# Heavy quark momentum diffusion coefficient during hydrodynamization

Jarkko Peuron(Lund University)

In collaboration with:
T. Lappi (University of Jyväskylä)
A. Kurkela (University of Stavanger)
K. Boguslavski (Vienna University of Technology)

April 8th 2022

LUND UNIVERSITY

QUARK MATTER KRAKÓW 2022

# Motivation: heavy quarks

- Previously: Heavy quark diffusion in the glasma: K. Boguslavski, A. Kurkela, T. Lappi, JP: JHEP 09 (2020) 077.
- Created at initial hard processes. No thermal pair production or annihilation → sensitive to pre-equilibrium.
- Also: heavy quark diffusion coefficient $\kappa$ important for quarkonium evolution.
- Example: PRD 100 (2019) 5, 054025 - modelling quarkonia using open quantum systems approach. Heavy quark diffusion coefficient enters the Lindblad equation as a parameter.

# Bottom up thermalization & heavy quark diffusion

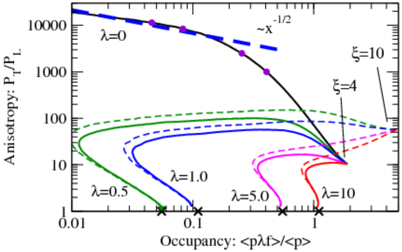



Figure: Kurkela & Zhu, Phys.Rev.Lett. 115 (2015) 18, 182301

Questions:

- Hydrodynamization: how $\kappa$ approaches equilibrium?
- Is $\kappa \gg \kappa_{eq}$ or $\kappa \ll \kappa_{eq}$ during hydrodynamization?
- How to compare equilibrium & nonequilibrium?

Methods:

- Effective kinetic theory (AMY) simulations, IC á la Kurkela & Zhu
- Compare with thermal system matching $\epsilon, m_D, T_* \rightarrow \kappa^{\epsilon, m_D, T_*}$

# Methods: Heavy quark diffusion (PRC 71 (2005) 064904) )

In the EKT $\kappa$ is given by ($gq \to gq$, t-channel gluon exchange):

$$\kappa = \frac{\langle \Delta k^2 \rangle}{\Delta t} = \frac{1}{6M} \int \frac{\mathrm{d}^3\boldsymbol{k}\,\mathrm{d}^3\boldsymbol{q}}{(2\pi)^6\, 8|\boldsymbol{k}||\boldsymbol{k}+\boldsymbol{q}|M} 2\pi\delta(|\boldsymbol{k}+\boldsymbol{q}| - |\boldsymbol{k}|) \times \boldsymbol{q}^2 |\mathscr{M}|^2_{\text{gluon}} f(k)(1+f(|\boldsymbol{k}+\boldsymbol{q}|)) \tag{1}$$

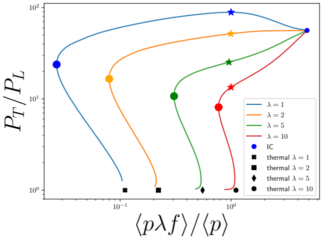
$k, k'$ gluon momenta, $q = k - k'$, $p, p'$ heavy quark momenta.

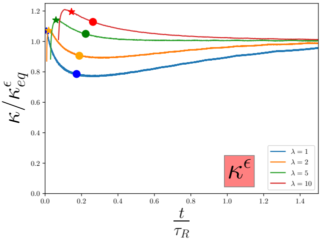
$$|\mathscr{M}|^2_{\text{gluon}} = \left[N_c C_H g^4\right] \frac{16M^2k^2\left(1+\cos^2\theta_{\boldsymbol{k}\boldsymbol{k}'}\right)}{(q^2+m_D^2)^2} \tag{2}$$

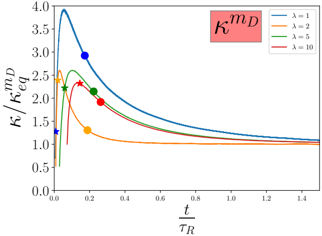
Equilibrium: use thermal distribution:

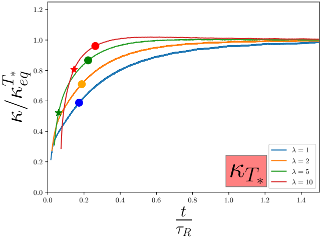
$$T_* = \frac{2\lambda}{m_D}\int \frac{\mathrm{d}^3 p}{(2\pi)^3} f(p)(1+f(p)), m_D^2 = 4\int \frac{\mathrm{d}^3 p}{(2\pi)^3}\frac{\lambda f(p)}{p}, T_\epsilon \sim \sqrt[4]{\epsilon}. \tag{3}$$

# Diffusion coefficient $\kappa$: approach to thermal (preliminary)




$$\tau_R = \frac{4\pi\eta/s(\lambda)}{T_\epsilon}$$

# Conclusions

We have

- Compared heavy quark diffusion coefficient $\kappa$ during bottom-up isotropization to its thermal value, matching $m_D, T_*, \epsilon$. Best match achieved with $\epsilon$. At later times matching $T_*$ also works. We observe no large deviations from thermal value.

Future plans:

- Near future: study $\kappa_\perp$ and $\kappa_z$ separately.
- Precision comparison of EKT and CYM (K. Boguslavski).
- Shear viscosity in overoccupied phase (P. Singh)

See also (Wednesday poster session):

- F. Lindenbauer: $\hat{q}$ using EKT
- D. Schuh: Momentum broadening in the glasma