

Discussion: Constraining Dense QCD with Neutron Stars

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INT program "The QCD Critical Point: Are We There Yet?"
INT University of Washington, 6 November 2025

Based on (2506.10065) with Niko Jokela and Matti Järvinen

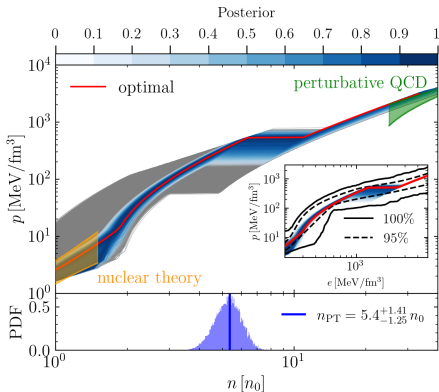
V-QCD hybrid EOS

- ▶ Holographic bottom-up model in Veneziano limit ($N_c, N_f \rightarrow \infty, \frac{N_f}{N_c} = 1$).
Järvinen, Kiritsis 1112.1261 (JHEP)
- ▶ Baryons, quark matter and transition between them from the same action

$$S_{V\text{-QCD}} = S_g + S_f + S_{nm}$$

similar hybrid construction as in: Demircik, CE, Järvinen 2112.12157 (PRX)

- ▶ Bayesian analysis of 10^5 model variants with astro and χ EFT constraints.
For details see: CE, Jokela, Järvinen, 2506.10065



Static neutron star properties

- ▶ Strong first-order transition $\Rightarrow$ no stable quark matter in static stars.
- ▶ Mass-radius estimates:

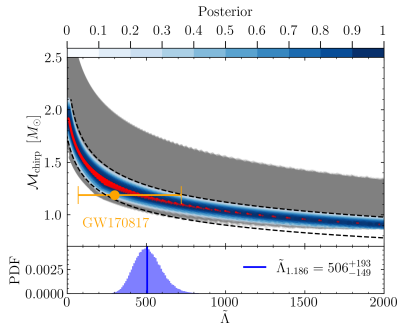
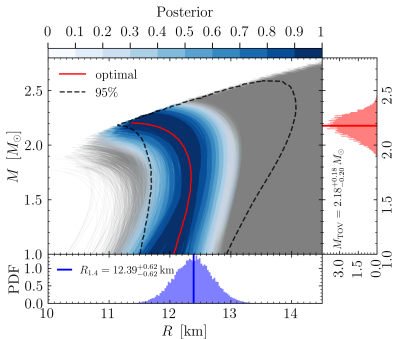
$$R_{1.4} = 12.39^{+0.62}_{-0.62} \text{ km}, \quad M_{\text{TOV}} = 2.18^{+0.18}_{-0.20} M_{\odot}.$$

- ▶ Bounds on binary tidal deformability parameter:

$$\text{V-QCD: } \tilde{\Lambda}_{1.186} = 506^{+193}_{-149} \text{ vs. model-agnostic (no PT): } \tilde{\Lambda}_{1.186} = 384^{+306}_{-158}.$$

via physics informed priors: [Magnol, CE, Rezzolla, Lasky, Goode 2504.21526 \(ApJL\)](#)

- ▶ Smaller error and larger mean value, because specific model with stiff NM.



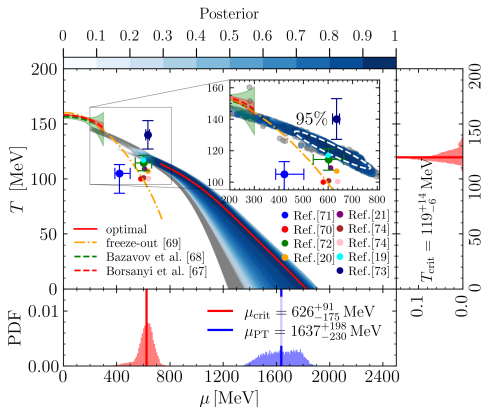
Phase diagram and critical endpoint estimate

- Excluded-volume corrected van der Waals model matched at $T = 0$.
Vovchenko, Motornenko, Alba, Gorenstein, Satarov, Stöcker 1707.09215 (PRC)

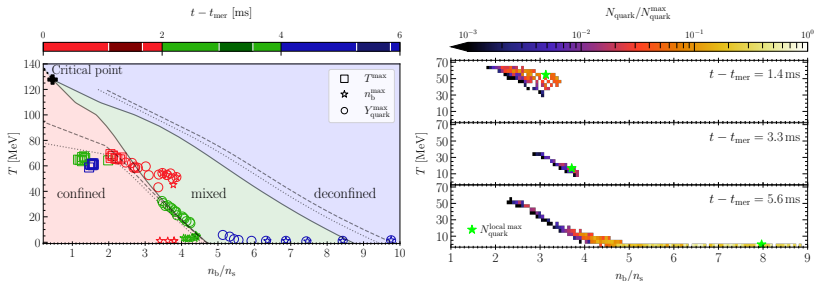
- Critical endpoint where (extrapolated) latent heat vanishes across PT

$$\Delta e(T_{\text{crit}}, \mu_{\text{crit}}) = 0, \quad \Delta e(T, \mu) = e_{\text{QM}}(T, n_{\text{QM}}^*(\mu)) - e_{\text{NM}}(T, n_{\text{NM}}^*(\mu))$$

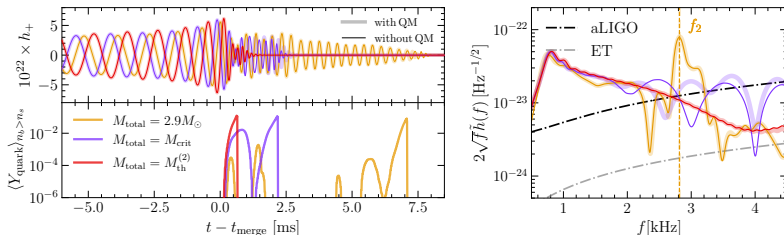
$$(\mu_{\text{crit}}, T_{\text{crit}}) = (626_{-175}^{+91}, 119_{-6}^{+14}) \text{ MeV}.$$



CEP probably not reached in BNS mergers



Tootle, CE, Topolski, Demircik, Järvinen, Rezzolla 2205.05691 (SciPost)



CE, Topolski, Järvinen, Stehr 2402.11013 (PRD)

Modulated Instability

- ▶ Nakamura-Ooguri-Park instability to spatially modulated chiral currents.
Demircik, Jokela, Järvinen, Piispa 2405.02392, Nakamura, Ooguri, Park 1011.4144 (PRL)

- ▶ Fluctuation analysis reveals $\text{Im}(\omega) < 0$ at finite momentum

$$\delta A_L^k(r, t, z) = e^{-i(\omega t - qz)} \delta A_L^{ka}(r) t^a, \quad (k = x, y)$$

- ▶ Instability driven by Chern-Simons term fixed by flavor anomalies of QCD.
- ▶ Ground state can have spatially modulated fields $A_L^{xa}(r, z)$, dual QCD phase has modulated currents: $\langle \bar{\psi} \gamma^x (1 - \gamma_5) t^a \psi \rangle$.

