H-cluster stars

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❖ Two important questions related to non-perturbative nature of QCD:

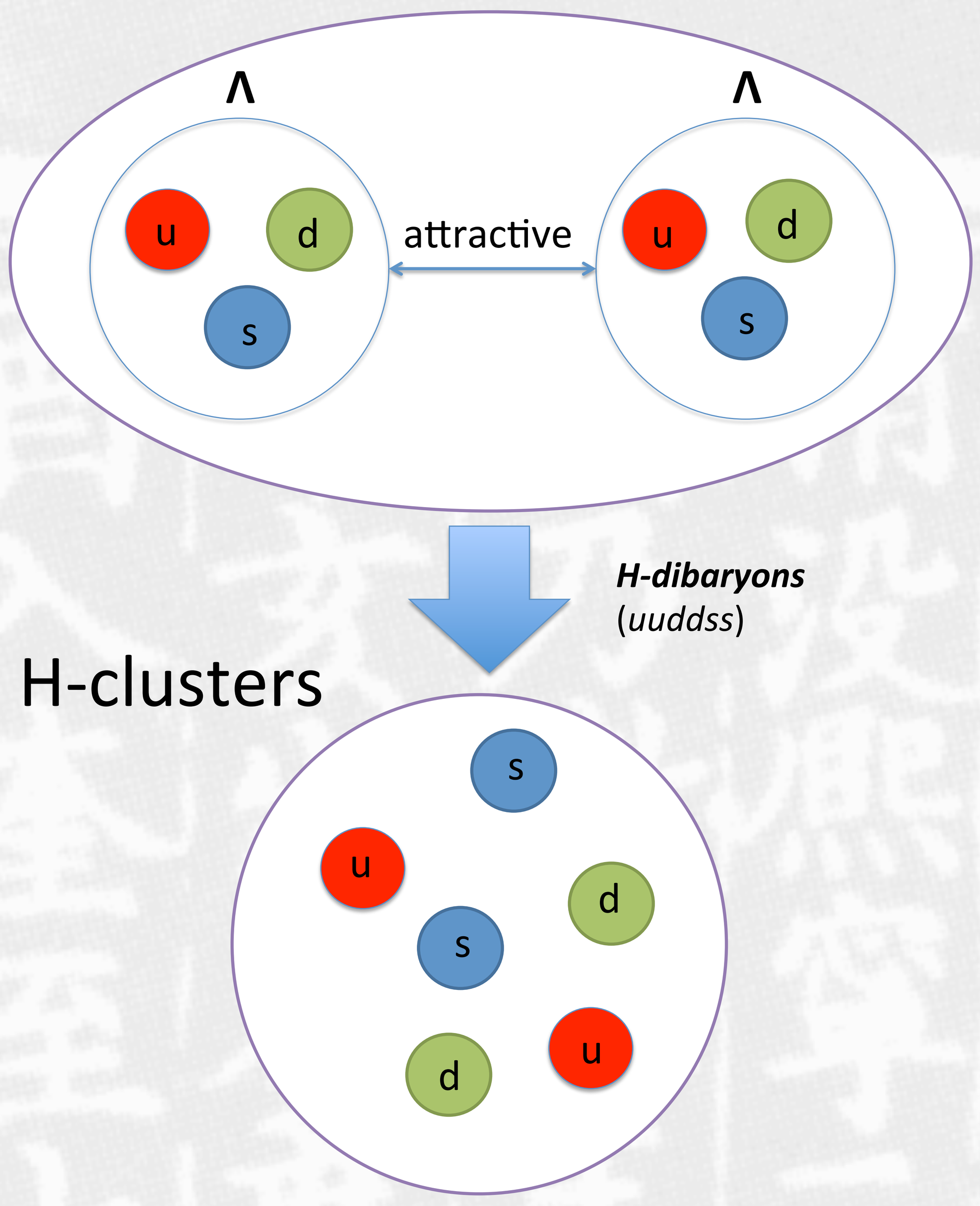
- What is the state of dense matter at supra-nuclear density?
- What is the nature of pulsar-like compact stars?

❖From *quark stars* to *quark-cluster stars*

- Self-bound stars without normal baryons are helpful for us to understand observations of pulsars
- Traditional quark stars: composed of weakly interacting quarks (from MIT bag model to color-superconductivity model)
- However, the energy scale ($2\rho_0 < \rho < 10\ \rho_0$) is ~ 400 MeV < E < 800 MeV: strongly coupled quarks & strangeness
- Quarks could be grouped into quark-clusters due to strong coupling: quark-cluster stars
- What if quarks are clustered at realistic density of compact stars?

❖ *H-dibaryons* as a possible kind of quark-clusters

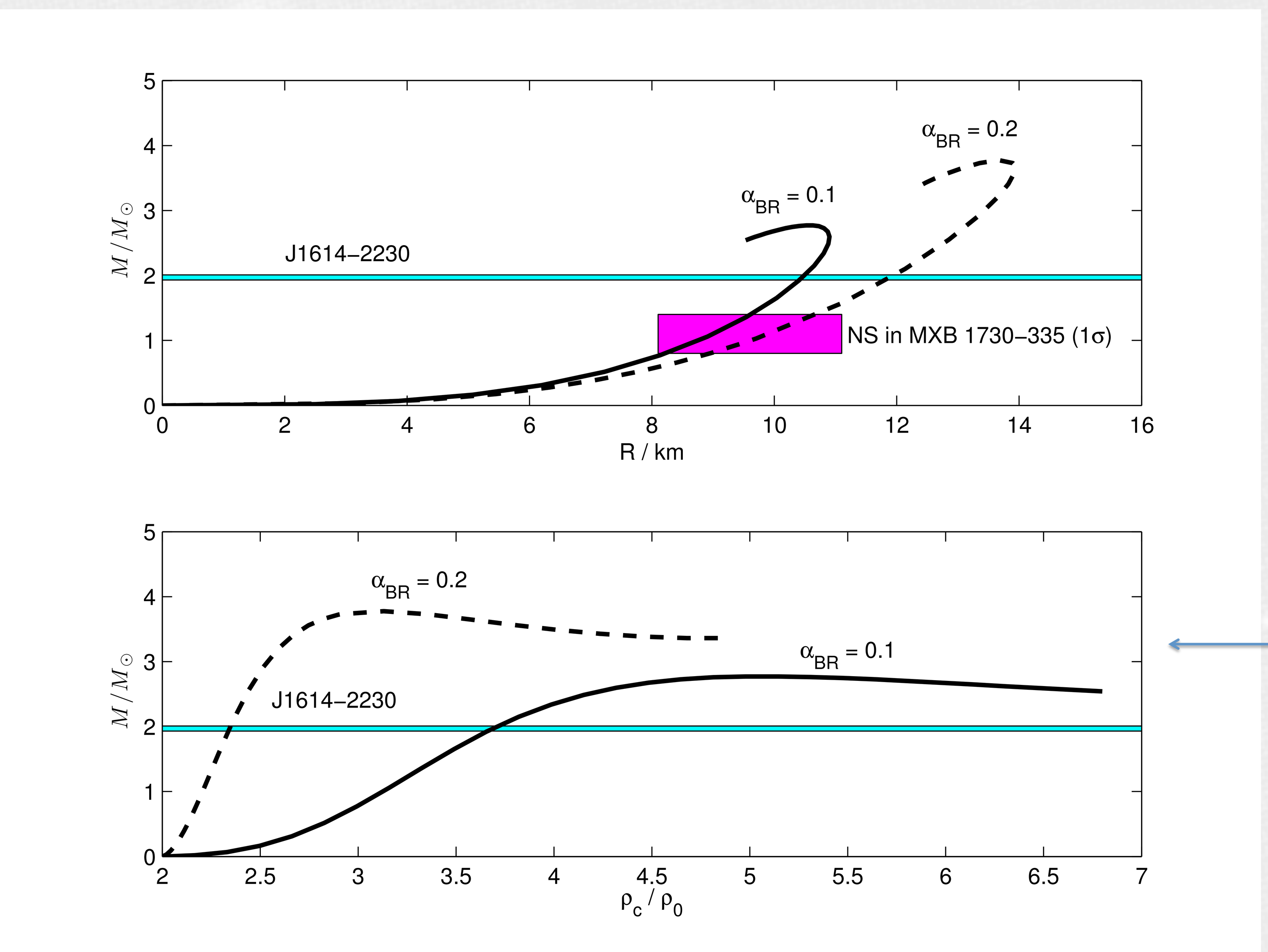
- H-dibaryons (with structure *uuddss*)
  - They have light-flavor symmetry
  - Predicted by Jaffe in 1977: a stable hardron bound state or resonance
  - Results in Lattice QCD in 2011: weakly bound state
  - What are their astrophysical implications to compact stars?
- Quark-clusters with light-flavor symmetry could very likely be H-dibaryons, i.e., H-clusters



❖ Stability of H-cluster matter

- In nucleon matter (*u*+*d*):
  - Isospin symmetry ($n_u=n_d$)+electrons: $E_{sym}=0$, $E_{Fermi}\neq0$
  - Isospin asymmetry ($n_d=2n_u$, no electron): $E_{sym}\neq0$, $E_{Fermi}=0$
- In matter with light flavor symmetry (*u*+*d*+*s*): $n_u=n_d=n_s$, no electron, $E_{sym}=0$, $E_{Fermi}=0$
- In H-cluster matter (H-dibaryon as degree of freedom):
  - In-medium stiffening effect: $\frac{m_H^*}{m_H}=\frac{m_N^*}{m_N}=\frac{m_M^*}{m_M}=1-\alpha_{BR}\frac{\rho}{\rho_0}$
  - Energy per baryon could be $E_{\text{H-matter}} < E_{\text{neutron matter}}$

H-matter would be more stable than neutron matter

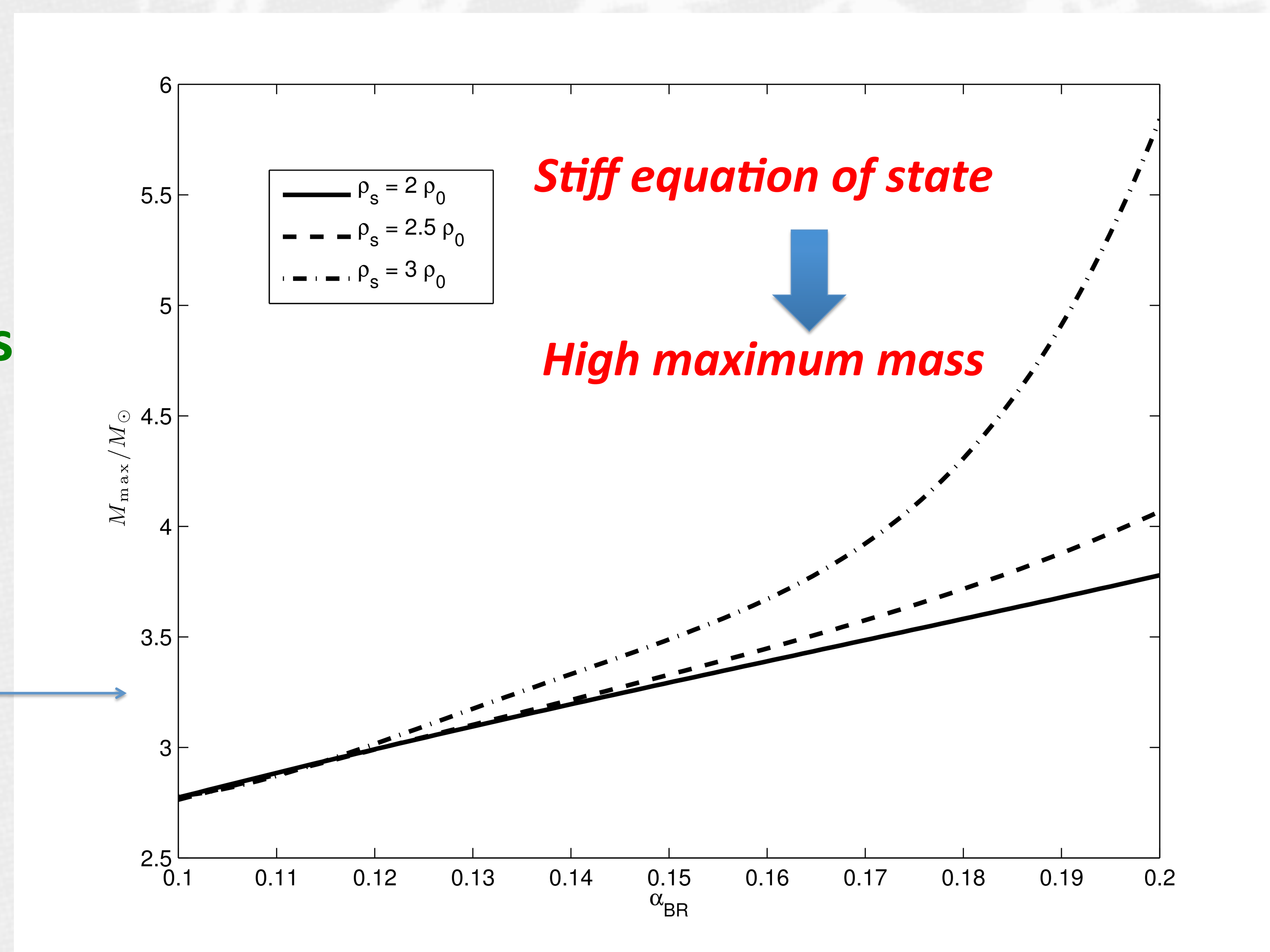


❖ Solid state of H-cluste matter

- H-H interaction: $V(r)=\frac{g_{\omega H}^2}{4\pi}\frac{e^{-m_\omega r}}{r}-\frac{g_{\sigma H}^2}{4\pi}\frac{e^{-m_\sigma r}}{r}$
- Strong repulsive core of H-H interaction: ***solidification***!

➢ **Understanding observations, e.g. pulsar mass**

➢ **Constraining parameters of dense matter**



❖ H-cluster stars

- Self-bound with stiff equation of state
- Obs. test: Very low mass & Very high mass

*Explain the **mass gap** between most massive pulsars ($\sim 2M_\odot$) and least massive black holes ($\sim 4.5M_\odot$)?*

Ref: Lai, X. Y., Gao, C. Y., Xu, R. X., arXiv:1107.0834