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An elementary approach to quantum gravity based on a flux model of a physical vacuum

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We begin with the hypothesis that empty space is permeated by an omnidirectional flux of particles moving at very high speed that do not interact with eachother appreciably, and interact with ordinary matter primarily by exchange of momentum in collisions. In the absence of ordinary matter, these dark matter particles could then be expected to travel undeflected through empty space; while if ordinary matter is present such a flux of dark matter particles could be expected to impact upon it, causing recurrent recoils.

The incidence of interactions of the flux with an individual particle of ordinary matter can be evaluated in terms of an interaction cross section which is a measure of the probability of occurrence of a collision or interaction. The cross section is the reaction rate per unit incident flux of dark matter particles per target particle of ordinary matter. Accordingly, the number of interactions per second of the flux with an individual object of ordinary matter will be given by:

$$n = fs \tag{1}$$

where f is the flux (in dark matter particles per square centimeter per second) and s is the interaction cross section (in square centimeters). The quantity s is a characteristic property of the particle or object of ordinary matter subjected to bombardment by the flux of dark matter particles.

In quantum theory, every particle of ordinary matter is characterized by a specific associated frequency evaluated by the de Broglie relation as [1,2]:

$$n_q = mc^2/h \tag{2}$$

Here, h is Planck's constant, m is the mass of the particle, and c is the velocity of light.

If impacts of dark matter flux particles on ordinary matter were involved in the quantum behavior of ordinary matter, it would appear that these two frequencies might be simply related. If these two frequencies are taken to be equal, combining the preceding equations yields:

$$m = (sfh)/c^2 \tag{3}$$

Thus, this approach leads to the concept that the cross section for interaction of an individual particle of ordinary matter with a flux of dark matter particles should be proportional to the mass of the particle of ordinary matter.

If only a single object of ordinary matter is present in an isotropic omnidirectional flux of high-speed particles of dark matter, it will on average be impacted uniformly from all directions. However, if circumstances are such as to cause a directional imbalance of dark matter flux on a particle or object of ordinary matter, the transfer of momentum during individual impacts would be expected to lead to an excess net rate of transfer of momentum to the impacted object along the direction of the flux imbalance, and hence the appearance of a net force on the object.

Let us assume that each incident dark matter flux particle interacting with the ordinary matter object transfers a momentum of average magnitude p_i. (In the case of scattering, the recoil direction may differ from the original direction of the incident dark matter particle, so a geometrical correction may need to be considered and incorporated into the average magnitude of momentum transfer.) The net force on an object produced by a net momentum transfer per unit time will be given by the product of

the average momentum transfer per interaction with the net imbalance in the number of interactions per unit time effectively transferring excess momentum (written as the product of a fractional excess or deficit f of flux imbalance with the total number of interactions per unit time):

$$F = p_i f s f \qquad (4)$$

If more than one object of ordinary matter is present, these objects may shield eachother from the dark matter flux by their individual interactions with this flux. Any shadowing effect of ordinary massive objects on eachother would accordingly lead to a force between massive objects mediated by directional flux differences.

While the impacts on a single isolated object of ordinary matter will come from all directions, the fraction f of the impacts coming from a particular solid angle W in steradians would be given by:

$$f = W/4p \qquad (5)$$

We will associate with two ordinary matter objects a and b the interaction cross sections s_a and s_b respectively. A cross section s has the dimensions of area, and at a distance r will determine an effective solid angle:

$$W = s/r^2 \qquad (6)$$

Then, if two objects are separated by the distance r, the effective solid angle of flux eliminated by the presence of one object from the flux otherwise impinging from all other directions surrounding the other object can be determined from the preceding expression; accordingly, we can evaluate the fraction f as:

$$f = s/(4pr^2) \qquad (7)$$

Hence, using the preceding equations, we find for the force on either object due to shielding effects of the other object:

$$F_s = p_i f s_a s_b /(4pr^2) \qquad (8)$$

It can be seen that the force between two objects originating from their mutual shadowing of the dark matter flux will be an attractive force and will vary inversely with the square of the distance between the two objects, and will depend directly on the product of the interaction cross-sections of the objects. Because of the symmetry of the expression with respect to the two objects, equal and opposite forces will be exerted on the two objects by the flux. Equation (8) can be compared with the familiar expression for the gravitational force between two objects:

$$F_{grav} = Gm_a m_b /r^2 \qquad (9)$$

In order for the flux mediated force to correspond exactly to gravitational force imposes the requirement that:

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$$p_i f s_a s_b = 4pGm_a m_b \qquad (10)$$

In this comparison, we see again that the masses of objects of ordinary matter must be proportional to their interaction cross sections with the dark matter flux.

So far, we have not provided sufficient characterization of the distribution and motion of the dark matter itself. We can evaluate the number density of dark matter particles by taking the value of the flux, f, measured in particles per square centimeter per second, and dividing it by the average speed

of these flux particles, v_{dm}, which would be measured in cm/sec. The number density, in particles per cubic centimeter, would then be:

$$N = f/v_{dm} \tag{11}$$

The cube root of the inverse of this will give us an average distance between the dark matter flux particles. If we make the assumption that the velocity of the dark matter flux particles corresponds to the velocity of light, then we find for the characteristic distance separating dark matter particles in space:

$$d = (c/f)^{1/3} \tag{12}$$

Let us explore the implications of an explicit requirement on the dark matter flux itself that the product of the average momentum p_i imparted by a dark matter particle and the average distance between dark matter particles be equal to Planck's constant. Then:

$$p_i d = h \tag{13}$$

In essence, in this approach we are associating a specific average amount of angular momentum given in magnitude by Planck's constant with a local attribute of the dark matter flux. Thus Planck's constant appears as a characteristic of the medium of dark matter that interacts with all ordinary matter.

We can use the preceding two equations to obtain another relationship between the average momentum transfer and the flux:

$$h = p_i (c/f)^{1/3} \tag{14}$$

The major equations that we have developed, Eqns. (3), (10), and (14), are sufficient to determine the new parameters in terms of known physical constants, and vice versa. Thus, for example, we find:

$$d = [4\pi Gh/c^3]^{1/2} \tag{15}$$

This distance may be compared with the Planck length, which is given in terms of fundamental constants by $d_p = [Gh/2\pi c^3]^{1/2}$.

It has already been shown in earlier studies that most features of quantum mechanics are derivable from stochastic mechanics of Brownian motion of matter particles affected by a subquantal medium [3,4,5,6]. The stochastic impacts of a dark matter flux as considered here, with minor numerical adjustments in the characterization of our original parameters, appear to be adequate to provide for an appropriate diffusion constant and thus to reproduce most aspects of quantum mechanics.

While the model discussed here was developed quite independently, earlier studies in this general direction conducted by other authors have appeared in the literature [7, 8].

The fact that a flux model of the physical vacuum with stochastic impacts on matter can create forces equivalent to classical gravitational forces and can also provide a basis for the quantum mechanical behavior of matter, and thus address features of quantum gravity as well as characteristics of the vacuum, presents us with an approach that has the advantages of simplicity and physical clarity and that also delivers striking and satisfying results. The many interesting implications of the present model cannot be examined in this brief essay but are discussed in greater detail in a separate longer paper [9].

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