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Resolving the Hubble Constant Discrepancy: Revisiting the Effect of Local Environments

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Abstract

Studies have found two differing sets of figures for the Hubble constant without clear direction for resolution of that difference. This article offers a direction for reconciling the measurement discrepancy. Research is reviewed and theory is described that indicate the resolution may be found in revisiting how the degree of mass in local environments affects computations. The idea that the expansion rate of the universe is invariably uniform is discounted, to be replaced by a range of figures depending on the mass density of the local environment underlying the measurement.

Keywords: Hubble constant; Spacetime density; Standard candle; Type 1a supernova; Classical Cepheid variable star; Helium flash; Cosmic microwave background.

Abbreviations: H_o: Hubble constant; SN: Supernovae; CMB: Cosmic Microwave Background.

Introduction

There is currently a highly significant measurement tension in determining the Hubble constant (H_o). Different observational methodologies have resulted in divergent figures for H_o with non-overlapping margins of error. Using any of three different standard candles, the measurements for H_o have statistically fallen into one range while the very precise use of the CMB as a "standard ruler" has resulted in a H_o clearly outside that range. Examples of research results using Type 1a SN, classical Cepheid variable stars, and the tip-of-the-red-giant-branch (helium flash) measures have estimated H_o as 72.8 ± 1.6 km/s/Mpc [1], 74.03 ± 1.42 km/s/Mpc [2], and72.4 ± 2.0 km/s/Mpc [3], respectively; that is, approximately in the range of 70–75 km/s/Mpc, centering around 73. Use of the CMB as a "standard ruler", however, resulted in a very precise H_o measurement of 67.4 ± 0.5 km/s/Mpc [4]. These examples illustrate that luminosity-based measures of H_o regularly show a difference from the CMB-based estimate, clearly indicating the discrepancy cannot be well explained by chance [5]. The consistency of results and quality of data across the studies using each methodology also minimize the likelihood of systematic errors in measurement.

This consistent difference across quality studies has left the field of cosmology needing to revise its understanding of one of its most fundamental measures. This article offers a research-supported, theory-based resolution to the H_o computational discrepancy.

Finding a Direction for Resolution

The simplest (most parsimonious) explanation for such a measurement-dependent variation in H_o is that there is a single (not yet sufficiently accounted for) covariate affecting the H_o assessments. The authors herein believe a candidate for such a single covariate is discernible from existing data.

To set the stage in explaining our perspective, we first point out that the standard measures used in every study of H_o involve a substantial body of mass. The research employs either a "standard candle" (involving a known degree of luminosity from certain stellar phenomena [1-3]) or a "standard ruler" [involving a known sound wave energy "spot" in the cosmic microwave background (CMB) [4]]. Importantly, the measurement of H_o is never a measure of the expansion of spacetime alone, but instead uses mass as a surrogate for its surrounding spacetime. That mass is necessarily being carried by the expansion of the local spacetime but has been viewed as of little other significance to the spacetime expansion rate.

Yet, the full range of amounts and density of mass involved in the H_o calculations have not been considered in its computations to date. To explicate why this omission could represent the needed covariate, we must look further at the specific measurement techniques.

Measurement Procedures and Findings

Using the first computational procedure mentioned, standard candles of type 1a supernovae (SN), classical Cepheid variable stars, and most recently the helium flashes from certain red giants necessarily involve the masses of certain stars ranging from less than 1 up to 20 solar masses. That is, standard candles stem from low to mid-range mass stars. The local environment of these stars contains minimal other mass. This means the mass density of the local volume of space is relatively low when compared to volumes of space containing larger structures. (Although type 1a SN stem from binary star systems containing a white dwarf and a second star within mass-accreting gravitational distance, the mass density of a type 1a SN's local environment is still considered low given that the two stars quite regularly involve a total mass far less than 20 solar masses). The mass density of the local volume of spacetime is of great importance because it is quite specifically the expansion rate of that volume of the universe we are trying to measure.

The "mass context" for the second procedure for computing H_o (using the "spots" in the CMB as the standard ruler) involves portions of the surface of last scattering from the time of photon decoupling. The amount or density of mass involved within the context of this measure is not known. However, because the "spots" are considered the basis for the development of large-scale structures (galaxies and galaxy clusters), we can easily assume that each spot involves a great deal more mass than is contained in single low mass stars or type 1a SN binary star systems. Likewise, while the local mass density of single stars or binary star systems is relatively low, the local mass density to a CMB spot is comparatively huge.

The point of this analysis is that there may be a consistent relationship between the measured H_o and one or more aspects of the mass used to make the measurement. The computed figure for H_o seems to be about 73 km/s/Mpc when the measurement procedure involves any of various low or mid-mass stars [1-3,6] but is about 67.4 km/s/Mpc when a far larger amount of mass is involved [4,5] (with non-overlapping margins of error).

Standard cosmological theory does not indicate or explain a relationship between local mass density and the local expansion rate of the universe. Even so, the possible relationship has been the subject of several simulation studies (conducted some years ago) [7-10], all of which indicated some local differences in H_o depending on the environment in which the measure was assessed. A very brief summary of the consistent findings across these studies is that: (a) H_o was smaller in denser environments, and larger in minimally dense environments, and (b) the differences in environments only accounted for the overall current discrepancy found in H_o to a very small degree. Presumably, the consistency of that latter finding was the reason this area of research became seen as no longer fruitful and was no longer pursued.

Premature Abandonment of certain Research

That decision was, in our view, premature. The early studies conducted simulations involving volumes of spacetime involving no more mass than found in a mid-sized star. The conclusion from that set of studies, that the local environment has only a small effect on H_o, was appropriate for the studies' very restricted comparisons between a void and small to mid-sized stars. However, these studies did not address the effect of the local mass density difference when comparing a low-mass star to something far more massive such as a portion of the CMB's surface of last scattering. The failure from that research to fully account for the current H_o discrepancy may therefore only reflect the very limited range in local environments studied.

Supportive Theory

A theoretical understanding as to how the local environment can affect H_o would facilitate future research in this regard. At least one theory exists that describes an underlying mechanism for such local differences [11]. That theory indicates that bodies of mass not only distort the spacetime field (in keeping with general relativity) but also are surrounded by an increased degree of spacetime field energy (what may be conceptualized as a clumping of the field). (The reader might be reminded of dark matter, but the theorized spacetime clumping and dark matter are not at all the same. The field energy referred to here is not a distinct type of matter, just a volume of spacetime with increased energy compared to background). The greater the mass density in the local spacetime environment, the greater the amount of clumping (i.e., increased energy) of the local spacetime field. This volume of increased field energy is slower to yield to any expansive force than would be any volume of the spacetime field that is not in the proximity of mass. The greater the proximate mass involved (local mass density), the smaller is the associated local H_o. By extension, the largest H_o should be found in the largest voids in the universe, while the smallest H_o should be found in the densest environments in the universe: the earliest universe (including the CMB) and very near supermassive black holes. Measures of H_o grounded in the CMB would necessarily be substantially different from H_o computed in the proximity of just one or two stars.

Conclusion

Suggested is that there is no single H_o but instead a range of figures depending on the mass density of the local environment used in the measurement. This theoretically supported hypothesis is neither demonstrated nor contradicted by existing data. The conflict in current observational H_o findings, however, clearly indicate existing cosmological theory seems in need of correction, and existing data indicate that an interaction with the amount/density of proximate mass may be of importance. This hypothesis is eminently testable, as are the theoretical assertions offered above. Our aspiration is for research to be pursued testing these ideas directly.

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