Merging Strangeon Stars and Kilonova

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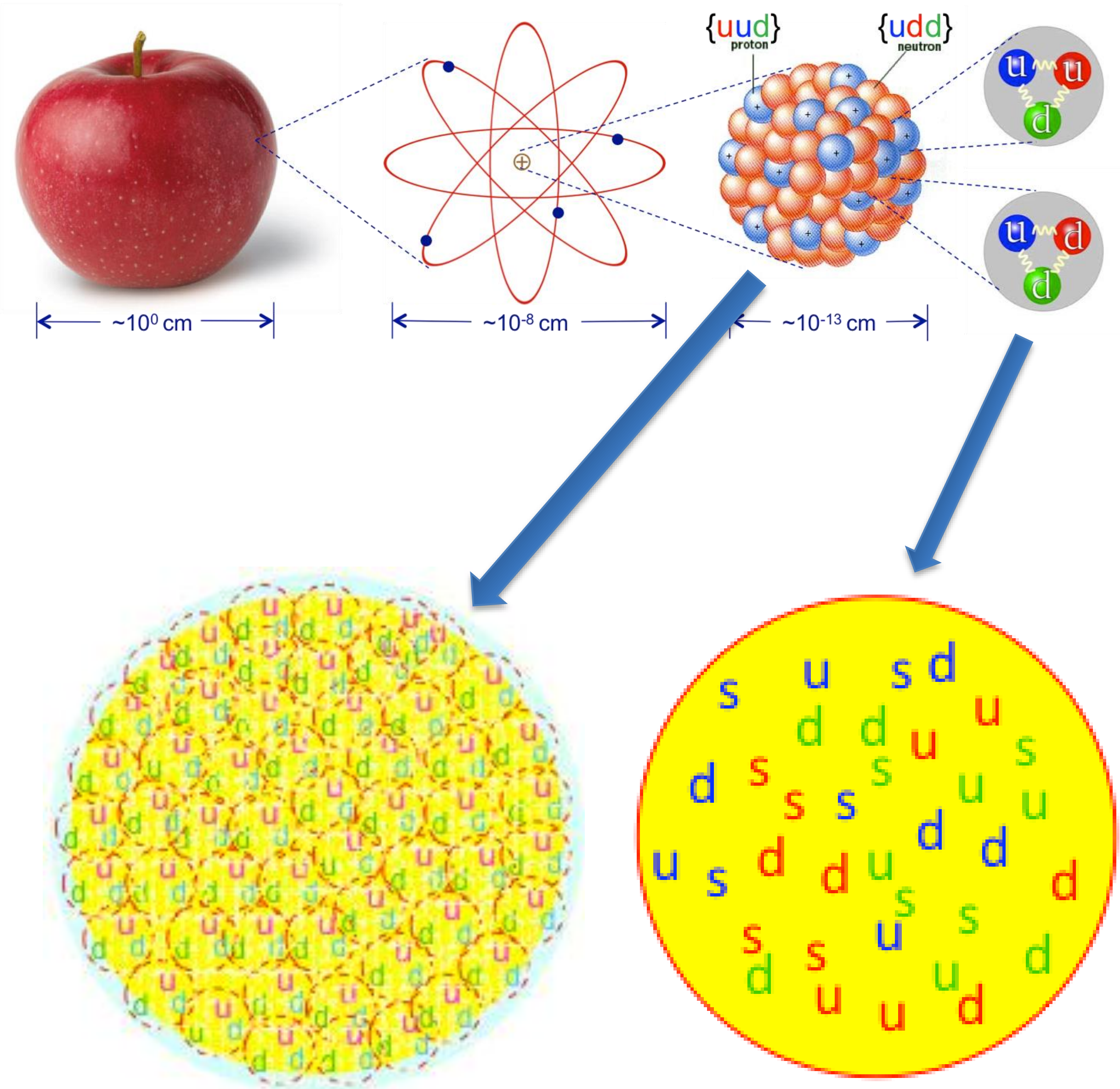
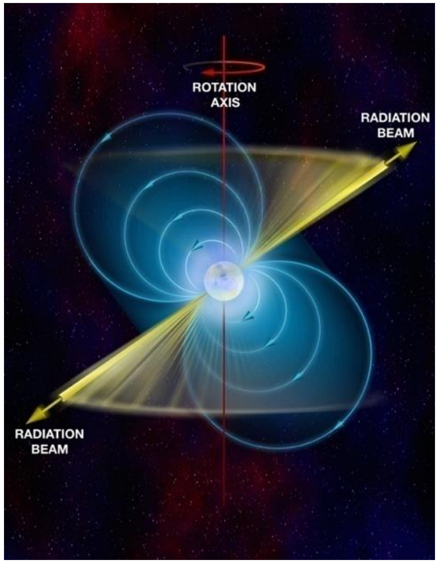
Outline

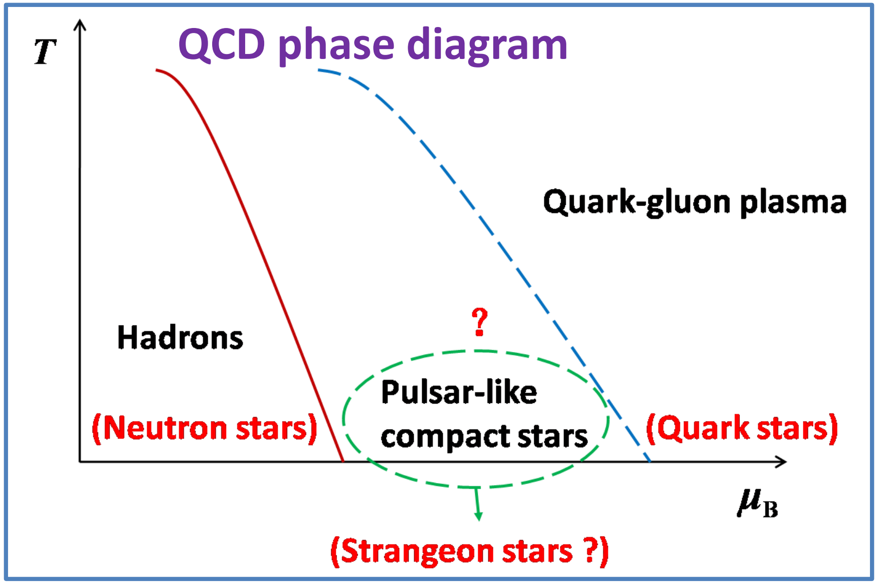
- What is strangeon star?
- Merging binary strangeon stars
- Kilonova: caused by merging strangeon stars?
- Summary





Neutron star

Quark star



Strangeon stars

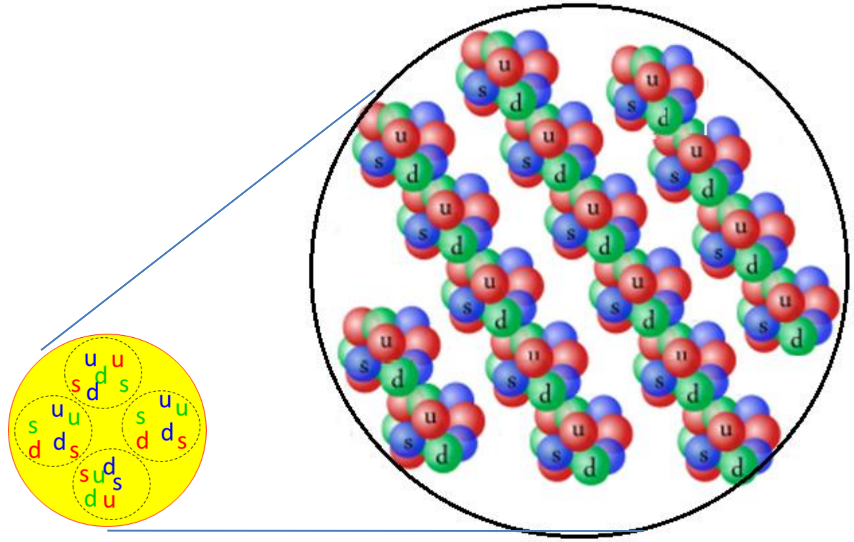
- "Strangeon" (奇子)

  = strange nucleon (奇异核子)

- Several u, d and s quarks are confined inside strangeons

Hadron star:	Quark star:	Hybrid/mixed star:	Strangeon star:
quarks confined	quarks de-confined	quarks de-con./con.	quarks localized
gravity-bound	*self-bound on surface*	*gravity-bound*	*self-bound on surface*

About strangeon stars



- Strangeons in pulsar-like compact stars:

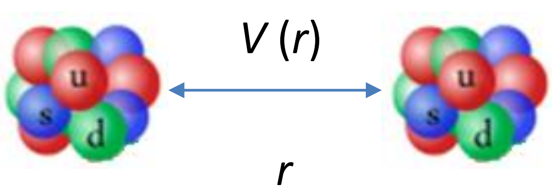
  3-flavored and **localized**

- **Stiff EoS** → High maximum mass

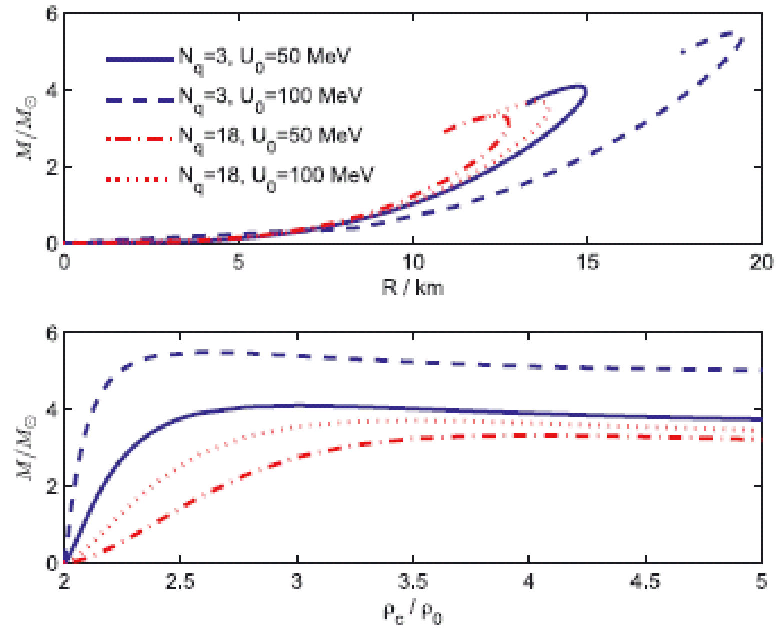
  Lai & Xu 2009ab, Guo et al. 2014, Lai et al. 2013

- $M_{\rm TOV}$ of strangeon stars:

$$M_{\rm TOV} > 2.3 M_{\odot}$$

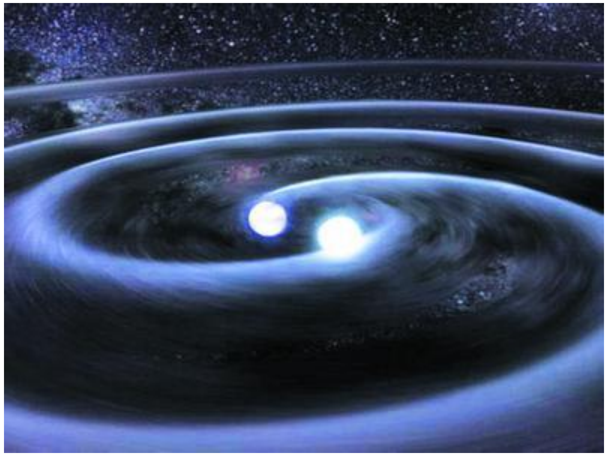


***V*(*r*) has a strong repulsive core**



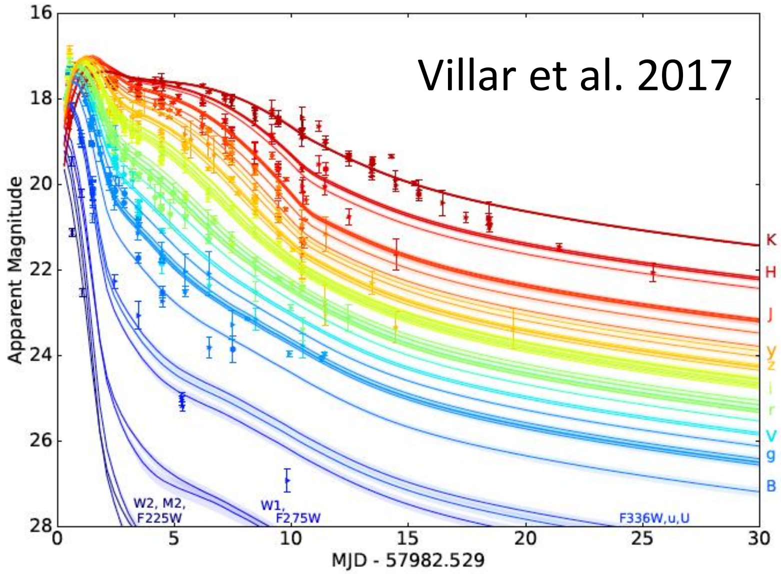
(Lai & Xu, 2009)

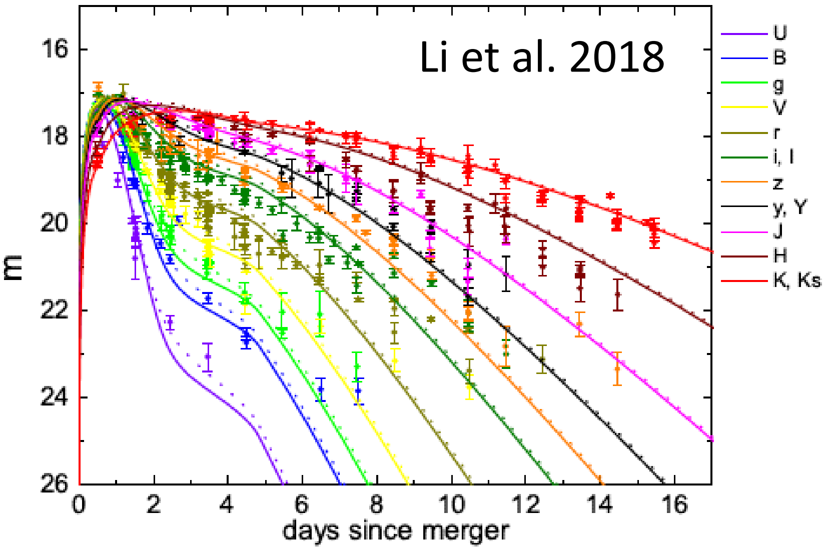
Binary “neutron star” merger



- **Tidal deformability from GW detection**
  - **A clean dynamical test for EoS**
- **EM counterpart: kilonova （千新星）**
  - **Indirect (?) test for EoS**

Multi-band light curves powered by a spinning-down NS

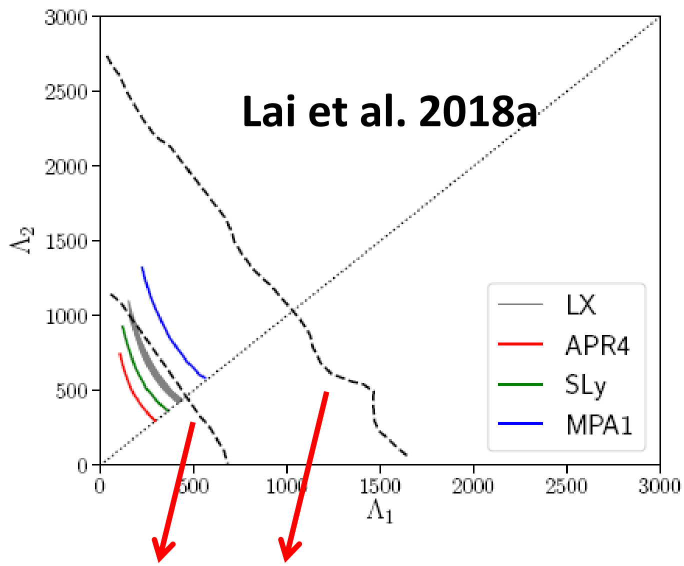




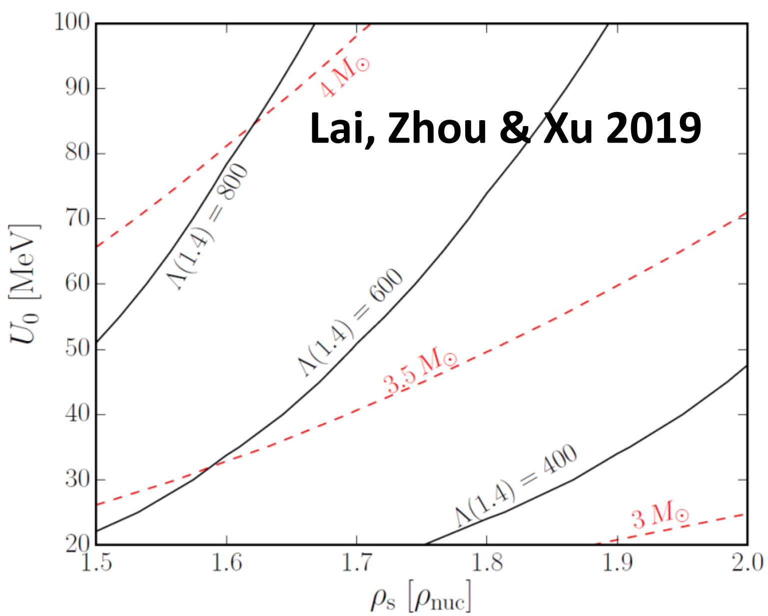
Merging binary strangeon stars

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

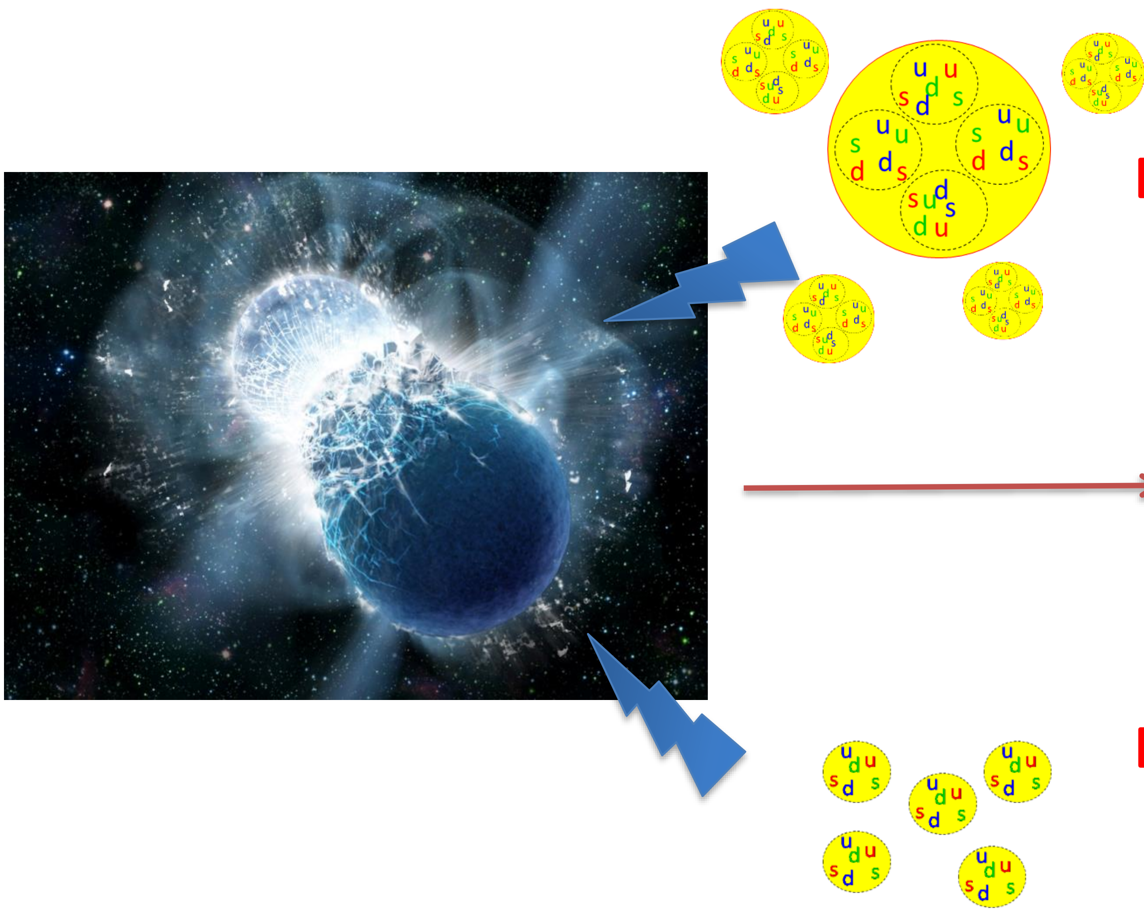
- Most of EoS parameters satisfy the constraint of GW170817
- The minimal Λ(1.4) is ~280 with $M_{\rm TOV}$ ~ $2.9M_{\odot}$
- High-mass strangeon stars could still pass the test of GWs



50% and 90% confidence contours by Abbott et al. 2017



Kilonova:
Caused by merging strangeons stars?

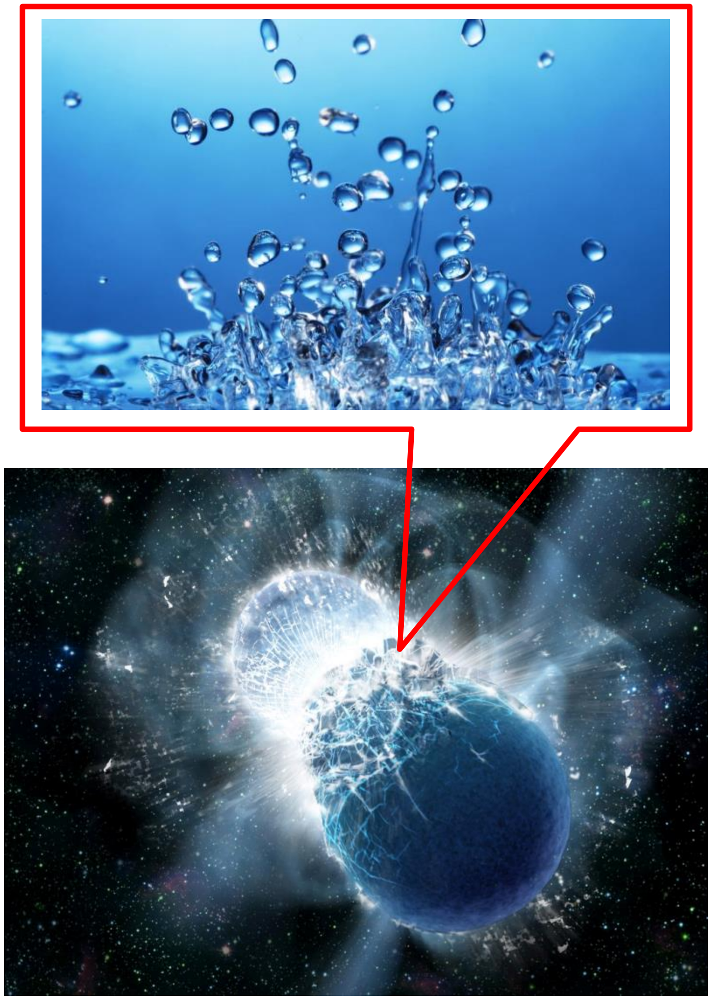


Ejected strangeon nuggets

Massive strangeon star
(M ~ 2.3 $M_\odot$)

Evaporated strangeons

The maximum size of strangeon nuggets



$$\begin{cases} \sigma r \simeq \dfrac{GMm}{R^3} r & \begin{pmatrix} \text{Surface tension} \\ = \text{Tidal force} \end{pmatrix} \\ m \simeq \rho r^3 \\ M = 1.4 M_\odot, \ R = 10 \text{ km} \end{cases}$$

$$r_{\max} \sim 1 \text{ cm} \left(\frac{\sigma}{10 \text{ MeV} \cdot \text{fm}^{-2}} \right)^{1/3}$$

The minimum size of strangeon nuggets

Weber number: $$W = \frac{\rho v^2 r}{\sigma} \geq 1$$

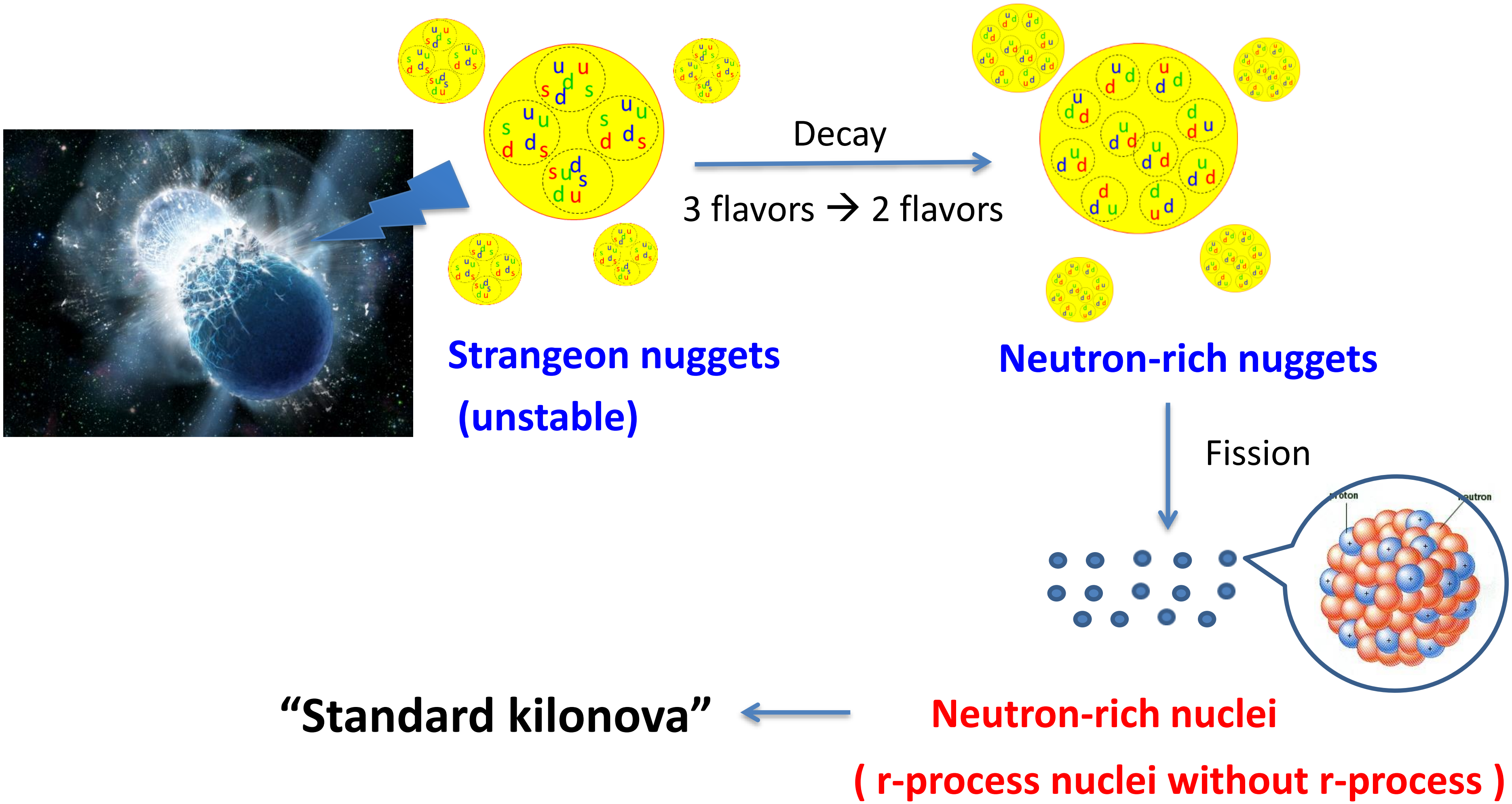
$$r \geq \frac{\sigma}{\rho v^2} \approx 1\,\mathrm{fm}\left(\frac{\sigma}{10\,\mathrm{MeV}\cdot\mathrm{fm}^{-2}}\right)\left(\frac{\rho_0}{\rho}\right)\left(\frac{0.1c}{v}\right)^2$$

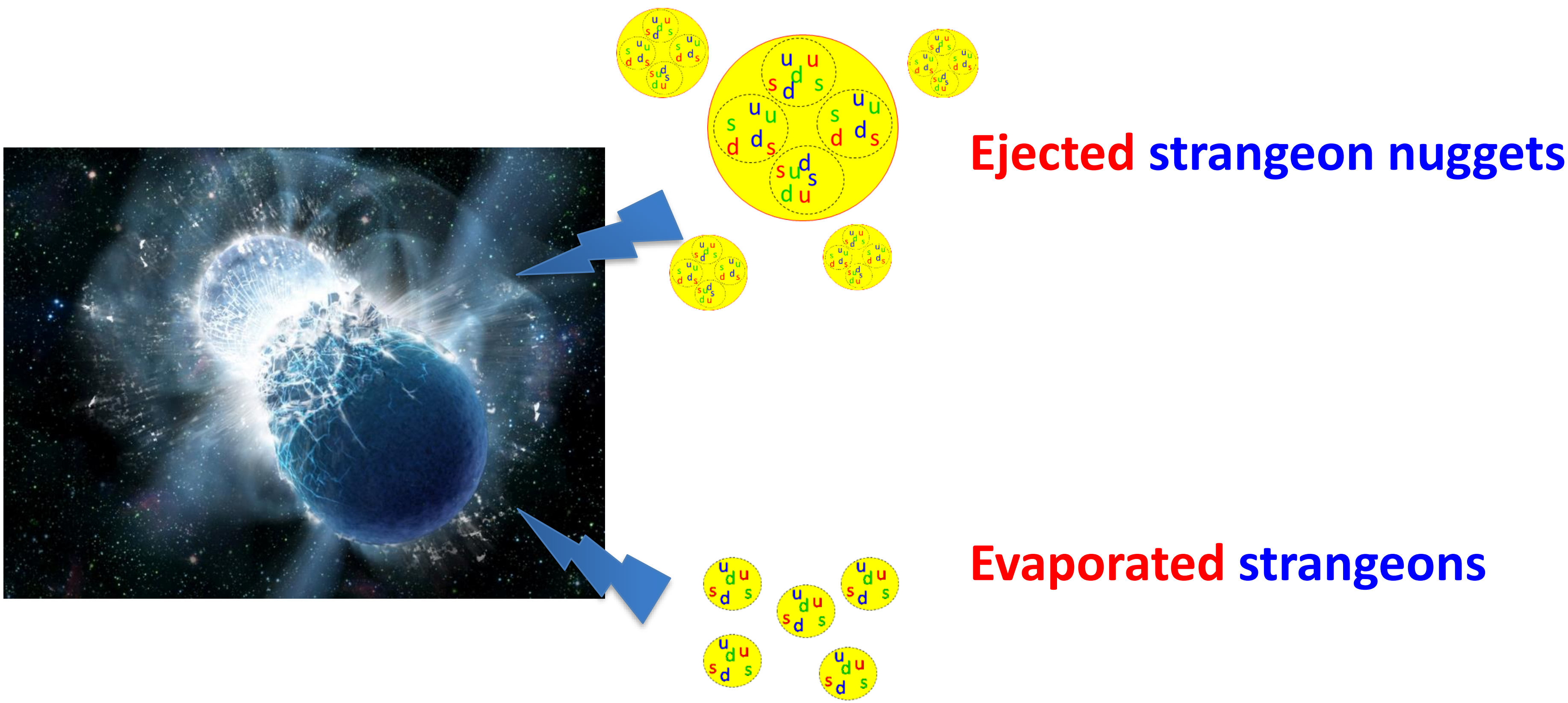
- **The baryon number range of initially ejected strangeon nuggets**

$$1 < A \leq 10^{38}$$

Stable or unstable under 3 flavors → 2 flavors ?

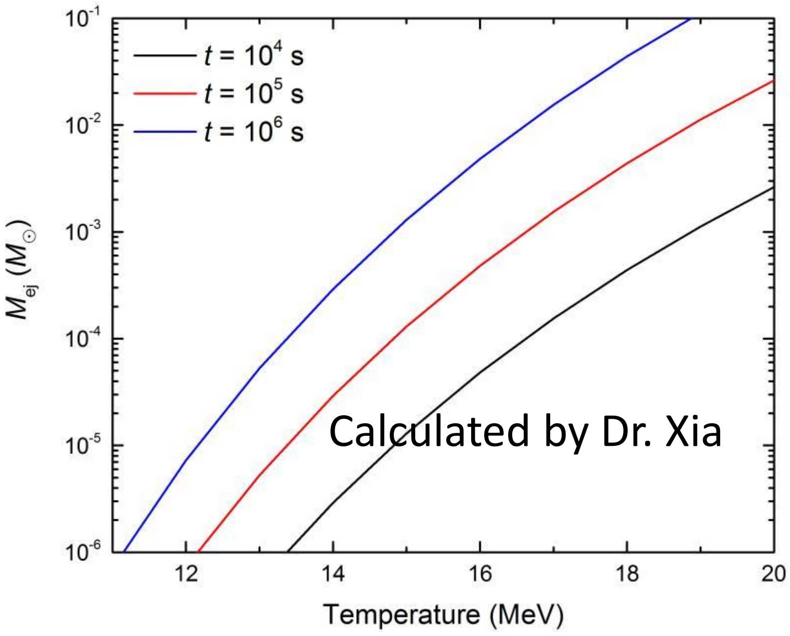
Strangeon nuggets: decay and fission




Ejected strangeon nuggets
Evaporated strangeons

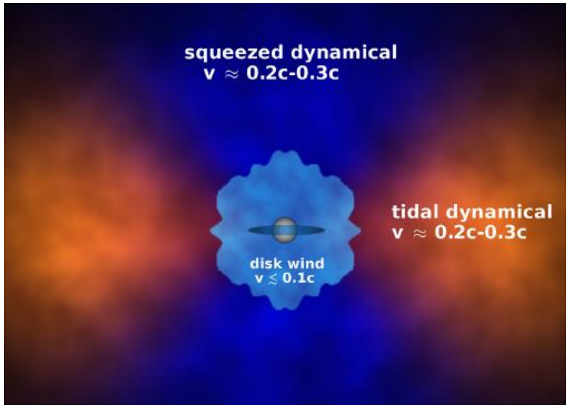
Evaporated strangeons

- The remnant of merger would have very high temperature, and strangeons could be evaporated from the surface
- M_{ej} by evaporation could be as large as $10^{-3}M_{\odot}$
- Strangeons are very short-lived (t ~ 10^{-10} s)
  - Strangeon → protons and neutrons
  - Energy released: E/A ~ 100 MeV
  - They would power the fireball of GRB
- The products of strangeons' decay
  - Not neutron-rich, so Y_e is high



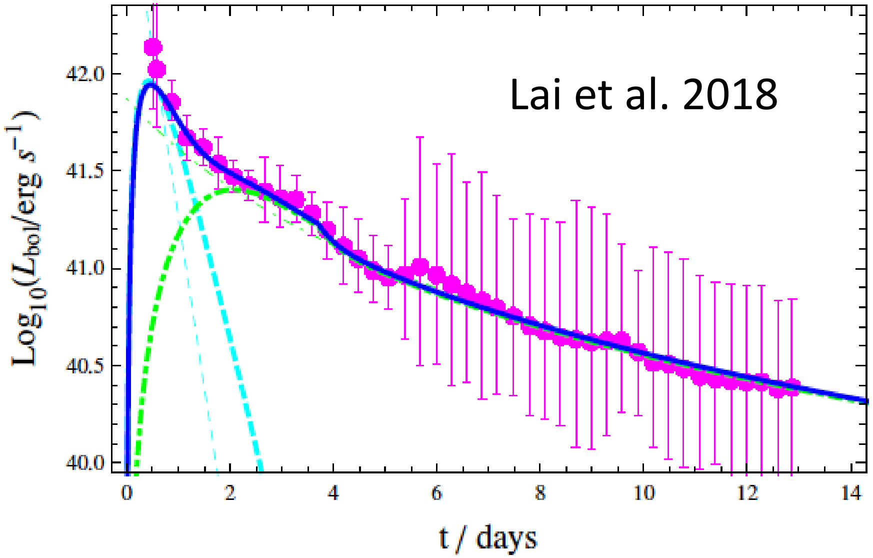
A possible scenario of kilonova event

- Blue component
  1. **Decay of strangeon nuggets to neutron-rich nuggets**
  2. Decay of evaporated strangeons to protons and neutrons



Kasen et al. 2017

- Red component
  1. **Spin-down power of the massive remnant**
  2. Decay of neutron-rich nuggets



Summary

If pulsar-like compact stars are strangeon stars

- Global structure of pulsars
- The gravitational wave signals of merger
- **The “kilonova” event**

Thank you !