A Strangeon Idea tested by GW170817

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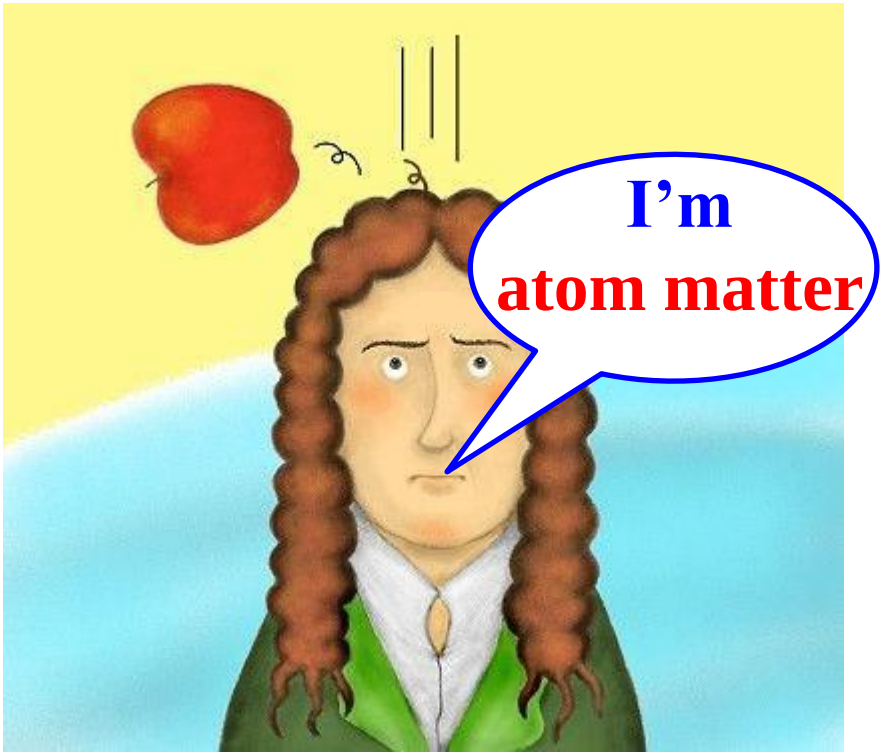
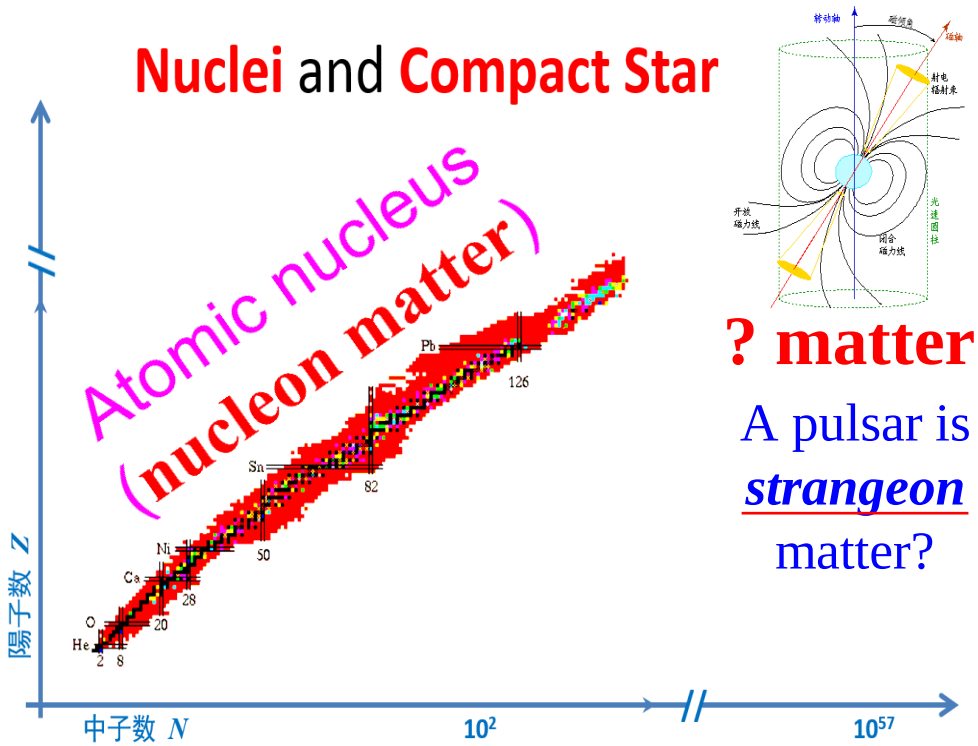
"EOS of dense neutron-rich matter in the era of Gravitational wave astronomy"

Jan. 3~7, 2019; Xiamen Univ., China

Nature of Condensed Matter

- Electric (electromagnetic) matter ***V.S.*** Strong matter





Electric Matter:
condensed by EM-force

Strong Matter:
condensed by strong force

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What is a strangeon?

Quick Answer: Strangeon is proposed to be the constituent of ***bulk*** strong matter (gigantic nucleus), as an analogy of nucleon for an atomic nucleus.

Essential difference:

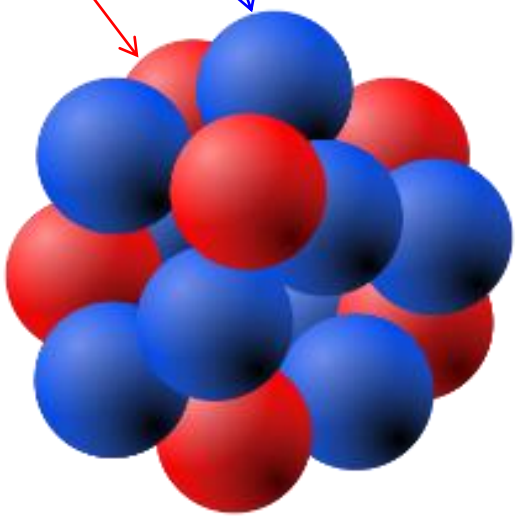
2-flavored nucleon but **3**-flavored strangeon
(***u*** and ***d***) (***u***, ***d*** and ***s***)

What is a strangeon?

- A **Gigantic Nucleus** is conjectured to be ***3-flavored***!

2-flavored world v.s. 3-flavored world

The constituent part of nucleus is then called nucleon (proton + neutron)



"micro-SM"

$A_c \sim 10^9$?

Small Big

"macro-SM"

Very similarly,
strangeon is the constituent part of 3-favored nucleus!

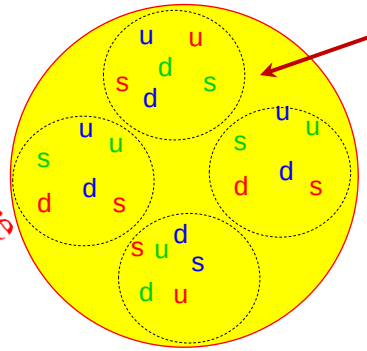
What is a strangeon?

- Another version (Witten 1984): ***similar*** but ***different*** ...

Strangeon matter in bulk constitutes the true ground state of the strong-interaction matter rather than ^{56}Fe.

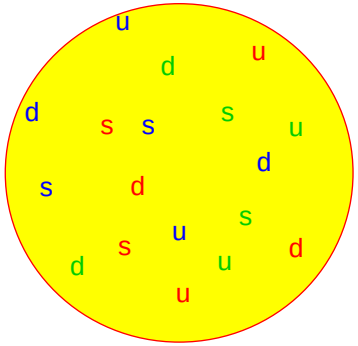
Strange quark matter in bulk constitutes the true ground state of the strong-interaction matter rather than ^{56}Fe.

Strangeon conjecture



Strangeon
(strange+nucleon)

Strangeon Matter
(strangeon number ~ 10^{57} for star)



Witten's conjecture

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

What is a strangeon?

- Q: Strangeon matter matters? I don't …

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

Trinity of Strangeon

- Strangeon stars: ***compact objects***
- Strangeon cosmic ray: **UHECR**
- Strangeon dark matter: **cosmology**

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Strangeon Stars

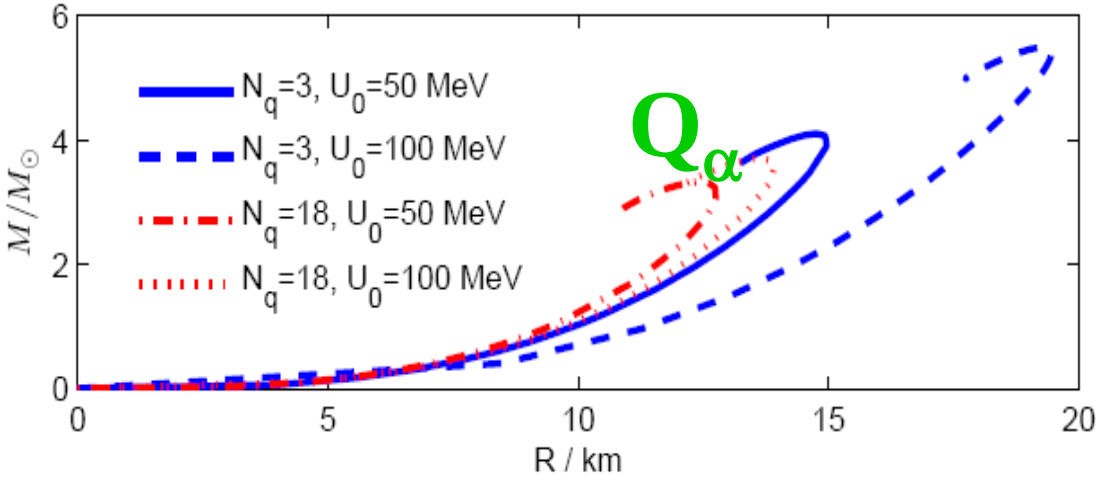
Strangeon Stars

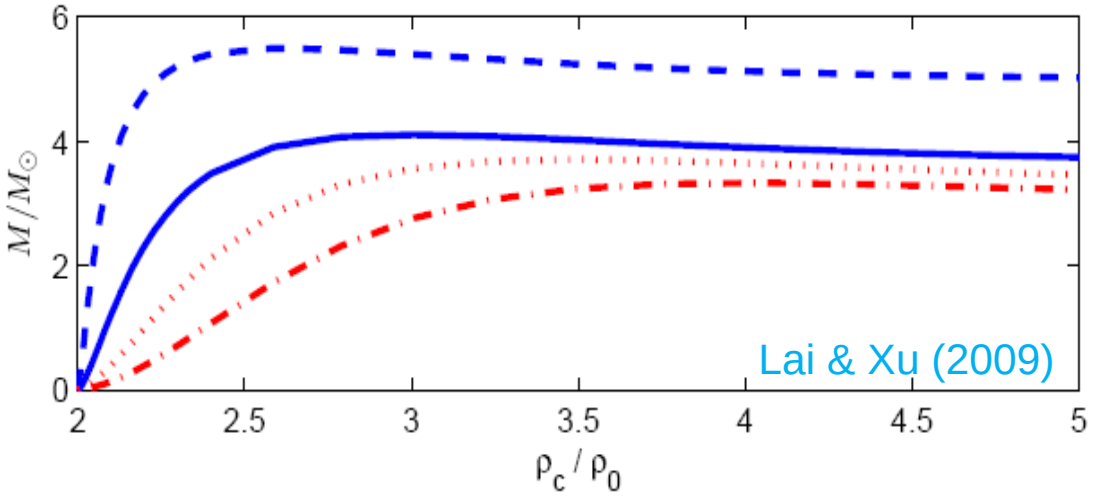
- Core collapse SN： Neutronization ***v.s.*** Strangeonization

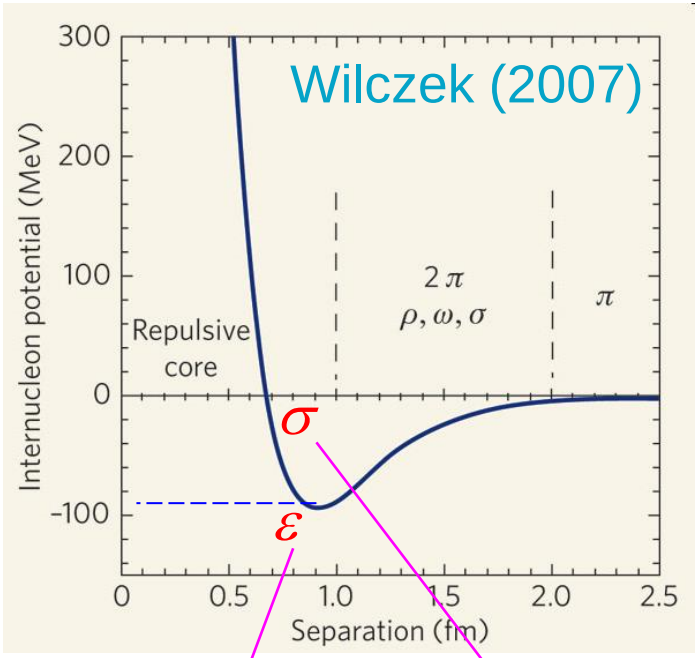
	Peculiarity	Manifestation	Mechanism	Ref.
surface	binding energy.	*drifting subpulse*, μstructure	gap sparking in RS75	Xu et al. (1999), Yu & Xu (2011)
		clean fireball for SNE/SGR	photon-driven explosion	Chen et al. (2007), Dai et al. (2011)
	self-bound	mass as low as ~$10^{-2}M_{\odot}$	bound not by gravity	Xu & Wu (2003), Xu (2005)
	none-atomic X	Plankian radiation of X-ray	no-atmosphere if bare	Xu (2002)
		absorption in thermal spec.	hydromagnetic oscillation	Xu et al. (2012)
	strangeness bar.	low-z emission, type-I XRB	$2f$ matter separated from $3f$	Xu (2014)
		optical/UV exce. of XDINS	bremsstrahlung radiation	Wang et al. (17/18)
global	stiff EoS, Λ	high $M_{\rm max}$ ($2\sim3M_{\odot}$)	NR strangeons, hard core	Lai et al.(09ab,18ab) Guo et al. (2014)
	anisotropic P	SGR/AXP's burst and flare	quake-induced ener. release	Xu et al.'06, Zhou et al.'14, Lin et al.'16
	rigidity	precession, GW radiation	solid, mountain building	Xu (2003) Xu (2006)

Strangeon Stars

- SM's EoS-**I**: Lennard-Jones-like ({σ, ε}-dependent)







$$u(r) = 4U_0\left[\left(\frac{r_0}{r}\right)^{12} - \left(\frac{r_0}{r}\right)^{6}\right]$$

Strangeon Stars

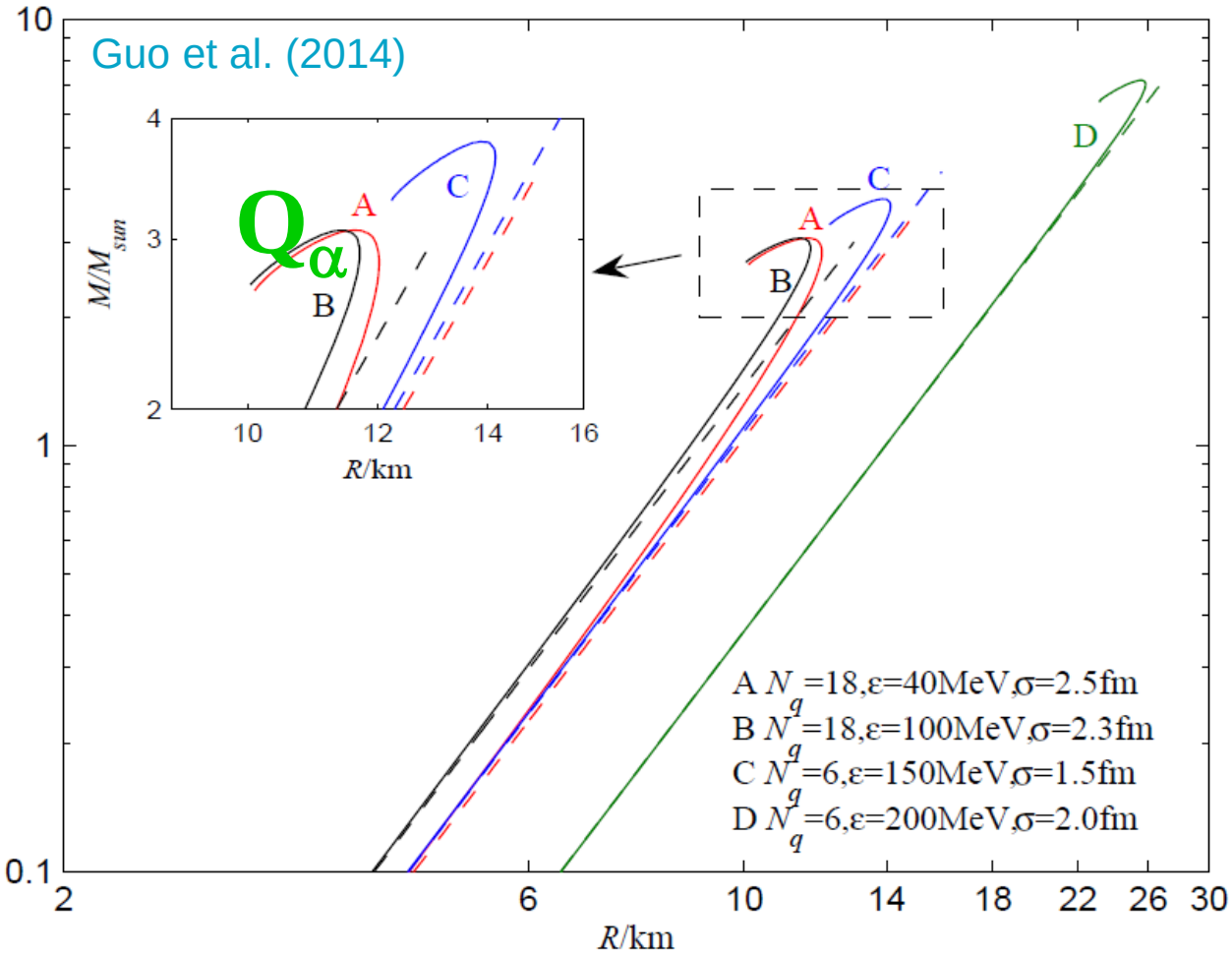
- SM's EoS-**II**: a corresponding-state approach

Dimensionless parameters:

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

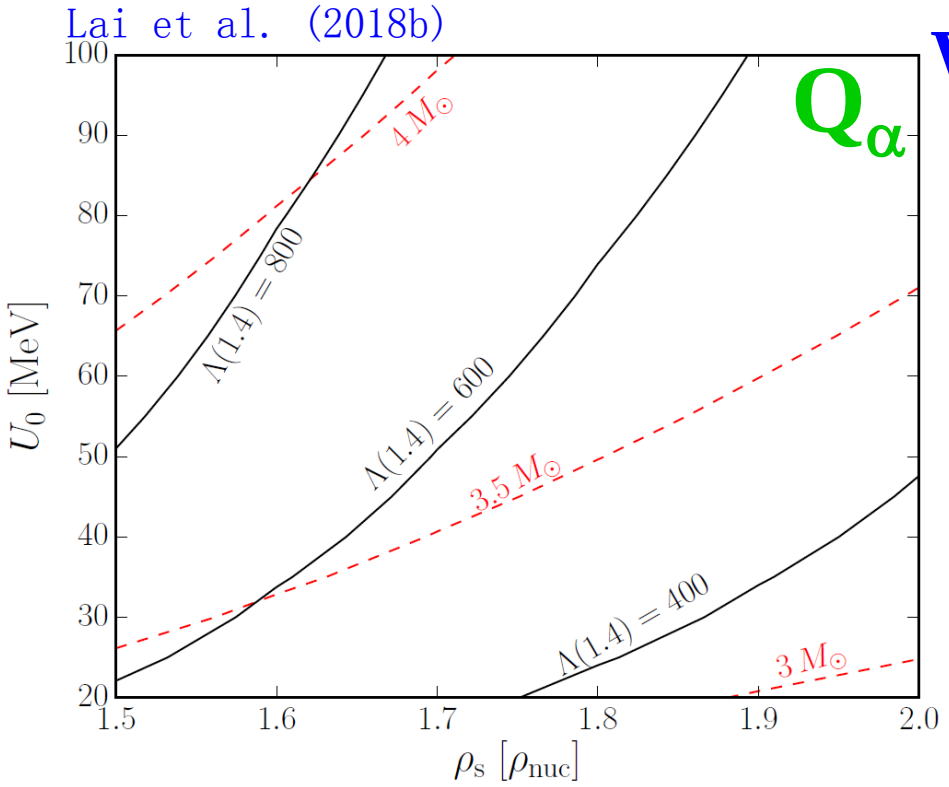
Corresponding state law EoS

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



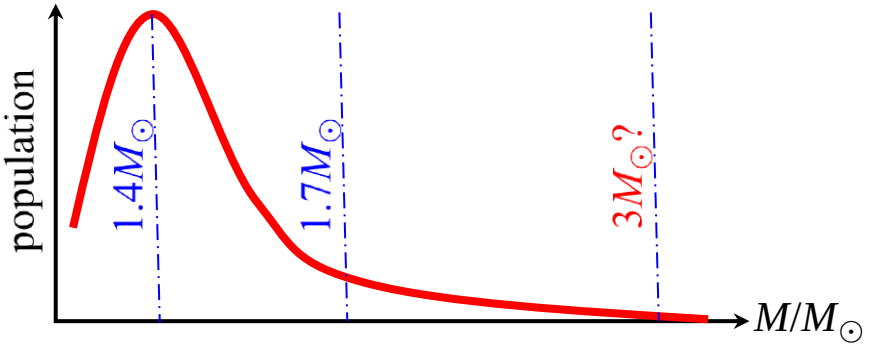
Strangeon Stars

- Strangeon star model passes ***dynamical*** test of Λ



Where are most massive SSs?

- SS merger: short GRB
- CCSN: (low population?)

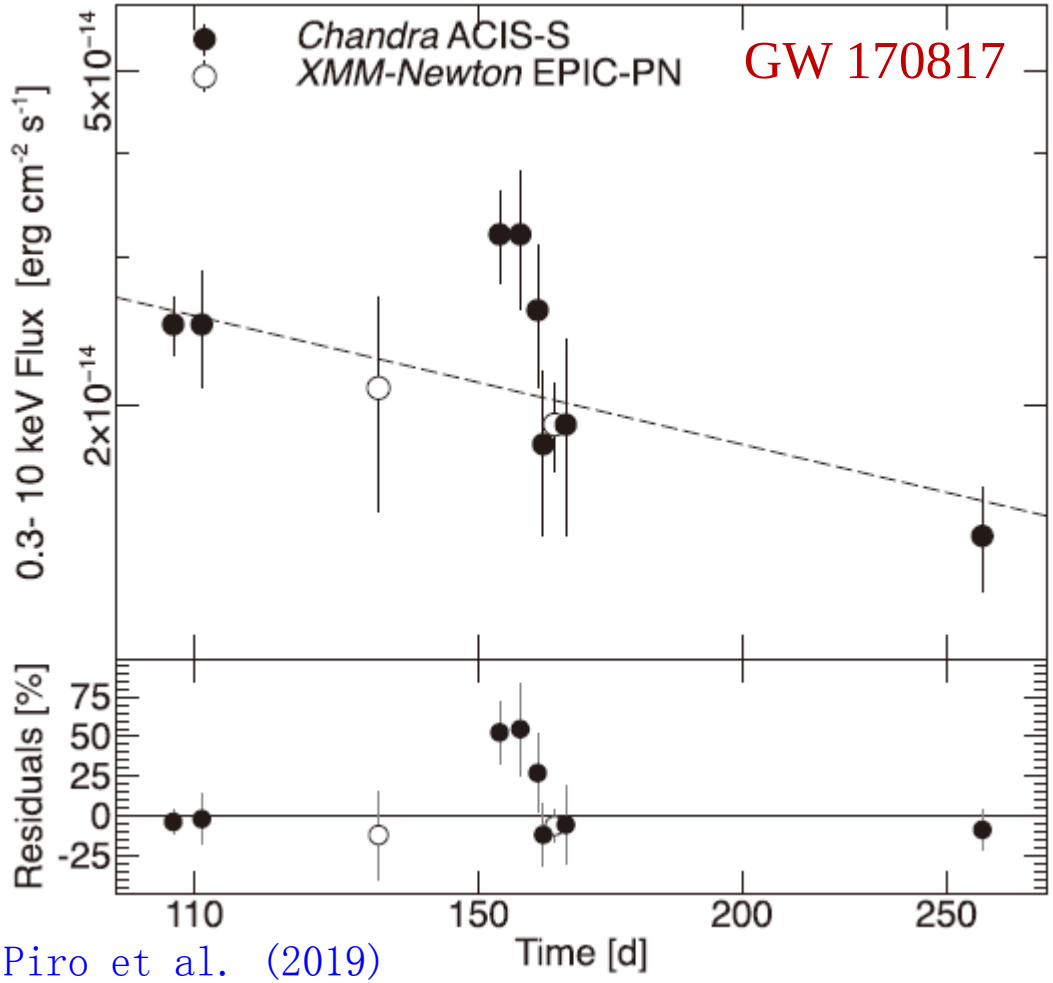


- ULXs

- $M_{\rm max}$: $\{npe\mu\}$-SLy $2.0M_\odot$, $\{npe\mu\}$- APR4 $2.2M_\odot$; SS ~ $3M_\odot$
- To discovery a pulsar with mass > $2.3M_\odot$ by Chinese FAST?

Strangeon Stars

- A massive strangeon star as a post-merger remnant?

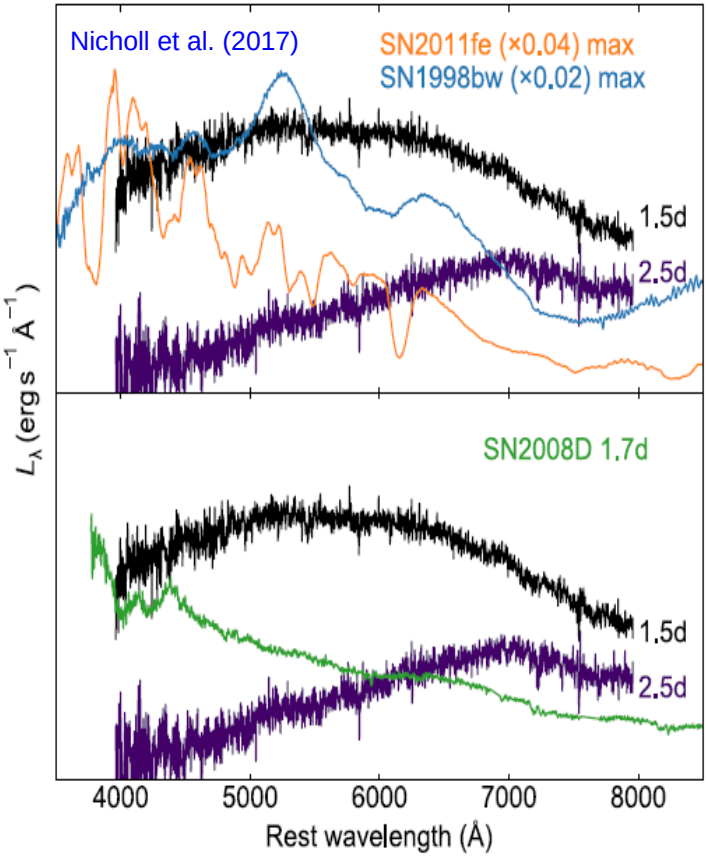


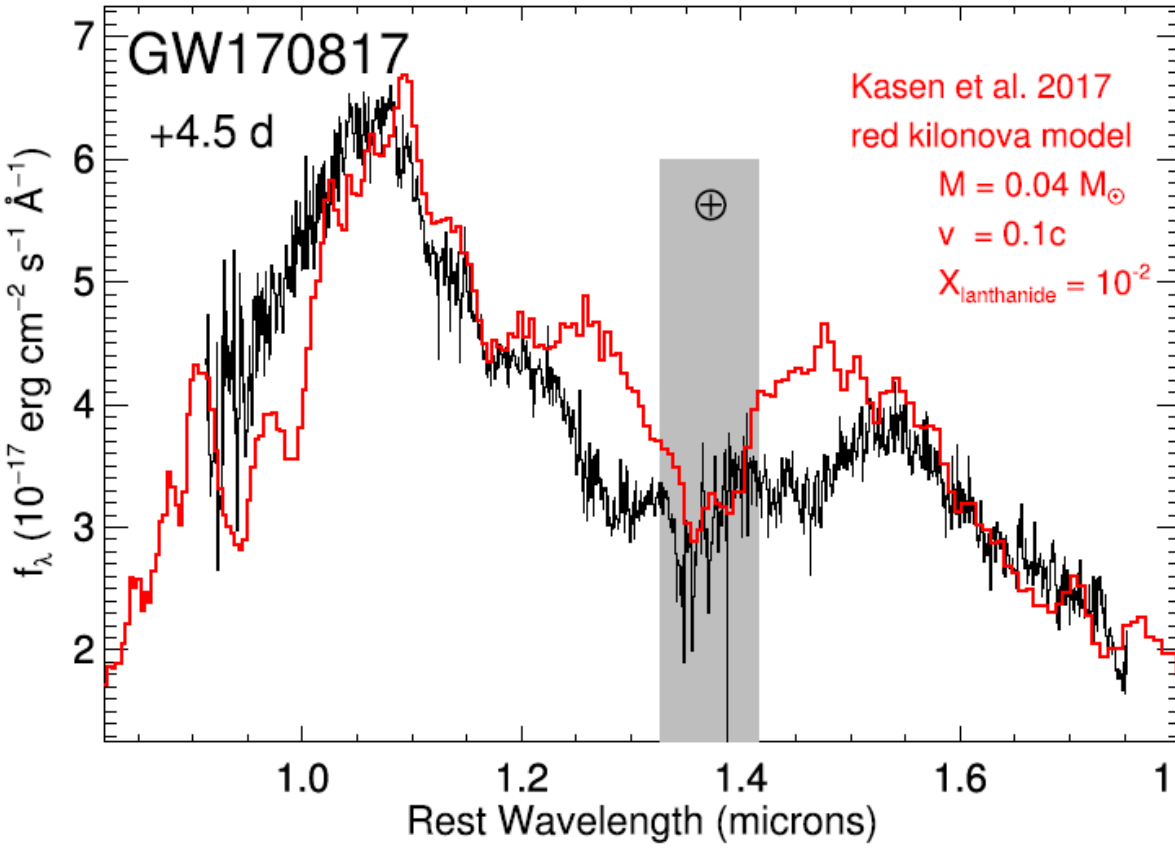
Piro et al. (2019)

- Solidification at ~ MeV:
  - Star-quake-induced energy release
  - Fireball is still powered by SS with normal field
- Negligible GW emission:
  - Significant GW radiates initially for tri-axial star
  - Tested in the future?
- GR simulation needed!!!

Strangeon Stars

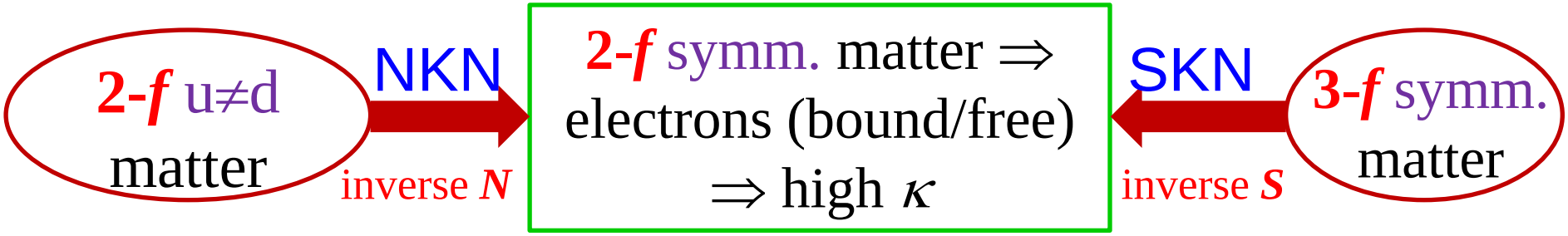
GW170817 spectra: 1, to be much redder than a supernova; 2, no line features resolved.





Strangeon Stars

- No detection of SN-like blue component of KN hints higher $\kappa/(\mathrm{cm}^2\mathrm{g}^{-1})$ of radiative medium



- Neutron KN: Post-merger = BH $\Rightarrow \kappa \sim 20$

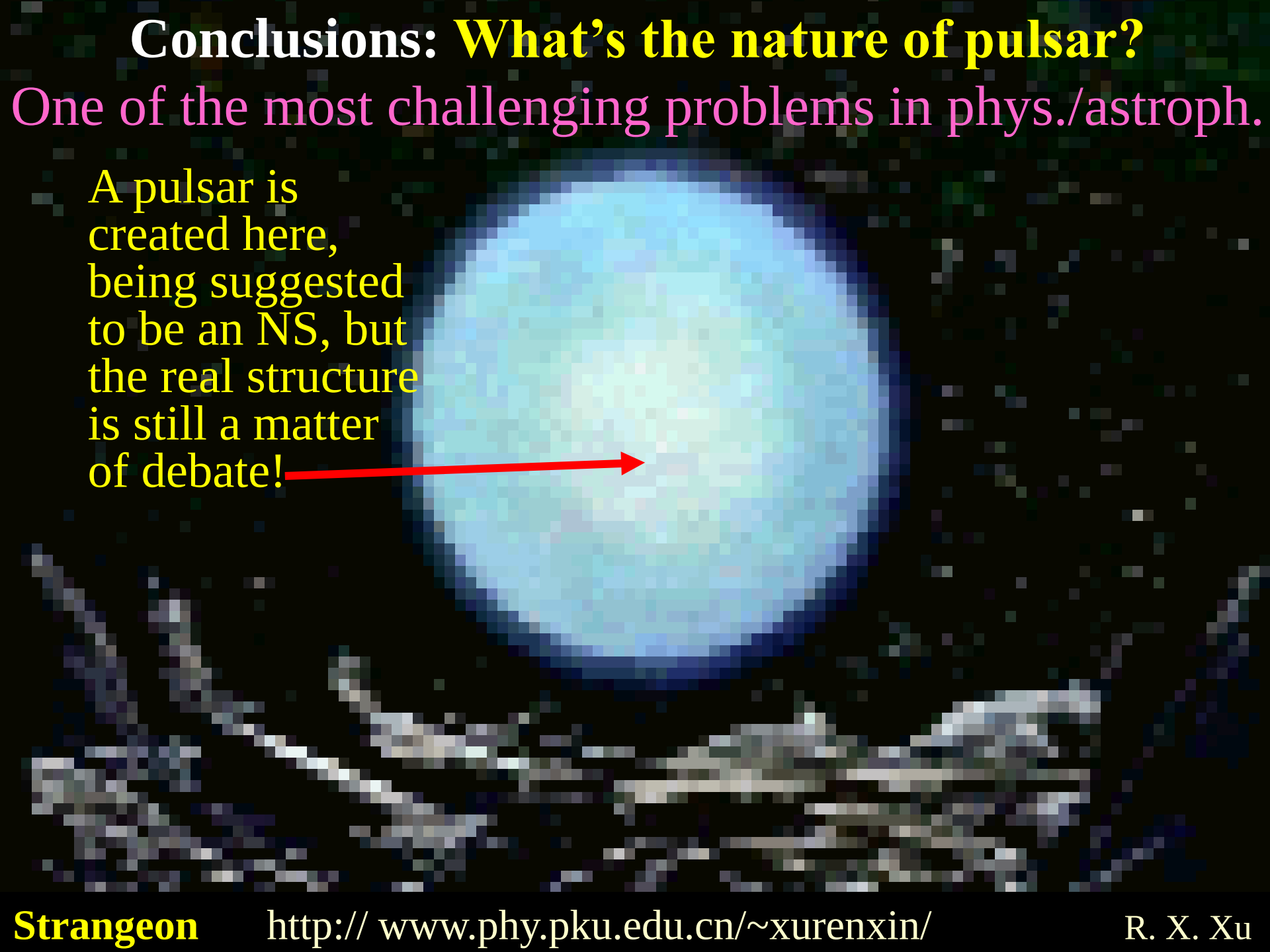
  Post-merger = NS $\Rightarrow \kappa \sim 5$

- Strangeon KN: Post-merger = SS $\Rightarrow \kappa > 1$?

Conclusions: What's the nature of pulsar?

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

A pulsar is created here, being suggested to be an NS, but the real structure is still a matter of debate!



Conclusions

- **Pulsar** = ***Proton*** Star ~~X~~
- **Pulsar** = ***Neutron*** Star

} nucleon star

- **Pulsar** = ***Strangeon*** Star

an option for you …

THANKS!