Reflections of a Physicist on the Cultural Ocean of his Time

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Abstract

The purpose of knowledge is to understand our world in the context of an evolving body of ideas, actually in a physical Universe in continuous transformation. Thus, science, a privileged form of enquiry, should be a homogeneous and interconnected endeavour spanning from physics and chemistry to biochemistry and biology, from biology to human and social sciences. In this talk we shall approach, through an impressionistic personal view, the similarities and the differences of development of the various branches of science. We shall briefly discuss how this cross-sectional view might map the way on how to overcome the great challenges and crossroads of our time.

Resumo

O objectivo do conhecimento e compreender o mundo em que vivemos no contexto de um conjunto de ideias em constante evolução e, mais fundamentalmente, num Universo físico em contínua transformação. Assim, a ciência, enquanto forma privilegiada de investigação e interrogação, deve constituir-se como um campo homogéneo e interligado que vai da física e da química à bioquímica e a biologia, da biologia às ciências sociais e humanas. Através de uma visão impressionista e pessoal, esta comunicação visa abordar as semelhanças e as diferenças no desenvolvimento dos vários ramos do saber e articular consistentemente como esta visão transversal pode ajudar na busca das respostas aos grandes desafios do nosso tempo.

Words. Was it their colours? He allowed them to glow and fade, hue after hue: sunrise gold, the russet and green of apple orchards, azure of waves, the greyfringed fleece of clouds. No, it was not their colours: it was the poise and balance of the period itself. Did he then love the rhythmic rise and fall of words better than their associations of legend and colour? Or was it that, being as weak of sight as he was shy of mind, he drew less pleasure from the reflection of the glowing sensible world through the prism of a language manycoloured and richly storied than from the contemplation of an inner world of individual emotions mirrored perfectly in a lucid supple periodic prose?"

A Portrait of the Artist as a Young Man
James Joyce

Introduction

Let me start saying that I am most honoured by the invitation to deliver a talk at this conference to celebrate the centenary of the Faculdade de Letras da Universidade do Porto (FLUP) and to give a contribution to the proceedings of this most prestigious conference.

Furthermore, I am most grateful for the opportunity to share some of mine sketchy thoughts and concerns about the historical period we are living in. In fact, I think that it s natural to expect that a reflection by any physicist and, most particularly, by this one, on the culture of our time involves necessarily a cosmic, a historic and an epistemological perspective of our understanding of the Universe as well as about the science that allows us exploring the inner workings of Nature and unravelling its hidden laws. Of course, a reflection of this nature must take into account the assumptions concerning the methods and tools that provide us with an understanding of the world on scales completely different from the ones we are familiar with on our day-to-day life. Furthermore, this reflection relies on the assumption that these very methods endow us with means to speculate about the physics that describe scales much smaller from the ones scrutinised in the existing particle accelerators to the ones extending beyond the observable Universe; and we expect that these methods are equally useful to examine the fleetest phenomena as well as those that spam over unthinkable aeons of time.

For sure, a physicist is not inhume from the cultural trends of his/her époque, which might reflect upon his/her work through a subtle and complex chain of associations, choices and believes, and conversely, his/her physical understanding of Nature might reflect upon the way aesthetics, culture, history, etc, are perceived. In this text, I will be predominantly concerned with the latter issue. This is a particularly relevant point: physics is unquestionably associated with a high form of rationality and thus, it might be seen as somewhat detached from the "noise" of human culture, somewhat away from aesthetics movements, economical, political and social trends. However, we are all well aware that this is not an entirely accurate statement. Indeed, poignant lessons learnt from the XXth century have changed the perspective of the physicists, and scientists in general, concerning their responsibility with respect to the legacy and the implications of

their discoveries. Indeed, after Hiroshima, physicists are painfully conscious that their discoveries are not necessarily on the side of the human progress and for the benefit of humankind and as such, in many instances, physicists and scientists have been compelled to act so to counterbalance some of the most harmful implications of their work. This concern has manifest itself in various forms such as the Russell-Einstein manifesto [1], the ensued Pugwash movement [2], some well known reflections [3,4,5] and, more recently, by the warning of more than 11 thousand scientists concerned with the "untold suffering" that the unfolding climate crisis will cause on millions of people in the near future [6].

On a broader sense, after Auschwitz, the very thought of an absolute rationality, unchecked by ethical principles is, on various accounts, philosophically untenable and seen as completely unacceptable on political grounds.

Of course, to these fundamental issues, we could also add the more mundane ones concerning the inevitable questions about the fairness of the public funding for research (see e.g. Ref. [7]), the historical discussion concerning the priorities among the various areas of research, the dichotomy between the apparently antagonist applied and fundamental research, the pedagogical methods to convey and to teach scientific ideas and the scientific method of enquire, the importance of case studies [8], etc.

The Cosmic Perspective of a Reflection

Physicists believe that any phenomenon as well as all forms of life, sentient or not, take place at a stage that we refer to as space-time. In its simplest representations of reality, physicists assume that space-time is continuous, has no "holes" and has 1 temporal and 3 spatial dimensions (for a broad discussion about the space-time, see, for

instance, Refs. [9,10,11] and references therein). The region of observable space-time that we refer to, as our Universe is believed to have came into existence at about 13.8 thousand million years. This "birth" is usually referred to as "Big Bang", gave origin to space-time and all the matter, which evolved to the manifestations that we observe at present. The existence of this initial event is based on a solid body of evidence, theoretical and experimental/observational, whose implications have been scrutinised in detail throughout several decades. But all this knowledge, likewise all scientific knowledge, is just a working model, a hypothesis, which can crumble once any theoretical prediction cannot be matched to the experimental/observational data.

This model allows for highly non-trivial predictions and provides meaning to an enormous amount of evidence in astronomy, astrophysics and observational cosmology. Thus, the Big Bang model is a fully operational physical model that can be seen as a ``paradigm" whose corner stones are the General Theory of Relativity, Quantum Field Theory (the theory that merges Special Relativity and Quantum Mechanics), Nuclear Physics and Statistical Mechanics. In fact, predictions and computations within the Big Bang model use virtually all known areas of physics, from High-Energy Physics to Nuclear and Atomic Physics, from Statistical Mechanics to Plasma Physics. For an extensive discussion of the Big Bang model and its implications, see, for example, Ref. [12]. For a discussion about the similarities and the differences between cosmology and, for instance, archaeology see Ref. [13].

The Big Bang model allows for a detailed description of the Universe evolution, and this reconstruction includes complex and highly non-linear phenomena such as the formation of structures like galaxies, clusters of galaxies and superclusters of galaxies. Indeed, within the

so-called Cold Dark Matter[1] the structure formation scenario is triggered by unknown non-relativistic particles, “cold dark", that do not manifest themselves in any wavelength of the electromagnetic spectrum. Later, structures are “carved” by the attractive and universal gravitational interaction. The result of these complex processes of assembly is the galactic structures and their networks that we observe at practically throughout the whole electromagnetic spectrum.

Furthermore, the Big Bang model, matches impressively well the observed abundance of light elements, He^4, He^3, deuterium and Li^7, which, according to the model, were synthesized a few minutes after the Big Bang, when temperatures were about 10^{11} K. This is a well-defined prediction of the model that clearly allows for its falsification. This prediction implies 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 prediction that allows for a verification of the predictions of the Big Bang model.

From the Big Bang we can explain galaxy formation and, in particular, how a galaxy like ours was formed about 10 thousand million years. From the galactic gas and dust, our Sun was formed at about 4.6 thousand million years ago and, in this process, its planetary disk in which the Earth appeared due to the process of gravitational accretion of the surrounding matter. The presence of water, hydrogen, ammonia and methane in primordial Earth atmosphere might have triggered the synthesis of aminoacids, RNA and DNA molecules and eventually life. Indeed, the first evidence of life in our planet dates about 3.6 thousand million years.

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[1] It is believed that dark matter is responsible for the cohesion of galaxies and clusters of galaxies, for the observed bending of light by the so-called gravitational lenses, among other phenomena (see, e.g., Ref. [12] for an acessible discussion).

Once established, life developed itself rather slowly at the beginning, but with a considerable plasticity. Here, just a few cardinal facts can be mentioned (see, for instance, Ref. [14]): the Cambrian explosion of life, at about 520 million years, in which a robust and wide spread emergence of life forms could only be matched by its incredible diversity; the first mammals appeared at about 225 million years; the first primates appeared at about 70 million years; the Cretaceous-Palaeogene extinction took place at about 65 million years ago. We should keep in mind that the appearance and the extinction of species takes place in a planet in a continuous process of transformation due to the dynamics of the plate tectonics, which continuously shape continents, give origin to oceans, trigger the activity of volcanoes, etc. And of course, the continuous and rather steady transfer of energy from the radiation of the Sun has shaped our planet and all its sub-components (atmosphere, biosphere, cryosphere, hydrosphere and lithosphere).

The Historical (Prehistorical) Perspective of a Reflection

The starting point of any reflection about the Humankind involves: the evolution of the first primates; the appearance of the Homo Habilis in Africa at about 2.5×10^6 years ago; the emergence of the Homo Sapiens also in Africa at about 250×10^3 years ago; and the profound change that allowed our ancestors to address complex conceptual challenges, a process usually referred to as the Cognitive Revolution, which gave origin to the Homo Sapiens Sapiens at circa of 100×10^3 years ago. From there on, endowed with an inherited anatomic equipment that was very much like our own, our ancestors evolved from a gathering-hunting way of life to a sedentary form of life based on the agriculture, a change that took place at about 12×10^3 years, the so-called Neolithic Revolution. This change was not free of impact on the environment as it led to the first human made mass extinction of

species as considerable areas of land were shaped for agricultural purposes and for raising domesticated animals. The next important step was the transformation of settlements into villages and the ensued increase in social complexity, which unfolded the invention of the writing systems at about 5500 years ago.

From there on, it is almost impossible to single out a set of historical developments that were unanimously more relevant that any other, however, I just mention the three ones that are particularly relevant for our discussion, namely: the Scientific Revolution at the XVII century in Europe at about 400 years ago; the dropping of the Atomic Bomb in Hiroshima, 74 years ago; and the beginning of the Anthropocene [15], the new geological age in which the Humankind is the main driver of changes on the surface of the planet, which, according to experts, started at about 70 years ago [16].

It is interesting to point out that in 1960's, the soviet radio astronomer Nikolai Kardashev after having observed an extremely bright far away object, speculated that it might be the signature of an advanced civilization[2] and put forward what we call today the Kardashev classification. According to this classification, due to the Anthropocene, we are already a Type I Kardashev Civilization as our species is at the verge of dominating all the resources of the planet.

It is clear that the Anthropocene poses quite new challenges to Humankind such as the climatic emergency as well as the ones associated to emerging new technologies such as artificial intelligence, wide spread use of robotic work, quantum computers,

[2] In fact, the object observed by Kardashev was a new kind of galaxy with a quite active nuclei that today we refer to as a quasar. Ironically, Kardashev nmissed the opportunity to report a quite extraordinary discovery.

genomic edition, internet of things and so on. These might cause considerable damage to the social fabric of our societies already plagued with historic and socio-economic problems such as famine, poverty, unemployment, war, etc. These difficulties lead us to speculate that we might be facing an important crisis, in fact, an "Age of Uncertainty", which might be full blown in about a decade or so. For us, it is also clear that these serious challenges as well as the already visible and palpable effects of the climate change on the stable climate conditions of the last 11700 years (the Holocene period) call for global stewardship measures to maintain the Earth System (ES), the integrated biological, physical and geological system that encompasses atmosphere, biosphere, cryosphere, hydrosphere and upper lithosphere and their interactions and feedbacks, as close as possible to its Holocene conditions. It is a very probable that without these measures we shall be facing, in a time scale of a few decades, the ES in a new state, with a higher average temperature, that might trigger the collapse of Earth's main stabilizing ecosystems [17,18] and, eventually, to the very breakdown of the civilization as we know it (see also Refs. [19,20,21] for a discussion and a proposal of a physical model to understand this transition from the Holocene to the "Hothouse Earth" state).

Shifting our discussion towards a cosmic perspective, it is reasonable to expect that in the next decades, it will be able to establish colonies on the Moon and, with the acquired knowledge, it might be possible to have subsequently human outposts in Mars and elsewhere in the nearby outer Space. However, it is important to understand that these colonies will be essentially designed for scientific purposes and cannot be thought as an alternative habit for any significant number of humans in the foreseeable future. In this respect, even if we assume that humankind will manage to overcome the challenges and hurdles ahead, it is impossible to predict if it will be ever able to reach the

level of a Type II Kardashev Civilization in its capability to dominate resources at the scale of our solar system or to go even further and reach the level of a Type III Kardashev Civilization achieving dominance at galactic level.

The Epistemological Perspective of a Reflection

Of course, a reflection about the culture of our time ensues an analysis about the conditions that allow for an articulate discourse about the elements for the understanding of reality as well and its historical evolution. In the opinion of this physicist, it would be completely misplaced to engage into a philosophical discussion about the assumptions of the scientific activity. In any case, without any considerations about the historical developments that led to the prevailing ideas concerning the philosophical assumptions of science, this physicist acknowledges his broad agreement of the idea, due to Karl Popper [22], that scientific theories are fundamentally conjectural and their main feature, as valid scientific assumptions, is their capability to provide theoretical and empirical statements that allow for their refutation. However, this physicist is also in agreement with the idea that the empirical and sometimes the theoretical refutation of a given theory is not immediate and may require a considerable spam of time and hence, for while, that theory may remain an useful working hypothesis. This means that, as discussed by Imre Lakatos [23], falsification might take the form an historical process or, in broad terms, a research programme that encompass the main thrust of the scientific enquiry around a given set of theories/hypotheses. This historical dimension of the scientific enquire and of its implied rationality criteria, puts it very much in line with all intellectual and human conceptualizations, which are inherently associated to specific historical contexts. Having settled the importance of the historical context of our discussion, let us gear it towards a broader perspective

of the creative process in the intellectual conceptualization of the world.

On quite general grounds, any “discourse” about the real or any imaginary world assumes a “field of meanings” whose elements manifest themselves through: equations, poems, symphonies, texts, theories, etc.

The elements of a discourse are composed by: particles, bodies, cells, words, musical notes, etc, and their evolution is set in motion due to the interactions among the elements of a given discourse.

In the realm of the most basic entities of reality, the elementary particles and the forces that affect them are the most basic interactions of Nature, namely: the nuclear strong interaction, the electromagnetic interaction, the nuclear weak interaction and the gravitational interaction. But, of course, within the broad sphere of human affairs, social pressures of various sorts are the ones that unleash social movements. In arts, aesthetic fashions determine how aesthetic movements arise, mature and, after a while, become anachronisms. In literature, to the above aesthetic dynamics one should also consider the historical usage and evolution of the grammar, semantics, etc. In music, the rules of fashion, harmony, taste, etc, are the ones that set what is considered the past and what is regarded as contemporary and so on.

Of course, the builders of the each field of meanings are composers, historians, poets, scientists, etc, who, most often, are the guardians of the tradition, however, once a given field of meanings becomes inadequate to face new findings, innovations and ideas, they are replaced by new concepts and meanings. In these instances, the agents act as active creators, focussing their energies towards the new set of precepts.

It is within a field of meanings that one builds the sense of an objective reality (OR) as well as of a subjective reality (SR). The OR is composed by particles, bodies, material structures in space and time, and, in very general terms, even space and time, in fact, space-time, become objective structures of the OR. Speeches, tales, institutions, and so on, are, on the other hand, the elements of a SR. Obviously, both realities are collective constructions, historically agreed and shaped by the interactions among agents of a given system of knowledge and society in general.

A quite interesting feature of the field of meanings in the context of a given form of discourse is what sets its limits. We choose to call these limits as "field of possibilities". For sure, in broad terms, what sets the field of possibilities is the boldness of the creativity and of the discoveries. It is within the field of possibilities that the most daring and interesting questions arise:

i. What is the physics within the event horizon of a black hole?

ii. How vast is the Universe beyond its event horizon?

iii. Is our Universe an element of a much vaster web of universes that make up a Multiverse? An issue that arises, for instance, in the context of the string theory landscape problem [24];

iv. In mathematics, issues of this type often arise. We can mention, for instance, the "Continuum Hypothesis" that appears in the context of Cantor's transfinite numbers theory, that is: is there an intermediate infinite between the infinite of the natural numbers and the denser infinite of the real numbers? A problem which, rather puzzling, seemed to admit both answers, a possibility that till Kurt Gödel's, incompleteness theorems, was completely new in mathematics, which have always assumed that, in the context of axiomatically constructed theories, all theorems could be shown to be false or true [25]. The Gödel's incompleteness theorems had a profound impact for

mathematics and have set completely new horizons for its development.

v. In fact, we could ask: What are the limits of the imagination?

Even though, this is an impossible question to answer, several possibilities crop up into mind:

a. Fractality or what is referred to in art as the “Droste effect” (after the Dutch brand of cocoa with an image designed by Jan Misset in 1904), that is, a pictorial representation recursively appearing within itself. In mathematics, this is associated to the invariance, self-similarity, of a given representation that remains unchanged throughout different scales. On its hand, this scale invariance, gives origin, after the mathematician Benoit Mandelbrot, to the so-called fractal dimension, an index of the complexity with which a pattern fills space.

b. In what concerns arts, a way to gauge the limits of the imagination is through the complexification of the language or of the means of a narrative setting. Indeed, this can be seen in most detailed descriptions of reality, objective or subjective, historical or even the mundane, which stretch language to its limits, creating completely new aesthetical worlds. This can be clearly witnessed through the reading of Shakespeare, Tolstoy, Proust, Joyce, and many others. In music this is also evident in the complex compositions of Bach, Bruckner, Mahler, and many others.

c. Another interesting way to expand the imagination is through the creation of alternative space and time frameworks, which lead viewers, readers, etc, to new realms of thought. This can be seen, for instance, in the drawings of Maurits Escher and through the description of imaginary cities, as in the "Invisible Cities” of Italo Calvino, or of the multiple forms time might assume as in "Einstein's Dreams" of Alan Lightman.

Having set the basic elements and forces in action within the various fields of meaning for each particular discourse, it remains to explain the dynamic forces that lead a description of an OR at a given time to the scientific theories and, likewise, how a SR leads to new works of art.

For a given OR, the starting point is the selection of a particular subset of relevant facts. These can then be examined via experimentation (observation) and of the scientific method, which allows for a systematic research on the causes of a transformation that took place within a relevant sample, which admit a suitable replication of results and a set of logical inferences to the raw material that, through a great deal of imagination, give rise to models and scientific theories.

In what concerns the SR, the aesthetic confrontation for a given selected subset of elements leads, through an active exercise of imagination, to new original works of art.

Even though, the described elements are fairly general and common to the processes of emergence of new scientific theories and works of art, there are some particularities that are inherent of each discourse. We shall describe them pictorially below. But, in fairly broad terms, we can say that the scientific discourse has proven its use when its emphasis shifted from the qualitative philosophical analysis of the objects of study as a whole to the quantitative study of the most elementary and fundamental structures that these objects are composed of. This leads the discussion of phenomena that could be perceived through our senses to the search of quantitative analyses of invisible components, initially considered intangible, that are accessible through analytic reasoning. Of course, this is the very antithesis of, for instance, the literary discourse, that, by its very nature, is focussed on the description of the appearances, the qualities that are perceived at their totality and through their holistic essence.

The literary and the artistic discourses are timeless and aim to capture the chance and the renewal. The literary and the artistic discourses are complementary to the aesthetics of any historical period and do refute or contradict any other [26,27].

Development of the Physical Sciences

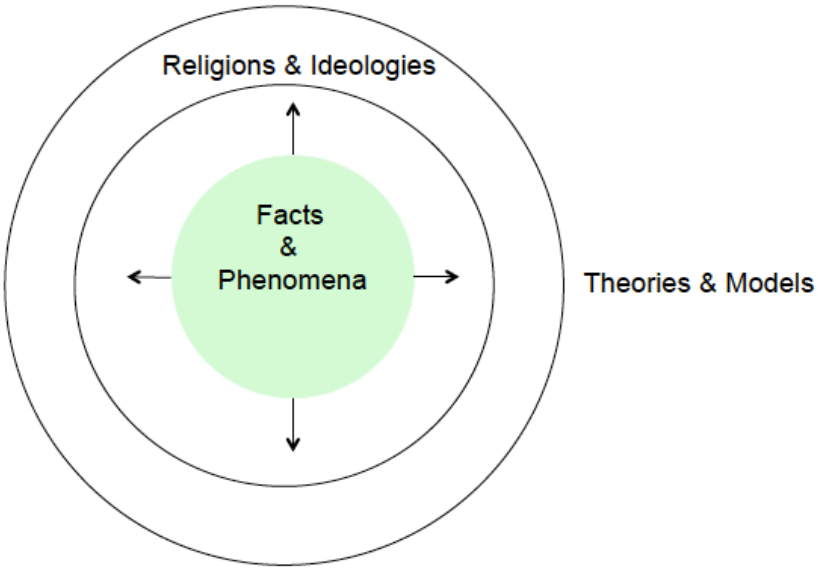

Figure 1.

The logic depicted in Figure 1 is that a New Theory arises whenever a set of facts and phenomena cross the "barrier" of the existing theories. The resulting pressure sets the wheels of creativity that are the raw material for the new interpretation of the facts. Throughout History, theories had to face the crushing and containing forces of tradition, religion and ideology. Notice that a well-known description of developments in terms of the contradiction between facts and concepts was put forward by Thomas Kuhn [28] so to account for the paradigm shifts that characterize the scientific revolutions. In opposition to Kuhn, we view clashes between facts and concepts as the very dynamics of the day-to-day scientific work, not necessarily attached to revolutionary developments or ground shifting discoveries and completely new theories. Variation, creativity and originality are the very essence of the day-to-day scientific work.

In terms of the cornerstone physical theories of the XXth century, the Theory of General Relativity and Quantum Mechanics lead to developments which suggest that certain facts and observations will require a new theoretical synthesis, Quantum Gravity, a theory that presumably describes the phenomena driven by gravity and quantum mechanics and involves extreme high energies (10^{19} times the energy/mass of a proton), concentrated in extremely small distances, 10^{-35} m (see Figure 2). This synthesis might have striking epistemological implications, potentially as deep as the ones ensued by Relativity and Quantum Mechanics in early XXth century, as since then physicists understood that the world per se is inaccessible, but just interpretable with the best available rationality criteria of a given historical context. The search of this new theoretical framework attracts a great deal of attention of the theoretical physicists [29].

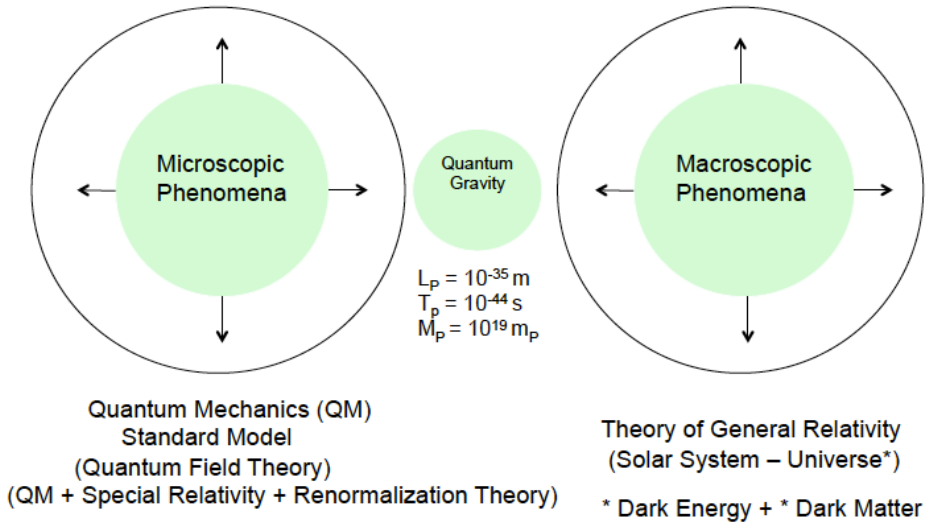

Figure 2.

Development of Biology

Despite a great deal of common experimental and methodological similarities, the development of Biology has distinct features from the one of the physical sciences. Indeed, it is found that the overwhelming complexity of the living world, from the functions of the organs, cells,

chromosomes and DNA [30], are all driven by the pressure to get adapted to the conditions of the surrounding environment. That is, the overall logic of the living beings is shaped within the ever-encompassing envelope of the Theory of Macroevolution [31] (Figure 3).

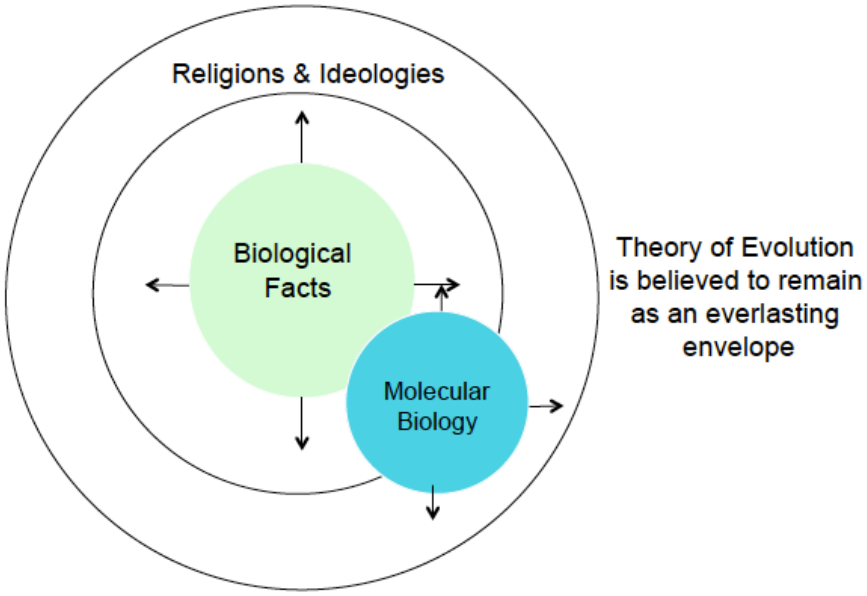

Figure 3.

This feature has been observed in all living organisms known so far, however this hypothesis might have to be reviewed if the discovery of Life elsewhere in the Universe reveals that adaptation is not a general property of the living matter.

Development of Geology

The dynamics of evolution of the geological sciences is somewhat similar to the one of Biology, the Plate Tectonics Theory playing the role of the envelope theory [32] (Figure 4).

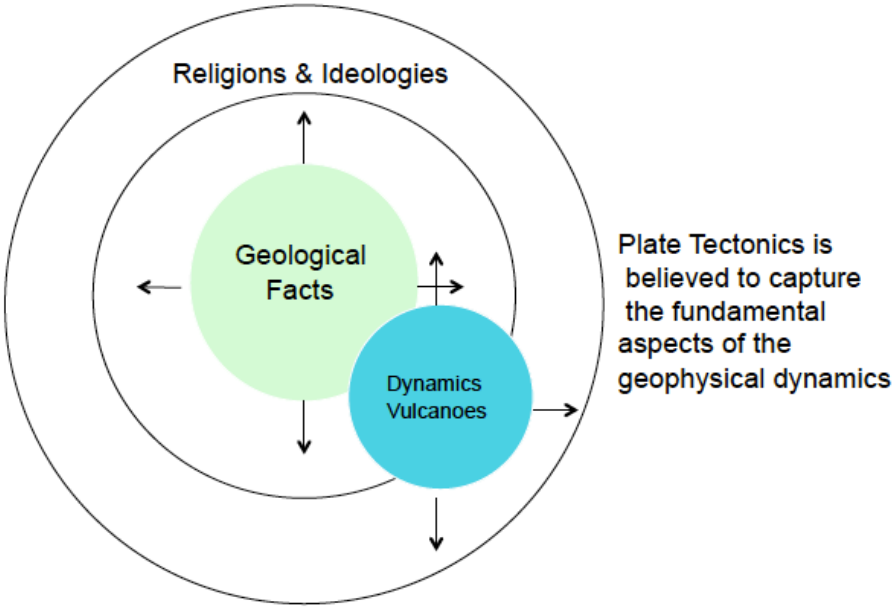

Figure 4.

An interesting question is whether the knowledge of the geological dynamics of exo-planets will unravel different dynamical drivers than the one arising from the plate tectonics and its causes. For instance, Venus and Mars do not exhibit any plate tectonics activity. The former has no moon, and the moons of the latter are too small to yield relevant tidal forces.

Development of the Human Sciences

Human sciences aim to understand manifestations of human culture and as such they are contained within the anthropological, historical, intellectual and social world it aims to describe and understand. Thus, building meaningful and general theories in Human Sciences is an incredibly demanding, if not a daunting task. In this respect, Human Sciences are always behind the events as these unfold themselves continuously. In this sense, a final or all encompassing understanding theory of the Human is somewhat beyond reach. A putative representation of the particularities that characterize the evolution of the Human Sciences is depicted in the diagram below, where two

general cornerstone theories are indicated for illustration purposes (Figure 5).

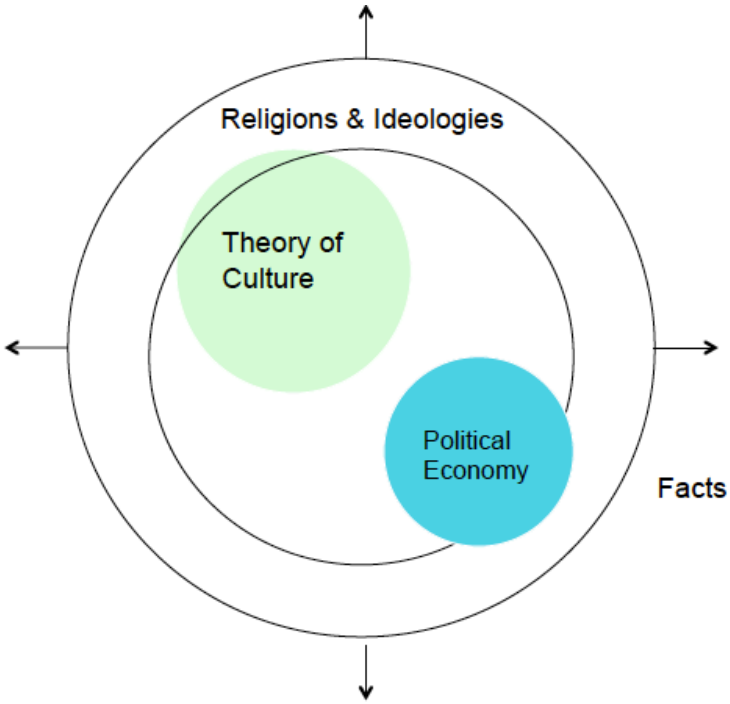

Figure 5.

The inner circles are indicative of the continuously evolving theories of culture and of political economy that aim to describe the ever growing ontological complexity of social facts and their developments [33].

Development of the Arts and Aesthetics

We find striking that there are similarities between the development of physical theories and of the arts and aesthetic movements. Both are guided by the wish to break free from constraining facts, existing theories and movements, being driven predominantly by the forces of creativity and originality. Of course, their scope is completely different. Physical sciences aim to understand the inner workings of Nature. Artistic manifestations aim to capture “beauty” and to reflect,

reproduce and revive human experiences and to perceive the human condition, its relationship with society, Nature and even the Universe as a whole, *in vivo* and as it breathes. Arts and aesthetic manifestations are the one of the most basic drivers of the human condition and express the most fundamental cravings of human existence. Arts and aesthetic manifestations are also one of the main drivers of civilization itself [34]. Pictorially, we express its dynamics as shown in Figure 6.

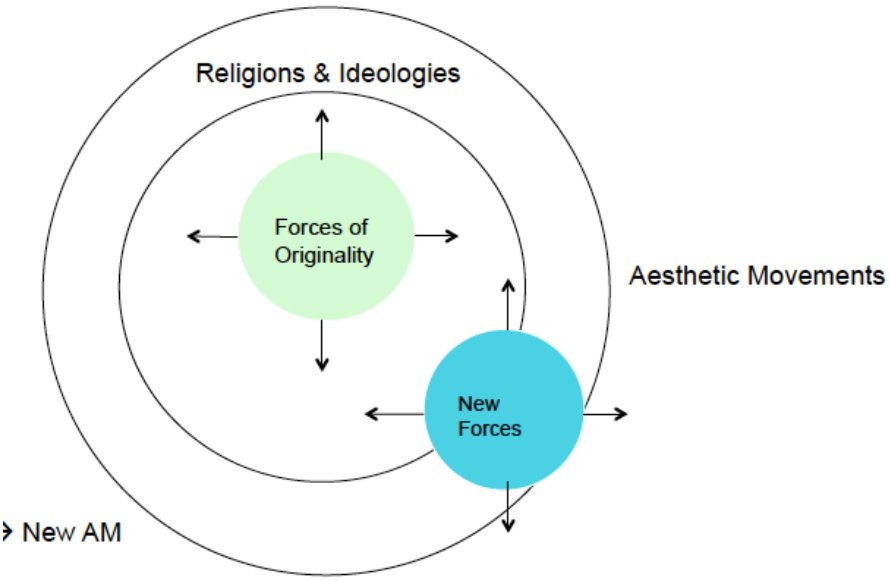

Figure 6.

Development of the Technology

There are also interesting parallels between the evolution dynamics of the technology, the set of all technical developments, and the development of the physical theories. Sure, the obstacles to overcome in what concerns technical developments are invariably related with pressures of the market, the degree of innovation with respect the technological development of a given society and its historical period, and son on. The parallelism between science and the technological developments can be understood as they are both originally inspired

by the wish to understand and to manipulate the world [35]. The development of the technology can be represented pictorially as shown below, where the outer boundary represents the current technologies (Figure 7).

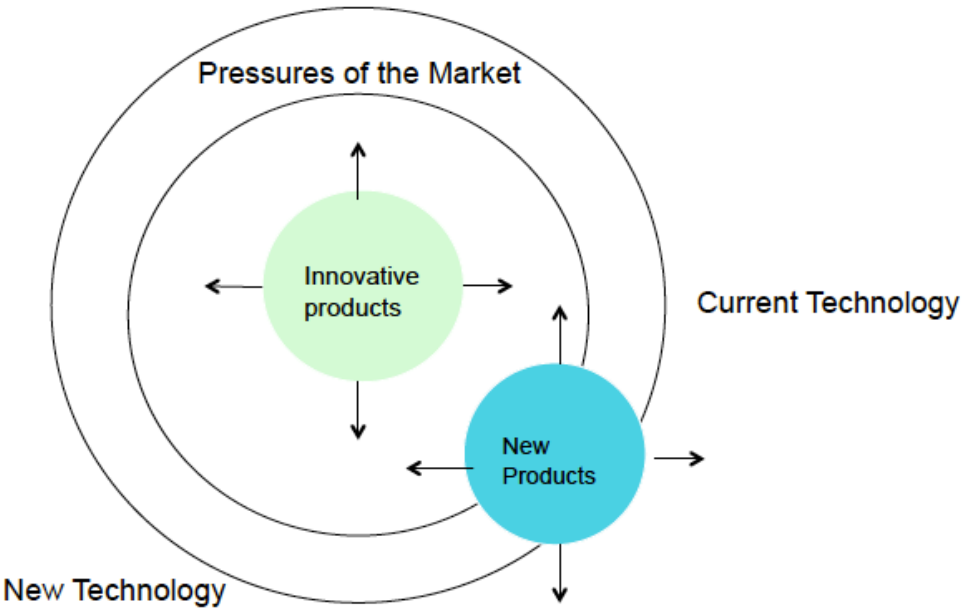

Figure 7.

Culture

Having sketched how the various branches of science, arts and technology evolve, we are now in conditions to advance with a definition, necessarily naive and tentative, of culture. We deliberately avoid the complexity of the issue in its anthropological, cultural, and sociological dimensions (see, for instance, the seminal discussions of Refs. [36,37,38,39]).

We characterize culture as the sum of all discourses that take place in the context of all fields of meanings. This sum assumes that the fields of meanings can be added, are open, and can have important and

palpable intersections among each other. In this enlarged set of fields of meanings, we can state that:

i. Culture is the synthesis of a given historical period, and what materializes the past into the present, projecting through its countless implications what will become;
ii. Culture is the way History enters into our life;
iii. Humans are beings driven anthropologically, geographically and historically by cultural constraints;

Of course, cultural and social developments can set us free from historical and current cultural trends, but they can also set up quite strong attracting points and traps. A few arbitrary examples are in order:

i. In China, during the Ming Dynasty (1405-1433), Admiral Zheng He used his huge and sophisticated armada to navigate through the Indian and the Pacific oceans; however, having judged that the new visited regions were much less developed than China, no effort was made to conquer new territories and resources. This historic decision has shut down China to the world for many centuries;
ii. The resistance to scientific discoveries and to the scientific method itself by groups of interest moved by economical interests, ideological and religious motivations are a constant force throughout History;
iii. For instance, in Soviet Union, developments in biology, in branches of theoretical physics and in social sciences were hampered by the tenets of Marxism-Leninism;
iv. Nowadays, even in the developed societies, there are pockets of resistance to the Theory of Evolution, to vaccines, to the scientific thinking and methods, and lobbies in favour of alternatives medicines, deniers of the evidence of a causal relationship between climate change and the human activities, and many other bizarre ideas about the world and the forces that guide its evolution;

Many other examples could be put forward, however, despite this historic resistance against change and the development of science, we can say that:

i. Since the Scientific Revolution in the XVIIth century in Europe, science and technology have became crucial drivers of History;
ii. Science and technology provide humans the means to be the dominating force in the Anthropocene;
iii. It is only through science, technology, a new juridical order and stewardship measures, that we shall be able to avert the impact of the changes we are inflicting on the Earth System and whose effects we are currently witnessing [40,41].

In fact, point (iii) is particularly pressing given that on a quite broad sense, the historical division of the world into disconnected and juridical independent sovereign states is dysfunctional, as in a global world like ours it is literally impossible to solve most of problems afflicting transversally all countries with local State based measures. Furthermore, the Earth System is currently being seriously affected by human activities as can be observed by the climatic change, and as a global mechanism its functionality can be ensured only through actions that go beyond the boundaries of the national States.

Our Brave New World and the Age of Choices

Our brave new world comprises remarkable cultural, scientific and social achievements, however, it also shows unsettling signs of unbalance and deregulation in the economic and technological fronts. Indeed, it suffices to mention the dramatic social effects that a robotic driven economy might have once coupled with disruptive new technologies such artificial intelligence, quantum computers, genomic edition, internet of things and so on, to understand the perils that the

future may unfold. Furthermore, it is not at all unlikely that without a set of suitable mitigating and regulatory measures we may be facing the problems of massive unemployment, generalised poverty and even a breakdown of the human civilization as we know it if the impact of the human activities on the Earth System are not refrained.
In this respect, our time can be regarded essentially as an Age of Uncertainty, which must be followed by an Age of Choice.

In fact, since about the second half of the last century, we are living in a new geological age, Anthropocene, after the Holocene, the period of remarkable climatic stability that prevailed in the previous 11700 years and within which human civilizations thrived and developed. For sure, the Anthropocene is already part of our culture and likewise all contemporary art and scientific discoveries it has been assimilated by the culture of our time through songs, films, etc. And naturally, all civilizational challenges inherited from other historical periods, like famine, poverty and inequality, as well as the ones of the Age of Uncertainty must be faced in the context of the Anthropocene and the ensued process of destabilization of the Earth System. To these already quite demanding set of collective goals, we could add that we must also assume a more active ethical responsibility towards all living species on the planet, and face more seriously the challenge of overcoming ignorance, religious and ideological hate and the ensued wars. We could argue that these demands ask for a "cosmic responsibility" [27,42,43].
And for sure, we must be prepared to face completely new issues:
So to create conditions for establishing human colonies in the nearby outer Space; to reflect upon the possibility of a post-human future; to foresee the implications of a material proof of the most likely possibility that we are not alone in the Universe, etc.

Some Tentative Conclusions

By its very nature, the future is unpredictable, and even more so when considering the complexity of our time and its implications. Hence, facing the challenges ahead will require multidimensional and multidisciplinary approaches based on hard scientific evidence that takes necessarily into account ethical, historical, political and social perspectives. As an example of the challenges ahead we present a short list of the most demanding and, in our opinion, the most pressing ones:

i. There is urgency in devising mitigation strategies, through stewardship measures, to control the impact of the human activities on the Earth System;
ii. These measures must endow the Earth System with a completely new global juridical framework;
iii. The struggle to mitigate and end famine, poverty and inequality must remain at the top of any global agenda;
iv. In my understanding there is no scenario for the future in which the role of social sciences and humanities is not of crucial importance;
v. In Portugal, the very thought of a future without a bubbling and innovative FLUP, in misalignment with its tradition of openness to new ideas, partnerships and challenges, is simply inconceivable. In fact, I consider a privilege to be a member of a University, which has FLUP as one of its most influential Faculties, and I very much hope to continue collaborating with FLUP in facing the challenges of the time future.

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