Journal Club at Kuno lab, Dec 04, 2017

Classic paper series II

Ace Model

G. Zweig, 1964

Yoshio Koide

My English is very poor.
Most of my talk will be given by Japanese

Today, I would like to give a brief review of the so-called Ace Model in 1964

AN SU_3 MODEL FOR STRONG INTERACTION SYMMETRY AND ITS BREAKING

II *)

G. Zweig **)

CERN—Geneva

ABSTRACT

Both mesons and baryons are constructed from a set of three fundamental particles called aces. The aces break up into an isospin doublet and singlet. Each ace carries baryon number 1/3 and is fractionally charged. SU_3 (but not the Eightfold Way) is adopted as a higher symmetry for the strong interactions. The breaking of this symmetry is assumed to be universal, being due to mass differences among the aces. Extensive space-time and group theoretic structure is then predicted for both mesons and baryons, in agreement with existing experimental information. Quantitative speculations are presented concerning resonances that have not as yet been definitively classified into representations of SU_3. A weak interaction theory based on right and left handed aces is used to predict rates for $|\Delta S| = 1$ baryon leptonic decays. An experimental search for the aces is suggested.

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*) Version I is CERN preprint 8182/TH.401, Jan. 17, 1964.

**) This work was supported by the U.S. Air Force Office of Scientific Research and the National Academy of Sciences - National Research Council.

8419/TH.412
21 February 1964

Maybe, you know this article published in the same year

Volume 8, number 3 PHYSICS LETTERS 1 February 1964

A SCHEMATIC MODEL OF BARYONS AND MESONS *

M. GELL-MANN
California Institute of Technology, Pasadena, California

Received 4 January 1964

If we assume that the strong interactions of baryons and mesons are correctly described in terms of the broken "eightfold way" [1-3], we are tempted to look for some fundamental explanation of the situation. A highly promised approach is the purely dynamical "bootstrap" model for all the strongly interacting particles within which one may try to derive isotopic spin and strangeness conservation and broken eightfold symmetry from self-consistency alone [4]. Of course, with only strong interactions, the orientation of the asymmetry in the unitary space cannot be specified; one hopes that in some way the selection of specific components of the F-spin by electromagnetism and the weak interactions determines the choice of isotopic spin and hypercharge directions.

ber $n_t - n_{\bar{t}}$ would be zero for all known baryons and mesons. The most interesting example of such a model is one in which the triplet has spin $\frac{1}{2}$ and $z = -1$, so that the four particles d^-, s^-, u^0 and b^0 exhibit a parallel with the leptons.

A simpler and more elegant scheme can be constructed if we allow non-integral values for the charges. We can dispense entirely with the basic baryon b if we assign to the triplet t the following properties: spin $\frac{1}{2}$, $z = -\frac{1}{3}$, and baryon number $\frac{1}{3}$. We then refer to the members $u^{\frac{2}{3}}$, $d^{-\frac{1}{3}}$, and $s^{-\frac{1}{3}}$ of the triplet as "quarks" [6] q and the members of the anti-triplet as anti-quarks $\bar{q}$. Baryons can now be constructed from quarks by using the combinations (qqq), $(qqqq\bar{q})$, etc., while mesons are made out of $(q\bar{q})$, $(qq\bar{q}\bar{q})$, etc. It is assuming that the lowest

"Quark model"
by M. Gell-mann
was published
in Physics Letters
at January 1964.

"Ace model"
by G. Zweig
appeared
as CERN preprint
at January 1964.

Both models are essentially same from the point of view of "physics".

However, the motivations are different.

Mathematics: SU(3) symmetry

--- a brief review for beginners ---

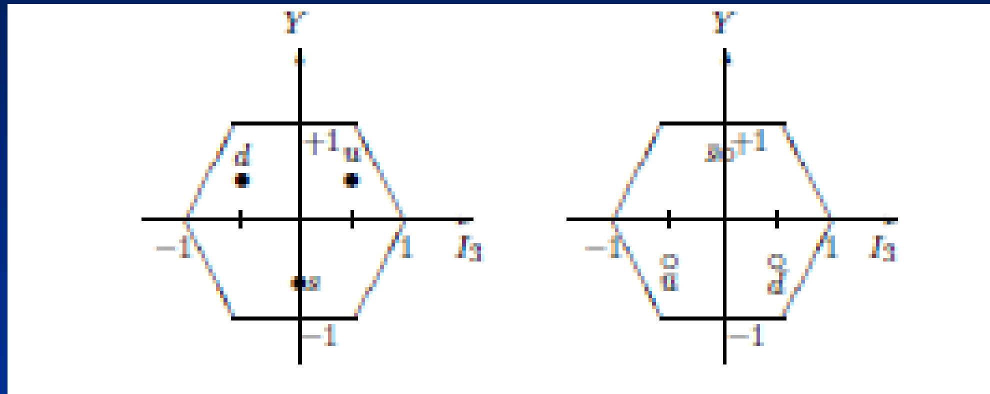
Gell-Mann has published many papers on the basis of group theoretical study **prior to** his Quark Model

Therefore, first, I would like to give a review of SU(3)
(not Physics, but Mathematics)

Special Unitary Group: SU(3)

- Fundamental representation

	I_3	$+\frac{1}{2}Y$	$=Q$
u	$+\frac{1}{2}$	$+\frac{1}{6}$	$+\frac{2}{3}$
d	$-\frac{1}{2}$	$+\frac{1}{6}$	$-\frac{1}{3}$
s	0	$-\frac{1}{3}$	$+\frac{1}{3}$



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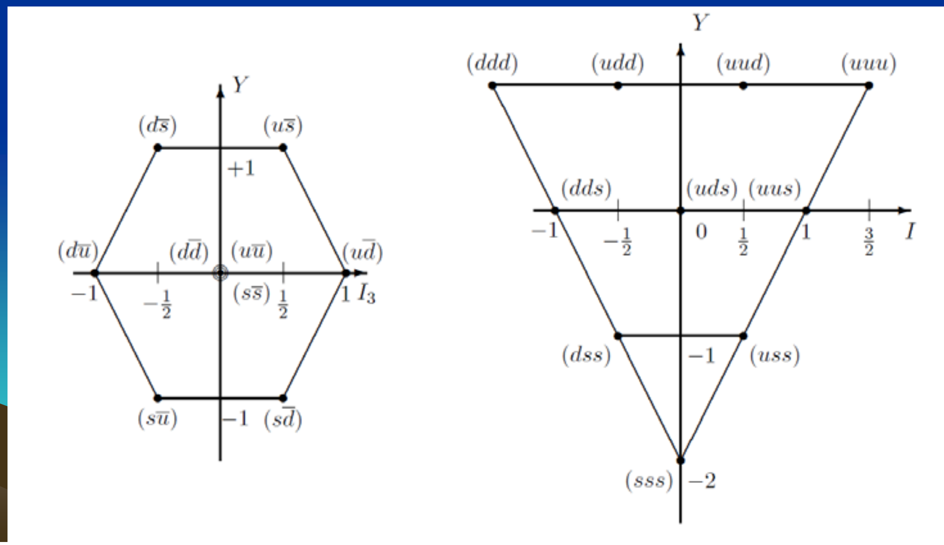
3*

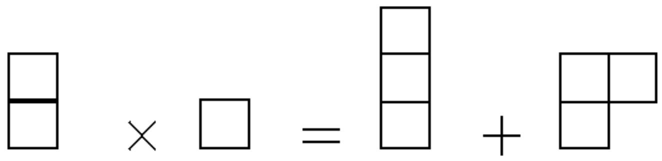
- Higher representations



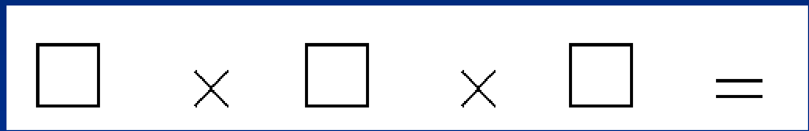
8

10

How to get higher dimensions



$$\mathbf{3}^* \times \mathbf{3} = \mathbf{1} + \mathbf{8}$$



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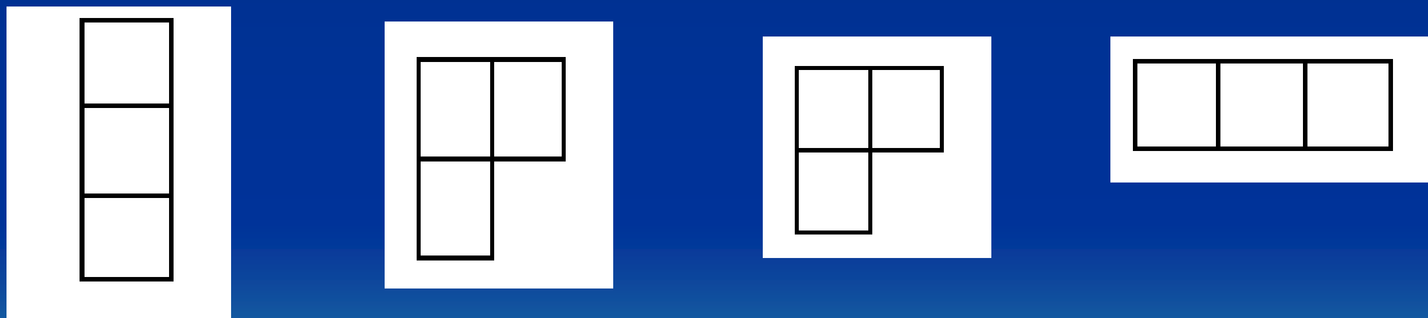


1 8 8 10

totally anti-symmetric

totally symmetric

Physics: SU(3)-flavor symmetry

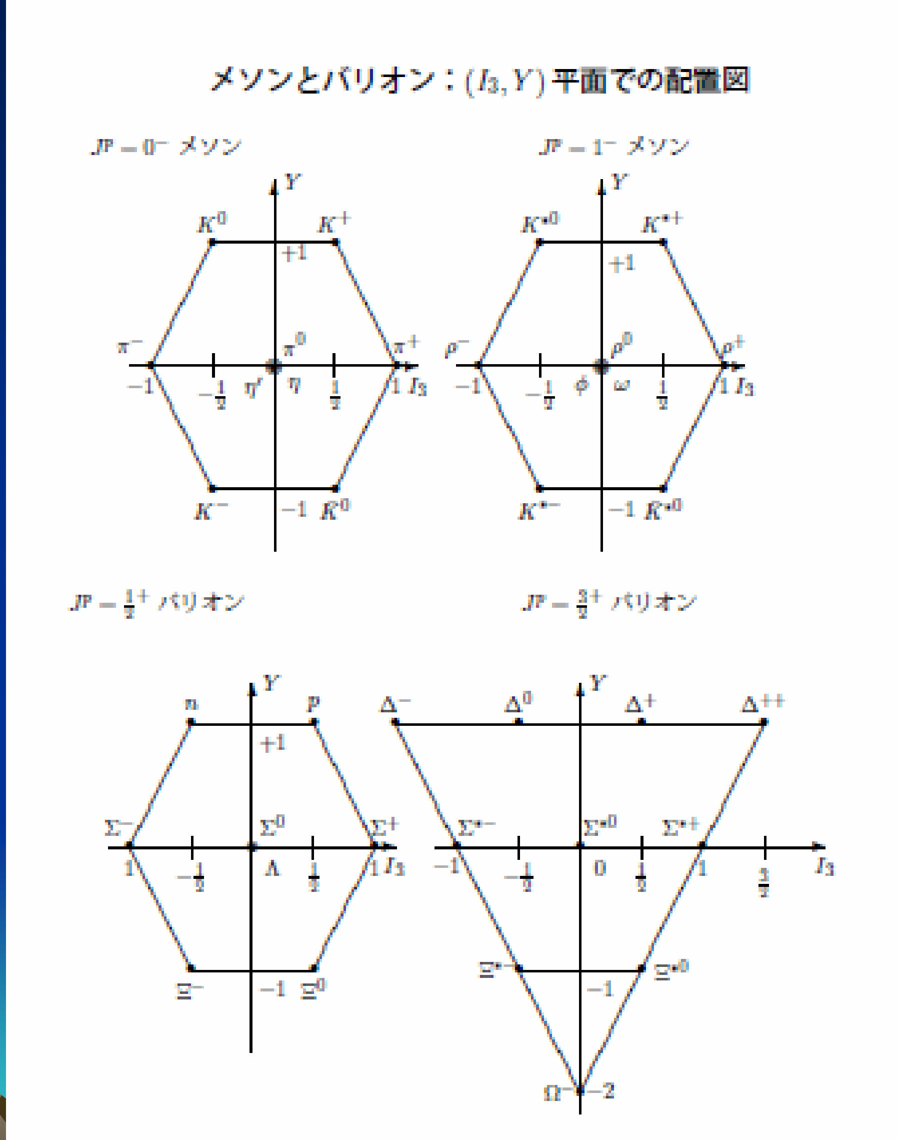
☆ We know that I and Y of mesons and baryons are assigned as the right:

Therefore, we conclude hadrons are composed of (u, d, s):

SU(3) -flavor symmetry

☆ "flavor" in contrast to "color"

☆ Don't confuse "flavor" and "family": LFV



Discovery of Omega: 1964

Gell-Mann's Quark Model

A simpler and more elegant scheme can be constructed if we allow non-integral values for the charges. We can dispense entirely with the basic baryon b if we assign to the triplet t the following properties: spin $\frac{1}{2}$, $z = -\frac{1}{3}$, and baryon number $\frac{1}{3}$. We then refer to the members $u^{\frac{2}{3}}$, $d^{-\frac{1}{3}}$, and $s^{-\frac{1}{3}}$ of the triplet as "quarks" 6) q and the members of the anti-triplet as anti-quarks $\bar{q}$. Baryons can now be

6) James Joyce, Finnegan's Wake (Viking Press, New York, 1939) p.383.

It is fun to speculate about the way quarks would behave if they were physical particles of finite mass

(instead of purely mathematical entities as they would be in the limit of infinite mass). Since charge

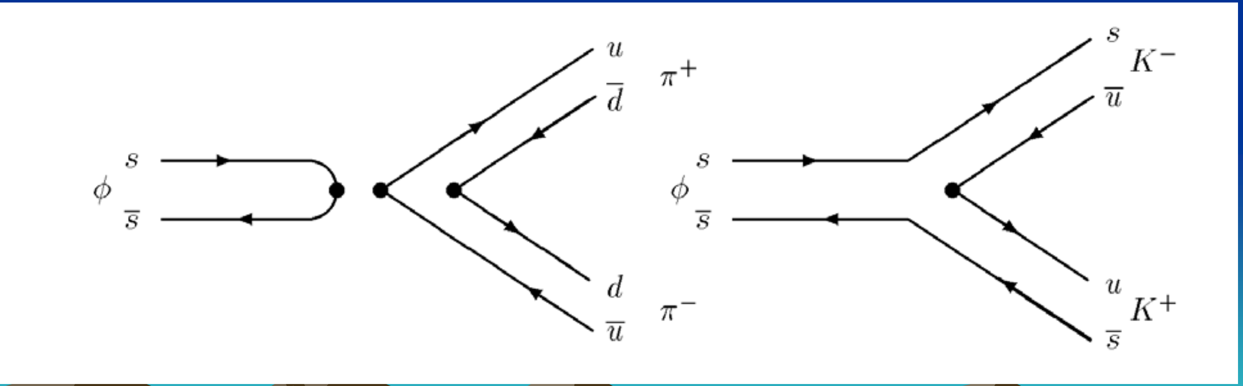
Zweig's Motive for the Ace Model

- ϕ(1020) m = 1019.460 ± 0.016 MeV

$Br = (7.4 \pm 0.5) \times 10^{-5}$ $(48.9 \pm 0.5)\%$

	ϕ	$\rightarrow$	$\pi^+\pi^-$	ϕ	$\rightarrow$	K^+K^-
$I_3:$	0		$+1+(-1)$	0		$\frac{1}{2}+(-\frac{1}{2})$
$Y:$	0		$0+0$	0		$1+(-1)$

This cannot understand from the conventional theory!



OZI rule (Okubo-Zweig-Izuka rule)

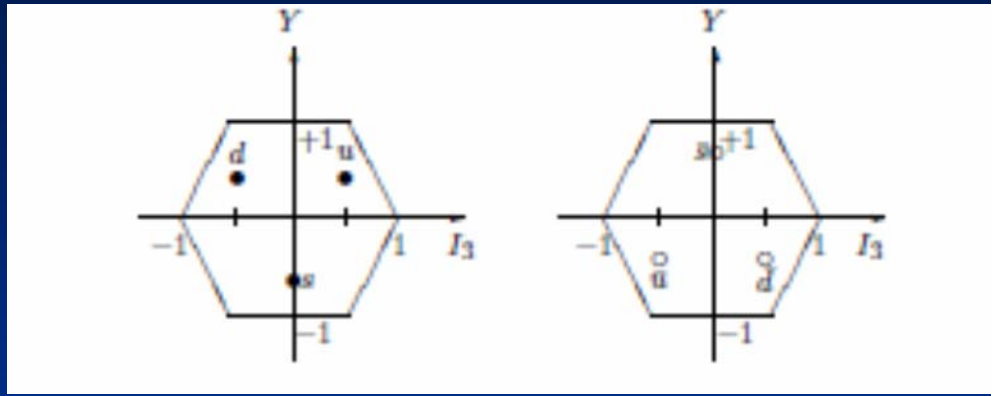
Response from the physics community of those days

The reaction of the theoretical physics community to the ace model was generally not benign. Getting the CERN report published in the form that I wanted was so difficult that I finally gave up trying[13,14]. When the physics department of a leading University was considering an appointment for me, their senior theorist, one of the most respected spokesmen for all of theoretical physics, blocked the appointment at a faculty meeting by passionately arguing that the ace model was the work of a "charlatan." The idea that hadrons, citizens of a nuclear democracy, were made of elementary particles with fractional quantum numbers did seem a bit rich. This idea, however, is apparently correct.

G. Zweig, "Origin of the quark model" CAIT-68-805
Invited talk, Baryon 1980 Conference

How about Sakata model

Quark-Ace Model
1964



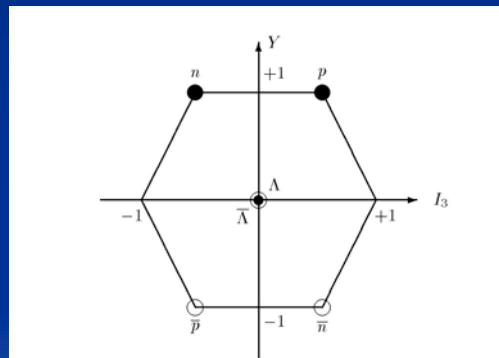
☆ Sakata Model (1956)
"Sakatons"

☆ Ikeda-Ogawa-Onuki

U(3) model: PTP (1959), (1960)

☆ **Why did he not reach to quark-ace model?**

☆ **They considered that the fundamental entities really exist.**



$$Q = I_3 + \frac{1}{2}Y$$

The Nobel Prize in Physics 1969

- "for his contributions and discoveries concerning the classification of elementary particles and their interactions"


Thank for your patient attention