# Translating Old Meson Names

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**Abstract**

*Prior to 1986, there was no clear convention for the names of mesons with authors suggesting names with initial observations. There were also mesons that had more than one name, and a number of confused states including the $E/\iota$ puzzle and the $\theta$ meson. In 1986, the Particle Data Group proposed a systematic naming scheme. This document describes that 1986 naming scheme, and provides a translation from the old names to the new ones. It also provides some historical information on the states.*

## The PDG Naming Scheme

In 1986, the Particle Data Group introduced a naming scheme for hadrons [1]. In particular, this new scheme changed the names of many of the light-quark mesons. This naming scheme can be concisely summarized in table 1. The names of the non-strange mesons depend on the $L$, $S$ and $J$ of the the $q\bar{q}$ system, while tose for the kaonic (strange) mesons depends only on the spin $J$ and parity $P$.

| $q\bar{q}$ | Isospin | $^{S=1}(L_{\rm even})_J$ | $^{S=1}(L_{\rm odd})_J$ | $^{S=3}(L_{\rm even})_J$ | $^{S=3}(L_{\rm odd})_J$ |
|---|---|---|---|---|---|
| $u\bar{d}$,$(u\bar{u}-d\bar{d})$,$d\bar{u}$ | $I=1$ | $\pi_J$ | $b_J$ | $\rho_J$ | $a_J$ |
| $(u\bar{u}+d\bar{d})$, $s\bar{s}$ | $I=0$ | $\eta_J$,$\eta'_J$ | $h_J$,$h'_J$ | $\omega_J$,$\phi_J$ | $f_J$,$f'_J$ |
| $u\bar{s}$,$d\bar{s}$ | $I=\frac{1}{2}$ | $J^P=0^-,1^+,2^-,\cdots$ | $K_J$ | $J^P=0^+,1^-,2^+,\cdots$ | $K^*_J$ |

Table 1: Naming Scheme of the light–quark mesons as described in reference [1].

| *State* | $S$ | $L$ | $J$ | $P$ | $C$ | $J^{PC}$ | *Mesons* | | | | *Name* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $^1S_0$ | 0 | 0 | 0 | $-$ | $+$ | $0^{-+}$ | $\pi$ | $\eta$ | $\eta'$ | $K$ | pseudoscalar |
| $^3S_1$ | 1 | 0 | 1 | $-$ | $-$ | $1^{--}$ | $\rho$ | $\omega$ | $\phi$ | $K^*$ | vector |
| $^1P_1$ | 0 | 1 | 1 | $+$ | $-$ | $1^{+-}$ | $b_1$ | $h_1$ | $h'_1$ | $K_1$ | pseudo–vector |
| $^3P_0$ | 1 | 1 | 0 | $+$ | $+$ | $0^{++}$ | $a_0$ | $f_0$ | $f'_0$ | $K^*_0$ | scalar |
| $^3P_1$ | 1 | 1 | 1 | $+$ | $+$ | $1^{++}$ | $a_1$ | $f_1$ | $f'_1$ | $K_1$ | axial vector |
| $^3P_2$ | 1 | 1 | 2 | $+$ | $+$ | $2^{++}$ | $a_2$ | $f_2$ | $f'_2$ | $K^*_2$ | tensor |

Table 2: The names and $J^{PC}$ of $q\bar{q}$ states as a function of **L**, **S** and **J**.

Prior to the 1986 renaming, the names of many of the mesons were at best random. If one looks through old literature, you will find many of these strange names. A great deal of early information can be found in the first edition of the Particle Data Book [2] published in 1964, and the subsequent version [3] published in 1965. Table 3 provides a translation from the old names to the post 1986 names, and the material following that provides a bit of history and a reference to either the first, or an early observation of the states.

| Old Name | New Name | Old Name | New Name | Old Name | New Name |
|---|---|---|---|---|---|
| $S(975)$, $S^*$ | $f_0(975)$ | $\delta(980)$, $\delta$ | $a_0(980)$ | $H(1190)$, $H$ | $h_1(1170)$ |
| $B(1235)$, $B$ | $b_1(1235)$ | $f(1270)$, $f$ | $f_2(1270)$ | $A(1270)$, $A_1$ | $a_1(1270)$ |
| $D(1285)$,$D$ | $f_1(1285)$ | $\epsilon(1300)$, $\epsilon$ | $f_0(1370)$ | $A_2(1320)$, $A_2$ | $a_2(1320)$ |
| $E(1420)$, $E$ | $f_1(1285)$ | $\iota(1440)$, $\iota$ | $\eta(1405)$ & $\eta(1475)$ | $f'(1525)$, $f'$ | $f'(1525)$ |
| $\omega(1670)$ | $\omega_3(1670)$ | $A(1680)$, $A_3$ | $\pi_2(1670)$ | $\theta(1690)$, $\theta$ | $f_0(1710)$ |
| $\phi(1850)$ | $\phi_3(1850)$ | $h(2030)$ | $f_4(2050)$ | $Q(1280)$, $Q_1$ | $K_1(1270)$ |
| $\kappa(1350)$ | $K_0^*(1430)$ | $Q(1400)$, $Q_2$ | $K_1(1400)$ | $K^*(1430)$ | $K_2^*(1430)$ |
| $L(1770)$ | $K_2(1770)$ | $K^*(1780)$, $K^*$ | $K_3^*(1780)$ | $K^*(2060)$ | $K_4^*(2045)$ |

Table 3: This tables provides a translation form the old particle names and the post 1986 names.

## Historical Information on Meson States

- The $S(975)$ or the $S^*$ is now known as the $f_0(980)$. The $S^*$ was reported in 1966 [4]. The state was first reported in the reaction $\pi^+ p \to \Delta^{++}\pi^+\pi^-$ and $\pi^+ p \to \Delta^{++}K^+K^-$ in 1973 [5].

- The $\delta(980)$ is now known as the $a_0(980)$. The state was first reported in $\bar{p}p \to K_S K^{\pm}\pi^{\mp}$ at rest, where the analysis focused on events without $K^*(890)$ in 1965 [6].

- The $H(1190)$ is now known as the $h_1(1170)$. The state was first observed in $\pi^- p \to \pi^+\pi^-\pi^0 n$ in 1981 [7].

- The $B(1235)$ is now known as the $b_1(1235)$. The state was first observed in an analysis of reactions of the type $\pi^+ p \to pX$ in 1963. [8]

- The $f(1270)$ is now known as the $f_2(1270)$. The state was first observed in $\pi^- p \to n\pi^+\pi^-$ in 1963 [9].

- The $A(1270)$ or the $A_1$ is now known as the $a_1(1260)$. An enhancement in the region of the $a_1$ mass was first observed in $\pi^-$ interactions on carbon. The authors separated their data into classes of events based on the number of pions. The so-called $A$ region contained $\pi^+\pi^-\pi^-$ events and a broad enhancement was seen [10]. The $A$ name stuck for mesons in this mass region. In subsequent work [11, 12], two states were resolved: the $A_1$ and $A_2$.

- The $D(1285)$ is now known as the $f_1(1285)$. The state was first reported in $\pi^- p$ interactions in three or more-body final states. It was first reported in 1967 [13]

- The $\epsilon(1300)$ is know known as the $f_0(1370)$. The state was first reported in $\bar{p}n \to \pi^+\pi^+\pi^-\pi^-\pi^-$ annihilation at rest as an enhancement in $\rho\rho$. It was first reported in 1966 [14].

- The $A_2(1320)$ is now known as the $a_2(1320)$. This appears to be first reported in $\pi p$ interactions, but I have been unable to track down the earliest reference. It was originally discussed as part of the $A$ which ultimately included both the $A_1$ and $A_2$ [10, 11, 12].

- The $E(1420)$ is now known as the $f_1(1420)$. The $E(1420)$ and the $\iota(1440)$ have a bit of a confused history. A state called the $E$ with $J^{PC} = 0^{-+}$ was first reported in $\bar{p}p \to K\bar{K}3\pi$ in the $K\bar{K}\pi$ invariant mass [15]. The $E$ was first reported in radiative $J/\psi$ decays in $K\bar{K}\pi$

with oin $J^{PC} = 0^{-+}$ [16]. A $J^{PC} = 1^{++}$ state was later observed in $\pi p$ interactions [17] and by 1984, the $E$ was assigned $J^{PC} = 1^{++}$ quantum numbers and the $\iota$ was assigned $J^{PC} = 0^{-+}$ quantum numbers. Hence, older literature will likely be very confused on these two states. The pseudoscalar states are produced strongly in both radiative $J/\psi$ decays and proton antiproton annihilation at rest. The axial state is produced in central production, photoproduction and $\pi p$ interactions.

- The $\iota(1440)$ is now two states, the $\eta(1405)$ and the $\eta(1475)$. See the above discussion of the $E(1420)$.

- The $f'(1525)$ is now known as the $f_2'(1525)$. This state was first observed in $K^- p$ unteractions in ${}_S K_S$ recoiling against a hyperon. The original observation is from 1965 [18] and a spin parity analysis from 1966 [19].

- The $\omega(1670)$ is now known as the $\omega_3(1670)$. Observed in $\pi^+ d \to p_s p \pi^+ \pi^- \pi^0$ in the $\rho\pi$ system [20, 21]. It was also observed in the reaction $K^- p \to \Lambda \omega \pi^+ \pi^-$ in the $\omega\pi\pi$ system [22]. The first observations were in 1968 and 1969.

- The $A(1680)$ or $A_3$ is now known as the $\pi_2(1670)$. The state was first observed in the reaction $\pi^\pm p \to p \pi^\pm \pi^+ \pi^-$ in the three pion invariant mass [23, 24]. It was reported in a conference in 1966, but the first published observations were in 1968.

- The $\theta(1690)$ is now known as the $f_0(1710)$. There was early uncertainty whether it was $J^{PC} = 0^{++}$ or $2^{++}$. It is now confirmed as $0^{++}$.The state was reported in $\pi^- p \to K_S K_S n$ [25, 26], where is was identified as $J^{PC} = 0^{++}$ and called the $S^*$. In radiative $J/\psi$ decays, $J/\psi \to \gamma\eta\eta$, a state identified as $J^{PC} = 2^{++}$ and called the $\theta$ [27] was reported. Finally, an enhancement below 2 GeV was reported in $J/\psi \to \rho^0\rho^0$ [28]. All of these observations were reported in 1982.

- The $\phi(1850)$ is now known as the $\phi_3(1850)$. First observed in $K^- p \to \Lambda K \bar{K}$ [29]. The state was first observed in 1981.

- The $h(2030)$ is now known as the $f_4(2050)$. This state was observed in $\pi^- p \to n\pi^0\pi^0$ and reported as the $h$ meson [30]. It was also reported in $\pi^- p \to n K^+ K^-$ and also reported as the $h$ [31]. Both of these observations are from 1975.

- The $Q(1280)$ or $Q_1$ is now known as the $K_1(1270)$. The state was first observed in the reaction $\bar{p}p \to K_S K_S \pi^+ \pi^-$ in the $K_S \pi^+ \pi^-$ invariant mass and was given the name $C$ [32]. This observation was made in 1964.

- The $\kappa(1350)$ is now known as the $K_0^*(1430)$. This state appears to have first been observed in $K^- p$ scattering in the $K\pi$ invariant mass [33]. It appears to be from LASS around 1976 or 1977.

- The $Q(1400)$ or $Q_2$ is now known as the $K_1(1400)$.First observed in $K^+ d \to K^+ \pi^+ \pi^- d$ and $K^+ d \to K^0 \pi^+ d$ in both $K\pi\pi$ and $K\pi$ [34]. It was also observed in $K^+ p \to p K^+ \pi^+ \pi^-$ and $K^+ p \to p K^0 \pi^0 \pi^+$ in both $K\pi\pi$ and $K\pi$ [35]. Both observations are from 1972.

- The $K^*(1430)$ is now known as the $K_2^*(1430)$. $K^- p \to \bar{K}^0 \pi^- p$ [36, 37]. It was also reported in $\pi^- p$ interactions [38]. Its spin and isospin were determined in 1965 [39].

- The $L(1770)$ is now known as the $K_2(1770)$. The state was first observed in $K^- p \to p K^- \pi^+ \pi^-$ and $K^- p \to p K^0 \pi^- \pi^0$ in the $K\pi\pi$ invariant mass [40]. The state was first observed in 1966.
- The $K^*(1780)$ or $K^*$ is now known as the $K_3^*(1780)$. First observed in $K^+ n \to K^+ \pi^- p$ and $K^+ n \to K^0 \pi^+ \pi^- p$ reactions in both the $K\pi$ and $K\pi\pi$ final states [41, 42]. This state was first observed in 1971.
- The $K^*(2060)$ is now known as the $K_4^*(2045)$.This state was first observed in $K^+ d$ interactions in both the $K\pi$ and $K\pi\pi$ final states [41, 42]. In the authors 1977 publication, they mention that a peak was reported at this mass earlier, possibly as early as 1971.

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