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Apparent Accelerated Expansion of the Three-Dimensional Spherical Universe Observed during Its Contraction Phase

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Abstract

In recent years, it has been thought that the expansion of the universe has begun to accelerate. However, there are other views against this. Here we propose a new theory based on the three-dimensional spherical (S^3) universe wherein the same observations as the present universe can also be found by the accelerated *contraction* of the universe. According to our theory, the expansion velocity of the S^3 universe slowed down after the Big Bang, and all the kinetic energy was converted into potential energy to reach the great sphere. After that, accelerated contraction begins, and the universe finally converges to an original single point. In the S^3 universe, the passage of time (referred to as "proper time") changes depending on its expansion velocity. The frequency of light emitted from celestial bodies is determined by their proper time on emission, and when the light is observed by observers having different proper time, a redshift or blueshift is observed. Observers in the expansion phase observe redshifts, because the proper time of the observer progresses faster than that of emitted light, but observers in the contraction phase observe an accelerated delay of the proper time, so the progress of the proper time is reversed based upon its order from nearby celestial bodies, a blueshift is observed, and its range of observable distance increases. The results of this early contraction phase are consistent with the observations of the current universe. In conclusion, the S^3 universe may be able to explain the geometrical structure of the current universe.

Keywords

Three-Dimensional Universe, Spherical Universe, Redshift, Big Bang

1. Introduction

Since the discovery of Hubble, the universe is expanding in an accelerated fashion according to the current cosmology [1] [2] [3] [4] [5]. The most reliable rationale of this expansion is the redshift of the light emitted from celestial bodies, where the extent of the redshift is larger if the celestial body is farther away [6]-[12]. Recently, the observation precision of the cosmic microwave background (CMB) radiation and the redshift of large galaxies has increased, and the measurement of the expansion velocity of the universe has become more accurate [13]. However, a basic question of what occurred at the beginning of the universe and an ultimate fate of the universe are still unknown [13]. Furthermore, the observation data of more distant celestial bodies are welcome, because they let us know what happened in the past universe. For instance, Chen *et al.* reported a redshift of $z = 6.68$ in their observation data of a distant celestial body [14]. However, Stern *et al.* claim that it may be impossible to observe the redshift of wavelengths less than 9300 Å at such a distance, because the intensity of the light is too weak to observe [15]. Although the observation data of very distant celestial bodies are important, there are questions relative to the data's reliability [15].

A question has also been raised against the accelerated expansion of the universe first pointed out by Hubble [1] [4]. Barrow *et al.* also pointed out a question of whether the expansion of the universe is accelerating or decelerating [16] [17]. Furthermore, although the primary force of the currently believed accelerated expansion of the universe derives from the "repulsive gravity" of dark energy [4], some researchers doubt even the existence of dark energy [18]. We hereby present the following proposal to construct a clearer theory regarding such a problem. Lehoucq *et al.* presented the existence of a 3-dimensional spherical universe as a basic structure of the universe [19]. The 3-dimensional sphere is a manifold having a spherical structure that exists in 4-dimensional space time, and the universe is considered to exist on its surface according to Shibata *et al.* [20]. We think that the universe began explosively from a tiny Big Bang and expanded soon after in an accelerated way. Next, the expansion velocity decreases and ceases, begins to contract in an accelerated fashion, and finally ends with the Big Crunch with contraction to a single point. According to our proposal, it is possible to explain the current structure of the universe without considering the dark energy, and to explain the expansion and contraction of the universe. Focusing on this point, we present a new concept of the current structure of the universe.

2. Three-Dimensional Spherical Universe

The 3-dimensional spherical (S^3) universe model we propose in this paper is composed of four dimensions, in which they are shown by 3-dimensional *x*-, *y*-, and z-coordinates that represent a space and a *w*-coordinate that has a dimension of distance by coordinate time *t* multiplied by light speed c (Equations (1) and (2)). In Equation (2), R represents the maximum radius of the S^3 universe.

$$w = ct, \tag{1}$$

and

$$w^2 + x^2 + y^2 + z^2 = R^2. \tag{2}$$

In this S^3 universe, the space expands and contracts while the coordinate time t advances from the birth of the universe ($w = -R$) to its end ($w = R$) in one direction (Figure 1(a)). At arbitrary coordinate time t, the S^3 universe can be observed as a 2-dimensional sphere of radius r mapped in a 3-dimensional space when it is observed from one direction outside of the S^3 universe fixing one of the space coordinates to zero (Figure 1(a)). On the other hand, for an observer inside the hypersphere S^3 universe, the universe is observed as a 3-dimensional observer-centred filled-in sphere, and numerous lights from celestial bodies scattered at each distance are observed as if they are coming straight to us (Figure 1(b)). This observed universe is a map of the light from a light source of a hypersphere of observer-centred space inside of the 3-dimensional sphere (Figure 1(b)).

3. Mathematical Characteristics of the S^3 Universe

When the S^3 universe is represented in polar coordinates, it is written as shown in Equations (3) - (6). ψ is elevation angle of space coordinate against the w coordinate axis, and it represents the expansion of the observable universe. It changes from zero to π upon the passage of coordinate time t. This ψ will be

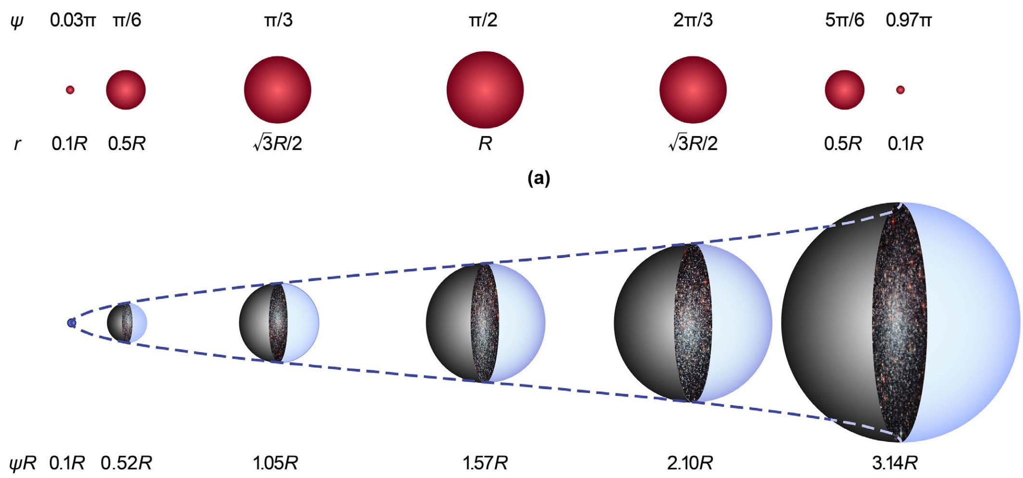

Figure 1. Expansion of the universe that accompanies the expansion contraction of the observable universe. (a) This shows expansion contraction of the universe from the birth to its end as a 2-dimensional sphere that follows the passage of coordinate time t with one dimension omitted. Upon the passage of coordinate time t, the expansion angle ψ of the S^3 universe increases, the radius r expands to R, but then returns to zero. (b) The three-dimensional spherical universe demonstrated as a 2-dimensional sphere. The balls represent cross sections of the observable universe at a respective expansion angle ψ of the S^3 universe with an arbitrary observation point in its centre. Upon increasing expansion angle ψ, radius ψR also increases, not only during the expansion but also during its contraction phase.

called expansion angle hereafter. θ is zenith angle at an arbitrary ψ, when the direction of the z-axis is facing upward, and the zenith top is zero and the zenith bottom is π. Likewise, η shows a deflection angle from the x-axis; it is positive when a right screw rotated clockwise goes ahead. This variable moves from zero to 2π.

$$w = -R\cos(\psi), \tag{3}$$

$$x = R\sin(\psi)\sin(\theta)\cos(\eta), \tag{4}$$

$$y = R\sin(\psi)\sin(\theta)\sin(\eta), \tag{5}$$

$$z = R\sin(\psi)\cos(\theta) \tag{6}$$

and

$$\psi = \cos^{-1}\left(\frac{-ct}{R}\right), \tag{7}$$

where $0 \le \psi \le \pi$, $0 \le \theta \le \pi$, and $0 \le \eta \le 2\pi$.

A radius r of the S^3 universe is shown in Equation (8), and it becomes the maximal R at a great sphere. The expansion velocity v of the S^3 universe at coordinate time t is shown in Equation (9).

$$r = R\sin(\psi) \tag{8}$$

and

$$\frac{\mathrm{d}r}{\mathrm{d}t} = v = -\mathrm{c}\cot(\psi). \tag{9}$$

The minute distance that light runs in the S^3 universe becomes cosec(ψ)-times larger than that when it runs on a flat space time, because the radius of the S^3 universe changes upon the passage of coordinate time t. This increase of the geodesic can be explained by the increase of the passage of proper time τ on the S^3 hypersphere against the passage of proper time τ on the expansion angle ψ, if the concept that light speed is always constant holds (Equation (11)). Therefore, if the ratio cosec(ψ) is integrated by coordinate time t, the ratio of the passage of proper time τ against that of coordinate time t from its origin ($-R/c$) to the coordinate time t is obtained (Equation (12)).

$$\mathrm{c}\Delta\tau = \mathrm{cosec}(\psi)\mathrm{c}\Delta t, \tag{10}$$

$$\frac{\mathrm{d}\tau}{\mathrm{d}t} = \mathrm{cosec}(\psi) \tag{11}$$

and

$$\frac{\mathrm{c}}{R}\int_{-\frac{R}{\mathrm{c}}}^{t}\mathrm{cosec}(\psi)\,\mathrm{d}t = \frac{\mathrm{c}}{R}\int_{-\frac{R}{\mathrm{c}}}^{t}\left[\cos^{-1}\left(\frac{-\mathrm{c}t}{R}\right)\right]\mathrm{d}t = \cos^{-1}\left(\frac{-\mathrm{c}t}{R}\right) = \psi. \tag{12}$$

4. Geodesic of Light in the S³ Universe

The result of this integration indicates that the angular distance of the light of the Big Bang (CMB) that ran in the S^3 universe is the same as the expansion angle ψ of the S^3 universe. Therefore, this expansion angle ψ is the angular distance that CMB runs, and the geodesic distance S_ψ is the same as the arc length ψR of the great sphere of radius R and angle ψ as shown in **Figure 2** (Equation (13)). The geodesic distance S_β that light reaches the observation point from a celestial body born after the Big Bang is βR, if the angular distance between an observation point and a space coordinate of the celestial body is β (Equation (14)). As shown in **Figure 2**, angular distance and the geodesic of a celestial body that remains in the S^3 universe are always constant despite the expansion·contraction of the S^3 universe.

$$S_\psi = \psi R \tag{13}$$

and

$$S_\beta = \beta R. \tag{14}$$

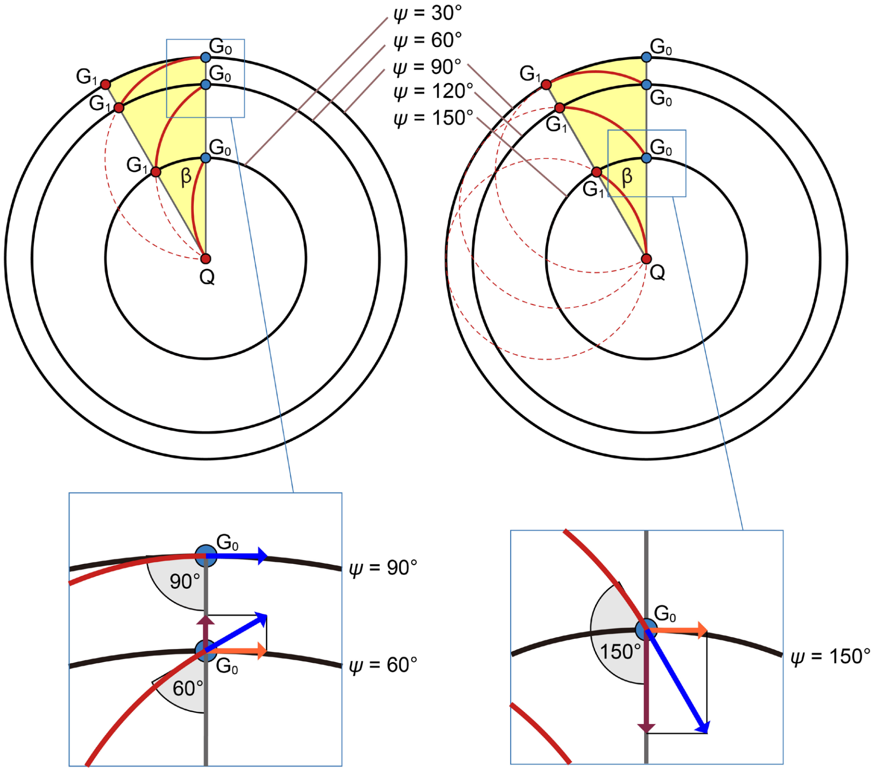

Figure 2. The geodesic of light in the S^3 universe. The concentric circles of the left upper panel show cross sections during expansion, and those in the right upper panel show cross sections during contraction of the S^3 universe at respective expansion angles ψ. The angular distance (longitude difference β) of the space coordinate formed between the stationary celestial bodies G_1 and G_0 is always constant despite the changes in expansion angle ψ. The red arcs are the geodesic of light that reaches from G_1 to G_0, and their distances are always constant in the course of the light, because the radius of the S^3 universe changes during the time it runs. The enlarged figures in the lower panels show that the incident angle of the light that reaches G_0 is the expansion angle ψ. The orange arrow shows the distance $c\Delta t$ that light runs during the passage of minute coordinate time t in a flat space time, the brown arrow shows the expansion $v\Delta t$ of the universe, and the blue arrow shows the elongation $c\Delta t\,\text{cosec}(\psi)$ of the geodesic of light due to the expansion of the S^3 universe.

5. Observable Universe

The observable universe that can be observed at the expansion angle ψ in the S^3 universe is an image mapped in the 3-dimensional sphere of the radius ψR with its center in the observation point. The radius ψR of the observable universe becomes large soon after the Big Bang, but then the expansion velocity slows down. Thereafter, when the S^3 universe enters the contraction phase, the expansion velocity decreases and the radius ψR becomes $\pi R/2$ in the great sphere of the S^3 universe and the expansion velocity increases again. The radius ψR then reaches maximal πR immediately before the end of the S^3 universe (Equation (13) and **Figure 3**).

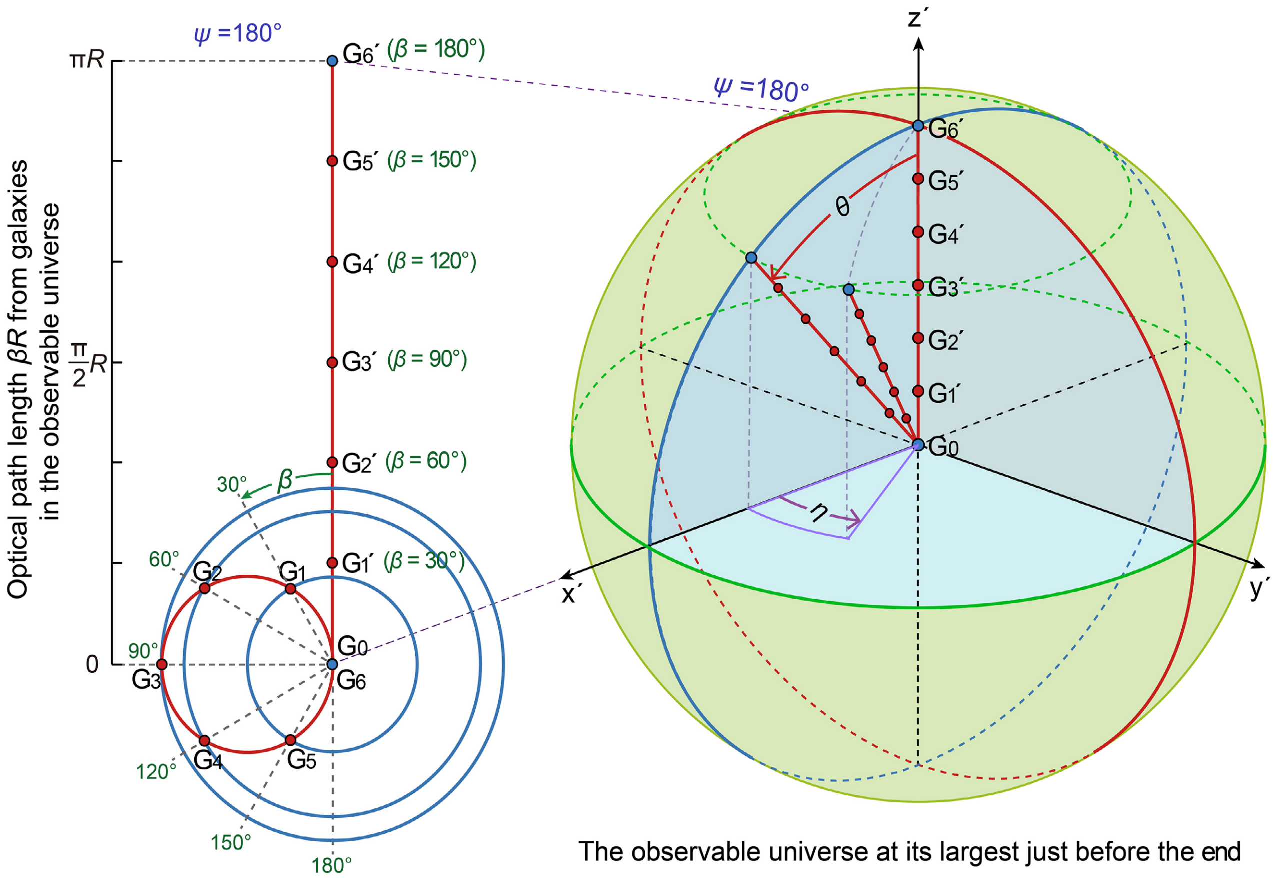

Figure 3. The observable universe that has become maximal just before the end of the S^3 universe. This figure shows the observable universe observed at an arbitrary observation point G_0 inside the S^3 universe just before it ends at an expansion angle $\psi = 180˚$. The left lower red circle that inscribes the outermost concentric circle shows optical paths of light that reach the observation point G_0 from the same direction just before the end of the S^3 universe, and the red points G_0 through G_6 on the circumference of the red circle show light sources of the galaxies of longitude difference (β) 30˚, 60˚, 90˚, 120˚, 150˚, and 180˚ (CMB), respectively. The points G_1' through G_6' on the red straight vertical line in the left figure are the points on the extended line of the light straight from the observation G_0 to the direction of the incident angle of the red circle, and are the mappings of the celestial bodies of the respective optical path length βR from G_0 in the observable universe. The sphere in the right figure shows the observable universe that has become a maximal size just before the end of the S^3 universe as a 3-dimensional space of x', y', and z' coordinates, and it shows the red segments of the line of the left figure which are expanded from observation point G_0 to all the directions of the observable universe. θ is a zenith angle of a celestial body mapped in the observable universe, and η is a deviation angle. The distance to a celestial body is shown as βR, if the longitude difference between the observation point to the celestial body is β.

6. Redshift of Light from Celestial Bodies

The optical path light reaches from an arbitrary celestial body to an observation point is always constant despite the expansion of the observable universe (**Figure 2**). However, a redshift (or blueshift when minus) is observed due to a difference in the wavelength of light between the time of emission and that of observation, because the passage of the proper time of the light at the time of emission and that of observation differs. The redshift z is shown in Equation (15), when the longitude difference of the space coordinate between the light source and the observation points is β. λ_s is the wavelength of the light source and λ is the wavelength of light at the observation point. The ratio between them is a ratio of the inverse of the elongation of the proper time (Equation (12)).

$$z = \frac{\lambda}{\lambda_s} - 1 = \frac{\operatorname{cosec}(\psi - \beta)}{\operatorname{cosec}(\psi)} - 1 = \frac{\sin(\psi)}{\sin(\psi - \beta)} - 1. \tag{15}$$

The redshift is observed in a flat space due to the receding velocity of the light source, but it is observed due to the difference of the proper times between those of emission and observation, both stationary, in the S^3 universe. From Equation (15), it can be concluded that the blueshift begins successively from neighbouring stars of smaller to larger longitudinal difference β when the S^3 universe enters the contraction phase (**Figure 4**).

This result agrees very well with the current observation of the universe that the universe apparently turned from decelerated to accelerated expansion [21]. In fact, the S^3 universe is contracting in an accelerated way, and is not expanding. In view of our theory, it would be important to mention the report of Lombriser [22]. He found that the redshift of galaxies can be interpreted to be an evolution of particle masses as a consequence of conformal transformation of the FLRW (Friedmann Lemaître Robertson Walker) metric to a Minkowski space [22]. Although his rationale behind the theory is different from that of our theory, he pointed out that the current universe may not be expanding based upon his theory. The conclusion of his theory is basically same as our conclusion.

Welch *et al.* recently reported observations of a distant star of redshift 6.2 ± 0.1 and 900 million years after the Big Bang [23]. Based upon their observations we calculated from Equation (13) that R is $13.8/\psi$ billion light years. The expansion angle of the light source is $9 = \psi_s R$ from Equation (13). Therefore, ψ_s is $9/R$ radians and $\psi_s = (9/138)\psi = 0.0652\psi$. If we assume that the expansion angle of a star at the time of emission is ψ_s, Equation (15) becomes

$$z = \frac{\lambda}{\lambda_s} - 1 = \frac{\sin(\psi)}{\sin(\psi_s)} - 1. \tag{16}$$

By substituting $z = 6.2$ and $\psi_s = 0.0652$ in the above equation, we obtain

$$6.2 = \frac{\sin(\psi)}{\sin(0.0652\psi)} - 1. \tag{17}$$

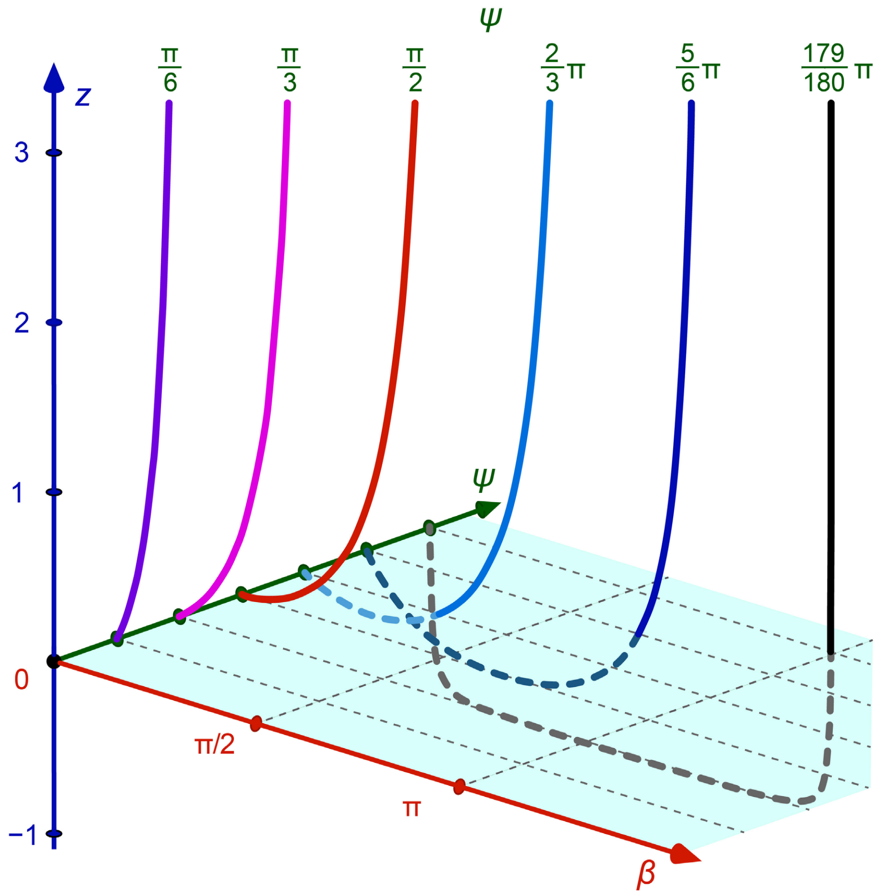

Figure 4. Redshift observed in the S^3 universe. This figure shows redshifts of celestial bodies that are observed on observation points at expansion angles $\psi = 30^\circ$, 60°, 90°, 120°, 150°, and 179°, and changes of redshift z at longitude difference β from the observation point up to the celestial bodies. The redshift is defined by the ratio $d\tau/dt$ (Equation (11)) of the passage of proper time of light at the time of observation against that of coordinate time t at emission minus one (Equation (15)). The above ratio of the passage of proper times is larger when the longitude difference β becomes larger, because the expansion velocity of the observation point becomes slower than that of the light source at its emission during the expansion phase of the S^3 universe. During the contraction phase ($\psi > \pi/2$), the redshift changes to blueshift ($z < 0$, broken lines) successively from the light of celestial bodies that have become slower in the passage of proper time of the emission than that at observation, because the observed recession velocity of celestial bodies increases due to the increase of the contraction velocity of the observation point. The blueshift of the light increases from neighbouring celestial bodies up to those close to the great sphere and then begins to decrease when they reach the great sphere. The redshift of the light from celestial bodies that are farther away from those of the light source of the same proper time as that at the observation point ($z > 0$, solid line) increases.

From this equation we obtain $\psi \approx 113$ deg (1.97 rad), indicating that the universe is in a stage after the beginning of the contraction.

In summary, we theoretically demonstrated that the increase in receding velocity of the observable universe is observed when the universe is contracting in an accelerated fashion even though it is not expanding. In our theory, the so-called unknown energy that expands the universe in an accelerated fashion in terms of the energy balance of the entire universe is unnecessary. Our results suggest that this model can be a potential candidate demonstrating the geometrical structure of the current universe.

7. Conclusion

We proposed in this paper a novel view of redshifts of the lights emitted from celestial bodies based upon the structure of the three-dimensional spherical (S^3) universe. Contrary to the common interpretation of the redshift that the universe is expanding in an accelerated fashion, we theoretically demonstrated that the redshift of the celestial bodies can also be observed in a *contraction* phase of the universe. In our theory, the so-called unknown energy, which is known to expand the universe in an accelerated fashion in terms of the energy balance of the entire universe, is not necessary. Our result suggests that our model can be a potential candidate that clearly explains the geometrical structure of the current universe, and it will open a new concept of the current status of the universe.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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