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Extended Schematic Model for Hadrons, and What Happens to the Radius of an Excited Hadron

It is well-known that making reliable predictions about low-energy QCD and hadrons is a great challenge, as perturbative methods of quantum field theory do not apply when the coupling constant is strong. The common approach has been to propose various dynamical models which are inspired by assumptions, ideas, and intuition borrowed from physical systems which are not QCD. In this talk, I present refs. 1, 2 below. I will show how a schematic model employing pure QCD ingredients can teach us about the dynamics of QCD. I will present a new extended schematic model for hadrons where diquarks serve as building blocks on equal footing with quarks, and use it to reclassify the hadron spectrum. The outcome is that there are no radially excited mesons and no radially excited baryons; mesons and baryons which were believed to be radially excited are actually orbitally excited states involving diquarks. The reclassification thereby provides a new set of relations between two fundamental properties of hadrons: their size and their energy. The relations state that the size of a hadron is largest in the ground state and shrinks when the hadron is excited, contrary to practically all dynamical models proposed for QCD where the quarks are allowed to be pushed apart by a centrifugal barrier or radial excitations. While this set of relations appears counter-intuitive, it provides a novel explanation for the relationship between confinement and asymptotic freedom. It shows that we can overcome confinement and reach asymptotic freedom by increasing a hadron's orbital excitation: the path from confinement to asymptotic freedom is a Regge trajectory. This sheds new light not only on the low energy regime of QCD but also on its connection with high energies.

It is significant that the above set of relations predicts a QCD effect whereby a hadron can shrink. It is especially important since protons and neutrons, which make up the bulk of ordinary matter, are hadrons, and as such they obey the said relations. Our prediction proved to be concrete and testable when it was confirmed by an experiment that showed that the size of the proton shrinks (Pohl et. al., Nature 466, 213) nine months after this work was posted.

1. T. Friedmann, "No radial excitations in low-energy QCD I: Diquarks and classification of mesons," arXiv: 0910.2229.
2. T. Friedmann, "No radial excitations in low-energy QCD II: Shrinking radius of hadrons,"arXiv:0910.2231.

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