

Detectability of a phase transition in neutron star matter with third-generation gravitational wave interferometers

Chiranjib Mondal

M. Antonelli, F. Gulminelli, M. Mancini, J. Novak & M. Oertel
(Caen-Meudon group)



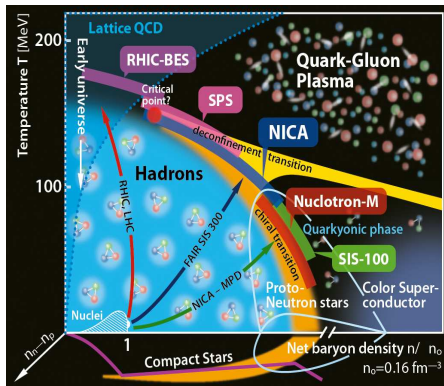
ET symposium, Cagliari
May 8, 2023

Hadron-Quark phase transition (PT)

In the context of Neutron Star

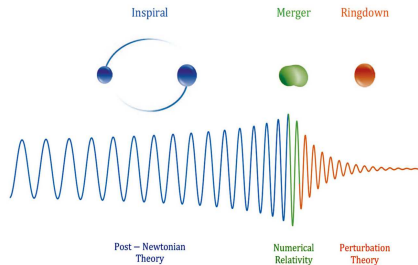
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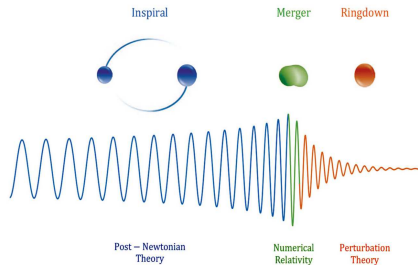
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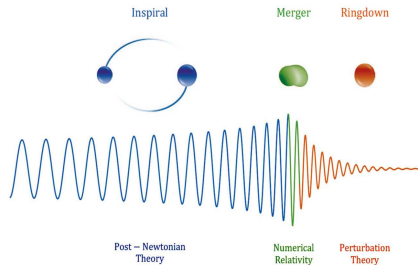
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Questions one can ask:

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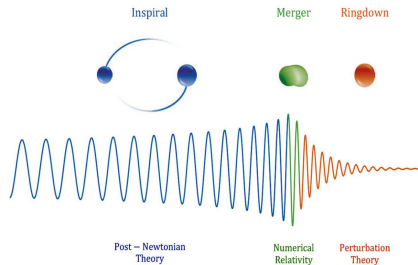


Questions one can ask:

- Can PT be detected through a GW signal?

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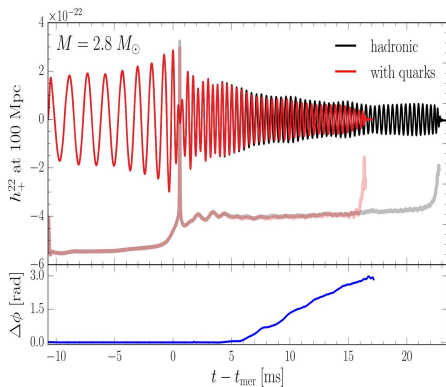


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Questions one can ask:

- Can PT be detected through a GW signal?
- In which conditions it can be detected? **Early/Late??**
- What are the signatures in the signal?
For overview see e.g. Blacker *et. al.* PRD 102, 123023 (2020).

Most *et. al.*, PRL 122, 061101 (2019)

NS-NS GW signal

Uncertainties in information

NS-NS GW signal

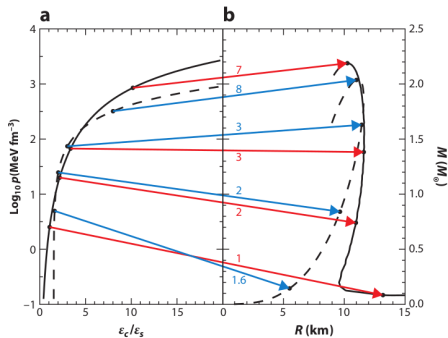
Uncertainties in information

Solve Tolman-Oppenheimer-Volkoff (TOV) equations, we can construct the unique M-R or Λ -M(R) relations.

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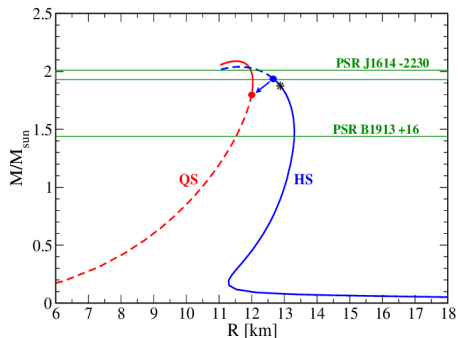


J. Lattimer, ARNPS 62, 485–515 (2012)

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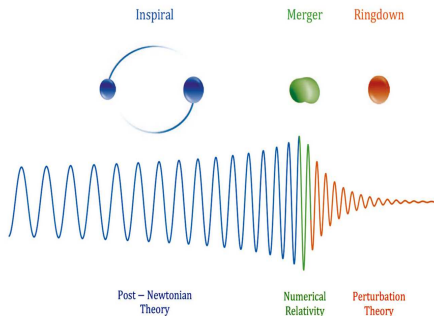


I. Bombaci, conference paper

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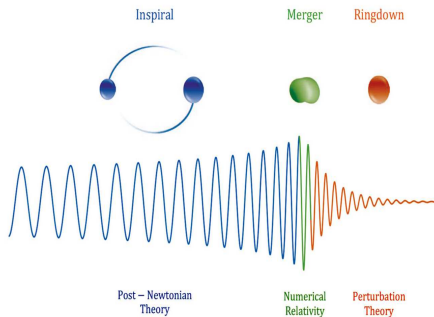


Information from the inspiral:

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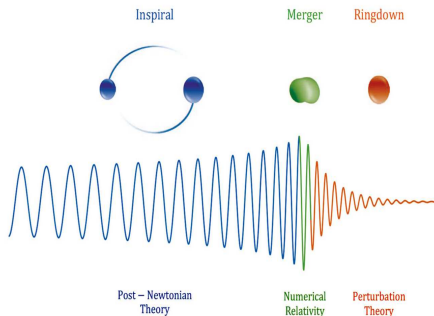
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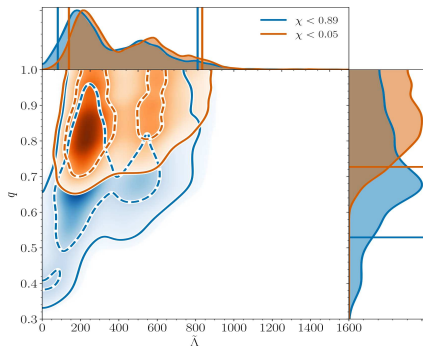
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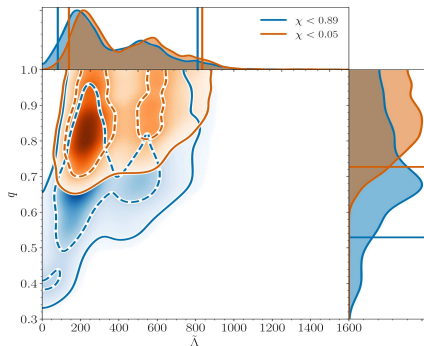


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LVC, PRX 9, 011001 (2019)

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Information from the inspiral:

- The joint tidal $\tilde{\Lambda}$ not Λ_1, Λ_2
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- The GW170817 case.
- Prospect of many NS-NS in ET with 3G detectors

LVC, PRX 9, 011001 (2019)

EoS modelling with PT

β -equilibrium at $T=0$, 1st order PT

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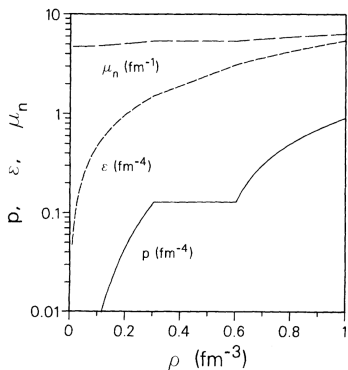
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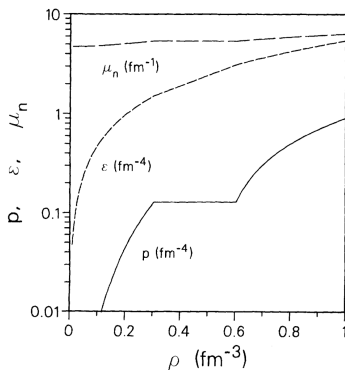


Glendenning PRD 46, 1274 (1992)

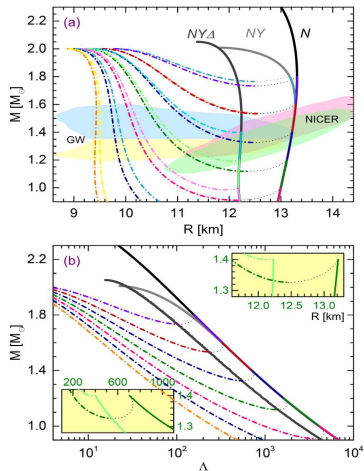
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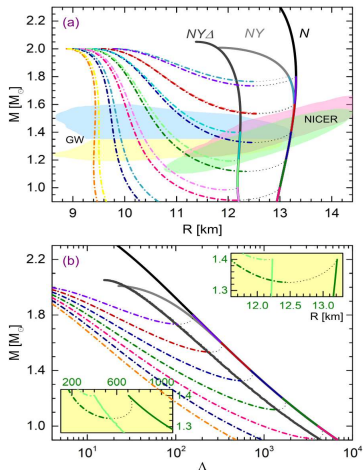
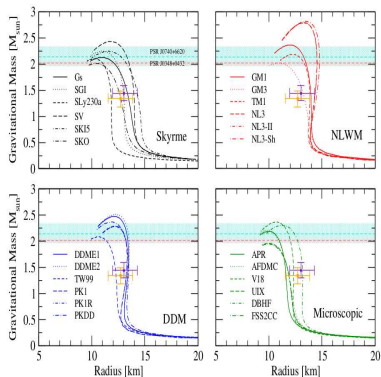


Li, Sedrakian and Alford, PRD 101, 063022 (2020)

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G. Burgio & I. Vidaña, Universe 6, 119 (2020)

Li, Sedrakian and Alford, PRD 101, 063022 (2020)

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Founding aspects [PRC 97, 025805 (2018)]

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Constraints in Bayesian studies:

χ -EFT, Finite nuclei, M_{max} , GW170817 *etc.*

Dinh-Thi *et. al.* 2021, CM *et.al* 2022, 2023.

Hybrid meta-modelling

CSS model in the quark phase

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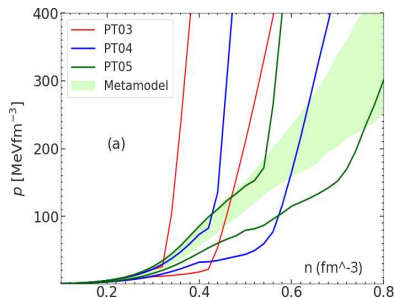
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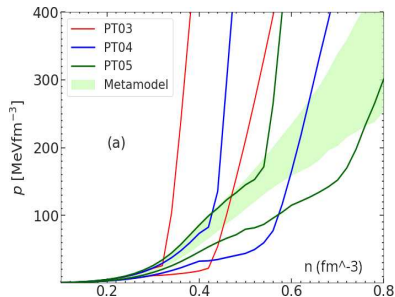
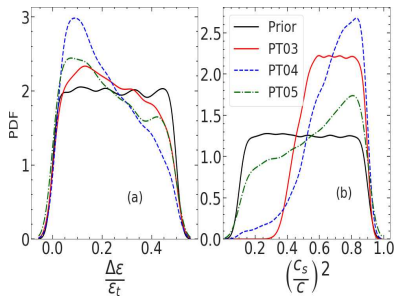


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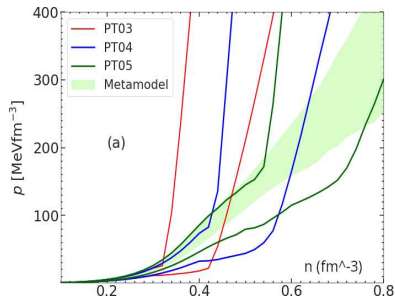
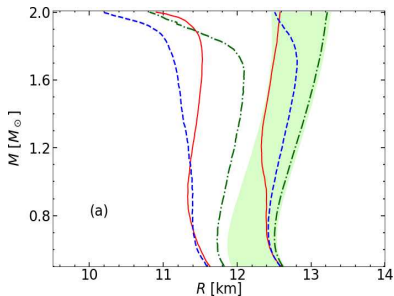


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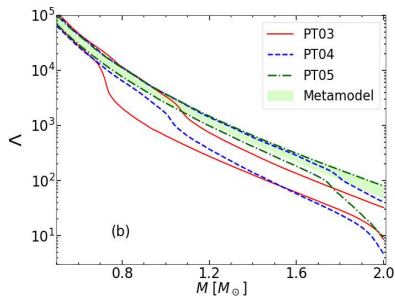
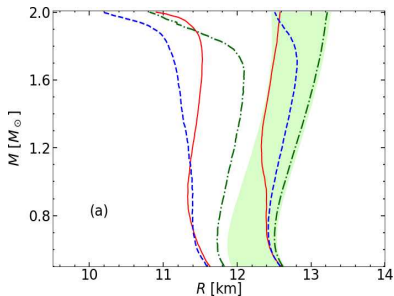


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Simulated observations with GWBench

Observable with uncertainties

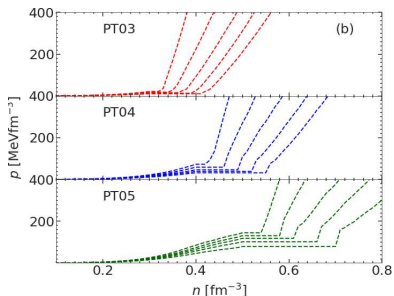
Different choices for q , \mathcal{M}_c , \mathcal{D}_L and PT injection models.

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Injection models with PT

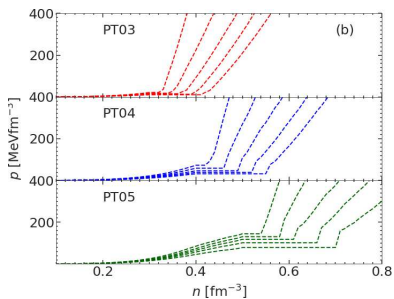


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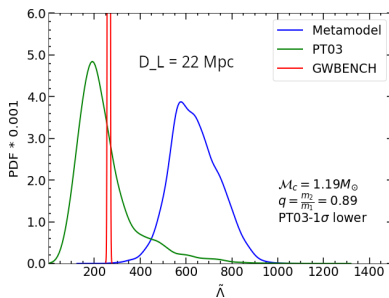
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$\tilde{\Lambda}$ distribution

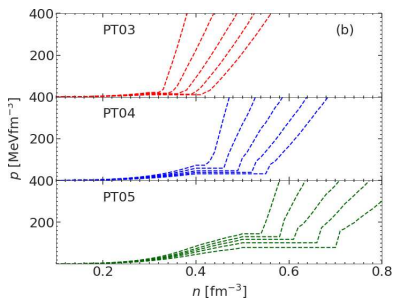


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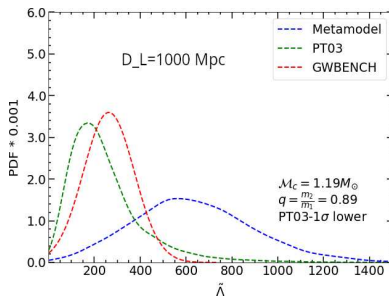
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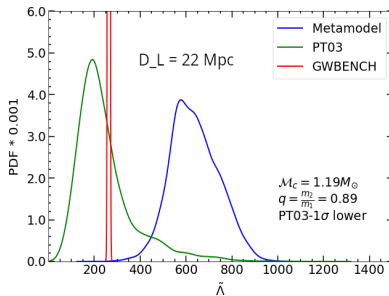
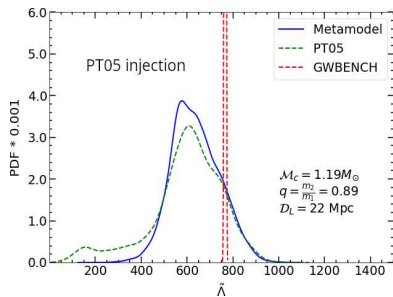


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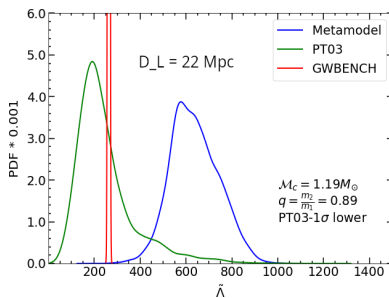
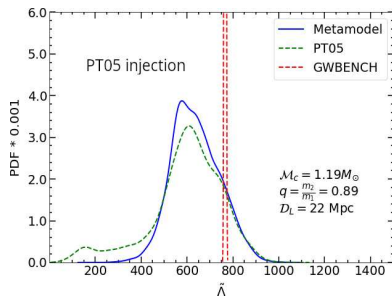


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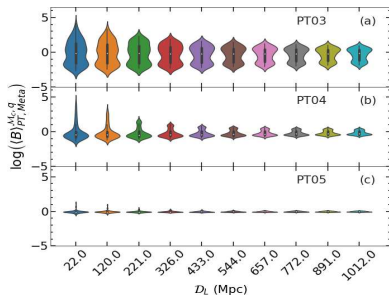
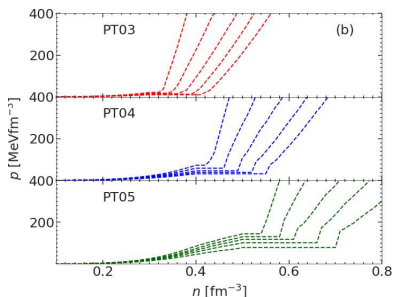


$$B_{\text{pt,meta}}(\tilde{\Lambda}) = \frac{P_{\text{pt}}(\tilde{\Lambda})}{P_{\text{meta}}(\tilde{\Lambda})} \quad \log(\langle B \rangle_{\text{pt,meta}}) = \int d\tilde{\Lambda} p_{\text{GW}}(\tilde{\Lambda}) \log \left[\frac{P_{\text{pt}}(\tilde{\Lambda})}{P_{\text{meta}}(\tilde{\Lambda})} \right]$$

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Summary and outlook

- A possible mechanism to detect the signature of 1st order phase transition was proposed.
- Hybrid metamodelling is used in the Bayesian framework.
- We assess the detectability of PT from a single loud event from the inspiral signal.
- We infer the presence of a PT at low densities with $B \approx 100$, upto distance 300 Mpc.
- Analysis based on many events are on the way.