Hot and dense quark matter with a large number of colors and flavors

$N_c = N_f = 3$ is ”large”

K. Kajantie

Helsinki Institute of Physics

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Järvinen-Kiritsis 1112.1261

Alho - Järvinen - Kajantie - Kiritsis –Rosen-Tuominen
1210.4516, 1309.2286, 1312.5199

Basic problem: QCD equation of state, phase structure

$$p_{\rm phase}(T, \mu; N_c, N_f; m_u, m_d, m_s, ...)$$

What are the possible phases at fixed T, μ ?

What is the stable phase, one with largest p ?

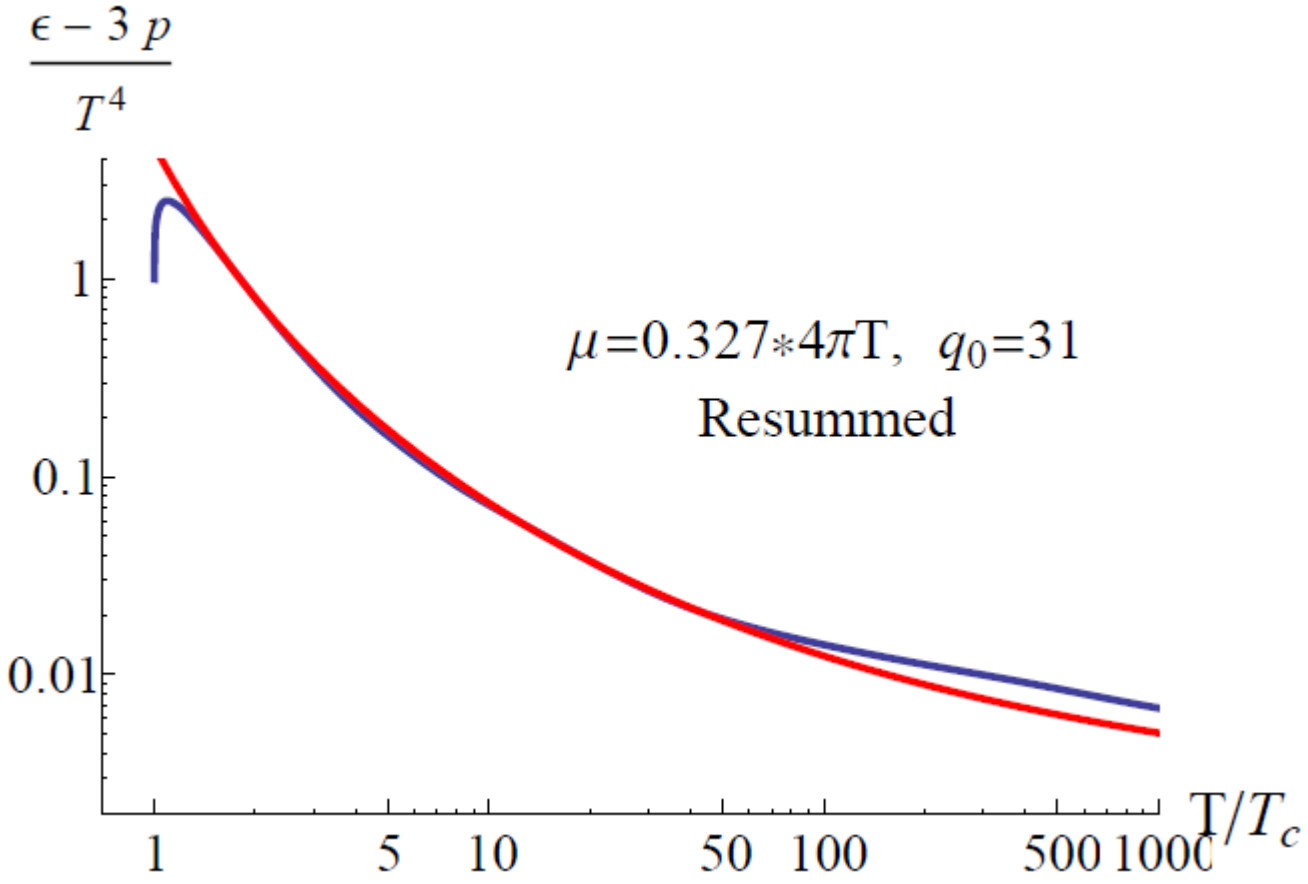
Approaches:

Phenomenologist: Hadrons dissolve into quarks and gluons

Lattice person: The 4dim configurations of SU(N) matrices in my computer change as a function of T, I need μ=0

Holographist: 5dim configurations minimising gravity action change, sometimes charged black holes dominate, sometimes those without horizon ~ T.

Perturbation theory is always a guaranteed method at large T



Precision SU(3) data from 1204.6184

Holography, gauge/gravity duality

Idea: you have solved a field theory when you can compute all Green's fns

Green's functions are known if the generating functional is known:

$$e^{-W(\phi(x))} = \int \mathcal{D}\psi\, e^{-S(\psi)-\phi(x)O(\psi(x))} \equiv \langle e^{-\phi(x)\,O}\rangle$$

Holography claims that for large g^2N_c, N_c

$$\langle e^{-\phi(x)\,O}\rangle = e^{-S_{\rm grav}[\phi(x,z)]}$$

z=5th dim

For QCD $$\phi(x)O(x) \to \frac{1}{\lambda(z)}F^2_{\mu\nu}(x,z) + \tau(z)\langle\bar{q}q\rangle + A_0(z)\langle\bar{q}\gamma_0 q\rangle + ..$$

Building blocks

$$ds^2 = b^2(z)\left[-f(z)dt^2 + d\mathbf{x}^2 + \frac{dz^2}{f(z)}\right] \quad \lambda(z) \quad \tau(z) \quad A_0(z)$$

are solved from the action

Λ_{QCD} = integration constant

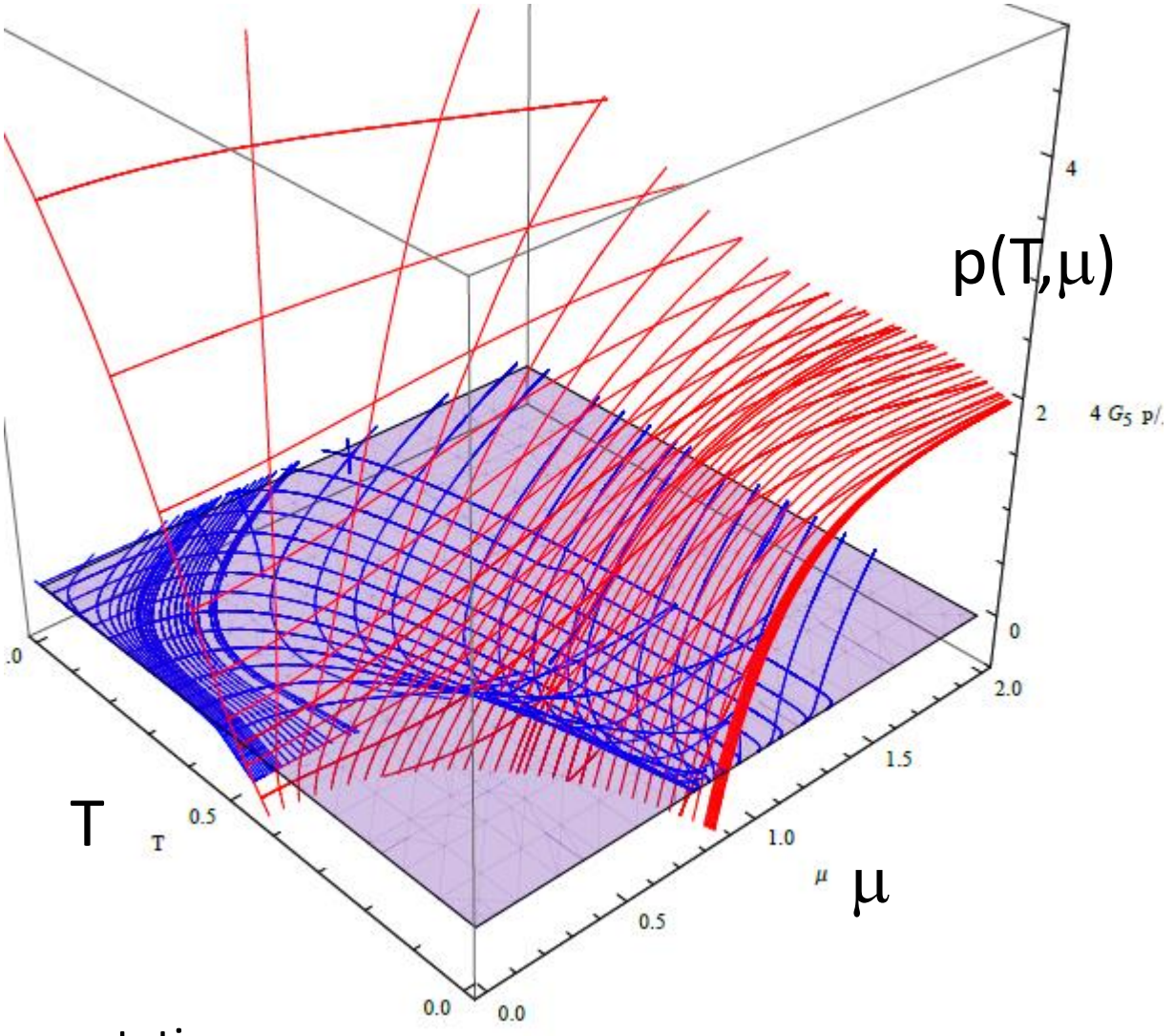
$$S = \frac{1}{16\pi G_5}\int d^5x\,\sqrt{-g}\,\left[R - \tfrac{4}{3}(\partial_z\phi)^2 + V_g(\phi) - V_f(\phi,\tau)\sqrt{1+(\partial_z\tau)^2+(\partial_z A_0)^2}\right]$$

Thermodynamics is that of 5d AdS charged black holes

V_g, V_f constrained by physical input: mass spectrum,...

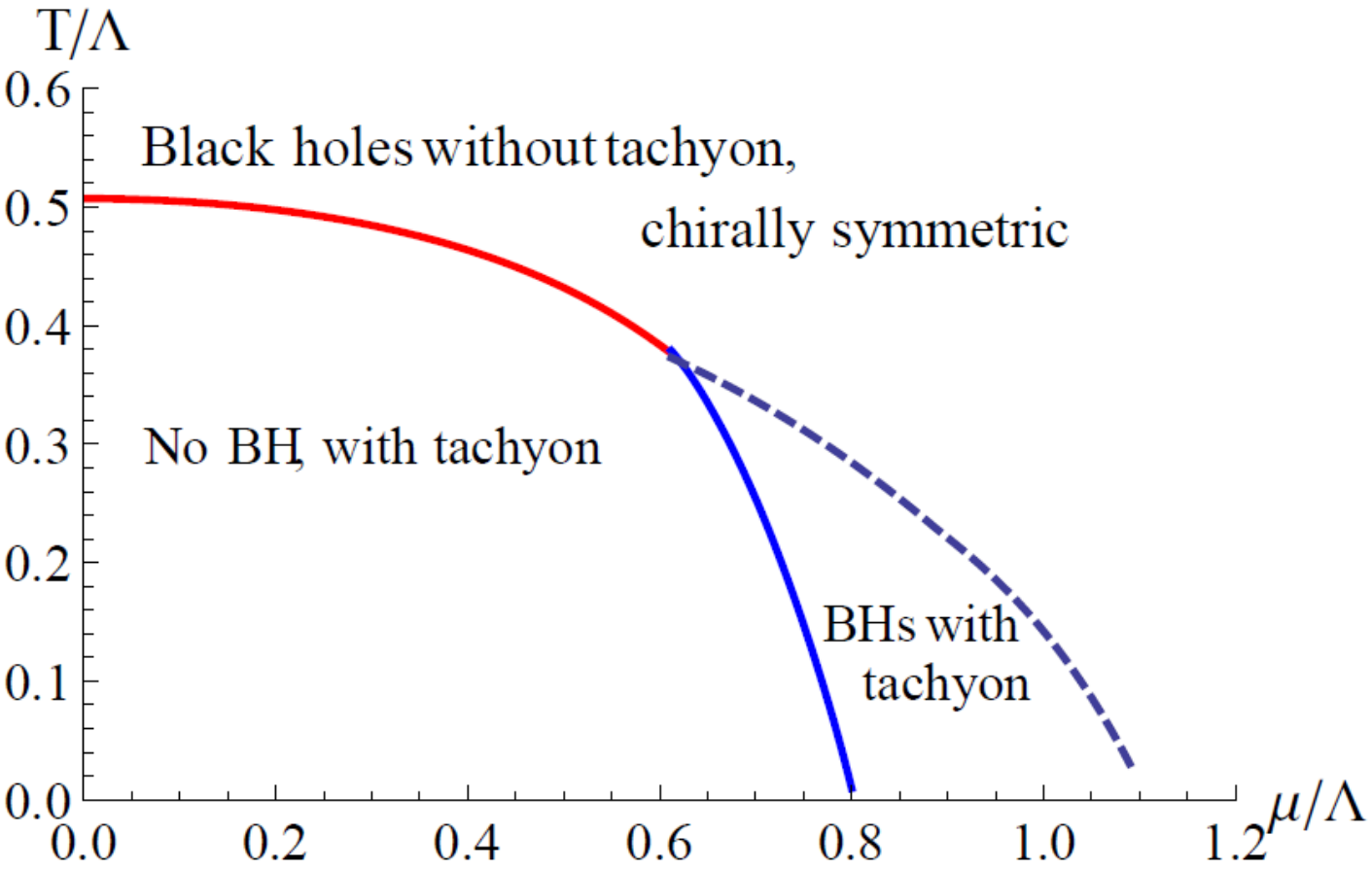
Timo Alho: Numerical code for thermodynamics of holographic V-QCD
https://github.com/timoalho/VQCDThermo (Mathematica code)

p(T,μ) for different phases:



Numerical effort ~
Gflop year; lattice computation
at μ=0 ~ Tflop year

Phase diagram for set of a potentials fitting mass spectrum:



Conclusions

I find it remarkable that a 5dim gravity scheme can produce 4dim thermo with physical properties

Goal: see whether including all properties of QCD, mass spectrum, thermo, anomalies, baryons,....at all energy scales would completely constrain the model