

CHARMED BARYONS

Revised March 2008 by C.G. Wohl (LBNL).

There are 17 known charmed baryons, and four other candidates not well enough established to be promoted to the Summary Tables.* Fig. 1(a) shows the mass spectrum, and for comparison Fig. 1(b) shows the spectrum of the lightest strange baryons. The Λ_c and Σ_c spectra ought to look much like the Λ and Σ spectra, since a Λ_c or a Σ_c differs from a Λ or a Σ only by the replacement of the s quark with a c quark. However, a Ξ or an Ω has more than one s quark, only *one* of which is changed to a c quark to make a Ξ_c or an Ω_c . Thus the Ξ_c and Ω_c spectra ought to be richer than the Ξ and Ω spectra.**

Before discussing the observed spectra, we review the theory of SU(4) multiplets, which tells what charmed baryons to expect; this is essential, because few of the spin-parity values given in Fig. 1(a) have been measured but have been assigned in accord with expectations of the theory. However, they are all very likely as shown (see below).

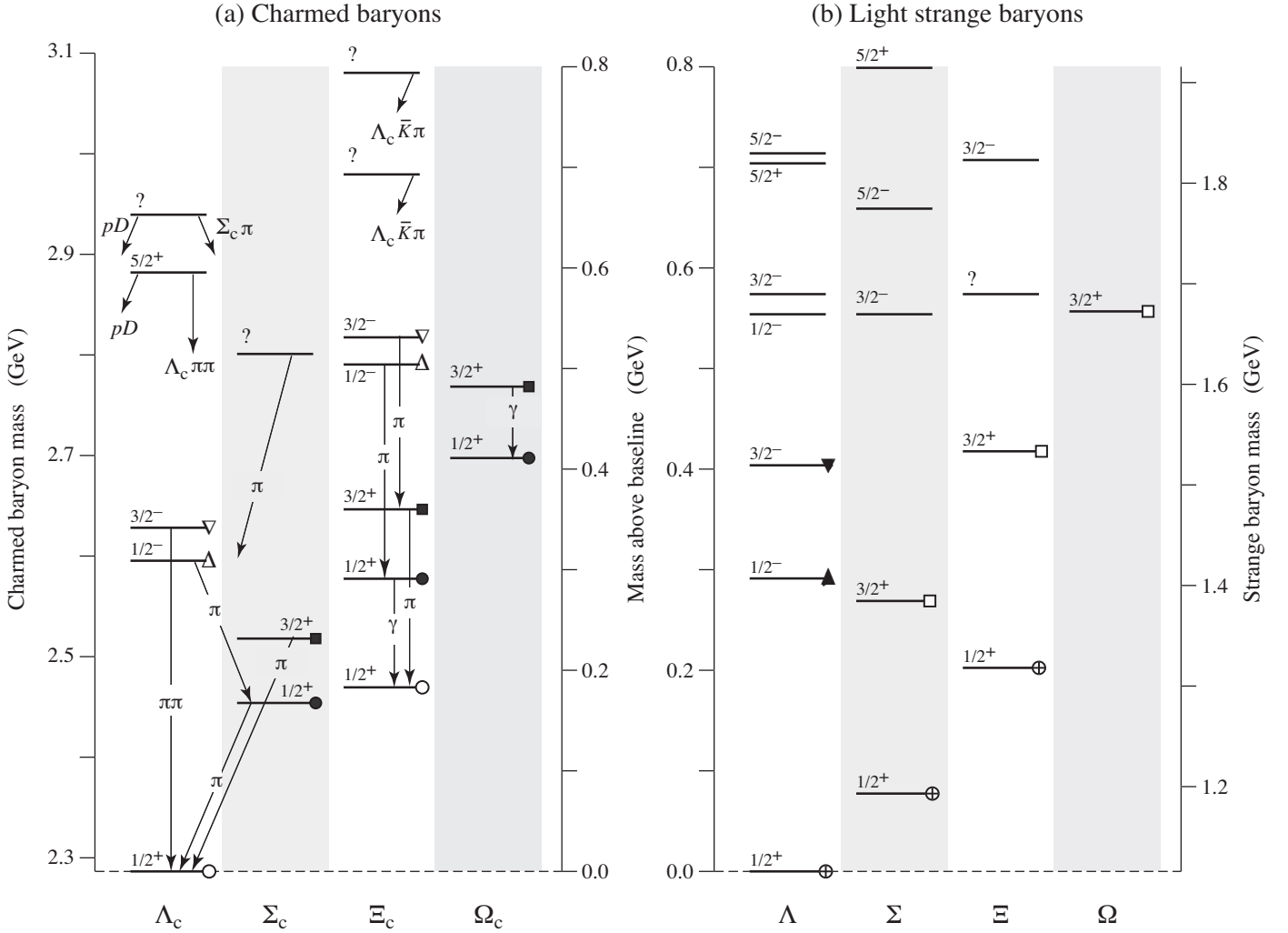


Fig. 1. (a) The known charmed baryons, and (b) the lightest “4-star” strange baryons. Note that there are two $J^P = 1/2^+$ Ξ_c states, and that the lightest Ω_c does not have $J = 3/2$. The $J^P = 1/2^+$ states, all tabbed with a circle, belong to the SU(4) multiplet that includes the nucleon; states with a circle with the same *fill* belong to the same SU(3) multiplet within that SU(4) multiplet. Similar remarks apply to the other states: same shape of tab, same SU(4) multiplet; same fill of that shape, same SU(3) multiplet. The $J^P = 1/2^-$ and $3/2^-$ states tabbed with triangles complete two SU(4) $\bar{4}$ multiplets.

SU(4) multiplets—Baryons made from u , d , s , and c quarks belong to SU(4) multiplets. The multiplet numerology, analogous to $3 \times 3 \times 3 = 10 + 8_1 + 8_2 + 1$ for the subset of baryons made

Figure 3 shows in more detail the middle level of the $20'$ -plet of Fig. 2(b); it splits apart into two SU(3) multiplets, a $\bar{3}$ and a 6. The states of the $\bar{3}$ are antisymmetric under the interchange of the two light quarks (the u , d , and s quarks), whereas the states of the 6 are symmetric under this interchange. We use a prime to distinguish the Ξ_c in the 6 from the one in the $\bar{3}$.

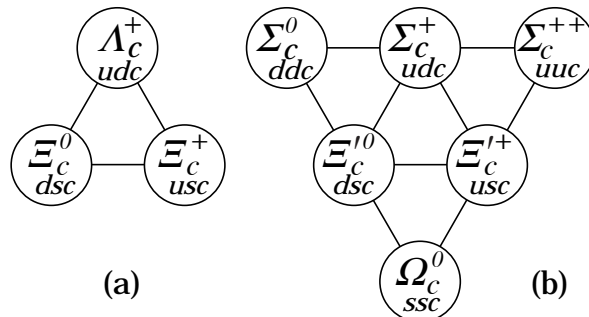


Figure 3: The SU(3) multiplets on the second level of the SU(4) multiplet of Fig. 2(b). The Λ_c and Ξ_c tabbed with open circles in Fig. 1(a) complete a $J^P = 1/2^+$ SU(3) $\bar{3}$ -plet, as in (a) here. The Σ_c , Ξ_c , and Ω_c tabbed with closed circles in Fig. 1(a) complete a $J^P = 1/2^+$ SU(3) 6-plet, as in (b) here. Together the nine particles complete the charm = +1 level of a $J^P = 1/2^+$ SU(4) 20-plet, as in Fig. 2(a).

The observed spectra—(1) The parity of the lightest Λ_c is defined to be positive (as are the parities of the p , n , and Λ); the limited evidence about its spin is consistent with $J = 1/2$. However, few of the J^P quantum numbers given in Fig. 1(a) have been measured. Models using spin-spin and spin-orbit interactions between the quarks, with parameters determined using a few of the masses as input, lead to the J^P assignments shown.[†] There are no surprises: the $J^P = 1/2^+$ states come first, then the $J^P = 3/2^+$ states . . .

(2) There is, however, evidence that many of the J^P assignments in Fig. 1(a) must be correct. As is well known, the successive mass differences between the $J^P = 3/2^+$ particles, the $\Delta(1232)^-$, $\Sigma(1385)^-$, $\Xi(1535)^-$, and Ω^- , which lie along

the lower left edge of the 20-plet in Fig. 2(a), should according to SU(3) be about equal; and indeed experimentally they nearly are. In the same way, the mass differences between the $J^P = 1/2^+$ $\Sigma_c(2455)^0$, $\Xi_c^{\prime 0}$, and Ω_c^0 ,[‡] the particles along the left edge of Fig. 3(b), should be about equal—assuming, of course, that they *do* all have the same J^P . The measured differences are 124.2 ± 2.9 MeV and 119.5 ± 3.9 MeV—not perfect, but close. Similarly, the mass differences between the presumed $J^P = 3/2^+$ $\Sigma_c(2520)^0$, $\Xi_c(2645)^0$, and Ω_c^0 are 128.1 ± 1.3 MeV and 122.2 ± 3.2 MeV. In Fig. 1(a), these two sets of charm particles are tabbed with solid circles and solid squares.

(3) Other evidence comes from the decay of the $\Lambda_c(2593)$. The only allowed strong decay is $\Lambda_c(2593)^+ \rightarrow \Lambda_c^+ \pi \pi$, and this appears to be dominated by the submode $\Sigma_c(2455)\pi$, despite little available phase space for the latter (the “ Q ” is about 2 MeV, the c.m. decay momentum about 20 MeV/ c). Thus the decay is almost certainly s -wave, which, assuming that the $\Sigma_c(2455)$ does indeed have $J^P = 1/2^+$, makes $J^P = 1/2^-$ for the $\Lambda_c(2593)$.

(4) The heavier charmed baryons, such as the $J^P = 1/2^-$ and $3/2^-$ Λ_c ’s, have much narrower widths than do their strange counterparts, such as the $\Lambda(1405)$ and $\Lambda(1520)$. The clean Λ_c spectrum has in fact been taken to settle the decades-long discussion about the nature of the $\Lambda(1405)$ —true 3-quark state or mere $\bar{K}N$ threshold effect?—unambiguously in favor of the first interpretation (which is not to say that the proximity of the $\bar{K}N$ threshold has no effect on the $\Lambda(1405)$). In fact, models of baryon-resonance spectroscopy should now *start* with the narrow charmed baryons, and work back to those broad old resonances.

Footnotes:

* The unpromoted states are a $\Lambda_c(2765)^+$, a $\Xi_c(2930)$, a $\Xi_c(3055)$, and a $\Xi_c(3123)$. There is also weak evidence for a baryon with *two* c quarks, a Ξ_{cc}^+ at 3519 MeV. See the Particle Listings.

** For example, there are three Ω_c^0 states (properly symmetrized states of ssc , scs , and css) corresponding to each Ω^- (sss) state.

† This is not the place to discuss the details of the models, nor to attempt a guide to the literature. See the discovery papers of the various charmed baryons for references to the models that lead to the quantum-number assignments.

‡ A reminder about the Particle Data Group naming scheme: A particle has its mass as part of its name if and only if it decays strongly. Thus $\Sigma(1385)$ and $\Sigma_c(2455)$ but Ω^- and Ξ'_c .