Können Kernkräfte durch quantenhydrodynamische
Photondruckdifferenzen beschrieben werden? –
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is slightly corrected and translated by Halil Güveniş:

Can nuclear forces be described by quantum hydrodynamic photon pressure differences?

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Abstract

The photon pressure difference between two nuclear shells is derived with the help of the vacuum solution of the fundamental equations of relativistic quantum hydrodynamics. It is thereby shown that, in principle, it is possible to describe nuclear forces by photon pressure differences in the inner and outer space of elementary particles and atomic nuclei. For an exact calculation of the photon pressure difference, it is, however, necessary to make fundamental corrections to our nuclear shell model.

Key words: Fundamental equations of relativistic quantum hydrodynamics, photon pressure difference, nuclear forces, binding states between two nuclear shells.

1 Introduction

The fundamental equations of relativistic quantum hydrodynamics are given [1] by the equation of continuity

$$\partial(\rho(E - e\Phi)/c^2)/\partial t + \boldsymbol{\nabla}\cdot(\rho(\boldsymbol{p} - (e/c)\,\boldsymbol{A})) = 0, \qquad (1)$$

and by the equation of motion

$$(E - e\Phi)^2 = m^2 c^4 + (\boldsymbol{p} - (e/c)\,\boldsymbol{A})^2 c^2 - e\hbar c\,\boldsymbol{\sigma}\cdot\boldsymbol{B} - \hbar^2 c^2 \rho^{-1/2}\Box\rho^{1/2}. \qquad (2)$$

If mass m, electric charge e and the external electromagnetic fields Φ and $\boldsymbol{A}$ are given, the space-time evolution of the probability density ρ and the momentum field $\boldsymbol{p}$ can be calculated with the help of the fundamental equations (1) and (2). The term $-\hbar^2 c^2 \rho^{-1/2}\Box\rho^{1/2}$ in Eq. (2) represents the photon pressure potential to which the quantum hydrodynamic systems are inevitably subjected due to permanent photon absorption and emission [2]. Giving the system variables m, e, Φ and $\boldsymbol{A}$ one obtains from quantum hydrodynamic fundamental equations in the inner and outer space of elementary particles and atomic nuclei characteristic photon pressure differences which lead to a force acting comparable to the Casimir effect [3].

In the present paper we want to pursue the question of whether it is possible to describe nuclear forces by quantum hydrodynamic photon pressure differences. To give an answer to this question, we search at chapter 2 the vacuum solution of the quantum hydrodynamic fundamental equations (1) and (2) and drive the photon pressure between two nuclear shells. At chapter 3, we make some conclusions concerning our considerations about photon pressure.

2 Photon pressure between two nuclear shells

In order to clarify the question whether nuclear forces can be described by quantum hydrodynamic photon pressure differences, we consider a simple quantum hydrodynamic system: photons which are enclosed between two nuclear shells in a one-dimensional box by infinite potential walls at $x = 0$ and $x = R$. In this case, all system variables must be set to zero, and the vacuum solution for the equation of motion (2) is to search. Since the continuity equation (1) yields $\partial(\rho E / c^2)/\partial t = 0,$ it follows from the equation of motion (2) in the one-dimensional case

$$E^2 = -\hbar^2 c^2 \rho^{-1/2} \Box \rho^{1/2}, \;\; \rho^{1/2} = \alpha \, exp(ikx) + \beta \, exp(-ikx), \;\; E^2 = \hbar^2 c^2 k^2, \qquad (3)$$

where α and β are two real constants and k is the wave number of the in- or out-going photon wave. If the boundary conditions $\rho(0) = 0, \rho(R) = 0$ are taken into account and the probability density between two nuclear shells is normalized in the area $0 < x < R$, it follows from (3)

$$\rho_n = (2/R) \sin^2(n\pi x/R), \;\; E_n = \hbar c k_n = \hbar c n \pi /R , \qquad n = 1,2,3,... \qquad (4)$$

Therefore, the photon pressure in the inner space of nuclear shells on the surface L^2 perpendicular to the x-direction is

$$P = (-dE_n / dR) / L^2 = \hbar c n \pi /(R^2 L^2). \qquad (5)$$

If we try to determine the photon pressure in the outer space of nuclear shells we must distinguish two areas:

1. The area $R < x < 2R$

In this area only the boundary condition $\rho_1(R) = 0$ is given, and because of the absence of a second boundary condition, the probability density cannot be normalized in the area $R < x < 2R$. From (3) it follows

$$\rho_1 = (2\alpha)^2 sin^2(k(x\text{-}R)),\ E_1 = \hbar ck \int_R^{2R} \rho_1\, dx = \hbar c\alpha^2(2kR - sin(2kR)) \approx (4/3)\hbar c\alpha^2(kR)^3. \quad (6)$$

The photon pressure on the surface L^2 perpendicular to the x-direction is

$$P_1 = (-dE_1 / dR) / L^2 = -2k\hbar c\alpha^2(1 - cos(2kR))/L^2 \approx -4\hbar c\alpha^2 k^3 R^2/L^2. \quad (7)$$

2. The area $-R < x < 0$

In this area only the boundary condition $\rho_2(0) = 0$ is given, and because of the absence of a second boundary condition, the probability density cannot be normalized in the area $-R < x < 0$. From (3) it follows

$$\rho_2 = (2\alpha)^2 sin^2(kx),\ E_2 = \hbar ck \int_{-R}^{0} \rho_2\, dx = \hbar c\alpha^2(2kR - sin(2kR)) \approx (4/3)\hbar c\alpha^2(kR)^3. \quad (8)$$

The photon pressure on the surface L^2 perpendicular to the x-direction is

$$P_2 = (-dE_2 / dR) / L^2 = -2k\hbar c\alpha^2(1 - cos(2kR))/L^2 \approx -4\hbar c\alpha^2 k^3 R^2/L^2. \quad (9)$$

If we now determine the photon pressure difference in the inner and outer space of nuclear shells, we obtain from (5), (7) and (9)

$$\Delta P = P + P_1 + P_2 \approx \hbar cn\pi /(R^2L^2) - 8\hbar c\alpha^2 k^3 R^2/L^2. \quad (10)$$

Therefore, nuclear shells are pushed outwards by the pressure $\hbar cn\pi /(R^2L^2)$ in the inner space of nuclei and inwards by the pressure $-8\hbar c\alpha^2 k^3 R^2/L^2$ in the outer space of nuclei. All in all, we obtain stable binding states for nuclear shells in the effective potential

$$\Delta E = E_n + E_1 + E_2 \approx \hbar c n\pi/R + (8/3)\hbar c\alpha^2(kR)^3, \tag{11}$$

where the deepest point of the potential hole is given by

$$R_0^{\,4} = n\pi/(8\alpha^2 k^3). \tag{12}$$

3 Conclusions

In the case of two nuclear shells, it is therefore, in principle, possible to describe nuclear forces by photon pressure differences in the inner and outer space of atomic nuclei. The effective potential (11) allows that stable binding states are given between nuclear shells. If we suppose, in addition to the photon pressure, a repulsive Coulomb potential between nuclear shells, the stable binding states can be still maintained as long as the repulsive Coulomb force does not dominate the attractive photon pressure difference. Nuclei are only unstable if the Coulomb force reaches a critical level at which the outer nuclear shells can no longer be held together by the attractive photon pressure difference.

Although our nuclear shell model allows a first insight into the mode of acting of nuclear forces, it may not be made the basis for an exact calculation of the photon pressure difference. For that, there are several reasons:

1. We have calculated the binding states of nuclear shells one-dimensional. Actually, nuclear shells are three-dimensional structures with distinct excited states for energy, spin and angular momentum. Therefore, in the fundamental equations (1) and (2) the three-dimensional quantities spin and angular momentum must be allowed so that an exact calculation of the photon pressure difference can be carried out.

2. We have assumed that nuclear shells can not be penetrated by photons, i.e. there are infinite potential walls at $x = 0$ and $x = R$. This assumption is not correct.

Nuclear shells can be very well penetrated by photons; they represent for photons a finite potential barrier of height $m c^2$, where m symbolizes the mass of nuclear shells. Therefore, it is not allowed to carry out an exact calculation of the photon pressure difference under the assumption that two nuclear shells are a one-dimensional box with infinite potential walls; they are, rather, a three-dimensional potential barrier – as in the *tunnel effect*.

3. Calculating the photon pressure difference between two nuclear shells we have assumed that the shells are given by the quadratic surface L^2 perpendicular to the x-direction. This assumption is only approximately correct; the real surface shape of nuclear shells can only be determined if previously through an independent photon pressure consideration the geometry of the shells has been calculated with the help of the fundamental equations (1) and (2), i.e., the exact calculation of the photon pressure difference between two nuclear shells is only possible if previously the photon pressure difference and the geometry of nuclear shells themselves have been determined. – Continuing this train of thought, we arrive at the conclusion that any exact calculation of the photon pressure difference must begin with that elementary particle which has previously no need of determination of the photon pressure difference and geometry of its constituents.

References

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