POTENTIAL IMPACT OF FCP IN FUNDAMENTAL PHYSICS AND COSMOLOGY

Introduction to editorial project about the foundations of space, time and knowledge, P. Journeau, phil@revuer.org

A '*Fourfold Co-necessity principle*' (FCP) was introduced through a series of short papers in the 2000s[1]. The driving idea is that a co-necessity of four specific dimensions – 'dimension' here relating to a type of dimension, a term with different meaning between Physics and Mathematics – suffices to derive the behavior of the world. One difficulty being that, consequently, none of the dimensions can be defined without involving the others.

One of the papers[2] proposed an applied instance from where Ω_Λ came predicted at $\pi/3\sqrt{2} \approx 0.74048$, in a way that may suffer a more detailed scheme of inference, hence our goal of a series of longer papers. Especially toward the aim of more precisely linking and deriving it from established theories and results in Physics and to the extent that the cosmological parameters so predicted currently seems consistent with recent observations[3].

The FCP, written as the base K ≡ (A, L, S, N), targets K as their co-necessity to define Knowledge, in a direction where theorem-proving procedures and formal linguistics have brought the seminal prover vs. verifier duality[4].

'A' here denotes a most important dimension, Time, after Gross[5], but in FCP not restricted to the usual, non oriented and either mathematically reversible t coordinate or physically related to most basic, electromagnetic phenomenon, although Hawking's example of Wick rotation $t \rightarrow i\tau$ already amazingly encircles it. We rather define time by its capacity to separate the future from the past. The future memorizes, hence somehow emulates the past, with some capacity to reduce, model and reproduce it. Conversely, to move toward a future, next 'event horizon', one integrates paths to their boundary of surface of dependence, from where is memorized their past.

This definition has many advantages, beyond its intrinsic irreversibility – furthermore mathematically demonstrated below – and its capacity to link phenomena ranging from physical to psychological: it seems particularly suited to relate definitions common to Formal and Computational linguistics with trends observed in Cosmology and Fundamental Physics such as strings, holography, correspondence, boundaries and new types of dimensions. For instance in Computational Complexity (CC) it can be related to the dimension of the Accepting (Oracle) or further to (psychological) Authoring Observer's type of ending boundary since this is what 'ends' or terminates a computational process. We have come to figure this Turing's Oracle as a Closed Timelike Curve – a case applied by Gödel to cosmology – which actually directly results from a Wick rotation which would, for the formal world, convert computers Oracle tape to a local circle, with then dynamics allowing to behave as a string.

This may also be in some sense related to the 'RG' Renormalization group scale that Verlinde has "*promoted to a real physical extra direction*[6]", especially while divergence is precisely what drives the future in the FCP.

'L' is the dimension for forms, hence the formal dimension, usually starting with most basic angular coordinate but then encompassing its dimension as a space of Languages, as seen from Category Theory to Linguistics, with cases such as usual Lagrangians in Physics. It may not look like a dimension at first and inasmuch as dimensionality refers to some pre-order but CC has discovered and progressively structured a hierarchy of Languages. Through the co-necessity, this hierarchy interacts with our definition of time since the external to event horizon may 'talk' through the boundary, as reflected from AdS/CFT correspondence with holography, where diverse levels of (formal) L level may be located and linked into A through 'sums over histories'.

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[1] http://dx.doi.org/10.1063/1.2737004
[2] http://dx.doi.org/10.1063/1.2947668,
[3] A. Riess et al., *A 2.4% Determination of the Local Value of the Hubble Constant*, ArXiv: 1604.01424, [Astro-ph.CO], 2016
[4] S. Goldwasser, S. Micali, C. Rackoff, *The Knowledge Complexity of Interactive proof-Systems*, ACM 1985
[5] D. Gross, *The Coming Revolutions in Theoretical Physics*, U. Berkeley event, 2007, U Tube
[6] H. Verlinde, *Holography and Compactification*, arXiv : hep-th/9906182

Central case of such integration in Physics is the Action, common to gravity as Einstein-Hilbert and to Quantum Mechanics, with links such as Hawking's wave-function of the universe[7]. The Action exemplifies FCP element with 'A' term as it closes a fourfold series of path integrals in the fully integrated term that a t_f, conversely, does not reflect at all. In other words A is the effective future and t_f a mere projection on base phenomenon. Penrose about decoherence, as well as Witten, about the central role of the Feynman graph, wonder whether anything exists of these events, which are what the concept and principle of co-necessity embed and activate.

'S' then naturally and conversely comes for Spontaneous Change, hence as opposed to an invariance particularly projected in L, although the FCP immediately implies the HUP. Now, something curious happens: entropy decreases along our time rather than increases, an apparently weird and even forbidden conclusion. It is however naturally compatible with the second principle, which states that entropy grows or is conserved in a defined system while our definition, and demonstration, implies that such system power conversely grows with time.

So, a concordance is happily recovered through this definition of time, whereby the proper time of a system implies that the system itself may not become more complex but only decays through a growing entropy – or is maintained on its self-defining CTC – that sends it toward its less organized, multiple, past interior. But where, from the exterior of the system and able to feed it with some low entropy, such as objects falling in a black hole, its next horizon is the future at the limit of the cutoff from where and when it is encompassed as an object.

Finally 'N' summarizes Natural... length, or space, whose apparent 3-dimensionality is another instance of the FCP[8]. One sees also, through Verlinde's transformations cases or already Wick rotation, that spatial (translation) may be turned into angular or (con)formal (rotation) when the type or form of change is itself… rotated. Rotations within the FCP are among self-induced manners to derive predictable effects from singularities.

Now, so principial or general a basis is meant to show a potential from which to derive other principles or models more restricted in scope but conversely more directly predictive, ranging from physical (for spatial manifolds) to grammar models such as Chomsky's natural for semantic spaces to formal and to computational, or Turing Machine models, already shown equivalent in the classical literature on formal linguistic[9].

Our claim is that a common geometry links them – each pertaining to an FCP complexity level or phenomenon Φ_i in some precise and oriented way, for instance when singularizing or rotating some projection into another one where the S dimension gets singularized for invariance.

From a principle, consequences depend upon application, in that case to objects characterized in Physics as primarily spatial, making it difficult to get to relativize the concept of space, although this is what CFT did. A universal R size phenomenon is then an object rather than some enormous aggregations of micro-states as highlighted by E. Witten about the paradoxical equality, for Black Holes, between microstates calculus and single R_{BH} based spherical area and by L. Smolin about the type of boundary that delineates Dark Matter.

In his summary of physics foundational issues, infra, D. Gross also exhibits a representation of a most basic formal/anti-symmetry coordinate as a fermionic $\theta_i\theta_j = - \theta_j\theta_i$. He further questions the foundations and emergence of space-time and quotes E. Witten's "*space-time may be doomed*" and N. Seiberg's "*space-time is an illusion*".

A question then comes: if space-time is emergent, then what or where from? Another page of Gross' showcases what is known as 'the Landscape' to summarize a picture of a multiverse where all kinds of universes seem to emerge, each with a different set of cosmological parameters and ongoing history. The mapping looks like a three dimensional spatial multiverse, the screen being two-dimensional though. The thing is sometimes hypothesized otherwise, the multiverse or many-worlds being then no more spatial than a singular, minimal

[7] J. Hartle, S. Hawking, *Wave function of the Universe*, Physical Review D **28** (12): 2960, 1983
[8] http://dx.doi.org/10.1063/1.4728011
[9] J. Hopcroft & Ullmann J., *Formal Languages and their Relations to Automata*, Addison-Wesley ed., 1969

Planck length vacuum string, from where universes would be all instances. Meanwhile, from our definition of the future, the wining universe is the one with most future, hence able to emulate the others, hence resulting from some common past wild divergence, but then better summarizing, and somehow compactifying it.

Not so important a space may then start from one dimensional manifold as explained by Witten[10], whom derives powerful results in a solely one-dimensional space. With another proper conversion and rotation of this remaining length space into then a Planck cell may result an FCP string, from which derives a whole universe.

One other reason to take interest in this relativity of space dimensionality is summarized as "*The expansion of voids render their interior similar to finite open universes with self-similar structures of their cosmic web (Gottöber et al. 2003; Aragon-Calvo et al. 2010)"* by Wojtak, Powel and Abel[11] at the start of their own paper.

Now if our Planck length dimensional FCP space, or kind of superspace, also plays the role of the entire vacuum, one sees that the 10^{120} or 10^{60} or 10^{16} cosmological constant magnitude problem vanishes, provided that the rescaling between the Universe scale and the Planck scale is appropriately accounted for, which is what the FCP allows through A as dimension that terminates the object, here a universe termed from its integral vacuum.

The increasing flexibility of the concept of vacua, as well as rescaling and CFT, facilitate seeing this with ongoing a vacuum Big Bang consistent with our definition of time and as White Hole (A, L, S, (L_p)) singular in spatial dimension rotated into conformal (A, L, N) full universe spatial boundary configuration to describe our end of the Universe. As pinpointed by Gross, this is where missing link was sought in current research, between interior well modeled by ΛCDM consensus and yet boundaries, start and end of time remaining major issues.

Now Wojtak, Powel and Abel's paper mentioned above precisely "*demonstrates a new method that yields a continuous mapping between boundaries of voids at all redshifts, from initial conditions to the present time*".

Remains to see the boundary where or when the late acceleration occurs, with a type of maximum that nevertheless differs from Hawking's since expansion rather than contraction occurs. This is where the critical role of the boundary synthesized and born into the A, vacuum dimension, comes into play: future to next complexity level involves an anti-symmetry level-up, beyond the gravitational, classical energy density one, where Black Holes may only grow inasmuch as a White Hole is able to feed them, hence from its own very Large Scale Structure Anti-symmetry. Then the next level able to emulate and sum matter over its own histories may be born only once a maximum is indeed reached at previous 'A' complexity level, in that case gravitational/LSS but, instead of contracting it to Big Crunch, rather accelerates the universe and repels further the void structure out of the walls – also mentioned by Verlinde – where the vacuum localizes next complexity.

Note that the puzzling Dark Matter non-local boundary similarly fits well with what the 'S' dimension implies. Now the thing often missing in science is the object itself, versus its subject, the observer, of whom Geroch[12] emphasizes the role for General Relativity while Penrose conversely focuses on the issue of some universally needed 'Objective Reduction' (OR). So this results from complexity density requiring space in order to take shape and conversely energetic space to trigger it to change level when its relative cap is reached.

So, a complexity level has some type of memorizing and objective reduction capacity that its own defining 'sum over history' summarizes toward the future that keeps it as an object in its CTC. Carroll[13] highlights this 'memory' aspect of time. Time is about terms embedding 'at once' – using a key aspect of the definition of the oracle – and conversely emulate the paths followed to it. If the paths are stringy, time is stringy inasmuch as summarizing the object as actualized from a supposedly pointlike start to a full A string level, once terminated.

[10] E. Witten, *What Every Physicist Should Know About String Theory*, String 2015
[11] R. Wojtak, D. Powell, T. Abel, *Voids in cosmological simulations over cosmic time, arXiv: 1602.08541 [astro-ph.CO]*
[12] R. Geroch & G. Horowitz, *Global Structures of Space-time in General Relativity*, an Einstein Centenary Survey, ed. S.W. Hawking & W. Israel, 1979
[13] S. Carroll, *From Eternity to Here, The Quest for the Ultimate Theory of Time,* Plume ed., 2010

An example was expressed through the introduction[14] of "*a 'physical' space-time (Ḿ, ǵ)"* that was "*associated to a smooth 'unphysical space-time (M, ω) and a smooth function Ω on M, such that Ḿ is a subset of M*", where the role of the second as 'term' of the first, from a semantic space that FCP nevertheless geometrize and link in a common reality and 'Integral Universe', giving it a physicality, as a future, similar to that of other divergences.

If it is the universe, then the time embeds the history that led to this universe, of which the CMB is an obvious sizable trace, but if we often tend to restrict this cosmological universe to its gravitational systematic or object.

As a summary the universe must become more complex in the direction of the future, thanks to some divergence and maximal local heterogeneity – which itself derives from this definition of the future and required increasing complexity density – and from this equivalence of the future with complexity density needs all the more room that the structure is complex. Or conversely, once a maximum is reached for some, phenomenological complexity level – here gravitational or mass-energetic, interpreted and visualized as the typically spherical embedding but otherwise as matrix - which correspond to the mass phenomenon in the interior, the expansion goes on by accommodating the next (FCP) complexity level, which m carries the properties of life inasmuch as definable by its capacity to emulate mass from its own object level and with its own reproducibility or CTC.

This FCP representation appears to solve several other issues, to be further detailed, such as non-local entanglement, but here seems to apply well to current cosmological issues, and a geometry gap also applies to intelligence. Penrose and Carroll recall that low entropy is generated from the sun and converted by life while the reemitted radiation is higher entropy, such as infrared, but does not bring the specific geometry of the living as a phenomenon of its own. Similarly for intelligence and the semantic spaces that come to manipulate mathematics of the continuum, and renormalization itself, the related geometry and stringy level is at hand when considering the power level embedded once considered as Turing's oracles. These intelligences obey our definition of the future and carry the emulating and memorizing capacities that enable them to be what Geroch requires from his definition of the Observers.

They may fit also along Verlinde's RG direction, to be further related to this 'FCP' framework and process along which, moreover, models and processes develop and find room along this overall anti-symmetrical and even divergent ladder –conversely renormalizing – to begin with, as an example, the case of fermions and the typical type of spatial extension that they, as a result, require when taking shape takes place.

To conclude, the principle of maximal complexity density growth, which we have previously shown an appropriate model and definition for oriented, effective time, hence for the Future, results from the way Nature resolves divergences,– which mathematically lead to such future. These appear as geometrically reached, for instance by opening new dimensions and conversely compactifying previous ones to result in structures of intermediary complexity, of which the enclosing 'term' are resumed in boundaries or horizon such as exemplified by Riemann sphere $\mathscr{I}$.

An example was given for the equivalent Dark Energy – effectively the future – being capped by what was interpreted as Kepler's limit of three-dimensional sphere stacking, of which the spatial projection could appear in the form of cosmic voids and related domain walls, hence the resulting equivalent energy density ratio.

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[14] L. Andersson, P. Chrusciel, *Solutions of the constraint equations in general relativity satisfying hyperboloidal boundary conditions,* 1996