

Reconciling reality, space and time: A graviton driven quantum mechanism of cosmic expansion and CMB radiation

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Abstract. The theory of emerging quantum mechanics (EQM) is a quantum field theory in flat 11 dimensional spacetime, quantizing gravity in the weak interaction limit. In EQM the quantum fields materialize (i.e., they become real) if they entangle with the gravonons, i.e. localized gravitons, thereby forming beables. If not entangled with gravonons, the quantum field is in a limbo state as e.g. exemplified by the state inbetween source and screen in the double slit experiment. Quantum diffusion proceeds via repeated limbo - beable transitions. This leads to the impression that particles having been measured at a certain separation in space suddenly disappear and reappear at a different separation. For any cosmological experiment this is consistent with the interpretation that space has expanded. The rate of cosmic expansion is then equal to the rate of beable - limbo transitions. This rate is calculated from first principles and equals the experimentally determined Hubble parameter. Explicit calculations on the generation of the cosmic microwave radiation (CMB) require to consider the beabling process of the electromagnetic quantum field. The beabling condition is fulfilled for light-atom-lattices (LAL). Temperature emerges in EQM by escape of the particle out of the warp resonance (beable). Without fitting any free model parameter the CMB radiation temperature is 2.2 K, which is to be compared to the experimental value of 2.7 K.

1. Introduction

The generation of structure from quantum fluctuations is postulated in inflationary cosmology where, however, the measurement problem (the so called collapse or reduction of the wave function which creates reality from potentiality) remains unsolved. Further problems refer to the unspecified physical nature of dark energy and dark matter, the coincidence problem, etc. Recently a solution of this problem has been suggested based on the ADD hypothesis [1] (i.e., existence of large extra dimensions) which leads to the formation of localized gravitons, so called gravonons [2, 3]. This theory of emerging quantum mechanics (EQM) is a quantum field theory in flat 11 dimensional spacetime. The gravonons create effects as postulated within the dark energy - dark matter scenario of cosmology [3]. Whether dark energy or dark matter effects appear, depends on the gravonon density in the considered spacial region.

In EQM the quantum fields materialize (i.e., they become real) if they entangle with the gravonons, thereby forming so called beables. If not entangled with gravonons, the quantum field is in a limbo state as e.g. exemplified by the state inbetween source and screen in the



double slit experiment. Quantum diffusion proceeds via repeated limbo - beable transitions. In the limbo state the quantum fields are not real (i.e. not measurable). This leads then to the impression that particles, having been measured at a certain separation in space, suddenly disappear and reappear at a different separation, there being no possibility to trace the particles inbetween. For any cosmological experiment this is consistent with the interpretation that space has expanded. The rate of cosmic expansion is then equal to the rate of beable - limbo transitions. This rate can be calculated from first principles and equals the experimentally determined Hubble parameter.

The formal definitions of the introduced terms is as follows:

- (i) A limbo state is a tensor product of a solution of Schrödinger's equation in four dimensional spacetime without gravitation with a wave functional of gravitons.
- (ii) A gravonon is a linear combination of graviton modes which is localized over a region of several molecules or a complex of atoms in a piece of matter.
- (iii) A beable is a state describing an entanglement between four dimensional brane states (not including gravitation) and gravitational states in 10 dimensional space, i.e. it is a (non-trivial) linear combination of limbo states:

$$|beable\rangle = \sum_{limbo} C_{limbo} |limbo\rangle. \quad (1)$$

- (iv) A limbo - beable transition is a time-dependent development of a wave packet of field configurations from a dominant limbo character to a dominant beable character.

As all measurement devices are made up of beables defined by eq. (1) (meter sticks and clocks) EQM has to distinguish between background parameter spacetime and physical space and time as they appear in experiment. Physical space and time are fixed by the density of beables (gravonons) and by the rate of beable-limbo transitions. Of course, this means that if in different regions of the universe we have different gravonon density and gravonon frequency, physical space and time will differ. With this definition of physical spacetime applied to intergalactic matter the Einstein-de Sitter result can be derived. Within EQM the gravitational constant is taken as a universal invariant. The velocity of light (being constant within any local Lorentz frame) and Planck's constant (relating the energy of quanta to their wave properties) depend on the specification of what is a clock, which changes with the expansion of the universe: time is what is read on the clock, length is what is read on the meter stick. In this connection it is worth mentioning that recently the meter and the second have been defined by the velocity of light as measured in our reference system here on earth and the kilogram is defined via Planck's constant [4]. The velocity of light and Planck's constant are no longer physical quantities the values of which can be improved by improved experiments, the numerical values assigned to these quantities are fixed by a definition of the human race.

The cosmic frequency redshift of light has to be explained within physical spacetime. Energy is conserved in EQM. Explicit calculations require to consider the beabling process of the electromagnetic quantum field. For this purpose light-atom-lattices are constructed in the spirit of experimentally investigated atomic aggregates in optical lattices, where recently light mediated collective atomic oscillations and lattice instabilities have been reported [5, 6, 7]. This allows to analyze Cosmic Microwave Background (CMB) radiation. Anisotropies in the CMB temperature distribution can only arise, if quantum fluctuations materialize (i.e. become real) in form of beables which then constitute "classical" primordial density variations (see [8] for an attempt to invoke decoherence theory for this purpose).

2. Outline of the physics

There can be no reconciliation of realism, space and time as long as quantum mechanics is interpreted in terms of probability amplitudes. The behaviour of hydrogen atoms in ultrahigh vacuum chambers is extremely well described by EQM [9]. This has also to be true for hydrogen atoms in the ultrahigh vacuum of intergalactic space. To assume that hydrogen atoms behave like small classical billiard balls is in no way justified.

The connections and differences between the common Copenhagen interpretation based on Born's rule and probabilities and the realistic beable formation are best illustrated with the example of the double slit experiment [10]. The limbo wave function has amplitude everywhere on the screen, but in the Copenhagen interpretation collapse is postulated to occur only at a single point. In EQM the wave function develops amplitude only at a single point on the screen. It is absolutely central to the theory developed here to have in mind why the matter field localizes at a particular spot on the screen [11]. It is determined by energy conservation and by extremely weak coupling between the matter field and gravitational degrees of freedom near the point of impact. Beables are configurations where a quantum field is localized because it is entangled to gravonons.

The *beabling condition* is that

- the initial energy of the wave packet when it was sent off from the oven matches exactly (with accuracy of typically 10^{-12} eV) the energy of the "warp resonance", where the particle resides when it entangles with the gravonons;
- in the "warp resonance" the matter field entangles with gravitational degrees of freedom of high density of states.

If experimentally we could prepare the emitted wave packet with an infinitely precise and pre-determined value of the energy then there might be only a single (or none) site of the screen where beabling is possible. Experimentally we then can identify the localized matter field only at this particular site on the screen or not at all. If there is only one particular site on the screen where entanglement to gravitational degrees of freedom is possible, then we have to try very many precise energies for our wave packet to fulfil the beabling condition.

The experimental findings for hydrogen quantum diffusion on metal surfaces can be rationalized in an analogous way by calculating the position of the warp resonance and the corresponding gravonon mode [9]. The consequence is that hydrogen atoms on metal surfaces can only be observed at very specific sites where the beabling condition is fulfilled. Inbetween these sites the H -atoms are not observable. The rate with which the H -atoms hop between those specific sites depend on the vibrational properties of the gravonons.

From a quantum mechanical point of view it is therefore clear that diffusion of H -atoms in the intergalactic space can only occur if such very specific beabling conditions are fulfilled. As the density is very sparse here the beabling conditions are much harder to fulfil than in the case of the double slit or for H -diffusion on metal surfaces. Quantum diffusion in the intergalactic space will therefore be extremely slow. It is the aim of this contribution to calculate the rate of H -diffusion in the intergalactic space and to put this in relation to the experimentally determined rate of expansion of the universe.

3. Model universe in EQM: universe expansion is quantum diffusion

Various estimates yield for the intergalactic density of hydrogen atoms 5 to 10 H -atoms per m^3 . Our model universe consists of eight hydrogen atoms per m^3 interacting via Newton's

gravitational law and forming a loose soft matter lattice. Softness and enormous lattice constant of matter in the universe imply that phonon Debye energy is enormously small and that therefore the phonon density of states near energy zero is enormously large. This means that configurations describing phonon deexcitation plus hydrogen excitation into plane wave limbo states are practically on-shell for an enormous number of such configurations. All these on-shell configurations mix and entangle with gravonon configurations.

3.1. Estimate of change of potential for vibration of atoms around equilibrium position by Taylor expansion

A hydrogen atom in the loose crystal feels gravitational attraction with all its neighbours and its equilibrium is unstable at a maximum of the energy. A local weak potential minimum arises because when hydrogen shifts away from the equilibrium position a weak repulsive wall appears. Imagine a hydrogen atom in the center of a bipyramid with 6 other hydrogen atoms at the apices surrounding it at distance a . If the central hydrogen atom shifts by a small distance Δ towards one of them the change of the potential equals:

$$\begin{aligned}\delta V &= GM^2 \left(-\frac{1}{(a-\Delta)} - \frac{1}{(a+\Delta)} - \frac{4}{a(1+\frac{1}{2}\frac{\Delta^2}{a^2})} + \frac{6}{a} \right) \\ &= \frac{2GM^2}{a^3} \Delta^2\end{aligned}\quad (2)$$

The expression for δV allows to derive the dependence of ω_{grav} on the size of the crystal a . $\omega_{grav} = \sqrt{\frac{K}{M}}$ where K is the force constant and M the mass. The force constant is the force per unit displacement, hence $K = 2\delta V$ if inserting $\Delta = 1$ in $\delta V = 1/2K\Delta^2$. It follows that

$$\omega_{grav} = \sqrt{\frac{4GM}{a^3}}.\quad (3)$$

For eight hydrogen atoms per m^3 the lattice constant equals $a = 0.81 \times 10^{10}$ bohr. The Hubble parameter in EQM is the gravonon mode frequency eq. (3) which turns out to be of the order of 10^{-10} per year in our theory. The inverse of this is the diffusion jump time which equals the Hubble time.

The calculated Hubble parameter is decisively determined by the averaged density of hydrogen atoms in the intergalactic space.

3.1.1. Expansion dynamics from diffusion model. Given that real space and time, as measured in experiment, emerge from gravonon formation, a diffusion equation can be set up as

$$\dot{a}(t) = C_{jump} a(t) \omega_{grav}.\quad (4)$$

This diffusion equation is explained by the fact that the lattice constant a of the intergalactic cluster can only change by discrete multiples of the present lattice constant a . This follows from the quantum diffusion model of expansion. The atom always hops to a predetermined possible lattice site. The factor $C_{jump} a(t)$ specifies an average jump length in terms of the lattice constant $a(t)$. Inserting the dependence of ω_{grav} on the lattice constant a from eq. (3) into eq. (4), yields with $C_\omega = \sqrt{4GM}$ and initial condition $a(0) = 0$

$$\dot{a}(t) = a(t) C_{jump} C_\omega a(t)^{-3/2}\quad (5)$$

$$a(t) = (3/2 C_{jump} C_\omega t)^{2/3}\quad (6)$$

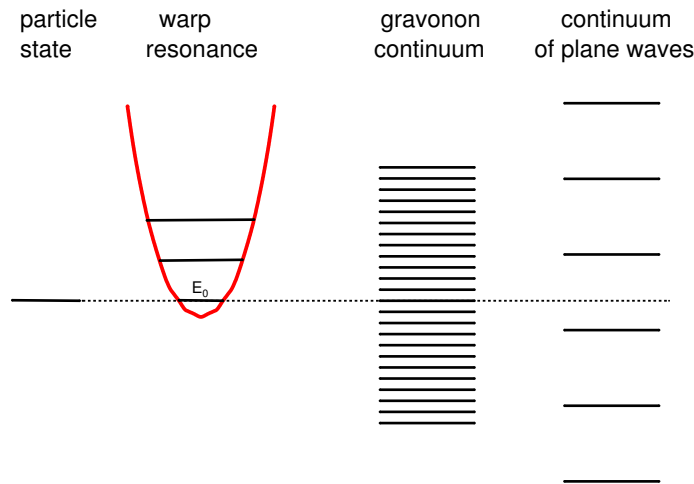


Figure 1. Level scheme illustrating the interaction between the warp resonance and the gravonons.

This is the Einstein-de Sitter result for a flat universe ($\Lambda = 0, k = 0$). Hence EQM predicts a flat universe in terms of an emerging classical spacetime. This is not a consequence of the flat background spacetime inherent in the Lagrangian, but is a consequence of spacetime expansion being interpreted as a diffusion process.

An atom in the intergalactic soft lattice is in limbo for a time ω_{grav}^{-1} . We can only observe it at time steps of ω_{grav}^{-1} , i.e. the clock ticks with an interval of ω_{grav}^{-1} . The possible clocks in the intergalactic space (which have to be constructed from the intergalactic matter) are a factor $\omega_{grav}^{-1}/\omega_{grav-today}^{-1}$ slower than the clocks we have presently here on earth. We would then conclude that for times, measured by the classical clocks constructed from matter here on earth, the velocity of atom diffusion is given by the above diffusion equation.

This way of deriving the Einstein - de Sitter equation is similar in spirit to chemical reaction kinetics. Here the elementary rate constants and pre-exponential factors are calculated from quantum mechanics, but the macroscopic (quasiclassical) reaction velocities as observed in experiment are obtained by feeding the quantum mechanical quantities into kinetic differential equations.

3.2. The beabling condition

This subsection summarizes the EQM-theory in ref. [2] with respect to cosmic diffusion. The interaction potential between atoms is Newton's gravitational potential:

$$V_{grav} = -GM_1M_2/r. \quad (7)$$

The time dependence of the beabling process is calculated by solving Schrödinger's equation.

The gravitational interaction which acts between two atoms separated by distances larger than millimeters is the ordinary Newton gravitation in 4 dimensional spacetime, which turns out to be much too small to induce a dimensionality-like coupling to vibrations with a frequency corresponding to the measured Hubble constant.

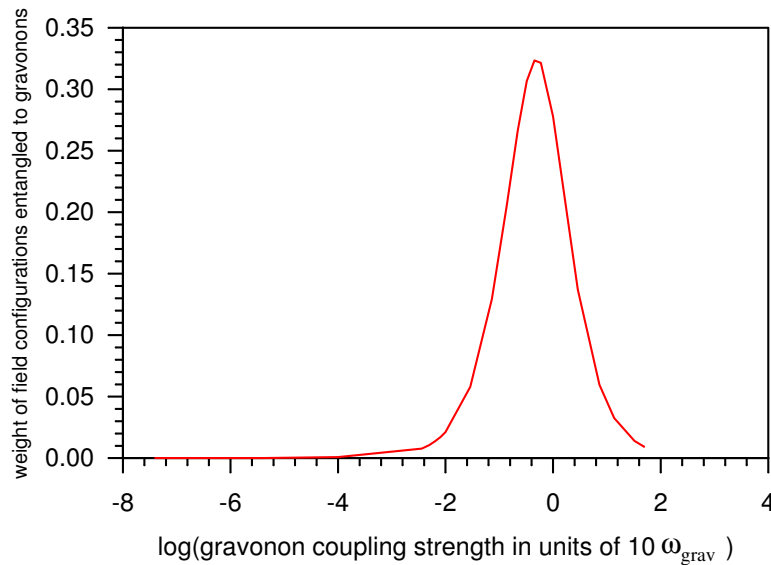


Figure 2. Summed weight of all field configurations entangled to gravitons versus the logarithm of the graviton coupling strength in units of $10\omega_{grav}$.

Then how does the beabbling process work? The condition for beabbling is a local and very weak interaction between the warp resonance and the gravitons, see fig. 1. If the interaction is zero we have no beabbling process. Turning on a very weak interaction with the gravitons means involving just those environmental configurations which are resonant or near-resonant with the initial configuration. (Perturbation theory shows that their involvement is inversely proportional to the energy difference with the initial configuration.)

If the interaction with the gravitons is localized and strong then environmental excitations of different nature over a broad energy interval will be involved, states describing particles in limbo reflection back into the vacuum included. So the particle wave will be preferentially in a limbo state rather than in beable.

Even if the warp resonances are exactly on the energy shell, the coupling to the gravitons must not become arbitrarily small for beabbling to occur. The reason is that the gravitons represent a local spacetime structure exhibiting few modes of extremely small but non-zero frequency. If the matrix elements for graviton coupling become smaller than the softest graviton mode, gravitons will no longer entangle with the particle motion. We have studied this by calculating the degree of entanglement as a function of graviton coupling strength. In fig. 2 the summed weight of all field configurations entangled to gravitons is plotted versus the logarithm of the graviton coupling strength. Entanglement to gravitons is effective over two orders of magnitude and becomes unimportant for weaker and stronger interaction. A variation of this interaction strength by a factor 10^2 or even less from site to site can decide, whether the particle sticks here or somewhere else. The results of fig. 2 are, of course, only valid for the model structure and the parameters applied here. They depend on the nature of the particle (shape, mass, electronic structure) and on the nature of the graviton continuum.

This means that in EQM a matter assembly with a density of the intergalactic matter as existing today (a few atoms per cubic meter) in an arrangement where single H -atoms have a distance from each other of half a meter or so will not beable due to the short range of ADD

high dimensional gravitation.

This shortcoming and problem can be solved, if we observe that the Newton gravonon frequency does only dependent on the matter density in the intergalactic space and is not bound to the condition that single hydrogen atoms, spaced at a definite distance a , form a kind of soft lattice:

$$\omega_{Newton\ mode} = \sqrt{4GM/a^3} = \sqrt{4G\rho_{int.galac.}} \quad (8)$$

It is possible to have e.g. 10^6 H -atoms grouped together at a separation $a_{group} \ll a$ and then to have these groups vibrate against each other with the same frequency $\omega_{Newton\ mode}$ given by eq. (8) if the distance $a_{group-group}$ between these groups is such that $M_{group}/a_{group-group}^3 = \rho_{int.galac.}$

The beabing condition then requires

$$V_{grav} \approx 10 * \omega_{Newton\ mode}. \quad (9)$$

3.2.1. Rearrangement of intergalactic matter: Atom clouds forming a soft Newton lattice. If we group N_{group} hydrogen atoms together and separate these groups at distances of

$$a_{group-group} = N_{group}^{1/3} * a \quad (10)$$

so that the average intergalactic matter density stays the same, the gravitational interaction energy increases to

$$\begin{aligned} V_{grav} &= -GM_{group}^2/a_{group-group} \\ &= -GM^2 N_{group}^{5/3}/a \end{aligned} \quad (11)$$

where we used eq. (10) and $M_{group} = MN_{group}$.

For example, enlarging the lattice constant by a factor 100 and increasing the number of atoms per group to $N_{group} = 10^6$ leaves the average matter density the same. The gravitational interaction between clouds increases according to eq. (11) by a factor $N_{group}^{5/3} = 10^{10}$, the bridge law might be fulfilled and the intergalactic lattice might beable.

3.2.2. Construct an example of a beabled form of intergalactic matter. The van der Waals force can pull the H -atoms together so that they form H_2 -molecules which then combine to a H_2 van der Waals solid. This beabing process is known from a long chemical experience to occur. When van der Waals solids of H_2 form and in a period of millions or billions of years arrange themselves at a lateral separation of 10 meters or so, the beabing condition is fulfilled and this form of matter is manifestly accessible to experimental observation. These matter aggregates expand then by quantum diffusion which is the phenomenon we refer to as spacetime expansion.

4. Light - Atom - Lattices (LAL)

There is, however, the possibility of another beabing process leading to a different form of beabled intergalactic matter. We will call this form a Light - Atom - Lattice (LAL).

Light in an optomechanical lattice generates vibrations and coupling between this optomechanical motion and the Newton mode vibrations in the lattice leads to modification of the latter [3].

4.1. Mechanism of beabling a light - atom - lattice

In the case of the LAL we need a new (non-adiabatic) kind of coupling in order that the light, which perturbs the atoms, makes the atoms beable. According to the principles of EQM, beabling can only occur if matter fields couple to gravonon modes of low frequency. The only low frequency gravonons that are around in our cosmological situation are the Newton mode vibrations. The optomechanical vibrations have a much too large vibrational energy ($\omega_{LAL} = 10^{-5}$ Hartree) for providing a beabling process.

The mechanism can be imagined as follows. A photon arrives and polarizes a H -atom. For an arbitrary photon wave length and an arbitrary distance between the intergalactic hydrogen atoms the effects are vanishingly small and the atoms remain in limbo. But now imagine that the wave length of the photon matches the distance between two intergalactic hydrogen atoms. Then according to the optomechanical experiments and their interpretation by Domokos et al. [5, 6, 7] we have a resonance like effect which makes the hydrogen atoms move due to the force exerted by the light. The frequency of the atomic vibrations is, according to the Domokos theory and the experiments, the same as the photon frequency. This is still a limbo description without any gravitational forces involved.

In order to come to beabling of the light - atom complex we have to include the Newton mode vibration which, according to the above calculations, coincides with the experimental Hubble parameter $\omega_{Newton\ mode} = 5.76 \times 10^{-35}$ a.u. time⁻¹ and hence is 29 orders of magnitude smaller than the photon frequency and the frequency of the light induced atomic vibrations ω_{LAL} .

The frequency of the light and the resonant atomic vibrations have to be 29 orders of magnitude smaller to match the frequency of the Newton mode. This would mean a wavelength of order 10^{29} cm $\approx 10^{27}$ m, which is 27 orders of magnitude larger than the average distance between two intergalactic H -atoms today.

Let us think more carefully and consider the two kinds of forces that act between two H -atoms at intergalactic matter densities today. These are the graviton mediated gravitational force and the photon mediated van der Waals force. The van der Waals potential varies with the inverse sixth power of the distance and hence at some large distance the gravitational potential becomes strongest. At these large distances the photon mediated forces, whether resonant or not, can no more determine the motions of the H -atoms, these motions are dictated here by Newton's law.

At small distances, where the van der Waals potential dominates, the gravitational force can no longer establish a Newton mode kind of vibration of the H -atoms, because the van der Waals force will pull away the hydrogen atoms from their symmetric positions, required to form the Newton mode.

So only at the distance where the van der Waals potential and gravitational potential have equal values there is a possibility that light induced interactions influence the atomic motion, without at the same time destroying the Newton mode vibrations, which are necessary for the beabling process. The coefficients for a hydrogen van der Waals crystal have been measured and can be found in the literature [12]. The two potentials are plotted in fig. 3.

4.1.1. Character of the non-adiabatic coupling between LAL and the global Newton crystal. In order that beabling of the light - atom lattice via the four dimensional Newton mode works, the following bridge law has to be satisfied:

$$V_{atom-Newton\ vibration} \approx 10\hbar\omega_{Newton\ mode} \quad (12)$$

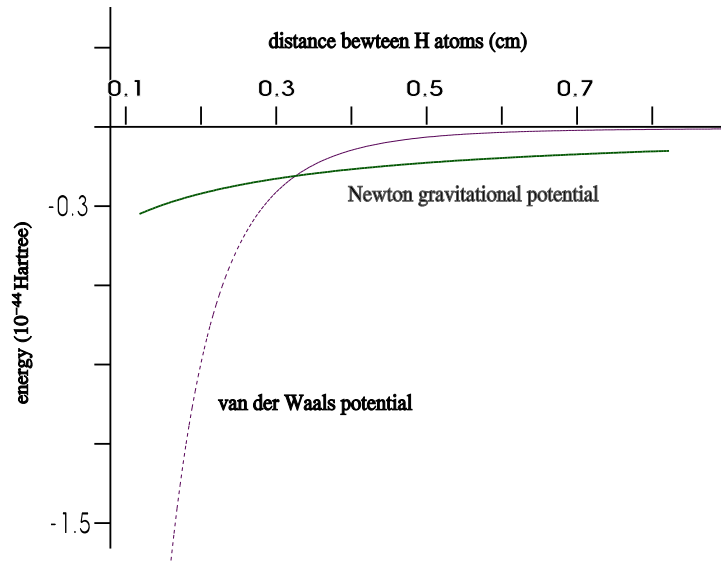


Figure 3. Van der Waals potential (dotted violet curve) and Newton’s gravitational potential (full green curve) as function of distance.

It is not at all obvious what the origin of the interaction $V_{atom-Newton\ vibration}$ should be. We suggest to investigate the model in ref. [13] with the following assignments:

- (i) The many atoms in the cluster of model [13] are the atoms performing the Newton vibration. ω_S in [13] is equal to $\omega_{Newton\ mode}$ and is of order 10^{-34} Hartree.
- (ii) The adatom in [13] is one arbitrarily chosen atom in the light - atom lattice performing a "phonon" vibration of frequency $\omega_{LAL} = 10^{-5}$ Hartree.
- (iii) The surface atom "x" in [13] is an atom out of the many atoms in the cluster, performing the Newton vibration. It is adjacent to the adatom and vibrates with $\omega_S = \omega_{Newton\ mode} = 10^{-34}$ Hartree.

We apply eq. (13) on page 110 in [13]. The first term in eq. (13) vanishes, because $q_A = 0$. We assume this, because the vibration of the "adatom" is so much faster (10^{29} times faster) than the Newton vibration so that its position can be replaced by its expectation value. The atoms of the Newton mode effectively experience only the average of q_A , which is zero.

The second term in eq. (13) gives a renormalization of the frequency $\omega_S = \omega_{Newton\ mode}$ of the surface atom "x" (see e.g. [14])

$$\begin{aligned}\omega_S &\rightarrow \sqrt{\omega_S^2 + \eta\gamma\omega_S^2} \\ &\approx \omega_S(1 + \frac{1}{2}\eta\gamma)\end{aligned}\tag{13}$$

which has to be small so that it does not spoil the results with respect to CMB, velocity of light, etc., i.e. $\eta\gamma \approx 1$. This frequency renormalization has to be small, it must not be larger than ω_S . Only then do we get the correct Hubble parameter, which equals the frequency of the Newton mode. This implies $\eta\gamma \approx 1$.

[h]

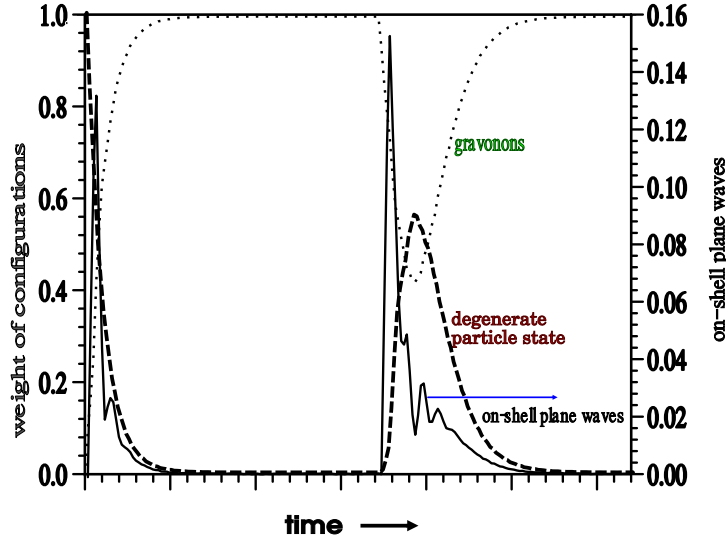


Figure 4. Partial sums of weights (i.e. squared coefficient of the field configurations) of configurations as a function of time as a solution of Schrödinger's equation. The dotted curve comprises all configurations entangled to gravonons (Newton mode). The dashed curve is the sum over all configurations with the LALs in their harmonic oscillator ground state. The full curve represents all configurations where H -atoms are in a plane wave state.

η has to be of order unity (i.e. ≈ 0.5 or so) in order to retain the phonon character of the light - atom lattice arising from the photon mediated van der Waals interactions and the graviton mediated gravitational interactions in the previous section 4.1. γ has to be larger than unity so that the soft mode resulting from the model in ref. [13] can be of order 10^{-34} Hartree.

The third and fourth terms of eq. (13) in [13] are then proportional to $(1 - \eta)\gamma$. The third term is $(1 - \eta)\gamma\omega_S^2 q_x q_n$. The frequency change due to this term can by means of perturbation theory be estimated as $\Delta\omega = \frac{V^2}{\omega_S}$, where V is the perturbing potential which has to be calculated from the $\gamma - \eta$ model. The frequency change due to the second term of eq. (13) in [13] has already been estimated as $\Delta\omega = \frac{1}{2}\eta\gamma\omega_S$. An analysis analogous to that of the second term of eq. (13), which has the form $\eta\gamma\omega_S^2(\text{distance})^2$, can be performed for the third term, which has the form $(1 - \eta)\gamma\omega_S^2(\text{distance})^2$. Comparing these two forms, we realize that the only difference is $\eta \rightarrow (1 - \eta)$. Therefore if the first form yields the frequency change $\Delta\omega = \frac{1}{2}\eta\gamma\omega_S$ then the second form yields $\Delta\omega = \frac{1}{2}(1 - \eta)\gamma\omega_S$. The factor 1/2 is without significance for an order of magnitude estimate. Therefore: $\Delta\omega \approx (1 - \eta)\gamma\omega_S$, $V^2 = (1 - \eta)\gamma\omega_S^2$, and $V = \sqrt{(1 - \eta)\gamma}\omega_S$. This is the potential with which the Newton mode couples to the optomechanical phononic vibrations and which has to satisfy the bridge law $V = \sqrt{1 - \eta}\gamma\omega_S \approx 10^{-34}$. Because ω_S is of order 10^{-34} we have $(1 - \eta)\gamma \approx 1$.

According to the spring model the force constant K of the Newton mode vibrations equals $M\omega_S^2 \approx 10^{-67}$ and the frequency of the 'adatom' mode equals $\omega_A = \omega_{LAL} \approx 10^{-5}$. Hence γ can be calculated as

$$\gamma = \frac{m\omega_A^2}{M\omega_S^2} \quad (14)$$

$$\begin{aligned}
&= \frac{m10^{-10}}{M10^{-70}} \\
&= \frac{m}{M}10^{60}
\end{aligned}$$

Because γ has to be of order $\gamma \approx 1$ we have $\frac{m}{M} = 10^{-60}$.

This signifies that the interaction mediating the entanglement of the hydrogen atoms to the Newton vibrations has a kind of non-adiabatic character. If the mass of the "adatom" would be zero there would be no entanglement to the Newton vibrations, no dimensionality effect [15] and no beabing. The mass of the "adatom" is a factor 10^{60} smaller than the mass of the atoms of the Newton mode which is just the right magnitude for the dimensionality effect [15] to get a grip.

η und γ can now be calculated as follows:

$$\eta\gamma = (1 - \eta)\gamma \rightarrow \eta = 0.5 \quad (15)$$

$$(1 - \eta)\gamma = 1 \rightarrow \gamma = 2 \quad (16)$$

Concluding we see that the lattice constant of the LAL (0.33 cm), the number of atoms in the LAL (10^6) and the distance separating the LAL crystallites (10 m) is determined by the beabing condition for the global Newton crystal.

4.2. Light emission from the Light - Atom - Lattice: emerging temperature

If a cosmic ray particle hits the LAL and forces a H -atom out of its harmonic oscillator ground state $|\psi_0\rangle$, it will make a transition into a plane wave. Because of the weakness of the potentials involved plane waves are to a very good approximation excited eigenstates of the unperturbed LAL. A transient perturbing potential V_{pert} due to a cosmic ray particle will hence induce transitions to plane waves with rate

$$\frac{2\pi}{\hbar} |\langle \psi_0 | V_{pert} | e^{-ikx} \rangle|^2 \rho_{pl.waves} \approx \frac{2\pi}{\hbar} |\langle \psi_0 | e^{-ikx} \rangle|^2 \bar{V}_{pert}^2 \rho_{pl.waves}.$$

The transition amplitude will be proportional to the overlap of a gaussian (the harmonic oscillator ground state) and the plane wave $\langle \psi_0(x) | e^{ikx} \rangle \propto e^{-\frac{k^2}{4\alpha^2}} = e^{-\frac{E_k}{2E_0}} \rightarrow e^{-\frac{E_k}{2k_B T}}$, where α is the exponent of the gaussian and $E_0 = \frac{\alpha^2}{m} \rightarrow \alpha^2 = mE_0$ ($\hbar = 1$). The energy E_0 can be substituted by the thermal energy $k_B T$, introducing the temperature T .

When squaring the overlap we see that the coefficients squared of the hydrogen plane waves in the limbo functional have a distribution $e^{-E_k * const}$ and the constant can then be set to define a temperature. This is the emergence of a temperature. It turns out to be just the temperature that is measured for the CMB radiation.

The cosmic particle has transferred the H -atom into a limbo state. When it rebeables from a particular plane wave k into its harmonic oscillator ground state, the energy E_k is regained. Because the hydrogen vibration couples to the photon field it means that the energy difference excites photons, i.e., the wave packet state describing the re-beabled hydrogen atom contains configurations with the excited photon with coefficients proportional to the Boltzmann factor. These photons can then be beabled in a measurement here on earth.

When then calculating the Planck distribution we have to take into account that the Boltzmann factor enters for the coefficients, with which the configurations having the excited photon with a special k -vector, are contained in the wave packet. When from this the expectation value of the photon number operator is calculated, we obtain the Bose-Einstein distribution. This has

then to be multiplied by the photon mode density to get the full Planck distribution.

Fig. 4 shows the solution of Schrödinger's equation of a model hamiltonian describing the dynamics of the intergalactic hydrogen matter. The weight of field configurations with plane wave component is given by the full curve. *During a beable - limbo transition the plane wave components of the total wave functional acquire weight according to the Boltzmann factor $e^{-\frac{E_k}{k_B T_{CMB}}}$.* $\omega_{LAL} = 2k_B T_{CMB}$. The wave vector k determines the energy of the respective plane wave $\frac{k^2}{2m} = E_k$ and the exponent $\alpha^2 = \frac{m\omega_{LAL}}{2}$ of the gaussian characterizes the oscillating H -atom. It scales with the kinetic energy of the H -atom $E_0 = k_B T$ in the vibrational ground state.

During a beable - limbo transition the LAL develops into a black body radiator, which emits the CMB radiation. In EQM temperature emerges as quantum mechanical phenomenon.

5. Conclusions

In this contribution a purely quantum mechanical model of the intergalactic hydrogen matter has been suggested where only three experimental quantities enter: the mass density of intergalactic hydrogen atoms, the experimentally determined parameter describing van der Waals hydrogen crystals and Newton's gravitational constant. The deterministic EQM theory has been applied to this model which leads to localization (beabbling) of the hydrogen atoms, if the beabbling condition is fulfilled. If the beabbling condition is not fulfilled the H atoms remain non-observable. Without fitting any free model parameters the following quantities have been calculated:

quantity	EQM	experiment
Hubble time	$1.3 * 10^{10}$ years	$1.36 * 10^{10}$ years (standard candles)[16]
CMB radiation temp.	2.2 Kelvin	2.725 Kelvin

The important physical insights gained are:

- Quantum diffusion of hydrogen atoms simulates expansion of three dimensional space.
- Numbers emerge by satisfying the beabbling conditions.
- Einstein-de Sitter expansion with zero curvature results.
- Temperature emerges from the model, a horizon problem does not exist.

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