Dark matter hypothesis to maintain theory of gravity

Wardah Intan Meidina¹, and Supardi, Akhmad Aminuddin Bama²

Dept. of Physics, Faculty of Mathematics and Natural Sciences, Sriwijaya University, Indonesia

¹Email: wardahintan22@gmail.com; ²Corresponding author: akhmadbama@yahoo.com

Abstract. In this paper, it will be explained pedagogically about the necessity of the emergence of the hypothesis of dark matter in an effort to maintain the existing theory of gravity. Astronomical observations of the rotation of stars in the center of galaxies show very large deviations from the predictions of existing gravitational theories. To maintain the theory of gravity, a new hypothesis is needed, i.e. by emerging the concept of dark matter. Dark matter is thought to play a major role in its interaction with gravity throughout the universe and is responsible for the regularity of the rotation speed that is (almost) constant from all galaxies in the universe.

1. Introduction (Theory of Gravity)

Newton (1643-1727) was one of the greatest scientists in the world of physics, Newton with Newton's law and together with Maxwell (1831-1879) with electromagnetism field theory was able to uncover and explain various phenomena in the field of classical physics. Newton formulated three laws of motion and a Newton's Universal Gravity law which included in his book entitled Philosophie Naturalis Principia Mathematica which was published in 1687 and considered the most influential book in the history of science. In hundreds of years Newtonian Mechanics has played an important role in science. Newtonian Mechanics is able to explain the behavior of atomic particles to explain the order of the universe.

The conversation about the movement of objects was done long before Newton explained the reason why objects move. Object movement is a branch of physics that is very closely related to other fields of physics, so learning motion is very important and scientific. Many scientists who are interested and busy learning about motion include Aristotle, a philosopher and scientist who poured out the results of his thoughts about motion. Aristotle (384 BC - 322 BC) divided motion into two major groups, namely: natural motion and violent motion.

Forced motion according to Aristotle is the movement of objects caused by external influences on objects and their direction can be in any direction such as encouragement and attraction that originates not from the object itself. Furthermore Aristotle also states that objects will only move when the object is given a force, the motion of the object will stop if the force is removed, meaning that forced motion will occur if the object is given continuous force. Aristotle's understanding of the acceleration of objects is based on the weight of objects, meaning objects that have a greater weight will fall faster to the ground compared to lighter objects. Thus the speed of the fall of an object is a proportion of the weight of the object. Examples given to support this Aristotelian understanding are: if there is an object that weighs the same weight as air then the object will float not far and not rise, if the object
weighs greater than the weight of the air then the object will fall, furthermore objects weighing less
than the weight of the air will move up. According to this understanding, the weight of the object
affects free fall motion.

Regarding the movement of celestial bodies, Aristotle stated that the movement of celestial objects
was very perfect due to the power given by the creator. Aristotle did not recognize the force of gravity,
and he believed that the earth was the center of the solar system. Plato (427SM-347SM) one of the
Greek scientists expressed an opinion relating to gravity, that stars and moons move around the earth
to form a perfect circular path. Furthermore Claudius Ptolemaus in the 2nd century AD provided
support for the opinion of the plateau which became known as the geocentric theory. According to the
geocentric theory the earth is the center of the solar system, therefore other planets like the moon and
the sun travel around the earth. But this opinion cannot explain the complex movements of the planets.
The geocentric theory proposed by Plato and Ptolemaus was disputed by Nicolas Copernicus (1473-
1543) a Polish scientist. Copernicus tried to find answers to the weaknesses of the geocentric theory
by arguing that the sun is the center of the solar system, so that the earth and other planets revolve
around the sun. As a result of the opinions expressed by Copernicus, there was a conflict between
scientists at that time, so that scientists competed to find evidence through careful search of data to
prove the truth of the theory being contested.

Tyco Brahe (1546-1601) managed to compile data about the motion of the planet carefully. The
data compiled by Tyco was then studied by Johannes Keppler (1571-1630). Keppler discovered the
regularity of planetary motion based on data compiled by Tyco, based on this order Keppler put
forward three rules regarding planetary motion, the rules he put forward were known as Law I, II, III
Keppler. Keppler laws read as follows[1]:

1. The trajectory of each planet around the sun is an ellipse, where the sun is located in one
   focus.
2. The area swept by the line between the sun and the planet is the same for each of the same
time periods.
3. The square of the time required by the planet to complete one orbit is proportional to the third
   power of the planet's average distance from the sun.

Copernicus opinions and Keppler's law have in common that style is the cause of the regularity of the
motion of planets in the solar system.

The thought of falling objects proposed by Aristotle that objects with greater weight will fall faster
to reach the ground than objects that have a lighter weight, and that the rate at which objects fall is
proportional to the weight of objects surviving until the emergence of Galileo's new ideas (1564-
1642). Galileo states that all objects when falling will experience the same acceleration if the object
does not experience obstacles and is in a vacuum. An object falling from rest will have a distance
proportional to the square of time. The ingenious argument Galileo gives is that if a heavy object
dropped from a height of 2 meters will hit a deeper pile than the same stone dropped from a height of
20 centimeters. According to Galileo, the stone clearly moved faster at the first height.

Furthermore Galileo also showed that a piece of paper and a ball dropped from the same height at
the same time, the ball would reach the ground first. But if the experiment is repeated by forming the
paper into small lumps it will be seen that the two objects will reach the ground at almost the same
time. In this experiment Galileo believed that air inhibits light objects and has a wide surface.
Therefore, when metal and feathers are dropped together in a vacuum column, they reach the bottom
at the same time.

Experiments using pendulum carried out by Galileo show that the shorter the pendulum rope, the
more time it takes to swing one shorter, with another move of pendulum faster. In addition, according
to Galileo we cannot fall from the earth because the earth has gravity. All objects have a weight, but
the center of gravity of an object is not always in the middle of things. Objects can be likened to a sun
so large that it can attract planets around it, but planets also try to maintain their position so that the
planet will move faster when it is in the farthest position from the sun and will move more slowly than
when it is at the position farthest from the sun and will move slower when it is in the position closest
to the sun. Because such planetary movements cause the shape of the orbit of the ellipse. The principle
of pendulum put forward by Galileo is known as isochronism which means uniformity of time. This principle can also be used to measure the movement of stars and control time which is the beginning of the dynamics of modern knowledge related to the laws of movement and style.

Regarding the movement of celestial bodies, Galileo is one of the scientists who followed the opinion of Copernicus, but what remains a mystery to him is the question "if the earth does move around the sun, why don't we feel it ?", then because the earth moves, if there is an object falling from a certain height then the object will not fall right at the point of fall but rather shift from the original point, and according to Galileo's calculations the object should have fallen 0.5 miles from that point. Galileo's explanation of this is that when objects fall, the earth and those object may not appear infront of us.. The object moves at the same horizontal speed as the earth while still moving vertically down so it falls just below the starting point of the object.

Objects that fall from an altitude always fall down are things that are considered normal and ordinary, but have you ever wondered why they fall and always go to the center of the earth and never vice versa rise up or stay where they are ? Towards the end of the 17th century Sir Isaac Newton (1642-1727), an English scientist managed to uncover the riddle of the interesting nature. Some people say that Newton's answer to the puzzle was when an apple fell on his head while he was contemplating this problem under an apple tree in his home garden (Is the incident of falling apples that hit Newton's head right? The truth is still doubtful). But according to the story, this incident that inspired Newton to find the law which became known as the "law of gravity of Newton".

The law of gravity proposed by Newton states that two objects separated by certain distances tend to attract one another which is a natural force, the magnitude of this natural force is proportional to the mass of each object and inversely proportional to the square of the distance between the two objects. Mathematically the statement of Newton's law of gravity can be written:

\[ F = \frac{G M m}{r^2} \]

with \( G \) is the gravitational constant gravitasi 6.67.10\(^{-11}\) \( \text{Nm}^2/\text{kg}^2 \), is mass the first and second objects, and \( r \) is the distance between the two objects. The mechanics of celestial bodies and earth mechanics, which were previously two separate knowledge, are considered to be a unit by Sir Isaac Newton.

When viewed against the question above, where there are two objects that influence each other, namely the earth and objects that fall towards the center of the earth. According to Newton between earth and objects arises attractive forces, where the earth attracts objects while objects also attract the earth. Earth's attraction to matter is called gravity or gravity and is more commonly known as the weight of an object. The opposite also applies to the same attraction that an object of the same magnitude does. In the law stated by Newton, the distance between objects and the earth is calculated from objects to the center of the earth which is around 4,670 kilometers below the surface of the earth.

With the help of Newton's gravitational law, people begin to understand the causes of the tendency of objects to fall into the center of the earth, but there are still further questions that block in people's minds, which is why objects fall towards the center of the earth. Regarding the movement of planets in the solar system, it turned out that at that time the law of gravity Newton succeeded in explaining how the mechanism of two mass objects interacting in gravitational attraction. The sun in the solar system according to this theory has a very large range of attractions so that it attracts space objects with relatively small masses of planets, asteroids floating in their orbits.

2. Newton's Irregularity of Gravity Law

Newton's success in finding the concept of the law of gravity can explain how gravity works in normal situations or conditions, the simplicity of calculations made by Newton makes ordinary people easily accept the law of gravity. But in reality the universe is not that simple, because the universe consists of billions and even trillions of space objects that influence each other's location. It turns out that the earth and solar system are only a small part of the contents in this universe. Then Einstein discovered the irregularities and incompatibility of Newton's gravitational theory so he proposed the special theory of relativity. Einstein tried to make the special theory of relativity proposed by him consistent with the electromagnetic theory put forward by Maxwell. In an effort to make Einstein's theory consistent according to him the speed of gravitational force must not exceed the speed of light. Therefore with a long distance range, it is clear that gravity requires a long time to explore or even
millions of kilometers, it is impossible to explore in an instant. Although Newton's gravitational theory is contradictory to Einstein's special theory of relativity, Newton's theory of gravity correctly predicts the shapes and orbits of planets in the solar system, even if calculations are made on the assumption that gravity works for a moment. Even if it is assumed gravity does not work for a moment, according to Einstein's relativity, then the planet's orbit must undergo correction. Strangely, if Einstein's correction was included, it actually gave the conclusion that there was a mechanism that had not been explained in Newton's Gravity theory.

Subsequent irregularities based on calculations through the Newton Gravity law formulation obtained the value of the gravitational interaction between the Earth, the Moon and the Sun in two conjunction positions. The results obtained by gravitational interactions that occur between the Sun-Moon are about twice as large as the interactions that occur between the Earth-Moon. If this calculation is adjusted according to Newton's theory, then the Moon should be attracted to the sun and cause the moon to circle the Sun. But based on the current theory, the Moon continues to circulate around the Earth and the difficulty in explaining the circulation of planets based on Newton's law. So there needs to be a theory or other thing that can explain why it happened. According to Einstein the circulation of the Earth, the Moon and the Sun where the moon is in the middle between the Earth and the Sun occurs due to curved time space. The sun curves space around the earth and space to push (not pull) the earth around the sun. In other words, Newton's Gravity law needs correction. Furthermore the irregularities of Newton's gravitational theory of each planet around the sun, the path of the planet in the form of an ellipse will not change, but in fact many planets found in the solar system, other planets apparently also exert gravitational influence on other planets so that the planet's orbit is not static but rotates (precision) against the sun. Einstein's theory of relativity was able to explain the shift in planetary orbit that could not be explained by Newton's theory of gravity.

The last phenomenon that Einstein put forward relates to the loss of some light energy when passing through a gravitational field, when light energy loses some energy, then the wavelength of light becomes longer resulting in the color of light shifting towards red, this phenomenon is called a red shift due to the gravitational field. But Einstein admitted that his own general relativity equation had weaknesses, he stated that the same left tribe that described the geometry of space and time was a strong tribe, while the right-hand tribe was a weak tribe.

3. An indication of the existence of dark matter

Because the theory put forward by Enystein, namely general relativity is still weak, in 1951 Frits Zwicky observed the motion of galaxies belonging to coma galaxy groups based on their velocity. Then carried out by Vera Rubin, examining the brightness of stars and gases that move in several galaxies around the Milky Way galaxy using spectrographs. Famous observations are bullet clusters, collisions between two galaxy clusters. The collision of the two galactic clusters resulted in the center of mass of each cluster supposed to be at the center of the baryon mass, apparently not in the center of the baryon. So that there seems to be an 'extra' mass that is not visible but can be detected through gravity resistance. This additional mass is indicated by the presence of dark matter. Theoretically, it is known that the total force needed to trigger the Big Bang is a certain amount (say X). Whereas observationally, the number of forces that can be detected is not as big as X, but smaller than X, say Y. This means that theoretically there is a force that "inhibits" the expansion of the X to Y, that is what we call gravity, and mathematically simple is written as \( M = X - Y \). Then observationally, astrophysicists again find a unique fact, that it turns out that the total force of gravity in the universe is not a number \( M \), but smaller than that, this time scientists agreed as m (m lowercase letters). The difference between large \( M \) with small m \( (M - m) \) or \( (\Delta M = \Delta M) \) is what is called DARK MATTER.

The existence of dark matter is stable, does not interact electromagnetically and its presence can be detected through gravitational interactions. This dark matter plays a major role in its interaction with gravity throughout the universe and is responsible for the regularity of the (almost) constant rotation speed of all galaxies in the universe. This dark matter is called dark because it cannot interact with light. This nature causes dark matter not to be seen by us. Then this material is called matter,because
the only thing we can know is that this material can affect gravity. We can mathematically write down the Big Bang theory as follows: Resultant Forced:

\[ F_B > F_P, \quad F_B - F_P = F_G \]

where: \( F_B \) = Force of Visible Objects, \( F_P \) = Observation Force, and \( F_G \) = Gravity Force.

Until now, scientists have not known exactly what Dark Matter is. What they know is that there are very many, more than \( 6\times10^5 \times (76\% \text{ of the total universe}) \) of the material we know or often referred to as Normal Matter [4]. And it is clear that Dark Matter is not a normal material on the periodic table of elements, because dark matter does not reflect light. He is also not antimatter because antimony will make material normally disappear when it meets.

The development of the theory of dark matter runs based on a very long process of observation and mathematical approach, full of corrections, objections, then reinforced, until it becomes a strong hypothesis up to the present. The process of developing this theory can be seen in the timeline of cosmological theories. Jan Hendrik Oort (1932) and Horace Babcock (1939) observed Galaxy Rotation Curve which concluded that the rotation of stars in the center of galaxies had a velocity that was almost the same as the rotation of stars in the outer part of the galaxy. This is very strange considering that in the solar system, the planets closest to the sun will have a revolution that is much faster than the planets in the outer part. That is only possible if, first, all the theories of gravity that have been discovered so far are wrong, or second, there are other materials that have not been detected before. The first hypothesis might occur, but that means a major overhaul must be done in the world of physics. Even at the most basic level. The overhaul means everything, everything we know about physics is wrong. This has not been obtained evidence until now. While the hypothesis that the whole theory of gravity is wrong is ruled out by scientists, we will go to the second hypothesis. That there is another material in the universe that we have not known at all. If calculated, the material we know well on the periodic table of elements is only able to meet around 4.6% of all elements in the universe. A very, very small number. A simulation conducted by NASA shows that without the Dark Matter, galaxies are not able to coalesce as we see it today. Stars and small clusters of planets will spread everywhere.

4. Spatial Distribution of Dark Matter
Observations of large-scale distribution of galaxies and simulations of grouping dark matter have produced images that are quite coherent, dark matter is distributed in structures such as foam / soap bubbles / spider webs, filaments and walls characterized by \( \sim 100 \text{ Mpc} \) (Mega Parsec, an Astronomical unit, one mega per second (Mpc) is 1 million parsec or 3,261,564 light years). In areas of high density, a nearly spherical structure known as halos dark matter is formed. Inside the collapsing barion is dissipated into the form of star galaxies and luminous gases. Dark halos combine into hierarchical mode into larger and larger halos. Today, the universe is filled with dark halos with masses ranging from dwarf galaxies to giant groups of galaxies. Inside each halo contains smaller subhalos, so that each halo mass circle is filled with a large number of galaxy halos and each halo is filled with a circle of light dwarf galaxy's mass. But this is also not always true, as most galaxy dark circles are actually not always related to other larger groups. But it is only located in one large area.
Figure 1. the distribution of galaxies in the structure of large-scale dark matter is illustrated schematically. The case for the existence of dark halos around the galaxy is now rather strong. As originally demonstrated by Ostriker & Peebles (1973), galaxy discs quickly turn into giant rods without the influence of massive stabilization, spheroidal components such as dark circles (source: Erik Zackrisson. 2005. Introduction to Dark Matter).

For 70 years, a new paradigm has been raised in some of the visible material observed using a telescope and only shows a small fraction of the total amount present in nature. Most matter appears as a material that does not emit light or light is very small. This shows symptoms like dark matter. Until now, this natural phenomenon is a component that is difficult to understand and becomes a natural mystery. The first detection of dark matter was demonstrated by Zwicky (1933) who calculated the speed of dispersion of the Coma galaxies and found speeds that far exceeded what could be attributed to luminous matter in the galaxy itself. Zwicky’s research in Coma was followed up by Smith (1936) for the Virgo cluster. This research also captures the speed of its constituent galaxies that show unexpected mass and high light ratios. Babcock (1939) using optical spectroscopy measures the rotation of the Andromeda Galaxy (M31) and finds the rotational speed at a distance far from the center to be too large to be associated with luminous components. From the speed of the Milky Way and Andromeda Galaxies to each other (around 70 miles/second or 112 km / sec) [8], Kahn & Wolter (1959) estimate the mass of a local group of galaxies (where the Milky Way and M31 are dominating members). From this comparison it can be estimated that the hopes of this luminous material come from two objects, they conclude that the most mass of the local group must be dark. In the 1970s, dark matter became a well-known concept. Evidence of the rotation of dark matter in M31 is increasing to be stronger and investigations of kinematics from other galaxy cycles give the same results. These observations indicate that dark matter is a common condition among galaxies, but does not limit its spatial distribution. Ostriker & Peebles (1973) shows that the rotation of galaxies between them is not stable because maybe they are surrounded by large circles [6]. Therefore, the important concept of dark circles, today is believed to be a condition that occurs in all galaxies at birth. The first conference to fully address the issue of dark matter was held in Tallinn, Estonia in January 1975. At the initial conference there were differences regarding the definition of dark matter. Some define barionic elements, which consist of three quarks - like protons and neutrons as dark matter. There are also those who suggest non-barionic particles, neutrinos, as candidates for dark matter. Since it is recognized that most of the material in this world is dark, this component is expected to dictate conditions for the formation of large structures such as galaxies and groups of galaxies.

References
[1] Bama A A 2015 Mengenal Fisika, dari Paradigma, Metodologi, hingga Implementasi (Palembang: SIMETRI) pp 43-44
[2] Djamaluddin T 2008 Proses Penciptaan Alam Semesta dalam Enam Masa. (online)
http://misykatulanwar.wordpress.com.

[3] Krane K 2008 *Fisika Modern* (Jakarta: UI Press) pp 54-58
[4] Halliday D and Robert R 2010 *Fisika Jilid 3 Edisi 7* (Jakarta: Erlangga) pp 45
[5] Dragan Huterer. *Dark Energy and the Accelerating Universe.*
   http://www-personal.umich.edu/~huterer
[6] *Cosmology timeline.* https://www.astro.rug.nl/~weygaert
[7] Zack and Gombez 2012. *Makalah Teori Terbentuknya Alam Semesta.* https://www.scribd.com/doc/98850033
[8] Erik Z 2005 *Introduction to Dark Matter* (online) http://astro.su.se/~ez/kurs/gradU/DM.pdf
[9] Space.com *The Andromeda Galaxy (M31): Location, characteristics and images.*
   https://gooleweblight.com.
[10] M. Ferry Simatupang. *Energi Gelap (Dark Energy) Dalam Model Standar Kosmologi Baru.*
    https://langitselatan.com.