Does Dark Matter solve the Hubble Tension Puzzle?

Authors: John Baruch

Date: 2025-11-03T00:00:00+00:00

Abstract

The Hubble constant H0 defines the rate of expansion of the Universe. Currently there are three conflicting values of the Hubble constant. The Planck team (Ade et al 2014), the Carnegie-Chicago team (Freedman et al 2019), and the SHoES team (Riess et al 2016) have all produced values that disagree beyond their errors. Baruch 2025a has reviewed recent data of the SHoES team (Riess et al 2021) where Hubble telescope photometric data for two groups of Cepheids at different distances were linked to Gaia parallax measurements of the same stars. It is shown how for this unique set of precise data the zero-point correction is equivalent to a wavelength independent (colourless) extinction of light across the Milky Way galaxy. This current paper seeks out the cause of this extinction and shows that the data of Freedman et al 2019 neatly fits a wavelength independent extinction when the cause of the extinction is attributed to dark matter. The extinction coefficients are derived. All the Riess and the Freedman values of the Hubble constant are shown to agree with the Planck Satellite (Ade et al 2014) value within the error bars when the differences are attributed to dark matter extinction. The SHoES team has shown that the Hubble constant is increasing in recent times (Riess et al 1998) reflecting an increase or acceleration in the rate of expansion of the Universe. Here it is shown that this apparent increase in the Hubble constant clearly matches the impact of intergalactic dark matter on the brightness of distant supernovae. The recent time increase in the Hubble constant is an illusion created by intergalactic dark matter extinction. The key properties required of the dark matter are defined.

Full Text

Preamble

John Baruch
Leeds Beckett University, UK
Tsinghua University, China

Greenside Cottage, Clayton Bradford BD14-6AU, UK
Email: john6174@outlook.com

Abstract

The Hubble constant H_0 defines the rate of expansion of the Universe. Currently, three conflicting values of the Hubble constant exist. The Planck team (Ade et al. 2014), the Carnegie-Chicago team (Freedman et al. 2019), and the SHoES team (Riess et al. 2016) have all produced values that disagree beyond their stated errors. Baruch (2025a) reviewed recent data from the SHoES team (Riess et al. 2021), where Hubble telescope photometric data for two groups of Cepheids at different distances were linked to Gaia parallax measurements of the same stars. It was shown how, for this unique set of precise data, the zero-point correction is equivalent to a wavelength-independent (colorless) extinction of light across the Milky Way galaxy. This paper seeks the cause of this extinction and demonstrates that the data of Freedman et al. (2019) neatly fit a wavelength-independent extinction when the cause is attributed to dark matter. The extinction coefficients are derived. All Riess and Freedman values of the Hubble constant are shown to agree with the Planck Satellite (Ade et al. 2014) value within the error bars when the differences are attributed to dark matter extinction. The SHoES team has shown that the Hubble constant is increasing in recent times (Riess et al. 1998), reflecting an increase or acceleration in the rate of expansion of the Universe. Here, it is shown that this apparent increase in the Hubble constant clearly matches the impact of intergalactic dark matter on the brightness of distant supernovae. The recent-time increase in the Hubble constant is an illusion created by intergalactic dark matter extinction. The key properties required of the dark matter are defined.

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

1. Background

The Hubble constant H_0 defines the rate of expansion of the Universe. The "Hubble Tension" describes the differing current values of the Hubble constant derived by different methods, which differ significantly beyond experimental errors. The methods used to derive the Hubble constant operate either in the microwave region below 250 GHz from the Planck satellite (Ade et al. 2014) or in the visible region above 300 THz (Riess et al. 2018a, 2018b; Freedman 2019).

Early-time Cosmic Microwave Background radiation measurements using the Planck satellite (Ade et al. 2014) produce a value of 67.4 ± 0.5 km s^{-1} Mpc^{-1}, while the Riess et al. (2018a, 2018b) value measured in recent time using light from supernova explosions, calibrated with Cepheid stars at frequencies above 300 THz, yields 73.2 ± 1.3 km s^{-1} Mpc^{-1}. These differences far exceed what could be expected from the published errors. The teams are highly experienced, and it can be accepted that the differences are not due to errors in their measurement techniques. The results of Riess et al. (2018b) are 8.6% greater than those of Ade et al. (2014).

A third measurement of the Hubble constant has been made by the equally distinguished Carnegie-Chicago group led by Professor Wendy Freedman (Freedman et al. 2019). They produced a value of 69.8 $\pm$ 0.8 ($±$1.1% stat) $\pm$ 1.7 ($±2.4^{-1}$ Mpc^{-1} using stars in the Large Magellanic Cloud (LMC). The results of Freedman et al. (2019) are nearly 3.6% greater than those of Ade et al. (2014). These three results use different methods to derive the Hubble constant, and their discrepancies are significant beyond the limits of their errors.

Baruch (2025a) showed mathematically that recent data from the SHoES group (Riess et al. 2021) can be analyzed to indicate wavelength-independent (colorless) extinction across the Milky Way of about 6% per kiloparsec. Here, the source of such extinction is discussed, and the SHoES results and the Carnegie-Chicago results are examined in light of this extinction and its effect on their derived values for the Hubble constant.

2. The Carnegie-Chicago Team

The Carnegie-Chicago team (Freedman et al. 2019) used Tip of the Red Giant Branch (TRGB) stars to calibrate the Hubble constant. The distance calibration was established through measurements of TRGB stars in the Large Magellanic Cloud (LMC). This was verified (Freedman et al. 2019; Freedman 2021; Palau and Miralda-Escudé 2022) with the distance scale resting on the use of Double Eclipsing Binary (DEB) stars and Cepheids in the LMC, calibrated with Cepheids in our Milky Way Galaxy.

The Hubble constant value derived by the Carnegie-Chicago team (Freedman et al. 2019) of 69.8 km s^{-1} Mpc^{-1} is 3.6% greater than the Planck satellite group value (Ade et al. 2014) of 67.4 km s^{-1} Mpc^{-1}. How can this value be reconciled with the SHoES group value of 73.2 $\pm$ 1.3 km s^{-1} Mpc^{-1}, particularly considering the work of Baruch (2025a), which questions the Hubble tension on account of a wavelength-independent extinction effect within the Milky Way? The TRGB stars in the LMC are 52 kpc away.

What sort of extinction can affect both the SHoES data for Cepheids in the Milky Way and the TRGB stars in the LMC? It has been suggested (Baruch 2020) that the extinction is due to matter, and here we explore whether this can be the case.

3. The Hubble Tension Discussions Have Not So Far Included Dark Matter

Over the past five years, as measurements of the Hubble constant have become more secure, the apparent Hubble tension has increased. Any discussion of the Planck (Ade et al. 2014) value would involve detailed modeling, but for the present discussion the Planck results are assumed correct, and the focus centers on why other observational programs produce different results.

Freedman et al. (2019) wrote that with "the others having unknown systematic errors," "normal experimental errors would scatter the results about the correct value." This is not observed. The scatter in the Hubble constant is consistently around values greater than the Planck result, pointing to a systematic error.

Numerous observers have reviewed and commented on "the tension." Eleonora Di Valentino (2021), working with Riess and others, surveyed the field. They confirm Freedman's approach, stating that "the simplest ΛCDM model provides a good fit to a large span of cosmological data but harbors large areas of phenomenology and ignorance." They remark that "the most statistically significant tension is the 4σ to 6σ disagreement between predictions of the Hubble constant H_0 made by early-time probes in concert with the 'vanilla' ΛCDM cosmological model and a number of late-time model-independent determinations of H_0 from local measurements of distances and redshifts."

Valentino (2021) pursued a thorough review of the problem, including a discussion of Hubble constant estimates and a summary of proposed theoretical solutions. The solutions were classified into eleven areas pursued in detail, plus fifteen alternative proposals. Valentino does not include the possible impact of dark matter on H_0. A further model she considers may solve the Hubble tension has been evaluated by Boyarsky et al. (2021) using the possible decay of Feebly Interacting Massive Particles (FIMPs) into neutrinos, as suggested by Bernal et al. (2017), but the possible impact on H_0 has not been derived. The possibility that currently existing massive dark matter particles could affect H_0 values now or at earlier epochs has not been considered in Valentino' s review or in any of the more than 1000 recent papers she surveyed that focus on the tension.

The paper (Valentino 2021) concluded that "while no specific proposal makes a strong case for being highly likely or far better than all others, solutions involving early or dynamical dark energy, neutrino interactions, interacting cosmologies, primordial magnetic fields, and modified gravity provide the best options until a better alternative comes along."

Baruch (2025a) showed that one possible better alternative is the inclusion of wavelength-independent (colorless) extinction in the Cepheid calibration. His mathematical analysis of the SHoES data clearly shows this would be observed as about 6% per kiloparsec in the disc of the Milky Way as an alternative to any Gaia zero-point correction. Baruch (2025a) shows that significant zero-point corrections beyond one or two microarcseconds are not supported, and most probably the only explanation is a tiny wavelength-independent extinction of 6% per kiloparsec. This wavelength-independent extinction changes the derived values of the Hubble constant.

This extinction effect easily explains why the SHoES Hubble constant disagrees with the Planck value. However, the Freedman value of the Hubble constant is significantly different and measured in a completely different environment—

the distances are of order 50 kpc rather than 2 kpc, and the TRGB sources are all extragalactic. Is an extinction effect possible as the explanation for the Freedman value? Can dark matter be the absorbing medium?

4. A Brief Resume of Our Present Knowledge of Dark Matter

Zwicky (1933, 1937) first suggested, from observations of the velocity dispersion of galaxies in the Coma cluster, and Smith (1936) from similar observations of the Virgo cluster, that the large relative motions of individual galaxies would disrupt the clusters unless each galaxy had a mass roughly one hundred times the then-accepted galaxy mass. From the 1970s, it became clear that galaxy rotation curves, including that of the Milky Way, indicated the presence of matter controlling rotation beyond what could be observed. For example, Einasto et al. (1974) collected evidence showing that galaxies included massive coronas comprising the majority of their mass. Ostriker, Peebles & Yahil (1974) similarly declared that "there are reasons, increasing in number and quality, to believe that the masses of ordinary galaxies may have been underestimated by a factor of ten or more."

The Planck satellite (Ade et al. 2014) determined that 27% of the mass in the Universe comprises dark matter. Karachentsev et al. (2018) measured the density of dark matter in intergalactic space, obtaining a value of 4×10^{-27} kg m^{-3}. For the density of dark matter in the solar neighborhood, Nesti and Salucci (2012) produced a value of 0.7×10^{-21} kg m^{-3} (i.e., 0.43 GeV cm^{-3}), which is about 2×10^5 times greater than the intergalactic dark matter density. This value was confirmed by the later work of McKee et al. (2015). Nesti and Salucci (2013) also examined the density of dark matter toward the galactic center, in the plane of the galactic disc, obtaining a slightly greater value of 3×10^{-21} kg m^{-3}.

The galactic rotation curves of Roberts and Rots (1973) indicate that the halo density of dark matter mirrors that in the solar neighborhood, declining out to 25 kpc. Navarro (1996) showed that dark matter halo density profiles fit a standard ΛCDM N-body simulation, confirmed in great detail by Zavala and Frenk (2019).

Gravito-Camargo et al. (2019) investigated the Large Magellanic Cloud and assumed a dark matter density comparable to that of the Milky Way solar neighborhood. The diameter of the LMC is taken as 7 kpc. For the present discussion, it is assumed that the density of dark matter in the LMC is the same as in the solar neighborhood.

The starting assumptions for the galactic dark matter topology are that the Milky Way dark matter halo and that of the LMC are spherical with diameter 7 kiloparsecs, generally confirmed by the recent work of Palau and Miralda-Escudé (2022).

5. The Wavelength-Independent Extinction and the Hubble Constant

Let us first consider the impact on the Hubble constant of the extinction coefficient for Milky Way Cepheids of 6% kpc^{-1} derived by Baruch (2025a) from the SHoES team data (Riess et al. 2021).

The SHoES team' s objective was to measure mean distances and brightnesses of a group of Cepheids using the same photometry as for their extragalactic counterparts. Baruch (2025a) has shown that the mean brightnesses of the Milky Way Cepheids are subject to wavelength-independent extinction. Let us speculate that, since Valentino had no good candidate to explain the Hubble tension, the wavelength-independent extinction in the Milky Way derived from the SHoES data (Riess et al. 2021) is due to dark matter.

Baruch's (2025a) analysis of the SHoES data produces a wavelength-independent extinction coefficient of around 6% per kiloparsec. The errors in this figure are at least \$±1±\$1%) per kiloparsec. The errors are, to first approximation, limited by the skewed nature of the Cepheid distance profile.

The 6% extinction rate applied to the mean Cepheid distance produces an intensity loss of 14% (\$±2±1±\$1.8%) greater than those of Ade et al. (2014). This strongly indicates that wavelength-independent extinction is the cause of the SHoES component of the Hubble tension.

Groenewegen (2021) suggested that the photometric parallaxes of the SHoES Cepheid group are underestimated by about 5%. This would significantly impact their absolute magnitude, lessening their intensity. In the SHoES program, with their smaller parallaxes, the absolute magnitude becomes fainter than it should be.

In the original measurements using HST, Riess et al. (2018a) noted that the precision of the HST scanning process used to determine parallax was about 45 microarcseconds, with a best value of 29 microarcseconds. At the mean distance of 2.3 kiloparsecs (i.e., a parallax of 0.434 milliarcseconds), this precision converts to 10% (or 6.7% in the best case). Thus, the 6% per kiloparsec wavelength-independent extinction derived by Baruch (2025a) is hardly visible within the noise of their data. Their concern was to eliminate the zero-point correction of the Gaia measurements, and to this end they used a second HST cycle to derive the parallax of Cepheids with photometrically predicted parallax greater than 0.8 milliarcseconds and a mean parallax of 1.03 milliarcseconds.

At these parallaxes, the limitations of the HST scanning program generate errors of 4.5% (or 2.8% in the best case). The 6% per kiloparsec wavelength-independent extinction continues to be hardly visible within the noise of their data. This contributes to their confidence in using their photometrically derived parallax, which is based on their value for the absolute magnitude of the Cepheids. As shown in Baruch (2025a), the wavelength-independent extinction makes their Milky Way Cepheids appear fainter, reducing the intensity of the derived Riess et al. (2021) absolute magnitude.

Riess et al. (2021), using the same absolute magnitude for Cepheids in nearby galaxies that host supernovae, find—according to Baruch (2025a)—that these extragalactic Cepheids appear brighter than they should be and thus nearer. There is almost no dark matter in intergalactic space to reduce the intensity. The reduced distance of the extragalactic Cepheids is passed on to the supernovae, which also appear nearer. The Hubble constant is derived from these distant supernovae using their photometrically derived distances linked to the redshifts of their host galaxies. If the CMB Planck satellite value of the Hubble constant (Ade et al. 2014) is regarded as correct, the derived Hubble constant is greater than it should be by around 7.5% ($±$1%). Within the stated error budget, this could be the cause of the SHoES-derived Hubble tension, but what about the Carnegie-Chicago tension?

6. The Extinction Coefficient

Continuing with the supposition that dark matter causes wavelength-independent extinction, we can derive an extinction coefficient for the solar neighborhood, the Milky Way halo, the LMC, and intergalactic space.

The Cepheids used by the SHoES team suffer a wavelength-independent extinction of 6%. These Cepheids are mainly in the Galactic disc, where Nesti and Salucci (2013) measured a dark matter density of 3×10^{-21} kg m^{-3} toward the galactic center. This is a factor of 4.3 greater than the value of 0.7×10^{-21} kg m^{-3} they obtained in the Milky Way halo and solar neighborhood. Thus, we would expect an extinction coefficient of 1.4% per kiloparsec for the solar neighborhood, the Milky Way galactic halo, and the LMC.

The Carnegie-Chicago Hubble Program (CCHP) value for the Hubble constant is significantly greater than the Planck value of Ade et al. (2014). The Carnegie-Chicago team anchored their distance ladder zero-point using TRGB stars in the LMC (Freedman et al. 2019). Let us also speculate that TRGB starlight from the LMC experiences a similar wavelength-independent extinction effect due to dark matter.

The light path from the LMC of about 52 kpc includes dark matter in both the LMC and the Milky Way galaxy. The greater part of the path length is through intergalactic space with minute amounts of dark matter. The light path through the LMC dark matter halo averages about 3.5 kpc. The LMC is about 80 degrees away from the direction of the Milky Way center and 30 degrees away from the plane of the Milky Way disc, giving the light a path length of about 27.5 kpc through intergalactic space and about 21 kpc through the Milky Way dark matter halo.

For the LMC TRGB stars, let us suppose there is a linear reduction in light intensity due to dark matter as it traverses the LMC, in addition to the normal inverse-square factor. When the light reaches the Milky Way, its intensity will already be reduced by the inverse-square factor by about a factor of ten, so the linear reduction of light in the Milky Way will have a small effect. Thus, a wavelength-independent extinction component of the light from LMC TRGB stars will be the linear reduction in magnitude from traveling through 3.5 kpc of LMC dark matter with density matching that of the solar neighborhood (1.4% kpc^{-1}).

For the 3.5 kiloparsec path length in the Magellanic Cloud, the intensity would reduce by 4.9%. In the 21 kpc traveling through the Milky Way, the intensity would average about one-tenth of its absolute magnitude, further reducing the intensity traveling 21 kpc through the Milky Way by $1.4 \times 21/10$ 2.9%, resulting in a total intensity reduction above the distance-squared factor of about 7.8%. With the squared loss of intensity with distance, this translates into a greater inferred distance of about 3.9%, thus reducing their value of the Hubble constant for the given redshifts by 3.9%. Within the errors, this neatly matches the value derived by the Carnegie-Chicago group.

7. The Wavelength-Independent Extinction

Within the errors around the density and size of the LMC dark halo and the density of dark matter in the Milky Way disc, this is regarded as a good result, making a strong case for dark matter being the source of the extinction for both the SHoES and Carnegie-Chicago team values of the Hubble constant.

Thus, the Carnegie-Chicago data indicate that absorption can account for their value of the Hubble tension, but more importantly, the absorption closely matches what would be expected from our knowledge of dark matter distribution and can be confidently attributed to dark matter.

So far, it has been shown that the Hubble tension can be removed by including light absorption by dark matter in the Milky Way galaxy, and an absorption coefficient has been produced. It is also true that light from Cepheids in nearby galaxies will be attenuated as it passes through our Milky Way galactic halo of ~25 kpc to reach Earth. This effect is subtractive from the total intensity and is trivial compared to the intensity reduction due to the distance (~500 kpc) of the nearby galaxies, being lost in the noise. Let us include the wavelength-independent extinction from the SHoES and Carnegie-Chicago teams in the calculation of Cepheid and supernova intensities. The calibrated absolute magnitudes of Cepheids will be decreased (regarded as brighter) by the inclusion of the tiny wavelength-independent extinction in our Milky Way galaxy. The Cepheids in nearby galaxies will not be regarded as nearer, nor will their associated supernovae or more distant supernovae. The Hubble tension will disappear.

8. Further Considerations and the Acceleration of the Expansion of the Universe

It is also worth considering the impact of dark matter in the wider universe. From this paper, where the dark matter density in the solar neighborhood is 0.7×10^{-21} kg m^{-3}, the attenuation length of dark matter is 1.4% kpc^{-1}. For intergalactic space, where the dark matter density is 4×10^{-27} kg m^{-3}, the extinction due to dark matter would be about 8% Gpc^{-1}.

The SHoES team (Riess et al. 1998), with others (Garnavich et al. 1998; Schmidt et al. 1998), measured the redshift of 34 nearby supernovae and 16 high-redshift supernovae with z   0.4. They noted that for a given redshift increment, the high-redshift supernovae were fainter. They declared that the distances to the high-redshift supernovae were on average 10% to 15% further than expected from local supernovae because the high-redshift supernovae were $(10\%)^2 = 19\%$ to $(15\%)^2 = 28\%$ fainter than expected from local supernova measurements. The mean redshift they examined was z = 0.55, which translates to a distance of about 2.36 Gpc. Taking the mean intensity loss as 23% yields an extinction coefficient of about 9.7% Gpc^{-1} if it resulted from wavelength-independent extinction. The extinction coefficient due to dark matter calculated from the SHoES and Carnegie-Chicago group data in the local Milky Way and LMC, when applied to intergalactic space, is 8% Gpc^{-1}. These values are well within the errors associated with the data and provide strong evidence that the recent-time acceleration in the expansion of the Universe is an apparition due to dark-matter wavelength-independent extinction of light from more distant supernovae.

Riess et al. (1998) interpreted the apparently fainter galaxies ($z > 0.4$) as being more distant for their redshift and thus indicating a lower value of the Hubble constant and a lower rate of expansion of the Universe. They concluded that in the local universe, where redshift velocities were greater for the distances of apparently brighter galaxies, the Hubble constant was greater and the rate of expansion of the Universe was increasing.

9. Wavelength-Independent Extinction by Dark Matter

If dark matter is the source of the wavelength-independent extinction, what are its properties? With the failure to find Weakly Interacting Massive Particles (WIMPs) (Aprile et al. 2023), it is already known that dark matter only reacts to gravity.

Although it produces an extinction effect of about 1.4% per kpc in the solar neighborhood, the Milky Way halo, and the LMC, it clearly has no effect on the CMB radiation. Therefore, there must be a threshold for the extinction effect where visible light is absorbed but microwaves are not. The extinction frequency threshold f could be described as 250 GHz $< f <$ 300 THz. This extinction is probably similar to the ionization of hydrogen by a 13.6 eV photon. While a scattering effect rather than an "ionization" effect is possible, this is unlikely to have a threshold and would cause images of stars at visible wavelengths (250 GHz $< f <$ 300 THz) to become blurred. There is no evidence for such blurring, so further work only considers "ionization."

It seems the explanation of the Hubble tension makes no other requirements of dark matter beyond an ability to absorb photons above a defined threshold.

10. Conclusions

It is shown here that recent data releases from the Gaia satellite, as analyzed by the SHoES group and supported by the Carnegie-Chicago group, provide strong evidence for absorption of visible light by dark matter. This can explain the Hubble constant values derived by both the SHoES and Carnegie-Chicago groups, which they interpreted as a Hubble tension. Here, it is shown that a tiny wavelength-independent extinction by dark matter explains their values of the Hubble constant and dismisses the Hubble tension.

A spin-off from this work is an explanation for the recent (z 0.4) apparent acceleration in the expansion rate of the Universe, which is also dismissed, with implications for the concept of dark energy.

Acknowledgements. The author is grateful to many colleagues who have commented on these ideas, particularly the Silk Road Astronomy collaboration based in Beijing and Heidelberg, and for support from Tsinghua University Beijing, South China Technology University in Guangzhou, and Leeds Beckett and the Open Universities in the UK. He acknowledges support from the Royal Astronomical Society Library and the Fred Hoyle Cosmology Club.

Data Availability. No new data were generated or analyzed in support of this research.

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