Inhomogeneous phases in strongly interacting matter

Discussion Session

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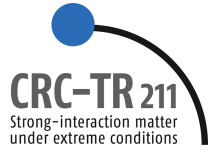

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Questions sent in by the speakers

- Are there any robust experimental signatures that could reveal the presence of an inhomogeneous phase (inside a neutron star?) independently of the details of the order parameter texture? What observables would one need to calculate to make such an experimental test possible?
- What are the long-term prospects for detecting an inhomogeneous phase on the lattice, in QCD or a QCD-like theory free of the sign problem?

- Do we expect that inhomogeneous phases exist in QCD?
- Which QCD-inspired models close to QCD (i.e. in 3+1D, with finite number of colors/flavors), but simpler (e.g. without sign problem, suited for lattice field theory studies) are promising with respect to the existence of inhomogeneous phases?

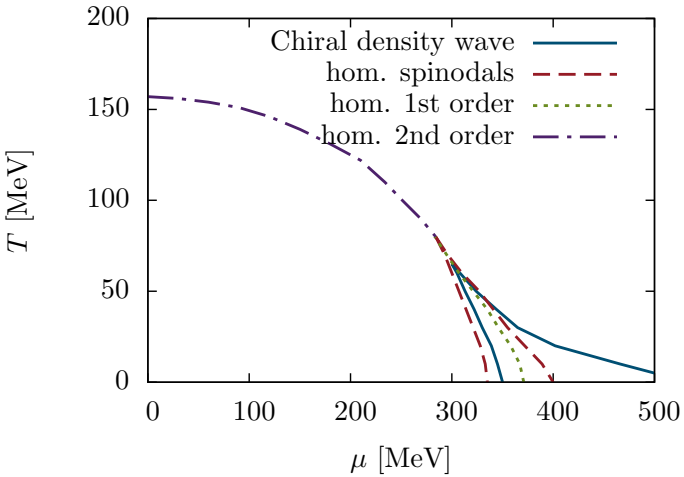
Inhomogeneous chiral condensates within the Functional Renormalisation Group – Discussion points and questions

- **Explicit treatment of inhomogeneous phases in the FRG framework by means of special ansatz functions**
  - Computations beyond the CDW/the chiral limit might not be possible/feasible?!
    - Diagonalization for GN/kink solution with suited unitary matrices (constructed from eigen vector spectrum)?
  - Extension beyond LPA (LPA', LPA'+Y, LA, …) with the CDW is possible
  - Full numerical solution of the LPA flow eq. for the CDW is challenging
    - Momentum integrals
    - Solution of the FRG flow eq. as an advection-diffusion eq.
    - Exponential scaling in the (deep) IR
    - 1+1 grid in q and ρ
- **Bottom up parameter fitting for low energy models (fitting observables in the FRG is more challenging than expected in LPA**
  - Consistency checks of the inhomogeneous phase fail when employing naïve BC parameter fitting scheme (usually used for LPA computations in MF and beyond)
  - Improved parameter fitting schemes based on the mesonic two-point functions evaluated on the LPA/MF flow for the pole masses and renormalized pion decay constant are necessary
  - Spatial/3D FRG regulators violate Poincare-invariance in vacuum: especially problematic for pole masses => further investigation of possible effects in the phase diagram required?!
- **RG consistency is an important aspect for the phase diagram of low energy effective models**
  - Implementation on MF level is trivial
  - Implementation on full FRG level is more involved since 'integrating up' the flow direction from small k to larger ones is not possible => boundary value problem/shooting method
  - Allows for a controlled recovery of standard MF (no-sea approximation) in the FRG frame work
- **RG consistent eMFA results for the inhomogeneous CDW phase diagram of the two flavour QM model in the chiral limit using improved parameter fitting schemes (RP or RP*)**
  - In qualitative agreement with existing eMFA results for low temperatures
  - Splitting of Lifshitz and critical point => probably one mayor remnant of the explicit Poincare-invariance/SO(4) violation caused by the spatial regulators!?
- **FRG based stability analysis of the homogeneous ground state as an alternative approach for the study of inhomogeneous chiral condensates (not discussed in this talk)**
  - Does not rely on a specific ansatz for the inhomogeneous chiral condensate(s): is based on computations in the homogeneous phase
  - Technically much easier/cheaper then explicit computations in the inhomogeneous phase
  - More general since no ansatz is required
  - Explicit statements about the inhomogeneous window are impossible -> only statements about the stability of the homogeneous ground state are possible

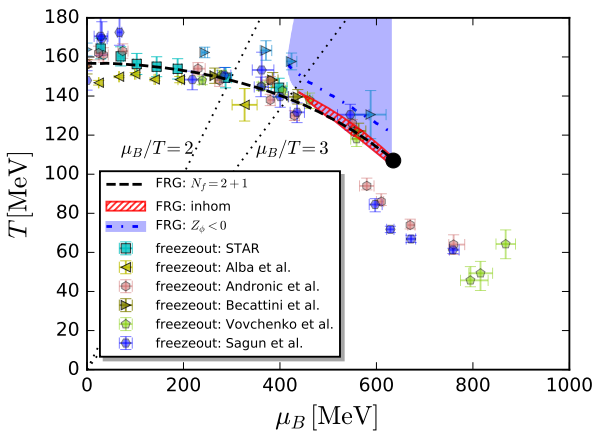
My personal questions (with some overlap with the others)

Inhomogeneous phases in QCD?

- Can we investigate inhomogeneous chiral phases directly within QCD?



DSE: [Müller et al., PLB (2013)]



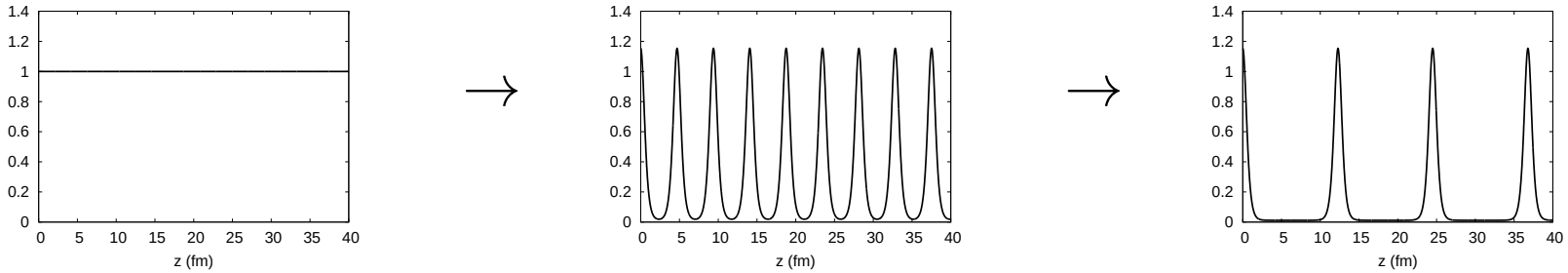
FRG: [Fu et al., PRD (2020)]

- Can we improve on this?
- Is there a chance to study inhomogeneous phases in lattice QCD?
  - by novel approaches to finite μ?
  - by a clever choice of parameters?

What is the role of baryons?

- 1D inhomogeneous solutions in GN and NJL:

  homogeneous matter decays into domain-wall solitons



- If it was 3D: Hadronization!

  ($\rightarrow$ revisit chiral solitons! [Alkofer, Reinhardt, Weigel; Goeke; Ripka; ...])

- Crossover (de-)confinement transition at low T, $\mu \neq 0$?

Your questions?

- Questions directly related to the talks
- Questions which have not yet been raised