3-*flavored* Nucleus

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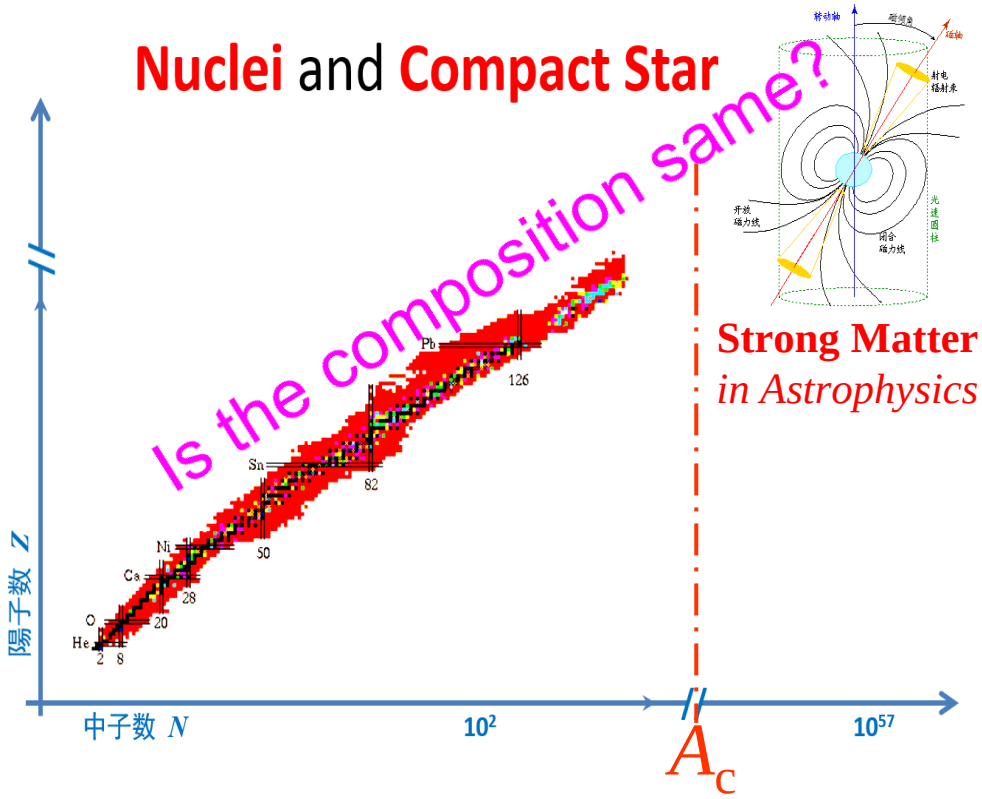
Strong matter: 2- or 3-flavored?

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



Electric Matter:
condensed by EM-force

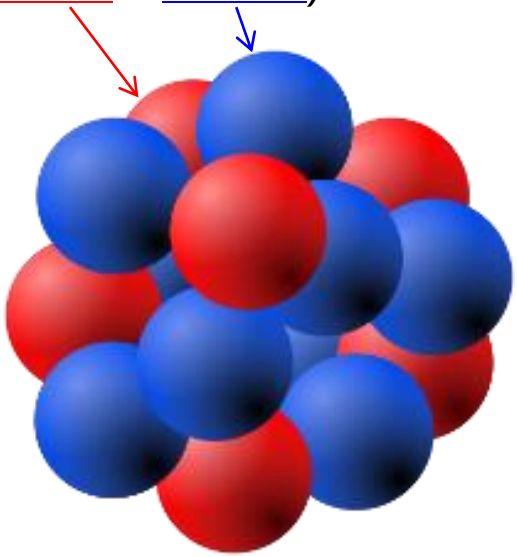
Strong Matter:
condensed by strong force

Strong matter: 2- or 3-flavored?

- 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)



"small SM"

$A_c \sim 10^9$?

Small Big

"big SM"

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

3-flavored Nucleus

Can strong matter be 3-flavored?

Can strong matter be 3-flavored?

Hobby

- God may love a matter state with ***f***lavor-maximization…

  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_{scale}, ~~**(c,b,t)**~~

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

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

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

- Strong matter should be **3**-flavored (***u***,***d***,***s***), but why are normal stable atomic nuclei **2**-flavored (***u***,***d***)?

Nuclear Symmetry Energy

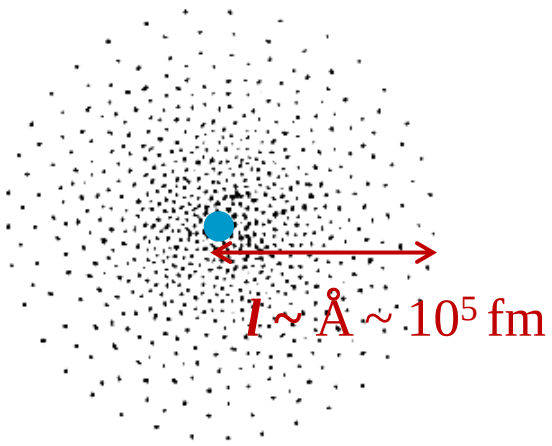
Can strong matter be 3-flavored?

Hobby

- God may love a matter state with ***f***lavor-maximization…

Q: why are normal stable atomic nuclei **2**-flavored (***u***,***d***)?

A: atomic nuclei are too small to be **3**-flavored (***u***,***d***,***s***)!



If the radius l of a nucleus is much larger than the *Compton wavelength* $\lambda_e = h/m_e c = 0.024$Å, $\Rightarrow A_c \sim 10^9$! most of electrons are inside nucleus and extremely relativistic, contributing a kinetic energy of $E_k \sim 200$MeV!

Because of $\Delta m_{uds} >> m_e c^2$, small 2-***f*** strong matter should be energetically stable if converting *s* to *u*/*d* by weak force.

Can strong matter be 3-flavored?

Hobby

- God may love a matter state with *f*lavor-maximization…

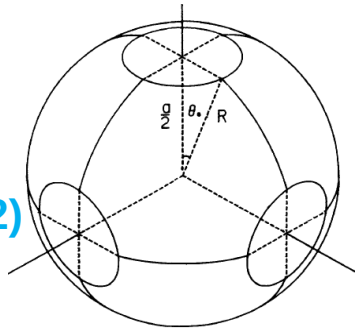
A ***philosophical argument*** about *f*lavor-maximization

quarks inside a bag-like vacuum non-perturbative

PHYSICAL REVIEW C VOLUME 46, NUMBER 6 DECEMBER

Nuclear equation of state in the MIT bag crystal model for nuclear matter

Zhang & Liu (1992)



We may come to a conclusion of

If length $\ell << \lambda_e$, the **2**-f matter is energetically favored;

if length $\ell >\sim \lambda_e$, the **3**-f matter is energetically favored.

3-flavored Nucleus

Where could 3-flavored nucleus exist?

Where could 3-flavored nucleus exist?

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

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

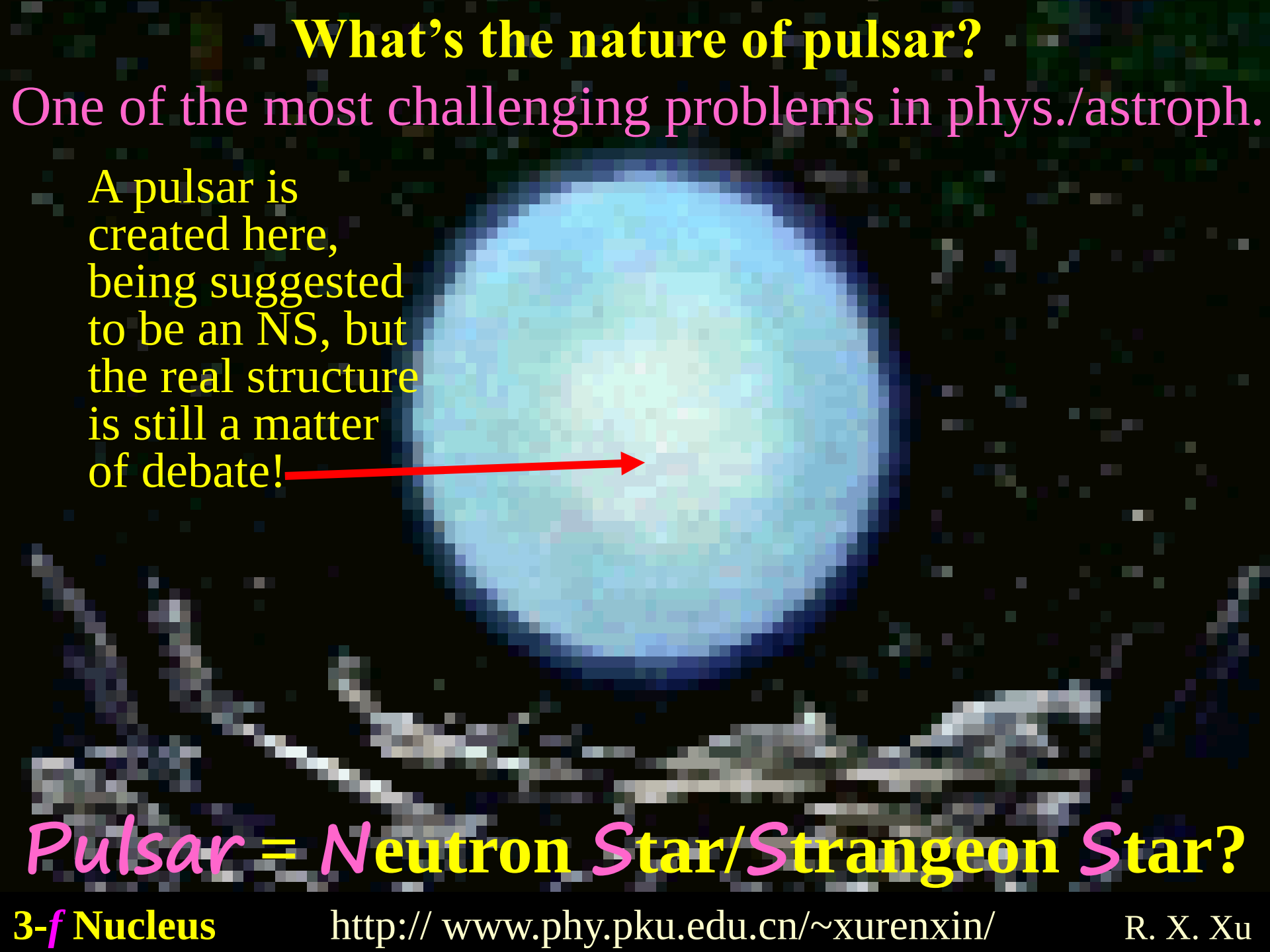
Trinity of Strangeon

- Strangeon star: ***compact object***
- Strangeon cosmic ray: **UHECR**
- Strangeon dark matter: **cosmology**

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!



Pulsar = Neutron Star/Strangeon Star?

Where could 3-flavored nucleus exist?

- 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, 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)

3-flavored Nucleus

How to rule out the possibility of 3-flavored nucleus?

How to rule out possibility of 3-*f* nucleus?

- Strangeon is not new…speculated 15 years ago

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SOLID QUARK STARS?

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Received 2003 July 9; accepted 2003 August 22; published 2003 September 15

ABSTRACT

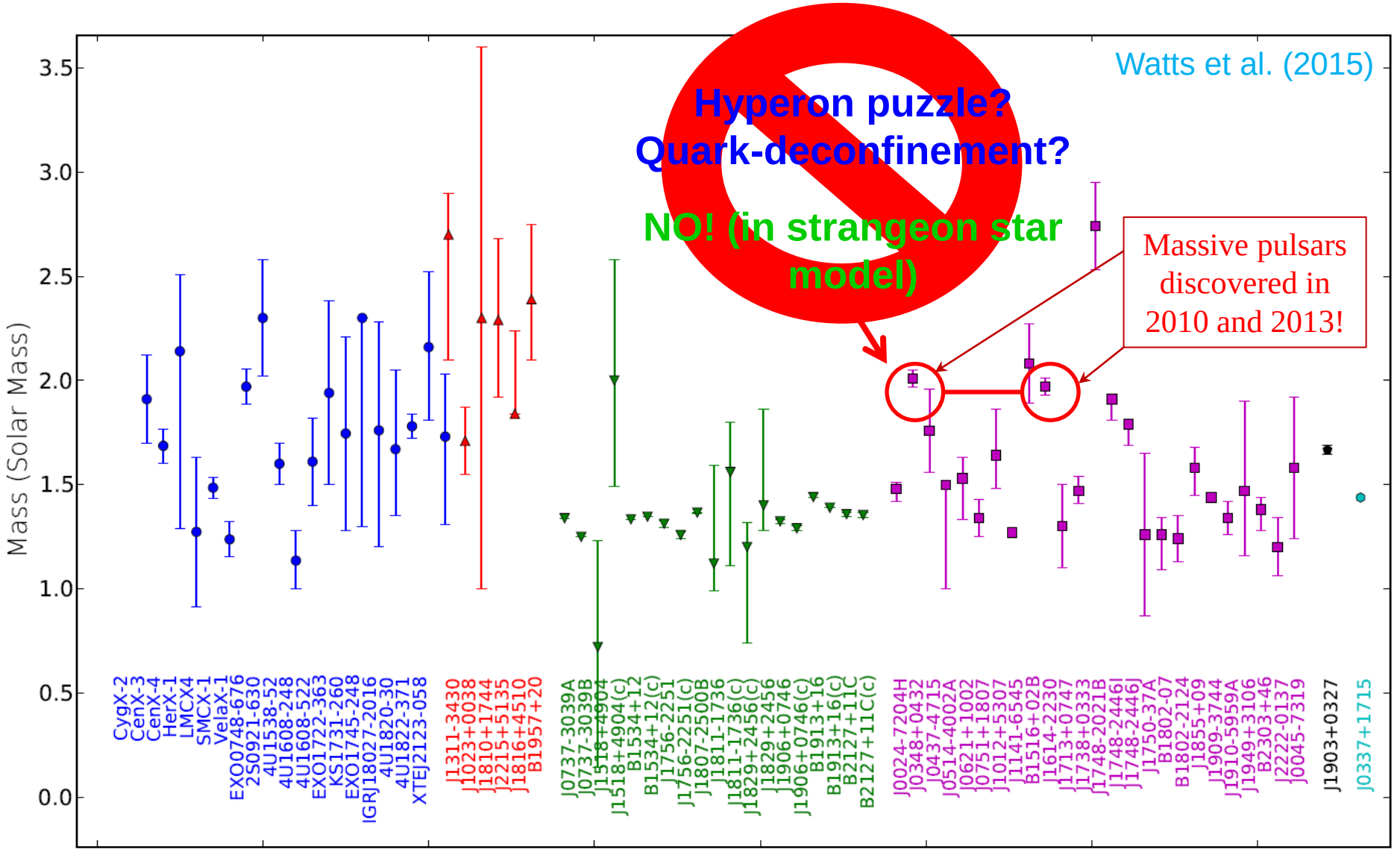
It is conjectured that cold quark matter with very high baryon density could be in a solid state, and strange stars with low temperatures should thus be solid stars. The speculation could be close to the truth if no peculiar polarization of thermal X-ray emission (as in, e.g., RX J1856) or no gravitational wave in postglitch phases are detected in future advanced facilities or if spin frequencies beyond the critical ones limited by *r*-mode instability are discovered. The shear modulus of solid quark matter could be $\sim 10^{32}$ ergs cm^{-3} if the kilohertz quasi-periodic oscillations observed are relevant to the eigenvalues of the center star oscillations.

Subject headings: dense matter — elementary particles — pulsars: general — stars: neutron

CSC inhomogeneity: chiral solid?

- condensation in ***x***-space, rather than ***p***-space, in ***solid*** state…astrophy.
- former names: strange cluster, quark cluster, solid quark...

How to rule out possibility of 3-*f* nucleus?



How to rule out possibility of 3-*f* nucleus?

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

Xu & Guo, 2016/2017, ***Strange Matter: a state before black hole***, in: centennial of general relativity, Ed. Cesar A. Zen Vasconcellos, World Scientific Publishing Company, p.119-146

Note added in proof

After submission of this chapter, the discovery of the gravitational waves is announced (Abbott *et al. PRL* **116**, 061102 (2016)). The proposed model of strange star with rigidity (i.e., solid strange quark-cluster star) is quite likely to be tested further by kilo-Hz gravitational wave observations of two kinds of events as follow, at least. (1) Merger of pulsar–pulsar/pulsar–black hole binary. The predicted waveform depends on the state equation of supra-nuclear matter, and the tidal effects during inspiral should be much weaker for solid strange star than for normal neutron star. (2) Starquake of pulsar-like compact star. Sensitive detectors may discover starquake-induced gravitational waves of compact stars, and then show very different signatures of neutron and strange stars.

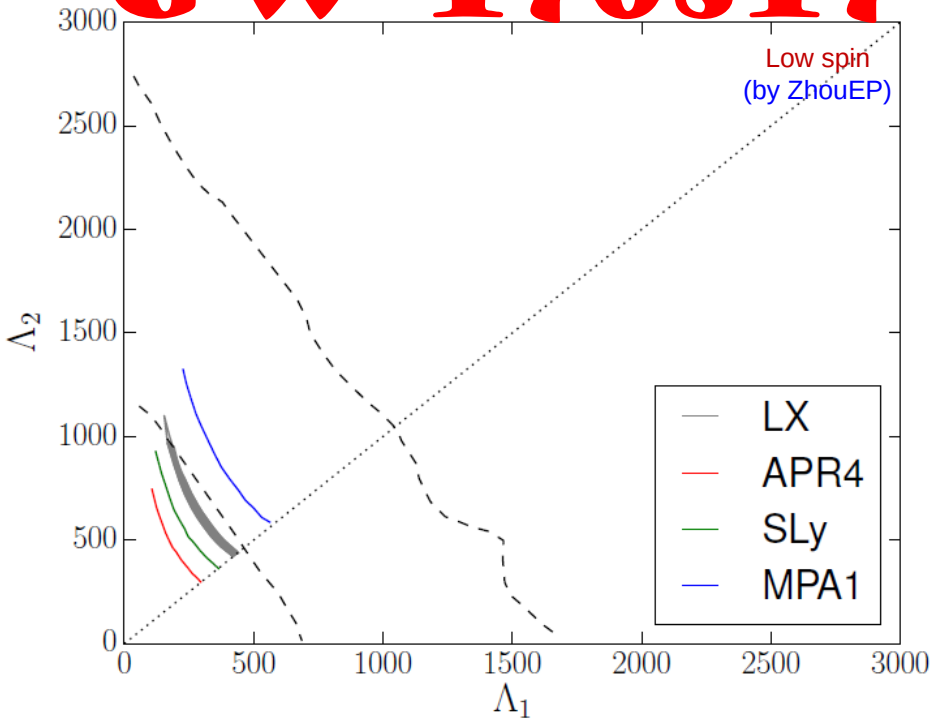
http://www.worldscientific.com/worldscibooks/10.1142/9690

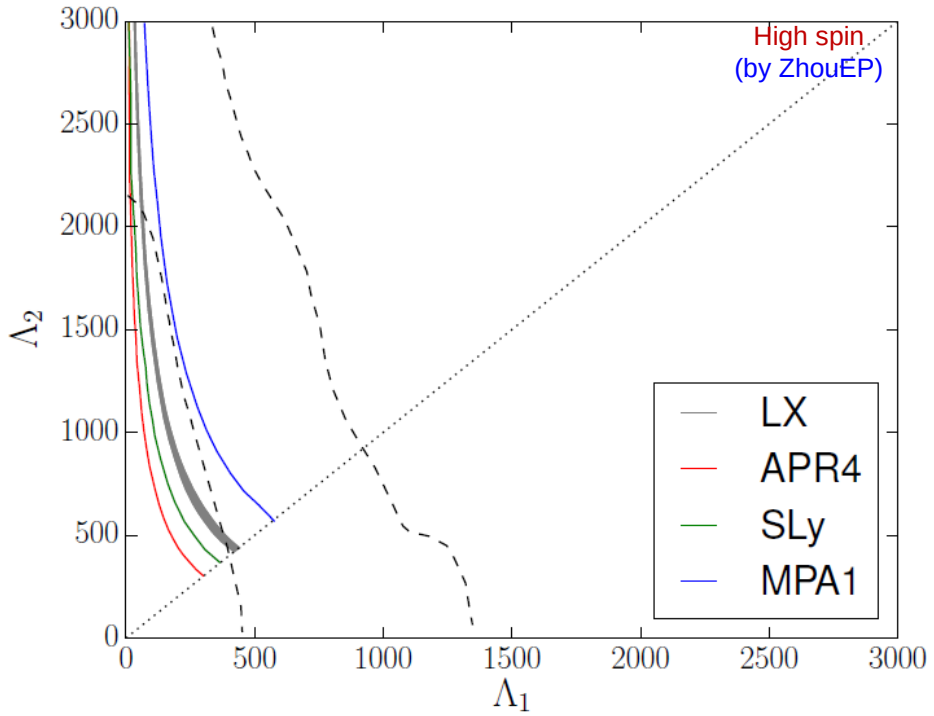
How to rule out possibility of 3-*f* nucleus?

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

GW 170817

Lai et al. (2018)





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

How to rule out possibility of 3-*f* nucleus?

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

KIAA-WAP II: *Cosmic rays in a new era*

KIAA@Peking University, August 17-19, 2017

http://kiaa.pku.edu.cn/aph2017/

The KIAA-WAP II (Workshop on Astroparticle Physics II) focuses on the physics & detection of cosmic rays, neutrinos, γ-rays, and new achievements of major facilities.

Special attention will be paid to future projects and techniques for strategic planning after the LHAASO construction.

Topics:

Astrophysical & cosmic neutrinos

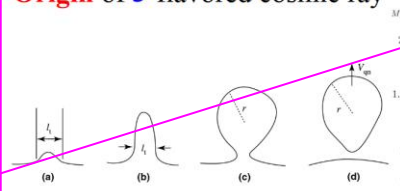
Ultra-high energy cosmic rays

Astrophysical sources

Techniques & future projects

Organizer

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



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

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

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

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]

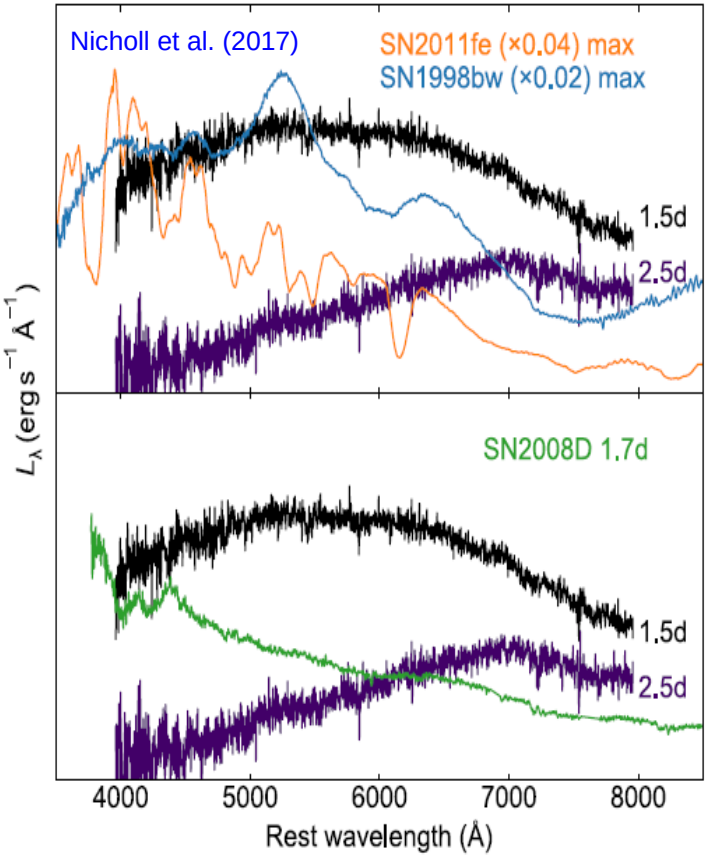
16:30 -- 17:00 Jorge Horvath[photo]: ***There may be no "gold" coming out from compact star mergers*** [pdf]

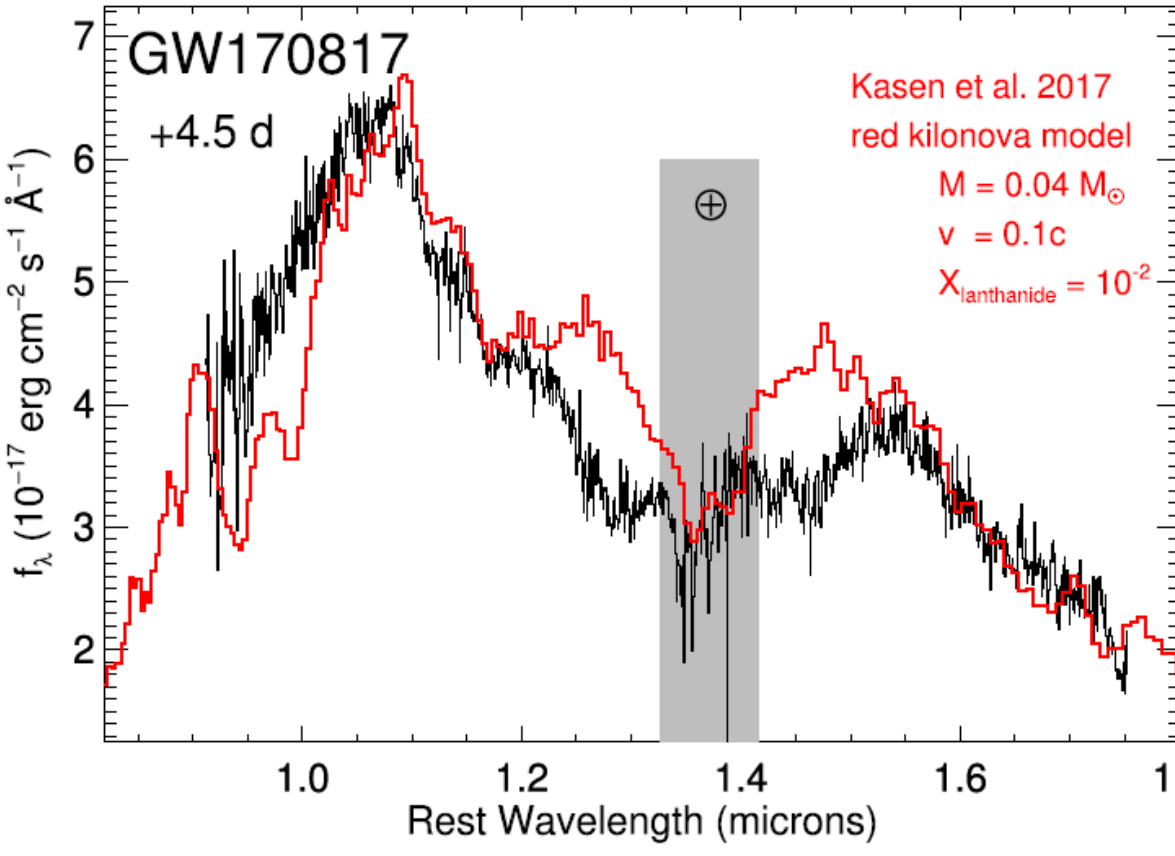
17:00 -- 17:30 Renxin Xu[photo]: ***Strangeness in cosmic rays*** [pdf]

* * * Banquet * * *

How to rule out possibility of 3-*f* nucleus?

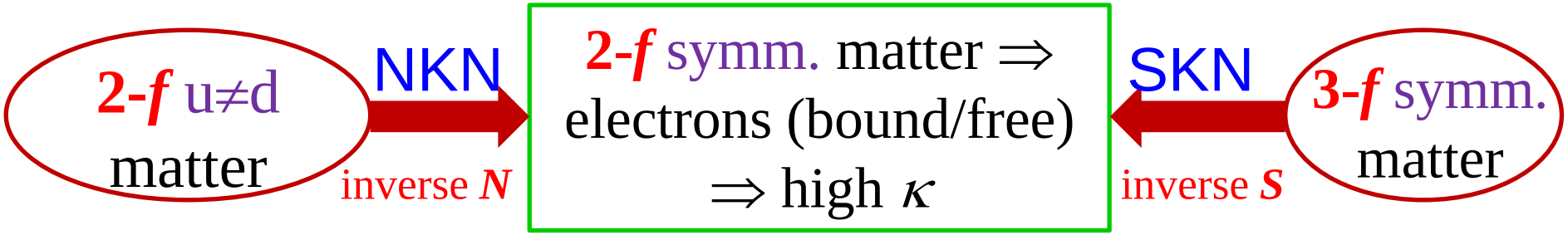
GW170817 spectra: 1, no line features resolved;
2, to be much redder than a supernova.





How to rule out possibility of 3-*f* nucleus?

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

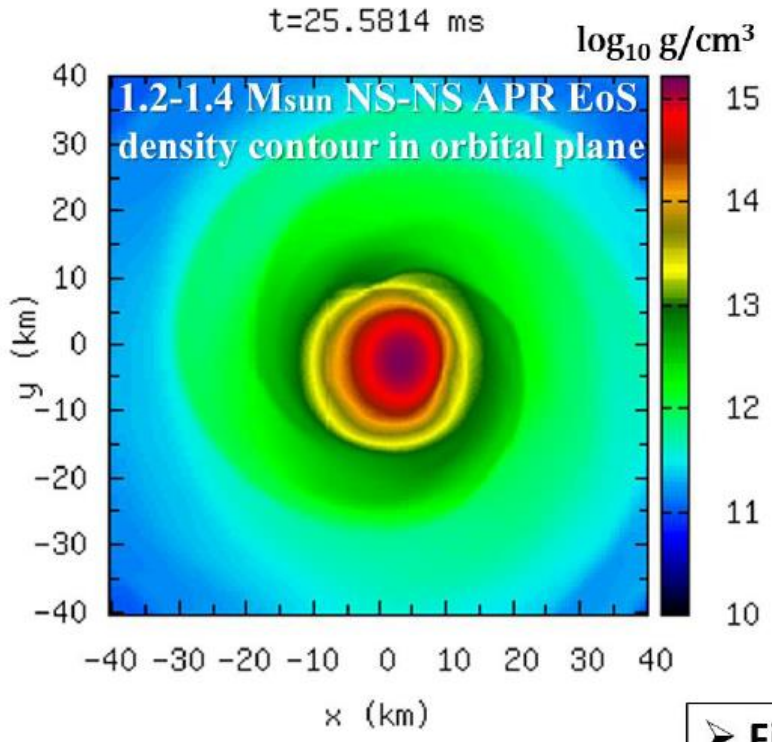


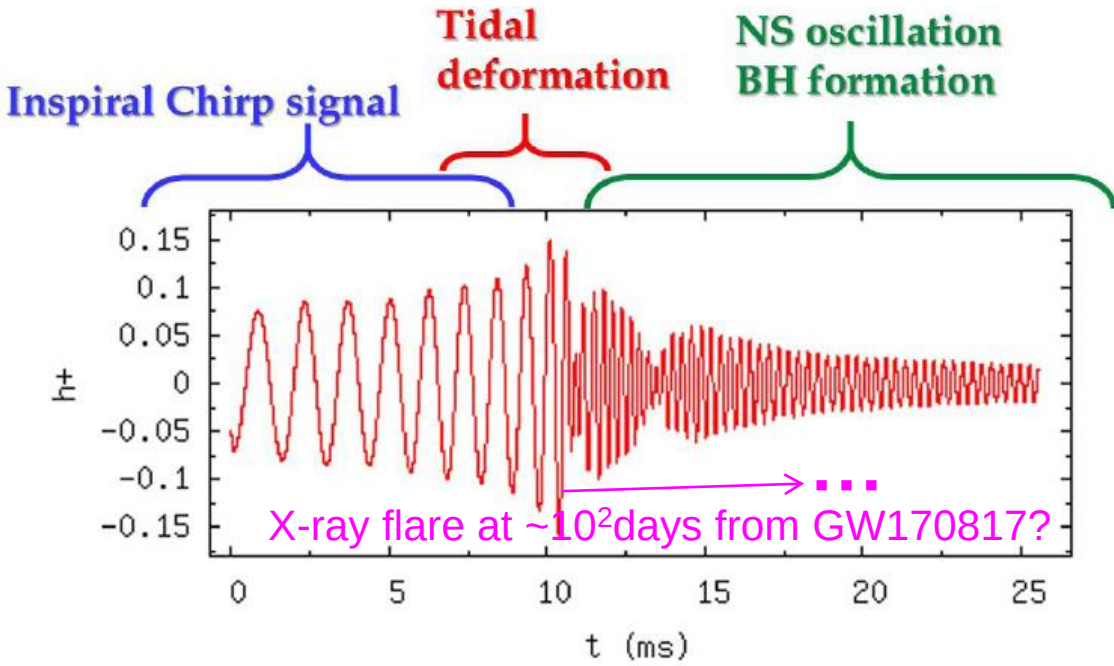
- Neutron KN: Poster merger = BH $\Rightarrow \kappa \sim 20$
  Poster merger = NS $\Rightarrow \kappa \sim 5$

- Strangeon KN: Poster merger = SS $\Rightarrow \kappa < 1$?

How to rule out possibility of 3-*f* nucleus?

Gravitational waves from NS-NS merger





First suggested by Shibata (2005)

- Point particle approx.
- Information of orbits, NS mass

- Finite size effects appear
- tidal deformability
- radius

- BH or NS ⇒ maximum mass
- GWs from massive NS
  ⇒ NS radius of massive NS

from Sekiguchi's talk (QCS2017, Kyoto)

Conclusions

Conclusions

- Can strong matter be 3-flavored? ***Yes***!
  God/Nature may love ***f***-maximization
- Where could 3-flavored nucleus exist? ***Trinity***!
  Astrophysical advantages of StrangeonS
- How to rule out the possibility of 3-flavored nucleus? ***Hmm***…
  Kilonova? more BNS/NSBH merging...

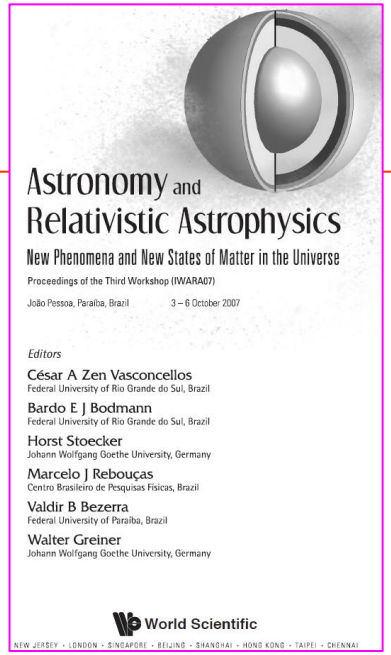
3-flavored Nucleus

Others

3-flavored Nucleus

Program List of IWARA2007

Schedule	Wednesday 03/10/07	Thursday 04/10/07	Friday 05/10/07	Saturday 06/10/07
9h - 10h	Ghirlanda	Weber	Ruffini	Aichelin
10h - 10:30h	Bodmann	Mosquera	Debora	Grunfeld
10:30h	Coffee Break and Poster Session	Coffee Break and Poster Session	Coffee Break and Poster Session	Coffee Break and Poster Session
11h – 12h	Starkman	Novello	Gay	Horvath
12h	Lunch	Lunch	Lunch	Lunch
14h – 15h	Mendes/Bauer	Hugo/Aurora	Xu	
15h – 15:30h	Scoccola	Dillig	Malheiro	
15:30h	Coffee Break and Poster Session	Coffee Break and Poster Session	Coffee Break and Poster Session	
16h				
16:10h	Taurines	Marasi	Marranghello	
16:30h	Boller	Varese	Valdir	
17h		Duarte	Rebouças	
17:30h – 18:30h	Opening Session Greiner	Rasanen	Horvath	
20:00	Cocktail and Dinner	Dinner	Dinner	



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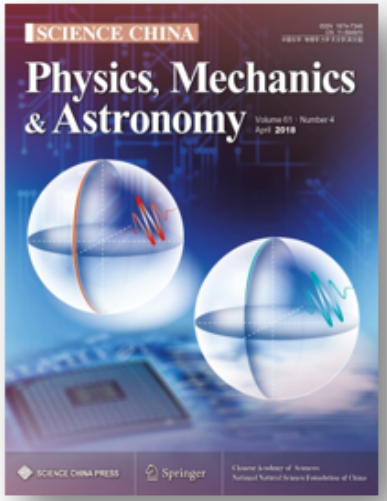
3-flavored Nucleus

Sci. China-Phys. Mech. Astron.



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THANKS!