# Dimensional Transitions in a Bose Gas

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**Abstract**

In the early universe, the density reached the order of the Planck density. As a result, there were gravitational instabilities in which dimensional transitions occurred. It should be taken into account that the early universe consists only of photons and black holes. Photons are bosons. The quantum physical model for many bosons, such as photons, is the Bose gas model. Here we can study the dynamics of the early universe more accurately (Hans-Otto Carmesin (2020): The Universe Developing from Zero-Point Energy Discovered by Making Photos, Experiments and Calculations. Berlin: Verlag Dr. Köster). This research aims to determine and apply the critical densities of dimensional phase transitions in Bose gases with the use of a computer simulation. This new type of phase transitions could be used in the future to apply them to the horizon problem. This might accordingly lead to the solution of the problem without including a hypothetical entity such as the so called *inflation field*. The project is presented as an example for teamwork in an ensemble of projects in the field of quantum gravity that are carried out in a research club at our school.

## 1. Introduction

Since the Big Bang our universe expands, so that the light horizon becomes larger and is $4.5\times10^{26}$ m large by now, although the light travel time amounts to only 13.8 billion years. If we trace the development of the size of today's light horizon back in time with general relativity through the Friedmann-Lemaître equation to the Planck length $l_P$, this length would be reached at a density which would be significantly larger than the Planck density $\rho_P$ (see figure 1.1). Already below a light horizon of 0.000014524m the Planck density would be exceeded with this model. But since no density can be larger than the Planck density a calculation with the general relativity theory is insufficient, and describes only the range of the light horizon with a size of 0.000014524m to $4.5\times10^{26}$m.

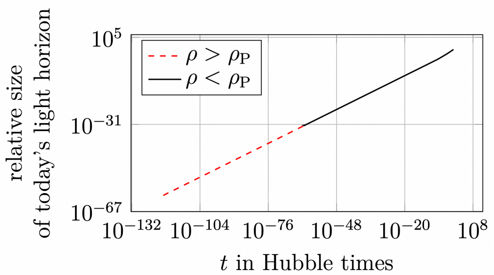


**Fig.1:** Time back tracing of today's light horizon according to the Friedmann-Lemaître equation. Both axes are logarithmically scaled

The range between $1.616\times10^{-35}$m and 0.000014524m cannot be modeled with the general theory of relativity, so that the dynamic factor of $0.000014524\text{m}\div1.616\times10^{-35}\text{m} = 8.71616\times10^{29}$ is not explained [Heeren et al., 2020].

Instead, another dynamic explains the rapid increase of the light horizon in the early universe. Quantum gravity allows to model dimensional phase transitions that can describe the missing factor below 0.000014524m [Schöneberg and Carmesin, 2020]. Thus, after the Big Bang, the universe had a high spatial dimension due to its high density. However, by increasing the distances, the density becomes lower, so that a gravitational instability occurs and a lower dimension becomes energetically more favorable. It follows that our three-dimensional space follows directly from the space dynamics. Dimensions $D \geq 3$ have already been experimentally proven [Lose et al., 2018], [Zilberberg et al., 2018]. To accurately model space dynamics in the early universe, it is essential to include the composition of space. Instead of our present heavy elementary particles, which did not exist in the early universe, the energy was present in photons and black holes. Since photons are bosons, a calculation in the Bose gas model with consideration of interactions is reasonable. The goal of the project is to model the early universe by determining the critical densities of dimensional phase transitions in Bose-gases and applying the critical densities to the time course of the universe. The project is particularly interesting because the new insights into the early universe may be purposeful in explaining the rapid increase in distances in the early universe. Furthermore, the phase transitions could be applied to the horizon problem so that it can be solved in the future.

## 2. **State of Research**

### 2.1. **Increase of distances in the early universe and the horizon problem**

In 1981 Alan Guth found out that in the early universe a fast increase of the distances by a factor of $10^{28}$ occurred [Guth, 1981]. This time is called "cosmic inflation" since then. However, since it is not an inflation of the space (lat. inflatus = expanded), but rather a rapid increase of the distances in the space, the term is inapplicable. In the publication Guth already points out that the enlargement of the distances in the early universe cannot be explained with usual physical concepts. Also, the high degree homogeneity of the structures and isotropy of the background radiation cannot be justified with a simple expansion model by the Friedmann-Lemaître equation. That problem is called horizon problem. To explain the increase of distances, the hypothesis of an inflation field was later proposed [Nanopoulos et al., 1983]. According to this hypothesis, space expanded by inflation due to a scalar field. The hypothesis of an inflation field with accompanying expansion would explain the increase of distances by a Distance Enlargement Factor Z, however, such a field cannot serve as a justification for the increase of distances, since a justification is always the consequence of a sound theory [Carmesin, 2020a], [Lipton, 1993]. The inflationary field hypothesis does not follow from generally accepted physical laws, nor have observations been made that would directly prove an inflationary field.

### 2.2. **Dimensions over three by quantum gravity**

Since the density in the early universe was very high, the modeling of the space dynamics must be quantized. The early universe consisted of a binary fluid of photons and black holes [Carmesin, 2020b]. The differential equation (2.1) describes the quantized dynamics of a pair consisting of two dynamical masses $\tilde{M}_j$, each of which can be either black holes or photons.

$$\frac{\hbar^2}{2m_j^2}\cdot\sum_{i=1}^{i=D}\partial_{x_i}^2\,\Psi(\vec{r_j}) - \mathrm{G}\cdot M_j\cdot\widehat{r_j^{-1}}\cdot\Psi(\vec{r_j}) = \frac{\hat{E}_j}{m_j}\cdot\Psi(\vec{r_j}) \qquad \{2.1\}$$

The wave function $\Psi_j(\vec{r}_j)$ describes the position $\vec{r}_j$ of a mass $m_j$ as a function of the neighboring mass $M_j$ in the binary fluid [Carmesin 2020b, p. 200].

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The special feature of this differential equation (2.1) is that the kinetic energy term $\frac{\hbar^2}{2m_j^2}\cdot\sum_{i=1}^{i=D}\partial_{x_i}^2\,\Psi(\vec{r_j})$

can be generalized for all Dimensions. The potential energy term can be generalized for all dimensions $D \geq 3$. Thus, quantized space dynamics allows space dimensions beyond three. This suggests that our three-dimensional space is directly the result of space dynamics. The computationally possible dimensions $D \geq 3$ have already been experimentally demonstrated. For example, there are several scientific projects that have experimentally explored wave functions in dimensions $D \geq 3$ [Lose et al., 2018], [Zilberberg et al., 2018]. Accordingly, quantum objects do not only exist on paper beyond three dimensions.

## 3. **Method**

### 3.1. **Energy between two adjacent objects in the early universe**

When the density was $1/2 \geq \tilde{\rho}_D \geq 1/9047$ in the early universe, there was a binary fluid consisting of photons and black holes [Carmesin, 2020b, p. 144]. The entire energy of the universe was present in these particles. The goal is to calculate the energy $E_{Dj}$ of a mass $\tilde{m}_j$ with an associated radius $\tilde{b}_j$ acting on an adjacent mass $\tilde{M}_j$ with a radius $\tilde{a}_j$ at a density $\tilde{\rho}_D$. Since the masses $\tilde{m}_j$ and $\tilde{M}_j$ in the early universe can only be photons (p) and black holes (b), there are four possible cases for a pair j of two dynamical masses:

- (bb) $\tilde{m}_j$ and $\tilde{M}_j$ are black holes
- (bp) $\tilde{m}_j$ is a black hole and $\tilde{M}_j$ is a photon
- (pb) $\tilde{m}_j$ is a photon and $\tilde{M}_j$ is a black hole
- (pp) $\tilde{m}_j$ and $\tilde{M}_j$ are photons.

The subject of this project is the analysis of the case (pp). Thus, the energy $E_{Dj}$ between neighboring photons is calculated for different dimensions as a function of the density $\tilde{\rho}_D$ in order to determine the most energetically favorable spatial dimension for each density $\tilde{\rho}_D$.

### 3.2. **Bose gas model**

Photons have an integer spin and are therefore bosons. At thermal equilibrium, they satisfy the Bose-Einstein distribution [Bose, 1924]. They have the special property that they can overlap completely and thus occupy the same quantum mechanical position. The ideal Bose gas is the quantum mechanical equivalent of the ideal gas for many bosons [Bose, 1924].

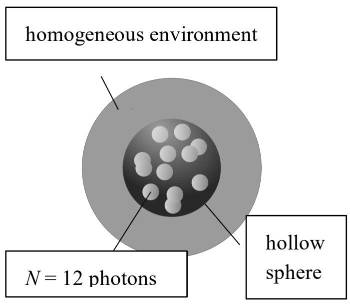


**Fig.2:** Bose gas with *N* photons in a hollow sphere with a homogeneous environment.

With an ideal gas, the interactions between particles are neglected. Phase transitions cannot be described with an ideal gas, because the interactions between the particles are responsible for them. Therefore, the bosons are modeled in the form of a quantum mechanical real gas. The interactions of the photons are combined to a resulting potential, in which the photons can interact independently. Since the interactions are gravitational, it is crucial that the modeling be done in a hollow sphere. In a hollow sphere with a homogeneous environment, no gravitational field from outside exists. Therefore, the hollow sphere is suitable to perform investigations with objects inside, which should not react to external gravitational effects. It is examined with this model, which dimension minimizes the energy in the Bose gas depending on the density. Since the model is a gas, a calculation of the gas pressure in dependence on the density for different dimensions is also purposeful.

3.3. **Energy term for a reference photon in a Bose gas**

The energy term of such a reference photon includes the kinetic energy $E_{kin}$, the potential energy $E_{pot}$ and the zero-point energy $E_{ZPE}$. To derive the energy term, we first need the radius $\tilde{a}$ of a dynamical mass $\widetilde{M}$ at a density $\tilde{\rho}_D$. The dynamical mass $\widetilde{M}$ of a quantum object is proportional to $1 \div \tilde{a}$. At the Planck length applies $l_P$, $\widetilde{M} = 1 \div 2$ [Carmesin, 2020b]. If you add both ratios together, you get:

$$\widetilde{M} = \frac{1}{2 \cdot \tilde{a}} \quad \text{for radiation} \qquad \{3.1\}$$

Converting to radius $\tilde{a}$ by multiplying by $\widetilde{M} = \tilde{\rho}_D \times \tilde{a}_D$ gives:

$$\tilde{a} = \frac{1}{(2\tilde{\rho}_D)^{\frac{1}{D+1}}} \quad \text{for radiation} \qquad \{3.2\}$$

The volume of the hollow sphere corresponds to $2^D$ times the volume of a single particle. However, in order for the density to remain constant, and not change with dimensional phase transitions, the number of possible states in the hollow sphere N must vary with dimension. It therefore follows for the model:

$$N = 2^D \qquad \{3.3\}$$

Now we can calculate the potential energy $\tilde{E}_{pot}$, the kinetic energy $\tilde{E}_{kin}$ and the zero-point energy $\tilde{E}_{ZPE}$ of the reference photon. Since the kinetic energy $\tilde{E}_{kin}$ of a photon is equal to the Planck constant h divided by the periodic time *T*, the scaled kinetic energy $\tilde{E}_{kin}$ is identical to its scaled mass $\widetilde{M}$:

$$\tilde{E}_{kin} = \widetilde{M} = \frac{1}{2 \cdot \tilde{a}} \qquad \{3.4\}$$

Of special importance for the energy term is the potential energy, because phase transitions are possible only by the gravitational interactions described by the potential energy phase transitions are possible. For the derivation of the potential energy $E_{pot}$ first the energy of the interaction of a pair of two objects with a mass M and a distance R is needed:

$$E_{pot}(R) = -\frac{G_D \cdot M^2}{(D-2) \cdot R^{D-2}} \qquad \{3.5\}$$

Converted into Planck units this corresponds to:

$$\tilde{E}_{pot}(\tilde{R}) = -\frac{\widetilde{M}^2}{\tilde{R}^{D-2}} \qquad \{3.6\}$$

We analyze one photon of the N photons in the center of the hollow sphere, this serves as a reference object. The other particles are randomly distributed in the hollow sphere - since it is a real Bose gas. The averaged potential energy $\bar{\tilde{E}}_{pot}$ of a reference photon with the other photons is determined accordingly. It holds [Carmesin, 2020b]:

$$\bar{\tilde{E}}_{pot} = \frac{\int_0^{\tilde{r}} \tilde{E}_{pot}(\tilde{R}) \tilde{R}^{D-1} d\tilde{R}}{\int_0^{\tilde{r}} \tilde{R}^{D-1} d\tilde{R}} \qquad \{3.7\}$$

Next, we insert equation (3.6). This gives:

$$\bar{\tilde{E}}_{pot} = -\widetilde{M}^2 \cdot \frac{\int_0^{\tilde{r}} \tilde{R} d\tilde{R}}{\int_0^{\tilde{r}} \tilde{R}^{D-1} d\tilde{R}} \qquad \{3.8\}$$

If the integrals are calculated, we get:

$$\bar{\tilde{E}}_{pot} = -\widetilde{M}^2 \cdot \frac{D}{2} \cdot \frac{\tilde{r}^2}{\tilde{r}^D} = -\widetilde{M}^2 \cdot \frac{D}{2 \cdot \tilde{r}^{D-2}} \qquad \{3.9\}$$

Next, we insert equations (3.1) and (3.2). For the radius $\tilde{r}$ of the hollow sphere applies $\tilde{r} = 2 \cdot \tilde{a}$:

$$\bar{\tilde{E}}_{pot} = -\frac{D}{2^{D+1}} \cdot (2 \cdot \tilde{\rho}_D)^{\left(\frac{D}{D+1}\right)} \qquad \{3.10\}$$

With equation (3.10) we get the energy of the averaged gravitational interaction $\bar{\tilde{E}}_{pot}$ of a photon to the surrounding photons depending on the density $\tilde{\rho}_D$ for different spatial dimensions. Now that we have calculated the kinetic energy and the potential energy, all that is missing is the zero-point energy $E_{ZPE}$. The zero-point energy is characterized by harmonic oscillators [Born and Jordan, 1925]. There are two main reasons for this. First, the quantized electromagnetic field is modeled by harmonic oscillators. Second, the harmonic potential of a zero-point oscillation is enabled in a very good approximation by the high density [Carmesin, 2018], [Carmesin, 2019], [Carmesin and Carmesin, 2020]. For the harmonic oscillator, [Casimir, 1948] holds:

$$E = \frac{\hbar \cdot \omega}{2} \qquad \{3.11\}$$

Since photons are transversal waves, there is transversal polarization. Therefore, there are D-1 polarizations. It follows accordingly:

$$E_{ZPE} = \frac{\hbar \cdot \omega}{2} \cdot (D-1) \qquad \{3.12\}$$

Converted into Planck units, it follows approximately:

$$\tilde{E}_{ZPE} = \frac{1}{2} \cdot (D-1) \qquad \{3.13\}$$

The averaged energy $\bar{\tilde{E}}$ of the reference photon in the bose gas can now be calculated adding up kinetic- (3.4), potential- (3.7) and zero-point-energy (3.13):

$$\bar{\tilde{E}} = \tilde{E}_{kin} + \tilde{E}_{ZPE} + \left(\frac{N-1}{2} \cdot \bar{\tilde{E}}_{pot}\right) \qquad \{3.14\}$$

The factor N-1 is given by the fact that the calculated potential energy so far describes the gravitational interaction of two particles. Since there are N objects in the Bose-gas, the potential energy must be correspondingly valid for a reference photon with N neighboring objects. Therefore, the potential energy $\tilde{E}_{pot}$ for two particles is first halved, so that half is assigned to each particle. Then it is multiplied by N-1 to obtain the interaction of a reference photon for N photons. The subtrahend -1 results from the fact that the photon does not interact with itself. For the complete energy term, in addition to equations (3.4), (3.9) and (3.13), we add the radius r = $2 \cdot \tilde{a}$ and equation (3.3) for the hollow sphere:

$$\bar{\tilde{E}} = \frac{1}{2\tilde{a}} + \frac{(D-1)}{2} - (2^D - 1) \cdot \left( \frac{D}{2^{D+1}} \cdot (2 \cdot \tilde{\rho}_D)^{\left(\frac{D}{D+1}\right)} \right) \quad \{3.15\}$$

3.4. **Simulation of dimensional phase transitions**

The computer simulation of the model was initially done using the spreadsheet program Excel. However, using Excel is relatively impractical. For example, the range of density to be simulated cannot be easily adjusted, so that a small change is very time-consuming. Adjusting the formulas used is also time-consuming, as each adjustment must be made separately for each dimension. In order to automate the simulation and increase its accuracy, it was essential to switch from Excel to a programming language. Thus, the R language was chosen for this project. R is an open-source scripting language for scientific and statistical calculations. Because of R's wide range of functions adapted to calculations, the simulation could not only be reproduced with R but also completely automated. The accuracy with which the calculation runs could also be improved. The most accurate simulation to date calculates the range between $0.44\tilde{\rho}_D$ and $0.5\tilde{\rho}_D$ in 60,000,000 steps. In the Excel calculation, this would correspond to 60,000,000 lines. This accuracy is sufficient for the critical densities up to dimension 33. In another calculation realized with R, the calculated critical densities are applied to the time course of today's light horizon. In doing so, the dimension is dynamically adjusted with the density as a function of time, so that a time course of the light horizon is created that takes higher dimensions into account.

4. **Results**

4.1. **Minimizing the pressure through a dimensional transition**

Figure (3) shows the gas pressure $\tilde{p}$ as a function of the density $\tilde{\rho}_D$ for dimensions 3 and 4. At a low density, the third dimension minimizes the pressure. The simulation shows that at a very high density, the pressures of the two dimensions converge until the dimensions coincide at a point - the critical density. Above the critical density, the fourth dimension minimizes the pressure. This can be clearly seen in the figure. A principle in nature is that in a system basically the energetically lowest state is adopted. At low density, this is the third dimension. Starting from the critical density, however, the fourth dimension is energetically more favorable. Therefore, a dimensional transition from the third to the fourth dimension follows together with a gravitational instability.

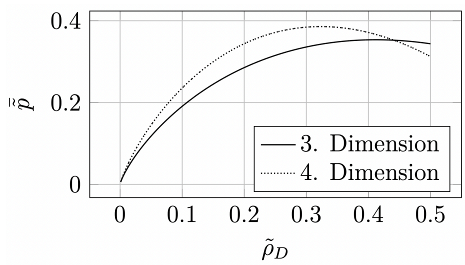


**Fig.3:** Pressure $\bar{\tilde{p}}$ as a function of density $\tilde{\rho}_D$ for dimension 3 and 4

4.2. **Dimensional condensation of photons**

The phase transitions occur largely analogously to condensation in the case of water. At very low density, water is present in gaseous form. A phase transition happens when the density is increased. At a critical point, the water becomes liquid. In the same way as for the dimensional phase transitions, the interactions of the water molecules are also responsible for the condensation.

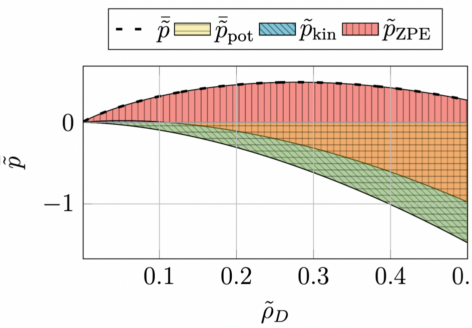


**Fig.4:** Proportions of the gas pressure $\bar{\tilde{p}}$ of a reference photon in the Bose gas as a function of density $\tilde{\rho}_D$. Potential pressure $\bar{\tilde{p}}_{pot}$, kinetic pressure $\bar{\tilde{p}}_{kin}$ and zero-point pressure $\bar{\tilde{p}}_{ZPE}$ are added up in a staggered manner, respectively.

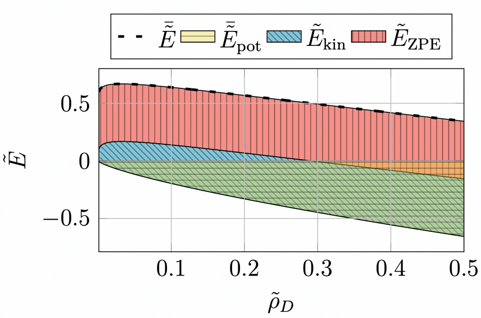


**Fig.5:** Proportions of the averaged energy $\bar{\tilde{E}}$ of a reference photon in the Bose gas as a function of density $\tilde{\rho}_D$. Potential energy $\bar{\tilde{E}}_{pot}$, kinetic energy $\bar{\tilde{E}}_{kin}$ and zero-point energy $\bar{\tilde{E}}_{ZPE}$ are added up in a staggered manner, respectively.

At very low density, kinetic energy also predominates in water. Due to the motion, the particles remain at a distance. However, if the molecules are close together due to high density, hydrogen bonds occur and the particles attract each other due to the strong interaction. Figure (4) illustrates the fractions of the averaged pressure $\tilde{p}$ as a function of the density $\tilde{\rho}_D$ for the third dimension. The proportions are staggered and added on top of each other.

The dimensional condensation in photons can be illustrated as follows:

**Fig.6:** One-dimensionally arranged particles

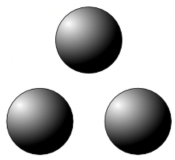

**Fig.7:** Two-dimensionally arranged particles

The particles in figure (6) are arranged one dimensionally and attract each other with $E_{pot}$ and repel each other with $E_{kin}$. As the density is increased, $E_{pot}$ becomes larger than $E_{kin}$. Thus, small distances minimize the energy. By a transition to a two-dimensional arrangement (figure (7)), these distances decrease correspondingly by increasing the number of directly neighboring particles. Therefore, above a critical density, a higher dimension or, in the case of water, the aggregate state change is energetically more favorable. In contrast to water, photons of course do not form droplets at a transition; however, it is decisive that in both systems the symmetry changes at a transition. At a certain density, the Bose gas has the same pressure and energy, respectively, for dimensions 3 and 4. Using computer simulation, we can determine that this critical density is $\tilde{\rho}_{3,krit} = 0.44097$. Analogous to the dimensional phase transition from the third dimension to the fourth dimension, dimensional phase transitions to higher dimensions also occur as the density is further increased (Figure (8)).

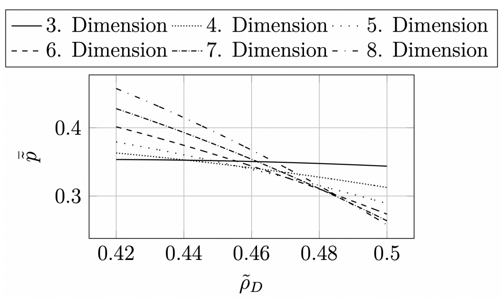


**Fig.8:** Pressure $\bar{\tilde{p}}$ as a function of density $\tilde{\rho}_D$ for different dimensions

The next dimensional phase transition from the fourth to the fifth dimension occurs at a critical density $\tilde{\rho}_{4,krit}$ of 0.45564. The subsequent critical density is $\tilde{\rho}_{5,krit}$ = 0.47002. All dimensional transitions from the transition from the 18th to the 19th dimension occur at a critical density $\tilde{\rho}_D$ in the interval of 0.49999 and 0.5. For example, the critical density $\tilde{\rho}_{21,krit}$ is 0.49999762. If we plot the dimension D as a function to the critical density $\tilde{\rho}_{D,krit}$ we can directly see that the dimension increases with density (Figure (9)).

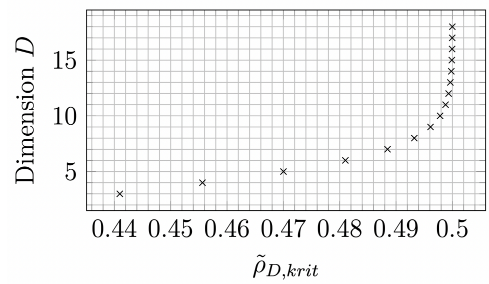


**Fig.9:** Critical densities $\tilde{\rho}_{D,krit}$ as a function of dimension $D$

Concluding from this, there was a dimensional unfolding sequence due to the high density in the early universe. At the beginning the space of the universe was folded into a high space dimension. As described by the Friedman-Lemaître equation, there was a slow expansion so that the density decreased. Due to the decreasing density, eventually a lower space dimension became energetically more favorable and minimized the pressure. A gravitational instability occurred and the smaller space dimension was adopted. Subsequently, at the next critical density, space assumed the next lower dimension, so that a series of dimensional transitions - each from a higher dimension D + s to a lower dimension - occurred. As mentioned, the process was also calculated using an R simulation. Figure (10) shows the corresponding time course with dimension transitions. This process continued until the third dimension was reached. Including dimension transitions in the early universe, our third-dimension results directly from space dynamics. The Distance Enlargement Factor Z resulting from the dimension transitions is Z = $7.985698 \times 10^{29}$.

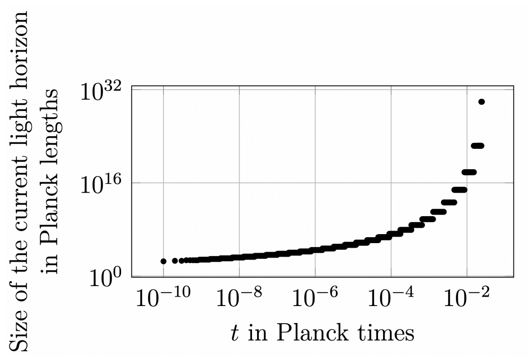


**Fig.10:** course of today's light horizon including dimensional transitions. Both axes are logarithmically scaled

## 4.3. Comparison to the "Cosmic Inflation"

The dependency of the dimensions to the density gives a significant impulse for the modelling of the distance enlargement in the early universe. So far, the rapid enlargement of the universe after the Big Bang is often explained by the inflation field hypothesis. In table 1 the model presented here is compared with the "cosmic inflation".

| **Dimensional transitions** | **"Cosmic Inflation"** |
|---|---|
| The model presented here can be completely derived from general relativity and quantum physics. | The "cosmic inflation" does not follow from known physical laws and has no theoretical basis. and is based on hypotheses instead. |
| Higher dimensions have already been demonstrated experimentally. | An inflation field that could have caused the cosmic inflation has not been experimentally confirmed. |
| Distance increases due to dimensional transitions satisfy the law of conservation of energy, since the volume does not change in these. | With the "cosmic inflation" there is the reheating problem. By the expansion of the distances the temperature would have decreased, so that it would be colder today. |
| When explaining the distance enlargement with dimensional transitions, no parameter estimations are necessary. | To solve the reheating problem, further hypothetical fit parameters have to be used. |

**Tab.1:** Comparison of Dimensional Phase Transitions in Bose gases and Cosmic Inflation

Against the background that an inflation field neither follows from physical laws, it is accordingly estimated as a hypothesis [Tanabashi et al., 2018]. Along with this, for example, the reheating problem cannot be solved because the nature of cosmic inflation is unknown. There is no empirical evidence for other hypotheses that contradict the inflation model, such as explaining the early universe with a variable speed of light [Albrecht and Magueijo, 1999]. The model presented here, on the other hand, can be derived directly from two very sound theories; quantum physics and gravity. By the described dimensional unfolding sequence, the distances have increased by a factor of $7.985698\times10^{29}$ without the space having expanded. Thus, for the justification of the increase of the distances in the early universe by a factor of $8.71616\times10^{29}$ the inflation field hypothesis must not be used any more, rather this factor results directly from the quantum gravity. Another advantage of the dimensional phase transitions is that these also explain how the light waves could thermalize the horizon of the expanding universe since the time of the Big Bang. The inflation hypothesis was developed not least because of the horizon problem. But also, the here calculated time course with dimension transitions solves the horizon problem. This was the subject of the Jugend forscht project "Solution to the Horizon Problem" by Philipp Schöneberg. Here the calculations were already successfully applied to the horizon problem. The problem was thus solved [Schöneberg, 2021].

## 5. **Conclusion**

The subject was the investigation of the early universe with the help of dimensional transitions within the framework of a Jugend forscht project. Specifically, since the early universe consisted to a large extent of photons, this was done using a Bose gas. The aim was to find out how the spatial dimensions behave as a function of density and what implications this has for the dynamics of space. In order to answer this research question, a Bose gas was modeled with which the energy in the gas and the gas pressure can be determined as a function of the density. The calculation has taken the form of a computer simulation using R. It shows that the dimensions depend on the density and increase with increasing density. The transition from one dimension to another dimension takes place by the concept of a condensation. Finally, the results show that there was a dimensional unfolding sequence in the early universe due to the decreasing density $\tilde{\rho}_D$ originating from the expansion. This provides an important input to the study of the early universe. Along with the dimensional unfolding, the distances became larger by a factor of $7.985698\times10^{29}$. This dynamic makes the hypothesis of an inflationary field unnecessary, as the problem has already been solved by quantum gravity. In contrast to the inflation field hypothesis, the model presented here is completely derived from known laws of physics. Furthermore, the model also solves the horizon problem. In the future, the simulation can be improved to optimize the model.

## 6. **Bibliography**


Albrecht, A. and Magueijo, J. (1999). A Time varying speed of light as a solution to cosmological puzzles. *Physical Review D*, 59:043516.

Born, M. and Jordan, P. (1925). Zur Quantenmechanik. *Zeitschrift für Physik*, 34(1):858–888.

Bose, S. (1924). Plancks Gesetz und Lichtquantenhypothese. Zeitschrift für Physik, 26(1):178–181.

Carmesin, H.-O. (2018). Entstehung der Raumzeit durch Quantengravi- tation - Theory for the Emergence of Space, Dark Matter, Dark Energy and Space-Time. Verlag Dr. Köster.

Carmesin, H.-O. (2019). Die Grundschwingungen des Universums - The Cosmic Unification. Nummer 1 in Universe: Unified from Microcosm to Macrocosm. Verlag Dr. Köster.

Carmesin, H.-O. (2020a). Explanation of the Rapid Enlargement of Distances in the Early Universe. In PhyDid B - Didaktik der Physik - Beiträge zur DPG-Frühjahrstagung, Seiten 11–17. Deutsche Physikalische Gesellschaft, V. Nordmeier and H. Grötzebauch.

Carmesin, H.-O. (2020b). The Universe Developing from Zero-Point Energy Discovered by Making Photos, Experiments and Calculations. Nummer 3 in Universe: Unified from Microcosm to Macrocosm. Verlag Dr. Köster.

Carmesin, M. and Carmesin, H.-O. (2020). Quantenmech- anische Analyse von Massen in ihrem eigenen Gravitationsfeld. In PhyDid B - Didaktik der Physik - Beiträge zur DPG-Frühjahrstagung, Seiten 43–46. Deutsche Physikalische Gesellschaft, V. Nordmeier and H. Grötzebauch.

Casimir, H. (1948). On the Attraction Between Two Perfectly Conducting Plates. Indag. Math., 10:261–263.

Guth, A. H. (1981). Inflationary universe: A possible solution to the horizon and flatness problems. Phys. Rev. D, 23:347–356.

Heeren, L., Carmesin, H.-O., and Sawitzki, P. (2020). Comprehensive Derivation of a Density Limit of the Evolution of Space. In PhyDid B - Didaktik der Physik - Beiträge zur DPG-Frühjahrstagung, p. 39–42. Deutsche Physikalische Gesellschaft, V. Nordmeier and H. Grötzebauch.

Lipton, P. (1993). The British Journal for the Philosophy of Science, 44(3):585–588.

Lose, M., Schweizer, C., and Price, H. (2018). Exploring 4D quantum Hall physics with a 2D topological charge pump. Nature, (553):55–58.

Nanopoulos, D., K.Olive, and Srednicki, M. (1983). After primordial inflation. Physics Letters, Section B: Nuclear, Elementary Particle and High-Energy Physics, 127(1-2):30–34.

Schöneberg, P. (2021). Lösung des Horizontproblems.

Schöneberg, P. and Carmesin, H.-O. (2020). Solution of a Density Problem in the Early Universe. In PhyDid B - Didaktik der Physik - Beiträge zur DPG-Frühjahrstagung, p. 19–27. Deutsche PhysikalischenGesellschaft, V. Nordmeier and H. Grötzebauch.

Tanabashi, M., Grp, P., Hagiwara, K., Hikasa, K., Nakamura, K., Sumino, Y., Takahashi, F., Tanaka, J., Agashe, K., Aielli, G., Amsler, C., Antonelli, M., Asner, D., Baer, H., Banerjee, S., Barnett, R., Basaglia, T., Bauer, C., and Beatty, J. (2018). Review of Particle Physics: Particle Data Group. Physical Review D, 98.

Zilberberg, O., Huang, S., and Guglielmon, J. (2018). Photonic topological boundary pumping as a probe of 4D quantum Hall physics. Nature, (553):59–62.