Equation of State Effects on Neutron Star Mergers

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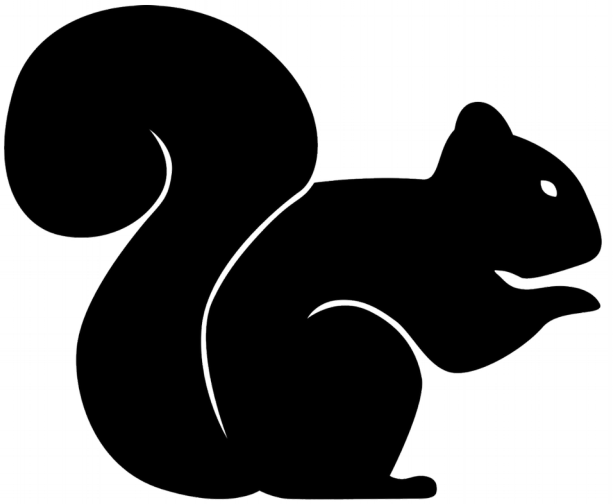

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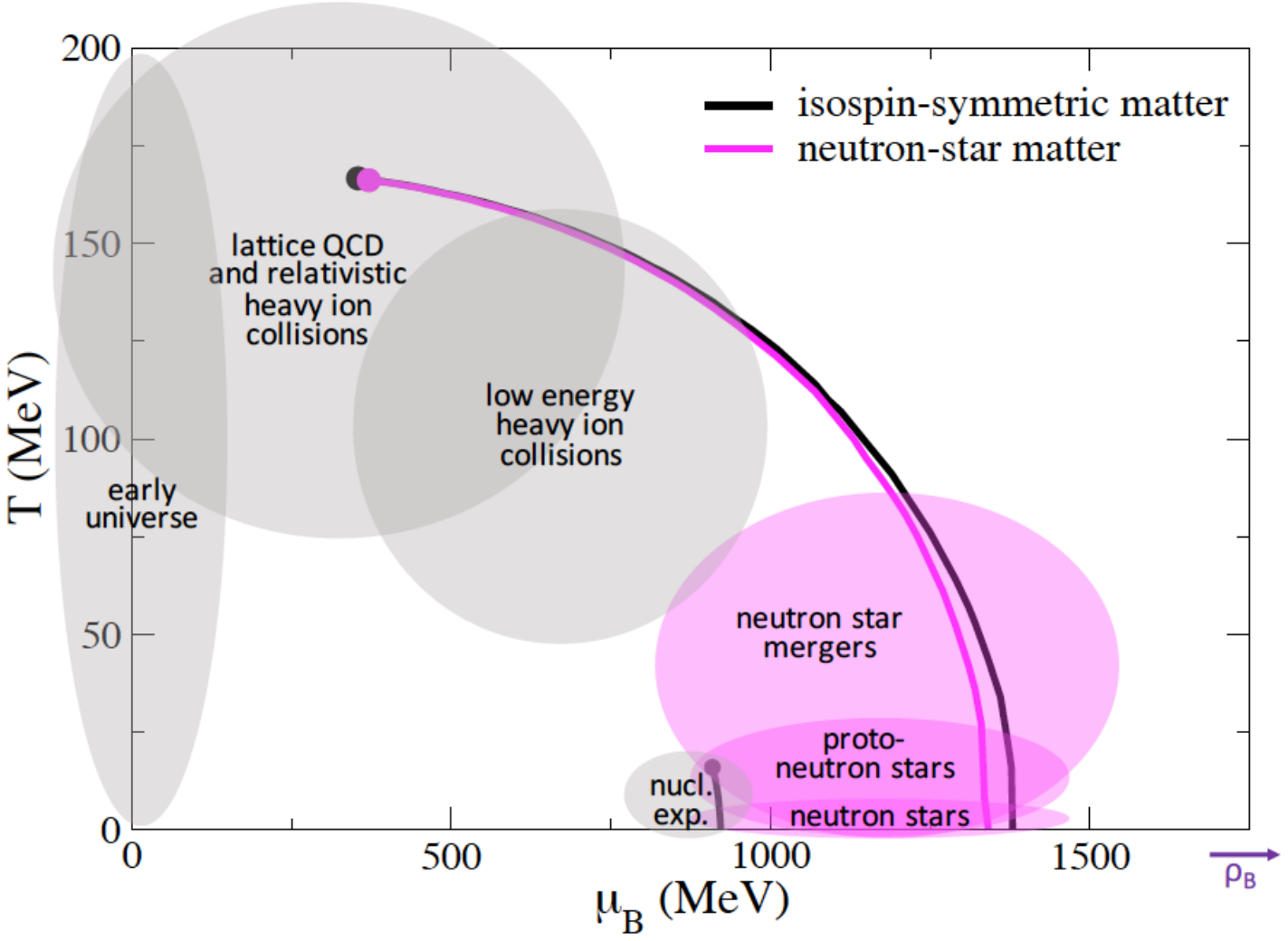
QCD Phase Diagram:



- results from CMF model (without mixture of phases)

CMF (Chiral Mean Field) Model:

- extended non-linear realization of SU(3) sigma model
- uses pseudo-scalar mesons as parameters of chiral transformation
- includes baryon octet (+ leptons) and quarks
- fitted to reproduce nuclear, lattice QCD and astrophysical constraints
- effective masses

$$m_b^* = g_{b\sigma}\sigma + g_{b\delta}\tau_3\delta + g_{b\zeta}\zeta + \delta m_b + g_{b\Phi}\Phi^2$$

$$m_q^* = g_{q\sigma}\sigma + g_{q\delta}\tau_3\delta + g_{q\zeta}\zeta + \delta m_q + g_{q\Phi}(1 - \Phi)$$

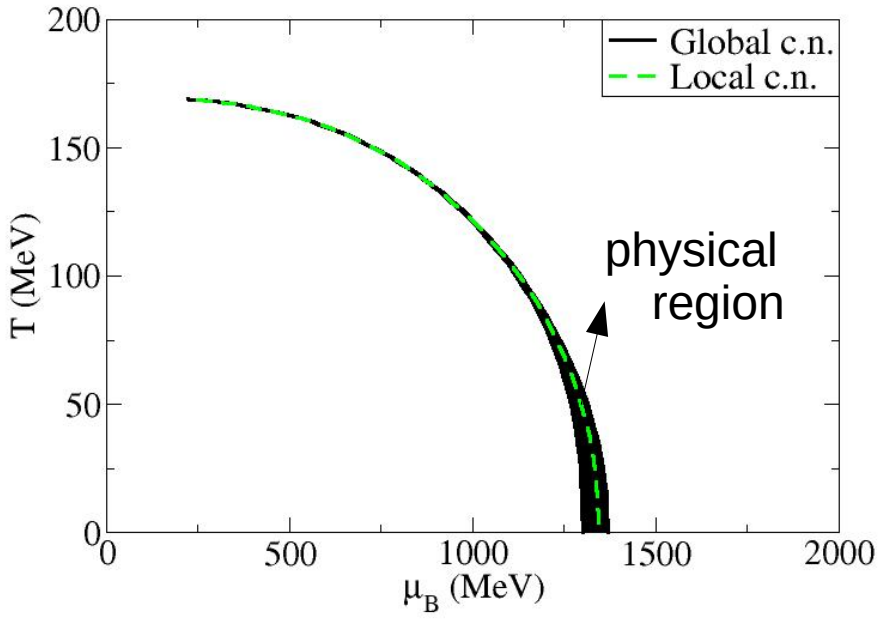
- 1st order phase transitions or crossovers (order parameters σ, Φ)
- potential for Φ (deconfinement)

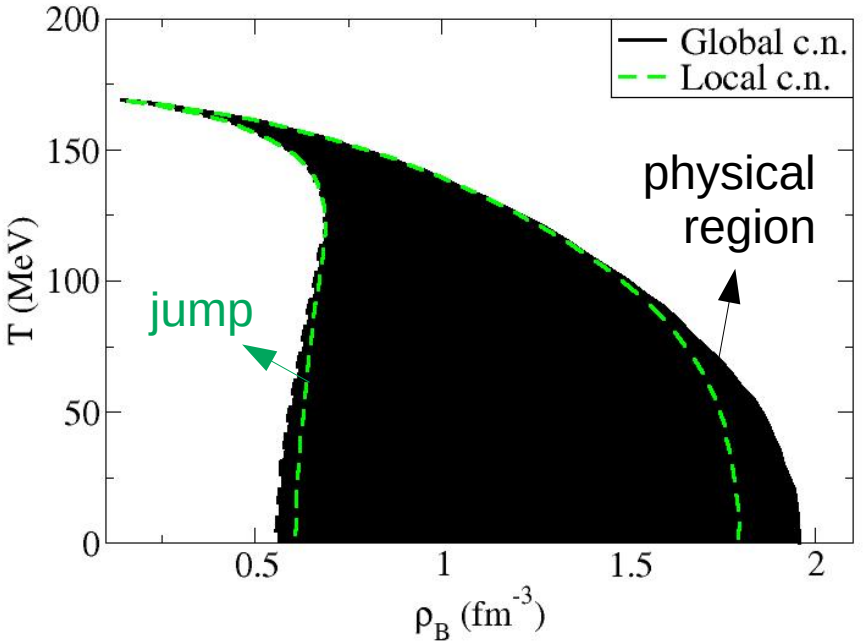
$$U = (a_0\ T^4 + a_1\ \mu^4 + a_2\ T^2\mu^2)\phi^2 + a_3\ T_0^4 \quad \ln\left(1 - 6\phi^2 + 8\phi^3 - 3\phi^4\right)$$

Neutron Star Matter: Local vs Global Charge Neutrality:

- absence / presence of mixture of phases: surface tension ???

- "mixed" quantities like $\rho_B = \lambda \rho_B^Q + (1-\lambda)\rho_B^H$





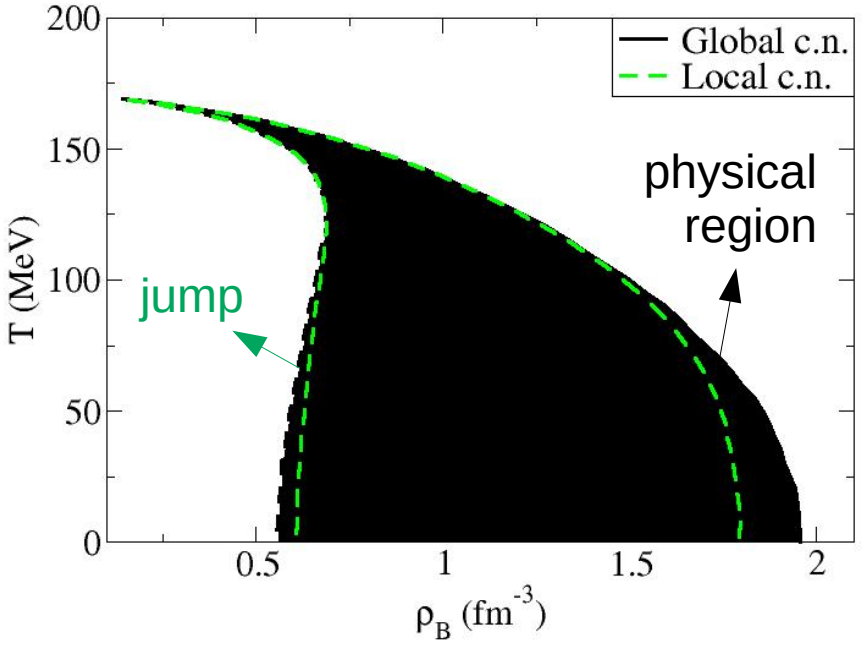
Non-congruent Phase Transitions:

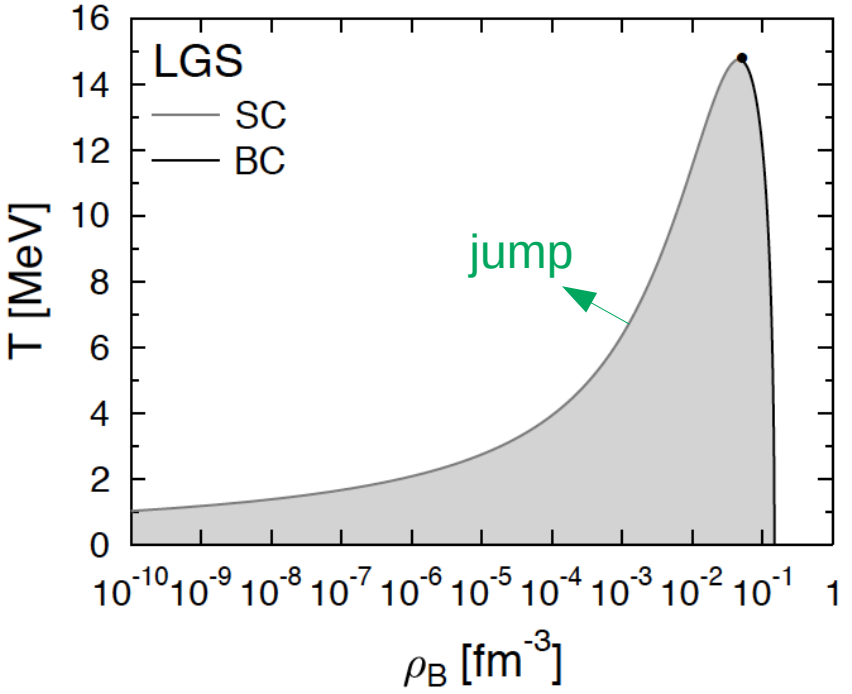
- more than one globally conserved charge within 2 macroscopic phases within a Coulomb-less model: baryon #, electric charge

- local concentration of a charges vary during phase transition

- same chemical potential (assoc. to charge) in both phases (μ_q)

- very different from symmetric matter liquid-gas (LGS)

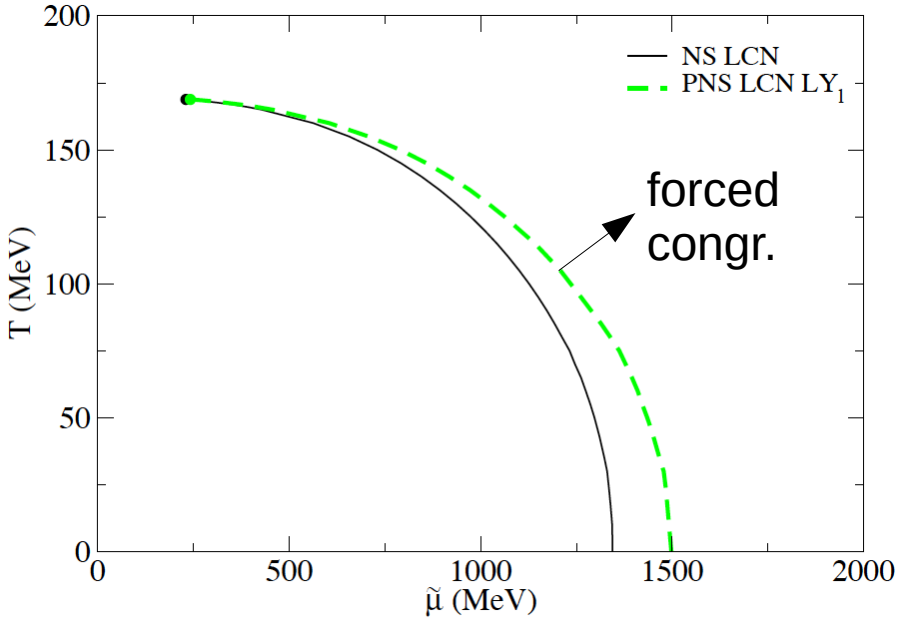


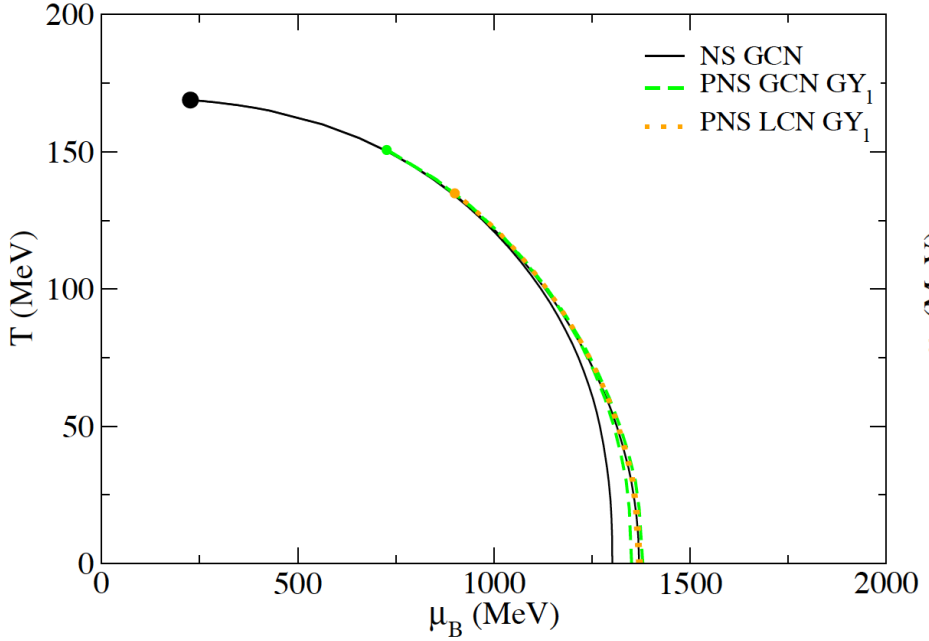


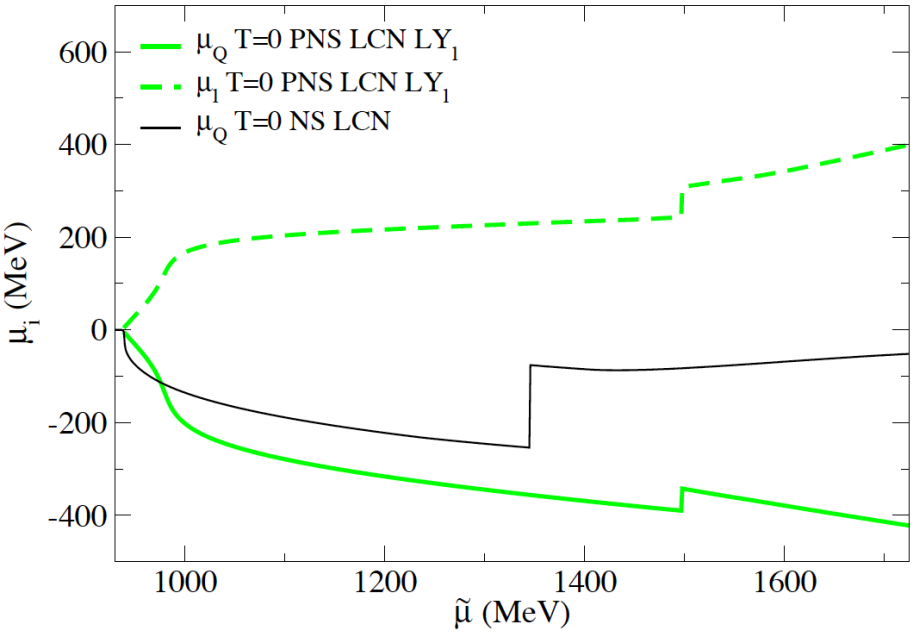
Proto-Neutron-Star Matter:

- charge neutral with $Y_l = 0.4$

- more than one conserved charge (baryon #, electric charge, lepton fraction): non-congruent phase transition!
  $\tilde{\mu} = \mu_B + Y_l \mu_l$





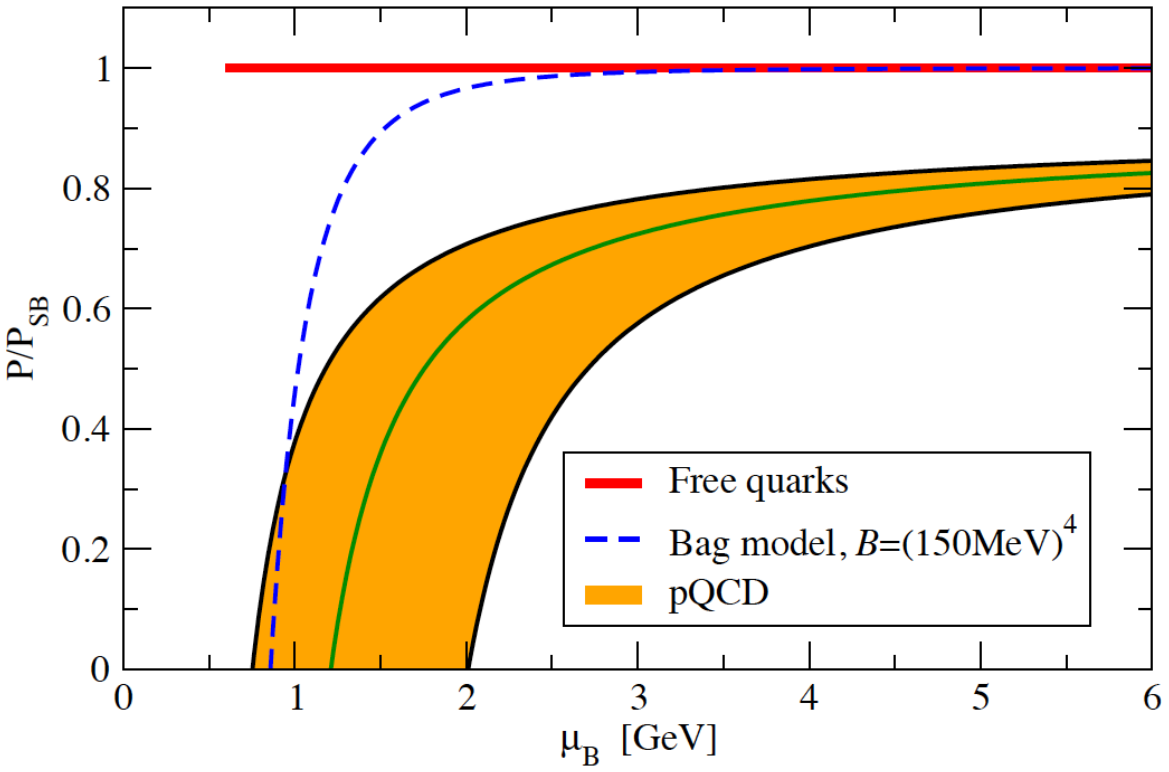


Perturbative QCD:

- figure from: Fraga, Kurkela and Vuorinen, Astrophys. J. 2014

- 3-flavor QGP at zero temperature including β-equilibrium and charge neutrality

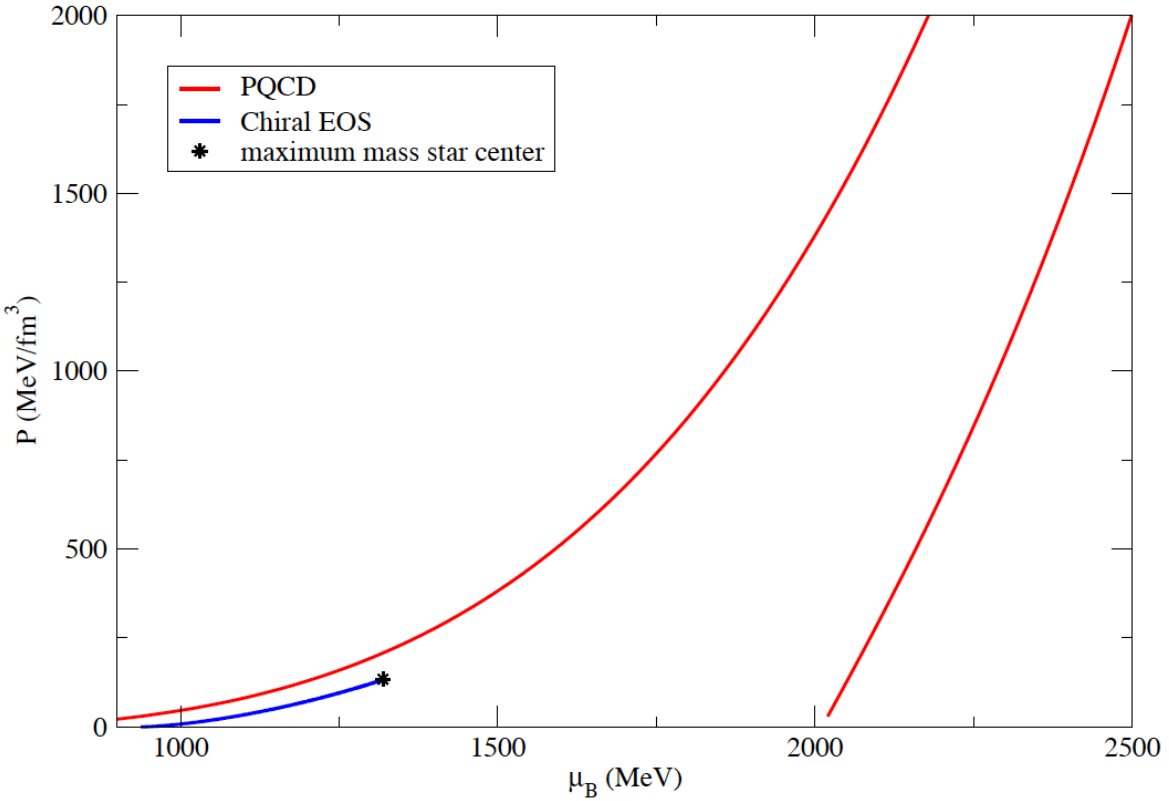
- Bag model failure !



Perturbative limit at T=0

- Chiral EoS until central density of most massive star ($\sim 2\ M_{Sun}$)

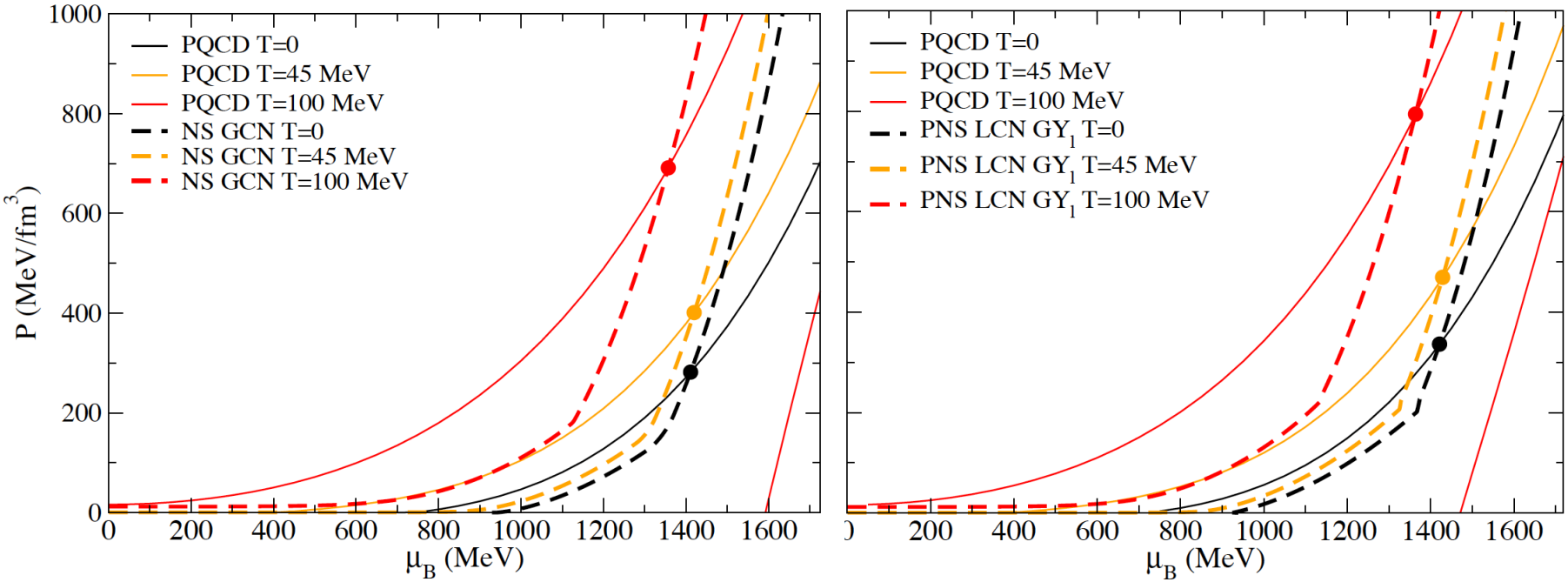
- no vector interactions for quarks



Perturbative limit at finite temperature

- Chiral EoS limits from PQCD

NS	$T = 0$:	$\mu_B = 1411.04$ MeV
	$T = 45$ MeV:	$\mu_B = 1419.76$ MeV
	$T = 100$ MeV:	$\mu_B = 1356.87$ MeV
PNS	$T = 0$:	$\mu_B = 1421.69$ MeV
	$T = 45$ MeV:	$\mu_B = 1429.09$ MeV
	$T = 100$ MeV:	$\mu_B = 1364.08$ MeV



Conclusions and Outlook

- more investigation of high density part of phase diagram is required (including comparisons with PQCD)!
  Signature for 1st order phase transition from astrophysics?

- better understanding of congruent/non-congruent deconfinement phase transitions: finite temperature description, unified EOS (used for L-G transitions) and that provides particle population

- we already have a 3D star merger hadronic EoS table available online at CompOSE (Publ. Astron. Soc. Aust. 34 (2017) e066)

- we are testing the effects of quarks on star mergers using a 3D table

- we are about to include magnetic field and quark pairing effects