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Opinion

Hawking Radiation Experimentally Verified? Can the Information Paradox be resolved?

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Abstract - The Information Paradox should definitively be solved if the equivalence between mass, energy and information were proven through the experimentation proposed by M. Vopson at the IPI. However, the concrete ways in which this information is preserved are not yet exactly known, especially in case of a universe that may theoretically end its existence with heat death and the evaporation of black holes through Hawking radiation; which now seems to have been experimentally proven. Assuming by hypothesis that such a scenario may really occur, this article aims to suggest a possible speculative conjecture to deepen and develop this topic of interest also to the Science, Theology and the Ontological Quest (STOQ) disciplines. But the final word is left to an electron-positron annihilation experiment already designed and proposed by M.Vopson at the IPI and not yet carried out. Such an experiment aims to test whether with the annihilation of matter the information that could be encoded in photons of a specific expected frequency also disappears.

Keywords - Hawking Radiation; Information Paradox; Information Conservation; Mass-Energy-Information-Equivalence; Black Hole Evaporation; Big Bang; Big Crunch; Universe Instability; STOQ; Page Time, Page Curve, Simulated Universe, Big Chill, Big Freeze; Heath Death; Infodynamic Principle.

1 Background

Beside the attempt to understand and comment on the work of Vopson - "Reality Reloaded: The Scientific Case for a Simulated Universe", also from the point of view of STOQ disciplines (Science, Theology and the Ontological Quest), this paper arises from the assumption, by hypothesis, that in the late destiny of our reality there could be a heat death of the universe, where the collapse of matter into black holes (only a huge one or even smaller ones) would be subjected - in a very long run – to evaporation through Hawking radiation. The first part of such an assumption, related to heat death (also known as the Big Chill or Big Freeze), appears to be a possible conjecture, while the second part, related to black holes and their evaporation and disappearance, does not. That is because while implying a final big crunch in a universe which seems expanding in an accelerated way it implies as well the disappearance into infrared radiation of the information inherent in all the matter of the universe, even if in a collapsed form. In other words, this is what is called the information paradox. However, one can reason according to the assumed hypothesis which, if denied by anything, leads to reductio ad absurdum. This contribution of reflection on the topic includes also a substantial revision and translation into English of the idea reported in the

post - dealing with such a paradox above mentioned - available here [1], which was written in March 2021 without knowing all of Vopson's works summarized in the post of April 2024 [2]. The dizzying leap from the inert to the living is justified by science through DNA, although, despite the enormous progress made, science still does not know exactly where it comes from and how DNA generates life. DNA represents a natural example of success, the most efficient known so far [3], for the storage of information into "matter". But, what will become of all the information inherent in the creation, the reality where we are living in, when the thermal death of the universe and the evaporation of black holes through Hawking radiation will have made all matter disappear and only a tenuous, feeble, "weak" thermal radiation will exist with a temperature that asymptotically tends to absolute zero? In this regard, a conjecture is proposed hereinafter assuming that the thermal radiation close to absolute zero can still be considered as electromagnetic radiation able to encode information in the constituent photons. Furthermore we must consider that:

"*In physics, a photon gas is a gas-like collection of photons, which has many of the same properties of a conventional gas like hydrogen or neon – including pressure, temperature, and entropy. The most common example of a photon gas in equilibrium is the black-body radiation. Photons are part of a family of particles known as bosons, particles that follow Bose–Einstein statistics and with integer spin. A gas of bosons with only one type of particle is uniquely described by three state functions such as the temperature, volume, and the number of particles. However, for a black body, the energy distribution is established by the interaction of the photons with matter, usually the walls of the container, and the number of photons is not conserved. As a result, the chemical potential of the black-body photon gas is zero at thermodynamic equilibrium. The number of state variables needed to describe a black-body state is thus reduced from three to two (e.g. temperature and volume)*" [4].

But, in circumstances of thermal death, i.e. absence of interaction with the matter (already all evaporated or in the process of evaporating) and without walls of a container, shouldn't the number of photons be conserved? The reasonable answer seems affirmative. It seems completely clear that if the experiment proposed by Vopson to verify the equivalence of Mass - Energy – Information (M/E/I) [5] were to give positive feedback, it would at the same time be a confirmation of the Principle of Conservation of Information and the paradox of the disappearance for ever of information through the evaporation of black holes loses all its meaning

Noting, with pleasure, that Vopson does not disdain labelling some of his "conjectures" as "philosophical theories", I hope it will be allowed to recall the Thomistic motto "Philosophia ancilla Theologiae" and therefore draw attention even to some past works of F.J.Tipler useful for discussing the conjectures set out below from a STOQ standpoint. As well as recall the pre-WWII L.Fantappié's vision of the universe, also called cybernetic, because energy, matter and information were exchanged in it. The universe-information nexus is very ancient as well known.

2 Some introductory aspects

In Physics, just as for the mass, even for information should be applicable a conservation principle (that is often taken for granted), to affirm the impossibility of information disappearing into nothingness. In the realm of physics, there are principles related to the conservation of information, just like Conservation of Quantum Information encompassing the position, velocity, and spin of all particles within an object. Such Law of Conservation of Quantum Information asserts that the quantum information of all objects, including the universe itself, must remain conserved. This information exists for every single entity in the universe. But is it all the information inherent in the reality that we perceive? What about of not observable universes (including those of possible Multiverses)? Does it comprise all the energy necessary to keep every single entity in relation with any other, for example bond

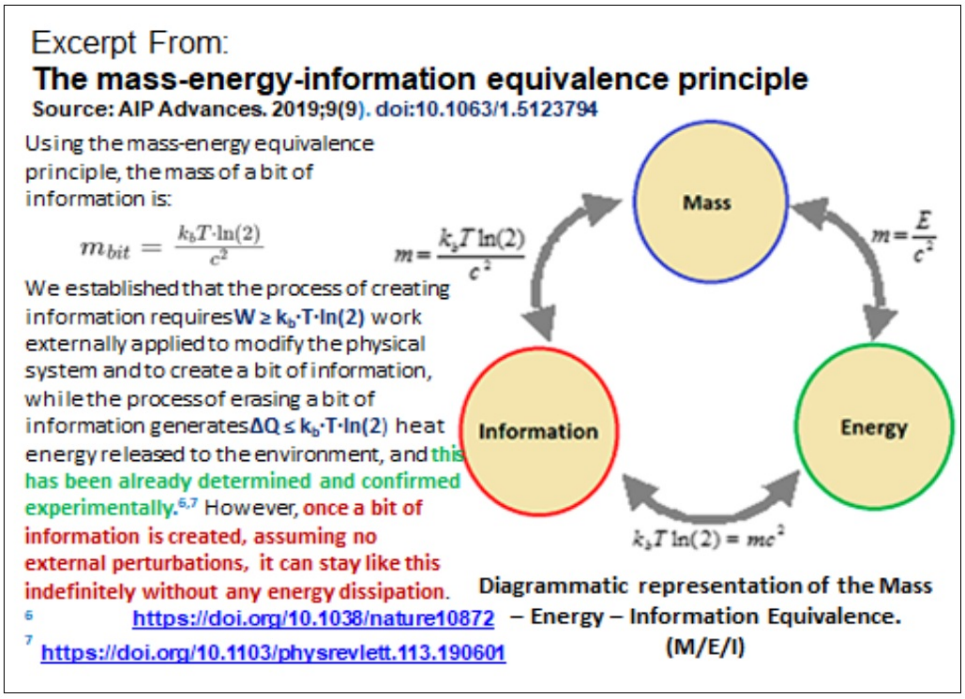

Figure 1: The Equivalence M/E/I/ in brief, as an extension of Landauer's Principle.

energy in the microscopic reality as well as in the macroscopic or multiverse one of an infinite and unlimited Multiverse? What about then of dark energy which we do not know yet what exactly it is, in spite of being the major part constituting our reality? Quantum effects in General Relativity investigate even quantum effects on black hole gravity incorporating quantum mechanics into the gravitational framework. In such framework it is deemed quantum potential energy, sensitive to "gravitational noise", may contributes to the mass density distribution of quantum black holes. At large distances (intergalactic scales), this additional energy might leads to repulsive gravity, overcoming the attractive Newtonian force. So dark energy deemed responsible for the accelerated expansion of the Universe, remains mysterious, but some repulsive gravitational force should be acting over cosmic scales. While not directly proven, this idea challenges our conventional understanding of gravity. In quantum mechanics, the informational content of isolated systems is assumed to remain constant over time, but our reality (as well any other!) is an isolated system? In summary, while energy conservation principle is well-established, the conservation of information in quantum physics provides for some deeper insights into how information flows and persists across interacting systems; but at the same time asks for more delve and confirmation when extended to any kind of information in general. Similarly, according to loop quantum gravity (which is often assumed to be death, because accused to be unable to unify all interactions) if we refer to questions concerning dark energy, it is necessary to take into account the cosmological force. Such a force F_λ in equation (1) is obtained from an exact solution of Einstein's equations with a cosmological constant λ [6]. It can be seen that it is very small because the cosmological constant is small, but it becomes important at cosmological distances determining a repulsive effect for a test mass.

$$F_\lambda = \frac{\lambda}{3} r \tag{1}$$

This appears in a context in which it is obtained, as reported in the work in reference, that «Gravity is attractive at small distances, but at large distances it becomes repulsive» [6] and also gives rise to the possibility of calculating an (unstable) equilibrium point, so that it seems possible: «This force (not a mysterious energy of the quantum vacuum or dark energy) is the reason why the expansion of the universe is currently accelerating». In the same

work, the cited author, investigating in general black hole and its interior finds out that [6]:

- the internal geometry is a three-dimensional cylinder, formed by the product of a 2-sphere and a line, which becomes increasingly narrower and longer; so when given the mass M, the radius r reaches the Planck scale near the value:

$$r \sim \sqrt[3]{\frac{G^2\hbar M}{c^5}} \tag{2}$$

  (with G = gravitational constant, $\hbar$ reduced Planck constant and c = speed of light)[6] quantum effects at this scale can no longer be neglected and the laws of classical General Relativity lose their validity;

- the cosmological force shows an equilibrium point (where is the distance in this case), which is also a point of instability in the transition from attractive to repulsive at very long distances, i.e. at:

$$r = \sqrt[3]{\frac{GM}{\lambda}} \tag{3}$$

  where λ here indicates the cosmological constant;

- the Einstein's equations are invariant under a time reversal t → - t thus identifying a region of space-time called a white hole, which is nothing more than a black hole with time reversed [7].

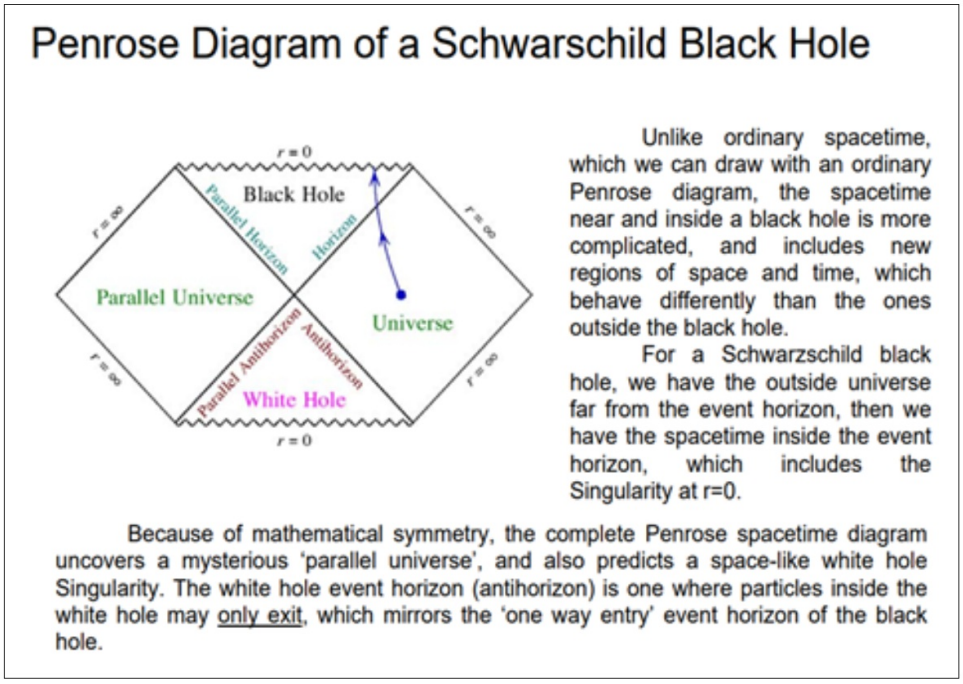

Figure 2: An excerpt from NASA Black Hole Math Book. (Source: Space Math http://spacemath.gsfc.nasa.gov)

In the past, the coexistence of white holes (WH) together with their respective black holes (BH) was a conjecture often derided smugly, but which today seems to have reasons to be seriously considered in the context of loop quantum gravity. In the aforementioned divulging work of this discipline on white holes to answer the question of what a white hole is, it is clearly highlighted that, although many doubted, black holes were known even before we began to see them astronomically, and therefore before to have proof of their

physical existence, because they were theoretical objects emerging from an equation which is a solution of Einstein's equations. Well, white holes are the same thing, emerging from the same solution that describes a black hole, but written with time reversed, as if projected back in time. Furthermore, in relation to the paradox of its loss of information, a close relationship is confirmed between the information, relating to everything that falls into a black hole beyond its horizon, and the white hole. So the information does not disappear. A black hole loses energy by emitting Hawking radiation, which can shrink its horizon to a very small size. To get a lot of information out with little energy from a very small horizon, a very long time is needed. In any case, the white hole that forms is smaller than the black hole that originates it. All this should not be surprising, nor should it be viewed with suspicion, when instead it is the same Feynman diagrams, now widely used in physics, that teach us today that an antiparticle can be interpreted as a particle that goes back in time. Similarly, we could also think that in the expansion of space-time a WH represents the imprint left by the respective BH that goes back in time. If we move from quantum gravity to classical physics, in the context of General Relativity (with speed of light c = 1) we have the Einstein equations:

$$R_{ab} - \frac{1}{2}Rg_{ab} + \lambda g_{ab} = 8\pi G T_{ab} \tag{4}$$

where λ is the cosmological constant, G is the universal gravitational constant, T_{ab} is the energy-momentum tensor of matter (a field that describes density and flow of energy and momentum in spacetime), R_{ab} is the Ricci curvature tensor, g_{ab} is the metric tensor and R is the scalar curvature, i.e. the trace of R_{ab} calculated with respect to the metric given by the metric tensor. If the energy-momentum tensor of matter $T_{ab} = 0$, then, ignoring the cosmological constant:

$$R_{ab} - \frac{1}{2}Rg_{ab} = 0 \tag{5}$$

When trough g_{ab} such an equation becomes:

$$R_{ab} = 0 \tag{6}$$

Defining an empty space according to the Einstein equations, G. Rovelli, in his cited book on "General Relativity - An introduction to Quantum Gravity" [6], underlines: where the Ricci tensor is zero everywhere, space is empty; while instead where the Riemann tensor is zero everywhere, space is flat (alternatively the space is flat when the metric tensor is constant everywhere). Consequently under the hypothesis of evaporated black hole, the following question immediately arises: in a universe where only thermal background radiation exists nearly at absolute zero, what value do these two tensors may have?
Analysing such question more in particular it comes out that :

- The Ricci tensor is a symmetric tensor of type (0,2), like the metric tensor, that reflects volume changes due to gravitational tides caused by spacetime curvature. The Ricci tensor is the tensor field defined by contracting two indices of the Riemann tensor $R_{ij} = R^k_{ijk}$. If black holes have evaporated, the Ricci tensor could still be non-zero in regions with other forms of mass or energy (such as radiation or dark matter).The information content (equivalent to mass/energy) could contribute to the curvature and affect the Ricci tensor.

- The Riemann tensor, which is a tensor of type (1,3) that most completely encodes the curvature of a Riemannian manifold (which is a differentiable manifold on which the notions of length, distance, geodesic, area and curvature are defined) characterizes the curvature of spacetime. In a universe where black holes have evaporated, the Riemann tensor would still exist, but its components would depend on the specific metric describing that universe. The absence of black holes does not imply a zero Riemann tensor; it merely means that the curvature is different from regions with massive black holes.

3 May information be encoded into photons?

With an article published on 4/March/2021 on Wired.it [8] it was received news that:

1. a micro-black hole was created;
2. experimental proof of the existence of Hawking radiation has been given;
3. it has been verified that this radiation is spontaneous and stationary.

In practice, it seems that experimental evidence has been given to predictions made by the great English scientist Stephen W. Hawking, who passed away a few years ago. Beyond the interesting details of the experiment (for example: the micro-black hole under study was ”built” starting from 8 thousand rubidium atoms; subjected to temperatures very close to absolute zero; held in position by a laser; etc.), with similar experimental evidence (if it is “real” evidence!) the Information Paradox seems to re-emerge even more strongly, to the point of becoming the negation of what seemed capable of emerging until now as the Principle of Conservation of Information. Since it is believed that the absolute loss of information is not permitted by quantum physics, a very controversial aspect is therefore reopened, also because we question whether we really violate the commonly accepted doctrine according to which the total information regarding a physical system at one point in time would determine its state (quantum?!?!) at any other time. Many questions therefore arise, perhaps pre-existing and not completely ”settled” so far, in addition to this one just mentioned. Presumably the Information underlying the Conservation principle does not correspond exactly to Information commonly understood. Nonetheless, the exercise of a preliminary albeit approximate in-depth study can be useful for more general purposes, first and foremost from the perspective of STOQ disciplines, always attentive to every development and characterised by a tension towards a ”dialogue ” with traditional sciences. For example, one wonders whether, in the presence of Information Loss, the question about the centrality of a current state determining the future one could be remedied with the proof or discovery of a new type of ”change of state”: quantum or even for example. from material state to immaterial state, in the future or in the past. This new, still ”unknown” state, provocatively, could in some way be related to that contemplated as ”spirit” in Philosophy and Theology. But so far, this still does not seem to be possible, nor desirable, in the Natural Sciences. Yet, there are examples such as the well-known Frank J.Tipler of Tulane University who - despite the ostracism of many of his fellow scientists - with his various works, in particular the two volumes published by Mondadori ”Physics of Immortality” first and ”Physics of Christianity”, then, he reclaimed the right of the Physical and Mathematical Sciences to theological research, which goes beyond the Philosophy of Science and Theology itself and beyond even that Omega Point Theory of which Teilhard de Chardin had spoken, albeit in different terms, in the first half of the 20th century. Similarly, Michael Mireau (1972-2014), a Catholic priest, interdisciplinary scholar of Science in its relationship to Faith, in an essay entitled “God the Creator: Developing a Trinitarian Understanding of Creation” recalls the coincidence in the Holy Scriptures of the incipit ”Bereshit...” (in Hebrew = ”In the beginning...”) in Genesis 1:1 as in John 1:1 – signifying a continuity of meaning and divine creative action perceived in Judaism first and in Christianity later - to then face the creative act as an act of Love of the Father exchanged towards the Son and reciprocated by Him. A creative act carried out through the Spirit which may be expressed as a ”field” in terms of the Trinitarian binder, through the exchange of Love (almost in a ”bosonic” function of unitive force!). For this purpose, the indirect reference to the “modus operandi” of some physical fields (e.g. electric, magnetic, gravitational, etc.), as in field theory, not visible but actually present and acting in nature, appears to have a great explanatory effect, as well as constituting an opening in the dialogue between Science and Faith. Similarly, one could speak, for example, of energy of a form not yet known in which information can be encoded to follow the same STOQ research paths. The long debate (especially between S. Hawking and J. Bekenstein, but also others,

for example L. Smolin) on the increase in entropy of a black hole when it swallows other matter, and therefore on the disappearance of the information associated with such matter, has led to the equation:

$$S = \frac{c^3 kA}{4\hbar G} \tag{7}$$

where S is the entropy, c is the speed of light, k is the Boltzmann constant, A is the area of the event horizon, $\hbar$ is the reduced Planck constant (or Dirac constant), and G is the gravitational constant.
It was believed on the basis of this equation (7) that every increase in entropy had to correspond to an increase in the surface of the black hole, so the surface itself could be considered the location in which the information of the incoming matter could be ”preserved” (in a different way depending on differently argued hypotheses, in a reasonably acceptable manner). This goes to the point of hypothesizing holographic universes produced by two-dimensional matrices, a hypothesis also explained somewhere else [9,10]. But it should be considered that black holes do not only have a horizon and a surface, but also an interior that could be involved and C. Rovelli with his cited works remind us of this, to the point that he studies its geometry and the consequences on the relative BH horizon. As per theory, black holes evaporate due to the effect of Hawking radiation in a sufficiently long time, and in any case longer than the age of the universe - says the cited article - which in itself would require some more explanation, reconnecting those existing links between cosmology and black holes. For example, in the Big Bang Theory (which can be classified as creatio ex nihilo) - an event that is believed to have created from nothing: time, space and radiation which then became matter through cooling and nucleosynthesis - three different scenarios are hypothesized: i) an open universe, which expands indefinitely; ii) a closed universe; and iii) a cyclical one. In the open universe, which currently seems to be the most probable hypothesis - (given that the expansion speed is accelerating, as ascertained in some experiments with supernovae assumed as ”standard candles” that allow distance measurements) - the final outcome should be an immense expansion and cooling leading to the so-called ”heat death”. In the hypothesis of a closed and cyclical universe, however, the final (or cyclically recurring) outcome should be the Big Crunch, i.e. matter that becomes increasingly aggregated and super-compact, under gravitational effects, until it becomes one or more black holes, which give rise to the final Crunch (followed by a new Big Bang in case of a cyclical universe). Given the Big Bang Theory, which is therefore the most accredited and present in every scenario; which has found various confirmations - (e.g. in the cosmic background radiation at around 3 °Kelvin, also in the expansion according to Hubble’s law; which can be observed in the redshift of galaxies, as well as in the abundance of light elements and in the detailed measurements of the CMB-cosmic microwave background radiation itself) - one wonders:

· Whether we really have any notion of the entire spacetime produced by the Big Bang (e.g. whether it is limited or unlimited; finite or infinite, how long will it last being itself a product of the Big Bang). Even ignoring modern theories on the existence of ”multiverses” (multiple universes: see H. Everett III et alia) we know that due to the finite value of the speed of light, and therefore of the cone of light in a Minkowski spacetime (Fig. 2), we cannot only observe, but even not have knowledge except of only a very limited part of the existing spacetime produced by the Big Bang. Particularly in the case in which the Big Bang did not originate in a ”point” (intended precisely in a geometric sense) as S. Hawking himself thought.
· What is a time longer than the age of the universe . At any point in space-time a hypothetical observer who is part of it (i.e. inside the universe, assuming that there can be an external one) can certainly have a notion of the space and time that has elapsed from the initial event up to his space temporal-position, but can he reasonably hypothesize a time and above all

a point in the spacetime of the end of his universe? Or are the end space-time coordinates indeterminate?[9]

· General Relativity tells us that space-time curvature in a certain region depends on the quantity of matter present locally; but, then, even more ”globally” (for different galactic regions all together)! A sort of general architecture of spacetime may be the same both in the case of a young universe in its initial and intermediate phases, where the hypotheses of homogeneity and isotropy appear reasonable, and in old age, in a phase close to the end, when the curvature as a result of the concentration of matter in a few black holes, if not in a single enormous black hole, spacetime is practically closed on itself?

· Is it correct to think of a model in which, while spacetime expands enormously in an accelerated manner, the matter locally (including interstitial spacetime) under gravitational effect concentrates autonomously and accumulates more and more in black holes capable of perceiving each other's gravitational effects at great distances? It seems reasonable to think that our instruments and measurement techniques are not able to perceive the local effects of the expansion or the expansion itself can be connected to reasons that do not yet find a plausible explanation (such as, for example, dark matter, dark energy or something else).

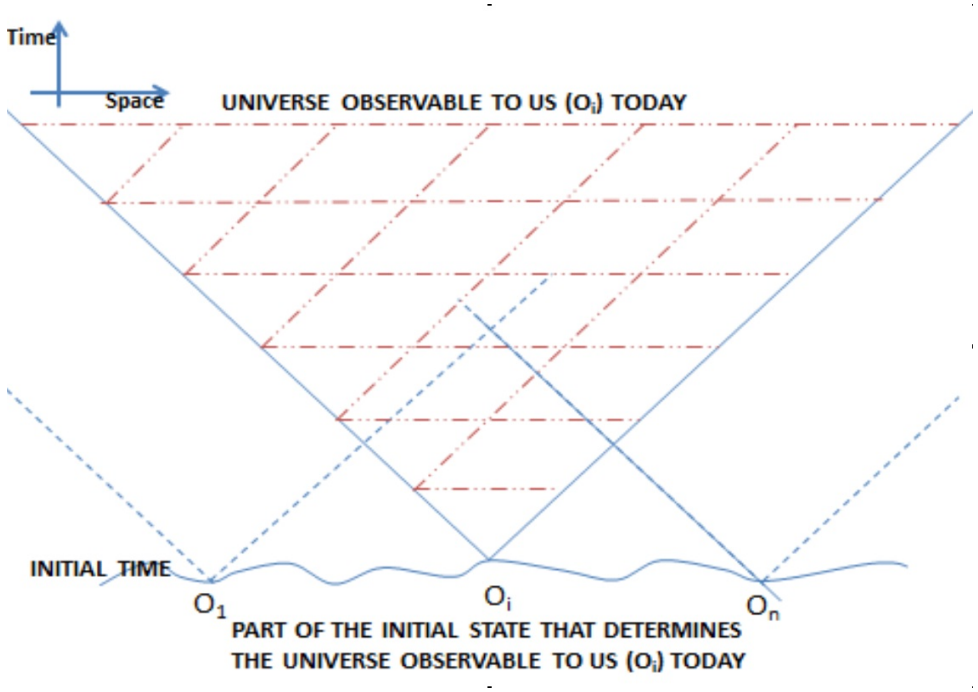

Figure 3: On the space-time, different initial states (at big-bang) determine different visible part of the universe

In any case, it is difficult to say whether ”ultimate time” (not to call it ”eschatological”) can be thought of as characterized by an infinitely expanded space and with a single huge black hole or multiple black holes of collapsed matter. But the fact that evaporation by Hawking radiation - now established - will cause them to ”dissolve” in any case, as black holes, makes their final fate unambiguous in whatever hypothesis is investigated or formulated. But this may lead to questioning the permanence of spacetime itself. Even thinking of quanta of space on the Planckian scale arranged in a reticular (spin network) or random way, but which themselves could presumably be compacted similarly to material granules [6,11] by ultimate conditions. The hypothesis of the Holographic Universe, however, although attractive and ”reasonable”, does not seem to have any other confirmation at the moment, other than mathematical-modelling simulations (sometimes with models and assumptions that would appear to be anything but verified or experimentally suitable) and should therefore be supported by data, evidence and tested theories to become ”proven and consolidated theory”. Therefore, that two-dimensional external surface of black holes, hypothesized as an ”archive” of Information by virtue of a Conservation Principle, which thus seems to vanish,

does not resist time and also vanishes together with the black holes to which it belongs. The idea of such a surface would also mean that information can exist as long as there is a material substrate (collapsed, compact or not) that allows its encoding. Apparently, it seems that with the disappearance of collapsed and supercompact matter, due to the Hawking radiation effect of black holes, information can disappear. That means it lasts as long as the black hole lasts . But wouldn't this represent, in a certain sense, the "Triumph of Death"? Not only in the sense of "heat death" (which for Science is one of the possible tragic ultimate perspectives of our universe), but in an even more absolute sense. That is a universe destined to disappear into "nothingness" together with everything that concerns it, that is far from the Parmenidean "being that cannot but be", or if you want, far from that Spinozian "divinity" imbued into the world, finally also subject to Cronos, assumed that proof of his mortality (as divinity) is given. This dark-toned question should only be the subject of Philosophy and Theology - which have so far found explanations either of a "dogmatic" type, or which transcend physical reality (and yet which sometimes reject pantheism), but which as such cannot be accepted from "Science" and in particular not from the Natural Sciences. However, how can we be certain that the ultimate space devoid of matter, but probably full of faint thermal radiation, "almost still vibration", i.e. low intensity electromagnetic radiation, which pervades the immense void, cannot itself have become in the meantime the seat of information, the "ultimate archive", which would also save the Principle of Conservation of Information? We therefore presume that, after the disappearance of the collapsed matter of a black hole through Hawking radiation, the background radiation survives at very low temperatures, for which radiation the laws of quantum mechanics apply, e.g.

$$\epsilon = h\nu = \frac{hc}{\lambda} \tag{8}$$

where ϵ is the quantum of energy (photon), h is the Planck's constant, ν is the frequency, c is the speed of light, λ is the wavelength. But then, remembering the wave-particle dualism, we must ask ourselves whether the disappearance of the collapsed matter of a black hole through Hawking radiation really means the definitive disappearance of any matter, energy or information in the "desolation" of the chilling great space, expanded over time and apparently becoming empty. Furthermore, given the low temperatures, we could remember that the so-called Bose-Einstein Condensates (BEC) represent a particular state of matter in which the "bosons", elementary entities that obey the Bose-Einstein statistics, mediate force and have integer spin and unitary (see Figure 3). When they are cooled to a fraction of a degree higher than absolute zero, these condensates begin to behave, in these conditions, as a unicum. In 1995, researchers made the ground-breaking discovery that there is a supposed "fifth state of matter": Bose-Einstein Condensates (BECs). Essentially, BECs are formed when particles are cooled to near absolute zero, causing them to coalesce into a single quantum object that acts as a wave in a relatively large packet. The independent particles are all in their identical lowest energy one particle state, i.e. in their ground state.

Some BEC Properties	Description
"*Unicum*" like Behaviour	The component particles stop acting as individual particles and behave like a single "super particle"
Superfluidity	A state of zero viscosity allowing fluid to flow without energy loss
Macroscopic Wave Function	Large-scale observation of interference and diffraction
Anomalous Magnetic Response	BEC atoms(°) repel each other when magnetised
Lowest, energy state	A large fraction of its particles occupy the same, namely the lowest, energy state
Slow down the light	An intriguing property of is that BECs can slow down light

Table 1: Some Property of Bose-Einstein Condensates.

That is, they do not behave like separate particles and also maintain at a macroscopic level all the quantum properties that they present at a microscopic level: for example, behaving like waves and not like particles, so the equations reported above and those that derive from them can be applied. More specifically, in a BEC of photons, they behave as a unicum, sharing the same phase and occupying the same quantum state. However, this "coherence" does not imply that information is stored identically for each photon. Phase coherence mainly concerns the behaviour of light waves and their interference. But information conservation in a quantum context may be more complex. Quantum mechanics introduces new nuances, such as quantum entanglement, which allows particles to be correlated even at a distance. Quantum information can be transmitted through entangled states, but not always in a direct or classical way. This must necessarily be reflected in the principle of equivalence between mass and energy (MEI) as well as in phenomenological modality study. It is good to remember that the following fundamental forces of nature: electromagnetism, weak nuclear force (linked to radioactivity), strong nuclear force, are mediated by bosons of unit spin; that is, the effect of the force is explained as the exchange of mediating bosons between interacting particles. For electromagnetism these are photons with spin equal to 1, without charge or rest mass; for the weak nuclear force these are W and Z bosons, with spin equal to 1, whose charge is unitary, for W +1 or -1 while Z has no charge; for the strong nuclear force these are gluons with spin equal to 1, without electric charge or rest mass.

But in our discussion we are talking about thermal radiation and therefore electromagnetic radiation where photons are involved. Roger Penrose, Steven Hawking's recognized master, in "The Road to Reality" (chap.22.7), teaches that "A non-massive particle, like a photon, can only rotate around its direction of motion. Greatness $|s|$ of this spin is always the same, for a given type of particle, but if the helicity s is different from zero (as in the case of the photon) then the spin can be a) right-handed (s ¿ 0; positive helicity) or b) left-handed (s ¡ 0; negative helicity). For a photon, we have $|s| = 1$ (in units of $\hbar$) which gives the two cases s = 1 for right-handed circular polarization, and s = -1 for left-handed circular polarization. Thanks to the quantum superposition principle, we can form complex linear combinations of these, thus producing the other possible polarization states." (refer to Fig. 4). From here we can presume the possibility that the immense empty space in case it remains in the "end times" after the formation and evaporation of black holes, is not actually empty, but remains the place of thermal and therefore electromagnetic radiation, however tenuous it may be. It needs to

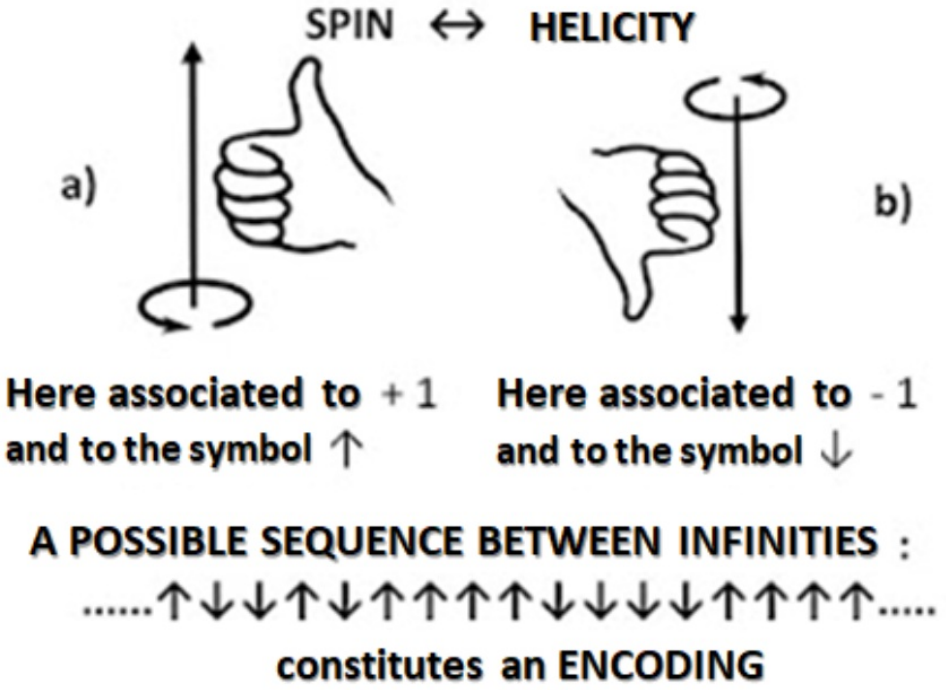

Figure 4: In theory it is possible to have encoding process in thermal radiation.

be verified scientifically, in this technological world that is already thinking of quantum computers, but it could be possible that this weak radiation of photons through sequences of different helicity could be encoded in the same way as the information on our computers and their memories is encoded in matter, through a coding based on a binary system, where the entities that allow coding can only assume two different self-excluding states, that is: ↑ or ↓ , as in Fig. 4. In this way it becomes possible to hypothesize that information codified and condensed in the form of radiation at temperatures close to absolute zero is present in that "void of the end times". One cannot help but think of that immaterial and platonic world of ideas, of the archive of all knowledge of which the eastern esoteric disciplines speak, but also of the depersonalized and indistinct return of all knowledge to its presumable original source [12]. Rather than in matter, information would remain "imprinted" in that radiation which is the residue of an "evaporated" universe. But can that residual radiation, condensed and codified, ever be assimilated to the concept of "spirit" in the absence of a requirement of transcendence from the remaining physical world, which, even if evaporated, remains present in more elusive forms in its vibrational residues? If despite everything one decided to answer in the affirmative, couldn't one doubt that it would be pantheism in more refined forms? Nonetheless, the preservation of the Principle of Conservation of Information would be safe, but directly linked to the persistence of that "almost still vibration" which would increasingly fade away, asymptotically, but which would never reach zero value, like a persistent dampened echo of a passed " creation" which was.

4 The ways of STOQ

Perhaps, also in light of all this, and in the framework of a "Reality Reloaded: The Scientific Case for a Simulated Universe" as proposed by Vopson [13], those aforementioned works by F.J.Tipler should be reread. Works that can be criticized as much as one wants, but which in today's rampant agnosticism, unaware rather than chosen, could represent an attempt - worthy of respect and appreciation, rather than an occasion for "scientific ostracism" . Also in the attempt to give the Judeo-Christian belief a perspective of concrete demonstration that: the incredible can be credible; not only through faith (man's movement towards God) and grace (God's response to man), or perhaps "predestination" for those who think like

this, but through the difficult rationality of the physical-mathematical sciences, which an act of faith can generate in those who cannot experience faith and have not yet received the gift of grace. Therefore, remembering that black holes - for which experimental confirmation of Hawking radiation has been found - are themselves "singularities", an extract [14] from Tipler's "Physics of Christianity" is reported below as an invitation to further study:
"In the Physics of Immortality I showed how the many universes solve the greatest theological problem, which is the main reason why people reject theism in favor of atheism: the problem of evil. In his autobiography, for example, the great evolutionary biologist Charles Darwin confessed that the existence of evil in the animal world - and the horrible suffering endured by his favorite daughter before dying at the age of less than twenty - had led him to abandon Christianity . The problem of evil disappears when one realizes that God has maximized good in reality, creating not only this universe but all possible universes, all of which ultimately evolve into God the Father, who is the Omega Point. I will return more fully to this many-worlds solution to the problem of evil in Chapter XI."

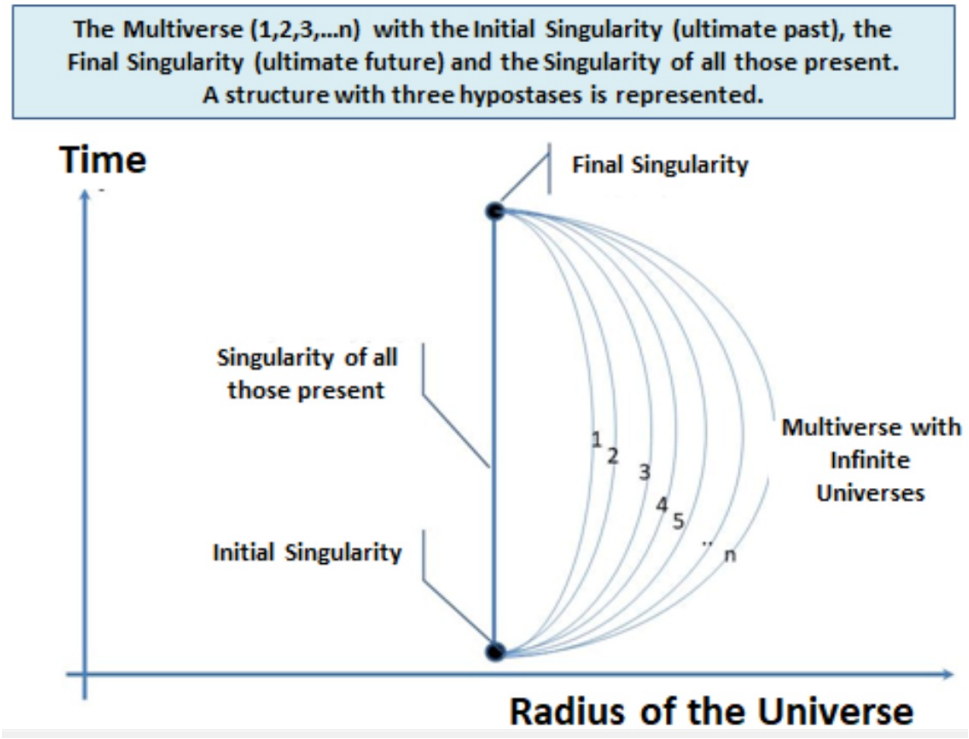

Figure 5: Alfa Point (Initial Singularity) and Omega Point (Final Singularity) in the vision of F.J. Tipler.

"But the many universes also show that the Singularity has a trinitarian structure. I didn't realize it when I wrote The Physics of Immortality more than a decade ago, but the Trinity is in my figures and my equations. Note figure VI.1 on page 177 of the Physics of Immortality, which is a schematic representation of the multiverse (reproduced here as Fig. 5). All reality exists between the initial Singularity and the final Singularity. In classical general relativity there is no connection between the initial and final Singularities, but in quantum general relativity there is a connection: the line that in Fig... (5 above) connects the two Singularities. This is also a singularity, existing at the "edge" of the multiverse, as indicated in the figure. It also exists in all times for all universes in the multiverse. The quantum singularity, in other words, has a tripartite structure: (1) the initial Singularity, before which nothing existed; (2) the final Singularity, after which nothing will exist; and (3) the singularity that connects the ultimate past and the ultimate future. I propose to identify the Singularity of the ultimate past with the Holy Spirit (in his transcendent divinity), on the basis of Genesis 1.2, which ends with the phrase "and the spirit of God hovered over the waters". This is a precise description of the initial Singularity of the multiverse, as represented in figure 5. I have already identified God the Father with the Singularity of the ultimate future, and I refer the reader to the extensive writings of Wolfhart Pannenberg, in which the theologian also gives reasons for thinking to God the Father as to the ultimate future. The Son - in his divinity, necessarily outside of time -

is the singularity that establishes the connection between the ultimate past and the ultimate future. The Son is fully integrated with the Holy Spirit and God the Father. The three are one. The Son, as is clear from figure... (5 above), was present at the beginning of the multiverse, in agreement with the description found in John 1,1-3: «In the beginning was the Word, the Word was with God and the Word was God. He was in the beginning with God: everything was made through him, and without him nothing of all that exists was made. The singularity is a "substance" in the same sense that electrons and protons are "substances". The main property of "substances" is that they can make their existence known by exerting effects, which can be revealed. The three Singularities—that of the Father, that of the Son, and that of the Holy Spirit—exercise effects on space, time, and matter, even though they are outside of space and time, and are not matter. The Singularities are the divine substance, and the Son is of exactly the same substance as the Father. We thus have in the three parts of the Singularity - ultimate future, all presents and the ultimate past - a full justification of the crucial Christian doctrine of homoousion. This Greek term is a compound word: homos means "equal " while ousia means "substance". Therefore homousion (consubstantial) refers to the fact that God the Father and God the Son (Jesus in his divinity) are made of the same divine substance".

It can be seen that it is not the vision of a stratified Trinitarian concept, as Newton had perceived it [15], with the pre-eminence of the Father, but of a Trinitarian concept that sees the three persons in action in the reality of creation in different roles and strictly connected to transcendence. Yet, all this proves nothing if we take the perspective of the current "Don Franco"[16], who, when questioned about it, responds, adorably with the humility he expresses: "what can we know about the intimacy of our God!".
The heat death of the universe by evaporation of collapsed and compact matter (BH) through Hawking Radiation and Tipler's ideas expressed above may seem antithetical. Yet, the idea of immortality that Tipler expresses through the Omega Point Theory, which from the future orders and directs and attracts to itself, teleo-logically, all creation from the initial point of the past (Big Bang), is supported by an articulated hypothesis of our universe in multiverse (Fig. 5) which envisages a final Big Crunch and a Physics of Immortality which sees a "different" universe, quasi-virtual, simulated at a higher level of implementation on a sort of universal computer in the same Omega Point. If Hawking Radiation is a scientifically established fact; if Tipler's theories have a scientific basis, which is not up to us to judge here in the present work, and if the preliminary considerations carried out above can contain some truthful intuition (although still to be verified) the codification of that radiant and residual post-evaporation thermal energy can be related to that higher level of implementation on a sort of universal computer that Tipler glimpsed in his coinciding reflection at the Omega Point and with the figure of the Father.
It is therefore the denial of any determinism which introduces possible explanatory hypotheses of retrograde causality, i.e. postponed in time, implying the possibility of the reality we experience as the implementation (emulation at higher levels than those known today) of an IT process being created by of an "Omega Point": a sort of singularity that teleo-logically – from an alien reality which transcends ours - governs and directs from the future (and not from the past) the same reality that we experience in the present.
The hypothesis by Vopson of "Reality Reloaded" – The scientific case for a simulated universe – is not the first of such a kind [13], but in this specific case we have proposal of possible tests to be executed on some of the presupposed phenomena as foundation. Invoking K. Gödel's incompleteness theorems to argue that a universe cannot be fully known from within by its observers, as any formulation of the Anthropic Principle might suggest, is difficult to say whether it is correct or not. What can be said, however, is that:

- an experiment to verify annihilation of matter and information as well is proposed at IPI (Information Physics Institute, in UK);
- a socio-economic model system that does not invest in very deep-knowledge and research is a social model destined to fail!

Someone could argue with the usual ostracism that with such STOQ discourses, questions and hypotheses we are creating science fiction and fantasy theology. But in the present case it would be necessary to argue it very well in order to be able to support it, at least as much as Tipler and Vopson did behind their works, always accompanied by logical reasoning as well as physical-mathematical investigations to support their arguments.

5 Additional Consideration

Already in 1944, an earlier report from 1942 became a book entitled: "Principles of a unitary theory of the physical and biological world". It was about the universe, in the vision of Luigi Fantappié, an Italian mathematician and scientist. That universe was also called cybernetic, because energy, matter and information were exchanged within it. Since then there has been significant research, and in 1961 with Landauer's Principle (refer to Fig. 1) we had a correspondence between minimum energy (heat ΔQ) and 1 bit of information lost, irreversibly erased, at temperature , through the relation:

$$\Delta Q = k_B T log(2) \tag{9}$$

Of course, if the bits are N in number, this factor must be added to the previous equation (multiplying both sides by N). This relationship is used to evaluate the minimum energy needed to erase the information. Assuming a principle of conservation of energy, it is also assumed that the same amount of energy is needed to create 1 bit, obviously with a different sign, because in one case energy is received and in the other energy is supplied to the system. The same equation (9), however, also tells us that the amount of energy involved is smaller (or larger) the lower (or higher) the temperature T. At this point the following considerations come to mind. The assumption of a principle of conservation of energy with a reversed sign finds a similarity in nature in the latent heat of fusion, for example of ice in water, which (neglecting the efficiency, i.e. process losses) is the reversed equivalent of the cooling energy that must be supplied to the water to cool it so that it turns into ice. In practice we have that:

Latent energy of fusion = - Latent energy of solidification

they are equal in absolute value, but have opposite signs. In the spontaneous and natural process of ice formation, it is the external environment that, with the lowering of temperature, compared to the temperature at which liquid water is found, creates an enthalpic jump at the expense of the environment itself, allowing the formation of ice crystals, of variable shapes depending on the environmental conditions. The crystals are equipped with structure and bonds (therefore information) that are formed by subtracting energy thanks to the natural (enthalpic) temperature jump that allows heat to be removed. As soon as one passes from spontaneous and natural processes to other types of real processes, losses occur and therefore the process efficiencies are involved which cannot exceed the unit value due to the losses. From here it can be deduced that with regard to equation (9):

i. "At least the same value is required to create or erase a bit of information" is certainly valid and verified, but limited to natural processes.

ii. It seems reasonable to assume for spontaneous and natural processes that the binding energy between the various parts (e.g., the bonds within a crystal and those with other adjacent crystals) – which also constitutes information – is included in the computation, which is not always true for non-spontaneous and non-natural processes.

iii. Information, understood as encoding according to a pre-established code, whether natural/spontaneous or not, happens - if it happens! - with energy that is lower the lower the temperature T (according to Landauer's Principle) and should be minimal (or almost zero) around absolute zero. Therefore, the ideal place where the energy to create a bit of information is minimal is located right in the cold of deep space of the end time. And no one can exclude that all this is not random at all; not a simple coincidence (even according to a STOQ approach). Because in the big chill of the end of time thermal photons reach such low energies in a BEC state, so that the rules of quantum mechanics dictate that they stop acting as individual photons and behave like a single "entity". An encoded final entity containing all existing information at the lowest possible energy. Immediately the suspect arises that such an entity, being the final archive produced by the big bang, is not a simple container of all information, but much more than this.

iv. It is well known that beyond the support needed for coding imprinting, the information preservation is favoured by very low temperatures. Low temperatures are beneficial not only for energy efficiency but even to mitigate various forms of noise and degradation, ultimately contributing to longer preservation times and higher data integrity.

v. Reconnecting to the theme of the information paradox and heat death through a possible encoding of all reality in the thermal photons of Hawking Radiation, the temperature of a black hole, although very low, will always necessarily be higher than that of the cosmic background. Therefore, an enthalpic jump will always be ensured at the last black hole (or even last black holes) to release heat to the surrounding environment, i.e. infrared radiation, i.e. photons in sequences $\uparrow \ldots \downarrow \ldots \uparrow \ldots$, until complete evaporation has occurred.. Once the evaporation is completed, i.e. the sequence of emission of new photons through Hawking Radiation, it could itself be a possible pilot signal for the subsequent BEC "unicum already formed and informed", which would be in its lowest possible energy level and in the highest possible information level, to activate a big bounce procedure already previously encoded in the unicum itself. In the hypothesis of a subsequent big bounce (after the black hole phase) loop quantum gravity also seems to be implicated, where it is stated (see Ref.[6] pg. 157-158) that: "The implication is that the big bang could have come after a previously contracted phase of the universe and a big bounce, at the scale where the density became Planckian. This event may have left traces in the cosmic microwave background". This should mean, according to the conjecture, that it is the same Hawking Radiation that ultimately encodes the information in the photons of the background radiation, even before the end of the evaporation of the black hole. « So it might be possible for black holes to turn into white holes at the end of their evaporation». This would activate a link between white holes (WH) and information present in matter (BH) through Hawking radiation as a means of encoding information in the residual background radiation of the end times. The BH/WH pair is an evolutionary structure that persists at least until the complete evaporation of the BH.

vi. How Nature acts when energy is involved is reminded by the principle of least action, also known as Hamilton's principle or more generally as the principle of stationary action. It is a fundamental concept in theoretical physics. It states that the path followed by a physical system between two points in space-time is such that the total action (the integral of the kinetic energy minus the potential energy along the path) is minimal. In other words, Nature tends to "naturally" follow paths that require the least energy or action. The processes of creating and processing information that characterize our reality are instead energy-intensive and highly dissipative, since they are affected by intrinsic losses with variable efficiencies also according to the types of technologies adopted, the state of research, innovation. Science and technology are trying to develop new, more efficient methods, but Nature has its own ways! We should therefore think that the process of encoding photons of Hawking Radiation emitted by black holes is the optimal and most "natural" way to encode the information that

remains trapped in them and that cannot disappear violating the principle of conservation of information, giving rise to the paradox of its loss.

vii. The M/E/I equivalence principle is an extension of the Landauer Principle, which in turn has already been verified experimentally. The estimates made at IPI on the basis of the knowledge and data available for THE INFORMATION CATASTROPHE [17] referred to in the work cited in the references, represent at least a trend that is difficult to dispute (beyond the corrective adjustments that do not change the orders of magnitude) although no one has a crystal ball to know the future effect of innovation (e.g. through the transition to quantum technologies). And in any case the calculated values represent only a minimum, according to the Landauer principle, and it is difficult to estimate what the impact of the foreseeable evolution of technologies and the efficiency for the related new processes could be from now on. In any case, it would be wise to worry about this trend - especially in a world that is constantly gripped by energy crises - by incentivizing technologies (quantum or others if they exist) that can mitigate this trend.

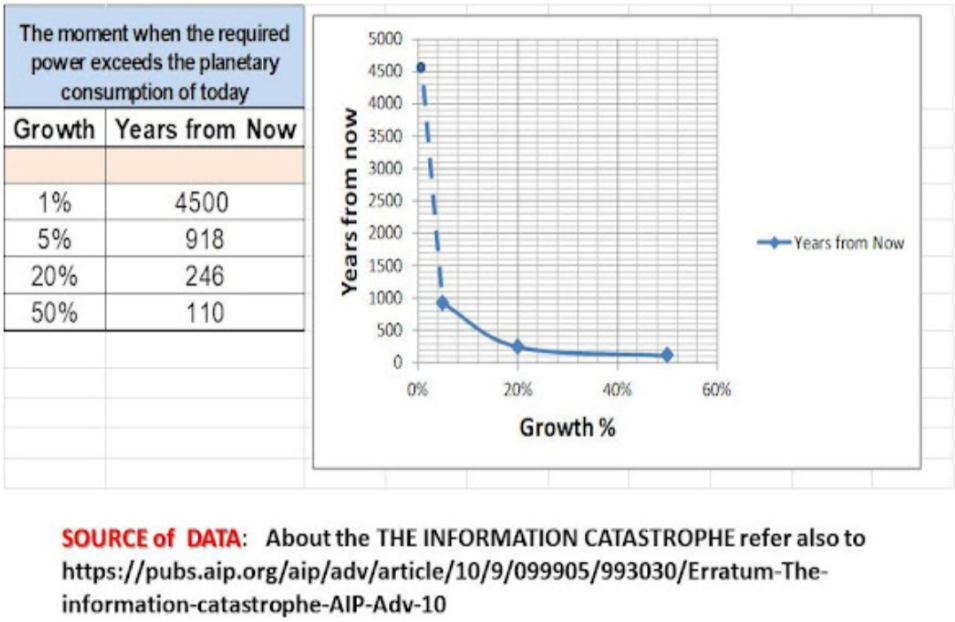

Figure 6: A trend that hypothesizes The Information Catastrophe.

Since 1961 and the contemporary Landauer principle, we have recently (2019) arrived, through the verified equivalence principle (M/E/I) - referred to in the work cited in the references [18] at the identification of a relation of inverse proportionality between wavelength λ and information content I bits, as well as temperature T, according to equation (10):

$$\lambda = \frac{hc}{Ik_B T log(2)} \tag{10}$$

On this basis, an experiment of particle annihilation of an electron-positron pair has been developed at the IPI, which should completely erase their information content, since with the annihilation both the rest mass and the kinetic energy contained are converted into radiation, according to two different configurations depending on the total spin of the pair. When the total spin is 1, the annihilation produces three gamma photons (also depending on the energies of the individual particles of the pair and on any magnetic fields); when instead the total spin of the pair is 0, two 511 keV γ photons are obtained, which due to the conservation of momentum will travel in opposite directions. The rest mass of the particle and antiparticle,

as well as the information energy are considered equal for each of them. But if the information energy that the M/E/I equivalence predicts is conserved, then the annihilation should also produce two information energy photons. These should be easily distinguishable because they are produced synchronously with the collision together with the 511 keV gamma photons and if their information content is from 1 to 3 bits they should belong to the MIR and FIR spectral regions with wavelengths typical of those recorded at very low temperatures. There is therefore a need to experimentally discriminate these information energy photons from those present in the background regardless of annihilation. But it is evident that if these information energy photons are detected in the expected MIR and FIR frequencies, this is the proof sought, and we can speak of experimental evidence of a M/E/I equivalence that is yet to be studied in terms of consequences . In short, it would be the opening of a new and extraordinary field of physics. However, it should be remembered that it is not possible to simultaneously measure the frequency and the spin of a photon with infinite precision. The Heisenberg uncertainty prevents us from knowing both properties simultaneously with absolute precision. Since they have no mass, photons cannot be located without destroying them because they cannot be identified by a vector in space. This makes the application of the Heisenberg principle impossible, and leads to the use of the formalism of the second quantization (for a beam of photons). In short, while we can determine the frequency of a photon, the spin remains a quantum property that cannot be measured simultaneously with complete precision. Through the Heisenberg Uncertainty Principle, however, and by the effect of Noether's Theorem (the mathematical result that links symmetries in physical systems to conservation laws) modern physics comes to argue [19] that the impossibility of having:

1) "Absolute spatial position" results in a symmetry in the "Translation in space" and hence the law of conservation of the "Quantity of motion" (Momentum);

2) "Absolute time" results in a symmetry in the "Translation in time" and hence the law of conservation of the "Energy";

3) "Absolute spatial direction" results in a symmetry in the "Rotation in space" and hence the law of conservation of the "Angular momentum".

For the same reasons should we be able to state that since it is not possible to simultaneously measure the frequency and the spin of a photon with infinite precision - since the Heisenberg uncertainty prevents knowing both properties simultaneously with absolute precision - all quantities that depend on both the spin and the frequency of the photon are subject to a conservation law? In the affirmative case, if this is true for the single photon, shouldn't we be able to think that this is also possible for a set of photons such as a unicum BEC, with the aim of verifying whether such a set of photons emerging from the Hawking radiation of the last evaporated black hole is stable (taking into account the metastability that will be discussed below) and seems to have the characteristics of a natural phenomenon that is not dissipative but conservative?

6 Metastability until equilibrium is reached – Page curve and time

The idea of a caducity and temporariness of aggregate matter is evident in nature, in the aging and degradation processes of organic matter in particular. Equation (3) in the introductory part reinforces that the concept of instability is intrinsic in universe and matter (see radioactivity decay and even the hypothetical proton decay in the long run, where half-life is estimated to be at least 1.67×10^{34} years). But such a concept does not emerge only from quantum mechanics (Loop Quantum Gravity in this case), but also from particle physics as developed in studies related to the physics of the Higgs Boson, where it is our entire universe

that seems positioned in a zone of meta-stability [20]. One might think that this is an old hypothesis (see Fig. 7) formulated while waiting for the discovery of the Higgs boson, but in fact it is even more valid today, since the masses of the Higgs boson and the top quark are known. According to the standard model, the universe is stable on cosmological timescales, but will eventually undergo a collapse. The mass of these particles plays a crucial role in this dynamics. The probability of transitioning to a state of complete stability is extremely low, so the universe will probably remain metastable for a very long time. However, it seems that research continues to explore these questions, and new discoveries could lead to a deeper understanding of the stability of the universe.

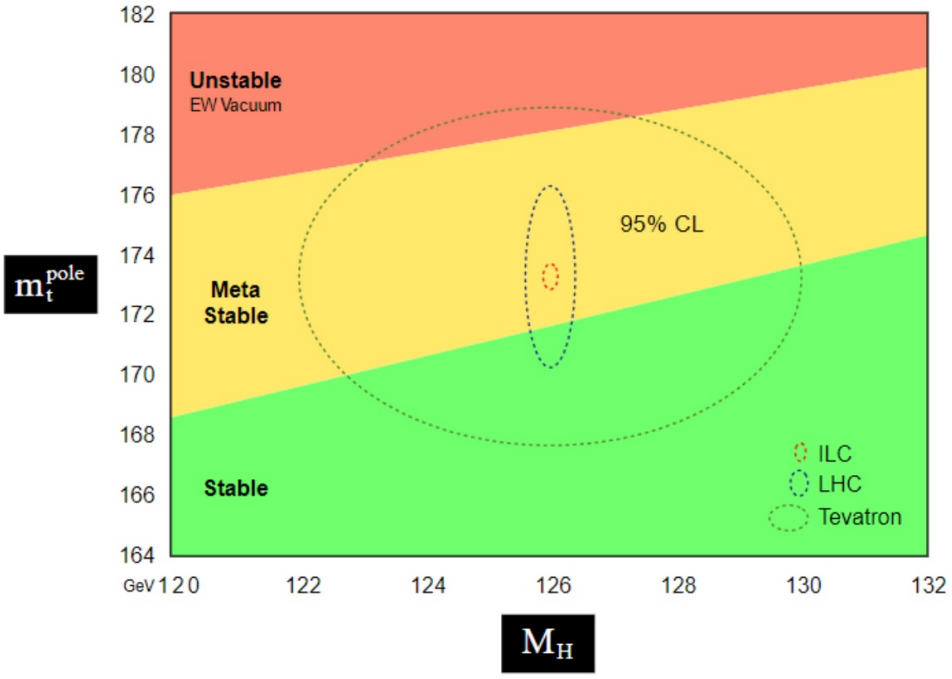

Figure 7: Universe Meta-Stability based on the Higgs boson and Top quark masses.

In our reality, the formation of non-equilibrium structures can exist as long as the system dissipates energy towards an external environment and remains in communication with it. An external environment to our universe of whose existence we still know nothing about, unless it is that "bulk" that Kip Thorne (Nobel 2017) talks about in his pleasant "Science of Interstellar" and that seems more like a multidimensional perspective tool than a physical reality [21]. The same phenomenon of Hawking Radiation is of a dissipative nature, since according to classical physics (Einstein's general theory of relativity), nothing could escape a black hole due to its intense gravity, instead such radiation suggests that black holes can emit particles and lose mass over time. But if black holes evaporate via Hawking radiation, what happens to the information (quantum state) of the matter that fell into them? A quantum entanglement exists between particles inside and outside the black hole, and the Page curve hereinafter is a theoretical construct that may describe the behaviour of entanglement entropy S_{Ent} as a function of time t during black hole evaporation. As NASA teaches in the Black Hole Math Book «rotating black hole can evaporate and lose mass, thanks to the quantum mechanical properties of 'empty' space. Pairs of electrons and anti-electrons are constantly appearing and disappearing in space. If this happens near the event horizon, one particle escapes, while the other carries 'negative mass' into the black hole. This causes the black hole to lose mass». The evaporation time t of a black hole with a mass of M in kilograms is given by:

$$t = \frac{10256\pi^2 G^2 M^3}{hc^4} \tag{11}$$

the temperature T of a black hole with a mass of M in kilograms is given by:

$$T = \frac{hc^3}{16\pi^2 GMk} \tag{12}$$

From equations (11) and (12) above we have:

$$\sqrt[3]{\frac{h2^4}{10256\pi^2 G^2}t} = M = \frac{hc^3}{16\pi^2 GkT} \tag{13}$$

It can be seen that time and temperatures are in inverse proportion to each other.

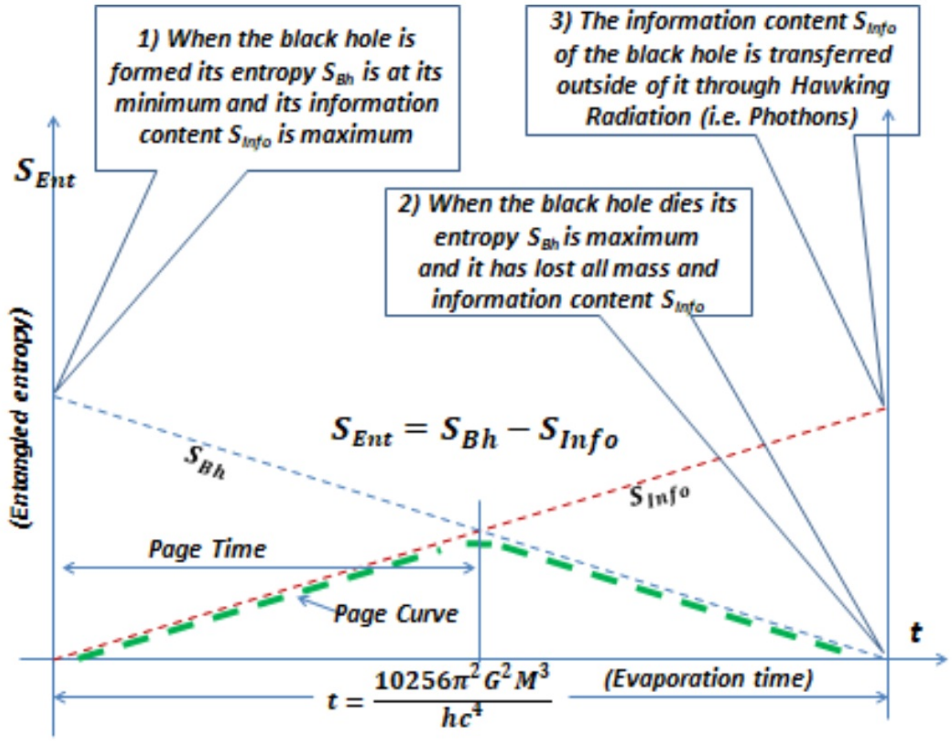

Figure 8: Page Curve and Page Time.

The Page curve has been used here-in Fig. 8, as a hypothetical-graphical construct that describes the behaviour of entanglement entropy (S_{Ent}) as a function of time (t) during black hole evaporation. Entanglement entropy measures the quantum entanglement between particles inside and outside the black hole. The Page curve starts at zero (when the black hole forms) and gradually increases as the black hole evaporates. At some point, it reaches a maximum at Page Time and then decreases, eventually approaching zero again. Page Time is then the Entropy Reversal crucial point on time axis. The Page time represents the moment when the entanglement entropy begins to decrease. It corresponds to the point where the black hole has emitted enough radiation that the information about the initial matter distribution is no longer trapped inside. In other words, the Page time marks the reversal of entropy associated with the black hole's evaporation process. Beyond this point, information starts escaping, and the black hole becomes an "open system". While the exact mechanism of information escape remains a topic of on-going research, the Page curve confirms that black holes do release information, albeit in a highly encrypted form due to quantum entanglement. With regard to the conjecture underlying this work and in light of all the above, a close connection can be glimpsed, and presumably a close relationship to be explored further, between: - equation (3) of Quantum Gravity according to Rovelli on the transition at large distances of the gravitational force from attractive to repulsive; - the curve

and the Page time mentioned above for the evaporation of black holes through Hawking radiation; - the behaviour of the background thermal radiation as a means of encoding a unicum formed by a BEC made of photons (presumably MIR and/or FIR to be tested with the electron-positron annihilation experiment planned in IPI); - the assumption of the second law of Infodynamic and its implications for the simulated universe hypothesis, according to the formulations of Vopson, where the total entropy of the system S is the sum of the physical entropy of the system S_{Phys} and its information entropy S_{Info}, from which:

$$S = S_{Phys} + S_{Info} \tag{14}$$

and then differentiating both terms:

$$dS = dS_{Phys} + dS_{Info} \tag{15}$$

and assuming dS = 0 we have:

$$\frac{dS_{Phys}}{dt} + \frac{dS_{Info}}{dt} = 0 \tag{16}$$

from which:

$$-\frac{dS_{Phys}}{dt} = \frac{dS_{Info}}{dt} \tag{17}$$

This last equation implies a variation of the two members, equal in absolute value, of the physical entropy and the informational entropy, but of opposite sign. So while the physical entropy grows towards a maximum, the informational entropy decreases by a similar amount. Such an equality, but of opposite sign, can make one think of a conservative system. Furthermore, seen on a ”complete cycle”, it is typically an isentropic transformation, similarly to what an adiabatic transformation does (i.e. without heat exchange with the outside) which is reversible (i.e. which occurs in successive very small, almost infinitesimal, time intervals) and therefore on very, very long times. Similar to what happens in our universe, for which one can well speak of a cosmological necessity for the overall entropy of the universe to remain constant. If all this is reasonable, the question remains whether the ”complete cycle” cannot be ”big bang ↔ big crunch”! That is: are we in a cyclic, conservative, isentropic, adiabatic and reversible, but metastable universe? The attribute “conscious” is missing, in the STOQ perspective, but perhaps it is premature to talk about it!

7 Conclusions

Conjecture aside, what is taken for granted is that near the event horizon of a black hole, quantum fluctuations can spontaneously create short-lived particle pairs. While one particle of the pair escapes the vicinity of the black hole, the other, negative-energy particle, disappears inside it. The escaping particle (Hawking radiation) has positive energy, and causes the black hole to lose energy and therefore mass. But Hawking radiation is not supposed to carry any information about the black hole that emitted it, although nowhere else in physics is there evidence that information is permanently lost. Ultimately, in the world of physics today there seems to be a sort of contradiction, especially in the eyes of those who are not involved and do not follow the developments of physics very closely and in a professional way across the board (for example, science communicators, amateurs of scientific disciplines, practitioners of natural philosophy, etc.). On the one hand, we continue to talk about the information paradox and on the other, there seems to be a consensus:

- on heat death as a possible final fate of the universe, sometimes associated with a big crunch, even in an accelerated expanding universe (dark energy problem);

- on the fact that in one way or another, all reality: energy, matter, radiation in general, including space-time itself and all information, ultimately seems may fall into a black hole where everything will remain trapped, except Hawking Radiation. But, if it is space-time itself that disappears (or at least a portion of it), it means that it is not at the root of reality, but something deeper must exist;

- on information that can escape its gravitational prison of the black hole, even without specifying with certainty where it will nest; which is why it is said, in a (somewhat ambiguous) way, that black holes can spread information;

- on the existence of white holes (first forbidden, then presumed and then almost expected on the basis of loop quantum gravity) in a more or less close relationship with information.

The consecutio of all this, even according to a STOQ approach, if on the one hand seems to confirm the evolutionary process equally applicable to the human phenomenon and the universal phenomenon, without denying but incorporating the classic Darwinian one, outlined in different steps by Teillard de Chardin (energy → matter → biosphere → noosphere → Christic entity, the latter implying the "sacrifice of oneself for the life of other livings") on the other hand seriously poses, among the others already listed above, the following questions to be answered:

1) Considering that the Big Bang is also the native event of spacetime, at the end of time, assuming that there will be a final big crunch (or a big bounce) with the collapse of the ultimate matter into a compact form (a single or multiple black holes), will there still be spacetime or will it disappear into the singularity and, in case of a cycle, at least for some discrete or infinitesimal spacetime, will the process pass through a singularity that is both final and initial at the same time? So approaching such a singularity by flattening like a pancake any three-dimensional entity "the reality" becomes effectively two-dimensional and crossing such a singularity becomes three-dimensional again, but will appear backwards [22]? There is an authoritative research and blog that raises the idea of the possibility that Earth's universe actually existed before the point known as the Big Bang and this would justify the idea of a time greater than what is now believed to be the age of the universe. As well as raising the idea that on the other side of the Big Bang there could be not only a contraction of space, but also of time or in any case a change of orientation.

2) At the end of time, in case the Black Holes (or the ultimate huge black hole of the Big Chill) that evaporate into the enormity of empty space through Hawking Radiation, constitute a dissipative system in which the huge "cloud" of photons that emerges is a non-equilibrium structure that is lost like an echo together with the pre-existing space-time?

3) At the end of time, during BH evaporation and WH formation the Bekenstein limit, conceptually tied to equation (7), maintains its validity for any system? So that:

$$I \leqslant \frac{2\pi ER}{kcln(2)} \tag{18}$$

where I = information of the system, E = total energy , R = max radius of the sphere enclosing the system, k = Boltzmann constant, c = speed of light, and expressing the energy in kg of mass and the radius in meters we can have the information in bit as follows [23]:

$$I \leqslant 2.57686 \cdot 10^{43} \left(\frac{M}{1Kg}\right)\left(\frac{R}{1m}\right) \tag{19}$$

What is illustrated above, without mathematical models, nevertheless based on the facts of Physics, is obviously a conjectural reasoning to draw the attention of Information Physics to a possibility of explaining definitively – with the appropriate in-depth analysis of the case – where ultimately all the information of the reality in which we are immersed ends up, on the basis of a specific conservation principle. Paraphrasing Karl Popper, one could say that here we insist in contributing to push modern physics to deal with "clouds" (conjectural Unicum in this case) leaving classical physics to deal with "clocks"(implying when and where). On the proposed conjecture, however, there are several clues in favour:

- the proposed conjecture conforms to the Equivalence M/E/I/ which is more than a conjecture being M/E/I in brief an extension of the proven Landauer's Principle; which is not questionable being experimentally proven;
- from loop quantum gravity we know of a close relationship between the black hole, the information contained in it and the relative white hole that emerges from it: "The information remains in the black hole. It comes out when this has transformed into a white hole capable of living for a long time" [7] pg. 136;
- the possibility that information remains encoded in the photons of Hawking radiation (or are the means to encode it) does not only appear theoretically possible, but can find support in the fact that modern quantum computer technologies in development can be based on photon encoding. In particular, photons are considered promising candidates for qubits (units of quantum information) in quantum computers;
- the Unicum, i.e. the resulting BEC acting as a single entity, far beyond a simple coalescence phenomenon, appears to be the product of a cyclic, conservative, isentropic, adiabatic and reversible, as well as metastable universe, as better described above;
- the extreme low temperature at which the hypothesized coding of information in the final Unicum would occur, i.e. in natural conditions at the lowest energy level; therefore in optimal conditions both from an energy point of view and from the point of view of information preservation. Furthermore – conjecture within the conjecture – the end of BH evaporation could be a signal for the Information already encoded in the Unicum of the possibility of a potential start of a new cycle; in line with the Standard Model, but presumably also in any appropriate hypothesis of a Conformal Cyclic Cosmology in accordance with the general scheme proposed by R. Penrose (Nobel 2020).

Unfortunately, or "fortunately", we are in an experimental physics context and it does not seem to be in a forensic process of an evident nature, where the custom and sometimes the norm is that one clue is a clue, two clues are a coincidence and three clues can constitute proof. In this case, the final proof could be found in the annihilation experiment described above; proof that information ultimately, in a context of BH/WH and thermal death, could be encoded by the same thermal radiation and stored in a coded way according to the energy/spin of the MIR and FIR photons.
The previous "fortunately", however, refers to the fact that if we were in a forensic trial of an evident nature we could already have more than three clues; and this in a STOQ discipline context would immediately bring to mind "New Heavens and a New Earth". That is, a lemma from the New Testament: "Then I saw a new heaven and a new earth, for the first heaven and the first earth had passed away, and the sea was no more." (Revelation 21:1). A scenario that a "Reality Reloaded" hypothesis can well realize from a physics point of view in an emulated universe reality, perhaps even changing the environment and leaving the virtual life that inhabits it intact. And everything could end up resembling one of the many virtual realities that our modern technology offers to our young people "for fun" (and for

business), while instead it is science, and not for fun.
In the face of the surprising and apparent coherence of all this, a STOQ approach could also recall, regarding the Creative Power, that: «... (His) power is in fact fully manifested in weakness... (2-Cor. 12,9)» of a faint, cold cloud of photons, residual light of a bright past world in sight of New Heavens and a New Earth! And it would not be a question of the Eternal Return of a mechanistic world, which would in any case be governed by probability and not by determinism as quantum physics already teaches us.
Humanism, positivism, empiricism; determinism, probability, are part of human culture; can all this as well as reductivism, relativism or absolutism, etc. still have any conflicting meaning in the processes of human knowledge? The physical laws that govern creation are laws of the Creator and therefore truths no less than those that can be deduced philosophically or theologically. We are all "on a journey", in search of the Truth in a historical moment in which Science seems to struggle to maintain its credibility, while Theology and Philosophy try to gain one that goes beyond cultural and religious reasons. The contributions that the Natural Sciences, and in particular the Physical-Mathematical ones, can also make to Philosophy, Natural Philosophy and Theology, even if only in terms of new themes of reflection and research, do not seem negligible, while respecting the autonomy of the individual Sciences involved, whether physical or humanistic,. It no longer seems possible, today, to think of cultural education and the humanistic disciplines without a scientific education and vice versa. The Unity of Knowledge returns to being a necessary prerequisite in academic studies and, in general. Even specialization in different branches of Science appears functional to the sustainability of a future in which Knowledge itself becomes synonymous with Human Dignity. All this also for those - ordinary unknown men of the great and indistinct river of life - who do not set themselves particular goals of success or gain, but simply of a sober normality, even if simply statistical, which however could allow them to approach the meaning of this existence to which they have been called.
In short, studying the universe of the end times, in the hypothesis of heat death, would be impossible without Quantum Physics, as well as Classical Physics, Information Physics, Philosophy, Theology, Biology, Maths, etc. Specialization is important, but a unified approach to all Sciences is therefore necessary, avoiding hyper-specific formation that could lead to One-Dimensional Man in the sense of the sociologist Herbert Marcuse. Perhaps this is where C. Rovelli's suggestion to his students comes from: "if you want to study science, study philosophy". From the point of view of a neophyte who loves science without having had the privilege (and perhaps the potential) of professing it professionally, the above mentioned WH/BH coexistence reason alone would be enough to counter the assertion that quantum gravity is dead. Contra-positions, rather than multi-disciplinary synergies, between different branches of science seem more frequent than ever and very often can be traced back to conflicts for scientific and academic survival. And as usual, funding problems hide behind them, often allocated with competitive criteria, as if Knowledge were a commodity, as already happens with the products of nature. Today there are those who highlight that in the East, some "alien systems", believers in autocracy but not far from competition-oriented, seek and experiment more, with faster growth and greater results than a declining West. A spontaneous digression far from the topic under discussion, but which may give rise to hope, that may bear fruit, because that growing process known as the intellectual unemployment (particularly in science field) of our young Europeans bears the signs of sin against humanity.

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accepted in the scientific community.

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