Measuring the neutron star equation of state with gravitational waves

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LIGO Document G1801164

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Outline

- Neutron stars as laboratories
- How neutron star matter effects gravitational waves
- First results from analysis of GW170817
- Updated results from recently released analyses of GW170817
- Future prospects

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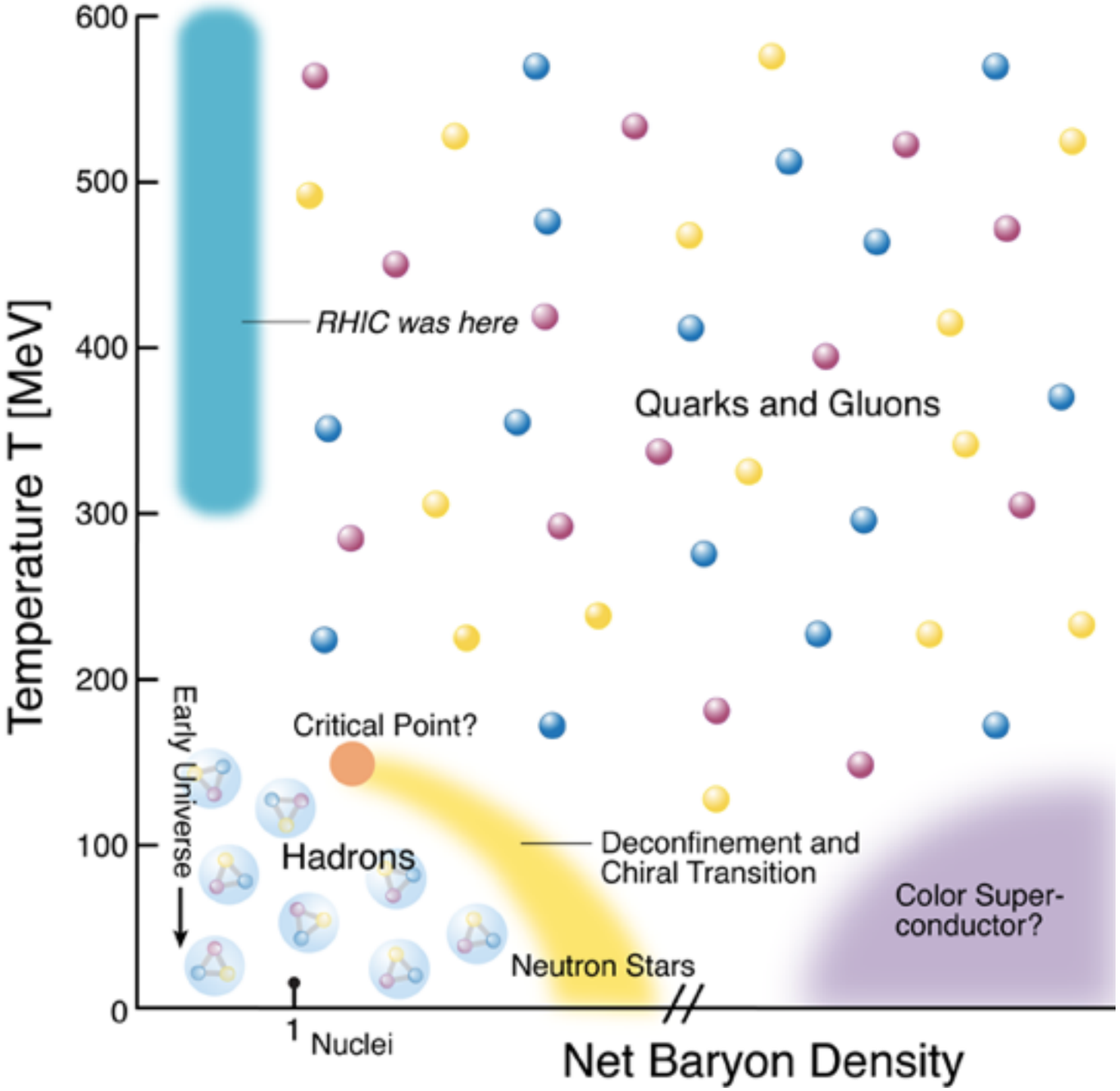
Phases of nuclear matter



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Candidate equation of states

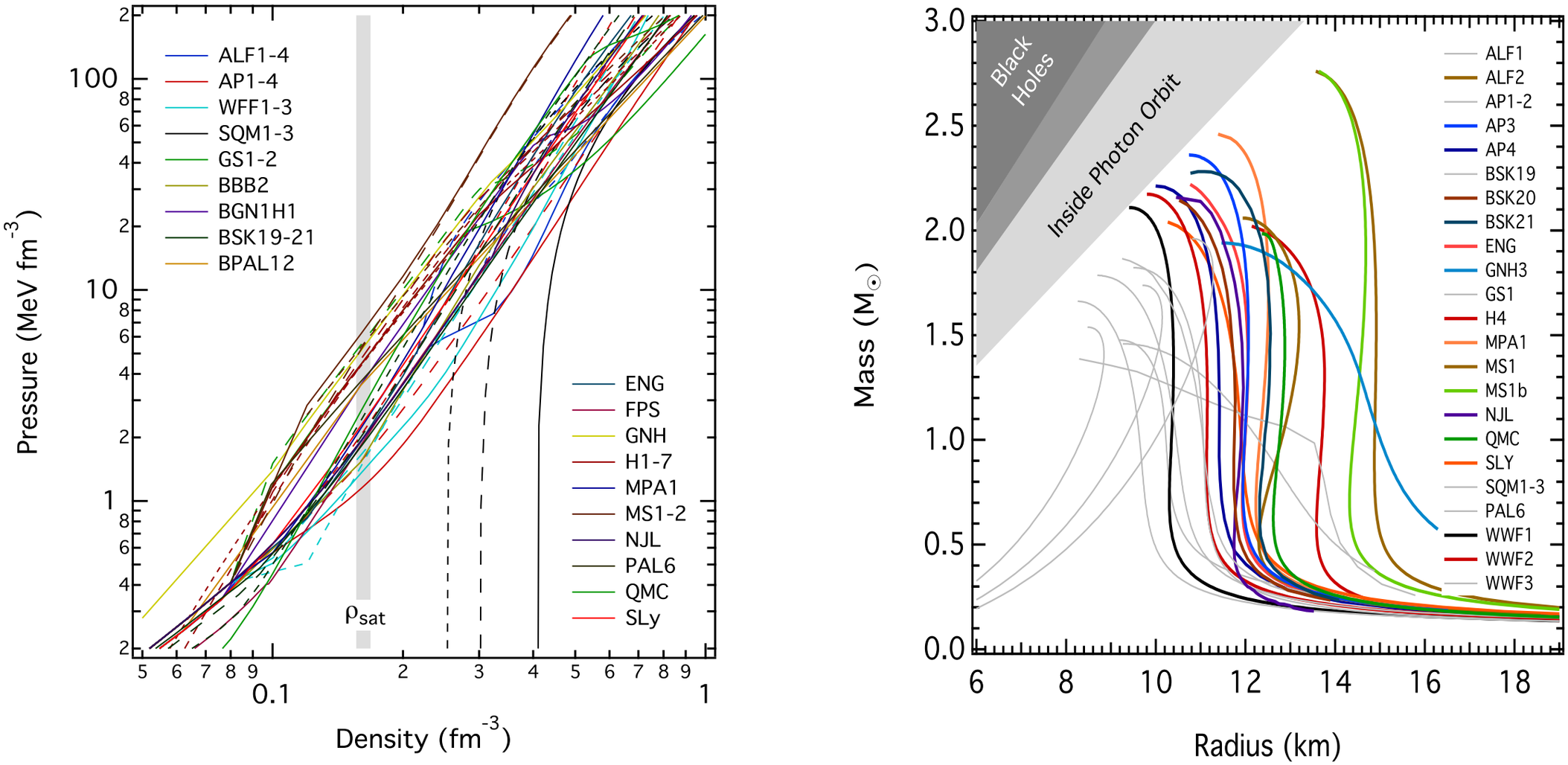
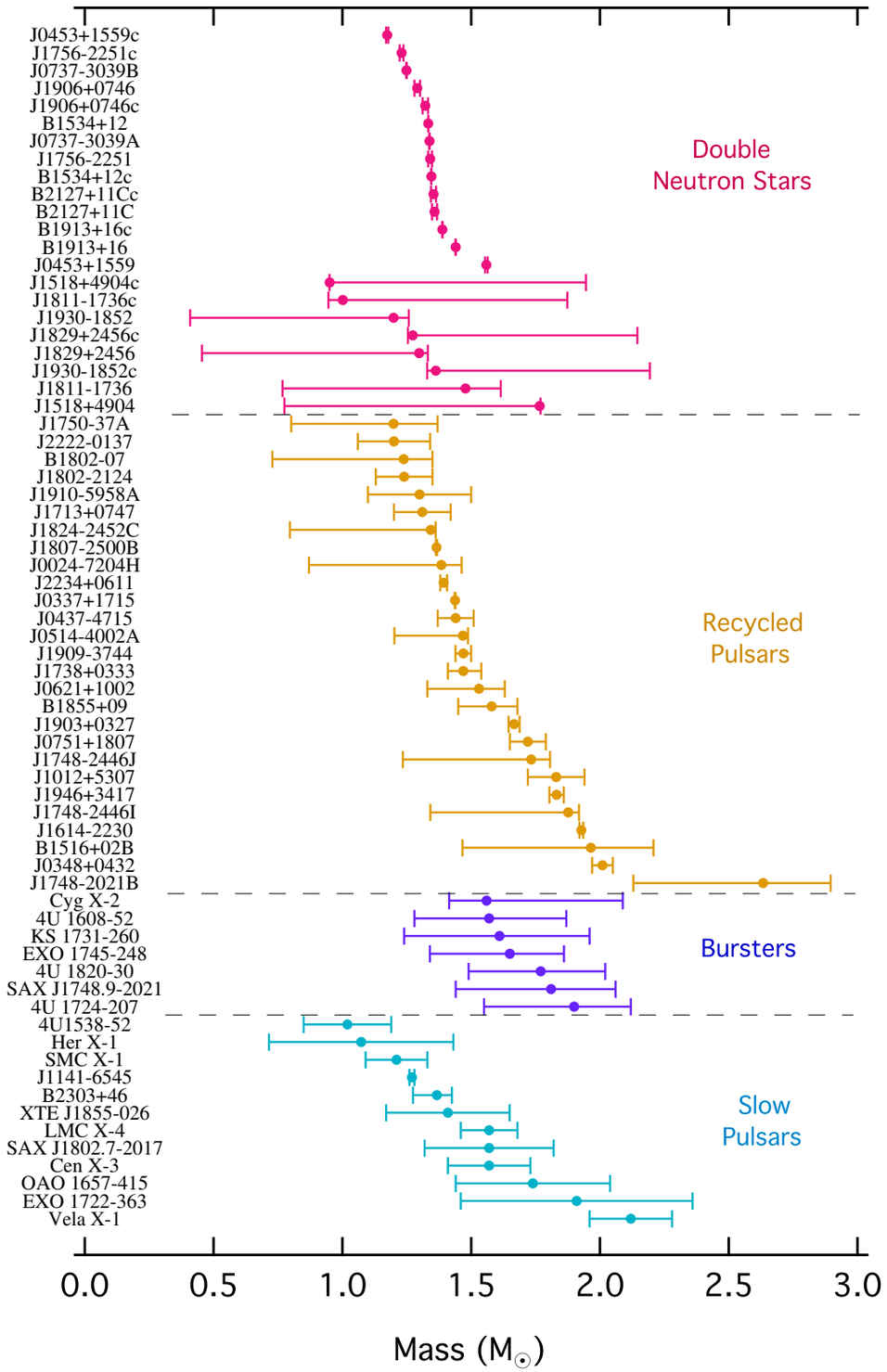


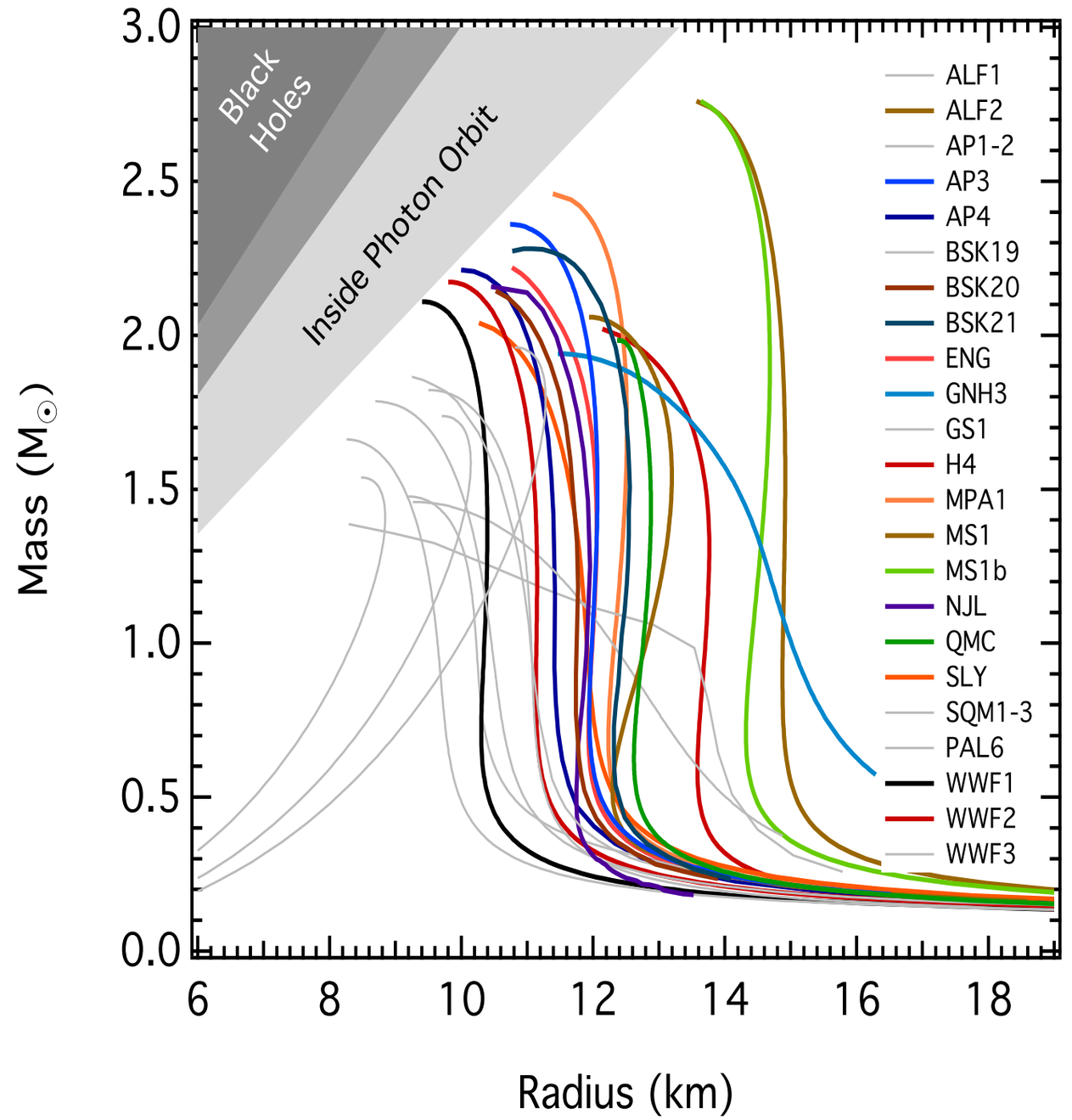
Figure 7

(Left) A large sample of proposed equations of state calculated under different physical assumptions and using a range of computational approaches. See the text for the descriptions of the equations of state, the acronyms, and the references. (Right) The mass-radius curves corresponding to the equations of state shown in the left panel.

Özel, Freire: 1603.02698

Observational constraints





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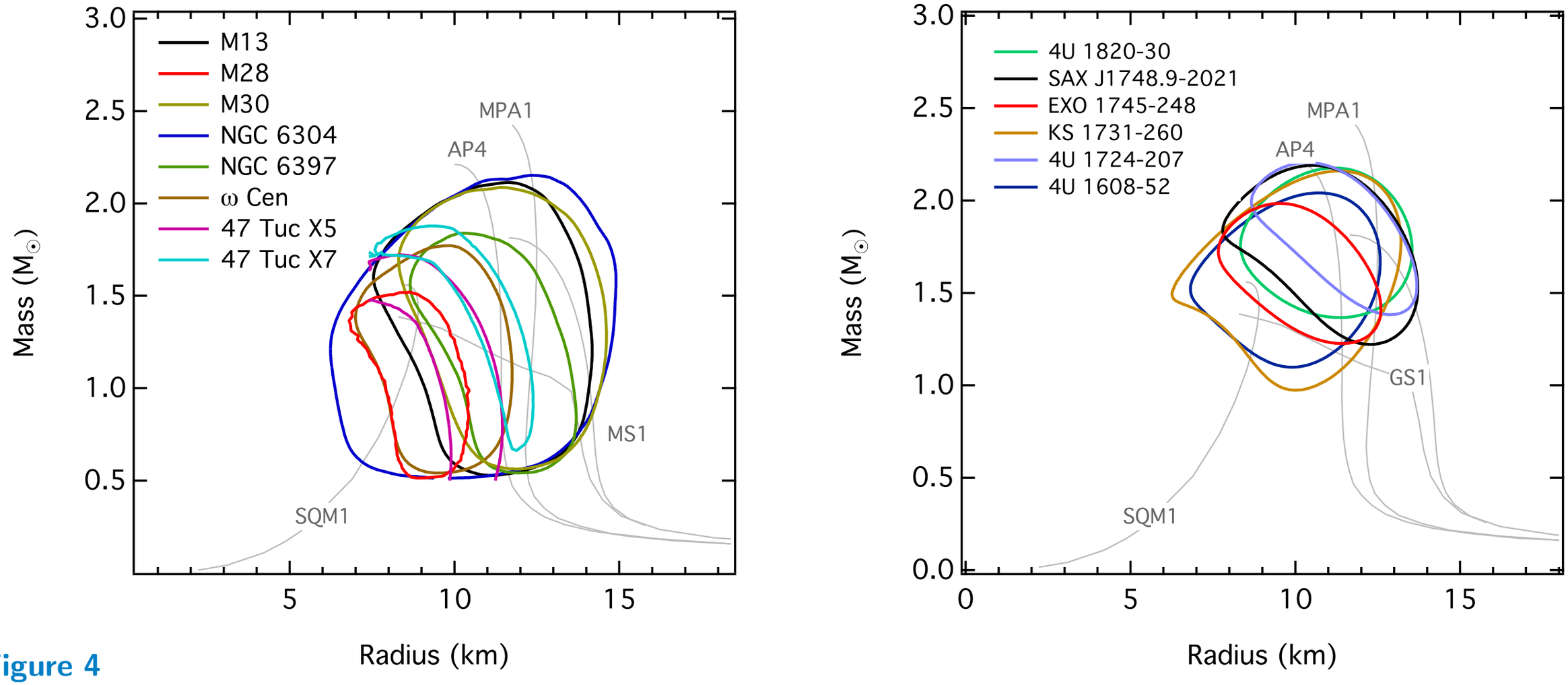

Figure 4

The combined constraints at the 68% confidence level over the neutron star mass and radius obtained from (Left) all neutron stars in low-mass X-ray binaries during quiescence (Right) all neutron stars with thermonuclear bursts. The light grey lines show mass-relations corresponding to a few representative equations of state (see Section 4.1 and Fig. 7 for detailed descriptions.)

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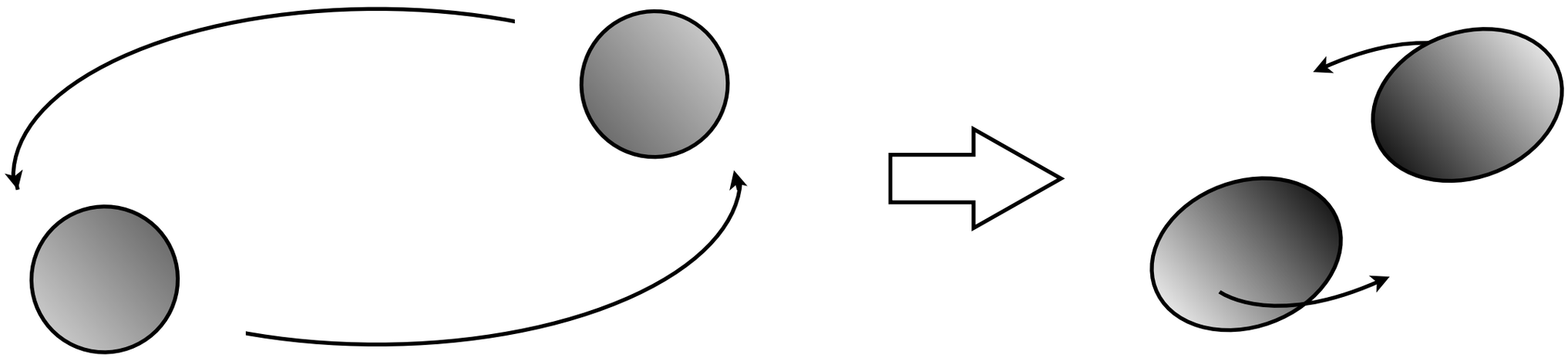
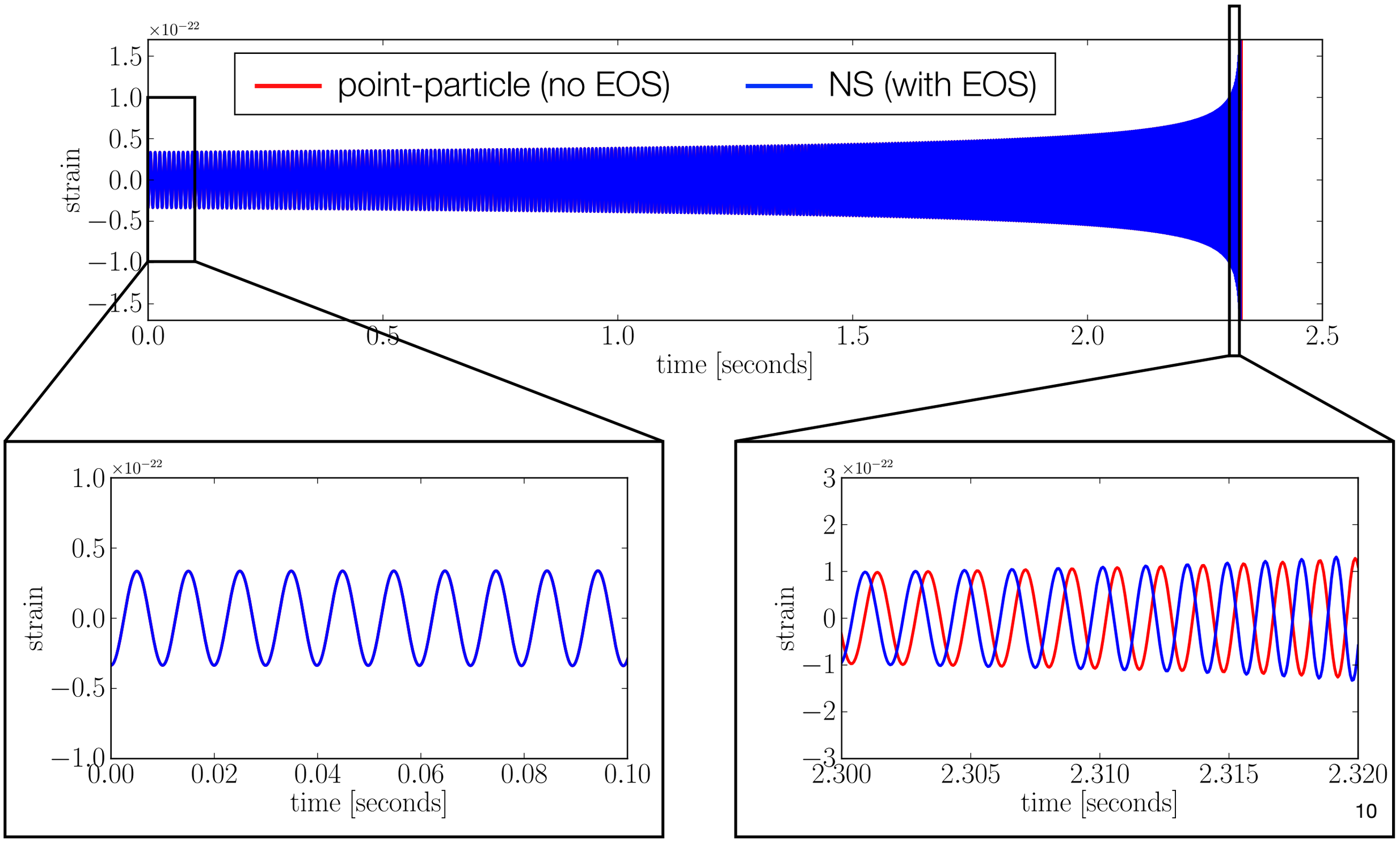
Binary neutron star systems

- At large orbital separations, tidal field is weak

- As NSs near, gravitational gradient across NS diameter deforms the star

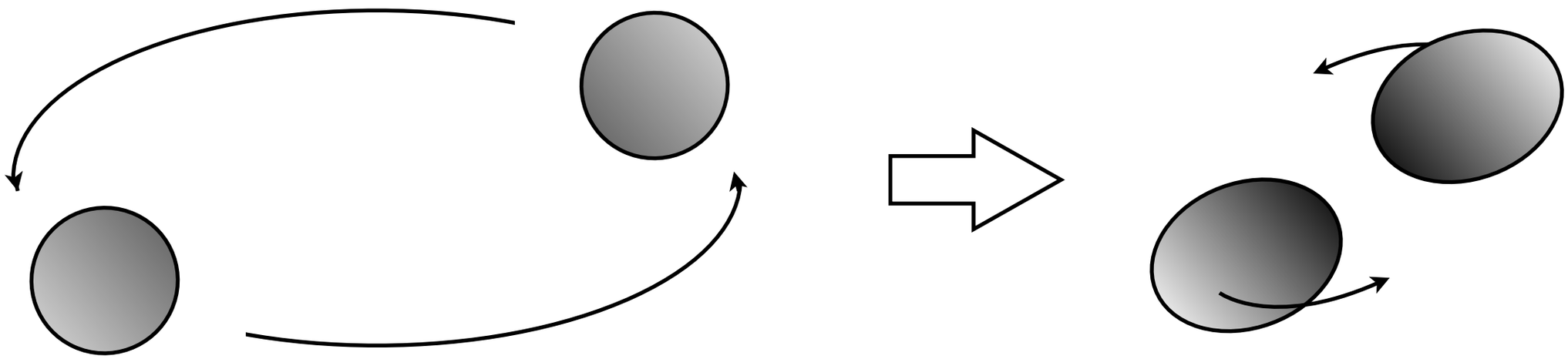


Tidal effects change phase and accelerate merger



Binary neutron star systems

- At large orbital separations, tidal field is weak
- As NSs near, gravitational gradient across NS diameter deforms the star
- The amount NS deforms is related to the EOS and radius

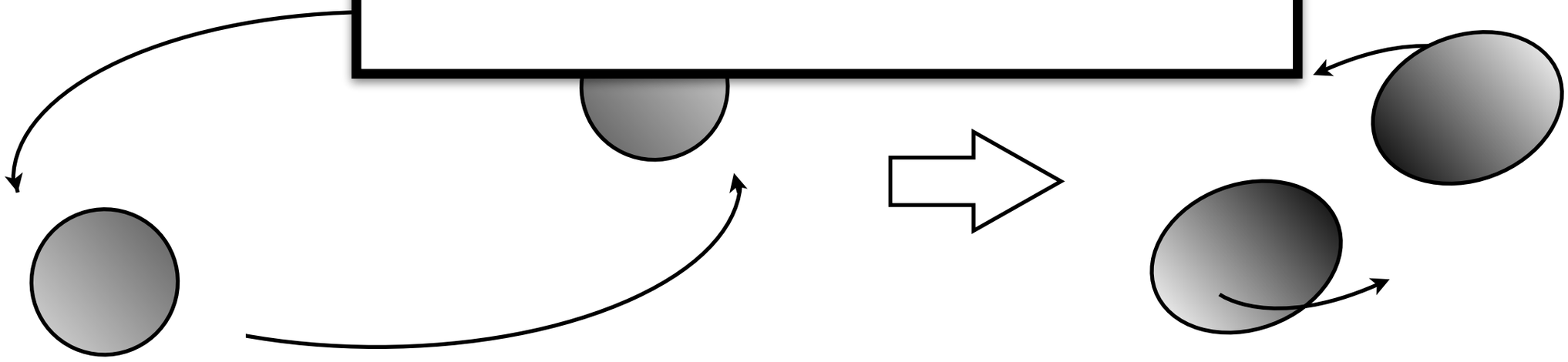


Binary neutron star systems

- At large orbital separations, tidal field is weak
- As NSs near, g deforms the star
- The amount N s

Deformability described by:

(Λ_1, Λ_2)



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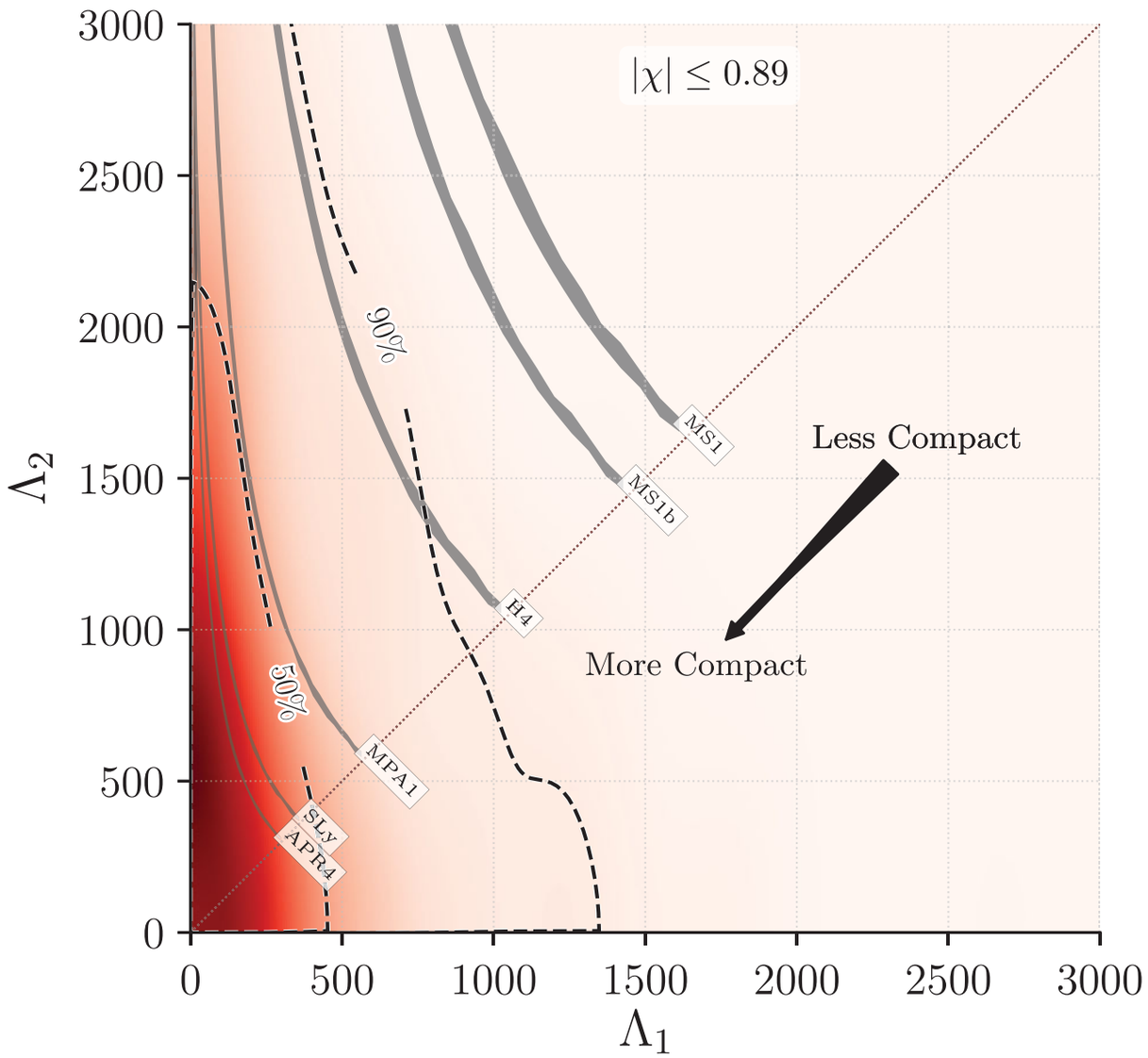
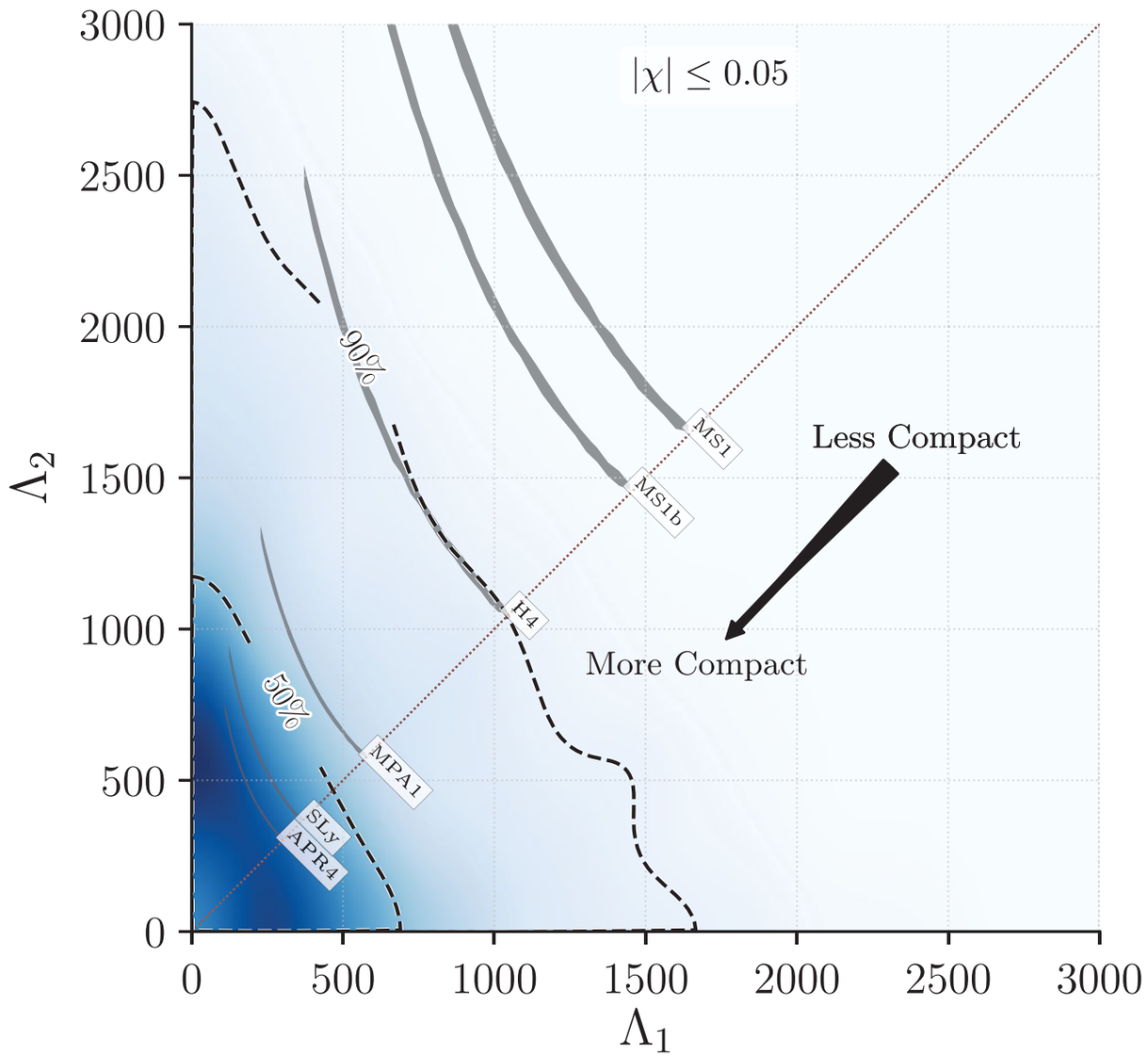
Tidal effects measured in GW170817

- high-spin prior: $\chi \leq 0.89$
- low-spin prior: $\chi \leq 0.05$





LIGO, Virgo Collaboration: 1710.05832

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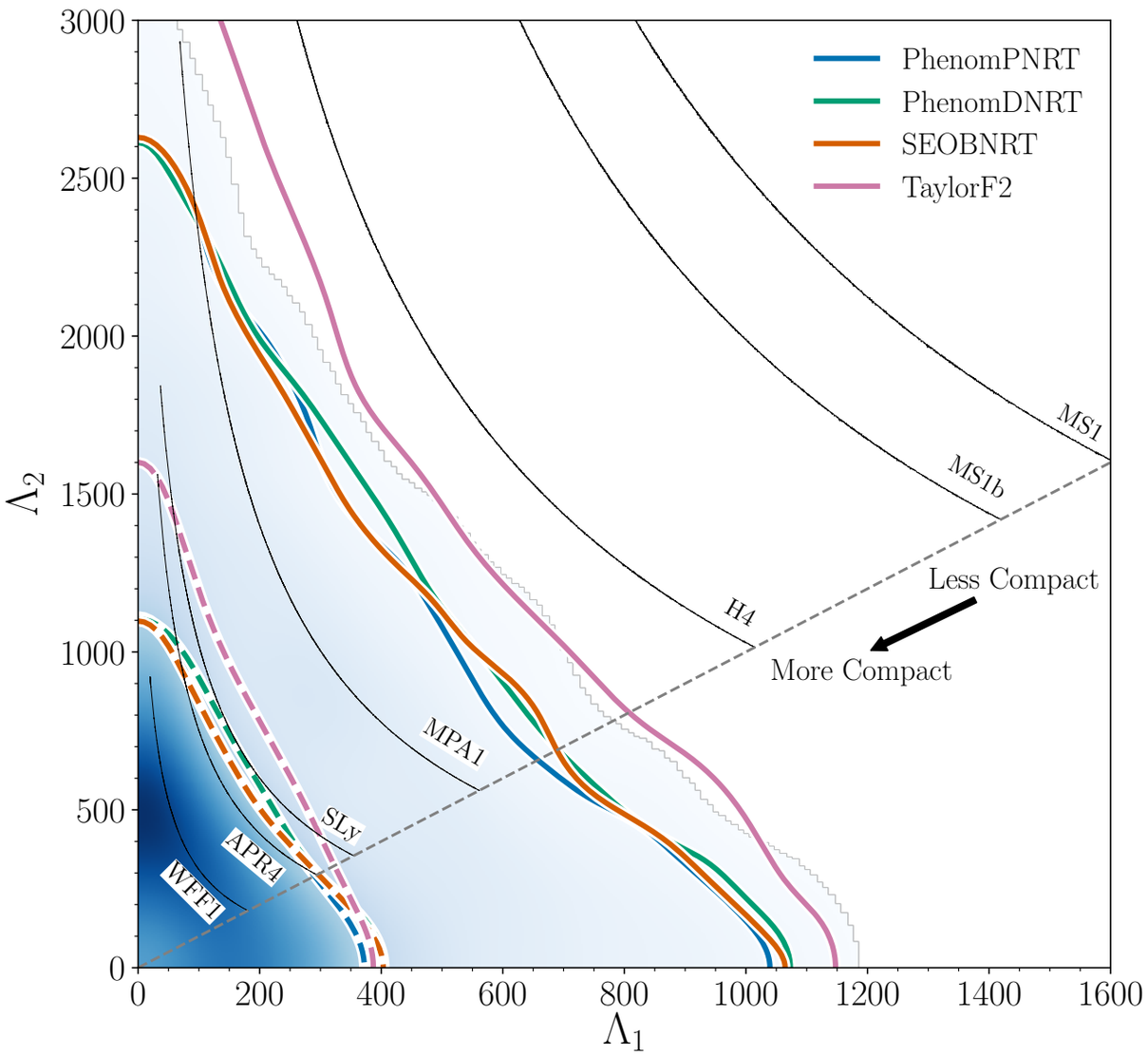

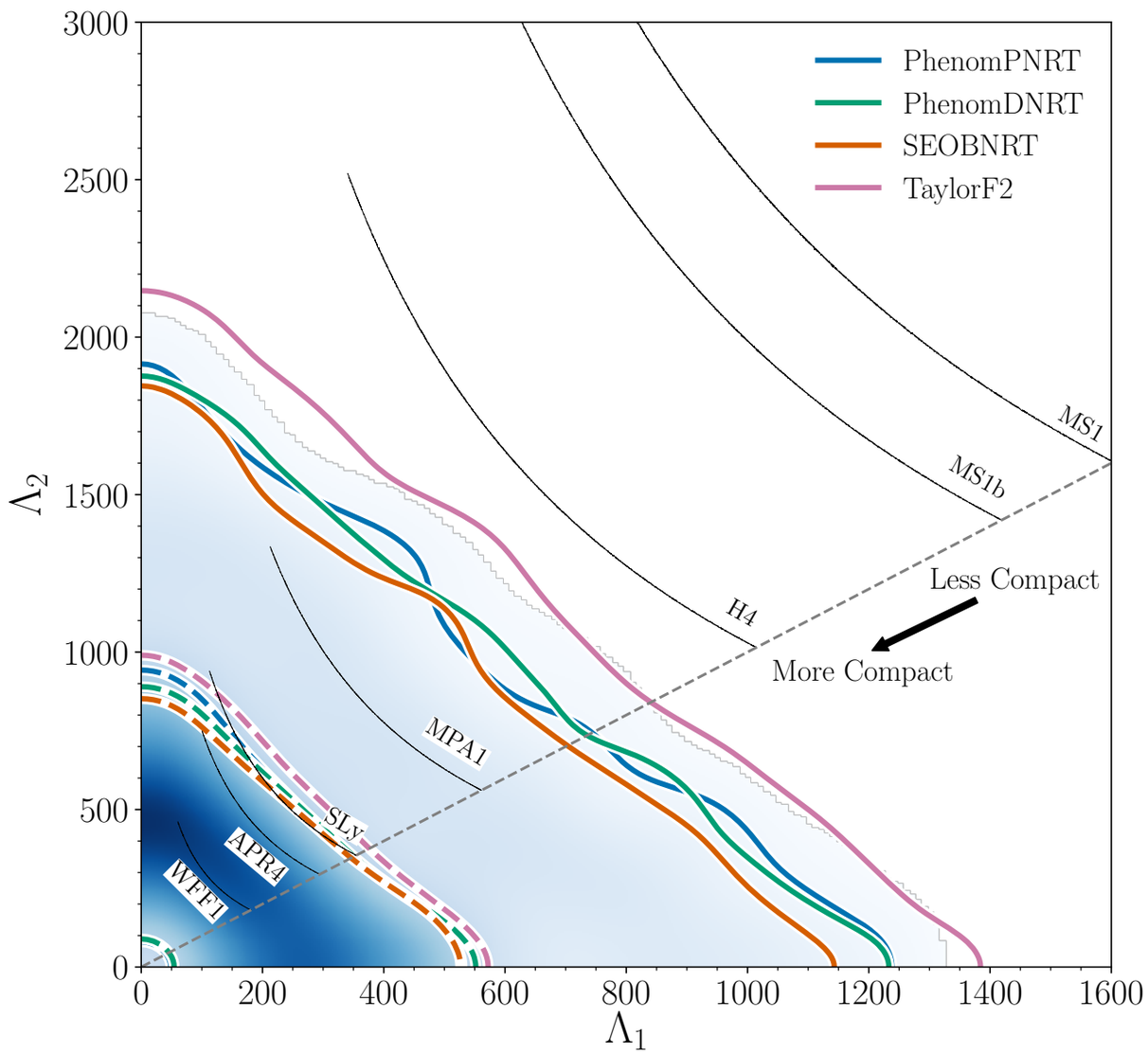

LIGO, Virgo Collaboration: 1805.11579

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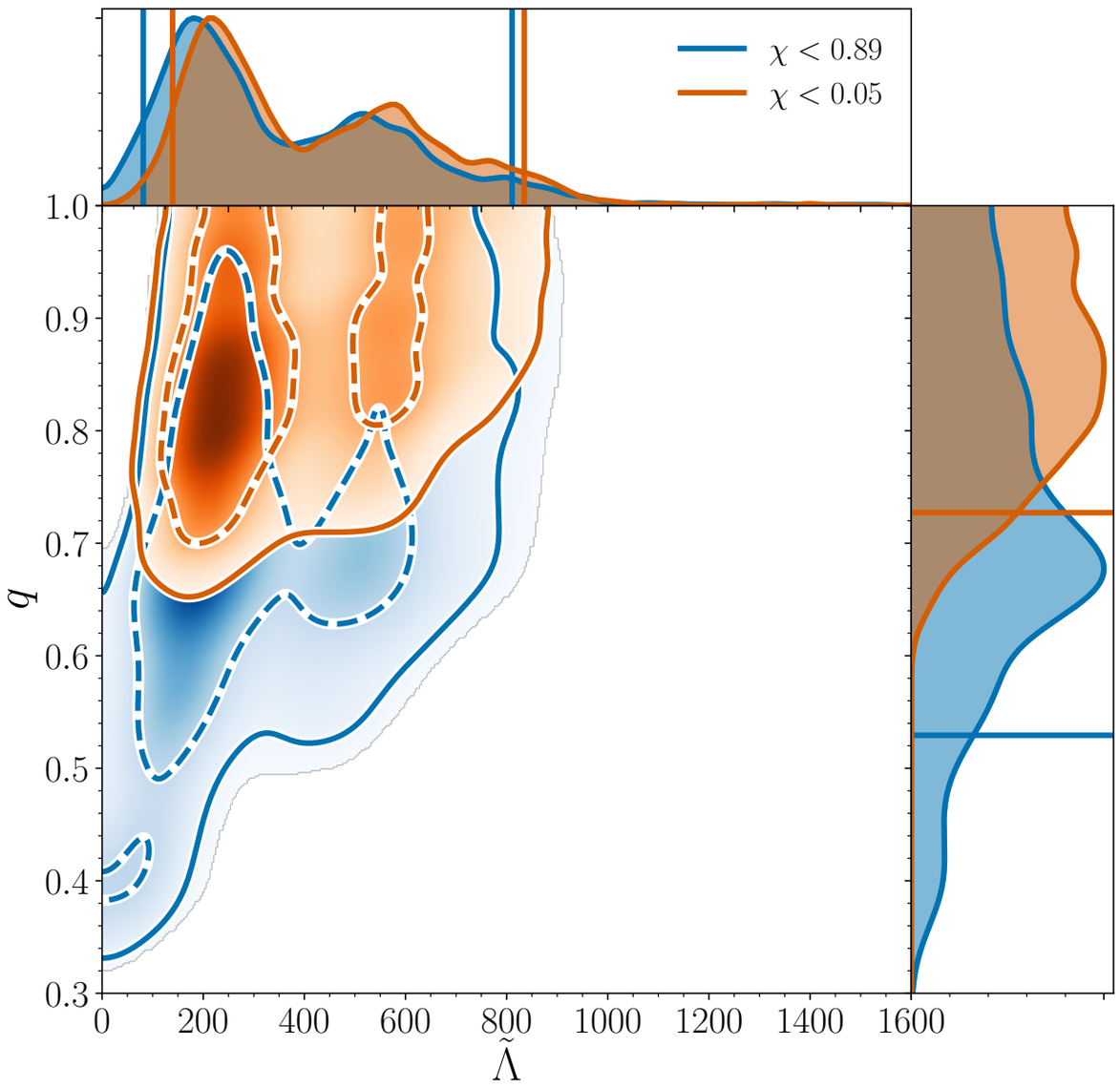

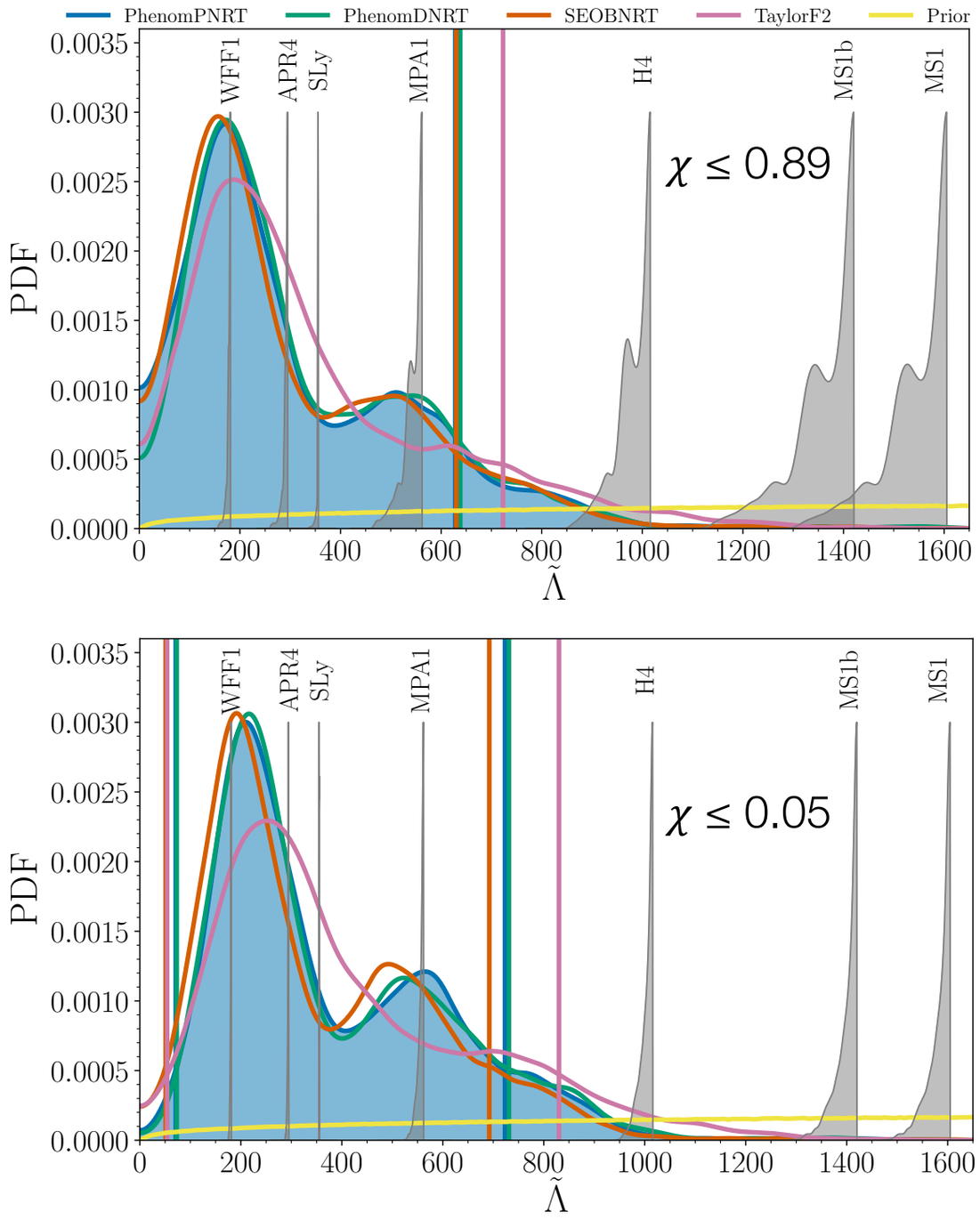

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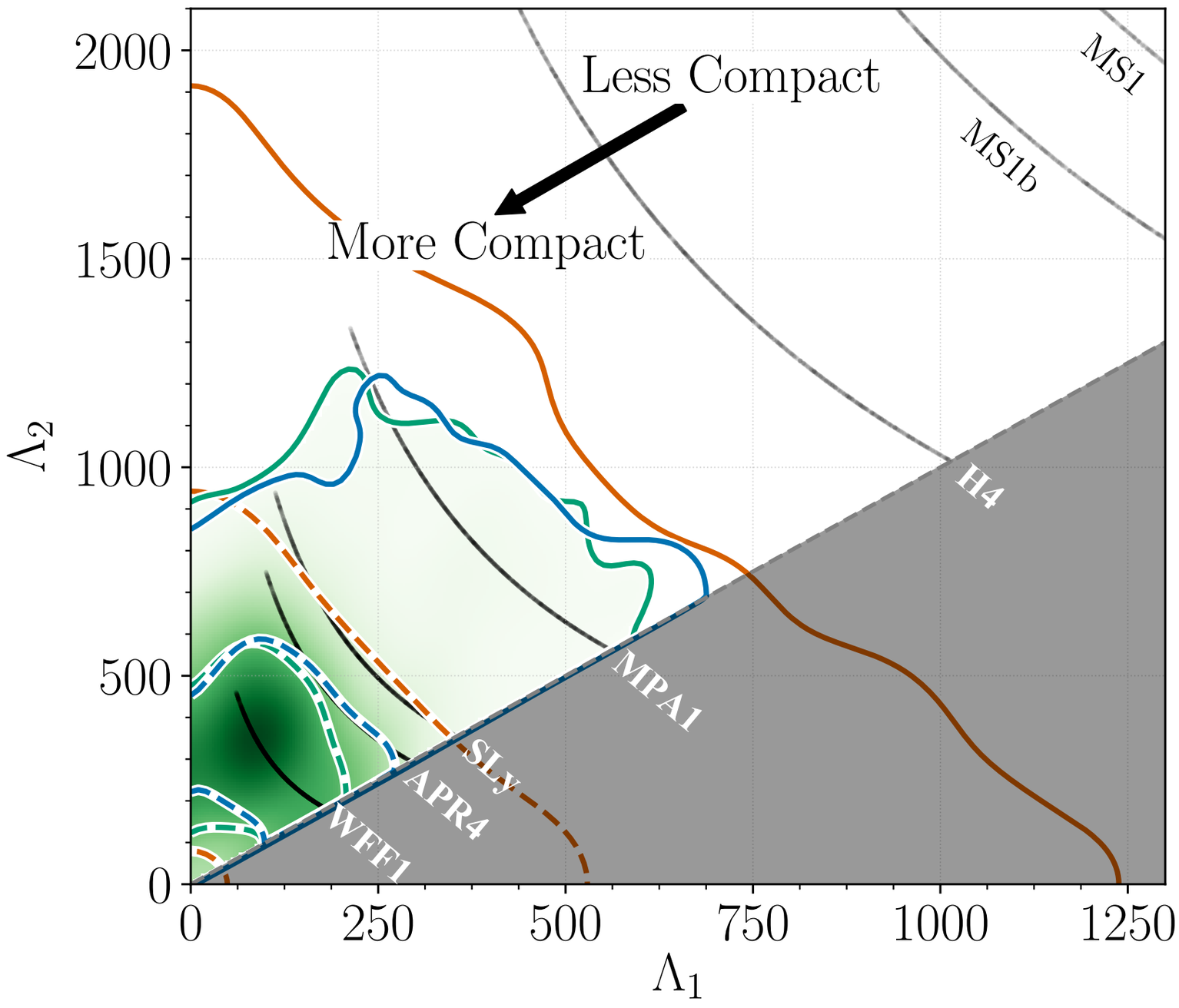
Assuming common equation of state



- No assumptions relating Λ

LIGO, Virgo Collaboration: 1805.11579

- Quasi-universal relations for Λ

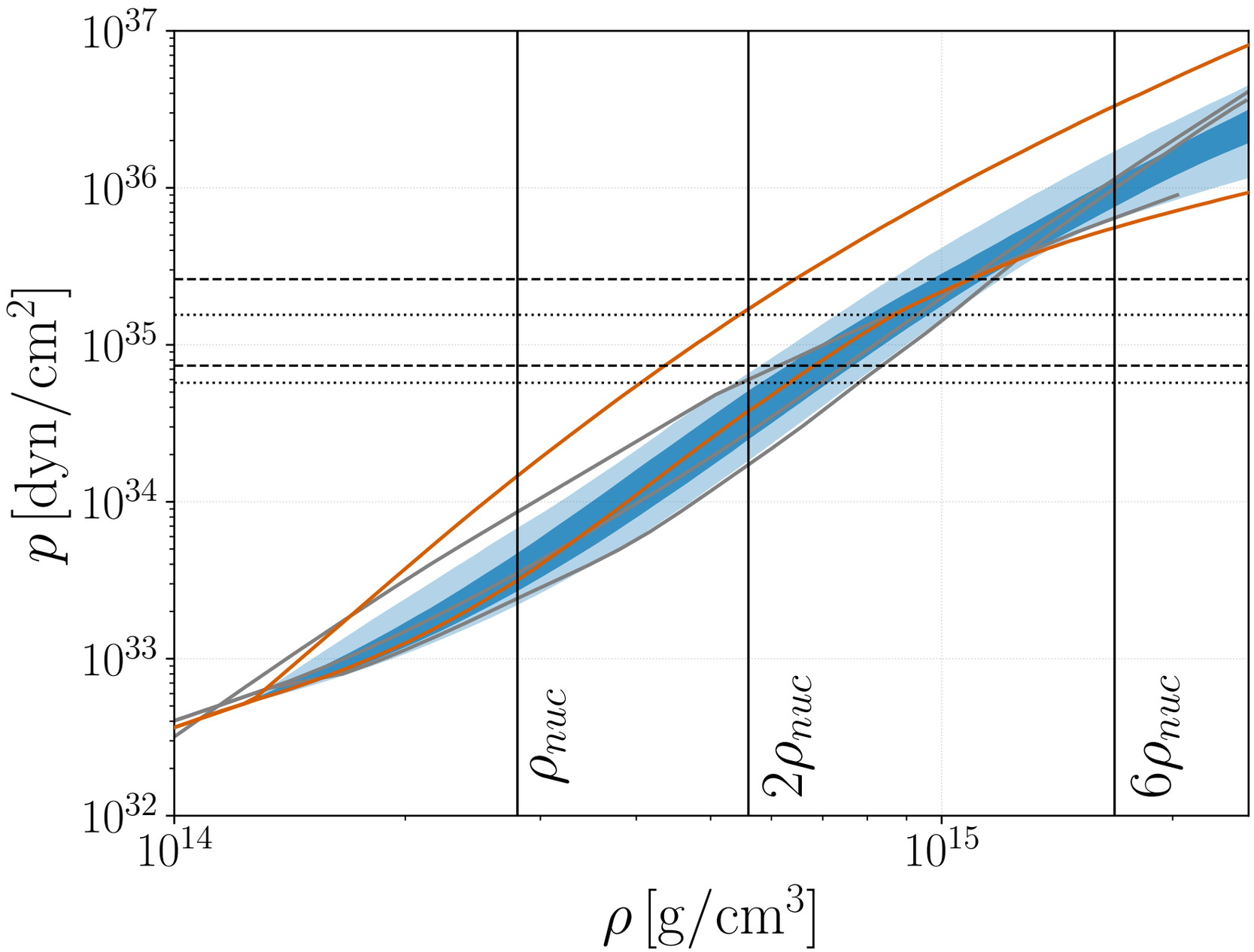
Chatziioannou et al: 1804.03221

- Parameterized EoS (without max-mass constraint)

Carney et al: 1805.11217

LIGO, Virgo Collaborations: 1805.11581

Assuming common equation of state

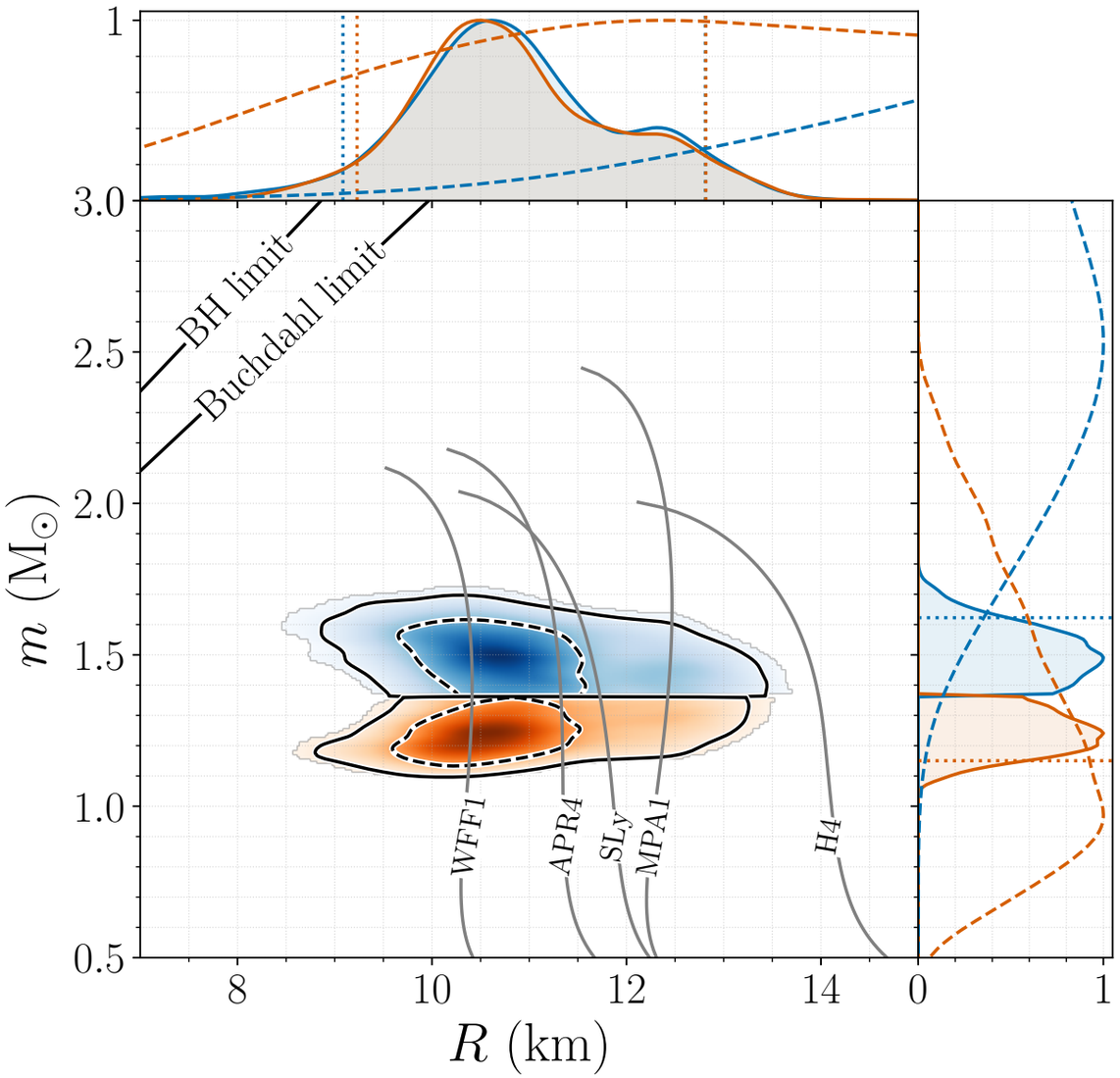


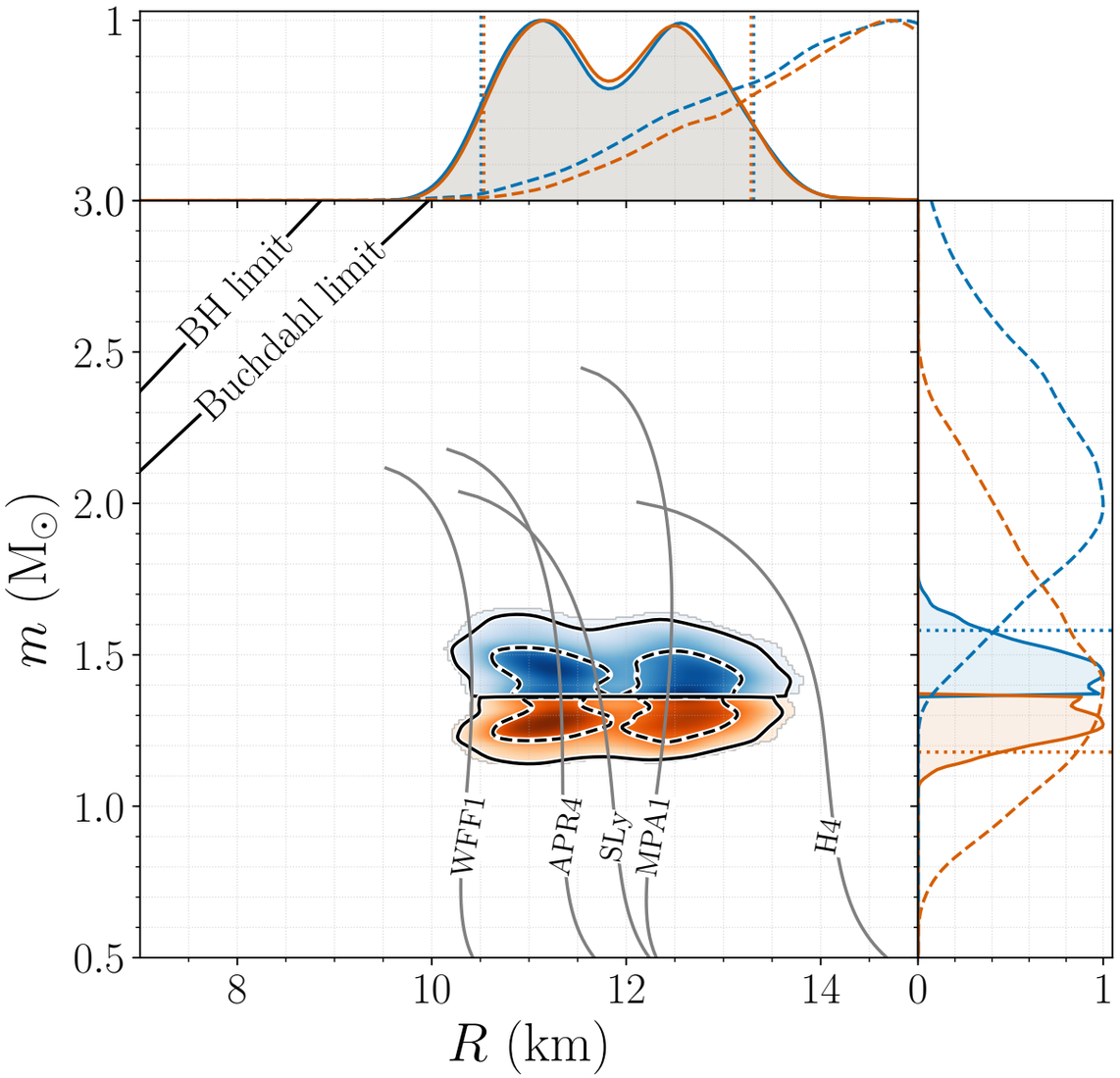
- With max mass constraint
- 90% credible levels for prior
- Candidate EoSs
- 50% and 90% credible levels for posterior

LIGO, Virgo Collaborations: 1805.11581

Common equation of state: mass vs radius

- quasi-universal relations
- Parameterized EoS with max-mass constraint





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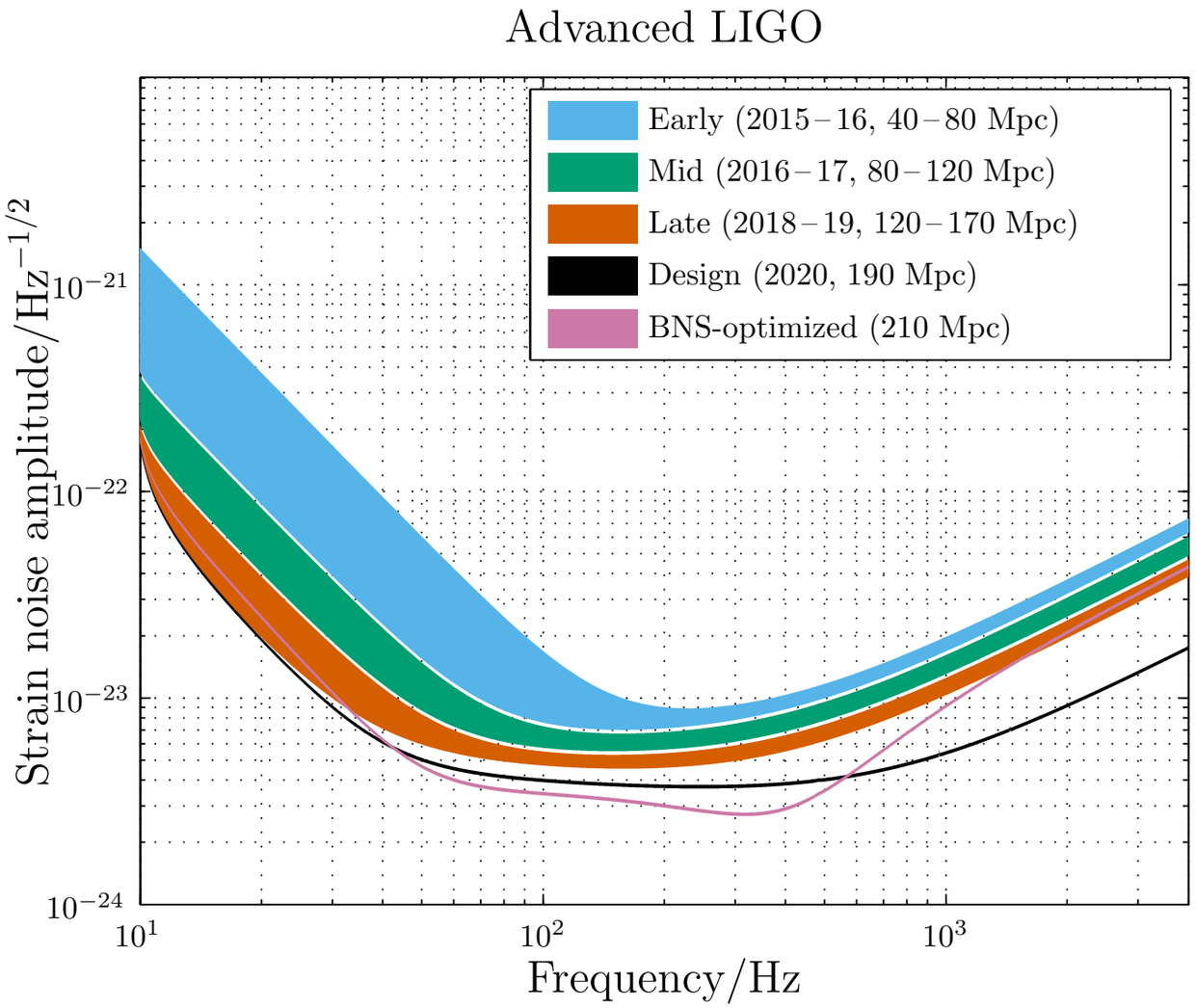
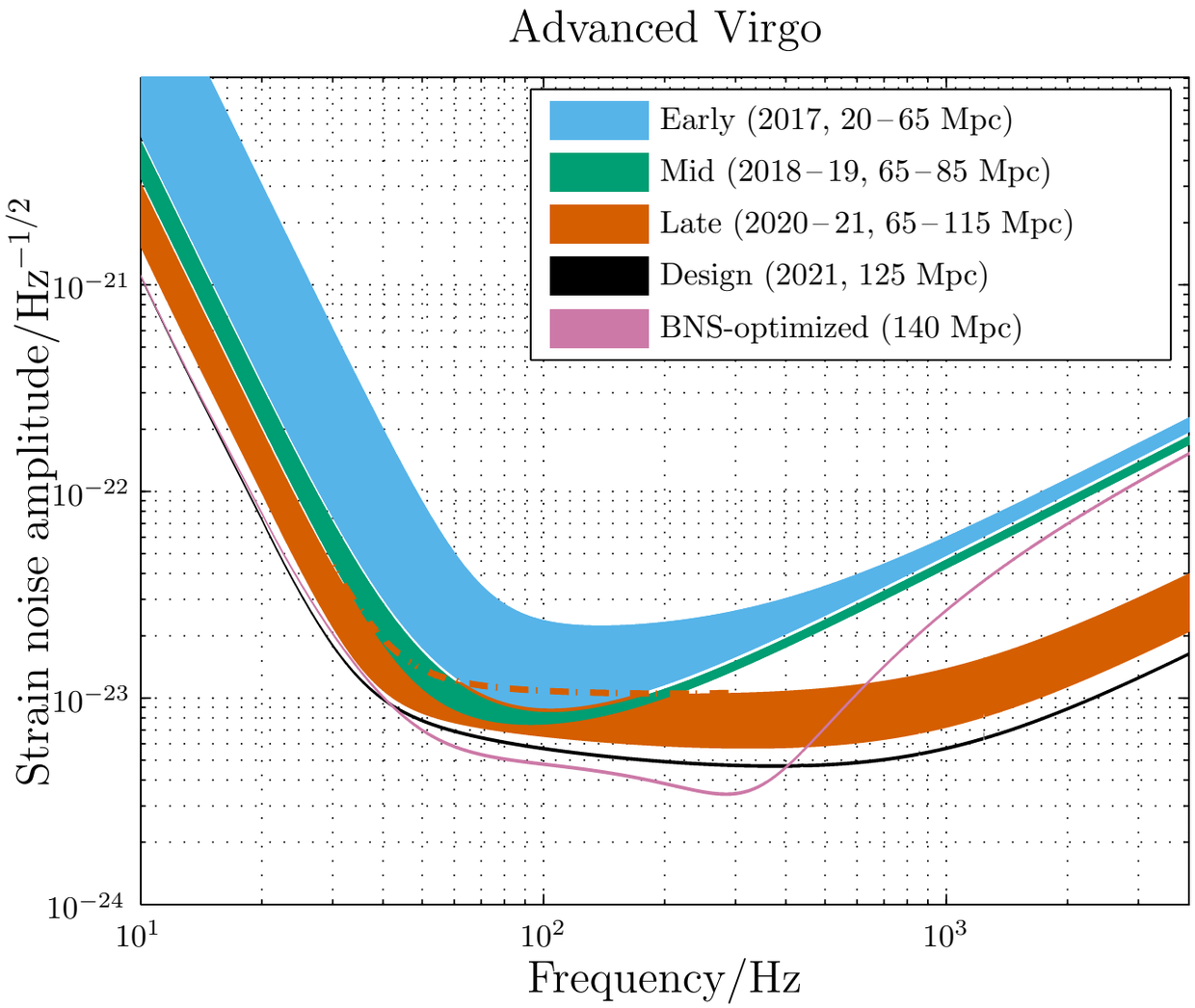
Increased sensitivity

- LIGO was operating "Mid"
- Virgo was operating "Early"

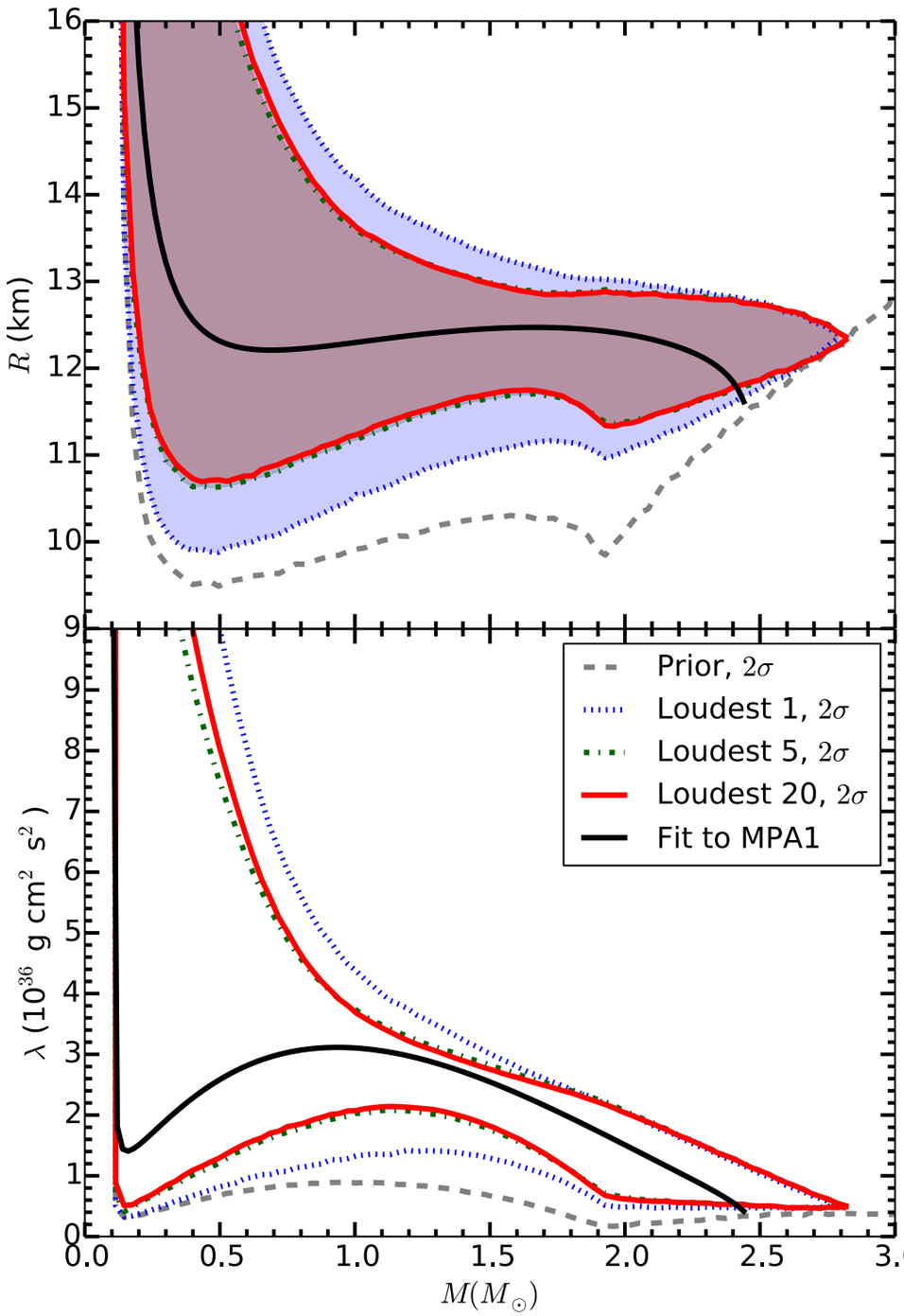




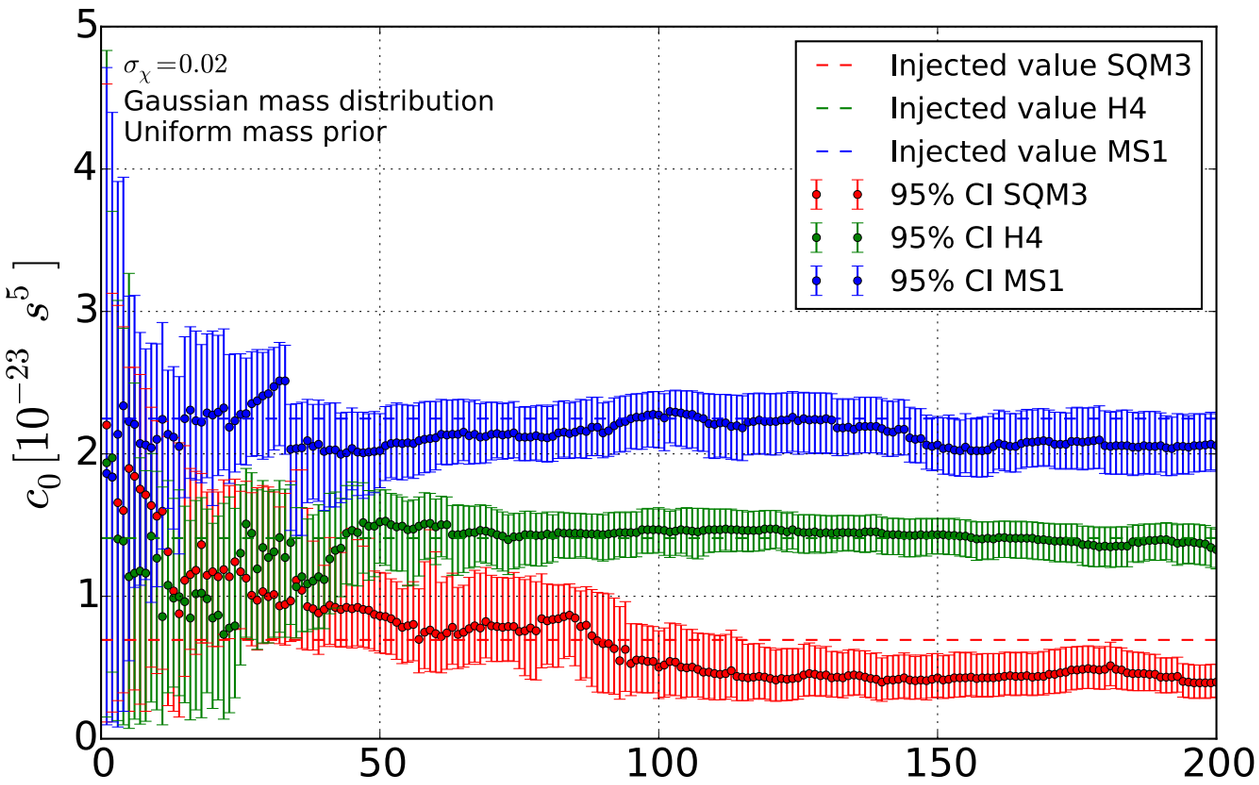
KAGRA, LIGO, Virgo Collaborations: 1304.0670

Joint constraints

Lackey, Wade: 1410.8866



Agathos, et al: 1503.05405



Thank you!

References

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