Next-generation dense matter science with binary neutron star inspirals

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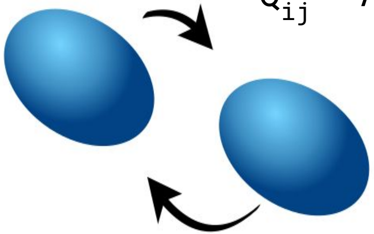
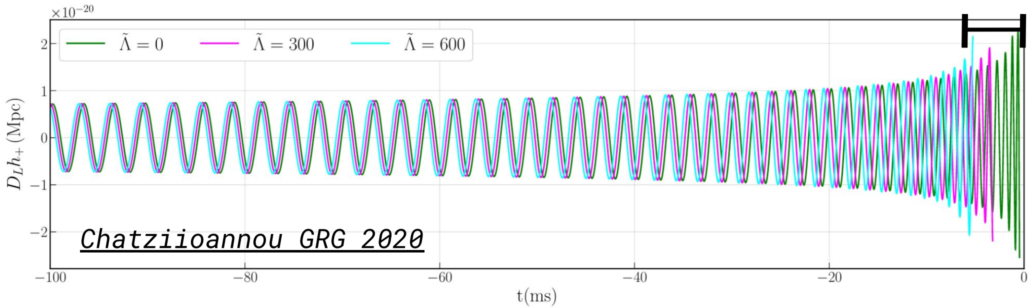
BNS inspirals for dense matter science

SUMMARY

A central objective of nuclear physics is to understand the phase structure of dense matter, such as that found in neutron star cores, and the nuclear interactions that support it. Gravitational waves from binary neutron star inspirals can address these questions because they are sensitive probes of the stellar interior. A next-generation observatory that can survey the complete nearby population of binary neutron star mergers, detecting hundreds of coalescences with a signal-to-noise ratio of 100 or more, will be a powerful probe of matter across the density range realized in neutron stars.

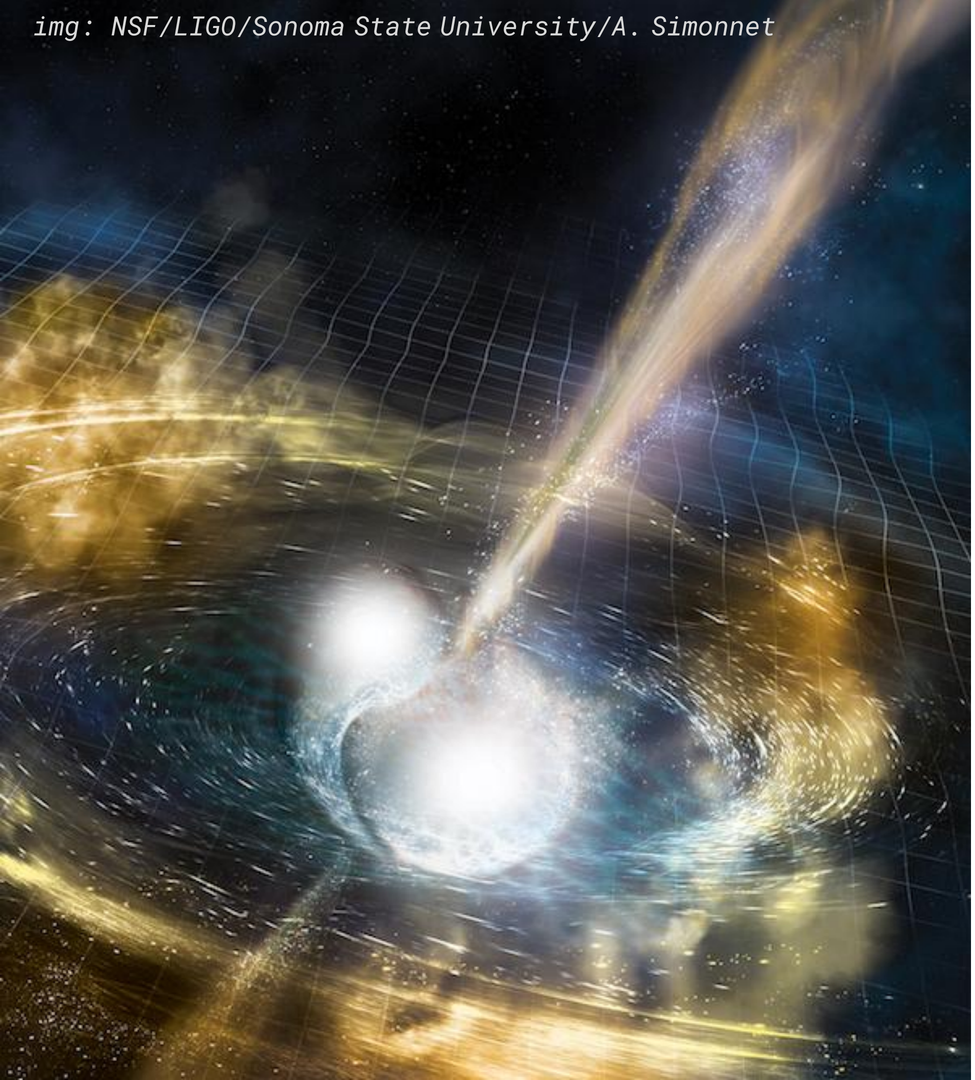


$Q_{ij} = -\Lambda m^5 \mathcal{E}_{ij}$



Chatziioannou GRG 2020

tidal phase

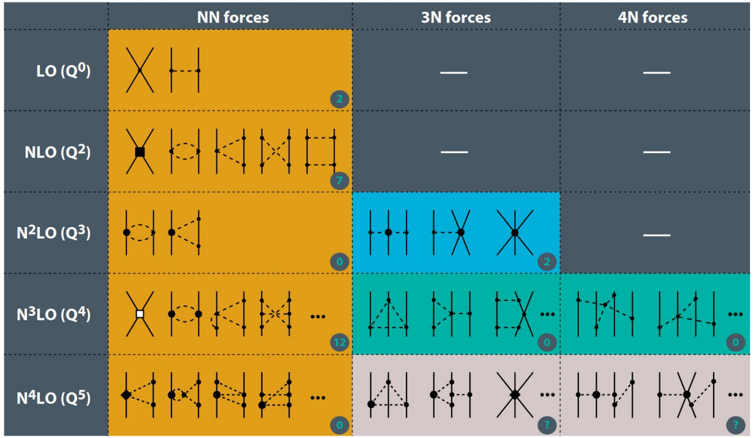

img: NSF/LIGO/Sonoma State University/A. Simonnet

Key questions

- *What are the **nuclear interactions** that support neutron star cores against gravitational collapse?*
- *Does cold nuclear matter undergo a **phase transition** at densities realized inside neutron stars?*

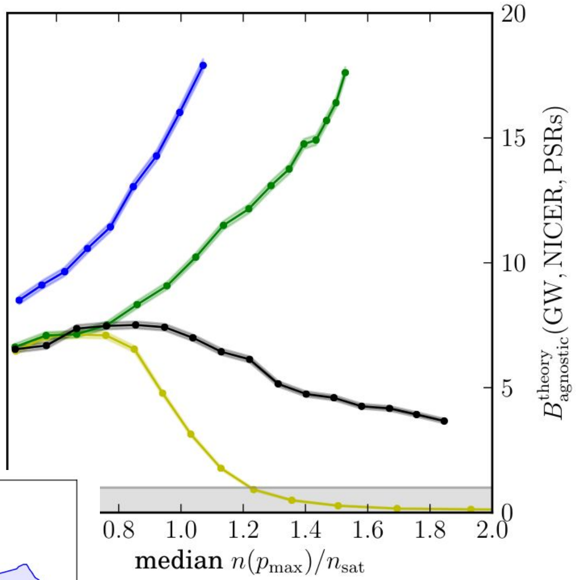
Probing nuclear interactions

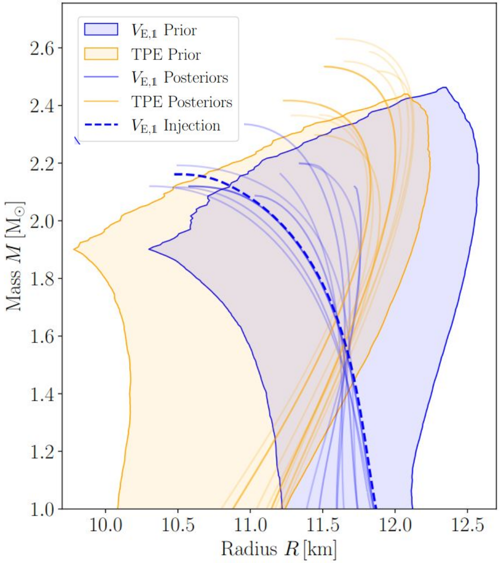
BNS inspiral observations can put competing models for nuclear interactions in zero-temperature dense matter to the test.



schematic of χEFT interactions from Drischler+ PPNP 2021

inference of χEFT breakdown scale Essick+ PRC 2020



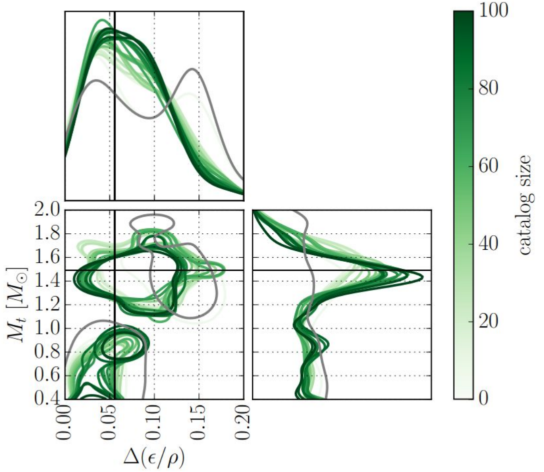


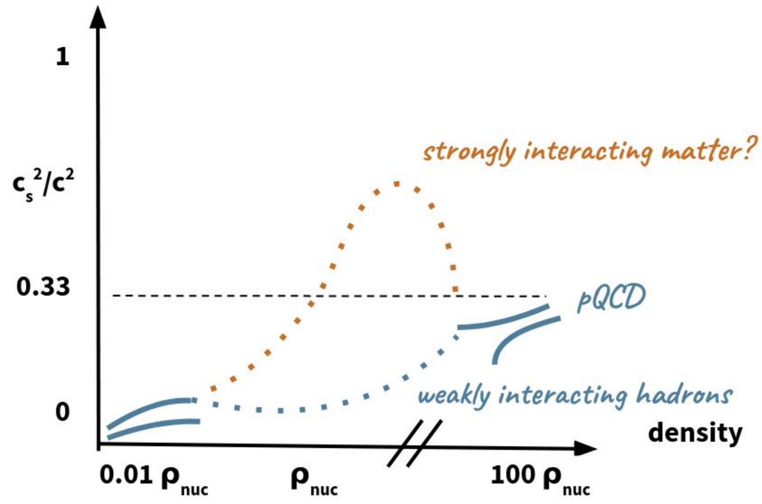
model selection on three-nucleon forces Rose+ arXiv:2303.11201

Searching for exotic phases

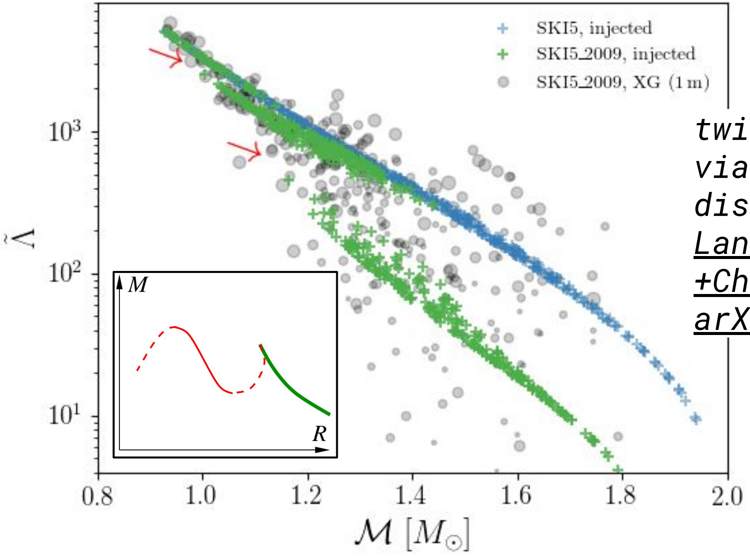
BNS inspiral observations may reveal exotic states of matter in neutron star cores.

Gaussian process-based phase transition recovery
Essick+ arXiv:2305.07411





conformal sound speed conjecture
see Bedaque+Steiner PRL 2015



twin star search via gaps in Λ distribution
Landry +Chakravarti arXiv:2212.09733

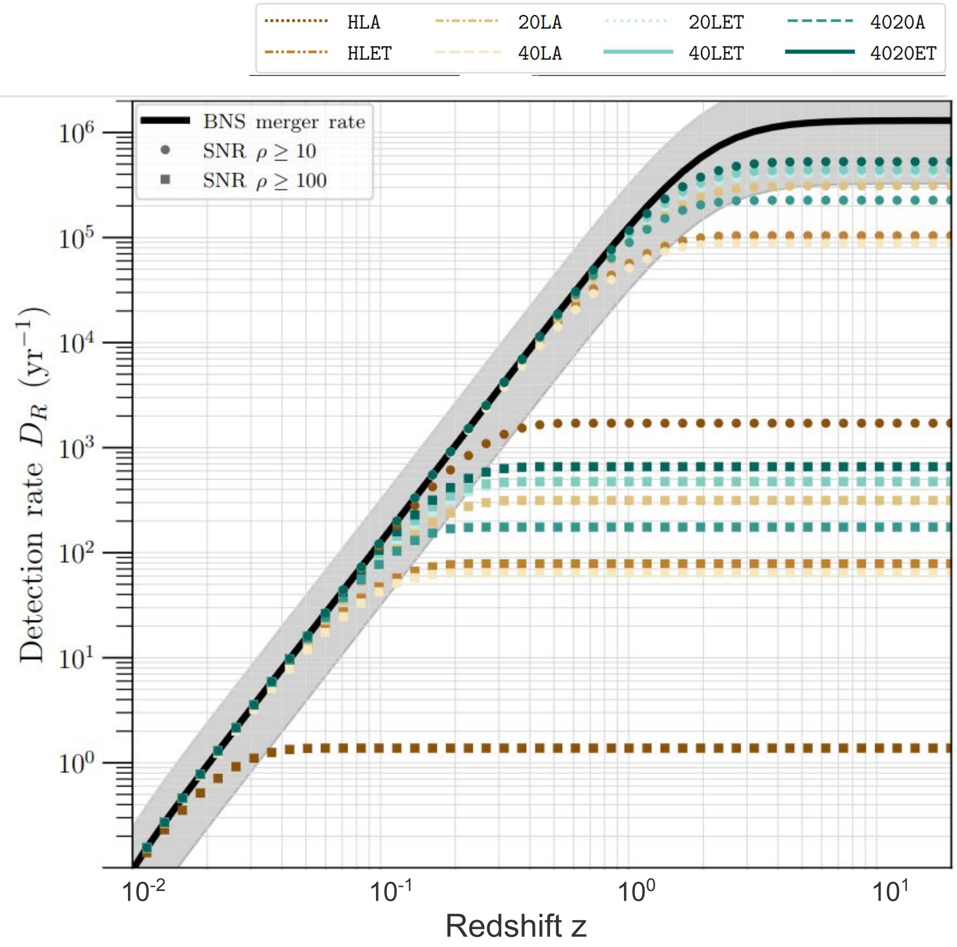
Benchmarks

◇ *BNS detection rate with SNR > 100*

$$R_{SNR>100} > O(100)\ yr^{-1}$$

◇ *Redshift horizon for complete BNS survey*

$$z_{100\%} > 0.2$$



Gupta+ arXiv:2307.10421

see also Borhanian+Sathyaprakash arXiv:2202.11048