4CF15-2015-000017

Abstract for an Invited Paper
for the 4CF15 Meeting of
the American Physical Society

The XYZ Affair: Tales of the Third (and Fourth) Hadron[1]

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In the past dozen years, a number of new particles have been discovered that, while clearly being hadrons (interacting via the strong nuclear force), do not seem to fit into either of the known hadron categories of meson (quark-antiquark) or baryon (3 quarks). Three species of these "exotic" particles, called X, Y, and Z, are now believed to be tetraquarks, and last July the LHC announced the discovery of pentaquark states. After briefly reviewing how the states were discovered, I turn to the question of how they are assembled. Several competing physical pictures attempt to describe the structure of exotics: as molecules of known hadrons, as the result of kinematical effects, and others. I propose that they arise due to the formation of compact diquarks, a well-known but under-appreciated phenomenon of QCD. The diquarks are created with large relative momentum, and hence wish to fly off as free particles. However, they also carry color charge and therefore cannot be free, due to confinement. These competing facts create an entirely new kind of bound state, not a molecule with well-defined orbits, but an extended object that lasts only as long as it takes for quantum mechanics to allow the separated quarks and antiquarks to "find" one another, and allow decays to occur. I will discuss several observed effects that support this picture.

[1]Work supported by the National Science Foundation under Grants PHY-1068286 and PHY-1403891.