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THE EVOLUTION OF DARK MATTER AND THE FORMATION BASIC THEORY OF STRUCTURAL GROWTH OF THE STANDARD UNIVERSE MODEL

Abstract. The formation and evolution of dark matter and galaxies is one of the basic topics in cosmological research. This thesis uses numerical simulation to study the evolution of the universe under the cold dark matter model. The first chapter introduces the relevant background, including the theory of cosmology and structure formation, the evolution of dark matter levels and the physical processes of galaxy formation, and the numerical simulation tools we use: N-body simulation and semi-analytical galaxies formation models.The second part solves the local cavity crisis by using high-precision numerical simulation combined with semi-analytical model. The local void is considered to be the crisis of the standard cosmological model because the density of the galaxies is too low, and some of the predecessors believe that such low density cannot exist in the cosmic structure predicted by standard cosmology. We look for a system similar to the local space in the numerical simulation of standard cosmology, and then look for a structure similar to the local void to verify whether the local void exists in standard cosmology. Our work found that 77 similar local space systems can be found in the simulation, with a 14% chance of finding local voids nearby, indicating that local voids can exist entirely in the cold dark matter model. The reason for the extremely low density of local hollow galaxies is that it is mainly due to the low density of dark matter halos, and the influence of the environment on the formation of galaxies also reduces the number of galaxies by 25%.
Key words: Standard cosmological model, dark matter halo, local cavity crisis.

1. Basic theory of structural growth of the Universe

Since the universe is expanding, the universe must be smaller than it is in the past, and it will continue to go back to the past. The universe collapsed into a state of extremely high density and extremely high temperature. The current structure is formed by the "big bang" and subsequent surges. Hubble's Law finally introduces the now widely accepted "Big Bang" universe model. At the beginning of the "Big Bang", most astronomers considered it a joke, but since 1964, the discovery of microwave background radiation [1] has made the "Big Bang" cosmological model gradually mainstream.

From the theoretical point of view, the same expanded universe. In 1917, Einstein used the general theory of relativity to study the universe and found that the universe was not static, so he introduced cosmological constants to try to keep the universe stable. Subsequently, in 1922, Friedman combined the Robertson-Walker metric [2] to obtain the Friedman equation: assuming that the universe is homogeneously isotropic, then Robertson-Walker can be used at any point in the universe. Gauge representation

$$ds^2 = (cdt)^2 - a^2(t)\left[\frac{dr^2}{1-kr^2} + r^2\left(d\theta^2 + sin^2\theta d\phi^2\right)\right] \quad (1)$$

Where c is the speed of light, it can also be written as 1, $(r,\ \theta,\ \varphi)$ is the spatial co-polar polar system, t is the time, $a(t)$ is the scale factor, today is equal to 1, k is a constant, only the three values 1, 0, 1 represent the open, flat, and closed Universe. Using this metric, the Einstein field equation can be reduced to the Friedman equation:

$$\ddot{a} = -\frac{4\pi G}{3}a(\rho + \frac{3p}{c^2}) + [\frac{1}{3}\Lambda ac^2], \quad (2)$$

$$\dot{a}^2 = -\frac{8\pi G\rho}{3}a^2 - kc^2 + [\frac{1}{3}\Lambda a^2c^2], \quad (3)$$

Here G is the gravitational constant, ρ is the average density of the universe, and Λ is the cosmological constant. Define the basic parameters: Hubble constant $H = \dot{a}/a$, cosmic density $\Omega_m = 8\pi G\rho/3H^2$ and cosmological constant density $\Omega_\Lambda = \Lambda c^2/3H^2$, and assume that the cosmic curvature density is $\Omega_\kappa = -k/(aH)^2$. This formulacan be simplified to:

$$\Omega_m + \Omega_\Lambda + \Omega_k = 1 \quad (4)$$

This formula simply gives the three energies in the universe: the relationship between matter, curvature, and dark energy. $\Omega_{m,0}$, $\Omega_{\Lambda,0}$, $\Omega_{k,0}$ represent the average material density, cosmological constant density and curvature density of the current universe. Then the variation of the density of the universe with the scale factor is $\Omega_m = \Omega_{m,0}/a^3$, $\Omega_\Lambda = \Omega_{\Lambda,0}$ and $\Omega_k = \Omega_{k,0}/a^2$. Moreover, the relationship between the redshift and expansion factors of cosmology is:

$$1 + z = \frac{a(t_0)}{a(t)} = \frac{\lambda_{obs}}{\lambda} \quad (5)$$

Then, Equation 4 can be written as:

$$\frac{H^2(z)}{H_0^2} = \Omega_{m,0}(1+z)^3 + \Omega_{k,0}(1+z)^2 + \Omega_{\Lambda,0} \quad (6)$$

Where $\Omega_{m,0}$, $\Omega_{\Lambda,0}$, H_0 are the three basic cosmological constants. The curvature of the universe Ω_k is confirmed to be very close to $k \approx 0$ [3]. Cosmological constants can be measured by supernovae, large-scale structures, and microwave background radiation, as shown in Figure 1. As can be seen from the figure, the observations show that our universe is a flat, dark energy-dominated, constantly expanding universe. The latest PLANCK (Planck Collaboration et al., 2013) of the microwave background survey is given by the satellite: $H_0 = 67.3 \pm 1.2\ km/s/\ Mpc$, $\Omega_m = 0.315 \pm 0.017$, $\Omega_\Lambda = 0.685$, $\sigma_8 = 0.828$.

After knowing the three cosmological constants, you can integrate the backtracking time for a given redshift according to Equation 6:

$$t_0 - t_z = \frac{1}{H_0}\int_0^z \frac{dz}{\sqrt{\Omega_{m,0}(1+z)^5 + \Omega_{\Lambda,0}(1+z)^3}} \tag{7}$$

or use a scale factor to represent:

$$t_0 - t_z = \frac{1}{H_0}\int_{a(z)}^1 \frac{ada}{\sqrt{\Omega_{m,0}a + \Omega_{\Lambda,0}a^4}} \tag{8}$$

when $z = \infty$, the result is the age of the universe.

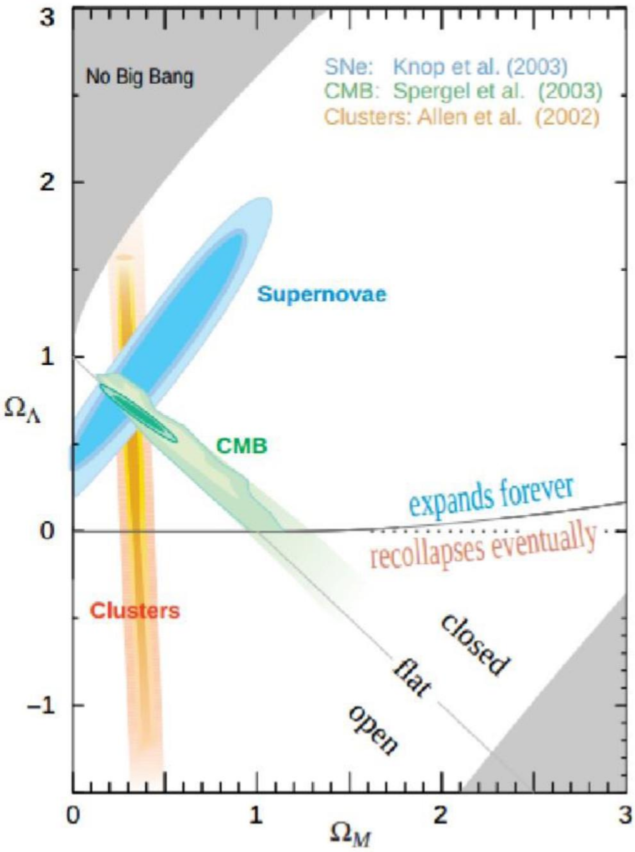

Figure 1 - CMB, supernova, and large galaxies are observed for $\Omega_{m,0}$ and $\Omega_{\Lambda,0}$ [4]

Existing observations and theories all herald a flat, accelerated expansion universe. According to the study of the structure of the universe, our universe is dominated by cold dark matter. This flat cosmological model dominated by cold and dark matter is what we usually call the standard cosmological model. The standard cosmological model can explain many of the major observations today, such as the large-scale distribution of galaxies [5], and the baryonic oscillations [6]. The small-scale clustering model of the cold-dark matter prophecy is also consistent with the observations, so the standard cosmological model is widely accepted. Our next work is carried out under the framework of standard cosmology. As observations and theoretical results advance, some observations seem to be unexplained using standard cosmological models, such as loss of satellite galaxies [7], density contours at dark centers [8]. . Some of these problems can be explained by galaxies forming models, and some may require new physical processes or alter the nature of dark matter. Looking forward to more deeper and broader observations in the future, it may bring us conceptual changes.

2. Basic properties of dark matter halo

The dark matter halo is the cornerstone of the cosmic structure. It is a system of Vary equilibrium, often defined as the area where the average density is 200 times the critical density of the universe. Of course there are other definitions of density, and we will not explain them one by one here. A very important parameter of dark matter halos is its mass distribution. From theoretical and numerical simulations, it is found that the density profile of dark matter conforms to the NFW profile:

$$\frac{\rho(r)}{\rho_{crit}} = \frac{\delta_c}{(r/r_s)(1+r/r_s)^2} \tag{9}$$

Here r_s is the characteristic scale of the dark matter halo, δ_c is the feature density, and $\rho_{crit} = 3H/8\pi G$ is the critical density of the universe. From the center to the edge of the dark matter halo, the density profile is excessive from r^{-1} to r^{-3}, and $\rho \propto r^{-2}$ at r_s. This density profile has been confirmed by many numerical simulations [9].

Through the density profile, you can define the compaction coefficient of the dark matter halo:

$$c = r_h / r_s \tag{10}$$

where r_h is the radius of the dark matter halo. In this paper, the radius of the dark matter halo is generally r_{200}, that is, when the density of the region is 200 times the critical density of the universe. The radius. The compacting factor is an important feature of the dark matter halo. It gives the degree of convergence of the material distribution in the dark matter halo. The larger the compacting factor, the darker material halo density distribution to the center, and vice versa. High-precision numerical simulations show that the compaction factor depends on the mass of the dark matter halo. For a given mass, the compaction factor depends on the formation time of the dark halo. The density profile of the dark matter halo determines its rotational velocity profile. After introducing the compaction factor, Navarro et al. (1997) also gave a rotational velocity profile at the NFW density profile:

$$\left[\frac{V_c(r)}{V_{200}}\right]^2 = \frac{1}{x}\frac{ln(1+cx) - \frac{cx}{1+cx}}{ln(1+c) - \frac{c}{1+c}} \tag{11}$$

Here V_{200} is the rotational speed at dark matter halo r_{200}, $x = r/R_{200}$. When $x \approx 2.16/c$, the rotation speed reaches the maximum V_{max}:

$$\left[\frac{V_{max}}{V_{200}}\right]^2 = \frac{0.216c}{ln(1+c) - \frac{c}{1+c}} \tag{12}$$

Therefore, the clamping factor can also be solved with V_{max}/V_{200}.

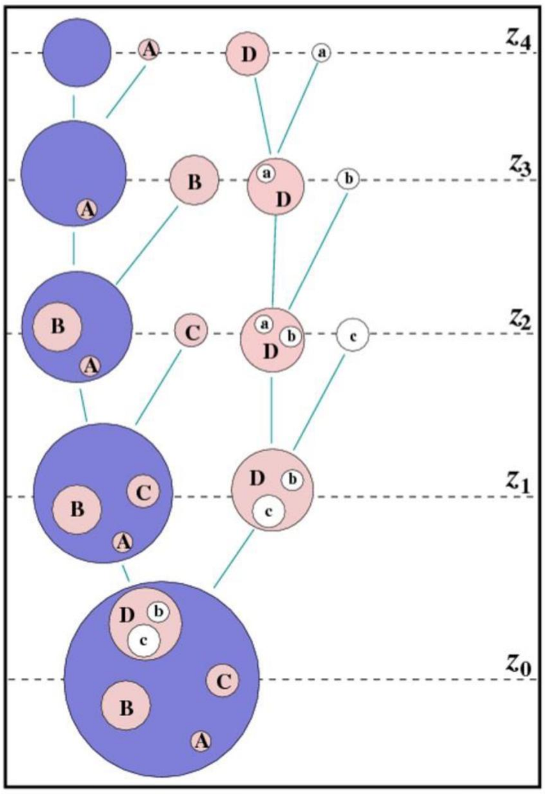

Figure 2 - Convergence tree of dark matter halos, you can see the structure of the dark halo after the combination

3. Dispels the Local Cavity Crisis of the Standard Cosmological Model

The neighboring galaxy survey found a hole around the cluster of galaxies, which does not contain galaxies, accounting for about 1/3 of the volume of the local space ($1Mpc < D < 8Mpc$ around the Milky Way). As the performance of the telescope increases, we can observe darker galaxies, and the samples are more complete, but with integrated optics and HI surveys, local voids still contain few galaxies [10].

Peebles and Nusser published an article in the American Journal of Nature in 2012 [11] claiming that the extremely low density of local voids cannot exist in standard cosmological theory. They combined the neighboring galaxy's catalogues at the time and found that there were 562 galaxies in the local space, and only three galaxies were in the local voids. However, in dark matter simulations, the dark matter halo density in the cavity is $1/10$ of the average density [12]. Combined with the HOD model [13], the luminosity function of the galaxy is monotonically related to the mass function of the dark matter halo. Peebles and Nusser believe that the standard cosmological numerical simulation predicts that there should be about 19 galaxies in the local cavity ($562 \times 1/10 \times 1/3$), 6 times higher than observation. Therefore, they believe that the extremely low density in the local void reality is a threat to the theory of the formation of cold dark matter structure. Maybe dark matter can't be cold, or you need to modify the intervention of gravitational theory to get this very low density cavity.

This view is limited by two factors. First, they only used a numerical simulation [14]. The scale of this simulation is not large. Using only one model to study local voids will make the results have large deviations and lose statistical significance. More numerical simulations are needed to statistically analyze the dark matter density in the cavity. Second, this work assumes that the HOD method applies the same law to dark matter halos in different environments. The effect of assembly bias is not considered. Dark matter halos, especially small mass dark halos, can be significantly different in different environments [15]. The galaxies in the local voids are very dark, and there are dark halos in the small mass, so the influence of the aggregation bias is large. Galaxies form a process of aggregation that depends on the dark matter halos of their host. So whether the HOD is directly used with a small mass of dark halo is still unknown.

Paper [16] used another method to detect whether the low density of local voids is consistent with standard cosmology. They also believe that local voids are a crisis. They assume that there are HI galaxies that can be observed in the dark halo with a wraparound speed greater than $25km \cdot s^{-1}$. They found that the number density of this dark halo in the cavity is an order of magnitude higher than the number density of the observed dwarf galaxies. But the correctness of their hypothesis remains to be discussed.

As mentioned earlier, the physical processes formed by galaxies and the evolution of dark matter halos are not exactly the same, and the dependence on the environment is not exactly the same. The above two work on local voids did not take this difference into account. In this paper, we use Millennium Simulation II [17], a large-scale high-precision simulation, combined with the formation of a semi-analytical model of the galaxy. The following question: Can the current understanding of standard cosmology and galaxies physics explain the existence of local voids; or whether new physical processes need to be invoked to explain observations.

4. Local voids in observations

The projected distribution of neighboring galaxies given in the work of [18] (Fig. 3). They used the neighboring galaxy catalog of Karachentsev [19] (K04) to select more accurately 337 galaxies from SDSS [20] and HIParkes All Sky Survey (HIPASS) [21], 172 and 53 galaxies were selected as supplements. It can be seen that about 1/3 of the area in the projection of the left figure in Figure 3 is a void with obvious boundaries, including only three galaxies.

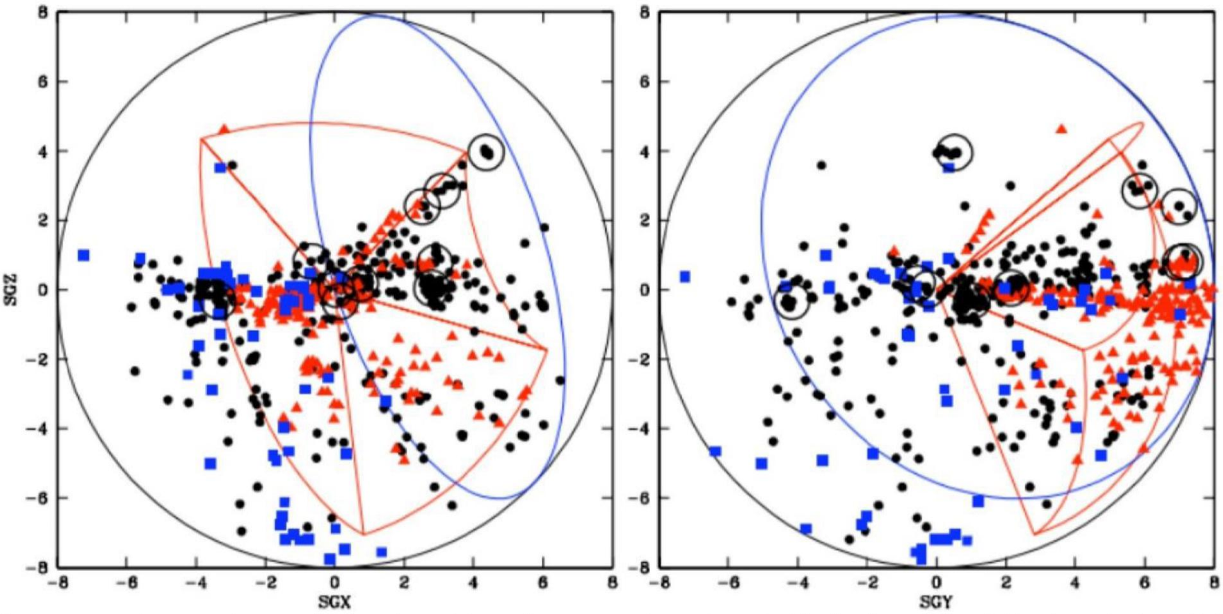

Figure 3 - Local space galaxy projections in Peebles and Nusser work. Each symbol in the figure is a neighboring galaxies within $1Mpc < D < 8Mpc$ around the Milky Way, and the left and right figures are the two projection directions in the super-galaxies coordinate system. The black dots in the picture are from K04, the red triangles are from the Sloan Digital Sky Survey, and the blue squares are from the HIPASS Sky Survey. Lines of the same color correspond to the coverage angles of these surveys

With the increase of observation accuracy, the observation samples of local space have been more complete in recent years. Karachentsev published the latest Neighbor Galaxy catalogue, newly added optical bands for the latest observations and HL surveyed galaxies, including SDSS [20] and HIPASS [21] data. The new catalogue measures the distance and luminosity of the galaxy more accurately; and removes some illuminating objects that are not galaxies. In this catalogue, the completeness of a galaxy with a $m_B < 17.5$, such as a star, is 70%–80%. In the new catalogue, within the range of $1Mpc < D < 8Mpc$ from the Milky Way, there are 486 galaxies that are brighter than $m_B < 17.5$, adding more than a hundred galaxies to K04. Peebles and Nusser also added SDSS and HIPASS galaxies to their work, but the distance measurements they added to the galaxy were not accurate, and some illuminating objects were misjudged as galaxies in the HIPASS patrol. So some of the galaxies they use don't exist in the latest catalogs we use, and there are many galaxies that change position on the projected map. We use the new star catalog to make the same projection of the neighboring galaxies in Figure 4. We only painted galaxies that are brighter than $m_B < 17.5$ and $1Mpc < D < 8Mpc$ from the Milky Way. Comparing Figure 4 with Figure 3, it can be seen that some of the galaxies in Figure 3 disappeared in Figure 4, and the three empty galaxies on the SGZ-SGX projection in Peebles work "disappear" in our diagram (Figure 4 in the blue dotted circle), one of the three missing galaxies is projected elsewhere, two galaxies that are judged to be false are not included in the new catalog, and some are scattered in the void projected in Figure 4 on.

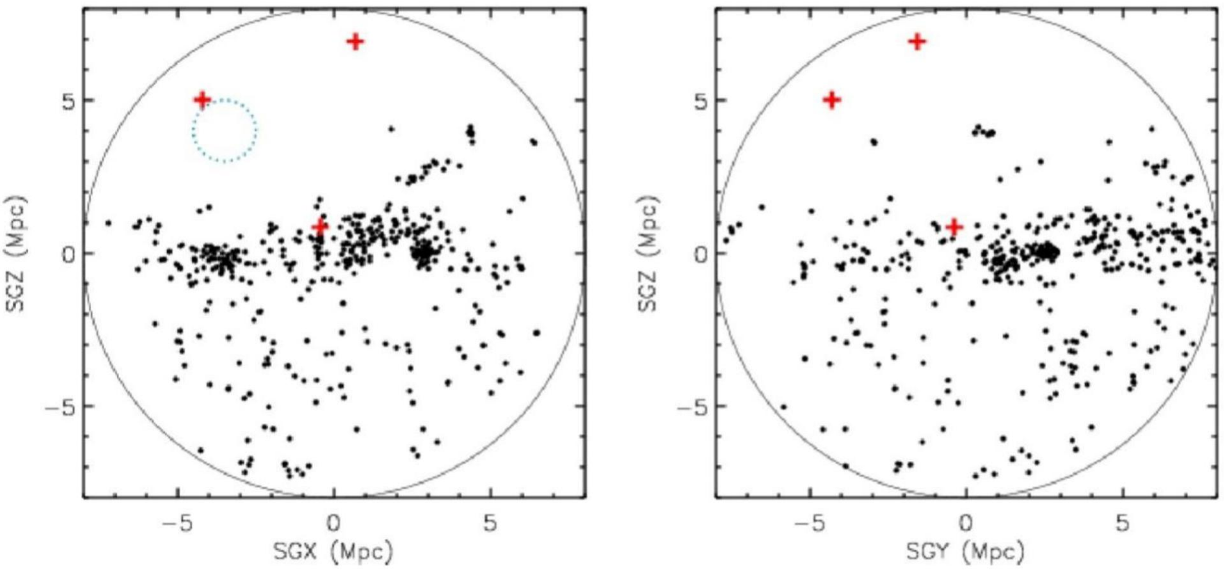

Figure 4 - Projection distribution of neighboring galaxies brighter than $m_B < 17.5$ in the nearest Galaxy K13 from the Milky Way $1Mpc < D < 8Mpc$. The left and right images are the projection directions in the two superclustered cluster coordinate systems. The red cross represents a galaxy that exists in a three-dimensional local void. The blue dotted circle gives the location of the three empty galaxies given in the Peebles and Nusser articles. But in the new catalog, the three galaxies “disappeared” because of the more accurate calculation of the distance

The size of the local hole depends on its definition. In the work of Peebles and Nusser, the volume of the cavity is calculated to be 1/3 of the total volume. It is worth noting that they are calculated from projections, and such voids are not real. In order to more accurately assess the degree of voiding in a local void, it is necessary to calculate the volume of the void in three dimensions. We use a cleaner and more accurate K13 to calculate the 3D volume of the local void, so that the resulting void is more realistic.

Because the local void is fan-shaped and has dense boundaries on the projected image, we suspect that the local void is similar to a cone in three dimensions. When determining local voids, we use a cone scan. Specifically, all of the neighboring galaxies are in a spherical shell of $1\,Mpc < R < 8\,Mpc$, and the center of the sphere is the Milky Way. We will have a cone representing the cavity, and the apex of the cone is the Milky Way. The orientation of the cone is determined by adjusting the orientation of the cone along the φ and θ of the spherical coordinates and calculating the number of galaxies falling into the cone. Because the void usually consists of a distinct boundary, the density of the star coefficients in the cone at the hole will plummet, so the shortest position we find is the local void. After finding the hole location, we experimented with different cone deflection angles and calculated the number of galaxies in the cavity to test the size of the hole. By this method, we get a cavity size of about π solid angle, which is 1/4 of the total volume, and contains three galaxies. These three galaxies are marked with a red cross in Figure 4.

5. Comparing simulated voids and observational voids

The actual hole size and star coefficient density are determined. Next, numerical simulations are needed to find out whether such holes exist in the numerical simulation of standard cosmology. First look for similar spaces in standard cosmological simulations based on the observed local space. The characteristics of the local space in the observation are: 1) The local galaxies in the observation contain a pair of giant galaxies: the Milky Way and M31, which are $0.77\,Mpc$ apart; 2) The Milky Way is a spiral galaxy with a mass of $6.4\times10^{10}\,M_\odot$ [22]; 3) The host dark halo mass of M31 is slightly smaller than that of the Milky Way host, but the mass of the star is larger, with $(10-15)\times10^{10}M_\odot$ [23]; 4) local galaxies There are no large clusters of galaxies in the surrounding $10Mpc$. In order to make the comparison between simulation and observation more authentic, we use the following constraints to find the local space from the numerical simulation.

First, we select galaxies like the Milky Way from the simulated star catalogues by stellar mass and morphology. The specific conditions are as follows: 1) The candidate galaxies must be disc-dominant, the nuclear sphere mass ratio is lower than $M_{bulge}/M_* < 0.5$; 2) the mass is similar to that of the Milky Way, $5.4\times10^{10}M_\odot < M_* < 7.4\times10^{10}M_\odot$. Then we find a system similar to the local galaxies from the candidate simulated galactic system by M31. The specific conditions are as follows: 3) Within 1Mpc around the candidate of the galactic system, at least one galaxies have a mass of $0.5\times M_{MW} < M_* < 2\times M_{MW}$ between. Because the Milky Way and M31 are the brightest galaxies in the galaxies, we require: 4) There are no galaxies in the $1Mpc$ space around the Milky Way that are twice as large as the Milky Way. Finally, because the nearest Virgo Cluster of Galaxy is about $12.8\,Mpc$ around the Milky Way, we require: 5) There is no dark halo in the $10\,Mpc$ around the simulated Milky Way with a mass greater than $10^{14}\,M_\odot$ to ensure that the local space in the simulation is also in a real situation. The same relatively isolated environment. Under these conditions, we have a total of 77 systems similar to local space in the MS-II numerical simulation.

Before finding a hole in a numerical simulation, in order to determine that our numerical simulation is believable, it is necessary to check whether the photometric function in our simulated local space is comparable to the observation. We use the distance to the Milky Way to calculate the visual star of the galaxy in the simulation. The black line gives the count of the galaxies in the observation K13, and the error bar is the Poisson error. The solid red line gives the median of 77 simulated local spaces and the dashed line is the 1 standard deviation range. It is clear that the star coefficient density of the simulated star catalog we used is very consistent with the observations. Note that in the figure, we have not corrected the completeness. In the observation, the completeness of the K13 galaxies is 70−90% at the apparent star $m_B = 17.5$. Therefore, the number of galaxies in the observation is evenly distributed at the dark end, while the number of galaxies in the simulation is continuously increasing at the dark end. We expect that higher-resolution observations in the future should complement more dark galaxies.

We use the method of finding local voids as described above to find holes in the simulated local space. We use a cone of the same size as the observed local hole, ie the solid angle is π scanned in the simulated local cavity, the position with the lowest density is defined as the void, and the number of empty galaxies is recorded N_{void}. Here, as with observations, the statistics are all galaxies that are brighter than $m_B < 17.5$. In our simulation, the shortest local void contains only one galaxy, even more empty than the local void in the observation. Considering the Poisson error, we have a sample with a number of empty galaxies less than 5 that are similar to local voids. Then, among our 77 simulated local spaces, there are local holes in 11 systems with a probability of 14%. Explain that the degree of voiding of local voids in the observation is not special.

A projection of the local void in the simulation is given in Figure 5. The figure shows the local space where the number of six empty galaxies is less than 5. Each figure shows all the galaxies in the $1Mpc < D < 8Mpc$ space around the simulated Milky Way, and the red cross represents the actual hollow galaxies (in three dimensions, not in the projected image that looks like voids). The local space of these simulations looks very similar to the actual observed local space (Figure 4).

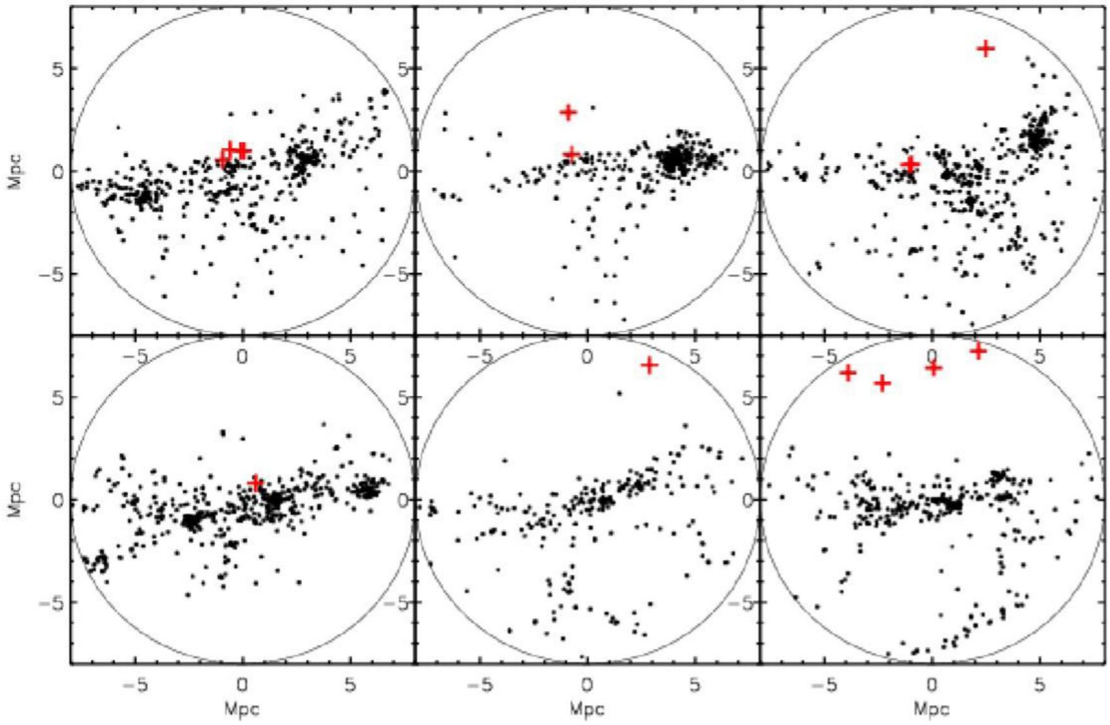

Figure 5 - Local voids in the simulation. Each black dot in the figure represents a galaxy, and all galaxies are brighter than mB< 17.5, within 1Mpc < D < 8Mpc of the simulated Milky Way. The red cross indicates the galaxy in the cavity

6. Summary

We use large-scale, high-precision dark matter numerical simulations of MSII,add the latest semi-analytical galaxy formation model [24], to study darker galaxies in local space. We focus on the problem of the degree of voiding in local voids. Prior to this, the local void problem was thought to be considered a threat to the theory of standard cosmological structure formation [25].

We use the latest star catalogue of neighboring galaxies [26] to recalculate the density of galaxies in local voids in 3D space. The star catalog we used and the star-to-surface ratio used by [25] added a large number of new galaxies and made more accurate measurements of distance. This catalogue has a completeness of 70−80% at a star level of $m_B = 17.5$. We use a cone to simulate the shape of a three-dimensional cavity, use a three-dimensional cone scan to find a three-dimensional local cavity in a new star table, and then adjust the size of the cone to measure the volume of the cavity. We found that the local void in the observations accounted for approximately 1/4 of the local space and contained three galaxies. We use the same approach in the simulated local space for systems of the same size and similar cavities. We found that 14% of the simulated local space contains structures similar in size and hole to local voids. These simulated local voids are not only similar in number to galaxies, but their projections are also very similar to the observed local voids. This shows that local voids are not a threat to standard cosmological theory, but exist in the predictions of standard cosmology. In other words, local voids are the success of standard cosmology.

In the local voids we simulated, the low density of galaxies was mainly due to the low density of dark matter halos in the voids. At the same time, the environmental convergence caused by the dark matter halo during the formation process will affect the formation process of the cavity galaxies, resulting in a 25% lower mass function of the galaxies in the same mass dark matter halo.

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ҚАРАҢҒЫ МАТЕРИЯНЫҢ ЭВОЛЮЦИЯСЫ ЖӘНЕ СТАНДАРТТЫ ӘЛЕМДІК МОДЕЛЬДІҢ ҚҰРЫЛЫМДЫҚ ӨСУІНІҢ НЕГІЗГІ ТЕОРИЯСЫ

Аннотация. Қараңғы материямен галактикалардың пайда болуы және эволюциясы – космологиялық зерттеулердегі негізгі тақырыптардың бірі. Бұл мақалада қараңғы материяның суық моделі бойынша ғаламның эволюциясын зерттеу үшін сандық модельдеу қолданылады. Бірінші бөлімде космология мен құрылымның қалыптасу теориясы, қараңғы материя деңгейінің эволюциясы және галактиканың қалыптасуының физикалық процестері, сондай-ақ біз қолданатын сандық құралдар: N-денені модельдеу және жартылай аналитикалық галактикалардың қалыптасу теориялары сияқты тиісті мәліметтер келтірілген.

Екінші бөлім жартылай аналитикалық модельмен біріктірілген жоғары дәлдікті сандық модельдеуді қолдану арқылы жергілікті қуыстың дағдарысын шешеді. Жергілікті бос орын стандартты космологиялық модельдің дағдарысы деп саналады, өйткені галактикалардың тығыздығы тым төмен, ал кейбір болжамдар мұндай төмен тығыздық стандартты космология тұжырымдамасында ғарыштық құрылымда бола алмайды деп санайды.

Біз стандартты космологияны сандық модельдеуде жергілікті кеңістікке ұқсас жүйені іздейміз, содан кейін стандартты космологияда жергілікті қуыстың бар-жоғын тексеру үшін жергілікті қуысқа ұқсас құрылымды іздейміз. Біздің жұмысымызда 77 ұқсас жергілікті ғарыштық жүйелерді модельде табуға болатындығы, жергілікті бос жерлердің 14% мүмкіндігі бар екендігі анықталды, бұл жергілікті бос орындар толығымен суық қара материя моделінде өмір сүре алатындығын көрсетеді. Жергілікті қуыс галактикалардың өте төмен тығыздығының себебі, бұл негізінен қараңғы материялар галосының тығыздығының төмендігі мен байланысты және галактикалардың пайда болуына қоршаған ортаның әсері де галактикалар санын 25% төмендетеді.

Түйін сөздер: стандартты космологиялық модель, қара матералды гало, қуыстың жергілікті дағдарысы.

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ЭВОЛЮЦИЯ ТЕМНОЙ МАТЕРИИ И ФОРМИРОВАНИЕ БАЗОВОЙ ТЕОРИИ СТРУКТУРНОГО РОСТА СТАНДАРТНОЙ МОДЕЛИ ВСЕЛЕННОЙ

Аннотация. Формирование и эволюция темной материи и галактик является одной из основных тем в космологических исследованиях. Этот тезис использует численное моделирование для изучения эволюции Вселенной в рамках модели холодной темной материи. В первой части представлен соответствующий фон, включая теорию космологии и формирования структуры, эволюцию уровней темной материи и физические процессы образования галактик, а также инструменты численного моделирования, которые мы используем: моделирование N-тел и полуаналитические модели формирования галактик. Вторая часть решает локальный кризис полости с помощью высокоточного численного моделирования в сочетании с полуаналитической моделью. Локальная пустота считается кризисом стандартной космологической модели, потому что плотность галактик слишком мала, и некоторые предшественники считают, что такая низкая плотность не может существовать в космической структуре, предсказываемой стандартной космологией. Мы ищем систему, подобную локальному пространству, в численном моделировании стандартной космологии, а затем ищем структуру, подобную локальной пустоте, чтобы проверить, существует ли локальная пустота в стандартной космологии. Наша работа показала, что в симуляции можно найти 77 подобных локальных космических систем с 14% -ной вероятностью нахождения локальных пустот поблизости, что указывает на то, что локальные пустоты могут существовать полностью в модели холодной темной материи. Причина чрезвычайно низкой плотности локальных полых галактик заключается в том, что это происходит главным образом из-за низкой плотности гало темной материи, а влияние окружающей среды на образование галактик также уменьшает количество галактик на 25%.

Ключевые слова: стандартная космологическая модель, гало темной материи, локальный кризис полости.

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