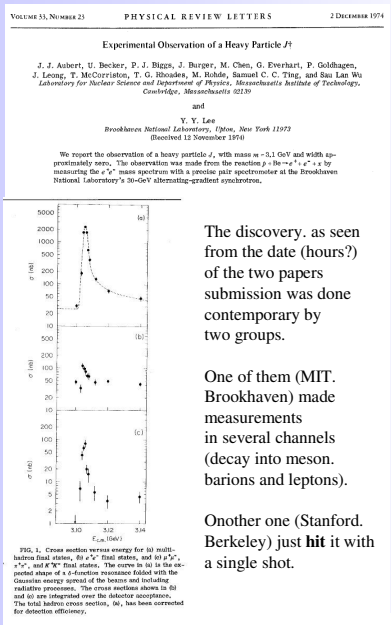
Charm of Charmonium

Scientists are very calm and equillibrated persons. Only sometimes they get very excited – in particular when they discover an elementary particle.

This was the case of "charmonium". the meson made of c$\underline{c}$ quarks. the first evidence of the fourth quark. completing the second family (that of *strange* quark)..


VOLUME 33, NUMBER 23 PHYSICAL REVIEW LETTERS 2 DECEMBER 1974

Experimental Observation of a Heavy Particle J†

J. J. Aubert, U. Becker, P. J. Biggs, J. Burger, M. Chen, G. Everhart, P. Goldhagen, J. Leong, T. McCorriston, T. G. Rhoades, M. Rohde, Samuel C. C. Ting, and Sau Lan Wu
Laboratory for Nuclear Science and Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

and

Y. Y. Lee
Brookhaven National Laboratory, Upton, New York 11973
(Received 12 November 1974)

We report the observation of a heavy particle J, with mass $m = 3.1$ GeV and width approximately zero. The observation was made from the reaction $p + Be \to e^+ + e^- + x$ by measuring the e^+e^- mass spectrum with a precise pair spectrometer at the Brookhaven National Laboratory's 30-GeV alternating-gradient synchrotron.

FIG. 1. Cross section versus energy for (a) multihadron final states, (b) e^+e^- final states, and (c) $p\bar{p}$, $\pi^+\pi^-$, and K^+K^- final states. The curve in (a) is the expected shape of a 6-fraction resonance folded with the Gaussian energy spread of the beams and including radiative processes. The cross sections shown in (a) and (c) are integrated over the detector acceptance. The total hadron cross section, (a), has been corrected for detection efficiency.

The discovery. as seen from the date (hours?) of the two papers submission was done contemporary by two groups.

One of them (MIT. Brookhaven) made measurements in several channels (decay into meson. barions and leptons).

Onother one (Stanford. Berkeley) just **hit** it with a single shot.

VOLUME 33, NUMBER 23 PHYSICAL REVIEW LETTERS 2 DECEMBER 1974

Discovery of a Narrow Resonance in e^+e^- Annihilation*

J.-E. Augustin,† A. M. Boyarski, M. Breidenbach, F. Bulos, J. T. Dakin, G. J. Feldman, G. E. Fischer, D. Fryberger, G. Hanson, B. Jean-Marie,† R. R. Larsen, V. Lüth, H. L. Lynch, D. Lyon, C. C. Morehouse, J. M. Paterson, M. L. Perl, B. Richter, P. Rapidis, R. F. Schwitters, W. M. Tanenbaum, and F. Vannucci
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305

and

G. S. Abrams, D. Briggs, W. Chinowsky, C. E. Friedberg, G. Goldhaber, R. J. Hollebeek, J. A. Kadyk, B. Lulu, F. Pierre,§ G. H. Trilling, J. S. Whitaker, J. Wiss, and J. E. Zipse
Lawrence Berkeley Laboratory and Department of Physics, University of California, Berkeley, California 94720
(Received 13 November 1974)

We have observed a very sharp peak in the cross section for $e^+e^- \to$ hadrons, e^+e^-, and possibly $p\bar{p}$ at a center-of-mass energy of 3.105 ± 0.003 GeV. The upper limit to the full width at half-maximum is 1.3 MeV.

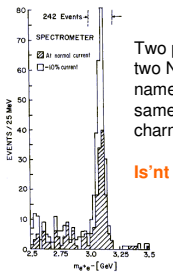
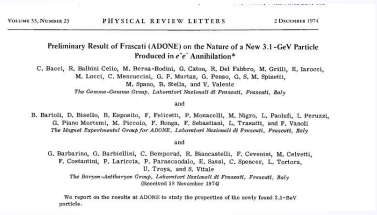


FIG. 2. Mass spectrum showing the existence of J. Results from two spectrometer settings are plotted showing that the peak is independent of spectrometer currents. The run at reduced current was taken two months later than the normal run.

Two paper. two groups. two Nobel prizes and two names are used for the same particle charmonium J and Ψ.

Is'nt it charming?


VOLUME 33, NUMBER 23 PHYSICAL REVIEW LETTERS 2 DECEMBER 1974

Preliminary Result of Frascati (ADONE) on the Nature of a New 3.1-GeV Particle Produced in e^+e^- Annihilation*

C. Bacci, R. Baldini Celio, M. Bernardini, G. Caton, R. Del Fabbro, M. Grilli, R. Iaroci, M. Locci, C. Mencuccini, G. P. Murtas, G. Penso, G. S. M. Spinelli, M. Spano, B. Stella, and V. Valente
The Genova-Gaussa Group, Laboratori Nazionali di Frascati, Frascati, Italy

and

B. Bartoli, D. Bisello, B. Esposito, F. Felicetti, P. Monacelli, M. Nigro, L. Paolini, L. Peruzzi, G. Piano Mortari, M. Piccolo, F. Ronga, F. Sebastiani, L. Trasatti, and F. Vitali
The Magnet Experimental Group for ADONE, Laboratori Nazionali di Frascati, Frascati, Italy

and

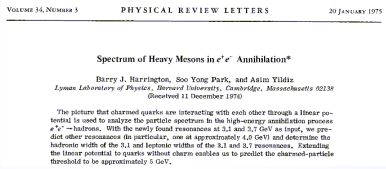
G. Barbarino, G. Barbiellini, C. Bemporad, R. Biancastelli, F. Cevenini, M. Celvetti, F. Costantini, P. Laricela, P. Parascandalo, E. Sassi, C. Spencer, L. Tortora, U. Troya, and S. Vitale
The Bari-Antiburyon Group, Laboratori Nazionali di Frascati, Frascati, Italy
(Received 16 November 1974)

We report on the results at ADONE to study the properties of the newly found 3.1-BeV particle.

There was also a third group, from Rome, who published a paper just below the two upper. But they declared to have adjusted their machine for the shot after the call from USA.

No Nobel prize for them…

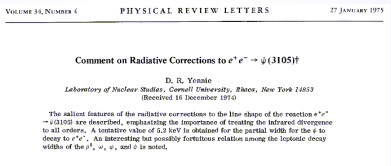
One discovery starts ("triggers") the whole series: there is enough work for both experimentalists and theoreticians.


VOLUME 34, NUMBER 3 PHYSICAL REVIEW LETTERS 20 JANUARY 1975

Spectrum of Heavy Mesons in e^+e^- Annihilation*

Barry J. Harrington, Soo Yong Park, and Asim Yildiz
Lyman Laboratory of Physics, Harvard University, Cambridge, Massachusetts 02138
(Received 11 December 1974)

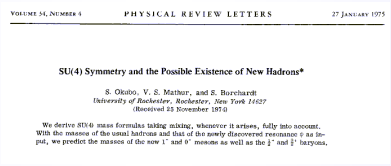
The picture that charmed quarks are interacting with each other through a linear potential is used to analyze the particle spectrum in the high-energy annihilation process $e^+e^- \to$ hadrons. With the newly found resonances at 3.1 and 3.7 GeV as input, we predict other resonances (in particular, one at approximately 4.0 GeV) and determine the hadronic width of the 3.1 and leptonic widths of the 3.1 and 3.7 resonances. Extending the linear potential to quarks without charm enables us to predict the charmed-particle threshold to be approximately 5 GeV.


VOLUME 34, NUMBER 4 PHYSICAL REVIEW LETTERS 27 JANUARY 1975

Comment on Radiative Corrections to $e^+e^- \to \psi(3105)$†

D. R. Yennie
Laboratory of Nuclear Studies, Cornell University, Ithaca, New York 14853
(Received 16 December 1974)

The salient features of the radiative corrections to the line shape of the reaction $e^+e^- \to \psi(3105)$ are described, emphasizing the importance of treating the infrared divergence to all orders. A tentative value of 6.2 keV is obtained for the partial width for the ψ to decay to e^+e^-. An interesting but possibly fortuitous relation among the leptonic decay widths of the ρ^0, ω, ψ, and ϕ is noted.


VOLUME 34, NUMBER 4 PHYSICAL REVIEW LETTERS 27 JANUARY 1975

SU(4) Symmetry and the Possible Existence of New Hadrons*

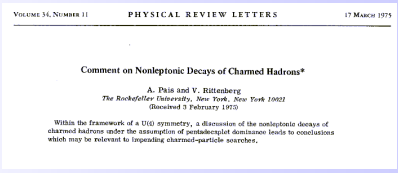
S. Okubo, V. S. Mathur, and S. Borchardt
University of Rochester, Rochester, New York 14627
(Received 25 November 1974)

We derive SU(4) mass formulas taking mixing, whenever it arises, fully into account. With the masses of the usual hadrons and that of the newly discovered resonance ψ as input, we predict the masses of the new 1^- and 0^- mesons as well as the $\frac{1}{2}^+$ and $\frac{3}{2}^+$ baryons.

Charmonium is a meson composed of *charm* quark and antiquark. This is quite an exception in mesons family - mesons *like* to be composed from mixed quarks: meson π (that of nuclear forces) of $\underline{u}$ and d (or vice versa), K-mesons (those of CP symmetry breaking) of $\underline{s}$ and d, B-mesons (those from "BaBar" and "Belle" experiments) of $\underline{b}$ and u.

The energy (mass) spectrum of the c$\underline{c}$ meson is really rich.

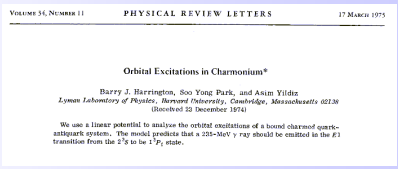
Two months is more or less the (quickest) time for answering a (scientific) letter.


VOLUME 34, NUMBER 11 PHYSICAL REVIEW LETTERS 17 MARCH 1975

Comment on Nonleptonic Decays of Charmed Hadrons*

A. Pais and V. Rittenberg
The Rockefeller University, New York, New York 10021
(Received 3 February 1975)

Within the framework of a U(6) symmetry, a discussion of the nonleptonic decays of charmed hadrons under the assumption of pentadecuplet dominance leads to conclusions which may be relevant to impending charmed-particle searches.

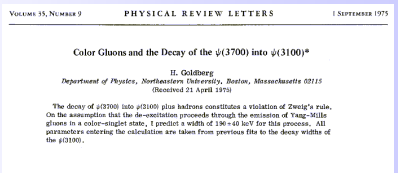

VOLUME 34, NUMBER 11 PHYSICAL REVIEW LETTERS 17 MARCH 1975

Orbital Excitations in Charmonium*

Barry J. Harrington, Soo Yong Park, and Asim Yildiz
Lyman Laboratory of Physics, Harvard University, Cambridge, Massachusetts 02138
(Received 23 December 1974)

We use a linear potential to analyze the orbital excitations of a bound charmed quark-antiquark system. The model predicts that a 255-MeV γ ray should be emitted in the $E1$ transition from the 2^3S to be 1^3P_1 state.

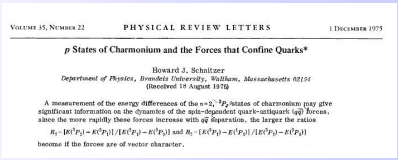
An than the story goes on, until the next (experimental and/or theoretical) shot…


VOLUME 35, NUMBER 9 PHYSICAL REVIEW LETTERS 1 SEPTEMBER 1975

Color Gluons and the Decay of the $\psi(3700)$ into $\psi(3100)$*

H. Goldberg
Department of Physics, Northeastern University, Boston, Massachusetts 02115
(Received 21 April 1975)

The decay of $\psi(3700)$ into $\psi(3100)$ plus hadrons constitutes a violation of Zweig's rule. On the assumption that the de-excitation proceeds through the emission of Yang-Mills gluons in a color-singlet state, I predict a width of 136 ± 40 keV for this process. All parameters entering the calculation are taken from previous fits to the decay widths of the $\psi(3100)$.

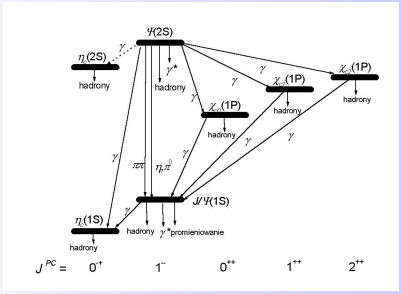

VOLUME 35, NUMBER 22 PHYSICAL REVIEW LETTERS 1 DECEMBER 1975

p States of Charmonium and the Forces that Confine Quarks*

Howard J. Schnitzer
Department of Physics, Brandeis University, Waltham, Massachusetts 02154
(Received 18 August 1975)

A measurement of the energy differences of the $n=2$, ^3P_J states of charmonium may give significant information on the dynamics of the spin-dependent quark-antiquark ($q\bar{q}$) forces, since the more rapidly these forces increase with $q\bar{q}$ separation, the larger the ratios $R_1 = [E(^3P_2) - E(^3P_1)]/[E(^3P_1) - E(^3P_0)]$ and $R_2 = [E(^3P_2) - E(^3P_1)]/[E(^3P_1) - E(^3P_0)]$ become if the forces are of vector character.

The fourth quark was discovered in 1974. but the theory (M. Kobayashi and T. Masakawa) in the same year predicted next two…



Baryons [mass in MeV/c²]	**Mesons**	**Baryons**	**Mesons**
			+ Charmed
uud p (proton) m=938.271998 ± 0.000038	$(u\underline{u} + d\underline{d})/\sqrt{2}$ π^0 (neutral pion) m= 134.9766 ± 0.0006	*ddc* Σ_c^0 (sigma-c) 2452.6 ± 0.6	*c*$\underline{c}$ J/Ψ(charmonium) also called η_c 3096.87± 0.04
udd n (neutron) m= 939.65330 ± 0.000038	*u*$\underline{d}$ π^+ (positive pion) m= 139.57018 ± 0.00035 *charge radius r=0.672x10^{-15} m*	*udc* Σ_c^+ (sigma-c) 2451.3 ± 0.7	*c*$\underline{u}$ D^0 1864.5 ± 0.5
$\underline{uud}$ p (antiproton) m= 938	*d*$\underline{u}$ π^- (negative pion) m= 139.57018 ± 0.00035 *charge radius r=0.672x10^{-15} m …*	*uuc* Σ_c^{++} (sigma-c) 2452.6 ± 0.6	*c*$\underline{d}$ D^+ 1869.3 ± 0.5
		…	$\underline{c}$*d* D^- 1869.3 ± 0.5 …
	+ Strange		**+ Bottom**
uds Λ (lambda) 1115.683 ± 0.006	*d*$\underline{s}$ K^0 (neutral kaon) 497.672 ± 0.031	*udb* Λ_b^0 5624 ± 9	*b*$\underline{b}$ Ψ (ypsylon 1977) 9460.30 ± 0.26
uds Σ^0 (sigma zero) 1192.642 ± 0.024	$\underline{d}$*s* $\underline{K}^0$ (neutral antikaon) 497.672 ± 0.031	*usb* Ξ_b^0 *Energy ?* *lifetime 1.39 ps*	*u*$\underline{b}$ B^+ 5279.0 ± 0.5 *lifetime 1.674 ps …*
uus Σ^+ (sigma plus) 1189.37 ± 0.07	*u*$\underline{s}$ K^+ (positive kaon) 493.677 ± 0.013	*s* *s*	
dds Σ^- (sigma minus) 1197.449 ±0.030	*s*$\underline{u}$ K^- (negative kaon) 493.677 ± 0.013 …	…	*to be continued …*