Quark Matter Phase Boundary Evolution in Neutron Star Mergers

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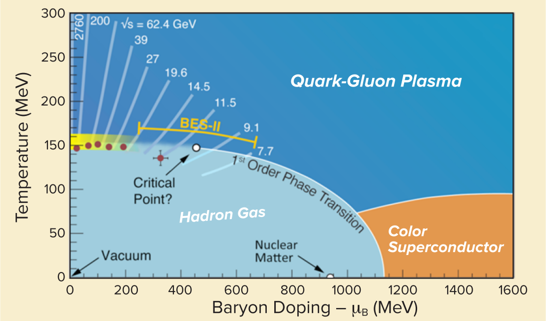


Two very different regimes:

- **High T, low μ_B**
  Quark-gluon plasma — explored at RHIC, LHC
  → the compelling frontier ∼20 years ago
- **Low T, high μ_B (∼1 GeV)**
  Dense cores of neutron stars
  → few experimental handles — until now

Open question: Is there a 1^{st}-order phase transition between nuclear matter and quark matter at low T?

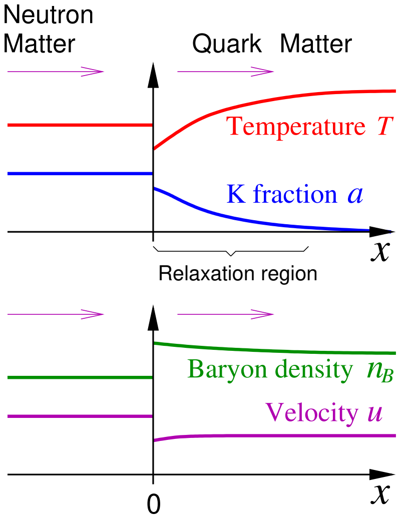
Strategy: assume yes $\Rightarrow$ what is the **GW signature** of such a transition in a merger?

$\Rightarrow$ Most important dynamical quantity: the **phase boundary velocity**

Setup: planar steady front propagating at velocity u_N

- **Upstream** ($x \to -\infty$): nuclear matter (NM)
  density n_B^N, temperature T_N, chemical potential μ_B^N
- **Downstream** ($x \to +\infty$): strange quark matter (QM)
  with "K" density $n_K = \frac{1}{2}(n_d - n_s)$, equilibrated when $\mu_K = 0$
- Key parameters: bag constant $B^{1/4}$, strong coupling α_s

EOS: RMF (QMC-RMF3) [1, 2] for NM | bag model [3] for QM



Steady 1-D front: conservation laws must hold across the interface.

Fluxes conserved : $\partial_\mu T^{\mu\nu} = 0\,, \quad \partial_\mu(n_B U^\mu) = 0$

$$\begin{aligned} j_B &= n_B\,u = \text{const} \quad \text{(baryon current)} \\ \Pi &= h\,u^2 + P = \text{const} \quad \text{(momentum flux)} \\ \mathcal{E} &= h\,u\,\gamma = \text{const} \quad \text{(energy flux)} \end{aligned}$$

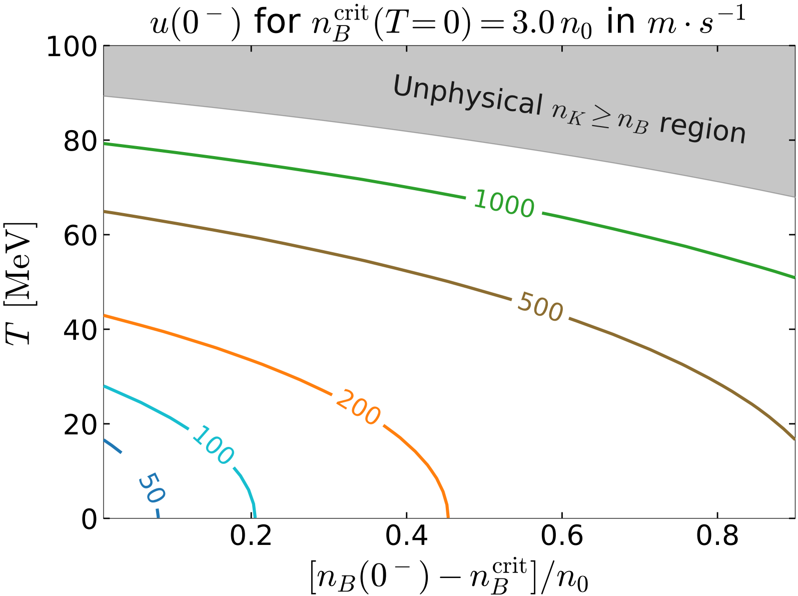
K production ODE (strangeness-changing weak interaction [6]):

$$j_K \equiv n_K\,u - D_K \frac{dn_K}{dx}, \qquad \frac{dj_K}{dx} = \Gamma_K(\mu_u,\,\mu_K,\,T)$$

Boundary conditions:

- $x \to -\infty$: NM in β-equilibrium, $n_K = 0$
- $x \to +\infty$: QM with $\mu_K = \mu_d - \mu_s = 0$

Front Velocity in Parameter Space



Summary

- ✓ Solved for **steady planar NM→QM conversion fronts** from first principles
- ✓ **Relativistic hydro conservation** (baryon, momentum, energy) coupled with **weak-interaction K production** in a unified BVP framework
- ✓ Front velocity mapped as a function of $(T, n_B, B^{1/4})$ — bounded by hydro closure and weak timescale τ_{weak}
- ☐ Collaborate with merger simulation community to get f_{peak} and maximum strain etc.

Thank you!

Work in collaboration with:

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