Effective field theories for dense nuclear matter

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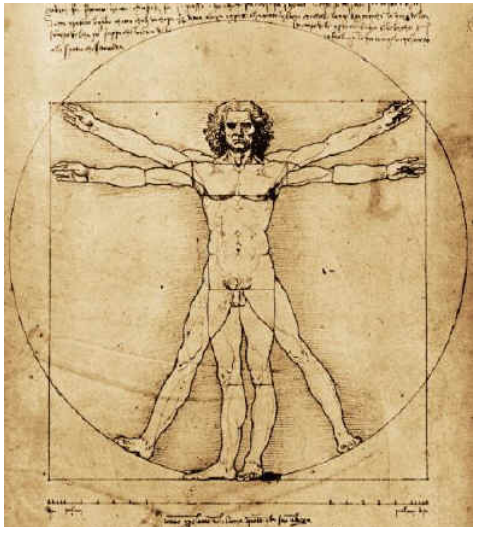
effective models

analytical, first-principle treatment of QCD is currently a cherished dream...

full model



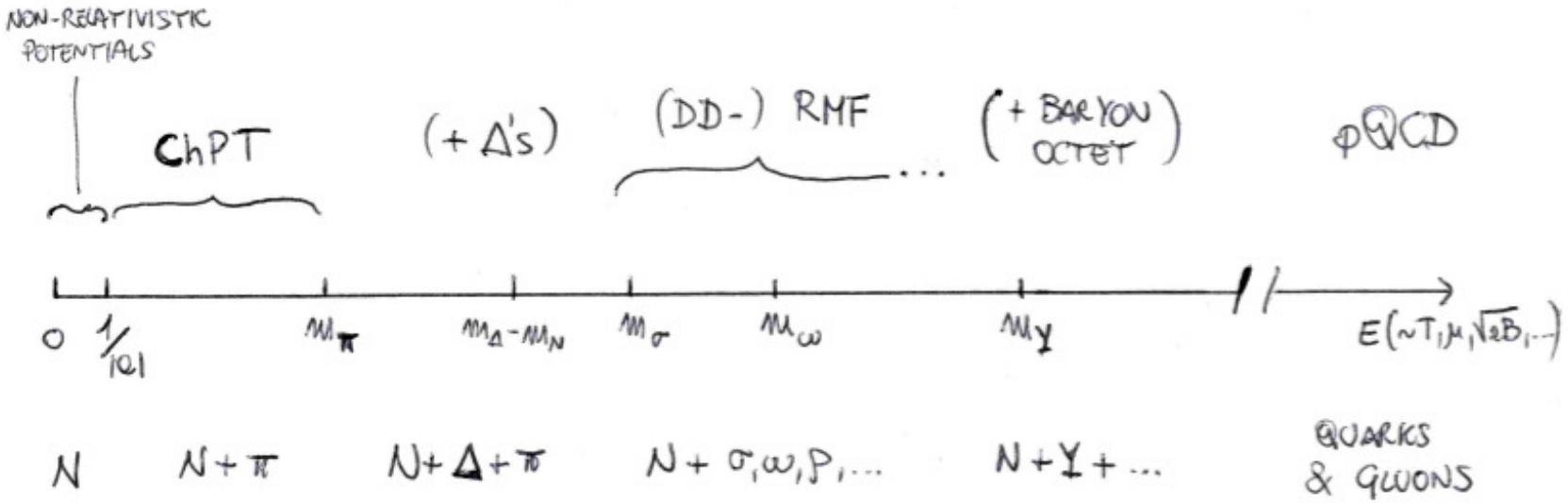
effective model

d.o.f.: observable particles (hadrons) instead of quarks and gluons

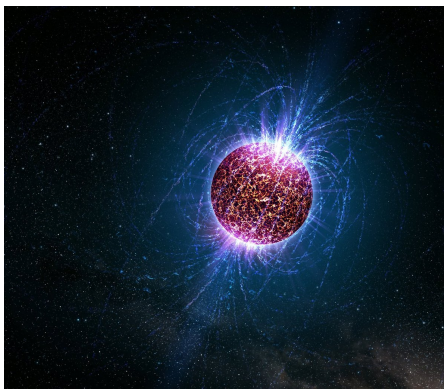
EFT program:

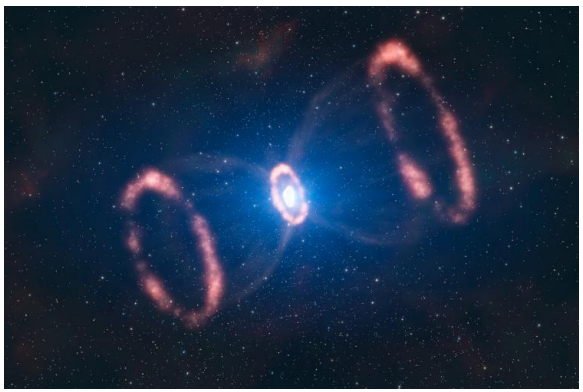
- define soft and hard scales
- identify relevant degrees of freedom
- construct the most general Lagrangian $\mathcal{L}$ (symmetries)
- compute the relevant diagrams
- determine the thermodynamic properties (EoS) of the system

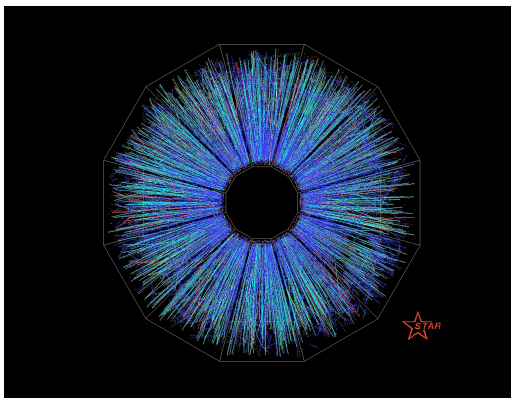
nuclear matter scales



(+ effective models for quark matter)







nucleon and pion effective mass

motivation:

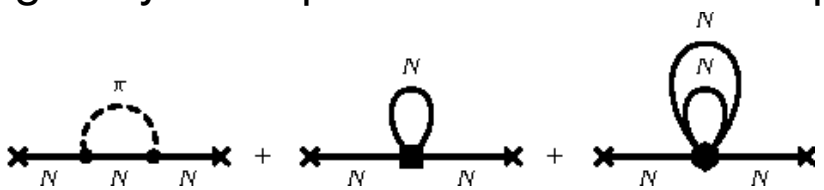
- systematic calculation in vacuum from EFT

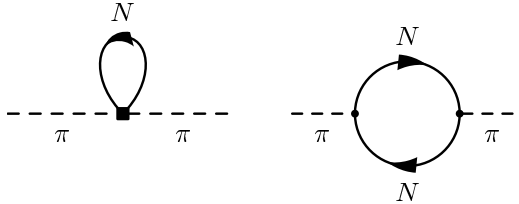
model used:

- chiral perturbation theory
- relativistic self-consistent Green's function approach

$$\mathcal{L}^{(1)}_{\pi N} = -\bar{\Psi}\left[\frac{g_A}{2f_\pi}\gamma^\mu\gamma_5\boldsymbol{\tau}\cdot\partial_\mu\boldsymbol{\pi} + \frac{1}{4f_\pi^2}\gamma^\mu\boldsymbol{\tau}\cdot(\boldsymbol{\pi}\times\partial_\mu\boldsymbol{\pi})\right]\Psi$$

solve separately Schwinger-Dyson equation for nucleon and pion

$\Sigma =$ 

$\Pi =$ 

possible applications:

- weak-processes in dense matter (pion-neutrino interactions)
- pion-nucleon dynamics in relativistic density functional models

[PRC 88, 015209 (2013)]

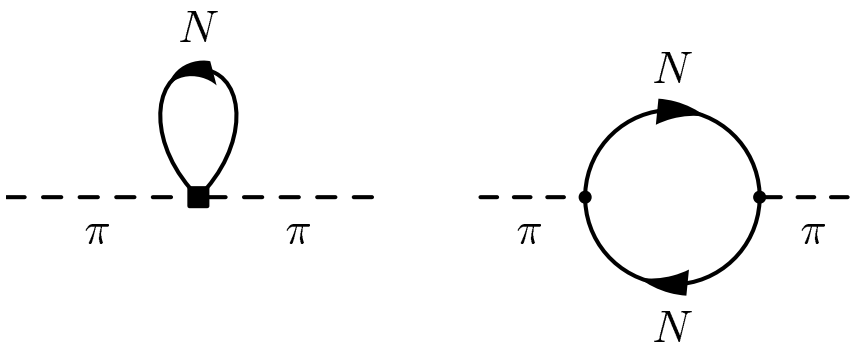
ChPT in a magnetic background

motivation:

- unknown behavior of dense (nuclear) matter in a magnetic background
- phenomenology of magnetars and HIC

model used:

- chiral perturbation theory
- strong magnetic field approximations



possible applications:

- magnetic pQCD calculations (one-loop quark and gluon self-energy)
- neutrino transport in a magnetized nuclear background

[PLB, in press, arXiv:1310.3742]

RMF - compact stars

motivation

- $2m_\odot$ compact star observation do not match with old hyperon and quark EoS, but they should be there!

model used

- density dependent relativistic mean field model (nuclear EoS)
- NJL with CSC (quark EoS)

results and outlook

- parameter study on a finite temperature EoS shows possible compatibility of hyperon and quark (hybrid) stars with observations
- need to constrain hyperon parameters (lQCD, lots of experiments: PANDA, HypHI, MAMI C, FINUDA, JLab, J-PARC,...)
- effect of rotation: phase transition to quark matter (transitional sequences - observable effects!)
- neutron star mergers and GW emission study

[PRC 87, 055806 (2013), A&A 559, A118 (2013)]