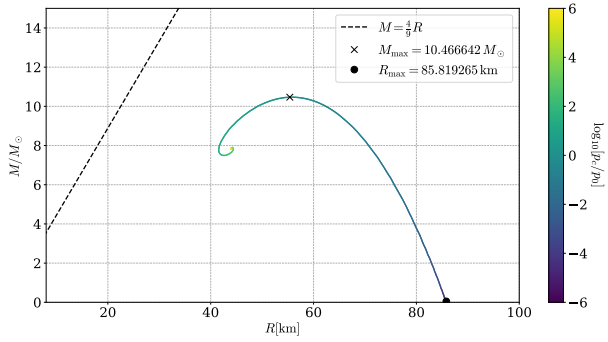
Pion stars

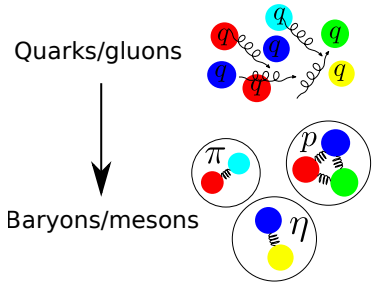
- New proposal: stars made of pions
- Microscopic part: what are the thermodynamics of pions?
- Macroscopic part: hydrodynamics of astrophysical objects



- Questions: What is the mass-radius relations of pion stars? How do EM-interactions/including three quarks/loop corrections influence the star?

Chiral perturbation theory

- Quarks bind into baryon (protons/neutrons) and mesons (pions) at low temperatures ($< \sim 10^{12}$ K)
- The strong force is strong, so we can't do perturbation theory.
  $\mathcal{L} = \sum_f \bar{q}_f(\gamma^\mu[\partial_\mu - iq\lambda^a A^a_\mu] + m_f)q_f + G^a_{\mu\nu}G^{\mu\nu}_a$



- Need an effective theory, The QCD vacuum spontaneously break a symmetry of the Lagrangian — Goldstone bosons (pions)
  $\mathcal{L}_{\text{eff}} = \frac{f^2}{4}\operatorname{Tr}\{\nabla_\mu\Sigma\nabla^\mu\Sigma^\dagger\} + \frac{f^2}{4}\operatorname{Tr}\{\chi^\dagger\Sigma + \Sigma^\dagger\chi\} + l_1\operatorname{Tr}\{\nabla_\mu\Sigma(\nabla^\mu\Sigma)^\dagger\}^2 + \ldots$
- $\mathcal{F} = -\frac{i}{V\beta}\ln\left[\int \mathcal{D}\pi\, \exp\left(i\int \mathrm{d}^4x\,[\mathcal{L}_{\text{eff}} + \mu J]\right)\right]$, equation of state $u = u(P)$.

Hydrostatic equilibrium

- TOV equation govern pressure of perfect fluids in hydrostatic equilibrium
$$\frac{\mathrm{d}P}{\mathrm{d}r} = -\frac{G}{r^2}\frac{(u+P)(m+4\pi r^3 P)}{\left(1-\frac{2Gm}{r}\right)},$$
- Numerical integration gives P, u and thus M, R.
- Found explicit expression for $R_{\text{max}} = \frac{\pi}{\sqrt{12}} r^0$.