Fundamental Physics with Gravitational Waves

Leonardo Gualtieri, "Sapienza" University of Rome

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Suddenly, the realm of physics has expanded:
we are able to study strongly gravitating object and phenomena,
of which - up to now - we only had indirect evidence or knowledge.

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Some of them are related
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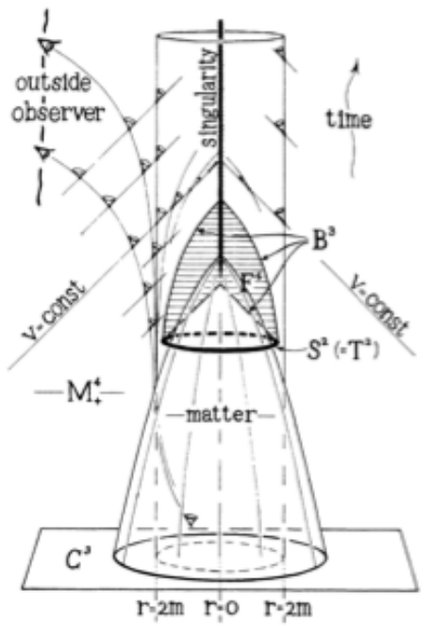
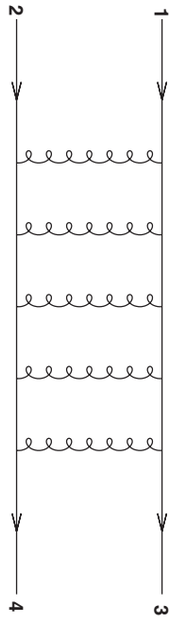
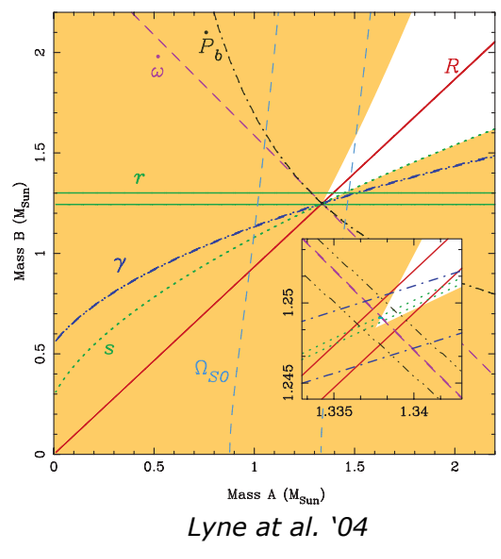


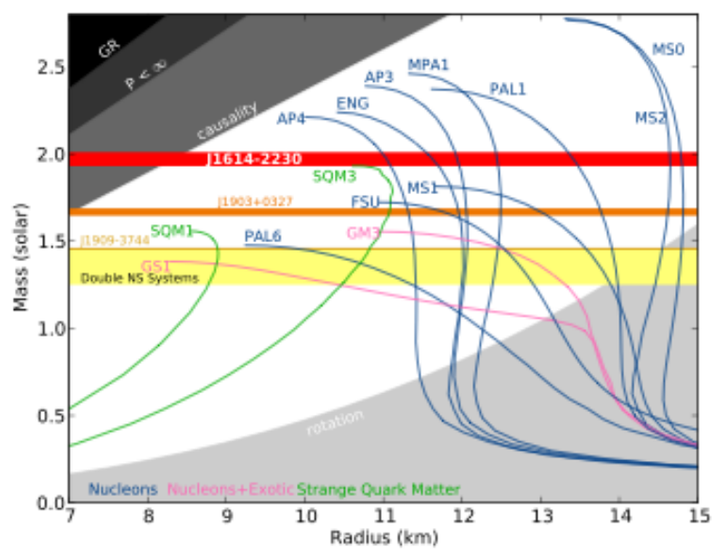
Penrose '74



Giddings et al. '10



Lyne at al. '04



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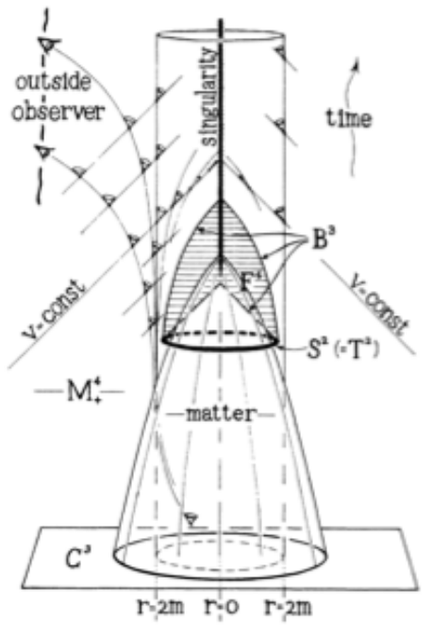

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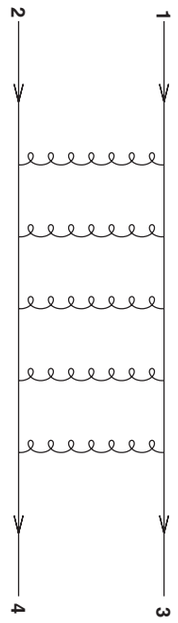

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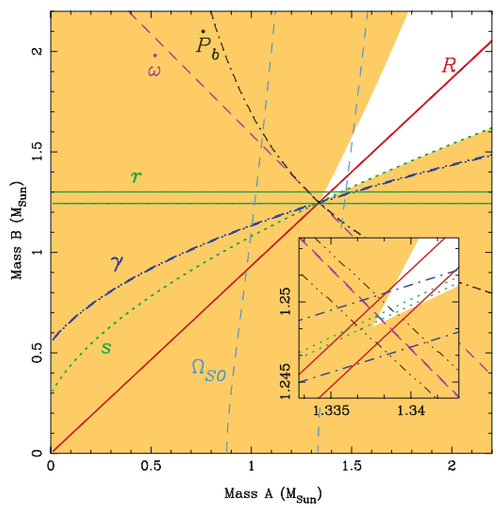

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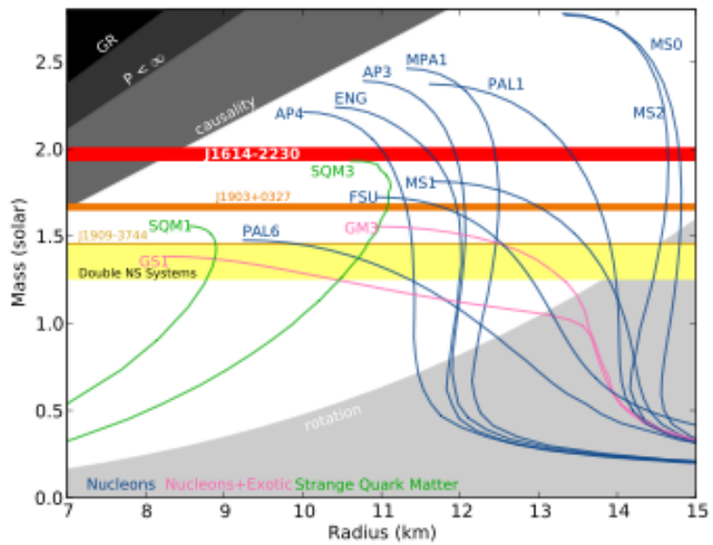

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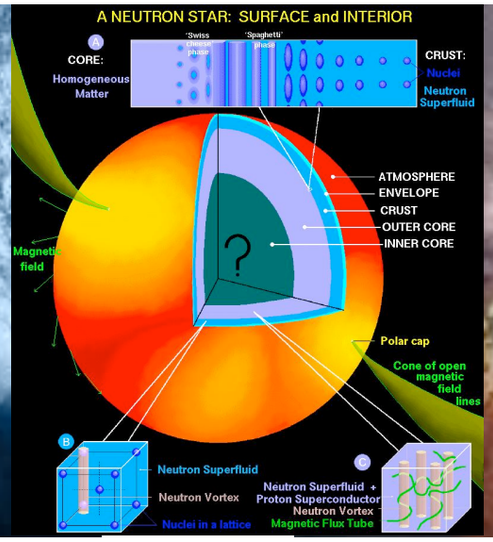
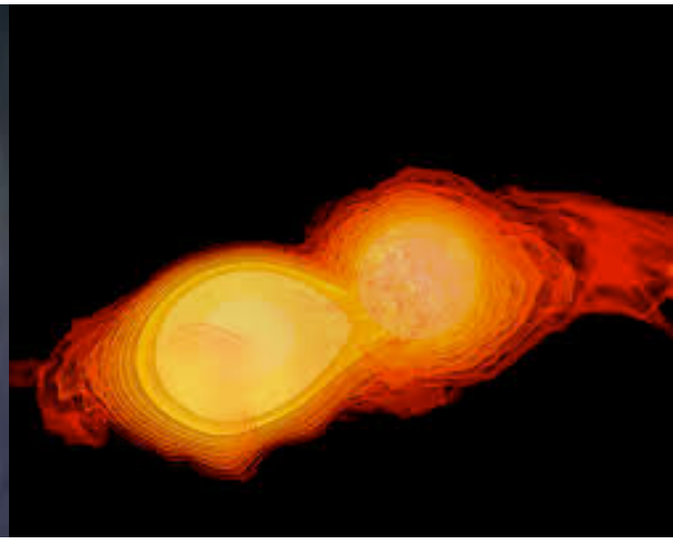
populating our Universe, and, ultimately, of the Universe itself





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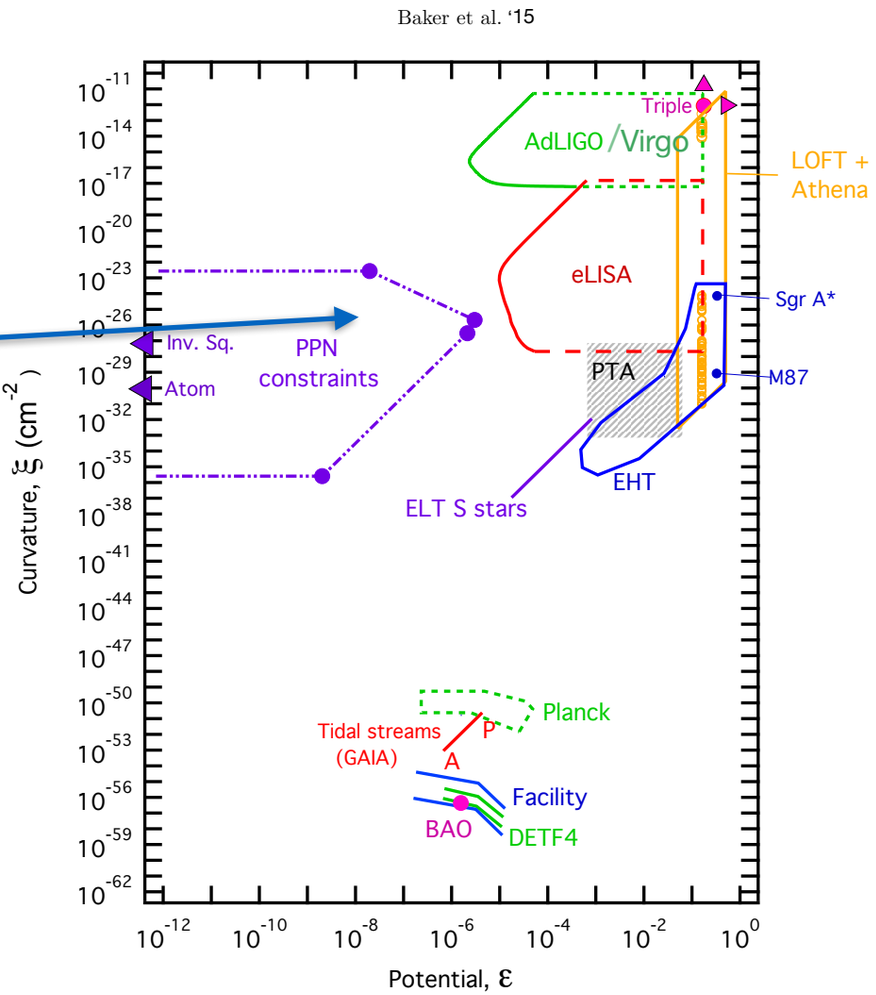
solar system &
binary pulsar tests



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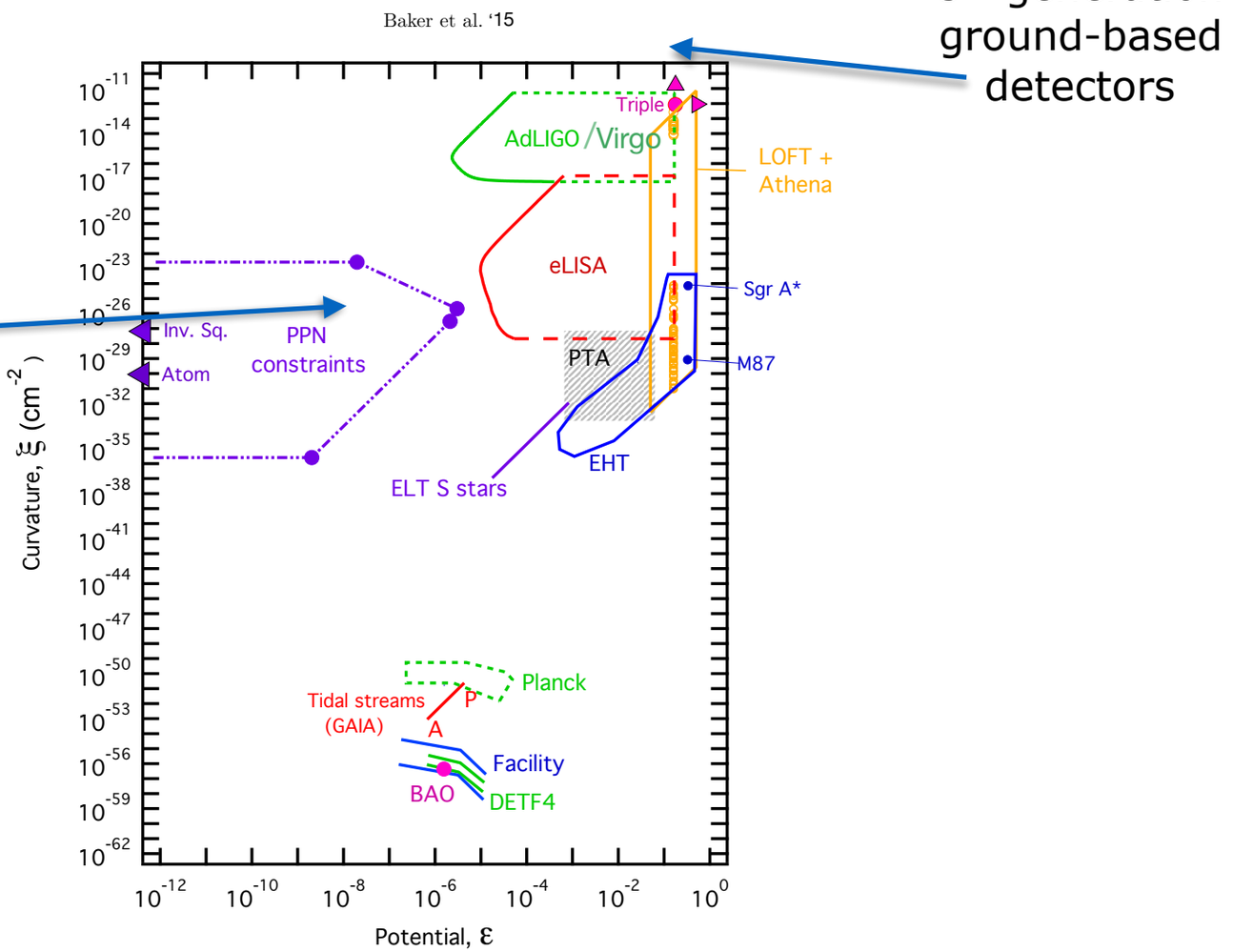

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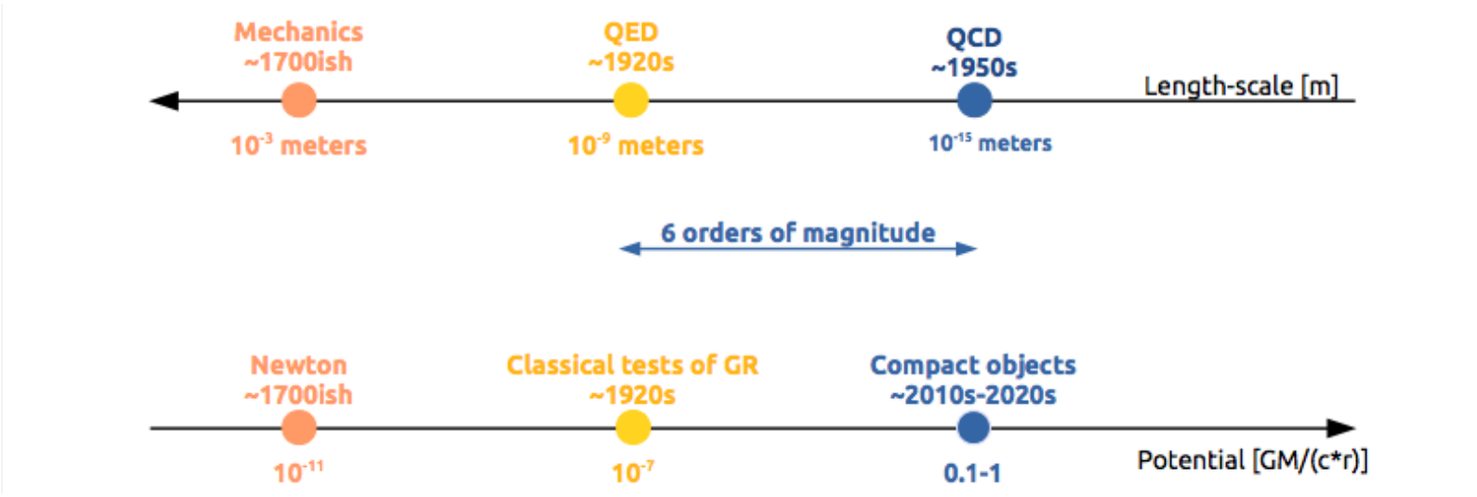

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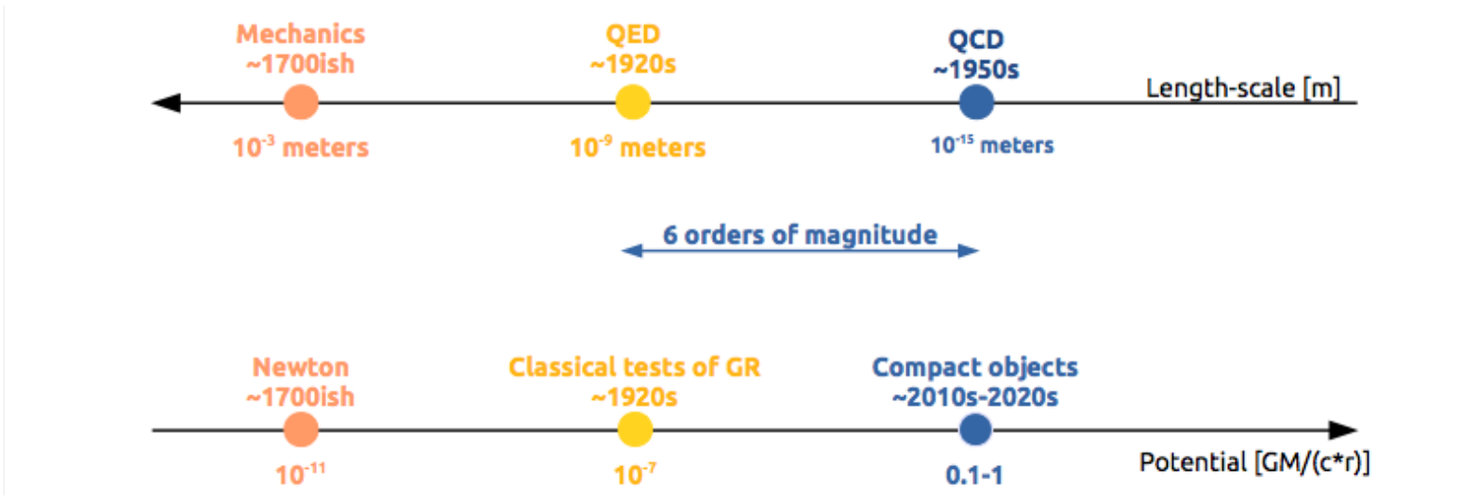

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GWs can *only* be emitted (strong enough) by phenomena in this regime
thus they are the *perfect probe* of strong gravity.

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New frontier: black-hole spectroscopy

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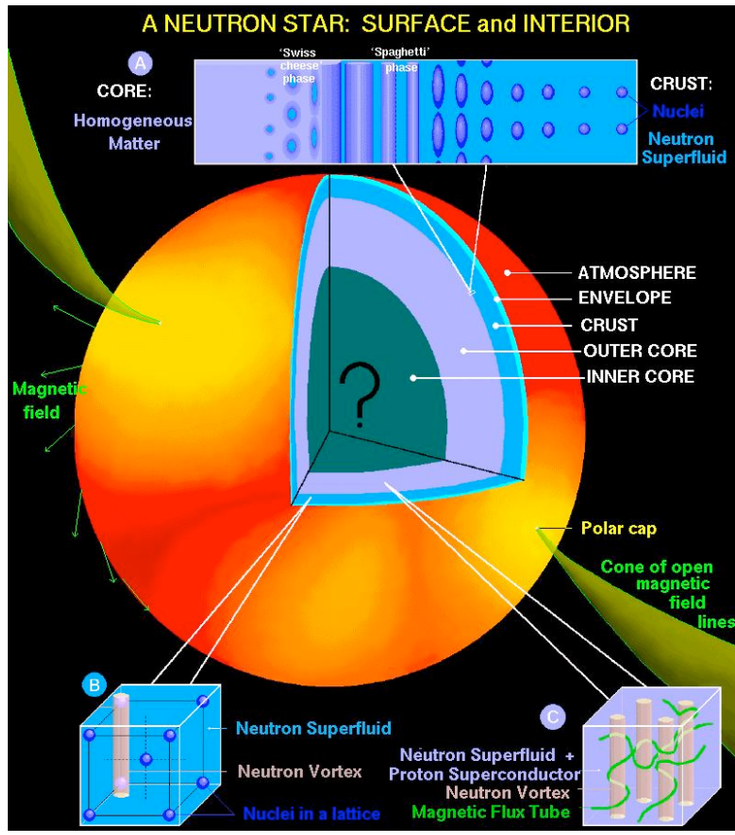
The composition of crust and outer core ~ understood, but we do not know the composition of the inner core: extreme conditions ($\rho \gtrsim 10^{15}$ g/cm^3, v~1kHz, B~$10^{10\text{-}15}$G)

- can not be reproduced in lab,
- are a challenge for the theory.



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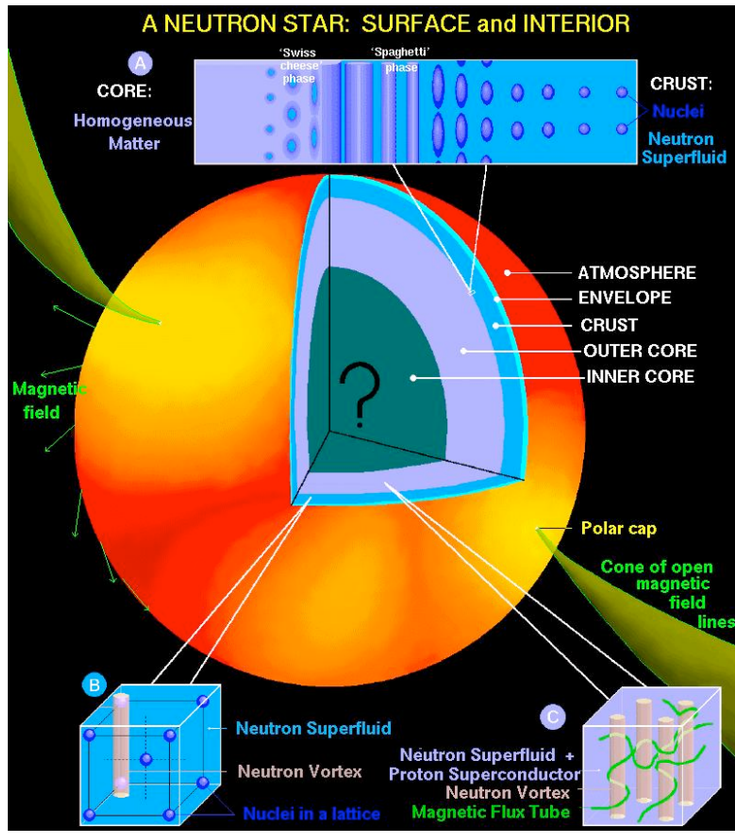

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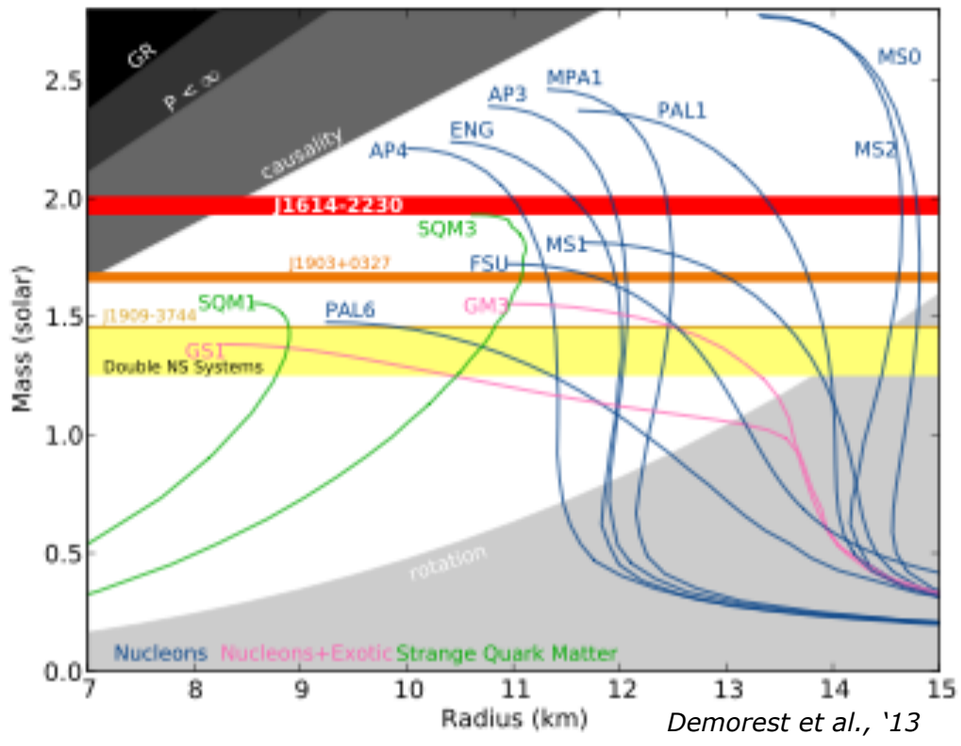

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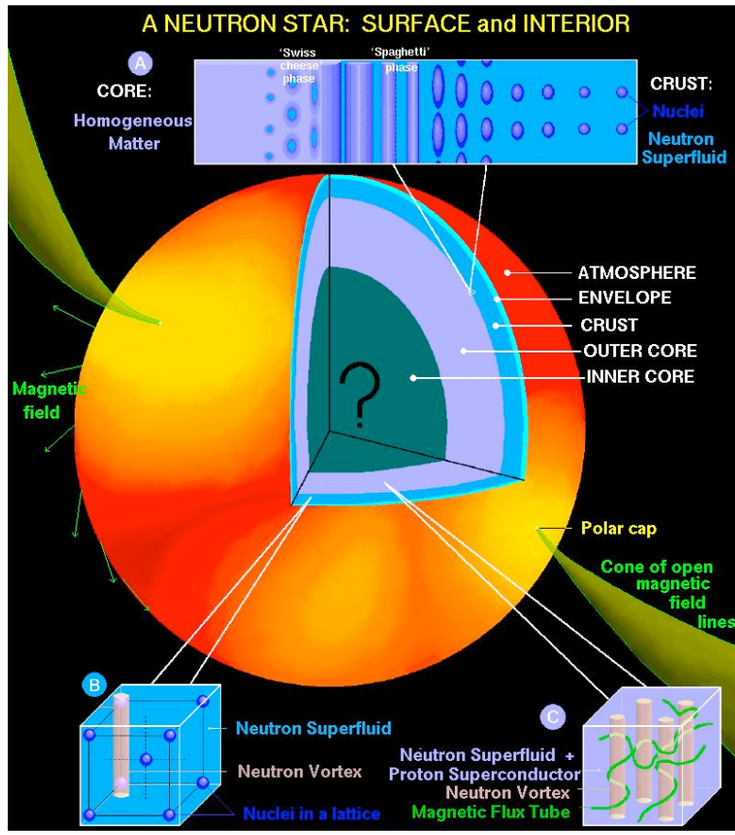

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Astrophysical observations are useful to constrain the EoS but only GWs can give a definite answer!

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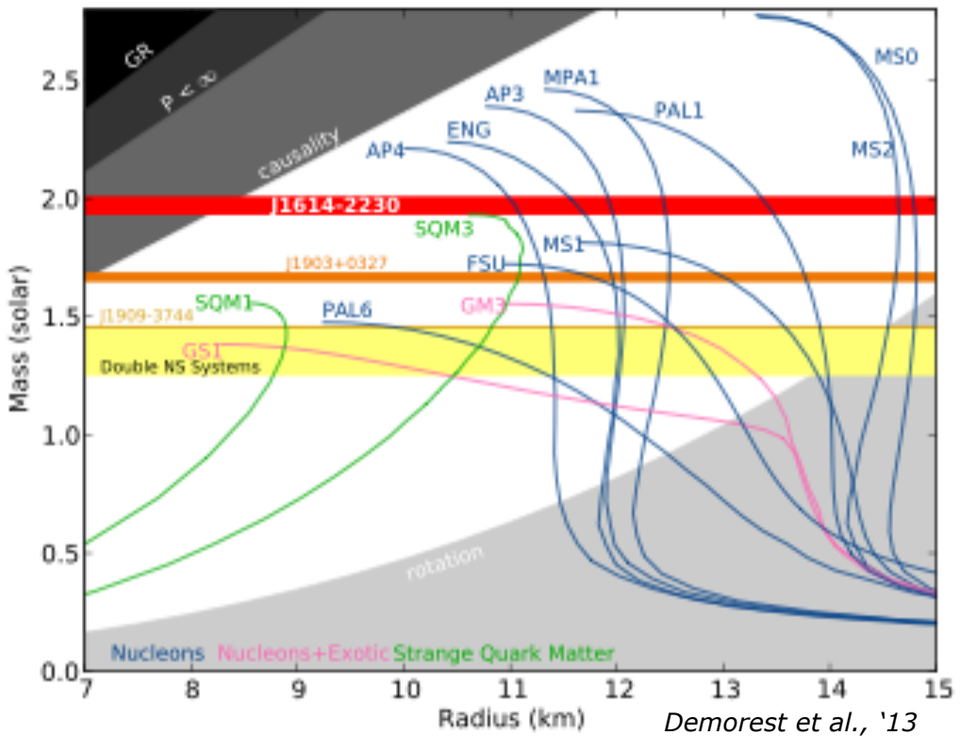

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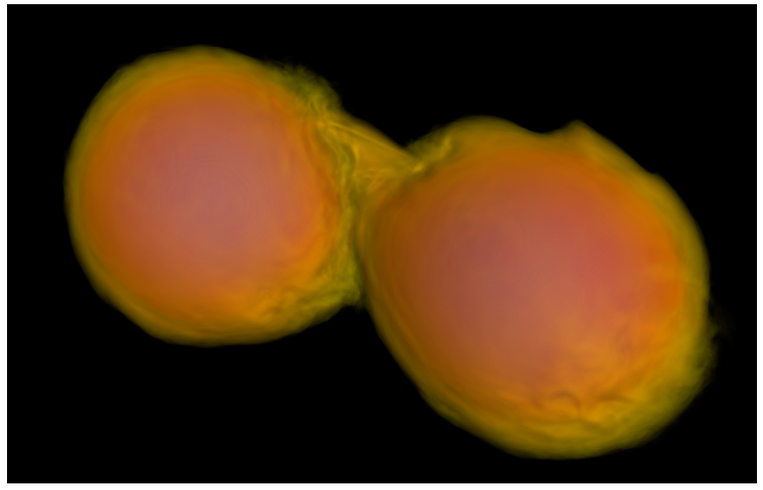

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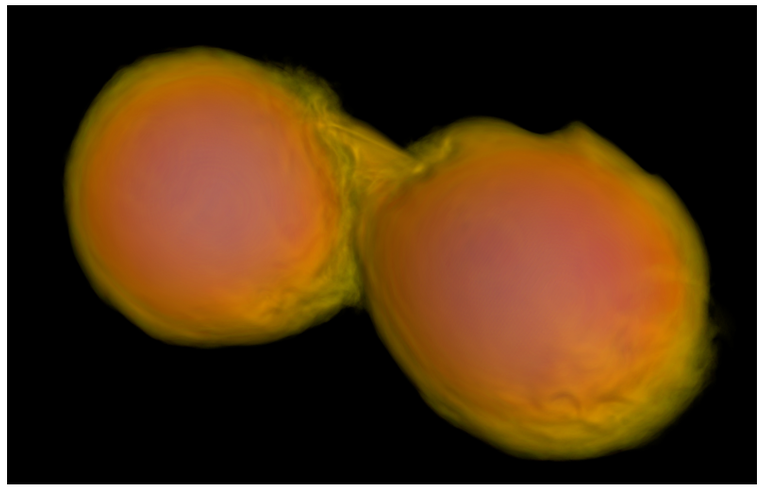

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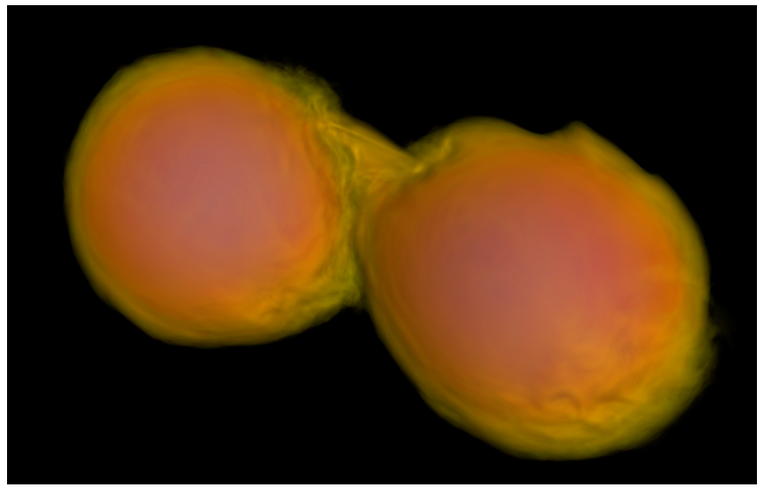

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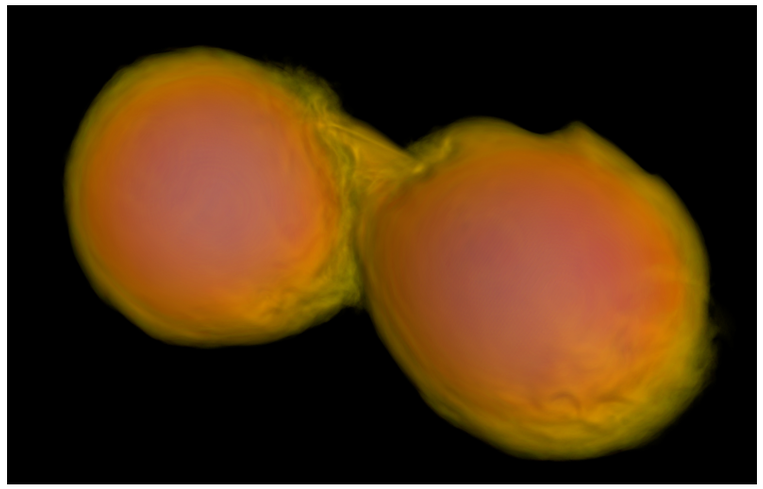

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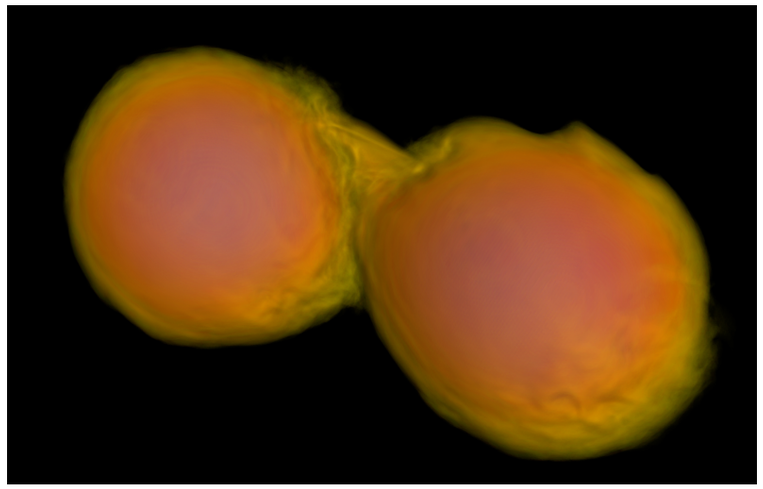

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- Other processes (interaction with a companion, accretion, etc.) could excite the quasi-normal modes of the neutron star ($\gtrsim$ 1 kHz). These modes encode the property of the matter composing the core, and then would reveal the EoS ("GW asteroseismology")

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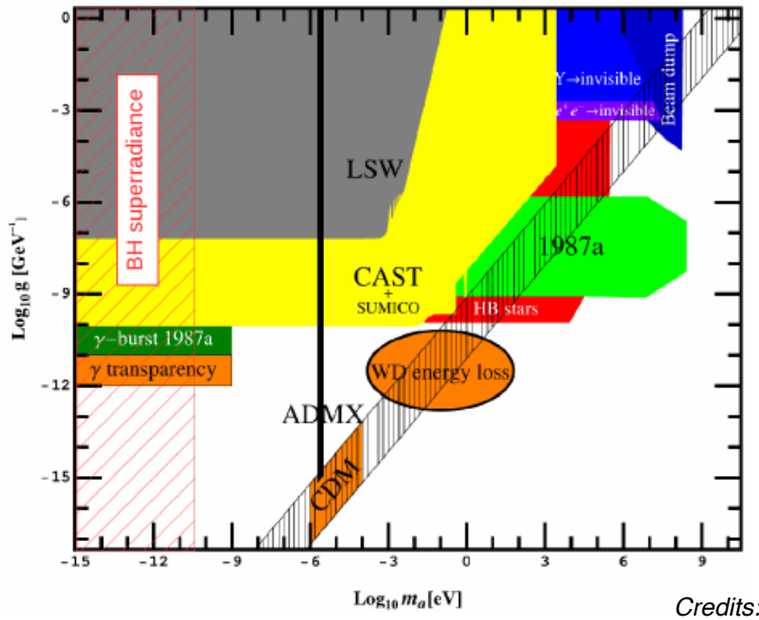

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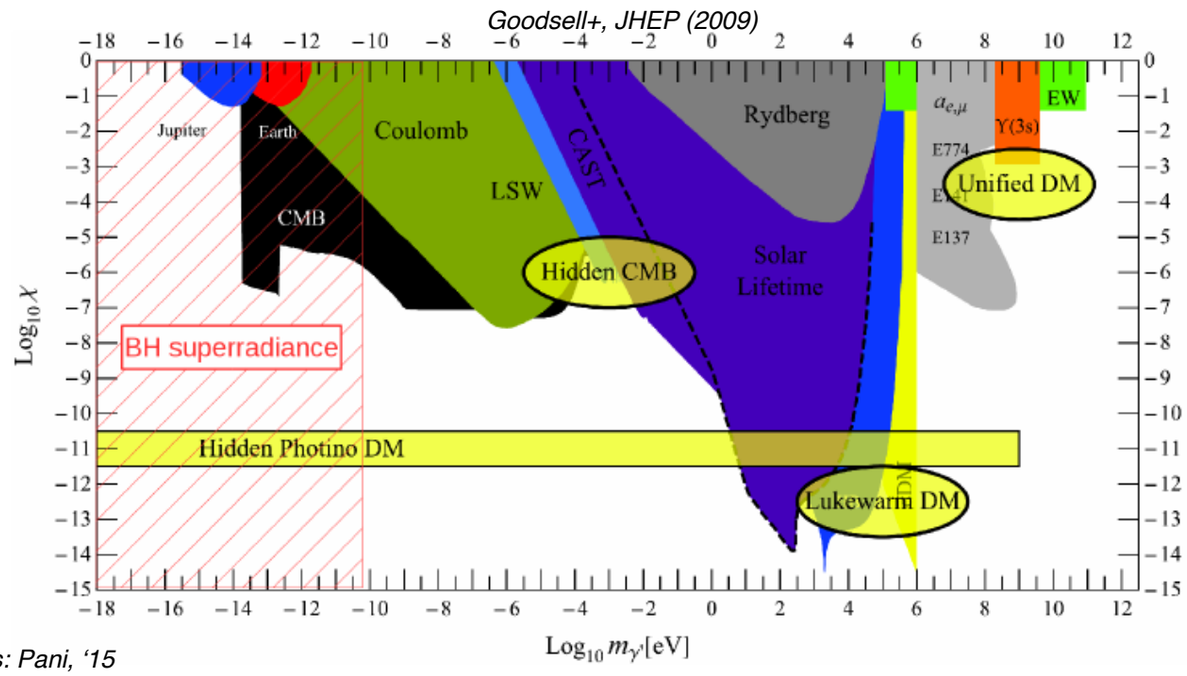

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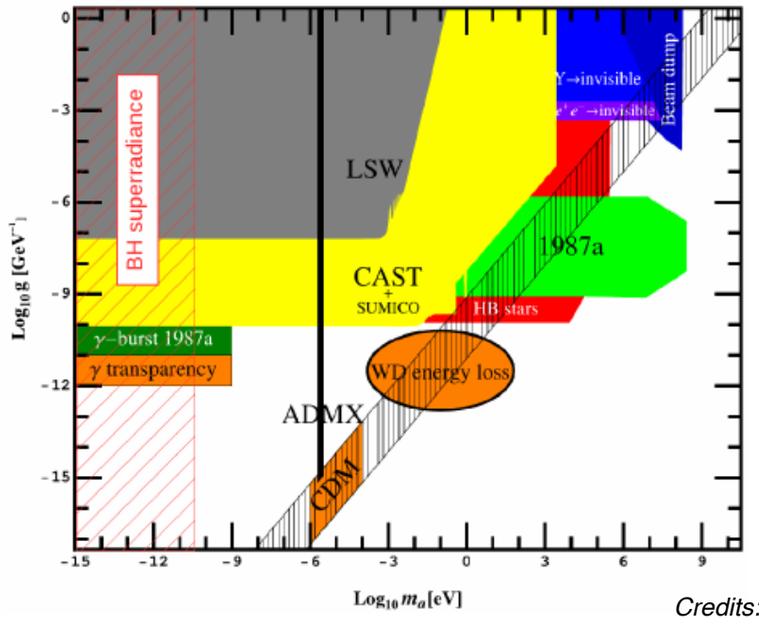

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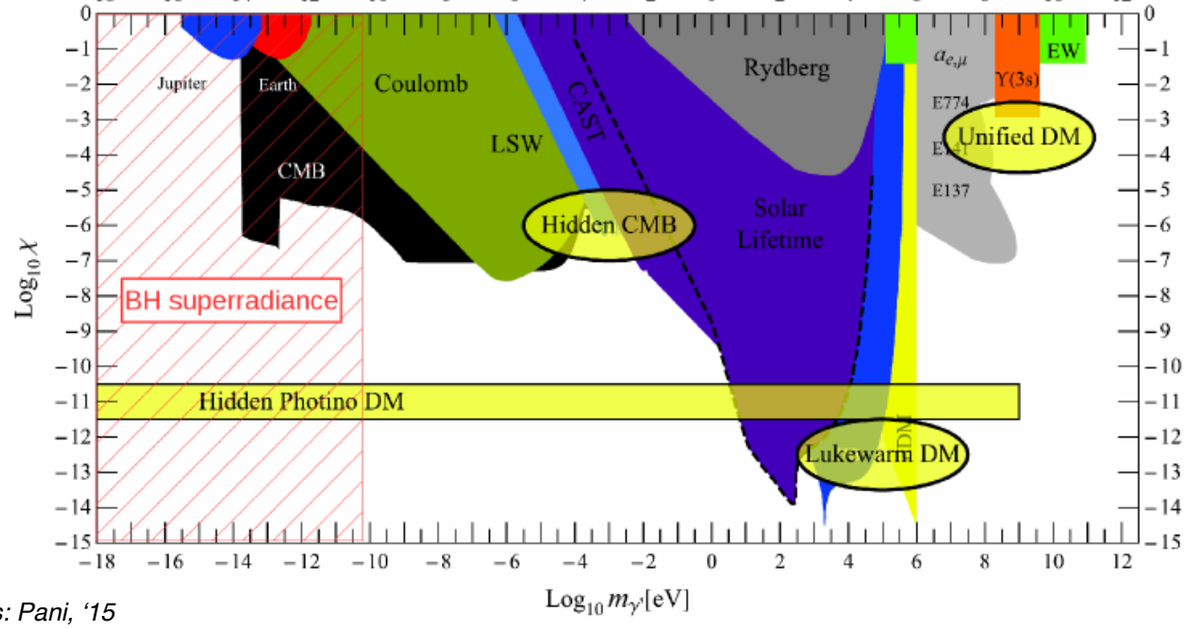

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- Beyond-standard-model effects (e.g. primordial phase transitions, domain walls etc.) could yield stochastic background detectable by ground-based interferometers

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Ground-based and space-based detectors
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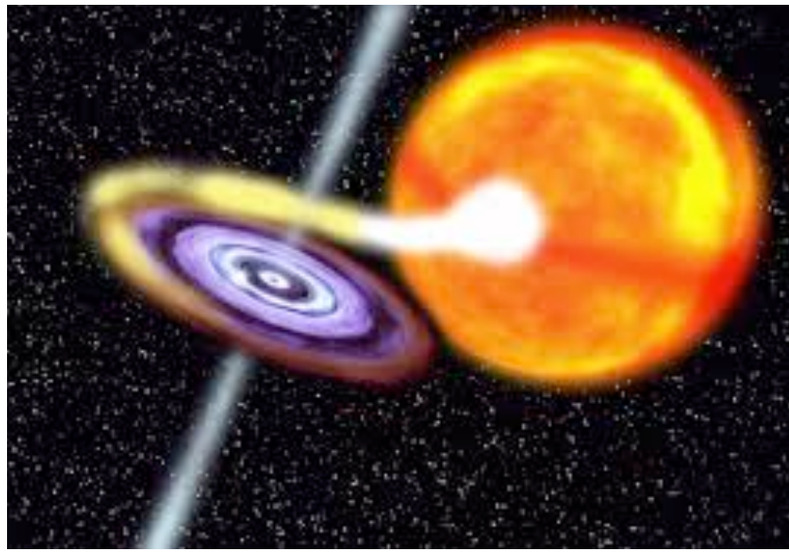

NASA/GSFC

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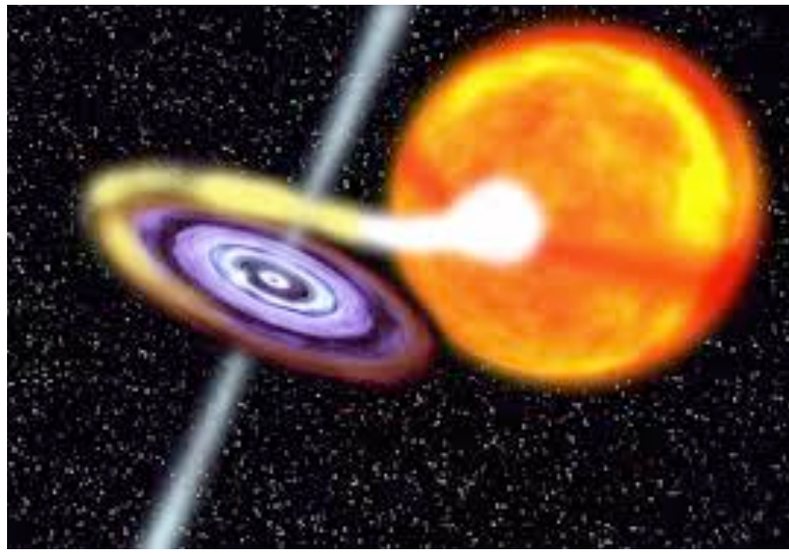

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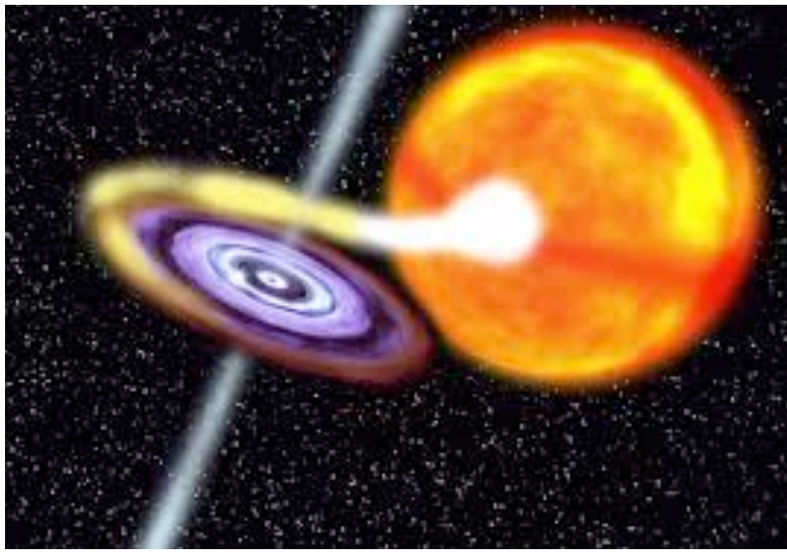
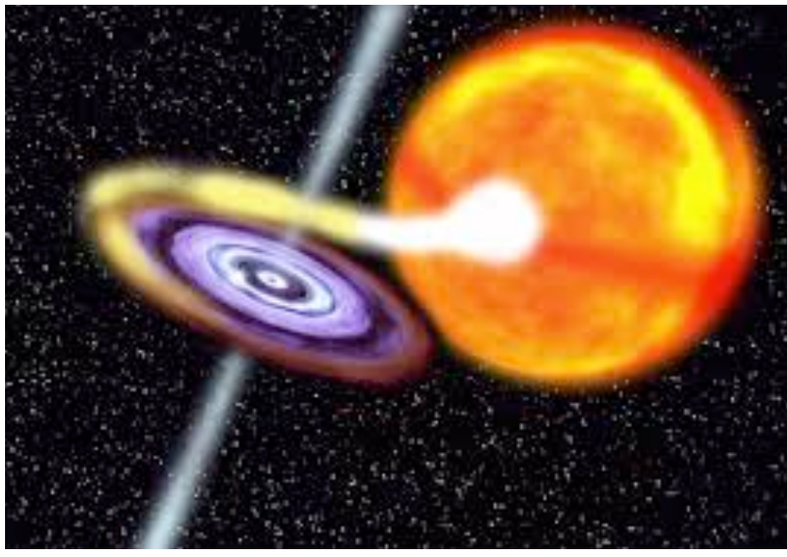
The mechanism limiting the spin rate is unclear,
most candidates are associated to GW emission.



NASA/GSFC

5) Why neutron stars do not spin faster?

LMXRB: Neutron star + "normal" star



NASA/GSFC

Observational puzzle:
accretion should be able to spin-up NS to v~1.5kHz,
but actual spin rates much smaller:
most of them v<300Hz, maximum value 714Hz.

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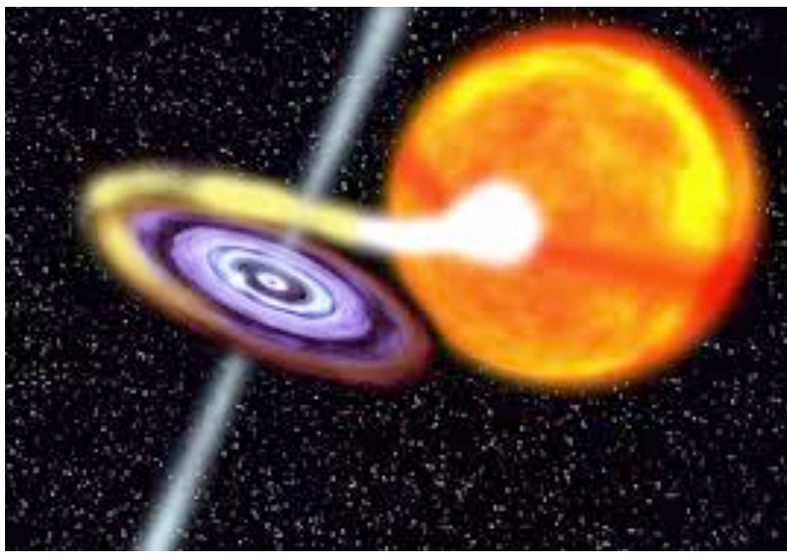

NASA/GSFC

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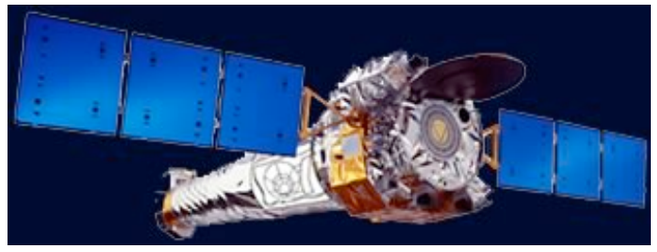
6) Does compact object coalescence source gamma-ray bursts?

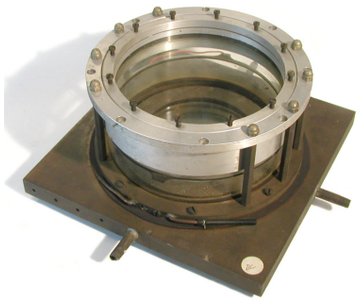
See Michele's talk

7) Can we learn more on the origin and evolution of our Universe using GWs?

See Michele's talk

8) Will totally unexpected sources show up?





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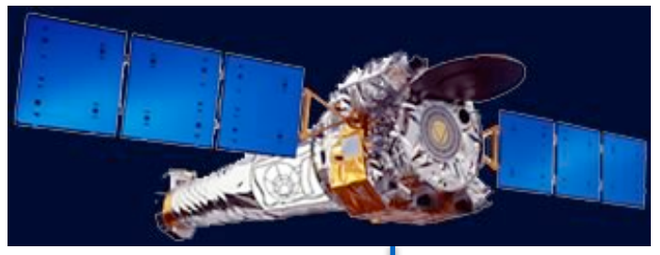

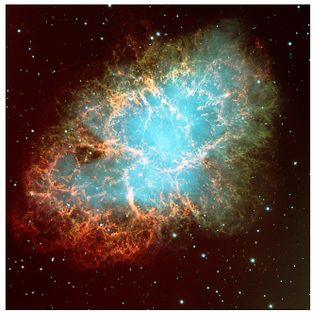

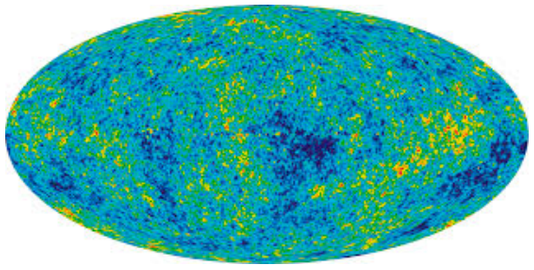

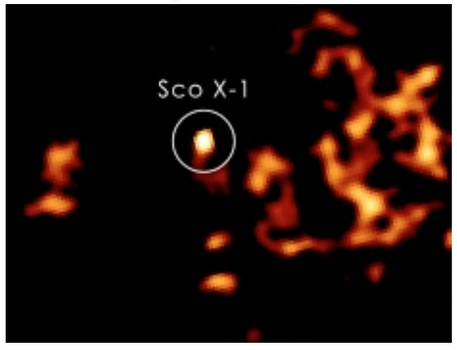

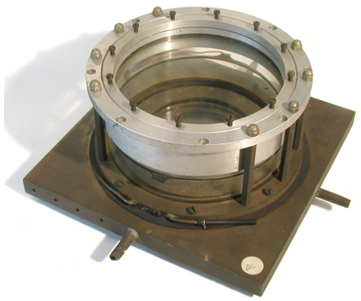

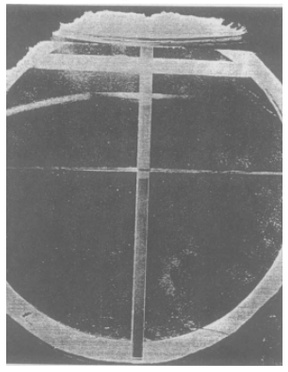

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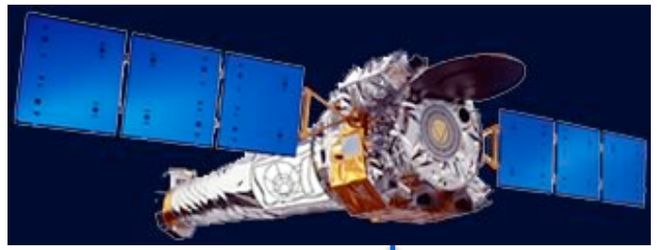

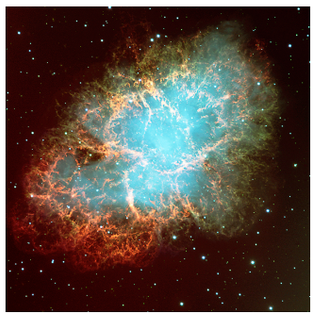

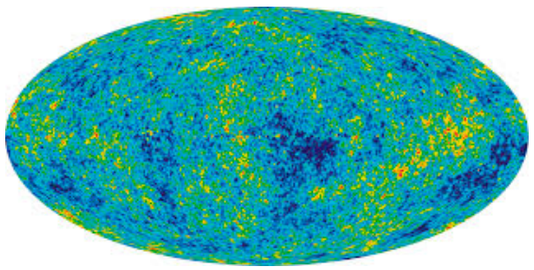

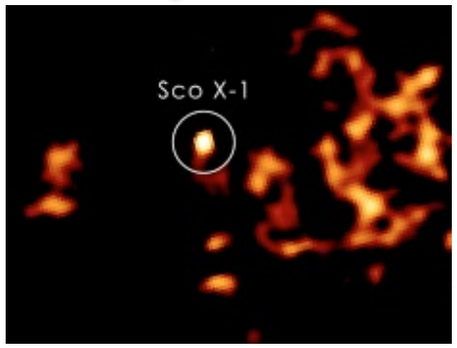

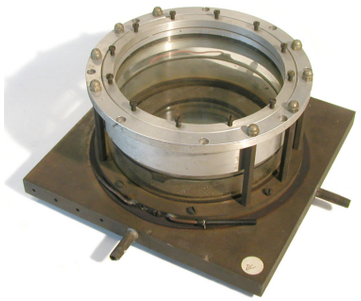

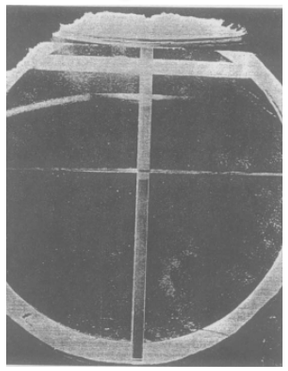

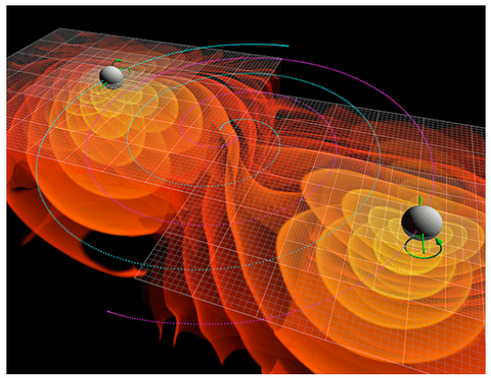

(unexpected to some extent…)

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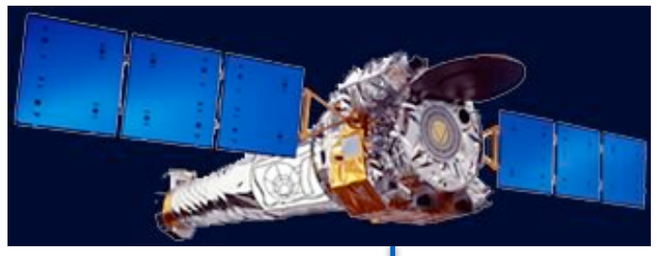

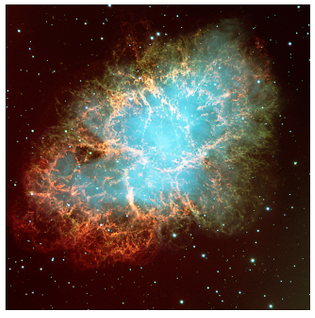

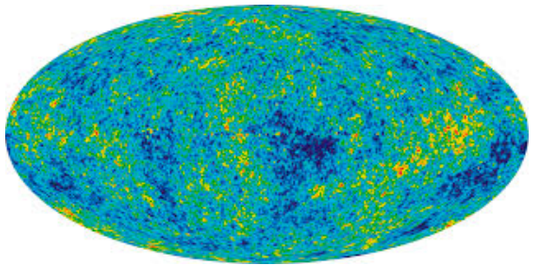

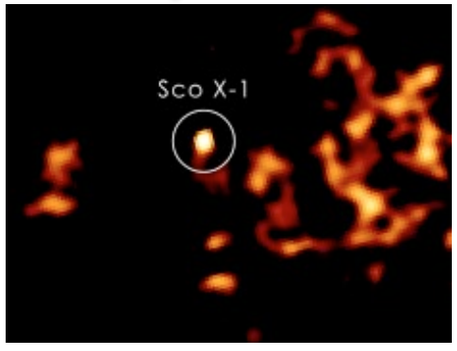

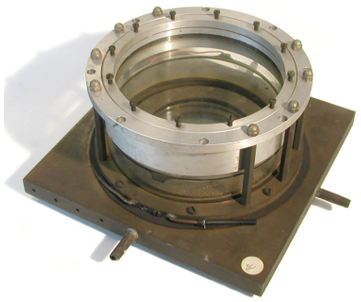

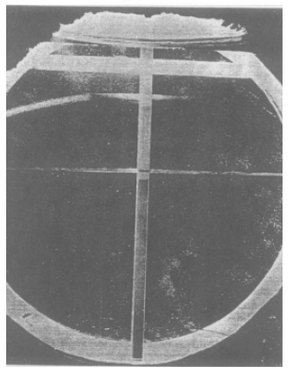

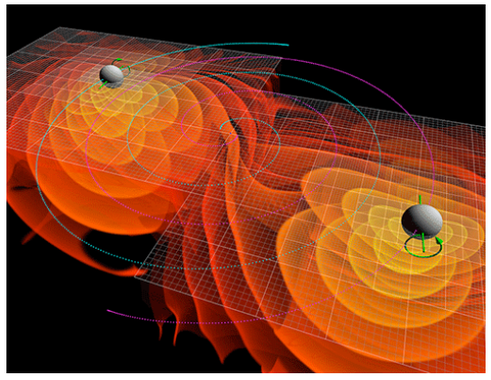

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\+ …. ?