Does Nature love the flavor *symmetry*?

（上帝喜歡味對稱嗎?）

To rethink from the bottom

正本清源

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"QCS2023"

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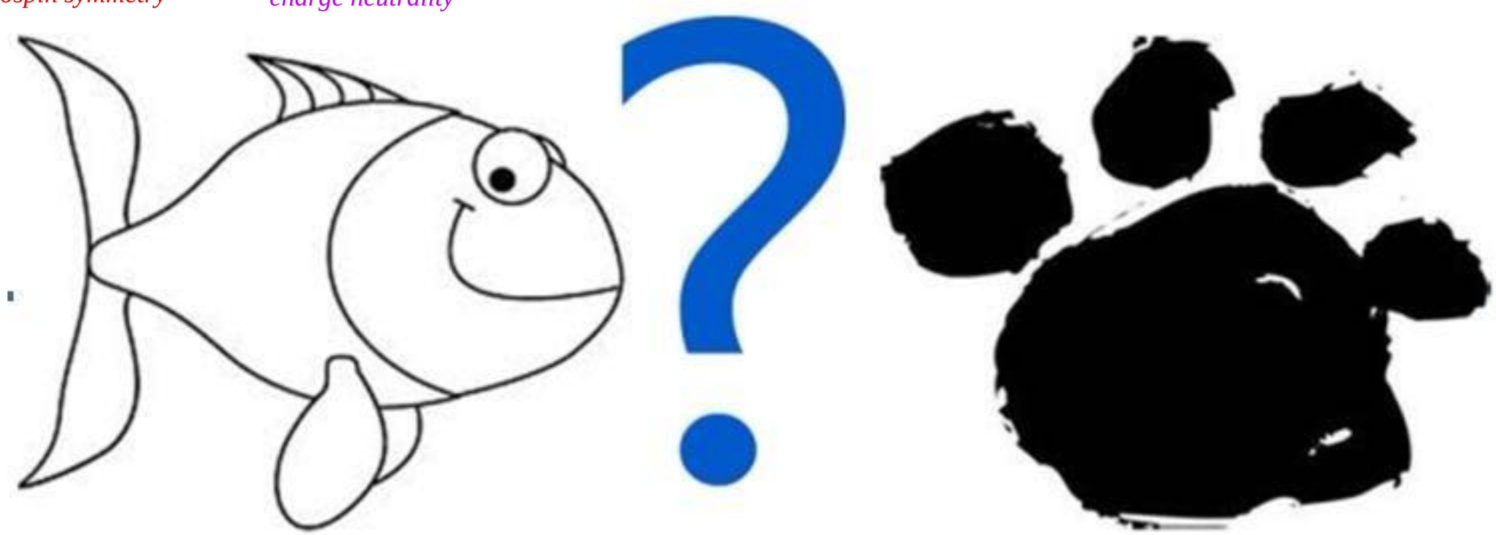
Does Nature love the flavor symmetry?

From *isospin symmetry* *and* *charge neutrality*
to the *atomic world*

（魚與熊掌不可兼得 → 原子世界）

isospin symmetry *charge neutrality*



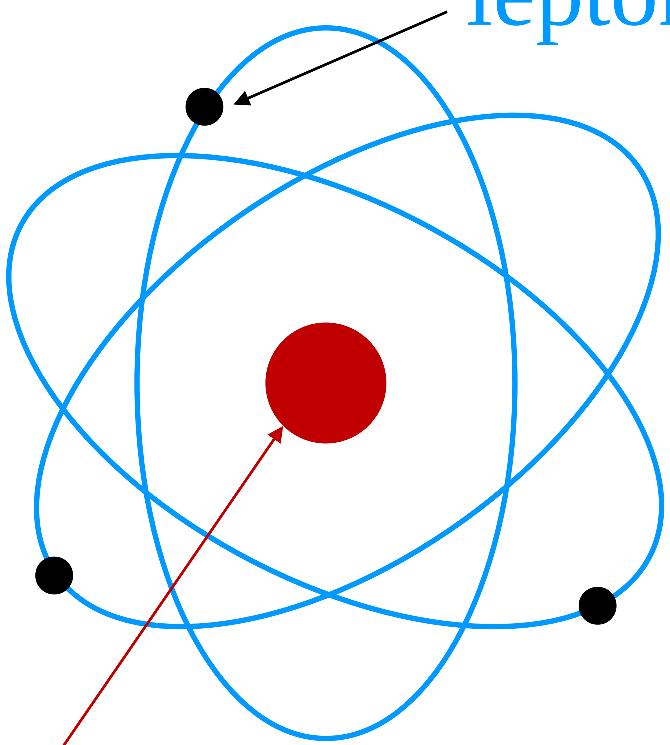
Isospin symmetry/charge neutrality

charge \ generation	1	2	3
~~+2/3~~ +1/3?	u	c	t
-1/3	d	s	b

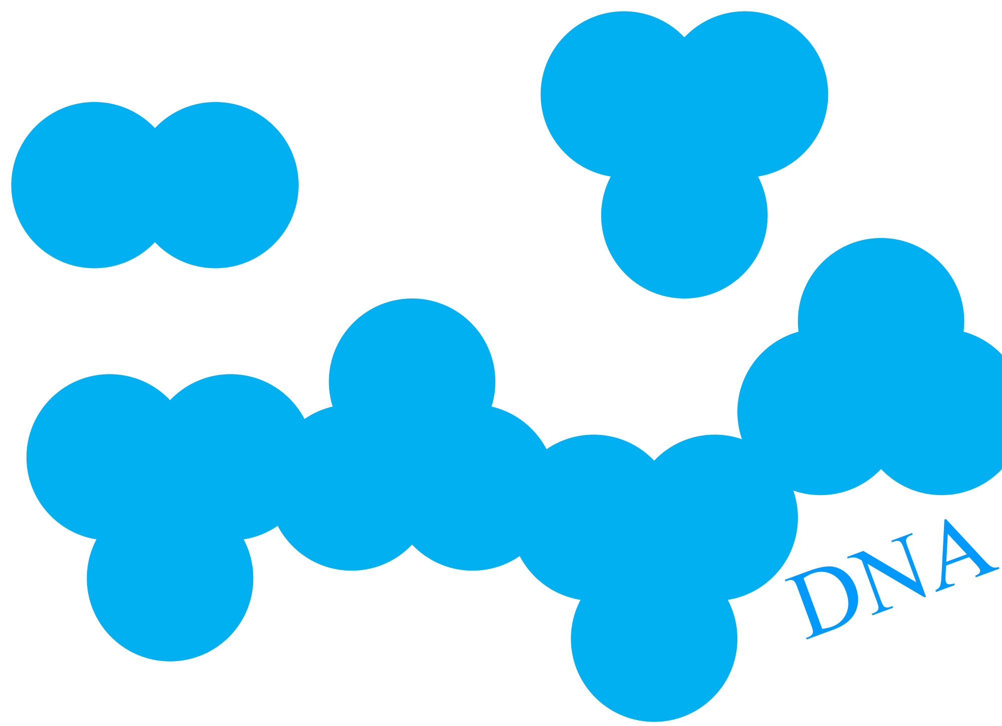
Isospin symmetry/charge neutrality

• We would therefore have atoms and beautiful world

leptons for neutrality, via EM-force



Our electric/atomic world



2-flaored strong matter

Isospin symmetry/charge neutrality

- Certainly, including the beautiful site of QCS2023

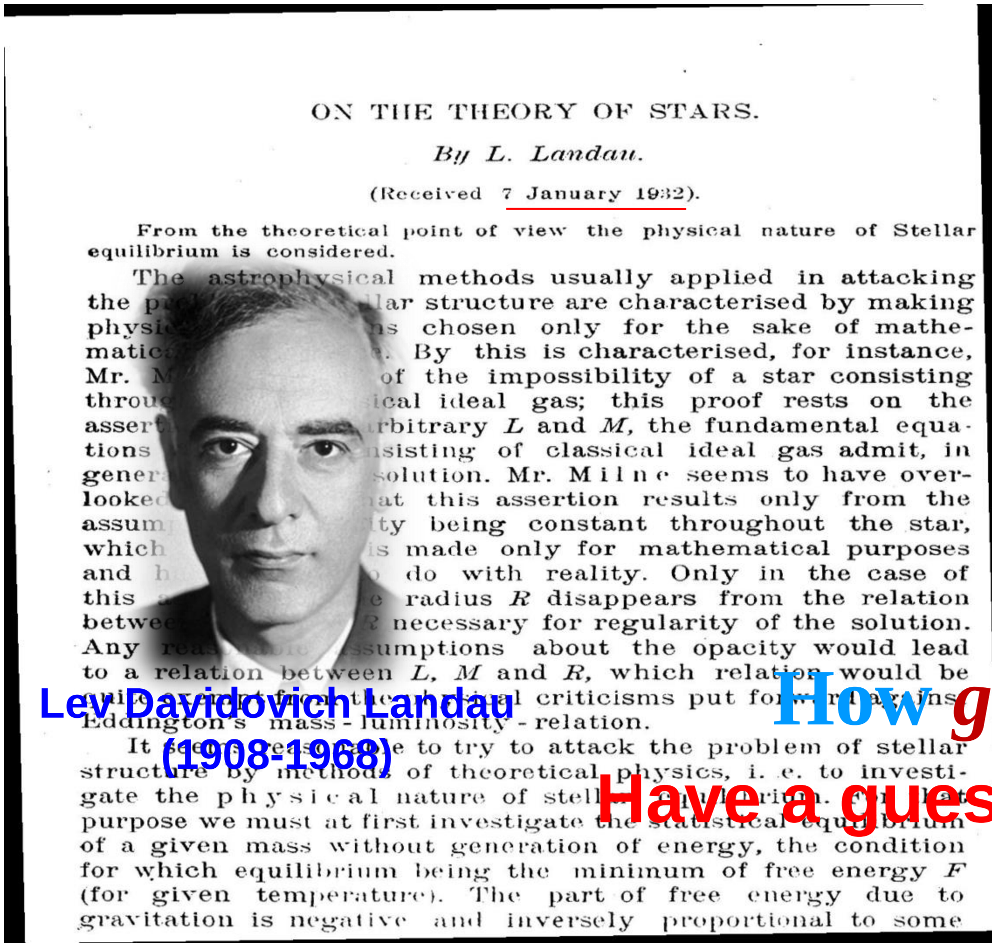
Does Nature love the flavor symmetry?

Can we have both *flavor symmetry and charge neutrality* when facing “gigantic nucleus”?

（望洋興嘆：既要又要?）

Strong matter in bulk

- What is a gigantic nucleus? anticipated by Landau'32



ON THE THEORY OF STARS.

By L. Landau.

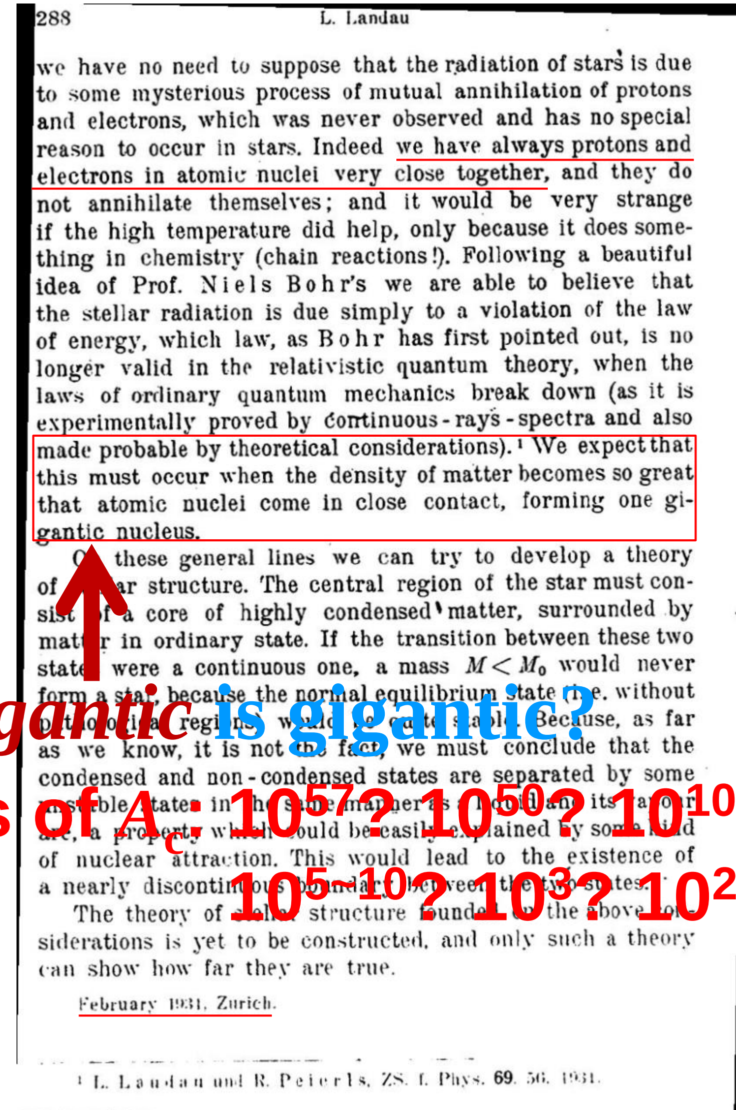
(Received 7 January 1932).

From the theoretical point of view the physical nature of Stellar equilibrium is considered.

The astrophysical methods usually applied in attacking the p[…]lar structure are characterised by making physi[…]ns chosen only for the sake of mathematic[…]. By this is characterised, for instance, Mr. M[…] of the impossibility of a star consisting throu[…]ical ideal gas; this proof rests on the assert[…]rbitrary L and M, the fundamental equations […]nsisting of classical ideal gas admit, in gener[…] solution. Mr. Milne seems to have overlooke[…]hat this assertion results only from the assum[…]ity being constant throughout the star, which […]is made only for mathematical purposes and h[…] do with reality. Only in the case of this […]e radius R disappears from the relation betwee[…] R necessary for regularity of the solution. Any rea[…]assumptions about the opacity would lead to a relation between L, M and R, which relation would be […]l criticisms put for[…] Eddington's mass - luminosity - relation.

It seems[…]e to try to attack the problem of stellar structure by methods of theoretical physics, i. e. to investigate the physical nature of stell[…]. For […] purpose we must at first investigate the statistical equilibrium of a given mass without generation of energy, the condition for which equilibrium being the minimum of free energy F (for given temperature). The part of free energy due to gravitation is negative and inversely proportional to some

Lev Davidovich Landau (1908-1968)



288 L. Landau

we have no need to suppose that the radiation of stars is due to some mysterious process of mutual annihilation of protons and electrons, which was never observed and has no special reason to occur in stars. Indeed we have always protons and electrons in atomic nuclei very close together, and they do not annihilate themselves; and it would be very strange if the high temperature did help, only because it does something in chemistry (chain reactions!). Following a beautiful idea of Prof. Niels Bohr's we are able to believe that the stellar radiation is due simply to a violation of the law of energy, which law, as Bohr has first pointed out, is no longer valid in the relativistic quantum theory, when the laws of ordinary quantum mechanics break down (as it is experimentally proved by continuous-rays-spectra and also made probable by theoretical considerations).[1] We expect that this must occur when the density of matter becomes so great that atomic nuclei come in close contact, forming one gigantic nucleus.

On these general lines we can try to develop a theory of stellar structure. The central region of the star must consist of a core of highly condensed matter, surrounded by matter in ordinary state. If the transition between these two states were a continuous one, a mass $M < M_0$ would never form a star, because the normal equilibrium state (i. e. without […] region) would […]. Because, as far as we know, it is not the fact, we must conclude that the condensed and non-condensed states are separated by some […] states in the same manner as […] are, a property which could be easily explained by some kind of nuclear attraction. This would lead to the existence of a nearly discontinuous boundary between the two states.

The theory of stellar structure founded on the above considerations is yet to be constructed, and only such a theory can show how far they are true.

February 1931, Zurich.

[1] L. Landau und R. Peierls, ZS. f. Phys. 69, 56, 1931.

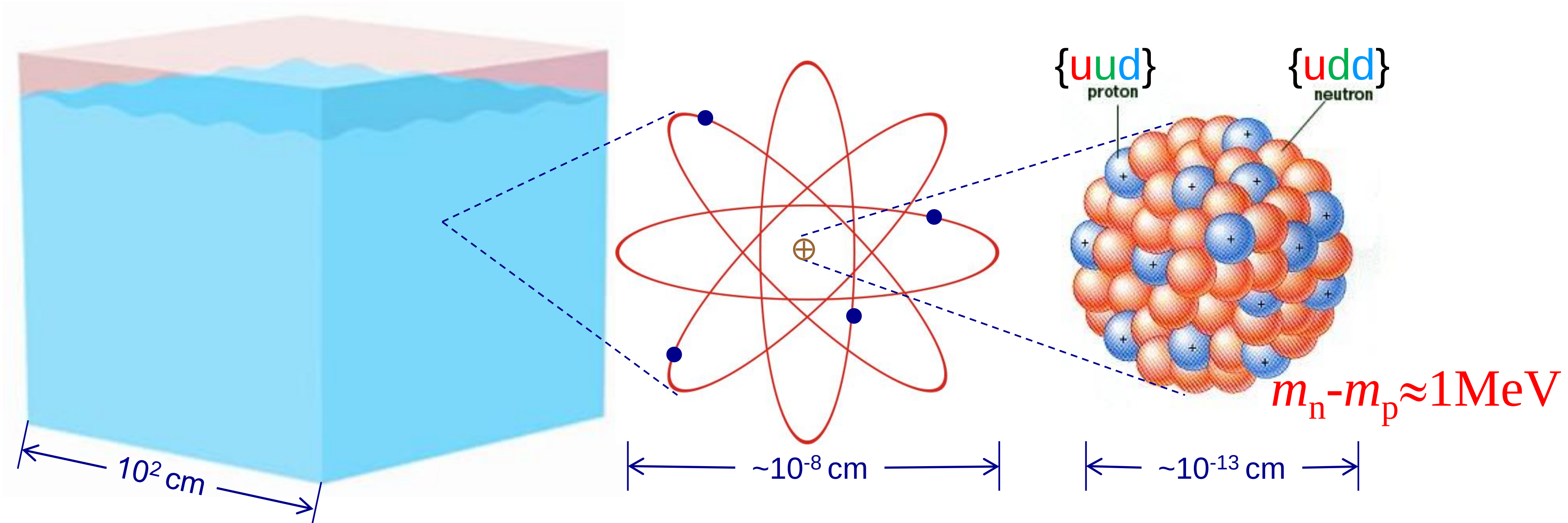
How *gigantic* is gigantic?

Have a guess of A_c: 10^{57}? 10^{50}? 10^{10}? $10^{5\sim10}$? 10^{3}? 10^{2} X

Landau L. 1932, *Sov. Phys.*, 1, 285

Strong matter in bulk

• Let's do an exercise…to squeeze one ton of water!



Before: baryon A_{water}~10^6g/u~10^{30}, Electrons E_e<1MeV

After the squeezing:

a, A giant "nucleus": $A_{water}^{1/3}$fm~10μm at ~ρ_{nucl}

b, Pauli principle ⇒ E_e~300MeV >> m_n-m_p > m_ec^2!!!

Strong matter in bulk

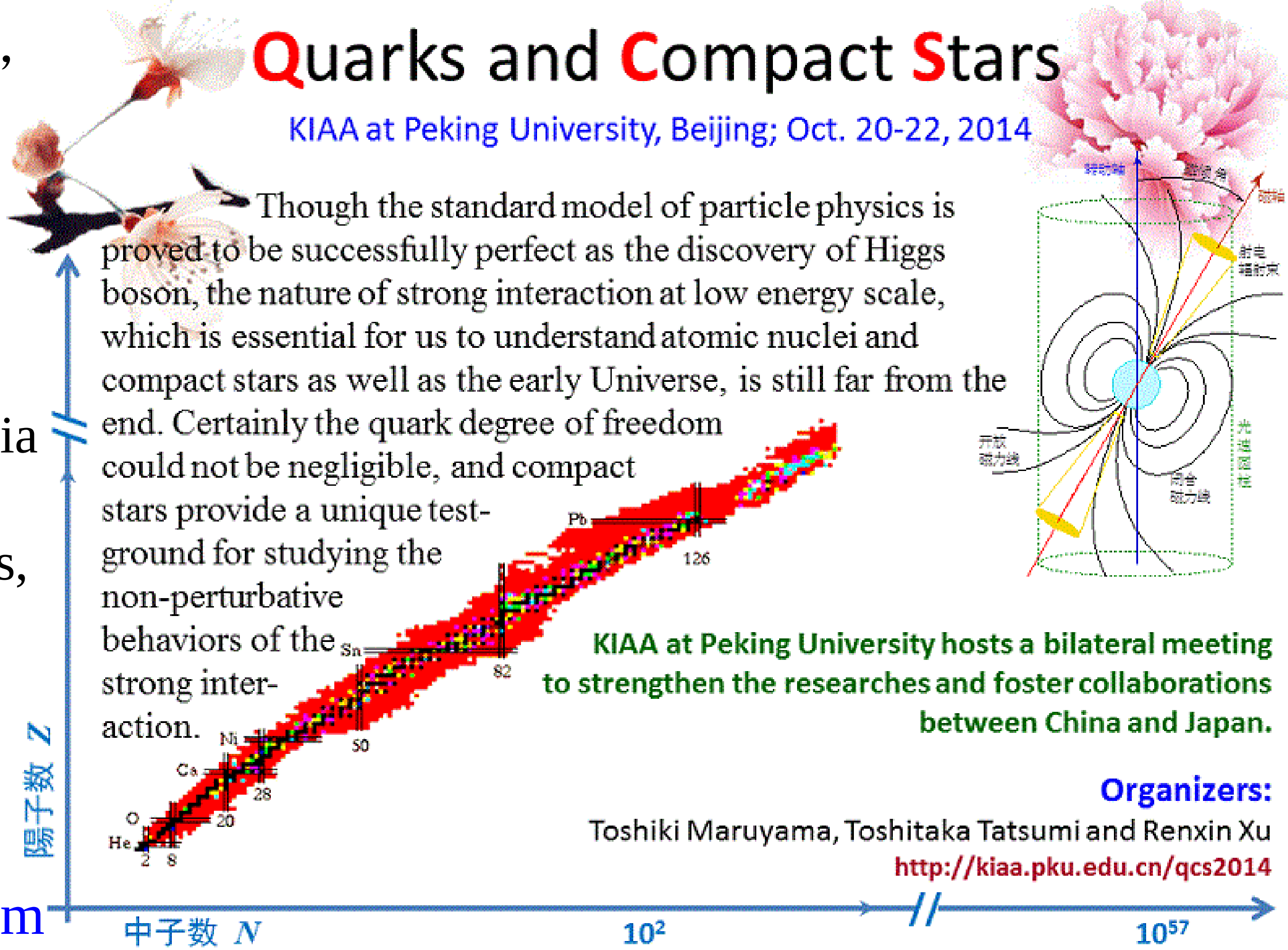
charge \ generation	1	2	3
+2/3	u	c	t
-1/3	d	s	b

neutronization

extremely asymmetric
isospin/2-flavors

Strong matter in bulk

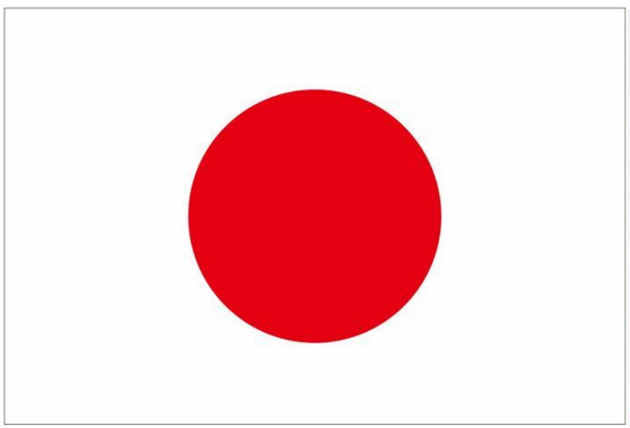
- **Nucleons** as the units: **atomic nucleus → NS**
- First QCS: 2014, KIAA @ PKU
- QCSII: 2017, Yukawa Institute, Kyoto
- QCSIII: 2019, Asia Pacific Center for Theoretical Physics, Busan Kyoto
- QCSIV: 2023, Yangzhou Univ., Sept. 23~26, qcs2023@126.com



Does Nature love the flavor symmetry?

What if Nature loves *flavor symmetry*?

Q



日本國旗

日本の国旗　日の丸

C

中國國旗

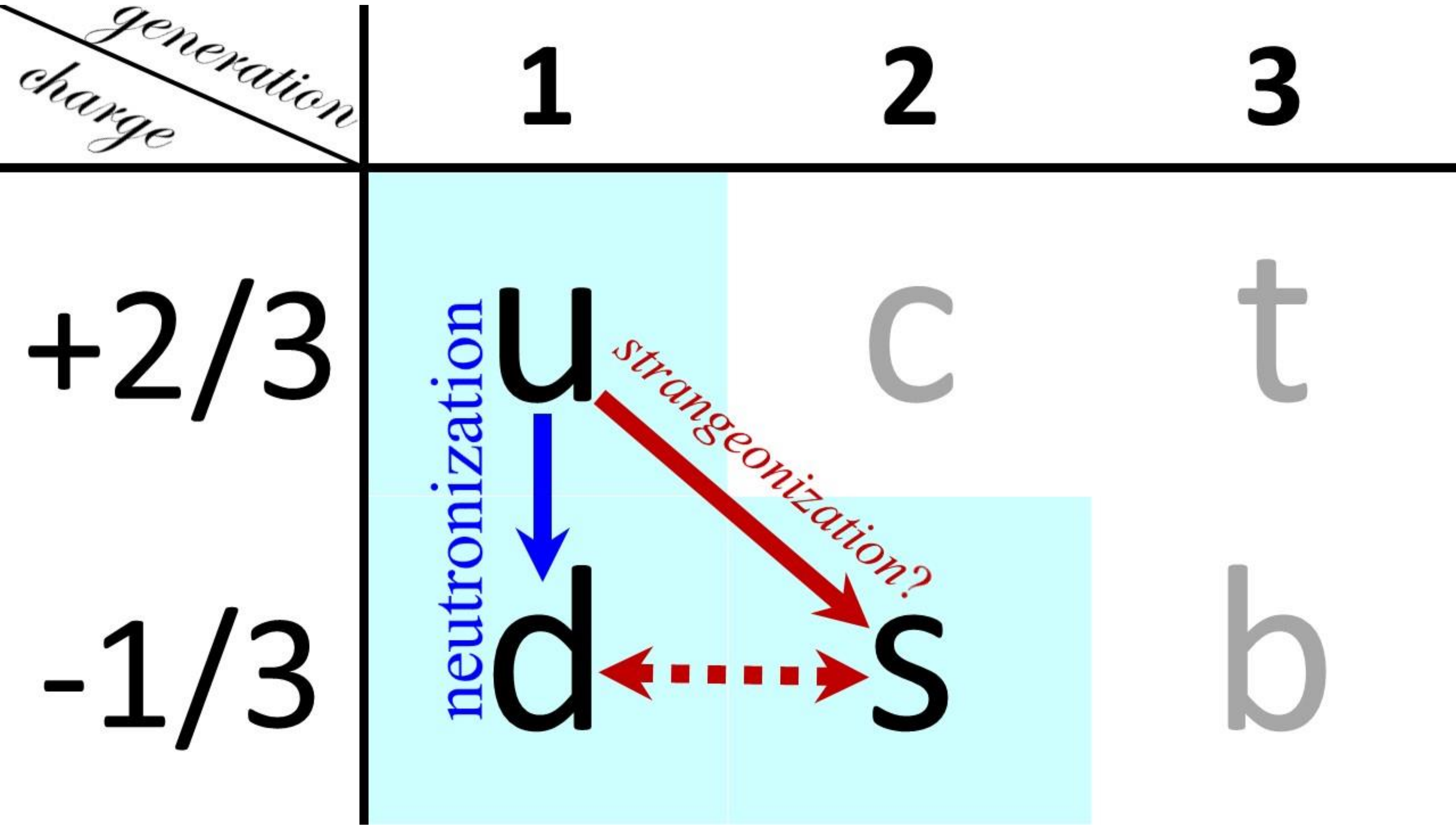
五星紅旗

S

大韓民國國旗

대한민국

What if Nature loves fla-symmetry?

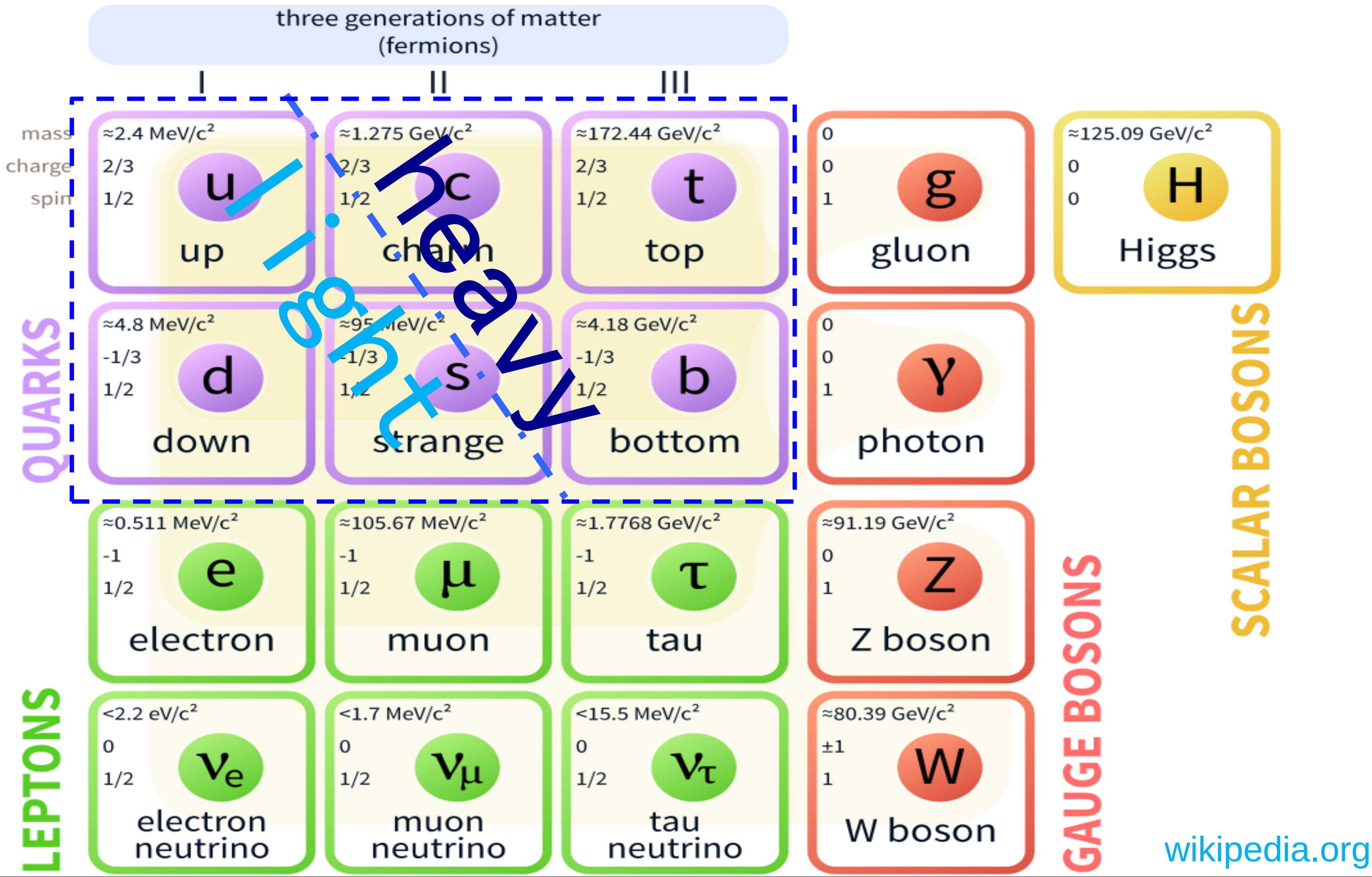


What if Nature loves fla-symmetry?

• Can we have both *fish*/fla.-sym. & *bear's paw*/neutrality?

$P = 0 \Rightarrow \ell \sim 0.5$ fm $\Rightarrow$

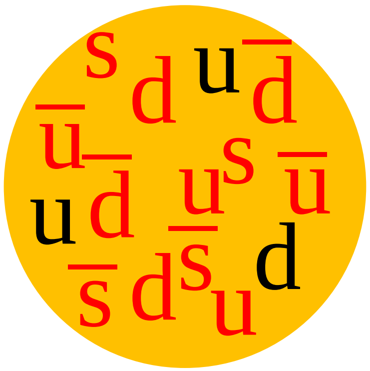
$pc \approx \hbar c/\ell \sim 0.5$ GeV!



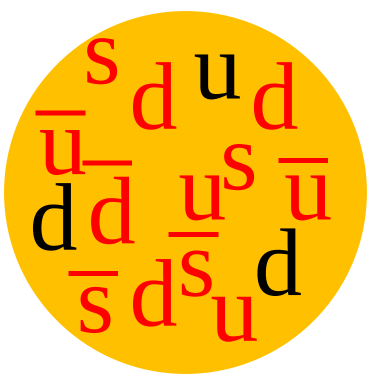
wikipedia.org

What if Nature loves fla.-symmetry?

- What's a **p**roton? What's a **n**eutron?



p$=\{u^{2}d^{1}s^{0}\}$



n$=\{u^{1}d^{2}s^{0}\}$

A perturbative calculation of quantum chromodynamics (QCD) may predict a nucleon sea with ***light-flavor symmetry***, but the observed flavor asymmetry in the light-quark sea would be the result of the non-perturbative nature.

Strangeness and Hadron Structure

John Ellis[a]

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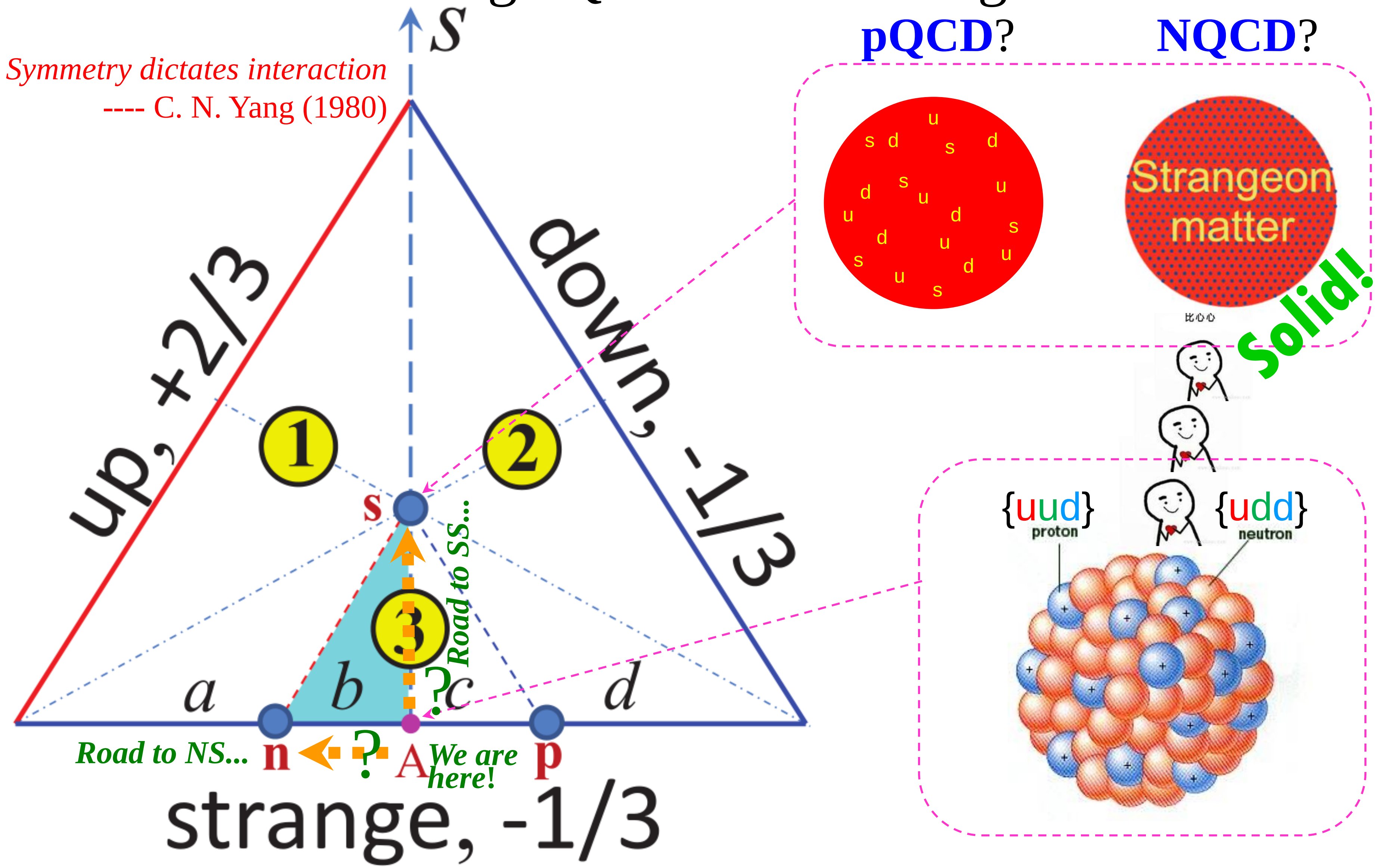
CH - 1211 Geneva 23

The nucleon wave function may contain a significant component of $\bar{s}s$ pairs, according to several measurements including the π-nucleon σ term, charm production and polarization effects in deep-inelastic scattering. In addition, there are excesses of ϕ production in LEAR and other experiments, above predictions based the naive Okubo-Zweig-Iizuka rule, that may be explained if the nucleon wave function contains a polarized $\bar{s}s$ component. This model also reproduces qualitatively data on Λ polarization in deep-inelastic neutrino scattering. The strange component of the proton is potentially important for other physics, such as the search for astrophysical dark matter.

CERN-TH/2000-112 hep-ph/0005322

What if Nature loves fla.-symmetry?

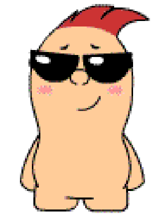
- Neutron star? Strange Quark star? Strangeon Star?



What if Nature loves fla.-symmetry?

- **Q**: Strangeon matter matters? I don't ...

- **A**: "***Old***" physics but particular consequence for us!



Trinity of Strangeon

- Strangeon stars: **compact objects**
  baryon number: $A \approx 10^{57}$!

to be testable!

- Strangeon cosmic ray: **UHECR**
  $A = 10^{10} \Leftrightarrow E_{\rm rest} \approx 10^{19}$ eV

- Strangeon dark matter: **cosmology**
  $n_{\rm sdm} \simeq 10^{-16}/A_{30}$ km^{-3} , Earth $\sim 80/A_{30}$ yr^{-1}
  Moon $\sim 6/A_{30}$ yr^{-1}

Strangeon forms first $\Rightarrow A_{\rm sdm} \geq A_{\rm c} \sim 10^9$?

Summary

Summary

- It has been more than ***90 years*** since Landau superficially anticipated "neutron"/neutral stars, but the real **basic unit** inside a gigantic nucleus is still a matter of debate, in fact.

- In the triangle, the units could be **3**-flavour ***symmetric strangeons*** rather than **2**-flavour ***asymmetric nucleons*** if the Nature really loves symmetry when building the world.

- To test the strangeon models in the future…

THANKS!