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VEDIC COSMOLOGY ON THE CHARACTERISTICS AND ROLE OF DARK MATTER: IMPLICATIONS FOR THE SEARCH OF DARK MATTER PARTICLE

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Abstract: Despite decades of efforts and an active intensive experimental program, the nature of dark matter (DM) remains an unsolved mystery. The problem is that we do not know what we are looking for. We submit that Vedic Cosmology (VC) expounded in Vishnu Purana (VP), an ancient Indian Text, may shed light on what DM might be and inform its search, and show why VC deserves serious scientific scrutiny. A critical examination of VP shows that it describes three constituents of the universe that are astonishingly similar to those of Standard Cosmology (SC): Vyakta or visible/ordinary matter; Pradhana, an invisible primary matter; and Purusha, an invisible nondescript energy. Vyakta or visible matter is common to both cosmologies. Pradhana is described as 'subtle, uniform, durable, self-sustained, illimitable, undecaying, and stable; devoid of sound or touch, and possessing neither colour nor form'. Thus, Pradhana has the essential widely-accepted characteristics of DM in that it does not emit or absorb light or other electromagnetic radiation, is illimitable or much more abundant than visible matter, and stable as DM is thought to be. Moreover, VP describes the morphology and constituents of a structure resembling a proto-galaxy in which a halo of this invisible primary matter surrounds ordinary matter with a central cavity/hole; which leaves little doubt that Pradhana of VP is most probably the DM of SC. Purusha, the third constituent of the universe in VC, is equated here with dark energy (DE) of SC. Pradhana is undecaying; which may explain why no decay product of DM has thus far been detected. Furthermore, consistent with the principle of conservation of mass, VP states that Pradhana/DM was not created, nor can it be destroyed, and that ordinary matter is a product of DM and converted back to DM over trillions of years. If so, the DM particle cannot be a sub-atomic elementary particle, nor a hypothetical light particle such as an axion, and has to be more massive than the sum of the masses of all elementary particles. And it implies that under certain unspecified conditions ordinary

matter could be synthesized into DM. Additionally, VC indicates that density of DM/Pradhana is constant, as is apparently the density of DE in SC and of the invisible nondescript energy Purusha in VC; which resolves the Cosmological Coincidence problem and is shown to yield a Hubble constant comparable in value to that measured locally.

Keywords: Dark matter, Dark energy, Dark matter's relationship with ordinary matter, search for Dark matter particle, ultimate fate of Universe and Earth

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1. Introduction

The existence of dark matter (DE) was first suggested almost a hundred years ago by the Dutch astronomer Jacobus Cornelius Kapteyn using stellar velocities, see [8]. Since then a number of astronomical observations have affirmed its existence. Zwicky in [24] and [25] tracked the velocities of galaxies within galaxy clusters and observed that the gravity of visible matter alone was not sufficient to keep the cluster from flying apart and that additional matter that was not visible was needed to keep the cluster together. Rubin et al. in [15] observed the velocities of stars on the outskirts of individual galaxies, and a stream of observations including gravitational lensing by galaxy clusters followed in the 1980s. Rubin et al. in [16] concluded that most galaxies must contain $\sim$ six times as much dark as visible mass. And by the 1980s it came to be widely accepted that astronomically observed gravitational effects could not be accounted for by existing theories of gravity unless matter that is invisible or dark is present in the universe, see Randall [13]. Alternatively, modifications to existing theories of gravity have been proposed to explain the need for the presence of DM. These modifications are, however, unsatisfactory on theoretical grounds and apparently still require the presence of DM to correctly describe the formation of large-scale structure of the universe, see [3].

At the present, DM is inferred to be 5 to 6 times more abundant than visible/ordinary matter, constituting $\sim 85\,\%$ of the matter in the universe and $\sim 25\,\%$ of its energy density, see Planck collaboration [11]. It is thought to be non-baryonic, mostly "cold" or that it moves much more slowly than the speed of light, stable on cosmological time scales, does not interact with ordinary matter through the strong nuclear force, but through gravity and possibly through the weak nuclear force, see [3]. Candidates include primordial black holes, and new-undiscovered particles such as axions, sterile neutrinos, and WIMPs or weakly interacting massive particles, see [3]. The current search for DM particles involves: indirect detection or observation of signals from deep in the universe emanating from the annihilation or decay of DM particles; creation of DM particles through high-energy collision of protons in the Large Hadron Collider; and direct detection based on the hope that DM particles may occasionally interact with ordinary matter such as liquid xenon through the weak force, see Toomey [20]. Unfortunately, despite decades of efforts

and an ongoing intensive experimental program, the search for DM particle(s) remains elusive. The problem is that none of the observations or computer simulations involving DM give a clear indication as to what DM is made up of. In short we do not know what we are looking for.

We submit that Vedic Cosmology (VC) may shed light on the characteristics of DM, its relationship with ordinary matter, and its role in the evolution of the universe; and consequently may inform the search for the elusive DM particle. Vishnu Purana (VP), a post-Vedic ancient Text in Sanskrit translated into English by Wilson, see [23], offers the principal tenets of VC. It describes in considerable detail the origins of the universe, its cyclic nature, the ultimate fate of planet Earth and the universe, cosmic cycles spanning billions to trillions of years, and three constituents of the universe, one of which appears to be the DM of the modern-day Standard Cosmology (SC). It is noteworthy that the late astrophysicist Carl Sagan in [17] aptly observed that the cosmic cycles described in VP "correspond, **no doubt by accident**, to those of modern scientific cosmology. Its cycles run from our ordinary day and night to a day and night of Brahma, 8.64 billion years long, longer than the age of the Earth or the Sun and about half the time since the Big Bang. And there are much longer time scales still". After a careful scrutiny of VP, Aggarwal in [1] showed that the time span of 8.64 billion years (Gy) noted by Sagan **was not an accident**, but apparently corresponds to Sun's useful life comparable to the current rough estimate of 10 Gy for Sun's life on the main sequence. In addition, the age of the universe and the timing of the formation of the first solar system in the Milky Way inferred from VP, and the sequence of events leading to the incineration of planet Earth by an expanding Sun in the next 4–5 Gy described in VP, agree remarkably well with current scientific data and/or models, see [1]. Here, after additional research, we go a step further and explore the nature of DM, dark energy (DE), space, and time and their roles in the formation and evolution of the universe as expounded or inferred from VP, and discuss their implications. We begin, however, with a brief review of the conclusions in [1]), clarifying and supplementing them as warranted that provides a foundational background of this paper and offers compelling reasons why VC merits serious scientific scrutiny despite the fact that its origins remain obscure. Thereafter, we describe and discuss the findings relating to DM.

2. Background

The VP is part of an ensemble of 18 post-Vedic Texts collectively denominated as Puranas, or literally "of ancient times" in Sanskrit. The Puranas are a vast literature of stories and allegory pertaining to cosmology, history, geography, and genealogies of kings, see Krishnananda [9], and not religion per se that requires adherence or blind faith. Not all Puranas were, however, created equal or written at the same time. The VP is one of the two finest Puranas, see [9] and considered to be among the oldest dating back to the first century B.C. for its written form and many centuries older

in its oral form, see Wilson [23]. A word of caution. In addition to describing the beginnings of the universe in material terms, VP invokes non-material elements and metaphysics subject to uncertain interpretations. Also, the Puranas often ascribe a result, outcome, or action to a mythological deity/actor and use different names for the same deity. We overcame such hurdles by separating the core tenets of VC that are beyond reproach from the more tenuous or speculative interpretations, and by focusing on the action or the result and ignoring the actor. Aggarwal in [1] provides a fuller description of VP, other sources supporting the conclusions therein, and methodology used in judging the cosmological content of VP. Note also that when quoting from VP, the word(s) in parentheses are not ours except those in italics.

The VP and the Bhagavata Purana (BP) translated by Prabhupada in [12] describe two major cycles of VC: Vishnu's cycle that lasts $\sim$ 311 trillion years and corresponds to the lifespan of the universe; and the 8.64 Gy long Brahma's cycle noted by Carl Sagan that apparently corresponds to Sun's life span and comparable to the widely used estimate of 10 Gy for Sun's life on the main sequence, see [1]. This rough estimate of 10 Gy, however, suffers from large uncertainties. It is based on Sun's current luminosity, a first order approximation of the amount of Sun's mass available for conversion into solar energy, and assuming a steady state system. Models of Sun's evolution, however, indicate that Sun's luminosity increases with the age of the Sun; and if a rough correction is made assuming a linear increase in Sun's luminosity from its inception to the Red-Giant phase using the model in Schröder and Smith [19], the Sun's life span on the main sequence decreases to $\sim$ 8.9 Gy or closer to the 8.64 Gy time span of Brahma's cycle. And a relatively small change of say 10 % in the fraction of Sun's mass available for fusion would result in a change of almost 1 Gy in Sun's life span.

The VP and BP do not explicitly state the age of the universe, but it can be rather accurately inferred from the past history of Brahma's cycle described in them. The cycle is divided into two equal parts, each 4.32 Gy long called a Kalpa and 2 Kalpas constitute a Brahma's cycle. During the first half of the cycle life evolves and flourishes on an earth-like planet, and during the second half life slowly perishes ending with the incineration of Earth. The VP and BP in fact describe the past history of this cycle, naming each half of the past cycles, and making it clear that one, and only one, Brahmas' cycle or two halves preceded the current cycle (BP, Canto III, Chap. 11, Prabhupada [12]; Aggarwal [1]). And since the current cycle began with the formation of our Solar system $\sim$ 4.57 Gy ago (see [2]), one can deduce from this history that our universe is at least $4.57 + 8.64 = 13.21$ Gy but not more than $13.21 + 4.32 = 17.53$ Gy old, in agreement with current estimate of $\sim$ 13.8 Gy (see [11]) for the age of the universe.

The history of Brahma's cycle indicates that a now-defunct solar system $\sim$ 13.2 Gy old should exist in the Milky Way, and implies that planets formed within less than a billion years of the currently accepted age of the universe. In 2003 the Hubble Space Telescope discovered the existence of a planet in the Milky Way galaxy that formed around a sun-like star $\sim$ 13 Gy ago, whose identity was confirmed by NASA,

see [10]. We quote: "NASA's Hubble Space Telescope precisely measured the mass of the oldest known planet in our Milky Way galaxy. At an estimated age of 13 billion years, the planet is more than twice as old as Earth's 4.5 billion years. It's about as old as a planet can be. It formed around a young, sun-like star barely 1 billion years after our universe's birth in the Big Bang", see [10]. No claim is made here that the primeval solar system discovered by NASA is the solar system predicted by VP. Suffice to note that VP's indication that a solar system formed in the Milky Way galaxy some 13.2 Gy ago is supported by NASA's discovery. This prediction also implies that the Milky Way should be at least ~ 13.2 Gy old. And since heavy elements are generally thought to have been released in supernovae, it follows that the solar system envisioned in VP was presumably preceded by several generations of stars that produced the heavy elements necessary to form the planets. Therefore, we may conclude that VP predicts that the Milky Way should be significantly older than 13.2 Gy and possibly almost as old as the universe itself. In fact, as discussed later, VP describes the morphology and constituents of a large-scale structure resembling a galaxy that apparently formed soon after the beginning of the universe. In 2018 a 13.5 Gy old low-mass metal-poor star was discovered in the Milky Way, indicating that the Milky Way is at least 13.5 Gy old and ~ 3 Gy older than previously thought, see Schlaufman [18].

We are roughly half-way through Brahma's cycle since the inception of our Solar system, just as the Sun is about half-way through its main sequence. The VP predicts that at the end of the current cycle or in ~ 4–5 Gy Earth will be incinerated by the Sun. Succinctly, the sequence begins with a 100-year drought causing havoc because of the failure of crops, followed by extensive evaporation of water, boiling over of rivers and oceans, and a moist runaway green-house effect that leaves the Earth a molten rock before it is consumed by the Sun. And we quote: "The seas, rivers, mountain torrents, and springs are all exhaled; and so are the regions of Patala, the regions below the earth. Thus fed, through his intervention, with abundant moisture, the seven solar rays dilate to seven suns, whose radiance glows above, below, and on every side; and sets the three worlds and Patala on fire. The three worlds, consumed by these suns, become rugged and deformed throughout the whole extent of their mountains, rivers, and seas; and the earth, bare of verdure, and destitute of moisture alone remains, resembling in appearance the back of a tortoise. The great fire, when it has burnt all the divisions of Patala, proceeds to the earth, and consumes it also", see VP, Book VI, Chap. III, Wilson [23]. Compare this description to that in [19] that describes the effects of Sun's evolution on Earth. We quote: In about a billion years "the water vapour content of the atmosphere will increase substantially and the oceans will start to evaporate by Kasting, 1988 in [19]. An initially moist greenhouse effect by Laughlin, 2007 in [19] will cause runaway evaporation until the oceans have boiled dry. The subsequent dry greenhouse phase will raise the surface temperature significantly faster than would be expected from our very simple black-body assumption, and the ultimate fate of the Earth, if it survived at all as a separate body, would be to become a molten remnant". The

Schröder and Smith model (see [19]), however, predicts that eventually the Earth along with Mercury and Venus will be engulfed by the Sun. The major difference, however, between VP and the SS (see [19]) model is that the incineration of Earth in VP takes place in the next $\sim$ 4–5 Gy, whereas in the SS model it takes $\sim$ 7.5 Gy. This difference in large part can be accounted for by the fact that in the SS model Sun's life on the main sequence is fixed at 10 Gy, and as discussed earlier it could be much shorter, possibly by as much as 2 Gy.

3. Constituents of the Universe

Vedic cosmology does not per se invoke a creator as an entity separate from the creation, but posits that underlying the phenomena of creation, evolution, and destruction is an unfathomable reality personified as Vishnu and Brahma that manifests itself in the forms of "Pradhana (primary or crude matter), Purusha (spirit), Vyakta (visible substance), and Kala (time)". See VP, Book I, Chapt. II, Wilson [23]. And, irrespective of whether one accepts or not the existence of such an underlying reality, it is amply clear from VP that the universe is the result of time (Kala) and composed, "in their due proportions" of Vyakta or visible matter, Pradhana or primary matter that is invisible, and Purusha, a nondescript energy that fills all space but is not detectable by the senses. The VP, however, does not specify the quantitative proportions of the three constituents; but implies that the three constituents are in unequal/differing proportions, and we can gauge their relative importance from their descriptions.

Compare these three constituents of VC to those of the SC in which the universe is also composed of three components in unequal proportions: visible/ordinary matter, DM, and DE. Note that visible/ordinary matter is common to both cosmologies. VP describes the characteristics of primary matter (Pradhana). It is characterized as "subtle, uniform, durable, self-sustained, illimitable, undecaying, and stable; devoid of sound or touch, and possessing neither colour nor form". See VP, Book I, Chapt. II, Wilson [23]. Hence, primary matter is invisible or does not emit or absorb light or other electromagnetic radiation, just as DM; is limitless and hence much more abundant than visible matter as DM is deduced to be; and durable and stable as DM is thought to be. Hence, it appears that the primary matter of VC and DM of SC are apparently one and the same thing. And the following description in VP of the morphology and constituents of a large-scale structure resembling a galaxy provides additional evidence that the primary matter of VP is in all likelihood the DM of SC.

Succinctly, VP indicates that ordinary matter is composed of ether, air, light, water, and earth; that these components or elements did not all form simultaneously or at once, but in stages; that ether "endowed with the property of sound" was the first, which in turn produced air, followed by light, then water, and lastly earth; and that "being unconnected, they could not without combination, create living beings, not having blended into each other". See VP, Book I, Chapt. II, Wilson [23]. Here,

we digress somewhat and ponder as to the nature of these five components or elements. Rather than thinking of these five components as building blocks of ordinary matter as is generally thought, we suggest that apart from radiation/light they may represent distinct phases of ordinary matter. In that case air, water, and earth would obviously represent respectively the phases of gas, liquid, and solid; and the question would be whether the remaining component ether (akasha in Sanskrit) is also another phase of matter. We first note that it is not the aether, quintessence, or the fifth element of the Greeks because aether was thought to be non-material (see Fludd [6]), whereas akasha or ether of VP is matter. We suggest that it could be plasma or the missing fourth phase of matter. If so, VP's characterization of ether/akasha as the first stage of matter "endowed with the property of sound" from which ensued air (gas) followed by light (photons) would be remarkably consistent with the following sequence in the evolution of matter and radiation in the early universe. The early universe is thought to have been a hot soup of dense plasma of electrons and baryons (protons and neutrons) in which counteracting forces of gravity and pressure created oscillations analogous to sound waves, see Eisenstein [5]. As the universe expanded, the plasma cooled such that electrons and protons combined forming neutral hydrogen (gas) atoms, allowing photons (light) to decouple from matter and free stream through the universe, see Dodelson [4]. Furthermore, VP's assertion that water and earth were the last to form is consistent with the current understanding that heavier elements such as oxygen formed in stars only after electrons and protons had combined to form hydrogen atoms and photons had decoupled from matter.

Notwithstanding the above digression, VP clearly states that these components then combined with each other and "assumed, through their mutual association, the character of one mass of entire unity" forming an "egg, which gradually expanded like a bubble of water". In that egg "were the (*future*) continents and seas and mountains, the planets, and divisions of the universe, the gods, the demons, and mankind. And this egg was externally invested by seven natural envelopes, or by water, air, fire, ether, and Ahankara the origin of the elements, each tenfold the extent of that which it invested; next came the principle of intelligence, and finally the whole was surrounded by the Indiscrete Principle (*primary invisible / dark matter*); resembling thus the cocoa-nut filled interiorly with pulp, and exteriorly covered by husk and rind." "Its womb, vast as mountain Meru, was composed of the mountains; and the mighty oceans were the waters (*liquid*) that filled its cavity" See VP, Book I, Chapt. II, Wilson [23]. Note that the invisible primary matter Pradhana is also called the Chief principle, Indiscrete principle, or the Equilibrium of the qualities and its characteristics described earlier were shown to be akin to those of DM. Despite some ambiguity concerning the components of ordinary matter, the preceding large-scale structure apparently resembles a galaxy both in its morphology and its constituents. Its shape is analogized with that of a coconut and hence it could be round or ellipsoidal, just as the vast majority of galaxies are observed to be. It has a large central cavity, albeit filled with water (liquid), consistent with the current knowledge that a massive black hole lies at the center of virtually all large galaxies.

Its pulp is made up primarily of ordinary/visible matter in all its phases; which in turn is surrounded by a halo of primary/dark matter. The clear description that the visible part of the structure/galaxy consisting of ordinary matter is surrounded by primary matter that is invisible leaves little doubt that the primary matter of VP is in all likelihood the DM of SC. Dark matter halos play a key role in current models of galaxy formation and evolution. The DM halo envelops the galactic disc and extends well beyond the edge of the visible galaxy, and although invisible, its existence is inferred by astronomical observations of its effects on the motions of stars and galaxies, see Wechsler and Tinker [21]. It appears, however, that the structure described in VP, although large with a cavity vast as mountain Meru, is still in its infancy, gradually expanding or growing like a bubble of water and not fully developed just like an egg waiting to hatch.

Unfortunately, VP does not describe in similar detail what the third component is, except that it is some sort of undetectable energy that apparently uniformly fills the entirety of space, and hence much more abundant than visible matter. On the other hand, we do not know much about DE either, except that it too remains undetected, is much more abundant than visible matter, and thought to be a repulsive energy of space that causes it to expand. Given the deficits in our knowledge on the nature of the invisible energy/spirit of VC and DE of SC and the numerous concordances between VC and SC or current science established above, we could reasonably assume that they are one and the same, especially since in both cosmologies the universe comprises three components of which the other two are apparently common to both.

4. Role of Dark Matter and implications

Table I summarizes the foregoing correspondences between VC and current science or SC. These concurrences cannot simply be fortuitous, but provide compelling evidence why VC merits serious scientific scrutiny. Unfortunately, the narrator in VP does not know the source of the knowledge and how VC came to be expounded, but informs us that this knowledge was passed on by Brahmin scholars learned in the Vedas. Nevertheless, having established that the primary matter of VC is in all probability the DM of SC, we can now enunciate the core tenets of VC that elucidate DM's relationship to ordinary matter and its role in the evolution of the universe. The following are the core tenets of VC, and we quote from VP supporting the inference or conclusion drawn.

First, VC posits that time is without a beginning and its end is not known and that the universe is cyclic. We quote: "The deity as Time is without beginning, and his end is not known; from him the revolutions of creation, continuance, and dissolution intermittently succeed". 2) Pradhana or DM and Purusha/Puman or DE pre-existed the current cycle. We quote: "There was neither day or night, nor sky nor earth, nor darkness nor light, nor any other thing, save only One, inapprehensible by intellect, or That which is Brahma and Puman (*DE*) and Pradhana (*DM*)". 3) That Pradhana/DM is without a beginning and that visible/ordinary matter is its product

Vedic Cosmology (VC)	**Feature/Characteristic**	Standard Cosmology (SC) Current science
> 13.2 Gy and < 17.5 Gy	**Age of the universe**	13.8 billion years (Gy)
> 13.2 Gy	**Age of Milky Way**	> 13.5 Gy
~ 13.2 Gy	**Oldest planet in the Milky Way**	~ 13 Gy
8.64 Gy	**Useful lifespan of Sun**	$\sim$ 8–10 Gy (see text)
In 4–5 Gy	**Incineration of Earth by the Sun**	In $\sim$ 5.5–7.5 Gy (see text)
Long drought, followed by extensive evaporation, boiling over of the oceans and rivers, a wet runaway greenhouse effect, resulting in a molten rock resembling the back of a tortoise.	**Events preceding the incineration of Earth by the Sun**	Increase in temperatures, extensive evaporation, boiling over of oceans, runaway greenhouse effect, resulting in a molten rock.
Visible matter, primary/invisible matter, and a nondescript spiritual energy in "their due proportions"	**Constituents of the universe**	Ordinary matter, dark/invisible matter, and dark energy in unequal proportions
Shaped like a coconut (rounded or ellipsoidal), with a massive central cavity surrounded by visible matter and a halo of primary/dark matter	**Morphology and constituents of Milky Way or protogalaxy described in VC**	Spiral (round), with a massive black hole in the center surrounded by ordinary matter and an extensive halo of dark matter
Subtle, uniform, durable, stable self-sustained, illimitable, undecaying, and devoid of sound or touch, and possessing neither colour nor form.	**Primary/Dark matter**	Does not absorb or emit electromagnetic radiation, much more abundant than ordinary matter, and apparently durable and stable.

Table 1: Similarities between vedic cosmology and current science or standard cosmology

and converted back into DM by the end of a cycle. We quote: "The chief principle (Pradhana) is the mother of the world; without beginning; and that into which all that is produced is resolved. By that principle all things were invested in the period subsequent to the last dissolution of the universe, and prior to creation" See VP, Book I, Chapt. II. Wilson [23].

The foregoing principal tenets of VC lead to the following inferences and/or conclusions. Since DM is without a beginning and is limitless, and according to general relativity matter cannot exist without space, it follows that space too is without a beginning and is unbounded; and so is time. Neither DM nor DE were created; are apparently constants from one cycle to another and fill the entirety of space. The implication is that the densities of DM and DE are constant and not functions of time. In contrast, DM in SC has a beginning, was presumably created in the Big Bang, and its density decreases along with that of ordinary matter as the universe expands.

The proposition that ordinary matter is a product of DM and converted back to DM by the end of a cycle, and that DM and ordinary matter both exist during the cycle, implies that a relatively small mass of DM is converted to ordinary matter at the beginning of a cycle; which incidentally also explains why DM is much more abundant in the universe than ordinary matter. The constituents of ordinary matter (protons, neutrons, and electrons) are by products of DM; which implies that the DM particle is not a subatomic elementary particle, nor a hypothetical light particle such as an axion. In fact, the principle of conservation of mass requires that it be more massive than the sum of the masses of all elementary particles; and suggests that it cannot be created by high-energy collisions of protons alone in accelerators such as the Large Hadron Collider (LHC), but could possibly be synthesized from ordinary matter under certain unspecified conditions. Furthermore, since Pradhana/DM is non-decaying, it may explain why no decay or annihilation product of DM has thus far been observed. Note also that the proposition that the density of DM is constant, as is apparently the density of DE, resolves the so-called Cosmic Coincidence problem as to why the current densities of DM and DE happen to be of the same magnitude. Also, the proposition that DM existed before the commencement of the current cycle and that it was not created in the Big Bang makes it possible for the density inhomogeneities observed in the Cosmic Microwave Background (CMB) to have grown much faster than envisioned in SC (see [3]); thus providing a head start to the formation of galaxies. This difference between VC and SC may also explain why galaxies such as the Milky Way formed soon after the beginning of the current universe $\sim 13.8\,\mathrm{Gy}$ ago.

Lastly, the proposition that DM density is largely constant in VC may account for the incongruity between the value of Hubble constant H_0 inferred from CMB using SC or the ΛCDM model and H_0 measured locally. Riess et al. in [14] determined a value for $H_0 = 74.03 \pm 2.82\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ (2σ) measured locally using Cepheids, that is significantly higher than the value of $H_0 = 67.4 \pm \mathrm{km\,s^{-1}\,Mpc^{-1}}$ (2σ) inferred from Planck CMB data and ΛCDM, see [11]. These values taken at face value indicate that Ho measured locally is higher by $\sim 10 \pm 5\,\%$ (2σ). The following simple calculation provides a rough estimate of the difference between the values of H_0 predicted by VC and the ΛCDM model from the CMB data. The Hubble parameter is a function of redshift z (see Wei and Wu [22]) and in a flat universe with constant lambda, H_0 can be expressed as:

$$H_0 = H(z)\sqrt{\Omega_{\rm BZ}(1+z)^{-3} + \Omega_{\rm CZ}(1+z)^{-3} + \Omega_{\Lambda\rm Z}}, \tag{1}$$

where the $\Omega_{\rm BZ}$, $\Omega_{\rm CZ}$, and $\Omega_{\Lambda\rm Z}$ are, respectively, the density parameters (densities expressed as fractions of critical density) for baryons, DM, and DE at redshift z at the epoch of CMB. The density of DM in VC is, however, constant. Hence, the ratio $H_0^{(\rm vc)}/H_0^{(\rm sc)}$ of the value of H_0 inferred by VC to that by SC is given by:

$$\frac{H_0^{(\rm vc)}}{H_0^{(\rm sc)}} = \frac{\sqrt{\Omega_{\rm BZ}(1+z)^{-3} + \Omega_{\rm CZ} + \Omega_{\Lambda\rm Z}}}{\sqrt{\Omega_{\rm BZ}(1+z)^{-3} + \Omega_{\rm CZ}(1+z)^{-3} + \Omega_{\Lambda\rm Z}}}. \tag{2}$$

For $z \sim 1100$ corresponding to the epoch of CMB, the components $\Omega_{\rm BZ}(1+z)^{-3}$ and $\Omega_{\rm CZ}(1+z)^{-3}$ are small or negligibly small and the ratio $H_0^{(\rm vc)}/H_0^{(\rm sc)}$ reduces to:

$$\frac{H_0^{(\rm vc)}}{H_0^{(\rm sc)}} < \sqrt{1 + \frac{\Omega_{\rm CZ}}{\Omega_{\Lambda\rm Z}}}. \tag{3}$$

The ratio is greater than 1. Thus, VC predicts a H_0 value greater than that inferred by the ΛCDM model. And since the densities of DM and DE are both constants in VC, their ratio is also a constant and does not change with time. Hence, if this ratio Ω_c/Ω_Λ at say $z = 0$ could be determined independent of the ΛCDM model, we could quantify the difference. Hollanda et al. in [7] determined the current density parameters independent of ΛCDM using supernovae and galaxy clusters, but dependent on the value of H_0. Their study gives values for the $\Omega_{\rm CO}/\Omega_{\Lambda\rm O}$ ratio comparable to that obtained by [11]. Adopting its value of ~ 0.34 from [7] we get $H_0^{(\rm vc)}/H_0^{(\rm sc)} < 1.157 \pm 0.021$. Thus, VC predicts $H_0 \sim 15 \pm 2\,\%$ higher than that inferred using ΛCDM, and comparable (within 2σ) to that measured locally. Note that the contribution of radiation to the total density was neglected in the above calculation. Its inclusion does not change the results.

5. Conclusions

We showed that VC concurs with SC or current science on numerous key aspects of our universe. In fact, it is mind boggling to ponder that a few thousand years ago Vedic scholars could stipulate that the Milky Way is older than 13.2 Gy when until recently the Milky Way was thought to be younger by ~ 3 Gy. It is equally beguiling that the ancient Vedic scholars visualized that Earth will be incinerated in the next 4–5 Gy preceded by a wet runaway greenhouse effect, consistent with current models of Sun's evolution. And perhaps above all they were aware that one of the constituents of the universe is matter that is invisible or dark, the modern-day existence of which was postulated only about a hundred years ago, see Kapteyn [8].

The differences between VC and SC as to the origins of DM and its role in the formation and evolution of the universe are equally profound, and the two cosmologies envision dramatically different scenarios as to how the universe came into being

and what might be its ultimate fate. In VC the universe is cyclic, whereas in SC its ultimate fate remains in limbo. In VC, time is without a beginning and its end is not known; that space, DM, and DE are constants from one cycle to another; and that DM and DE existed before the beginnings of the current universe. In SC, space, time, DM came into being in or at the time of the Big Bang. In VC, ordinary matter is created from DM at the beginning of a cycle and synthesized back into DM by the end of the cycle in trillions of years. In SC, the relationship between ordinary and DM remains unknown (except that DM acts gravitationally on ordinary matter). In SC, DM having been created in the Big Bang, its density decreases as space expands while that of DE remains constant; which creates the Cosmological Coincidence problem as to why the current densities of DM and DE happen to be of similar magnitude. In VC, the density of DM is constant, just as the density of DE; which resolves the long-standing Cosmological coincidence conundrum. Additionally, we showed that the proposition that DM density is constant apparently resolves the current unexplained incongruity between the value of Hubble constant inferred from CMB and SC or the ΛCDM model and its value measured locally.

If dark matter is undecaying as described in VP, it would explain why attempts to detect products of annihilation or decay of DM have thus far not been successful. Furthermore, the proposition that ordinary matter is a product of DM implies that the elusive DM particle should be massive and not light such as neutrino or axion. In fact, conservation of mass requires that it be more massive than the sum of the masses of all elementary particles. It also suggests that under certain unspecified conditions ordinary matter could be synthesized into DM, but that attempts to create DM particle(s) by high-energy collisions of protons alone in the Large Hadron Collider may not be fruitful.

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