Damping of density oscillations in unpaired quark matter

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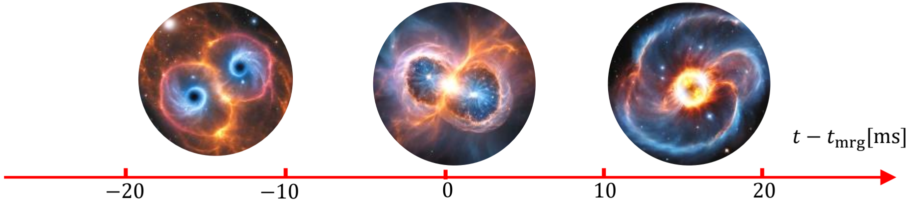
1. Introduction

We study the damping of density oscillations in the unpaired quark matter phase that might occur in compact stars. To this end, we compute the bulk viscosity ζ and the damping time τ and analyze their dependence on the density n_B, temperature T and value of the strange quark mass m_s[1].

Dissipation from bulk viscosity may be relevant for mergers [2]



Neutron star mergers

Neutron star dynamics studied by means of Relativistic Hydrodynamics:

Fluid elements locally neutral, so that the particle number densities n hold

$$n_e + \frac{1}{3}n_s + \frac{1}{3}n_d = \frac{2}{3}n_u$$

Weak processes are relevant because they occur at the timescale of mergers (from ms to s)

1. $\boldsymbol{u + s \leftrightarrow u + d}$
2. $u + e^- \longrightarrow d + \nu_e$
3. $d \longrightarrow u + e^- + \bar{\nu}_e$
4. $u + e^- \longrightarrow s + \nu_e$
5. $s \longrightarrow u + e^- + \bar{\nu}_e$

At low temperatures neutrinos escape of the star

How bulk viscosity is generated in neutron stars?

Density oscillations after the merger drives the system **out of equilibrium**

$$\delta n_B = \Delta n_B e^{i\omega t}$$

Deviations of chemical equilibrium

$$\mu_1 = \mu_s - \mu_d, \quad \mu_2 = \mu_s - \mu_u - \mu_e, \mu_3 = \mu_2 - \mu_1$$

Detailed balance breaking

Source and sink terms change the particle number densities from their equilibrium values

$$\partial_\mu(n_s u^\mu) = -\boldsymbol{\lambda_1}\mu_1 - \boldsymbol{\lambda_2}\mu_2$$
$$\partial_\mu(n_e u^\mu) = \boldsymbol{\lambda_2}\mu_2 - \boldsymbol{\lambda_3}\mu_3$$

Nonequilibrium pressure Π

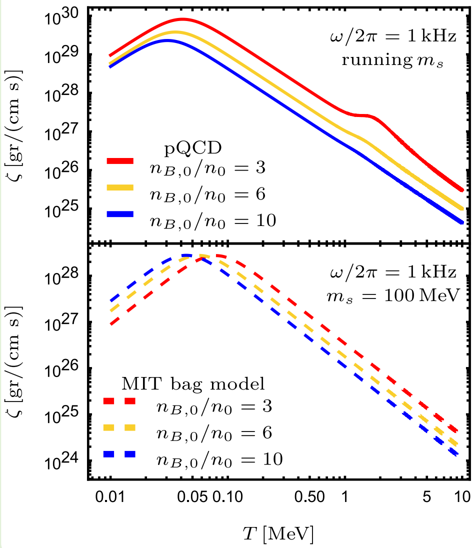
2. Results

Bulk viscosity in strange quark matter

$$\zeta \equiv \mathrm{Re}[\Pi]/\theta = \frac{\kappa_1 + \kappa_2\omega^2}{\kappa_3 + \kappa_4\omega^2 + \omega^4}$$

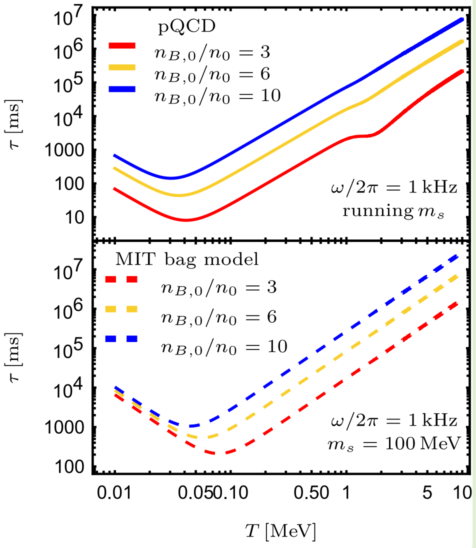
$$\kappa_j\left(\mu_{i,0}, (\partial\mu_i/\partial n_i)_0, n_{B,0}, m_s, \lambda_1(T), \lambda_2(T), \lambda_3(T)\right)$$

with $i = u, d, s, e$ and zero denotes chemical equilibrium



Damping time by bulk viscosity of a harmonic density oscillation

$$\tau = \frac{n_{B,0}^2}{\omega^2\zeta}\left(\frac{\partial^2\varepsilon}{\partial n_B^2}\right)_0$$



3. Conclusions

The bulk viscosity and the damping time in quark matter strongly depend on m_s. Bulk-viscous damping might be relevant in the post-merger phase if deconfined matter is achieved in the process.

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References

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[2] M. G. Alford, L. Bovard, M. Hanauske, L. Rezzolla, and K. Schwenzer Phys. Rev. Lett. **120**, 041101

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