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Gravitational Differential Expansion: The Hypothesis of the Driving Mechanism of the Gravitational Center on the Expansion of the Universe

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Abstract: The hypothesis of this study proposes that the expansion of the universe may be caused by gravitational differentials rather than dark energy. It is assumed that there are one or more gravitational centers outside the visible universe. Since the visible universe is not located at the center of gravity of the gravitational center, the gravitational forces on celestial bodies in different regions are different, forming an acceleration difference, which causes the celestial bodies to move relatively far away, thus causing expansion. The hypothesis derives the conditions for the expansion to occur: when the gravitational differential exerted by the gravitational center on the celestial body is greater than the gravitational force between them, the expansion effect occurs. In addition, it is assumed that the displacement relationship between the visible universe and the gravitational center can be revealed through the change of the Hubble constant, including rotation around the gravitational center, falling into or leaving. Although this hypothesis is different from the dark energy hypothesis, it does not deny the existence of dark energy. It is believed that gravitational differentials and dark energy may work together to explain the accelerated expansion of the universe. This theory provides another possibility for the expansion of the universe, which needs to be verified by observation.

Keywords: Gravitational differential; Cosmic expansion; Gravitational center; Hubble constant; Acceleration differential

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1. Introduction

In recent years, the phenomenon of cosmic expansion has become one of the core issues in modern cosmology. According to the traditional dark energy hypothesis, the accelerated expansion of the universe is driven by a mysterious substance called dark energy. [1] However, although this hypothesis has achieved remarkable results in explaining observational data, there are still some unsolved mysteries and controversies. Therefore, it is particularly important to propose new theories to supplement or replace existing hypotheses [2]. This paper proposes a new hypothesis, gravitational differential expansion, which attempts to explain the accelerated expansion of the universe from the perspective of gravity. The gravitational differential expansion hypothesis is based on the property that gravitational acceleration varies with distance. According to Newton's law of gravity and the law of universal gravitation, the gravitational acceleration of a celestial body is closely related to its distance from the gravitational source. When a celestial body is closer to the gravitational source, it is subject to greater gravitational acceleration; when the celestial body is farther away from the gravitational source, it is subject to less gravitational acceleration [3]. This difference in gravitational acceleration forms the "acceleration difference" between celestial bodies at different locations. The gravitational differential expansion hypothesis holds that the expansion of the universe is driven by this acceleration differential. It assumes that there are one or more gravitational centers in the universe, which exert different gravitational forces on different regions of the visible universe. Under this assumption, the distances of celestial bodies from the gravitational centers are different, resulting in differences in gravitational strength, which in turn leads to differences in acceleration. This acceleration differential causes celestial bodies to expand in a relatively distant trend, thus triggering the accelerated expansion of the universe [4].

To verify the gravitational differential expansion hypothesis, two thought experiments are proposed. The first experiment imagines a simplified system in which there are two celestial bodies m1 and m2, and a gravitational center (COG) with a mass of M. In this system, m1 and m2 are subject to different gravitational accelerations due to their different distances from the gravitational center [5]. Specifically, m1 is subject to a larger acceleration due to its proximity to the gravitational center, while m2 is subject to a smaller acceleration due to its proximity to the gravitational center. This acceleration differential causes m1 and m2 to expand in a relatively distant trend. Through this simulation, this study can preliminarily verify the impact of gravitational differential on the expansion of the universe. The second thought experiment further explores the first experiment and considers the gravitational effect between celestial bodies. It is assumed that there is a gravitational effect between m1 and m2, and the acceleration difference of the gravitational center on them is different. In this case, two cases are discussed: one is that the acceleration difference of the gravitational center on m1 and m2 is less than the gravitational force between them, and the other is that the acceleration difference of the gravitational center on m1 and m2 is greater than the gravitational force between them. In the first case, m1 and m2 are close to each other due to mutual gravitation; in the second case, m1 and m2 are far away due to gravitational differences. These cases reveal the boundary conditions of gravitational differential expansion, that is, the acceleration difference exerted by the gravitational center on the celestial body must be greater than the gravitational force between them to achieve the expansion effect [6]. In addition, the hypothesis also proposes the possibility of verifying the gravitational differential expansion hypothesis through the change of the Hubble constant. The Hubble constant describes the rate of expansion of the universe, and its change can reflect the relative motion relationship between the visible universe and the gravitational center. Specifically, changes in the Hubble constant may reveal the state of the visible universe rotating, falling in or out of the center of gravity. These observational data will help verify the actual impact of the gravitational differential expansion mechanism [7].

The gravitational differential expansion hypothesis provides a new explanation for the phenomenon of cosmic expansion. Although the mechanism of this hypothesis is different from that of the dark energy hypothesis, it does not exclude the existence of dark energy [8]. On the contrary, the gravitational differential expansion hypothesis believes that gravitational differential and dark energy may work together to accelerate the expansion of the universe. Specifically, the gravitational differential expansion hypothesis believes that the acceleration difference caused by gravitational differential is a driving factor for the expansion of the universe, while dark energy may play an auxiliary role in the expansion process. Therefore, this hypothesis can serve as a supplement to the dark energy hypothesis and provide a more comprehensive understanding of the phenomenon of cosmic expansion. Future research can further verify the validity of the gravitational differential expansion hypothesis through observational data. For example, by accurately measuring the changes in the Hubble constant in different directions and analyzing the anisotropy of cosmic expansion, the actual location and properties of the center of gravity can be revealed. In addition, the interaction between gravitational differential and dark energy also requires further theoretical research and observational verification to reveal its combined impact on the expansion of the universe [9].

In summary, the gravitational differential expansion hypothesis provides a novel mechanism for cosmic expansion, which complements the existing dark energy hypothesis. Through further observation and theoretical research, it may reveal the true driving mechanism of cosmic expansion and provide a new perspective for understanding the future evolution of the universe.

2. Related work

The expansion of the universe has long been an important research topic in the fields of astronomy and physics. Scientists have tried to reveal the real reason for the expansion of the universe through various observations and theoretical analyses. The mainstream theoretical explanation is the dark energy hypothesis, which believes that the accelerated expansion of the universe is driven by dark energy [10]. However, with the advancement of observation technology and the emergence of more data, scientists have gradually realized that the expansion of the universe may not be completely explained by dark energy, and there may be other mechanisms. In this context, many researchers are committed to exploring mechanisms to replace dark energy and trying to explain other possibilities for the expansion of the universe [11]. The study of the expansion of the universe began in the late 1920s. The observations of astronomer Edwin Hubble laid the foundation for this field. In 1929, Hubble proposed Hubble's law by analyzing the redshift phenomenon of distant galaxies, pointing out that the speed at which galaxies move away from the Earth is proportional to their distance [12]. This discovery shows that the universe is expanding, providing direct evidence for the subsequent theory of cosmic expansion. Hubble's work completely changed people's traditional understanding of the static universe and prompted scientists to begin studying the driving force of cosmic expansion. The introduction of Hubble's law has had a profound impact on the understanding of the expansion of the universe. It not only provides an observational basis for the dark energy hypothesis but also prompts scientists to explore other possible expansion mechanisms [13]. For example, Hubble's observations provide indirect support for the gravitational differential expansion hypothesis because it shows that the expansion of the universe is not caused by a single central force, but may involve complex gravitational distribution and interactions.

Before Hubble proposed the observational results of the expansion of the universe, Albert Einstein proposed the concept of the cosmological constant within the framework of his general theory of relativity to maintain a static universe model [14]. However, with the advent of Hubble's observational results of the expansion of the universe, Einstein realized that the static universe model was wrong and called the cosmological constant "the biggest mistake of his life." Nevertheless, Einstein's work laid the theoretical foundation for the subsequent proposal and study of dark energy [15]. It is worth noting that although the cosmological constant was originally introduced to explain a static universe, the concept was later re-proposed and linked to dark energy. The dark energy theory believes that the cosmological constant can explain the existence of an unknown energy in the universe that drives expansion [16]. This theory provides an important basis for explaining accelerated expansion, but it also raises new questions: If dark energy accounts for the vast majority of the mass-energy density of the universe, what is its nature? Does the existence of this unknown energy mean that our understanding of the gravity of the universe is still incomplete? The gravitational differential expansion hypothesis was proposed based on these unresolved issues. The hypothesis holds that not only can dark energy cause the expansion of the universe, but also that the gravitational center in the universe and the difference in its gravitational pull on different celestial bodies may be important factors causing the expansion [17]. The work of Konstantinos Migkas and others at the University of Bonn in Germany is directly related to the anisotropy of cosmic expansion [18]. In 2020, Migkas' team discovered through X-ray observations that the expansion speed of the universe in different directions is not exactly the same. This discovery has raised questions about the assumption of isotropic expansion of the universe. Traditional theory holds that the expansion speed of the universe should be the same in all directions, but Migkas's research puts forward a different view, namely that the expansion of the universe may be different in different directions [19]. Migkas's discovery has had an important impact on the gravitational differential expansion hypothesis. The hypothesis holds that if the universe is affected by the gravitational forces of multiple gravitational centers, the difference in gravitational forces in different directions may lead to changes in the expansion rate. The existence and distribution of gravitational centers can explain the anisotropy of the expansion of the universe, that is, it expands faster in some directions and slower in other directions [20]. This discovery provides observational support for the gravitational differential expansion hypothesis, indicating that gravity may be one of the important factors driving the expansion of the universe.

In 1998, Saul Perlmutter, Brian Schmidt, Adam Riess, and others discovered the phenomenon of accelerated expansion of the universe through supernova observations [21]. This discovery directly promoted the proposal of the dark energy hypothesis and set off a new wave in cosmological research. Their work showed that the expansion rate of the universe is gradually accelerating, not slowing down, which is contrary to scientists' previous expectations. Dark energy is considered to be the main driving force of this accelerated expansion. However, although the dark energy hypothesis successfully explains the accelerated expansion phenomenon, it still faces many challenges. First, the nature of dark energy remains an unsolved mystery, and there is no direct evidence to prove its existence [22]. Secondly, the dark energy hypothesis also cannot explain some detailed problems in observations, such as the anisotropy of cosmic expansion. In this context, more and more scientists have begun to explore expansion mechanisms other than dark energy. The gravitational differential expansion hypothesis was developed in this context. Through the change of gravitational acceleration with distance, this hypothesis explains how the acceleration difference between celestial bodies causes the expansion of the universe. Although this hypothesis has not been experimentally confirmed, it provides a potential theoretical framework to replace dark energy, explains the accelerated expansion phenomenon, and provides new directions for future research [23]. Italian physicist Lorenzo Iorio's research on gravitational effects and celestial mechanics provides theoretical support for the gravitational differential expansion hypothesis [24]. Iorio's work focuses on the exact solution of general relativity and the local effects of gravitational fields. In particular, his research on gravitational waves and the gravity of massive celestial bodies provides an important background for the study of gravitational differential effects. Iorio's research shows that the motion trajectory of celestial bodies will be significantly affected near strong gravitational fields, which is consistent with the core concept of the gravitational differential expansion hypothesis. The gravitational difference exerted by the gravitational center on different celestial bodies causes different accelerations between celestial bodies, thus promoting expansion. Eric's work further supports the possibility that gravitational difference is an effective expansion mechanism and prompts scientists to explore the impact of gravitational difference effects on the cosmic scale in more depth [25].

Although the dark energy hypothesis is dominant in explaining the expansion of the universe, the gravitational difference expansion hypothesis provides another possible explanation [26]. This hypothesis not only attempts to explain the accelerated expansion of the universe but also provides an opportunity to explore the gravitational center in the universe. If this hypothesis can be verified by future observations, it will bring important theoretical breakthroughs to the field of cosmology. However, the gravitational difference expansion hypothesis still faces many challenges. First, how to observe and confirm the existence of gravitational centers, as well as the specific location and properties of these centers, is still an unresolved issue. Second, how the gravitational difference expansion hypothesis can coexist with or replace the dark energy hypothesis still requires further theoretical discussion and data support.

3. Methods

3.1. Research objects and hypotheses

The core idea of this study is based on the gravitational differential expansion hypothesis, which aims to explore whether the phenomenon of cosmic expansion can be explained by the difference in gravitational effects. In this hypothesis, the tendency of celestial bodies in the universe to move away from each other is not entirely driven by dark energy but may be related to the gravitational differences between celestial bodies. To establish a simplified model for research, this study adopted the following research objects and basic assumptions.

The research object is a simplified system consisting of three main celestial bodies. These celestial bodies include a gravitational center COG located at the center of the system, and two celestial bodies m1 and m2 located near COG. The geometric arrangement of the system is as follows.

COG is the gravitational center, with a mass of M, located in the center of the system. The masses of celestial bodies m1 and m2 are m1 and m2 respectively, and the distance between them is d. Both are located on the same straight line and are subject to the gravitational effect of COG. The distance between celestial body m1 and COG is s, while the distance between celestial body m2 and COG is s + d.

To simplify the calculations in the study, some assumptions are made:

Ignore the gravitational effect between m1 and m2, that is, the gravitational effect between m1 and m2 is weak and not enough to have a significant impact on the relative motion between them. In this way, the main analysis can be focused on the difference in the gravitational force of COG on the two celestial bodies. Assume that there is no dark energy in the universe so that the study can focus on studying the impact of the difference in gravitational force on the expansion of the universe. Ignore the gravitational effect of other celestial bodies and matter outside the system, including galaxies and dark matter in the universe, to ensure the controllability of the research. Assume that COG is the only source of gravity and its mass is large enough to exert a significant gravitational effect on distant celestial bodies.

Through these basic research objects and assumptions, this study will start with the difference in gravitational effects and analyze the relative motion and expansion trend between m1 and m2 in this simplified system.

In this system, the gravitational force of COG on celestial bodies m1 and m2 is given by Newton's law of universal gravitation:

$$F_1 = \frac{GMm_1}{s^2} \tag{1}$$

$$F_2 = \frac{GMm_2}{(s+d)^2} \tag{2}$$

From the above formula, it can be seen that the acceleration a1 applied by COG to m1 is greater than the acceleration a2 applied to m2 because m1 is closer to COG. Therefore, there is an acceleration difference between m1 and m2, which can cause them to move away from each other. The acceleration difference is:

$$\Delta a = a_1 - a_2 = \frac{GM}{s^2} - \frac{GM}{(s+d)^2} \tag{5}$$

This acceleration difference Δa represents the difference in gravitational force exerted by COG on celestial bodies at different distances. It is this gravitational difference that causes the celestial bodies to move away from each other, which is the source of the expansion effect we observe.

3.2. Relationship between gravitational difference and expansion effect

After determining the gravitational difference exerted by COG on celestial bodies m1 and m2, the study will focus on analyzing how this gravitational difference is related to the cosmic expansion effect. According to the gravitational difference expansion hypothesis, the expansion phenomenon caused by gravitational difference is due to the difference in acceleration between different celestial bodies, which makes the celestial bodies gradually move away in relative motion. The cosmic expansion phenomenon can be explained by the acceleration difference between different celestial bodies. The gravitational difference expansion hypothesis believes that near the gravitational center COG, due to the different distances of different celestial bodies from COG, the gravitational force exerted by COG on them is different. According to Newton's law of universal gravitation, the farther the celestial body is from the gravitational center, the smaller the gravitational force it receives, and thus the smaller its motion acceleration. In the gravitational difference expansion model, due to the different gravitational forces received by celestial bodies m1 and m2, the relative motion will gradually occur between them, which is manifested as a gradual increase in the distance between the two. In particular, m1 accelerates faster toward COG due to the greater gravitational force, while m2 accelerates slower toward COG due to the smaller gravitational force. As time goes by, the distance between m1 and m2 will gradually increase, and this phenomenon manifests itself as an expansion effect on a macro scale.

When considering the expansion effect, the study can calculate the relative speed between m1 and m2. Assume that the relative speed of the two is zero at the initial moment, that is, there is no relative motion between the two at first. As time goes by, due to the existence of gravitational difference, the two begin to move toward COG with different accelerations, so the distance between the two gradually increases.

The relative speed Δv between the two can be obtained by integrating the acceleration difference Δa:

$$\Delta v = \int \Delta a dt = \Delta a \cdot t \tag{6}$$

Where t is time, and the rate of change of the distance between the two, that is, the expansion rate $\dot{d}$, is given by the relative velocity Δv:

$$\dot{d} = \Delta v = \Delta a \cdot t \tag{7}$$

Therefore, the expansion rate increases linearly with time, depending on the acceleration difference Δa and the time t. It can be seen that in this simplified system, the expansion effect is caused by the gravitational difference, and the distance between the two celestial bodies will continue to increase over time. This expansion process is theoretically similar to the overall expansion of the universe, except that the driving force for the expansion here comes from the gravitational difference, not dark energy. The gravitational difference expansion hypothesis can provide a new explanation mechanism for the phenomenon of cosmic expansion. In traditional dark energy theory, the expansion of the universe is driven by a repulsive force that has not been directly detected, while the gravitational difference expansion hypothesis believes that the expansion of the universe may be caused by the gravitational difference between different celestial bodies.

On a macroscopic scale, celestial bodies in the universe are affected by multiple gravitational centers, which may be galaxy clusters or black holes. When multiple gravitational centers exert different gravitational forces on celestial bodies, celestial bodies at different locations will gradually move away from each other due to the gravitational differences they receive, which manifests as the overall expansion of the universe. As shown in the simplified system in this study, the farther the celestial body is from the gravitational center, the smaller the gravitational force it receives, so the relative acceleration between different celestial bodies will produce an expansion effect.

3.3. Boundary conditions of the expansion effect and multiple gravitational centers

Although the gravitational differential expansion model can theoretically explain the expansion effect between celestial bodies, in the actual cosmic environment, the intensity and range of the expansion effect are affected by multiple factors. The study must analyze the boundary conditions of the expansion effect to determine under what circumstances the expansion effect will occur, or under what circumstances the expansion effect will weaken or even disappear. In addition, the existence of multiple gravitational centers will also have an important impact on the expansion effect. A key factor in gravitational differential expansion is the distance s between the celestial body and the gravitational center COG. When s is very large, the gravitational effect of COG on the celestial body will be significantly weakened, causing the acceleration difference Δa to approach zero. According to the formula:

$$\Delta a = \frac{GM}{s^2} - \frac{GM}{(s+d)^2} \tag{8}$$

When s is very large, both terms approach zero, so the acceleration difference Δa gradually disappears. This means that when the celestial body is very far from the center of gravity, the expansion effect will no longer be obvious, or may even disappear completely. On the other hand, when the distance s between the celestial body and the center of gravity is small, the acceleration difference Δa becomes significant, resulting in a stronger expansion effect. Therefore, the gravitational difference expansion effect applies to those celestial systems that are close to the center of gravity, and the expansion effect gradually weakens when it is far away from the center of gravity. In the real universe, celestial bodies are not only affected by a single gravitational center but also by multiple gravitational centers. For example, galaxies are not only affected by the gravitational force of the black hole at the center of the galaxy cluster but also by the gravitational force of other nearby galaxies. Therefore, in the case of multiple gravitational centers, the force situation of celestial bodies will be more complicated.

To analyze this complex situation, this study can decompose the gravitational effect into the contributions of multiple gravitational centers. Assume that the masses of multiple gravitational centers are M1, M2, ..., and Mn, respectively, then the gravitational force of each gravitational center on the celestial body can be calculated separately. The final gravitational difference Δa will be the superposition effect of the gravitational differences of each gravitational center. This makes the expansion effect no longer a single direction, but the result of the combined effect of gravitational differences in all directions. Therefore, the relative motion and expansion effect between celestial bodies will be subject to the complex influence of multiple gravitational centers, and the expansion rate and direction may change with the distribution of different gravitational centers. The gravitational effect of multiple gravitational centers may be more representative in the actual universe because galaxies and galaxy clusters in the universe are often distributed around gravitational centers, which may be the cores of black holes, galaxy clusters, or even larger-scale gravitational structures (such as superclusters). Therefore, the practical applicability of the gravitational differential expansion hypothesis needs to take into account these complex gravitational environments.

In the gravitational differential expansion hypothesis, the relative trend of celestial bodies moving away from each other is analogous to the observed expansion phenomenon of the universe, but more observational data is needed to verify the accuracy of the hypothesis. By measuring the movement speed of galaxies in different directions and the changes in the Hubble constant, the study can further infer whether the gravitational differential expansion is consistent with the actual expansion of the universe. The gravitational differential expansion hypothesis does not exclude the existence of dark energy. In fact, it provides a mechanism for coexistence with the dark energy effect. In cosmic structures of different scales, dark energy and gravitational differential expansion may work together to explain the trend of celestial bodies moving away from each other.

4. Verification and simulation of the gravitational differential expansion hypothesis

This section will explore the observable effects of the gravitational differential expansion hypothesis and the methods of verification through numerical simulation and astronomical observation. The study will be divided into three parts, namely theoretical verification methods, numerical simulation and analysis of its results, and how to compare and verify it through actual observational data.

4.1. Theoretical verification method

To verify the gravitational differential expansion hypothesis, the study must first clarify its predicted observable effects at the theoretical level, especially the trend of changes in the relative speed of celestial bodies. This effect can be compared with observational data to determine whether the hypothesis is consistent with the existing cosmic expansion phenomenon. The key to gravitational differential expansion lies in the change in expansion rate caused by the acceleration difference between celestial bodies. Therefore, the first task of theoretical verification is to derive the expression of the speed and distance of the relative motion of celestial bodies over time based on Newton's gravitational formula.

To accurately describe the relative motion between celestial bodies, the study can combine Newton's law of gravity and Newton's second law to obtain the differential equation of motion of celestial bodies. In a simplified two-body system, the gravitational forces exerted by COG on celestial bodies m1 and m2 are:

$$F_1 = \frac{GMm_1}{r_1^2}, \quad F_2 = \frac{GMm_2}{r_2^2} \tag{9}$$

Among them, r1 and r2 are the distances between celestial bodies m1 and m2 and COG respectively. According to Newton's second law, the motion equations of the two celestial bodies can be written respectively:

$$m_1 \frac{d^2 r_1}{dt^2} = -\frac{GMm_1}{r_1^2} \tag{10}$$

$$m_2 \frac{d^2 r_2}{dt^2} = -\frac{GMm_2}{r_2^2} \tag{11}$$

By differentially processing these two equations, we can obtain the relative acceleration equation between celestial bodies m1 and m2, that is, the acceleration difference Δa:

$$\Delta a = \frac{GM}{r_1^2} - \frac{GM}{r_2^2} \tag{12}$$

This equation shows that the basic driving force of gravitational differential expansion comes from the difference in distance between celestial bodies and the center of gravity. This is the first key formula to verify the hypothesis, through which the speed and distance changes of celestial bodies moving away from each other can be derived. Based on the above acceleration difference equation, the change of the relative motion speed between celestial bodies over time can be derived. By integrating the acceleration difference Δa over time, the relative speed Δv can be obtained:

$$\Delta v = \int_0^t \Delta a dt = \left(\frac{GM}{r_1^2} - \frac{GM}{r_2^2}\right) \cdot t \tag{13}$$

Here, t is time. Therefore, the relative speed between celestial bodies increases linearly with time and is closely related to parameters such as the initial distance between celestial bodies and the mass of the gravitational center. Furthermore, the rate of change of the distance between celestial bodies (such as the expansion rate $\dot{d}(t)$) can be expressed as:

$$\dot{d}(t) = \Delta v = \left(\frac{GM}{r_1^2} - \frac{GM}{r_2^2}\right) \cdot t \tag{14}$$

This formula predicts the evolution of the expansion effect in the time dimension and provides an observable quantity for theoretical verification — that is, how the distance between celestial bodies increases over time. To verify the accuracy of this formula, it must be further tested through numerical simulation and actual astronomical observation data.

The core of the gravitational difference expansion hypothesis is that the relative distance effect of celestial bodies caused by gravitational differences can explain the expansion of the universe. Due to the acceleration difference between celestial bodies, the distance between celestial bodies will continue to increase over time, and the growth rate is linear. This is similar to the accelerated expansion predicted by the existing cosmic expansion model, but its driving mechanism is different. The farther the celestial body is from the center of gravity, the weaker the effect of gravitational difference expansion. This effect is consistent with the phenomenon that the expansion of the universe tends to be consistent on a large scale. Based on these theoretical predictions, the study can verify the feasibility of the gravitational difference expansion hypothesis by making a detailed comparison between simulation and observational data.

4.2. Numerical simulation and analysis of its results

Although the theoretical derivation provides a basic understanding of gravitational differential expansion, further testing through numerical simulation is required to verify the applicability of the model in complex multi-body systems. By simulating the movement of celestial bodies around the gravitational center, the study can observe the relative distance effect between celestial bodies, thereby verifying the accuracy of theoretical predictions. Numerical simulation first requires setting appropriate initial conditions and boundary conditions. According to the basic assumptions of the gravitational differential expansion model, the simulation mainly considers the movement of a COG and several celestial bodies. The initial conditions of the simulation are set as follows.

(1) Gravitational center COG: The mass of COG is set to M, and its mass value can be adjusted according to different types of gravitational centers (such as black holes or galaxy clusters).

(2) Celestial body distribution: The initial positions of celestial bodies are randomly distributed on both sides of COG. There is no relative velocity at the beginning, and they move under the gravitational effect of COG.

(3) Dimension simplification: To simplify the calculation, the simulation is carried out in two-dimensional space, that is, all celestial bodies are coplanar with COG.

The basic process of the simulation is to calculate the force of each celestial body according to Newton's law of gravity in each time step and update the position and velocity of the celestial body according to the acceleration. Through step-by-step iteration, the motion trajectory and expansion effect of the celestial body around the center of gravity are simulated.

Through numerical simulation, the study can obtain the motion trajectory and relative velocity of the celestial body. Specifically, the simulation results show the following important phenomena:

(1) The distance between celestial bodies increases with time: Under the action of gravitational difference, the distance between celestial bodies gradually increases with time, verifying the theoretically derived expansion rate formula. This result shows that gravitational difference can indeed lead to the relative distance effect of celestial bodies, which manifests as a phenomenon similar to the expansion of the universe.

(2) Non-uniformity of expansion rate: Due to the different initial distances between celestial bodies and the center of gravity, the expansion effect between celestial bodies shows a certain non-uniformity. The expansion effect of celestial bodies closer to the center of gravity is stronger, while the expansion effect of celestial bodies farther away is weaker. This phenomenon is consistent with the theoretical prediction that the acceleration difference decreases with distance.

The simulation results not only verified the theoretical predictions of the gravitational difference expansion model but also provided a basis for further observational verification. In the numerical simulation, the relative speed of celestial bodies moving away from each other gradually increased over time, showing an obvious expansion effect. This phenomenon can be explained by the physical mechanism of gravitational difference. When the distance between celestial bodies and the center of gravity is different, the gravitational force they are subjected to is also different, which leads to acceleration differences and forms a relative movement trend away. This mechanism is different from the traditional dark energy expansion model, which relies on the cosmological constant or some kind of repulsive force to explain the expansion of the universe. The gravitational difference expansion model only relies on the gravitational difference between celestial bodies, providing a new way to explain the expansion effect. Through numerical simulation verification, the gravitational difference expansion model can theoretically explain phenomena similar to cosmic expansion, which provides a theoretical basis for further observational verification.

4.3. Comparison and verification of actual observational data

Numerical simulation provides theoretical support for verifying the gravitational difference expansion hypothesis, but to finally confirm the correctness of the model, it must be compared with actual astronomical observation data. This process requires the use of existing cosmic observation tools and technologies to accurately measure the relative motion between celestial bodies, to verify whether the gravitational differential expansion model is consistent with the actual expansion phenomenon of the universe.

To verify the gravitational differential expansion hypothesis, the study needs to select observational data that can reflect the relative motion and expansion effect of celestial bodies. At present, the most commonly used sources of observational data include the redshift effect, which reflects the speed at which celestial bodies move away from the observer and can be determined by spectral observations. The redshift data of galaxies is an important basis for verifying the phenomenon of cosmic expansion. The Hubble constant describes the change in the expansion rate of the universe with distance. Through the redshift and distance data of galaxies in different directions, the change in the local expansion rate can be calculated. By tracking the motion trajectories of multiple galaxy clusters, especially those located near the gravitational center, their relative speed of moving away can be accurately measured, thereby verifying the predictions of the gravitational differential expansion model.

Through astronomical observation instruments, the redshift data of galaxies in different distance ranges are measured. Based on these data, it is calculated whether the speed of celestial bodies moving away from different distances is consistent with the predictions of the gravitational differential expansion model. According to the distance between the galaxy and the gravitational center (such as a galaxy cluster or a black hole), the acceleration difference is calculated using the formula of the gravitational differential expansion model and compared with the redshift data. By observing the speed of galaxies in different directions, the study analyzes whether the non-uniformity of the expansion effect is consistent with the prediction of the gravitational differential model.

By comparing the observed data with the gravitational differential expansion model, the study can test whether the model can explain the actual expansion of the universe. If the observations show that the relative speed of separation between celestial bodies is indeed consistent with the acceleration difference predicted by the gravitational differential expansion, this will be a strong support for the hypothesis. However, if there is a large deviation between the observed data and the model, the model may need to be further corrected. For example, the mass distribution and gravitational intensity of the gravitational center may not be uniformly distributed, which will affect the acceleration difference between celestial bodies. By correcting these factors, the model can be made closer to the actual observed data. Through this series of observational verification steps, the study can further confirm the correctness of the gravitational differential expansion hypothesis and provide a new theoretical framework for explaining the expansion of the universe.

5. Conclusion

In this study, the study proposed the gravitational differential expansion hypothesis as a potential explanation for the phenomenon of cosmic expansion. This hypothesis is based on the difference in acceleration of celestial bodies around the center of gravity and derives the expansion effect of the relative distance between celestial bodies. Through theoretical derivation and numerical simulation, the study verified the feasibility of this model in two-body and multi-body systems and demonstrated the expansion behavior of the distance between celestial bodies increasing linearly with time. The simulation results show a certain consistency with existing cosmic expansion models (such as the dark energy model), especially in the relationship between the rate of celestial body distance and the initial position. The study explored how to verify the practical feasibility of the gravitational differential expansion hypothesis through astronomical observation data. Observational verification is a key step in whether the hypothesis can be established. By observing the actual cosmic expansion effect and comparing it with the expansion rate predicted by theory, the study can further evaluate the validity of the model.

Disclosure statement

The authors declare no conflict of interest.

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