Temperature dependence of shear viscosity in SU(3)-gluodynamics

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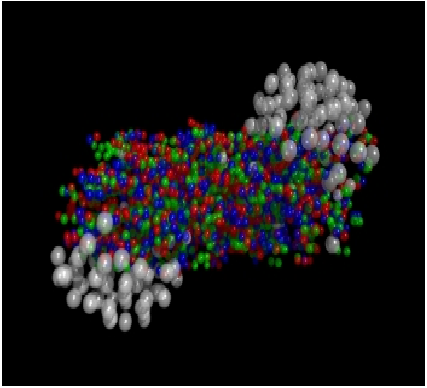
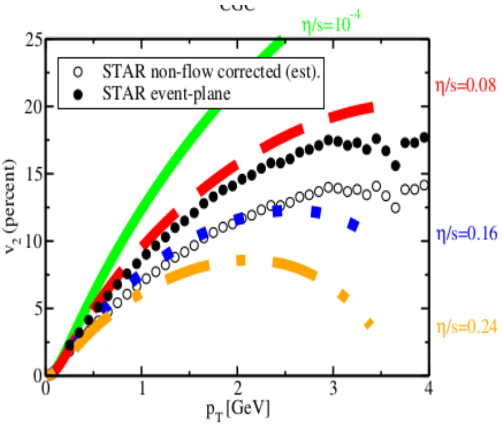


Hydrodynamical description of distribution of final particles

- One heavy ion collision produces a huge number of final particles
- Large number of paticles $\Rightarrow$ hydrodynamical description can be used
- In hydrodynamics transport coefficients control flow of energy, momentum, electrical charge and other quantities

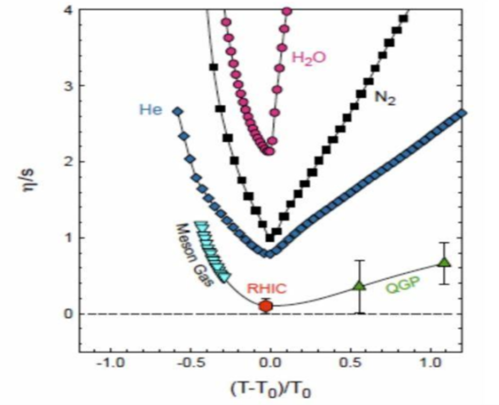


Elliptic flow at STAR (Nucl. Phys. A 757, 102 (2005))

$\frac{dN}{d\phi} \sim (1 + 2v_1 cos(\phi) + 2v_2 cos^2(\phi))$, ϕ-scattering angle

QGP close to ideal liquid ($\frac{\eta}{s} = (1-3)\frac{1}{4\pi}$)

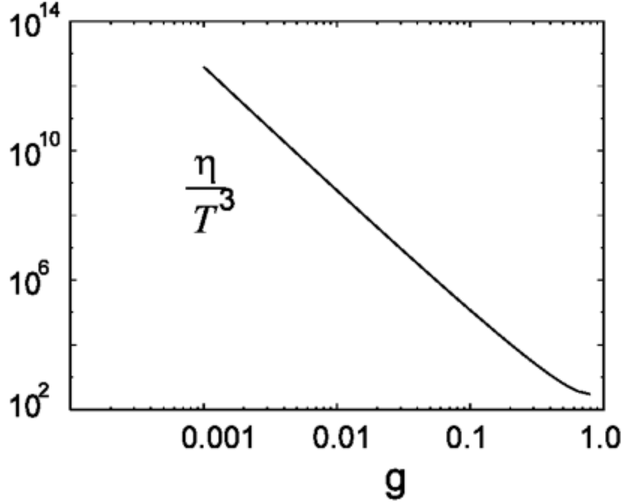
M. Luzum and P. Romatschke, Phys. Rev. C 78, 034915 (2008)



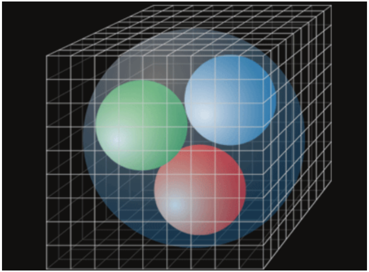
Comparison of different liquids

QGP the most superfluid liquid

The aim: first principle calculation of transport coefficients



Viscosity is small, this means that the plasma is strong-interacting.



Lattice simulation of QCD

- Allows to study strongly interacting systems
- Based on the first principles of quantum field theory
- Acknowledged approach to study QCD
- Very powerful due to the development of computer systems

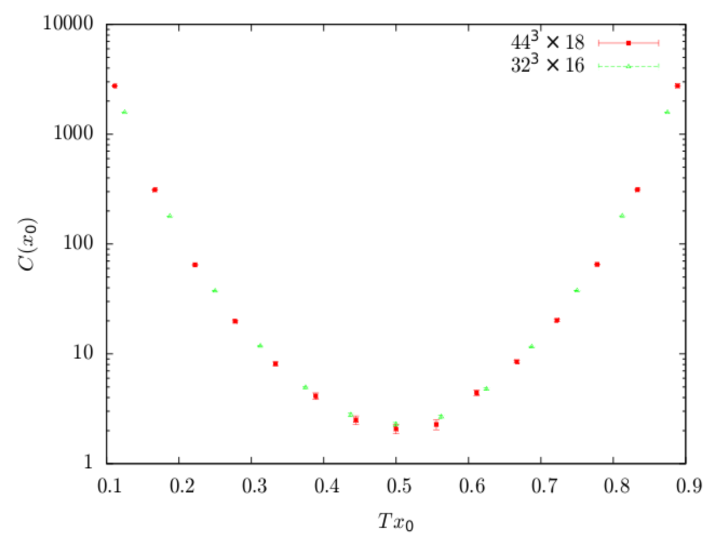
Shear viscosity and lattice calculations

- Lattice measurement of the Euclidean correlator $C(t) = \langle T_{12}(t) T_{12}(0) \rangle$
- Calculation of spectral density $\rho(\omega)$ from the correlator $C(t) = T^5 \int_0^\infty d\omega \rho(\omega) \frac{ch\left(\frac{\omega}{2T} - \omega t\right)}{sh\left(\frac{\omega}{2T}\right)}$
  In the hydrodynamical approximation $\rho(\omega)|_{\omega\to 0} \sim \frac{\eta}{\pi}\omega$
- Calculation of viscosity $\eta = \pi \lim_{\omega\to 0} \frac{\rho(\omega)}{\omega}$

Details of the calculation

- SU(3) gluodynamics
- Two level algorithm for generation of gauge field configurations
- Lattices $32^3 \times 16$

Correlation function



Determination of the spectral function

$$C(t) = T^5 \int_0^\infty d\omega \rho(\omega) \frac{ch\left(\frac{\omega}{2T} - \omega t\right)}{sh\left(\frac{\omega}{2T}\right)}$$

Properties of the spectral density:

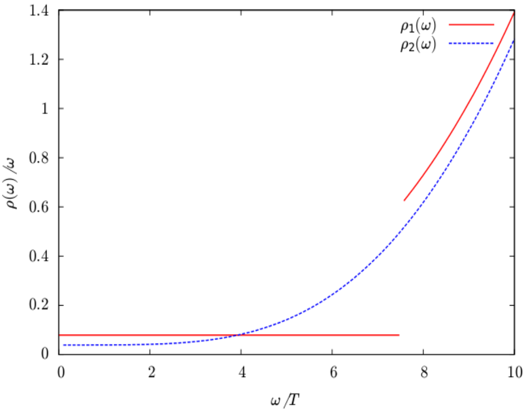
- $\rho(\omega) \geq 0$, $\rho(-\omega) = -\rho(\omega)$
- Asymptotic freedom: $\rho(\omega)|^{NLO}_{\omega \to \infty} = \frac{1}{10} \frac{d_A}{(4\pi)^2} \omega^4 \left(1 - \frac{5 N_c \alpha_s}{9\pi}\right)$

  7/8 of the total contribution at the point $t = \frac{1}{2T}$
- Hydrodynamics: $\rho(\omega)|_{\omega \to 0} = \frac{\eta}{\pi} \omega$

Ansatz for the spectral density

$$\rho(\omega) = \frac{\eta}{\pi}\omega\theta(\omega_0 - \omega) + \theta(\omega - \omega_0)A\rho_{asym}(\omega)$$

$$\rho(\omega) = \frac{\eta}{\pi}\omega + \text{th}^2\,\frac{\omega}{\omega_0}A\rho_{asym}(\omega)$$



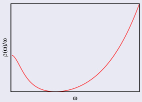
Ansatz for the spectral density

$$\rho(\omega) = \frac{\eta}{\pi}\omega\theta(\omega_0 - \omega) + \theta(\omega - \omega_0)A\rho_{asym}(\omega)$$

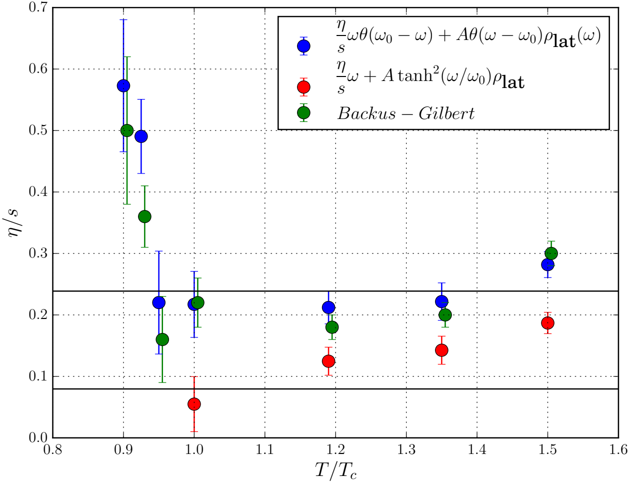
$$\rho(\omega) = \frac{\eta}{\pi}\omega + \mathrm{th}^2\,\frac{\omega}{\omega_0}A\rho_{asym}(\omega)$$

Other variants

- $\mathrm{th}^2\,\omega/\omega_0 \rightarrow \sum A_k\,\mathrm{th}^{2k}\,\omega/\omega_0$ ✓
- Transport peak ✗ $\rightarrow$ Strong Interaction
- Backus-Gilbert method ✓

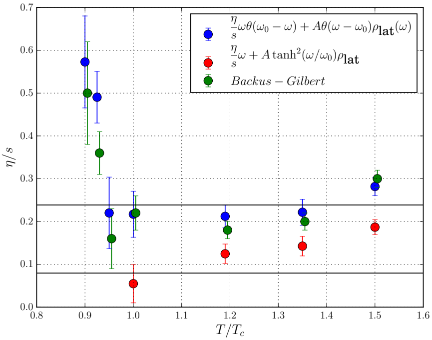


η/s versus T, $SU(3)$ gluodynamics



The results of the calculation ($T/T_c = 1.2$)

- $\frac{\eta}{s} = 0.178 \pm 0.06$ (V.V. Braguta et. el.)
- $\frac{\eta}{s} = \frac{1}{4\pi} \simeq 0.08$ N=4 SYM $\lambda = \infty$ (Phys. Rev. Lett. 87 (2001) 081601)
- $\frac{\eta}{s} = (1-3)\frac{1}{4\pi} \simeq 0.08 - 0.24$ Experiment (Phys. Rev. C 78, 034915 (2008)
- $\frac{\eta}{s} \sim 2$ Perturbative result (JHEP 11 (2000) 001)
- $\frac{\eta}{s} = 0.102 \pm 0.056$ (Phys.Rev. D76 (2007) 101701)



Conclusion

- Lattice calculation of viscosity in $SU(3)$ gluodynamics was performed
- The result of the calculation is in agreement with heavy ion collisions
- QGP is strongly correlated system which is close to SYM and far from to weakly interacting plasma