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# Bohm Confirmed by NonRelativistic Quark Model

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## Abstract

The effectiveness of the NonRelativistic Quark Model of hadrons can be explained by Bohm's quantum theory applied to a fermion confined in a box, in which the fermion is at rest because its kinetic energy is transformed into PSI-field potential energy. Since that aspect of Bohm's quantum theory is not a property of most other formulations of quantum theory, the effectiveness of the NonRelativistic Quark Model confirms Bohm's quantum theory as opposed to those others.

# 1 Bohm and NonRelativistic Quark Model

The effectiveness of the NonRelativistic Quark Model of hadrons can be explained by Bohm's quantum theory applied to a fermion confined in a box, in which the fermion is at rest because its kinetic energy is transformed into potential energy of interaction with the  $\Psi$ -field. Since that aspect of Bohm's quantum theory is not a property of most other formulations of quantum theory, the effectiveness of the NonRelativistic Quark Model confirms Bohm's quantum theory as opposed to those others.

Bohm's Hidden Variable papers I and II, were published in the Physical Review in 1952 [1], well before QCD was known.

Although Bohm's theory does not explain why quarks are confined by QCD inside hadrons, if you assume that quark confinement by QCD acts to contain each valence quark fermion within the impenetrable and perfectly reflecting boundary of the hadron, then Bohm's Theory explains why the NonRelativistic Quark Model of light-quark hadrons works so well.

Consider paper II, section 5, which is reprinted at page 387 of [3]:

"A more striking illustration ... is afforded by the problem of a "free" particle contained between two impenetrable and perfectly reflecting walls, separated by a distance L. For this case, the spatial part of the  $\Psi$ -field is

$$\Psi = \sin(2\pi nx/L)$$

where n is an integer and the energy of the electron is

$$E = (1/2m)(nh/L)^2$$

Because the  $\Psi$ -field is real, we deduce that the particle is at rest.

"Now, at first sight, it may seem puzzling that a particle having a high energy should be at rest in the empty space between two walls. Let us recall, however, that the space is not really empty, but contains an objectively real  $\Psi$ -field that can act on the particle. Such an action is analogous to (but of course not identical with) the action of an electromagnetic field, which could create non-uniform motion of the particle in this apparently

”empty” enclosure. We observe that in our problem, the  $\Psi$ -field is able to bring the particle to rest and to transform the entire kinetic energy into potential energy of interaction with the  $\Psi$ -field. To prove this, we evaluate the ”quantum-mechanical potential” for this  $\Psi$ -field

$$U = \frac{-h^2 \nabla^2 R}{2m R} = \frac{-h^2 \nabla^2 \Psi}{2m \Psi} = \frac{1}{2m} \frac{nh^2}{L}$$

and note that it is precisely equal to the total energy,  $E$ .”

If you apply the Bohm result for an electron confined between two walls to the QCD picture of a light quark confined within a hadron, then the Bohm result may explain the effectiveness of the NonRelativistic Quark Model of light-quark hadrons.

Conversely: the effectiveness of the NonRelativistic Quark Model of light-quark hadrons may be considered to be experimental support for Bohm’s theory.

The NonRelativistic Quark Model of light-quark hadrons is described in many textbooks, including [2] by Mike Guidry, who, at page 381 (see also page 311) says:

”By uncertainty principle arguments the momentum of a quark confined to the radius of one fermi is [about 200 MeV] ... For u or d quarks [the current mass is about 10 MeV or less and the constituent mass is about 300 MeV] ... and a nonrelativistic approximation is questionable ... relativity effects should be significant. Nevertheless, nonrelativistic models of quark structure for hadrons have been found to work surprisingly well, even for light hadrons. ...”

## References

- [1] D. Bohm, Phys. Rev. 85 (1952) 166-93.
- [2] Mike Guidry, *Gauge Field Theories*, John Wiley (1991).
- [3] Wheeler and Zurek, ed., *Quantum Theory and Measurement*, Princeton (1983).