On the Failure of Particle Dark Matter Experiments to Yield Positive Results

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It is argued that the failure of *particle* dark matter experiments to verify its existence may be attributable to a *non-Planckian* "action", which renders dark matter's behavior contradictory to the consequences of quantum mechanics as it applies to luminous matter. It is pointed out that such a possibility cannot be convincingly dismissed in the absence of a physical law that prohibits an elementary "action" smaller than Planck's. It is further noted that no purely dark matter measurement of Planck's constant exists. Finally, the possibility of a non-Planckian cold dark matter particle is explored, and found to be consistent with recent astronomical observations.

The search for dark matter (DM) remains one of the most vexing of the unresolved problems of contemporary physics. While the existence of DM is no longer in dispute, its composition is a matter of lively debate. A variety of subatomic particles with exotic properties have been proposed as possible candidates. However, as is well known by now, after more than three decades of experimentation, and considerable expenditure, none have yet been detected. If the past is any guide, such negative results often force us to radically reexamine some of the basic tenets underlying physical concepts. It is the purpose of this paper to propose a plausible, experimentally verifiable, explanation for the persistent failure of *particle* DM experiments to yield positive results.

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 it applies to luminous matter (LM), which is particularly troubling since it necessarily brings into question the applicability of Planck's constant as a viable "action" in this *non-luminous* domain. 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.

While it is true that very little is known about DM, some progress has been made on the astronomical front. 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 [1], 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 [2–3], which is clearly significant since it essentially rules out the idea that particles of DM can somehow interact and collide with each other. Taken together these astronomical findings are suggestive of a non-relativistic, non-interacting, particle whose coherent mode of behavior is a characteristic of *classical light*. Clearly, for such a particle, the condition of quantization can only become a physical possibility if its "action" is considerably *smaller* than Planck's.

Upon reflection one comes to the realization that such a possibility can be accommodated in the context of the framework of quantum mechanics, whose formalism allows for *two* immutable "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). While this *non-Planckian* constant appears to have no discernible role in our luminous world, it is, nevertheless, clearly of interest since it may be sufficiently *smaller* than Planck's constant to account for DM's astronomical behavior; a possibility that cannot be convincingly dismissed in the absence of a physical law that prohibits an *elementary* "action" smaller than Planck's.

Whether or not we know DM's nature, the undisputed fact remains that *all* elementary particles exhibit wavelike properties. Hence, if DM's behavior is orchestrated by this *non-Planckian* "action" it should be possible to describe such particle waves quantum mechanically. In order to facilitate matters we shall assume 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

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

and the de Broglie relation for the momentum

$$p = \frac{j}{\lambda} = mv = \frac{m_0 v}{\sqrt{1 - v^2/c^2}}, \qquad (2)$$

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

$$E = \frac{1}{2m} p^2 \qquad (3)$$

we can replace E and p with the differential operators

$$E = i \frac{j}{2\pi} \frac{\partial}{\partial t} \qquad (4)$$

and

$$p = -i \frac{j}{2\pi} \frac{\partial}{\partial x} \qquad (5)$$

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

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

which is Schrödinger's general wave equation for a non-relativistic *free* particle. Its solution describes a *non-Planckian* particle that is the quantum mechanical analog of a non-interacting *classical* particle that is moving in the x direction with constant velocity; a result that closely mirrors DM's elusive behavior, and can be simply explained in the context of this generalization. That is, the *classical* concept of two particles exerting a force on each other corresponds to the quantum mechanical concept that the de Broglie wave of one particle influences the de Broglie wave of another particle. However, this is only possible if the de Broglie wave propagates *non-linearly*, in sharp contrast with Schrödinger's general wave equation for which the propagation of waves is described by a *linear* differential equation. Hence the presence of one wave *does not* affect the behavior of another wave, allowing them to pass right through each other without colliding, which is consistent with the results of the aforementioned astronomical observations [2–3].

If it exists, this non-Planckian particle would easily have eluded detection because of the diminutive magnitude of the non-Planckian "action". More succinctly, the closer one comes to the *classical* limit the *less* pronounced are the quantum effects. As a result, its behavior is expected to be *more* wave-like than particlelike, which is consistent with the observed coherent mode of behavior of large aggregates of DM [2–3]. Clearly, the detection of this non-Planckian particle in a terrestrial laboratory setting will, almost certainly, require the use of a wholly different set of experimental tools than those presently employed in conventional DM experiments, which are, after all, specifically designed to detect *particle* interactions.

While, as has been shown, DM's behavior in the astronomical arena can be satisfactorily accounted for quantum mechanically, in terms of this non-Planckian "action", the detailed implications remain to be worked out. Nevertheless,

the introduction of this *non-Planckian cold DM particle* in the context of quantum mechanics, provides a fundamentally plausible means of explaining the failure of *conventional* experiments to provide conclusive evidence for the *particle* nature of DM. After these many decades of null experimental results, the time has come to acknowledge the possibility that DM's behavior may be orchestrated by a richer variety of fundamentally different mechanisms than previously recognized.

Appendix

I have taken note of the fact that if the reader is to grapple with some of the concepts generated by this paper, it would be advisable to ascribe an appropriate name to this non-Planckian particle. Clearly, the basic aspect that one should be mindful of is this particle's indispensable role in enabling the *warping* of spacetime sufficiently enough to cradle whole galaxies. Hence, I believe *"warpton"* would be the name of choice.

It is hoped that the experimental community can be sufficiently motivated to make a determined search for this provocative particle.

References

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