Strangeness in Neutron Stars

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Motivation

What do we know about the content of NS cores *beyond significant doubt*?

A Brief History of the Hyperon Crisis

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- 1967 Jocelyn Bell & Anthony Hewish discover PSR B1919+21

In the beginning there was the TOV limit

$$\frac{dp}{dr} = -\frac{G}{r^2}\left(\epsilon(p(r)) + \frac{p}{c^2}\right)\left(M + 4\pi r^3 \frac{p}{c^2}\right)\left(1 - \frac{2GM}{c^2 r}\right)^{-1}.$$

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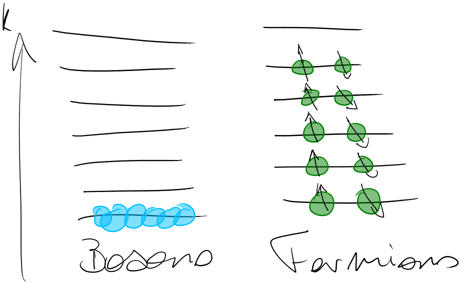

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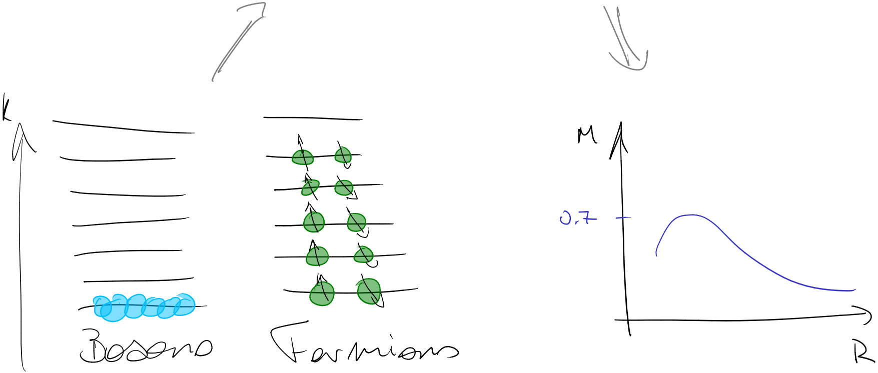
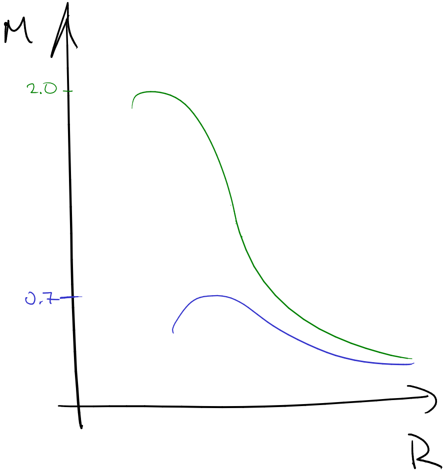


Beyond Degenerate Fermi Gas



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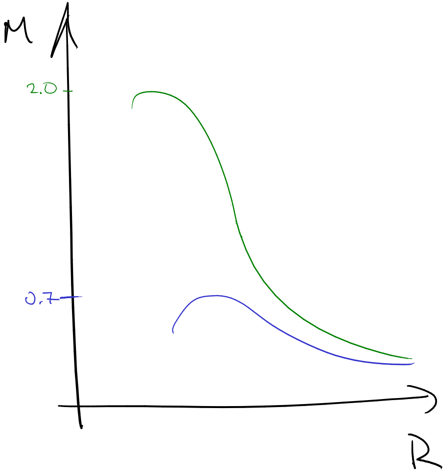

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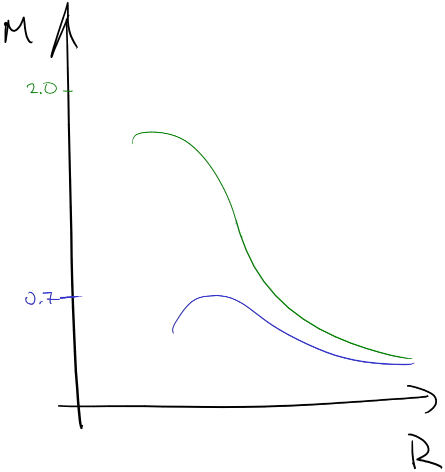

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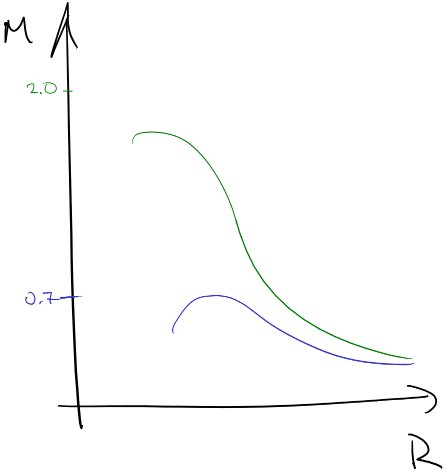

- PSR J1614-2230
  $M = 1.908 \pm 0.016 M_\odot$
- PSR J0348+0432
  $M = 2.01 \pm 0.04 M_\odot$
- PSR J0740+6620
  $M = 2.08 \pm 0.07 M_\odot$

Hyperon Puzzle in a Nutshell

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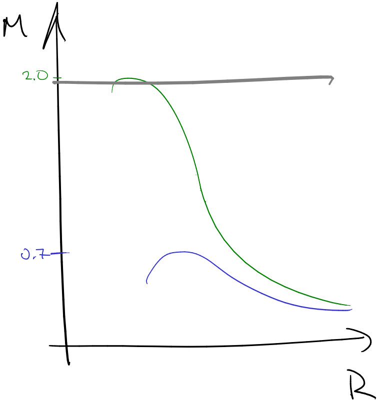
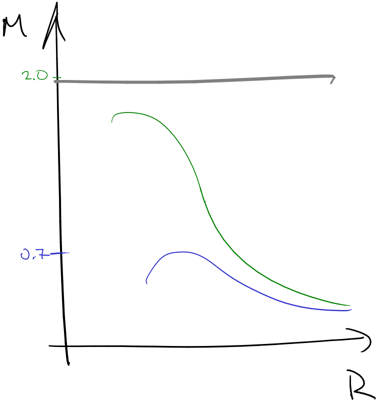


Mass good

Content bad



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- Extra hyperon repulsion
- Kaon condensation
- Also the deconfinement question...

The Quark-Meson Coupling Model

QMC

- The QMC model is one of the relativistic phenomenological models. What we want, fundamentally, is

$$\mathcal{L} = \bar{\Psi}_B(i\partial\!\!\!/ - M_B)\Psi_B + \mathcal{L}_{\text{mesons}} + \mathcal{L}_{\text{interactions}}$$

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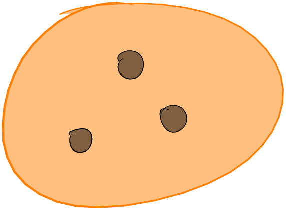

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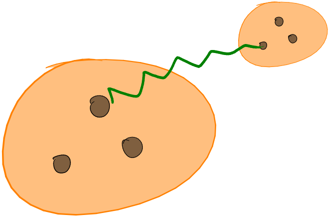
- However, we also want to retain some information on the *baryon structure*.
- We choose to model baryon-baryon interactions as a quark-meson interaction in the subhadronic level.



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where $m^\star = m - g_\sigma^q \bar{\sigma}$

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Some QMC Highlights

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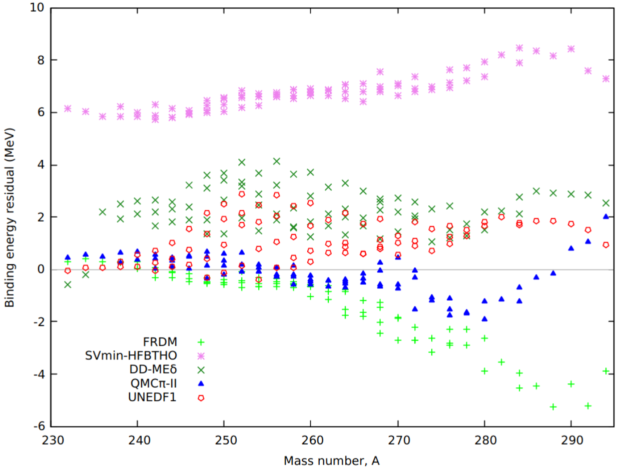

Figure: Nuclei binding energies from Martinez et al. [2019]

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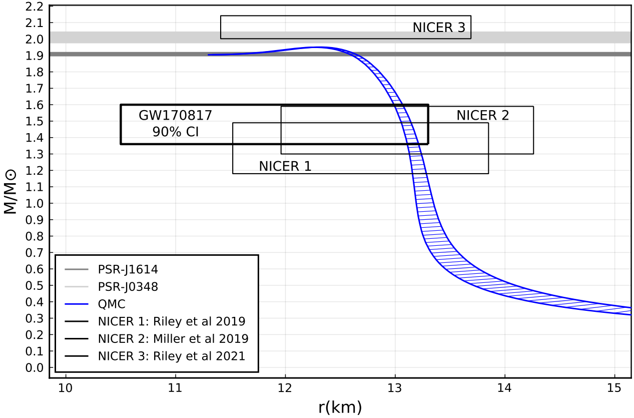

Figure: Stellar structure results from Motta et al. [2021] plus recent NICER results such as et al [2021]

The Nature of Strangeness Puzzle

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- However, one puzzle to be addressed is that of deconfinement.
- One interesting approach is to try the inverse problem, get NS constraints and from there infer what the EoS is. See Annala et al. [2020]

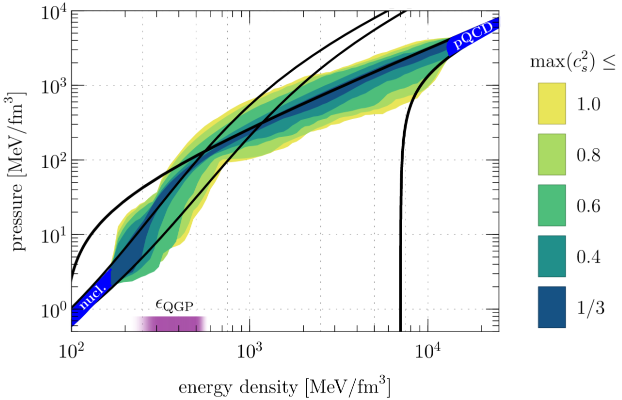


Figure: Results from Annala et al. [2020]

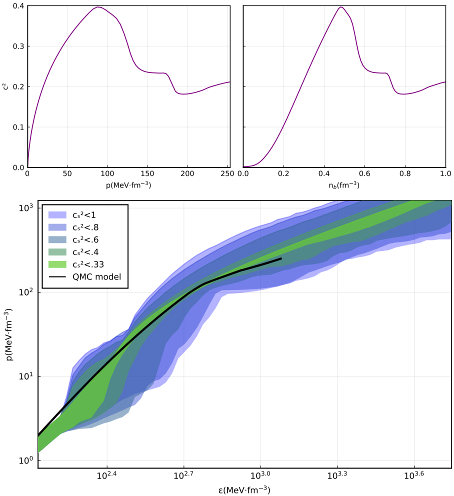
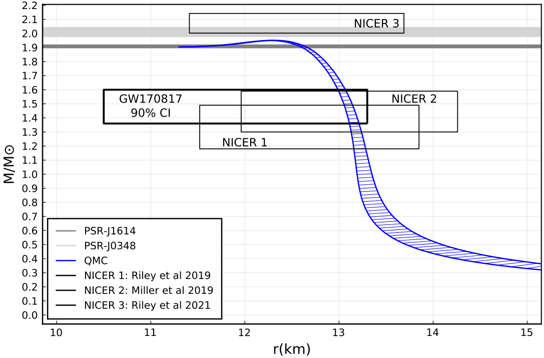


Figure: Motta et al. [2021] comparing QMC with Annala et al. [2020]

Conclusions

- The QMC model is in agreement with data
- There isn't much of a Hyperon puzzle anymore
- We still cannot discriminate between QM and Hyperonic matter



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