Question of Planck's constant in dark matter direct detection experiments

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Recent astronomical observations have revealed important new clues regarding dark matter's behavior. However, the fact remains that *all* experimental efforts to detect dark matter directly, in a laboratory setting, have failed. A natural explanation for these failed efforts may be possible by postulating that dark matter's behavior is governed by a *non-Planckian* "action." It is pointed out, as a preliminary to advancing this possibility, that *no* purely dark matter measurement of Planck's constant exists. The resulting hypothesis advocates the existence of a *new*, experimentally verifiable, dark matter candidate. An extension of this hypothesis to the cosmological realm suggests that dark matter may have come into existence 10^{-44} seconds after the big bang; an order of magnitude *prior* to the Planck era.

I. Introduction

As evidenced by recent experimental data [1] the search for dark matter (DM), in a terrestial laboratory setting, remains one of the most vexing of the unresolved problems of contemporary physics. After nearly three decades of experimentation none have yet been detected. If the past is any guide, such negative results often compel us to re-examine some of the basic tenets underlying physical phenomena which, in this particular case, is long overdue.

Clearly, since DM's existence is inferred solely from its gravitational effects, and its nature is otherwise unknown, one cannot rule out the possibility that DM's behavior may be contradictory to the consequences of quantum mechanics as they apply to luminous matter; a possibility that is particularly troubling since it necessarily brings into question the applicability of Planck's constant as a viable "action" in this *non-luminous* domain [2]. It is important to point out that *no* purely DM measurement of Planck's constant exists. Indeed, all that we know about Planck's constant is based on electromagnetic and strong interaction experiments, whose particles and fields account for only 4.6% of the mass-energy density of the observable universe, which pales when compared to the 23.3% attributable to DM.

What little is known about DM derives from the astronomical realm. Recent observations have revealed important new clues regarding its behavior. Particularly important, an analysis of cosmic microwave background observables has provided conclusive evidence that DM is made up of slow-moving particles [3]; a development that has firmly established the *cold* DM paradigm as the centerpiece of the standard cosmology. Equally revealing, large aggregates of DM have been observed passing right through each other without colliding [4-5], which is clearly significant since it essentially rules out the idea that particles of DM can somehow interact with each other non-gravitationally. While these astronomical observations strengthen the case for DM's existence the fact remains that *all* experimental efforts to detect DM directly have failed; a rather puzzling situation that has generated considerable debate in the experimental community.

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II. Non-Planckian "action"

One way out of this difficulty is to assume that DM's behavior is orchestrated by a *non-Planckian* "action;" a possibility that can be accommodated in the context of the framework of quantum mechanics, whose formalism mandates *two* immutable *elementary* "actions." Namely, Planck's familiar constant, h, which has been shown experimentally to play a crucial role in the microphysical realm, and the more diminutive, less familiar "action" e^2/c where e is the elementary charge, and c is the velocity of light in a vacuum (denoted by the symbol j for simplicity of presentation). It is interesting to note that Einstein considered this ratio to be an *elementary* "action" [6]. However, he expressed his frustration at not finding a suitable system in which it would play a fundamental role similar in scope to Planck's constant. It is, nevertheless, clearly of interest since it may have a significant impact in the *non-luminous* domain of DM. Indeed, it may be sufficiently *smaller* than Planck's constant to account for the negative results obtained in terrestial DM laboratory experiments; a possibility that cannot be convincingly dismissed in the absence of a physical law that prohibits an elementary "action" smaller than Planck's.

III. Dark matter

Since DM has been observed to be slow-moving [3], such a determination can be facilitated by restricting ourselves to the *classical* treatment of particles in the *Schroedinger* form. Let us assume for this purpose that DM's non-Planckian *particle/wave* properties are consistent with both the Einstein relation for the total energy of a particle, in the form

$$E = jf = mc^2 = \frac{m_0 c^2}{\sqrt{1 - v^2/c^2}} \tag{1}$$

and the de Broglie relation for the momentum

$$p = \frac{j}{\lambda} = mv = \frac{m_0 v}{\sqrt{1 - v^2/c^2}} \tag{2}$$

where $j = 7.6956 \times 10^{-30}$ erg s is the conjectured DM "action" quantum, which may be compared with the Planck constant, h, found in our luminous world (i.e., 6.6260×10^{-27} erg s). Now, since the relation between energy and momentum in *classical* mechanics is simply

$$E = \frac{1}{2m} p^2 \tag{3}$$

we can replace E and p with the differential operators

$$E = i \frac{j}{2\pi} \frac{\partial}{\partial t} \tag{4}$$

and

$$p = -i \frac{j}{2\pi} \frac{\partial}{\partial x} \tag{5}$$

and operate with the result on the wave function $\psi(x, t)$ that represents the de Broglie wave. We then obtain

$$i \frac{j}{2\pi} \frac{\partial \psi}{\partial t} = -\frac{(j/2\pi)^2}{2m} \frac{\partial^2 \psi}{\partial x^2}, \tag{6}$$

which is Schroedinger's general wave equation for a non-relativistic *free* particle, whose behavior, in this case, is governed by a *non-Planckian* "action." Its solution describes a particle that is the quantum mechanical analog of a *classical* particle that is moving in the x direction with constant velocity, and *no* interactions, which is consistent with the observed astronomical behavior of DM [3-5].

Such a particle would have *no* difficulty avoiding detection in the fiducial volume of some monitored detector material because of the *diminutive* magnitude of the conjectured DM "action" constant, which is *three* orders of magnitude *smaller* than Planck's. More succinctly, if DM's behavior is orchestrated by this non-Planckian "action," its detection will, most certainly, require the implementation of a wholly new set of experimental tools that are capable of detecting particle collision events involving *two* quantitatively different *elementary* "action" constants. Such an undertaking necessitates the probing of previously *uncharted* sensitivity thresholds, mandated by the fact that in such a collision the DM particle's quantum effects are *considerably* less pronounced than those associated with luminous matter; a fact of nature that underscores the contention that one cannot completely rule out the possibility that DM's quantum mechanical properties may be incompatible with those of luminous matter. Such an outcome would, undoubtedly, have negative connotations experimentally since it would imply that DM *only* interacts gravitationally with luminous matter, as manifested by its astronomical behavior [3-5]. Of course there is always the lurking possibility that such collision events may already have been detected, but the experimenters did not understand what they had observed in the absence of *computer simulations* of such an unfamiliar event.

IV. Cosmological implications

What follows is a summary of results obtained by a heuristic application of this non-Planckian "action" to quantum *uncertainty*, as formulated by Heisenberg, in the analogous form

$$(\Delta x)\,(\Delta p) \simeq \frac{j}{2\pi} \tag{7}$$

where, as usual, Δx is uncertainty of position, and Δp the uncertainty in momentum. It is well to note that this relation gives rise to a submicroscopic level of quantum uncertainty whose degree of determinism *surpasses* the limit imposed by Planck's constant in our luminous world. Its implications for the major events that make up the big bang model can be simply illustrated in terms of the *non-Planckian* unit of time, $T_{0'}$ analogous to the Planck time $T_p = (\hbar G/c^5)^{1/2}$, in the form

$$T_0 = \left[(j/2\pi)G/c^5\right]^{1/2} \tag{8}$$

where G is the Newtonian gravitational constant, c is the velocity of light in a vacuum, and T_0 is the time it takes a photon to travel one *non-Planckian* unit of length, L_0, symbolized by

$$L_0 = \left[(j/2\pi)G/c^3\right]^{1/2} \tag{9}$$

from which we obtain $T_0 = 1.837 \times 10^{-45}$ seconds. However, because of the *non-Planckian* uncertainty principle, Eq. (7), we are prevented from speculating on times shorter than 10^{-44} seconds after the big bang, which is an order of magnitude *prior* to the Planck era (i.e., 10^{-43} seconds). The disparity in this temporal sequence of events implies that a *non-Planckian* epoch *preceded* the Planck era, which would have allowed sufficient time, from a submicroscopic perspective, for DM to have come into existence; a development that would, undoubtedly, have far reaching cosmological implications. Indeed, its gravitational signature would provide a unique mechanism for determining the evolution of DM structure immediately following the big bang.

V. Concluding remarks

The acknowledgment of this *non-Plankian*, elementary quantum of "action," in the context of the framework of quantum mechanics, elicits a fundamentally plausible, experimentally verifiable, explanation for failure of conventional DM experiments to affirm its existence. Moreover, it brings into better focus, after these many decades of null experimental results, the possibility that *mainstream* concepts of DM may be fundamentally untenable.

It is important to point out that, irrespective of this hypothetical particle's existence, the extension of this non-Planckian "action" to the cosmological realm has far-reaching implications, not least of which is the formulation, in the context of the framework of quantum mechanics, of a *pre-Planckian* epoch 10^{-44} seconds after the big bang; a development that offers a *new* avenue of investigation of DM's timeline in cosmic evolution.

VI. Appendix

What name to ascribe this *cold*, non-Planckian "action," DM particle? Clearly, the basic aspect that one should be mindful of is its indispensable role in enabling the *warping* of spacetime sufficiently enough to cradle entire clusters of galaxies. However, there is also a time honored tradition to be considered. That is, the customary practice of ending the particle's name in *-on*. Hence, in deference to both of these considerations, "*warpton*" suggests itself as a most appropriate name.

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