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# Galaxy Evolution by the Incompatibility between Dark Matter and Baryonic Matter

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## Abstract

**The paper derives the galaxy evolution by the non-interacting (incompatibility) between dark matter and baryonic matter in terms of the short-range separation between dark matter and baryonic matter, so dark matter cannot contact baryonic matter. In the conventional CDM (cold dark matter) model, dark matter and baryonic matter are interactive (compatible), so dark matter can contact baryonic matter. However, the conventional CDM model fails to account for the failure to detect dark matter by the contact (interaction) between dark matter and baryonic matter, the shortage of small galaxies, the abundance of spiral galaxies, the old age of large galaxies, and the formation of thin spiral galaxies. The non-interacting (incompatible cold dark matter) model can account for these observed phenomena. The five periods of baryonic structure development in the order of increasing non-interacting (incompatibility) are the free baryonic matter, the baryonic droplet, the galaxy, the cluster, and the supercluster periods.**

## Keywords

**Galaxy Evolution, CDM, Dark Matter, MOND, Baryonic Matter, Incompatible Dark Matter, ICDM**

## 1. Introduction

The conventional model for galaxy evolution is the CDM (cold dark matter) model. In the CDM model, dark matter and baryonic matter are interactive (compatible), so dark matter can contact baryonic matter. In the CDM model, the primordial fluctuation led to uneven distribution of dark matter. The cooling of the universe allowed clumps of dark matter and baryonic matter to condense, resulting in the first protogalaxies consisting of hydrogen, helium, and dark matter. The condensation of hydrogen and helium in protogalaxies led to the first stars, resulting in the first galaxies. The small first galaxies merged to form large galaxies in terms of hierarchical formation. The CDM model is successful to explain some phenomena, but there are a number of fundamental pro-

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blems [1] as follows:

1) Dark matter has not been detected by the contact (interaction) between dark matter and baryonic matter.

2) For the purpose of merger, the CDM model predicts too many small galaxies in disagreement with the observation.

3) The CDM model underestimates the number of spiral galaxies. Spiral galaxies are very fragile, and can be destroyed easily by galaxy merger.

4) Contrary to hierarchical formation, large elliptical galaxies on average are older than small elliptical galaxies. This effect is called downsizing.

5) The CDM model cannot produce thin spiral galaxies which are quite common in observation.

The fundamental problems in the CDM model imply that a fundamental change for the CDM model is needed. The purpose of the paper is to propose a new model that is able to solve these problems in the CDM model. The proposed model for such change is the ICDM (incompatible cold dark matter) model. In the ICDM model, dark matter and baryonic matter are incompatible in term of the short-range separation between dark matter and baryonic matter, so dark matter cannot contact baryonic matter. The short-range repulsive gravitational force and the long-range attractive gravitational force exist between dark matter and baryonic matter. The solutions for the problems listed above are as follows:

1) In the ICDM model, the incompatibility explains the failure to detect dark matter by the contact (interaction) between dark matter and baryonic matter.

2) The way to form the first generation galaxies in the ICDM model is different from the CDM model. The first generation galaxies in ICDM model appeared to be small, but the condition to form large galaxies (elliptical, spiral, and irregular) already existed in the surrounding gas without the need of galaxy merger. The subsequent external and internal interactions in the first generation galaxies generated the second generation galaxies. Most galaxies are the first generation galaxies. The ICDM model does not need many small galaxies for merger.

3) In the ICDM model, most of spiral galaxies were formed as the first generation galaxies without the need of merger.

4) In the ICDM model, most large galaxies were formed typically as the first generation galaxies, so they are older than small galaxies which were formed typically as the second generation galaxies from the interactions among first generation galaxies.

5) In the ICDM model, the first generation galaxies include the thin spiral galaxies as well as all other types of galaxies.

In Section 2, the separation and the incompatibility of baryonic matter and dark matter is by the repulsive gravitational force based on MOND. Section 3 deals with the early universe before the formation of galaxies, Section 4 describes the formation of the first generation galaxies, and Section 5 explains the formation of the second generation galaxies.

## 2. The Separation of Baryonic Matter and Dark Matter

Gentile, Famaey, Zhao andSalucci found a close correlation between the enclosed surface densities of baryonic matter and dark matter in galaxies [2]. Within one scale length of the dark halo in galaxies, the baryonic matter surface density and the dark matter surface density are constant, even though total baryonic matter-to-dark matter ratio is not constant.Li and Zhou propose a fifth force for dark matter to account for the universality of galactic surface densities and the segregation of dark matter and baryonic matter [3].

In this paper, such fifth force is proposed to be the short-range repulsive gravitational force [4] based on modified Newtonian dynamics (MOND) [5] [6] existed in the interfacial region between baryonic matter and dark matter. The long-range attractive gravitational force continues to exist between baryonic matter and dark matter. The short-range repulsive gravitational force is to maintain the incompatibility between dark matter and baryonic matter in terms of the short-range separation between dark matter and baryonic matter. The model is the ICDM (incompatible cold dark matter) model.

Such incompatible dark matter is defined in the Reference [7]. Defined in the Reference [7], dark matter does not have electromagnetism, and is incompatible with baryonic matter. Dark matter has been detected only indirectly by means of its gravitational effects astronomically. The short-range incompatibility explains the failure to detect dark matter by the contact (interaction) between dark matter and baryonic matter. The Reference [7] provides the mass ratio (5 to 1) of dark matter to baryonic matter in agreement with the observation [8]. Basically, during the inflation before the Big Bang, dark matter, baryonic matter, cosmic radiation, and the gauge force fields are generated. Without electromagnetism, dark matter cannot emit light, and is incompatible to baryonic matter. Like nonpolar oil, dark matter is completely nonpolar. The common link between baryonic matter and dark matter is the cosmic radiation. With the high concentration of cosmic radiation at the beginning of the Big Bang, baryonic matter and dark matter were completely compatible. As the universe aged and expanded, the concentration of cosmic concentration decreased, resulting in the increasing incompatibility between baryonic matter and dark matter until the incompatibility reached the maximum value with low concentration of cosmic radiation.

The incompatibility is expressed in the form of the repulsive MOND (modified Newtonian dynamics) force field. MOND proposes the deviation from the Newtonian dynamics in the low acceleration region in the outer region of a galaxy. This paper proposes the MOND forces in the interface between the baryonic matter region and the dark matter region [9]. In the interface, the same matter materials attract as the conventional attractive MOND force, and the different matter materials repulse as the repulsive MOND force between baryonic matter and dark matter.

In **Figure 1**, the inner part is the baryonic matter region, the middle part is the interface, and the outer part is the dark matter region. The MOND forces in the interface are the interfacial attractive force (conventional MOND force), $F_{\text{i-A}}$, among the same matter materials and the interfacial repulsive force (repulsive MOND force), $F_{\text{i-R}}$, between baryonic matter material and dark matter material. The interfacial repulsive force enhances the interfacial attractive force toward the center of gravity in terms of the interfacial acceleration, $a_i$.

The border between the baryonic matter region and the interface is defined by the acceleration constant, $a_0$. The interfacial acceleration is less than $a_0$. The enhancement is expressed as the square root of the product of $a_i$ and $a_0$. In the baryonic matter region, $a_b$ is greater than $a_0$, and is equal to normal Newtonian acceleration as Equation (1).

$$\begin{aligned} &a_0 \ll a_b,\ a_b = a_N \ \text{ in the baryonic matter region} \\ &a_0 \gg a_i,\ a_i = \sqrt{a_N a_0} \ \text{ in the interfacial region} \end{aligned} \tag{1}$$

The interfacial attractive force in the interface with the baryonic matter region is expressed as Equation (2) where m is the mass of baryonic material in the interface.

$$F_{\text{i-A}} = m a_N = m \frac{a_i^2}{a_0} \tag{2}$$

The comparison of the interfacial attractive force, $F_{\text{i-A}}$, and the non-existing interfacial Newtonian attractive force, $F_{\text{i-Newton}}$ in the interface is as Equations (3)-(5), where $G$ is the gravitation constant, $M$ is the mass of the baryonic materialin the baryonic matter region, and $r$ the distance between the gravitational center and the material in the interfacial region.

$$\begin{aligned} F_{\text{i-A}} &= \frac{GMm}{r^2} = m\frac{a^2}{a_0} \\ F_{\text{i-Newton}} &= \frac{GMm}{r^2} = ma \end{aligned} \tag{3}$$

$$\begin{aligned} a_i &= \frac{\sqrt{GMa_0}}{r} \\ a_{\text{i-Newton}} &= \frac{GM}{r^2}, \end{aligned} \tag{4}$$

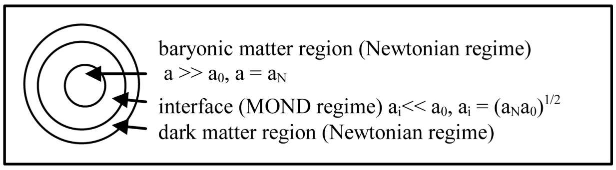

**Figure 1.** The interfacial region between the baryonic and the dark matter regions.

$$
\begin{aligned}
F_{\text{i-A}} &= \frac{m\sqrt{GMa_0}}{r} \\
F_{\text{i-Newton}} &= \frac{mGM}{r^2},
\end{aligned}
\tag{5}
$$

The interfacial attractive force decays with $r$, while the interfacial Newtonian force decays with $r^2$. Therefore, in the interface when $a_0 \gg a_i$, with sufficient dark matter, the interfacial repulsive force, $F_{\text{i-R}}$, is the difference between the interfacial attractive force and the interfacial Newtonian force as Equation (6).

$$
\begin{gathered}
a_0 \gg a_i, \text{ in the interfacial region} \\
F_{\text{i-R}} = F_{\text{i-A}} - F_{\text{i-Newton}} = m\left(\frac{\sqrt{GMa_0}}{r} - \frac{GM}{r^2}\right)
\end{gathered}
\tag{6}
$$

The same interfacial attractive force and the interfacial repulsive force also occur for dark matter in the opposite direction. Thus, the repulsive MOND force filed results in the separation of baryonic matter and dark matter.

The acceleration constant, $a_0$, represents the maximum acceleration constant for the maximum incompatibility between baryonic matter and dark matter. The common link between baryonic matter and dark matter is cosmic radiation resulted from the annihilation of matter and antimatter from both baryonic matter and dark matter. With the high concentration of cosmic radiation at the Big Bang, baryonic matter and dark matter are completely compatible. As the universe ages and expands, the concentration of cosmic concentration decreases, resulting in the increasing incompatibility between baryonic matter and dark matter. The incompatibility reaches maximum when the concentration of cosmic radiation becomes is too low for the compatibility between baryonic matter and dark matter. Therefore, for the early universe before the formation of galaxy when the concentration of cosmic radiation is still high, the time-dependent Equation (1) is as Equation (7).

$$
a_i = \sqrt{\frac{a_N a_0 t}{t_0}} \quad \text{for } t_0 \geq t,
\tag{7}
$$

where $t$ is the age of the universe, and $t_0$ is the age of the universe to reach the maximum incompatibility between baryonic matter and dark matter. The increase in time leads to the increase in the repulsive force up to the maximum value.

$$
\begin{gathered}
a_0 \gg a_i, \text{ in the interfacial region} \\
F_{\text{i-R}} = F_{\text{i-A}} - F_{\text{i-Newton}} = m\left(\frac{\sqrt{GMa_0 t/t_0}}{r} - \frac{GM}{r^2}\right)
\end{gathered}
\tag{8}
$$

To minimize the interface and the interfacial forces, the same matter materials increasingly come together to form the matter droplets separating from the different matter materials. The increasing formation of the matter droplets with increasing incompatibility is similar to the increasing formation of oil droplets with increasing incompatibility between nonpolar oil and polar water. Since there were more dark matter materials than baryonic matter materials, baryonic droplets were surrounded by dark matter materials. The early universe was characterized by the increases in the size and the number of the matter droplets due to the increasing incompatibility between baryonic matter and dark matter. As the universe expanded, dark matter materials could not cover the whole universe continuously, so voids appeared in the dark matter region, resulting in the formation of continuous dark matter filaments as dark matter halo surrounding baryonic droplets.

## 3. The Early Universe before the Formation of Galaxies

The Inflationary Universe scenario [10] provides possible solutions of the horizon, flatness and formation of structure problems. In the standard inflation theory, quantum fluctuations during the inflation are stretched exponentially so that they can become the seeds for the formation of inhomogeneous structure such as galaxies and galaxy clusters.

This paper posits that the inhomogeneous structure comes from both quantum fluctuation during the inflation and the increasing repulsive MOND force between baryonic matter and dark matter after the inflation. As mentioned in the previous section, the increasing repulsive MOND force field with the increasing incompatibility in the early universe resulted in the increase in the size and number of the matter droplets.

For the first few hundred thousand years after the Big Bang (which took place about 13.7 billion years ago), the universe was a hot, murky mess, with no light radiating out. Because there was no residual light from that early epoch, scientists cannot observe any traces of it. But about 400,000 years after the Big Bang, temperatures in the universe cooled, electrons and protons joined to form neutral hydrogen as the recombination. The inhomogeneous structure as the baryonic droplets by the incompatibility between baryonic matter and dark matter is observed [11] as anisotropies in CMB (cosmic microwave background).

As the universe expanded after the time of recombination, the density of cosmic radiation decreased, and the size of the baryonic droplets increased with the increasing incompatibility between baryonic matter and dark matter. The growth of the baryonic droplet by the increasing incompatibility from the cosmic expansion coincided with the growth of the baryonic droplet by gravitational instability from the cosmic expansion. The formation of galaxies is through both gravitational instability and the incompatibility between baryonic matter and dark matter.

The pre-galactic universe consisted of the growing baryonic droplets surrounded by the dark matter halos, which connected among one another in the form of filaments and voids. These dark matter domains later became the dark matter halos, and the baryonic droplets became galaxies, clusters, and superclusters.

When there were many baryonic droplets, the merger among the baryonic droplets became another mechanism to increase the droplet size and mass. When three or more homogeneous baryonic droplets merged together, dark matter was likely trapped in the merged droplet ((c), (d), (e), and (f) in **Figure 2**). The droplet with trapped dark matter inside is the heterogeneous baryonic droplet, while the droplet without trapped dark matter inside is the homogeneous baryonic droplet ((a) and (b)).

In the heterogeneous droplets (c), (d), (e), and (f), dark matter was trapped in the cores of the baryonic droplets. Because of the prevalence of dark matter, almost all baryonic droplets were the heterogeneous droplets. There were the dark matter core, the baryonic matter shell, and the dark matter halo around the baryonic droplet, resulting in two repulsive forces as the pressures between the dark matter core and the baryonic matter shell and between the baryonic shell and the dark matter halo. In the equilibrium state, the internal pressure between the dark matter core and the baryonic matter shell was same as the external pressure between the baryonic shell and the dark matter halo.

## 4. The Formation of the First Generation Galaxies

When the temperature dropped to ~1000˚K, some hydrogen atoms in the droplet paired up to create the primordial molecular layers. Molecular hydrogen cooled the primordial molecular layers by emitting infrared radiation after collision with atomic hydrogen. Eventually, the temperature of the molecular layers dropped to around 200 to 300˚K, reducing the gas pressure and allowing the molecular layers to continue contracting into gravitationally bound dense primordial molecular clouds. The diameters of the primordial molecular clouds could be up to 100 light-years with the masses of up to 6 million solar masses. Most of baryonic droplets contained thousands of the primordial molecular clouds.

The formation of the primordial molecular clouds created the gap in the baryonic matter shell. The gap allowed the dark matter in the dark matter core to leak out, resulting in a tunnel between the dark matter core and the external dark matter halo. The continuous leaking of the dark matter expanded the tunnel. Consequently, the dark matter in the dark matter core rushed out of the dark matter core, resulting in the "droplet eruption". The ejection of the dark matter from the dark matter core reduced the internal pressure between the dark matter core and the baryonic matter shell.

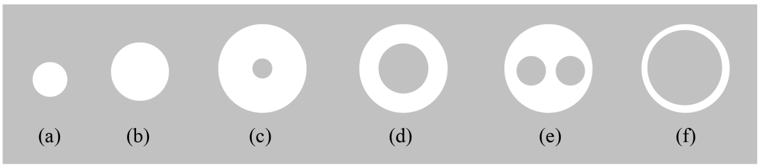

**Figure 2.** Homogeneous baryonic droplets (a), and (b), and the heterogeneous baryonic droplets (c)-(f).

During the ejection of dark matter, the ejected dark matter carried some baryonic matter to travel along the dark matter filaments of dark matter halo. The ejected baryonic matter was dominated by dark matter, resulting eventually in the dark matter-dominated dwarf spheroidal galaxies which are observed as satellite galaxies arranged on a plane. The explanation of dwarf spheroidal galaxies is essentially same as the explanation by Noam I. Libeskind who proposes that the satellite galaxies did not flock to the Milky Way from all directions, but were shot towards it along cosmic superhighways of dark matter, thus giving the satellites a preferred direction and alignment [12].

The external pressure between the baryonic matter shell and the dark matter halo caused the collapse of the baryonic droplet. The collapse of the baryonic droplet is like the collapse of a balloon as the air (as dark matter) moves out the balloon. The collapse of the baryonic droplet forced the head-on collisions of the primordial molecular clouds in the baryonic matter shell. In the center of the collapsed baryonic droplet, the head-on collisions of the primordial molecular clouds generated the shock wave as the turbulence in the collided primordial molecular clouds. The turbulence triggered the collapse of the core of the primordial cloud. The core fragmented into multiple stellar embryos, in each a protostar nucleated and pulled in gas. Without the heavy elements to dissipate heat, the mass of the primordial protostar was 500 to 1000 solar masses at about 200˚K. The primordial protostar shrank in size, increased in density, and became the primordial massive star when nuclear fusion began in its core. The massive primordial star formation is as follows.

$$\begin{aligned}
&\text{incompatible dark matter and baryonic matter} \longrightarrow \text{homogeneous baryonic droplets} \\
&\xrightarrow{\text{combination}} \text{heterogeneous baryonic droplet} \xrightarrow{\text{the cooling}} \text{molecular clouds in baryonic matter shell} \\
&\xrightarrow{\text{eruption, collapse, and collision}} \text{protostar} \xrightarrow{\text{nuclear fusion}} \text{massive primordial star}
\end{aligned}$$

The intense UV radiation from the high surface temperature of the massive primordial stars started the reionization effectively, and also triggered further star formation. The massive primordial stars were short-lived (few million years old). The explosion of the massive primordial stars was the massive supernova that caused reionization and triggered star formation. The heavy elements generated during the primordial star formation scattered throughout the space. The dissipation of heat by heavy elements allowed the normal rather than massive star formation. With many ways to trigger star formation, the rate of star formation increased rapidly. The droplet eruption that initiated the star formation started to occur about 400 million years after the Big Bang, and the reionization started to occur soon after. The rate of star formation peaked about 2 billion years after the Big Bang [13].

Since the head-on collision of the molecular clouds took place at the center of the collapsed baryonic droplet, the star formation started in the center of the collapsed baryonic droplet. With other ways to trigger star formation, the star formation propagated away from the center. The star formation started from the center from which the star formation propagated, so the primordial galaxies appeared to be small surrounded by the large hydrogen blobs. The surrounding large hydrogen blobs corresponds to the observed Lyman alpha blobs of Lyman alpha (Lya) emission by hydrogen, which have been discovered in the vicinity of galaxies at early cosmic times. The amount of hydrogen in the blobs was also increased by the incoming abundant intergalactic hydrogen. The repulsive dark matter halos prevented the hydrogen gas inside from escaping from the galaxies. Dijkstra and Loeb [14] posited that the early galaxies grew quickly by the cold accretion mode from the observed Lyman alpha blobs. The growth by the merger of galaxies was too slow for the observed fast growth of the early galaxies.

If there was small dark matter core as in the heterogeneous baryonic droplet ((c) in **Figure 2**), the droplet eruption took relatively short time to cause the collapse of the baryonic droplet. The change in the shape of the baryonic droplet after the collapse was relatively minor. The density was high for the small dark matter core in the droplet. The high density led to high rate of star formation. All the gas was used up in an initial burst, the galaxy formed as a smooth round shape, an elliptical.The collapse results in elliptical shape in $E_0$ to $E_7$ elliptical galaxies, whose lengths of major axes are proportional to the relative sizes of the dark matter core. Because of the short time for the collapse of the baryonic droplet, the star formation by the collapse occurred quickly at the center (**Figure 3**).

Most of the primordial stars merged to form the supermassive center, resulting in the quasar galaxies. Such first quasar galaxies that occurred as early as $z = 6.28$ were observed to have about the same sizes as the Milky Way [15]. This formation of galaxy follows the monolithic collapse model in which baryonic gas in galaxies

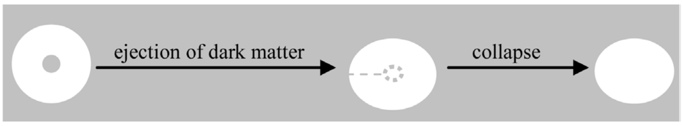

**Figure 3.** The formation of elliptical galaxy.

collapses to form stars within a very short period, so there are small numbers of observed young stars in elliptical galaxies. Elliptical galaxies continue to grow slowly as the universe expands.

If the size of the dark matter core is medium ((d) in **Figure 2**), the collapse of the baryonic droplet caused a large change in shape, resulting in the rapidly rotating disk as spiral galaxy. The density was medium for the medium dark matter core in the droplet. The medium density led to medium rate of star formation. All the gas was not used up in an initial burst, so the gas underwent collisions and conservation of angular momentum formed a spiral. The rapidly rotating disk underwent differential rotation with the increasing angular speeds toward the center. After few rotations, the structure consisted of a bungle was formed and the attached spiral arms as spiral galaxy as **Figure 4**.

The spiral galaxy took longer time to erupt and collapse than the elliptical galaxy, so the star formation was later than elliptical galaxy. Because of the large size of the dark matter core, the density of the primordial molecular clouds was lower than elliptical galaxy, so the rate of star formation in spiral galaxy is slower than elliptical galaxy. During the collapse of the baryonic droplet, some primordial molecular clouds moved away to form globular clusters near the main group of the primordial molecular clouds. Most of the primordial massive stars merged to form the supermassive center. The merge of spiral galaxies with comparable sizes destroys the disk shape, so most spiral galaxies are not merged galaxies.

When two dark matter cores inside far apart from each other (E in **Figure 2**) generated two openings in opposite sides of the droplet, the dark matter could eject from both openings. The two opening is equivalent to the overlapping of two ellipses, resulting in the thick middle part, resulting in the star formation in the thick middle part and the formation of barred spiral galaxy. The differential rotation is similar to that of spiral galaxy as **Figure 5**.

As in normal spiral galaxy, the length of the spiral arm depends on the size of the dark matter core. The smallest dark matter core for barred spiral galaxy brings about SBa, and the largest dark matter core brings about SBd. The stars form in the low-density spiral arms much later than in the nucleus, so they are many young stars in the spiral arms. In barred spiral galaxy, because of the larger dark matter core area than normal spiral galaxy, the star formation occurred later than normal spiral galaxy, and the rate of star formation was slower than normal spiral galaxy.

If the size of the dark matter core was large (F in **Figure 2**), the eruption of the dark matter in the dark matter core occurred easily in multiple places. The baryonic matter shell became fragmented, resulting in irregular galaxy. The turbulence from the collapse of the baryonic droplet was weak, and the density of the primordial molecular clouds was low, so the rate of star formation was slow. The star formation continues in a slow rate up to the present time.

## 5. The Formation of the Second Generation Galaxies

At the end of the droplet eruption, vast majority of baryonic matter was primordial free baryonic matter resided in dark matter outside of the galaxies from the droplet eruption. This free baryonic matter constituted the intergalactic medium (IGM). Stellar winds, supernova winds, and quasars provide heat and heavy elements to the IGM as ionized baryonic atoms. The heat prevented the formation of the baryonic droplet in the IGM.

Galaxies merged into new large galaxies, such as giant elliptical galaxy and cD galaxy ($z > 1 - 2$). Similar to the transient molecular cloud formation from the ISM (inter-stellar medium) through turbulence, the tidal debris and turbulence from the mergers generated the numerous transient molecular regions, which located in a broad area [16]. The incompatibility between baryonic matter and dark matter transformed these transient molecular regions into the stable second-generation baryonic droplets surrounded by the dark matter halos. The baryonic droplets had much higher fraction of hydrogen molecules, much lower fraction of dark matter, higher density, and lower temperature, and lower entropy than the surrounding.

During this period, the acceleration constant reached to the maximum value with the maximum incompatibility between baryonic matter and dark matter. The growth of the baryonic droplets did not depend on the increasing incompatibility. The growth of the baryonic droplets depended on the turbulences that carried IGM to the

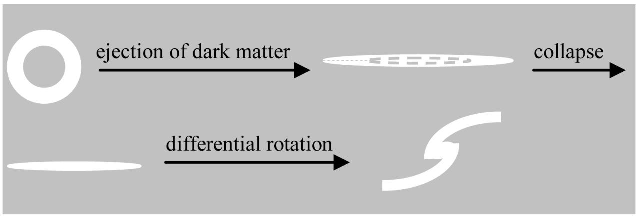

**Figure 4.** The formation of spiral galaxy.

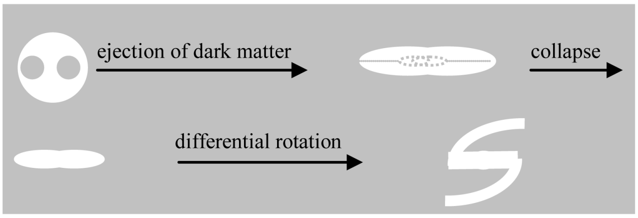

**Figure 5.** The formation of barred spiral galaxy.

baryonic droplets. The rapid growth of the baryonic droplets drew large amount of the surrounding IGM inward, generating the IGM flow shown as the cooling flow. The IGM flow induced the galaxy flow. The IGM flow and the galaxy flow moved toward the merged galaxies, resulting in the protocluster ($z$ - 0.5) with the merged galaxies as the cluster center.

Before the protocluster stage, spirals grew normally and passively by absorbing gas from the IGM as the universe expanded. During the protoculster stage ($z$ - 0.5), the massive IGM flow injected a large amount of gas into the spirals that joined in the galaxy flow. Most of the injected hot gas passed through the spiral arms and settled in the bungle parts of the spirals. Such surges of gas absorption from the IGM flow resulted in major starbursts ($z$ - 0.4) [17]. Meanwhile, the nearby baryonic droplets continued to draw the IGM, and the IGM flow and the galaxy flow continued. The results were the formation of high-density region, where the galaxies and the baryonic droplets competed for the IGM as the gas reservoir. Eventually, the maturity of the baryonic droplets caused a decrease in drawing the IGM inward, resulting in the slow IGM flow. Subsequently, the depleted gas reservoir could not support the major starbursts ($z$ - 0.3). The galaxy harassment and the mergers in this high-density region disrupted the spiral arms of spirals, resulting in $S_0$ galaxies with indistinct spiral arms (z - 0.1 - 0.25). The transformation process of spirals into $S0$ galaxies started at the core first, and moved to the outside of the core. Thus, the fraction of spirals decreases with decreasing distance from the cluster center.

The static and slow-moving second-generation baryonic droplets turned into globular clusters. The fast moving second-generation baryonic droplets formed the second-generation baryonic stream, which underwent a differential rotation to minimize the interfacial area between the baryonic matter and dark matter. The result is the formation of blue compact dwarf galaxies (BCD), such as NGC 2915 with very extended spiral arms. Since the star formation is steady and slow, so the stars formed in BCD are new.

The galaxies formed during $z < 0.1 - 0.2$ are mostly metal-rich tidal dwarf galaxies (TDG) from tidal tails torn out from interacting galaxies. In some cases, the tidal tail and the baryonic droplet merge to generate the starbursts with higher fraction of molecule than the TDG formed by tidal tail alone [18].

When the interactions among large galaxies were mild, the mild turbulence caused the formation of few molecular regions, which located in narrow area close to the large galaxies. Such few molecular regions resulted in few baryonic droplets, producing weak IGM flow and galaxy flow. The result is the formation of galaxy group, such as the Local Group, which has fewer dwarf galaxies and lower density environment than cluster.

Clusters merged to generate tidal debris and turbulence, producing the baryonic droplets, the ICM (intracluster medium) flow, and the cluster flow. The ICM flow and the cluster flow directed toward the merger areas among clusters and particularly the rich clusters with high numbers of galaxies. The ICM flow is shown as the warm filaments outside of cluster [19]. The dominant structural elements in superclusters are single or multi-branching filaments [20]. The cluster flow is shown by the tendency of the major axes of clusters to point toward neighboring clusters [21]. Eventually, the observable expanding universe will consist of giant voids and superclusters surrounded by the dark matter halos.

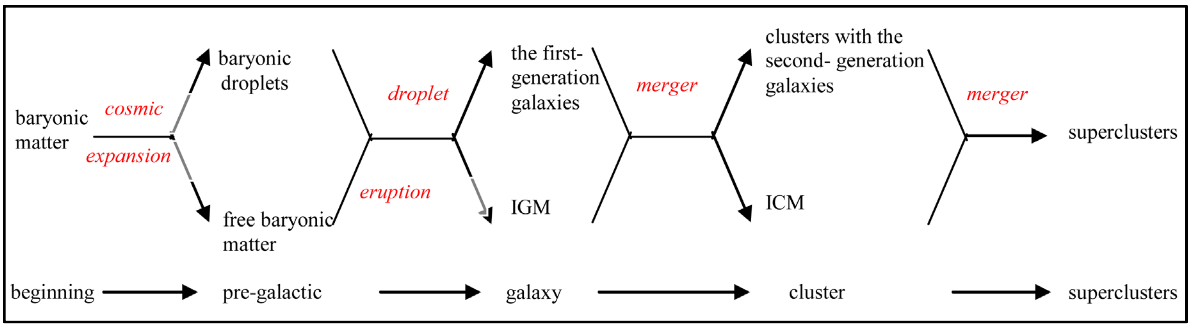

**Figure 6.** The five levels of baryonic structure in the universe.

In summary, the whole observable expanding universe is as one unit of emulsion with incompatibility between baryonic matter and dark matter. The five periods of baryonic structure development are the free baryonic matter, the baryonic droplet, the galaxy, cluster, and the supercluster periods as **Figure 6**. The first-generation galaxies are elliptical, normal spiral, barred spiral, and irregular galaxies. The second-generation galaxies are giant ellipticals, cD, evolved S0, BCD, and TDG. The universe now is in the early part of the supercluster period.

## 6. Summary

In this paper, galaxy evolution is derived by the incompatibility between dark matter and baryonic matter in terms of the short-range separation between dark matter and baryonic matter. In the conventional CDM (cold dark matter) model, dark matter and baryonic matter are compatible, so dark matter can contact baryonic matter. In the ICDM (incompatible CDM) model, dark matter and baryonic matter are incompatible, so dark matter cannot contact baryonic matter. The short-range repulsive gravitational force and the long-range attractive gravitational force based on modified Newtonian dynamics (MOND) exist between dark matter and baryonic matter. The ICDM model explains the failure to detect dark matter by the contact (interaction) between dark matter and baryonic matter, and also solves many difficult problems in galaxy evolution by the CDM model. The incompatibility increases with decreasing cosmic radiation density and increasing age of the universe up to the maximum incompatibility. Without electromagnetism, dark matter is dark and incompatible with baryonic matter like incompatible nonpolar oil and polar water to produce oil droplet surrounded by water in emulsion. In the early universe, baryonic matter was in the homogeneous baryonic droplets surrounded by continuous dark matter filaments to form the cosmic emulsion. Subsequently, the mergers of the homogeneous baryonic droplets resulted in the heterogeneous droplets with the dark matter cores within the baryonic droplets. The incompatibility caused dark matter in the dark matter core to eject from the heterogeneous droplets, resulting in the droplet eruption followed by the droplet core collapse which led to the rapid star formation and the first generation galaxy formation in the early universe. During the first generation galaxy formation, different sizes and locations of dark matter cores in the droplets resulted in large and small elliptical, spiral, and irregular galaxies. The subsequent external and internal interactions in the first generation galaxies generate the second generation galaxies in agreement with the observations in both high-$z$ and low-$z$ universes.

The five periods of baryonic structure development in the order of increasing incompatibility are the free baryonic matter, the baryonic droplet, the galaxy, the cluster, and the supercluster periods. The transition to the baryonic droplet generates density perturbation in the CMB. In the galaxy period, the first-generation galaxies include elliptical, normal spiral, barred spiral, irregular, and dwarf spheroidal galaxies. In the cluster period, the second-generation galaxies include modified giant ellipticals, cD, evolved S0, BCD, and tidal dwarf galaxies. The whole observable expanding universe behaves as one unit of emulsion with increasing incompatibility between dark matter and baryonic matter. The ICDM model provides the solutions for the failure to find dark matter by the contact (interaction) between dark matter and baryonic matter, the overestimation of small galaxies, the underestimation of spiral galaxies, the downsizing.

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