A General

Bodmer-Witten Conjecture

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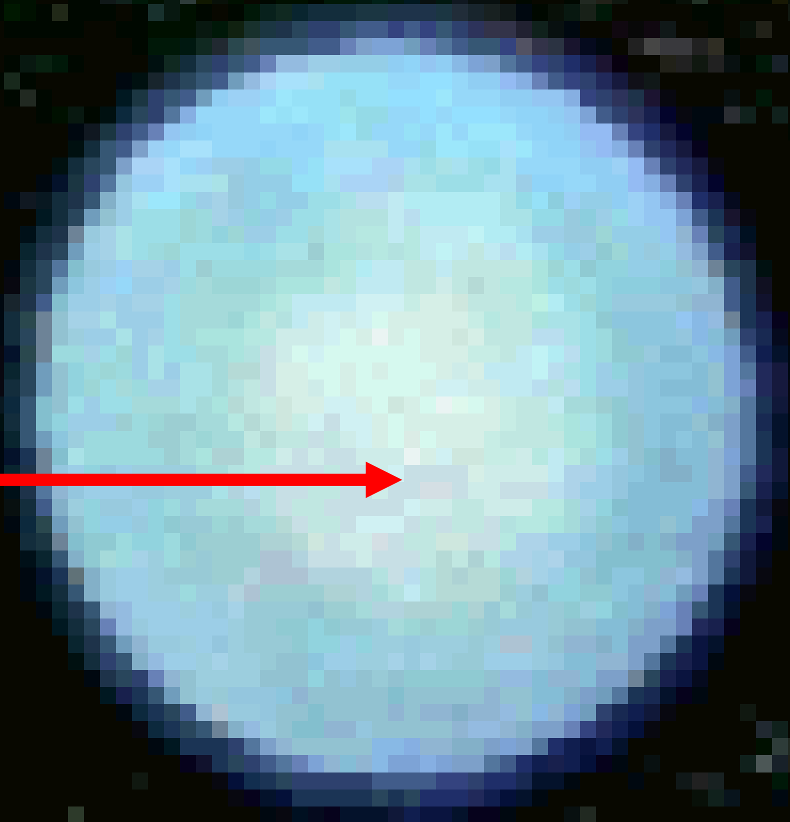
Compact Stars in the QCD phase diagram V

May 23-27, 2016; GSSI/LNGS, Italy

What's the nature of pulsar?

One of the most challenging problems in phys./astroph.

Normal baryonic matter is intensely compressed by gravity here!



Pulsar = Strange Star if B-W conjecture is correct.

I would like to explain the conjecture and its extension…

Summary

- What's Bodmer-Witten conjecture?
- B-W conjecture generalized?
- Observational proof?
- Conclusions

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What's Bodmer-Witten conjecture?

- What's Bodmer-Witten conjecture?

It is also called as *Witten conjecture*, but ***NOT*** that in algebraic geometry.


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Witten conjecture

From Wikipedia, the free encyclopedia

In algebraic geometry, the **Witten conjecture** is a conjecture about intersection numbers of stable classes on the moduli space of curves, introduced by Witten (1991), and generalized in Witten (1993). Witten's original conjecture was proved by Kontsevich (1992).

Witten's motivation for the conjecture was that two different models of 2-dimensional quantum gravity should have the same partition function. The partition function for one of these models can be described in terms of intersection numbers on the moduli stack of algebraic curves, and the partition function for the other is the logarithm of the τ-function of the KdV hierarchy. Identifying these partition functions gives Witten's conjecture that a certain generating function formed from intersection numbers should satisfy the differential equations of the KdV hierarchy.

Contents [hide]

What’s Bodmer-Witten conjecture?

- Witten’s impact on dense matter/*strangeness* phys.

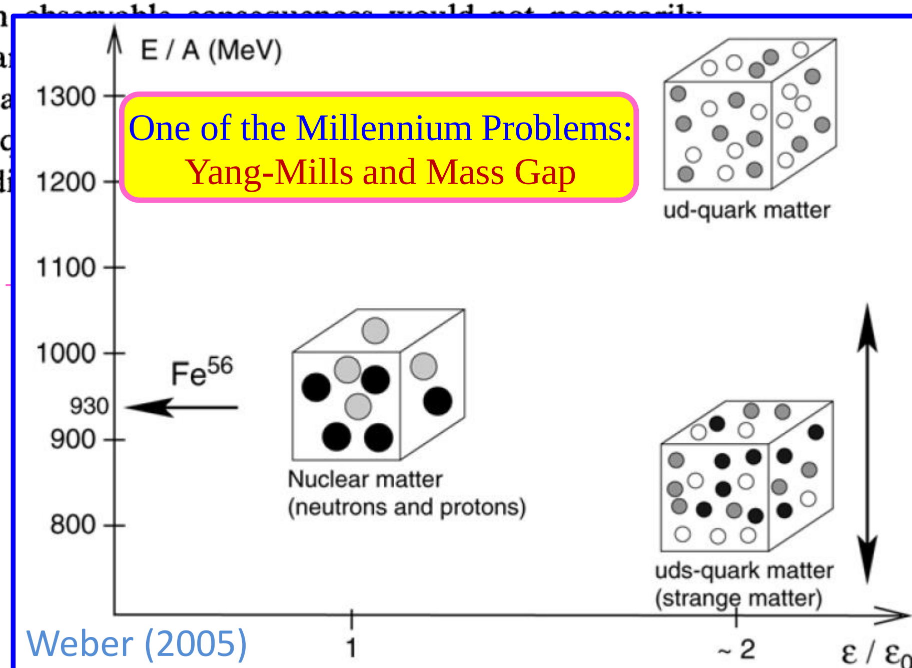
PHYSICAL REVIEW D VOLUME 30, NUMBER 2 15 JULY 1984

Cosmic separation of phases

Edward Witten*
Institute for Advanced Study, Princeton, New Jersey 08540
(Received 9 April 1984)

A first-order QCD phase transition that occurred reversibly in the early universe would lead to a surprisingly rich cosmological scenario. Although
survive, it is at least conceivable that the phase tra
cess in dense, invisible quark nuggets, providing a
QCD effects only. This possibility is viable only if c
MeV. Two related issues are considered in appendi
quark-matter component of cosmic rays, and the
have produced a detectable gravitational signal.

Strange quark matter in bulk may constitute the true ground state of the strong-interaction matter rather than ^{56}Fe.



Weber (2005)

What's Bodmer-Witten conjecture?

- An intuitional explain of Witten conjecture

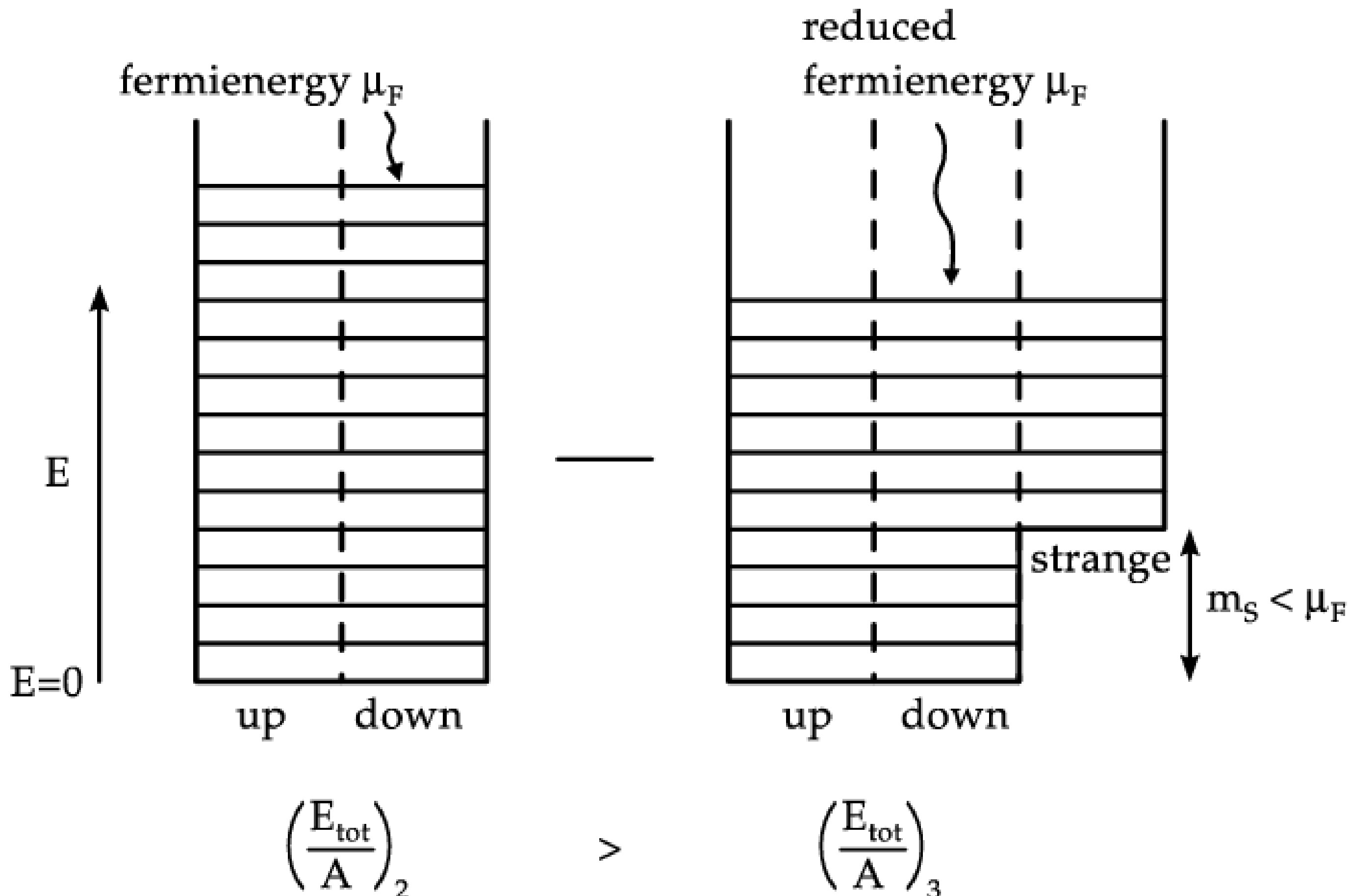
$m_u = 2\sim8$ MeV

$m_d = 5\sim15$ MeV

$m_s \sim 100$ MeV

$\rho = 2\rho_N$

$\mu_F \sim 500$ MeV



Greiner et al. (1998)

What's Bodmer-Witten conjecture?

- Witten's idea had already discussed in 1970s

PHYSICAL REVIEW D VOLUME 4, NUMBER 6 15 SEPTEMBER 1971

Collapsed Nuclei*

A. R. Bodmer
Nuclear Physics Laboratory, Oxford, England
and Argonne National Laboratory, Argonne, Illinois† 60439
and University of Illinois, Chicago, Illinois† 60680
(Received 29 March 1971)

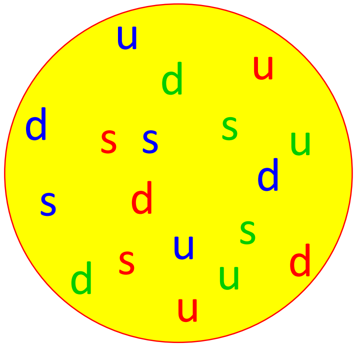
We discuss the observational consistency, possible properties, and detection of collapsed nuclei C_A. These may be considered as elementary particles with mass number $A>1$ and of much smaller radius than ordinary nuclei N_A. The existence of C_A of (perhaps much) lower energy than N_A is observationally consistent if N_A are very long-lived isomers against collapse because of a "saturation" barrier between C_A and N_A. Barrier-penetrability estimates show that sufficiently long lifetimes $\gtrsim 10^{31}$ sec are plausible for $A \gtrsim 16-40$. The properties of C_A are discussed using composite baryon and quark models; small charges and hypercharges and, especially, neutral C_A are possible. C_A can be effectively a source or sink of baryons. Some astrophysical implications are briefly discussed, in particular the possible large scale presence of C_A and the possibility that accelerated collapse in massive objects may be a source of energy comparable to the rest mass.

Therefore, we call it as Bodmer-Witten conjecture.

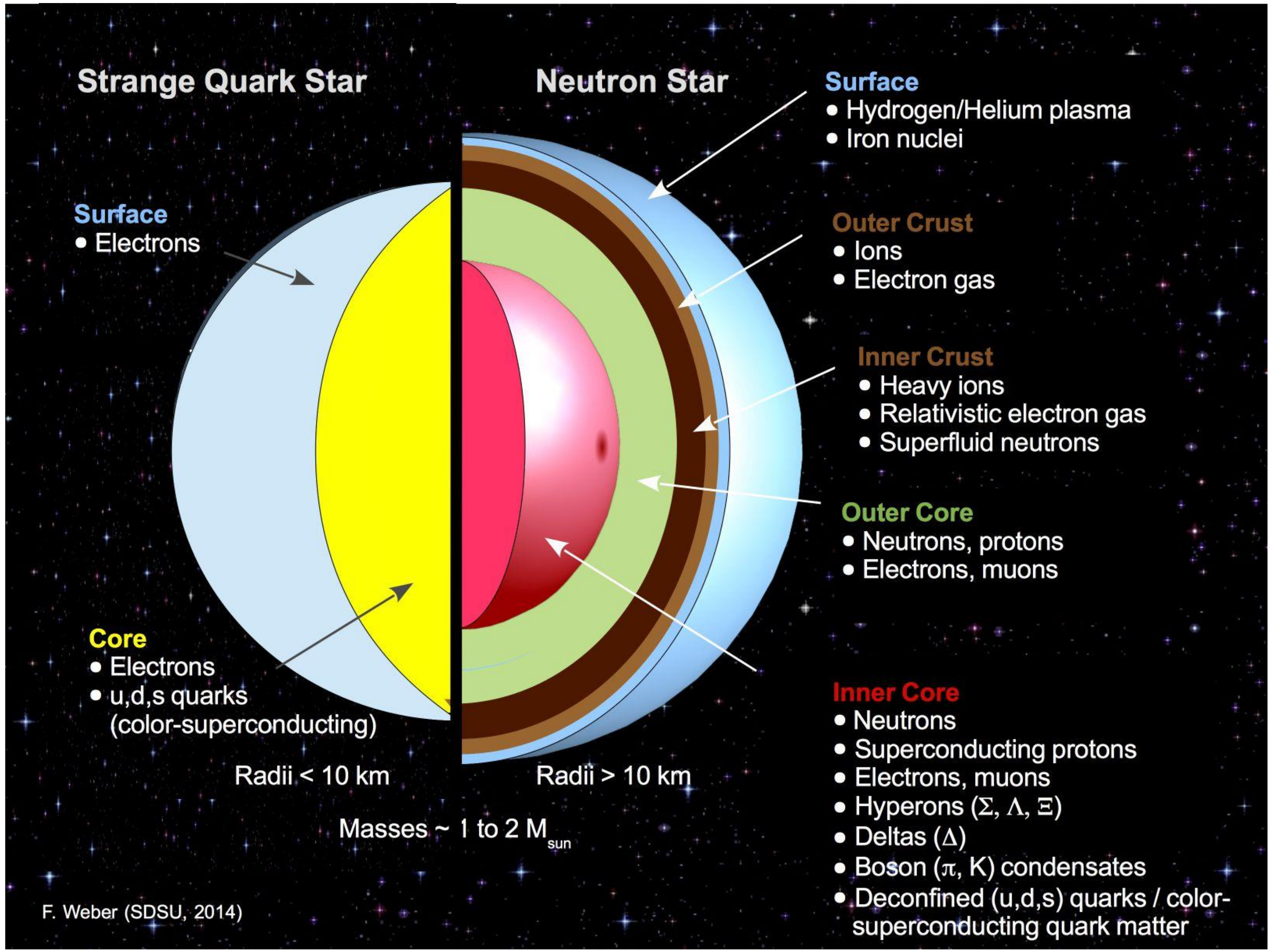
What's Bodmer-Witten conjecture?

- What if Bodmer-Witten conjecture is correct?

Pulsars are strange quark stars, rather than neutron stars! *simply*



number ~ 10^{57}!



Summary

- What's Bodmer-Witten conjecture?

✓ B-W conjecture generalized?

- Observational proof?
- Conclusions

B-W conjecture generalized?

- A general B-W conjecture?

Strange ~~quark~~ cluster matter in bulk may constitute the true ground state of the strong-interaction matter rather than ^{56}Fe.

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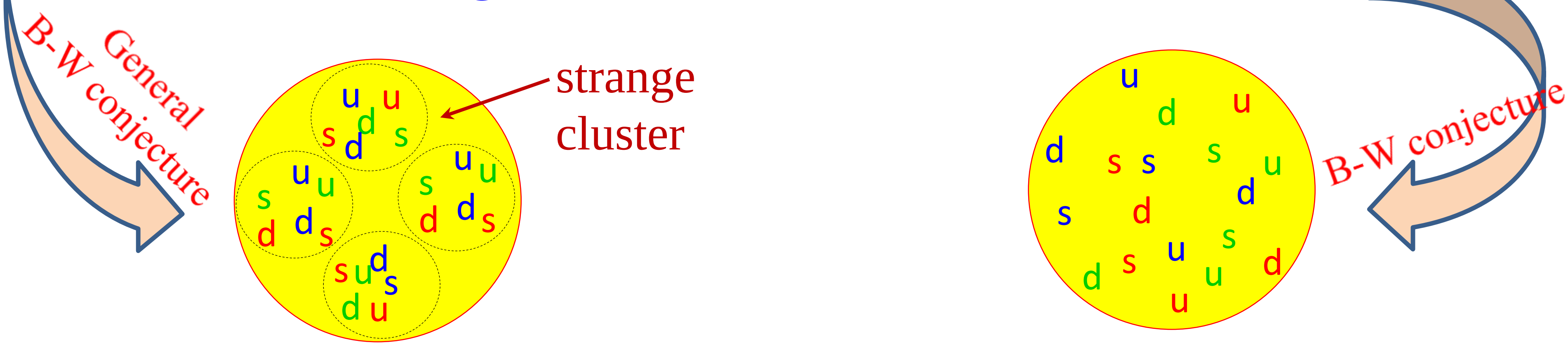
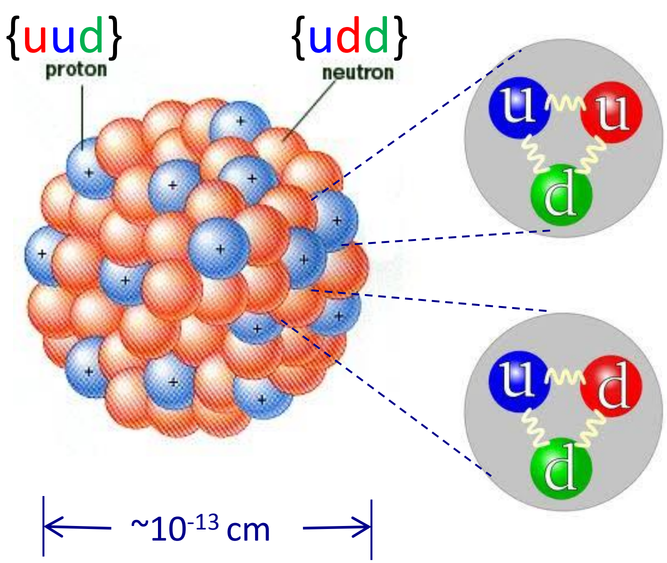


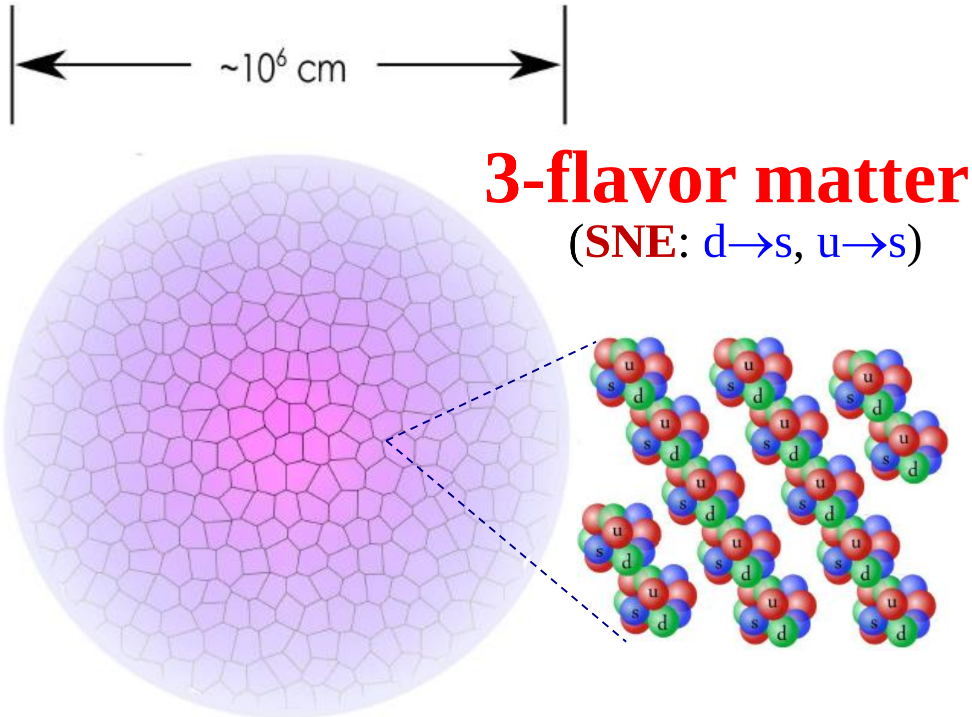
Strange ***Cluster*** Matter
(cluster number ~ 10^{57} for star)

Strange ***Quark*** Matter
(quark number ~ 10^{57} for star)

B-W conjecture generalized?

- A strange *cluster* star is 3-flavor gigantic nucleus





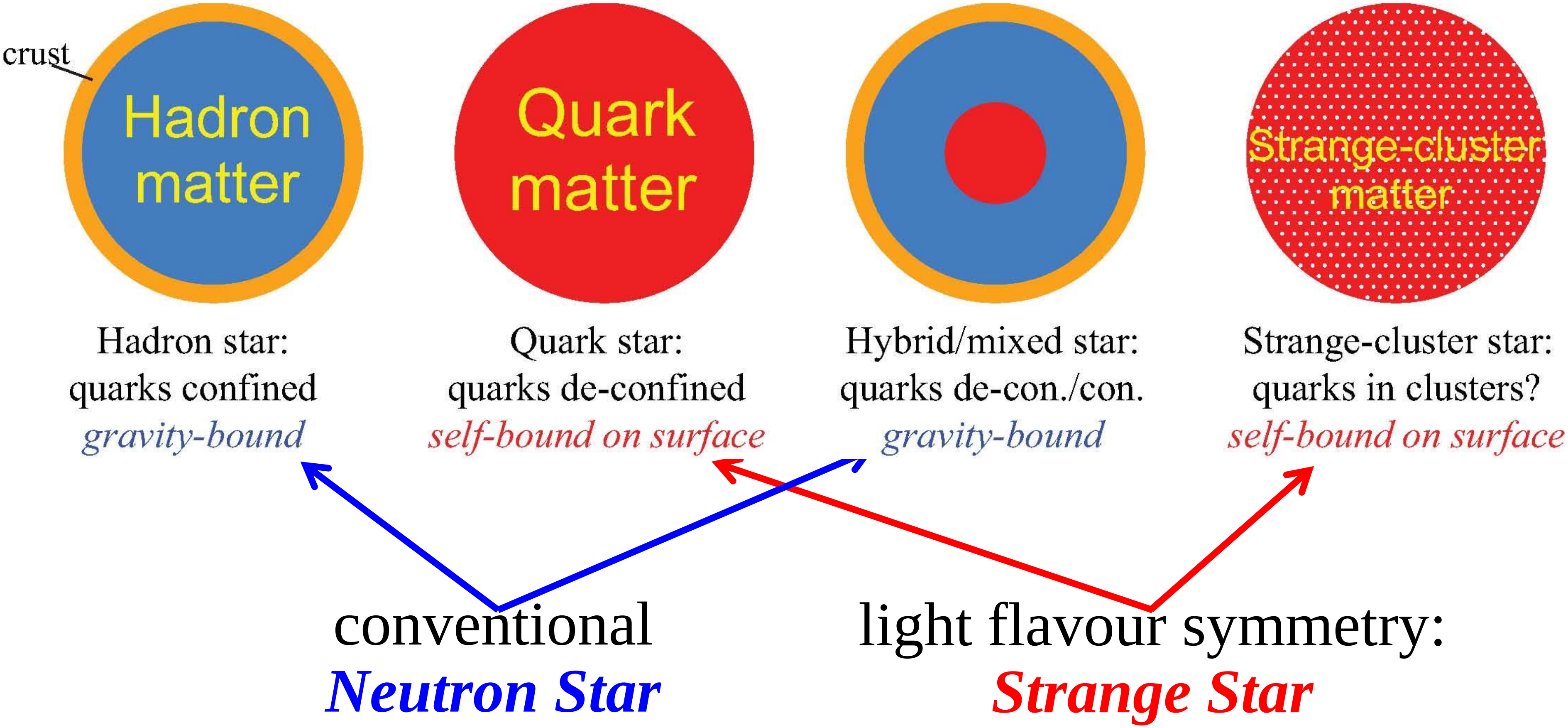
Neutrons are stable inside nuclei.

2-flavor matter
(**SNE**: u→d)

Strange-clusters, as multi-quark particles, don't decay in compact stars if the general Bodmer-Witten conjecture is correct.

B-W conjecture generalized?

- Different models of pulsar's nature in the market: *to differentiate by observations*!



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✓ Observational proof?

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Observational proof?

- Fluid (quark star) ***v.s.*** Rigidity (cluster star)
  - Quarks (even nucleon) are quantum particles, while clusters could be classical ones because of large mass (small wavelength $\lambda \sim \hbar/mc$).
  - Strange clusters would be localized in lattice points if $kT << U_0$.
  - Strange cluster star with rigidity is helpful for us to understand:
    - ✓ pulsar glitch, with/without X-ray enhancement (Zhou et al. 2014)
    - ✓ free energy (gravitational/elastic) to power AXPs/SGRs (Xu et al. 2006)
    - ✓ precession, free/torqued (Xu 2003, Qiao et al. 2003)
    - ✓ no turbulence: stable ferromagnetic origin of B-field (Lai, Xu 2016)
    - ✓ cutoff of GRB plateau during solidification? (Dai et al. 2011)
    - ✓ oscillation-driven magnetospheric radio-activity? (Lin et al. 2015)
    - ✓ implication for GW radiation: mountain building? (???)

Observational proof?

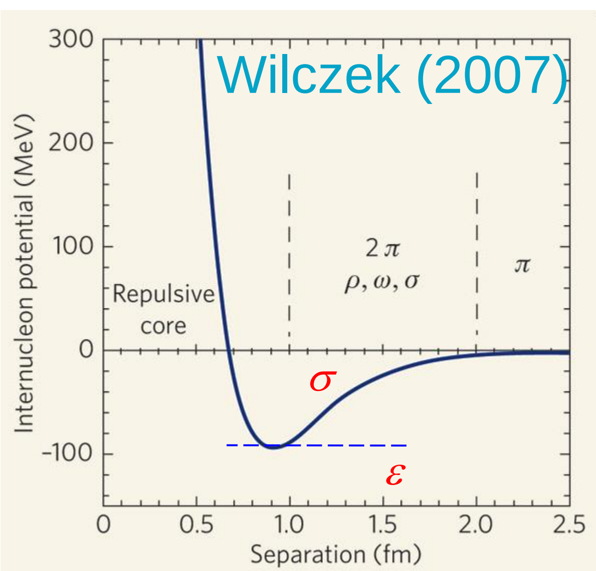
- Equation of state: Soft (QS) ***v.s.*** Stiff (CS)
  - Although relativistic quarks usually results in soft EoS:

$$E = (c^2p^2+m^2c^4)^{1/2} \sim p \rightarrow \text{pressure } P \sim \rho^{\gamma}\ (\gamma \sim 1),$$

non-relativistic clusters leads to stiff EoS (Lai & Xu 2009): $P \sim \rho^{\gamma}\ (\gamma > 1)$!

$\Rightarrow$ ***No*** embarrassment of confinement/deconfinement:
only 3-flavor (u, d, s) symmetry restoration in strange cluster matter!

$\Rightarrow$ ***No*** hyperon puzzle for strange cluster matter to have stiff EoS.

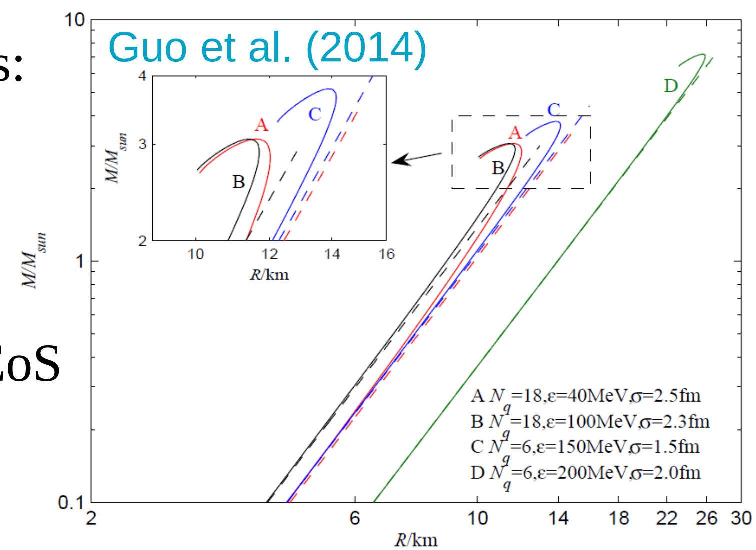


Dimensionless parameters:

$$P^* = P\sigma^3/\varepsilon$$
$$V^* = V/(N\sigma^3)$$
$$T^* = kT/\varepsilon$$
$$\Lambda^* = h/(\sigma\sqrt{m\varepsilon})$$

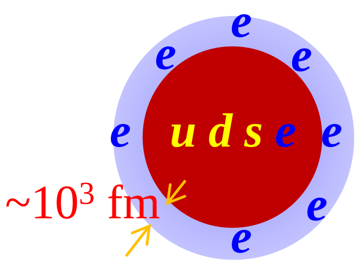
Corresponding state law EoS

$$P^* = f(V^*, T^*, \Lambda^*)$$



Observational proof?

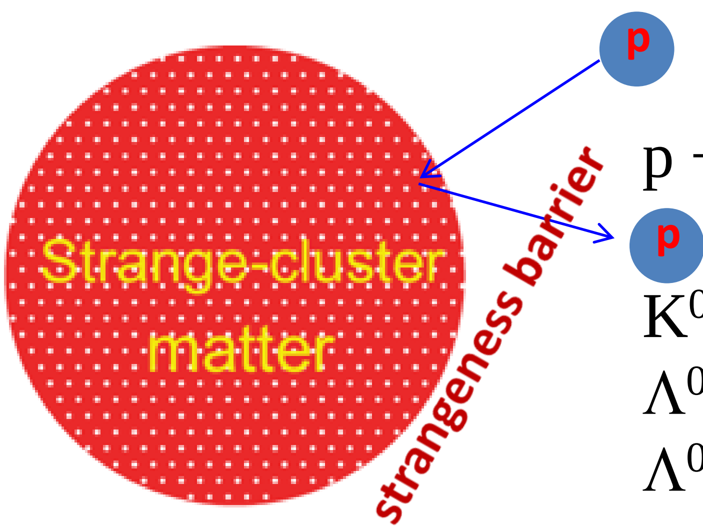
- Barrier: Coulomb ***v.s.*** Strangeness/Coulomb
  - To exist Coulomb barrier ~10 MeV on surface due to 3-f sym. broken



$$E=\sqrt{\frac{2\alpha}{3\pi}}\frac{9V_q^2}{\left(\sqrt{\frac{6\alpha}{\pi}}V_q z+4\right)^2}\sim\frac{7.2\times10^{18}}{(1.2z_{11}+4)^2}\quad \text{V/cm}$$

(Xu & Qiao 1999)

  - Proton with E_k ~ GMm_p/R ~100 MeV could penetrate Coulomb barr.
  - Strangeness barrier of strange-cluster star: weak interaction needed

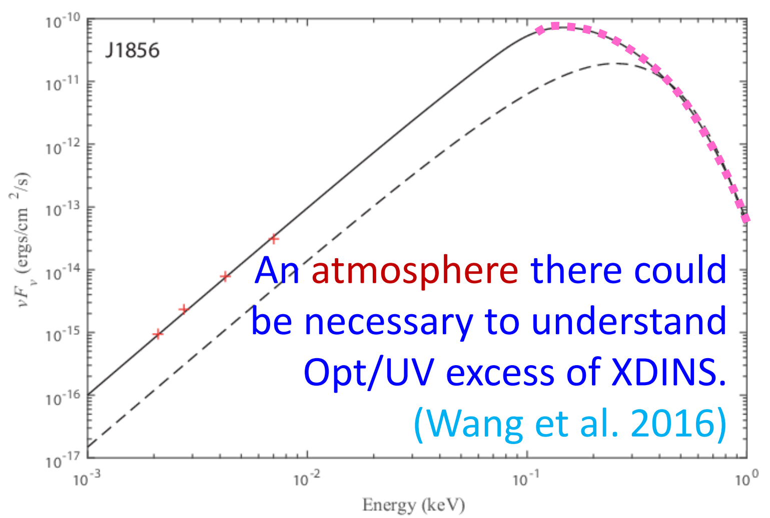


$p + \pi^- \leftrightarrow \Lambda^0 + K^0$

$K^0 \rightarrow \pi^+ + \pi^-$

$\Lambda^0 \rightarrow p + \pi^-$

$\Lambda^0 + \Lambda^0 \rightarrow H?$



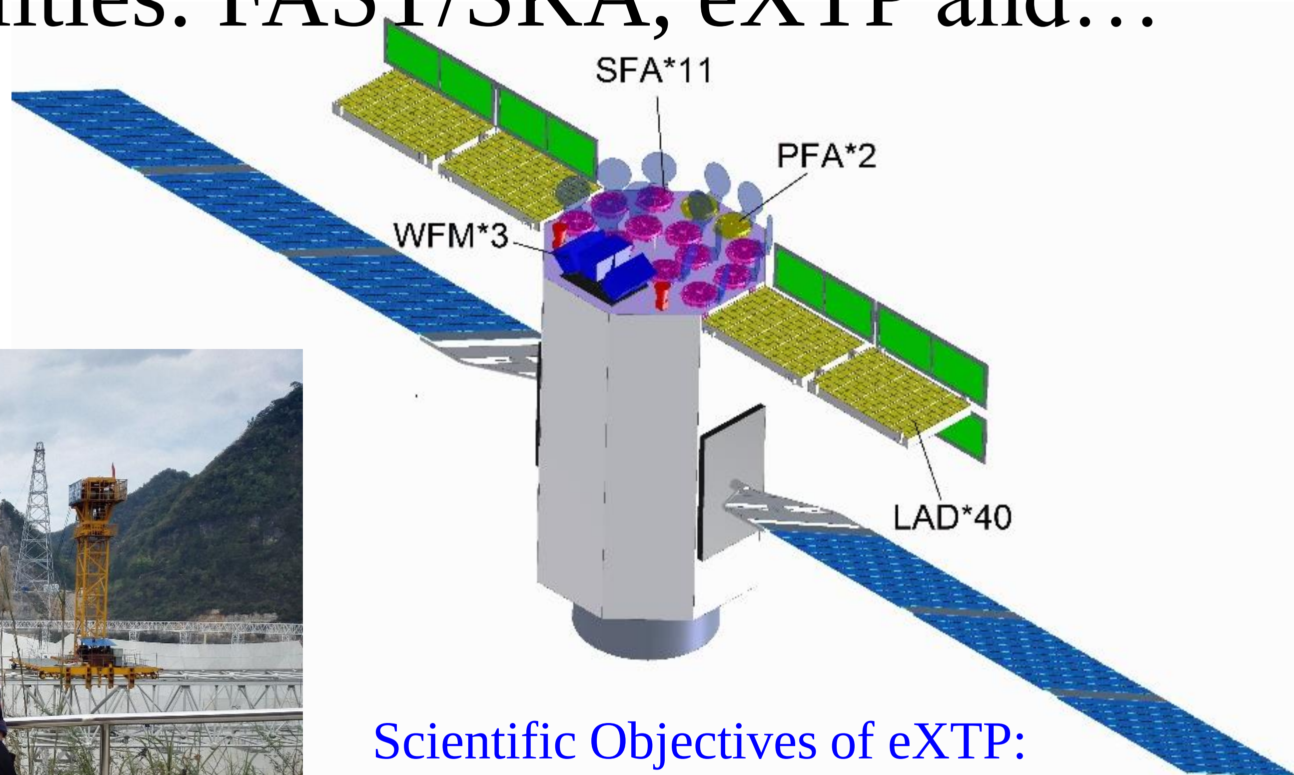
Observational proof?

- Advanced facilities: FAST/SKA, eXTP and…

Chinese SKA "2+1"

"2" = HI & PSR

"1" = others



Scientific Objectives of eXTP:

One singularity (BH)
Two stars (NS or SS)
Three extremes (gravity, density, magnetism)

- What if ***a universe*** has stable ***strange matter***…

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Conclusions

- An extension of the Bodmer-Witten conjecture is suggested, i.e., strange matter in bulk may constitute the true ground state of the strong-interaction matter (quarks are not necessary free, but could be grouped in clusters).

- Pulsars could be strange-cluster stars if general B-W conjecture is correct, that could be helpful to understand different manifestation, and we expect to test further.

THANKS!