# Flavour symmetry:
# from nucleon to strangeon

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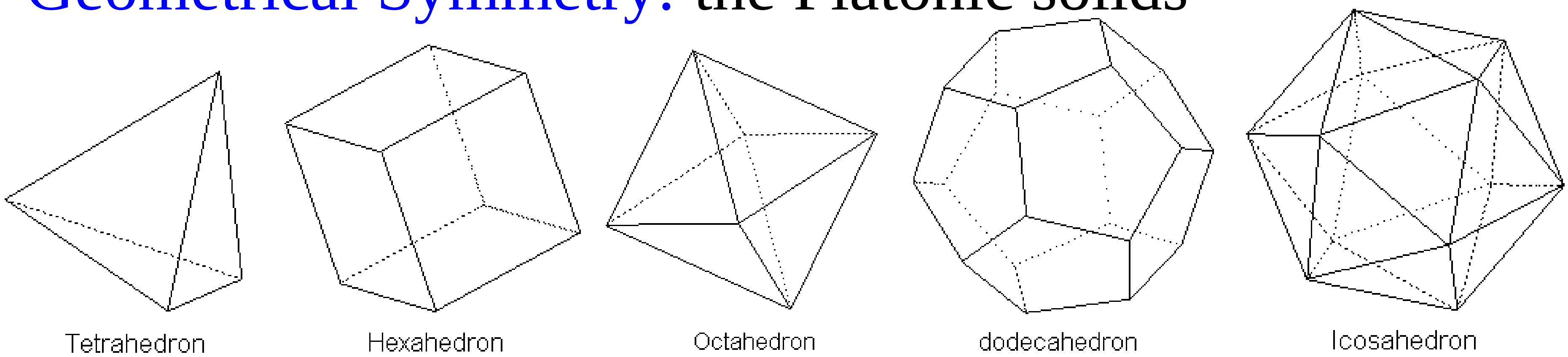
# Symmetry works: ET? You can guess…

**Strangeon Star?** **Neutron Star?**

# Symmetry: from ***Plato*** to ***Flavour***

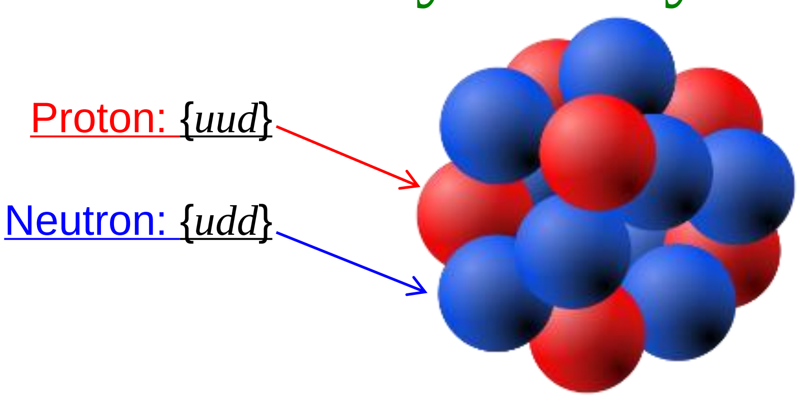
- **Geometrical Symmetry:** the Platonic solids




**4**:*fire* **6**:*earth* **8**:*air* **12**:*quintessence* **20**:*water*

**Plato's Theory of Everything**

- **Quark-flavour Symmetry:** **2**-flavoured ***v.s.*** **3**-flavoured



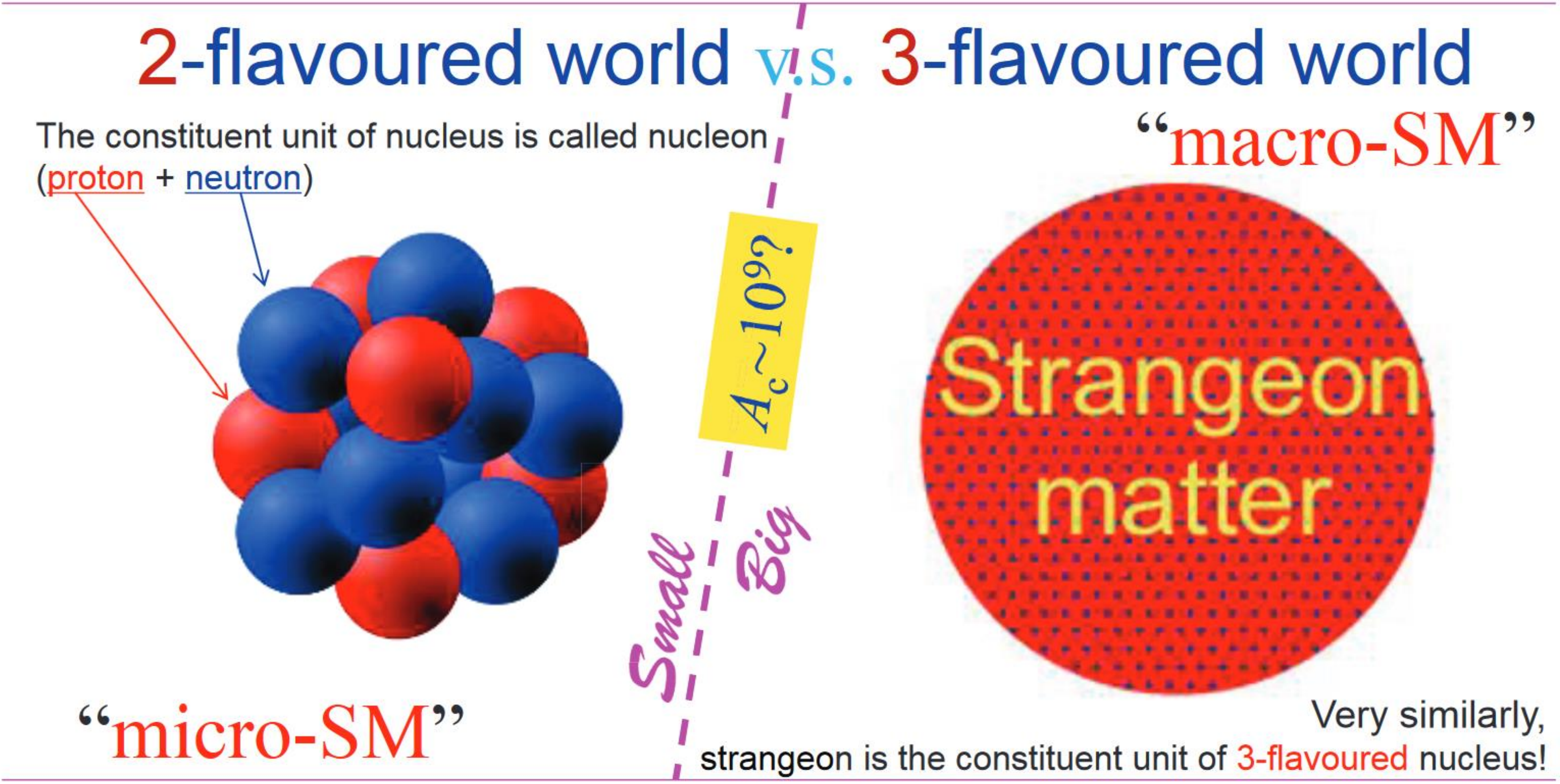

$$\Delta m_{\rm uds} \ll E_{\rm scale} < \Lambda_\chi$$

Nucleus: **2**-flavoured!

why not **3**-flavoured?

# Strangeon: 3-*flavoured* nucleus!

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



# Strangeon: 3-*flavoured* nucleus!

- From quark to ***Nucleus*** and ***Strangeon***: a bag model…

poster

## A BAG MODEL OF INFINITE STRANGEON MATTER

ZHI-QIANG MIU, CHENG-JUN XIA, REN-XIN XU, ANG LI

### Introduction

We adopt a bag model to describe both infinite nuclear matter and strangeon matter, which was first introduced by Q. R. Zhang [1]. In this model, bags arrange themselves as simple cubic crystal and overlap with each other. Therefore we cut off the overlapping parts and the bags interconnect to compose of a huge bag.

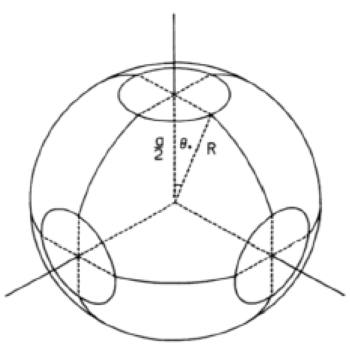



Fig.1 The shape of a bag

### The model

### Thermodynamical potentials

The thermodynamical potentials ar

$$\Omega_{i,V} = -\frac{\mu_i^4}{4\pi^2}\Big((1-\lambda_i^2)^{1/2}(1-\frac{5}{2}\lambda_i^2$$

$$-\frac{2\alpha_s}{\pi}(3\{(1-\lambda_i^2$$

$$-3\lambda_i^4 \ln^2$$

$$\Omega_{i,S} = \frac{3}{4\pi}\mu_i^3\Big(\frac{(1-\lambda_i^2)}{6} - \frac{\lambda_i^2(1}{3}$$

$$-\frac{1}{3\pi}\{\arctan\big[\frac{(1}{}$$

$$\Omega_{i,C} = \frac{\mu_i^2}{8\pi^2}\Big(\lambda_i^2 \ln\big[\frac{1+(1-\lambda_i^2}{\lambda_i}$$

where $\lambda_i \equiv m_i/\mu_i$. $\alpha_s$ is the QCD fin point. Here we only consider the one

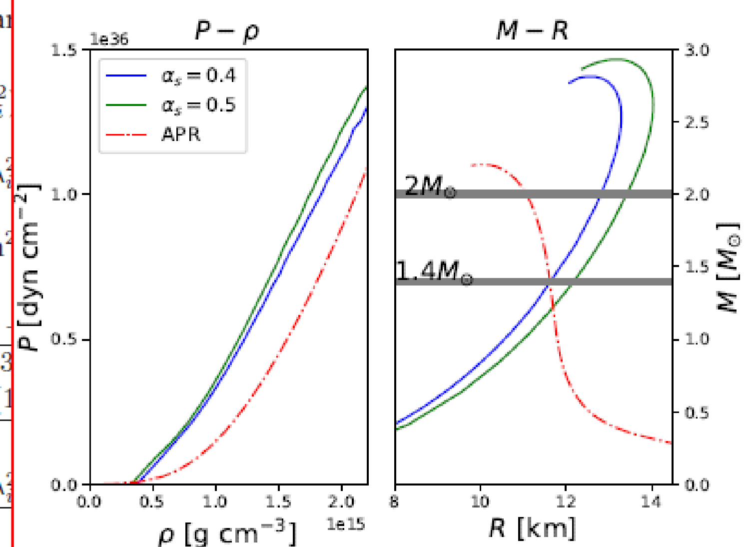
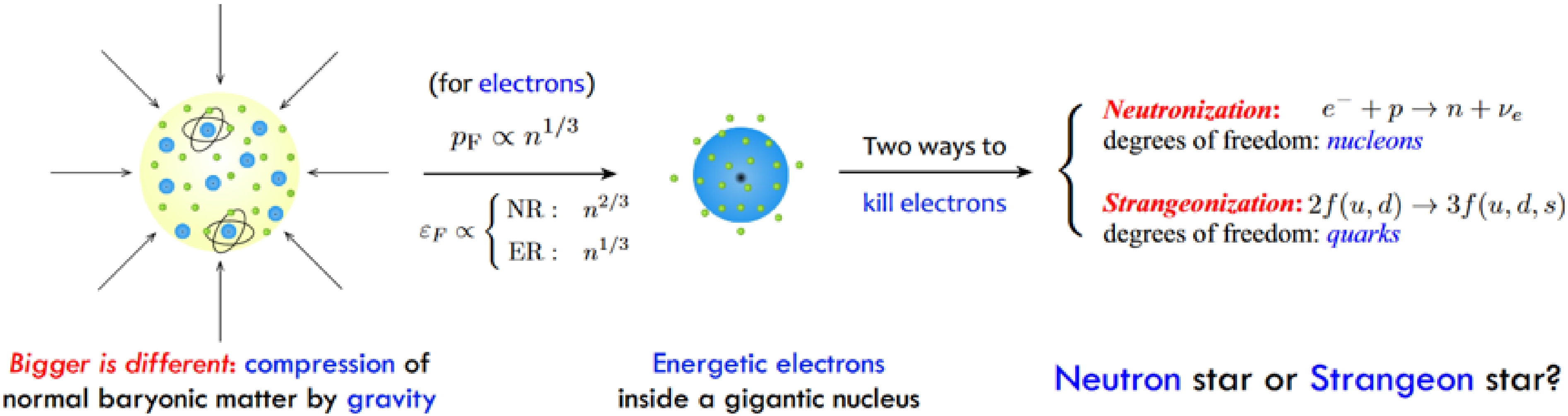



Fig.4 EOS and M-R relation of strangeon star at $\alpha_s = 0.4$ and $\alpha_s = 0.5$. The results of the APR model is also presented (dash dot line).

### Fitting of $z_0$ in nuclear matter

# Basic units: nucleon/strangeon?

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



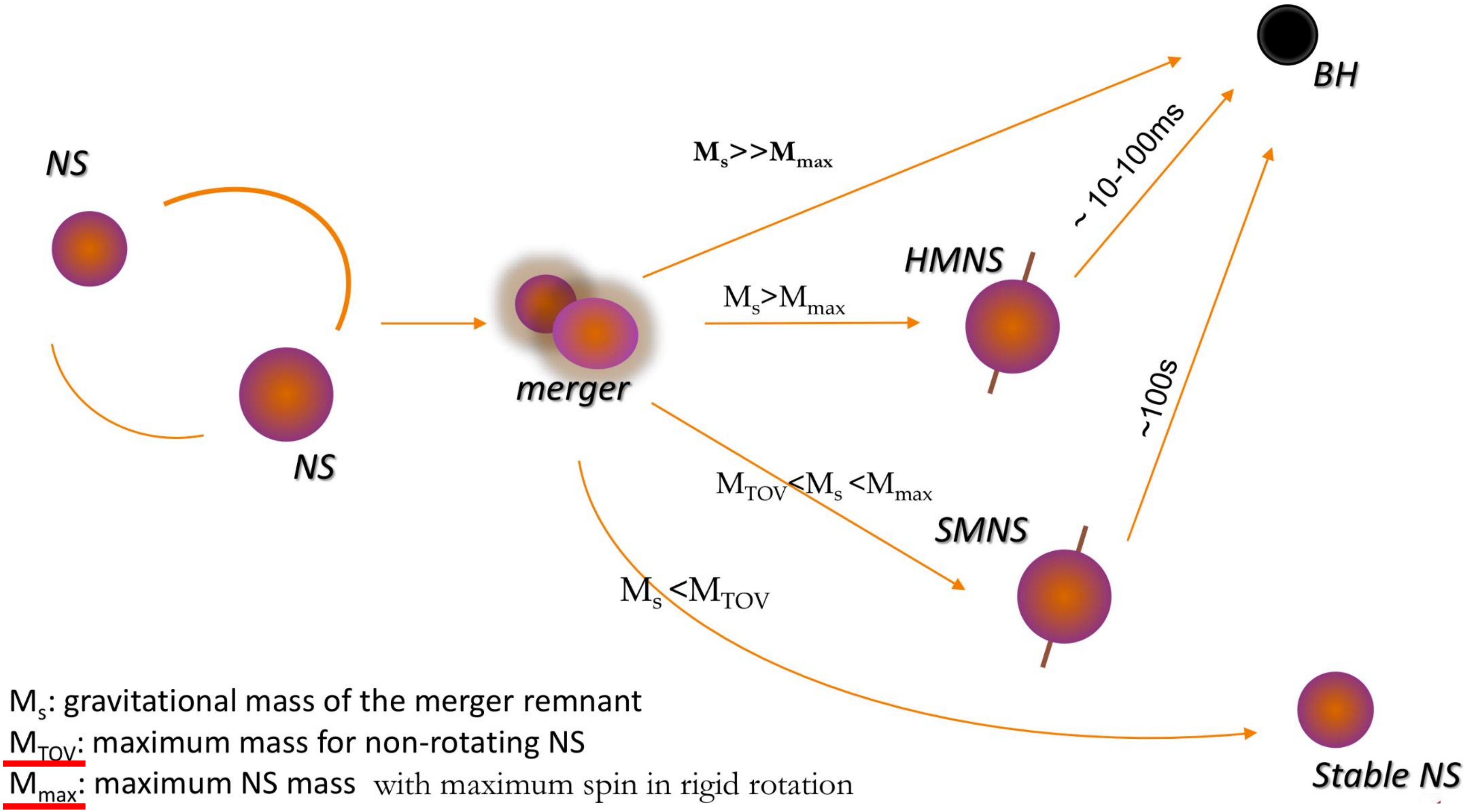

## *from a symmetrical perspective*

**TABLE 2.** Compact star models: a comparison.

| Models | Basic unit | Flavour | Asymmetry | Quark coupling, EoS | Surface binding |
|---|---|---|---|---|---|
| Neutron Star | nucleon | **2** ($u$ & $d$) | $\delta > 0.8$ | strong, stiff if no hyperon | gravity |
| Strange Quark Star | quark | **3** ($u$, $d$ & $s$) | $\delta < 10^{-4}$ | weak, softened with $s$ | self strong force |
| Strangeon Star | strangeon | **3** ($u$, $d$ & $s$) | $\delta < 10^{-4}$ | strong, stiff in any case | self strong force |

To test strangeon idea in the era of gravitational wave astronomy (multi-messengers…)

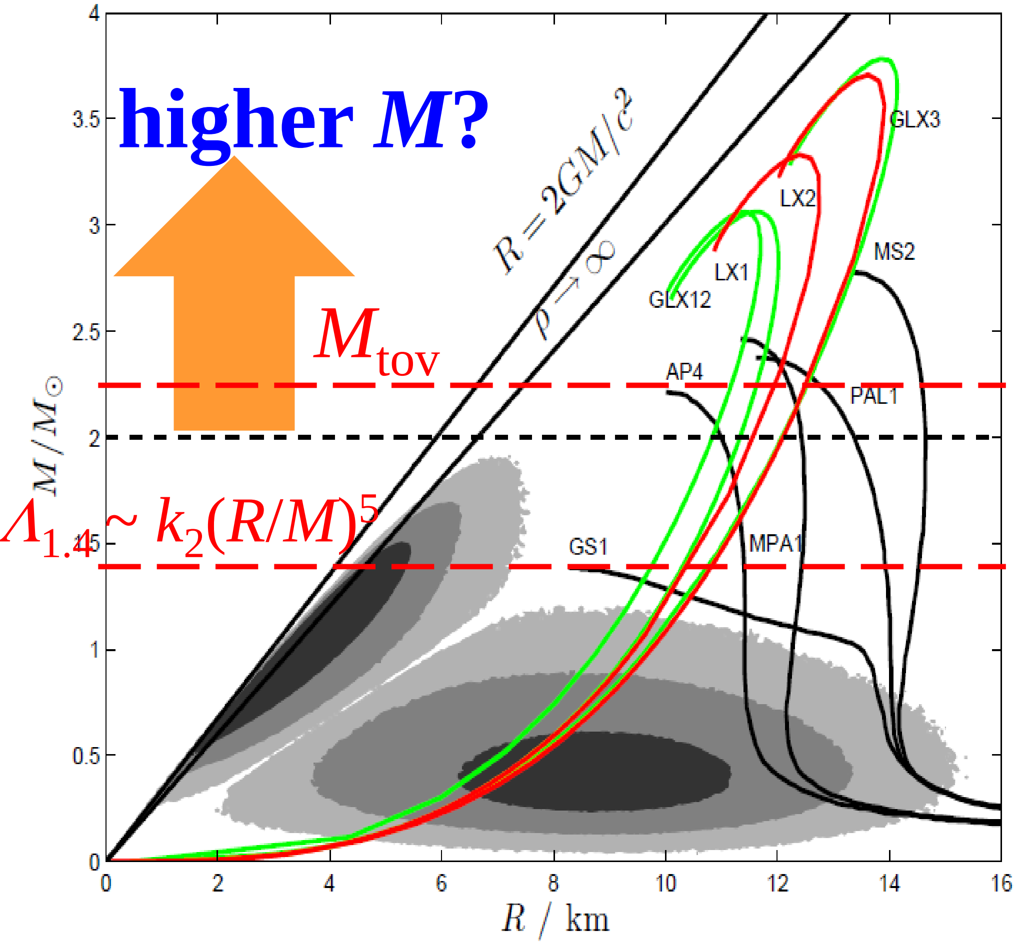
# To test in era of GW astronomy




from Bing Zhang's talk

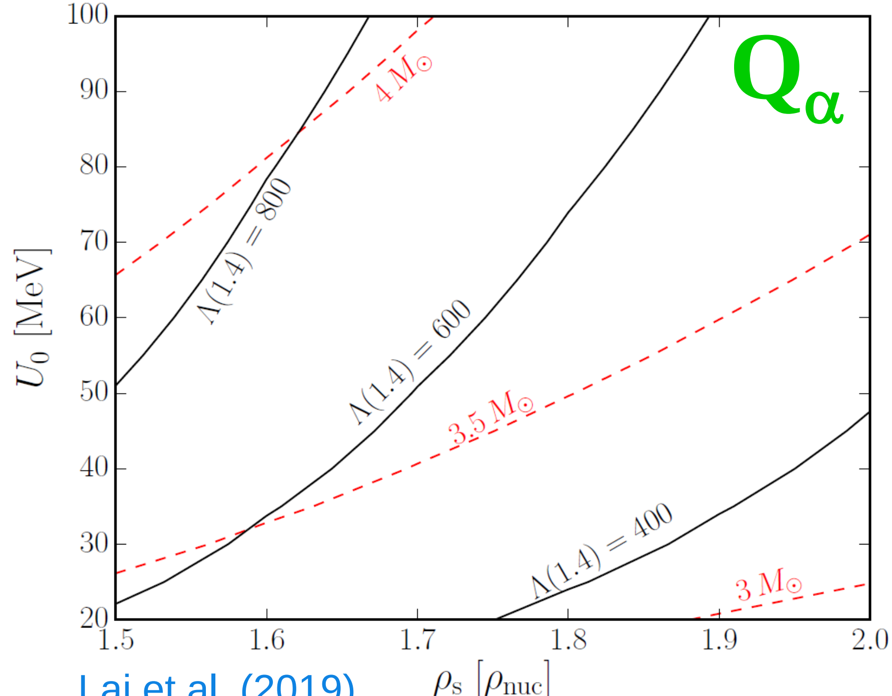
# To test in era of GW astronomy

• 1, Tidal deformability ($\Lambda_{1.4}$) and Maximum mass ($M_{tov}$)




Li, et al. (ApJ, 2015)

⇒ Strangeon star can have small $\Lambda_{1.4}$ (< 300) but large $M_{tov}$ (>2.5$M_\odot$)!

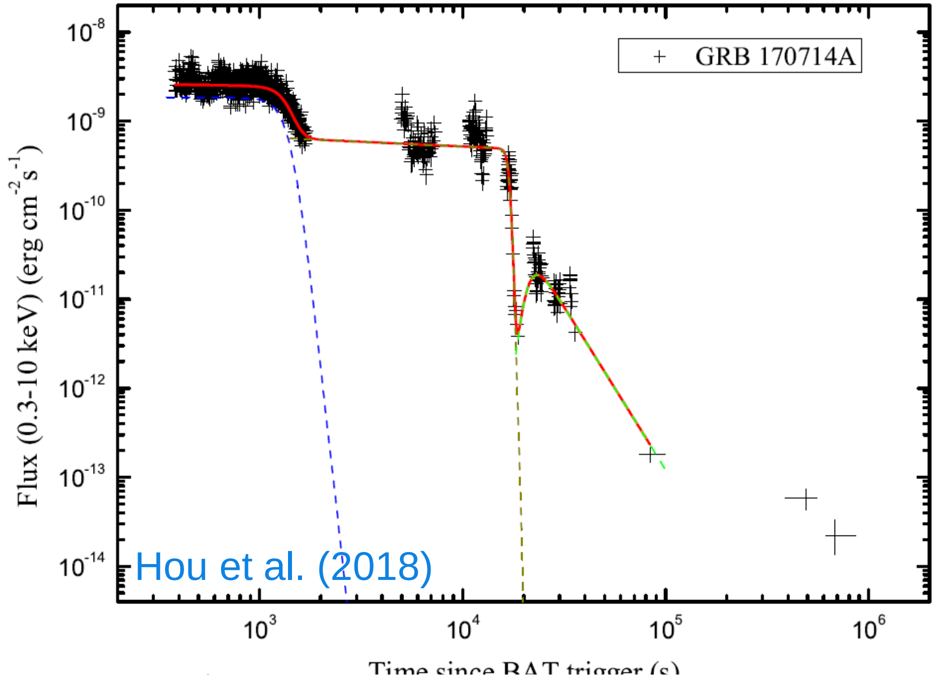


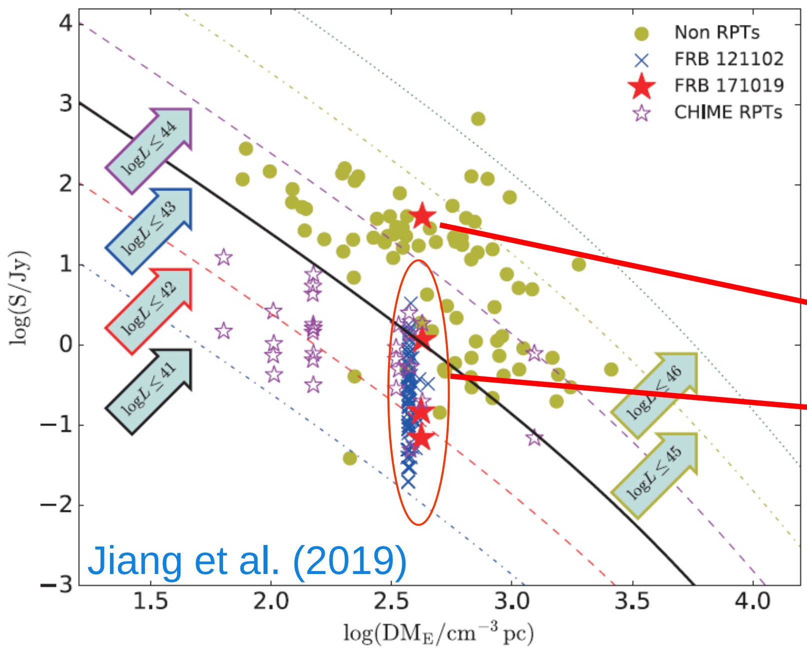

Lai et al. (2019)

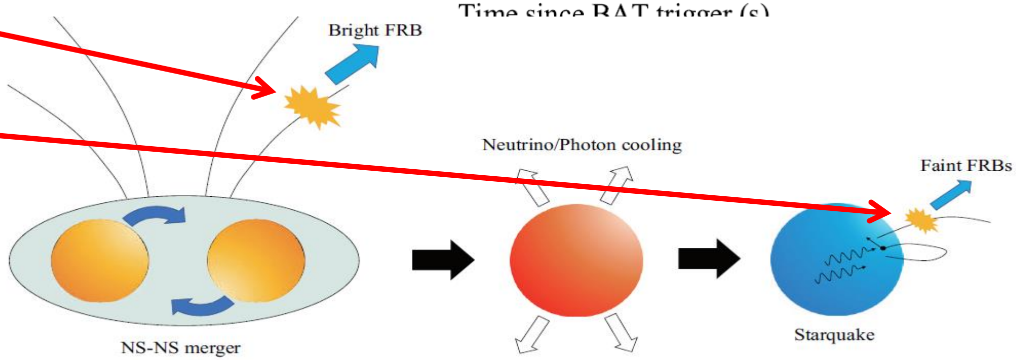
# To test in era of GW astronomy

• 2, Phenomenological study of GRBs/FRBs

⇒ Long-lived post-merger: large $M_{tov}$?!



# To test in era of GW astronomy

• 3, Phenomenological study of pulsar-like stars

| | 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 | $2f$ matter separated from $3f$ | Xu (2014) |
| | | optical/UV exce. of XDINS | bremsstrahlung radiation | Wang et al. (17/18) |
| **global** | stiff EoS, $\Lambda$ | high $M_{max}$ ($2 \sim 3 M_\odot$) | NR strangeons, hard core | Lai et al. (09ab, 18) 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) |

# Summary

- The basic units inside pulsar-like stars could be **3**-flavour ***symmetric strangeons*** rather than **2**-flavour ***asymmetric nucleons*** if the Nature really loves symmetry when building the world.

- The strangeon model would be tested further in the era of multi-messenger astronomy via $\Lambda_{1.4}/M_{\rm tov}$, GRB/FRB, and compact star's phenomenology.

**THANKS!**