

Equation of State Effects on Neutron Star Mergers

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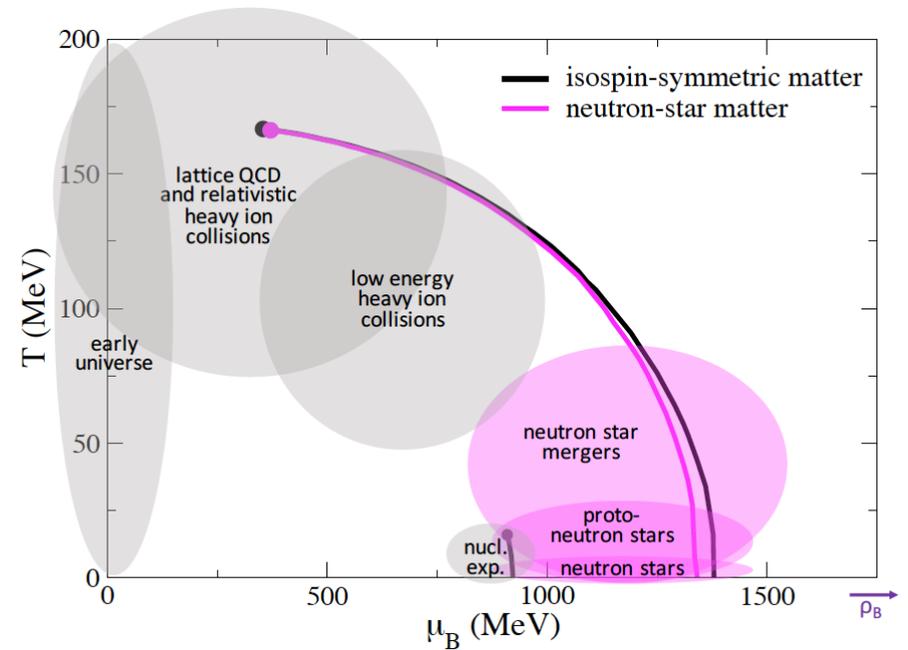


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★ EoS Ingredients for NS Mergers: (in addition to nuclear and astrophysical constraints)

- high density description
- quantum relativistic description
- finite/high temperature description
- provides particle population
- include hyperons and quarks
- include chiral symmetry restoration
- in agreement with lattice QCD
- in agreement with heavy-ion collision results
- in agreement with perturbative QCD results



★ CMF (Chiral Mean Field) Model:

- includes baryons (+ leptons) and quarks
- fitted to reproduce nuclear, lattice QCD, heavy ion and astrophysical constraints
- baryon and quark effective masses

$$M_B^* = g_{B\sigma}\sigma + g_{B\delta}\tau_3\delta + g_{B\zeta}\zeta + M_{0B} + g_{B\Phi}\Phi^2$$
$$M_q^* = g_{q\sigma}\sigma + g_{q\delta}\tau_3\delta + g_{q\zeta}\zeta + M_{0q} + g_{q\Phi}(1 - \Phi)$$

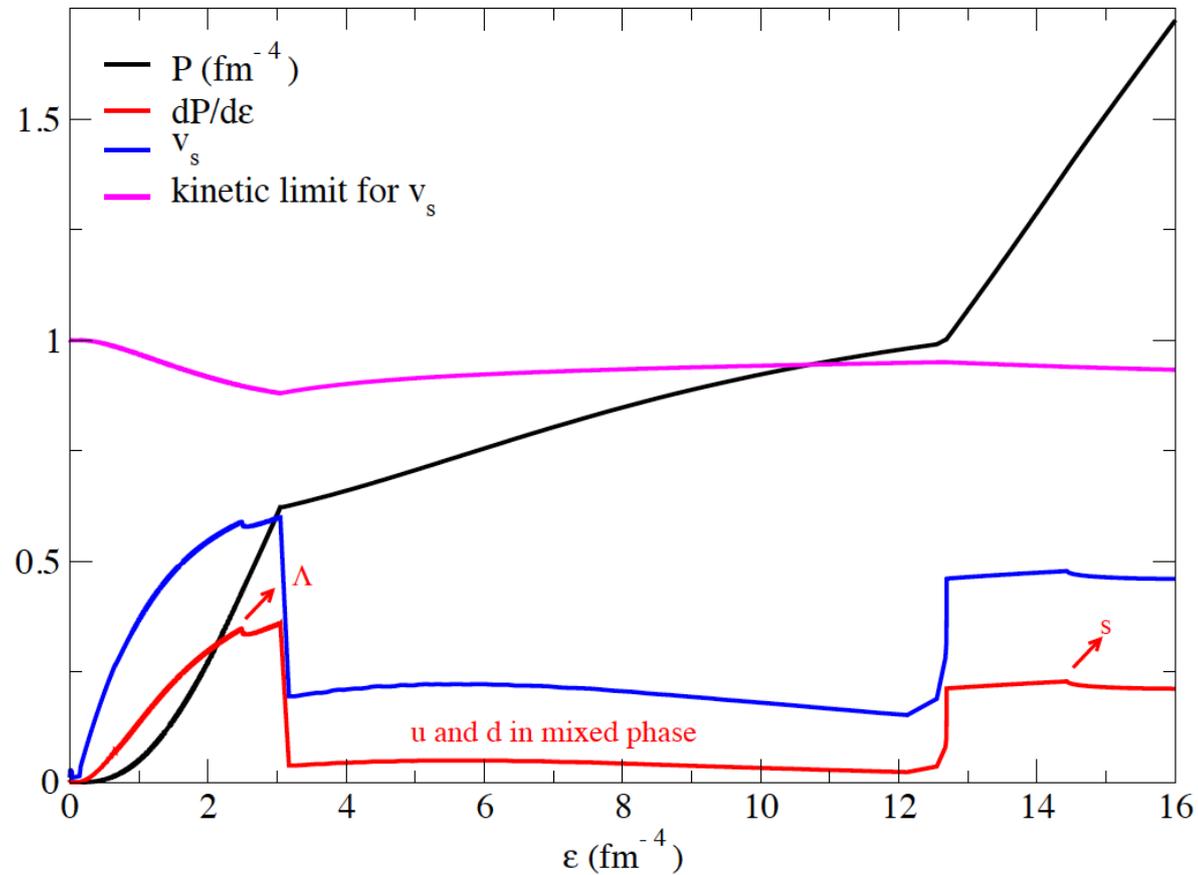
- 1st order phase transitions or crossovers

- potential for deconfinement order parameter

$$U = (a_0 T^4 + a_1 \mu_B^4 + a_2 T^2 \mu_B^2) \Phi^2 + a_3 T_o^4 \ln(1 - 6\Phi^2 + 8\Phi^3 - 3\Phi^4)$$

★ Speed of sound at T=0 for neutron-star matter:

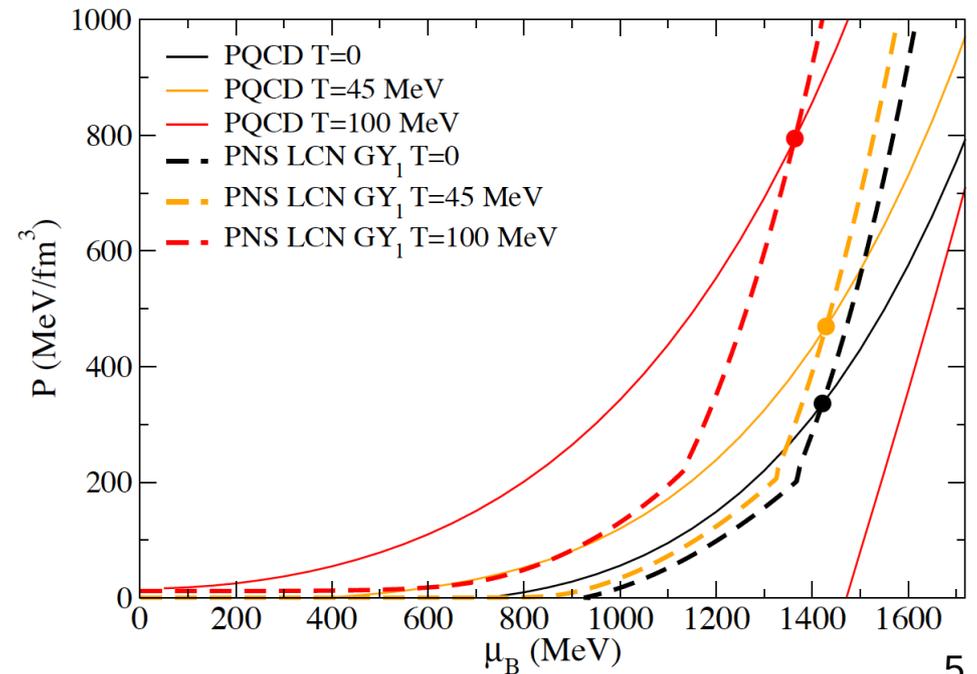
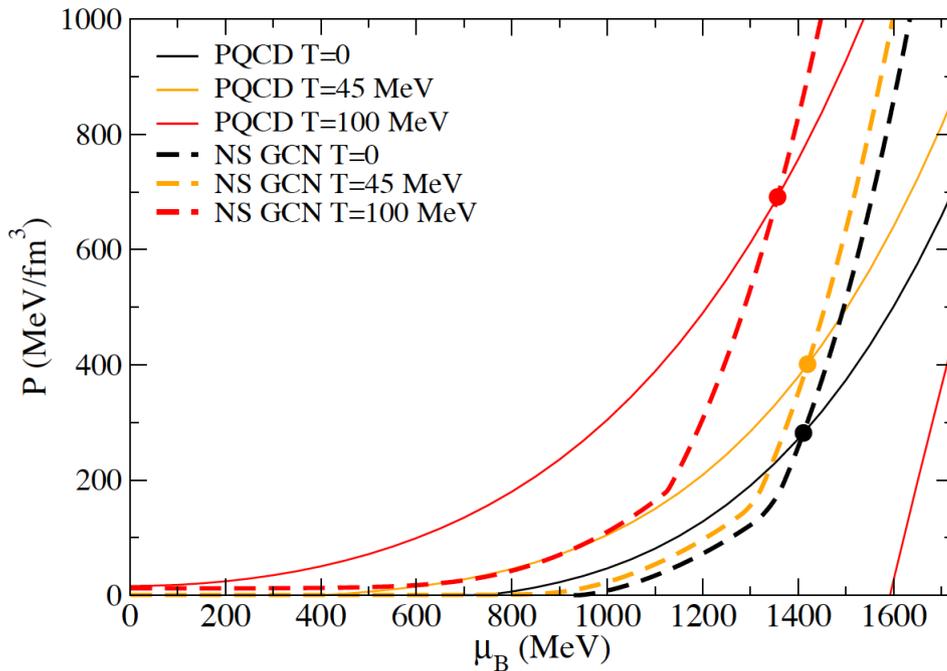
- $dP/d\varepsilon \sim 1/3$ at very large energies



★ Perturbative QCD at finite temperature:

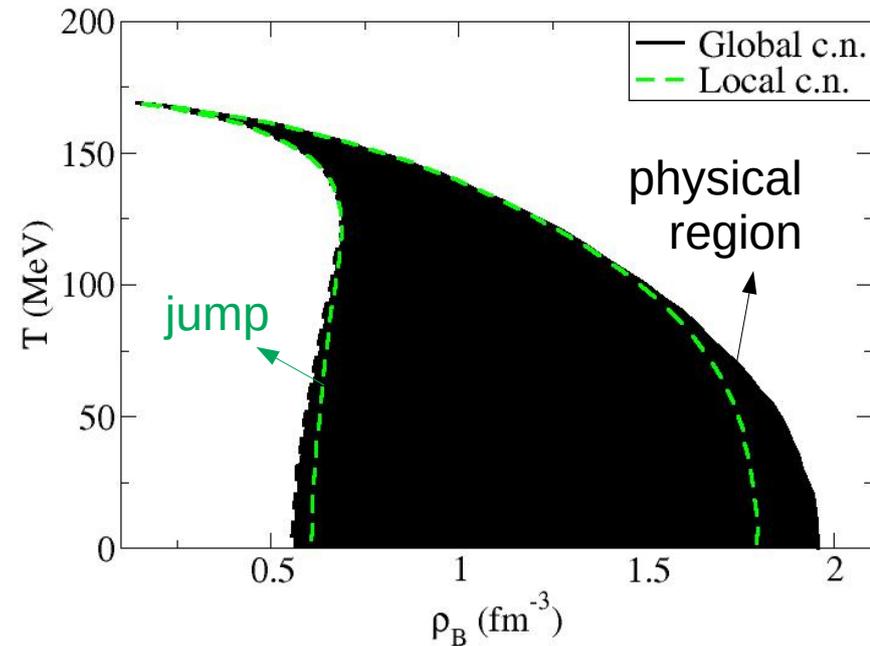
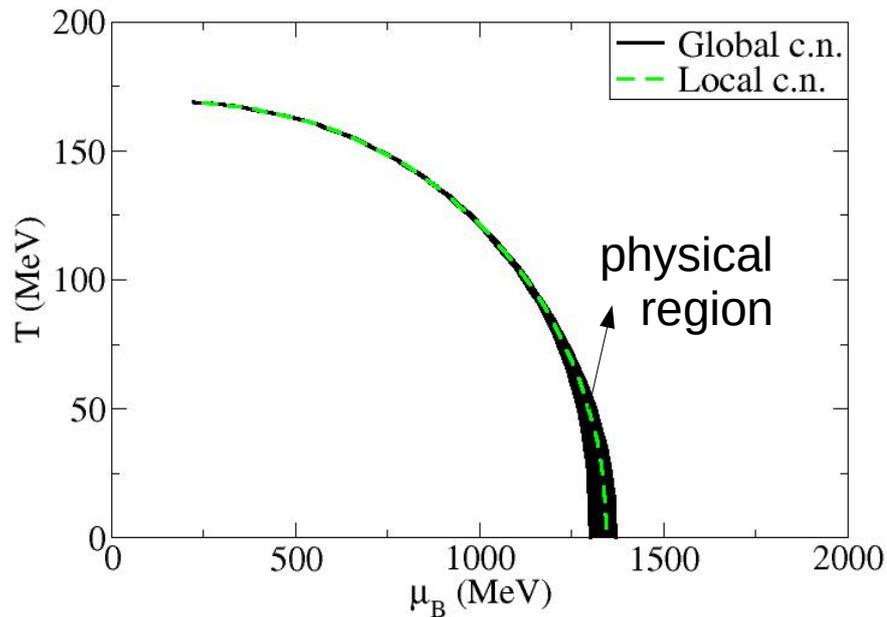
- CMF EoS limits from comparison with PQCD from Vuorinen et al.

NS	$T = 0:$	$\mu_B = 1411.04,$	$\rho_B/\rho_0 = 14.93$
	$T = 45 \text{ MeV:}$	$\mu_B = 1419.76,$	$\rho_B/\rho_0 = 17.27$
	$T = 100 \text{ MeV:}$	$\mu_B = 1356.87,$	$\rho_B/\rho_0 = 20.20$
PNS ($Y_I=0.4$)	$T = 0:$	$\mu_B = 1421.69,$	$\rho_B/\rho_0 = 15.67$
	$T = 45 \text{ MeV:}$	$\mu_B = 1429.09,$	$\rho_B/\rho_0 = 17.80$
	$T = 100 \text{ MeV:}$	$\mu_B = 1364.08,$	$\rho_B/\rho_0 = 20.60$



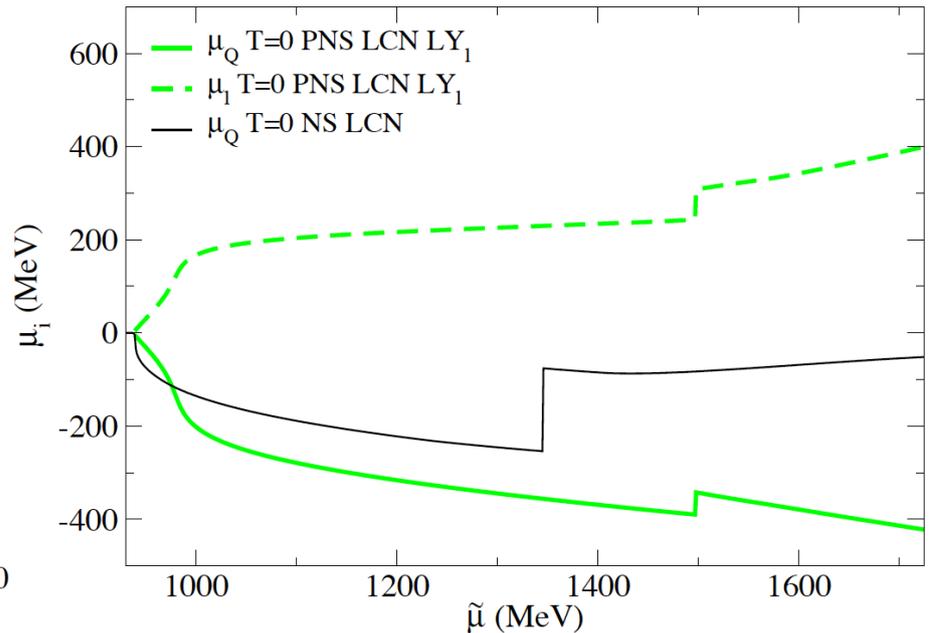
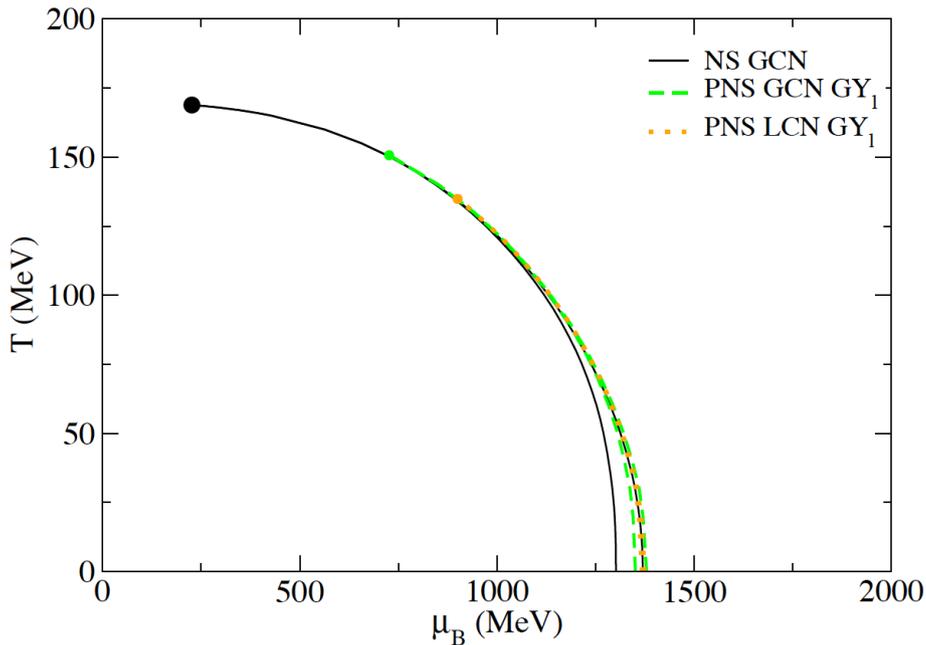
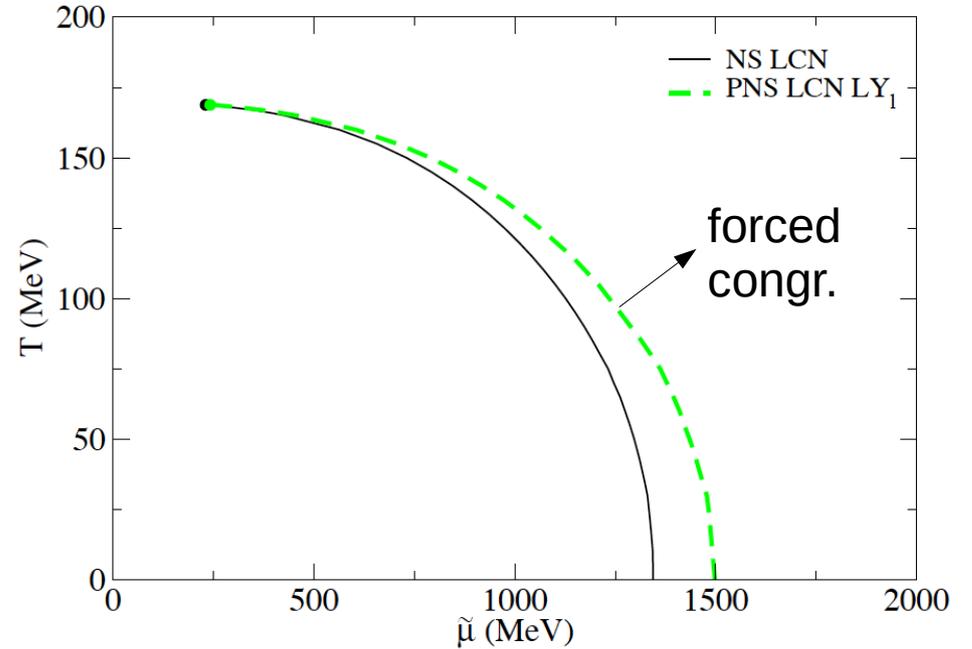
★ Neutron Star Matter: Local vs Global Charge Neutrality

- absence / presence of mixture of phases: surface tension ???
- “mixed” quantities like baryon number density



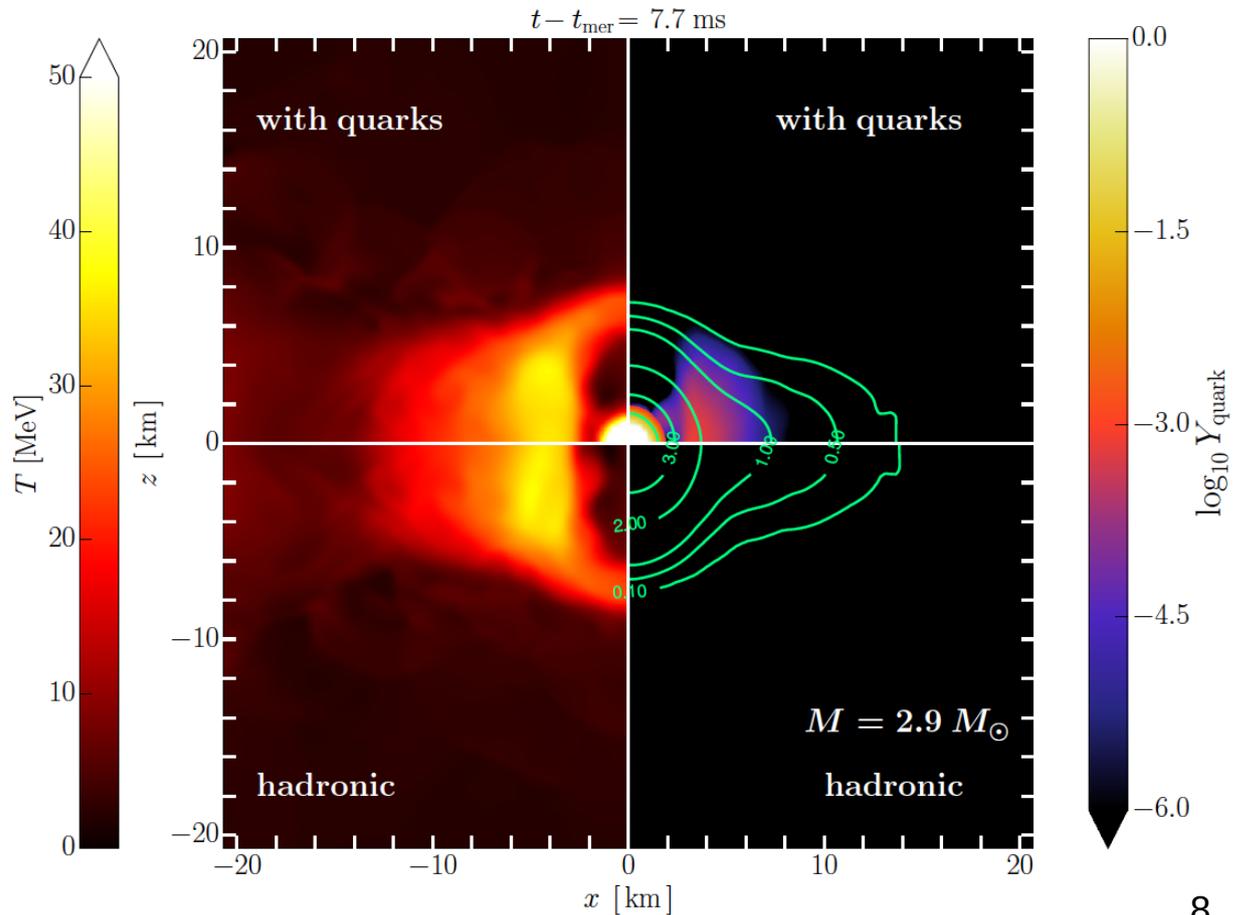
★ Fixed lepton fraction:

- local or global $Y_l=0.4$?
- more kinds of mixed phases
- higher μ_B, ρ_B but less extensive



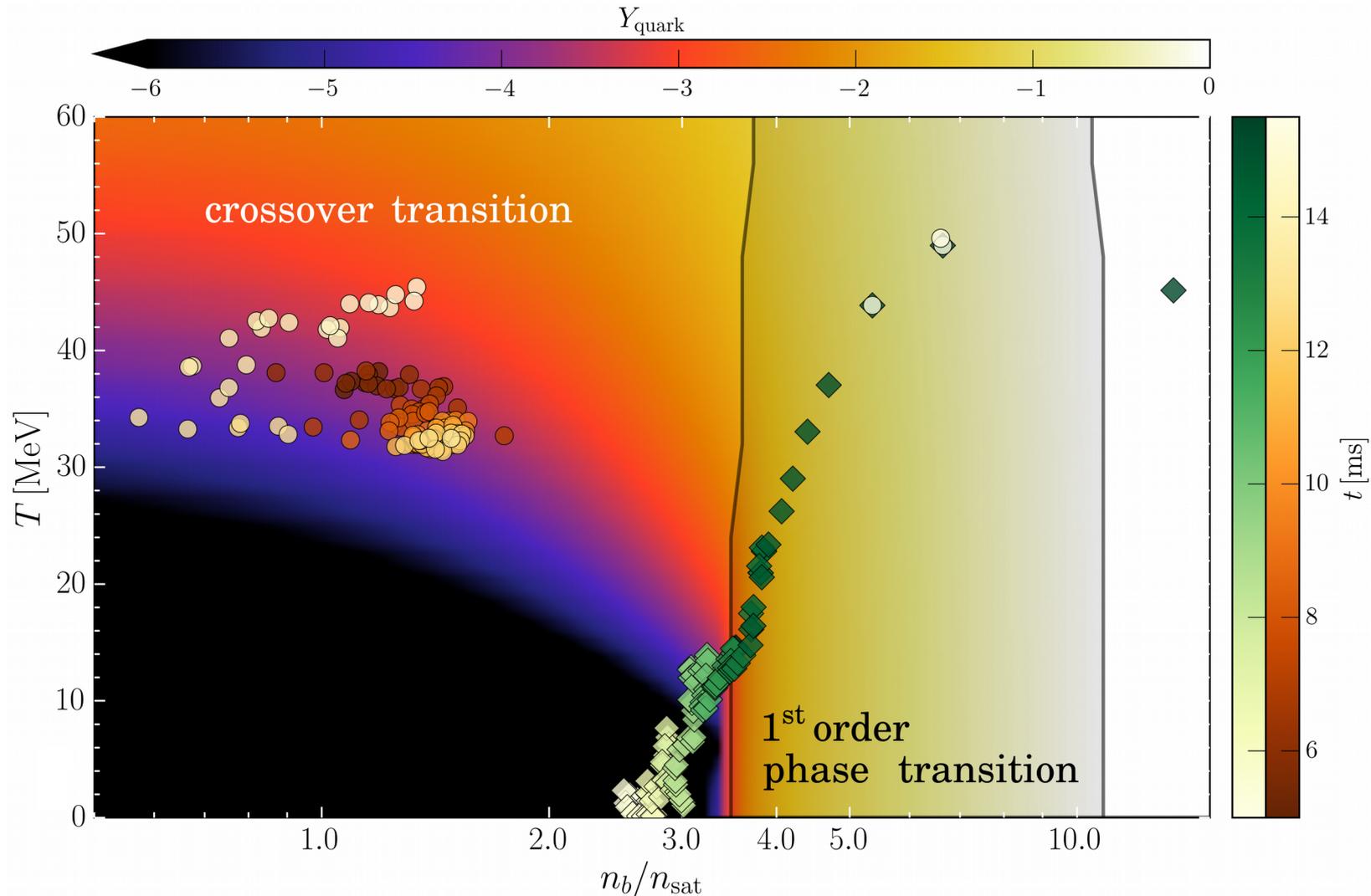
★ Merger simulation:

- 3D CMF EoS with/without quarks
- solve coupled Einstein-hydrodynamics system using Frankfurt/IllinoisGRMHD code (FIL)
- interesting results for binaries with masses 2.8 and 2.9 M_{Sun} after merger
- right before collapse to black hole:



★ Merger in the QCD phase diagram:

- Tracking maximum density ● and temperature ◆ in merger



★ Conclusions and Outlook

- more investigation of high density part of phase diagram is required
- signature for 1st order phase transition from astrophysics?
- need of more realistic (finite temperature) EoS's

- we have a 3D stellar-merger hadronic EoS table available online at CompOSE (Publ. Astron. Soc. Aust. 34 (2017) e066)
- we are testing the effects of quarks on mergers
- we are including a crust, magnetic field and quark pairing effects

- **what else can I provide?**