given the nature of such an interesting meeting and the fact that one of the main motivations of the International Year of Astronomy is to discuss the role that astronomy and cosmology has on our world, this author cannot refrain from leaving the ground of his expertise in order to discuss the role that the cosmological reasoning has played and will continue to play on the cultural development of humankind.

Most likely, astronomy is the most ancient of all sciences thanks to the fact that the Universe shines magnificently in the optical region of the electromagnetic spectrum and that our atmosphere is

transparent in this range wavelengths. This allowed our ancestors to observe the cosmos and wonder about its beauty and inner workings since early on. Indeed, the first astronomical instruments, stone circles and stone constructions, used to guide human activities with the apparent motion of the sun, date back to about 2000-2500 B.C.

It is useful, in order to put things under perspective, to point out that civilization has emerged after the Neolithic Revolution in the Near East, about 15 thousand years ago, and the ensued appearance of city states about 10 thousand years ago. Civilization, as we know it, involves the emergence of a form of kingdom and the development of a writing system. Evidence shows that the latter took place about 6 thousand years ago[52].

Speculative thinking about the nature, the dimension, the duration and of our standing in the cosmos was a central concern of the first civilizations in Mesopotamia, Egypt, India, China and Crete. Later, at about 400 - 350 B.C., Hellenic thinking, most particularly through the systematical approach of Aristotle (384 - 322 B.C.) to all matters of the physical and philosoph-ical world, put Earth at the center of the Universe. Consensus about this view was challenged by Aristarchus (310 - ca. 230 B.C.) of Samos, the Greek astronomer and mathematician, who suggested that the Sun should be at the center of the solar system 1800 years earlier than Copernicus (1473 - 1543).

But before diving into the modern view of the cosmos and its impact of human thinking, it is worth discussing the very origin of the cosmological thinking. Most of the ideas discussed in this section can be found in Ref.[53] and in the bibliography therein. To start with, one could not fail to note that any civilization, when reflecting upon its standing in the world traces back its historical roots, and in the process it speculates on its origin, creating for that a cosmogony. This historical reconstruction about the origin is usually encapsulated into a myth, a myth of creation. These myths treat the Universe as a living being and connect the creation process to the divine intervention, emphasizing in this way the supernatural and the extraordinary. Myths of creation range from the most original, when pristine, to somewhat rich in influences of the neighbouring civilizations, often more powerful and ancient. Anthropocentric reasoning is a fundamental principle in most of the myths of creation. Myths of creation of the world are conveyed in an epic and solemn language and most often start with the transformation of order out the chaos and the separation of the sky and the earth. In opposition, the creation of humankind features more mundane deeds and often involves some sort of copulation or masturbation.

Another common feature among the myths of creation is the concept of design with a purpose, which is encapsulated by the Word, the divine code or recipe for creation. This are encountered, for instance, in the Sumerian cosmogony, in the Genesis of the Hebrew Torah, in the geometrical universe of the Greeks, etc. These features can also be found in completely different cultural contexts, as exemplified by the myth of creation of the Guarani Indians, who lived throughout Brazil and South

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52 Michael Cook, "A Brief History of the Human Race" (Granta, London 2003).

53 Orfeu Bertolami, "O Livro das Escolhas Cósmicas" (Gradiva, Lisboa 2006).

America till recent centuries. The god Namandu, the true father, the one who knows the meaning of the creative Word:

"...In his divine knowledge of things,
knowledge that unfolds things,
he knows by himself
the source of what is supposed to be gathered; Earth is not yet,
the original night remains,
the knowledge of things is not known yet,
but he by himself
the source whose fate is to be gathered."

Actually, a myth must be regarded as the most basic form of savage (pristine) thinking, and despite the cultural differences, the common features of the myths, and of the myths of creation in particular, can be understood according to the anthropologist Claude Lévi-Strauss[54], by the fact that the myths have an essential kern of irreducible and unchanging elements, the mythemes. Mytheme are the fundamental units of myth. These minimal units are reassembled in various ways and linked in more complicated relationships, likewise a molecule in a compound. The relation between mytheme is that of binary (dialectic) opposition.

In order to close the discussion on the myths of creation, one brief describes a form of mythical thinking that is still active, and that connects a whole range of cultural and ritualistic activities, the Dreaming of the Australian Aborigines.

For the Australian Aborigines, the ancestral beings moved across the land creating life and the important geographical features of the landscape. This creative power is revealed through the Dreaming. Dreaming, sometimes also referred to as Dreamtime, as it is translated from the Arrernte language, also means «to see and to understand the big law».

Dreaming stories pass on the knowledge, the cultural values and the belief system of the Australian Indigenous people to later generations. It should be pointed out that Australian Aborigines have most likely the longest continuous cultural history of all humans groups. The history of this human group is estimated to date back between 50,000 and 65,000 years. Before the European settlement of Australia, there were around 600 different Aboriginal nations, based on language groups. Their rich cultural heritage connects the ancestral subjective experience with the objective world.

Dreaming stories manifest themselves through song, dance, painting[55] and story-telling and allow the Aborigines to maintain a bond with their cultural lineage from ancient times till present. Even though, most often Dreamings refers to somewhat mundane occur-rences and mani-

54 Claude Lévi-Strauss, "Anthropologie structurale" (Plon, Paris 1958).

55 Fred Meyers, "Painting Culture The Making of an Aborigenal High Art" (Duke University Press 2002). Roger Benjamin and Andrew C. Weislogel, "Icons in the desert" (Cornell University Press Ithaca, New York 2009).

festations of nature, seduction, wandering, flood, thundering and so on, it is rather remarkable that they might also involve a «cosmic» connection. A quite representa-tive example is the Milky Way Dreaming which materializes in a pictorial form through the strikingly beautiful Seven Sisters canvas of the Australian artist Grabiela Possum Nungarrayi (http://www.authaboriginalart.com.au/index.asp), a painting which gave origin to a series of painting representing the Pleaides constellation (Figure 1) from 1998 onwards.

The background story of this Dreamtime involves the chasing of a group of seven Napaltjarri spirit women by a Tjakamara spirit man who had noticed them occupied in ceremonial singing and dancing. In the words of Gabriella Possum Nungarrayi:

«The sisters could feel nothing else but their own music and dancing as if they were hypnotized. Like a corroboree. Then they saw a bright light in the distance and knew it was the man coming.» The Tjakamara man hid nearby and tried to use «love magic» to attract them. The magic did not work on the young women and none of them had any intention of spending time with the man. They ran away into the sky to cluster into seven stars known as the Pleiades in the constellation of Taurus. The Tjakamara man followed them and became the Morning Star in Orion's belt. As the constellations move across the night sky in front of the Milky Way the sisters can be seen flying ahead of the Tjakamara man who can never catch up with them. The sisters come back to earth through Dreaming ceremonies performed by Aboriginal women and then return to their eternal freedom in the sky where they keep watch over their earthly sisters.

The artist also states: «People think we don't have writing. Our writing is on the ground and all around us. The old people can see the signs when the sisters have been back.» This is all quite remarkable as it shows that the Australian Aborigines still keep a close bond with their ancestral culture and hence with their land and with the cosmos itself.

Carrying our discussion further on, it should be remembered that the emergence of the socalled rational religions, circa 3000 B.C., associated the creation to the divine and actually the regularity of the natural phenomena got attributed to the judgment, mood, choices and wishes of the gods. Hesiod (VII-VI B.C.), the Greek poet, was the first to rationalize myth and nature through the process of semantic duplication: the name of the gods were used to denote the natural phenomena they were the incarnation of. According to Hesiod, the origin of the world corresponded to the birth of the gods.

Figure 1: «Milk Way Dreaming» by Grabiela Possum Nungarrayi

In ancient times, physics was considered in the context of philosophy, it was the natural philosophy. The cosmos encompassed the world, the city-states and their citizens. In its development, physics broke free from philosophy and that brought the origin of the world to the realm of natural phenomena, which can be studied and subjected to the same rationalization and methods used to analyse nature.

Although cosmic thinking was an important part of rationalization of the world and of thesky mechanics in the Hellenic period, it was only after the Copernican revolution, and more particularly with the scientific revolution in the XVII century, that cosmological speculation could be completely freed from the theological and philosophical burden it was subjected so far. Galileo observations, Newton's mechanics and gravitation are universal and describe to the whole cosmos. Its universal prevalence allows one to speculate about the «theory of the sky» as developed by Kant («Algemeine Naturgeschichte und Theorie des Himmels», 1755) and Laplace («Sistème du monde», 1810). This scientific revolution initiated of a cultural tradition one still lives on. For Kant, Laplace and followers, Newton's mechanics could explain the origin of the solar system and of all planetary systems. The laws of the «universal clock» would keep, through the conservation of energy, linear and angular momenta, the Universe working without the need of any supernatural intervention. This conceptual expansion was closely followed by an expansion of the astronomical observation. Indeed, the observations by Herschel in late the XVIII century and the early XIX century, suggested that «nebulae» were quite generic and widespread, and that the Milk Way was a complex and quite rich system of stars, gas and dusk (and dark matter as it is currently known), but, in any case, a single element in a vast Universe composed by a great number of similar systems. That these systems, galaxies, are independent from each other was shown by Hubble in 1923.

Thus, scientific developments shifted definitely the discussion about the origin of the world towards science. he following step was given by Einstein when he proposed in 1917 the first cosmological model based on general relativity, a model where the universe was a static and eternal. Thus, theoretical cosmology has emerged from the understanding that the general theory of relativity was the suitable framework to address the cosmological problem, given the that this theory concerns the global nature of the four dimensional space-time (see Ref.[56] for a discussion of this historical development). In the context of the general theory of relativity, space-time acquires a plasticity that is shaped by matter configurations and can therefore behave in quite unusual and unfamiliar ways (see e.g. Refs.[57] for discussions on the space-times that arise from attempts of unifying the fundamental interactions of nature and on the issue of causality). Indeed, developments in string theory, the most studied unification scheme, suggests that our Universe is actually a single element in vast multitude of about 10^{500} universes, a multiverse[58], a context where even the interaction between universes can be considered[59].

A vast body of evidence, arising astronomy, physics, chemistry, geology, paleontology, biology, genetics, archeology, history, etc, support the current picture of Universe's history and evolution. This

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56 O. Bertolami, "The Mystical formula and the mystery of Khronos". Contribution to "Minkowski Spacetime: A Hundred Years Later", Springer series on Fundamental Theories of Physics, Ed. V. Petkov (http://arxiv.org/abs/0801.3994).

57 O. Bertolami, " The Adventures of Spacetime". Contribution to "Relativity and the Dimensionality of the World", Springer series on Fundamental Theories of Physics, Ed. V. Petkov (http://arxiv.org/abs/gr-qc/0607006).

58 R. Bousso and J. Polchinski, "Quantization of four form fluxes and dynamical neutralization of the cosmological constant", JHEP 0006 (2000) 006. L. Susskind, "The cosmic landscape: String theory and the illusion of intelligent design" (Little, Brown, New York 2005).

59 O. Bertolami, "A Curvature Principle for the interaction between universes", Gen. Rel. Grav. 40 (2008) 1891.

cosmo-vision, still under construction, is the result of the laborious work of several generations of intellectuals and researchers, and is one of the finest constructions of the human spirit. This picture allows for the understanding of the articulation of «origins», from the origin of the Universe to the emergence of life on Earth and its subsequent evolution till the first human social organizations.

From studies of the Microwave Background Radiation, the surface of last scattering corre-sponding to the transition to transparency, about 370 thousands years after the Big Bang, one can estimate the age of the Universe as about 13.7 thousand million years (Gys). The first galaxies and stars are estimated to have formed about 10 Gys ago. Radiative dating allows estimating the age of Earth to about 4.5 Gys. Evidence arising from dating of stromatolitesfossils suggests that life on Earth appeared 3.6 Gys ago. The first macroscopic fossils seem to have first appeared 700 million years ago. The tectonic processes which gave origin the Atlantic ocean took place about 100 million years ago and our primate ancestors walked on their inferior members about 3 million years ago. The first human population's organizations appeared 40 thousand years ago and the impressive first human artistic manifestations, the cave and rock paintings found Europe and Australia, date back to about 40 to 50 thousand years.

But back to the origin of all origins, the Hot Big Bang emerges as the most successful model to harmonize the vast set of observations stating that the origin of the observable Universe took place about 13.7 thousand million years ago from a extremely hot initial state. From the epistemological point of view, one could argue that the strength of the model lies on the fact that it can be falsified in a great number of ways. Some sceptics might argue however, that the model is too flexible model as it naturally allows for fairly easy extensions, such as inflation, dark energy and dark matter, that are crucial to render the model consistent with the observations. If from one hand, one can feel uneasy with the diversity of ways the above mentioned fixes can be implemented, the fact is, on the other, that these fixes are suggested by a quite abundant and diverse set of observations.

For sure, it would be quite useful if there were available contending models to the Hot Big Bang, However in the XX century, only the Steady State model played this role, and only for a fairly brief eriod. Thus, one can regard the Hot Big Bang model together with inflation, dark matter and dark energy are the paradigm and the methodological touching stone of contemporary cosmology. Epistemologically, the main virtue of a paradigm is that it can be falsified. For instance, the inflationary paradigm (see e.g. Ref.[60] for an extensive review), has been recently challenged by the so-called ekipyrotic collisional branes proposal; however, given the complexities of the involved string theory (see e.g.[61]), few believe that the emerging picture is mature enough for a fair comparison. But the point here is that this alternative scenario has, in what concerns, for instance, gravitational waves, a distinct signature (actually, a much more modest contribution) than the one predicted by inflation. This might allow for a falsification criterion.

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60 K. Olive, "Inflation", Phys. Rep. 190 (1990) 307.

61 J. Khoury, B. Ovrut, N. Seiberg, P. J. Steinhardt and N. Turok, "From big crunch to big bang", Phys. Rev. D 65 (2002) 086007.

In the context of the Big Bang, all known areas of physics (high-energy physics, nuclear physics, statistical mechanics, etc) are required in the process of deciphering the features of Universe's evolution. This reconstruction includes fairly complex and highly non-linear phenomena such as structure formation. Indeed, the Cold Dark Matter «paradigm», the model based on the structure formation being triggered by non-relativistic particles after the decoupling with the primordial plasma, allows, through N-body simulations, to match the observed matter distribution on large scale and even to predict the size of the smallest structural seeds, actually Earth-mass structures[62]. More recently, simulations even allow for some understanding on the formation process of the very first stars[63].

Furthermore, the Hot Big Bang model matches fairly well the observed abundance of light elements, He^4, He^3, D and Li^7, that according to the model were synthesized a few minutes after the Big Bang, when temperature was about a few MeV, that is 10^{11} K. All the remaining elements had to be synthesized in the interiors of the stars, and the observation of early stars with rather few elements is yet another consistency check of the model.

Of course, one could conceive that different cosmological setups might arise if instead of general relativity one would start from some alternative theory of gravity. However, the funda-mental underlying principle of general relativity, namely the connection between curvature and matter--energy as established by Einstein's field equations, is consistent with all experimental evidence to considerable accuracy (see e.g. Refs.[64] for reviews). Despite that, there are a good number of reasons, theoretical and experimental, to question if general theory of relativity is the ultimate description of gravity (see e.g.[65] and references therein). These concerns are related with fundamental issues, such as the singularity problem, the cosmological constant problem (see e.g.[66] and references therein) and the underlying mechanism of inflation, difficulties that cannot be satisfactorily addressed in the context of general relativity. Therefore, it is not impossible that the Big Bang scenario may turn out to be inaccurate and/or fundamentally incomplete. Even though, evidence strongly suggests that this is not the case at all.

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62 J. Diemand, B. Moore and J. Stadel, "Earth-mass dark-matter haloes as the first structures in the early Universe", Nature 433 (2005) 389.

63 N. Yoshida, K. Omukai, and L. Hernquist, "Protostar Formation in the Early Universe", Science 321, no. 5889 (2008) 669.

64 C.M. Will, "Was Einstein Right? Testing Relativity at the Centenary", in "100 Years of Relativity: Spacetime Structure - Einstein and Beyond", ed. Abhay Ashtekar (World Scientific, Singapore) (http://arxiv.org/abs/gr-qc/0504086). O. Bertolami, J. Páramos and S.G. Turyshev,"General Theory of Relativity: Will it survive the next decade?", in 359th WE-Heraeus Seminar: "Lasers, Clock, and Drag-Free: Technologies for Future Exploration in Space and Gravity Tests" (http://arxiv.org/abs/gr-qc/0602016).

65 O. Bertolami, "Dark Energy, Dark Matter and Gravity", Int. J. Mod. Phys. D 16 (2008) 2003.

66 O. Bertolami, "The Cosmological constant problem: A User's guide", to appear in Int. J. Mod. Phys. D (http://arXiv.org/abs/0905.3110).

2. **POST-MODERN THINKING: THE COSMOLOGICAL DIMENSION**

For sure, it is quite evident that technological developments have shaped and conditioned the evolution of humankind, most particularly from the XIX century onwards. Most likely this interaction will be even more intense in the future. However, it is not so clear how effectively the most fundamental scientific concepts, ideas and discoveries materialize themselves in day to day life. For instance, comparative genetic studies and the human genome mapping indicate that the genetic variations between the most anthropologically distant human groups is fairly modest. Despite that we live in a divided world and often in crisis due to cultural and civilizational differences. It is even less clear the impact that the cosmological discovery of the modest standing of humankind in the Universe, however special it might be, has on human culture. Another example has been pointed out by Bronowski[67] and concerns the tragic historical circumstance of physics in 1920s coming to terms with the fact that, on the most fundamental level, absolute knowledge is impossible, given the limitations of the uncertainty principle in quantum mechanics, in a time of emergence of absolute ideological certainties. Actually, a quite dark historical period when totalitarian ideologies seized power over a good part of the civilized world and staged the most barbaric war that ever took place in the history of the humankind. A war that was fundamentally different from the previous ones as it was primarily fought on the basis of scientific and technological knowledge and unquestionable ideological certainties that trivialized human condition. A path the humankind has to avoid to repeat at all cost.

Despite these considerations, it would not be too exaggerated to state that contemporary cosmology is an indissoluble part of the post-modern thinking. Indeed, science, and cosmology in particular, do permeate our culture, and one has already seen some of these manifestations in contemporary arts[68] science fiction, cinema[69], music[70] and so on. Literature and most particularly, contemporary literature, is not indifferent to the appeal of cosmology. One presents some representative examples.

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67 Jacob Bronowski, "A Escalada do Homem" (Universidade de Brasília 1979).

68 For concreteness, one could mention the Italian artist Laura Pesce (http://www.laurapesce.it/index.html), who has been using scientific ideas and concepts as inspiration for her work. Conversations with this author has led her also to consider the «invisible» Universe dominated by dark energy and dark matter, as the object of her artistic concerns. Figure 2 depicts her view of the unifying model of dark energy and dark matter, the generalized Chaplygin gas. A. Kamenshchik, U. Moschella, V. Pasquier, "An Alternative to quintessence", Phys. Lett. B 511 (2001) 265; N. Bilić, G.B. Tupper, R.D. Viollier, "Unification of dark matter and dark energy: The Inhomogeneous Chaplygin gas", Phys. Lett. B 535 (2002) 17; M. C. Bento, O. Bertolami and A. A Sen, "Generalized Chaplygin gas, accelerated expansion and dark energy matter unification", Phys. Rev. D 66 (2002) 043507; T. Barreiro, O. Bertolami and P. Torres, "WMAP5 constraints on the unified model of dark energy and dark matter.", Phys. Rev. D 78 (2008) 043530.

69 The scene of a boy in one of Woody Allen's films - most likely the director himself – who refuses to eat because the Universe is expanding is an example that strikes the memory of this author. [4]One could also recall that «Big Bang», «Neutrinos», «Gamma-Ray Bursts», «Spiders from Mars», «Dark Matter» and the like are the names of some rock bands; «Supermassive Black Holes», the motto of a rock song.

70 J. A. Caballero, S. Gonzalvéz Sanchéz and I. Caballero, "Music and Astronomy" (http://lanl.arxiv.org/abs/0810.2032).

In «Zuckerman unbound», the main character of Philip Roth's (1933 -) novel, in a moving and elaborate piece of literature, uses the latest ideas about the origin of the Universe to comfort his dying father. Roth's character assumes that conveying the grandeur of the beginning of the cosmos would be a more effective balm rather than exposing the complexity of his feelings and disgust about the limitations of human existence.

Figure 2: «Dark (Energy-Matter) intertwining» by Laura Pesce (2007)

In a contribution to the Cosmology Across Human Culture meeting, which took place in 8-12 September, 2008 in Granada, Spain, this author discussed on the influence that cosmological thinking has had on the writings of authors like Italo Calvino, Ernesto Sábato, José Saramago and Fernando Pessoa[71].

Actually, for many authors, the Universe, with its laws and dynamics, is an active framework for the literary expression. Furthermore, the understanding of the machinery of the cosmos are seen by some authors as guidelines for an ethics[72].

Of course, the role of the allegorical in the literary exercise has always been present and the development of humankind has shifted the trend from the divine to the profane. Astronomy and cosmology has expanded considerably the boundaries of literature. The Moon was first visited by Cyrano de Bergerac (1619 - 1655), in his «The Other World: The Comical History of the States and Empires of the Moon», where injustice and the prominent anthropocentric view of man's place in creation at the time were subtly criticized. La Fontaine's (1621 - 1695) fables anthropomorphized animals, plants and objects to convey moral lessons. In «Gulliver's Travels» (1726) the fantastic adventures of the surgeon and captain Lemuel Gulliver and his contact with other «civilizations» in remote parts of the world, was the way found by Swift (1667 - 1745)) to examine human shortcomings and to criticize the society of his time. Inadequacy could not be more expressively depicted than through the «Verwandlung» of Gregor Sansa into an insect. Indeed, Kafka's (1883 -1924) metamorphosis of Gregor Sansa has inspired many authors who discovered that there should be no limit to their imagination and the door of opportunity was then wide open to works of art such as Philip Roth's «The Breast» (1972), the work of the widely acclaimed contemporary Japanese author Haruki Murakami (1949 -), etc. iterarysurrealism, whose roots can be possibly traced back to «Hieroglyphic tales» (1785) of Horace Walpole (1717 - 1797), has put all the emphasis on the subjective and on the unconscious world, but its scope has always been the analysis of the dee-

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71 Orfeu Bertolami, "Some New Reflections on Mr. Palomar", in Cosmology across cultures: Impact of the Study of the Universe in Human Thinking, Granada, Spain, 8-12 Sep 2008. Astronomical Society of the Pacific, Volume 409. Eds. José Alberto Rubiño-Mat´ın, Juan Antonio Belmonte, Francisco Prada and Antxon Alberdi (http://arxiv.org/abs/0811.3681).

72 Joel R. Primack and Nancy Ellen Abrams, "The View from the Center of the Universe Discovering our Extraordinary Place in the Cosmos" (Riverhead Books, New York 2006).

pest human in a Universe ruled by well defined and stable laws. Understanding the «origin and formation of reality», was the declared purpose of the novel «Kosmos» (1965) by Witold Gombrowicz (1904 -1969). A novel crowed with disconnect and unlikely events, even though all of them possible in the realm of the physical world. Most likely, this is the common pattern of all fantastic literature, which deliberately introduces supernatural elements in a world that evolves according to the physical and sociological laws. Most likely, this is the most effective way to explore and develop contradictory conceptual elements, the quintessential function of a genuine work of art.[73]

3. **A COSMIC RESPONSIBILITY**

In ancient cultures, historical development was seen as an extension on the human sphere of a cosmogony which took place in the natural world; given that the latter was due to a divine intervention, it leads to an umbilical relationship between religion and ethical values. Thus, cosmology and religion were once genetically connected. This is fairly clear in the context of the great religions, a connection that can be found in many cultures.

Therefore, an interesting question is whether one could envisage a «cosmic ethics» without relating it to a religious view of the world. That is, could one conceive taking cosmology as the cornerstone for an ethics based on values such as universal harmony and responsibility?. A strictly scientific answer can only be negative, given that scientific advances and discoveries were achieved independently from humanistic and anthropocentric concerns. The scientific facts that describe and allow for the understanding local dynamics is a limit of a general set of laws that govern the Universe, and hence, it is improper to ask for the ethical implications that research on the infinitely large and on the infinitely small might have. Furthermore, cosmology provides an eloquent perspective of the modest standing of humankind in the cosmos. Nevertheless, cosmology renders a view of how unique, and this is a somewhat anthropocentric interpretation, are the conditions required to shelter life, and particularly sentient and reflective life. Even if life is a wide spread phenomenon in the Universe, a firm believe of this author, humankind is most likely, quite unique within the family of self-conscious species that exist throughout the Universe. In either case, human species has the collective responsibility of keeping the balance of the world and to ensure its continuity.

Similar thoughts were raised by Hannah Arendt, back in 1963, when reflecting upon the ethical implications of the conquest of space[74]. How is humankind enlightened by the possi-bility of being able to go beyond its ancestral home was then the question. On a broader sense, cosmology has acquainted humankind with events at the very edge of the observable Universe. It has expanded our scale of space and time beyond anything that could be envisaged from the

73 One refrains from bringing examples from science fiction, as in this genre the connection with science is rooted from the very start.

74 Hannah Arendt, "La crise de la culture" (Gallimard, Paris 1972).

observation of the nearby world. But, the question is if cosmology on its own is able to provide the necessary driving force to be the basis for an ethical system of values. Values based on the likelihood that one might have at last, through the Hot Big Bang model or actually any other theory, a considerable grasp of the inner workings of Universe's dynamics. This author is sceptical whether this purpose can be achieved on purely scientific grounds and through a scrupulous, yet inevitably judicious, exhibition of the facts. Indeed, if there is any chance of reaching an universal ethical code, this has to be based on the history of humankind itself. It should be based on the lessons drawn from the heroic development of humankind against op-pression, irrational forces and dogma. A centenary, and still unfinished struggle, where reason and science, cosmology included, play a crucial role.

Even though the future might not be more than «a structure of hopes and expectations, whose residence is in the mind and has no reality»[75], one feels that future trends are taking shape and that these are continuously emerging from current tendencies, developments, crises and catastrophes. It is a believe shared by many, that what future might have on stock is closely related with the above mentioned struggle. One has reached a time when the inability of the institutions, national and international, to tackle the urgent needs and problems of humankind does give room to the development of forces that question the very foundations of what made possible the noblest achievements of the human civilization. Currently one witnesses a dangerous clash between obscurantism and humanist values. By these one means the set of values that allow for a rational and scientific view of reality in societies based on equality civil rights and democracy. For sure, values that act upon reality through imperfect constructions and foundations, but that are, nevertheless, the most effective way to ensure the well being of the human community. Values that allow for regarding societies with a critical eye and to fix their mistakes. Of course, it would be most absurd to deny that social injustice exist also in democratic societies. It would be intellectually dishonest not to see that science has greatly multiplied the power to alter the environment and that this power may turn out to be a major threat for humankind's future. Despite that, abandoning altogether humanistic values would bring even more serious risks. Without science and democracy, the world would be even more exposed to unhappiness and hopelessness. Unfortunately, the fate of these values, and in a way the very future of humankind, is not yet free from danger. At least three major causes for concern can be identified:

1. The inability to properly tackle social injustice and poverty, which besides the problems they pose, lead in some parts of the world to the fragmentation of the state and the breakdown of all cultural and civilizational values. This collapse pushes civilization back to the rule of the arbitrariness and dogma. It is unquestionable that the continuation of these conditions is a threat to the stability of the whole world.

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75 John Coetzee, "Elizabeth Costello" (Secker & Warburg, London 1993).

2. The recent arousal of religious fundamentalism, a phenomenon that is now emerging through various guises in many parts of the world, including in the most developed countries, does represent a serious challenge to the humanist set of values discussed above. One does not need to go as far as to state that faith is the enemy of humanism, even though it can be argued that it menaces science (see e.g.[76]). But it is undeniable that any form of religious or political fundamentalism is incompatible with the intellectual tolerance that is essential for the development of culture, science, human equality and solidarity.

3. One has been witnessing, most particularly in the most developed parts of the world, a sharp and worrisome fall of the cultural and educational standards. This decline breeds a culture of intolerance, of misunderstanding and mistrust of cultural and intellectual achievements. It nurtures a culture based on blind and selfish materialism and consumerism. Needless to say that this social trend puts at risk social stability and imperils the balance of the environment and ecosystems.

It would be a mistake to assume that the above discussed humanistic values are a one way road towards a globalized and culturally homogeneous world. If so, that would impoverish human existence and make the world intellectually uninteresting and eventually sterile.

Humanism is the result of a historical evolution which involved the whole humankind. It is perfectly consistent with a multi-cultural and multi-centered world. The diversity of the human experience is at the very foundation of a system of values that puts the integrity of the human life, and actually of all life on our planet, above everything else. As emphatically expressed by George Steiner in «After Babel»[77], the true tragedy of Babel is not the scattering of languages, but the reduction of human speech to a handful of planetary, «multinational» tongues. A reduction impelled by market forces and information technology, and that dangerously threaten the survival of some languages and of the human culture on a broad sense.

«When a language dies, it is not only the vital lineage of remembrance - past tenses or their equivalence - it is not only a landscape, realistic or mythical, calendar, which are blotted out: it is configuration of a conceivable future»[78]. Humanism can only thrive and fully blossom in a multi-cultural world.

In what concerns this point, it is relevant to remember that a multi-cultural society existed till the XIII century in Europe. It was centered in Cordoba and was the result of the historical development of 700 years of Muslim ruling of the Iberian Peninsula. In Cordoba, individuals of different faiths excelled in science, philosophy, theology, agriculture, art, and architecture. Their lasting contributions created an advanced and thriving center of innovation for both material culture and sciences. In Cordoba, leading intellectuals and scholars worked in medicine, urbanism, astronomy and philosophy. They translated and scholarly commented on the mathematical and

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76 Richard MacKenzie, "Is Faith the Enemy of Science?" (http://lanl.arxiv.org/abs/0807.3670v1).

77 George Steiner, "After Babel: Aspects of Language and Translation" (Oxford University Press, Oxford 1975).

78 George Steiner, "The Tongues of Eros" in "My Unwritten Books" (Weidenfeld & Nicolson, London 2008).

philosophical achievements of the Hellenic culture. It is through these texts and studies, most often in Arabic and sometimes also in Hebrew, that the richness of the pre-Socratic thinking, and the work of Plato and Aristotle have survived and reached modern times. In Cordoba, Muslims, Catholics and Jews lived side by side and built a quite sophisticate society which gave rise to important contributions that shaped the prevailing philosophical and theological thinking for several centuries. Two names stand out, given the depth and the prevalence of their contributions: Averroes and Maimonides.

From a family of Muslim Andalusian scholars, Ibn Rushd, Averroes as he is known in the Western world, was born in Cordoba in 1126 and died in Marrakech in 1198. His extensive comments on Aristotle's work (but the «Politics») and on Plato's «Republic» are a fundamental starting point for the understanding of those Greek authors. In his «Incoherence of the Incoherence», his most original philosophical contribution, Averroes argued, in opposition to previous Muslim scholars, that Aristotle was not self-contradictory and that his ideas were not against the teachings of Islam. He also believed that there was no conflict between philosophy and religion, which he regarded as complementary paths to reach the truth. Averroes contributions to Astronomy were also relevant. He rejected the eccentric deferents introduced by Ptolemy and defended a concentric planetary system and Universe. He has also made the first descriptions of sunspots and of the reflection of sun's light on the surface of the moon. For Averroes, the Universe was eternal.

In medicine, Averroes discussed dissection and autopsy, although he has never performed any of them himself. He supported that their practice as a way to «strengthen the faith» as it allowed to observe «the remarkable handicraft of God in his creation». He also diagnosed the Parkinson's condition and suggested that the photo-reception was the main feature of the retina, which according to him was the central organ of sight.

Moshe ben Maimon, but better known as Maimonides, was also born in Cordoba, in 1135. He was a rabbi, physician and philosopher who also lived briefly in the holy land, in Morocco and passed away in Fostat, Egypt in 1204. He is associated with the end of the golden age of Jewish orthodox culture and his rationalism and strong opposition to mysticism exerted substantial influence in non-Jewish scholastic philosophers like Albert the Great, Thomas Aquinas and Duns Scotus. In Egypt, he was the physician of Grand Vizier Alfadbil and Sultan Saladin. He also treated Richard Lionheart while on the Crusades. Maimonides wrote extensively on Jewish scholarship, rabbinic law, philosophy and several medical texts (Treatise on Poisons and their Antidotes, Treatise on Regimen and Health, Treatise on Causes and Symptoms, Treatise on Cohabitation, Laws of Human Temperament and Treatise on Asthma), most of them in Arabic. His most well known work in Hebrew, the Mishnet Torah (Second Torah) comprises a code of Jewish law and the fundamental 13 principles of faith (Existence of God, Unity of God, God's eternity, spirituality and non-corporeal nature, etc), and constitutes the foundations of orthodox Judaism. In his extraordinary «Guide for the Perplexed», Maimonides confronts the spatial infinity and the eternal cosmos of Aristotle with the Torah's cosmogony which presumes a genesis for the start of the world, a contradiction which was never properly acknowledged by Christian scholastics.

Just 160 km from Cordoba, stands another multi-cultural town, Granada. Originally, Jews and Muslims emigrated to Granada, from the nearby town of Elvira, by the VIII century. At the time,

most of the Iberian Jews inhabited the area where Muslims immigrants began developing the city at the base of the Sierra Nevada Mountains. In mid XIII century king Fernando III conquered many cities, including Muslim-ruled Seville and Cordoba. To prevent the Christian king imminent invasion, Granada ruler Muhammad Ibn Ahmar made a treaty which consisted in the payment of an annual tribute and in providing assistance to Fernando III military campaigns. Ibn Ahmar and his descendants ruled the kingdom of Granada for more than two centuries. Throughout their reign, Muslim and Jewish refugees arising from cities conquered by Christians flocked the Granada. The city was the last Muslim kingdom on the peninsula and eventually, on January 2nd, 1492, Isabella and Ferdinand, the Catholic Kings, forced its last Muslim ruler, Boabdil, to surrender.

Alhambra stands as a magnificent remainder of the most glorious days of Muslim Europe and the adjoint palace of Carlos V is an example on how different cultures can live side by side despite their differences. Alhambra is among the most remarkable monuments of the Muslin architecture in the Western world and the multi-cultural and historical conditions which gave rise this most magnificent construction can be regarded as a particularly appealing model for the future of humankind.

4. **OUR COSMIC FUTURE**

"Voyages dans les futur» by the astrophysicist Nikos Prantzos[79] is a quite stimulating read-ing about scenarios, based on science and on science fiction literature, for the future of our civilization. From plans to get back to Moon to the research on new propulsion methods to explore the solar system and beyond, the reader is wrapped by the irresistible call of exploration that impels our species towards space. If from one hand, cosmology provides the measure that allows one to understand the modesty of any such undertaking, on the other, it urges one to deepen the quest for knowledge. An endless and humble quest, but by all means, an inevitable one.

Even though space exploration is nowadays an essentially scientific goal, in the future it might turn out to be ecological and economical imperatives. The growth of the human popula-tion and the finiteness of resources of our planet might require the search for new habitats and raw materials. However, in order to achieve that scientific and technological knowledge must be considerably advanced, most particularly in what concerns methods of propulsion in space. Special relativity does provide an objective way to gauge technological achievement through comparison with the speed of light, c = 300, 000 km/s, the ultimate speed limit. In what concerns elementary particles, high-energy physics colliders allow accelerating particles up to 99; 9999% of the speed of light; however, in what refers to macroscopic objects, and spacecraft in particular, science is still fairly rudimentary as the greatest velocity ever achieved is Earth's scape velocity, that is 11.2 km/s or 3.6×10^{-5}c. Indeed, space exploration necessarily involves the release of considerable amounts of energy kept in fairly compact devices. Using special relativity once again, the

79 Nikos Prantzos, "Our Cosmic Future: Humanity's Fate in the Universe" (Cambridge University Press, Cambridge 2000).

well known equation $E = mc^2$ provides the metric to measure the process of mass conversion into energy. The rocketry of our days, based on chemical propulsion, involves the release of chemical energy that corresponds to a conversion of 10^{-10} of the initial mass, yielding ejection velocities of propellants up to about 10 km/s. Nuclear energy methods are millions of times more efficient, and in fission reactions, a conversion factor of about 7×10^{-4} can be achieved. In the process of fusion of the hydrogen isotopes, a conversion factor of about 5×10^{-3} can be reached. At least theoretically, these conversion factors might allow reaching ejection velocities of about 0.01c to 0.1c.

It should be kept in mind that the propulsion process is based on Newton's third law, according to which action and reaction are equal and opposite to each other, so that linear momentum carried by the ejected propellant is transmitted to the rocket. The relationship between the final velocity of the rocket, v and the ejection velocity of the propellant, v_p is given by the Tsiolkovsky or rocket equation, $v = v_p \ln(M/m)$, where M is the initial mass of the rocket and m its mass when the velocity is v. Konstantin Eduardovitch Tsiolkovsky was the Russian visionary and mathematics teacher who in 1897 deduced this equation. In his 1903 book «Cosmic Space Exploration with Reaction Engines», he discussed for the first time propulsion based on a mixture of liquid hydrogen and oxygen, multistage rockets, space suits and attitude control through the use of gyroscopes among many other daring and revolutionary ideas. His statement: «Our planet is the cradle of intelligence, but one cannot live forever in a cradle» summarizes the believe, shared by many, that space exploration is an inevitable implication of the human development. Inspired by Tsiolkovsky, scientists, engineers, science fiction authors have come up with exciting ideas for new methods of propulsion which involve for instance, matter-antimatter annihilation, space sailing using solar radiation, navigation impulse produced by intense laser or microwave beams, spacecraft that gather interstellar hydrogen for its nuclear fusion engine, etc.

One the most imaginative ways ever conceived to reach space is the one that involves the control of gravity itself. Suggested by H.G. Wells in 1901 in his book «The First Men in The Moon», a rather unlikely crew eached its destination using a spacecraft made out of a material endowed with anti-gravity properties, the cavorite. Since then the possibility of switching off gravity has been discussed in the science fiction, Internet groups and more rarely in the scientific literature. Sparked by the interest of Boeing and of NASA, study programmes where setup to examine this and other innovative ideas for propulsion, NASA's Breakthrough Propulsion Project (1996 - 2002) and the British Greenglow Project (1997 - 2002) being the most well known.

The European Space Agency (ESA) has sponsored a study on the subject of gravity control which involved this author and Martin Tajmar, and its conclusions were, as expected, negative. Indeed, it has been throughly argued and discussed that gravity cannot be controlled, and even if this were feasible, only under quite particular conditions it would be more effective than conventional means of propulsion[80]. Even though these findings were obtained in the context of

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80 O. Bertolami and Martin Tajmar, "Gravity Control and Possible Influence on Space. M. Tajmar and O. Bertolami, "Hypothetical gravity control and possible influcence on space propulsion", J. Propulsion Power 21 (2005) 692 (http://arXiv.org/abs/physics/041217).

Newtonian mechanics, subsequent work has shown that conclusions would be essentially similar even after general relativistic considerations[81]. Furthermore, in the ESA's study other means of cosmic traveling such as wormholes, warp-drives, etc were also critically assessed and general arguments based on the positiveness of the energy were used to argue that these space-time shortcuts are most likely unstable and physically unfeasible.

Of course, besides the limitation of the laws of physics, one has also to consider the vastness of the cosmos, which prevents any foreseeable exploration undertaking much beyond our most immediate stellar neighbourhood. However, this might not be the final word on the human exploration of the cosmos as one could instead envisage a robotic exploration based a self-replicating robot spacecraft, a «von Neumann probe»[82]. These probes would consist of a propulsion system and a universal von Neumann intelligent replicator, to be launched toward a neighbouring stellar system. Upon arrival it would seek out raw materials, from local sources and use them to make several copies of its hardware. The copies would then be launched to the following set of neighbouring stars. The replication of the process and the continuous increase of probes would allow exploring ever more remote regions of the Galaxy. Actually, it has been argued by Tipler[83] that the von Neumann probe approach is so logical and economical that it would be adopted by any advanced civilization. He estimated that if probes could reach velocities of up to about 0.1 c, a complete galactic colonization could be achieved in about 200 million years, less than 5% of the age of the Galaxy. From the fact that no such devices have been detected, he draws the conclusion that that humans are the only intelligent species among the Galaxy's several hundred billion stars. The validity of the argument has however, been questioned by Sagan and Newman[84], on the basis that if the growth of the number of probes were exponential, a single self-replicating probe could be expected to convert the entire mass of the Galaxy into copies of itself within 2 million years! Therefore, concluded Sagan and Newman, any species intelligent enough to build such probes would realize the danger of such an «infectious» project. Of course, these arguments refer to civilizations that are much more advanced technologically, and may not concern humankind, at least in the foreseeable future. However, through for instance the exploration of Mars, despite the model scale of this achievement, one could draw conclusions about the advantages and the relative simplicity of employing robotic based strategies in the space exploration. It would not be an unthinkable stretching of imagination to conceive going beyond the solar system using a robotic based approach. The evelopment of self-replicating von Neumann machines would be then the next technological hurdle to master.

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81 O. Bertolami and F. Gil Pedro, "Gravity control propulsion: Towards a general relativistic approach", J. British Interplanet. Soc. 60 (2007) 285 (http://arXiv.org/abs/physics/0610116).

82 Chris Boyce, "Extraterrestrial Encounter: A Personal Perspective" (Chartwell Books, New York 1979).

83 F. Tipler, "Extraterrestrial Beings Do Not Exist", Quarterly Journal of the Royal Astronomical Society 21 (1981) 267.

84 C. Sagan, and W. Newman, "The Solipsist Approach to Extraterrestrial Intelligence", Quarterly Journal of the Royal Astronomical Society 24 (1983) 113.

At this point it is rather natural to speculate about the possibility of detecting evidence for life. For this author, arguments based on the absence of evidence are not quite satisfactory as they do not necessarily imply any evidence of absence. A somewhat more pleasing argument is the one that arises from the universality of the laws of physics, and hence of the laws of chemistry. From this universality once can conclude that from a set of favourable conditions, such as the ones found on Earth, the emergence of life must be a rather common occurrence given the vastness of the Universe. How common is still an open question. However, one might not have to wait too long to get a clearer idea of the answer once it is understood how general is the occurrence of planets around the stars, to what degree the so-called habitable zone can be extended to the satellites of large gaseous planets, what are the most reliable markers to detect the presence of life, etc. An exciting prospect, but till then, human civilization has to face the immediate challenge of coping with the menace it posed itself by the misuse of its own planet. Alas wisdom prevails.

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