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HOW SHOULD RECENT CREATIONISTS RESPOND TO DARK MATTER AND DARK ENERGY?

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ABSTRACT

For too long, recent creationists have dismissed the existence of dark matter and dark energy as rescuing devices for the big bang model. A proper survey of the history of both dark matter and dark energy reveals that this assessment of dark matter and dark energy is false. There are three robust lines of evidence for dark matter, two of which were known long before the big bang model became widely accepted. If the big bang model were to fall out of favor, the reality of dark matter would remain. Thus, the existence of dark matter has nothing to do with the big bang model. Dark matter easily can be included within a recent creation model, so I discourage recent creationists from rejecting the dark matter hypothesis in an attempt to nullify the big bang model. The unexpected downturn in the Hubble relation at great distances is the evidence for dark energy, albeit interpreted in terms of the big bang model. What the downward inflection of the Hubble relation might mean in a biblical cosmology/cosmogony is unknown, for no such model yet exists. In developing such models, I encourage recent creationists to consider the evidence generally interpreted in terms of dark matter and dark energy.

KEYWORDS

Dark Matter, Dark Energy, Cosmology, Cosmogony

I. INTRODUCTION

Since the turn of this century, dark matter and dark energy have been widely accepted in cosmological models. These models are based upon the big bang, the assumption that the universe suddenly appeared nearly 14 billion years ago in a very hot, dense, expanding state. The big bang model further posits that as the universe expanded and inevitably cooled, stars and structure (galaxies) arose, eventually resulting in the universe that we observe today. Since this model contradicts many aspects of the Genesis creation account, recent creationists reject the big bang model. Perhaps because of their close association with the big bang model, many creationists also reject dark matter and dark energy. However, is this rejection warranted?

In this paper, I will review the evidence for dark matter and dark energy. I will demonstrate that the evidence for dark matter is very robust, predating the wide acceptance of the big bang model by nearly 40 years. Hence, the evidence for dark matter has very little to do with the big bang model, and I discourage recent creationists from rejecting the dark matter hypothesis as a strategy to nullify the big bang model. On the other hand, there is a much more intimate relationship between dark energy and the big bang model. There are data that when interpreted in terms of the big bang model leads to the conclusion of dark energy. While we reject the big bang model, the data remain. Creationists need to address the question of what that same data may mean within a truly biblically based cosmology.

II. DARK MATTER

There are three independent lines of evidence for dark matter:

1. Dispersion velocities of galaxy clusters
2. Rotation curves of spiral galaxies
3. Gravitational lensing of distant galaxies and quasars by closer galaxy clusters

As I explained in an earlier paper (Faulkner 2017a), measurements of the dispersion of velocities of galaxies in clusters was the first observational evidence for dark matter, dating back 90 years ago (Zwicky 1933, 1937c; Ostriker, 1999). Zwicky measured the Doppler velocities of galaxies in the Coma Cluster. Assuming that the measured Doppler motions of those galaxies were due to orbital motion of the members of the Coma Cluster, Zwicky used the virial theorem to calculate the *dynamic mass*, the amount of mass required to account for the orbital motion. As explained below, astronomers already knew how much mass was required to produce the light we receive from galaxies. Therefore, from measurement of the brightness of galaxies on photographs of the Coma Cluster, Zwicky was able to determine the *lighted mass* of the Coma Cluster. Zwicky found that the dynamic mass of the Coma Cluster exceeded its lighted mass by two orders of magnitude. Adjustments in the cosmic distance scale since then have reduced the mismatch to only a factor of 50. Meanwhile, Smith (1936) found a similar discrepancy between the dynamic mass and the lighted mass of the Virgo cluster. Other clusters of galaxies show similar differences between their dynamic and lighted masses. Interestingly, Kahn and Woltjer (1959) found that the mass required to account for the mutual orbital motion of the Milky Way Galaxy and the Andromeda Galaxy (M31) required six times the combined mass of the two galaxies. In his first paper (in German), Zwicky referred to *dunkle materie*, which translates into English as *dark matter*. However, that term was not used by astronomers for decades. Instead, astronomers used the term *missing mass*. It was only since the 1980s that astronomers changed back to Zwicky's original term.

Slusher (1974) was the first to mention in the creation literature the discrepancy between the dynamic and lighted masses of galaxy clusters as a possible argument for recent origin (see p. 343 of Faulkner [2019] for other references of this in the creation literature). Slusher saw this as evidence for recent origin. His reasoning was that since the velocities of galaxies in clusters exceed the orbital velocities implied by the lighted masses of the clusters, the galaxies were not orbiting. Rather, the motions of galaxy in clusters indicated that clusters are not gravitationally bound and thus are expanding. This expansion could continue indefinitely, but it could not have been going on very long, much less than the supposed billions of year age of the universe. Bouw (1977a, 1977b) offered an early discussion in the creation literature of the velocities of galaxies in the Virgo cluster and recommended caution in using this argument based upon observations that suggest that the observed motions of its members is orbital. This amounts to a conclusion that dark matter may be real. I have agreed with this assessment (Faulkner 1998, 2017a). The opposition to dark matter that some recent creationists have may stem from a desire to maintain this argument for recent origin that Slusher pioneered.

The second line of evidence for dark matter, the rotation curves of spiral galaxies, goes back nearly as far as Zwicky's work with the Coma Cluster. A century ago, astronomers began to measure the orbital motion of objects within galaxies to determine the masses of those galaxies. The nuclei of spiral galaxies account for much of the light of those galaxies, and presumably much of their masses (more mass translates into more stars, which translates into more light). Spiral galaxies appear to be radially symmetric, suggesting the mass distribution in spiral galaxies is also radially symmetric. When mass is distributed with radial symmetry, the only mass that affects an object's orbital velocity is that mass orbiting more closely to the center than the object. Therefore, measuring the Doppler motion across the long axis of a spiral galaxy acts as a probe of the mass distribution as a function of distance from the galaxy's center. The summation of the mass distribution yields the total mass. A correction must be applied for how out of the line of sight the orbital motion is. For any spiral galaxy, this angle is easily determined by measuring the galaxy's major and minor axes in a photograph. Radial velocity studies of the nuclei of spiral galaxies showed a linear relationship between orbital velocity and distance from the centers of those galaxies. If the amount of light is directly proportional to mass, then this linear relationship in the nuclei of galaxies is expected. Therefore, these studies confirm the relationship between light and mass, what astronomers call the *mass to light ratio*, at least in the nuclei of spiral galaxies.

Since spectroscopy disperses light, it is a very inefficient use of light. A century ago, these studies required the largest telescopes that then existed, with photography that was at best 1-2 percent efficient. This severely limited how faint these studies could be conducted. Therefore, only the closest galaxies were sampled, and then only their nuclear regions. This resulted in finding only the masses of the nuclei of galaxies. But since the nuclei of spiral galaxies accounted for much of the light of the galaxies, masses measured this way were expected to be well within an order of magnitude of the entire masses of the galaxies, probably within a factor of 2-3. It was these studies, along with kinematic studies within our Milky Way Galaxy, that established the light to mass ratio that Zwicky used to establish the lighted mass of clusters of galaxies.

What was the expected behavior of orbital motion outside of the nuclei of spiral galaxies? Since the light outside the nuclei of galaxies abruptly decreases just outside the nuclei and then continues to gradually decreases with increasing distance, the mass distribution was expected to similarly decline with increasing distance as well. When objects orbit a large, centrally located mass, orbital motion is inversely proportional to orbital distance. For instance, the sun contains more than 99.8% of the solar system's mass. Consequently, the orbital speeds of planets are inversely proportional to their orbital distances. Since this condition fits planetary motion well, and Kepler's laws describe planetary motion, then orbital velocity that is inversely proportional to orbital distance is called *Keplerian*. Since there is light emanating beyond the nuclear regions of spiral galaxies, the mass distribution beyond the nuclei is not zero, but it would be expected to be much smaller than the mass in the nuclei. Hence, the expected velocity function would be to begin to abruptly decrease beyond the nuclei and approach Keplerian behavior (See Fig. 1).

A century ago, the size of telescopes and the observational techniques then in use did not make it feasible to extend radial velocity studies beyond the nuclei of spiral galaxies. At the edge of the nuclei, the radial velocity curves appeared to turn over, suggesting that beyond that point the radial velocities curves approached Keplerian behavior, so there was no reason to pursue the radial velocity curves farther out. Pushing the limits of what was technologically possible at the time, Babcock (1939) showed that the orbital velocities of a few objects some distance from the nucleus of the Andromeda Galaxy (M 31) were not Keplerian. Indeed, those objects had velocities that were about as high as the turnover point. The following year, Oort (1940) found similar anomalous results for the lenticular galaxy NGC 3115. He wrote that "the distribution of mass in the system appears to bear almost no relation to that of light."

Astronomers tended to ignore these anomalies for three decades. Perhaps it was because they didn't know what to make of them. During these three decades, the masses of additional galaxies were determined by stopping at the turnover points on their radial velocity curves, again assuming that those curves were Keplerian beyond the turnover points. For instance, as I have documented (Faulkner 2021), between 1959 and 1965 Geoffrey and Margaret Burbidge and their collaborators published more than two dozen papers applying this technique to various galaxies. The non-Keplerian nature beyond the turnover point was obvious in many of those radial velocity curves. However, the Burbidges ignored this and calculated galaxy masses from the portion of the radial velocity curves in the galaxy's nuclei. Since the Burbidges were so respected by other astronomers, they

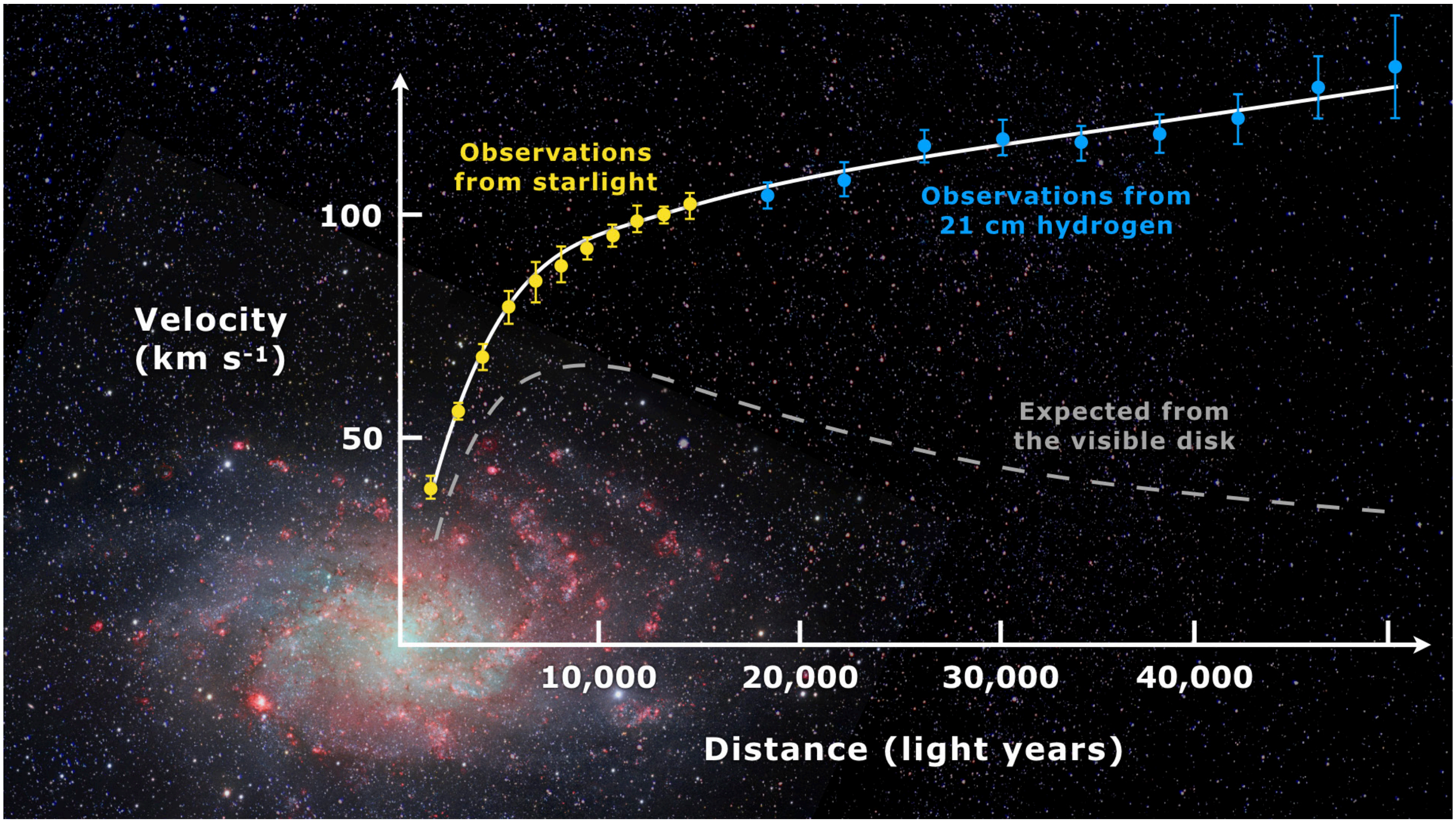

Figure 1. A measured rotation curve of the galaxy M33 superimposed upon an image of the galaxy. The origin of the rotation curve is at the galaxy's center. The horizontal axis is distance from the galactic center, with radial velocity on the vertical axis. The dashed line is the rotation curve expected from the light distribution, assuming that light and mass are directly related. Beyond the turnover around 9,000 light years from the galactic center, the expected curve approaches Keplerian. Contrast this with the observed orbital velocity consisting of yellow and blue data points fitted to the solid line.

probably played a role in astronomers overlooking the evidence for dark matter in these radial velocity curves.

It is interesting that Vera Rubin was a collaborator with the Burbidges in five of the papers in the last two years of their work on radial velocity curves of galaxies. About the time of this collaboration, Rubin was first author on a paper that did not involve the Burbidges which examined motions of stars within the Milky Way (Rubin, et al. 1962). They found that "for $R > 8.5$ kpc, the stellar curve is flat, and does not decrease as is expected for Keplerian orbits." This may have been the first clear indication that a similar problem exists in the Milky Way Galaxy.

About this time, Rubin met instrument maker Kent Ford, which a few years later resulted in a decade-long collaboration extending radial velocity curves of spiral galaxies. Ford combined image tubes, the latest technology used in astronomy in the late 1960s, to boost the sensitivity of cameras recording spectra. When combined with the larger telescopes coming into use at that time (especially the two 4-meter telescopes at the recently opened national optical observatories) allowed extending good observations over the supposed Keplerian part of galaxy radial velocity curves for the first time. Being the closest and hence brightest spiral galaxy, M 31 was the first target (Rubin and Ford 1970), in which they confirmed Babcock's earlier work. It is worth noting that more than a decade earlier, a study of 21-cm radiation of neutral hydrogen in M 31 showed the same thing (van de Hulst, et al. 1957; Schmidt 1957). Additionally, Roberts and Whitehurst (1975) extended the rotation curve of M31 beyond what Rubin and Ford had. Roberts and Whitehurst found that the mass-to-light ratio in the outermost regions of M31 had to be at least 200. Rubin and Ford spent the 1970s investigating the radial velocity curves of many spiral galaxies, culminating in 1980 (Rubin, et al. 1980). While Rubin was pursuing this work optically in the 1970s, radio astronomers were using 21-cm radiation to produce radial velocity curves of galaxies that agreed with the visible light results of Rubin and Ford (Rogstad and Shostak 1972). By the 1980s, this groundbreaking work began to convince most astronomers of the reality of dark matter. It was not until 1984 that Bond, et al. (1984) resurrected Zwicky's original term *dark matter*.

In the 1980s, cosmologists began to discuss dark matter within big bang models, though that discussion did not begin in earnest until the 1990s. One would think that inclusion of dark matter in cosmological models would have been motivated by the desire to have realistic models. After all, if gravity is the dominant force in cosmology, and if gravity is caused by matter, then cosmological models that omit 90% of the mass of the universe cannot be very good. However, this does not seem to have been the case. One reason why cosmologists began to include dark matter was to explain galaxy formation. The density of the universe in big bang models at the time could not account for galaxy formation. It was hoped that dark matter could help solve this problem. Another reason dark matter was considered in cosmology was the desire to achieve critical density in a Friedmann universe. In a roundabout way, this addresses the need to have a more realistic big bang model by considering all the matter in the universe. However, we don't live in a Friedmann universe (dark energy is not compatible with a Friedmann universe). Frankly, I never understood this bias among cosmologists. Even before the discovery of dark energy, the assumption of a Friedmann universe seemed like an unnecessary imposition. And even if we live in a Friedmann universe, why must its density be critical? The density of the universe ought to be a measured quantity, not an assumed boundary condition.

The third line of evidence for dark matter is gravitational lensing. If a very massive object is nearly in the line of sight of a much more distant object, the strong gravity of the nearer object can distort spacetime so that the light of the more distant object is bent, resulting in an altered view of the more distant object. Since this bending is similar to the refraction of a lens, this phenomenon is called gravitational lensing. While there were several early publications suggesting the possibility of gravitational lensing, the phenomenon is most associated with Albert Einstein, who published a paper about it in 1936. These early treatments were primarily theoretical. The first practical discussion of gravitational lensing was the following year when Zwicky (1937a, 1937b), proposed that clusters of galaxies could act as gravitational lenses of more distant galaxies.

Depending upon the geometry, gravitational lensing can take several forms. One form of gravitational lensing is two or more images of the same object. The first discovered gravitational lens was of this type (Walsh, Carswell, and Weymann 1979). The twin quasar SBS 0957+561 consists of two quasars separated by just six arcseconds and having the same redshift (z = 1.41) and nearly the same apparent magnitude. On images of SBS 0957+561, the giant elliptical galaxy Q0957+561 G1 with redshift z = 0.355 is asymmetrically located between the twins. Since Q0957+561 G1 has a much smaller redshift, it is presumed to be in the foreground of SBS 0957+561. The proximity of two quasars with similar spectra, identical redshifts, and nearly the same apparent magnitude suggested that they were two images of the same quasar. Confirmation came when identical variations in brightness of the two quasars separated in time by 417 days were discovered. This is interpreted as a delay due to different travel distances of light on two different paths caused by the galaxy Q0957+561 G1 not lying exactly along the line of site to the midway between quasar SBS 0957+561.

The more common situation is gravitational lensing of a distant galaxy or galaxies by a nearer cluster of galaxies. One of the best examples of this is CL 0024+17 (aka ZwCl 0024+1652) (Anonymous, no date) (see Fig. 2). Most of the cluster members in this HST image of CL 0024+17 appear yellow. However, near the center of the cluster there are a series of blue concentric arcs that are gravitationally lensed images of more distant galaxies. Modeling the observed lensing allows determining the amount of mass required to produce the lensing, as well as the distribution of the mass (see Fig. 3). In every case of gravitational lensing caused by clusters of galaxies, the total inferred mass exceeds the lighted mass by a factor of 5-10.

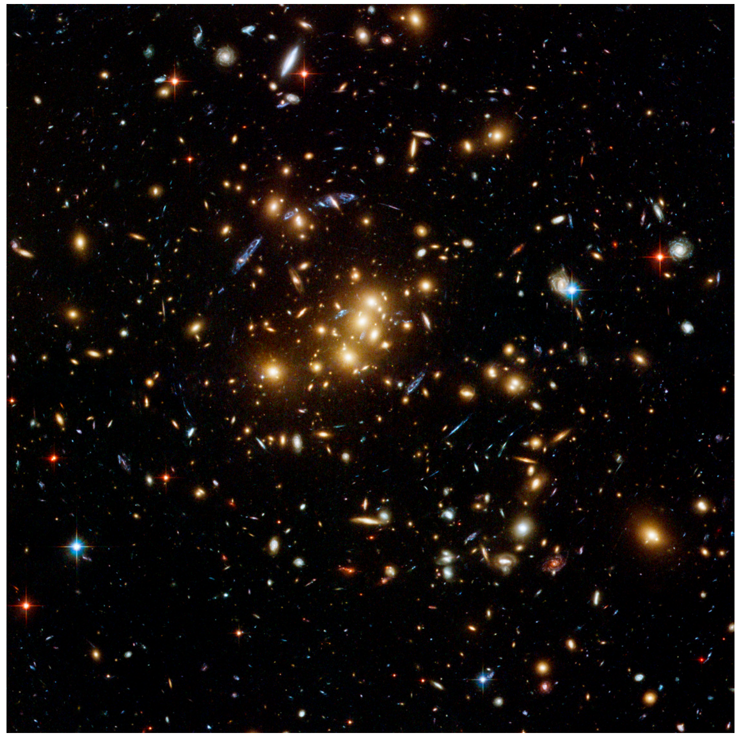

Figure 2. A Hubble Space Telescope (HST) image of CL 0024+17. Photo credit: NASA/ESA/HST.

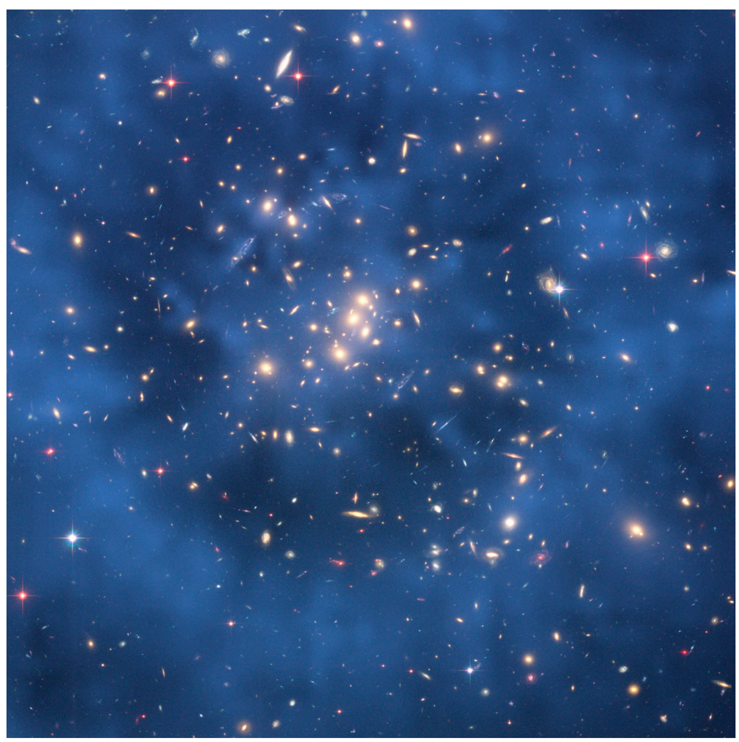

Figure 3. The gravity map of CL 0024+17 determined from the amount of gravitational lensing superimposed on the image of Figure 2. Image credit: NASA/ESA/HST.

III. CREATIONISTS' RESPONSES TO DARK MATTER

The concordance from the three lines of evidence for dark matter on the amount of dark matter required to explain the observations is striking. Under most circumstances, such concordance constitutes a strong case, but astronomers were very reluctant to reach this conclusion, though they eventually did. Many creationists seem to be under the illusion that astronomers and cosmologists rapidly incorporated dark matter into their models or that astronomers and cosmologists entirely made dark matter up to explain away problems with their evolutionary models. For instance, this quote by Hartnett (2014) demonstrates this latter thinking:

> …we need to understand that **dark matter**, dark energy, and other "unknowns" … **were only proposed in the standard big bang cosmology to resolve some conflicts between the standard paradigm and astrophysical observations**. [emphasis added]

However, a frank assessment of the history of dark matter as outlined here reveals that neither astronomers nor cosmologists were quick to embrace dark matter, nor that dark matter was invoked merely as a rescuing device for evolutionary ideas.

There are many examples of articles in the creation literature doubting the existence of dark matter (*e.g.*, Dobberpuhl 2017; Hartnett 2006, 2007, 2017; Hebert 2013). Some of this criticism of dark matter stems from reports of failure to detect dark matter more directly. Theoretical physicists have proposed several theories as to what dark matter is made of. One promising candidate is weakly interacting massive particles (WIMPs). WIMPs were thought to be new elementary particles that interact only with gravity and possibly a hitherto unknown force. Most attempts to search for WIMPs focused on detection of products of WIMP annihilation, such as neutrinos, gamma rays, and cosmic rays. All these searches have been fruitless.

Another candidate for dark matter has been massive compact halo objects (MACHOs). MACHOs would be normal matter in exotic forms, such as quiescent black holes and neutron stars. There have been tests of their existence by looking for gravitational lensing that might happen as MACHOS pass in front of halo stars in the Milky Way. These searches have been fruitless too.

Another candidate has been axions, a potential particle conceived apart from dark matter so was readily at hand. Axions were hypothesized to explain the preservation of charge conjugation symmetry and parity symmetry in quantum chromodynamics. Like the other candidates, axions have yet to be detected. Sterile neutrinos would interact via gravity but no other force. There are good reasons to think sterile neutrinos exist. They would have left-handed chirality, whereas all known neutrinos are right-handed. All other fermions exhibit both right-handed and left-handed chirality. If sterile neutrinos were ever discovered, and if they have enough mass and are plentiful enough, then they may be the elusive dark matter. However, there has not yet been any detection of sterile neutrinos.

Another potential candidate for dark matter that was already at hand is the gravitino. Quantum mechanics views the fundamental forces as being mediated by a particle and an associated supersymmetry particle. The hypothetical particle that mediates gravity is called the graviton, and its associated particle is called the gravitino. It is possible that the gravitino has a large enough mass to account for dark matter. The graviton and the gravitino will be very difficult particles to detect.

Many times, news accounts of these studies report that the scientists involved failed to detect dark matter. Worded this way, these reports are very misleading. Scientists did not fail to detect dark matter in general. Rather, the scientists failed to detect particular candidates for dark matter, thus eliminating those candidates from further consideration. The null results of tests of dark matter candidates are disproof of particular models of dark matter, not disproof of the existence of dark matter. Unfortunately, some comments on these stories by some recent creationists fail to reflect this distinction.

Furthermore, the evidence for dark matter is based upon operational science, the study of how the world operates today. In contrast, inclusion of dark matter into the big bang model and for the origin and maintenance of galactic structure are historical science. Creationists ought to be aware of this distinction, but alas, many of them don't appear to be.

There are relatively few articles in the creation literature supportive of dark matter. While not necessarily supportive of dark matter, DeYoung (2000) offered a rather neutral evaluation of dark matter. What is the reason why creationists are so resistant to dark matter? As I have already stated, there appear to be two reasons for this resistance. One of those reasons is ignorance of the data supporting dark matter, thinking that dark matter is a rescuing device. One of the main purposes of this paper is to counter the notion that dark matter is a rescuing device. The history of our understanding of dark matter as presented here reveals a very different story. Those who think dark matter is a rescuing device seem to have picked up the story of dark matter only after astronomers and cosmologists widely accepted the reality of dark matter.

The other reason why so many recent creationists doubt the reality of dark matter may be the desire not to give up what many creationists see as a good argument for recent origin (at least not over billions of years), that, as previously mentioned, galaxy clusters may not be gravitationally bound and could be breaking up. If the dispersion velocities of galaxies in clusters were the only observations supporting dark matter, then this may be a viable possibility. However, how does one handle the rotation curves of spiral galaxies? One could posit that just like clusters of galaxies, individual galaxies are not stable and hence are disrupting as well. Consequently, that might be an argument against individual galaxies being billions of years old. But that would only apply to the regions of galaxies outside their nuclei. Why would the nuclear regions of spiral galaxies be subject to bound orbits while the outer regions of galaxies are not? Simply positing that this is the way the world operates is not a satisfactory answer. Furthermore, this tack cannot explain gravitational lensing of distant galaxies by closer clusters of galaxies, so observations of this would require yet another explanation.

There is one additional problem with this explanation. Creationists have long advanced the idea that there is design and stability in the world. For instance, some creationists speak about the stability of both planetary orbits and the orbits of the planets' natural satellites, and even the stability of systems beyond the solar system (*e.g.*, Burgess 2008; Wilson 2003). Which is it? Did God create a stable world, or did He create an unstable world? Are creationists willing to sacrifice the stability argument in favor of a lesser argument for relatively recent origin?

Some creationists have embraced modified Newtonian dynamics

(MOND) as an alternate explanation for the observations generally attributed to dark matter (*e.g.*, Hartnett 2002; Worraker 2002). Proposed by a non-creationist (Milgrom, M. 1983), MOND hypothesizes that Newton's simple inverse square of the distance law of gravity is a good description of gravity over relatively short distances (at least on the scale of the solar system), but for distances spanning thousands of light years, Newtonian gravity fails to adequately describe how gravity operates. Thus, Newtonian gravity must be modified in such a way that its long-scale behavior is masked over distances spanning less than a few thousand light years.

This modification comes across as radical, but is it? Newton derived his law of gravity by comparing the measured acceleration of gravity on the earth's surface to the centripetal acceleration required for the moon to orbit the earth, and he further tested his hypothesis by showing it accurately described the motions of the planets and the natural satellites of Jupiter and Saturn (Faulkner 2017b). MOND proposes to extend Newton's original approach of fitting orbital motions of objects at distances seven or more orders of magnitude greater than those directly tested in the solar system. In this sense, MOND would just be a modification of our understanding of gravity, with Newtonian gravity as a special limiting case, much as general relativity modified our understanding of gravity a century ago. So, perhaps MOND is not so radical after all. However, since Newtonian gravity and general relativity are consistent with one another in the regimes under discussion, MOND would require modification of general relativity as well. To my knowledge, this has not yet been attempted.

There are tests of MOND that we can perform. If MOND correctly describes how gravity operates, then MOND ought to apply to all galaxies of sufficient size. However, astronomers have found a few galaxies that have no need of dark matter, that is, spiral galaxies which have rotation curves that follow Keplerian behavior outside their nuclei. The first example of this was the galaxy NGC 1052-DF2 (Faulkner 2018). If MOND properly describes the observed departure from Keplerian motion outside the nuclei of most spiral galaxies, then why does it not apply to galaxies with Keplerian motion outside their nuclei? It may seem counterintuitive, but the existence of a few large galaxies that have no evidence of dark matter amounts to evidence of dark matter in other galaxies.

Another test of MOND was presented by the discovery of the interacting galaxy cluster 1E0657-558, aka the Bullet Cluster (Clowe, Gonzalez, and Markevitch 2008). This object is two galaxy clusters that appear to have recently undergone a collision. Most of the emitting mass in clusters of galaxies is in the form of hot intergalactic gas. Stars are very small compared to the scales of galaxies and clusters of galaxies, so when clusters of galaxies collide, the stars and galaxies largely pass through one another with only modification of their trajectories. However, the diffuse intergalactic clouds directly collide and stall, leaving the gas originally in the two clusters between them. The high-temperature intergalactic gas is detected by the X-rays they emit, while the stars and galaxies are detected by optical light. When images of the two are superimposed as in Fig. 4, the intergalactic gas is located between the two galaxy clusters. Since the mass of the intergalactic gas dominates the visible mass, MOND would predict that most of the mass would be aligned with the gas and not the visible galaxies. However, dark matter does not appear to interact with normal matter, so the prediction of the mass distribution based upon the assumption of dark matter is that most of the mass would align with the galaxy clusters, not the gas. 1E0657-558 acts as a gravitational lens of more distant objects, allowing its distribution of mass to be mapped. The bulk of the mass is centered on the two clusters, not the interposing stalled gas, thus MOND is eliminated as a possibility. The same sort of observations and reasoning applied to the colliding cluster MACS J0025.4-1222 reach the same conclusion (Brada et al. 2008).

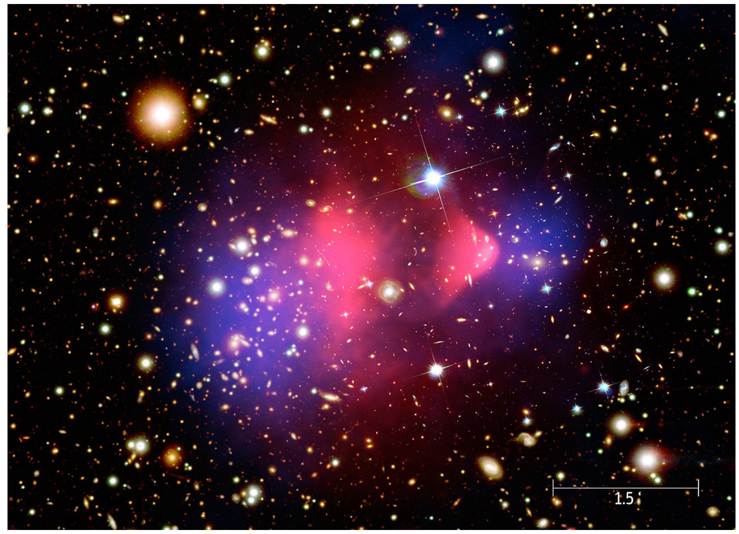

Figure 4. Composite image of 1E0657-558 (the Bullet Cluster). Superimposed over a visible light image of the galaxies is an x-ray image (pink), showing the emission of gas, and the inferred distribution of dark matter (blue) from gravitational lensing. The dark matter coincides with the galaxies, not the intergalactic gas, which has greater mass than the galaxies. MOND would predict the coincidence of the gas and the need for unseen matter.

It's not as if dark, or yet unseen, matter is a new concept. Neptune was discovered in 1846 based upon calculations of a hypothetical planet responsible for perturbations of the orbit of Uranus. In 1980, the two Voyager spacecrafts discovered that Saturn's F Ring appeared braided. The inferred explanation was that there were two small natural satellites, or moons, nearby that perturbed ring particles to produce the braiding. A search for these shepherd moons quickly led to the discovery of Prometheus and Pandora. More recent studies suggest that Prometheus plays the dominant role in this process. One can even argue that Wolfgang Pauli's 1930's proposal of the neutrino to salvage the conserveation of energy, linear momentum, and angular momentum in beta decay was a form of dark matter because neutrinos remained undetected until 1956. To be fair, the hypothetical planet Vulcan that was proposed in the 19^{th} century to explain the anomaly in the perihelion advance of Mercury's orbit is an example of a failed dark matter prediction. The solution to the problem with Mercury's orbit came with the publication of Einstein's theory of general relativity in 1915. Hence, there is precedent for new physics. However, the question is which of the two, dark matter or new physics, best explains what we see today. Dark matter is a much better explanation than new physics.

There has been at least one refreshing approach for an alternative to dark matter offered by recent creationists. Tenev and Horstemeyer (2019) suggested that the evidence for dark matter could be explained by the inherent structure of space at galactic scales, with the curvature of space amplifying the gravity of ordinary matter in galaxies. While I may not agree with this proposal, I encourage this sort of original thinking.

IV. DARK ENERGY

In a finite universe governed by Newtonian mechanics, gravity will eventually collapse all matter to its center. For centuries, most scientists had thought the universe is eternal. But if the universe is eternal, then collapse should have happened long ago. The fact that this hasn't happened ought to have convinced astronomers that the universe is not eternal. But rather than make this straightforward conclusion, astronomers instead postulated that the universe also is infinite. In an infinite universe, there is an equal amount of matter in all directions whose gravity pulling on matter in all locations so that there is no net motion of matter to bring about a collapse. Therefore, the universe was envisioned as being eternal, infinite, and with no net motion. This *static universe* prevailed for more than two centuries.

Albert Einstein published his theory of general relativity (GR) in 1915. A year later, Einstein followed up this work by applying GR to the universe. However, one of the differences between Newtonian gravity and GR is that in a universe governed by GR, the universe will collapse under its own gravity, even if the universe is infinite. To preserve a static universe, Einstein included in his cosmology the *cosmological constant*, usually indicated by the Greek letter λ. The cosmological constant acts as a repulsion term that space has for itself. If the value of λ has the right value, then its outward force of repulsion balances the inward force of gravity, producing a universe with no net motion.

In 1922, Alexander Friedmann showed that Einstein had failed to realize the general solution of GR applied to the universe. In the general case, the universe is either expanding or contracting. By insisting on a static universe, Einstein had settled on the intermediate case between the two extremes of the general case. Friedmann favored the expanding case, though it is not clear why. It may be that he thought expansion made more sense than contraction in a universe that has always been governed by naturalism. Or it may be that Friedmann was aware of Vesto Slipher's work commencing in 1912 showing that what eventually were recognized as galaxies had large redshifts, consistent with an expanding universe. The little-known Carl Wilhelm Wirtz (1918) certainly understood the implication of Slipher's work. Perhaps Friedmann had read Wirtz's paper. At any rate, credit for discovery of the expansion of the universe generally goes to Edwin Hubble in 1929, though Georges Lemaître had published a similar thing two years earlier. The difference between the two was that Lemaître's work was theoretical, based upon Friedmann's cosmology, while Hubble's approach was observational.

Though Einstein originally opposed an expanding universe, he soon abandoned the static universe, calling his introduction of λ his greatest blunder. However, this assessment is a bit harsh. Einstein had thought the universe was static, so he enforced this boundary condition on the universe by including λ. Friedmann and Lemaître chose boundary values that permitted an expanding universe, with the preferred value of λ being zero. This cosmology was dominant for about 70 years, but in the late 1990s astronomers discovered the need to reintroduce something akin to the cosmological constant.

What changed? Consider the effect of gravity on the expansion of the universe. The gravity of the matter of the universe tends to slow expansion, which is why Einstein introduced λ to counter this effect to preserve a static universe. If the universe is not static, then expansion will slow, with the amount of slowing in expansion related to the density of the universe. Density is an important parameter of the universe, so a good measure of density is important. Assuming a constant speed of light, distance amounts to a lookback time. If the expansion of the universe does not change, then galaxies will demonstrate a strictly linear relationship between their recession and distance. However, if expansion has slowed, then very distant galaxies will have greater recession than expected from a linear relationship observed in the local universe, which, assuming lookback time, has been subjected to slowing. Thus, slowing expansion would show up as an upturn in the Hubble relation at great distance. This expected behavior of the Hubble relation has been known for a long time, but limits of accurately measuring the distances of faraway galaxies made testing this impossible. Classical techniques, such as Cepheid variables, were limited to distances of tens of millions of light years, but this effect is not likely to show up except on the scale of several billion light years (for a survey of astronomical distance determination methods in the creation literature, see Faulkner [2013]).

By the 1970s, astronomers realized that type Ia supernovae provided an opportunity to extend distance determination methods to billions of light years. This is because type Ia supernovae are very bright (far brighter than other standard candles) and are homogeneous in their maximum brightness. Therefore, if one observes a type Ia supernova at maximum brightness, then one knows its intrinsic brightness, and comparison to its observed brightness readily yields its distance. Type Ia supernovae are relatively easy to distinguish from other supernovae. The problem is that supernovae of all types are relatively rare, happening perhaps a few times per century in any given galaxy. Consequently, it may be centuries before a type Ia supernova may be seen in a galaxy that astronomers regularly monitor. By the 1990s, moderately large robotic telescopes were taking images of hundreds, if not thousands, of galaxies every clear night and comparing the images to reference images to search for supernovae. Subtracting a reference photo of a galaxy from a newly obtained photo in which there is no supernova yields a blank image. But if a supernova has occurred in a galaxy, then subtraction of the reference photo from a new photo will result in an obvious bright spot that computers can readily detect. Once a supernova was detected in a galaxy, alerts were sent to major observatories where astronomers could quickly turn very large telescopes to further study the erupting supernova. This process ended up producing many new supernova discoveries each year that would have been missed in the past.

In the 1990s, two international teams of astronomers formed to make use of this new technique of detecting and observing type Ia supernova to assess the amount of deceleration of the universe. One group was the High-Z Supernovae Search Team, headed by Brian Schmidt and Adam Riess. The other group was the Supernova Cosmology Project, led by Saul Perlmutter. The two teams hoped to accurately find the distances of enough high redshift galaxies to find the expected upturn in the Hubble relation and hence measure the amount of gravitational deceleration in the universe. To the astonishment of both teams, they discovered that rather than an upturn in the Hubble relation at great distance, there is a downturn. This result was so unexpected that it delayed publication while the two teams attempted to find what they had done wrong. Once they decided that their results were real, the implication was clear – just as an upturn in the Hubble relation would have indicated deceleration of the universe, a downturn in the Hubble relation indicates an acceleration of the universe. The teams published their findings in 1998-1999, and this result was so groundbreaking that the three leaders of the teams shared the 2011 Nobel Prize in Physics.

After seven decades, it seemed the cosmological constant was back. However, rather than being a constant repulsion term in the universe as the cosmological constant was, cosmologists today entertain the possibility that the repulsion in the universe may change over time. Hence, cosmologists chose a new term to describe this repulsion, *dark energy*. Why choose those two words? For a long time, cosmologists have used fields to describe various effects in the universe, such as a field to drive cosmic inflation in the early universe. In physics, a field is associated with a force (the force is the negative of the gradient of the field, thus transforming a scalar field into a vector force). A field represents a potential energy, so when formulated this way, the accelerating force of the universe requires energy to drive it. The word "dark" was chosen in comparison to dark matter, though dark matter and dark energy have nothing in common. The similarity of the terms "dark matter" and "dark energy" is most unfortunate because it confuses many people who do not understand the difference.

Quantum field theory (QFT) did not exist in the 1920s when modern cosmology took form. QFT offers a physical basis for λ. The cosmological constant appears as the expectation value of the quantum fields in their lowest energy state. One manifestation of the so-called "zero-point energy" is "vacuum polarization" that drives the Casimir effect. The energy in that state is non-zero and the expectation value of the fields will appear as a contribution to the stress-energy tensor. The contribution to stress-energy turns out theoretically to be equivalent to a "cosmological constant" as proposed originally by Einstein, but in this case it is not ad hoc. It is true that the present state of QFT does not provide a known method for producing a finite value of λ. A finite value can be obtained if a UV cutoff is introduced in momentum space for the vacuum energy. However, a theoretical basis for computing the cutoff is unknown at the present. Such cutoffs would depend on new unknown theoretical parameters, which could indicate new physics yet to be discovered.

Both dark matter and dark energy are now incorporated into the standard cosmology, indicated as the λCDM model. The λ refers to the inclusion of dark energy. The CDM refers to "cold dark matter." The term cold here does not refer to temperature but rather to the assumed speed of the particles comprising dark matter as compared to the speed of light. Models in which dark matter particles move slowly seem to fit other parameters of the big bang model than fast moving dark matter particles, hence the exclusion of fast moving (or "hot") dark matter particles in the latest big bang models. As the perceived association of dark matter with the big bang model accounts for some of the opposition many recent creationists have to dark matter, so the close association of dark energy with the current big bang models probably explains why recent creationists generally resist dark energy (e.g., Coppedge 2008; Hartnett 2002; Hebert 2012; Sarfati 2018).

Indeed, as Hill (2017) has shown, the evidence for dark energy, the downturn in the Hubble relation at great distances, has been interpreted entirely within the big bang model and hence, unlike the case for dark matter, the existence of dark energy does rely upon the big bang model. However, as Hill also pointed out, even if the big bang model is incorrect, the evidence from the Hubble relation remains. A different cosmology/cosmogony may result in an interpretation of that evidence that is different from the interpretation of dark energy. How might a biblical cosmology/cosmogony reinterpret the downturn in the Hubble relation at great distances? We don't know, because no such detailed model exists yet. I encourage recent creationists to be more guarded in their comments about dark energy, making a distinction between the conclusion of dark energy and the data upon which that conclusion is based. We need to honestly and publicly admit that the downturn in the Hubble relation at great distances is real and awaits a different interpretation.

V. CONCLUSION

Many recent creationists reject both dark matter and dark energy, though their reasons are not always clear. I perceive that some of the motivation in resisting dark matter and dark energy is an attempt to refute the big bang model. However, as discussed in this paper, this is an ill-advised tactic. Much of the criticism of dark matter coming from recent creationists tends to focus on two fronts:

1. Treating dark matter as a rescuing device for the big bang and other evolutionary ideas
2. The negative results of the tests of different theories of the identity of dark matter particles

However, these discussions do not properly handle the facts. There are three lines of evidence for dark matter. Two of those three lines of evidence preceded dark matter's inclusion in the big bang model and modern ideas of galactic evolution by many decades. It wasn't until after astronomers eventually became convinced of the reality of dark matter from the evidence that astronomers and cosmologists began to employ dark matter to solve problems with their models. Keep in mind that astronomers greatly resisted dark matter for decades – they hardly embraced dark matter as a rescuing device. Rather than denying the existence of dark matter, recent creationists must effectively engage with the immense amount of evidence for dark matter.

Similarly, recent creationists tend to view dark energy as a rescuing device for the big bang model. The reality is that within the big bang model, dark energy is the best interpretation of the downward inflection of the Hubble relation at great distance. That is, dark energy is based upon real data that is interpreted in terms of an evolutionary model. Simply dismissing dark energy out of hand is tantamount to dismissing the data. What the downturn in the Hubble relation might mean in a creationary cosmology/cosmogony model must await the development of such a model. At the very least, recent creationists ought to acknowledge the reality of the downturn in the Hubble relation at great distance, while making it clear why they don't agree with the interpretation of the downturn within the big bang model.

Even better, as with the evidence for dark matter, recent creationists must seriously engage with the evidence usually interpreted as indicating dark energy in the universe and interpret it on their own terms. Science progresses only when we change and develop our models as new data are found. Rather than ignoring or denying the data that are invoked in support of dark matter and dark energy, recent creationists must produce their own models to interpret this data. Only through this difficult process can significant progress be made in achieving a robust, truly biblical cosmology/cosmogony.

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