五年来征程于大江南北，FPS像“宣传队和播种机”一样点燃脉冲星之“火”。

—— 摘自《FPS5会议文集》

GW170817 and Strong Matter

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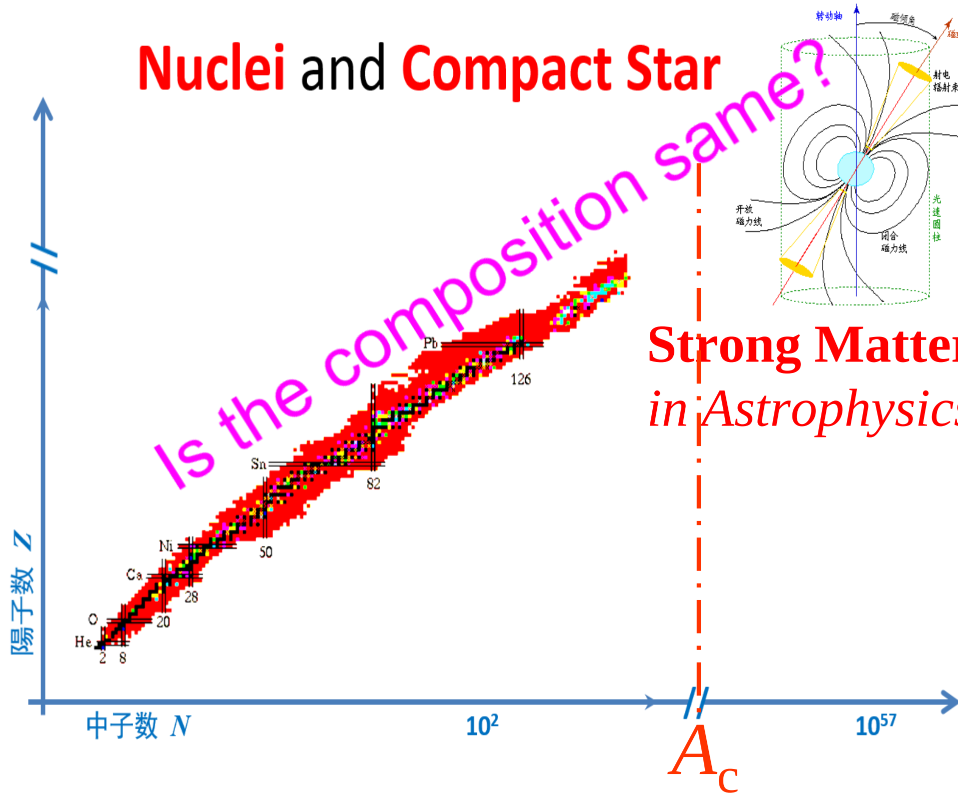
GW170817 and Strong Matter

The unknown state of ***strong matter*** could be the first big problem to be solved in the era of ***gravitational-wave astronomy***.

What is strong matter?

- Electric (electromagnetic) matter *v.s.* Strong matter



Electric Matter:
condensed by EM-force

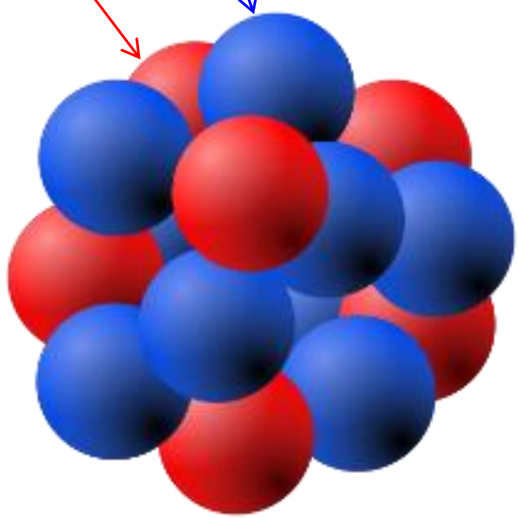
Strong Matter:
condensed by strong force

Strong matter: nucleon/strangeon

- Flavor symmetry of strong matter: **2**(u,d) or **3**(u,d,s)?

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

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



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

Ahh...Strangeness!

- Why are we ***loving*** strangeness in strong matter?

For strong matter around the ***nuclear density***, the separation between quarks, $\Delta\ell$, could be ~ 0.5 fm, determined by α_s!

From Heisenberg's uncertainty relation, $\Delta\ell\cdot\Delta p \approx \hbar$, one may have an energy scale for strong matter, $E_{\rm scale}$,

$$E_{\rm scale} \approx \hbar c/\Delta\ell \approx 0.2\,{\rm GeV}\cdot{\rm fm}/0.5\,{\rm fm} = 0.4\,{\rm GeV}.$$

Note that... we may expect 3-flavored strong matter because

$$E_{\rm scale} \gg \Delta m_{\rm uds} \equiv (m_{\rm s} - m_{\rm ud})c^2!$$

(but…our baryonic matter is ***not*** 3-flavored! *why*?)

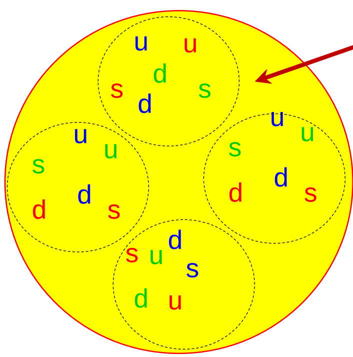
Ahh...Strangeness!

- Other ones love it too, but in ***different*** way (Witten'84)...

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

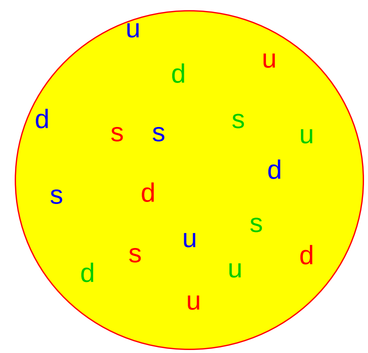
Strange quark matter in bulk constitutes the true ground state of the strong-interaction matter rather than ^{56}Fe.

Witten's conjecture



Strangeon
(strange nucleon)

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



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

Strangeon tested...

• Astrophysical tests of ***strangeon*** star model

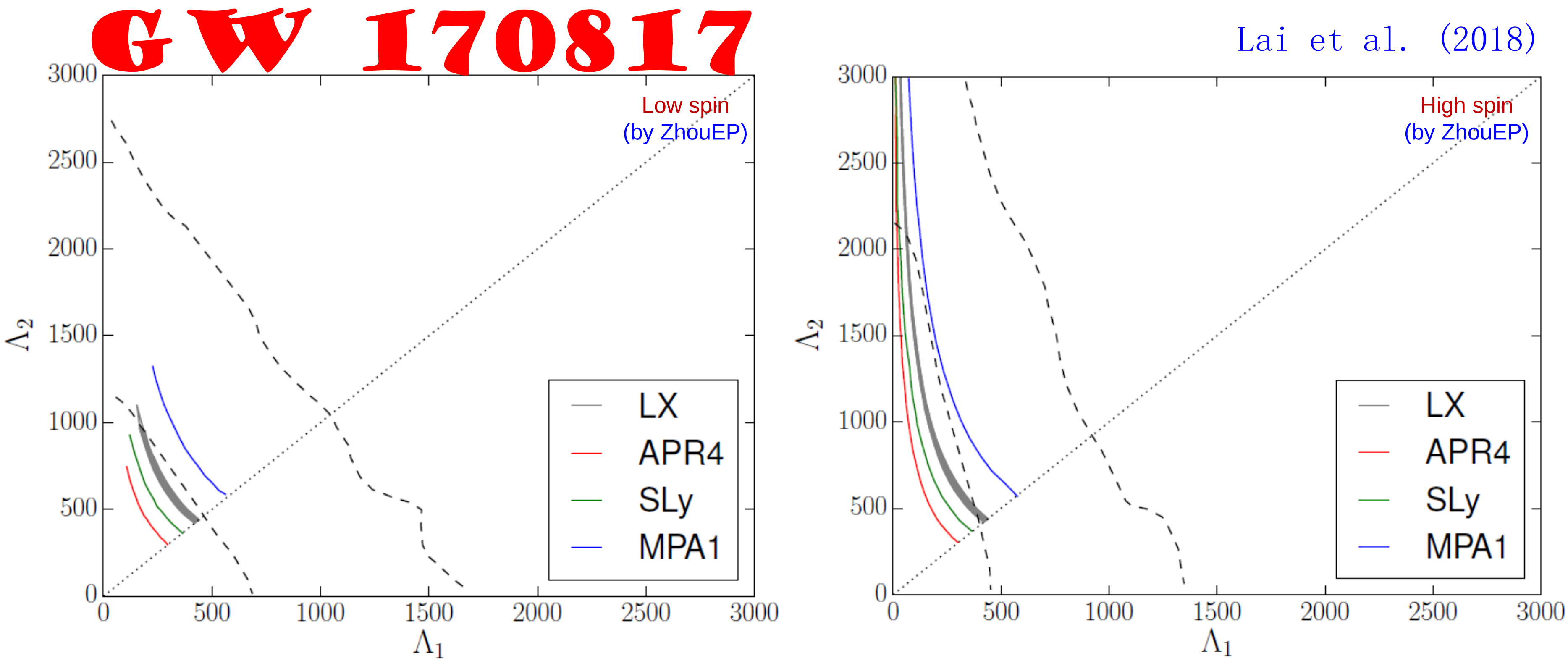
	Peculiarity	Manifestation	Mechanism	Ref.
surface	binding energy.	*drifting subpulse*, μstructure	gap sparking in RS75	Xu et al. (1999), Yu & Xu (2011)
		clean fireball for SNE/SGR	photon-driven explosion	Chen et al. (2007), Dai et al. (2011)
	self-bound	mass as low as $\sim 10^{-2} M_\odot$	bound not 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	2*f* matter separated from 3*f*	Xu (2014)
		optical/UV exce. of XDINS	bremsstrahlung radiation	Wang et al. (2017)
global	stiff EoS	high M_{max} ($2 \sim 3 M_\odot$)	NR strangeons, hard core	Lai et al. (09ab, 13) 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)

GW170817 and Strong Matter

Strangeon star has ***not*** been ruled out after the discovery of GW170817.

Strangeon tested by GW170817

- Strangeon matter passes ***dynamical*** test: Λ



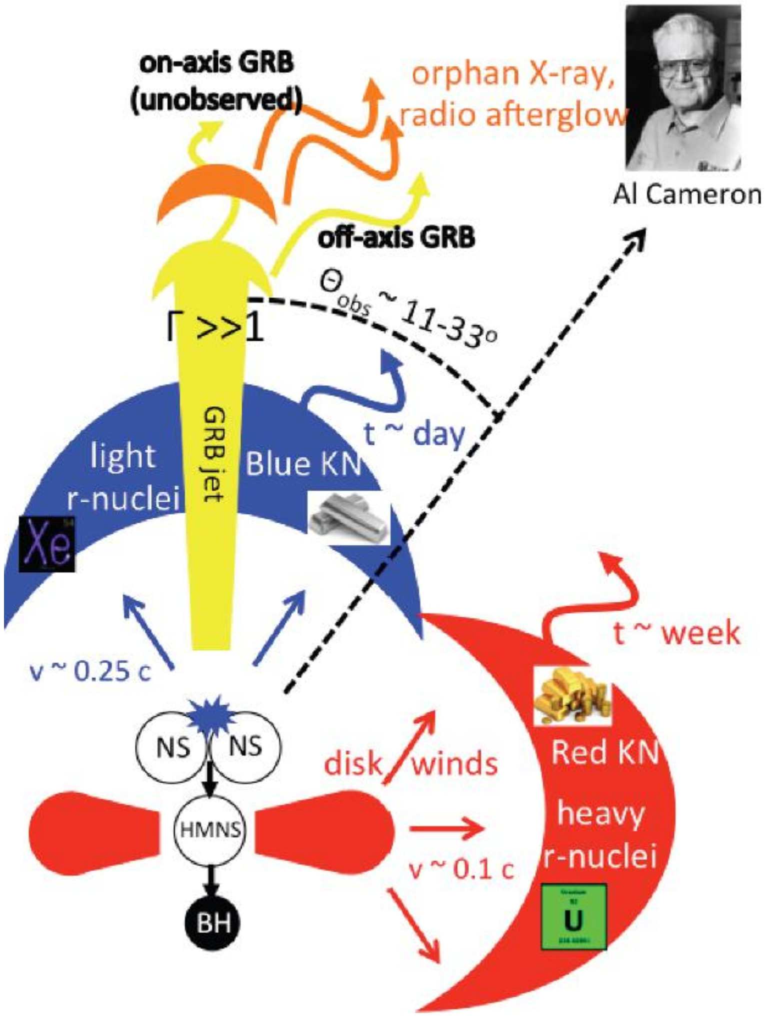
- M_{max}: {$npe\mu$}-SLy 2.0$M_\odot$, {$npe\mu$}- APR4 2.2$M_\odot$, LX ~3$M_\odot$
- To discovery pulsars with mass > 2.3$M_\odot$?

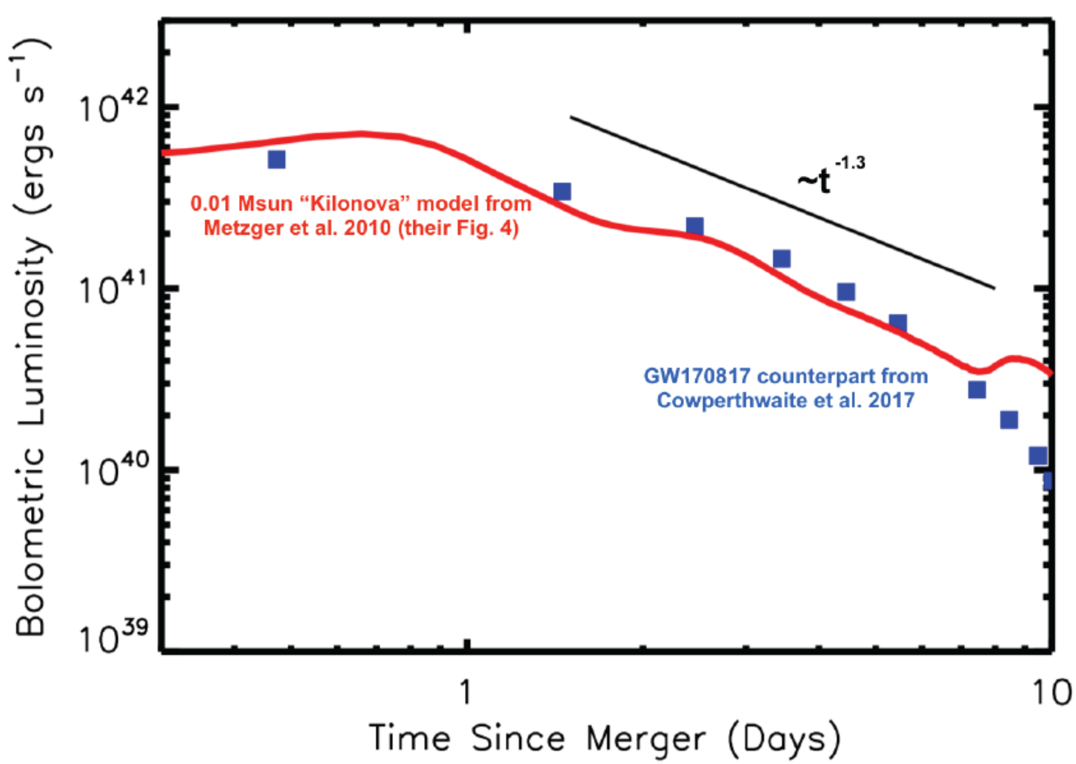
Strangeon tested by GW170817

•Kilonova: neutron kilonova

r-process nucleosynthesis and radiative decay...

Metzger (arXiv:1710.05931)

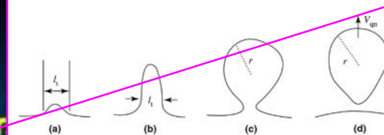


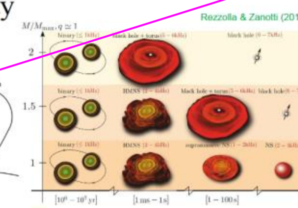


Strangeon tested by GW170817

- The ***first*** astro-meeting after detecting GW170817!

- **Origin** of **3**-flavored cosmic ray





① 3-flavored cosmic ray could be ejected from strangeon star surface during CCSN, 4 steps

Fig. 1 in Xu (2006, *Astroparticle Physics*)

② although speculative, but could also happen during merger, GW

Madsen (2005, *PRD*)

Session 8: Theory IV

Chair: Ke Fang

16:00 -- 16:30 Mingming Kang[photo]: *Cosmic Rays during BBN to Solve Lithium Problem* [ppt]

16:30 -- 17:00 Jorge Horvath[photo]: *There may be no "gold" coming out from compact star mergers* [pdf]

17:00 -- 17:30 Renxin Xu[photo]: *Strangeness in cosmic rays* [pdf]

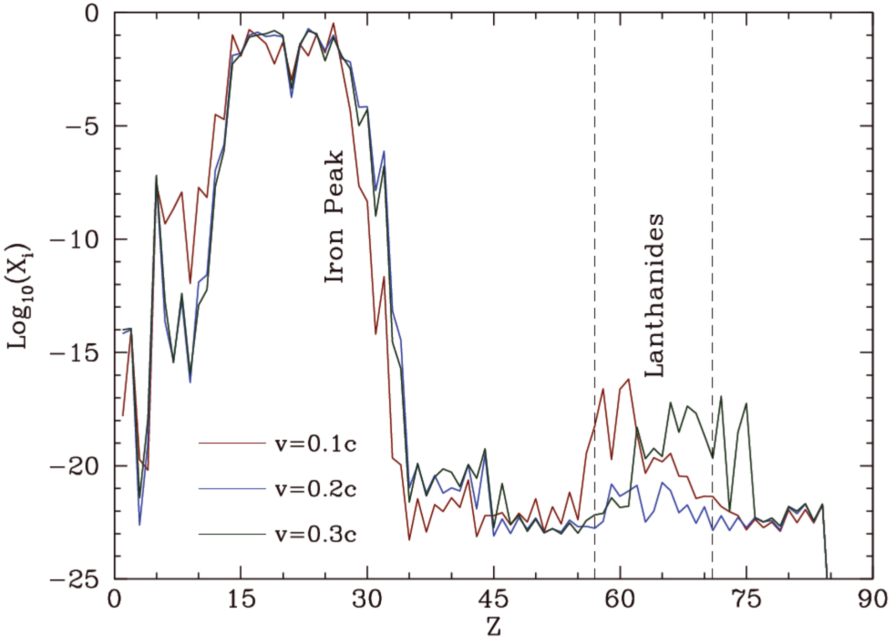
* * * Banquet * * *

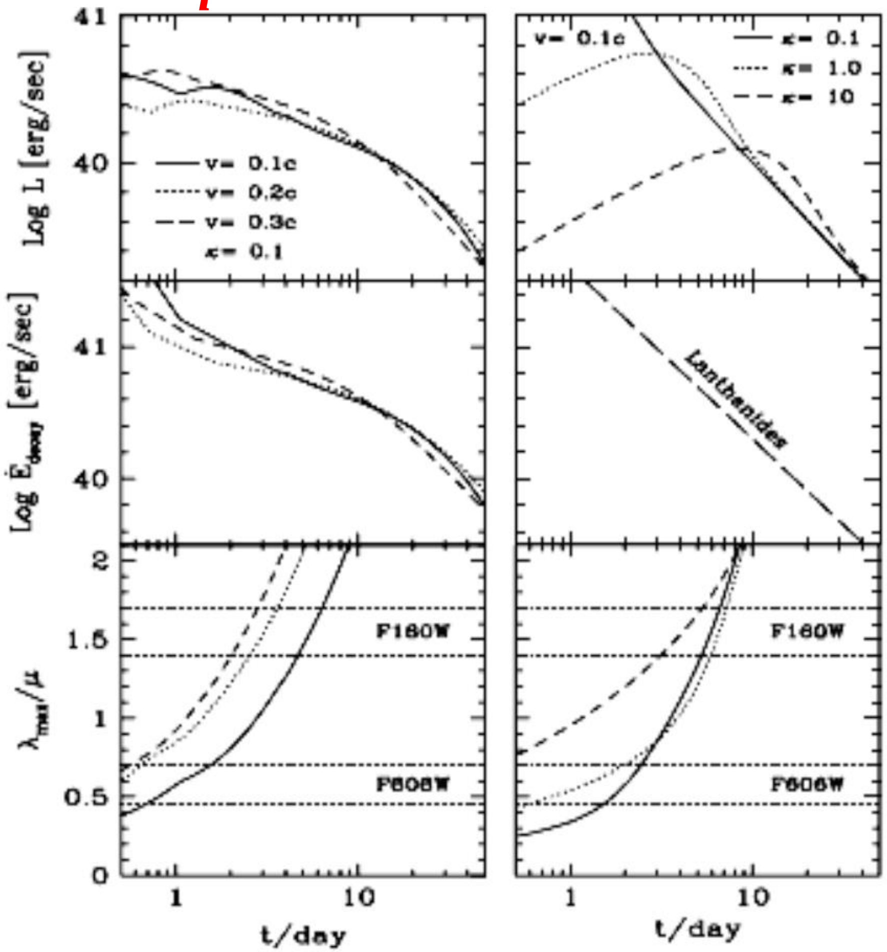
Strangeon tested by GW170817

•Kilonova： quark kilonova (Horvath's talk in KIAA-WAP II)

There are no lanthanides, nor "gold" (*r*-process actinides) in quark-kilonova.

Crucial observation: detection of *r*-elements and/or lanthanides!!!

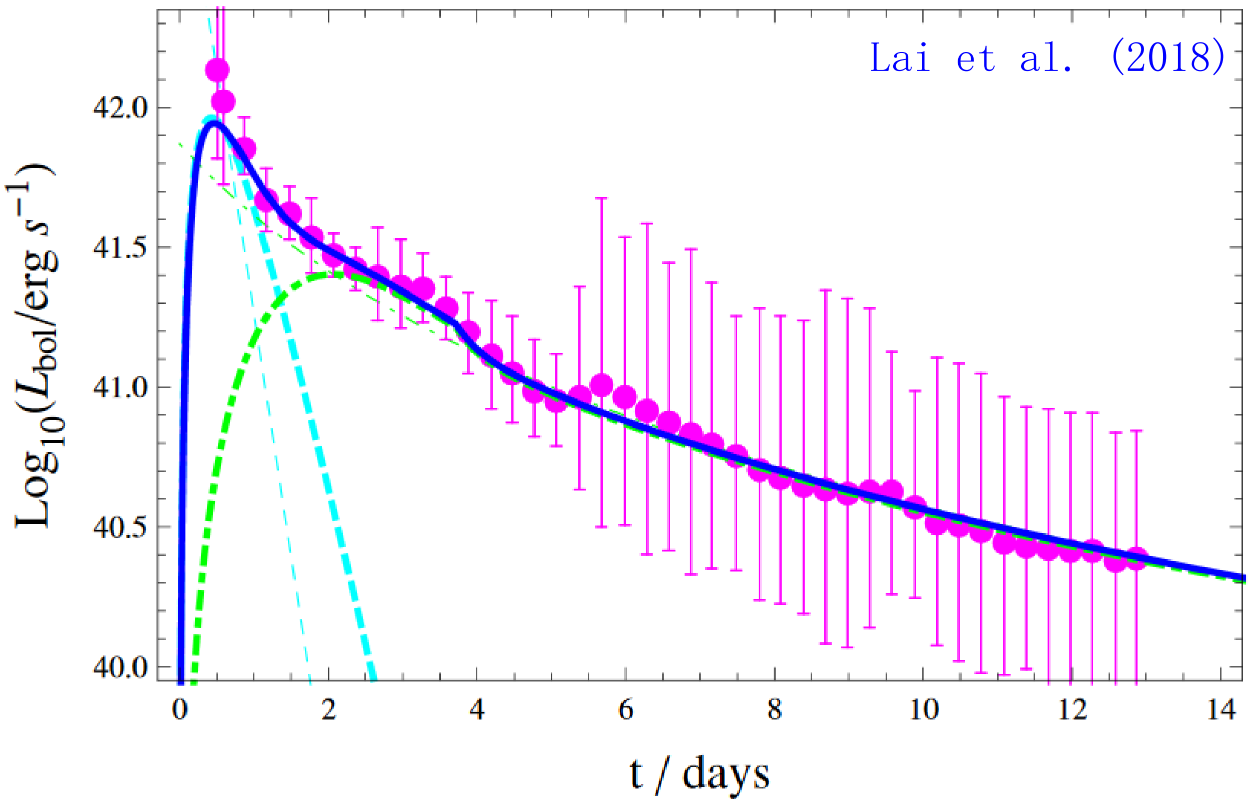




Strangeon tested by GW170817

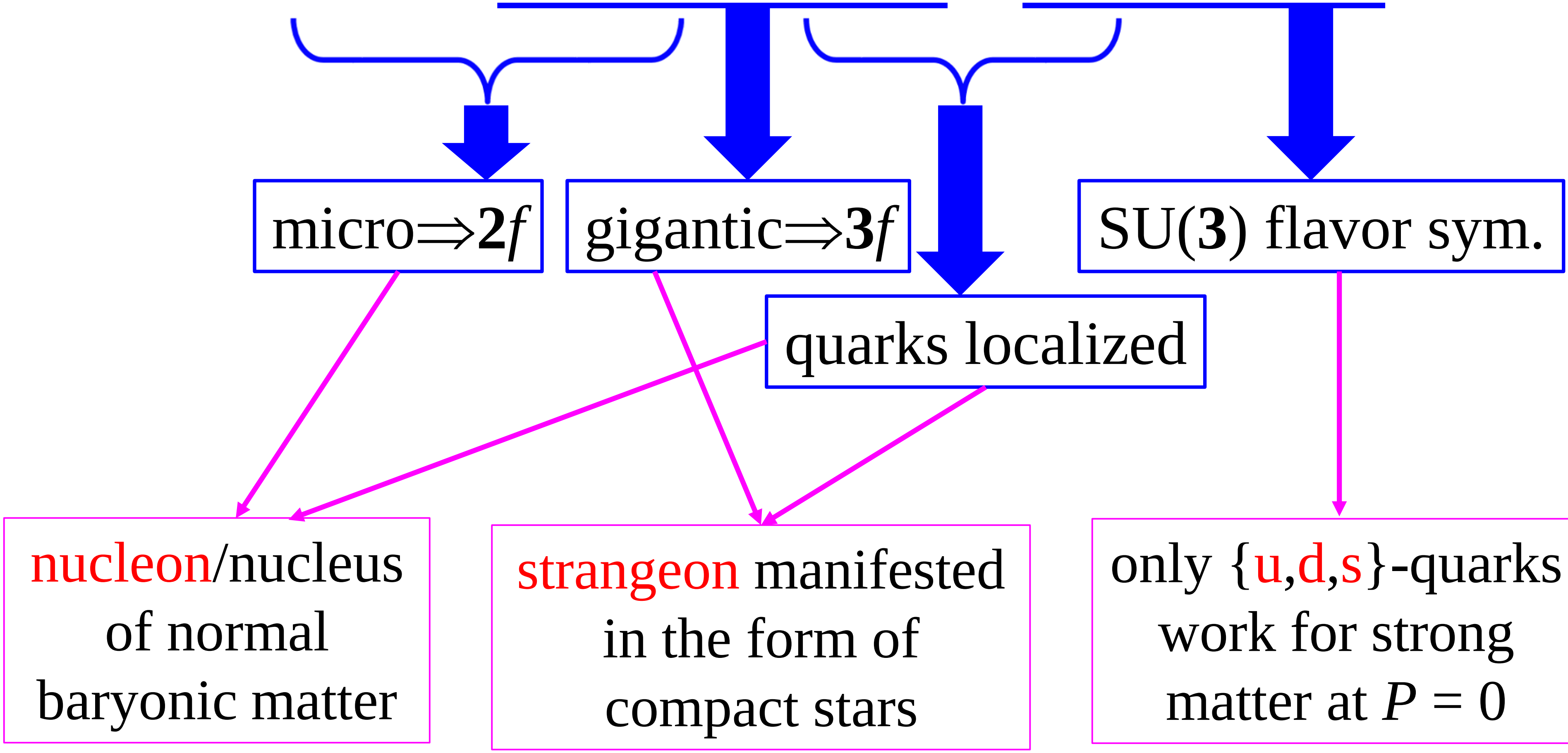
•Kilonova: strangenon kilonova

$$L_{\rm strangeon\ kilonova} \sim 10^{42} {\rm erg\ s^{-1}} \left(\frac{M_{\rm unstable}}{10^{-4} M_\odot}\right) \left(\frac{\Delta\eta}{1\ {\rm MeV}}\right) \left(\frac{1\ {\rm day}}{\tau}\right)$$



Discussions

$$m_{\rm e} \ll \Delta m_{\rm uds} \ll E_{\rm scale} < \Lambda_\chi \lesssim m_{\rm heavy}$$



Conclusions

- We propose that strangeon matter in bulk may constitute the true ground state of strong-interaction matter, and pulsar-like stars could then be strangeon stars (condensed matter of strangeons).

- Different manifestations would be understood if pulsars are strangeon stars (2 dynamic tests!), and we are expecting to test further by more advanced facilities.

THANKS!