AN EXPLANATION OF 3D STRUCTURE OF NEUTRONS AND PROTONS USING STRING THEORY

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1. INTRODUCTION

In string theory, all the elementary particles are different modes of the vibrating strings of Planck size. We have closed strings for fermions and open strings for bosons in superstring theory in 10 dimensions [1,2]. The strings can expand and contract minimum upto Planck length since the length smaller than Planck length is meaningless [1-3]. Within the neutrons and protons, the three quarks are different vibrational modes of three strings of Planck size in which spin of one string interacts with another string. In the strong interaction between three quarks, there is exchange of gluon particles which is represented by open string in string theory. The quarks in string theory can be understood using brane structures or space-times [3]. The colour charges carried out by the gluons are at the two ends of the open string attached with a quark and an antiquark. Using infinite amount of energy, one end of the string can ripped off the brane extending out into the fifth dimension of the gravitational theory. We will get just a quark or an antiquark after removal of one of the colour charges from the brane. The interaction between two such quarks can be studied in the presence of gluons. The strings will always intend to lie in the curved space-time according to gravitational description in order to minimize their energy. It is possible to join the two strings and form a loop in the gravitational space by making the space energetically favourable. The quarks can be considered to be tied up by string which is in higher-dimensional space than the QCD quark theory and energy is needed to separate the quarks since the string has to be stretched [4]. At a critical temperature, the protons and neutrons are ceased to exist which can be replaced by free quarks and gluons. The QCD phase transitions corresponds to the transition in the shape of the gravitational space-time can be understood in terms of QCD-gravity duality [5,6]. Some papers in which the 3D structure of the neutrons and protons has been studied are as given in ref. [7-10].

2. 3D STRUCTURE OF NEUTRONS AND PROTONS USING STRING THEORY

The total energy of neutrons and protons can be given as:

$$E_T = \widehat{m}_p + \int d^3x \left|\vec{E}\right|^2 + E_S \sim \widehat{m}_p + 4\pi \int \frac{r^2 dr\left(\frac{4e^2}{9}+\frac{4e^2}{9}+\frac{e^2}{9}\right)}{r^4} + \frac{3}{4}J\hbar^2\left(-\frac{1}{2}J\hbar^2\right) \quad (1)$$

$$E_T = \widehat{m}_p + \frac{Ce^2}{\Lambda} + \frac{3}{4}J\hbar^2\left(-\frac{1}{2}J\hbar^2\right) \quad (2)$$

$$E_T = \widehat{m}_n + \int d^3x \left|\vec{E}\right|^2 + E_S \sim \widehat{m}_n + 4\pi \int \frac{r^2 dr\left(\frac{4e^2}{9}+\frac{e^2}{9}+\frac{e^2}{9}\right)}{r^4} + \frac{3}{4}J\hbar^2\left(-\frac{1}{2}J\hbar^2\right) \quad (3)$$

$$E_T = \widehat{m}_n + \frac{2Ce^2}{3\Lambda} + \frac{3}{4}J\hbar^2\left(-\frac{1}{2}J\hbar^2\right) \quad (4)$$

where Λ is cut off energy which is Planck energy. Equations (1) and (2) describe total energy of proton while equations (3) and (4) describe total energy of neutron. $\widehat{m}_p$ and $\widehat{m}_n$ are bare masses of neutron and proton respectively. In equations (1)-(4), E_S is energy due to spin-spin interaction between up and down quarks inside neutrons and protons, J is coupling strength and four states of spin of three quarks can be $\left(+\frac{1}{2}+\frac{1}{2}+\frac{1}{2}\right), \left(+\frac{1}{2}+\frac{1}{2}-\frac{1}{2}\right), \left(+\frac{1}{2}-\frac{1}{2}-\frac{1}{2}\right)$ & $\left(-\frac{1}{2}-\frac{1}{2}-\frac{1}{2}\right)$.

The mass of string in string theory is defined in terms of string length as [11]

$$M_{string} = \frac{1}{l_{string}}, \quad (5)$$

where $M_{string} \sim 10^4 - 10^6 GeV$. The Regge Slope is defined as

$$\alpha' = l_{string}^2. \quad (6)$$

The string tension is defined as

$$T = \frac{potential\ energy}{spatial\ length} = \frac{1}{2\pi\alpha'}. \quad (7)$$

The mass spectrum for quantized closed bosonic string can be given by [12]

$$\mathrm{M}^2_{\mathrm{closed}} = \frac{2}{\alpha'}(\mathrm{N} + \breve{\mathrm{N}} - 2) \quad (8)$$

where N denote left-moving level, $\breve{\mathrm{N}}$ denote right-moving level. Here we take $\mathrm{N} = \breve{\mathrm{N}} = 2$ in 10 dimensions. The mass spectrum corresponding to quantized Neumann strings is given by

$$\mathrm{M}^2_{\mathrm{open,N}} = \frac{1}{\alpha'}(\mathrm{N} - 1). \quad (9)$$

The mass spectrum corresponding to Dirichlet strings is given by

$$\mathrm{M}^2_{\mathrm{open,D}} = \left(\frac{l}{2\pi\alpha'}\right)^2 + \frac{1}{\alpha'}(\mathrm{N} - 1) \quad (10)$$

where $\frac{l}{2\pi\alpha'}$ gives the energy of a string which is stretched between two D-branes. The tension in Dp brane is defined as [11]

$$T_p \sim \frac{1}{l_s^{p+1}} \frac{1}{g_s}. \quad (11)$$

The coupling constant g_s is given by expectation value of the dilaton field [11,12]

$$g_s = \langle e^{\phi} \rangle. \quad (12)$$

3. CONCLUSIONS

The total energy of protons and neutrons as well as mass spectrum corresponding to Neumann and Dirichlet strings can help us in determining the 3D structure of neutrons and protons. Since total energy is constant and there is stretching of the strings during the transition in the shape of the gravitational space-time and strong nuclear force within protons and neutrons in QCD-gravity duality. The size of the interacting strings in QCD-gravity duality can expand upto the size of the protons and neutrons in Dp brane in order to acquire the tension in the string as described by equation (11). Finally, we have come to the conclusion that String of Planck length size can be expanded upto size of neutrons and protons in higher dimensional space i.e. for D=5-10. During interaction between three closed strings Thus the 3D structure of neutrons and protons can be determined using QCD-gravity duality in string theory.

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