From Quark to *Quake*

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"Quakes: from the Earth to Stars"

Dream Field (桃源洞) near FAST, Guizhou; May 20~23, 2023

丰富多彩的物质世界

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- the **Material world**: ***strong*** besides ***electric***?

electric matter

interaction inbetween ***electric***magnetic

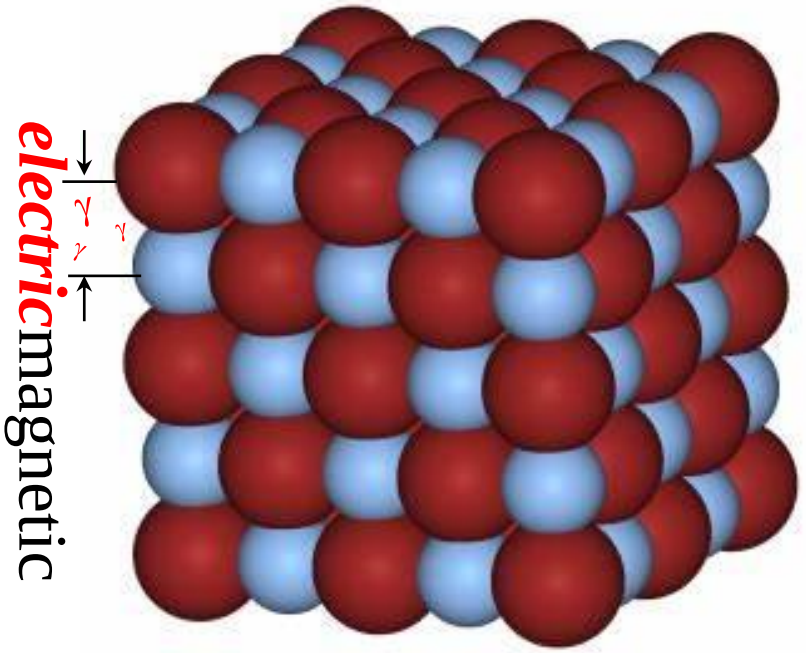
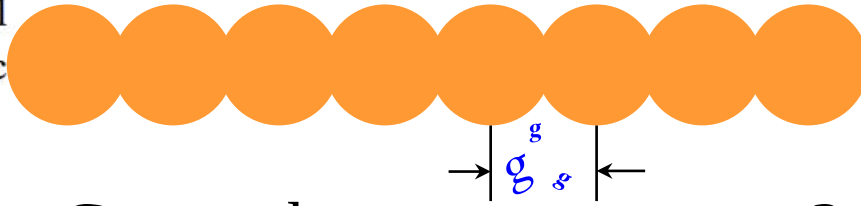


FIGURE 1 A rock containing copper (Malachite). Normal atom matter at pressure free is condensed by the electromagnetic (or simply electric) force, while the strangeon matter, to be explained in §6, is by the fundamental strong interaction. Multiscale forms can exist for both kinds of condensed matter, the electric and the strong ones

Xu (2023)



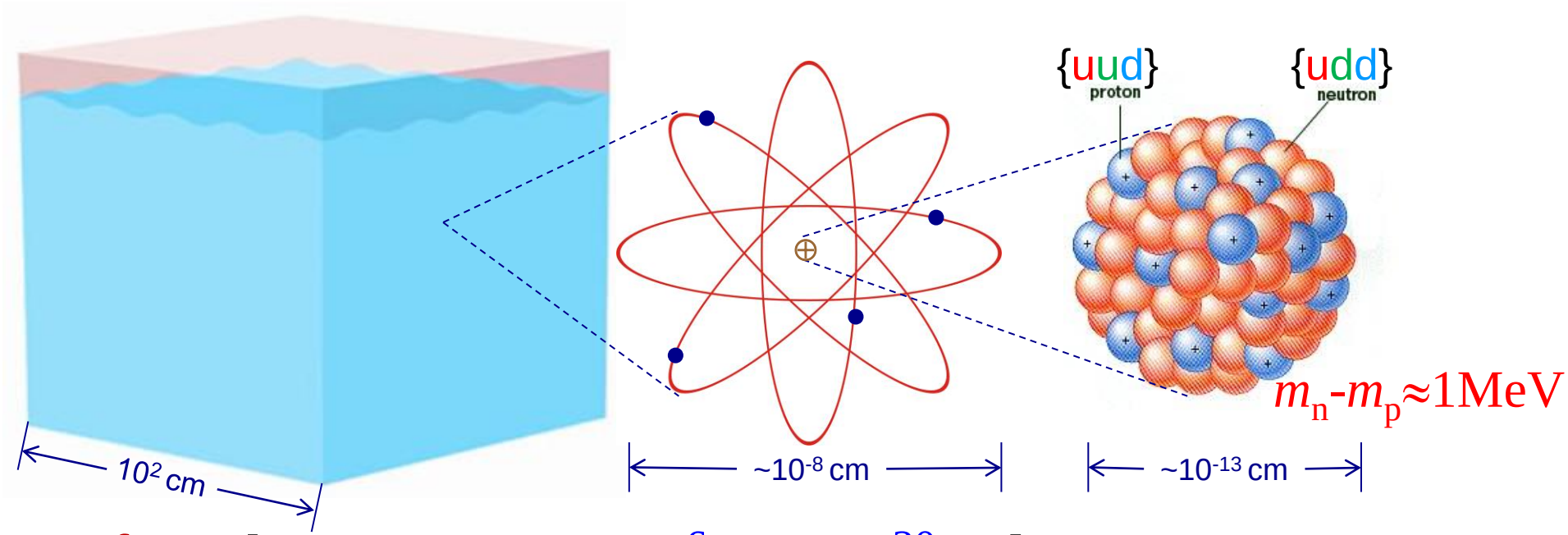
Can we have ***strong*** matter?

凝聚态物质：

从电到强

凝聚态物质：从电到强

- 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 >> $m_e c^2$!!!

屠龙之术?

凝聚态物质：从电到强

- Landau (1932)'s neutralization: $e^- + p^+ \rightarrow n^0 + \nu_e$

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 s chosen only for the sake of mathe- matic . By this is characterised, for instance, Mr. M of the impossibility of a star consisting throu ical ideal gas; this proof rests on the asser rbitrary L and M, the fundamental equa- tions sisting of classical ideal gas admit, in gener solution. Mr. Milne seems to have over- looke at this assertion results only from the assum ty being constant throughout the star, which is made only for mathematical purposes and h do with reality. Only in the case of this radius R disappears from the relation betwe necessary for regularity of the solution. Any rea ssumptions about the opacity would lead to a relation between L, M and R, which relation would be [illegible] criticisms put for Eddington's mass-luminosity-relation.

It seems possible to try to attack the problem of stellar structure by methods of theoretical physics, i. e. to investigate the physical nature of stellar equilibrium. For that 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)

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

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.

How *gigantic* is gigantic?

these general lines we can try to develop a theory of ar 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 [illegible] regions) would be stable. 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 unstable states in the same manner as a liquid and its vapour 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.

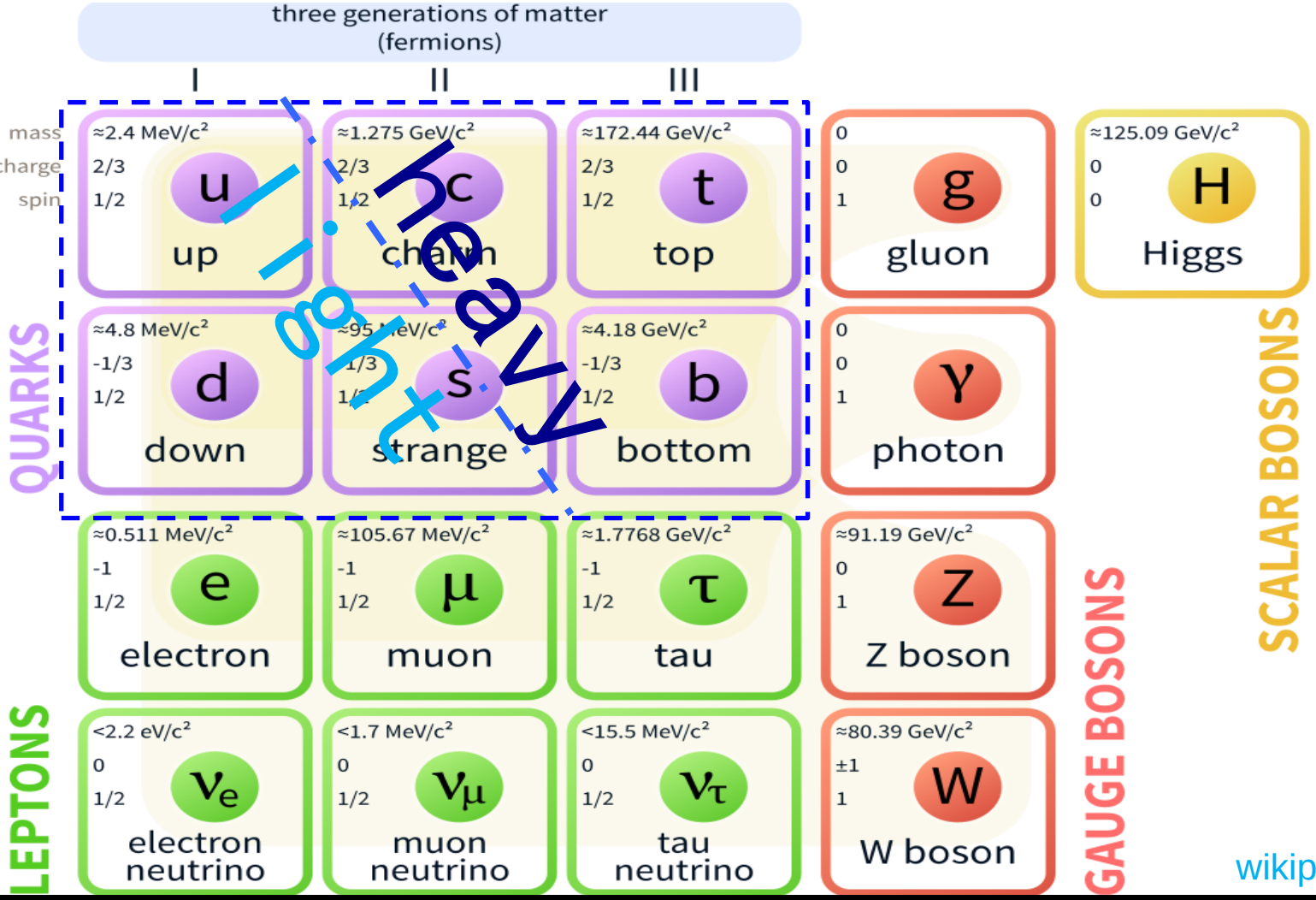
The theory of stellar structure founded on the above considerations is yet to be constructed, and only such a theory can show how far they are true.

February 1931, Zurich.

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

Now is era of the *standard* model!

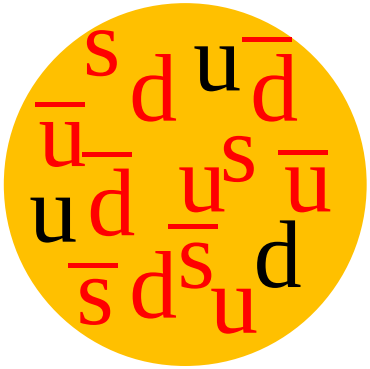
- Quark flavors in the standard model of particle physics



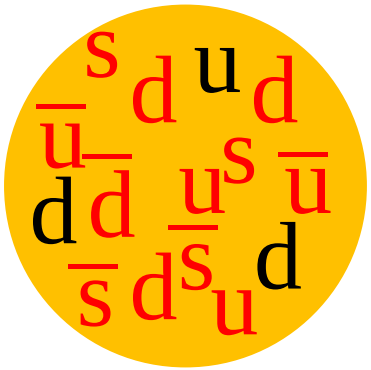
wikipedia.org

Now is era of the *standard* model!

- 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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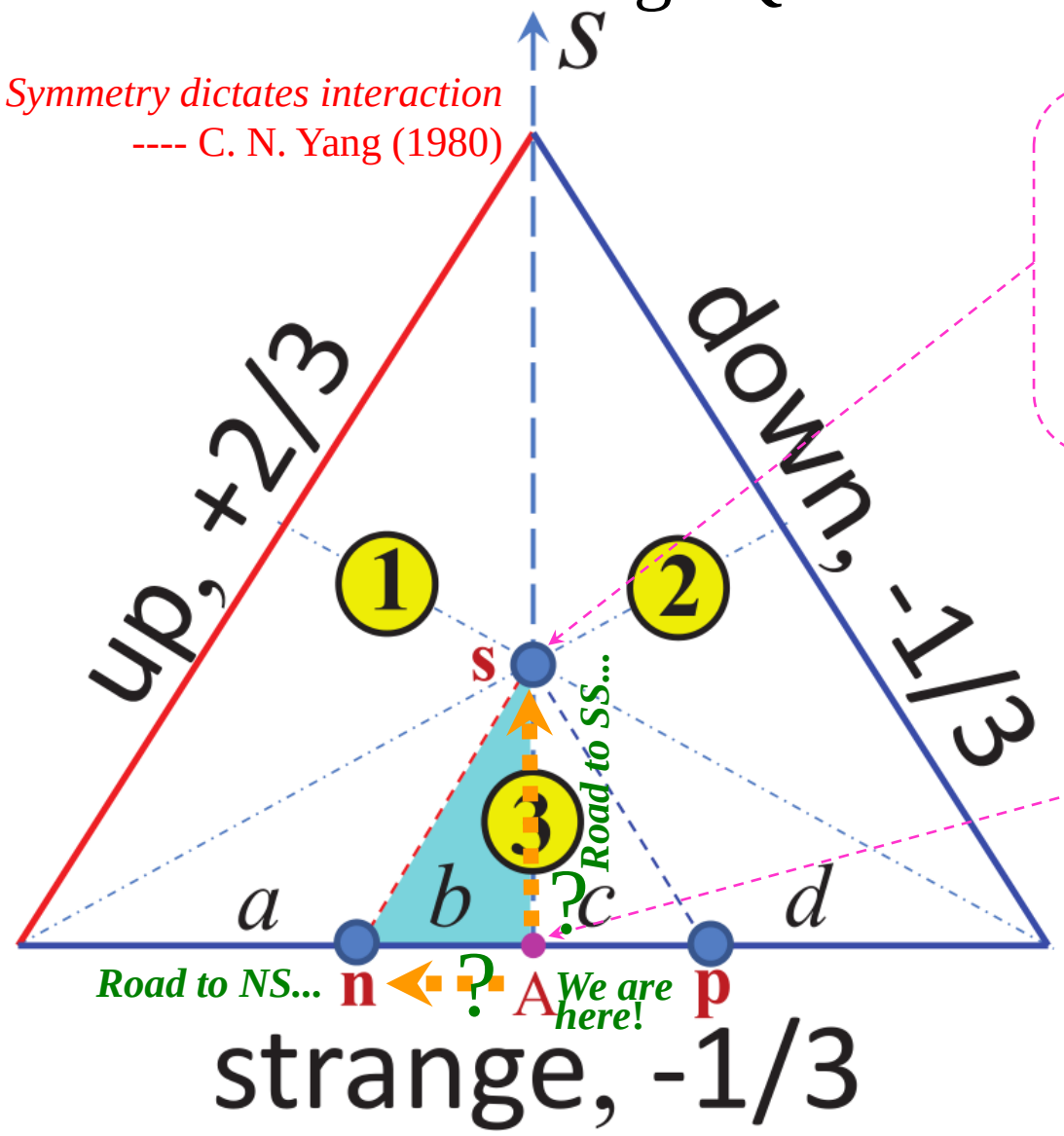
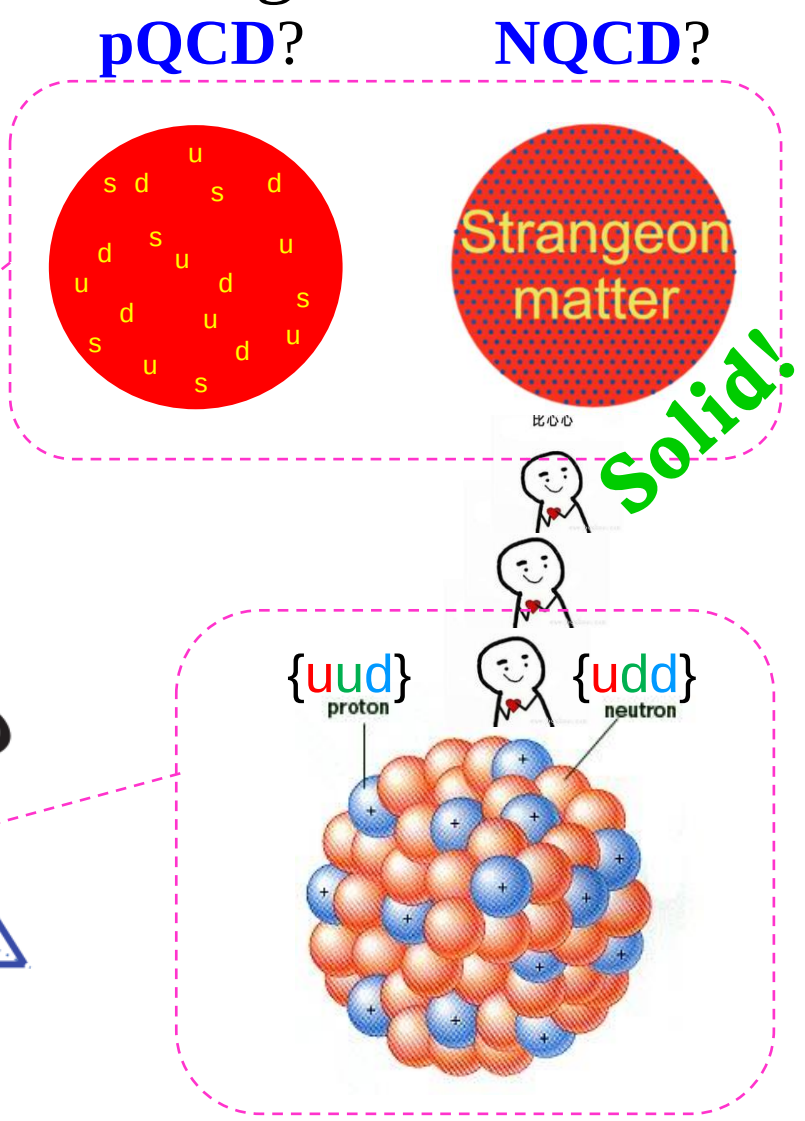
The nucleon wave function may contain a significant component of $\bar{s}s$ pairs, according to several measurements including the π-nucleon σ term, charm production and polarization effects in deep-inelastic scattering. In addition, there are excesses of ϕ production in LEAR and other experiments, above 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

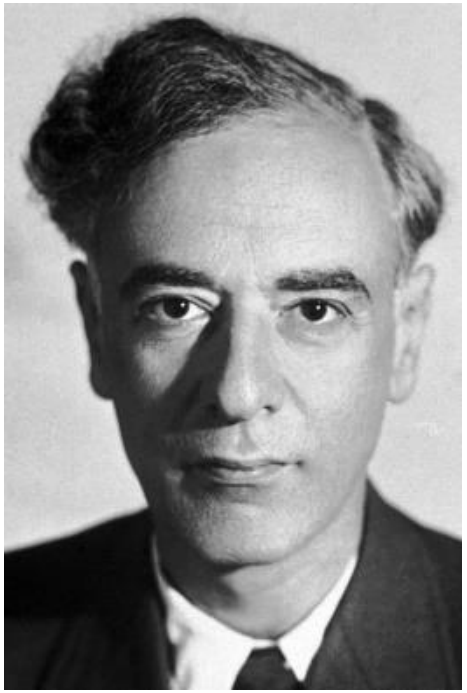
Other ***two*** along with Landau (1932)

- Neutron star? Strange Quark star? Strangeon Star?





Three Arguments to Strangeon Star



Lev Davidovich Landau
(1908-1968)

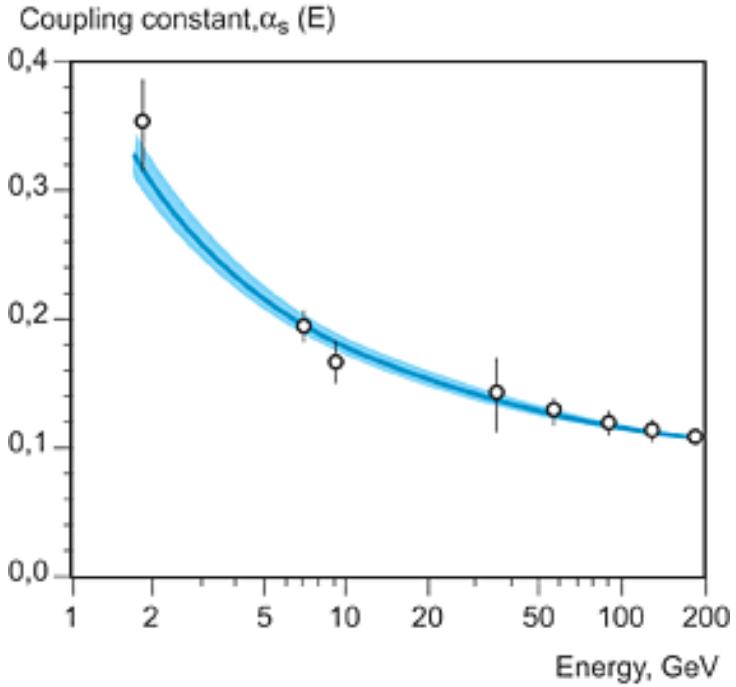
Neutrality

Proton Star?

Edward Witten
(1951-)

New-degree

Symmetry Energy?



Strong-coupling QCD
(1973-)

No-perturbativity

Nucleons in Nucleus?

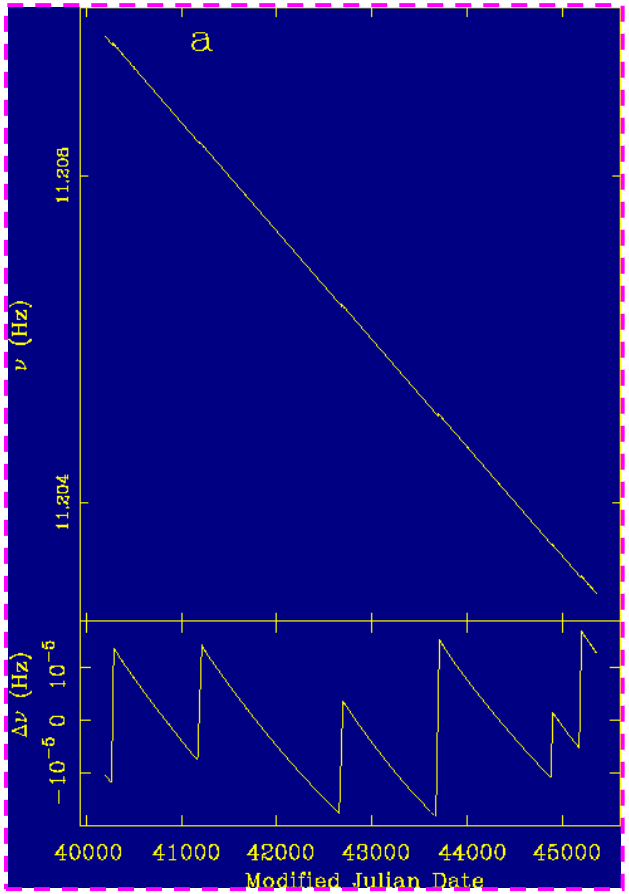
strangeon star

星震诱发的后果：

自转/释能

星震诱发的后果：自转/释能

- Quake-induced decrease of I



Glitches

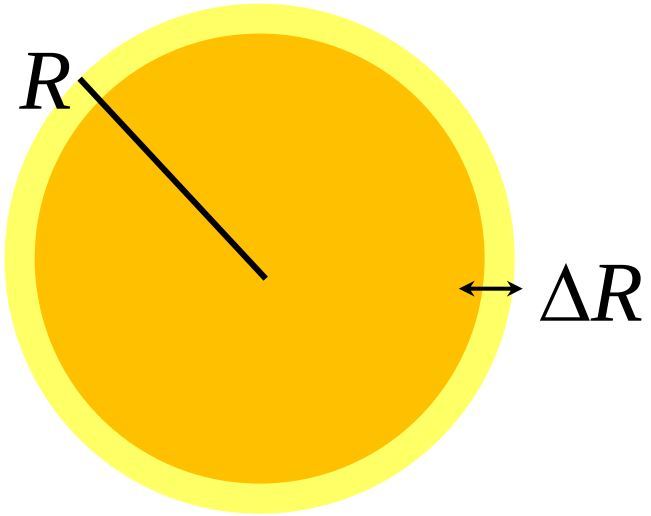
$$\delta(I\cdot\Omega) = 0$$

$$\delta\Omega/\Omega = -\,\delta I/I$$

Glitch amplitude:
$\delta\Omega/\Omega \sim 10^{-5}, \ldots 10^{-9} \ldots$

星震诱发的后果：自转/释能

- Quake-induced release of *free energy*



$$E_{\rm stored} \approx \frac{GM^2}{R} \sim 10^{53}\,\frac{\Delta R}{R}\ \ {\rm ergs}$$

for $M \sim M_\odot$

AXP/SGRs (flares, even superflares), GRBs, FRBs…

magnetars vs. *strangeon stars*?

- Seismological feature: a series of quakes?

E. T. Herrin & V. L. Teplitz (1996 PRD)

总　结

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- 理解丰富的物质世界促进人类文明与进步。
- 类似于电磁力凝聚原子而成的物质，**原子核**由强力凝聚**核子**（p/n）而成，但不足10fm。
- 宇宙中存在**巨核**（gigantic nucleus）吗？Landau于1932年就给出肯定回答：中子星！
- 推测构成致密星的基本单元是**奇子**，则固体奇子星的**星震**导致：自转突变和能量释放。
- 星震的深入研究值得期待...

THANKS!