



Uniwersytet
Wrocławski

POSTER FLASH TALKS



National Science Centre
Project No. 2021/43/P/ST2/03319

HYBRID NUCLEAR MATTER EOS WITH COLOR SUPERCONDUCTING QUARK PHASE: BAYESIAN CONSTRAINTS FROM OBSERVATIONS

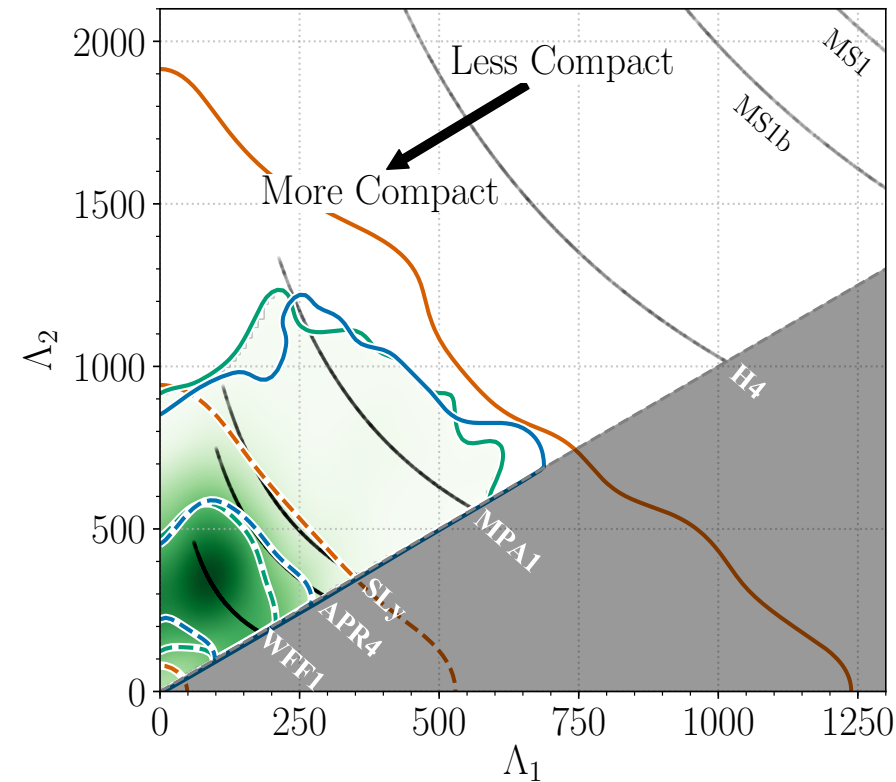
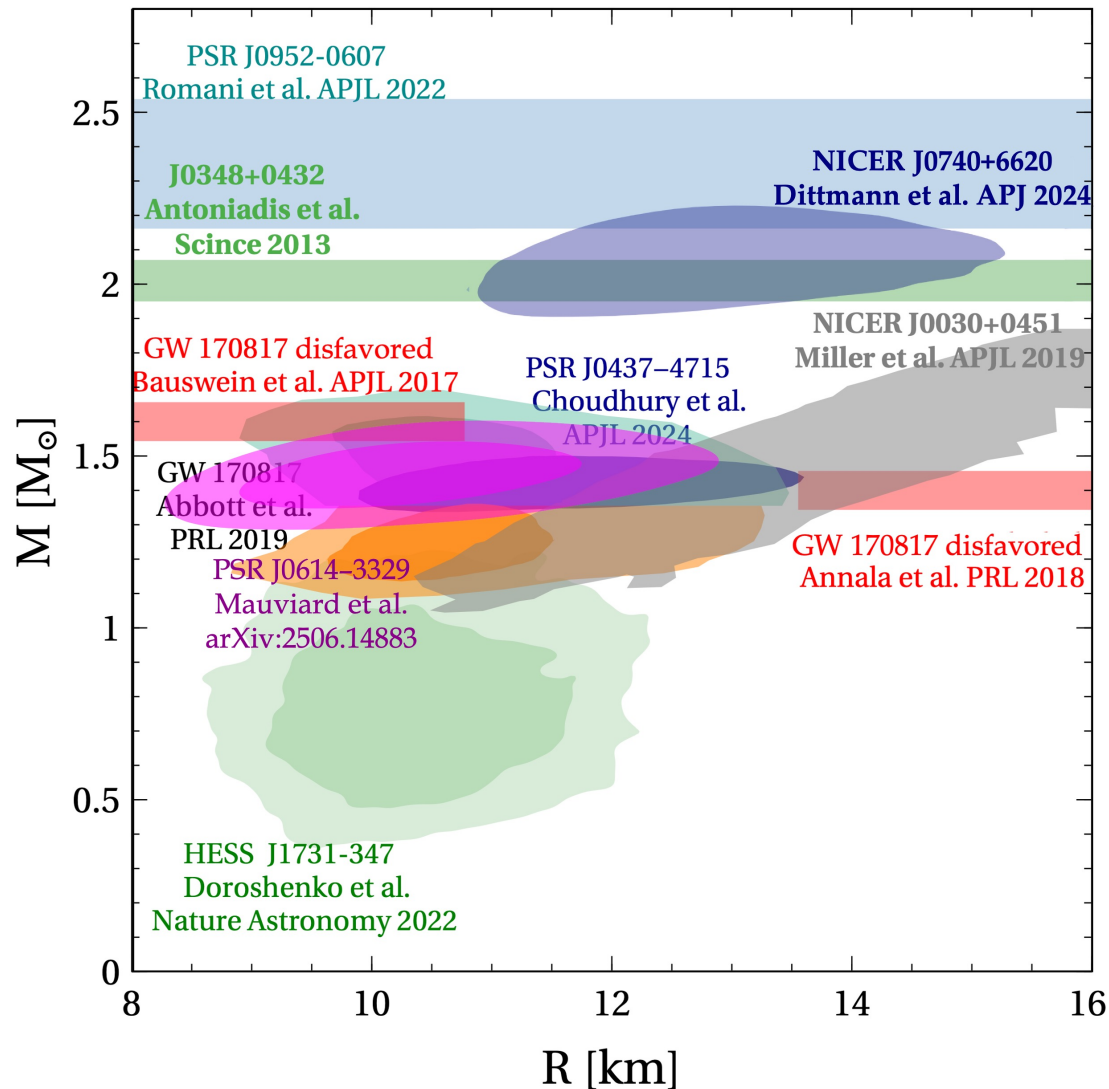
Ayriyan et al. Universe 11(5), 141 (2025)

Alexander Ayriyan

Uni. of Wrocław (Wrocław)

Hungarian-German Wilhelm and Else Heraeus Seminar
"Partiales and Plasmas in Strong Fields"
Görlitz & Dresden, June 22-26, 2025

BAYESIAN INFERENCE FROM MULTI-MESSENGER ASTRONOMY



Bayes' theorem:

$$p(H_1 | D, I) = \frac{p(D | H_1, I) p(H_1 | I)}{p(D | I)}$$

Posterior

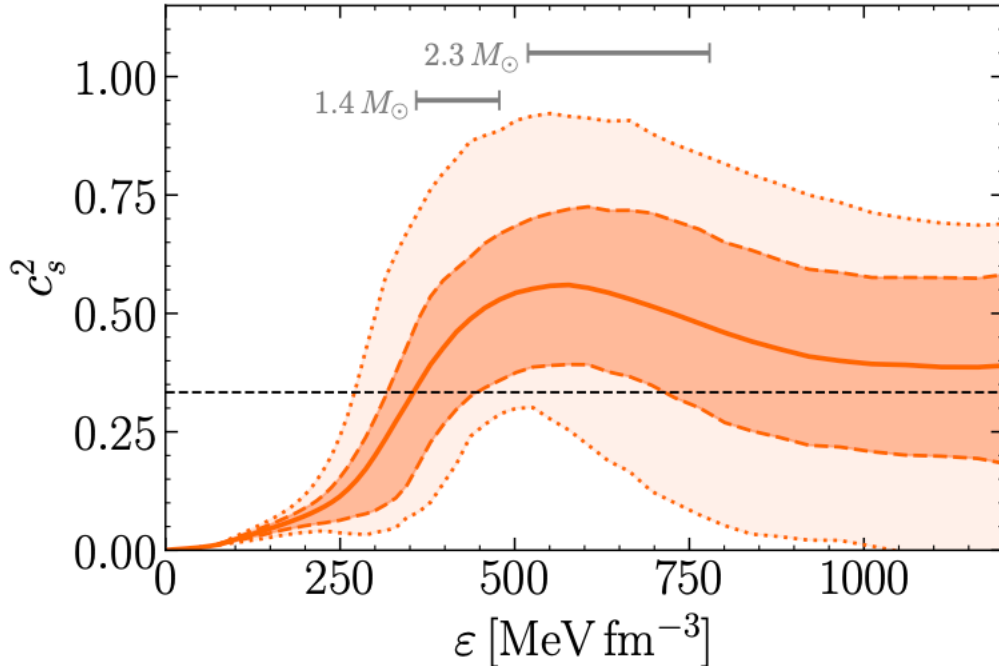
Likelihood

Prior

Evidence

MOTIVATION

Brandes, Weise & Kaiser. PRD108, 094014 (2023)



$$c_s^2(\varepsilon, \theta) = \frac{(\varepsilon_{i+1} - \varepsilon)c_{s,i}^2 + (\varepsilon - \varepsilon_i)c_{s,i+1}^2}{\varepsilon_{i+1} - \varepsilon_i}$$

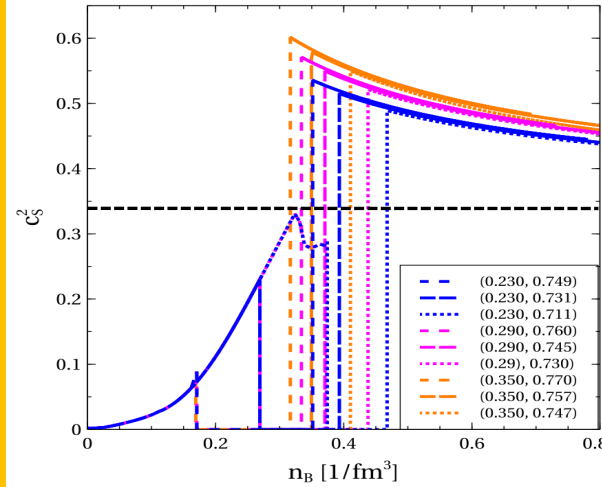
Annala et al. Nature Phys. 16, 907 (2020)

QM: $c_s^2 \leq 1/3$

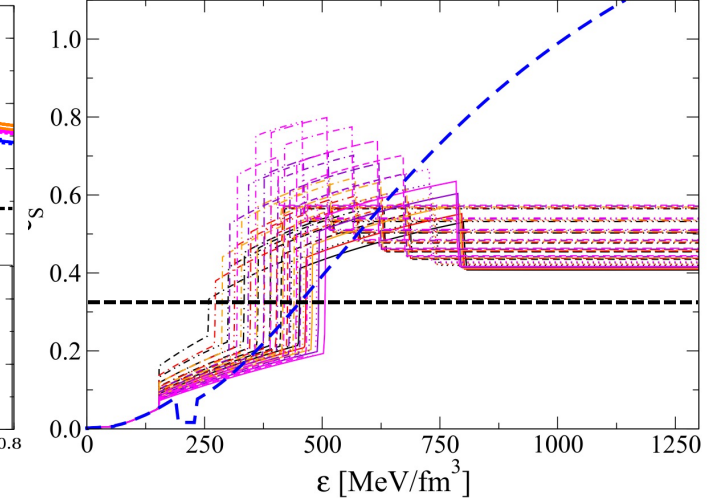
HM: $\max(c_s^2) > 0.5$

Color Superconducting Matter

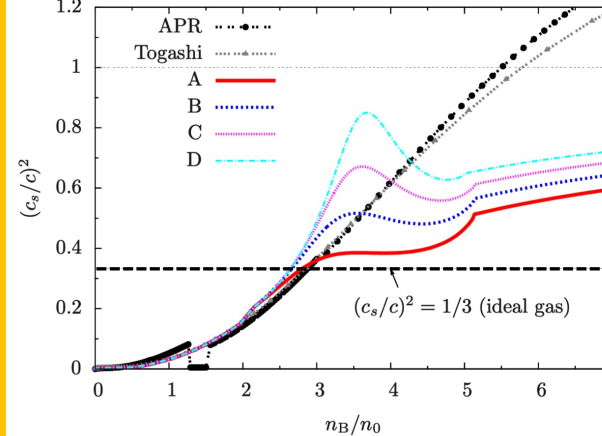
Gärtlein et al. PRD108, 114028 (2023)



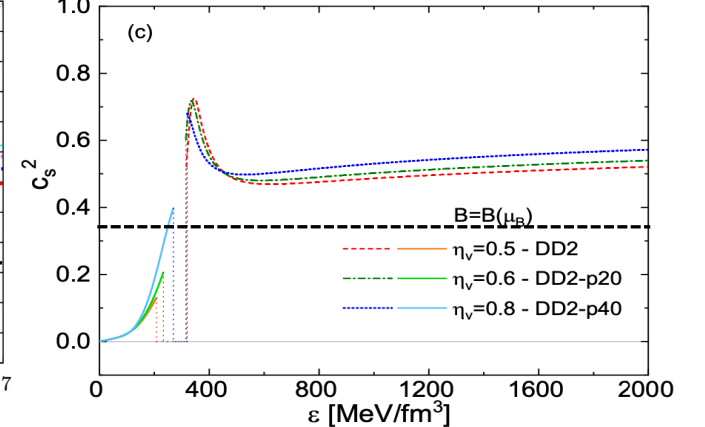
Ayriyan et al. EPJA57, 318 (2021)



Baym et al., ApJ885, 42 (2019)



Contrera et al. PRC105, 045808 (2022)



HYBRID NS EoS: DD2 + NLNJL

Two-flavor color-superconducting quark matter with 3DFF nonlocal chiral quark model defined by an effective Euclidean action functional that in the case of two light flavors is given by

$$S_E = \int d^4x \left\{ \bar{\psi}(x) (-i\not{\partial} + \hat{m} - \gamma_0 \hat{\mu}) \psi(x) - \frac{G_S}{2} [j_S^f(x) j_S^f(x) + \eta_D [j_D^a(x)]^\dagger j_D^a(x) - \eta_V j_V^\mu(x) j_V^\mu(x)] \right\}.$$

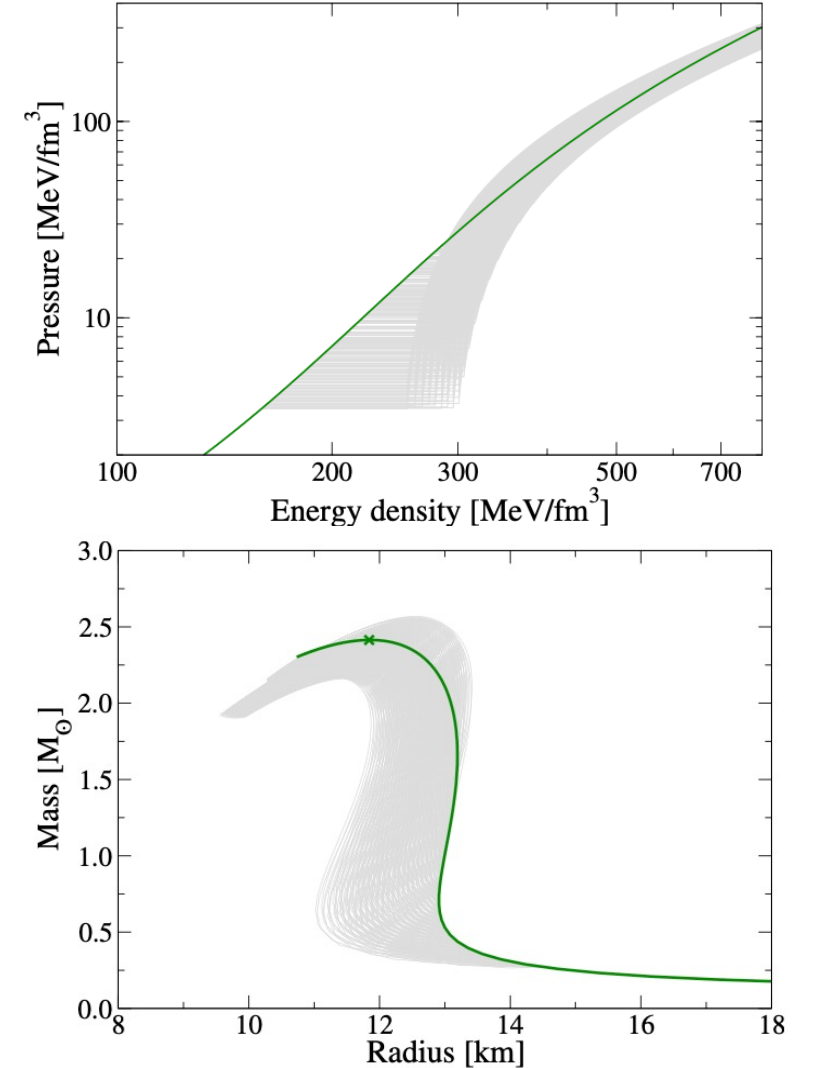
$$j_S^f(x) = \int d^4z g_S(z) \bar{\psi}(x + \frac{z}{2}) \Gamma_f \psi(x - \frac{z}{2}),$$

$$j_D^a(x) = \int d^4z g_D(z) \bar{\psi}_C(x + \frac{z}{2}) i\gamma_5 \tau_2 \lambda_a \psi(x - \frac{z}{2}),$$

$$j_V^\mu(x) = \int d^4z g_V(z) \bar{\psi}(x + \frac{z}{2}) i\gamma^\mu \psi(x - \frac{z}{2}),$$

For the nonlocality a Gaussian ansatz is employed

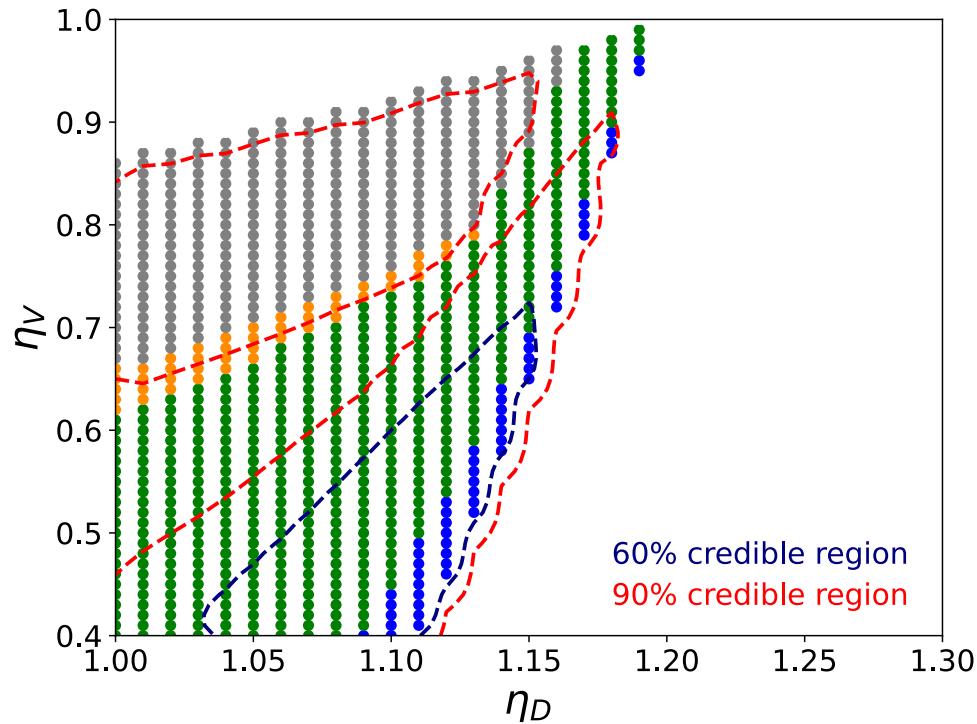
$$g_i(\vec{p}) = \exp(-\vec{p}^2 / \Lambda_i^2), \quad i = S, D,$$



SUMMARY OF RESULTS

The Bayesian posterior favors:

- Low-to-moderate $\eta_V \lesssim 0.6 \rightarrow$ **moderate stiffness**
- High $\eta_D (\gtrsim 1.1) \rightarrow$ **early deconfinement** at $M \approx 0.5\text{--}0.7 M_\odot$
- Hybrid stars are favored to have: maximum masses up to $\approx 2.2 M_\odot$ and radii $R \approx 12$ km for $M \approx 1.2\text{--}2.0 M_\odot$



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- **Large η_V (stiff EOS) are disfavored** due to failure to match tidal deformability constraints.
- **Twin star configurations are allowed** in a narrow region.
- **New NICER M-R favors** even less onset and low mass twins

