Superfluid fraction in the inner crust of neutron stars

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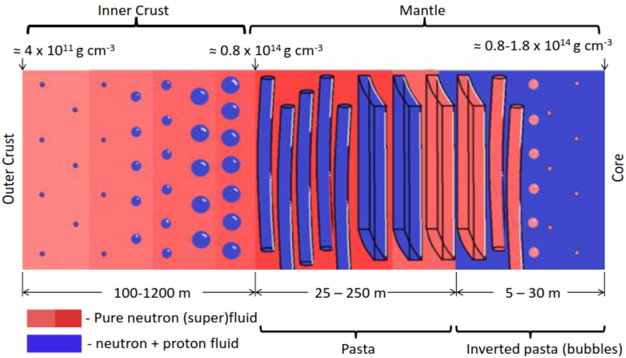
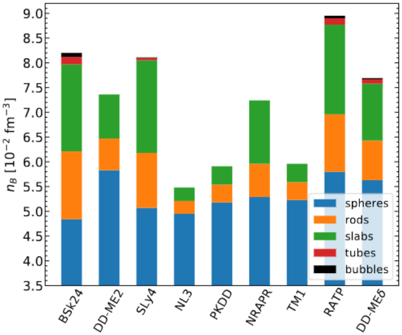
Inner crust of neutron stars...

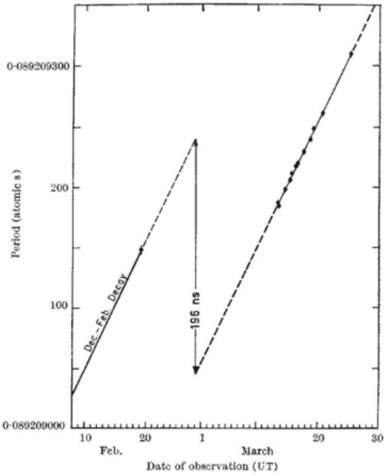




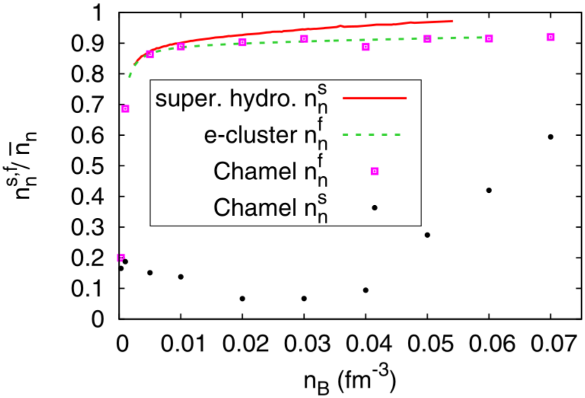
W.G. Newton et al,
Sym.En.,In.Crust,Gl.Mod. (2011)

H. Dinh Thi et al,
A&A 654, A114 (2021)

...and its superfluid fraction



Radhakrishnan & Manchester,
Nature 222, 228-229 (1969)



Martin & Urban,
Phys. Rev. C 94, 065801 (2016)

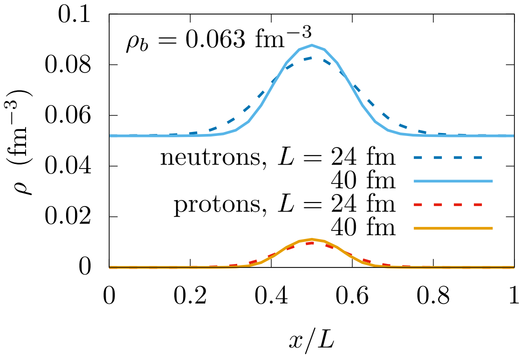
Hartree-Fock-Bogoliubov in the pasta phases

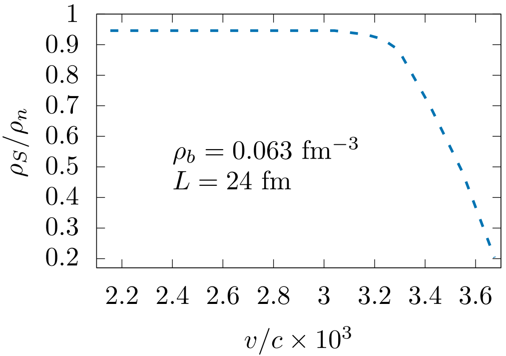
$$\begin{pmatrix} h-\mu & -\Delta \\ -\Delta^\dagger & -\bar{h}+\mu \end{pmatrix} \begin{pmatrix} U_\alpha^\star \\ -V_\alpha \end{pmatrix} = E_\alpha \begin{pmatrix} U_\alpha^\star \\ -V_\alpha \end{pmatrix}$$

This setup gets us access to densities and other relevant quantities. Then applying the formalism due to Andreev and Bashkin we can compute the superfluid fraction

$$\vec{\rho}_n = (\rho_n - \rho_S)\vec{v} + \rho_S \vec{V}_n \quad ; \quad \vec{\rho}_p = \rho_p \vec{v}$$

Lasagna

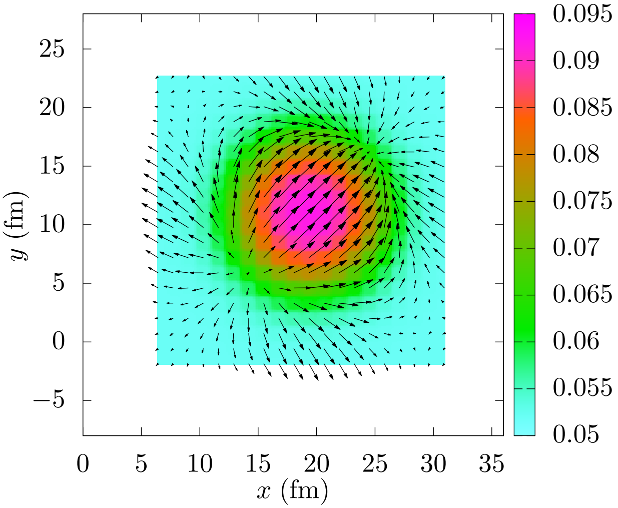




Almirante & Urban, Phys. Rev. C 109, 045805 (2024)

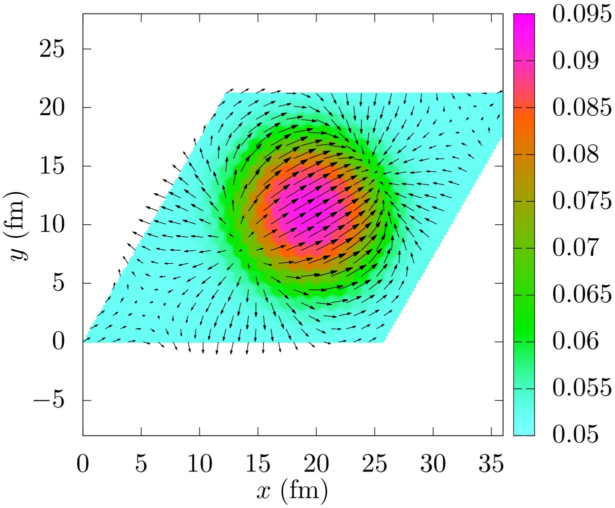
Spaghetti square

$\rho_b = 0.062\ \mathrm{fm}^{-3}$; $\rho_S/\rho_n = 0.94$



Spaghetti hexagon

$\rho_b = 0.062 \text{ fm}^{-3}$; $\rho_S/\rho_n = 0.94$



Outlook and perspectives

- previous calculations in normal band theory seem to overestimate the entrainment effect
- changing geometry does not directly affects the superfluid fraction
- we will see what happens in the 3D crystal phase

Thanks for your attention!