The lambda hyperon and the hyperon puzzle

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What is a neutron star?

Remnant from the gravitational collapse of the core of a giant star during type II supernova.

- Radius in the range of 10-12 km
- Extremely dense matter (10^{17}kg/m^3)

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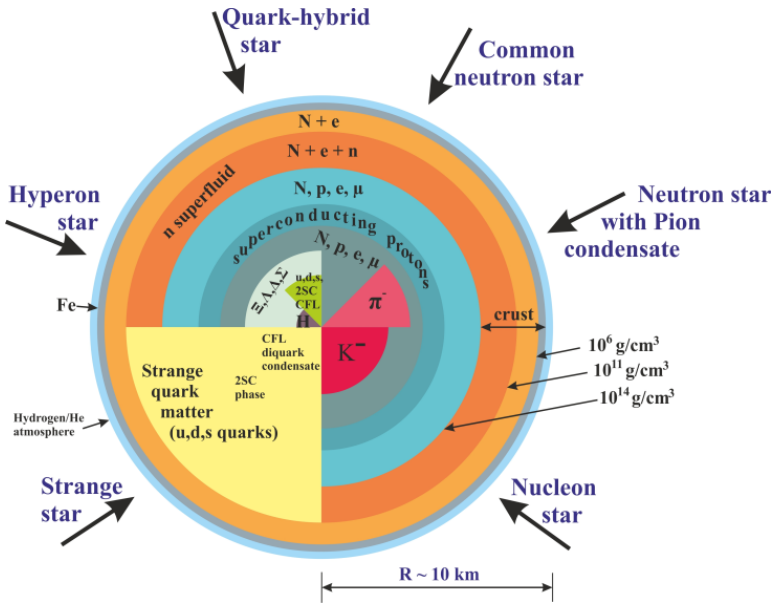
Equation of State (EoS)

The Equation of State is a relation between the pressure and energy density of a fluid.

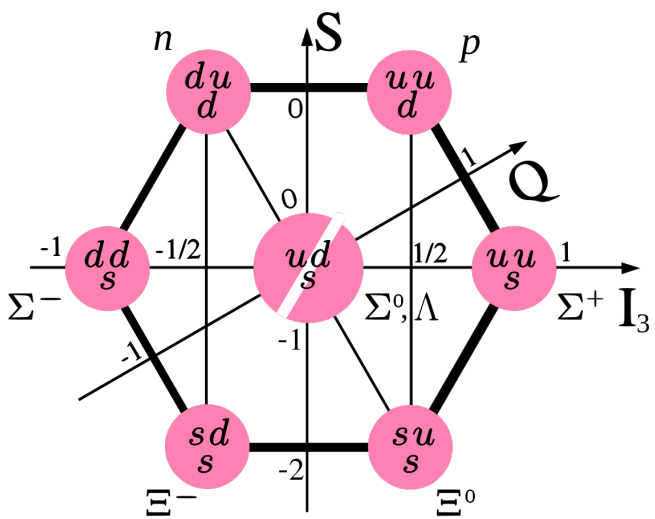
- Describe matter in the interior of a neutron star.
- The EoS for a neutron star is unknown.



F.Weber et al (2009)

Hyperons in neutron stars...

- Due to extreme neutron star densities, additional hadronic degrees of freedom are expected to be populated.
- These additional hadronic degrees of freedom includes hyperons (baryons with strange quark content).
- The equilibrium conditions in neutron stars can make the capture of hyperons occur.



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The effect of hyperons on neutron star properties

- Hyperons (baryons with strange quark content) have the effect of softening the neutron star equation of state.
- Leading to a reduction in the neutron star maximum mass.
- Gives maximum masses not compatible with observations. Recent observations of pulsars PSR J1614-2230 ($1.97 \pm 0.04 M_{\odot}$), and PSR J0348+0432 ($2.01 \pm 0.04 M_{\odot}$)
- This is known as the "hyperon puzzle".

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Normal neutron star EoS

The neutron star is modeled as a strong interacting system of matter composed of nucleons and leptons at zero temperature...

- Beta equilibrium

$$\mu_n \quad \leftrightharpoons \quad \mu_p + \mu_e.$$

- Charge neutrality

$$\rho_b \quad \leftrightharpoons \quad \rho_{lep}$$

Hyperon neutron star EoS

The relativistic mean-field theory (RMF) is applied to a relativistic description of nuclear matter.

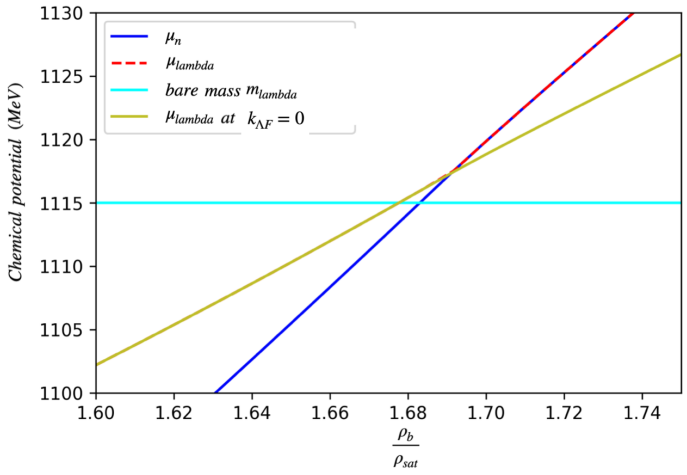
- Strong nuclear force described by the exchange of mesons.
- Nucleons, leptons and lambda hyperon

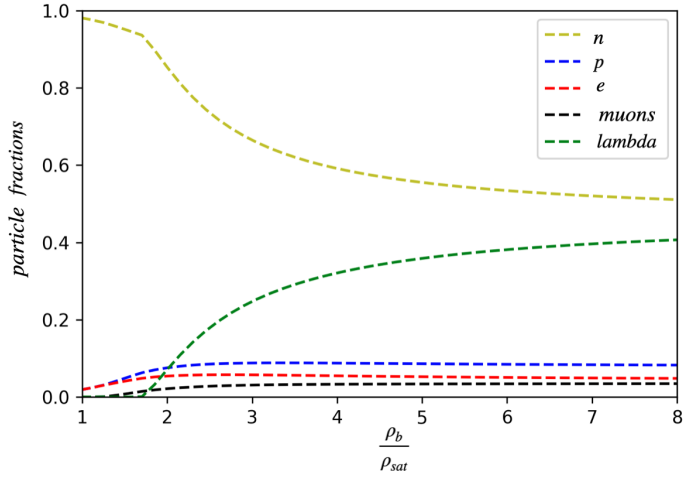
$$N + N \rightarrow N + \Lambda.$$

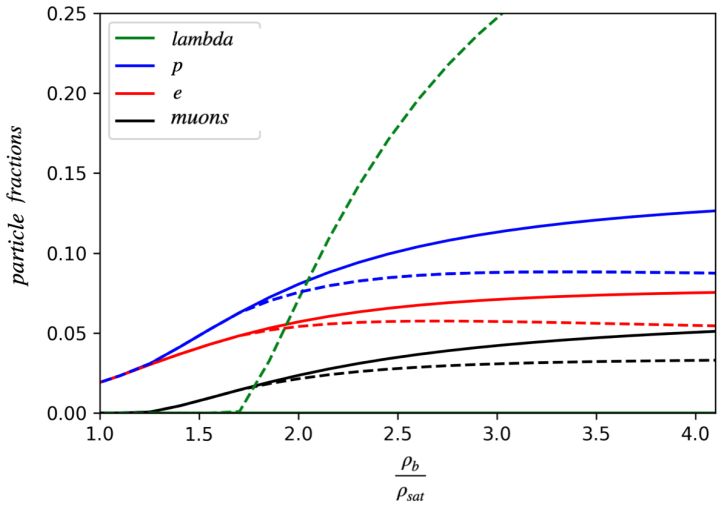
- The chemical potential would be

$$\mu_n = \mu_\Lambda$$

Results and Analysis







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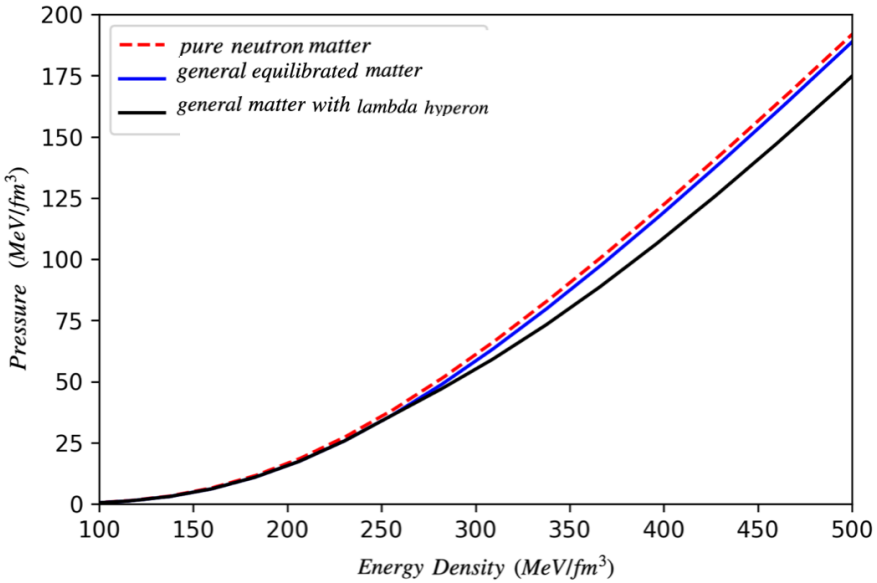

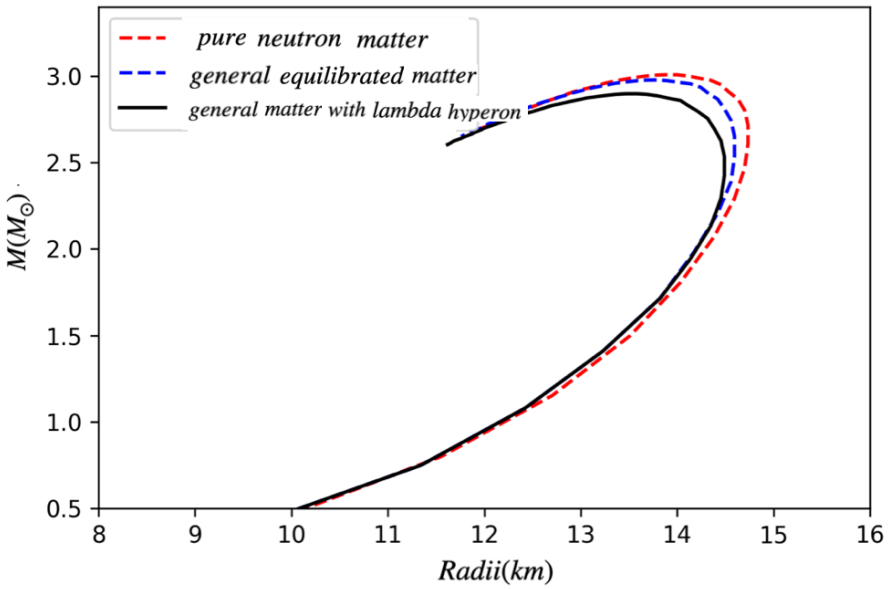

M-R plot

Conclusions

- The inclusion of the lambda hyperon softens the neutron star EoS.
- The inclusion of the lambda hyperon reduces the neutron star maximum mass.
- This is known as the "hyperon puzzle". Explanations needed to this.
- Observational data from massive new radio-telescopes like the Square Kilometer Array (SKA) will provide observations that can be supported and evolve theoretical models of nuclear matter.

www.skatelescope.org

Thank you