Evidence that Wavelength Independent Extinction by Dark Matter Solves the Hubble Tension & Generates New Physics.

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Abstract

This paper is the original work that was previously divided into several parts: "Is the Hubble Tension dismissed" (ChinaXiv202511.00067), which was a modified version of "Are Stellar Distance Measurements Opening a Window into New Physics" (ChinaXiv 202502.00012); "Does Dark Matter Solve the Hubble Tension Puzzle"(ChinaXiv202502.00166); and "Wavelength Independent Extinction in the Milky Way" (ChinaXiv.00308). This paper integrates all the aforementioned components into a coherent and accessible form. The SHOES paper by Riess et al. (2021) is reviewed, wherein the most precise available Hubble Space Telescope photometric data for Cepheid stars are utilized to define their absolute magnitudes. The resulting distances are compared with Gaia parallax distances for the same stars. Riess et al. (2021) uniquely modified the Gaia parallax measurements through a zero-point correction to achieve agreement and support the SHOES value of the Hubble constant. Without this correction, agreement is achieved by incorporating a tiny wavelength-independent extinction across the galaxy. It is demonstrated that this would invalidate virtually all evidence supporting the Hubble Tension. The SHOES team also plotted the parallaxes against each other and claimed no conflict exists. Plotting parallaxes removes any extinction, which becomes lost in the noise as parallax increases. The cited supporting evidence for the SHOES value of the Hubble constant is reviewed, including Zinn et al. (2019) and Zinn (2021), and the photometry of 2000 first-ascent red giant stars with distances derived from their asteroseismology. Similarly, the detached eclipsing binaries (DEB) of Stassun and Torres (2021) and Pietrzyński et al. (2019) are shown to rely on photometry, as do Mira variables cited by C. Huang et al. (2018) and (2019). The water maser support and the primary red clump stars cited by Y. Huang et al. (2020 and 2021) are considered. Finally, the strong-lensing support for the Riess value of the Hubble constant is reviewed. It is demonstrated how all this support is based primarily or secondarily on photometry. The non-photometric support for the

Hubble Tension has attracted strong criticism, which is discussed. It is shown mathematically that accepting the Gaia parallaxes as correct indicates a tiny wavelength-independent extinction of light across our Galaxy. This is strongly supported by plotting the two distance measurements (inverse of the parallaxes) of the Cepheids against each other, with the SHoES ten microarcsecond Gaia correction removed. The source of the tiny extinction is investigated, and it is shown that extinction by dark matter neatly explains both the Riess and Freedman values of the Hubble constant. It is further shown that intergalactic dark matter extinction clearly explains the claimed recent time increase

Full Text

Preamble

Evidence that Wavelength Independent Extinction by Dark Matter Solves the Hubble Tension & Generates New Physics

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Abstract

This paper synthesizes previous work on the Hubble tension, presenting a coherent and accessible analysis. The SH0ES team (Riess et al. 2021) used Hubble Space Telescope photometry for 66 Cepheid stars to define their absolute magnitude, comparing these distances to Gaia parallax measurements. Riess et al. (2021) applied a zero-point correction to the Gaia parallaxes to achieve agreement and support their Hubble constant value. Without this correction, agreement is achieved by including a tiny wavelength-independent extinction across the galaxy, which would invalidate virtually all Hubble tension supporting evidence. The SH0ES team plotted parallaxes against each other, claiming no conflict, but this approach removes extinction effects that become lost in the noise as parallax increases.

We review the cited supporting evidence for the SH0ES Hubble constant value, including Zinn et al. (2019, 2021) photometry of 2000 first-ascent red giant stars with distances from asteroseismology, detached eclipsing binaries (Stassun & Torres 2021; Pietrzyński et al. 2019), Mira variables (C. Huang et al. 2018, 2019), water masers, and primary red clump stars (Y. Huang et al. 2020, 2021). Strong-lensing support for the Riess value is also examined, showing that all such support relies primarily or secondarily on photometry. Non-photometric support has attracted strong criticism, which we discuss.

Mathematically, accepting Gaia parallaxes as correct indicates a tiny wavelength-independent extinction across our Galaxy. This is strongly supported by plotting the two distance measurements (inverse of parallaxes) of Cepheids against each other, with the SH0ES ten micro-arcsecond Gaia correction removed. We identify dark matter extinction as the source, which neatly explains both the Riess and Freedman values of the Hubble constant. Intergalactic dark matter extinction also explains the claimed recent-time increase in the Hubble constant and provides an alternative explanation for Olbers' paradox. Following Stephen Hawking' s linking of quantum mechanics to strong gravitational fields, we conjecture how dark matter can absorb light, yielding a dark matter particle mass of just over 10^{13} GeV.

Keywords: Stars—distances; Stars—variables—Cepheids; Galaxy—general; Cosmology—dark matter; Cosmology—observations

1. Introduction

The SH0ES group (Riess et al. 2021) used the Hubble Space Telescope (HST) to obtain precise photometry for 66 Cepheid stars, deriving their absolute magnitude as the first step in the distance ladder to measure the Hubble constant H_0. In the same paper, they compared Gaia satellite parallax values with their derived photometric parallaxes. The two values did not agree—the Gaia values would have eliminated the Hubble tension. The SH0ES group subtracted ten micro-arcseconds from each Gaia parallax value, thereby maintaining the Hubble tension. We first discuss in detail the validity of this subtraction, showing it has questionable justification.

The SH0ES value of the Hubble constant, 73 ± 1.3 km s^{-1} Mpc^{-1}, versus the CMB value of 67.27 ± 0.60 km s^{-1} Mpc^{-1}, has attracted considerable discussion (Thakur et al. 2020, 2021, 2023a,b) and a large-scale Community Consensus Report review of the supporting evidence (Casertano et al. 2025). In Section 2, we review support for the SH0ES values in detail.

We show mathematically that if the ten micro-arcsecond correction to the Gaia data is unjustified, a tiny wavelength-independent extinction causes the disagreement. The mathematics equally explains why others introduce further zero-point corrections to the Gaia data to support the SH0ES H_0 value. We confirm the mathematical justification and produce a revised absolute magnitude for the Cepheids. With this revised magnitude, the tension between the SH0ES and Planck CMB (Ade et al. 2014) values of the Hubble constant disappears.

Section 3 considers the Freedman et al. (2019) H_0 value, which differs significantly from both the SH0ES and CMB values. We discuss the cause of this extinction, reviewing Thakur and Valentino et al. (2021), who found no acceptable explanation (Valentino did not consider dark matter). We review our knowledge of dark matter and show that the Freedman et al. (2019) data, when corrected for the same tiny wavelength-independent extinction by dark matter, neatly coincides with the CMB value. The SH0ES H_0 value also coincides with the CMB value when this extinction is included in determining the Cepheid absolute magnitude. McGruder (2024) concluded that dark matter was responsible for extinction in the Milky Way halo, revealed by the change in quasar number density with galactic latitude.

Section 4 applies this dark matter extinction to the much lower density dark matter in intergalactic space, providing alternative explanations for both the apparent recent-time increase in the Hubble constant and Olbers' paradox, currently explained by the finite size of the universe.

Section 5 moves beyond widely accepted data to conjecture how dark matter could absorb light. We review present knowledge of dark matter, photon-gravitational interactions, and General Relativity, discussing General Relativity' s failure to account for inertial properties of matter. Since individual dark matter particles cannot interact with electromagnetic radiation, we conjecture that a pair of dark matter particles held together by gravity would. Following Hawking (1974), we suggest that quantum mechanics also applies to gravity. We calculate the mass of such particles and discuss the conjectured formation and disruption of dark matter binary particles and their equation of state within the galaxy and its stars. We show that in the universal environment of CMB radiation, they cannot exist for any significant length of time bound to baryonic matter but are relatively stable as binaries. We list ideas for testing these conjectures.

2.0 The SH0ES Group Measurements of the Hubble Constant

The SH0ES group (Riess et al. 2021) used the Hubble Space Telescope to obtain precise photometry for 66 Cepheid stars in HST cycles 22 and 27. Using this photometry and measuring distances with reddening extinction to account for dust, they derived a Cepheid absolute magnitude. Knowing the absolute magnitude in different colors and measuring Cepheid brightness, the SH0ES group derived photometric distances for the Cepheids.

These distances do not agree with parallax distances that include the Gaia team corrections of the Early Data Release 3 (EDR3) data from the Gaia satellite. In Riess et al. (2021), the SH0ES group removed this conflict with an ad hoc ten micro-arcsecond reduction in the Gaia parallaxes. The Gaia parallaxes were already corrected by the Gaia team (Lindegren et al. 2021a,b) with an algorithm producing an uncertainty of "a few microarcseconds."Here we discuss the validity of this ten micro-arcsecond reduction.

2.1 The Precision of the Gaia Parallaxes

The Riess team produced a second paper comparing Gaia parallaxes with photometrically derived parallaxes (Riess et al. 2022), claiming this supports their H_0 value without subtracting ten micro-arcseconds. We discuss this second paper in detail to show its precision is significantly inferior to the first paper (Riess et al. 2021). We also show conclusively that ten micro-arcseconds was subtracted from all Gaia parallaxes in the first paper.

The best way to reveal tiny distance-dependent extinction is to plot parallax-determined distances against photometrically determined distances (the inverse of parallaxes). The Riess et al. (2021) paper supports their case by plotting parallaxes, which we show here hides any distance-dependent extinction. The statement that Gaia parallaxes were already corrected by the Gaia team (Lindegren et al. 2021a,b) to produce an uncertainty of "a few microarcseconds" comes from Riess et al. (2021). Despite this, Riess et al. (2021) reduced the Gaia parallaxes for every Cepheid by ten micro-arcseconds, using this reduced value to support their derivation of the Hubble constant.

2.2 The Riess et al. (2022) Paper

The Riess et al. (2022) paper repeatedly refers to the tiny uncertainty in Gaia parallax data of "a few microarcseconds." In this second paper, they abandon the ten micro-arcsecond reduction and work with earlier data from Gaia Data Release 2. This seems strange since they commented in Riess et al. (2021) about the marked improvement in Early Data Release 3: "The quality of the parallaxes of MW Cepheids has markedly improved from Gaia DR2 to EDR3···The improvements result from an increase in the sampling (34 versus 22 months), improved analysis of the data (Lindegren et al. 2020a,b) and an improved characterization of the leading systematic uncertainty."

The second paper, Riess et al. (2022), takes Cepheids residing in stellar clusters and compares Hubble-derived photometric parallaxes with Gaia-derived parallaxes. These Cepheids have similar distances and magnitudes to those in Riess et al. (2021), and the HST photometric process is nearly identical in both cases. However, the Gaia process differs. In Riess et al. (2022), they follow Turner (2010), claiming "it is possible to obtain parallaxes with still greater individual precision and lower systematic uncertainties for Cepheids that reside in Milky Way open clusters." As shown below, this is not justified by the errors on the derived data. They claim that Gaia cluster parallaxes are more precise than those from individual Cepheids, deriving the parallax from an average of >300 stars per cluster, which they use for individual Cepheids.

The problem with Gaia Data Release 2 (DR2) is that several zero-point errors in Gaia parallax measurements require corrections, including dependencies on position, color, and brightness. The Gaia team produced an algorithm to correct these issues in Early Data Release 3 (EDR3), which Riess et al. (2022) agree increases precision to one or two micro-arcseconds. Their work is based on millions of quasars (effectively infinitely distant), Large Magellanic Cloud stars (effectively all at the same distance), and nearly a million binary stars at the same distance but with different brightnesses and colors. They claim their algorithm-corrected parallax distances in EDR3 are correct to one or two micro-arcseconds. The Riess et al. team only disputes the precision of Gaia EDR3 parallaxes in the Riess et al. (2021) paper.

This approach in Riess et al. (2022) can be questioned based on the quality of data it produces. A clear quality indicator is the standard deviation of differences between Gaia parallaxes and photometric parallaxes for each Cepheid, which should be identical. A larger standard deviation indicates uncorrected error sources in both photometry and parallax measurements. The standard deviation of differences is much larger than accepted errors. In Riess et al. (2022), the standard deviation of differences between the two parallaxes is larger than in Riess et al. (2021), despite Riess et al. (2022) claiming that cluster distance measurement precision for their contained Cepheids would produce better data than direct Gaia parallax measurement of the Cepheid. This is clearly untrue and supports the Gaia team approach that Gaia Early Data Release 3 parallaxes corrected with their algorithm are precise to within one or two micro-arcseconds.

Our approach uses the original Gaia data from Riess et al. (2021), corrected with the Gaia algorithm (Lindegren et al. 2021a,b) to "within a couple of microarcseconds" as generally agreed, justifying removal of the Riess ten micro-arcsecond additional correction.

2.2.1 Questions Around the Ten Micro-Arcsecond Reduction in the Gaia Parallax

The ten micro-arcsecond reduction has been disputed. Examining Riess et al. (2021), note "e" for data in Table 1 states: "Includes L20b parallax offset, does not include addition of best-fit residual parallax offset found here, -14 μas." In the arXiv version (arXiv 2012.08534), the same words appear as note "d." The L20b parallax offset is detailed on page 6 (page 8 in the arXiv version): "L20b suggests an uncertainty of 'a few microarcseconds' in the parallax offset across the well-calibrated range. Because our Cepheids are at the bright end of this range, we will adopt a somewhat more conservative a priori uncertainty of 10 μas for the L20b parallax offset." This statement makes it absolutely clear they are correcting the Gaia parallaxes with a ten micro-arcsecond reduction.

The discussion of Gaia parallax data (Section 4.2) differs completely between the arXiv 2012.08534 version and the ApJ Letters published version, suggesting considerable internal discussion. The L20b derivation includes data from nearly a million binary stars where brightness and color effects in Cepheids compared to quasars are easily corrected. Riess et al. (2021) note that as Cepheid magnitude changes, so does color, but this is a tiny effect making only a small addition to their errors. Thus, the Riess et al. statement justifying abandonment of Gaia precision ("one or two microarcseconds") to reduce Gaia parallaxes by ten microarcseconds– "Because our Cepheids are at the bright end of this range" – is questionable. Riess et al. do not use this argument in any other papers.

The Riess (2021) paper plots the two parallaxes against each other. For each Cepheid, the Gaia parallax measurement is plotted against the calculated parallax derived from Cepheid brightness. Plotting parallaxes against each other completely obscures any tiny colorless extinction of light as parallax increases. Such extinction is too small to be seen on the graph for stars with large parallaxes. The effect is more pronounced at considerable distances, but at those distances the parallax is tiny, making a tiny extinction invisible within the errors. If distances (rather than parallaxes) of Cepheid stars as measured by Gaia and Hubble are plotted against each other, a clear loss of 6% of the light per kiloparsec (3,260 light-years) is seen.

2.3 Wider Considerations

This paper describes the situation mathematically in Section 2.9 and Appendix A, including both a variable zero-point correction to Gaia parallax data and a variable galactic extinction for photometric measurements. The mathematics indicates that for the Riess 2021 paper, where Gaia parallaxes are larger than photometrically derived parallaxes, there are two equivalent solutions: a zero-point subtraction applied to Gaia parallaxes or a tiny wavelength-independent extinction.

If we assume errors in algorithm-corrected Gaia data are only a few micro-arcseconds (supported by Riess 2022), then the data supporting Riess et al. (2021) could indicate a conflict between photometrically derived distances and parallax-derived distances, shown mathematically to be due to a tiny wavelength-independent extinction of light in our Milky Way galaxy.

2.4 The Hubble Constant

Behind the conflict between the two distance measurements lies the determination of the Hubble constant, which measures the universe' s expansion rate. The value derived from cosmic microwave background (CMB) measurements by the Planck satellite (N. Aghanim et al. 2020; Y. Akrami et al. 2018) conflicts with recent-time measurements using distant supernovae by the SH0ES group and others. This second conflict is the Hubble tension. CMB measurements rest on the successful standard ΛCDM cosmological model, producing $H_0 = 67.27 \pm 0.60$ km s^{-1} Mpc^{-1}. The SH0ES group (Riess et al. 2021) led recent-time derivations to produce $H_0 = 73.2 \pm 1.3$ km s^{-1} Mpc^{-1}.

If the Gaia distances in Riess et al. (2021) are correct, it changes the Cepheid absolute magnitude and the Hubble tension disappears. The SH0ES subtraction of ten micro-arcseconds from Gaia parallaxes removes the possibility of finding a tiny wavelength-independent extinction.

The SH0ES group (Riess et al. 2021) derived Cepheid absolute magnitude from Hubble photometry corrected for dust reddening using the Wesenheit index (Madore 1982). They used this absolute magnitude to support their reduction of Gaia parallaxes by ten micro-arcseconds. With the abandonment of this correction in Riess et al. (2022), all this Hubble-derived photometry can be regarded as subject to additional tiny wavelength-independent extinction.

This is checked in Khan et al. (2023) data, which introduces a distance-varying zero-point correction for Cepheids up to 10 kiloparsecs distant. The mathematics (Appendix B) shows that the same wavelength-independent extinction is an equally valid solution. With this extinction included, we can derive real Cepheid distances and revise the absolute magnitude. The revised magnitude, used to correct the first step on the Hubble distance scale, produces a Hubble constant not in conflict with Planck CMB measurements (N. Aghanim et al. 2020; Y. Akrami et al. 2018).

The Hubble tension raises two questions. Eleonora Di Valentino examined over 1000 papers seeking an explanation and failed. The Casertano (2025) Community Consensus Report on measuring the Hubble constant at 1% precision produced a wealth of data supporting the Hubble tension. At the base of all this data are what Casertano calls "Anchors"—the starting calibration distances. All quoted anchors are included here. He accepts the Riess et al. (2021) subtraction of ten micro-arcseconds from Gaia parallaxes, which we show above to be unjustified. We suggest further work to confirm extinction by dark matter in the cited Hubble constant programs. Others, particularly Thakur et al. (2020, 2021, 2023a,b), have pursued the Hubble tension, producing useful results but like Valentino reaching no explanation.

2.5 The Riess et al. (2021) Cited Support

We examine considerable support for Hubble constant values that, within errors, support the Riess value. Casertano et al. (2025) assembled 23 direct measurements of the recent-time Hubble constant, with 21 within a standard deviation of the Riess value. Below we examine a dozen core support papers cited by Riess and central to Casertano (2025). These depend on photometry and would be corrupted by tiny extinction of light, affecting derived distances and the absolute magnitude ascribed to the standard candle. The remaining supporting papers have been seriously questioned by workers in the field.

The SH0ES group cited support is used to justify their adoption of the ten micro-arcsecond zero-point correction to Gaia parallaxes in Riess (2021) and their support for the Hubble tension. In Riess et al. (2022), they drop the necessity for the ten micro-arcsecond zero-point correction, leaving the conflict between photometric and parallax distances in Riess et al. (2021) even more visible. The SH0ES group cited support includes analysis of red giants with asteroseismological data from the Kepler satellite by Zinn et al. (2019) and Zinn (2021). The SH0ES group also uses Stassun and Torres (2021) detached eclipsing binaries as distance references. They cite Yang Huang et al. (2021), who used primary red clump (PRC) stars for an independent check on Gaia EDR3 parallax bias. Khan et al. (2023) also support the Hubble tension using red clump stars but require a distance-dependent correction of Gaia data, considering red clump stars out to 10 kiloparsecs.

Mira variables are also used to determine distances. Oxygen-rich Miras have a very tight period-luminosity relationship in the near-infrared and are used to measure extragalactic distances. Caroline Huang et al. (2018, 2019) are cited as support by the SH0ES group. They calibrated Mira distances in the Large Magellanic Cloud, which had already been calibrated photometrically with Cepheids in the Milky Way. Riess et al. also use water masers in NGC 4258 by Caroline Huang et al. (2018, 2019) to support their distance measurements.

Further support for the Riess H_0 value was quoted by Verde et al. (2019) from a Kavli Institute workshop on "Tensions between the Early and Late Universe." Potter et al. (2018) measured distances to SN Ia galaxies using IR Surface Brightness Fluctuations, independently of SN Ia photometry and "other distance ladders." This support is now analyzed.

2.5.1 The Zinn Photometry

Zinn (2021) and Zinn et al. (2019) analyzed 2000 first-ascent red giant stars with distances from asteroseismology, concluding similarly to the SH0ES group that Gaia corrections are too large by 15 ± 3 micro-arcseconds. Like the SH0ES group, the fundamental calibration of the asteroseismology parallax rests on photometry, which we argue would be affected by any wavelength-independent extinction in the galaxy. Zinn et al. use the effective temperature of red giant stars, T_{eff}, a critical component in their asteroseismology defined for stars with known radius and total luminosity. These stars define a true fundamental T_{eff} reference system. Thus, the asteroseismology comparison using total luminosity also suffers from any wavelength-independent extinction, producing a systematic error. In this review, it cannot justify the zero-point correction, and it is not surprising that Zinn gets the same value within errors as the SH0ES group around Riess et al. (2021).

2.5.2 Detached Eclipsing Binaries

Detached eclipsing binaries (DEBs) are also used as distance references. Stassun and Torres (2021) obtained a result similar to the SH0ES group but with much larger errors—too large to see a 6% per kiloparsec wavelength-independent extinction. Pietrzyński et al. (2019) described how the limiting precision using DEBs is set by existing calibrations of surface brightness. To improve calibration of the relation between surface brightness and color, they carefully selected a sample of 41 nearby red clump giant stars in the core helium-burning phase. They used the surface brightness (S_V) definition: $S_V = V_0 + 5\log(\phi)$, where V_0 is the V-band magnitude corrected for reddening and ϕ is the stellar angular diameter. They collected precise near-infrared photometry at the South African Astronomical Observatory and complemented it with high-quality homogeneous V-band photometry. Thus, wavelength-independent extinction produces a systematic error in their distances. Their citation by Riess et al. to support the ten micro-arcsecond zero-point correction cannot be justified in the face of a tiny wavelength-independent extinction in the Milky Way.

2.5.3 Miras and Water Masers

Mira variables are also used to determine distances. Miras are asymptotic giant branch variables existing in oxygen- and carbon-rich subclasses. Oxygen-rich Miras have a very tight period-luminosity relationship in the near-infrared. Caroline Huang et al. (2018, 2019) calibrated Mira distances in the Large Magellanic Cloud (already calibrated photometrically with Milky Way Cepheids) and used Miras to measure the distance to NGC 4258. This is clearly another photometrically based check on the SH0ES group work and their H_0 value, suffering from photometric calibration limitations with a tiny wavelength-independent extinction in the Milky Way.

Caroline Huang et al. (2018) and Reid et al. (2019) further check their calibration against water masers in NGC 4258 and other water masers. Water masers exist in galaxies with supermassive black holes at their centers. The distance to these galaxies and the mass of their central supermassive black holes have an entangled relationship solved by modeling. The modeling must account for the galaxy plane relative to the sky plane, the disc' s eccentricity associated with viscous dissipation, its distortion in the galaxy plane, and traveling density waves within the disc. The adoption of orbital motion for the maser dynamics is the simplest explanation of a complex system with typically 30 masers across 8 degrees of disc azimuth. This orbital approach supports a geometric distance measurement but relies on an accurate central black hole mass. The mass formula for a massive black hole with orbiting matter is:

$$M = \frac{4\pi^2 r^3}{GT^2}$$

where M is the black hole mass, r is the orbit' s semi-major axis, G is the gravitational constant, and T is the period for a single rotation. For NGC 4258, the complex disc rotation is modeled using maser velocity and acceleration, which occupy static positions. The errors derive from likelihood functions resting on assumed error floors, including contributions from line profile components. In this complex situation, the distance to NGC 4258 appears to be valid support for the SH0ES group' s zero-point correction and Hubble tension, but it is not simple support. Efstathiou (2020) noted that "the maser analysis is considerably more complicated than DEB distance estimates and so it is extremely important that the maser analysis is revisited."

2.5.4 Primary Red Clump Stars

Yang Huang et al. (2021) used primary red clump (PRC) stars to perform an independent check on Gaia EDR3 parallax bias. They used over 65,000 PRC stars identified by Huang et al. (2020) from the LAMOST galactic surveys (Deng et al. 2012; Liu et al. 2014) and high-quality Kepler asteroseismology data. The PRC stars were selected based on their positions in metallicity-dependent effective temperature–surface gravity and color–metallicity diagrams. They did not assume a constant absolute magnitude. Huang et al. (2020) performed a new calibration of the K_s absolute magnitude for PRC stars, for the first time considering both metallicity and age dependencies, using over 10,000 PRC stars with accurate distance estimates from Schönrich et al. (2019). Schönrich et al. (2019) based their distances on Kepler satellite asteroseismology data, which relied on high signal-to-noise ratio photometry. In this complex situation, differences between Yang Huang et al. (2020) results and EDR3 Gaia parallaxes show mean LAMOST parallaxes about 35 micro-arcseconds less. They attribute this to a required zero-point correction but note it is slightly larger than that indicated from distant quasars. This conflict between LAMOST and EDR3 distances can be regarded as supportive evidence for a small extinction effect.

2.5.5 Asteroseismology-Derived Distances

The paper by S. Khan et al. (2023) compares asteroseismology-derived distances in G magnitudes with Gaia parallaxes for 3,500 red clump stars. Whereas Riess et al. (2021) generated an extra ten micro-arcsecond zero-point correction for Gaia data for Cepheids between 1 and 4 kiloparsecs to achieve agreement with photometric distances, Khan et al. generated an increasing zero-point correction for their red clump stars. They too assumed any required distance correction is due to zero-point errors in Gaia parallax measurements. They show that for red clump stars at apparent distances between 6 and 10 kiloparsecs (i.e., G magnitude from 12.5 to 13.5), the required correction is approximately a straight line increasing the zero-point correction with distance from about 20 to 40 micro-arcseconds. Both the Khan data and the Riess data precisely agree with Gaia data if one alternatively assumes the Gaia data is correct and there is a tiny, 6% per kiloparsec, wavelength-independent extinction of visible light across the Milky Way. When applied to the Khan (2023) case, it matches precisely the apparently required parallax corrections of 20 micro-arcseconds for 12.5 magnitude stars and a further 20 micro-arcseconds for 13.5 magnitude stars. All three Khan star groups show approximately the same required correction. The mathematics is detailed in Appendix B.

2.5.6 Strong Lensing of Time Delays Between Multiple Images of Background Quasars

Further support for the Riess H_0 value was quoted by Verde et al. (2019) from the Kavli Institute workshop on "Tensions between the Early and Late Universe." One method derived from strong lensing of time delays between multiple images of background quasars (Wong et al. 2019). They summarized work by Treu et al. (2016) on inferring H_0 from time-delay cosmography. Their obtained H_0 values neatly match those from Riess et al., but many assumptions are involved. There are 128 distinct model configurations. At the heart of this is a model of angular diameter distance relations, where values of angular diameter distances from observer to source, observer to deflector, and deflector to source are modeled by assuming a mass distribution. This appears to be valid support for the Hubble tension, claimed as "totally independent of the supernovae analyses," but it is hard to believe that galaxy modeling does not use galactic photometry for calibration, which would naturally produce values little different from the SH0ES values with the same systematic errors due to a conjectured wavelength-independent extinction coefficient.

2.5.7 IR Surface Brightness Fluctuations of Galaxies

The work on IR Surface Brightness Fluctuations by Potter et al. (2018) measured distances to SN Ia galaxies independently of SN Ia photometry and "other distance ladders" but admitted that results "varied within the error by altering the source of the calibration of the Surface Brightness Fluctuations luminosity from Cepheids to Tip of the Red Giant Branch stars (in the LMC)." Their errors were large but, as expected, they supported the SH0ES group H_0 value. Their photometry would include systematic errors due to a wavelength-independent extinction and cannot be regarded as support.

2.5.8 Photometry Summary

When considering the possibility of a small wavelength-independent extinction, photometric support for the SH0ES group correction of Gaia parallaxes is not possible. The non-photometric support from strong lensing and NGC 4258 masers is derived from complex modeling of galactic processes and gravitational lens appearances around black holes with many routes to systematic errors, questioned by Efstathiou (2020) and others.

The extinction discussed here is wavelength-independent, considered as a photon absorption process such as atom ionization where gamma radiation is absorbed by matter. Much work has been done on wavelength-dependent extinctions in normal photometric bands in our Milky Way, used by the SH0ES group to derive reddening-free Cepheid magnitudes. HST observations of Cepheids in the F555W, F814W, and F160W wavebands were combined in a reddening-free Wesenheit index (Madore 1982) to remove normal wavelength-dependent extinction. Any further extinction must be wavelength-independent.

2.6 Non-Photometric Consideration of the Photometry-Parallax Conflict

Few papers address EDR3 Gaia zero-point correction and Cepheid distances in our Milky Way that are not totally based on photometry. These include papers by Groenewegen (2021) and Efstathiou (2020).

2.6.1 Groenewegen' s Evaluation of EDR3

Groenewegen's objective was an independent investigation into the parallax zero-point offset (PZPO) of Gaia EDR3 data with all its dependencies on position, brightness, and color. He used a large quasar sample to provide a zero-point for Gaia parallaxes since all quasars are so distant their Gaia parallax distances can be considered infinite. Physical binaries were also considered to derive the parallax zero-point offset. The quasars were selected differently from the Gaia team method.

For bright stars, the parallax zero-point offset was applied to a different star set than earlier workers. This different set was independently observed by Hubble to produce independent photometric parallaxes. The derived parallax zero-point offset was also applied to the Classical Cepheid sample used by Riess et al. (2021) and compared with results from the Gaia team (Lindegren et al. 2021a). For the classical Cepheid sample of Riess et al., they suggested that photometric parallaxes may be underestimated by about 5%. This is precisely what is expected with a small wavelength-independent extinction, clearly supported by this non-photometric evaluation of the Gaia zero-point offset. This result undermines adoption of the ten micro-arcsecond zero-point parallax subtraction used by Riess et al. (2021) and supports our case for examining the data considering an alternative wavelength-independent extinction.

2.6.2 Efstathiou’ s Review of Evidence for Hubble Constant Values

Efstathiou (2020) used the Covid lockdown to review evidence for the Hubble tension. His starting point was that a systematic bias in the intercept of Cepheid period-luminosity relations derived by the SH0ES group of 0.1 to 0.15 magnitudes would remove the Hubble tension. This is equivalent to a 6% per kiloparsec wavelength-independent extinction for the SH0ES team’ s Milky Way Cepheids, which have a mean distance of 2.23 kiloparsecs. Efstathiou claims he shows that the Hubble tension and differences between SH0ES values for H_0 and those of the Carnegie–Chicago Hubble Programme (CCHP) of Wendy Freedman’ s group (Freedman et al. 2019) are caused mainly by a “systematic calibration offset” —the same case made here, but for different reasons. This offset is equivalent to the ten micro-arcseconds subtracted from Gaia parallaxes by Riess et al. (2021). Efstathiou considers extinction only in passing, as a possible cause for TRGB stars in the Large Magellanic Cloud appearing fainter than expected from Cepheid calibration of the LMC distance.

Efstathiou does not consider the possibility of a small wavelength-independent extinction that would undermine support for the SH0ES team’ s LMC distance based on photometry. He highlights disagreement with LMC and NGC 4258 distance anchors. He accepts that if the tension is correct, there must be new physics impacting the ΛCDM cosmological model. He surveys the theoretical and observational base of the ΛCDM model and concludes that “no compelling theoretical solution to the Hubble tension has yet emerged. The alternative is that the SH0ES result is biased by systematic errors that are not included in their error estimates.” This is precisely the case made in this paper.

2.7 The Gaia Team Evaluation of Their Data

The Gaia EDR3 parallaxes included all SH0ES Cepheids. The Gaia team used 1.3 million background quasars supplemented by LMC stars and nearly a million binaries to correct parallax variations due to position, color, and magnitude across the sky. The Gaia team produced an algorithm including all noted errors in Gaia satellite parallax data to produce corrected parallax data, declaring that remaining errors in corrected parallax measurements are "a few microarcseconds" (cited by Riess et al. 2021 from Lindegren et al. 2021a,b).

Other Gaia team publications (Andrae R. et al. 2023) for Data Release 3 show that Gaia parallax distances of clusters are significantly less than published photometric distances (Cantat-Gaudin T., et al. 2020), noted without explanation.

2.8 The Gaia Data Indicates a Wavelength-Independent Extinction

We now include data from Riess (2021) that supports a tiny wavelength-independent extinction. We plot distances (inverse of Gaia parallaxes) against the inverse of Riess et al. photometrically derived parallaxes. This indicates a tiny extinction of about 6% per kiloparsec in the Galactic arms where Cepheids are observed, equivalent to a distance of approximately 11.2 kiloparsecs to reduce stellar radiation intensity by half.

The Gaia team (Lindegren L., et al. 2021a,b) first produced data of precision necessary to be interpreted as evidence for wavelength-independent extinction. In Figure 1, we show the plot of Gaia algorithm-corrected inverse parallaxes as published by Riess et al. (2021) without the SH0ES subtraction of ten micro-arcseconds from Gaia parallaxes. These Gaia parallax-derived distances are plotted against SH0ES photometrically derived distances. A best-fit line through the points has slope 1.06, indicating a conflict in derived distances interpreted here as wavelength-independent extinction of about 6% per kiloparsec.

Data with the SH0ES subtraction of ten micro-arcseconds from Gaia parallax data is also plotted, with a best-fit straight line slope of 1.0027, which within errors removes any extinction indication out to Cepheid distances of about 4 kiloparsecs.

Figure 1. Graph of Gaia published data against photometrically derived distances indicating a 6% per kiloparsec extinction (left) and graph indicating no extinction with a 10 micro-arcsecond zero-point correction of Gaia parallaxes (right).

The SH0ES team justified their Gaia parallax reduction by ten micro-arcseconds by noting their 66 Cepheids were brighter and redder than considered by the Gaia team, even though the Gaia team declared their corrected values had errors reduced to "a few microarcseconds," corrected mainly from distant quasar parallaxes and many binaries. Data from almost a million binaries would cover the correction necessary for both magnitude and color.

The SH0ES-derived change in Gaia parallaxes then supports the SH0ES H_0 value. This justification for requiring a ten micro-arcsecond subtraction was abandoned in Riess et al. (2022).

2.9 The Mathematical Analysis of the Gaia & SH0ES Cepheid Data

Mathematical expressions for real Cepheid distances are derived, including a variable zero-point correction for Gaia parallax measurements and a variable galactic extinction for photometric measurements. The Cepheids were divided into two groups: Distance < 1.5 kiloparsecs and $D > 3.0$ kiloparsecs around HST observing cycles 22 and 27, one averaging about 4 kiloparsecs distant and the other about 1 kiloparsec distant. The Gaia and HST parallax data generate four equations: two from Hubble Space Telescope cycles 22 and 27, and two from Gaia using mean values for each Cepheid group. The mean of the inverse of these parallaxes gives the distances for each group, as distances follow a more normal distribution than parallaxes.

Thus we have four unknowns: the actual mean distances to the two Cepheid groups, the possible wavelength-independent extinction, and any zero-point correction for Gaia measurements. We also have four equations, so theoretically we can determine the four unknowns. Unfortunately, two unknowns are product-logarithmically related (Lambert W functions). Fortunately, we can solve numerically using our data as a framework to constrain and optimize solutions. We first generate the equations.

Working in distances to each Cepheid cluster: Let D_{R1} and D_{R2} be the apparent mean of the reciprocals of SH0ES photometrically derived parallaxes for cycles 22 and 27 in kiloparsecs. The word "apparent" is used since it is the mean which includes any extinction. Let R_1 and R_2 be the actual distances when corrected for any zero-point errors or galactic extinction for cycles 22 and 27.

Let: - PG_1 = inverse of mean Gaia parallax-derived distances for cycle 1 (Hubble cycle 22) in milliarcseconds - PG_2 = inverse of mean Gaia parallax-derived distances for cycle 2 (Hubble cycle 27) in milliarcseconds - ϵ = extinction coefficient of intensity in percent per kiloparsec - zp = remaining zero-point offset for Gaia measurements in milli-arcseconds

For the mean distance of cycle 22 Cepheid stars in the SH0ES paper (Riess et al. 2021), defined through photometrically derived parallax $\pi_{\text{phot}} = 10^{-0.2(\mu-10)}$ as $\pi_{\text{phot}} = 1/D_{R1}$:

$$1/D_{R1} = 10^{-0.2(\mu-10)}$$

where, from Riess et al. (2021):

$$W = m_{F160W} - 0.386(m_{F555W} - m_{F814W})$$

which is the reddening-free Wesenheit index (Madore 1982) using HST filters. The photometric distance modulus of a Cepheid is given by the difference in magnitudes of apparent and absolute flux, $\mu_0 = m_{HW}$. This follows the P-L relation derived by Riess et al. (2016) for the ith Cepheid:

$$\mu_{0,i} = m^H_{W,i} - (M^H_W, 1 + b_W(\log P_i - 1) + Z_W[\mathrm{Fe/H}]_\mathrm{i})$$

where $M^H_{W,1}$ is the absolute magnitude for a Cepheid with $\log P = 1$ ($P =$ 10 days) and solar metallicity, while b_W and Z_W define the relation between Cepheid period, metallicity, and luminosity. The distance modulus is $\mu_0 = 5\log D + 25$, with D being luminosity distance in megaparsecs. $\mu = m^H_W - M^H_W$, where M^H_W is the absolute Wesenheit magnitude and m^H_W the measured magnitude determined from Cepheid period and distance scale from Riess et al. (2016), where $b_W = -3.26$, $Z_W = -0.17$ mag dex^{-1}, $M^H_{W,1} = -5.93$ mag, and D_{R1} is in megaparsecs.

We calculate results as in Table A1 in Appendix A. Starting with $1/D_{R1} = 10^{-0.2(\mu-2.5)}$, we substitute for μ and D_{R1} is in kiloparsecs.

To consider possible extra wavelength-independent extinction beyond color-derived corrections from the Wesenheit work, we write:

$$1/R_1 = 10^{-0.2(\mu-2.5-m_1)}$$

where m_1 is the added wavelength-independent extinction in magnitudes for R_1 and m_2 for R_2.

For linear extinction we have:

$$I/I_0 = e^{-\epsilon R_1}$$

where I is measured intensity, I_0 is intensity without extinction, and R_1 is real distance.

For measurements in magnitudes, $I/I_0 = 2.512^{-m}$, so for cycle 22:

$$I/I_0 = e^{-\epsilon R_1}$$

Converting to base e and taking logs:

$$-\epsilon R_1 = -0.92108\, m_1$$

where $\ln(2.512) = 0.92108$. The extinction in magnitudes is:

$$m_1 = 1.08568\,\epsilon R_1$$

Thus the equation for the mean real distance of cycle 22 Cepheids is:

$$R_1 = D_{R1}\left(10^{0.2(-1.08568 R_1 \epsilon)}\right)$$

and for cycle 27:

$$R_2 = D_{R2}\left(10^{0.2(-1.08568 R_2 \epsilon)}\right)$$

The two Cepheid groups are defined by their distances D as measured by the SH0ES group: $0.5 < D_{R2} < 1.5$ and $3 < D_{R1} < 6$.

The apparent mean of cycle 22 SH0ES photometric distances in kpc (errors from Riess et al. 2021) is:

$$D_{R1} = 4.05723 \pm 3.2\%$$

The apparent mean of cycle 27 SH0ES photometric distances in kpc is:

$$D_{R2} = 0.98410 \pm 3.4\%$$

We have two more equations for Gaia parallaxes including any zero-point offset:

$$R_1 = \frac{1}{PG_1 - zp}$$

where zp is the zero-point offset and R_1 is the real distance for cycle 22 Cepheids, and for cycle 27 Cepheids:

$$R_2 = \frac{1}{PG_2 - zp}$$

assuming the zero-point offset zp is the same in each case, inserted as a possible remaining offset after everything the Gaia team could account for.

The mean Gaia parallax for cycle 22 in milliarcseconds and for cycle 27 in milliarcseconds:

$$PG_1 = 0.26510 \pm 4.8\%$$

$$PG_2 = 1.04185 \pm 2.2\%$$

The mean parallaxes are the reciprocal of mean distances used for Gaia measurements since these follow a more normal distribution than parallaxes.

Thus we have four equations and four unknowns: zp, ϵ, R_1, and R_2. We can solve them numerically by scanning values of R_1, calculating resulting values of other unknowns, and using external circumstances to choose a solution. We define the scan to cover values from zero extinction to zero zp zero-point correction. We know the real distance equals the SH0ES measured distance if there is no extinction, and we seek the extinction ϵ value when zp is within a few arcseconds of zero.

Before scanning R_1 values, we restructure equations to give ϵ for each Cepheid group.

For equation (1) R_1:

$$R_1/D_{R1} = 10^{0.2(-1.08568 R_1 \epsilon_1)}$$

where we associate R_1 with ϵ_1 and R_2 with ϵ_2.

To transform equations (1) and (2) to base e:

$$e^{-0.49998} = 10^{0.2(-1.08568)}$$

Substituting the value for D_{R1}:

$$0.24647 \cdot R_1 = e^{-0.49998 R_1 \epsilon_1}$$

Taking logs and solving for ϵ_1:

$$\epsilon_1 = \frac{1}{0.49998 R_1} \ln\left(\frac{4.05723}{R_1}\right)$$

and for ϵ_2:

$$\epsilon_2 = \frac{1}{0.49998 R_2} \ln\left(\frac{1}{1.0162 R_2}\right)$$

From equations (3) and (4):

$$zp = PG_2 - \frac{1}{R_2} = PG_1 - \frac{1}{R_1}$$

Substituting known values of PG_1 and PG_2 and rearranging:

$$\frac{1}{R_2} = 0.77675 + \frac{1}{R_1}$$

which gives a set of R_2 values as we scan R_1. We seek a tiny extinction: at most 6% per kiloparsec, which would result in a real R_1 value of about 3.7 kiloparsecs. We scan R_1 in equation (5) from 3.7 kiloparsecs up to 4.06 (the zero-extinction value for R_1), followed by R_2 using equations (6) and (8). For each R_1 value we derive R_2, ϵ_1, and ϵ_2. The scans produce values for ϵ and zp to satisfy mean measured photometric distances and Gaia parallaxes. All are equally valid mathematically. As R_1 increases, the mathematical solution space including both extinction and zero-point correction (or a combination) lies between $R_1 = 3.773$ (where zero-point correction ceases to be negative) and $R_1 = 4.04$ or 4.01 (where extinction becomes negative).

Negative extinction values have no physical reality. Negative zero-point corrections reflect real errors for the Hubble tension. The zero-point correction to produce the Hubble tension from these equations must be positive. These solutions support a range of real distances for the mean Hubble cycle 22 Cepheids of 3.773 to 4.1 kiloparsecs. Each scanned distance R_1 reflects a singular Cepheid absolute magnitude value and resulting Hubble constant.

The scanning and derived values for R_2, zp, ϵ_1, and ϵ_2 are given in Appendix A Table A1. These are the Lambert W function numerical solutions. Table C1 presents the derived absolute magnitude and resulting Hubble constant for each scanned real mean Cepheid distance.

2.10 The Mathematical Analysis of the Gaia and Khan Red Clump Star Data

A similar approach to the red clump star data of Khan et al. (2023) checks the wavelength-independent extinction and shows it completely explains their need to change the Gaia zero-point correction with distance. Considering Khan et al. (2023) data, we check the effect of wavelength-independent extinction. In that case, distances derived from magnitudes are "apparent distances" with real distances slightly less. We modify the Lambert W function, produced for Cepheids, to apply to red clump stars with reddening accounted for, shown in Appendix B Table B1. Starting with:

$$AD_1 = R_1 \cdot 10^{0.2(R_1 \epsilon)}$$

where AD_1 is apparent distance, R_1 is real distance, and ϵ is the extinction coefficient. We use the ϵ value from Riess data analysis: 6% per kiloparsec.

First, we convert Khan magnitudes to distances. Parallaxes are then derived from distances to compare Khan data corrections required to match Gaia data.

The proposed wavelength-independent extinction of 6% per kiloparsec is included in equations. Considering G magnitude stars of 12.5 and 13.5 in Khan (2023), we use the approximate absolute magnitude of red clump stars of -1.5, assuming all reddening is accounted for.

Using the Pogson equation:

$$m = M - 5 + 5\log_{10}(AD)$$

where m is measured magnitude, M is absolute magnitude, and AD is apparent distance. This produces apparent distances $AD_1 = 6.3$ kiloparsecs and $AD_2 = 10$ kiloparsecs for the two magnitudes. Between these distances, there is a drop in required Gaia correction of just over 20 micro-arcseconds.

To include wavelength-independent extinction, we scan R_1 values in equation (9) until they match apparent distance AD_1. Using numerical scanning (Appendix B) for the Lambert W function, we get an approximate real star distance. For the 12.5 G magnitude, scanning real distance across 5.42 kiloparsecs matches the apparent distance of 6.3 kiloparsecs. Using inverse distances to obtain parallaxes, we get a parallax change of about 24 micro-arcseconds, approximately the correction value in Figure 2 of S. Khan (2023). Repeating for G magnitude 13.5 gives an apparent distance of 10 kiloparsecs, which Lambert scanning gives as a real distance of 8.0 kiloparsecs. Expressing as parallax values gives a difference of 25 micro-arcseconds. Considering errors and assumptions, 25 micro-arcseconds is reasonably close to the Khan required increase in Gaia zero-point correction (Figure 2 of S. Khan et al. 2023).

Thus, wavelength-independent extinction provides a good explanation for Khan et al. (2023) required increase in Gaia "parallax correction" as distance increases.

2.11 Is the Mathematical Analysis Justified?

The mathematical analysis of SH0ES Cepheid data requires linking to external reality to distinguish solutions. For the analysis in Appendix A Table A1, the Gaia zero-point correction zp crosses zero at $R_1 \approx 3.773$ kiloparsecs, supporting a mean extinction value of about 4.55% per kiloparsec. This justifies further analysis of data supporting the Hubble tension in light of small extinction.

Extinction values become zero at $R_1 \approx 4.1$ kiloparsecs, providing support for the SH0ES approach using zero-point correction. The SH0ES group decided to follow the impact of a zero-point correction maintaining the Hubble tension. This paper investigates the impact of wavelength-independent extinction of about 4.5% kpc^{-1} (discussed below). In reality, there is likely a small zero-point correction linked to the extinction coefficient. More precise values require more data. The zero-point correction takes off at about 2 micro-arcseconds when $R_1 = 3.8$ kiloparsecs and mean extinction is about 4.4% per kiloparsec, a good fit to the external reality suggested by the Gaia team.

The extinction coefficient ϵ found here is the real extinction coefficient useful for determining real stellar distances. It is extracted from the combination of extinction coefficient and inverse square reduction in stellar intensity with distance. This combination is observed photometrically. The extinction coefficient interacts linearly and multiplicatively with stellar intensity, so observed photometric intensity is reduced by the combination. The real extinction coefficient contributes linearly but only partly to reduced observed intensity. In the data discussed here, the extinction coefficient of 4.55% per kiloparsec contributes to the 6% per kiloparsec increase in distance found in HST observations. Their inequality is due to this multiplicative effect. Initially, we examine the impact of a 6% per kiloparsec observed extinction coefficient with its 15% errors to determine its effects on the Hubble constant.

The range of derived values for real distances, wavelength-independent extinctions, and zero-point corrections are solidly locked into the numerical solution, well inside the errors. Total errors in extinction and zero-point correction values are the product of errors in HST and Gaia measurements, totaling about 15%. This means all figures ϵ_1, ϵ_2, R_1, and R_2 have errors around 15%.

The Khan analysis of red clump star data produces an increasing zero-point correction for Gaia data, directly related to red clump star distance (magnitude). The alternative of wavelength-independent extinction is much simpler, more attractive, and at this stage equally valid.

2.12 The Hubble Constant Is Derived From the Real Absolute Magnitudes of the Cepheids

We consider scanned values of the mean real distance R_1 of Cepheids, each producing a Cepheid absolute magnitude value. Riess et al. (2021) show how H_0 is derived from Cepheid absolute magnitude and show the derived H_0 from measured Cepheid absolute magnitude or Cepheid luminosity (their Figure 4). We plot absolute magnitude values and derived H_0 in Figure 3.

Let M_1 be the Riess et al. (2021) Cepheid absolute magnitude value reflected in their H_0 value, based on zero wavelength-independent extinction and a real mean distance $D_1 = 4.06$ kiloparsecs (4060 parsecs) for cycle 22 Cepheids. Let M_2 be the derived absolute magnitude reflecting the revised real mean Cepheid distance due to extinction, found as R_1 in scanning.

For absolute magnitude:

$$M_1 = m - 5\log\left(\frac{D_1}{10}\right)$$

where m is measured magnitude, log is base 10, and D_1 is distance in parsecs.

To find the correction due to wavelength-independent extinction using revised real mean distance D_2:

$$M_1 - M_2 = 5\left(\log\left(\frac{D_2}{10}\right) - \log\left(\frac{4060}{10}\right)\right)$$

Riess et al. (2021) assumed no wavelength-independent extinction and that their derived absolute magnitude was correct. With extinction, the correction is shown above.

Apart from the SH0ES subtraction of ten micro-arcseconds from Gaia parallaxes, the data is also satisfied by a small zero-point correction and a real extinction of 4.55% per kiloparsec, observed as 6% per kiloparsec. Such extinction reduces the real mean Cepheid distance to 3.773 kiloparsecs (i.e., D_2), reducing the absolute magnitude by:

$$M_1 - M_2 = 5\left(\log\left(\frac{3773}{10}\right) - \log\left(\frac{4060}{10}\right)\right) = -0.1592$$

The absolute magnitude M_1 used by Riess et al. (2021) is -5.915. With the subtraction of 0.1592, the absolute magnitude becomes -6.074. From Riess et al. (2021) Table 4 data and resulting equation, this produces $H_0 = 67.8$ km s^{-1} Mpc^{-1}. Within errors, this is compatible with the Planck CMB value of 67.27 ± 0.60 km s^{-1} Mpc^{-1}. The Hubble tension evaporates. Derived absolute magnitude and H_0 values are shown in Appendix C Table C1.

2.13 Progress So Far

We have shown that the conflict between photometrically derived parallaxes and Gaia parallaxes for Cepheids, as evaluated by the SH0ES group, and for red clump stars as evaluated by Khan et al. (2023) can be attributed to two causes. The popular explanation is a variable zero-point error in Gaia parallaxes, with Riess et al. (2021) adopting a subtraction of ten micro-arcseconds for Cepheids and Khan et al. subtracting varying amounts depending on distance for red clump stars. This is widely supported despite the Gaia team calculating that their latest data release is correct to "a few microarcseconds."

Riess et al. (2022) abandon the ten micro-arcsecond subtraction, but their data is questioned. The Riess and Khan reduction of Gaia parallaxes ensures support for maintaining their proclaimed Hubble tension.

3.0 Introducing Dark Matter

We have shown that a tiny wavelength-independent extinction observed across the Milky Way of about 6% per kiloparsec is mathematically equivalent to Riess' s claim of a ten micro-arcsecond zero-point error and fully explains Khan et al. (2023) results.

Thus, support for the Hubble tension rests upon subtracting a ten micro-arcsecond zero-point correction from Gaia data. An equally valid mathematical description is a galactic wavelength-independent extinction of 4.55% per kiloparsec (observed as 6% per kiloparsec). Such extinction also removes all photometric support for the Hubble tension. The real mean distance of 3.773 kiloparsecs for the SH0ES Cepheids gives an H_0 value within errors identical to the Planck value, supporting the case that wavelength-independent extinction causes the Hubble tension. Analysis of Cepheid luminosities in light of a tiny wavelength-independent extinction observed as 6% per kiloparsec also dismisses the Hubble tension.

A wavelength-independent extinction in visible wavebands is not a product of any known physics. If confirmed with further work on Gaia parallaxes and the conflict with photometric parallaxes, supported by Gaia Data Release 4, it clearly indicates new physics. We now examine other H_0 measurements seeking clues to the cause.

The different methods to derive H_0 are either in the microwave area below 250 GHz from the Planck satellite (Ade et al. 2014) or in the visible above 300 THz (Riess et al. 2018a,b; Freedman 2019). Early-time cosmic microwave background measurements using Planck (Ade et al. 2014) produce $H_0 = 67.4 \pm 0.5$ km s^{-1} Mpc^{-1}, while Riess et al. (2018a,b) recent-time measurements using supernovae light, calibrated with Cepheids at frequencies above 300 THz, produce $H_0 = 73.2 \pm 1.3$ km s^{-1} Mpc^{-1}. These differences far exceed published errors. The teams are highly experienced, and it can be accepted that differences are not due to measurement technique errors. Riess et al. (2018b) results are 8.6% greater than Ade et al. (2014).

A third measurement by the distinguished Carnegie-Chicago group around Professor Wendy Freedman (Freedman et al. 2019) produced $H_0 = 69.8 \pm 0.8$ (stat) ± 1.7 (sys) km s^{-1} Mpc^{-1} using Large Magellanic Cloud stars. Freedman et al. (2019) results are nearly 3.6% greater than Ade et al. (2014). The three results use different methods, and their differences are significant beyond error limits.

Above and in appendices, we have mathematically shown that recent SH0ES group data (Riess et al. 2021) can indicate wavelength-independent (colorless) extinction across the Milky Way of about 6% per kiloparsec. We now seek the possible source of such extinction, examining SH0ES and Carnegie-Chicago team results in this light.

3.1 The Carnegie-Chicago Team

The Carnegie-Chicago team (Freedman et al. 2019) used Tip of the Red Giant Branch (TRGB) stars to calibrate H_0. The distance calibration was set up through TRGB star measurements in the Large Magellanic Cloud (LMC), checked (Freedman et al. 2019; Freedman 2021; Palau & Miralda-Escudé 2022) with the distance scale resting on double eclipsing binary (DEB) stars and Cepheids in the LMC calibrated with Milky Way Cepheids.

The Carnegie-Chicago H_0 value of 69.8 km s$^{-1