How do qubits interact? Implications for fundamental physics.

Thomas Dandekar, dept of bioinformatics, University of Würzburg, 97074 Würzburg, Germany; e-mail: Thomas.dandekar@uni-wuerzburg.de

Abstract (499 words)

Proteins fold in water and achieve a clear structure despite a huge parameter space. Inside a (protein) crystal you have everywhere the same symmetries as there is everywhere the same unit cell. We apply this to qubit interactions to do fundamental physics:

We modify cosmological inflation: we replace the big bang by a condensation event in an eternal all-encompassing ocean of free qubits. Rare interactions of qubits in the ocean provide a nucleus or seed for a new universe (domain), as the qubits become decoherent and freeze-out into defined bit ensembles. Next, we replace inflation by a crystallization event triggered by the nucleus of interacting qubits to which rapidly more and more qubits attach (like in everyday crystal growth). The crystal unit cell guarantees same symmetries (and laws of nature) everywhere inside the crystal, no inflation scenario is needed.

Interacting qubits solidify, quantum entropy decreases in the crystal, but increases outside in the ocean. The interacting qubits form a rapidly growing domain where the n**m states become separated ensemble states, rising long-range forces stop ultimately further growth. After this very early modified steps, standard cosmology with the hot fireball model takes over. Our theory agrees well with lack of inflation traces in cosmic background measurements.

Applying the Hurwitz theorem to qubits we prove that initiation of qubit interactions can only be 1,2,4 or 8-dimensional (agrees with E_8 symmetry of our universe). Repulsive forces at ultrashort distances result from quantization, long-range forces limit crystal growth. The phase space of the crystal agrees with the standard model of the basic four forces for n quanta. It includes all possible ensemble combinations of their quantum states m, a total of n**m states. We describe a six-bit-ensemble toy model of qubit interaction and the repulsive forces of qubits for ultra-short distances. Neighbor states reach according to transition possibilities (S-matrix) with emergent time from entropic ensemble gradients. However, in our four dimensions there is only one bit overlap to neighbor states left (almost solid, only below Planck´s quantum is liquidity left). The E_8 symmetry of heterotic string theory has six curled-up, small dimensions. These keep the qubit crystal together and never expand. We give energy estimates for free qubits vs bound qubits, misplacements in the qubit crystal and entropy increase during qubit crystal formation.

Implications are fundamental answers, e.g. why there is fine-tuning for life-friendliness, why there is string theory with rolled-up dimension and so many free parameters. We explain by cosmological crystallization instead of inflation the early creation of large-scale structure of voids and filaments, supercluster formation, galaxy formation, and the dominance of matter: the unit cell of our crystal universe has a matter handedness avoiding anti-matter. Importantly, crystals come and go in the qubit ocean. This selects for the ability to lay seeds for new crystals, for self-organization and life-friendliness. Vacuum energy gets appropriate low inside the crystal by its qubit binding energy, outside it is 10**20 higher. Scalar fields for color interaction/confinement and gravity could be derived from the qubit-interaction field.

Key words: protein folding; crystallization; qubit; qubit interaction; decoherence; modified inflation; early cosmology;

Running head: qubit interactions and fundamental physics

Introduction

Motivation: Qubit crystallization should be a deep explanation in cosmology. Cosmology is a mystery, particularly the very early stages: the textbook “Big Bang” just happens for no reason, next there takes over the incredible “inflaton” and inflation, never seen again afterwards (Weinberg, 1977; Dodelson and Schmidt, 2020). Strange unexplainable things happening in a physics theory are usually a clear indication that this theory is wrong. However, we know that the hot fire ball universe and subsequent expansion is well established, not just as a theory but by detailed and many observations in agreement with this theory and none or very few are not compatible with observation. Hence, we want to modify cosmology only at the start: *we only replace the most early two steps in cosmology* by different phenomena motivated by normal physics and we are (as the mainstream in cosmology) convinced that thereafter the standard cosmological model takes over, the expanding hot fireball early universe cooling down over billions of years (Dodelson and Schmidt, 2020). Ade et al. ‘(2018) and other observations (Chen et al., 2019) make it at least more plausible that inflation (Linde, 2017) is not an optimal second early step for cosmology and not being able to answer “*why*” there is a big bang is also a major flaw for any explanation relying on a bang as explanation for a start.

In this spirit, relying on our over two decades-long experience in protein folding and protein structure analysis (Dandekar and Argos 1994, 1996; till Sarukhanyan et al., 2022 Sarukhanyan and Dandekar, 2023), we develop own previous efforts on fundamental physics further (Dandekar, 1991; Dandekar 2022; Dandekar 2023a-c). However, we changed from a radical inspiration (Dandekar, 2022) like in Edgar Allen Poe´s vision of the expanding universe long before astronomy showed it (“Eureka”, Poe 1848) to a more physics textbook formulae developed further and mathematics supported approach. For this, we are particularly stimulated by recent advances regarding the description and observation of qubits (e.g. Lopez-Bezanilla et al., 2023,2024) which helps to develop our mathematical formalisms further.

Motivated by everyday phenomena we are observing, applying and modelling since decades, *protein folding and crystallization* including protein crystals (Kawasaki and Tanaka, 2010) we see that proteins get order only by allowing more entropy happening in the water around and that natural crystals come and go when conditions are right. This suggests that in cosmology we also should not start by creation from nothing but rather from a big ocean of free qubits of any dimension at start: this ocean is assumed here as the start and foundation (**Fig. 1**). If in this ocean qubits interact at all and subsequent conditions permit (non-cosmological example: Lopez-Bezanilla et al., 2024) that even qubit crystals (non-cosmological example: Kagome qubit ice; Lopez-Bezanilla et al., 2023) can form, you need no inflation to guarantee the same laws of nature everywhere: Rather the symmetry unit in a typical everyday normal crystal (e.g. protein crystal for X-ray structure resolution) makes sure that everywhere in the normal crystal there are the same symmetries. As this is a natural phenomenon observed so many times, we think it is important and correct to replace inflation and the never observed inflaton (Rosa and Ventura, 2019) by crystallization.
At first you would think that the crystallization should then rapidly take over all the ocean, but normal crystallization again shows that this is not the case, you get a couple of crystals typically and the stock solution remains liquid, too.

Strengths of our theory: As we are convinced that observable phenomena should even in cosmology be the source of inspiration for the best describing theory, the *formal framework we offer* starts with frameworks (Hamilton operator etc.) from latest observations on qubits and quantum computing and different observed qubit states such as *Kagome qubit ice* (Lopez-Bezanilla et al., 2023). Similarly, evolution is usually the explanation for complex fine-tuning and hence we invoke this also (like some other cosmologists also do, e.g. Smolin, 1997) to explain the cosmological fine-tuning problem for life-friendly conditions (Davis, 2007). Finally, qubit crystallization provides for this and other fundamental questions real explanations, largely missing in the textbook cosmology: Why is there not more antimatter? How did early structure generate? Why is vacuum energy so low inside the crystal? Why is there colour confinement? Why are there rolled-up dimensions? Why is string theory so open in its parameter choice?

We deliver here for a number of phenomena higher level explanations, particularly for the openness of string theory and the rolled-up dimensions (Yau and Nadis, 2010) in string theory and answer the ultimate question: The deep question is not how our universe did start but *why is our universe real* (the mystery of decoherence; Zeh, 1970, Schlosshauer, 2005). This reconciles then also general relativity with quantum theory, as we realize this is only possible inside the qubit crystal, so our frozen-out qubit ensembles are the basis for our universe and as they are clearly defined states they also do not become infinite as in many textbook calculations due to smaller and smaller distances (Jackiw, 1999; Gross and Wilczek, 1973). In contrast, outside of our crystal we have the free, fathomless, undefined qubit ocean (called "bulk" in string theory) where more and more virtual particles are considered and vacuum energy becomes 10**20 higher.

Limitations of our theory: A major limitation is that our mathematical framework is only starting to evolve. We outline clearly how further development should evolve but we do not deliver a full framework yet but only a sketch. Hence, a simple test of mathematical consistency of our theory is not yet possible, let alone calculations showing quantitative better agreement to cosmological observations then the standard cosmological theory. However, the deep explanations delivered in a qualitative way should motivate interested experts to develop the framework further.

Moreover, for most cosmological theories including this one the problem is rather the opposite one: so many free parameters that I can of course fit my own new theory always to cosmological observations. This implies no objective decision between the theories is possible in this way. Hence our insistence to find the correct cosmological theory to start with normal, observable phenomena which we can exactly measure in laboratory experiments and then refine our framework accordingly. However, unfortunately this requires to modify the formulae from their laboratory framework to a cosmological description, even for those phenomena we took inspiration from which deal with qubits in physical laboratory settings. This is a major limitation of this manuscript as this is only sketched and not actually done here. Another challenge is not so obvious: In our world we can never create "really free qubits" matching the freedom in the qubit ocean (called "the bulk" in string theory) outside of our qubit crystal (called "our domain" in cosmological terms). This is of course not necessary and not done for instance in quantum computations in the laboratory or observations of qubit ice in superconducting materials. Hence, also this has later to be considered in developing our framework further and is again only mentioned here but not properly implemented into our framework yet.

Results

Basic qubit interaction scenario explained in a toy model: The reasoning outlined in the introduction brought us to look at qubits interacting with low probability in an ocean of qubits, forming a rare seed of two interacting qubits, which next grow by a magnetization-like process (non-cosmological parallel described in Lopez-Bezanilla and Nisoli, 2023) until long-range forces stop further growth (like in normal magnets, Devizorova et al., 2019; see Fig. 1).

However, looking more at qubit interaction made clear that cosmology is all the time asking only a particular question: "how did the universe start" while we realize, looking at qubits with all their many possibilities at the same time, the proper question should

be “why is our universe real” (Zeh, 1970, Schlosshauer, 2005). The mystery of decoherence is tackled here head-on: Despite that the whole quantum world shows that qubits are naturally multistate and undefined, our universe (our domain in the following) it is really difficult to preserve qubits undisturbed and coherent for instance for quantum computing. And this decoherence is the essential property of our universe and this happens in my opinion not due to esotherics such as the “act of conscious observation” (Wheeler, 1977) but rather is an inherent building principle of our universe applying for all time points, and, in fact, all system states. We show emergent time from crystallization of n “free qubits” with m states each into a more or less “solid aggregate” of n**m bit-ensembles each composed of n bits in a toy model with 6 qubits with 2 states each giving rise to 2**6=64 bit-ensembles of 6 bits each (**Fig. 2**).
Note that our theory shows that we only have n**m bit ensembles of n bits, as the total system state of the world and never more. In particular, we do not get an astronomical high number of ever more parallel worlds with every decision as in Everett-type multiverse models (Tegmark, 2007). Rather, different trajectories are possible connecting this fixed number of states and each is separated by h dash from its neighbors (**Fig. 3**). Moreover, the qubits are not completely frozen out but below h dash there is still the quantum world as we know from quantum physics.

Moreover, it turns out that crystallization of n “free qubits” with m states each into a more or less “solid aggregate” of n**m bit-ensembles each composed of n bits is not yet a world: you can access via the quantum probabilities for instance of the S-matrix from one state to the neighbor states accessible for each bit ensemble as direct neighbors. However, such separated bit states at least for the macroscopic world lack a glue holding everything together. We need hence a glue to have a stable world and this glue are provided in our theory by the rolled-up dimensions and interactions suggested for instance from string theory (Kaya and Rador, 2003). They can never expand and this holds our universe stable together, limiting also the maximum size the qubit growth in a magnetization-like process can reach.

Furthermore, as normal crystals come and go, we think that a population of qubit crystals each existing only a finite time in the vast qubit ocean is prone to selection processes and a type of evolution: if there is any small variation in the population (e.g. by quantum fluctuations) then those crystals will be favored for the next generation that generate the best seeds. Hence, this could explain fine-tuning, why our universe is so life-friendly: If the whole crystal is under selection pressure to be capable to seed the next generation, this definitely makes it possible that conditions for any self-organizing and life-like processes get selected, too, over the generations.

Qubit interaction reduces step-wise parameter space for fundamental physics: In the following we give the physics and a simplified mathematical foundation for the qubit interaction theory. This theory is in one perspective a modified inflation theory, replacing big bang and inflation by qubit interactions triggering a seed and subsequent crystallization. However, the complementary perspective is also important: How do the absolutely free and open qubits become more and more defined. Why is our world real and not a limbo of quantum waves? To ask “*why there is decoherence so permeating present in our universe”* is the more fundamental question to ask then what was at the start of the universe, it is a time-less big question.
Hence, our main physics task in establishing the framework how to test this theory in actual physics formulae is to reduce the space of free parameters more and more until we end up with the observed parametrization of our universe. **Table I** shows our program and illustrates where the openness of the parameter space is useful and how we step-by-step approach our universe.

Currently, we have here only (i) the logic of arguments, (ii) the use of observable normal phenomena throughout and (iii) the strong philosophical and phenomenological explanatory power of our theory.
(iv) the typical validation part of a physics theory is currently not possible: Just taking the mathematics and checking and showing that there is a better fit to observation then current standard theory is not possible just by comparing the parametrization:
As both textbook cosmology and this alternative cosmology fit their parameters such that they fit well to available astrophysical and quantum physics data, the difference here is far more difficult to establish and not actually shown yet here.
(v) However, the qualitative argument that early structure formation is quite easy to explain from our theory but a challenge for standard textbook cosmology is very clear, the same applies to the missing of anti-matter and, most importantly, for fine-tuning (why is the universe so life-friendly), the openness of string theory (10**600 solutions allow selection to operate for optimal crystal seed formation implying life-friendliness), why there is confinement (unified field is the qubit interaction field, breaks down to scalar fields for strong force and for gravity / Higgs fields). These qualitative arguments are so strong that they should encourage better mathematical physicist to establish here a unifying qubit-condensation, qubit-growth and universe forming mathematical framework explaining why our universe is real: as qubits condensed and formed defined bit ensembles with only little quantum certainty below h left.

However, for this reason, the mathematical results focus on the general question how qubits can interact at all. Starting from a general Hamiltonian of the energy function of interacting qubits we show that qubits of any dimension cannot interact, but rather this is stably only possible of qubits of 1D, 2D, 4D and 8D. Some basic formulas on qubit interactions can nevertheless be given and they are really well tested in efforts for quantum computing, solid state physics (Imhof et al., 2018), protein folding and crystallization of normal crystals.

We then discuss, how this starting insight is vindicated by observations, in particular that the basic symmetry unit of our universe is 8-dimensional (Wolchover, 2019), both in string theory and in particle physics and suggests further insights available from a mathematical further developed qubit interaction theory including explanations on dark matter (**Fig. 4**), large-scale early structure formation in the universe, dark energy, why there is only matter and not more antimatter, why there should be heterotic string theory (Polchinski, 1998; Gross et al., 1985) and rolled-up dimensions (Green, 2000; Randall, 2005) and why our universe has a limited life-time (e.g. Pain and Astier, 2012) and why there is fine-tuning for life-friendly conditions.

Qubit interaction (F1): The Hurwitz theorem proofs that only a 1D,2D,4D and 8D solution is possible for qubits (or strings) of arbitrary dimension to really interact.

Proof: The Hurwitz theorem proofs that only a 1D,2D,4D and 8D solution is possible for strings of arbitrary dimension to really interact, nothing else → E_8 symmetry is part of the 8D solution. E8 is our symmetry unit in our world (Wolchover, 2019) and a representation of the 8-dimensional solution, hence an explanation *why* there is string theory in our world: E_8 with 8 dimensions is the main possibility how qubits interact.

We examine the following scenario: First we have really free qubits, in full entanglement in the qubit ocean, and of any dimension; then with a really low probability (calculation and estimate see below) we need two qubits to interact with any D, so double circle. This event triggers then the seed for a new condensation nucleus and world.
If two qubits really can interact, according to the Hurwitz theorem (see below) there are only four solutions possible, restricting hence the interaction possibilities and dimension

possibilities for interaction drastically: Either only a 1D (one dimensional) interaction, a 2D, a 4D, or last solution 8D (8 dimensional) interaction is mathematically possible, so for an initial first start two qubits have to interact and they can have **any** dimension (**fat circle**) have to interact:

$$\left|\begin{matrix}0\\1\end{matrix}\right\rangle \otimes \left|\begin{matrix}0\\1\end{matrix}\right\rangle \quad \text{2 qubits} \quad nD \quad m \text{ states}$$

$$\Downarrow$$

Then more qubits align (like in magnetization), e.g. 4 qubits,

$$\left|\begin{matrix}0\\1\end{matrix}\right\rangle \otimes \left|\begin{matrix}0\\1\end{matrix}\right\rangle \ldots \otimes \left|\begin{matrix}0\\1\end{matrix}\right\rangle \quad \begin{matrix}n \text{ qubits}\\ m \text{ states}\end{matrix} \quad nD$$

$$\Downarrow$$

Introducing qubits directly: However, the new concept introduced by me here are qubits and we 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.

So, we first remind by accurate mathematics how Hurwitz came to this proof, following as accurate as possible his proof (blue font: directly following and citing Hurwitz, 1898):

In the domain of quadratic forms of n variables a composition theory will take place, if for any three quadratic forms ϕ, ψ, χ of non-vanishing determinant the equation

$$(1) \qquad \varphi(x_1, x_2, \ldots x_n)\psi(y_1, y_2, \ldots y_n) = \chi(z_1, z_2, \ldots z_n)$$

can be satisfied by replacing the variables $z_1, z_2, \ldots z_n$ by appropriately chosen bilinear functions of the variables $x_1, x_2, \ldots x_n$ and $y_1, y_2, \ldots y_n$. Since a quadratic form can be transformed into a sum of squares by linear transformation of the variables, so one may, without affecting the generality, substitute the following equation (1):

$$(2) \qquad (x_1^2 + x_2^2 + \cdots + x_n^2)(y_1^2 + y_2^2 + \cdots + y_n^2) = z_1^2 + z_2^2 + \cdots + z_n^2$$

According to this, the question whether a composition theory exists for quadratic forms with n variables is essentially identical with the other one, whether one can satisfy equation (2) by appropriate bilinear functions $z_1, z_2, \ldots z_n$ of the 2n independent variables $x_1, x_2, \ldots x_n$ and $y_1, y_2, \ldots y_n$. In the following lines I will show that this is only possible in the cases n = 2; 4; 8.
so that only for binary forms, for quaternary forms and for forms with 8 variables

a composition theory exists. By this proof then in particular also the old controversy whether the known product formulas for sums of 2, 4 and 8 squares can be applied to sums of more than 8 squares is finally decided in the negative sense[2].
In order to simplify the presentation, I make use of the calculation with linear transformations, which can probably be traced back to Cayley[3].
Calculus with linear transformations. Denotes (3)

$$A = \begin{Bmatrix} a_{11}, & a_{12}, & \dots & a_{1n} \\ a_{21}, & a_{22}, & \dots & a_{2n} \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ a_{n1}, & a_{n2}, & \dots & a_{nn} \end{Bmatrix} \tag{3}$$

or more briefly $A = (a_{\alpha\beta})$ such a transformation, then A_0 should be understood as that transformation which results from A by interchanging the horizontal and the vertical series.
The task to solve equation (2) by n bilinear functions

$$z_\alpha = a_{\alpha 1} y_1 + a_{\alpha 2} y_2 + \cdots + a_{\alpha n} y_n \qquad (\alpha = 1, 2, \dots n)$$

can now obviously be formulated in this way:
Let the elements a□□ of the transformation A be linear homogeneous functions of the variables
$x_1, x_2, \dots x_n$ such that the transformation A satisfies the equation

$$AA' = (x_1^2 + x_2^2 + \cdots + x_n^2) \tag{4}$$

If A is ordered by the variables $x_1, x_2, \dots x_n$, then you obtain

$$A = x_1 A_1 + x_2 A_2 + \cdots + x_n A_n, \tag{5}$$

where $A_1, A_2, \dots A_n$ denote transformations with constant coefficients, and the equation (4) gains the shape:

$$\begin{aligned}(x_1 A_1 + x_2 A_2 + \cdots + x_n A_n)(x_1 A_1' + x_2 A_2' + \cdots + x_n A_n') \\ = (x_1^2 + x_2^2 + \cdots + x_n^2).\end{aligned} \tag{6}$$

The comparison of the terms with X_n^2 shows that $A_n A'_n$ must be 1. Hence, one next carries out the transformations

$$B_1 = A_1 A_n', \; B_2 = A_2 A_n', \dots B_{n-1} = A_{n-1} A_n' \tag{7}$$

and sets accordingly

$$A_i = B_i A_n, \qquad A_i' = A_n' B_i', \qquad (i = 1, 2, \dots n-1)$$

then the equation (6) changes into the following equation:

$$\begin{aligned}(x_1 B_1 + x_2 B_2 + \cdots + x_{n-1} B_{n-1} + x_n)(x_1 B_1' + x_2 B_2' + \cdots + x_{n-1} B_{n-1}' + x_n) \\ = (x_1^2 + x_2^2 + \cdots + x_n^2).\end{aligned} \tag{8}$$

If we develop the left side here, the coefficient comparison yields

$$B_iB_i' = 1, \qquad B_i' = -B_i, \qquad B_iB_k' = -B_kB_i', \qquad (i \lesseqgtr k)$$

and the latter equations can obviously also be replaced by the following ones:

$$B_i^2 = -1, \qquad B_iB_k = -B_kB_i, \qquad B_i' = -B_i. \qquad (i \gtrless k) \tag{9}$$

In this way, every transformation A which satisfies the condition (4) yields, n-1 transformations B_1, B_2, …B_{n-1} which satisfy the equations (9). Conversely, if B_1, B_2, …B_{n-1} satisfy the equations (9), if furthermore A_n denotes an arbitrarily chosen orthogonal transformation, then the transformation

$$A = x_1B_1A_n + x_2B_2A_n + \cdots + x_{n-1}B_{n-1}A_n + x_nA_n$$

satisfy the equation (4).

After this we only have to deal with the task of determining all systems of n-1 transformations B_1, B_2, …B_{n-1} which satisfy the equations (9). We now subject equations to a more detailed discussion, which will show that only in the cases n = 2; B_{n-1}

the cases n = 2; 4; 8, systems of n-1 transformations B_1, B_2, …B_{n-1} can exist, for which the equations (9) are satisfied.

Let us first consider the equations $B'_I = -B_i$

The same states that the transformations B_i are skew symmetric. Therefore, the equations (9) are incompatible if n is odd. Because in this case the determinant of B_i would have to vanish, which contradicts the equation $B_i^2 = -1$.

In the further discussion we may assume that n is even. Because of the equations (9), any integer function of B_1, B_2, …B_{n-1} is linearly representable by the 2^{n-1} transformations

$$1, \quad B_{i_1}, \quad B_{i_1}B_{i_2}, \quad B_{i_1}B_{i_2}B_{i_3}, \ldots, \quad B_1B_2\ldots B_{n-1}, \tag{10}$$

where the indices or all, satisfying the inequalities

$$0 < i_1 < n, \quad 0 < i_1 < i_2 < n, \quad 0 < i_1 < i_2 < i_3 < n, \ldots$$

value systems have to be preserved. Regarding these transformations (10) the following equation teaches

$$\begin{aligned}(B_{i_1}B_{i_2}\cdots B_{i_r})' &= B'_{i_r}\cdots B'_{i_2}B'_{i_1} = (-1)^r B_{i_r}\cdots B_{i_2}B_{i_1}\\ &= (-1)^{r+(r-1)+(r-2)+\cdots+1}B_{i_1}B_{i_2}\cdots B_{i_r},\end{aligned}$$

that the transformation

$$B_{i_1}B_{i_2}\cdots B_{i_r}$$

is symmetric or skew-symmetric, depending on whether r $\equiv$0, 3 (mod 4) or r $\equiv$1,2 (mod 4). This fact allows us to decide whether there can be a linear dependence between the transformations (10).

Let us denote in general by R, R_1, R_2, … linear combinations of the transformations (10) with non-vanishing coefficients, then R = 0 will introduce the general shape of a linear relation between the transformations (10).

Each of the transformations (10), which in such a relation is afflicted with a nonvanishing

coefficient in such a relation, should be termed connected to the relation or "involved" in the relation. Furthermore, if $R_1 = 0$; $R_2 = 0$ are two relations, then I want to call them

"alien to each other", if there is no transformation, which is involved in both relations at the same time.
Finally, a relation R = 0 is called "reducible", if its left side can be put into the form $R = R_1 + R_2$ such that $R_1 = 0$; $R_2 = 0$ represent two relations which are alien to each other. In the opposite case R = 0 is called "irreducible".
Obviously, it is sufficient to consider the irreducible relations. Such a relation remains irreducible, if one multiplies it by one of the transformations (10), and by such a multiplication one can achieve that transformation 1 goes with a non-vanishing coefficient into the relation. Furthermore, it is clear that transformations in an irregular relation are either all symmetric or all are skew symmetric. Now we have

$$(11) \qquad 1 = \sum c_{i_1 i_2 i_3} B_{i_1} B_{i_2} B_{i_3} + \sum c_{i_1 i_2 i_3 i_4} B_{i_1} B_{i_2} B_{i_3} B_{i_4} + \cdots$$

as an irreducible relation. By multiplication with B_i, where i denotes any of the indices 1, 2,… n -1 the same passes into:

$$B_i = \sum c_{i_1 i_2 i_3} B_{i_1} B_{i_2} B_{i_3} B_i + \sum c_{i_1 i_2 i_3 i_4} B_{i_1} B_{i_2} B_{i_3} B_{i_4} B_i + \cdots .$$

Here only skew-symmetric transformations are allowed to occur. Therefore, it must be $c_{i1}, c_{i2}, c_{i3} = 0$, if the index i is not among the indices i_1, i_2, i_3. But since the index i is arbitrarily selectable, all coefficients $c_{i1}, c_{i2}, c_{i3} = 0$. Likewise it follows that $c_{i1}, c_{i2}, c_{i3}, c_{i4} = 0$, if the index i occurs among the indices i_1, i_2, i_3, i_4, consequently, all the coefficients $c_{i1}, c_{i2}, c_{i3}, c_{i4} = 0$.

Concluding in this way, we see that the relation (11) can only have the form

$$(11') \qquad 1 = c \cdot B_1 B_2 \ldots B_{n-1}$$

where, moreover, $n \equiv 0$ (mod: 4) must hold, because otherwise $B_1, B_2, \ldots B_{n-1}$ would be a skew-symmetric transformation. If we square the two sides of the relation (11'), we see that c must be equal to +/-1. Apart from the relation (11') no other irreducible relations can exist.
Summarizing the above considerations, we can say:
If the n-1 transformations $B_1, B_2, \ldots B_{n-1}$ satisfy the equations (9), then necessarily n is an even number. The 2^{n-1} transformations (10) are furthermore linearly independent, if $n \equiv 2$ (mod: 4). In the case of $n \equiv 0$ (mod 4) they are either linearly independent, or there
exist between them the relations which result from

$$(12) \qquad B_1 B_2 \cdots B_{n-1} = \pm 1$$

by multiplication with the transformations (10) and no other irreducible relations. Thus, the first 2^{n-2} of the transformations (10) are linearly independent under all circumstances.

From this it follows that the solvability of the equations (9) satisfies the inequality

$$(13) \qquad 2^{n-2} \leqq n^2$$

since there is always a linear dependence between more than n^2 transformations. But the inequality (13) is no longer fulfilled from n = 10 on. Hence, there are only the cases n = 2; 4; 6; 8, in which possibly the equations (9) allow a solution.

The case n = 6 can be excluded without much work:
In this case the $2^5 = 32$ transformations (10) need to be linearly independent. Among these transformations we find 5+10+1 = 16 skew symmetric ones.

In general, there are between n(n-1)/2 + 1 skew symmetric transformations with n variables and linear dependence, and for n = 6 the value of n(n-1)/2 + 1 equals 16.

In the cases n = 2; 4; 8 there is an easy, though somewhat complex discussion. This yields the real solvability of the equations (9) and thus the existence of transformations A which satisfy the condition (4). The result of this discussion is as follows: One understands by A_0 in these cases n = 2; 4; 8 respectively the transformation

$$A_0 = \left\{ \begin{array}{cc} x_1, & -x_2 \\ x_2, & x_1 \end{array} \right\},$$

$$A_0 = \left\{ \begin{array}{cccc} x_1, & -x_2, & -x_3, & -x_4 \\ x_2, & x_1, & -x_4, & x_3 \\ x_3, & x_4, & x_1, & -x_2 \\ x_4, & -x_3, & x_2, & x_1 \end{array} \right\},$$

$$A_0 = \left\{ \begin{array}{cccccccc} x_1, & -x_2, & -x_3, & -x_4, & -x_5, & -x_6, & -x_7, & -x_8 \\ x_2, & x_1, & -x_4, & x_3, & -x_6, & x_5, & -x_8, & x_7 \\ x_3, & x_4, & x_1, & -x_2, & -x_7, & x_8, & x_5, & -x_6 \\ x_4, & -x_3, & x_2, & x_1, & x_8, & x_7, & -x_6, & -x_5 \\ x_5, & x_6, & x_7, & -x_8, & x_1, & -x_2, & -x_3, & x_4 \\ x_6, & -x_5, & -x_8, & -x_7, & x_2, & x_1, & x_4, & x_3 \\ x_7, & x_8, & -x_5, & x_6, & x_3, & -x_4, & x_1, & -x_2 \\ x_8, & -x_7, & x_6, & x_5, & -x_4, & -x_3, & x_2, & x_1 \end{array} \right\}.$$

Then the most general transformation A satisfying condition (4) is the following:

$$A = PA_0Q,$$

where P and Q denote arbitrary orthogonal transformations with constant coefficients. The above investigation raises some questions which are pointed out briefly:
If it is impossible, except for the cases n = 2; 4; 8, to calculate the product of two quadratic forms of n variables each $x_1, x_2, \dots x_n$; $y_1, y_2, \dots y_n$ as a quadratic form of n bilinear functions $z_1, z_2, \dots z_n$ of those variables, then a representation of that point as a quadratic form of a sufficiently large number of bilinear functions of the variables $x_1, x_2, \dots x_n$; $y_1, y_2, \dots y_n$ is always possible. The question now is, which is the smallest admissible value of this number. Transforming the quadratic forms to sums of squares, the question takes the following form:
What is the smallest value of m for which the equation

$$(x_1^2 + x_2^2 + \cdots + x_n^2)(y_1^2 + y_2^2 + \cdots + y_n^2) = z_1^2 + z_2^2 + \cdots + z_m^2 \tag{14}$$

can be satisfied by suitably chosen bilinear functions $z_1, z_2, \dots z_m$ of the variables $x_1, x_2, \dots x_n$ and $y_1, y_2, \dots y_n$?
This question can be further generalized by substituting the equation (14) by the following:

$$(x_1^2 + x_2^2 + \cdots + x_p^2)(y_1^2 + y_2^2 + \cdots + y_n^2) = z_1^2 + z_2^2 + \cdots + z_m^2 \tag{15}$$

where p and n denote given numbers and again the minimum value of m is the question.
On the other hand, in the above equation one can also take n and m as given and ask for the largest admissible value of p. This question allows in the case n = m a different formulation: If one considers in the space of n^2 dimensions, in which the n^2 coordinates of a point can be denoted by a_{ik} (i; k = 1, 2,… n), the entity, which is given by the equations

$$\sum_{i=1}^{n} a_{i1}^2 = \sum_{i=1}^{n} a_{i2}^2 = \cdots = \sum_{i=1}^{n} a_{in}^2, \ \sum_{i=1}^{n} a_{ih} a_{ik} = 0 \quad (h,\, k = 1,\, 2, \ldots n;\ h \gtrless k)$$

then the maximum value of p denotes nothing else than the highest dimension of linear spaces lying on this entity. By the way, an analysis which is quite similar to the one presented above shows that this maximum value of p is equal to 1 in the case of an odd n and in the case of an even n, it is constrained by the inequalities $2^{p-1} \leq n^2$ and $2^{p-2} \leq n^2$, respectively, depending on whether n $\equiv$ 2 or n $\equiv$0 (mod 4). Thus, if n is an even number, the maximum value of p cannot exceed (2 lg n / lg 2)+ 1 or (2 lg n /lg 2) + 2, respectively.

Now, to be really sure about the applicability of the Hurwitz theorem to the general energy terms of qubit interaction we have to transform the energy terms correctly into an addition of complex or hyper complex numbers.
Thus, 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 cited and given above

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

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.).

Using time t as just another dimension coordinate all can then be written as shown before, but introducing now qubits of any dimension instead of numbers of any dimension as well as any type of interaction field or particle instead of mathematical operations.

This shows 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 so the eight-dimensional symmetry of all particles and forces of the standard physics and of the world itself (Wolchover, 2017, 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).

Discussion

The path of physics formula necessary to develop our scenario further

Our qubit-crystallization approach is a new concept replacing only the first two steps in cosmology and then reaching again the early hot fireball universe of the textbook (Dodelson and Schmidt, 2020): we have no big bang, inflation, or a start from nothing but rather we are *becoming real and defined* in an ocean of eternal, free, uncoherent qubits. This is an important alternative to inflation as the symmetries of the crystal created guarantee everywhere inside the crystal the same symmetries and laws of nature. As the magnetization-like process of qubit interaction and growth shows, this is a flavor of a modified inflation cosmology (many other examples, e.g. Iijas and Steinhardt, 2016; Rosa and Ventura, 2019). Uniquely strong are the fundamental explanatory powers of our theory, giving answers to fundamental questions, e.g. why is our universe real? Why is there no antimatter? Why is string theory so open? Why are there rolled-up dimensions? Moreover, the theory explains well the surprising early structure formation in our universe and other structural arrangements as natural results of the qubit crystallization process (filaments and voids, dark matter sorted in galaxy halos etc.).

As a major result, we have here a new theory with many strong philosophical implications, for example the vindication of the statement "*god does not play dice*" (Albert Einstein´s letter to Max Born on 4.12.26; quoted in Einstein et al., 1972; "god" means in this context the ultimate reason for the qubit ocean): There is no dice invoked or any single random outcome but in our theory *all possibilities* of the interacting qubits have become real bit-ensembles. There is recent evidence that we actually live in such a Bohm-like world where all quantum trajectories are real (Mahler et al., 2016). However, a conscious observer does not know in which world trajectories he/she lives in (**Fig. 3**), future remains hence unknown to him/her and own free will remains from the internal perspective of a healthy conscious observer. Similarly, in our theory life is no accident and intelligent life neither. Our ethical obligation is to protect nature and planet earth and after mastering this, we can achieve much more but should ultimately increase the probability of the next generation of crystals. However, a selective advantage for intelligent life is there for our qubit crystal if there is at least in one trajectory one civilization on one planet successful with this, this is sufficient as all possibilities are realized, we cannot loose -- even if the *a priori* probability is really low, only the possibility needs to be there. In this theory we and our world are not an ongoing (quantum) computer calculation (Chandler, 2023) but rather *the result* (we have become real) of a quantum computer calculation on all possibilities – and the rules may be simple (Chandler, 2023) but life is definitely not, let alone the whole universe (see p.20).

A major weakness of our theory is its currently uncomplete mathematical formulation, making internal consistency checks only rather limited possible. Moreover, only quantification allows direct quantitative comparison to astronomical data. On the other hand, its strong reliance on natural, observed laboratory phenomena such as protein folding and crystallization but also quantum computing and solid-state physics allows direct tests after using these phenomena for formulating the theory mathematically more solid and obtaining quantitative predictions (first qualitative estimates: **Fig. 5-7**).

Our theory of course profits from previous ideas such as studying standard cosmology by everyday phenomena in the laboratory (Chuang et al., 1991) or studying crystal defects to get insights into gravity (Kleinert, 1987), considering evolution of universes over several generations (Smolin, 1997) and having selected fundamental phenomena such as time or gravity considered and shown to be emergent (Verlinde, 2017). An eternal ocean of qubits as a foundation for everything can also be found e.g. in Kaku (2021). The formalisms required profit from recent advances describing qubit aspects in cosmology (a qubit of space, Czelusta and Mielczarek, 2021; a qubit clock, Nambu, 2022), and qubits investigated in quantum computing and superconducting materials (Menke et al., 2022; Lopez-Bezanilla et al., 2023, 2024; Lopez-Bezanilla and Nisoli, 2023).

We are next examining in which direction a full formalism could be established using often only the classical description while a full quantum treatment of qubits is required and currently missing (only a preprint, accurate treatment will have to follow). Examination of qubits may shed light on many fundamental aspects, for instance emitted light (particle/wave) is just the wave-like bit state following the non-emitting bit ensemble state (so, as in many other quantum-minded theories and textbook physics of course no acceleration necessary).

The different formulas required are summarized in **Table 2.** For the microscopic structure we show suitable starting references but do not develop the mathematics or physics further. However, for the large-scale structure, **Table 2a** gives first details and formulae, explained in the results and developed further in the appendix. Moreover, validating observations motivating to follow up our theory are summarized in **Table 3**. First estimates of bound and free qubits are given in **Fig. 5**, misplacements in the qubit crystal can be estimated (**Fig. 6**) and should trigger structure formation in the universe far earlier then in the standard cosmology. Using dipeptide entropies as model, we can also derive first estimates for our qubit decoherence cosmology (**Fig. 7**).

In the following we refer in bold letters to the formulas **F1** (low probability interaction of qubits), F2 (entropy treatment of crystallization) to **F3** (long range interactions limiting further growth of the crystal) in **Table 1** and give a bit more detail how to derive concrete equations **Eq.1** to **Eq. 6** describing the processes involved.

The path is as follows:

A key challenge for our qubit crystallization scenario is that two different areas need to be tackled and considered:

(i) A scalar interaction field between all qubits, the stronger, the more qubits interact (based on the “small”, rolled-up dimensions of string theory, see below) and

(ii) Qubits have to overlap in our four “long” dimensions (time and space), otherwise the world is broken up into independent frozen-out defined ensemble states. Here we think that one qubit overlap allows to connect one ensemble state with its neighbor states (**Fig. 2**) with transition probabilities according to S-Matrix theory (Barut, 1971) and different layers of the crystal realizing defined, different world lines.

a) **Formula F1: strong interaction force between n qubits** → linear increase with number of qubits, scalar field at grand unification energy scale; only possible if correct dimensionality and direction as well as closeness → really low *a priori* probability.

For this we use the Hurwitz theorem (Hurwitz, 1898) to proof that if qubits of any form and dimension should interact at all, they only can so in four ways: There is only a 1D,2D,4D and 8D solution is possible for strings or qubits of arbitrary dimension to really interact, nothing else → E_8 symmetry is part of the 8D solution. E8 is our symmetry unit in our world (Wolchover, 2019) and a representation of the 8-dimensional solution, hence explanation why there is string theory in our world: E_8 with 8 dimensions is the main possibility how qubits interact.

So, then we derive: First we have really free qubits, in full entanglement in the qubit ocean, and of any dimension; then with a really low probability (calculation estimate see below) we need two qubits to interact with any D, so double circle. Then this triggers the seed for a new condensation nucleus and world.

Ad Eq. 1 - Probability calculation to reach our "well-tuned" universe from chaos: As the latter is the qubit ocean and has full degrees of freedom, we have not only as low probability as to reach E_8 symmetry compared to any 8-dimensional (8D) solution, but we have to consider our very special parametrization and hence can estimate:

(i) 200 bits specify each "large" dimension → total of 600 bits for each direction x, y and z.

(ii) Further 600 bits to specify all particles, fields, their strengths (may be even more bits).

→ really low probability to reach our high order universe from our chaos: 1 in 2**1200 or about 10**360 (estimate for our universe, all time points, bit states / possibilities / trajectories)

Ad Eq. 1b (energy difference between free and bound qubits): The next formula in **Table 1** describes this energy difference starting from the Hamiltonian corresponding to the kinetic and potential energies of a system:

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

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 (**Fig. 5**). To get here any further we have to start from the text book calculation for vacuum energy (see e.g. Jaffe, 2005) 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 in the textbook calculation by 10**20 when we consider that all is now bound in the qubit crystal, so hence we could derive by this additional field from the qubit-crystal the correct potential energy in our everyday world, as all is decoherent, solidified and defined and no longer free undefined quantum state.

Formula F2: Repulsive force for ultrashort distances

This prevents to have just a singularity from the strong scalar unified field between the qubits. For this we can at least show how a loop quantum gravity (LQG for short; textbook on LQG by Rovelli, 2004) treatment of **Eq. 2** could look like, following closely the paper by Ashtekar et al. (2006). These authors describe how loop quanta interact and then the next point in this paper shows how due to appropriate quantization the result is 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 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 from (Asthekar et al., 2006) 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):

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

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, in this example achieved using LQG.

Formula F3: Equilibrium between further growth and surface loss against "boiling bulk":

Classical model as pragmatic first step: Here we need estimates for the long-range surface loss term to get the long-range forces limiting further growth of the qubit-interaction initially rapid growing crystal (**Eq. 3**). I hope that the experts for inflation models will have hear better insight, because we are proposing as our modified cosmology a modified inflation model focusing on qubit interaction, but do not yet show the actual quantum treatment, here an expert treatment has to await the next iteration of our model.

A first estimate takes a quadratic growth of surface term as estimate (for 3 macroscopic dimensions and time), also in this confrontation with the n-dimensional or nD bulk.
As an example: if this quadratic limiting long range force is in equilibrium with 2**1200 qubits (we are background-free in this generalized nD LQG approximation, so no distances, gravity fields etc., but just the number of qubits counts) then we would have for 2**1100 qubits (so 100 qubits less extension) only a long-range surface loss term from this smaller crystal that is 2**100 or 10**30 times smaller.

A first glimpse of the quantum model for the solid qubit crystal: Here we can start from qubit phenomena we can actually measure in the laboratory and then would have to transfer it to a cosmological treatment. For instance, we can start with the reconfigurable spin ice model according to King et al. (2021). They write (in italics):

The quantum annealing (QA) system comprises a set of superconducting flux qubits that interact through two-body couplers, physically realizing the transverse-field Ising model generically described by the Hamiltonian

$$
\mathcal{H} = \mathcal{J}\left(\sum_{\langle ij\rangle} J_{ij}\hat{\sigma}_i^z\hat{\sigma}_j^z + \sum_i h_i\hat{\sigma}_i^z\right) - \Gamma\sum_i\hat{\sigma}_i^x \qquad (1)
$$

where ^σ_i are Pauli matrices describing the qubit degrees of freedom, the tensor J_{ij} describes the action of the couplers, and h_i is a per-qubit longitudinal field. The terms J_{ij} and h_i can be programmed at will; local fields h_i are always set to zero except when specified. Unlike in the Hamiltonians proposed to describe quantum spin ice in pyrochlores, we have no quantum entanglement in the two body coupling terms. Thus, in absence of the transverse field G, the ground state of H is a set of Fock states that can be mapped into purely classical ones—namely, the Fock product of eigenvectors of the Pauli matrices ^σ^z. However, switching on the transverse field entangles the binary quantum variables, subjecting them to quantum fluctuations.

However, in our cosmological case we have to modify the transverse field G, as we do not have such a field to achieve a realization of spin ice in a lattice of superconducting qubits (King et al., 2021) but rather the qubits spontaneously interact and the overall quantum interaction has then to be represented by G. Further treatment of the artificial created qubit spin ice can be found in King et al. (2023) for magnetic arctic circle in a square Ice qubit lattice and in Lopez-Bezanilla et al. (2023) for a Kagome qubit ice.

A first glimpse of the quantum model for drop or seed detachment: This considers the phase transition between the completely free, unbound qubits of any dimension and the partly frozen-out qubit to bit ensemble transition becomes more a liquid, and then in the end a solid-state crystal. This better describes then the boundary of the nearly frozen-out qubit crystal and seed formation would follow more formations of droplets at the surface of a liquid. Classically a drop of liquid from a tube is suspended from the surface and hold back by surface tension (Hansen and Rodsrun, 1991). The force due to surface tension is given by

$$
F_\gamma = \pi d\gamma
$$

where d is the tube diameter and gamma the proportionality constant. For our qubit crystal gamma needs of course the full quantum treatment, reflecting the stability of the crystal made of interacting qubits. More general, the drop adhesion to a solid (for our treatment: adhesion to the qubit crystal) has to be divided into lateral adhesion and normal adhesion. Lateral adhesion resembles friction, the force required to slide a drop on the surface. The normal adhesion reflects the force required to detach a drop from the surface in the normal direction (so away from our qubit crystal). Both forces need then a qubit treatment for a realistic estimate how easy a seed is formed on the surface of the qubit crystal. A detailed classical treatment of single-drop fragmentation for normal raindrops is given by Villermaux and Bossa (2009).

F 3.2 (remaining quantum liquidity of the crystal): As soon as equilibrium is reached, there is freezing-out of qubits with defined reality and emergent time. It remains the typical observed freedom for quantum phenomena below h, e.g. Heisenberg´s uncertainty principle, the formal inequality relating the standard deviation of position σ_x and the standard deviation of momentum σ_p

$$\boxed{\sigma_x \sigma_p \geq \frac{\hbar}{2}}$$

Where we have the reduced Planck´s constant h modified to

$$\hbar = \frac{h}{2\pi}$$

Our theory assumes that as soon as an equilibrium is reached between further growth and direct surface loss (see above) the crystal of qubits can solidify further. Hence, the overlap between the qubit ensembles is getting less and less until only one qubit overlap is reached.

It is necessary to have at least this "liquidity" left: (i) to move or get from one ensemble state to the next neighbor of the ensemble states. All neighbor states are directly connected as observed in quantum physics, simple description is by S-matrix theory, better description by string theory. This liquidity is exactly one Planck´s quantum big, as observed, here we still have the full quantum overlap (Formula **F 3.2**; here only qualitatively described).
Furthermore, this loss in quantum entropy is compensated by an increase in entropy in the chaotic qubit ocean around the crystal. Starting from a mother solvent, here an eternal qubit ocean, this is a new thought for cosmology, but everyday practice and routinely observed in protein folding as well as in mundane crystal formation.

Connected large dimensions: In my theory this is necessary so that the four "large" dimensions form a universe and become not completely separated bit ensembles which do not connect.

Emergent time: Moreover, in this way, the arrow of entropy connects all 1-bit neighbor states by an emergent time. Interestingly, if you are in any reasonable high energy state (as now and for the next billions of years), the past is well determined (only one solution to the next lower entropy state) whereas the future is unclear (several options for next 1-bit states with lower entropy). This is illustrated in our toy example with 6-bit ensemble states (**Fig. 2**).

Curled-up dimensions hold the crystal together as constant scalar field: However, at the same time, the remaining strong unified force field holds everything together and this is provided by the "rolled-up" six dimensions of our $E_8 \times E_8$ heterotic string theory: They are already microscopic, 1 bit in length. In compactification this is usually considered as small, "rolled-up" Kalabi-Yau manifold (Yau and Nadis, 2010), accommodating the 6 additional dimensions in this way in the macroscopic only four-dimensional space-time of our universe.
These dimensions do not change when the crystal freezes out. However, the "rolled-up" six dimensions provide a pretty strong field, unchanging, holding the crystal together and allowing our everyday macroscopic dimensions to freeze out and become a "real", defined universe for bit-ensembles (only one h dash quantum liquidity left) instead of a qubit-limbo the whole original universe is.
There are already first results supporting this: Kaya and Rador (2003) analyze a cosmological model in 1 + m + p dimensions, where in m-dimensional space there are uniformly distributed p-branes wrapping over the extra p dimensions. They find that

during cosmological evolution m-dimensional space expands with the exact power-law corresponding to pressure-less matter while the extra p dimensions contract. These authors derive in formula 27 for the rolled-up dimensions r_p a really small dimension of

$$r_p \approx 10^{-5} \times 10^{-138/[p(p+4)]}\ \mathrm{m}.$$

While their formula (23) implies that the radius after the early phase stays fixed.

$$ds^2 = -dt^2 + (\alpha_1 t)^{4/m}\, dx^i\, dx^i + (\alpha_2 t)^{-4\omega/[p(1+\nu)]}\, dy^a\, dy^a, \qquad (23)$$

Adding matter, they also obtain solutions having the same property. This hence might explain in a natural way why the extra dimensions are small compared to the observed three spatial directions. However, these results are given here only for illustration how our new cosmological model fits with literature.

The Hot fireball universe is resulting from this, next text book cosmology continues: We modify here only big bang and inflation by qubit interaction as trigger, next qubit ensemble growth until equilibrium and finally subsequent freezing out of qubits to separated bit-ensemble states in the universe. After that, as vindicated by all observations until now, the hot fireball universe continues to expand as in the text-book scenario. We are hence confident, that this theory fits well to observation, is compatible but modifies current inflation theories by a more realistic and fundamental scenario of qubit interaction, growth and crystallization. We have different crystal universes coming and going in a large ocean of qubits.
Interestingly, as the hot unified scalar field cools down, the basic four forces separate at lower temperature. In our view, the basic strong scalar field from the E8 string theory and postulated strong interaction of the six rolled-up dimensions gives rise then to the scalar field of color interaction, implying a reason for the observed confinement, and, with cooling down but quite early, gives also rise to the scalar field for gravity, acting on the Higgs boson.

Formula F1* (seed formation with crystal growth)**, next generation of crystals:** Any normal, everyday observed crystal exists only a limited time and is ultimately dissolved. Also in our picture of the world, a large ocean in which at different places and times crystals form and dissipate again, seed generation for the next generation of crystals is advantageous and if it can happen at all, it will be preferred and selected over several generations of crystals generating their own seeds for further children (if you look closely again only a modification of the well-known cosmological scenario of “eternal inflation” to a more everyday-like picture of generations of crystals.

How and where could seed generation happen? For seed generation in a universe, a previous suggestion was made by Lee Smolin (1996), fecund universes generated from black holes. In my view this is not so plausible, as a black hole, at least by its gravity is still part of our universe. Moreover, in a second droplet-like scenario to separate from our big crystal universe as a crumble or a droplet, such a true separation would require a lot of energy and create major ripples in gravity up till now never observed.

Instead, black holes stay pretty connected with our universe and form for instance the detailed shape of many galactic nuclei and this applies up till now also to super-massive black holes, they never separate.

Hence, in our crystal theory, the seed generation happens only at the surface (or “the limit” of the universe) by the entropic or “tugging” forces of the boiling vacuum around it. To model then the seed generation at the surface hence needs only further details and modifications of **formula F3** (see p. 15) adapting formulae from droplet formation (Hansen and Rodsrun, 1991; Villermaux and Bossa, 2009) to our qubit condensation and crystallization cosmology. Moreover, the long-range force considerations above show that seed generation "inside" the crystal is hopeless, requiring too much energy as the scalar field holds everything together and the long-range surface forces become too weak.

How could this select for life-friendly or even intelligent life-friendly universes?
The mainstream consensus in cosmology is that life is something unexpected and with low probability (Davis, 2007, Koonin, 2007; Hawking, 1988).

a) Selection for survival of surface / replication at the surface → selection for properties which also allow selection of survival at surfaces as is the case for early life
b) Selection of long survival and long evolution in a universe → selection for processes such as intelligent life → so could be that this particular "higher life friendliness" selection implies that higher life also useful for enhancing replication of the universe. In particular, intelligent life can technically use any natural process in a better, controlled, technological way. We know this for motors and energy generation. However, this allows us to create an artificial sun (nuclear fusion bomb, atomic power plant and fusion reactor). We can speculate that research and knowledge on dark matter may allow us generation of an artificial galaxy and ultimately knowledge on dark energy will allow us creation of the next universe in a controlled way (including understanding the entropy tugging of the chaos ocean on the formed crystal and may be surface interactions imprinting some directions of development into the seed).

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. For a civilization to trigger qubit-interaction seeds it may of course not be necessary to travel to the surface of the qubit crystal but the seed could be created anywhere: For instance, you can reach the outside ("bulk", qubit ocean) by just using the perspective from one dimension more (all 2D flat-landers live on a surface watching from three dimensions). Natural qubit crystal seed generation is just resulting from the surface properties of the crystal according to this theory, allowing even 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.

Formulas F1, F2, F3: Condensed mathematics could provide a frame work to describe free and bound qubits.

As an interesting point to be explored (not shown here), we recommend a full treatment of the phase space of the standard model (Oerter, 2006) by the new mathematical field of **condensed mathematics** („verdichtete Mathematik" see Scholze, 2019). It describes topological algebraic structure based on condensed sets.

In the light of our approach, this should open deep insights on general relativity and quantum physics as this will help to distinguish a phase space with frozen-out bits where general relativity holds (our domain and crystal) from a "liquid" type of phase space with free qubits, only quantum physics holds and corresponding wave functions describing the qubit ocean around our domain and crystal. In the latter, a condensed set can be used to identify the many states accessible to a qubit to pertain in fact to the same qubit.

In particular, Peter Scholze, in joint work with Dustin Clausen, established condensed sets (Scholze, 2019; Lecture I) and locally compact Abelian groups (lecture IV). He explained also globalization (Lecture IX) and coherent duality (lecture XI) in the light of condensed mathematics. However, this is only a suggestion for further exploration.

Conclusions:

(i) Clear: We show here only **a very general solution for the interaction field between qubits** and how they can form a crystal, but we only point out where there should be again a size limit after crystallization. However, for all formulae necessary for our theory we show a clear path how to derive them. We start with an exact mathematical physics treatment on how can qubits interact proving **it can only be 1,2,4 or 8-dimensional**. in particular we find that “rich” 8-dimensional theories are an allowed solution for the qubit interaction field (besides less interesting 1,2 and 4 dimensional solutions) and thus the E_8 heterotic string theory would also qualify not only as a solution to the qubit interaction potential but also to have the necessary openness in parameters (like all string theories) to allow evolution over several generations to select best life-like parameters.

(ii) **Exciting but speculative:** In other parts we give non-cosmological models and corresponding qubit treatment, e.g. on how should a *magnetization-like qubit interaction cluster growth* look like? How should *droplet or seed formation on the qubit crystal surface* look like? Remaining parts have only a classical and otherwise qualitative treatment, for instance the **inspiring glue-like function of rolled-up dimensions** to prevent that our world falls apart into isolated bit-ensembles in its large dimensions if these are completely frozen out (a Poe-like Eureka moment). This is truly exciting if it could be mathematically proven, but this is absolutely non-trivial to show. Moreover, as in string theory the mathematical formalism derived here allow many different parameters to fulfil it. But if we are right, this happened with a deeper implication: we need this **open-ness of string theory** (or related formalisms) so that evolution over several generations can operate on the parameters to select optimal crystals with best reproduction rate, stability and resulting high self-organization potential and overall fitness. The result is fine-tuning of conditions **for best seeding** the **next generation of crystals** including that the optimized crystals are particularly favorable to life.

(iii) **Life is not simple – let alone the universe:** We note that in stark contrast to cosmological theories starting with inflation or any simple starting conditions (Wolfram, 2002), we have here a theory which starts not simple but rather has always the same complexity according to the number of qubits involved. This is more realistic and considers that many phenomena observed are irreducible complex (Chaitin, 2006) including life, planets or the whole universe. This avoids problems from starting with very simple conditions and find out why our universe could get so complex in the end. Nevertheless, in our theory there is a clear, limited set of rules which describe the qubit interactions (starting from textbook physics).

(iv) **Qubits can now be investigated in detail:** As we rely in our cosmology on normal, observable phenomena, there are many options for validation, in particular, the growth process of qubit magnetization can at least be measured in field-induced magnetic phases in a qubit Penrose quasicrystal (Lopez-Bezanilla and Nisoli, 2023 and magnetization can of course also be observed and investigated in normal crystals (e.g. Kato et al., 2023) and we now know true qubit crystals (Lopez-Bezanilla et al., 2023 on Kagome qubit ice) though not in the proper cosmological treatment of being surrounded by the eternal infinite ocean of free, unentangled qubits (Kaku, 2021).

Appendix: Additional remarks to the formula overview in Table 2

Eq. 1, interaction dynamics of qubits **F1**:
The collective dynamics of qubits in a ferromagnetic lattice is described by a quantum transverse-field Ising model, governed by the Hamiltonian:

$$H = \mathcal{J}(s)\left(J_L \sum_{\langle\sigma,\sigma'\rangle} \hat{\sigma}^z \hat{\sigma}'^z + J \sum_{\langle\sigma,\Sigma\rangle} \hat{\sigma}^z \hat{\Sigma}^z\right) - \Gamma(s)\left(\sum_{\sigma} \hat{\sigma}^x + \sum_{\Sigma} \hat{\Sigma}^x\right)$$

where ^ over σ, ^ over Σ are Pauli matrices of the corresponding qubits on σ, Σ sites, respectively (Lopez-Bezanilla et al., 2024). Following these authors (see also Lopez-Bezanilla et al., 2023 on Kagome qubit ice) and transferring this to our cosmological postulated early magnet-like growth for interacting qubits we now get:

In the absence of interaction, Γ = 0, Fock products of eigenstates of σ^z are eigenvalues of the Hamiltonian. If Γ ≠ 0, the qubit crystal growth will start as in a classical magnet but now the terms within the first parenthesis do not commute with the terms within the second parenthesis, and the transverse field subjects the spin degrees of freedom to quantum fluctuations. The unitless parameter s = t/tf controls the annealing progress from the quantum mechanical superpositions of states at s = 0 to the classical state at s = 1. The Ising energy scale is thus controlled by J ›sfi which increases as the quantum fluctuations Γ(s) away out according to well-established annealing protocols.
Qubit interaction leads to decoherence, splitting of quantum superposition to single bit ensembles. This consumes energy, reduces quantum entropy.
However, the rolled-up dimensions interact firmly (otherwise nothing happens with them, they stay perfectly entangled, do not vary or yield in a defined state bit ensembles), they do not expand or change as the macroscopic dimensions do. For their interaction there is instead a linear increase of the interaction field and the released interaction energy with the number of qubits. The field is a type of gravitational field between the rolled-up dimensions (introduction: Randall, L., 2005). At the same time there is a square increase (n * n-1)/2 of the qubit-qubit interaction terms (higher orders neglected for now), which then consumes more and more energy by "freezing out" the bit ensembles / the negentropy (quantum entropy disappearing). As soon as equilibrium is reached, there is no more decoherence and further qubit accumulation possible, the “universe” (the qubit crystal in our theory) has reached its maximum size, it cannot consist of more qubits.
Closely connected to this is the seed formation formula **F1***:
The Hamiltonian for a seed looks similar to **F1**, but we need to consider the challenging surface effects for a break-away (how? when?) of the seed.

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

Eq. 2 (entropy treatment in crystallization)
To derive this, we consider everyday protein folding and crystallization and apply it to our qubit crystal. In particular, the creation of spontaneous order in the protein is paid for by increasing disorder (entropy) in the solvent around. Similar this explains how order can be created within the qubit crystal, as in the free qubit ocean around entropy increases. 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

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

The treatment for qubits needs 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). **Fig. 7** compares different entropies between free and bound qubits (including also quantum entropy of entanglement or removing it).

Eq. 2b (Dark energy is in fact entropic tugging of the crystal)

Here we start 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., $\Delta\Delta$ G), at least close to equilibrium. The most often invoked relationship has been based on the principle of detailed balancing or a transition-state 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 $\Delta\Delta$ 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).

The resulting time has to satisfy the cosmological constraints of a typical big rip scenario. We give here as a first estimate of the cosmological treatment result a typical “big rip” scenario. You can use a hypothetical example with $w = -1.5$, $H_0 = 70$ km/s/Mpc, and $\Omega_m = 0.3$ (Caldwell et al., 2003; *w*, the ratio between the dark energy pressure and its energy density; Hubble constant; and matter density, respectively). In this case the Big Rip (Fernandez-Jambrina and Lazkoz, 2022) is estimated to occur 22 billion years from the present.

$$t_{\mathrm{rip}} - t_0 \approx \frac{2}{3\,|1+w|\,H_0\sqrt{1-\Omega_{\mathrm{m}}}}$$

We think the time horizon is actually 70 Gyrs. This is better compatible with observations (e.g. Vikhlin et al., 2009) and takes also into account that according to our theory the “dark energy” is in fact resulting from tugging of the crystal by entropic forces of the solvent (which would be here the vast ocean of free qubits, sometimes interacting destructively with the more solid qubit-to-bit crystal). The next step would be 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 or **F3** (Long range interactions limiting growth of the cosmological crystal)
F3.2 remaining quantum entropy or “liquidity” in the crystal

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).

Eq. 4 (standard calculations for vacuum foam, free qubits 10**20 higher energy)
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 that the high energy calculation is correct but applies only outside our domain in the qubit ocean (see also simulation estimates below, **Fig. 5**). Inside the crystal, our everyday world, we have bound, interacting qubits, a drastically smaller zoo or possibility for virtual particles to play a role and hence the observed really low vacuum energy of our universe.

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 $t \to t + \delta t$, 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, similarly, there may also be translational Invariance. 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 E_8 Lie group has applications in theoretical physics and especially in string theory and supergravity. $E_8 \times E_8$ 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. E_8 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 E_8 to its maximal subalgebra SU(3)×E_6.
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.

Eq. 6 or **F2** (repulsive force by quantization for ultrashort qubit distances, modified LQG treatment starting from formula 4.1 in Ashtekar et al., 2006):
see above.

Most importantly, the next step will be to bring the toy model (Fig. 2) to a more general treatment of qubit interactions, which is only partly sketched here looking also at qubit crystals examined for quantum computations (Lopez-Bezanilla et al., 2023).

However, for our cosmological case everything is far more complicated:
(i) The “free qubits” have 10**120 times more energy than the bound version of qubits used in our world for quantum computation in the Lopez-Bezanilla papers,
(ii) a background free treatment is required (as is routine in LQG) and we get from the crystallized bit ensembles then by following the arrow of entropy an emergent time.
(iii) The proper qubit treatment of the “glue” holding the crystallized bit ensembles together while there is only little entanglement and “liquidity” left in our world (all has to be below Planck´s quantum) would be a mathematical corner stone of this theory.

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Table I. Qubit interaction nails down parameter space for fundamental physics

Start situation: a general Hamiltonian provides the energy function of interacting qubits

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

(Everything goes!)

Reduction 1: we show that qubits of any dimension cannot interact, but rather this is stably only possible of qubits of 1D, 2D, 4D and 8D. This starting insight is vindicated by observations, in particular that the basic symmetry unit of our universe is 8-dimensional, both in string theory and in particle physics.

Reduction 2: E8xE8 heterotic String theory.
Internal, mathematical and physical consistency reduces the possible state space further, the string theory still allows many parameter choices (up to 10**600) but restricts the general 8-dimensional solution from reduction 1 strongly to reduction 2.

Reduction 3: To achieve our observed universe, in particular, the relation of the four basic forces, the ratios of the four forces are limited to a quite low solution space of parameter values.

This is the so-called "fine-tuning problem" or "why is our universe so life-friendly, if so many alternative solutions exist?". We claim that string theory needs to be so open in parameters so that over many generations of crystals those with best seeding capacity are selected. As this is a life-like process of creating off-spring and requires self-organisation and permitting such reproduction processes this selects for this really narrow life-friendly parameter range.

Table 2. Quantum action theory formula overview

Large-scale structure (validation: astronomical observations, see results)

Eq. 1 or **F1** (when and how qubits interact: restricted to 1,2,4 and 8 dimensions); closely connected to this is the seed formation formula F1* for magnet-like growth or more and more attached, interacting qubits getting defined states.

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 or **F3** (Long range interactions limiting growth of the cosmological crystal)
F3.2 remaining quantum entropy or "liquidity" in the crystal

Eq. 4 (standard calculations for vacuum foam, free qubits 10**20 higher energy)

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

Eq. 6 or **F2** (repulsive force by quantization for ultrashort qubit distances)

Microscopic structure (validation: particle physics, quantum experiments)

Eq. 7 (S-matrix theory; Barut, 1971)

Eq. 8 (Term scheme; e.g. Gross and Wilczek, 1973)

Eq. 9 (quantum computations for proton mass; Yang et al., 2018)

Eq. 10 (quantum action and qubit-to-bit transition for a proton; starting from Yang et al., 2018, but now adding quantum action theory formalisms)

Eq. 11 (decoherence of quantum states in a multiple particle system; Schlosshauer, 2005)

Eq. 12 (confinement of quarks by a scalar field; see Gross and Wilczek, 1973; Politzer 1973; but scalar field derives new from the cosmological qubit interaction field)

Table 2a. Quantum action theory large-scale structure approximations
(validation: astronomical observations, for formula derivation and citations, see results)

Eq. 1 or **F1** (when and how qubits interact: restricted to 1,2,4 and 8 dimensions):
General Hamiltonian, satisfying the general qubit interaction

$$\hat{H} = \hat{T} + \hat{V}$$ and this equals qubit interactions for any dimension

$$\left| {}^{0}_{1} \right\rangle \otimes \left| {}^{0}_{1} \right\rangle$$

This yields a convenient representation of the evolution of the system. At any time t, we can divide the n degrees of freedom in H into a number $n_e(t)$ that are entangled with each other (responsible for the spacetime structure), and a number $n_u(t)$ that are not entangled with anything

$$\mathbf{n = n_e(t) + n_u(t).}$$

Crystal generation by interacting qubits: A first approximation is the Hamiltonian for a quantum annealing system:

$$\mathcal{H} = \mathcal{J}\left(\sum_{\langle ij \rangle} J_{ij}\hat{\sigma}_i^z\hat{\sigma}_j^z + \sum_i h_i\hat{\sigma}_i^z\right) - \Gamma\sum_i\hat{\sigma}_i^x \qquad (1)$$

However, in our cosmological case we have to modify the transverse field G, as we do not have such a field to achieve a realization of spin ice in a lattice of superconducting qubits (King et al., 2021) but rather the qubits spontaneously interact and the overall quantum interaction has then to be represented by G.

Surface seed or droplet generation: closely connected to **F1** is the seed and crystal growth formation formula **F1***, where the classical treatment calculates the surface tension

$$F_\gamma = \pi d\gamma$$

and then from this one calculates lateral adhesion and normal adhesion. Lateral adhesion resembles friction, the force required to slide a drop on the surface. The normal adhesion reflects the force required to detach a drop from the surface in the normal direction (so away from our qubit crystal). Both forces need then a qubit treatment for a realistic estimate how easy a seed is formed on the surface of the qubit crystal

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

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

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.

Eq. 2 (entropy treatment in crystallization)

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

Eq. 2b (Dark energy is in fact entropic tugging of the crystal)
Dissolution rate in a crystal

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

and resulting time has to satisfy the cosmological constraints of a typical big rip scenario

$$t_{rip} - t_0 \approx \frac{2}{3\,|1+w|\, H_0 \sqrt{1-\Omega_m}}$$

Eq. 3 or **F3** (Long range interactions limiting growth of the cosmological crystal)

A first estimate takes a quadratic growth of surface term as estimate (for 3 macroscopic dimensions and time), also in this confrontation with the n-dimensional or nD bulk.
As an example: if this quadratic limiting long range force is in equilibrium with 2**1200 qubits

F3.2 remaining quantum entropy or "liquidity" in the crystal: The typical observed freedom for quantum phenomena below h, e.g. Heisenberg´s uncertainty principle, the formal inequality relating the standard deviation of position σ_x and the standard deviation of momentum σ_p

$$\boxed{\sigma_x \sigma_p \geq \frac{\hbar}{2}}$$

Eq. 4 (standard calculations for vacuum foam, free qubits 10**20 higher energy)

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

Eq. 6 or **F2** (repulsive force by quantization for ultrashort qubit distances, modified LQG treatment starting from formula 4.1 in Ashtekar et al., 2006)

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

Table 3. Observables supporting qubit decoherence as new concept

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-There is the same symmetry by S-Matrix connections between neighbor states if you have a crystal of qubits. As in normal crystals due to the symmetry of the unit cell you have hence everywhere the same symmetries and hence laws of nature and do not have nor require inflation to guarantee this.
Observations: There is no inflation after BICEP/2 experiments were corrected (Ade et al., 2018)

- large voids and filaments (as they come in fact from a normal crystallization process, for big bang scenario instead rather difficult to explain)
Observations: El-Ad et al., 1997 and later works

-supercluster formation; (misplacements in the crystal happen naturally and provide seeds).
Observations: e.g. Long et al. (2020).

-galaxy formation, see **Fig. 4**; optimal distribution of dark matter in halo regions and normal matter in center: Crystal arrangement makes this easy to happen.
Observations: e.g. Boylan-Kolchin, 2017.

-Fine tuning and live-friendly conditions
our explanation: many generations of crystals seeded by rarely interacting qubits in the ocean of free qubits select for better seeds for next generation which then selects for self-organization and life-friendly conditions. Interesting corollaries: (i) there seems to be a similar selection for intelligent life, so should in this sense help in some way for generation of next generation seeds; (ii) however, as all bit-possibilities are realized in the crystal, it would even be sufficient for efficient selection if the success of the next generation of crystals can rely on fitness gain in at least one world-line and for one type of life.
Observations: observed by all conscious observers (e.g. Barrow and Tipler, 1986; Smolin, 2013).

-Decoherence mystery explained: this has nothing to do with the act of observation but is actually the basis for the formation of our world, happened at “start”, to allow emergent time within the crystal.
Observations: see Schlosshauer (2005); Zeh (1970);

-dominance of matter - **Observations**: see e.g. BESIII Collaboration (2022)
A big mystery for standard theories, how matter could dominate. In my theory this symmetry of the crystal is chosen (only matter), another crystal (and domain) has the antimatter variant, unreachable and unobservable for us from here (our domain), separated by the free qubit ocean.

-there can be more added, remember, all features stemming from the hot fireball model, e.g. primordial synthesis of helium and lithium, agree anyway also with this theory as we only change the earliest steps, directly after that we arrive again at the hot fireball model.

Figure Legends

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 free qubits.** 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 is established. **(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" scenario, 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 E_8 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).

Figure 5. Comparing energy levels of defined bits from quantum computation to free qubits in our domain and really free qubits. we give our first estimates comparing free qubits in a quantum computer to the decoherent result state from quantum computation in our domain, our physical world (Gilbert et al., 2007, **Fig. 5**, bottom). There is some energy difference, but not so large: The quantum computer is part of our real world and as such, the "free" qubits used in the quantum computer calculation are not really free and the energy difference is not large. However, we show also in this plot our calculation for really free qubits, following the textbook calculation of free vacuum energy (Jaffe, 2005): then you have a 10**20 higher energy value (indicated here using logarithmic scaling; **Fig. 5**, top).

Figure 6. Misplacements in the qubit crystal: We compare the typical observed amount of misplacements in a normal, everyday crystal (sodium salt, glutathione reductase etc.; Louros et al., 2023) with misplacements observed in cosmology and calculated for our qubit crystal. For cosmology, there are well known calculations for the quantum fluctuations in the early universe assuming that inflation by an inflaton happened (so different but related process to our crystal growth). Analogous to the situation in normal crystals (Mc Coy, 2001) we see that we in fact get by quantum fluctuations a reasonable number of seeds for later growth into large-scale structures, however, these fall short of the amount really required.

Figure 7. Qubit decoherence cosmology allows also to have entropy estimates
The curves shown are citing the results by Brady and Sharp (1997) for illustration. These authors compare entropies looking at the two dipeptides cGG and cAA regarding vibrational frequencies in the gas phase (open squares and triangles) and crystal phase (black squares and triangles) for cGG (triangles) and cAA (squares).

We predict estimates comparing for the complete system of qubit ocean and a smaller crystal inside it will give qualitative similar results regarding entropy but will of course require a full quantum treatment and qubit interaction calculations to come up with correct quantities. The total system of our qubit ocean should have as boundary condition not the full ocean of free qubits but for a first estimate be deliberately terminated by several shells of free qubits around the toy "universe" (see **Fig. 2**) of 6 qubits forming a physical real universe and freezing out their individual bit states. As in the everyday example cited and given for illustration, the entropy of course has to increase in the solvent if within we form order by having the ensemble bit states nicely separated and frozen out. Moreover, then the comparison should not be between two peptides but for instance between normal matter and dark matter.

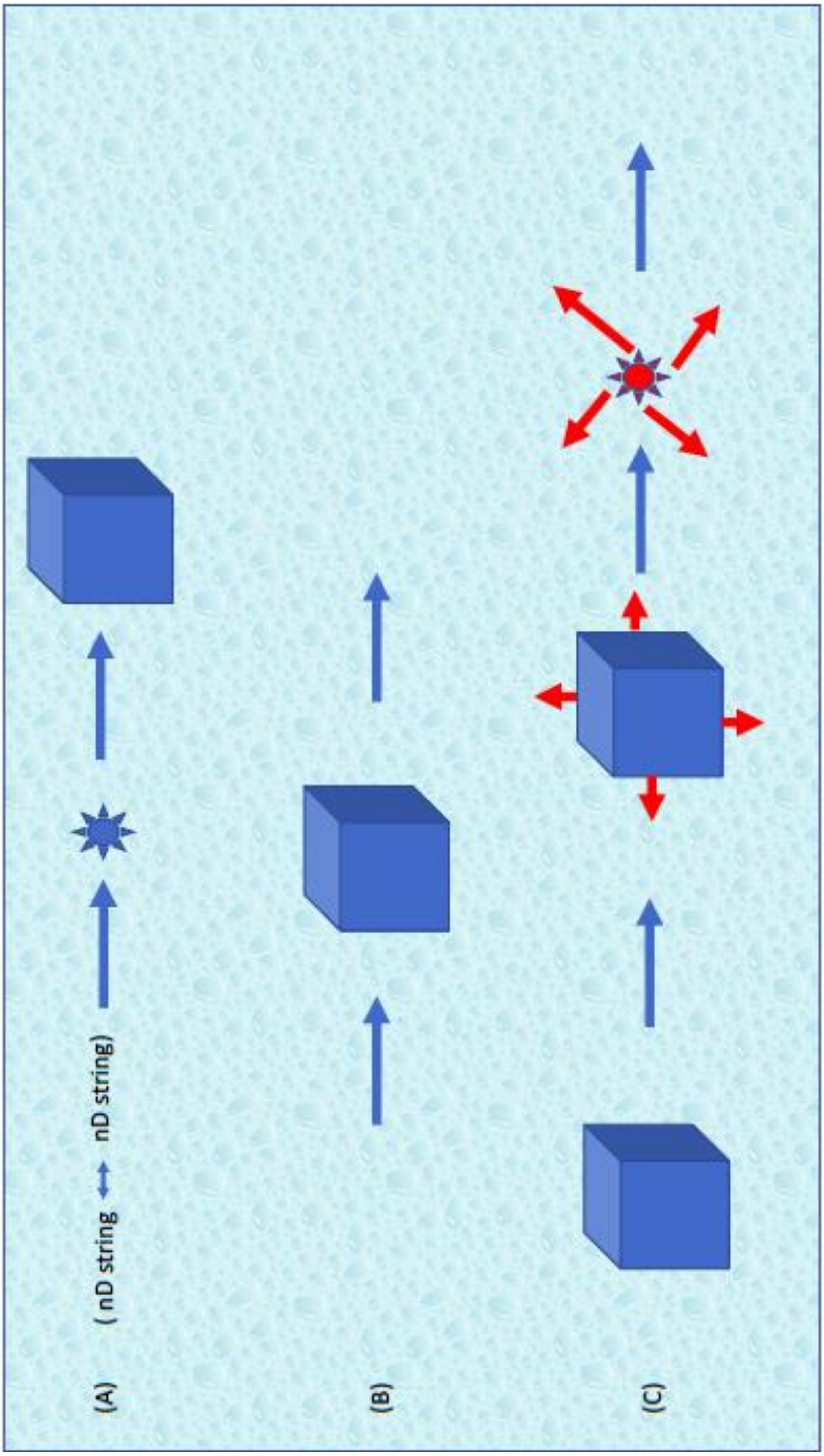

Fig. 1


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

Fig. 2

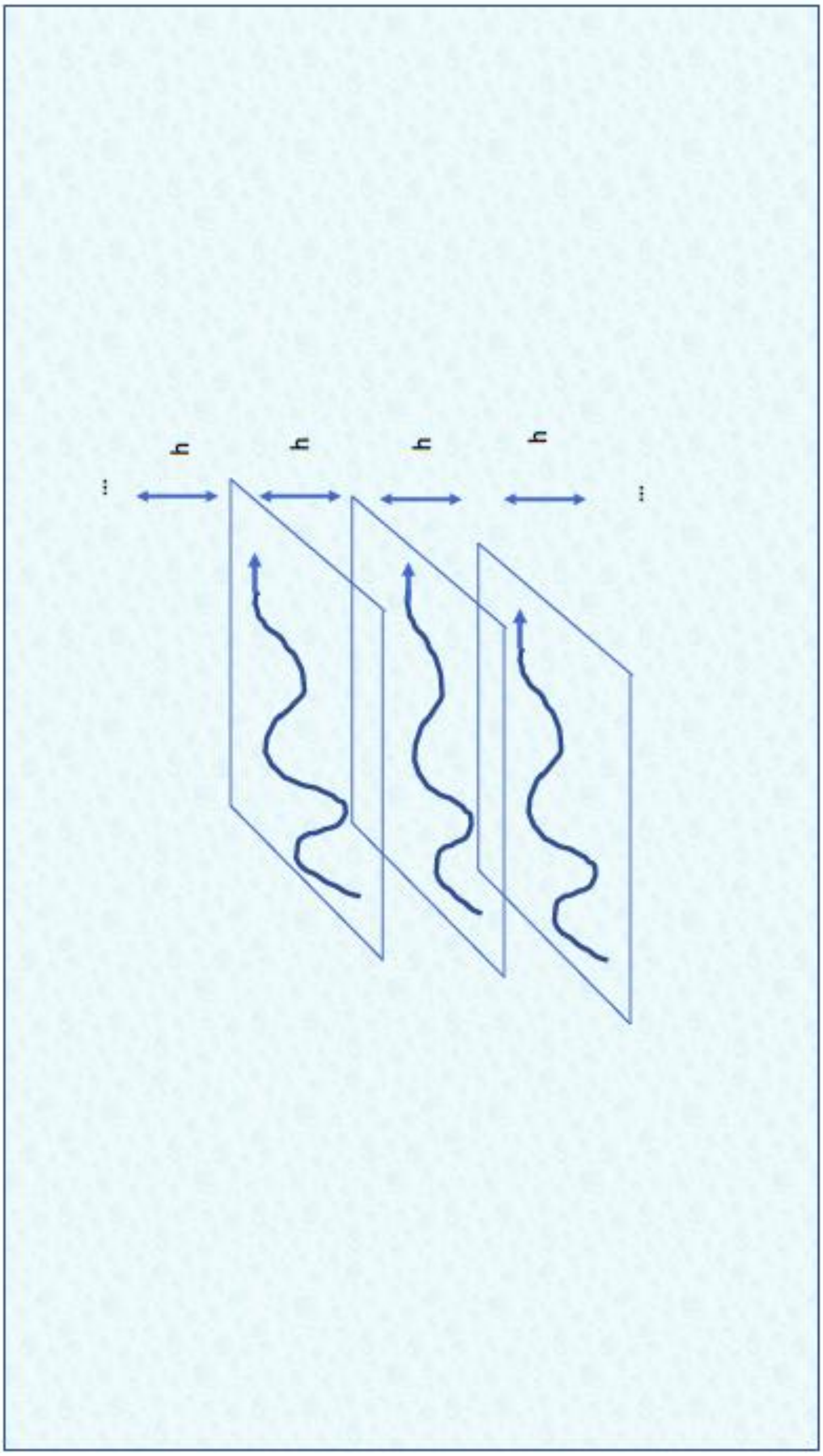

Fig. 3

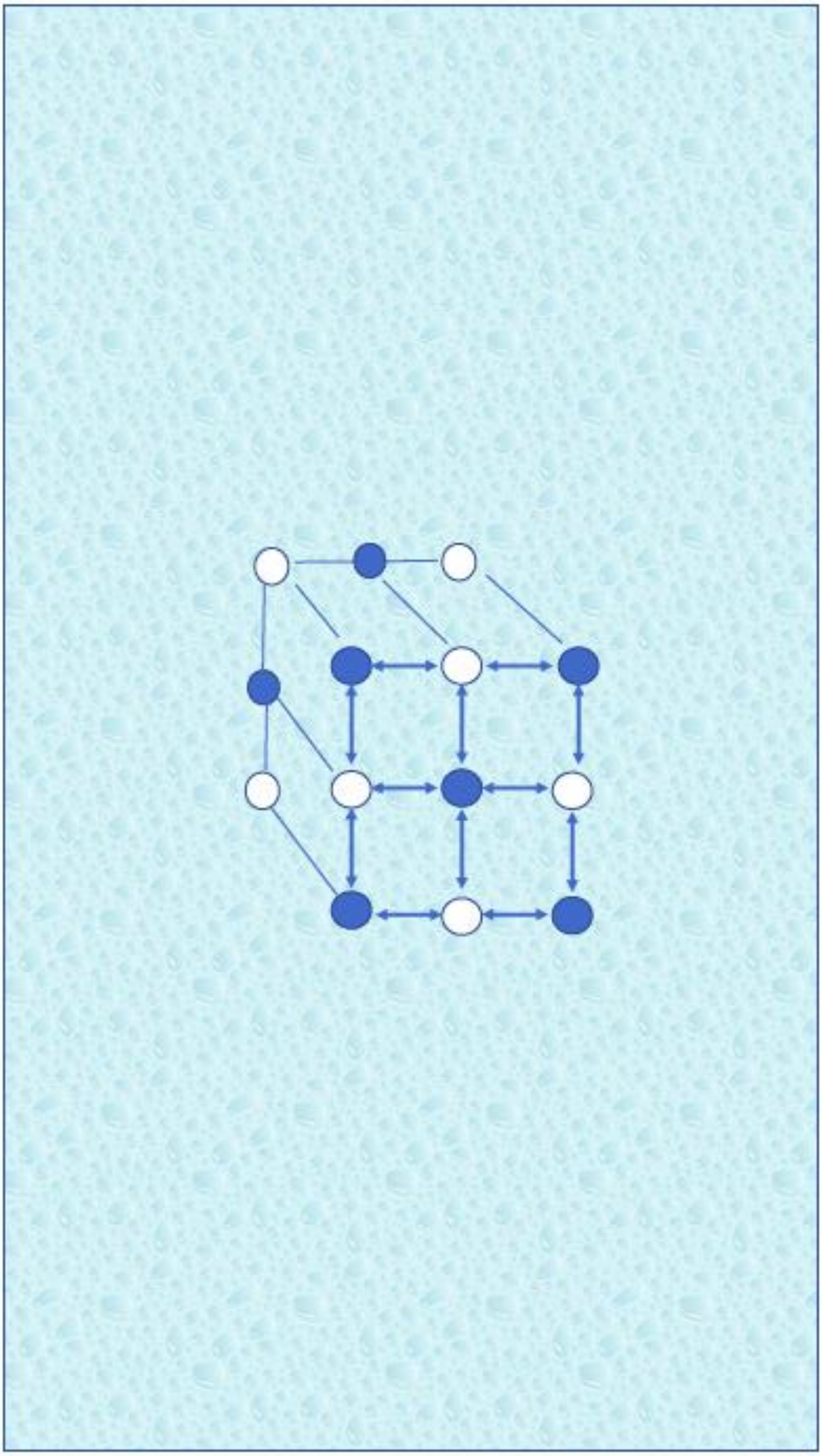

Fig. 4

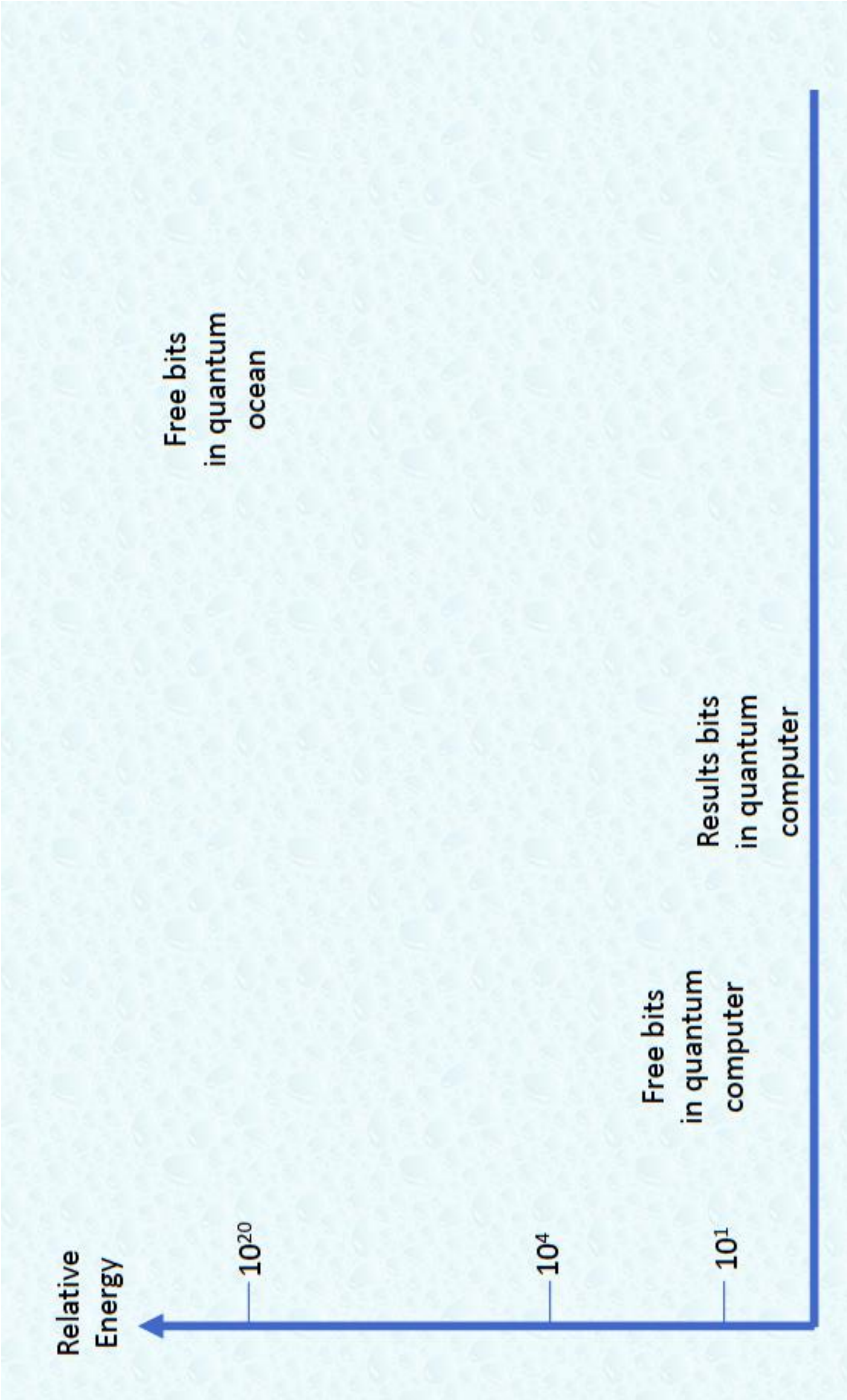
Relative Energy
10^20
10^4
10^1
Free bits in quantum computer
Results bits in quantum computer
Free bits in quantum ocean

Fig. 5


Misplacem
ents per
unit cell
10^{-3}
10^{-6}
10^{-9}
Misplacem
ents in a
Normal
crystal
Early universe
Quantum
Fluctuations,
Standard model
Misplacements in
a condensed
Qubit- crystal

Fig. 6

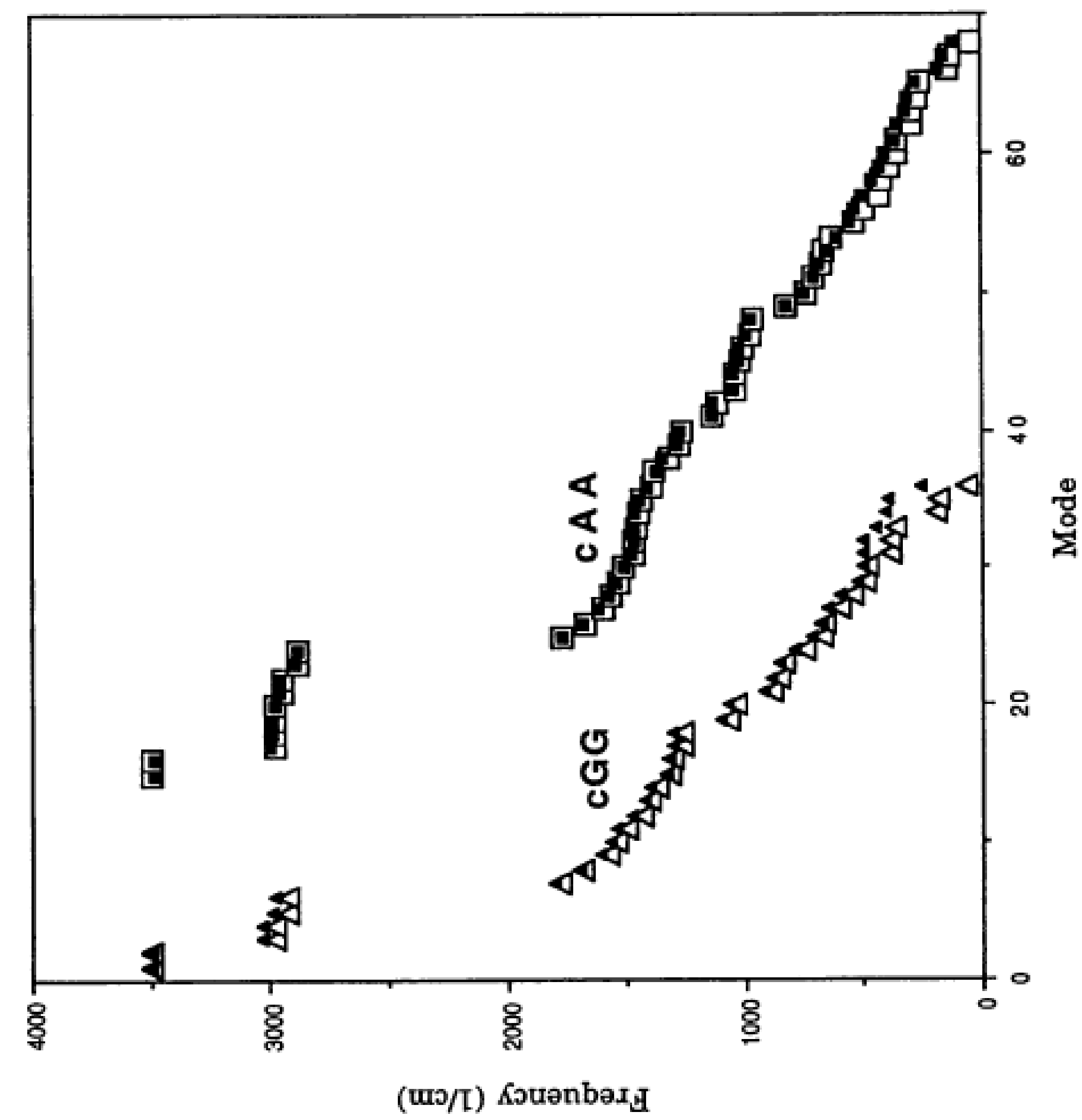

Fig. 7