Free the quarks: Calculating the strong force

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This year sees the 40th anniversary of the ground-breaking proposal that the interactions between quarks becomes weaker as they come closer together, laying the foundations of quantum chromodynamics, or QCD, the modern theory of the strong interaction.

In 1972, the jury was still out as to the nature of quarks, and the strong interaction, while not quite *terra incognita*, was hostile territory for theorists, full of competing ideas. None of these offered a framework for carrying out calculations with clear, testable predictions. However, within less than two years the situation transformed radically when the theory of quantum chromodynamics, or QCD, emerged in more or less its current form.

The key theoretical breakthrough was the realization by David Gross, Frank Wilczek and David Politzer that strong interactions become weaker at shorter distances. This allowed calculations that could be controlled and which led to precise, beautiful equations. Submitted in the spring of 1973, two papers – one by Gross and his student Wilczek and one by Politzer – appeared side-by-side in Physical Review Letters in June, describing how the interaction strength between quarks can decrease with increasing energy, making quarks "asymptotically free" at high energies or, equivalently, at short distances, deep within protons and neutrons.

Quarks and the strong interaction are now part of the fundamental fabric of particle physics, and are well understood within the context of the Standard Model. Gross, Politzer and Wilczek were later rewarded with

the 2004 Nobel prize in physics "for the discovery of asymptotic freedom in the theory of the strong interaction".

More information: A watershed: The emergence of QCD" –an account by David Gross and Frank Wilczek in *CERN Courier*

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