Dark Matter

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Abstract

Dark matter has never been directly observed. Its presence is indicated by unexplained gravitational effects on stars and galaxies. It is sought within galaxies, in galaxy clusters and throughout space. Surprisingly, dark matter appears to comprise the bulk of the entire universe. This article surveys the evidence along with possible micro and macroscopic dark matter candidates. The entire idea is then evaluated from the creation perspective.There are also theological implications.

Introduction

Astronomy is sometimes presented as successfully having answered the most basic questions about the universe. One popular book attempts to explain the complete evolution of the universe to within 10^{-43} seconds of its origin (Hawking, 1996). This number is called the *Planck time*, when some cosmologists think the present laws of physics originated. In truth, of course, many fundamental questions remain. We actually know very little about our neighboring planets, and much less about the deep space beyond. Consider just a few of the mysteries in modern astronomy:

- Origin of the moon
- Star and galaxy formation
- Source of cosmic rays
- Nature of quasars and their distances
- Absence of evolved life elsewhere
- Dark matter

The last entry is explored in this article. Dark matter is so called because it emits no detectable radiation. In our current understanding of astronomy and physics, dark matter must comprise the majority of mass in the universe, between 90–99 percent. Yet it has never been detected with certainty, if it indeed exists. Carl Sagan described it as dark, quintessential, deeply mysterious stuff wholly unknown on earth (Sagan, 1994, p. 399). Astronomers therefore have no idea of the composition of the bulk of the entire universe. So much for a fundamental understanding of the physical universe! Dark matter is an apt topic for review and for a creationist evaluation. There is a large number of dark matter discussions and references currently available on the internet.

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What Dark Matter is *Not*

The term *dark matter* does not refer to dark nebulae. These are abundant interstellar clouds of dust, which block the light from background stars, and therefore appear as dark silhouettes. Nearby examples include Orion's Horsehead nebula, the Great Rift in Cygnus and the Coal Sack near the Southern Cross.

Some students of the Bible have described a particular dark region in the northern sky. This is further proposed as the literal direction toward heaven. The idea is based on Job 26:7 which describes the north stretched out "over the empty place." However, there is no such northern region of space which is devoid of stars or galaxies. The Job reference simply describes the vastness of space in which stars exist, including the northern sky (DeYoung, 1986).

Neither does dark matter refer to dark line spectra. Stellar light spectra typically show dark lines where certain wavelengths have been absorbed by the star's own atmospheric gases. Also, dark matter does not refer to black holes. Finally, dark matter does not involve Olber's paradox, the profound question of why the sky is dark at night, in spite of seemingly endless stars.

The Location of Dark Matter

There are several alternate names for dark matter including missing mass, hidden matter, shadow matter and hot or cold dark matter. Why is it thought to exist and where must it be located? Dark matter will be discussed in three hierarchical categories. It is sought first within single galaxies. Next, the invisible material is thought to "glue" galaxy groups or clusters together. Finally, popular versions of the big bang model require immense amounts of dark matter existing throughout space. These three reservoirs for dark matter will be considered in the following sections.

Single Galaxies

In our solar system, inner planets travel faster than the outer planets. Mercury has an orbital velocity of about 107,000 miles/hour (172,000 km/h), while Pluto's velocity averages nearly ten times less, only 10,000 miles/hour (16,000 km/h). This variation in speed follows directly from Kepler's third law of planetary motion,

$$T^2 = \frac{4\pi^2}{GM} r^3 \tag{1}$$

$$v = \sqrt{\frac{GM}{r}} \tag{2}$$

Here T, r, and v are the planet's orbital period, average radial distance from the sun and velocity. G is the universal gravity constant and M is the solar mass.

The stars within galaxies also experience orbital motion. In this case, however, the main gravitational mass is not concentrated at the center as in the solar system. Instead, stellar masses are spread throughout the galaxy, with vast orbits about the center. Isaac Newton proved that for such orbits, only mass lying within a star's orbit affects the star's motion. The gravity force from external mass cancels completely. This is exactly true only for a uniform spherical or circular distribution of mass. However a galaxy provides a fair approximation, including the disk-shaped spiral galaxies.

Equations 1 and 2 can be applied to an entire galaxy of revolving stars. Each star responds to the total gravitation of the partial mass of the galaxy that lies within its orbit. And it is exactly as if this mass were all positioned at the center of the galaxy. The orbital velocity of a star can be measured from the Doppler shift of its light. If the star is near the outer edge of a galaxy, taking r as the galaxy radius and knowing v, equation 2 then gives the total mass M of the galaxy. And here a major problem arises. In every case, the calculated galaxy mass is at least 5–10 times the mass of all the visible stars and other matter in the galaxy. This missing mass component is considered to be invisible dark matter.

There is a second way to look at the mass problem with spiral galaxies. One can plot a *rotation curve*, a graph of velocity versus distance from the galaxy center for component stars. Equation 2 shows that, for the solar system, planet velocity decreases as the inverse square root of distance from the sun. Because of the mass distribution of a spiral galaxy, equation 2 is not followed precisely. However, star velocities should still decrease as their outward distance increases. Instead, however, measurements show *flat* rotation curves for galaxies (Figure 1). That is, the orbital velocities of remote galaxy stars are largely constant, or even *increase* slightly with distance. The unexpected nature of the rotation curve was first noted by astronomers Vera Rubin and Kent Floyd in 1970, for the Andromeda galaxy. Said in another way, the outer galaxy stars revolve unexpectedly fast. If galaxies are stable, this implies a large amount of dark matter affecting stellar motion. Otherwise, spiral galaxies should be flying apart. One possible mass distribution is a giant halo of invisible matter surrounding and permeating entire galaxies. X-ray telescopes, including *Rosat*, have shown possible evidence for this halo around the Milky Way. However the question remains, how can 90 percent of galaxy mass remain invisible to optical telescopes?

Galaxy Clusters

The terms *missing mass* and *dark matter* were first suggested in 1933 by Cal Tech astrophysicist Fritz Zwicky. He observed the Coma cluster, a group of at least 1,000 galaxies located 400 million light years distant. These galaxies are assumed to be gravitationally bound together. Zwicky noticed that the galaxies had random velocities, and moved much faster than expected. In fact the galaxy cluster should have disintegrated by now. This anomalous motion is likewise true of our own *local group* of galaxies. This local group consists of the Milky Way, Andromeda, Magellanic Clouds and about 30 other galaxies, all lying within about a three million light year region.

Why have not these galaxies within clusters escaped from each other? As before, an invisible binding mass of galaxy groups is considered as dark matter. The galaxy motions suggest that the dark matter mass totals at least ten times that of all the visible galaxies. This shortfall in mass is much greater for the galaxy clusters than that within individual galaxies. The Coma cluster is found to be 90 percent missing. Another example, the Virgo cluster is 98 percent missing. That is, there is assumed to be 50 times more mass than is actually observed. Figure 2 is a photo-

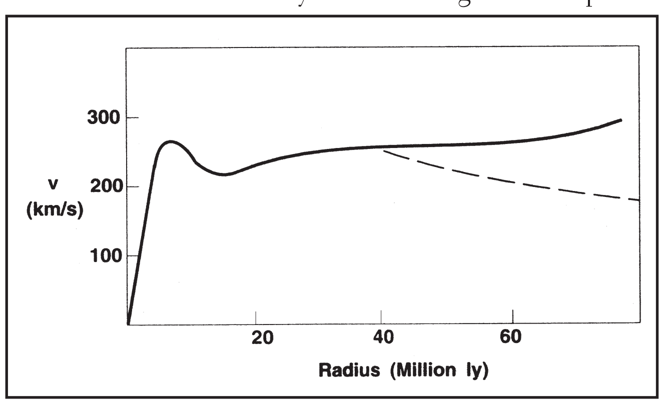

Figure 1. A schematic rotation curve for a typical spiral galaxy. The dashed line shows the trend of star velocities expected from Equation 2, if most of the mass of the galaxy were within 40 million light years of the center. The solid line shows actual measurements (Hawley and Holcomb., 1998, p. 390).

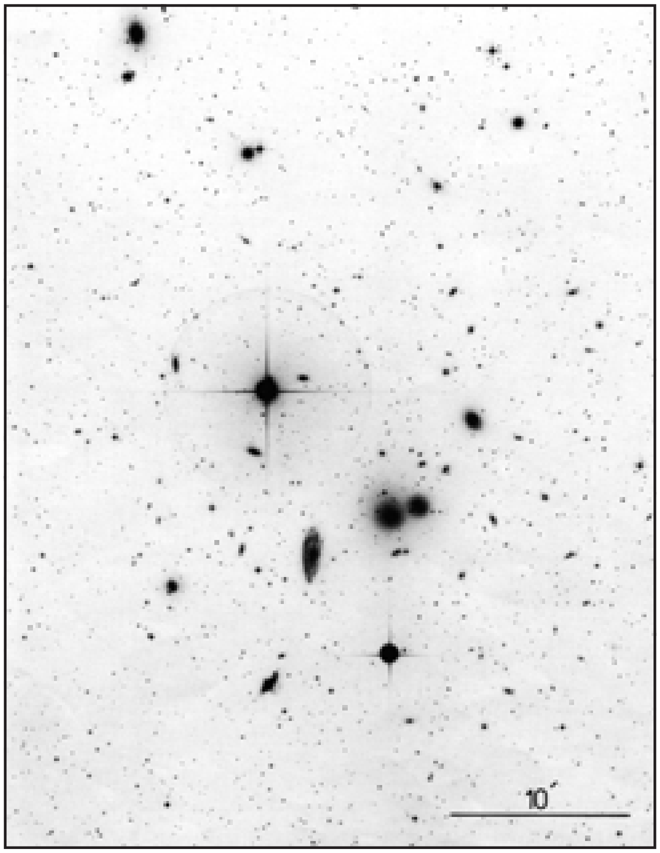

Figure 2.The central part of the galaxy cluster Abell 1060. The photo is from the Royal Observatory, Edinburgh, England (Bruck, 1990, p. 96).

graph negative of the center of the galaxy cluster Abell 1060. The smaller pinpoints of light are nearby Milky Way stars. The spirals and elliptical galaxies shown in the figure are a few of Abell 1060's two hundred galaxy members. The cluster is about 220 million light years away.

Visible gas clouds within galaxy clusters also have added to the dark matter requirement. X-ray observations reveal vast clouds of hot, low-density gas within the clusters. Elsewhere, similar clouds appear to suffuse regions of space far from galaxy clusters. These energetic gas molecules are moving so fast that the observed clouds would quickly leak away and dissipate on an evolutionary time scale. It is therefore concluded that the clouds must contain much more matter than we see, binding them together.

In several cases, *gravitational lenses* appear to give multiple images of the same quasar. Quasars are thought to be far distant, very bright sources of light. Apparently, separate light signals from a distant quasar can be bent by an intervening galaxy and then directed toward the earth. In some cases the light-deflecting galaxies also can be seen. On a more local scale, similar gravity lensing sometimes appears to occur for stars within or near the Milky Way galaxy. However in these cases there is no observed intervening object. Dark matter is suggested as the cause of this light deflection. Several gravity lens surveys are currently underway. It is hoped that positive results may help determine the *size* of dark matter objects (Holz, 1999).

Virial Theorem

The *virial theorem* can be used to calculate the mass of a single galaxy or a galaxy cluster. It applies if a system is gravitationally stable, without collapse or disintegration taking place. The theorem states that the total gravitational potential energy of the star system equals exactly twice the total kinetic energy. If this condition is not met, the component objects either will cascade inward or escape, depending on the direction of imbalance.

From the virial theorem comes the mass formula for a galaxy cluster (Bruck, 1990, p. 99),

$$M = \frac{3V^2 R}{G} \tag{3}$$

Here V is the average of the squared radial velocities observed for member galaxies within the cluster. R is an estimate of the geometric radius of the entire cluster and G is the gravity constant.

As an example, consider Abell 1060, a cluster of about 200 galaxies located 220 million light years away (Figure 2). Its V is about 7.14×10^5 m/s (0.24% light speed) and R is 6.1×10^{22} m (6.5 million light years). The virial mass result is 14×10^{44} kg, or about 7×10^{14} solar masses. If there are 200 galaxies, each then averages 3.5×10^{12} solar masses. This is about 10 times higher than the known mass of Andromeda and the Milky Way galaxies. The Abell 1060 galaxies probably do not contain this much extra mass. Instead the mass may exist as dark matter spread between the galaxies. A similar numerical discrepancy exists for *every* galaxy cluster, assuming they obey the virial condition.

Some astrophysicists have proposed that galaxy clusters are *not* gravitationally bound after all, so the virial theorem does not apply. The use of the theorem to calculate unseen mass has been called "totally unreasonable" (Burbidge, et al., 1999, p. 42). However if the galaxies are disrupting, then the clusters must be far younger than the multi-billion year age usually assigned to them (Bowers and Deemings, 1984, p. 504).

The Universe

Dark matter is also required on the largest scale of all, that of the entire universe. In this case it is tied to versions of the big bang theory in at least two ways. First, dark matter is enlisted to explain the large-scale structure of the universe. In this view, the initial universe expansion from a singularity must have experienced positional variations in temperature or energy density. This resulted in a "clumpiness" of matter, with subsequent formation of gas clouds, stars and galaxies. The initial clumps grew larger in this way because of the gravity attraction of invisible cold dark matter concentrations.

Dark matter is also involved in the popular inflationary big bang model which predicts that the curvature of the universe must be *flat* (Figure 3). This means that the density of matter is exactly balanced between a universe which eventually collapses (a closed, finite universe), and one which expands forever (an open, infinite universe). The required *critical* density for a flat universe is about 10^{-26} g/cm^3. This corresponds to approximately 10 hydrogen atoms per cubic meter of space. Observed density estimates, although crude, lead to a value 10–100 times smaller than the critical density. Therefore a great amount of dark matter is needed to result in a flat, closed universe with zero curvature.

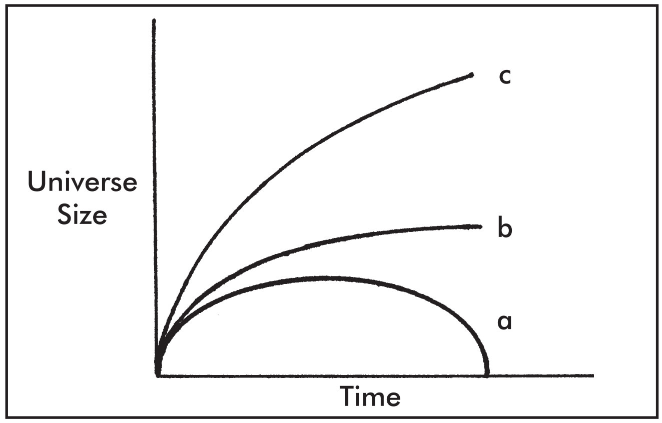

Figure 3.Three views of the expansion of the universe over evolutionary time. The universe is either a: closed, eventually collapsing on itself, b: flat, ceasing expansion after infinite time; or c: open, expanding outward forever.

What is Dark Matter?

This is an unanswered question since dark matter has never been directly observed, and may not even exist. Nevertheless, many possible candidates have been suggested (Trimble, 1987). Several will be listed and briefly evaluated here.

Non-luminous stars include primordial black holes; black, brown or red dwarfs; and energy–depleted white dwarfs. An immense number of these unlit stars would be needed to supply the necessary dark matter. If they average 0.1 solar mass and comprise 90 percent of the total known universe mass, then there must be at least 10^{25} such stars. The basic problem is that *none* have been detected and identified with certainty. Surely, such an astonishing number of non-luminous stars easily should be detected with modern instruments. Even black holes themselves remain as theoretical constructs which have not been verified with certainty.

The brown dwarfs are a special case of failed, low mass stars which never ignited their internal nuclear fusion reactions. They are sometimes pictured as large gaseous planets, somewhat like Jupiter. They have also been called MACHOS, or massive compact halo objects. Efforts have been made to detect brown dwarfs indirectly by their eclipsing of normal stars. That is, one watches for a distant star to temporarily disappear when covered. The background starlight might also be distorted in a *microlensing* effect. No clear brown dwarf evidence has been found in this way, in spite of detailed searches (Hawley and Holcomb, 1998, p. 391). There may be many brown dwarf stars, or they may be vary rare.

Diffuse matter would consist of unseen dust or gas particles that are widely dispersed. It has been described as molecular clouds, intergalactic matter, and as halo or coronal material which surrounds and permeates galaxies. The Milky Way contains 10^{11} solar masses. The required invisible dark matter is 100 times greater, 10^{13} solar masses worth. This would be an incredible amount of unseen diffuse matter.

Neutrinos are an abundant product of nuclear fusion, the process thought to energize stars including our sun. Creationists have suggested that gravity contraction may also be occurring within stars (Steidl, 1983). Whatever the combination, some nuclear fusion does occur with resulting neutrino production. From the sun, this sends a continuous flood of neutrinos toward earth with a flux as great as 10^{12} neutrinos/cm$^2 \cdot$ s.

Solar neutrinos have been detected, although only at about one-third of their expected number. Neutrinos require large, highly specialized detectors since the particles are very elusive and unreactive. Most travel directly through the earth's 8,000 mile diameter without any atomic collisions occurring.

Thus far, laboratory studies of neutrinos show zero mass. However, there is a suggestion that neutrinos might oscillate between different forms as they travel along at light speed. This behavior could mask a vanishingly small but finite mass. With their large abundance throughout space, neutrinos could thus comprise much of the sought-after dark matter. The proposed dynamical behavior for neutrinos might also explain their low abundance as measured from the sun. The problem remains, however, that no one has observed any mass whatsoever for neutrinos. The idea of neutrino mass appears to be a desperate hope for solving the embarrassing mass deficit.

Exotic particles are wisps of localized energy in space that have been theorized but never observed. In physics jargon, exotic particles are *nonbarionic*. They have much less mass than normal baryons such as neutrons and protons. Exotic particles are often given fanciful acronyms. WIMPS, or weakly interacting massive particles, are predicted by certain theoretical physics models. No one knows whether such dark matter particles exist. Nevertheless, they have been enlisted to help solve the solar neutrino problem. It is proposed that WIMPS inside the sun might help spread heat throughout the solar core. Solar energy could then be generated at a slightly lower temperature, with fewer neutrinos produced than now expected.

A WIMP detector has been built in England, deep underground. It consists of 200,000 liters of pure water. Scientists hope that an occasional WIMP particle speeding in from space might interact with a hydrogen atom in a detectable way. Results thus far have not been encouraging (Seife, 1999).

Axions, whimsically named for a laundry detergent, are another type of hypothesized subatomic particle which contribute mass to space. Other proposed but unobserved particles include photinos, neutralinos, gravitons, mini-black holes and antimatter. Astronomers also speak of *bowling balls*, a shorthand title for ordinary space matter in some hard-to-detect form.

Other exotic particle candidates include cosmic strings or membranes, preons and monopoles. There is certainly no shortage of suggestions to identify dark matter. In reality, however, the dark matter mystery remains completely unsolved after seven decades of intense study.

A Creationist Response

We have seen that dark matter is required if the laws of motion and gravity hold for galaxies, and if galaxy systems are stable. Since creationists are not locked into the big bang theory or evolutionary time, there are several options to consider. They will be discussed here as questions.

Are the laws of nature universal? This question allows for entirely different, unknown laws operating elsewhere in space. Dark matter then might be only an illusion, based on our local understanding of physics. However, there is no reason to expect such an unknowable *multi*verse instead of a *uni*verse. Instead, light signals coming from deep space, in all the intricate details of their spectra, appear much like light sources within our laboratories. Therefore the dark matter problem cannot easily be solved by rejecting known physics. Newton's and Kepler's laws of motion and gravity appear to be universal in their extent and application.

Are galaxies stable? If dark matter is lacking in galaxies, then over time they will simply disintegrate. This would be a major problem for evolutionary time, since galaxies then should no longer exist. In the recent creation view, however, little galaxy change would be noticeable since the creation event. After all, galaxies average 100,000 light years in diameter. In just 10,000 years, galaxy enlargement would be minimal.

Still, there is little reason to expect that galaxies are unstable in this way. With few exceptions, mainly within the solar system, transients and instabilities are not found in space studies. Instead, the created universe is marked by great durability. Consider our sun, which has sufficient hydrogen fuel to last for billions of years into the future, although the Creator, of course, may have other plans. Galaxies can be assumed to be stable, and thus must contain some form of dark matter.

Are galaxy clusters stable? Clusters are an entirely separate category from individual galaxies. There is little reason from a creation perspective why these clusters need to be bound together by unseen matter. The Creator may simply have placed these clusters throughout space much as we see them, with random galaxy velocities. Even if unbound, these clusters would only dissipate on a billion year time scale because of their vast size. Galaxy clusters may well be unstable in the long term.

Must the universe be flat? The creation view has no such requirement. The flatness requirement arises only with the big bang theory. The Creator, with equal ease, could have made a closed, flat or open universe. However, I suggest that it may well be open, with a lack of large scale dark matter. The simple reason may be to frustrate all natural origin theories, most of which call for a closed or flat universe. Something similar occurs for the planets. We find sufficient created variety and uniqueness in the solar system to cancel all natural attempts at an explanation, including the popular nebular hypothesis.

What then is dark matter? I have suggested that dark matter exists within galaxies, if not elsewhere. We have considered various physical micro and macro-size possibilities. But there is another option. Perhaps the dark matter we seek is in reality the unseen hand of the Creator. We know from Colossians 1:17 that God in some way holds all things together. Therefore at some point, physical reality must mesh with the spiritual. And that point may lie in the unexplicable problems of modern science.

The law of gravity has been known since it was first explained by Isaac Newton in 1687. On a deep level, however, gravity remains a mystery. That is, we have no idea how objects physically communicate their positions and interact with each other. This ignorance about gravity or dark mater, for both creationists and non-creationists alike, should be a humbling experience. We know very little about physical reality, since we presently "see through a glass darkly" (I Corinthians 13:12). Creationists look forward to the future, when our understanding will be made complete.

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Book Review

The Design Inference by William A. Dembski
Cambridge University Press, New York. 1999, 243 pages, $59.95

This book is based on the author's doctoral work in mathematics at the University of Chicago, his post doctorate work in complexity theory at Princeton, and his second doctorate in philosophy at the University of Illinois. Dembski's work is critical to the creation-evolution controversy because it deals with the essential question "What is the probability that life and the universe are the product of design versus a product of chance?" Creationists often use probability arguments to show the enormous unlikelihood of life evolving by natural law and chance.

A common analogy is the calculation of the likelihood of the body's 206 bones being placed by chance in the correct order (Bergman, 1999). This analogy, while useful, is limited because life does not result from placing existing structures in the proper order, but is dependent upon many highly improbable events. It is well recognized by creationists and most evolutionists that the probability of life evolving naturalistically is extremely small. In Gould's famous analogy, if earth's history were to be replayed "a thousand times," it probably would not produce the human brain again (Gould, 1989, pp. 233–234).

The application of probability calculations to life's origin is often obscured by evolutionists who argue that highly improbable events happen every day. Therefore, they argue, because life is highly improbable does not prove that a creator must exist to explain life's existence. An example which shows that the problem is not the mathematics, but its application was originally discussed by Polanyi (1962, p. 33). Both the chances that 100 stones randomly placed in a garden in any one pattern as well as to spell "Welcome to Wales by British Railways" are infinitely small. If we are looking for one *special arrangement* of stones only, the likelihood of finding it in thousands of gardens is minuscule unless intelligence arranges the stones in the desired order. Therefore, the likelihood of a meaningful message requires intelligence to produce a specific order of stones. One could spend several lifetimes examining gardens, and the likelihood of finding the phrase "Welcome to Wales, etc." produced by chance still has a probability of zero.

Mathematics, especially statistics, is a tool that can be used and abused as the classic book by Huff (1953) eloquently demonstrates. A common example used by evolutionists to explain away creationists' probability arguments is noting the minuscule likelihood of a given assemblage of the specific persons at a creation conference occurring by chance. The problem is an almost infinite variety of combinations will meet our criteria, such as when 100 paid registrations are received, the criteria has been met and the conference will be held. Any 1,000 persons attending meet our criteria, not a certain combination. As a result, the likelihood of the particular combination occurring is not minuscule but one. Conversely, events produced by intelligence require the combination of a *specific* set of events which *as a set* will not occur by chance.

Dembski illustrates how intelligent design can be proven utilizing examples including determining if an electronic signal is random or the result of intelligence. This problem has been worked out years ago in connection with SETI and other programs which attempt to find evidence