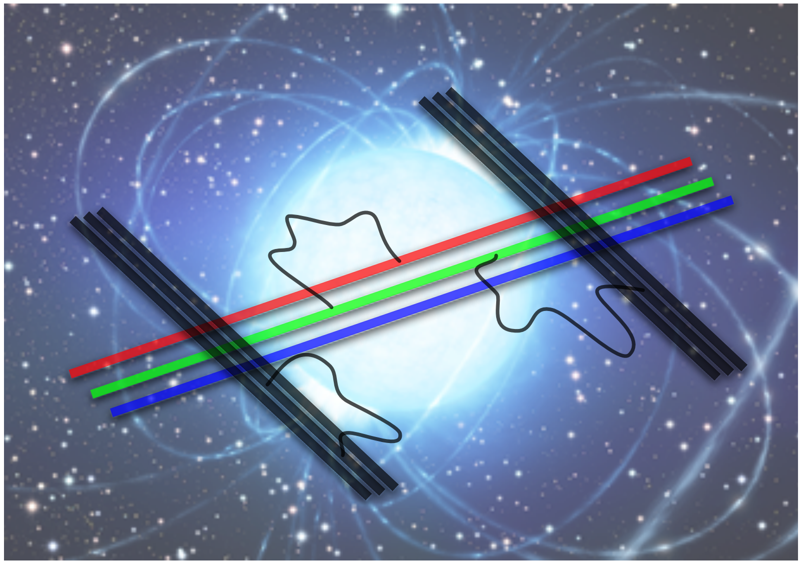
Andreas Schmitt

Mathematical Sciences and STAG Research Centre
University of Southampton
Southampton SO17 1BJ, United Kingdom

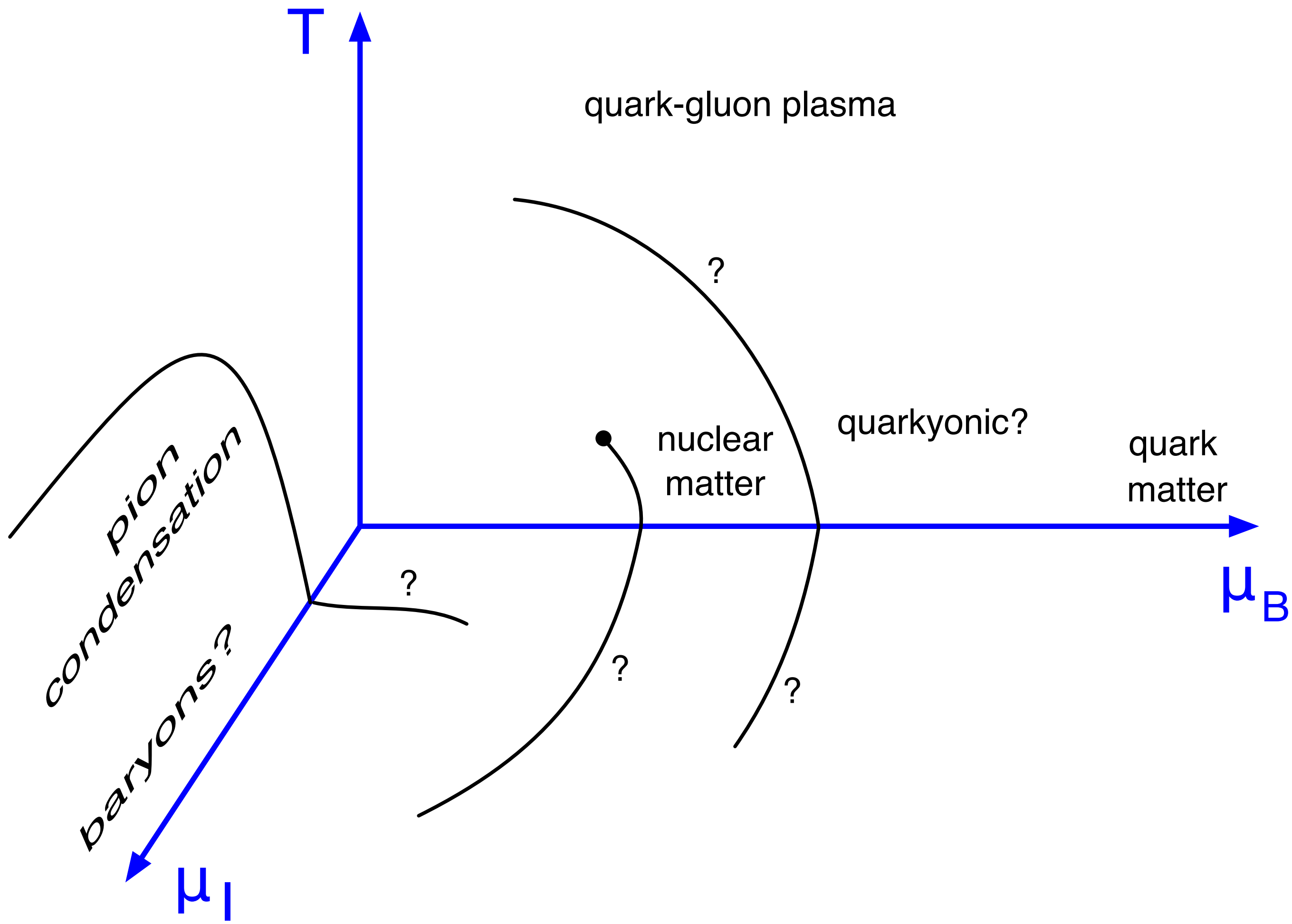
Dense QCD matter and neutron stars from holography

N. Kovensky, A. Poole, A. Schmitt

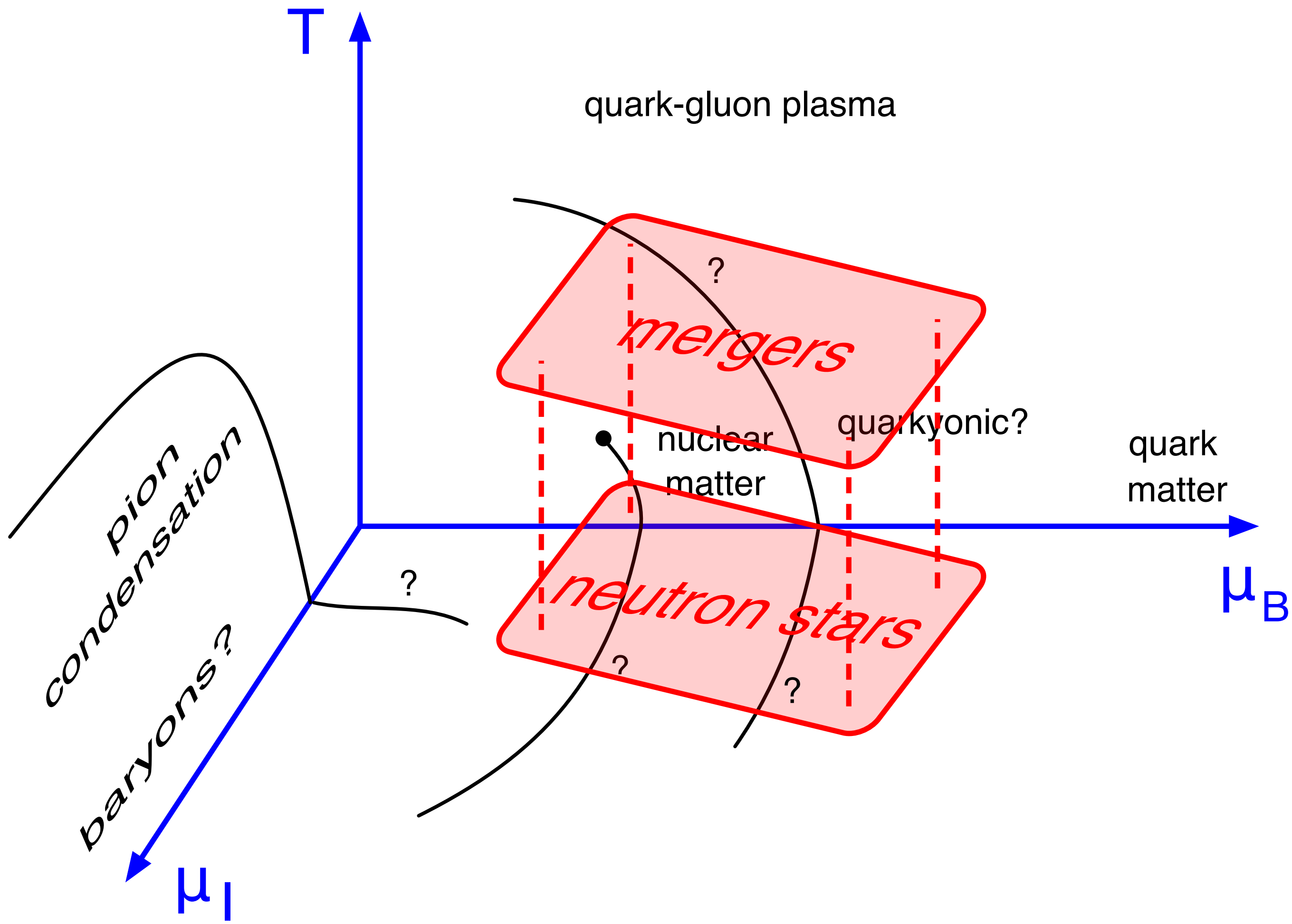


A. Schmitt (foreground); ESO/L. Calçada (neutron star)

Motivation: Phases of QCD and neutron stars



Motivation: Phases of QCD and neutron stars

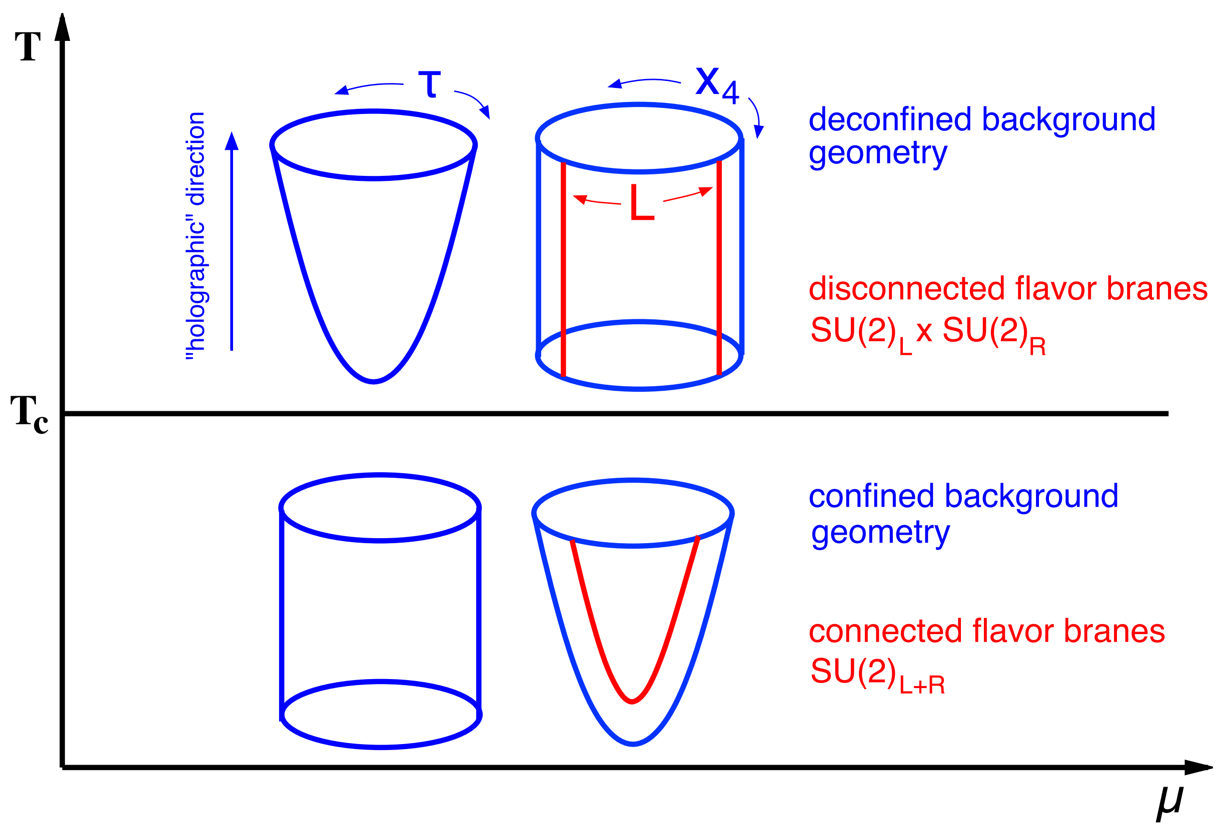


Use holography: Witten-Sakai-Sugimoto model

E. Witten, Adv. Theor. Math. Phys. 2, 505 (1998)

T. Sakai and S. Sugimoto, Prog. Theor. Phys. 113, 843 (2005)

- top-down approach with only 2 (or 3) parameters: λ, $M_{\rm KK}$ (and L)
- supersymmetry and conformal symmetry broken
- successfully applied to meson, baryon, glueball spectra

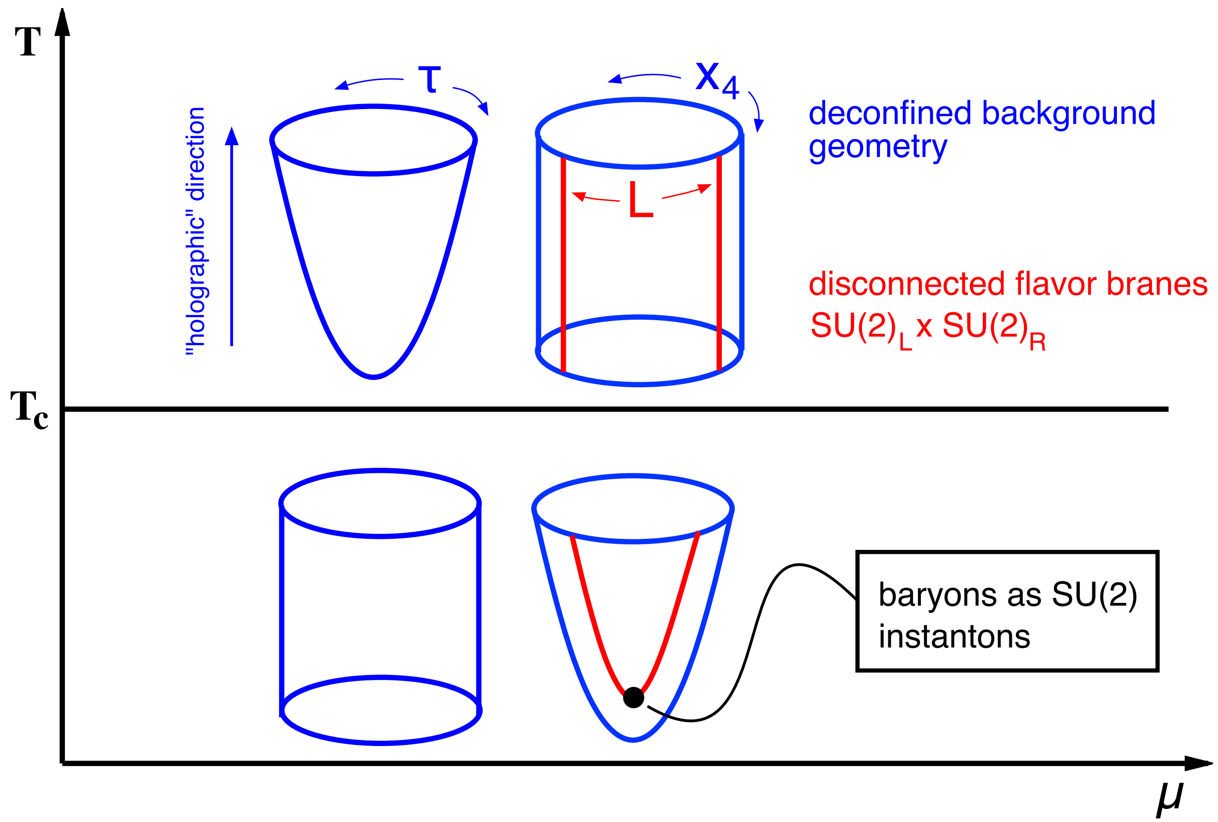


Use holography: Witten-Sakai-Sugimoto model

E. Witten, Adv. Theor. Math. Phys. 2, 505 (1998)

T. Sakai and S. Sugimoto, Prog. Theor. Phys. 113, 843 (2005)

- top-down approach with only 2 (or 3) parameters: λ, $M_{\rm KK}$ (and L)
- supersymmetry and conformal symmetry broken
- successfully applied to meson, baryon, glueball spectra

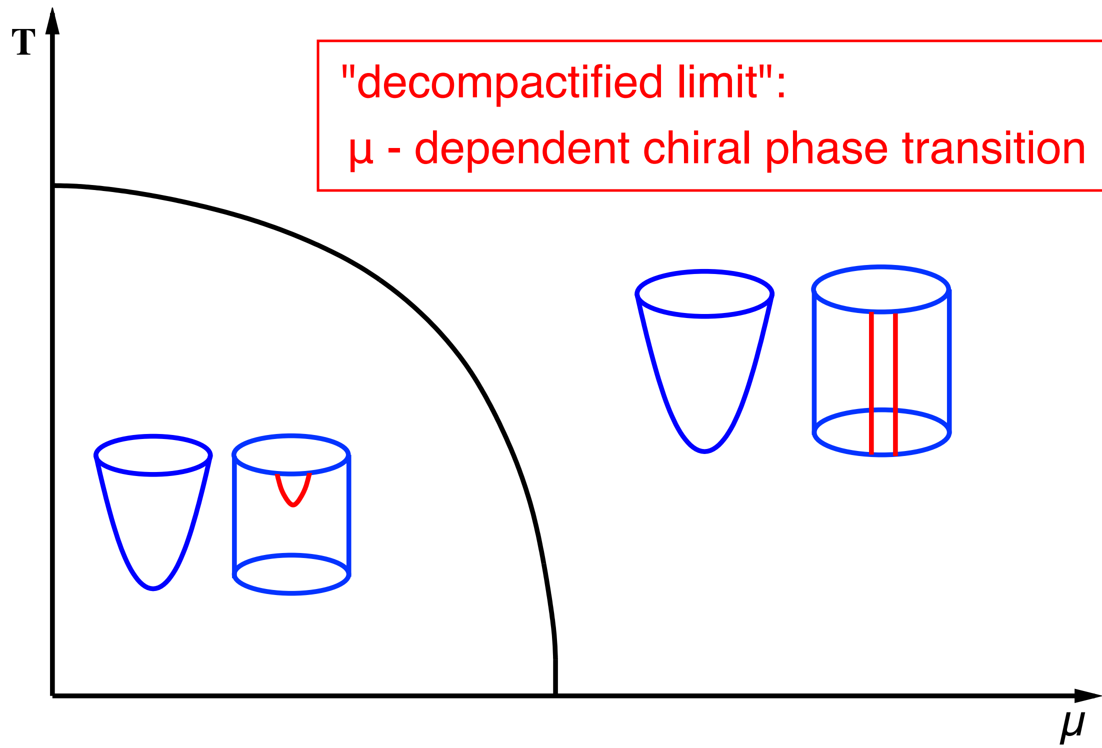


Use holography: Witten-Sakai-Sugimoto model

E. Witten, Adv. Theor. Math. Phys. 2, 505 (1998)

T. Sakai and S. Sugimoto, Prog. Theor. Phys. 113, 843 (2005)

- top-down approach with only 2 (or 3) parameters: λ, $M_{\rm KK}$ (and L)
- supersymmetry and conformal symmetry broken
- successfully applied to meson, baryon, glueball spectra



Results

1. thermal pion condensation (decompactified limit)
   N. Kovensky and A. Schmitt, work in progress

2. baryons, pions and rho mesons in the μ_B-μ_I plane at $T = 0$ (confined geometry)
   N. Kovensky, A. Poole, A. Schmitt, SciPost Phys. 15, 162 (2023)

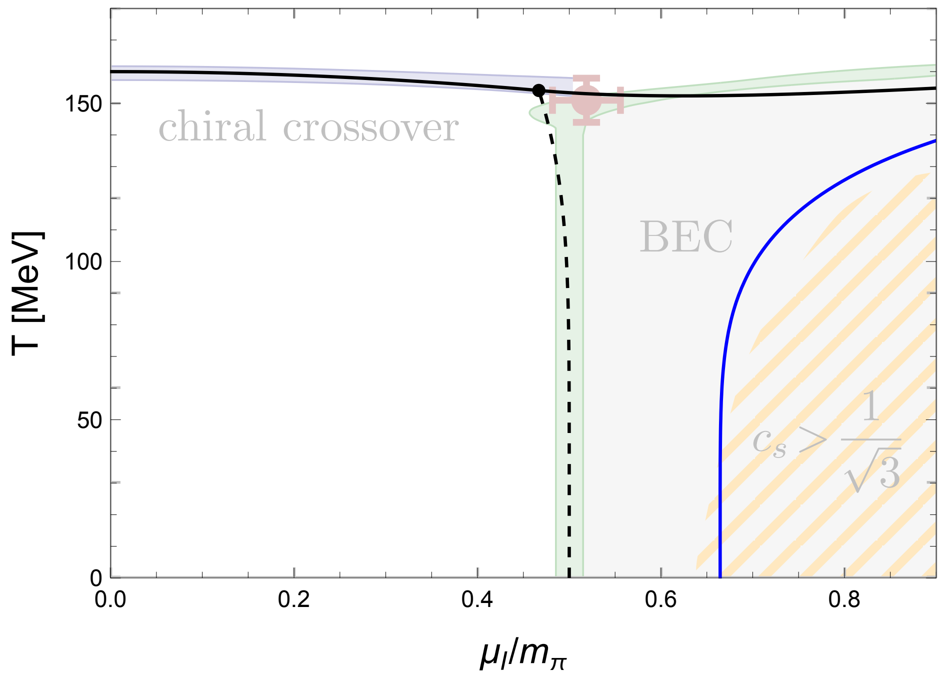
3. neutron stars (confined geometry)
   N. Kovensky, A. Poole, A. Schmitt, Phys. Rev. D 105, 034022 (2022)
   N. Kovensky, A. Poole and A. Schmitt, SciPost Phys. Proc. 6, 019 (2022)

Thermal pion condensation

N. Kovensky and A. Schmitt, work in progress

comparison to lattice QCD: B. B. Brandt, F. Cuteri and G. Endrődi, JHEP 07, 055 (2023)

parameters fitted to m_π, f_π, $T_c(\mu_I = 0)$



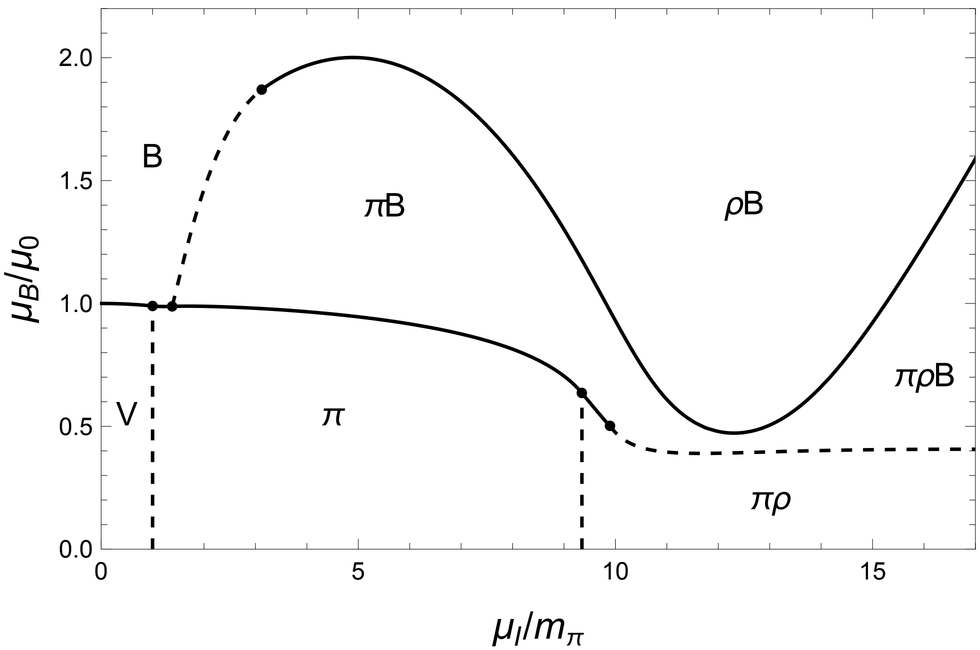
1st order chiral phase transition, 2nd order onset of pion condensation

speed of sound $c_s^2 > 1/3$ for large μ_I

Isospin-asymmetric (baryonic) matter at $T = 0$

N. Kovensky, A. Poole, A. Schmitt, SciPost Phys. 15, 162 (2023)

parameters fitted to m_π, m_ρ, f_π



no baryons at low μ_B

O. Aharony, K. Peeters, J. Sonnenschein and M. Zamaklar, JHEP 02, 071 (2008)

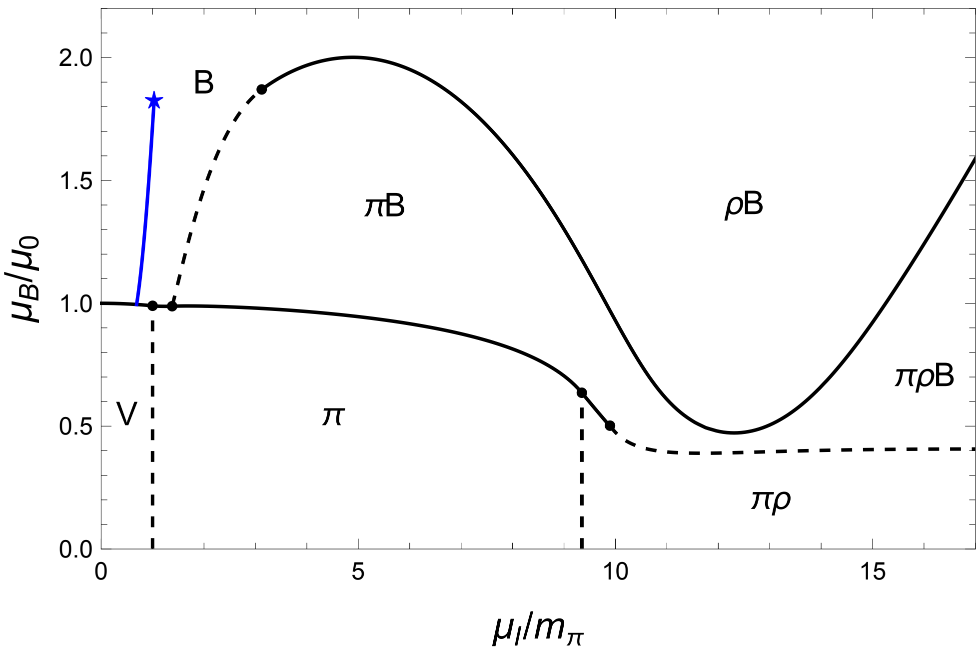
D. T. Son and M. A. Stephanov, PRL 86, 592-595 (2001)

effective pion mass increases in baryonic medium

Isospin-asymmetric (baryonic) matter at $T = 0$

N. Kovensky, A. Poole, A. Schmitt, SciPost Phys. 15, 162 (2023)

parameters fitted to m_π, m_ρ, f_π



no baryons at low μ_B

O. Aharony, K. Peeters, J. Sonnenschein and M. Zamaklar, JHEP 02, 071 (2008)

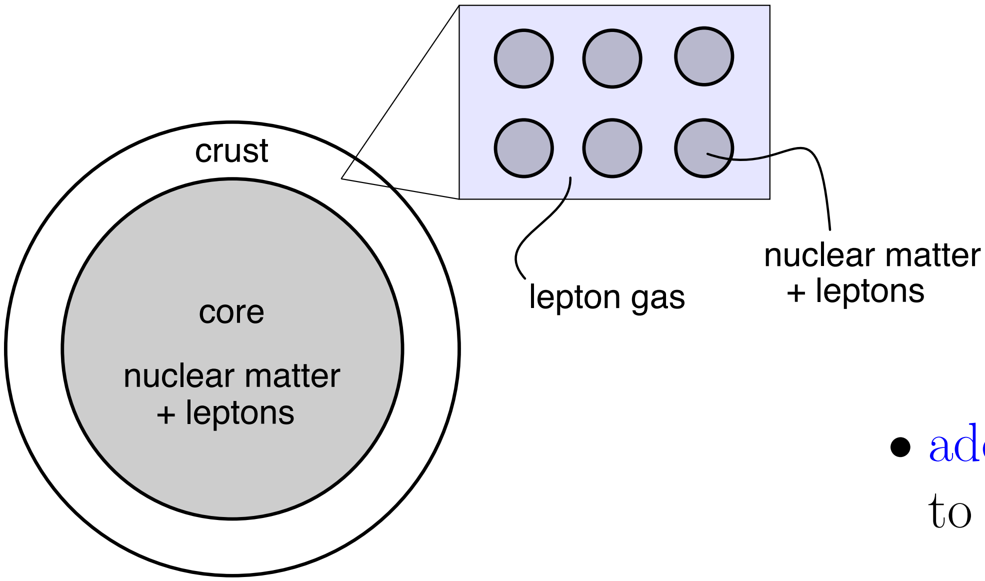
D. T. Son and M. A. Stephanov, PRL 86, 592-595 (2001)

β-equilibrium + charge neutrality

$\rightarrow$ no pion condensation in neutron stars

Building a neutron star from holography (page 1/2)

N. Kovensky, A. Poole, A. Schmitt, Phys. Rev. D 105, 034022 (2022)



- add leptons (electrons + muons) to holographic nuclear matter

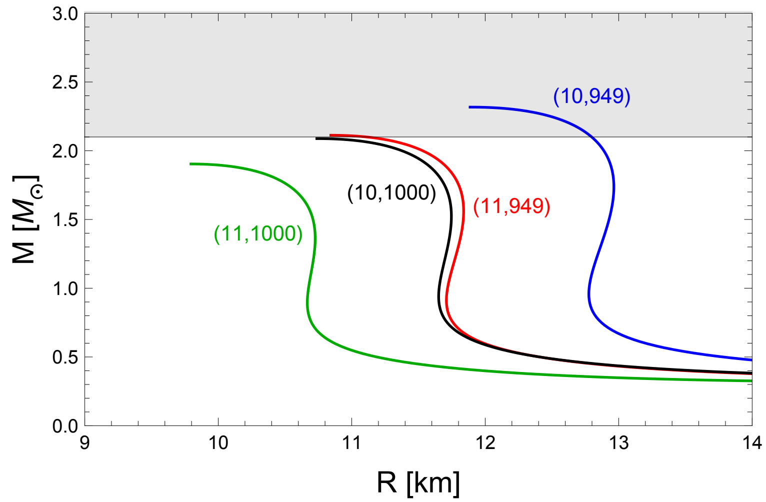
- construct uniform (locally neutral) and mixed (globally neutral) phases in β-equilibrium

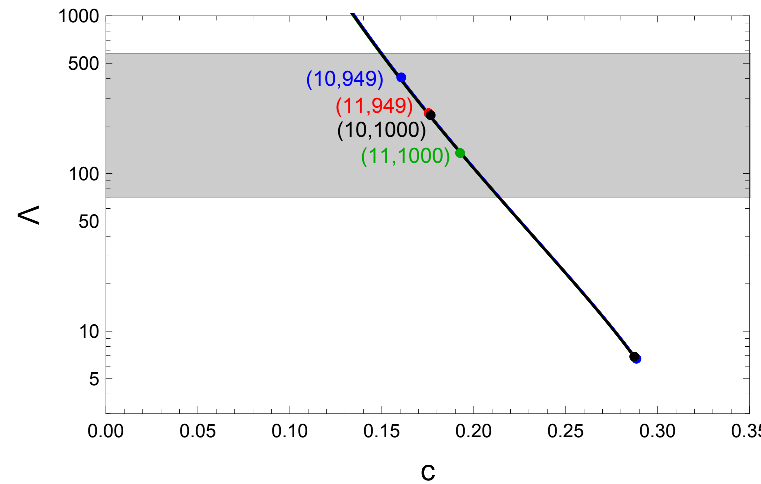
- use Wigner-Seitz approximation and step-like interfaces (surface tension Σ as input parameter)

dynamic calculation of clusters and crust-core transition

Building a neutron star from holography (page 2/2)

"holographic stars" meet astrophysical constraints for certain $(\lambda, M_{\mathrm{KK}})$





combine with astrophysical data for predictions

N. Kovensky, A. Poole and A. Schmitt, SciPost Phys. Proc. 6, 019 (2022)

	parameter independent		QCD window	
	lower bound	upper bound	lower bound	upper bound
$M_{\max}\,[M_\odot]$	(2.1)	2.46	2.11	2.40
$R_{1.4}\,[\mathrm{km}]$	11.9	(14.3)	12.4	14.1
$R_{2.1}\,[\mathrm{km}]$	(11.4)	13.7	(11.4)	13.7
$\Lambda_{1.4}$	277	(580)	286	(580)
$\Lambda_{2.1}$	9.13	49.3	10.1	43.7

Summary

- holographic Witten-Sakai-Sugimoto model gives a "QCD-like" theory with all necessary ingredients
  (chiral transition, baryons, pion condensation, ...)

- introducing isospin-asymmetric baryonic matter allows us to
  - study phase structure for finite μ_B, μ_I, T
  - construct neutron stars from a single model

Outlook

- improve holographic crust (pasta structures, inner crust, compute surface tension dynamically)
- include magnetic field
  pointlike baryons: F. Preis, A. Rebhan and A. Schmitt, JPG 39, 054006 (2012)
- include strangeness (kaon condensation, hyperons)
- holographic quark-hadron (quarkyonic-hadron) phase transition in neutron stars?
  quarkyonic matter: N. Kovensky and A. Schmitt, JHEP 09, 112 (2020)
- compute transport properties
  D3-D7 and VQCD: C. Hoyos *et al.*, PRD 105, 066014 (2022)