# Emergence of a complete heavy-quark spin symmetry multiplet of seven molecular pentaquarks

With the support by the National Natural Science Foundation of China and the Thousand Talents Plan for Young Professionals, the international research team led by Prof. Geng LiSheng (耿立升) and Prof. Manuel Pavon Valderrama of Beihang University proposed a hadronic molecule picture to explain the latest LHCb discoveries of three narrow pentaquark states, which was published in *Physical Review Letters* (2019, 122: 242001).

The quark model first proposed by Gell-Mann and Ne'eman in 1964 has been tremendously successful in explaining the observed hadrons (the smallest particles observed in nature which interact strongly). Starting from 2003, a series of new particles, collectively referred to as XYZ states, such as the X(3 872) and Zc(3 900), have challenged the naïve quark model and our understanding of the non-perturbative strong force, by unveiling the existence of multi-quark states. In 2015, the LHCb collaboration reported the discovery of two pentaquark states, the Pc(4450) and Pc(4380), giving the first evidence on the existence of multiquark heavy flavor baryons. In 2019, the LHCb collaboration surprised the world again by discovering a splitting of the Pc(4450) into two states, Pc(4440) and Pc(4457), and a new narrow state Pc(4312). The research team of Geng et al. demonstrated that these states might be bound states of a charmed antimeson and a charmed baryon and belong to a multiplet of seven members using an effective field theory constrained by heavy quark spin symmetry, which fit the experimental discoveries very well.

This multiplet is reminiscent of the eightfold way by which Gell-Mann and Ne'eman organized the then observed meson and baryon states into SU(3) multiplets. Here a beautiful parallelism can be drawn. While the eightfold way stems from the lightness of the up, down and strange quarks, the pentaquark septuplet is grounded on the heaviness of the charm quark. If future experiments find the missing members of the septuplet, they will confirm the nature of these pentaquark states and we may look forward to a completely new periodic table.

The predicted masses and spin-parities of the septuplet. Scenario A: the spins of Pc(4 457) and Pc(4 440) are 3/2 and 1/2; Scenario B: the opposite. The horizontal dotted lines dictate the experimental states discovered by LHCb.

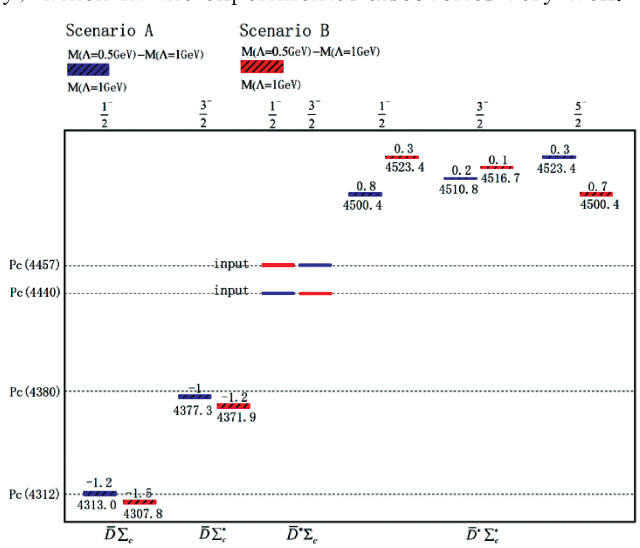


**Figure** The predicted masses and spin-parities of the septuplet. Scenario A: the spins of Pc(4 457) and Pc(4 440) are 3/2 and 1/2; Scenario B: the opposite. The horizontal dotted lines dictate the experimental states discovered by LHCb.