Qubit transition into defined Bits: A fresh perspective for cosmology and unifying theories

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Running head: qubit cosmology – a fresh perspective

Abstract: In this view point we do not change cosmology after the hot fireball starts (hence agrees well with observation), but the changed start suggested and resulting later implications lead to an even better fit with current observations (voids, supercluster and galaxy formation; matter and no antimatter) than the standard model with big bang and inflation: In an eternal ocean of qubits, a cluster of qubits crystallizes to defined bits. The universe does not jump into existence ("big bang") but rather you have an eternal ocean of qubits in free super-position of all their quantum states (of any dimension, force field and particle type) as permanent basis. The undefined, boiling vacuum is the real "outside", once you leave our everyday universe. A set of n Qubits in the ocean are "liquid", in very undefined state, they have all their m possibilities for quantum states in free superposition. However, under certain conditions the qubits interact, become defined, and freeze out, crystals form and give rise to a defined, real world with all possible time series and world lines. GR holds only within the crystal. In our universe all n**m quantum possibilities are nicely separated and crystallized out to defined bit states: A toy example with 6 qubits each having 2 states illustrates, this is completely sufficient to encode space using 3 bits for x,y and z, 1 bit for particle type and 2 bits for its state. Just by crystallization, space, particles and their properties emerge from the ocean of qubits, and following the arrow of entropy, time emerges, following an arrow of time and expansion from one corner of the toy universe to everywhere else. This perspective provides time as emergent feature considering entropy: crystallization of each world line leads to defined world lines over their whole existence, while entropy ensures direction of time and higher representation of high entropy states considering the whole crystal and all slices of world lines. The crystal perspective is also economic compared to the Everett-type multiverse, each qubit has its m quantum states and n qubits interacting forming a crystal and hence turning into defined bit states has only n**m states and not more states. There is no Everett-type world splitting with every decision but rather individual world trajectories reside in individual world layers of the crystal. Finally, bit-separated crystals come and go in the qubit ocean, selecting for the ability to lay seeds for new crystals. This self-organizing reproduction selects over generations also for life-friendliness. Mathematical treatment introduces quantum action theory as a framework for a general lattice field theory extending quantum chromo dynamics where scalar fields for color interaction and gravity have to be derived from the permeating qubit-interaction field. Vacuum energy should get appropriately low by the binding properties of the qubit crystal. Connections to loop quantum gravity, string theory and emergent gravity are discussed. Standard physics (quantum computing; crystallization, solid state physics) allow validation tests of this perspective and will extend current results.

Introduction

Current cosmology fits well except early time points: current cosmology provides good descriptions for everything after the hot fireball started, including distribution of different elements, microwave background, current age (13.8 Gyrs; Planck Collaboration, 2018) and expansion of the universe. Challenging are the early time points, for instance inflation scenarios are now in trouble after BICEP/2 could not detect turbulences from rapid early expansion (Ade et al., 2018; Chen et al., 2019). Moreover, superclusters and galaxies seem to have formed too fast and too early (Long et al., 2020), and some observed components are unexplained such as dark matter and dark energy (Huterer and Shafer, 2018) while others are postulated and but not directly observable such as the inflaton (Albrecht et al., 2015; Rosa and Ventura, 2019). Moreover, this standard model, in good academic tradition, is just descriptive: there is no explanation *why* there was a big bang, *what* was before, and *why* this universe is so optimal suited for life including us. This is called the fine-tuning problem for optimal life conditions in our own universe. The textbook answer to this is the anthropocentric principle (Barrow, 1986), which is only a logical argument (or a bizarre nightmare: "we are a freak coincidence and just incredible unlikely but possible, however, if there is no observer nobody can wonder about his/her existence in the myriads of other dead and unconscious worlds") but the anthropocentric principle does again not really explain the *why* there is life and conscious existence in our universe.

My new perspective looks at qubits to provide new clues. Qubits are known from quantum computing (Pan et al., 2021), they sample over all possibilities with their wave function in coherent state and, under appropriate conditions, they "freeze", i.e. they become decoherent and a defined state to deliver the result of the quantum computer computation. We ask here:

Could our whole universe be the result of such a qubit cluster solidification process?

Our new concept extends own previous efforts (Dandekar, 1991, 2021). It does not change much cosmology after the hot fireball starts (hence agrees well with observation), but the changed start and resulting later implications (formation of voids, superclusters, galaxies; matter) lead to an even better fit with current observations than the standard model with big bang and inflation.

In an eternal ocean of qubits, a cluster of qubits crystallizes to defined bits. In our perspective, the universe is not created out of the blue and jumps into existence but rather you have an eternal ocean of qubits in free superposition of all their quantum states and of any dimension, force field and particle type as permanent basis for everything. This is completely undefined, the really boiling vacuum and in this perspective this is the real "outside", once you leave our everyday universe. If you consider here n qubits they are hence in a "liquid", very undefined state, they have all their m possibilities for quantum state each in a "wild" and free superposition in them (**Fig. 1**). However, under certain conditions the qubits interact (**Fig. 1a**), become defined and freeze out, crystals form and give rise to a defined, real world with all possible time series ("multiverse"; Tegmark, 2007) and world lines. GR holds only within the crystal (**Fig. 1b**). Moreover, crystals come and go in the ocean, selecting for the ability to lay seeds for new crystals (**Fig. 1c**).

As a result, all n**m possibilities are nicely separated, have become defined bit states, are real – and this creates our universe (**Fig. 2**): The toy example with 6 qubits each encoding 2 states illustrates, that this is completely sufficient to encode space using 3 bits for x,y and z and particle type (1 bit) as well as state (2 bits). Just by crystallization, space, particles and their properties emerge from the ocean of qubits, and following the arrow of entropy, time emerges, following an arrow of time and expansion from one corner of the toy universe to everywhere else (**Fig. 2**). This new perspective on cosmology provides hence time as emergent feature considering entropy: crystallization of each world line leads to defined world lines over their whole existence, while entropy ensures direction of time and higher representation of high entropy states considering the whole crystal and all slices of world lines (**Fig. 3**). The crystal perspective is also economic compared to the Everett-type multiverse, each qubit has its m quantum states and n qubits interacting forming a crystal and hence turning into defined bit states have only n**m states and not more states and there is not any world splitting (**Fig. 3**) but rather individual world trajectories reside in individual crystal layers (**Fig. 4**): So in some trajectories Schrödinger´s cat is dead and in others alive, but in a macroscopic world there are never limbo states of alive and dead in superposition (this is only possible in the chaos ocean outside the crystal).

Our conceptual advance explains all current astronomical observations a bit better: Only (i) “big bang” and (ii) inflation are replaced by (i) a qubit condensation event in an ocean of qubits and (ii) the unit cell symmetries of the resulting crystal, respectively. The crystal unit cell assures the same symmetries everywhere in a crystal. There is hence no need for inflation. After these very early steps the normal expansion scenario of a hot fireball representing our early universe and standard cosmology starts, fitting well to all current observational data. So why bother to introduce here a new model and perspective?
First, several astronomical observations are better explained by the new theory which are difficult to understand assuming inflation, e.g. early supercluster formation, galaxy formation, no strong perturbations at start. In particular, voids and filaments on the largest scales in the observed universe are difficult to explain if derived from inflation as everything should be equalized whereas in a crystal such central voids and filamentous structures around the voids can easily form. Similarly, misplacements happen usually and often in crystals. For cosmology this implies very early starting seeds for supercluster formation which are difficult to explain in inflation cosmologies. Furthermore, galaxy formation requires dark matter in the halo and normal matter in the galactic center and disk. Such a specific distribution is easily furnished during a crystallization-like process but again rather difficult to reconcile with inflation.

Finally, the big question why there is only matter and no antimatter around is easily answered using the crystal paradigm: in our universe we have as symmetry unit for the crystal one, which has the handedness of allowing only matter, in another type of crystal we would have the opposite handedness and only antimatter. This scenario is inherently more plausible then the idea that by a gigantic annihilation process of matter and antimatter just a tiny fraction of matter survived and hence we have our present universe only with matter. Whether such a reasoning can even help string theory with its supersymmetric particle zoo where the supersymmetric particles have never been observed up till today yet remains open but should be examined. The big mathematical advantage of having the supersymmetric partner to cancel out infinities much more elegant then QCD renormalization should be an incentive.

Second, new and old problems should get an answer: Dark energy, vacuum energy calculation and the two complementary views of general relativity and quantum physics should be better reconciled. We provide for this here a new perspective, however, we rely on established formalisms and explain in which direction new developments can be triggered by our perspective.

Thirdly and finally, we get a real conceptual advance on the great questions of cosmology: in particular we get an idea why our universe is so life friendly (many generations of crystals were selected to self-organize best to seed the next generation of crystals and our universe is in fact one layer, one defined world line of the crystal) and why our macroscopic world is defined and solid and not an ocean of super-positioned wave functions – in other words, why is there a defined reality and decoherence in our macroscopic world? Even the most fundamental question of all is tackled here: why is there a universe in the first place and not nothing or just chaos.

Platonic philosophy starts from the Platonic space of ideas. To form a world, ideas have to come together and form a world with constant and variable features. This basic concept is taken here to a physics level: Qubits of any dimension and state are shown to only possibly interact in a one, two, four or eight dimensions, no other solutions are possible. Hence the E8 symmetry is the richest of all four solutions and exactly that observed in our universe. The super-heterotic string theory is according to this reasoning a good first approximation of a theory of everything. The open question how to fix the many open parameters is answered by looking how the crystal can best seed its next generation: it has to be favorable for self-organization including life. Hence, the parameters have to be fixed such that we derive a life-favorable universe. The mathematical appendix explains which routes have to be followed to derive a proper mathematical description of my theory, but this perspective is foremost a creative adventure like Poe´s "Eureka" (Poe, 1848): an inspiring concept to tackle the fundamental problems with a new perspective and spirit. I am convinced that following my perspective will allow to find real answers to the fundamental questions of physics of our time. We examine also how different theories of physics may contribute: QCD and lattice theories, the latter should include gravity; loop quantum gravity (LQG) and string theory; emergent gravity. I hope the perspective is an incentive for all interested theoreticians to provide a more in-depth treatment of the questions discussed.

Results

Overview: We sketch here the road to represent this scenario by formulas which actually can be quantified and applied (**Table 1**).

Table 1. Quantum action theory: Mathematical overview

Large-scale structure (validation: astronomical observations, see results)
Eq. 1 (when and how qubits can interact: is restricted to 1,2,4 and 8 dimensions)
Eq. 1b (energy difference between free and bound qubits)
Eq. 2 (entropy treatment in crystallization)
Eq. 2b (Dark energy is in fact entropic tugging of the crystal)
Eq. 3 (Long range interactions limiting growth of the cosmological crystal)
Eq. 4 (standard calculations for vacuum foam, free qubits 10**20 bigger then bound)
Eq. 5 (conservation laws expressed as symmetries of the crystal)
Eq. 6 (repulsive force for ultrashort distances between qubits)

Microscopic structure (validation: particle physics, quantum experiments)
Eq. 7 (S-matrix theory)
Eq. 8 (Term scheme)
Eq. 9 (quantum computations for proton mass)
Eq. 10 (quantum action and qubit-to-bit transition for a proton)
Eq. 11 (decoherence of quantum states in a multiple particle system)
Eq. 12 (confinement of quarks by a scalar field)

Framework to start from: QCD lattice theory
extend by the permeating interaction field of the qubit crystal (**eq. 1 – 6**)
extend step-wise the toy models (**Fig. 2; eq. 7 -12**) → full-scale model
Derive two scalar fields from eq.1 to 6 acting on lattice: quark confinement (**eq. 12**);
Extend Higgs scalar field to cover all aspects of gravity (see end of appendix)

All formulas are given and discussed in the mathematical appendix followed by a sketch of a unified framework. We have to stress however, the arguments in this results section are a heuristic, general perspective to find a new view on cosmology and fundamental physics. Hence, our arguments are completely independent of the particular formalism used. We are open to everybody interested in our arguments to test them for their consistency by the method of choice. Hence, the equations chosen are more taken to encourage development of the mathematical physics implied, but not with the idea to prefer one formalism over others, e.g. QED, QCD and lattice theories; LQG, string theory; emergent gravity; qubit calculations. Even wild scenarios for qubit behavior can in the end be tested by quantum computing experiments, this is clearly an advantage of our perspective.

Derivation of only four possible solutions for qubit interaction (see **eq. 1;** all equations are discussed in the mathematical appendix)

Quantum computing considers everything of course as a calculation. Here the *Hurwitz theorem* (1898) comes in handy: It proves there are only real and complex numbers as well as quaternions and octonions.
Hence considering that qubit interactions are analogous to a calculation operation, this implies that qubits cannot have any dimension if they interact, but *there are only one, two, four or eight dimensional interactions* possible,
The amazing point is that our real universe has eight-dimensional symmetry regarding the *standard model of particle physics and forces*, so implements in this sense the richest solution, the octonion result (Wolchover, 2018, 2019).

This *basic eight-dimensional symmetry of our world* regarding basic forces and particles is also taken-up by the heterotic string theory (Gross et al., 1985). One gauge group or flavour is SO(32) (the HO string) while the other flavor is $E_8 \times E_8$ (the HE string) (Polchinski, 1998). this is only a compatibility argument that we can in principle apply our Hurwitz theorem argument also to the existing string theories, in particular the HE string flavor with the E8 exceptional simple lie groups. The other four string theories are closely related and all are part of the M-theory (Duff, 1996). The E8 algebra is the richest and most complex group. (Adams, 1996), so an optimal basis for our rich world and easily includes also an eight-dimensional symmetry, being itself 248 dimensional (so 31 x 8).

Moreover, one has to consider the energy difference between qubits in their free state and in the bound, crystallized state yielding a world (**eq. 1b**, see mathematical appendix).

Order such as protein folding requires increasing entropy in the outside solvent:
Moreover, natural processes such as *protein folding* illustrate (Ghosh and Dill, 2009), that the folding and creation of high order is possible, if outside of the protein, in the surrounding liquid phase, the entropy increases (**eq. 2**). This would also be our cosmological notion, the universe created is allowed to develop an ordered state as according to the laws of thermodynamics, the disorder in the ocean of qubits outside should increase.

Furthermore, processes such as *crystallization* or *magnetization* illustrate that after a condensation nucleus triggers crystallization the crystal grows but only to a typical size, limited by long-range interactions becoming stronger and stronger (**eq. 3**). Magnetization-like processes and Weiss zone growth may be even closer come to the actual process, so that all qubits involved form one Weiss zone of the same “field orientation”, of being now in decoherent, frozen-out, “real state”, inside the crystal and this is in turn inside the much larger ocean and wild foam of qubits in undefined state. The wild foam will have the true vacuum

energy according to standard calculations (**eq. 4**) while inside the solid-state crystal of qubits you have a bound state and hence the vacuum energy is 10**20 times less as observed in our everyday world, a long-term physics conundrum is solved: The bound state in the qubit rystal suppresses the zoo of virtual particles.
Moreover, a real crystal made from minerals or proteins has a unit cell symmetry, ensuring always the same symmetries everywhere in the whole crystal. Hence, this perspective provides an alternative to cosmological inflation of just a single quantum state (“inflation”, Linde, 2017), as a crystallization or magnetization-like process of qubits ensures the same symmetries to any point in the crystal: The laws of nature are guaranteed inside our domain without any need for inflation! Crystallization can take as long as it needs and needs no rapid expansion as an inflaton-scenario would require. Moreover, any real crystal is *not* perfect and hence very small misplacements lay the seed for large-scale structures in our universe such as superclusters. Moreover, a crystal can accurately position in its structure normal matter and dark matter during crystallization such that galaxy growth starts early and optimal (**Fig. 4**).

Solid bit-states reside inside the cosmological crystal, outside there are free qubits: Inside the crystal all states are decoherent bits, no longer free qubits, and so hence, the vacuum energy is 10**20 in this bound qubit state, general relativity holds and space emerges (**Fig. 2**). General relativity does not apply to the ocean of free qubits outside of the crystal only described by quantum theory. Instead, the quantum world applies in the almost completely solid crystal only for the remaining uncertainty h dash below which the product of energy and time or mass with impulse cannot forced to become smaller. Our perspective is that this small “distance” separates different world lines and trajectories (**Fig. 3;** frozen-out bit states for each trajectory). Hence general relativity and quantum physics have here clearly separated domains where they apply and are bridged by the solid-state physics of qubits. String theory is mathematically consistent and by its mathematical beauty captures an important theme of our universe. In our perspective string theory captures the central symmetries of our universe as the basic symmetries (and laws of nature) are encoded in the symmetry groups of the crystal made from almost completely crystallized qubits (**eq. 5**). Strong repulsive forces at ultra-short distances prevent collapse of the crystal (**eq. 6**).

Getting our universe life-friendly by many generations of new crystal seeds: Achieving high ordered states is typically explained in biology by evolutionary scenarios over time and is the answer why a protein has adapted so well to its environment. Our universe exists only a finite time (13.8 billion years) and hence, it is reasonable to assume that it has also only a limited future. However, our crystal scenario would of course assume that crystals are not forever, they come and go. This implies that a crystal that creates condensation nuclei or seeds for its next generation is favored over crystals without these properties. This creates then an evolutionary process where better self-organization helps to create more offspring and fine-tunes the crystal to be favorable for self-organizing processes including life.

Normal everyday crystals exist only a limited time and dissolve again into the liquid solution. If there is the ocean of qubits around the little crystal of condensed, solid-state qubits turned into their “real” bit state, then it will try to dissolve the crystal by tugging at the crystal surface with the solvent and starting to dissolve the crystal. A speculation is that this tugging from outside on the crystal, trying to dissolve it, we observe (“inside the crystal”) as dark energy. The “big rip” scenario postulated for increasing dark energy would mirror the normal dissolution of a crystal in its solvent, but of course on a very abstract, cosmological level.

The new frame work: Quantum Action Theory
Heisenberg´s uncertainty principle is here the foundation: Below h dash all is possible, nothing is defined and real, only above it there is reality, are defined quantum states for

time, position and energy. In other words, we pursue here a concept analogous to quantum computation: everything is in an undefined superposition state, and only results are real and defined and this required the interaction of qubits at the start of our universe. However currently we are living or residing in the almost completely solid crystal (above h dash) so the established qubit interactions make sure that beyond h dash all is defined, implying also emergent time, space, energy, impulse, GR and so on.
Hence, for one simple quantum interaction you can rely on standard formalisms such as the S-matrix (**eq. 7**) or a term scheme (**eq. 8**). However, for an ensemble of n quanta with m defined states you have a multi-quanta interaction system and you have to consider and solve it completely to get the correct lattice of quantum actions.
We show this for a really simple case of six quanta which each can have only two possible states (Fig. 2). There is emergent time: along the arrow of entropy as indicated. You can easily consider entropy in such a multiple interaction system, a strength of this approach. We show also emergent space (another quantum property). Energy is inverse to entropy, and there are more refined emergent properties such as impulse. The next step will be to tackle a more realistic case for this "quantum action theory" by modelling a system of multiple quanta of action more realistically and considering again all states or "end results" (**eq. 9**; as in a quantum computation; Gilbert et al., 2007). However, this has to be done, following our perspective, for a complex multiparticle system like the proton considering all quantum states and considering the transition from a liquid, typical quantum state to a solid, decoherent, fixed state considering all its possible quantum states. Regarding the proton, this is an interaction-system of three quarks (up, up and down) in a lake of gluons (all color charges and many virtual particles and complex force fields). This is quite demanding in calculations if you do it in a classical way (**eq. 9**; Yang et al., 2018). Our theory explains also the confinement of quarks: There is asymptotic freedom of quarks in QCD (Gross and Wilczek, 1973; Politzer 1973). As color charge is confined by a scalar field it is impossible to have free quarks, they can only be freed by being color neutral or white. According to the qubit crystallization theory, the resulting seed and crystal is a very strong interaction over the whole crystal and provides a scalar field at level of grand unification (see mathematical appendix) which then in our present-day cooler universe broke down (symmetry breaking) into the four basic forces following the standard model.

However, according to our new perspective we have to identify all the decoherent, defined end results of quantum states larger then h dash and consider here the "free, liquid" qubit to "defined" bit transition (**eq. 10**). Hence, we want to tackle the problem of decoherence of quantum states from this new angle (**eq. 11**). It is critical for this new perspective to consider all such end results and even their entropy as otherwise derivation of emergent time, space and more complex properties such as impulse and energy is not possible. Hence, it is also clear that we think that LQG or string theory typically simply treat different scenarios far below h dash in the resulting total action. They often do not treat decoherence and often do not consider multiple particle interactions. This gap has been noticed also by theories such as emergent gravity (Verlinde, 2017) and others. We think, this perspective should help to extend fundamental physics in this direction – and this includes string theory or LQG. However, most promising is a "grand unified" lattice theory extending the toy model depicted in **Fig. 2**. This "quantum action theory" (**Table 1**) connects the astronomical, large-scale interactions of the qubits once they interact: they hence solidify and form our universe of defined bit states. Using a QCD lattice theory formalism, we have to extend this to include gravity. Importantly, in addition to the basic lattice necessary for the calculations and enumerating all quantum states, there is a lattice made of Planck´s quanta to mark the phase transition of the qubit lattice: below all is possible, Heisenberg´s uncertainty principle. However, above the threshold all becomes defined and clear bit states (**see Fig. 2**). The theoretical extension to include gravity considers the permeating interaction field of the qubit crystal (**eq. 1 – 6**) and extends step-wise the toy models (**Fig. 2; eq. 7 -12**) to a full-scale model of our universe. In particular, we can derive from this two scalar fields: one to explain confinement of quarks (**eq. 12**) by the permeating qubit interaction field acting on the strong force, and one extending the Higgs scalar field to cover all aspects of gravity (**Table 1**). Moreover, it should be comparatively easy possible to experimentally verify our framework, in particular by experiments on quantum states using well controllable lab systems such as super cold atoms (Bentsen et al., 2019; Swingle et al., 2016).

Discussion

Standard cosmology is kept intact after start: This perspective is well compatible with observation, as it completely agrees with and accepts the standard model as soon as the hot fireball is there. However, it replaces two postulated, but otherwise never observed processes, the big bang and inflation, by two natural processes (condensation nucleus and magnetization/ crystallization, respectively) and at the very least provides new ideas how to better represent these two very early processes of the universe by some better modelling ideas taking this perspective in mind. After these very early events, the textbook cosmological model is otherwise supported here fully: starting from the hot dense fireball the universe expands, after a dark time the universe gets transparent, primordial nucleotide synthesis starts etc.. However, by replacing the very early start scenario by more reasonable phenomena more amenable to testing and description, a number of deep questions in fundamental physics can be better answered, too. This paper is only a heuristic lead, a vision, everybody is most welcome to replace e.g. the formulas given in the appendix for a first detailed description by something more accurate, consistent or elegant including a string theory treatment (Green, 2000), lattice theory or QCD or new approaches such as emergent gravity.

Compatibility with and support from observation:
As our very early scenario transforms into the hot fireball textbook cosmology soon, agreement with observation regarding later steps of cosmology is excellent, as good as it currently is, for instance Hubble constant and expansion rate, primordial helium formation, start of the transparent phase. However, the suggested new very early steps actually agree better with observation: crystal misplacements explain far better observed really early galactic supercluster formation. These misplacements occurring in all natural crystals replace tiny quantum fluctuations blown up by inflation (replacing never observed inflaton, cosmic background is too even). There are a number of otherwise puzzling observations better understandable by the perspective: (i) why is there only matter and no equal amounts of anti-matter? The handedness of the crystal explains this far better than the classical fire-ball like annihilation scenario where a tiny bit of matter survives for unexplained reasons. (ii) Dark energy is a natural result of entropic tugging of the crystal. Dark matter is already prearranged at defined positions by the crystal structure to allow early galaxy formation and there are even more observations better explained by our perspective. Moreover, an evolutionary scenario explains independent of these first arguments the fine-tuning of all conditions to be favorable for life and self-organizing processes in general as self-organizing crystals survive better, seeding new generations of crystals. The evolutionary scenario relies only on the postulate that our universe has not only a finite past (13.8 Gyrs) but hence also a finite future (about 70 Gyrs, according to estimates according to the increasing rapid expansion driven by dark energy).

Compatibility of critical ingredients of the theory with established physics:

This theory was inspired from protein folding where creating of order in an evolutionary selected sophisticated structure is happening with concomitant increasing entropy in the outside water solution. This process is taken to cosmology: there is no creation from nothing but rather we have an ocean of qubits at start. The second inspiration was taken from crystal growth: here we need first a seed, a condensation nucleus, which then triggers crystal growth which finally stops once long-range forces get too strong. This is again a normal phenomenon taken to cosmology: Doing this predicts that as space and time and general relativity (GR) emerge and the bits crystallize out, limiting long range forces stop the growth of the interacting qubits. Next the hot fireball scenario takes over, grand unification is soon left by symmetry breaking with cooling down and expansion to create our fundamental four forces. This perspective assumes, however, a wild boiling ocean of qubits with vacuum forces high. The surprisingly low vacuum energies observed are explained from this perspective as occurring only inside our world, the "crystal". Why should qubits interact in the first place? Well, in everyday physics qubits for quantum computation interact so eagerly that larger qubit ensembles are not possible and new solutions such as to create more stable topological qubits are eagerly sought in the quantum computation field. However, in this perspective the high interaction potential of qubits in our everyday world is only the result that we are part of the crystal whereas "outside", or as a start seed for a world, the probability will be massively lower (many orders of magnitude, 20, 100 or even more). Hence, though inspired by two everyday phenomena, both the triggering condensation nucleus of qubits (**eq. 1**) as well as the size-limiting long-rage forces taking over (**eq. 3**; only then GR with normal space and time starts to hold and bits are crystallized out) are very difficult to calculate and need non-standard physics to be described (lattice field theory extending QCD to include gravity, LQG string theory, new qubit formalisms). Normal crystals dissipate and break after some time, so this perspective believes in dark energy leading to a big rip scenario in about 70 Giga-years though of course now particles such as protons are really stable and do not decay. The whole perspective is relying on a multi-particle theory in contrast to many textbook cosmologies. An important hint how solid and strong interactions between qubits can become under the correct conditions are majorana qubits (Aguado and Kouwenhoven, 2020).

Compatibility with established fundamental theories:
Imagining that *string theory* is only a reflection of the unit cell of our crystal may be inspiring (see **eq. 5**): First, there is the E8 symmetry as super heterotic string theory already there, but may be the perspective above can help to find out where the supersymmetric particles postulated by string theory reside (e.g. in dark matter or somewhere else) or to actually remove disturbing additional sets of particles postulated by string theory (super symmetry partners) and we replace also here the inflation scenario by a magnetization-like process.

Loop Quantum Gravity (LQG) shows that a big bounce scenario can be derived considering proper quantization (e.g. Ashtekar et al., 2006) but as here the quantization did do the trick, having qubits from start may be the inspiring new point: if all is made of qubits from the start, they cannot be smashed (see **eq. 6**). Moreover, a qubit treatment of LQG could remedy the problems with special relativity notorious in LQG.

Most notably, in contrast to typical cosmological scenarios from LQG for this perspective multiple particle interactions are critical, to probe the phenomena invoked (multi qubit interaction and condensation). Simple cosmologies with two infinite Hilbert space Hamiltonians (Ashthekar et al., 2006), one presenting inflation and one gravity fields is not sufficient to tackle a qubit phase transition as postulated here. Hence, very helpful are concepts on emergent time (Rovelli, 2004; Smolin, 2013a) and emergent gravity (Verlinde, 2017; Swingle and van Raamsdonk, 2014; Kleinert, 1987). Particular emergent gravity has central concepts close to our perspective and could actually implement and accommodate our perspective by implementing the formulas collected and sketched in Table 1.

Infinities in force field calculations (Yang Mills fields but also already electron force field) arise from the fact that you assume you can have infinitesimal small granularity. In our perspective this is not the case: qubits which are free in the soup are completely free, but as soon as you form the solidified interaction state as basis for our universe and having real, defined bit states instead of qubits all condenses to a grid. Its granularity is the elementary quantum of action, Planck´s constant of 6.626 x 10-34 Js. Hence, this is a master grid made from actions, not a space grid. Smaller than the size of the master grid of actions we have continuity and complete freedom, but anything larger occurs only in discrete quantum states (Fig. 2). This is according to observations. However, this is only a perspective, there is quite a mathematical road to master to incorporate this correctly: renormalization of other, finer grids for correct physics (e.g. effective electron radius), however, there is also the granular grid of Planck quantum actions to consider (see Appendix).

Fundamental symmetries may be simple, but fine-tuning and the universe are complex:
The “theory of everything” or a “world formula” generally refers only to the interaction of the four basic forces electromagnetism, nuclear and weak force (all integrated using the standard model) plus the challenge of gravity. In this perspective the integration is assured by the symmetry unit of the crystal. Inflation is not necessary, the qubit-interaction assures by its solidification and crystallization that we always have the same symmetry unit in all the crystal and the crystal needs not to form extremely rapid, so there is no inflation necessary. In fact, there are no extreme microwave background perturbations observed (Ade et al., 2018). This stimulates the search for theoretical alternatives to cosmological inflation (Chen et al., 2019).

This perspective sees that the basic symmetries have to occur out of necessity during qubit crystal formation and hence in this respect, the world has a simple explanation (the “world formula”). However, it is more important that a real crystal is *not* simple and that everything beyond the basic fact that the crystal has to form using always the same unit cell is in fact irreducible complex (cannot be represented by a shorter program; Chaitin, 2006) for instance living beings in this universe are definitely very complex and even more so ecosystems, solar or galactic systems or any other specific features of the universe beyond its basic symmetries.

Fine tuning, why the universe is so life-friendly, is explained here by evolution of crystals and the necessity to generate seeds for the next generation of crystals. Hence, in general self-organizing processes are favored. The fact that we live even in a universe as conscious observers implies that we are in a very life-friendly, fine-tuned universe as stressed by the anthropocentric principle (Barrow, 1986; Wheeler, 1990).

Selective advantage of a life-friendly universe:
More speculative and independent from above arguments on the early universe we can state: (i) If the evolutionary perspective is correct, we would go further than the anthropic principle. Allowing consciousness in this universe should imply this has a selective advantage, in particular that at least one civilization in the whole qubit crystal becomes so powerful that it not only implements artificial suns (our hydrogen fusion efforts; e.g. Costley, 2019, Surrey, 2019), artificial galaxies (mastering dark matter, critical for galaxy formation; Springel et al., 2005) but can promote better seed formation for the next universe. The improved seed for the crystal needs not to be simple as it is extended and made of many qubits. It can even include specific programming information, e.g. interacting surfaces reproduce seed patterns, and hence can be even irreducible complex. (ii) Qubit condensation as basis of our universe means furthermore that ALL states crystallize out and hence it is completely sufficient if there

is only a remote possibility to reach this powerful civilization state in any of the world trajectories: if it is at all possible, it is already there, for sure, as all bit states are realized by the crystallization of the qubits. Hence, in this sense "god does not play dice": Maybe our civilization is one of the failing trajectories. However, taking all intelligent life and worlds together in this qubit crystal, we cannot and will not lose: All possibilities are crystallized out, so hence also the at least one successful civilization and world trajectory leading to a fitness gain for the crystal is realized in one layer of the crystal – otherwise this phenomenon would not have been selected for. If we want to become one of the long-term civilizations so powerful, we should not remove us prematurely and have for the foreseeable future to patiently live really ecofriendly and be carefully creative, staying in harmony with our environment to be able to survive really long.

Some general implications of our argument:
First, I suggest here that *god does not play dice* (Einstein is considered to be right): In fact, everything bigger than Planck´s quantum is defined in our universe, otherwise there is no universe but the limbo state of the chaotic soup around (including Schrödinger cats, they occur only in the chaotic ocean soup outside of our universe but not here).

Second, there is the fact that "life is *not* simple", let alone the universe.
However, the Planck´s action grid the universe is made up from can have simple, basic and general symmetries by the basic fact of its multiple qubit interaction state which crystallized out nearly completely out. Symmetry breaking creates more richness (e.g. our four everyday forces instead one unified at very high energy), and is one of the self-organizing processes occurring and evolutionary selected for in our universe.

Thirdly, we can test this perspective really in the laboratory, looking at everyday crystallization, protein folding, as well as topological materials (Imhof et al., 2018) and quantum computations to better understand qubit physics.

Conclusion: We bring a new perspective to the cosmology of our universe: To come into existence it had to become real, from the eternal ocean qubits. Under appropriate conditions there was a solid phase transition of qubits (completely free) to real bit states, all of them becoming decoherent and real, only minimal liquidity left (uncertainty principle describes this). Limited interaction possibilities for qubits according to Hurwitz´s theorem explain why the richest Hurwitz solution, E8 symmetry occurred, as observed. The qubit condensation event replaces Big Bang, the growth of the condensation nucleus into a full qubit crystal replaces inflation. Implications: The transition and crystallization lead to emergent time and space. In the crystal basic symmetries (unit cell) hold everywhere replacing the need for the unrealistic inflation scenario, while natural little misplacements in the crystal explain rapid formation of galaxy superclusters and local qubit crystal symmetries optimal distribution of dark matter for galaxy formation. Evolutionary scenarios of most efficient self-organizing qubit crystal replication lead to fine-tuning of optimal replication and renders the universe life-friendly.

Experiments in quantum computing, protein folding and crystallization will help to fix free parameters, the mathematical appendix gives some formulas and ground work for a more comprehensive unified lattice theory-based framework: while quantum formalisms describe the continuous quantum world with uncertainty and probability, there is in our view a clear transition for anything bigger then h dash to a discrete lattice of defined, well separated quantum states so that our macroscopic world gets defined, decoherent and real and GR holds. The perspective should stimulate further theoretical work, for instance the landscape problem (Smolin, 2013b) for string theory gets a solution path and string theory may be encrypted in the unit cell of the envisioned qubit crystal. Furthermore, LQG presents a pragmatic solution and points out the repulsive quantum force for ultrashort distances in our concept and it could also be further developed taking this concept into account. Finally, emergent gravity (Verlinde, 2017) is related and can profit from our theoretical perspective.

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Figure 1. (a, top**): qubit interaction creates a condensation nucleus.** Further grows (star symbol) forms a crystal. Size limiting for the growth are long range interactions, a solid "crystal" of all interacting qubits "frozen-out" into their bit states is the end result. This is a very abstract type of crystal and it is made of interacting qubits (or strings of any dimension, abbreviated as nD-strings). Their interaction is only possible for the types of interaction allowed by the Hurwitz theorem (see results). We symbolize this crystallized world by a cube to remind the reader that the unit cell with its symmetries (e.g. a cube) will be repeated again and again over the whole crystal ensuring that everywhere are the same basic symmetries and laws of nature. Within the crystal all states are well separated, no longer liquid as in the background quantum foam "soup" shown as transparent bubbles in the background (superposition of all possibilities). **(b,** middle**): Crystal in ocean of string soup.** Only within h, Planck´s quantum, there is flexibility. outside: all is quantum fuzzy and the boiling soup of superposition with no decoherence, all states at the same time. GR holds only within the crystal; only here there is a clear reality, a strong decoherence field as stable as the qubit crystal. **(c,** bottom**): Dark energy allows to dissolve the crystal over time.** Entropic forces from the soup tug and grow (red arrows, middle). Beyond a threshold the crystal dissolves ("big rip", right), only the quantum bubble soup remains. Crystals which create new condensation seeds before they dissolved should be selected over time (external time, not the entropy-driven internal time bound to the crystal stability).

Figure 2. Emergent time and space in the solid, frozen-out qubit ensemble. The crystal formed by the solidifying qubit ensemble (box with black rims) is just resulting from the freezing out of the quantum states of m quanta which can be each in n states. For illustration, this is shown for 6 quanta ("world" made of 6 quanta) which each can have 2 states (blue up or down arrow). Direction of higher entropy (thick blue arrow on the right) provides an arrow of time for each trajectory connecting system states as edges. Just as these quanta have in the free state all 6**2 states superposed, they have due to the string interaction potential in the solid state, i.e. the "frozen-out" state, simply all these accessible quantum states separated from each other („decoherent"). There is no splitting after each decision or other strange things happening as in Everett-type models of our universe: there are just a clearly defined number of quanta in solid state instead of the liquid coherent state. Left: System states with the same entropy are „close by" in the crystal, and the entropy gradient forms an internal arrow of time (within the crystal). A specific world line or world trajectory is shown by the three black arrows on the left.
Similarly, emergent space is easily resulting from assigning 3 of the 6 bits to encode the three space coordinates x,y,z. In this case, there is the high energy / low entropy state (e.g. all bits "up" → all resides in the upper starting corner) and then with increasing entropy the other areas of the mini-universe of 2x2x2 space units are populated.
The remaining three bits of our toy example could encode quantum / particle type (1 bit) and quantum properties (2 bits, e.g. charge, spin).
It is clear that easily more bits and hence larger emergent space, more particle types and quantum states can be considered and created by the qubit decoherence and forming a solid-state qubit ensemble with frozen out bit states.

Figure 3. World-lines. The layers of the crystal separated by h dash (indicated on the right) are the alternative worlds, within one quantum all is still "fuzzy", the elasticity of the crystal. Only here is a defined time-trajectory for each layer, each "fate" of the world in one layer of the crystal (indicated by the slightly different trajectories in blue), only small decisions are different. Figure 2 with its more detailed view still applies: There is

no Everett multiverse which myriads of splits but there are still only a total of m**n states (all combinations of m qubits with n different states).

Figure 4. **Dark matter and normal matter.** Qubit crystals contain in their frozen-out state two important entities of matter (like in a NaCl salt crystal): Dark matter and normal matter; for visualization of their specific interactions only these key ingredients are shown (however, in this abstract crystal and its E8 symmetry group far more ingredients, particles, basic symmetries and hence emergent "laws of nature" are built in just by propagation of the basic symmetry unit – there is no inflation necessary). The figure visualizes that both types of matter easily interact in the crystal (in particular via gravity). The proper distribution of dark matter is important for galaxy formation inside the crystal. This applies to our universe: in halo regions is the dark matter, this is necessary to have nuclei of dwarf galaxies as well as for normal galaxies (Boylan-Kolchin, 2017).

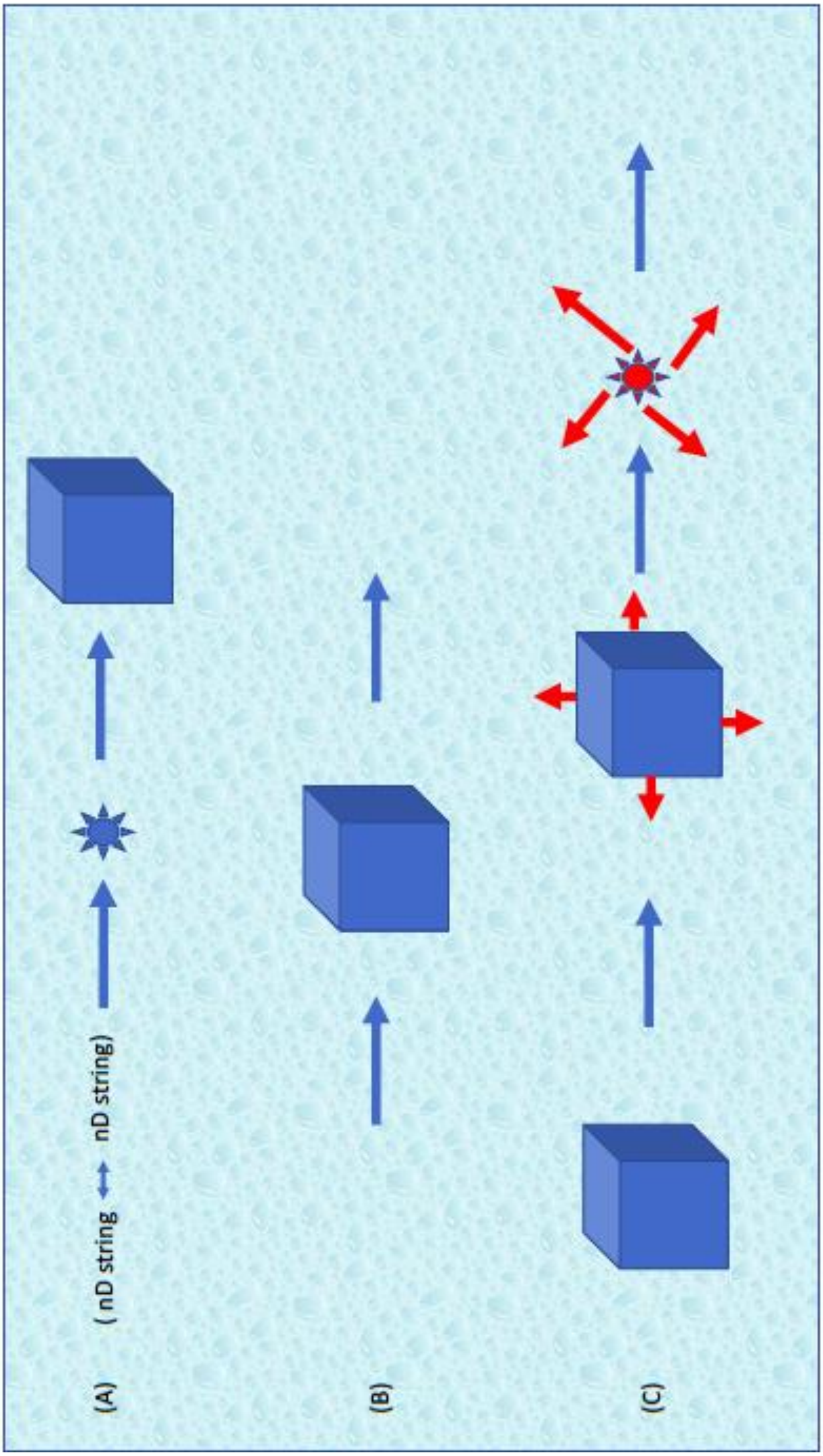

Fig. 1


System
states
Entropy
(arrow
of time)
top energy
high energy
middle energy
low energy

Fig. 2

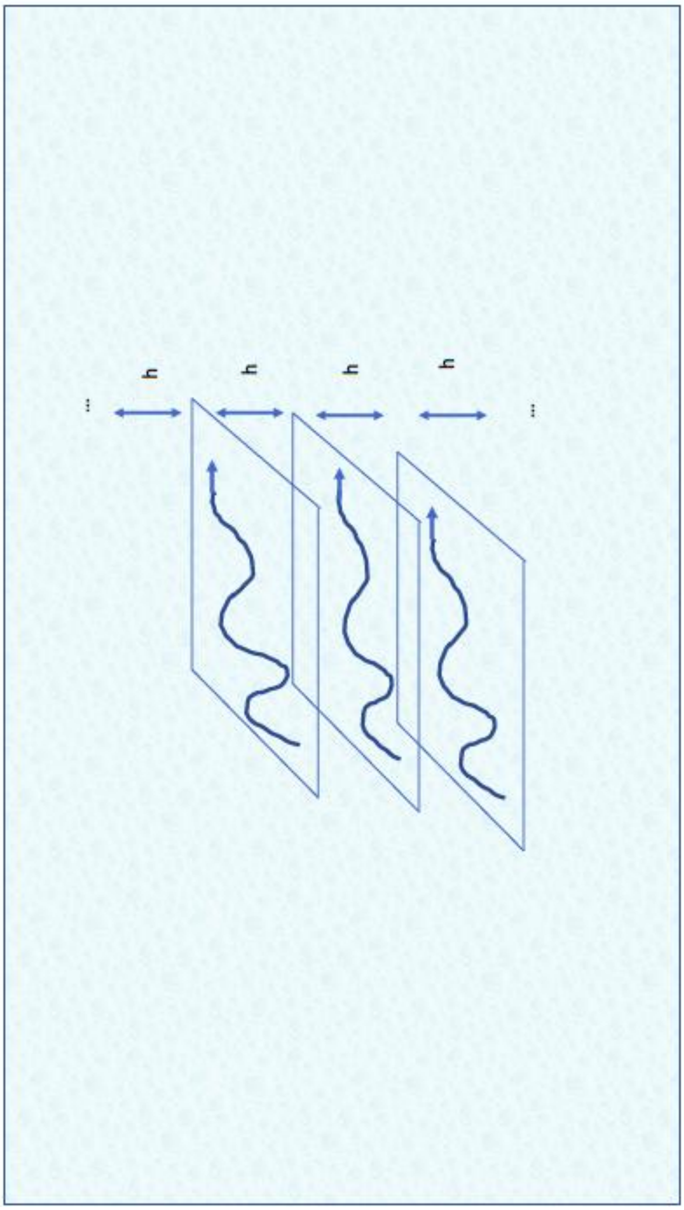

Fig. 3

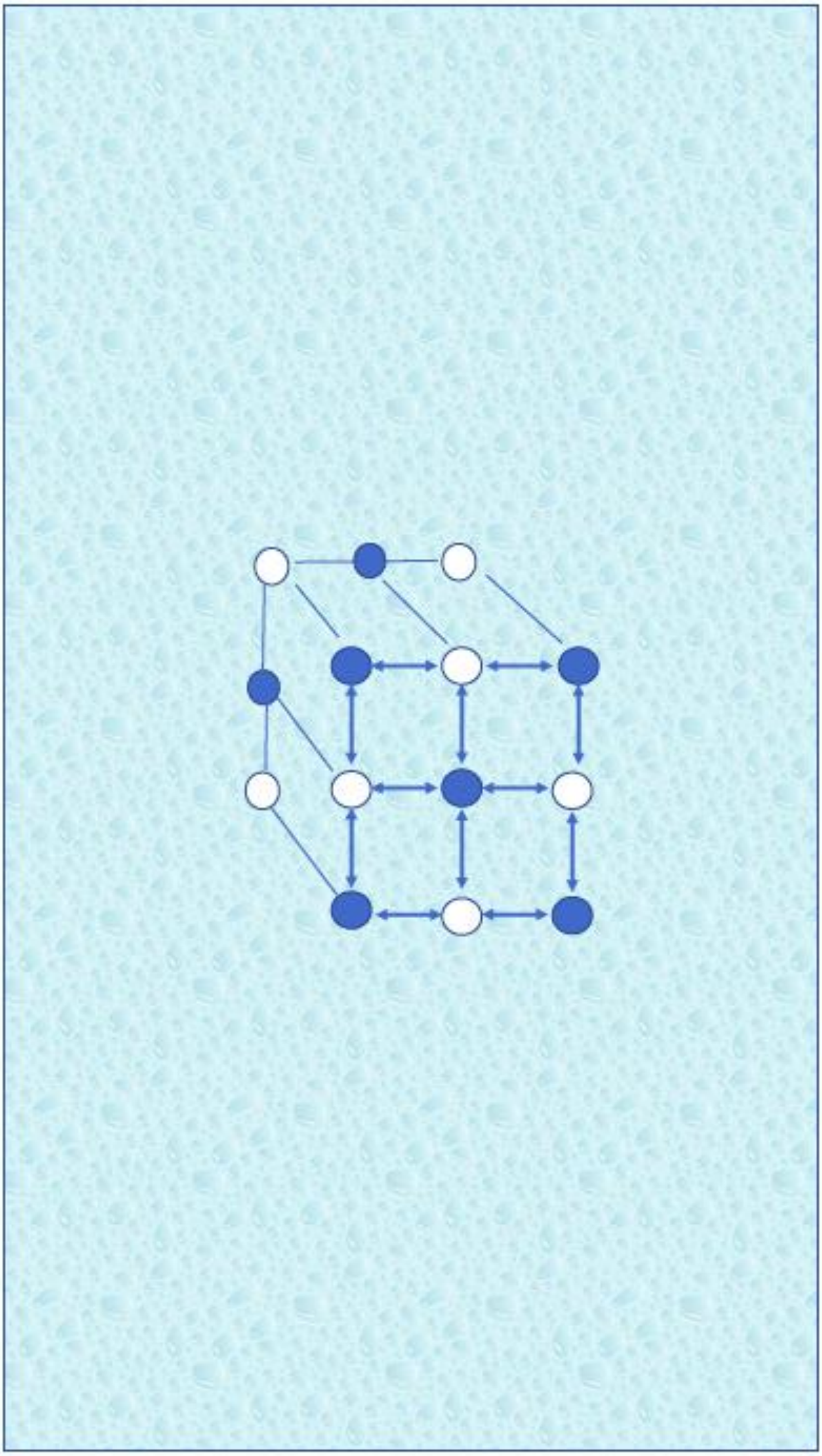

Fig. 4

Mathematical Appendix

General arguments independent of the mathematics used: Our concept is to replace big bang and inflation, so events in the very early universe and not directly testable or observable, by qubit interaction in a chaotic soup and subsequent growth of the multiple qubit assembly which gets solidified and defined (qubits solidify to the vast number of bit states implied) subsequently. After the very early universe we have in our theory a transition to the early, hot fireball standard universe of standard cosmology. By replacing two unobservable phenomena by observed entities, crystallization and crystal growth, we can explain many up to now unexplainable phenomena including: why is there matter (and no antimatter), early development of galaxies by misplacements in the crystal, the lack of an inflation signature etc. Most important is the concept that in a crystal you have everywhere the same symmetries, the unit cell is propagated and does not require inflation. If you investigate the creation of the universe from an ocean of qubits (Kaku, 2021 considers such an ocean or chaos soup, too) and not a freak jump into existence as in big bang and inflation you get more realistic in your cosmological model.

Independent from this scenario, we postulate many generations of crystals (as normal crystals also exist only a finite time) and hence selection for optimal surviving crystals and generation of new crystal seeds. This explains then one of the toughest problems of all, why is our universe so life-friendly. Evolutionary scenarios have been proposed before: e.g. early black holes have been proposed by Smolin (1997). However, this was only regarding fecundity of a universe and black hole production, not regarding fine-tuning for life-friendly conditions. Similarly, application of observable phenomena have been advocated before, but only to investigate aspects of standard cosmology (Chuang et al., 1991).

Finally, important features of this cosmology are emergent time (Smolin, 2013a) but here I consider also entropy (rarely done), emergent gravity (Verlinde, 2017) and unified symmetries by the shear process of qubit crystallization (Fig. 2). The mathematical treatment of cosmology from the start as a multi particle system is usually not attempted (both in inflation models and LQG cosmologies) but I hope I have here overwhelming arguments that only by this you get a correct emergence of our everyday features of forward time, gravity and reality (decoherence), otherwise you stay in the undefined qubit ocean every world has to come from (Kaku, 2021). However, a multiparticle system as cosmology is not often given but makes the mathematics of the start even more challenging, similarly the entropic treatment. If theoreticians think more in this direction, then this perspective has already helped a lot in the quest of finding the correct cosmology.

These key arguments from the main paper have been repeated as they are reasonable and a clear model, they hold independent from the specific mathematics used or applied. Hence, in the following, if the formula we give is not your favorite theory, please replace it by your own language, we are open for any effort from quantum chromo dynamics (QCD) and lattice theory, string theorists, LQG experts, cosmologist and particle physicists to take the simple concepts voiced here and check whether they could not lead to a consistent and strong new and unified theory of the universe.

This having said, this mathematical appendix helps to pinpoint where mathematical consistency checks of this perspective can be done. The text part (main paper) is completely independent from the particular way how the equations (astronomical **eq. 1** to **eq. 6**; microscopic **eq. 7** – **eq. 12**) are phrased, the physical processes invoked can all even be tackled in a classical way (without quantum theory or cosmology). The problem is only that then there comes the huge mathematical challenge, that these equations then have to be phrased in a quantum theory such that both the cosmological implications and the fundamental physics implied can be mathematically checked and are consistent. This is really demanding and not shown here, rather we state here the problems how they can be phrased (at least in a first approximation) and give an initial treatment to show directions and open questions. This is typically for bioinformaticians, the systems treated are usually quite complex, so we give just a first hint where the solution should be searched for and understanding this hint and new perspective, the subsequent work can start: **validation**, in biology by experiment, for this model typically by brilliant mathematics taking usually years to develop. However, help may also come from experiments on qubits, quantum computing, protein folding and strong solid state physics.

Part I: Formulas cited and perspectives for their further development

We only need few formulae to describe the whole concept of our new "quantum action theory" (**Table 1**). We give now more details for the development of each equation.

Eq. 1 (when and how qubits can interact, is restricted to 1,2,4 and 8 dimensions):

a) general treatment of qubits: The Hamiltonian is commonly expressed as the sum of operators corresponding to the kinetic and potential energies of a system in the form:

$$\hat{H} = \hat{T} + \hat{V}$$

So kinetic energy operator T plus potential energy operator V, in classical writing like this:

$$\hat{V} = V = V(\mathbf{r}, t)$$

and

$$\hat{T} = \frac{\hat{\mathbf{p}} \cdot \hat{\mathbf{p}}}{2m} = \frac{\hat{p}^2}{2m} = -\frac{\hbar^2}{2m}\nabla^2$$

is the kinetic energy operator in which m is the mass of the particle, the dot denotes the dot product of vectors,
and

$$\hat{p} = -i\hbar\nabla$$

is the momentum operator where the upside down triangle is the del operator. The dot product of the del operator with itself is the Laplacian. In three dimensions using Cartesian coordinates the Laplace operator is

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$$

Although this is not the technical definition of the Hamiltonian in classical mechanics, it is the form it most commonly takes. Combining these yields the familiar form used in the Schrödinger equation:

$$\begin{aligned} \hat{H} &= \hat{T} + \hat{V} \\ &= \frac{\hat{\mathbf{p}} \cdot \hat{\mathbf{p}}}{2m} + V(\mathbf{r}, t) \\ &= -\frac{\hbar^2}{2m}\nabla^2 + V(\mathbf{r}, t) \end{aligned}$$

which allows one to apply the Hamiltonian to systems described by a wave function

$$\Psi(\mathbf{r}, t)$$

.

This is the approach commonly taken in introductory treatments of quantum mechanics, using the formalism of Schrödinger's wave mechanics. One can also make substitutions to certain variables to fit specific cases, such as some involving electromagnetic fields.

The formalism can also be extended to N particles:

$$\hat{H} = \sum_{n=1}^{N} \hat{T}_n + \hat{V}$$

Where potential energy is described as

$$\hat{V} = V(\mathbf{r}_1, \mathbf{r}_2, \ldots, \mathbf{r}_N, t),$$

now a function of the spatial configuration of the system and time (a particular set of spatial positions at some instant of time defines a configuration) and;

$$\hat{T}_n = \frac{\mathbf{p}_n \cdot \mathbf{p}_n}{2m_n}$$

is the kinetic energy operator of particle n, and del operator (upside down triangle) is the gradient for particle n, giving the Laplacian for each particle using the coordinates:

$$\nabla_n^2 = \frac{\partial^2}{\partial x_n^2} + \frac{\partial^2}{\partial y_n^2} + \frac{\partial^2}{\partial z_n^2},$$

Combining these yields the Schrödinger Hamiltonian for the -particle case:

$$\hat{H} = \sum_{n=1}^{N} \hat{T}_n + \hat{V}$$

$$= \sum_{n=1}^{N} \frac{\hat{\mathbf{p}}_n \cdot \hat{\mathbf{p}}_n}{2m_n} + V(\mathbf{r}_1, \mathbf{r}_2, \ldots, \mathbf{r}_N, t)$$

$$= -\frac{\hbar^2}{2} \sum_{n=1}^{N} \frac{1}{m_n} \nabla_n^2 + V(\mathbf{r}_1, \mathbf{r}_2, \ldots, \mathbf{r}_N, t)$$

Here we have to sum up terms to get Energy (kinetic and potential) correct:

a) Introducting qubits directly:

However, the new concept introduced by me here in this mathematical part is now to introduce qubits and allow qubit interactions over any number of dimensions (including even several time-like dimensions) and then we see immediately that the summation over energies as given above can only work if the mathematical operation of summation is possible despite the high or low number of dimensions chosen.

Strikingly, according to the Hurwitz theorem (1898) any type of mathematical operation for complex or hyper complex numbers is mathematically consistent only possible for 1,2,4 or 8 dimensions.

Nevertheless, to be really sure about the applicability of the Hurwitz theorem to the general energy terms of qubit interaction one would have to transform the energy terms correctly into an addition of complex or hyper complex numbers. This remains to be accurately shown.

However, then, following Hurwitz (1898) we consider transformations A such that they fulfil the equation

$$AA' = (x_1^2 + x_2^2 + \cdots + x_n^2)$$

(formula (4) of Hurwitz, 1898)

This implies that we have to satisfy the equation 9 of Hurwitz

$$B_i^2 = -1, \qquad B_iB_k = -B_kB_i, \qquad B_i' = -B_i. \qquad (i \gtrless k)$$

which, as Hurwitz shows, is only possible, apart from real numbers (so dimension 1) for dimensions 2, 4 or 8 (for other values you get undefined division by zero etc.).
Using time t as just another dimension coordinate all can then be written as shown before, showing that there are only 1D, 2D, 4D and 8D interaction of qubits possible.

Hence, then we can link up our theory of qubit interaction to our real world (see text part above), so the eight-dimensional symmetry of all particles and forces of the standard physics and of the world itself (Wolchover, 2018, 2019), and hence our real universe in fact implements the richest solution, the octonion result.

Moreover, this basic eight-dimensional symmetry of our world regarding basic forces and particles is also taken-up by the heterotic string theory (Gross et al., 1985). One gauge group or flavour is SO(32) (the HO string) while the other flavor is $E_8 \times E_8$ (the HE string) (Polchinski, 1998).

b) LQG treatment of qubit interaction potential:

As the qubit treatment is challenging, there is alternatively a LQG (loop quantum gravity) treatment possible following definitions and formulas introduced by Rovelli (2004):

A background free (BGF, without time) spin-network is introduced (see Rovelli, 2004):

Dynamics (so things happening for a particle or a system of several particles in a space-time like our everyday world) are described in the spin network as follows (the amplitude, as shown by Feynman, encodes full quantum dynamics) and we write for the amplitude w (s) of spin network states (formula 1.12. in Rovelli, 2004):

$$W(x,t,x',t') = \langle x|e^{-\frac{i}{\hbar}H_0(t-t')}|x'\rangle = \langle x,t|x',t'\rangle.$$

In this notation, the particle is first observed at x´, t´ and then found at x, t.
The resulting space of events (x´,t´, x, t) is called G and includes (as long lists) all data-sets of the events.

For another variable different from the position, the Amplitude becomes

$$A = \langle \psi_{\rm out}|e^{-\frac{i}{\hbar}H_0(t-t')}|\psi_{\rm in}\rangle.$$ (1.13; Rovelli, 2004)

(requiring then the tensor product of the Hilbert space of initial states and (the dual of) the Hilbert space of the final state).

The physical transition amplitudes w (s,s´) are obtained by summing over spin foams bounded by the spin networks s and s´

$$W(s,s') \sim \sum_{\sigma \atop \partial\sigma = s \cup s'} \mu(\sigma) \prod_v A_v(\sigma).$$ (1.17; Rovelli, 2004)

--Now all this treatment of the spin network according to the LQG formulas above *does not* specify here a specific dimension (the G, the dataset could be collected and applied to study events in a space-time of any number of dimensions). However, to calculate amplitudes we have to sum up between states in the spin network to follow a succession of events.

We now only need to allow (x´, t´, x, t) over any number of dimensions (including time-like dimensions) and further we need a summation over amplitude squares (which should then be the actual quantum probabilities) then we see immediately that the summation over amplitude squares modifying formula 1.17 (Rovelli, 2004) accordingly can only work if the mathematical operation of summation of amplitude squares is possible despite the high or low number of dimensions chosen.

Strikingly, according to the Hurwitz theorem this is only possible for 1,2,4 or 8 dimensions. Specifically, following Hurwitz (1898) we consider transformations A such that they fulfil the equation

$$AA' = (x_1^2 + x_2^2 + \cdots + x_n^2)$$ (formula (4) of Hurwitz, 1898)

This implies that we have to satisfy the equation 9 of Hurwitz

$$B_i^2 = -1, \qquad B_i B_k = -B_k B_i, \qquad B_i' = -B_i. \qquad (i \gtrless k)$$

which, as Hurwitz shows, is only possible, apart from real numbers (so dimension 1) for dimensions 2, 4 or 8 (for other values you get undefined division by zero etc.).

So, in summary, the LQG formalism allows any dimension in its formulation, such as for the interaction potential, the datasets of events and the amplitude for other properties then the position. Knowing this and then applying the Hurwitz theorem to it shows then that any summations or any more general mathematical operations are only possible for dimensions 1,2, 4 and 8. Hence LQG or any type of many-dimensional string interactions or many-dimensional spin networks are only possible for 1,2,4 and 8 dimensions or symmetries. The last one corresponds to the richest case and is our observed E8 symmetry of our domain.

Eq. 1b (energy difference between free and bound qubits):

Generally you would write again:

$$\hat{H} = \hat{T} + \hat{V}$$

But now you have a huge difference for the potential energy operator V:

In the bound state it is 10**20 times higher and that explains why the vacuum energy inside our crystal is so much lower than you would expect with the typical calculation of virtual particles.

*To get here further we have to start from the text book calculation for vacuum energy and derive the derivation of the qubit binding energy from this, knowing that the real vacuum energy in our world is 10**20 lower: probably the kinetic term of the qubit interaction goes down by 10**20, as all is now bound, so hence potential energy in our everyday world, as all is decoherent, solidified and defined and no longer free undefined quantum state.*

Majorana qubits: An important example how solid and strong interactions between qubits can become under the correct conditions are majorana qubits (Aguado and Kouwenhoven, 2020). Majorana qubits can be generated in topological materials at extreme low temperatures at the end of a connected chain of supra-conducting electrons. They are then half quasi-particles with zero excitation energy and so called zero modes. Several such zero mode paths can be braided with each other and then one has really stable majorana zero-modes and thus stable qubits for longer calculations (Ball, 2021). However, experimental verification of observed majorana qubits is very challenging, in particular alternative quantum states can look very similar and are also experimentally explored but not yet clearly nailed down either (bound Andreev state; other anyons, skyrmions in magnetic materials; Frolov, 2021).

However, our cosmological scenario is quite different, we have an ocean of usually free qubits but if they interact they become tightly bound and a seed for a new universe. We think that the binding energy for such a qubit seed is of the order of the calculated free vacuum versus the observed much lower energy. Braiding and separation allow in topological qubits longer conservation of states, however, in our perspective the topology of space and time is created (emergent time and space) by the tight interaction of the aggregate of qubits which rapidly grows by a magnetization-like process. The build-up of long-range forces limits growth, leads to the emergence of space and time and general relativity. This is only partly analogous to braiding of majorana qubits in a topological material but much more fundamental and leads to separated, frozen-out states of qubits.

Eq. 2 (entropy treatment in crystallization)

Entropy equations for protein folding are well established (Brady and Sharp, 1997). Thus the Boltzmann expression for the entropy S reads for a system consisting of N atoms of protein, solvent ligand etc. is given by

$$S = -K_B \int P(r) \ln(P[r]) dr = -k_B \sum_i P_i \ln P_i \qquad (1)$$

Where K_B is the Boltzmann constant, T is the temperature and

$P(r) \propto e^{-U(r)/kT}$ is the probability of the system to being in a particular configuration with energy U(r), requiring 3n coordinates for n atoms to calculate the energy with r degrees of freedom. Subsequent treatment in the paper explains then conformational entropy considering backbone and sidechain and of course, solvent entropy is also considered (p. 218).

However, the treatment for qubit would need to take this to a cosmological level, the solvent being the qubit ocean around, which experiences an entropy increase (even more chaos) while the condensation nucleus forms (like in everyday biophysics, Kawasaki and Tanaka, 2010).

Eq. 2b: Dark energy, big rip tugging

Here one can learn from the dissolution of normal crystals (phrased after Lasaga and Lüttge, 2003; 2001), in particular the simple case, treat for crystal dissolution the rate law as a simple linear relationship between rate and deviation from equilibrium (e.g., Δ G), at least close to equilibrium. The most often invoked relationship has been based on the principle of detailed balancing or a transitionstate theory (TST) approach and leads to the rate law

$$Rate = A \quad (1 - e^{\sigma \frac{\Delta G}{RT}})$$

where A is a general constant, which could vary with pH, T, inhibitor molecules, etc., and c should be 1 if Δ G is based on 1 mol of the rate-limiting component. McCoy (2001) presents a population balance model for crystal size distributions: reversible, size-dependent growth and dissolution. The population balance equation, in combination with a mass balance for solute, can be solved for mass moments of the crystal size distribution. Furthermore, there are crystal dissolution kinetics since long time available (Uttormark et al., 1993).

However, these models have then to be transferred to our cosmological model, which requires a qubit quantum treatment, replacing the crystal fields by Yang-Mills fields or, may be still better, formalisms of LQG and string theory, not attempted here.

Eq. 3 (Long range interactions limiting growth of the cosmological crystal)

An inherent challenge is to implement the build-up of the long-range interactions correctly, the classical treatment focusses on the energies. In the original Weiss theory the mean field H_e is proportional to the bulk magnetization **M**, where alpha is the mean field constant.

$$H_e = \alpha M$$

Then next, the size of the domain and the contributions of the different internal energy terms is described by the Landau-Lifshitz energy equation

$$E = E_{ex} + E_D + E_\lambda + E_k + E_H$$

The total energy is composed of E_{ex} (exchange energy; critical for the overall size, lowest when dipoles all pointed in the same direction. Additional exchange energy is proportional to the total area of the domain walls), E_D is magneto-static energy (self-energy, due to interaction of the field created by the magnetization in one part on other parts and reduced by minimizing overall energy, incorporating again large-range forces effects), E_λ is magneto-elastic anisotropy energy, E_k is magneto-crystalline anisotropy energy and E_H is Zeeman energy. Hence, detailed consideration of these energy terms allows to calculate the self-limiting growth of the Weiss domain by considering long-range versus short-range forces (Devizorova et al., 2019).

However, taken to cosmology, there are challenging n-dimensional string interactions and repulsive forces to calculate. It is a bit easier to transport the classical formulas to a first condensation nucleus and limitations by long range interactions.

Moreover, a good hint is then to apply again LQG, as then the energy considerations are again far easier transported to interactions of any number of dimensions.

Note that we show here only a very general solution for the interaction field between loop quantums (or strings) and how they can form a crystal, where there is also again a size limit after crystallization. The mathematical formalism derived here allow many different parameters to fulfil it. Importantly, we need this open-ness so that evolution over several generation can operate on the parameters to select optimal crystals with best reproduction rate, stability and resulting overall fitness. The result is fine-tuning: The optimized crystals are particularly favorable to life.

This argument would similarly well apply to the openness of string theory, in particular we assume that 8-dimensional theories are allowed for the qubit interaction field (besides less interesting 1,2 and 4 dimensional solutions) and thus the E8 heterotic string theory would also qualify not only as a solution to the qubit interaction potential but also to have the necessary openness (like all string theories) to allow evolution over several generations to select best life-like parameters.

Note also, that the basic unit cell of the crystal with its free parameters represents then one form of encoding the properties ("laws of nature") of the crystal. However, also surfaces of the crystal ("membranes") can influence the next generation of the crystal ("break away seeds"). This has the advantage that more detailed and specific information (and hence adaptation) can be transferred including a specific arrangement of world-lines reoccurring in the next generation of the crystal. Interestingly, this includes then also world-lines imprinting the success or failure of complex processes such as life and evolution or even an intelligent civilization in the next generation of the crystal. Phrased like this, this may sound quite esoteric, but it is just resulting from the surface properties of the crystal according to this theory, imprinting on the surface of the next generation of crystals. Different possibilities exist for this process of imprinting; normal crystals and the triggering of crystallization by condensation nuclei allow this to investigate. More mundane processes to validate the modelling include simple everyday processes such as rain and rain cloud formation.

Eq. 4 (standard calculations for vacuum foam, free qubits 1020 bigger then bound)**

Vacuum energy effects are observed in experiments such as the Casimir effect and the Lamb shift. Considering the cosmological constant, the vacuum energy of free space has however been estimated to be 10^{-9} joules (10^{-2} ergs) ~5 GeV per cubic meter. Using instead quantum electrodynamics, consistency with the principle of Lorenz covariance and considering Planck´s constant derives a much larger value of 10^{113} joules per cubic meter due to a zoo of virtual particles. This discrepancy is huge and described as the cosmological problem (details in Jaffe, 2005). **Fig. 1** shows: The high energy calculation is correct but applies only outside our domain in the qubit ocean.

Eq. 5 (conservation laws expressed as symmetries of the crystal)

In our perspective the conservation laws of nature in our horizon of observation (and may be beyond) are explained not by inflation of one quantum particle or field (we reject the idea of inflation) but rather reflect basic symmetries of our almost completely solidified qubit crystal we live in. These basic symmetries follow everywhere the symmetry unit of the cosmological qubit crystal (the typical "unit cell" of any normal crystal) and this makes sure that in every part of the crystal the same laws hold.

Examples include conservation of momentum and energy, and more advanced embodiments such as the Noether theorem:
For instance a Lagrangian that does not depend on time, i.e., that is invariant (symmetric)under changes of time $t \rightarrow t + \delta t$, without any change in the coordinates $\mathbf{q}$.
In this case, $N = 1$, $T = 1$ and $\mathbf{Q} = 0$;
the corresponding conserved quantity is the total energy H

Time invariance

$$H = \frac{\partial L}{\partial \dot{\mathbf{q}}} \cdot \dot{\mathbf{q}} - L.$$

Similarly, there may also be translational Invariance

$$p_k = \frac{\partial L}{\partial \dot{q}_k}.$$

Here, our claim is that the invariance or conservation law exists in our universe only as these are basic symmetries of the unit cell our condensed qubit crystal is made from.
This applies even more so to our E8 symmetry underlying our domain.
In mathematics, E8 is any of several closely related exceptional simple Lie groups, linear algebraic groups or linear algebraic groups or Lie algebras of dimension 248; the same notation is used for the corresponding root lattice, which has rank 8. The designation E8 comes from classification of the complex simple Lie algebras by Wilhelm Killing and Elie Cartan. There are four infinite series A_n, B_n, C_n, D_n, and five exceptional labeled G2, F4, E6, E7 and E8. The E8 algebra is the largest and most complex of these exceptional cases.

Important for us here is that of course the E8 Lie group has applications in theoretical physics and especially in string theory and supergravity. E8×E8 is the gauge group of one of the two types of heterotic strings and is one of two anomaly-free gauge groups that can be coupled to the N = 1 supergravity in ten dimensions. E8 is the U-duality group of supergravity on an eight-torus (in its split form – again 8 dimensional).

Independent of such string-theoretical considerations, one way to incorporate the standard model of particle physics into heterotic string theory is the symmetry breaking of E8 to its maximal subalgebra SU(3)×E6.
According to our theory, qubits can only interact, if they interact at all in an 1,2, 4 or 8 dimensional way and the richest case possible is the E8 symmetry. Our claim is furthermore that the richest solution is favored as particular favorable for self-organization, complex processes and life, and the formation of new seeds from the qubit-crystal.

New interpretations from our perspective considering string theory

The mathematical beauty of string theory is well known (Green, 2000). It is mathematically very consistent and elegant and hence, this model is in a deep mathematical sense true. String theory developed to avoid infinities, in particular for very small distances. Instead of having the uncertainty principle

$$\Delta x \Delta p \ \sim \ \hbar$$

Yielding infinities for Δx approaching zero, there is the modification by the string

$$\Delta x = \frac{\hbar}{\Delta p} + \alpha' \frac{\Delta p}{\hbar}$$

And here we have

$$\alpha' = \frac{1}{2\pi T_s}$$

With T_S describing the String-tension. This yields a minimal distance considering

$\alpha' \frac{\Delta p}{\hbar}$ with $x_{\min} \ \sim \ 2\sqrt{\alpha'}$ and as a´ is now no longer zero, you avoid infinities. An estimate how small this length is yields the famous Planck length:

$$\ell_P = \sqrt{\frac{\hbar G}{c^3}} \cong 1{,}61624(12) \cdot 10^{-35}\,\mathrm{m}$$

Subsequently you can formulate open strings (Type 1 string theory), closed strings, Nambu-Goto action (Zwiebach, 2003), so a Bosonic string theory without fermions, next Polyakov action and String Sigma model

$$S_\sigma = -\frac{T}{2} \int \mathrm{d}^2\sigma \, \sqrt{-h} h^{\alpha\beta} \partial_\alpha X \cdot \partial_\beta X$$

allow to formulate the theory including movements much better and you get general solutions for the wave equation for closed strings

$$X_R^\mu = \frac{1}{2} x^\mu + \frac{1}{2} l_s^2 p^\mu (\tau - \sigma) + \frac{i}{2} l_s \sum_{n \neq 0} \frac{1}{n} \alpha_n^\mu e^{-2in(\tau - \sigma)}$$

and open strings

$$X_L^\mu = \frac{1}{2} x^\mu + \frac{1}{2} l_s^2 p^\mu \tau + i l_s \sum_{m \neq 0} \frac{1}{m} \alpha_m^\mu e^{im\tau} \cos(m\sigma)$$

Where x^μ is the position of the center of mass and p^μ the total impulse of the string and the exponential function describes activated states. An impressive world-wide work of the best string theoreticians did then lead to the well-known five candidates for superstring theories:

Type I string theory, with open ends of the strings (but coupling to closed strings by contact of the ends, corresponding to gravitational interaction) and symmetry SO(32) with charge at the ends.
Type IIA and the type IIB string theories (closed strings); in type II A the massless fermions have both handednesses (left/right), in II B only one handedness (chirality).
Heterotic string theory with closed strings has two variants: E-heterotic and O-heterotic string theory with reference to their symmetry groups E8 × E8 and SO(32), respectively. Right-handed and left-handed modes (RH, LH) are described individually: RH by a 10-dimensional superstring theory (describing bosons and fermions), LH by a 26-dimensional bosonic string theory, but compactifying to 10 dimensions, giving rise to the gauge field charges, E8 × E8 and SO(32), respectively. And, stated first by Ed Witten in 1995, all five are flavors of M-theory (Zwiebach, 2003).
How could string theory shed light on our perspective?

It does not help to replace the tiny strings by the bigger quanta of action:
Strings are completely consistent with the Uncertainty principle. Though the impulse of a particle confined to string length would be quite high, theoretical works confirm that high-energy and high-momentum transfer behavior of string scattering is consistent with the space-time uncertainty principle. For example, Yoyenava (2000) showed that string theories in 10 dimensions generically exhibit thus a characteristic length scale which is equal to the well-known 11-dimensional Planck length $g1/3s\ell s$ of M-theory as the scale at which stringy effects take over the effects of classical supergravity, even without involving D-branes directly.

However, this perspective gives an explanation why there is string theory in our physical real universe: As the chaos (free qubits) solidifies (defined bits) you get a solid-state, a crystal and this can – if there is an interaction at all – only crystallize in 1,2,4 or 8-dimensional way. The last one yields the E8 heterotic string theory out of shear necessity of a mathematically allowed interaction for qubits (see Hurwitz theorem). There is also no inflation necessary: in the whole qubit crystal as well as in any more mundane crystal there is always the same unit cell of the crystal. This makes sure you have everywhere the same laws and symmetries in the crystal, even if the crystal crystallized over a long time period and hence this explains *why* there is E8 heterotic string theory: it is the richest solution how qubits can interact. Two other notorious problems of string theory could also be solved by this perspective:
(ii) In its supersymmetric flavor (Dine, 2007) there are supersymmetric partners postulated, always the ino-particles, for instance the supersymmetric partner photino of the photon. The **lightest supersymmetric particle** (**LSP**) such as a mixture of neutral higgsinos, the bino and the neutralino should be found captured by Earth´s magnetic field and form heavy hydrogen-like atoms. However, this has so far not been observed (e.g. Byrne et al., 2002). However, as already noted for anti-matter (also not observed in our domain and universe) our perspective thinks our observable universe, i.e. our domain, is only one layer of a qubit crystal and there is a vast ocean of free qubits giving rise to many such crystals that come and go. Some of them have simply other handedness and would hence bear the symmetries and particles not observed here, in our domain.

(iii) Finally, the many free parameters of String theory are in this perspective no mistake of the theory (a theory with too many parameters has the risk to become purely metaphysical, as it cannot be falsified; Hedrich, 2006), but rather a clear consequence of the crystallization event making our universe real: First of all, only 1,2,4 or 8D symmetries allow qubits to interact at all, and the richest solution is 8 dimensional. Taking further consistencies into account (you have to start with one unified force field, which by symmetry breaking gives rise at lower energy to all four interactions, including gravity) the only mathematical consistent theory remaining is string theory, easiest seen in this perspective for the E8 superheterotic string theory. However, then, according to this perspective, there is a selection for best offspring for the next generation of crystals. This favors fine-tuning of the relation of the basic forces such that various self-organizing processes are allowed including life, as otherwise offspring goes down. However, for selection and evolution to operate on, a theory with many free parameters is essential, and string theory fits this point excellently: Our perspective points out a solution for the landscape problem (Smolin, 2013b). The big hope is that all this encourages string theoretician to pursue this perspective given here a bit further.

Eq. 6 (repulsive force for ultrashort distances):

If Qubits interact (**Eq. 1**) there must be a counterforce to prevent that they (or ultimately even the whole qubit ocean) converge into a point or black hole etc. Here my suggestion would be to follow Ashthekar et al., 2006, who used LQG to show that quantization creates here a repulsive potential strong enough to resist even a “big crunch” of our whole universe. Evidently, this method can also be applied if you formulate the **Eq. 6** using another approach, e.g. from string theory, you would have a repulsive force from the quantization and it will be quite strong (we want to have here repulsion for really small distances, for below the granularity of our action grid of Planck´s quantum). The repulsive force is derived as follows:

The formulas by Asthekar et al. (2006) describe how loop quanta interact and then the next point in the paper shows how this may even resist the big crunch**.** Specifically, in section IV of their paper (Asthekar et al., 2006) the authors return to LQC (Loop quantum cosmology) and construct the physical sector of the theory. The LQG (Loop quantum gravity) Hamiltonian constraint is given by eq. (2.34) in their paper:

$$\begin{aligned} \partial_\phi^2 \Psi(v, \phi) &= [B(v)]^{-1}(C^+(v)\Psi(v+4, \phi) \\ &\quad + C^o(v)\Psi(v, \phi) + C^-(v)\Psi(v-4, \phi)) \\ &=: -\Theta\Psi(v, \phi), \qquad (4.1) \end{aligned}$$

This is just a first glimpse how then the repulsive potential for qubits would have to be formulated using LQG as a first hint on how to get repulsion from appropriate quantization.

For LQG section V shows then how quantum states which are semiclassical at late times are then numerically evolved backwards, starting from eigenfunctions (and using these in simulations on a lattice):

$$e_{\omega}(v)\overset{v\gg 1}{\longrightarrow} A\underline{e}_{|k|}(v) + B\underline{e}_{-|k|}(v),$$
$$e_{\omega}(v)\overset{v\ll -1}{\longrightarrow} C\underline{e}_{|k|}(v) + D\underline{e}_{-|k|}(v). \qquad (5.2)$$

The classical big bang is then replaced by a quantum bounce when the matter is extremely compressed to acquire a Planck scale density (Asthekar et al., 2006). However, this is only one way and one example how to derive the strong repulsive force for ultra-short distances by appropriate quantization.

Quantum action theory

We give here standard formalisms and none from string theory or LQG as the innovation in our Quantum action theory is to consider multiple particle systems, decoherence, entropy and overall action above Planck´s quantum of action so that the system is forced to adapt a defined state. We sketch here only the first steps for this (microscopic equations, **eq. 7** – **eq. 12**), but the direction and required mathematical development should be clear by this: S-matrix theory the pre-runner of string theory shows how you can derive a very simple picture of the qubit-to-bit transition considering input and output states. For sure, a string theory treatment is also possible and much more general and better, but beyond this work. We start with an old, simplistic pre-runner of string theory, S-matrix theory (**eq. 7**). Term schemes (**eq. 8**) show again quantum transitions, best summarized by Feynman graphs. The mathematics behind those graphs is a good basis to achieve a mathematical formulation of quantum action theory. The next more complex example tackled is the calculation of proton mass (**eq. 9**), followed by first steps on quantum action theory (**eq. 10**). Decoherence of quantum states in a multiple particle system is important to develop quantum action theory further (**eq. 11**). The full quantum action theory would then provide a nice basis (**eq. 12**) to explain quark confinement by the resulting scalar field as well as gravity by the resulting generalized Higgs field. The latter is again a scalar field but comes according to this perspective from the interaction force that keeps the qubit crystal together (see **final section**).

Eq. 7 (S-matrix theory)

S-matrix theory is a work around to replace local quantum field theory using basic principles of elementary particle physics. By its limited two states of input and output it avoided the problems of zero interaction phenomena and was a pre-runner of string theory. For practical application it is now replaced by QCD. The S-matrix theory has a flat space limit related to the holographic principle and the AdS/CFT correspondence (in AdS space is the boundary conformal theory). In our perspective, the S-matrix input-output formalism instead of space and time shows how you get the space of all possible outcomes (full qubit result space) from bit states as inputs. So it is hence a toy model how the correct mathematical treatment of quantum action and qubit-to-bit transition would look like.

The basic mathematical properties of the S-matrix are:

1. Relativity: The *S*-matrix is a representation of the Poincaré group;
2. ;
3. Analyticity: integral relations and singularity conditions which include:

3.1 Crossing: The amplitudes for antiparticle scattering are the analytic continuation of particle scattering amplitudes.

3.2 Dispersion relations: the values of the *S*-matrix can be calculated by integrals over internal energy variables of the imaginary part of the same values.
3.3 Causality conditions: the singularities of the *S*-matrix can only occur in ways that don't allow the future to influence the
3.4 Landau principle: Any singularity of the *S*-matrix corresponds to production thresholds of physical particles.

These principles replace hence the notion of microscopic causality in field theory, the idea that field operators exist at each spacetime point, and that spacelike separated operators commute with one another.

Eq. 8 (Term scheme)

Term schemes can again be used to consider all quantum states completely and are hence a toy example that shows how all quantum states "crystallized out" can be fully enumerated. These can start even simpler then S-Matrix theory, e.g. the transition probabilities or term schemes in spectroscopy. However, in full they consider quantum transitions, all paths and energy levels and are concisely summarized by Feynman diagrams.

Infinities in force field calculations (Yang Mills fields but also already electron force field) arise from the fact that you assume you can have infinitesimal small distances. In our perspective this is not the case: qubits which are free in the soup are completely free, but as soon as you form the solidified interaction state as basis for our universe and having real, defined bit states instead of qubits all condenses to a grid. Its granularity is the elementary quantum of action, Planck´s constant of 6.626 x 10-34 Js. Hence, this is a grid made from actions, not a space grid. Smaller than the size of the grid we have continuity and complete freedom, but anything larger occurs only in discrete quantum states (Fig. 2).

We review here typical renormalization strategies to get a hint how the path and renormalization from quantum action granularity can be applied in an instructive, non-trivial way.

Simple example: Electron charge or more general mass of a charged particle becomes infinite for $r_e \rightarrow 0$.

$$m_{\text{em}} = \int \frac{1}{2} E^2 \, dV = \int_{r_e}^{\infty} \frac{1}{2} \left(\frac{q}{4\pi r^2} \right)^2 4\pi r^2 \, dr = \frac{q^2}{8\pi r_e}$$

So, to prevent that, there is the classical electron radius,

$$r_e = \frac{e^2}{4\pi\varepsilon_0 m_e c^2} = \alpha \frac{\hbar}{m_e c} \approx 2.8 \times 10^{-15}\ \mathrm{m}$$

With fine structure constant alpha = 1/137 and $\hbar/(m_e c)$ is the reduced Compton wave length of the electron.

--Similar short-cuts to obtain the true values, i.e. observed values arise also in QED, the divergences often appear in radiative corrections involving Feynman diagrams with closed *loops* of virtual particles in them, for instance

(a) A photon creates a virtual electron–positron pair, which then annihilates. This is a vacuum polarization diagram.
(b) An electron quickly emits and reabsorbs a virtual photon, called a self-energy.
(c) An electron emits a photon, emits a second photon, and reabsorbs the first (*vertex renormalization;* Feynman "penguin diagram"). These integrals are often *divergent* and infinite. Examples are the region in the integral where all particles in the loop have large energies and momenta, very short wavelengths and high-frequency fluctuations of the fields, in the path integral for the field, very short proper-time between particle emission and absorption, if the loop is thought of as a sum over particle paths.

The second class of divergence called an infrared divergence, is due to massless particles, like the photon. Every process involving charged particles emits infinitely many coherent photons of infinite wavelength, and the amplitude for emitting any finite number of photons is zero. For photons, these divergences are well understood. For example, at the 1-loop order, the vertex function has both ultraviolet and infrared divergences.
the infrared divergence does not require the renormalization of a parameter in the theory involved.

The infrared divergence of the vertex diagram is removed by including a diagram similar to the vertex diagram with the following important difference: the photon connecting the two legs of the electron is cut and replaced by two on-shell (i.e. real) photons whose wave lengths tend to infinity; this diagram is equivalent to the bremsstrahlung process. This additional diagram must be included because there is no physical way to distinguish a zero-energy photon flowing through a loop as in the vertex diagram and zero-energy photons emitted through bremsstrahlung. From a mathematical point of view, the IR divergences can be regularized by assuming fractional differentiation and turning them into a UV divergence.

--For QED the quantities such as the Lagrangian for electric charge and mass and the normalizations of the quantum fields themselves, did not actually correspond to the physical constants measured in the laboratory. Such bare quantities take not into account the contribution of virtual-particle loop effects to the physical constants themselves. These would include the quantum counterpart of the electromagnetic back-reaction that so vexed classical theorists of electromagnetism. In general, these effects would be just as divergent as the amplitudes under consideration in the first place; so finite measured quantities would, in general, imply divergent bare quantities.

--However, we see the renormalization is necessary to fit the theory to observation in QED, QCD and not to be trapped by infinities (Jackiw et al., 1999), however, these are different from the granularity resulting from the quantum of action.

The granularity in our perspective results from decoherence and defined results, as our world is real and defined and no longer an ocean of undefined qubits. Qubits crystallized out to separated bits for all actions equal or larger than h dash. This is shown in more detail in the final section of this appendix.

Eq. 9 (quantum computations for proton mass)

One can start simple (the proton composed of two up and one down quark and color charge):

$$m_p = 2m_u + m_d + \Delta E$$

and next consider the colour charge e in more detail:

$$\Delta E = \frac{2\pi}{3}\frac{e_i e_j}{m_i m_i}|\psi(0)|^2 \boldsymbol{\sigma}_i \cdot \boldsymbol{\sigma}_j$$

And then it becomes step-wise more and more complex, e.g. considering the Baryon octet of spin parity ½ you then get for the proton the wave function:

$$\begin{aligned}\phi(P, J_z = +\tfrac{1}{2}) = \frac{1}{\sqrt{18}}[&2u{\uparrow}u{\uparrow}d{\downarrow} + 2d{\downarrow}u{\uparrow}u{\uparrow} + 2u{\uparrow}d{\downarrow}u{\uparrow} \\ &- u{\downarrow}d{\uparrow}u{\uparrow} - u{\uparrow}u{\downarrow}d{\uparrow} - u{\downarrow}u{\uparrow}d{\uparrow} \\ &- d{\uparrow}u{\downarrow}u{\uparrow} - u{\uparrow}d{\uparrow}u{\downarrow} - d{\uparrow}u{\uparrow}u{\downarrow}].\end{aligned}$$

Next, you derive from this the mass and do the more detailed calculation.

Eq. 10 (quantum action and qubit-to-bit transition for a proton)

In the next step you have then to apply our new perspective of a qubit to bit transition to this description of the proton mass, so applying **eq. 1, eq. 1b** and **eq. 3** to this. However, next one has to consider multiple particle systems:

Eq. 11 (decoherence of quantum states in a multiple particle system),

this is of course far more difficult and not shown in this appendix. Instead, **Fig. 2** gives a toy example for a system with 6 qubits who only can have two quantum states. In full superposition they have their 64 different possible bit states mixed together as qubits, in decoherence each of them “freezes out”. There is emergent time according to the arrow of entropy and emergent space according to quantum state. However, to transfer the full enumeration of all quantum states to something more complex, for instance the proton, is far more difficult.

Eq. 12 (**confinement of quarks by a scalar field**)

Unfortunately, there is not yet an analytic proof of color confinement in any non-abelian gauge theory. There is only asymptotic freedom of quarks in QCD (Gross and Wilczek, 1973; Politzer 1973). Qualitatively one can state that the force-carrying gluons of QCD have color charge, unlike the photons quantum electrodynamics (QED). However, our theory opens a perspective to find an analytical solution: As color charge is a *scalar field* it is impossible to have free quarks, they can only leave if being color neutral or white by one or two balancing quarks. According to the qubit crystallization theory, the resulting seed and crystal is a very strong interaction field over the whole crystal (our whole domain; see eq. 1, eq. 1b and eq. 3) and provides a scalar field at level of grand unification which then in our present-day cooler universe broke down (symmetry breaking) into the four basic forces, one of them being gravity.

Describing the transition between free, liquid qubits and solid bits

String theory, LQG or classical quantum theory should help the mathematics of our new theory and describe the transition between free, unbound, “liquid” and bound, “solidified” qubit states more properly.

Free qubits are well described by quantum physics including LQG. However, though generally these formalisms allow a complete sampling over all possibilities, they (i) do not consider that the bits are frozen out and defined if a real macroscopic world like ours is formed and crystallizes out.

(ii) Moreover, typical cosmological formalisms like that one by Ashthekar et al. (2006) and later LQG cosmologies (LQC) focus on just two Hamilton operators and are essentially only two particle systems. To properly describe world formation we need multiple particle systems (as illustrated in **Fig. 2**).

(iii) For the same reason, a proper treatment of time is only possible in a multiple particle system: to derive an appropriate arrow of time and include entropy we need a multiple particle system (arrow of time and entropy is illustrated in **Fig. 2**).

Hence, we need here two formula regimes:

The quantum world, all phenomena smaller than h dash we describe by formalisms of quantum physics, and also string theory or LQG is fine.

However, as soon as the disturbance or the phenomenon is bigger than h dash we need a lattice theory: This will describe then the different layers of the crystal and how all forms if I have a full and defined world like ours. This has as its backbone essentially the layers of bit states, emergent time according to entropy arrow and discrete quantum states of particles as sketched in **Fig. 2**. How does the unit cell then look like?

Well, we know from our considerations above that the qubits can only interact in four ways, if they can at all interact: 1,2,4 and 8D. Only the 8D interaction is rich enough for an interesting world with life and four forces and time and space. Moreover, we postulate a selection operating on the free parameters the crystal has to form, with a selection for qubit crystals with best self-organizing properties, as they are “fine-tuned” to give rise to best survival capacities regarding seeds for the next generation. This implies selection for optimal parameter settings in eq. 1 – eq 12; independent of setting parameters to obtain our stable universe required by our theory.

Develop our toy model further: However, it is important to realize that this is an effort to unify and reconcile the different approaches. The new full description allows to have a phase transition (“solidification”) from the full liquid regime of LQG or string theory or quantum field descriptions (QED, QCD) according to the parameter h dash (in our real universe Planck´s quantum is quite small) such that for larger actions (bigger than h dash) all becomes solid and defined and is described by a lattice field theory with lattice size h dash and the unit cell of the crystal formed according to E8 string theory.

The results given above for a quantum action theory developed around a toy example of six quanta which only have 2 possible quantum states should be developed further, either by classical approaches (QCD) or by novel ones (string theory, LQG). The key is to recognize that also cosmology needs more calculations on multiparticle systems, consideration of entropy, and applying emergent time and emergent gravity.

Lattice QCD extended step by step to quantum action theory

Further development of the approach would orient itself from existing lattice QCD approaches, but using the view from our perspective to integrate gravity (see **Table 1**). Lattice QCD tries to solve the theory exactly from first principles, though in practice calculation power is of course limited. One needs to choose an action which gives the best physical description of the system, I suggest here to investigate exactly the transition behavior in our „grand unified lattice“ for actions crossing Planck´s quantum and leading to the defined, crystallized-out state.

The road to this is a real challenge, first the scattering matrix is expanded for lattice perturbation theory into powers of the lattice spacing, a. Results then renormalize Lattice QCD Monte-Carlo calculations. In perturbative calculations both the operators of the action and the propagators are calculated on the lattice and expanded in powers of a. Expansions need for comparison a common continuum scheme (e.g. MS-bar scheme) on which the same expansion is done. Lattice regularization can study strongly coupled theories non-perturbatively. Perturbation theory is a challenge, requires an expansion in the coupling constant, and is well justified in high-energy QCD where the coupling constant is small, but fails if higher order corrections are larger than lower orders in the perturbative series. Their then non-perturbative methods are necessary, e.g. Monte-Carlo sampling of the correlation function. Closer to the focus of our perspective, lattice perturbation theory can also provide results for condensed matter theory where the lattice represents the real atomic crystal. Moreover, an universal quantum computer (Byrnes and Yoshihisa, 2006) can be used to simulate U(1), SU(2), and SU(3) lattice gauge theories using "spin qubit manipulations".

Nevertheless, there are limitations: no full real-time dynamics of a quark-gluon system such as quark–gluon plasma have been simulated, calculations are computationally intensive (flops but even more so memory access). Reliable predictions are only achieved for hadrons containing heavy quarks (e.g. hyperons with a strange quark, ALICE collaboration, 2020). This has to be extended as follows:

Recent advances in the field (reviewed in Zohar et al., 2022) should help to make first steps towards a more general lattice theory for QCD *and* gravity implementing this perspective, considering matter fields and transformations and lattice gauge fields in more dimensions (e.g. see Zohar et al., 2022, formula 3)

$$\theta_g(\mathbf{x})\,\psi^{\dagger}_{\mathrm{m}}(\mathbf{x})\,\theta^{\dagger}_g(\mathbf{x}) = \psi^{\dagger}_{\mathrm{m}'}(\mathbf{x})\,D_{\mathrm{m}'\mathrm{m}}(g)$$

and gauge fields. Most notably we should mathematically include first the restrictions by our perspective regarding qubit crystal formation (**eq. 1**- **eq. 6**) and derive (**Table 1**) by this also the two important scalar fields suggested by my theory: the generalized interaction field of the qubit crystal leads after cooling down from the hot fireball at unification energies to two scalar fields, one for color confinement and one for gravity (extending the Higgs scalar field to general gravity). These two fields allow then to obtain a complete quantum field theory.

Task 1: All quantum states have to be collected systematically for the system you want to model with this approach and next they are in this theory considered to be "frozen out" or defined for a mash size of Planck´s quantum, but tackling a multiple-quanta system big enough to derive a first system description. The toy example in **Fig. 2** does this for 6 qubits which "frozen-out" yield 64 different 6-bit states. Hence, we assume in our universe for everything bigger then Planck´s quantum that all is defined and there is no uncertainty but you have to consider the complete system and all quantum states to achieve this. We hence follow here the philosophy of Bohm and note that notions of considering Bohm trajectories surrealistic (Englert et al., 1992) were observed in the end (Mahler et al., 2016). This suggests that we may be on the right track assuming that all quantum states of the qubits are realized and crystallized out.

Only if we consider the entropy we can derive next an emergent arrow of time (see **Fig. 2**). Similarly, we have to consider the bit state to derive emergent space (see **Fig. 2**), and of course the other bit states denoting other quantum aspects (particle type, forces, quantum states). This is already a huge task and the systems above were picked to show a series of systems with more and more complex quantum states. Moreover, to achieve emergent space and emergent time, usually a background free treatment as known from LQG is necessary, here only demonstrated for the toy example in **Fig. 2**.

Task 2: There are other grids to take care of in addition. For instance, Planck length is important as at this length scale gravity becomes similarly strong and it is speculated that this is the basic length scale (e.g. string length). Other grid lengths (including other dimensions of the grid) will become important for optimal calculation reasons. These have to be treated technically well, but they are not central for this approach.
However, the grid composed of actions bigger than Planck´s quantum is central for this approach, because only at and beyond this limit there is decoherence and the physical

reality of our world starts. The reason for the freezing out of the states is the interaction field holding the whole crystal together (**eq. 1** to **eq. 6**) as explained qualitatively in the results section. The "world crystal" of our theory is a type of multiverse, envisioned as a stack of different world lines and evolutions, each separated by one Planck´s quantum from the other. It is important to see that our multiverse is maximally economic: There is not always a new splitting of worlds as in Everett-like models. Instead, we have a crystal made of m quanta with n states frozen out to all their bit states, that is all (**Fig. 2**, **Fig. 3**).

Task 3: **Include scalar fields for color charge and for gravity**
It is exciting that we can give a reason for
(i) quark confinement by a scalar field. The scalar field is observed in quantum physics and **QCD**, allowing only asymptotic freedom (Gross and Wilczek, 1973; Politzer 1973), but we know by our perspective the reason for the scalar field:
The astronomical equations (**eq. 1** till **eq. 6**) allow to calculate the general force field holding the crystal together, leading to the crystallization process and this force is the reason not only for this scalar field acting on gluons.
(ii) However, we should even be able to derive also the different scalar field acting on the Higgs boson and generalize it for gravity. As there is no "white" color for gravity, it will act throughout the crystal, and we know how to parametrize it, as it should yield the observed universal gravitational constant. As is typical for unified approaches, we would also consider that **eq. 1** till **eq. 6** describe the very high energy early phase of the crystallization from free qubits and subsequent cooling and symmetry breaking yields then the two different scalar fields for gravity and for gluons / color confinement and it should be parameterized such that the observed forces result. May be this works for string theory or LQG, too, and emergent gravity is by its similar emergent aspects close to our approach (see conclusions in the paper). No matter which road is taken, the key would be to consider a multiple particle system, emergent time and entropy and consider the two permeating scalar fields and the qubit phase transition. The race is open, our perspective can be incorporated by all these approaches.

The new perspective will help to better tackle notorious problems of fundamental physics: Instead of trying blindly to integrate gravity in a lattice-type unified theory of all four forces we know that according to **eq. 1, eq. 1b** and **eq. 3** the interaction potential can be calculated, the astronomic (**eq. 1-6**) and microscopic (**eq. 7-12**) constraints have to be considered. Among other things, the model should deliver the right vacuum energy calculated by considering the bound qubit state. Importantly, we consider a phase transition from free qubits (coherent) to bound, almost completely solid bits (nearly everywhere, only below Planck´s quantum there is still free choice of quantum states in our domain). To model this and compare the results with experimental data is possible and has been tried before, whereas the hypothetical scenarios of a big bang or an inflaton with inflation (Linde, 2017) are not reachable by experiments. "Big Bang" and inflation remain in this sense metaphysical and cannot be tested. Hence, connecting all available data and concepts, we offer here an alternative theory at least as well compatible with all observations and explaining far better the fundamentals and the "why?".