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# Discrete and Continuous Matter

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## ABSTRACT

Current cosmology assumes the universe built up of baryonic matter, cold dark matter, and dark energy. Considering an invisible *continuous* matter with the embedded elementary particles as the only matter constituents, the changes of states in the universe can be explained everywhere and at different cosmic times in consistency with the experimental and observational data available today. The continuous matter expands to eliminate the tensions caused by its local gradients of mass density. These gradients started the universe's expansion at supercritical mass density and provide its expansion until now. At a critical matter density the continuous matter produced the elementary particles by phase transition. In interacting gravitational fields, the continuous matter reduces its tensions by contraction. The contraction produces the impulses acting as gravitational forces on the discrete matter objects at the center of the fields. Radiation and gravitational waves result from the interactions of particles and other discrete objects of matter with the continuous matter, which transmits the waves through the space at the speed of light depending on its matter density. On this basis, the article discusses several changes of states on Earth and in the universe.

*Keywords:* gravitation, radiation and gravitational waves, structure of the universe

## 1. INTRODUCTION

As a result of the Renaissance, physicists started discussing the problems of the correct *rational* interpretation of the reality we live in. Descartes and B. Pascal defined the reality by its matter content. Others considered the space as part of this reality. Huygens assumed the ether in space to explain the transmission of the light waves. Newton assumed an immovable empty space, in which he considered the motion of the bodies as the observable discrete matter objects.

In 1905, Einstein banned the ether cocept with his theory of special relativity. Assuming the constancy of the speed of light in reference frames moving relatively to each other without acceleration, the theory determined space contraction and time dilation. By the theory of general relativity of 1915, Einstein defined the space as an active part of the reality with its own energy, causing gravitation by its curvature. The universe became a closed physical system in a four-dimensional complex space-time. Current quantum physics supposes additionally to the elementary particles the vacuum energy in space, astrophysics the dark energy ($\Lambda$) and the "Cold Dark Matter" (CDM).

Cosmology assumes the dark energy causing the expansion of the universe by its *negative* pressure. To explain the rotational velocities of the stars in galaxies and the relative motions between galaxies by Newton's law of gravitation, astrophysics assumes the CDM consisting of a new kind of particles, causing gravitation without producing radiation. Nowadays, the CDM is also considered as responsible for the observed gravitational lensing and the structure evolution in the universe. But the supposed new particles could not be detected and the observations of colliding galaxies do not support the CDM-concept (Harvey et al. 2015).

These and other problems of current physics justify looking for another interpretation of the reality and its changes of state, considering thereby all experimental and observational data available today.

## 2. GRAVITATION

The wavelike behavior of free moving particles of mass $m$ requires outside the particles matter producing the impulses driving the particles back to their path. This *invisible* matter must be of smoothly changing mass density $\varrho$. As *continuous* matter, it provides the conservation of the momentum $p = mv$ transversely to the particles' path, despite of the permanently changing transversal velocity $v_{tr}$ of the particles by their oscillations.

The oscillating particles produce in the continuous matter gradients of mass density $\nabla\varrho_{tr}$. The gradients, in turn, produce the impulses driving the particles at the transverse velocity $v_{tr}$ back to their path. Due to their momentum $p_{tr} = mv_{tr}$, the particles produce on the other side of their path oppositely directed gradients $\nabla\varrho_{tr}$ in the continuous matter.

The particle oscillations define the continuous matter as a fundamental constituent of matter producing the impulses acting on the discrete objects of matter as forces. Outside the elementary particles, the continuous matter is present everywhere in the universe. It is present in the interacting fields surrounding the elementary particles and their bound systems up to the stars, galaxies, and galaxy clusters. It is also present outside the fields, where it causes the expansion of the universe and - via the gravitational fields - the co-motion of the discrete objects of matter.

A hypothetical experiment explains the appearance of the gravitational fields in the universe. Imagine an infinite region of continuous matter of the same mass density $\varrho_0$ everywhere. Such region would be in a state of equilibrium. Putting into the region a non-rotating spherical star of radius $R$, mass $M$, and mass density $\varrho_M > \varrho_0$ on its surface, the difference $\varrho_M - \varrho_0$ violates the equilibrium state. To get a smooth distribution of its mass density from $\varrho_0$ at infinity to $\varrho_M$ on the surface of the star, the continuous matter *contracts* towards the star.

The resulting distribution of the mass density $\varrho$ in the region outside the star is determinable in a reference frame with the coordinates $r, \theta, \phi$ originating at the center of the star. A common equilibrium state of the physical system "star and continuous matter" is achieved, if all impulses produced by the gradients $\nabla\varrho$ in the continuous matter compensate each other. This is the case, if all concentric spherical shells of thickness $dr$ outside the star contain the same amount of matter, i.e. the same mass. This condition defines the region of the continuous matter outside the star as a gravitational field, describable by its mass density distribution $\varrho$:

$$(\varrho - \varrho_0)\left[\frac{4\pi}{3}(r + dr)^3 - \frac{4\pi}{3}r^3\right] = \text{const.} \tag{1}$$

Neglecting terms with $dr^2$ and $dr^3$, Eq.(1) writes:

$$(\varrho - \varrho_0)r^2 dr = \text{const.} \tag{2}$$

The condition $\varrho = \varrho_M$ at the radius $R$ of the star replaces the constant in Eq.(2) by

$$\varrho = \varrho_0 + (\varrho_M - \varrho_0)\frac{R^2}{r^2}. \tag{3}$$

Considering the long-term expansion of the universe, the condition $\varrho_0/\varrho_M \ll 1$ holds. This simplifies Eq.(3) to

$$\frac{\varrho}{\varrho_M} \approx \frac{R^2}{r^2}. \tag{4}$$

The resulting distribution of the mass density in this gravitational field is shown in Fig.1. The figure illustrates that the mass density $\varrho$ decreases rather quickly with the distance $r > R$ from the star. Due to the condition $\varrho_0 = \text{const.}$, the field is of spherical symmetry and the star rests in the continuous matter.

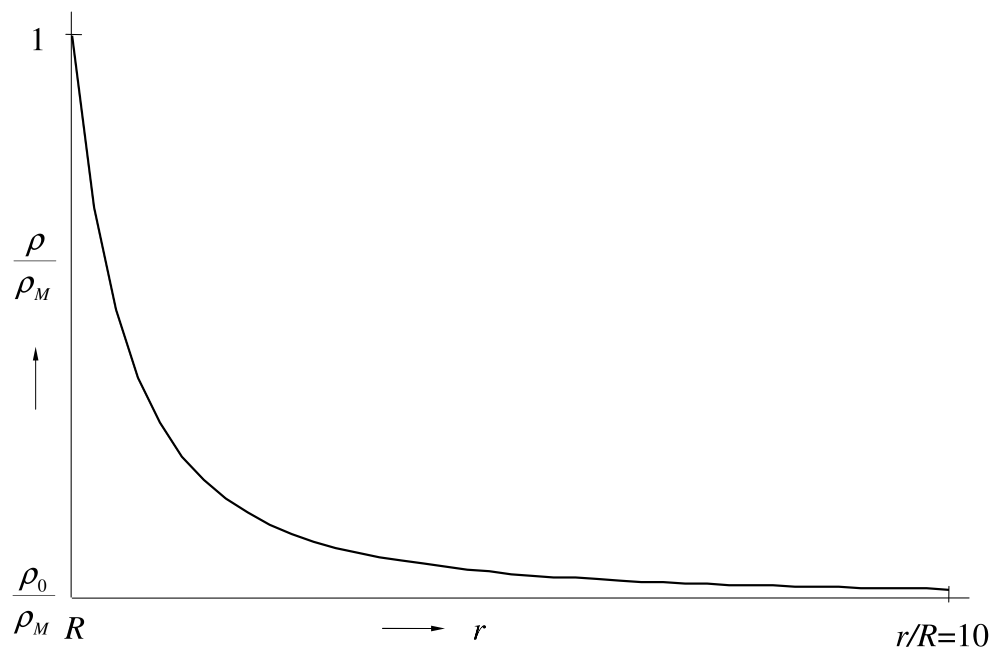


**Figure 1.** Mass density distribution $\varrho/\varrho_M(r/R)$ in a gravitational field of spherical symmetry that surrounds a star of mass $M$, radius $R$, and mass density $\varrho_M$ on its surface

In the real universe, no gravitational fields of exact spherical symmetry exist. At large scale, the continuous matter expands by its gradients $\nabla\varrho_0$, and the interactions between neighboring gravitational fields violate the spherical symmetry of the fields additionally.

Fig.2 illustrates the mutual deformation of two interacting gravitational fields in the infinite region of continuous matter, having the constant mass density $\varrho_0$ at infinity. The fields surround two identical spherical objects 1 and 2, placed at distance $d$ from each other. Together with their gravitational fields, the two discrete objects of matter could be imagined as a double-star system.

Outside the objects 1 and 2, three different regions of mass density are distinguishable: two inner regions with $\varrho_i \leq \varrho_M$ and an outer region with $\varrho_a \geq \varrho_0$. The outer region represents the common gravitational field of the two objects, separated from the two inner regions $\varrho_i$ by surfaces of mass

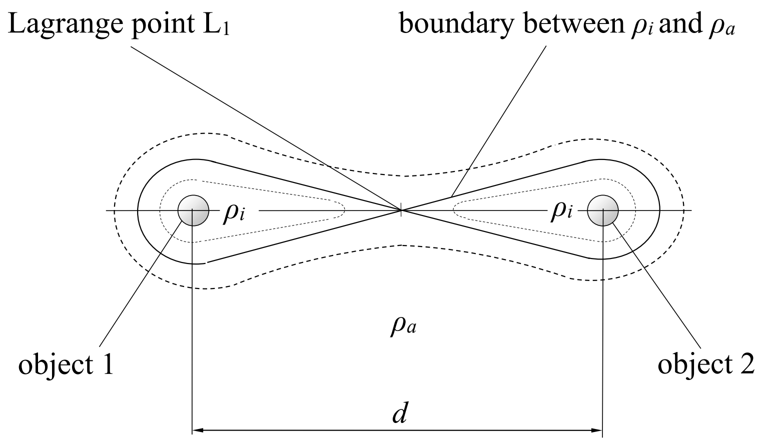


**Figure 2.** Different regions of mass density $\varrho$ in two interacting gravitational fields surrounding the objects 1 and 2

density $\varrho_i = \varrho_a$, illustrated in Fig.2 by full lines. These surfaces are the well-known Roche lobes. They are of rotational symmetry and join the Lagrange point $L_1$ between the two objects.

In the two inner regions of mass density $\varrho_M \geq \varrho_i \geq \varrho_a$, the surfaces of equal mass density $\varrho_i$ (dashed lines) lose their spherical shape with the distance from the two objects. In the outer region $\varrho_a \geq \varrho_0$, the surfaces of equal mass density obtain with increasing distances from the two objects again a spherical shape. The surfaces of equal mass density in the two inner regions indicate that towards the Lagrange point $L_1$ the mass density $\varrho_i$ decreases less quickly than in other directions. Therefore, compared with a gravitational field of spherical symmetry, the mass density along the line connecting the two objects is increased. In the outer region, the mass density $\varrho_a$ decreases less quickly perpendicularly to the line connecting the two objects.

Along the line connecting the two objects 1 and 2, a region of higher mass density has appeared. The more the two objects approach each other, the higher is the mass density of the continuous matter between them. Such region of higher mass density should also exist between galaxies and galaxy clusters, if their gravitational fields interact. Indeed, using the lensing of radiation from sources behind, a "bridge" of higher mass density between the two components of the Abell 222/223 supercluster was discovered, interpreted as a "dark-matter filament" (Dietrich et al. 2012). The lensing effect, produced by the higher mass density of the continuous matter between the two components of the supercluster, is explained in the next section.

The structure of the two gravitational fields in Fig.2 is describable by surfaces of $\varrho =$ const. and field lines perpendicular to these surfaces. The field lines indicate the directions of the mass density gradients $\nabla\varrho$ in the two fields and in the common outer region.

The two gravitational fields have the same shape as two interacting electric fields, surrounding two spherical discrete objects of matter of equal charge. Classical physics describes the electric fields by surfaces of constant electric potential. The field lines perpendicularly to the surfaces indicate the direction of the impulses produced by the electric field strengths.

In gravitational fields, the surfaces of constant mass density $\varrho$ could be considered as surfaces of constant gravitational potential $\Phi$ and the gradients $\nabla\varrho$ as the gravitational field strengths $\nabla\Phi$. Despite of the same shape, the gravitational fields produce by their interactions attracting forces, the electric fields – due to the oppositely polarized electric field strengths – repulsing forces.

The tides on Earth illustrate the deformation of the terrestrial gravitational field by the lunar and solar gravitational fields. The deformation by the lunar gravitational field could be measured, placing a space station at different positions in the corresponding region of the terrestrial gravitational field. For the measurements, a reference frame could be applied that originates at the center of the Earth and connects Earth and Moon by the coordinate $r$.

To hold the space station at a given position in the terrestrial gravitational field, its engine should produce the force $\mathbf{F}$, compensating just – together with the centrifugal force – the gravitational force $\mathbf{F}_{\mathtt{grav}}$ acting on the space station. The centrifugal force appears due to the rotation of the reference frame. Considering forces as vectors, the magnitude of the force $\mathbf{F}$ allows determining the magnitude of the gravitational force $\mathbf{F}_{\mathtt{grav}}$ acting on the space station at the given position. The force $\mathbf{F}$ is like the centrifugal force oppositely directed to the gravitational force $\mathbf{F}_{\mathtt{grav}}$.

The mass of the space station is, compared with the mass of the Earth, negligibly small. This allows assuming that at a given position in the terrestial gravitational field the gradient $\nabla\varrho$ is proportional to the gravitational force $\mathbf{F}_{\mathtt{grav}}$ but oppositely directed. Measuring this way at different positions the gravitational force acting on the space station, the structure of the terrestrial gravitational field, deformed by the lunar gravitational field, could be determined.

The measurements would demonstrate that the Lagrange point $L_1$ between Earth and Moon belongs to a surface separating the two fields from each other. Compared with the gravitational field of spherical symmetry, along the coordinate $r$ the mass density $\varrho$ is increased. At $L_1$, the gradients $\nabla\varrho$ turn by 90° and spread out like a fan. The fan is the curved boundary surface between the terrestrial and the lunar gravitational fields, defined by the condition $\nabla\varrho = 0$ in the perpendicular direction to this boundary, on which the two fields have the same mass density $\varrho$.

The interactions between the two fields cause additional stress for the continuous matter. To reduce the stress, the continuous matter contracts between Earth and Moon. The contraction produces the impulses acting as gravitational forces on Earth and Moon. The forces try to move Earth and Moon towards the Lagrange point $L_1$ between them. Due to the rotation of the Moon around the Earth, the gravitational forces are balanced by other impulses, produced in the continuous matter outside the fields and acting via the fields as centrifugal forces on Earth and Moon.

The rotation of Earth and Moon around their common center-of-mass determines for the physical system "Earth, Moon, and continuous matter" a *local* dynamic state of equilibrium. Of course, the interactions of the terrestrial and lunar gravitational fields with the solar gravitational field violate this state permanently. To get a corresponding state of equilibrium, the continuous matter contracts also along the line connecting the Sun with the center-of-mass of the physical system "Earth, Moon, and continuous matter". Other gravitational forces appear, balanced by other centrifugal forces. They cause the rotation of the physical system "Earth, Moon, and continuous matter in their gravitational fields" around the Sun as a common local state of equilibrium that includes the Sun with its gravitational field.

Classical physics determines the rotational velocity $v_r$ of the Earth around the Sun of mass $M_{\mathtt{S}}$ by Newton's law of gravitation, balancing the centrifugal force by the gravitational force acting from the opposite side on the Earth. At given distance $r$ between Earth and Sun, the rotational velocity of the Earth around the Sun determines as

$$v_r = \left(\frac{GM_{\mathtt{S}}}{r}\right)^{1/2} . \tag{5}$$

Eq.(5) determines the rotational velocities of the Earth and the other planets around the Sun according to the observations, even though it does not consider the masses of the planets. This is possible, since the Sun represents more than 99% of the total mass of all discrete objects of matter in the solar system. Such concentration of discrete matter at the center of the solar system causes in the solar gravitational field a mass density distribution nearly identical to that shown in Fig.1. This, in turn, allows neglecting the effects resulting from the deformation of the solar gravitational field by the gravitational fields of the planets.

In our host galaxy, at the center of the size of the solar system less than 1% of the total mass of all discrete objects of matter is concentrated. The stars, distributed over the galaxy, represent together with their planets and other discrete objects of matter the most discrete matter of the galaxy. The low concentration of discrete matter at the galactic center causes in the inner part of the galactic gravitational field a mass density distribution different from that shown in Fig.1.

Observations of spiral galaxies have revealed that at distances $r \geq 5$kpc from the galactic center the rotational velocities of the stars remain, at first, more or less constant (Rubin 1970). Only at greater distances from the galactic centers, the rotational velocities of the stars slow down. The observed velocities exclude applying Eq.(5). Relying on it, either additional discrete matter in the galaxies should be assumed, either an increased gravitational constant $G$.

Current astrophysics uses the first option, assuming the CDM-particles as the missing discrete matter. A more appropriate interpretation of the observations would be, considering the interactions of the inner galactic gravitational field with the gravitational fields of the stars rotating around the galactic center.

Near the Lagrange point $L_1$ on the coordinate $r$ connecting a rotating star with the galactic center, the galactic gravitational field and the gravitational field of the star should have the same mass density gradients $\nabla\varrho$. However, at distances $r \geq 5$kpc from the galactic center, the gradients $\nabla\varrho$ in the galactic gravitational field near the Lagrange point $L_1$ are stronger than in the gravitational field of the star. The different gradients near the Lagrange point $L_1$ would cause a disbalance between the two interacting gravitational fields.

To get the balance, the continuous matter in the gravitational field of the star contracts more than in the galactic gravitational field. The greater contraction causes a stronger gravitational force, compensated by the higher rotational velocity $v_r$ of the star around the galactic center.

In Newton's law of gravitation, the higher rotational velocity $v_r$ of the stars could be considered by the factor $\varrho_{\mathtt{LP}}/\varrho$. The mass density $\varrho_{\mathtt{LP}}$ is the real mass density of the continuous matter at the Lagrange points $L_1$, the mass density $\varrho$ is given by Eq.(4). The factor $\varrho_{\mathtt{LP}}/\varrho$ depends on the distance $r_{\mathtt{LP}}$ of the Lagrange point $L_1$ from the galactic center.

If at distance $r$ from the galactic center a star orbits the enclosed galactic mass $M_{\mathtt{G}}$, its rotational velocity determines then as

$$v_r = \left[\frac{GM_{\mathtt{G}}}{r}\left(\frac{\varrho_{\mathtt{LP}}}{\varrho}\right)\right]^{1/2} . \tag{6}$$

The factor $\varrho_{\mathtt{LP}}/\varrho$ in Eq.(6) should be concluded from the observed rotational velocities $v_r$ of the stars.

Considering a galaxy as a rotating region of the continuous matter with embedded stars and other discrete objects of matter, the rotation of the region in its outer parts should slow down if in the intergalactic space the continuous matter does not rotate accordingly. The lower rotational velocity in the outer parts causes in the gravitational fields of the stars mass density gradients producing impulses in tangential directions. They cause the spiral arms in huge galaxies.

The decision whether a star orbits a galactic center or co-moves with the expanding universe needs a new theory of gravitation. The theory should consider the different impulses produced by the mass density gradients of the continuous matter. Inside the interacting gravitational fields, the impulses try to reduce the gradients $\nabla\varrho$ by *contraction*, outside the fields by *expansion*.

In the universe, the motion of stars, galaxies, and galaxy clusters depends thus on the balance of these impulses. If the impulses acting as gravitational forces dominate, stars, galaxies, and galaxy clusters move peculiarly in the universe. If the oppositely directed impulses dominate, stars, galaxies, and galaxy clusters co-move with the expanding universe.

## 3. RADIATION AND GRAVITATIONAL WAVES

The impulses, produced in the continuous matter by the gradients of matter density, are at the speed of light $c$. They cause not only the motion of the discrete objects of matter, but also radiation and gravitational waves traveling at this speed through the continuous matter.

In interacting gravitational fields, the speed $c$ of the impulses explains, for instance, the perihelion shift of the planet Mercury, orbiting the Sun on a rather eccentric orbit. In particle accelerators, such impulses explain the restriction of the particle velocities to $v \le c$.

Classical physics determines the acceleration of charged particles of given mass $m$ and charge $e$ in electric fields by Newton's second law as $\mathbf{a}_{\mathtt{N}} = \mathbf{F}/m$, where $\mathbf{F} = \mathbf{E}e$ denotes the electric field force and $\mathbf{E}$ the electric field strength. Newton's second law supposes thus the immediate effect of the field force $\mathbf{F} = \mathbf{E}e$, i.e. the accelerating impulses at *infinite* speed. Supposing the field impulses at the finite speed of light $c$ (Ziegler 2009), the more realistic acceleration $a$ of the particles along their path determines with the Newtonian acceleration $a_{\mathtt{N}}$ as

$$a = a_{\mathtt{N}}(1 - \frac{v}{c})^2. \tag{7}$$

The acceleration $a$ turns by Eq.(7) at $v \to c$ to zero. Supposing the terms $a_{\mathtt{N}} = F/m$ and $c$ as constant and integrating, the velocity of the particles in accelerators results as

$$v = \frac{a_{\mathtt{N}}t}{1 + a_{\mathtt{N}}t/c}. \tag{8}$$

Eq.(8) illustrates that classical physics supposes by accelerations the speed $c$ as infinite.

Since in gravitational fields the speed $c$ depends on the matter density of the continuous matter, i.e. on the mass density $\varrho$ , radiation travels from the source at the center of a field at increasing speed $c$. The gravitational redshift of sunlight illustrates such dependence for the solar gravitational field. The mass density $\varrho$ in the field decreases according to Fig.1 from $\varrho_m$ on the Sun's surface of radius $R_{\mathtt{S}}$ with the increasing distances $r > R_{\mathtt{S}}$. At greater distances, the mass density $\varrho$ approaches the mass density $\varrho_0$. Therefore, the speed of the sunlight in the Sun's gravitational field is at the instant of emission lower than at the instant of observation on Earth.

The continuous matter inside and outside gravitational fields transmits all waves as *spatially extended* waves. When, for instance, an exited hydrogen atom changes into its ground state, the jump of its electron towards the proton at the center produces impulses in the fields surrounding these two particles. The impulses produce a spatially extended wave, leaving the atom in a certain direction depending on the direction of the jump. At first, the speed $c$ of the wave depends on the mass density $\varrho$ in the interacting fields, later on the mass density of the continuous matter outside.

Fig.3 illustrates such a spatially extended wave in the continuous matter, polarized along the $x$-coordinate of the reference frame and traveling along the z-coordinate.

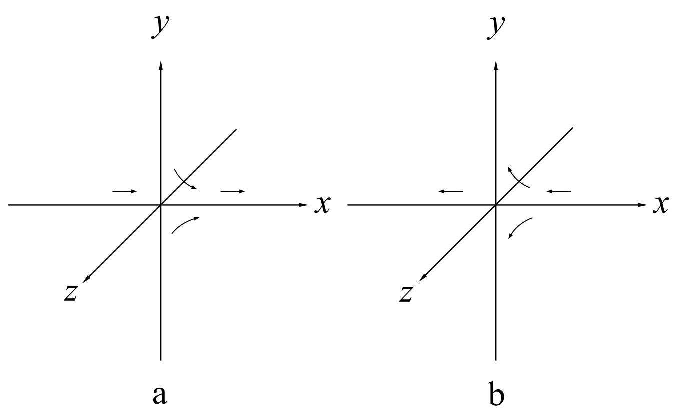


**Figure 3.** Oscillation of a spatially extended wave in the $x, y$ - plane; a - first quarter period; b - second quarter period

The wave produces transversely to its path gradients of mass density in the continuous matter like the oscillating particles. The gradients, in turn, produce the impulses causing the oscillations of the matter-filled volume elements $\Delta V = \Delta x \Delta y \Delta z$ in the $x, y$ - plane.

During a period $\tau = \lambda/c$, the matter-filled volume elements $\Delta V$ move in the $x, y$ - plane in different directions. In the first quarter of the period $\tau$, the elements $\Delta V$ on the $x$-coordinate move in direction $+x$. On the right side of the $z$-coordinate, the elements $\Delta V$ contract thereby. The contraction causes increasing mass density gradients $\nabla\varrho$ in the continuous matter. The gradients along the $x$-coordinate produce impulses directed towards the $z$-coordinate. On the left side, the elements $\Delta V$ expand, diminishing the existing gradients $\nabla\varrho$.

The elements $\Delta V$ placed on the $y$-coordinate move towards the $z$-coordinate, but also in direction of the $x$-coordinate. All these elements expand, diminishing the existing gradients $\nabla\varrho$.

The second quarter of the period begins, when on the right side of the $z$-coordinate the elements $\Delta V$ on the $x$-coordinate have arrived at their maximal possible distances from the $z$-coordinate. From then on, the produced impulses drive the elements $\Delta V$ back to their initial positions and states.

The elements $\Delta V$ on the $y$-coordinate return similarly to their initial positions and states. In the next two quarters of the period $\tau$, the oscillations are mirrored with respect to the $z$-coordinate. Throughout the oscillations, the wave moves along the $z$-coordinate at the speed $c$.

During the period $\tau$, the elements $\Delta V$ on the $x$-coordinate fulfill sinusoidal motions. The elements on the $y$-coordinate, starting beneath and above the $x$-coordinate, fulfill sinusoidal motions along this coordinate, superposed by sinusoidal motions along the y-coordinate with a phase of $\pi/2$. The motions of all involved matter-filled volume elements $\Delta V$ describe the wave as a massive, spatially extended *perturbation wave* in the continuous matter.

Its mass is proportional to the mass $m$ of the continuous matter, involved into the oscillations. With that mass the wave produces the momentum $p = mc$ along its path, causing the radiation pressure.

Considering a sufficiently small spatially extended wave as photon, the mass $m$ allows defining a potential energy of the photon in gravitational fields. Supposing energy conservation, in a first approximation the changing speed of light $c$ in the solar gravitational field becomes determinable.

If the photon started its motion towards the Sun of mass $M_{\mathtt{S}}$ and radius $R_{\mathtt{S}}$ at infinity, its increasing potential energy is determinable classically by the action of Newton's gravitational force on the photon along its path. Assuming at infinity $\varrho_0 = \mathtt{const.}$ and $c_0 = \mathtt{const.}$, at *finite* distances $r > R_{\mathtt{S}}$ the photon's potential energy determines by the action of Newton's gravitational force on it as

$$(\Delta E_{\mathtt{pot}})_r = -\int_{\infty}^{r} G\frac{M_{\mathtt{S}}m}{r^2}dr = G\frac{M_{\mathtt{S}}m}{r}. \tag{9}$$

By energy conservation, the kinetic energy of the photon decreases accordingly by

$$-(\Delta E_{\mathtt{kin}})_r = \frac{m(c^2 - c_0^2)}{2}. \tag{10}$$

With $R_{\mathtt{Schw}} = 2GM_{\mathtt{S}}/c_0^2$ as the Schwarzschild radius of the Sun, the speed of the sunlight in its (isolated) gravitational field results as

$$c(r) = c_0\left(1 - \frac{R_{\mathtt{Schw}}}{r}\right)^{1/2}. \tag{11}$$

The measured on Earth speed of light $c_{\mathtt{E}} = 299792.458\,\mathrm{kms}^{-1}$ allows determining by Eq.(11) the speed of light $c_0$ at infinity. Supposing the terrestrial gravitational field as infinite, with the mass $M_{\mathtt{E}} = 5.973 \times 10^{24}\,\mathrm{kg}$ of the Earth and its radius $R_{\mathtt{E}} = 6.378 \times 10^6\,\mathrm{m}$ the speed $c_0$ determines as

$$c_0 = \left(c_{\mathtt{E}}^2 + G\frac{2M_{\mathtt{E}}}{R_{\mathtt{E}}}\right)^{1/2} = c_{\mathtt{E}} + 0.2\,\mathrm{ms}^{-1}. \tag{12}$$

With $c_0$, Eq.(11) determines the speed of the sunlight on the Sun's surface as $c_{\mathtt{S}} \approx c_{\mathtt{E}} - 636\,\mathrm{ms}^{-1}$. This means, the speed of the sunlight increases in the solar gravitational field by $636\,\mathrm{ms}^{-1}$. Behind the Lagrange point $L_1$ between Sun and Earth, the sunlight enters the terrestrial gravitational field. In this field, its speed decreases by $0.2\,\mathrm{ms}^{-1}$. The gravitational redshift of the sunlight on Earth determines thus as $z = 2.128 \times 10^{-6}$, according to the observations.

At $r = R_{\mathtt{Schw}}$, Eq.(11) determines the speed of light $c = 0$. Since the speed of light is also the speed of the accelerating impulses, in the reality no changes of state would be possible. The condition $c > 0$ supposes in turn always a finite mass density of the continuous matter. The scenario providing the finite mass density of the continuous matter in the universe is explained in section 4.

The condition $c > 0$ restricts the application of Eq.(11) to cases of $R_{\texttt{Schw}} \ll R$, where $R$ denotes the radius of the stars. Nevertheless, Eq.(12) allows two important conclusions. First, in the terrestrial gravitational field, the speed of light is nearly constant ($c \approx c_0$). Second, the speed $c_0$ could be used as a measure of the mass density $\varrho_0$ of the continuous matter in the universe outside the gravitational fields. Of course, this needs to know how the speed of light $c$ depends on the mass density $\varrho$ of the continuous matter.

For weak gravitational fields of nearly spherical symmetry, surrounding discrete astronomical objects like the Sun, the combination of Eq.(11) with Eq.(3) yields:

$$c^2 = c_0^2 \left[ 1 - \frac{R_{\texttt{Schw}}}{R} \left( \frac{\varrho - \varrho_0}{\varrho_m - \varrho_0} \right)^{1/2} \right] \tag{13}$$

Considering radiation as a beam of spatially extended waves in the continuous matter, the bending of radiation in gravitational fields becomes explainable physically. If the direction of the waves differs from the direction of the mass density gradients in the fields, referred to their path the primordial symmetry of the waves is violated. Especially near the discrete objects of matter at the centers of the fields the violation is remarkable, because the continuous matter has here its greatest mass density gradients $\nabla\varrho$ (Fig.1).

On the side nearer to the discrete object of matter at the center of a field, the mass density is higher and the speed $c$ of the wave lower than on the opposite side. This symmetry violation bends the wave towards the side of higher mass density. An example is light from a far astronomical source, traveling towards the Earth near the Sun.

Radio waves on Earth demonstrate thereby that the bending of such waves increases with their wavelengths. Longer wavelengths cause greater amplitudes of the waves and the impact of the mass density differences on the two sides of the waves increases.

The symmetry violation of the spatially extended waves explains also the *lensing effects* produced when radiation travels perpendicularly to the line connecting discrete matter objects at the centers of interacting gravitational fields. An example is the mentioned Abell 222/223 supercluster. The huge extension of the interacting gravitational fields of the two clusters causes then the bending of the waves, despite of the relatively low mass density gradients in the fields.

In the region along the line connecting the two clusters, the mass density is increased (Fig.2). If the radiation travels through this region at a certain distance from the line but more or less perpendicularly to it, the mass density of the continuous matter nearer to the line is higher and the speed $c$ lower than on the opposite side of the radiation. This effect causes the bending of the radiation towards the line connecting the two clusters.

The redshift of signals from far astronomical sources depends on two superposing effects. First, the large-scale expansion of the continuous matter in the cosmic space stretches the wavelengths of the signals. Second, the diminishing thereby mass density of the continuous matter increases their speed $c$. The superposition of the two effects should be considered determining the age of the universe from the observations of the Cosmic Microwave Background radiation (CMB-radiation).

To determine the distances radiation waves travel through the expanding universe, it needs imagining Newton's three-dimensional immovable space with constant units of lengths as background for the applied reference frame. To define its coordinates, it needs an appropriate geometry. To determine the travel times of radiation or gravitational waves, constant units of time should be used.

The traveling of radiation through the cosmic space is describable by a *velocity vector* with changeable direction and changeable speed of light $c$ as magnituide. At a given point in the cosmic space, the direction of the vector depends on the direction of the mass density gradients $\nabla\varrho$ in the countinuous matter, its magnitude $c$ on the mass density $\varrho$ of this matter.

On Earth, many experiments have been performed to investigate the optical effects produced when light travels through transparent material. Inside such material, the speed of light reduces and its direction changes. The speed of light reduces due to the higher mass density $\varrho$ in the fields inside such material, the direction changes due to the different direction of the mass density gradients $\nabla\varrho$ in those fields.

Fizeau's experiment of 1851 with light traveling through running water demonstrated that the speed of light refers to the running water, i.e. to the co-moving fields inside the water molecules. Another remarkable experiment was the Michelson-Morley experiment of 1887, performed to investigate the impact of the Earth's motion on the speed of light. In the experiment, two rays of coherent light traveled perpendicularly to each other, but parallel to sea level. It was expected that the speed of the two rays would add differently with the velocity of the Earth through the cosmic space. This should have caused interference, when the two rays were brought together. However, no interference could be observed. To explain the result, space contraction was assumed.

The distribution of the continuous matter in the terrestrial gravitational field explains the experiment without space contraction. The two rays traveled on a surface of constant mass density $\varrho$ in the terrestrial gravitational field, co-moving with the Earth through the cosmic space. On this surface, the speed of light $c$ of the two rays remains unchanged, due to the constant mass density of the continuous matter on this surface.

In 1974, a small periodic variation of the arrival times of the radiation from the rotating source of the binary pulsar PSR1913+16 was observed and explained relativitically. Considering the continuous matter in the cosmic space, the observed radiation could be referred to the gravitational fields through which the radiation traveled towards the Earth.

At first, the speed $c$ of the radiation refers to the gravitational field rotating with the source at the velocity $v$ around the center-of-mass of the binary pulsar. As long as the radiation travels through this field, it has in the reference frame "Earth" the speed $c \pm v$. Leaving the field, the radiation travels independently of the source's rotation through other gravitational fields. Finally, the radiation travels at the speed $c_{\mathrm{E}}$ through the terrestrial gravitational field. This means, the variation of the arrival time of the radiation resulted from its traveling through the gravitational field co-moving with the rotating source.

The synchrotron radiation, produced by the bending of charged particles in magnetic fields, illustrates another feature. An example is the synchroton radiation produced when electrons rotate in a storage ring at high velocities $v \to c$. The oscillating electrons produce in the continuous matter co-moving resonance waves. If the magnets along the storage ring bend the electrons, the resonance waves do not react to the magnetic impulses. They travel as x-rays at the speed of light $c$ tangentially away from the storage ring. This feature underlines that radiation cannot be interpreted as a beam of electromagnetic waves, traveling by self-induction of electric and magnetic fields through the space.

It should be underlined that the production of radiation and gravitational waves supposes a sufficiently low mass density of the continuous matter. Inside the event horizon surrounding black holes, for instance, the mass density $\varrho$ of the continuous matter in their gravitational fields is already to high. The resulting low speed $c$ of the impulses excludes producing and transmitting spatially extended waves. That makes the black holes invisible. The early universe was similarly enclosed by an event horizon and therefore without radiation.

## 4. COSMOLOGICAL ASPECTS

Replacing the dark energy $\Lambda$ and the CDM of the current cosmological $\Lambda$CDM-model by the continuous matter, the appearance of the universe and its subsequent expansion can be described in consistency with the experiments and observations available today. The experiments with colliding high-speed particles indicate the reasons for the universe's appearance. There should have been a preceding universe with mass density gradients $\nabla\varrho_0$ too low to compensate the gravitational forces produced in the interacting gravitational fields. By contraction of the continuous matter in the gravitational fields, all discrete objects of matter began to move at increasing velocities $v$ towards a *center of contraction* in the cosmic space.

As the first stars or other compact discrete objects of matter collided at this center, they produced between them – due to their relative velocities $v > c$ – in their co-moving gravitational fields a region at *supercritical* mass density $\varrho$, higher than the mass density inside the elementary particles of the colliding objects. The supercritical region appeared, because the continuous matter in the gravitational fields could expand only by impulses at the speed of light $c$. And this speed should have been much lower than on Earth at present cosmic time.

The supercritical mass density destroyed the incoming discrete matter objects and dissolved their elementary particles to continuous matter by phase transition. With the elementary particles the fields disappeared, and with the fields the impulses causing the contraction of the preceding universe. By the subsequently incoming discrete objects of matter, the supercritical region grew and its mass density increased. At the center of contraction, the supercritical mass density became maximal values. The resulting distribution of mass density in the supercritical region produced impulses, pointing away from the center of contraction.

As these impulses became stronger than the impulses produced by the further incoming matter, at the center of the supercritical region the continuous matter started its expansion as a new universe. The center of contraction became a center of expansion. The moment this happened defined a new cosmic time $t = 0$. From the supercritical region outside, the new universe was separated by a boundary surface, defined by $\nabla\varrho = 0$ perpendicularly to the boundary. Through this surface, the new expanding universe acquired continuously matter from outside and became a more and more spherical shape.

The expansion of the new universe reduced the supercritical mass density in it. As on the boundary the mass density $\varrho$ decreased to *critical* values, equal to the internal mass density $\varrho_m$ of the elementary particles ($\varrho_{\texttt{crit}} = \varrho_m$), the partial phase transition of the continuous matter to new elementary particles started. The amount of the produced elementary particles depended on the total matter content of the supercritical region, on the gradients $\nabla\varrho$ near the boundary $\nabla\varrho = 0$, and on the speed $c$ of the impulses causing the expansion.

As the supercritical region disappeared, the new universe consisted of the expanding continuous matter at *subcritical* mass density $\varrho_0$, the new elementary particles, and the matter incoming further from outside. At the central region of the new universe, the continuous matter expanded now without producing elementary particles. Outside this region, the ongoing expansion of the continuous matter produced the fields surrounding the new elementary particles.

The contraction of the continuous matter in the interacting fields and its ongoing expansion outside produced the first bound particle systems as local dynamic states of equilibrium, initiating thus the *structure evolution* in the new universe. Each step of this evolution revealed new matter properties. In the very early expanding universe could be concluded only the gradients of mass density producing the impulses changing the states of the continuous matter. Then, by interactions between the fields, the elementary particles revealed such matter properties like charge, polarization, and magnetic momentum.

As the elementary particles combined to bound systems, radiation was produced. Later the atoms combined to molecules. The gravitational fields, which became continuously stronger, produced by their interactions such astronomical objects like stars, galaxies, and galaxy clusters. All matter properties revealed so far – including the property of life – are properties of the primordial continuous matter.

To describe the changing states of the universe, different kinds of interactions should be distinguished: interactions inside the continuous matter, interactions of the continuous matter with the discrete objects of matter, and interactions between the discrete matter objects via their fields. The first kind of interactions causes the expansion of the universe and provides the transmission of radiation. The second kind produces the fields, via the fields the co-motion of the discrete matter objects with the expanding continuous matter, and the radiation. The third kind produces the impulses acting as field forces on the discrete objects of matter. A special kind of interaction is the phase transition from the continuous matter to the elementary particles and vice versa.

The contraction of the continuous matter in interacting gravitational fields produces the impulses causing the acceleration of the discrete matter objects towards each other. Interpreting the integral over all impulses acting on the discrete objcts of matter as forces allows describing their moving states by the terms "momentum" and "kinetic energy".

In the universe, all interactions are ruled by *causality*, *matter conservation*, and *directionality* as laws of nature. They determine the changes of states of the matter components regardless of the local conditions. Causality is the precondition for matter conservation, matter conservation the precondition for causality. By the directionality of the interactions, the continuous matter tries to get an equilibrium state without gradients of mass density. An absolute equilibrium state of the continuous matter is neither achievable by its expansion nor by its contraction. This impossibility causes the never-ending changes of state in the universe as long as it exists. As a "compromise", the continuous matter produces local dynamic states of equilibrium with the discrete matter objects.

Mathematics allows describing the causality of the changes of states by its logic, the matter conservation by its equations. Otherwise, mathematics allows reversing the direction of the changes of states, contrary to the reality. Moreover, using mathematics to determine by physical laws real changes of state, it needs human-made *a priori* assumptions about the involved matter components, about the mechanisms they interact, and about the local conditions for their interactions.

The changes of state in the very early universe can be described, applying a three-dimensional reference frame "center of expansion" with spherical coordinates. The local gradients $\nabla\varrho(r,t)$ of the supercritical mass density produce then the impulses causing the accelerated expansion of the very early universe. With $a_r$ as the acceleration in radial direction, this allows formulating:

$$-\frac{\delta\varrho}{\delta r} \rightarrow a_r = \frac{dv_r}{dt} = \frac{\delta v_r}{\delta r}\cdot\frac{dr}{dt} + \frac{\delta v_r}{\delta t}\cdot\frac{dt}{dt} = v_r\frac{\delta v_r}{\delta r} + \frac{\delta v_r}{\delta t} \qquad (14)$$

The velocity $v_r$ describes the radial motion of the volume elements $dV$, containing an infinitely small amount of matter $\varrho(r,t)$. In analogy to Newton's second law, the equation of motion of the elements $dV$ can be written as

$$-\frac{\delta \varrho}{\delta r} = \varrho \left( v_r \frac{\delta v_r}{\delta r} + \frac{\delta v_r}{\delta t} \right) f(\varrho). \tag{15}$$

The unit $\mathrm{m}^{-2}\mathrm{s}^2$ of the function $f(\varrho)$ indicates the function as the squared inverse of the speed $c$, at which the continuous matter transmits the impulses. Considering the dependence of this speed on the mass density $\varrho$ of the continuous matter, the equation of motion writes

$$-\frac{\delta \varrho}{\delta r} = \frac{\varrho}{c_\varrho^2} \left( v_r \frac{\delta v_r}{\delta r} + \frac{\delta v_r}{\delta t} \right). \tag{16}$$

Since through its boundary surface $\nabla \varrho = 0$ the expanding universe acquires continuously matter from outside, with the divergence $\nabla \cdot \varrho \mathbf{v}$ the incoming matter is determinable by the continuity equation

$$\frac{\delta \varrho}{\delta t} + \nabla \cdot \varrho \mathbf{v} = 0. \tag{17}$$

The two equations (16) and (17) describe the very early universe as an expanding sphere $0 \leq r \leq r_{\mathtt{crit}}(t)$ of continuous matter. Of course, this needs to know the initial, boundary, and inner conditions, so the maximal mass density of the continuous matter at the new cosmic time $t = 0$, the amount of matter continuously acquired from outside, the mass density $\varrho_{\mathtt{crit}}$, and the speed $c$ in dependence on the mass density $\varrho(r,t)$.

The presence of the continuous matter in the early universe explains not only the Gaussian fluctuations in the CMB radiation, but also the "residual dipole" and the "cold spot", concluded from recent astronomical observations.

The Gaussian fluctuations are explainable, considering that due to their peculiar motion not all discrete objects of matter of the preceding universe collided head on. This means, there should have been tangential gradients of mass density in the new universe, causing the Gaussian fluctuations in the CMB radiation.

The residual dipole in the CMB radiation appears, subtracting the "solar dipole" from the primordial frequency maps of the Planck mission (Planck Collaboration: Adam, R. et al. 2016). This residual dipole is explainable by the eccentric position of the space telescope "Planck" relatively to the center of expansion in the universe. The CMB radiation coming from behind this center traveled through the expanding universe greater distances and longer times to the space telescope "Planck" than the CMB radiation coming from the opposite side. In other words, the eccentric position of the space telescope "Planck" in the expanding universe has caused additional differences of the measured CMB wavelengths.

The residual dipole is small compared with the solar dipole determined from the primordial frequency maps of the Planck mission. This indicates the Earth relatively near to the center of expansion in the universe.

The present distance of the Earth from the universe's center of expansion can be estimated from the motion of the "Local Group", to which our host galaxy belongs. The velocity of this group of galaxies in the "CMB rest frame" has been determined from the data of the "Cosmic Background

Explorer" (COBE) as $627\,\mathrm{kms}^{-1}$. If the region of the universe, containing nowadays the Local Group, started its motion about $14{\times}10^9$ years ago at constant acceleration, at present cosmic time the Earth is about $14.6 \times 10^6$ l.y. away from the universe's center of expansion.

The cold spot in the CMB radiation has a considerable extension and shows a "hot ring structure" (Planck Collaboration: Ade, P. A. R. et al. 2016). Maybe, this spot is the central region of the universe, produced by the expansion of the subcritical continuous matter after the supercritical region had disappeared.

## 5. SUMMARY AND CONCLUSIONS

Descartes and Pascal were right. Our current knowledge indicates that the reality is exclusively defined by its matter content. Of course, determining the relative positions of its matter components and their motions, the imagination of space and time with constant units of lengths and time is inevitable.

The invisible continuous matter with its astonishing properties should be considered as primordial matter of the universe. The structure evolution in the expanding universe revealed already many of its properties.

The continuous matter tries to get a state of equilibrium either by expansion either by contraction. Considering its changeable mass density and its interactions with the discrete objects of matter, all changes of states on Earth and in the universe can be explained according to the experimental and observational data available today.

The laws of nature rule the changes of states independently of the local conditions. Determining the changes of states on Earth or in the universe by physical laws, it needs *a priori* assumptions about the involved matter components with their properties, about their interactions, and about the local conditions, under which the changes of states happen.

The expansion of the continuous matter provides the expansion of the universe. As by phase transitions the elementary particles appeared, the continuous matter produced by its ongoing expansion the fields surrounding the particles and their bound systems. In interacting gravitational fields, the continuous matter contracts. The resulting impulses act as gravitational forces on the discrete objects of matter at the center of the fields. If the gravitational forces cause relative motions of the discrete objects of matter, the continuous matter outside the fields produces opposite impulses, acting via the fields on the discrete objects as inertial forces.

The gravitational fields are superposed by other fields, depending on the specific properties of the elementary particles and their bound systems. These fields produce their own impulses. Bound systems of the elementary particles appear, if the inertial forces become centrifugal forces, balancing the attracting field forces.

If the discrete objects of matter interact via their fields with the continuous matter, they produce under appropriate local conditions radiation and gravitational waves. The continuous matter transmits both as spatially extended waves. The speed of light $c$ depends thereby on the mass density of the continuous matter, the direction on the direction of mass density gradients. The dependencies explain the optical effects observable on Earth and in the universe, including the gravitational waves.

If by the expansion of the continuous matter the gravitational forces become to strong, the contraction of the universe towards the earlier center of expansion begins. When at this center the discrete objects of matter collide at velocities exceeding the speed of light, they will be destroit, including the elementary particles.

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