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The cool potential of gluons

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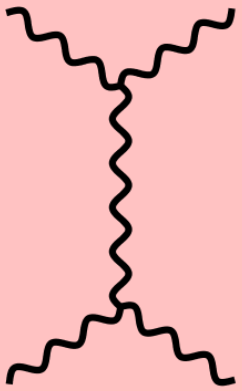
Gluon chemical potential

QGP equilibration described by QCD Boltzmann eqn $\mathcal{D}f = C[f]$

elastic scatterings

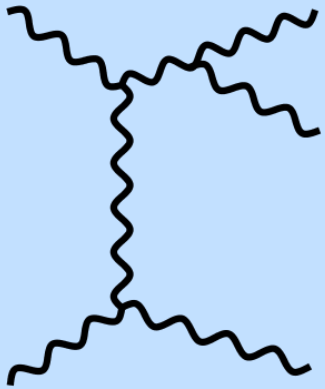


- gluon number conserved

$$\Delta n = 0\,, \quad \mu \neq 0$$

- $\mathcal{O}(\alpha^2)$ … **"fast"** (… ?)

inelastic scatterings



- gluon number not conserved

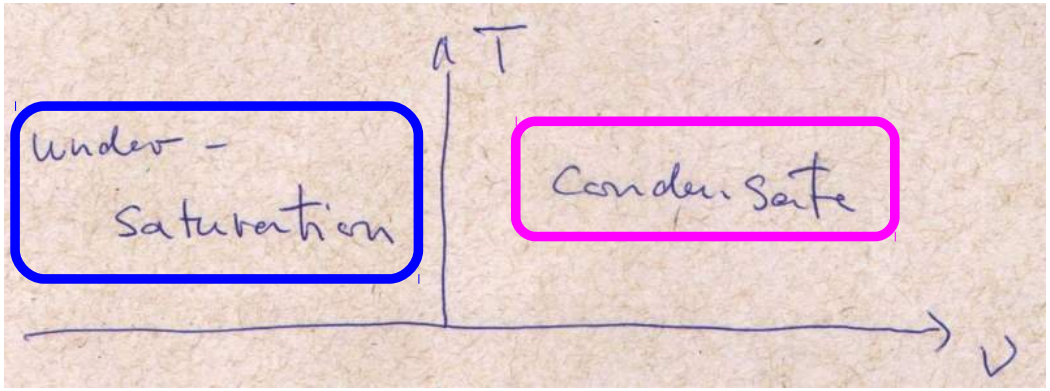
$$\Delta n \neq 0\,, \quad \mu \equiv 0$$

- *formally* higher order … **"slow"** (..?)

possible time window: transient equilibrium with $\mu \neq 0$

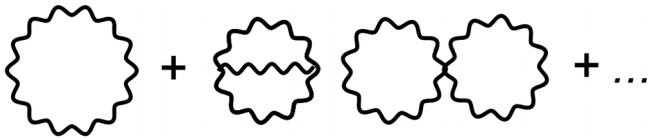
Perturbative view: gluon mass $m = 0$

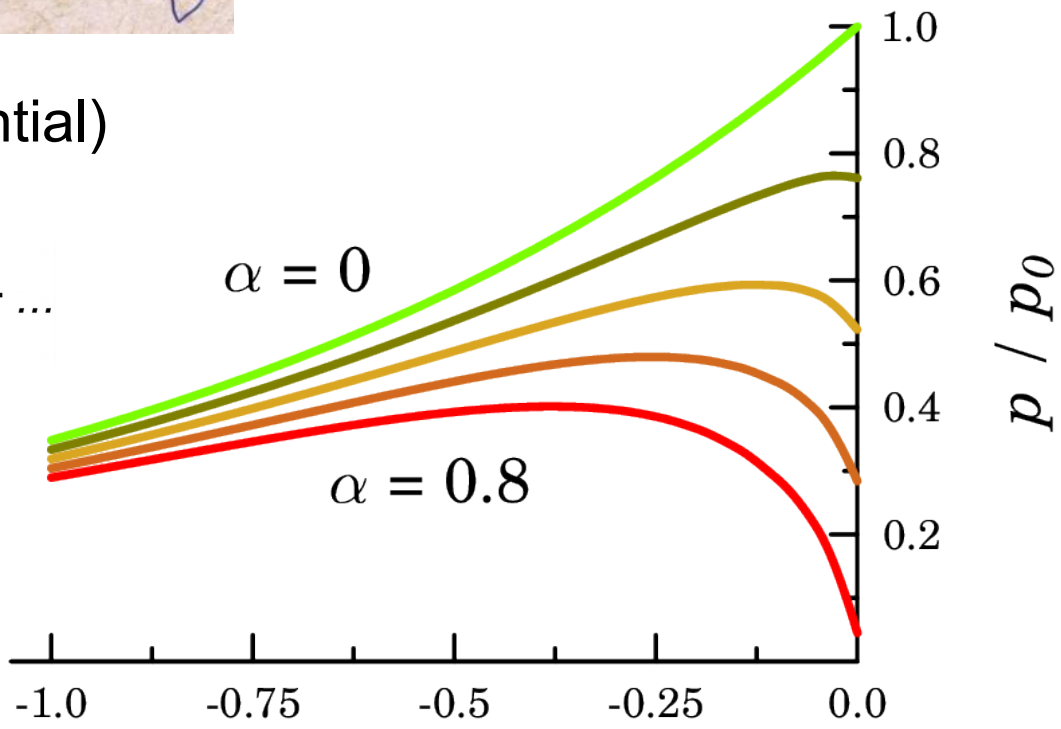
gluon distribution function $f(k) = \left[e^{(k-\mu)/T} - 1\right]^{-1} + n_c \delta(k)$



$$\nu = \begin{cases} \mu & (\leq 0) \\ n_c^{1/3} \end{cases}$$

pressure (= thermodynamic potential)

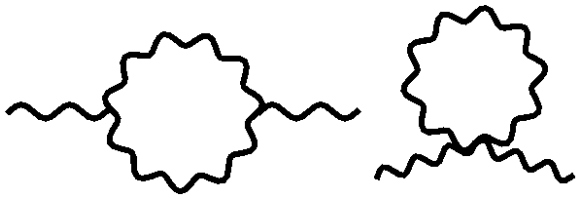
$p(T, \nu) =$  $+ \ldots$



QCD quasiparticles @ $\mu = 0$

[AP et al, PRD 1996]

gluon self-energy

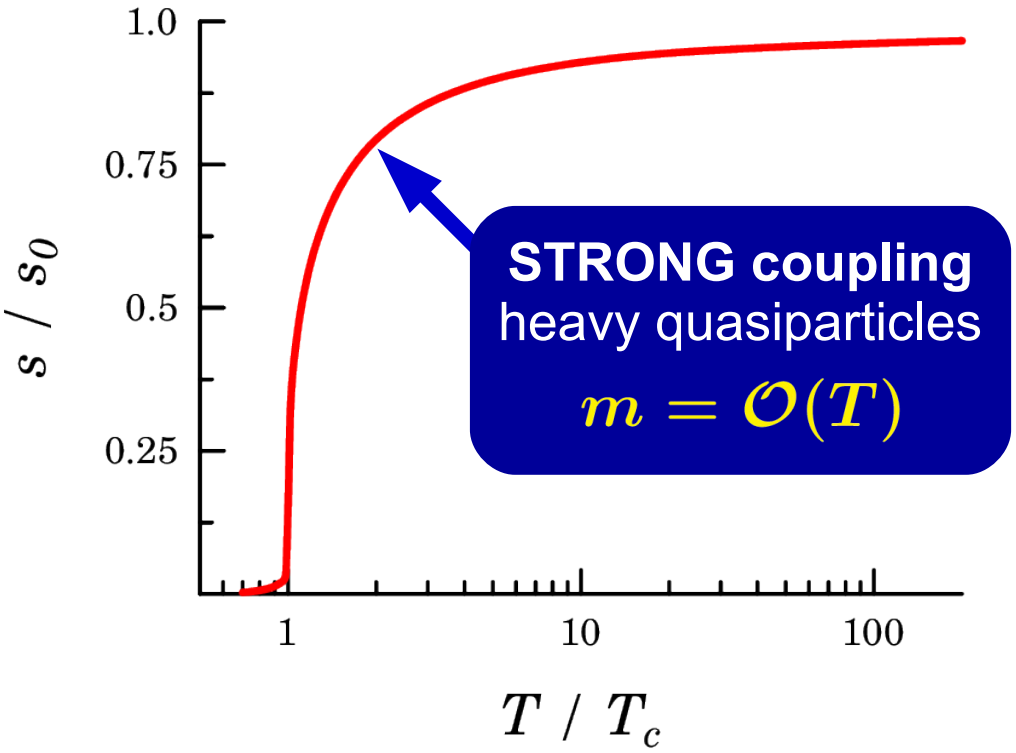


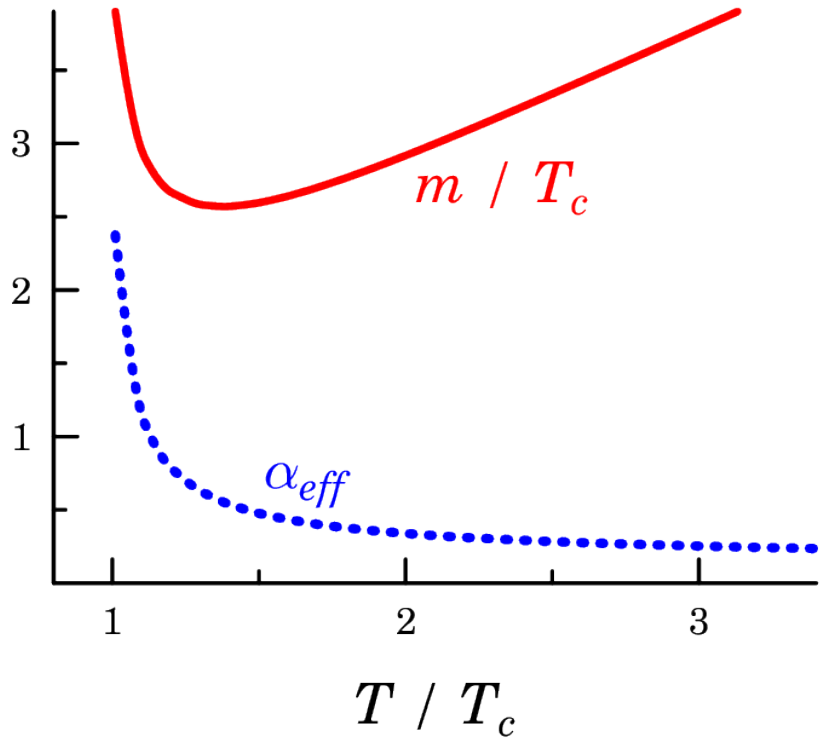
$$m \sim gT$$

$$g^2(T) \sim 1/\ln(T^2/\Lambda^2)$$

quasiparticle model

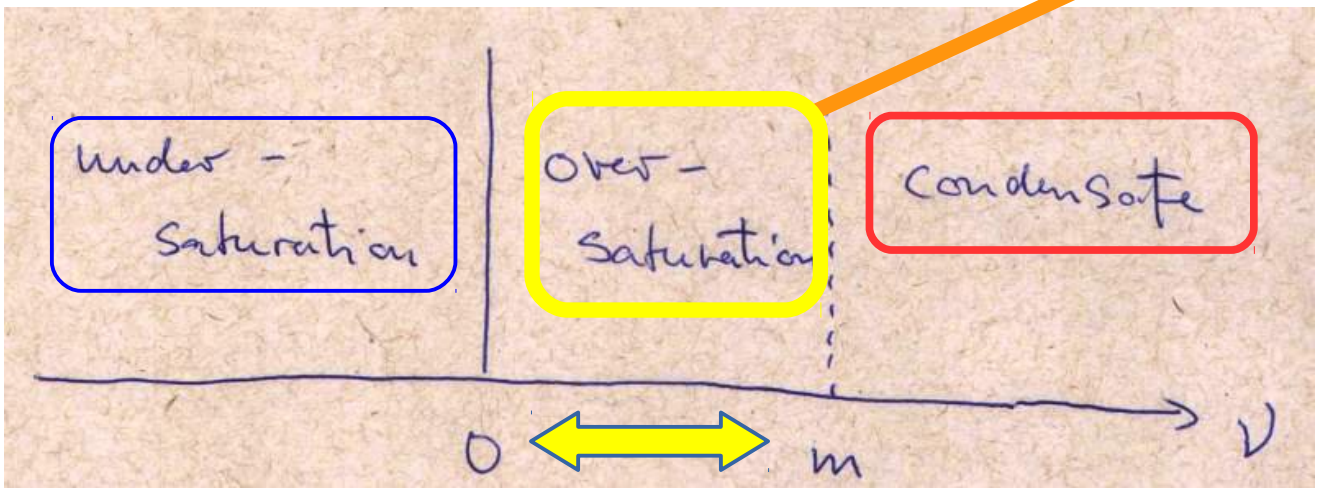
$$s(T) = s_{QP}(T, m(T)) \propto T^3 \begin{cases} 1 - \#g^2 + \dots \\ e^{-m/T} \end{cases}$$

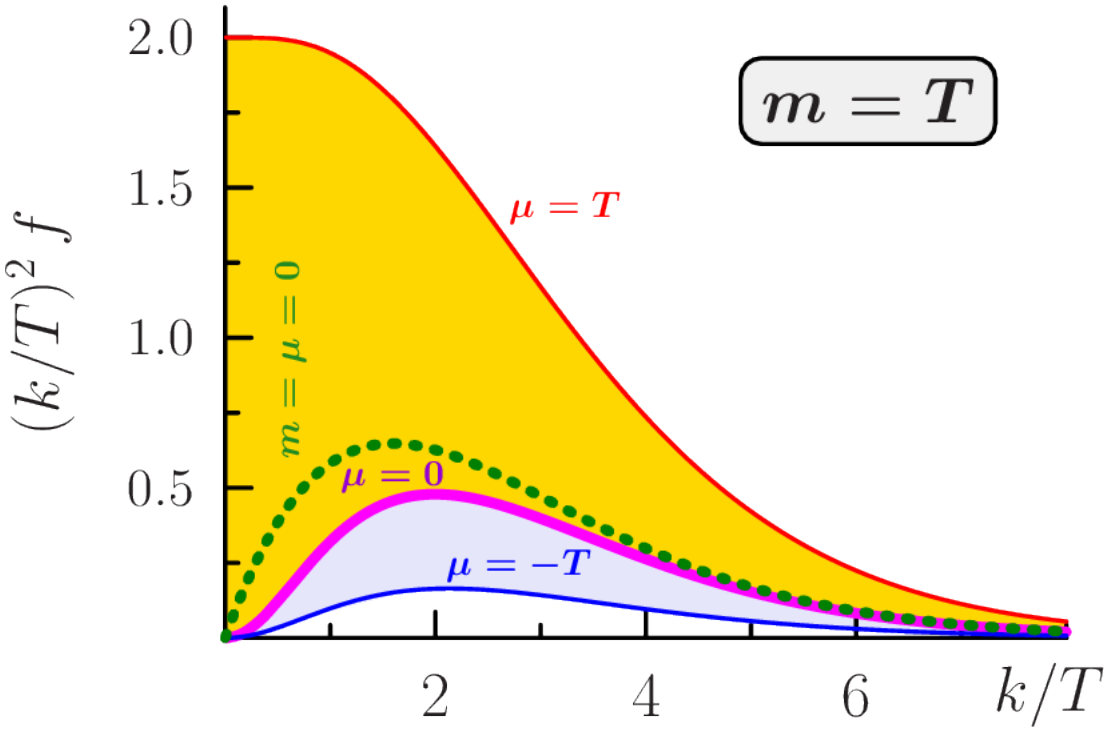




$\mu \leq m$: **massive** effects*!*

transient/apparent equilibrium
for over-populated initial CGC





Bose function: $\dfrac{1}{e^x - 1} \to \dfrac{1}{x}$

$$\frac{\sqrt{k^2 - m^2} - \mu}{T} \to \begin{cases} k/T \\ \dfrac{k^2}{2mT} + \cdots \end{cases}$$

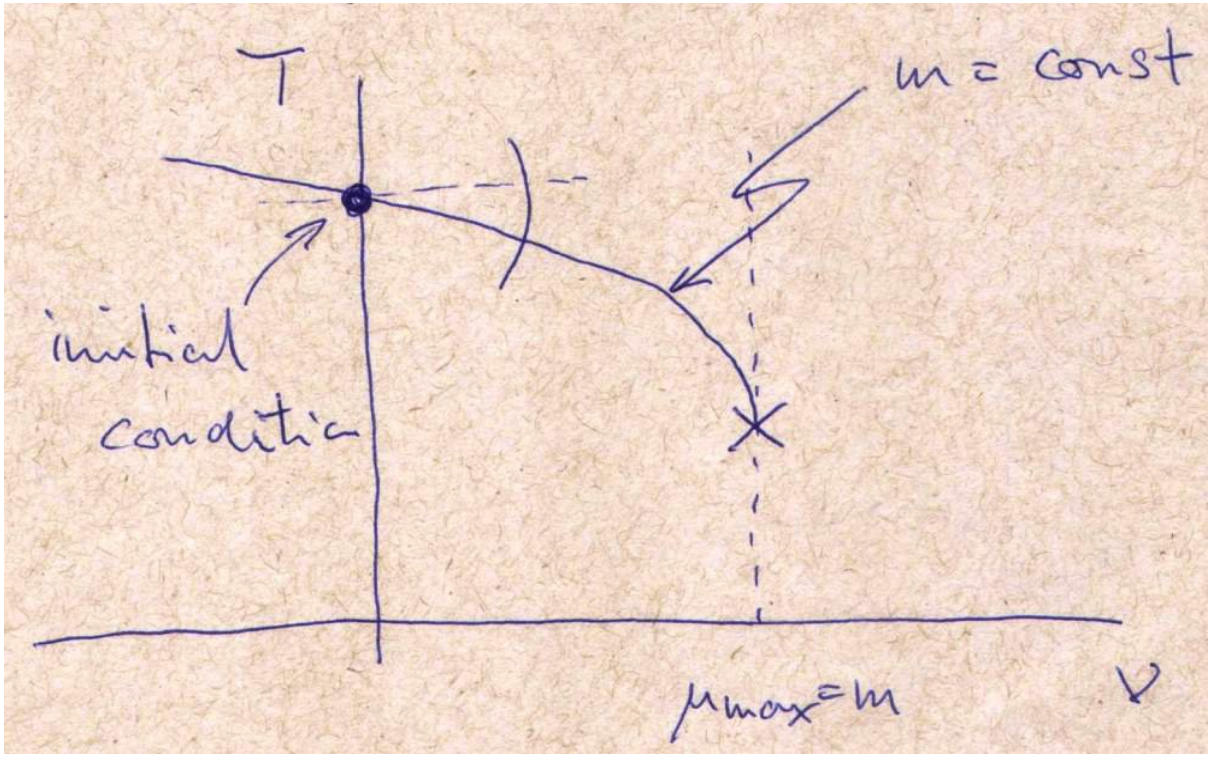
Getting quantitative: Maxwell flow

[AP, D Giovannoni, tbp]

Maxwell relation $\dfrac{\partial s}{\partial \mu} = \dfrac{\partial n}{\partial T}$ $\qquad s = \dfrac{\partial p}{\partial T}, \quad n = \dfrac{\partial p}{\partial \mu}$

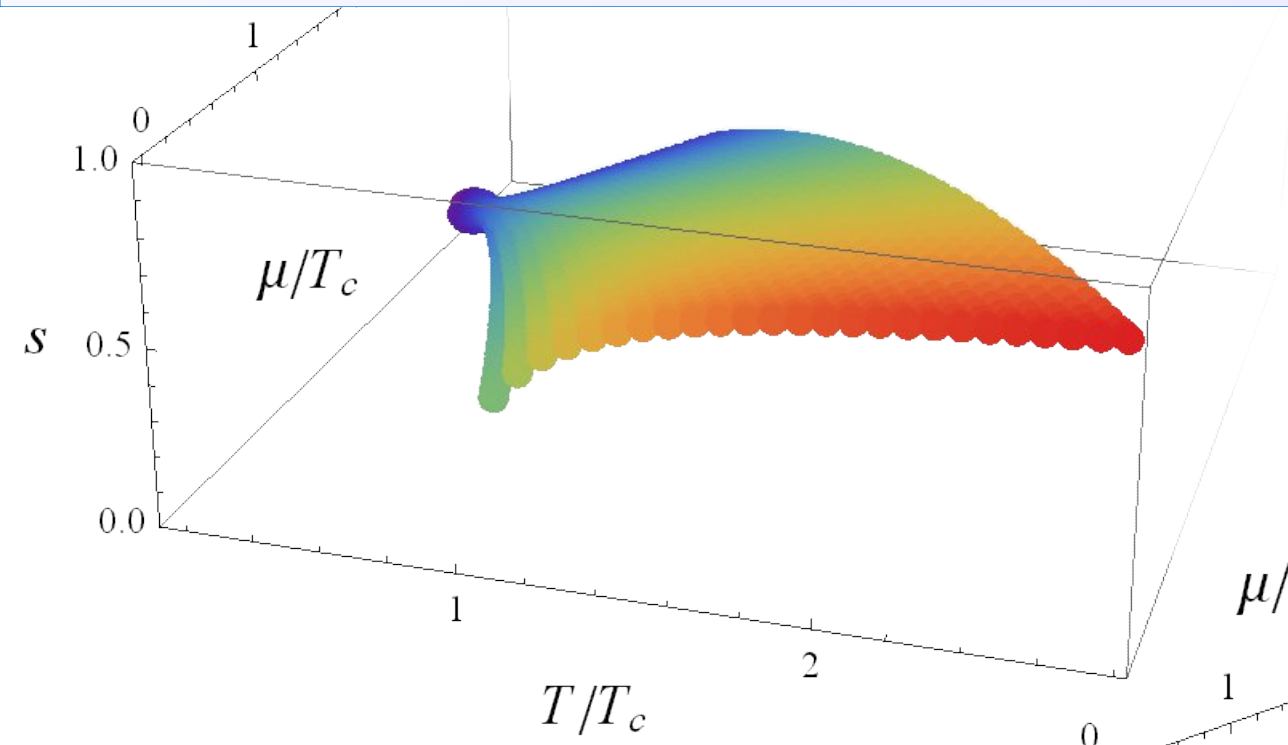
$s_{QP}\left(T, \mu, m^2(T,\mu)\right)$ (similar for number density)

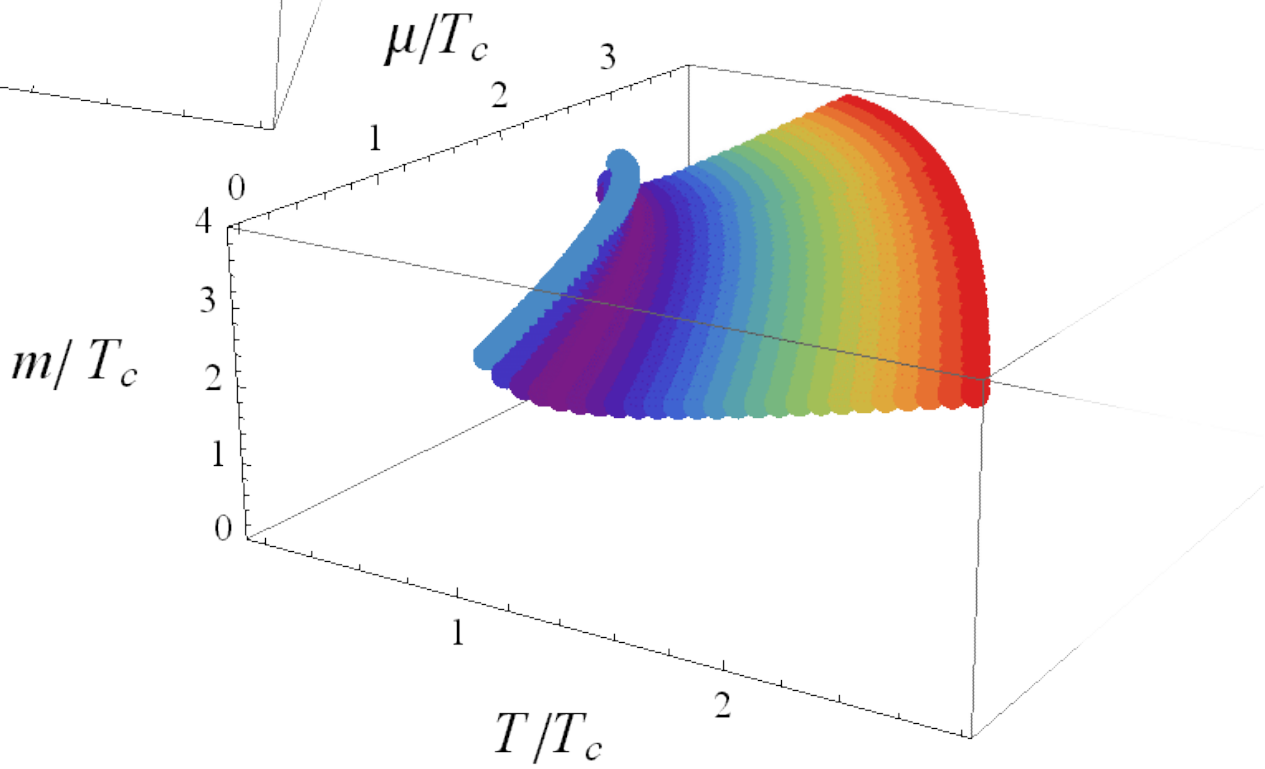
flow equation for $m^2(T,\mu)$ $\qquad \dfrac{\partial m^2}{\partial \mu} + A\left(T, \mu, m^2(\bullet,\bullet)\right)\dfrac{\partial m^2}{\partial T} = 0 \cdot m^2$



Over-saturation thermodynamics

[AP, D Giovannoni, tbp]





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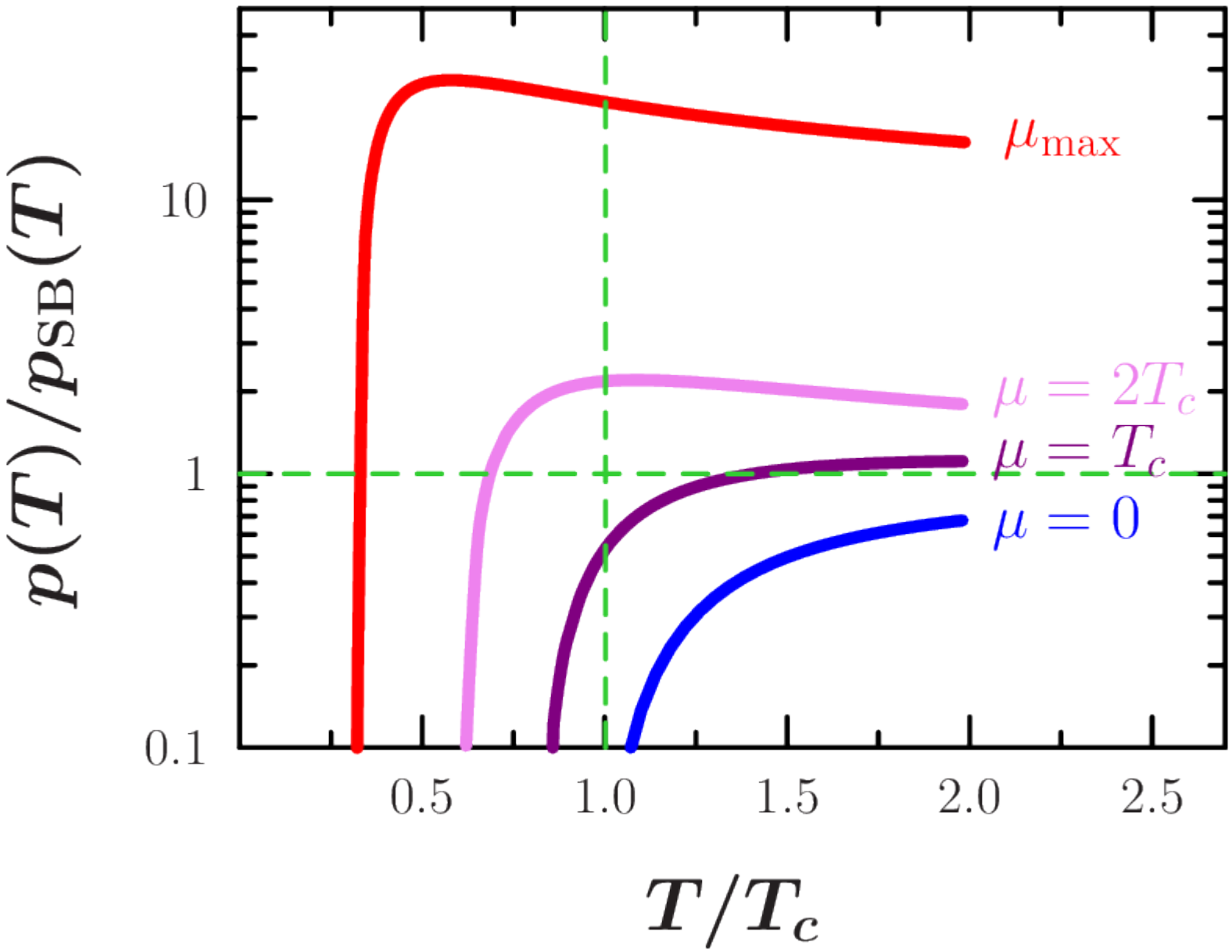
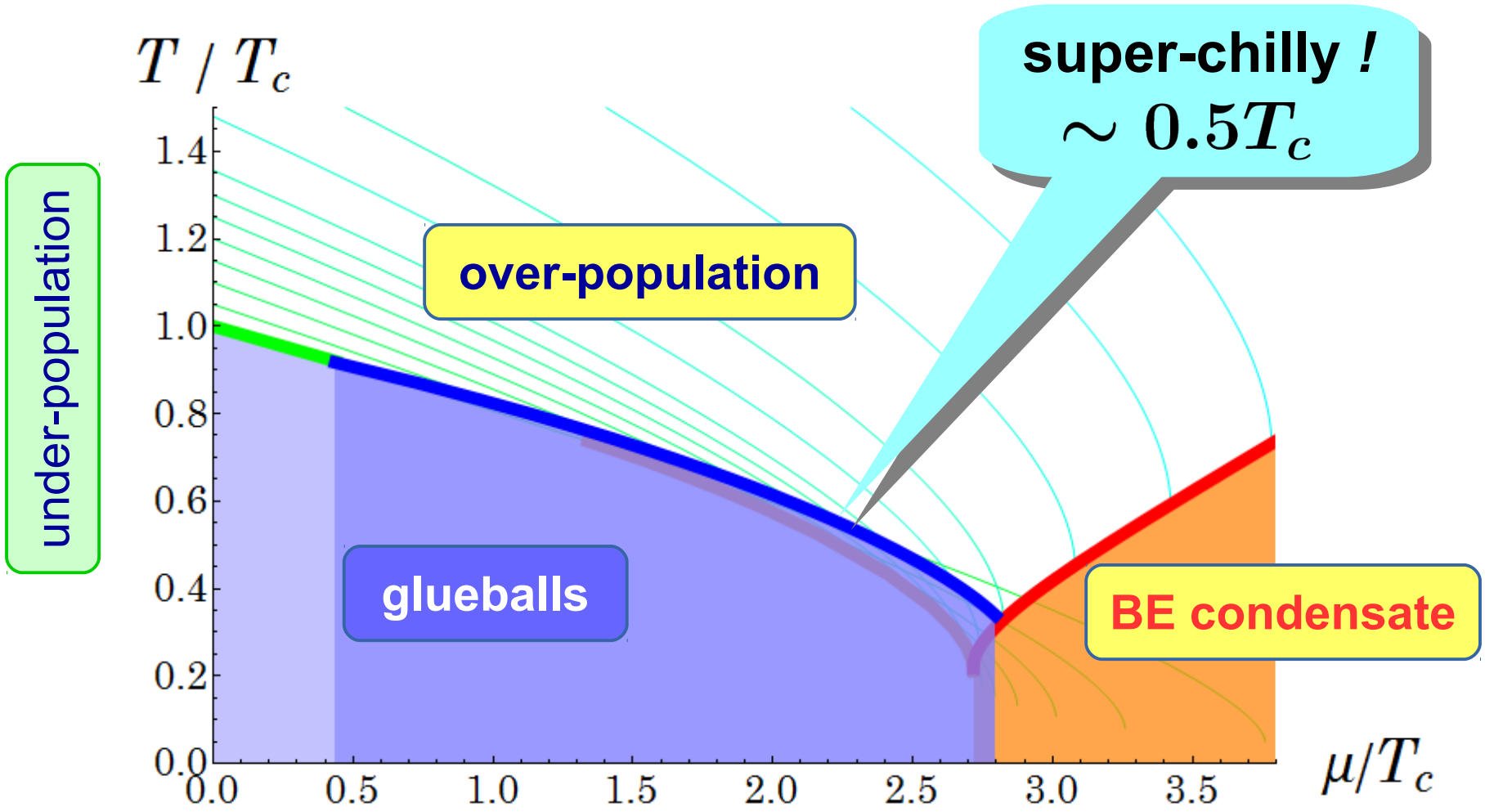


Phase diagram of gluon plasma

[AP, D Giovannoni, tbp]



Summary

<u>if elastic gluon scatterings are sufficiently effective:</u>

- (Q)GP approaches *transient equilibrium* with **gluons over-populated and/or Bose-condensed**
- **super-chilly** QGP exists below "T_c" … perhaps down to **100 MeV**