The interplay between neutron stars and particle physics

M. Albino, T. Custódio, **H. Pais** and C. Providência
CFisUC, University of Coimbra, Portugal

Contribution to the Portuguese Discussion on the European Strategy for Particle Physics

LIP, Lisbon, January 20 2025

Acknowledgments:

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

POPH QUALIFICAR É CRESCER.

QREN QUADRO DE REFERÊNCIA ESTRATÉGICO NACIONAL

GOVERNO DA REPÚBLICA PORTUGUESA

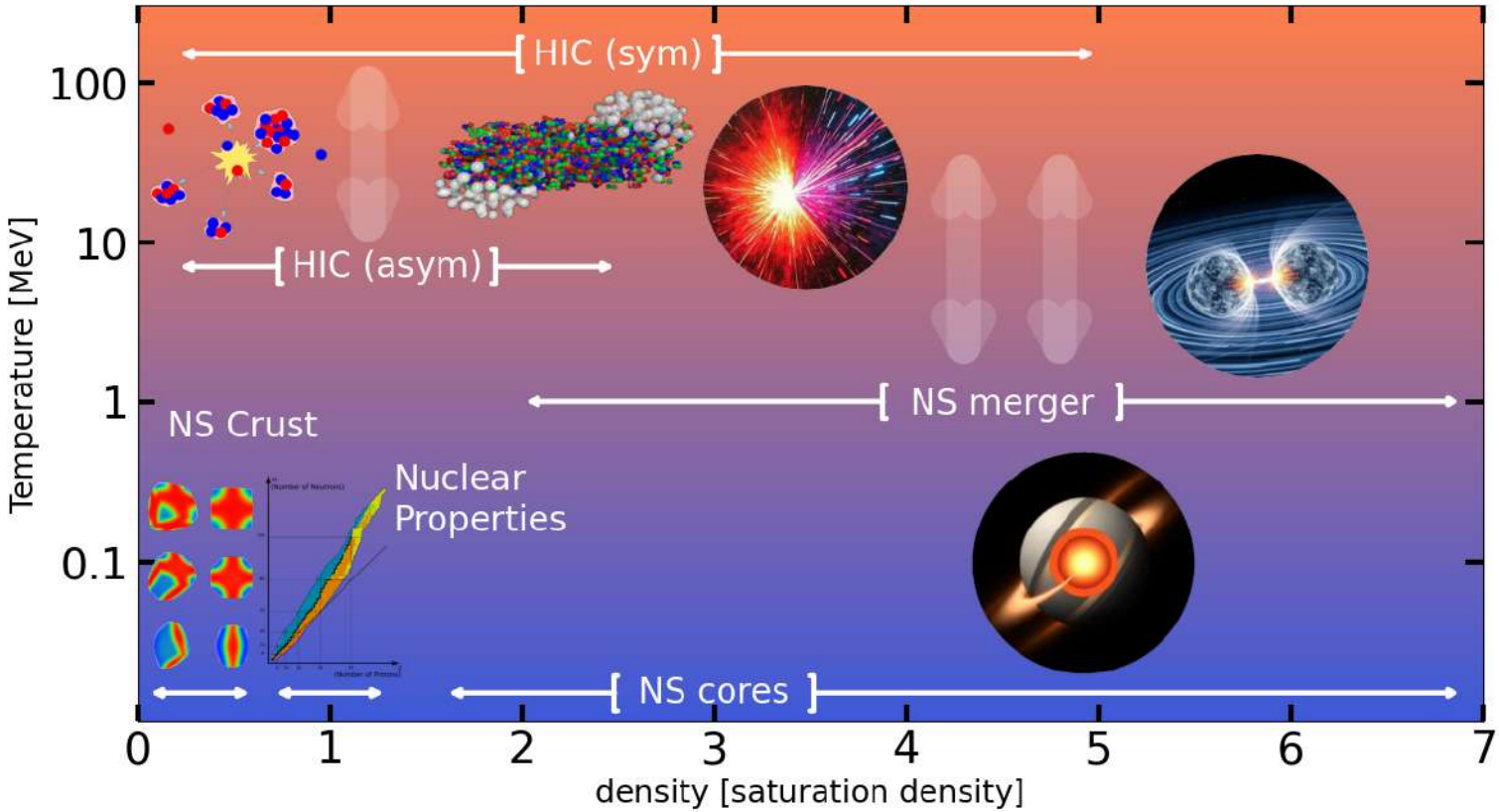
UNIÃO EUROPEIA
Fundo Social Europeu

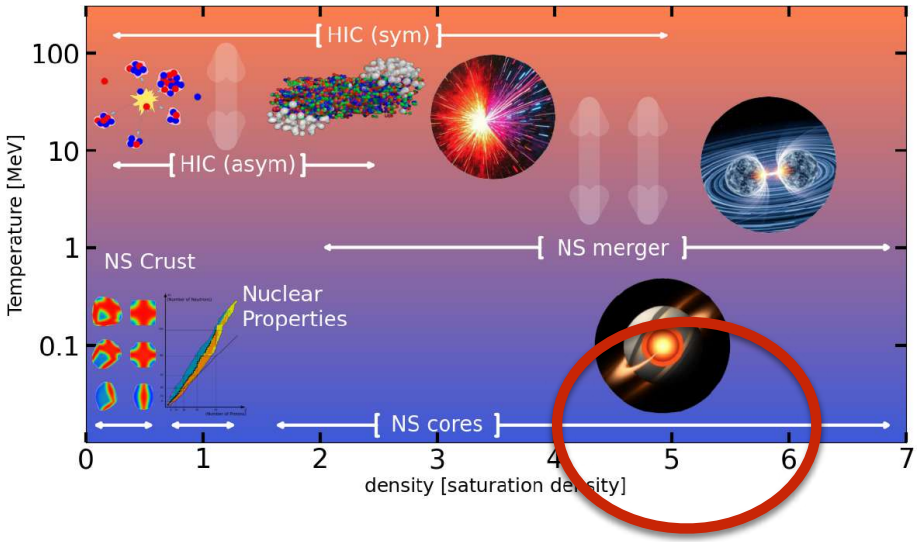
https://magstarmatter.com

CFisUC

MAGSTARMATTER

Neutron stars (T=0, very neutron-rich) and neutron star merger events (finite T, less asymmetric) provide a laboratory to test Nuclear physics, Particle Physics and QCD (deconfinement, quark matter).

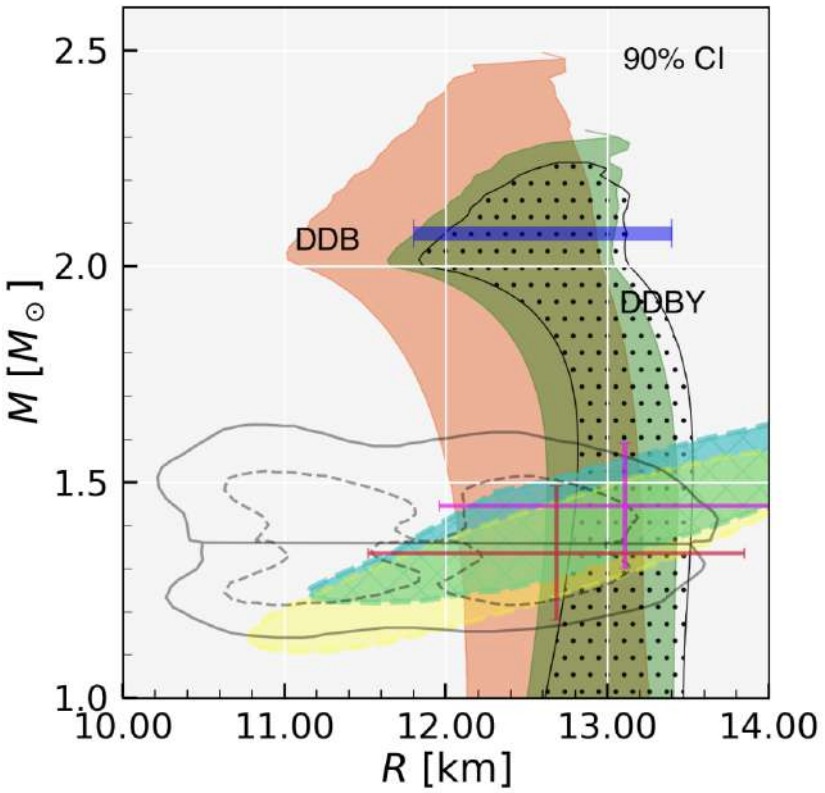


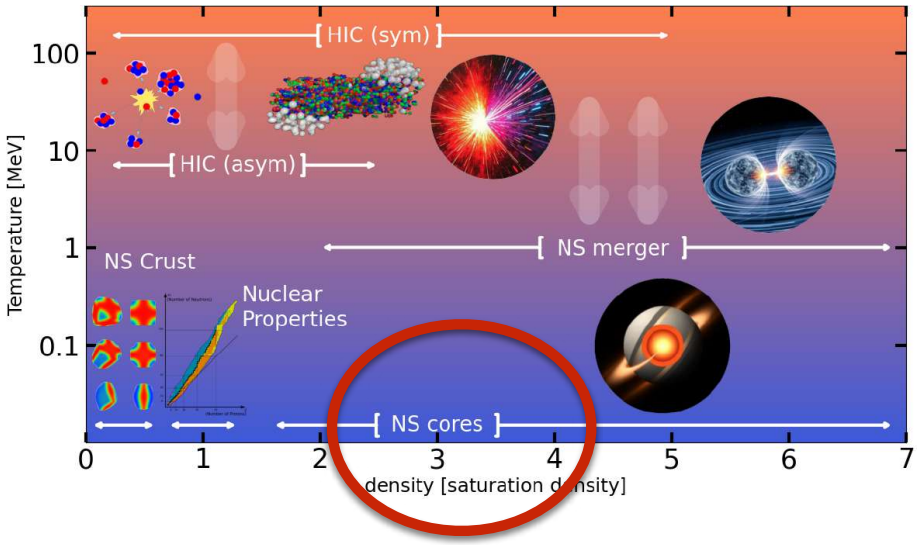


- Can we infer the high-density EoS?
- Can we get information from M(R)?

This figure illustrates the difference in M(R) relations, using hyperonic and nucleonic EoS.

Malik et al, PRD 106, 063024 (2022)

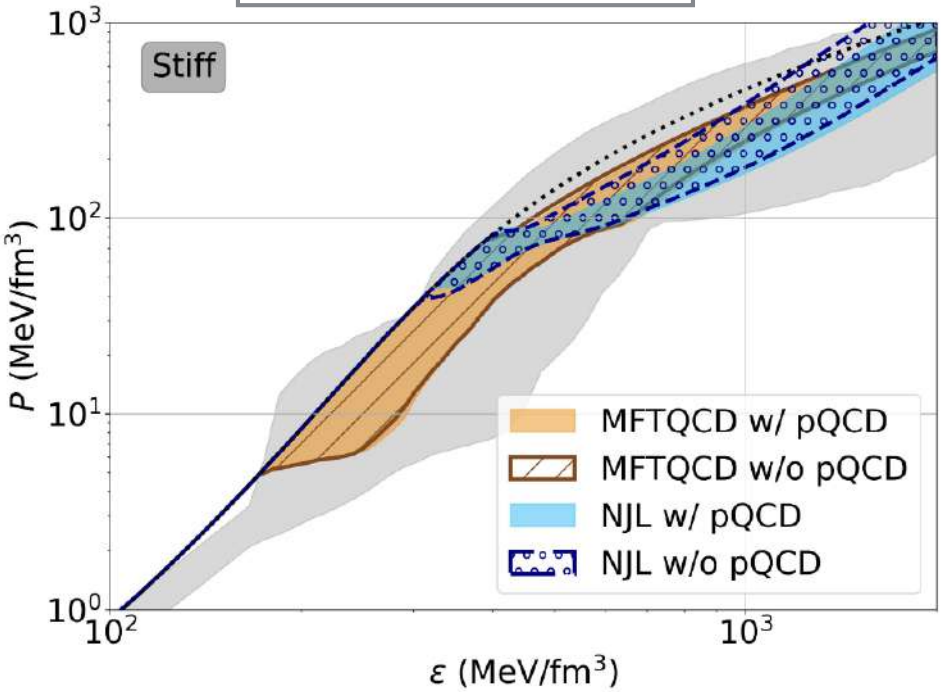


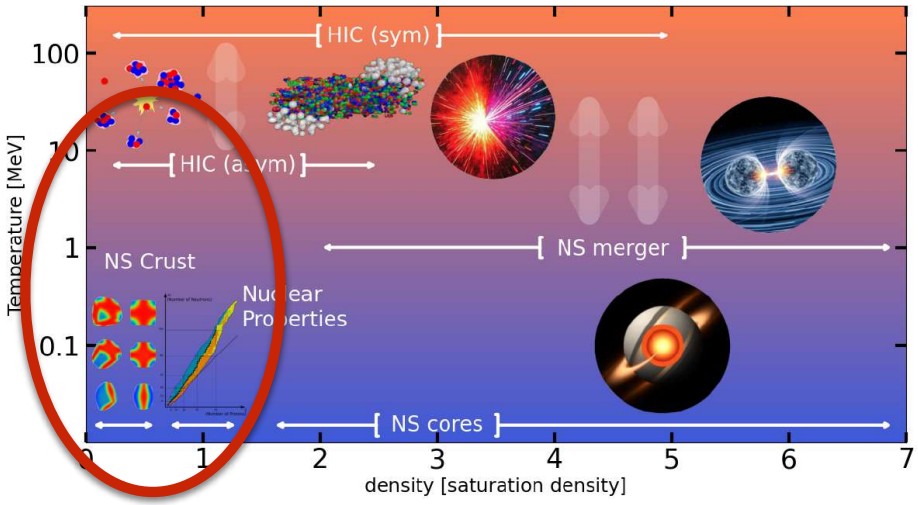


- Is there a deconfinement phase transition?
- Which observables can help us identify the deconfinement?

This figure illustrates hybrid stars.
The deconfinement depends on the EoS model:
With MFTQCD, it happens at much lower densities.

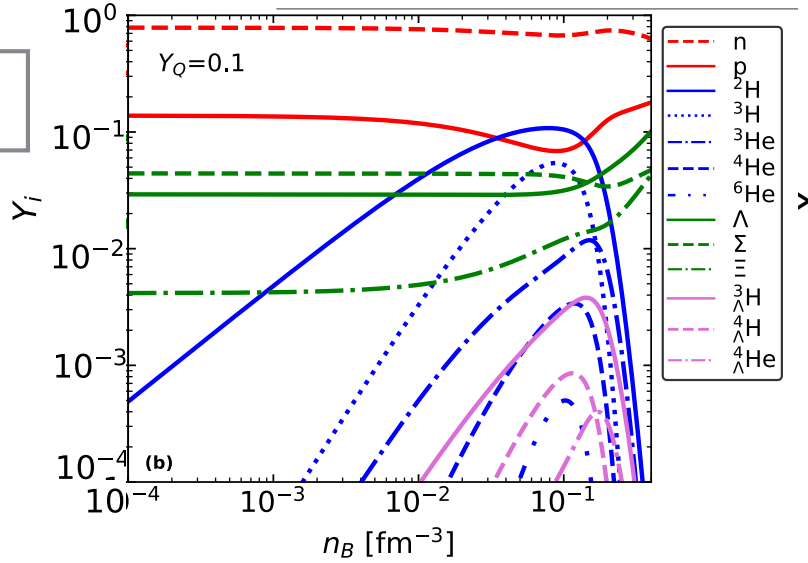
Albino et al arXiv:2406.15337



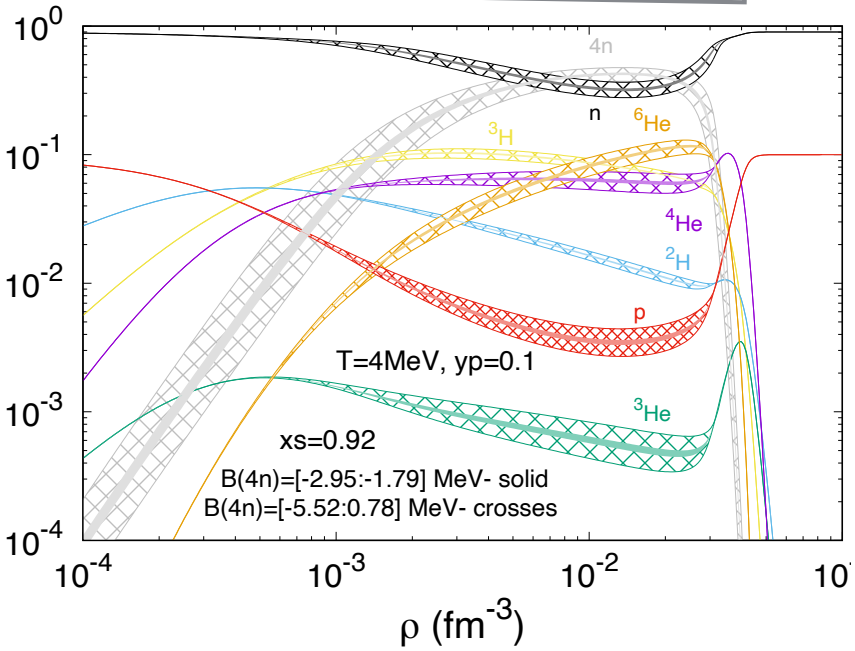


- What is the abundance of light clusters in warm low-density EoS?
- Do exotic clusters like hypernuclei or tetraneutron play a role?

Custódio et al, PRC 104, 035801 (2021)

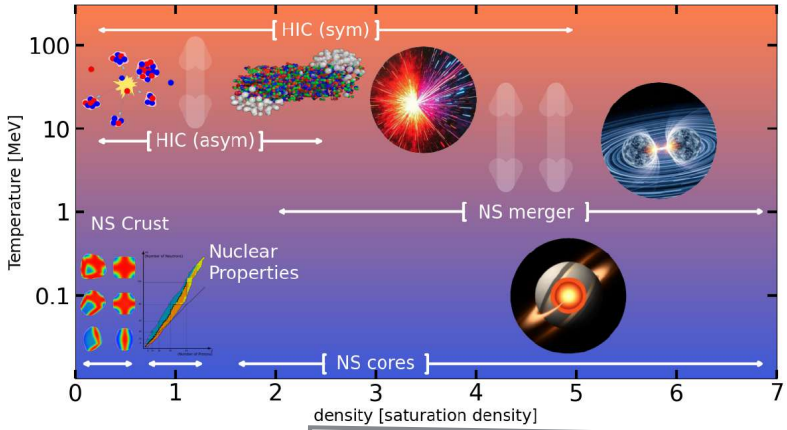


Pais et al, A&A 679, A113 (2023)



For neutron-rich systems:

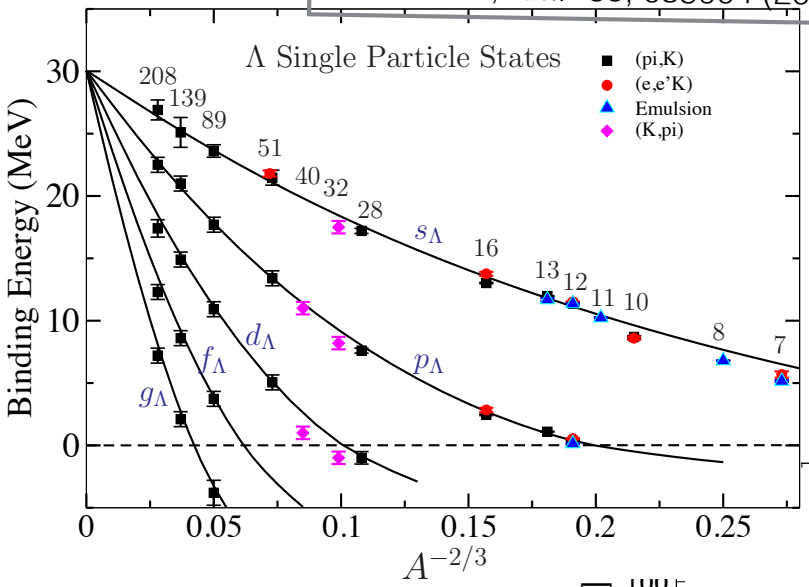
- Hypernuclei and 4n can be more abundant than 4He –> transport properties can be affected.
- The presence of hyperons and heavy baryons make the dissolution density of light clusters increase and also their mass fractions.



(Some examples of) **Missing information**:

- Hyperon binding energies, potentials –> to constraint the EoS couplings
- Symmetry energy above saturation density
- ....

A. Gal et al, RMP 88, 035004 (2016)



A. Sorensen et al, PPNP 134, 104080 (2024)