Commentary on Modern Meson Spectroscopy: The Fundamental Role of Unitarity

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Commentary

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ABOUT THE STUDY

The main goal of meson spectroscopy is to consistently describe the masses of the ground and excited states of mesons observed at the various particle accelerators all over the world. Mesons are systems of integer spin, composed of one quark and one antiquark. When the total mass and quantum numbers so allow, a meson falls apart very fast into a pair of lighter mesons, *via* the creation of a new quark-antiquark pair. In this case, the disintegrating meson is called a resonance, whose decay width is inversely proportional to its life time. Mesons that cannot decay in this way are for simplicity considered stable in meson spectroscopy, although they can still decay though much more feeble electromagnetic or weak processes, resulting in widths many orders of magnitude smaller.

The force that holds a quark-antiquark pair together is not fully understood, as it results from Quantum Chromodynamics (QCD), which is a theory that cannot be solved at low energies and only approximately at high energies. Even so, we know empirically that the corresponding force grows indefinitely according as the quark intrapair distance increases, since (anti)quarks have never been observed in isolation. Therefore, this property is called quark confinement and has already been confirmed in numerical simulations on discrete space-time lattices employing extremely powerful computers, typically referred to as Lattice QCD (LQCD).

A still very frequently used and cited meson model by Godfrey and Isgur (GI) from 1985 employs a confining potential with a linear long-range part suggested by certain LQCD simulations and a Coulombic short-range part modelled according to perturbative QCD. Its main feature is a quite exhaustive computation of meson excitation spectra for a variety of quantum numbers and all possible combinations of the then already known quark flavours up, down, strange, charm, and bottom, moreover even including some hypothetical top-antitop states.

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However, the GI model dramatically overestimates the experimentally observed radial level splitting's in the light meson sector, besides failing completely in predicting the light scalar mesons below 1 GeV. These shortcomings lay bare the limitations of the Coulomb + linear confining potential and also the static description of mesons as stable Quark-antiquark systems. This emphasises the necessity to take into account the dynamical effects of strong decay on meson spectra, going far beyond the usual approach to merely computing meson resonance widths perturbatively.

In their review paper, Van Beveren and Rupp presented a detailed analysis of these facets of meson spectroscopy and also discussed two static relativistic models, before revisiting several unitarised and coupled-channel approaches to meson spectroscopy, which do treat mesons as resonances. Next they reviewed many successful descriptions of enigmatic meson resonances in the framework of their own

Resonance-Spectrum-Expansion (RSE) model. The RSE approach to mesons with non-exotic quantum numbers treats such resonances as resulting from the scattering of a pair of lighter mesons, which after one quark-antiquark annihilation propagates in the intermediate state as a tower of bare mesons with the same quantum numbers. A subsequent quark-antiquark creation then allows for a final state of again two mesons, which may be different from the incoming ones. The resulting multichannel S-matrix is manifestly unitary and can be solved in closed form. The RSE model also gives rise to a straightforward extension to production processes.

Several RSE predictions have meanwhile been confirmed by LQCD computations.