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Quarks as Black holes

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ABSTRACT

The concept of the mass in (QCD) was discussed. The Schwarzschild radii and the Compton wave length of different types of quarks have been found. The comparison between the Schwarzschild radii with the proton and neutron radii shows that the quarks behave like a point particle inside the nucleon. It is found that the Compton wave lengths of the up and down quarks are of the order of the nucleon radii.

Keywords: Quark, the Schwarzschild radius, black holes.

الكواركات بوصفها ثقوبا سوداء

الملخص

تمت مناقشة مفهوم الكتلة في الكروموداينمك الكمي. و تم ايجاد نصف قطر شوارزجايلد وطول موجة كومبتون لمختلف انواع الكواركات. واظهرت مقارنة انصاف اقطار شوارزجايلد مع انصاف اقطار البروتون والنيترون ان الكواركات تتصرف بوصفها جسيمات نقطية داخل المكونات النووية. ووجد ان اطوال موجة كومبتون للكواركات من نوع اعلى واسفل بحدود أنصاف أقطار البروتون والنيترون.

الكلمات الدالة: كوارك، نصف قطر شوارزجايلد، الثقوب السوداء.

INTRODUCTION

From experiments, physicists learned that protons, neutrons, and other strongly interacting particles are made from quarks, antiquarks, and gluons. But we never see an isolated quark because; one never has enough energy to separate the quark and antiquark a macroscopic distance. The theoretical framework for analyzing quark confinement is the *SU* (3) gauge theory of the strong interactions, known as Quantum Chromo dynamics QCD (Witten, 2001).

On the other side, classically, a black hole absorbs everything that comes too close and does not emit anything, so we never see it. The theoretical framework for analyzing the black hole is the theory of General Relativity which describes the gravity.

Quantum mechanically, no black hole can exist, because if the Hamiltonian operator H has a nonzero matrix element $< f\,|H\,|i>$ for absorption, then, as H is hermitian, there is also a nonzero matrix element $<i|\,H\,|f>$ for emission.

In spite of the difference between quarks and black holes, many authors (Kov′acs *et al*., 2009) study the relation between them according to that; they are both part of nature, and so a theory of quantum gravity is needed to be described, but this is not simple because the mathematics of General Relativity is nonlinear and so does not satisfy the requirements of quantum theory.

But (Hawking, 1975) showed that quantum mechanically a black hole does emit thermal radiation. And, in cosmology, (Thakur, 2008) shows that a black hole cannot collapse to a singularity, instead it may end up as a quark star. (Kov′acs *et al.,* 2009) investigate the possibility that stellar mass black holes, with masses in the range of $3.8M_{sun}$ and $6M_{sun}$, respectively, could be in fact quark stars. (Siopsis, 2009) discuss the possibility that the quark-gluon plasma at strong coupling admits a description in terms of a black hole in asymptotically anti-de Sitter space.

In this work, we try to answer the question, is the quark a black hole, by using the condition for the black hole in the Schwarzschild solution to Einstein's field equations in the theory of general relativity, as the massive body which satisfy the relation (Narlikar, 1979):

$$\frac{2GM}{Rc^2} = 1 \qquad \text{……………………..} \quad (1)$$

Where, G is the gravitational constant, M is the mass of the body, R is the Schwarzschild radius, and c is the speed of the light at vacuum. Because of the difficulty which arises from the ambiguity in the notion of the mass of the quark in (QCD), we firstly discuss the quark mass before answering our question, then substituting the quarks masses for all the known quarks in equation (1) to find the Schwarzschild radius that make every quark a black hole. And calculating the Compton wave length for every quark to compare them with the radius of the nucleon, to see if they are compatible with them.

Quark mass

Unlike other fundamental interactions in nature such as electromagnetism, the strong interaction described by (QCD) is difficult to measure directly due to a property of this interaction known as quark confinement. The inability to measure the masses of these particles in an isolated system has made direct experimental inquiries of QCD difficult (Angerami and Cole, 2006).

Although one speaks of quark mass in the same way as the mass of any other particle, the notion of mass for quarks is complicated by the fact that quarks cannot be found free in nature, and are confined inside hadrons. So, the notion of quark masses is a theoretical construct which must be determined indirectly through their influence on hadronic properties (Göckeler *et al.*, 2006).

So, quantum field theory must be used to discuss quark masses at a fundamental level. The particle aspect of the quark is point-like even at scales thousands of times smaller than the proton size. The wave aspect of the quark extends over the size of the atomic nucleus. Light quark masses have not yet been well determined. This appears to be a consequence of quark confinement as well as the fact that the light quark masses are significantly lighter than the typical hadronic scale and as such their impact on most of the hadron masses or other properties is very small (Guo *et al.*, 2010).

Heavy quark masses, charm, bottom and top quarks, are obtained from the masses of hadrons containing a single heavy quark and one or two light antiquarks light quarks and from the analysis of quarkonia. Lattice QCD computations using the heavy quark effective theory (HQET) or non-relativistic quantum chromo dynamics (NRQCD) are currently used to determine these quark masses. The top quark is sufficiently heavy that perturbative QCD can be used to determine its mass.

Schwarz child's radius of the quark

The Schwarzschild's solution of Einstein's gravitational field equations for spherical symmetric mass tell us that, a massive object is a black hole if it satisfies equation (1), which can be written as

$\mathbf{R= 1.48 \times 10^{-27}\ m}$ ……………..................... (2)

M is the mass in kg

or as

$\mathbf{R_q= 2.6344x10^{-57}\ m}$ ………………………. (3),

M is the mass in MeV unit.

So, knowing the mass of the quark gives us the possibility to find the Schwarzschild radius that makes the quark a black hole. But as it was discussed previously the quark mass is not well defined, so, we take several estimated masses for each quark, Tables (1, 2),

Table 1: Light quark mass values (in unit of MeV) (Koide, 1994)

Source	$\mathbf{m_u}$	$\mathbf{m_d}$	$\mathbf{m_s}$
Okubo (1969)	300	300	500
Veltman (1980)	250	250	300
Grasser and Leutwyler (1982)	5.1 ± 1.5	8.9 ± 2.6	175 ± 55
Domingues and Rafael (1987)	5.6 ± 1.1	9.9 ± 1.1	199 ± 33
Narison (1989)	5.2 ± 0.5	9.2 ± 0.5	159.5 ± 8.8
El Naschie (2002)	5.236	8.47	179.4
Eidelman *et al*. (2004)	1.5 – 4.0	4-8	80-130
Allison (2005)	1 − 5	5 − 9	80 − 130

Table 2: Heavy quark mass values (in unit of MeV) (Koide, 1994)

Source	m_c	m_b	m_t
Okubo (1969)	1700	5000	180 00
Veltman (1980)	1500	5000	20 000
Gasser and Leutwyler (1982)	1270. ±0.05	4250 ±0.10	
El Naschie (2002)	1270.820393	4236.067977	42360.67977
Eidelman *et al*. (2004)	1150 – 1350	4100 – 4400	174300
Allison (2005)	1150 – 1350	4100 – 4400	175000

And we find Schwarz child's radii Tables (3, 4) that make the corresponding quarks a black hole.

Table 3: Radius for light quarks (in unit of meters)

Source	R_u	R_d	R_s
Okubo (1969)	7.9476 x10^{-55}	7.947x10^{-55}	1.492 x10^{-54}
Veltman (1980)	6.6156 x10^{-55}	6.6156x10^{-55}	7.9976 x10^{-55}
Grasser and Leutwyler (1982)	1.3510 x10^{-57}	2.357 x10^{-56}	4.635 x10^{-55}
Domingues and Rafael (1987)	1.4835 x10^{-56}	2.622 x10^{-56}	5.2717 x10^{-55}
Narison (1989)	1.3775 x10^{-56}	2.436 x10^{-56}	4.225 x10^{-55}
El Naschie (2002)	1.387x10^{-56}	2.2436 x10^{-56}	4.7536 x10^{-55}
Eidelman *et al*. (2004)	3.9738x10^{-57} - 1.05968x10^{-56}	1.0596 x10^{-56}- 2.1193 x10^{-56}	2.11936 x10^{-55}-3.4336 x10^{-55}
Allison (2005)	2.6493x10^{-57} - 1.3246x10^{-56}	1.324 x10^{-56}- 2.3842 x10^{-56}	2.11936 x10^{-55}-3.433 x10^{-55}

Table 4: Radius for heavy quarks (in unit of meters)

Source	R_c	R_b	R_t
Okubo (1969)	4.5036 x10^{-54}	1.3246 x10^{-53}	4.7685 x10^{-52}
Veltman (1980)	3.9738 x10^{-54}	1.3246 x10^{-53}	5.2984 x10^{-53}
Gasser and Leutwyler (1982)	3.3644 x10^{-54}	1.1258 x10^{-53}	
El Naschie (2002)	3.3665 x10^{-54}	1.122 x10^{-53}	1.222 x10^{-52}
Eidelman *et al*. (2004)	3.046 x10^{-54} 3.576 x10^{-54}	1.08617 x10^{-53}-1.1656 x10^{-53}	4.617 x10^{-52}
Allison (2005)	3.046 x10^{-54}- 3.576 x10^{-54}	1.08617 x10^{-53}-1.1656 x10^{-53}	4.636 x10^{-52}

Compton wave length of the quark

As a consequence of the duality behavior, any massive particles must have a Compton wave lengths associated with their masses which can be calculated using the known formula:

$$\lambda = \frac{h}{Mc} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Or, by using ($h=6.625\times10^{-34}$J.s, $c=3\times10^{8}$ ms^{-1}, MeV$=1.6\times10^{-13}$ J, and $E=Mc^{2}$) we can write

$$\boldsymbol{\lambda = 2.20980 \times 10^{-42} M^{-1}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

With (M in kg)

Accordingly we can find the wave lengths associated with every quark, Tables (5, 6). As the nucleons compose of three quarks ($1q_d + 2q_u$) or ($1q_u+2q_d$) one can compare the wave lengths of these quarks with the radius of the nucleons.

Table 5: wave length λ for light quarks (in unit of meters)

Source	λ_u	λ_d	λ_s
Okubo (1969)	4.1150×10^{-15}	4.1150×10^{-15}	2.469×10^{-15}
Veltman (1980)	4.943×10^{-15}	4.943×10^{-15}	4.1150×10^{-15}
Grasser and Leutwyler (1982)	2.4206×10^{-13}	1.387×10^{-13}	7.055×10^{-15}
Domingues and Rafael (1987)	2.2045×10^{-13}	1.2470×10^{-13}	6.2038×10^{-15}
Narison (1989)	2.3740×10^{-13}	1.3425×10^{-13}	7.740×10^{-15}
El Naschie (2002)	2.3578×10^{-13}	1.457×10^{-13}	6.8800×10^{-15}
Eidelman *et al*., (2004)	8.230×10^{-13} _ 3.086×10^{-13}	3.086×10^{-13} _ 1.54315×10^{-13}	1.5453×10^{-14} _ 9.525×10^{-15}
Allison (2005)	1.234×10^{-12} _ 2.469×10^{-13}	2.4690×10^{-15} _ 1.3716×10^{-15}	1.5431×10^{-14} _ 9.525×10^{-15}

Table 6: wave length λ for heavy quarks (in unit of meters)

Source	λ_c	λ_b	λ_t
Okubo (1969)	7.2619×10^{-16}	2.469×10^{-16}	6.8584×10^{-18}
Veltman (1980)	8.23016×10^{-16}	2.4690×10^{-16}	6.172×10^{-17}
Gasser and Leutwyler (1982)	9.7206×10^{-16}	2.90495×10^{-16}	
El Naschie (2002)	9.7176×10^{-16}	2.9143×10^{-16}	2.9143×10^{-17}
Eidelman *et al*. (2004)	1.07350×10^{-15} _ 9.144×10^{-16}	3.01103×10^{-16} _ 2.8057×10^{-16}	7.0829×10^{-18}
Allison (2005)	1.07350×10^{-15} _ 9.144×10^{-16}	3.01103×10^{-16} _ 2.8057×10^{-16}	7.0544×10^{-18}

RESULTS AND DISCUSSION

It is clear from Tables (1, 2) that rest mass of the quarks is not well defined and that is because we can not find free quark. Tables (3, 4) show that the Schwarzschild radii of the quarks make them point-like particles and this agree with the particle aspect of the quark (Guo *et al*., 2010). The boundary conditions that governed the existence of the quarks inside the nucleon, that they are free particles surrounded by a very strong potential barrier, make them like particle in a box, the known quantum states, and so they behave as standing waves.

This expected behavior means that they can be in different energy states and that is why we take different masses to them. And it is shown from the first two rows of Table (5) that the nucleon radius (R_n=5.751 ± 0.175 (exp) ± 0.026 fm, R_n-R_p=0.302 ± 0.175fm) where R_p is the point proton radius. (Horowitz *et al*., 2012) is comparable with the Compton wave length of the (up) and (down) quarks.

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