Heavy-quark diffusion coefficient in out-of-equilibrium plasmas

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Introduction

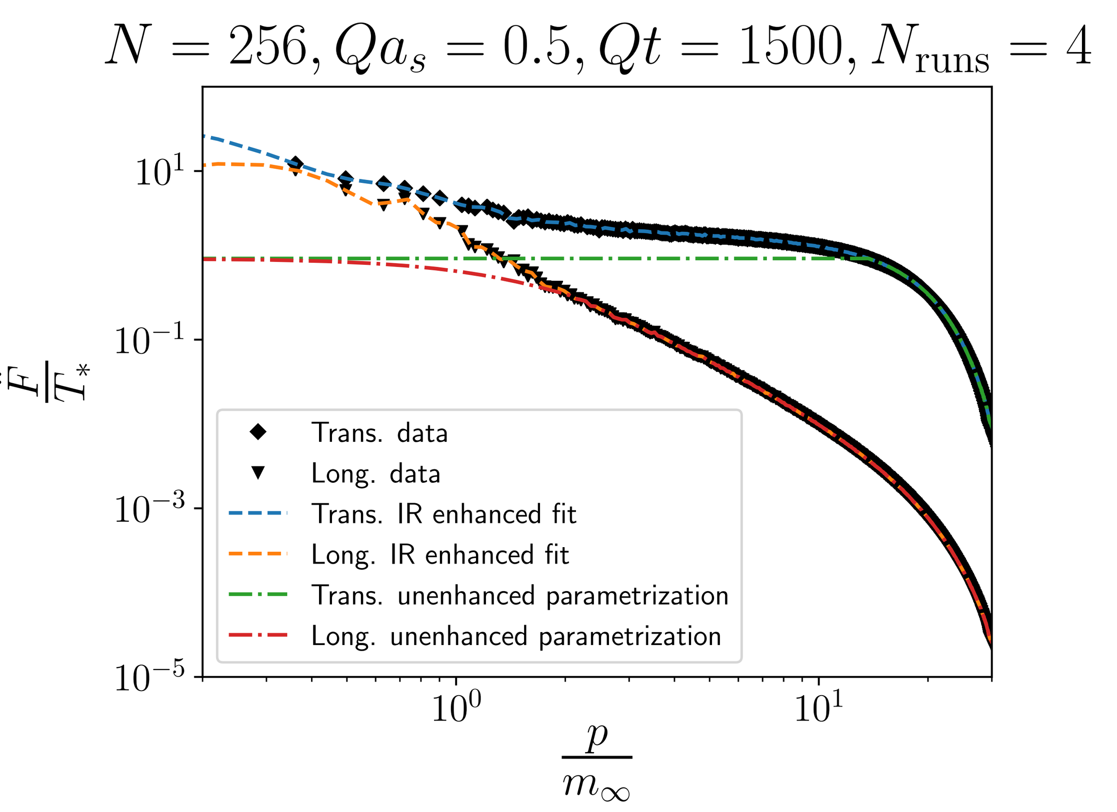
Transport coefficients contain information about the microscopic properties of the medium. We study the **heavy quark** (HQ) **momentum diffusion coefficient** κ **out of equilibrium** by using classical Yang-Mills (CYM) simulations in the **self-similar regime**. With this setup we aim to **mimic the medium consisting of overoccupied gluon fields** created **at the initial stages of an ultrarelativistic heavy ion collision**.

Extracting κ, 3 methods

CYM Measure the force-force correlation , $A^0 = 0$ [3].

$$\kappa(t,\Delta t) = \frac{1}{3N_c}\int_t^{t+\Delta t} \mathrm{d}t' \frac{1}{V}\int \mathrm{d}^3x \sum_{i=1}^{3} \times \langle gE_i^a(\boldsymbol{x},t)\, gE_i^a(\boldsymbol{x},t')\rangle = \int_t^{t+\Delta t} \mathrm{d}t'\ \kappa(t,t')\,. \quad (1)$$

HTL Use results from LO HTL perturbation theory to estimate $\ddot{F}(t,t+\Delta t) \approx \langle E(t)E(t+\Delta t)\rangle$. Include our data [2] on the quasiparticle damping rate and $\ddot{F}$.



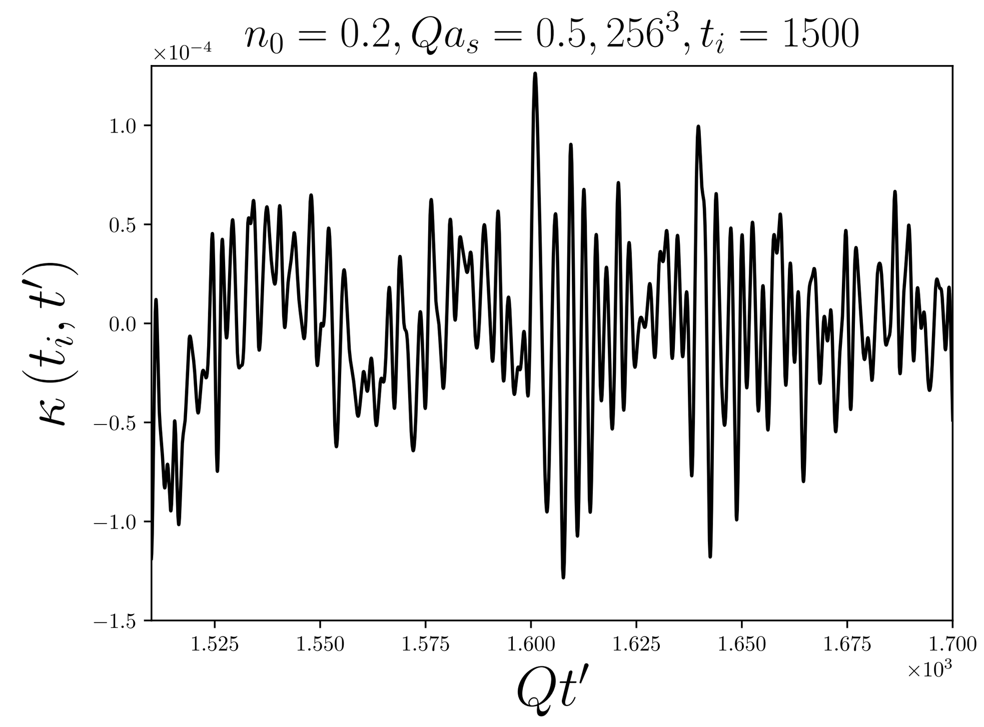
Measured $\ddot{F}(t,t)$ (black points). Dash-dotted lines: HTL expectation.

KT Kinetic theory [1]. Extract $f(k)$ from lattice, compute:

$$\kappa_{\mathrm{KT}}^{\tilde{t}\to\infty} = \frac{1}{6M}\int \frac{\mathrm{d}^3\boldsymbol{k}\mathrm{d}^3\boldsymbol{k}'\mathrm{d}^3\boldsymbol{p}'}{(2\pi)^9\, 8k^0k'^0M}(2\pi)^3 \times \delta^3(\boldsymbol{p}+\boldsymbol{k}'-\boldsymbol{p}'-\boldsymbol{k})\, 2\pi\delta(k'-k)\, \boldsymbol{q}^2 \times |\mathscr{M}|^2_{\mathrm{gluon}} f(k) f(k')\,, \quad (2)$$

Signal from real time lattice

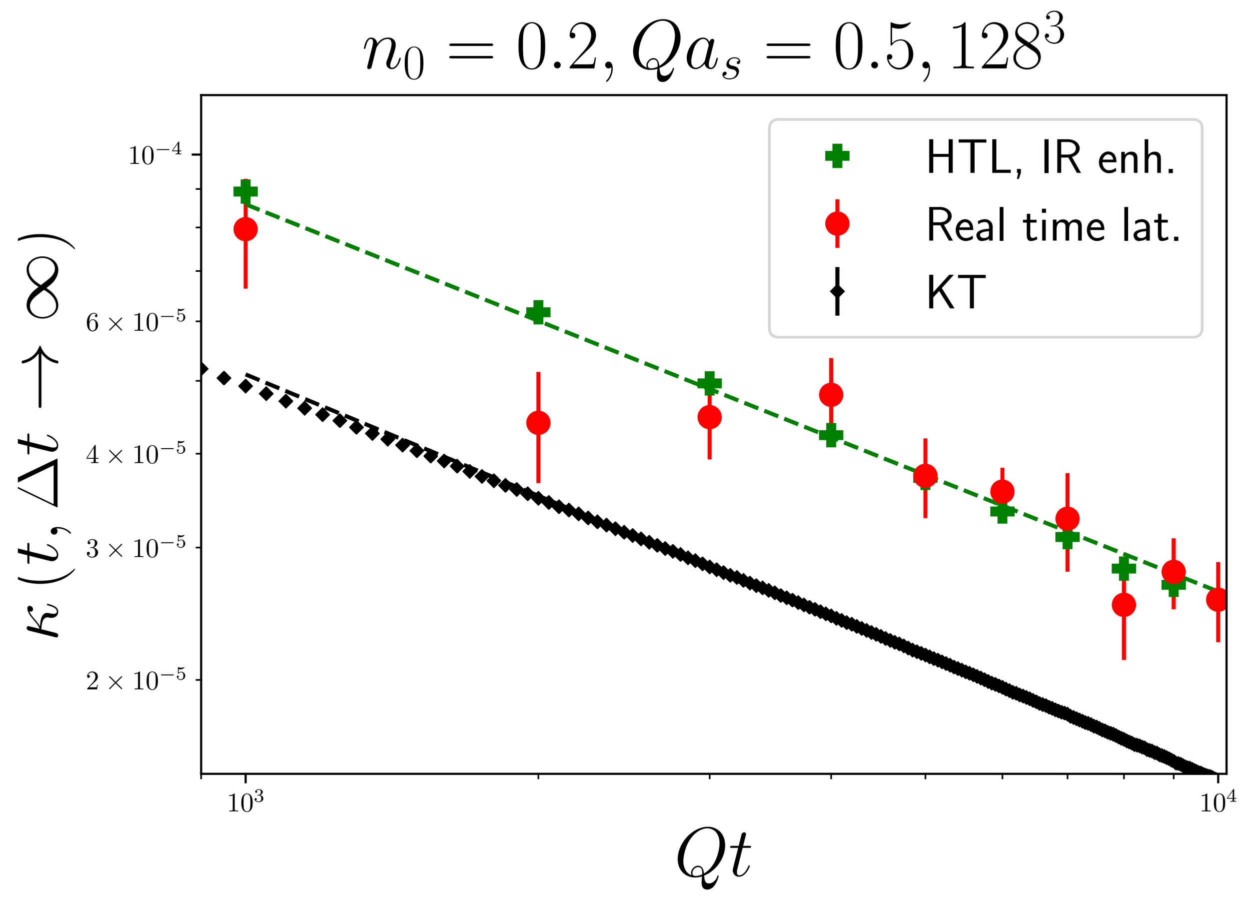
Extracted signal in time and frequency domains



- The signal $\kappa(t,\Delta t)$ in the t-domain, initially large, fast oscillations not shown.

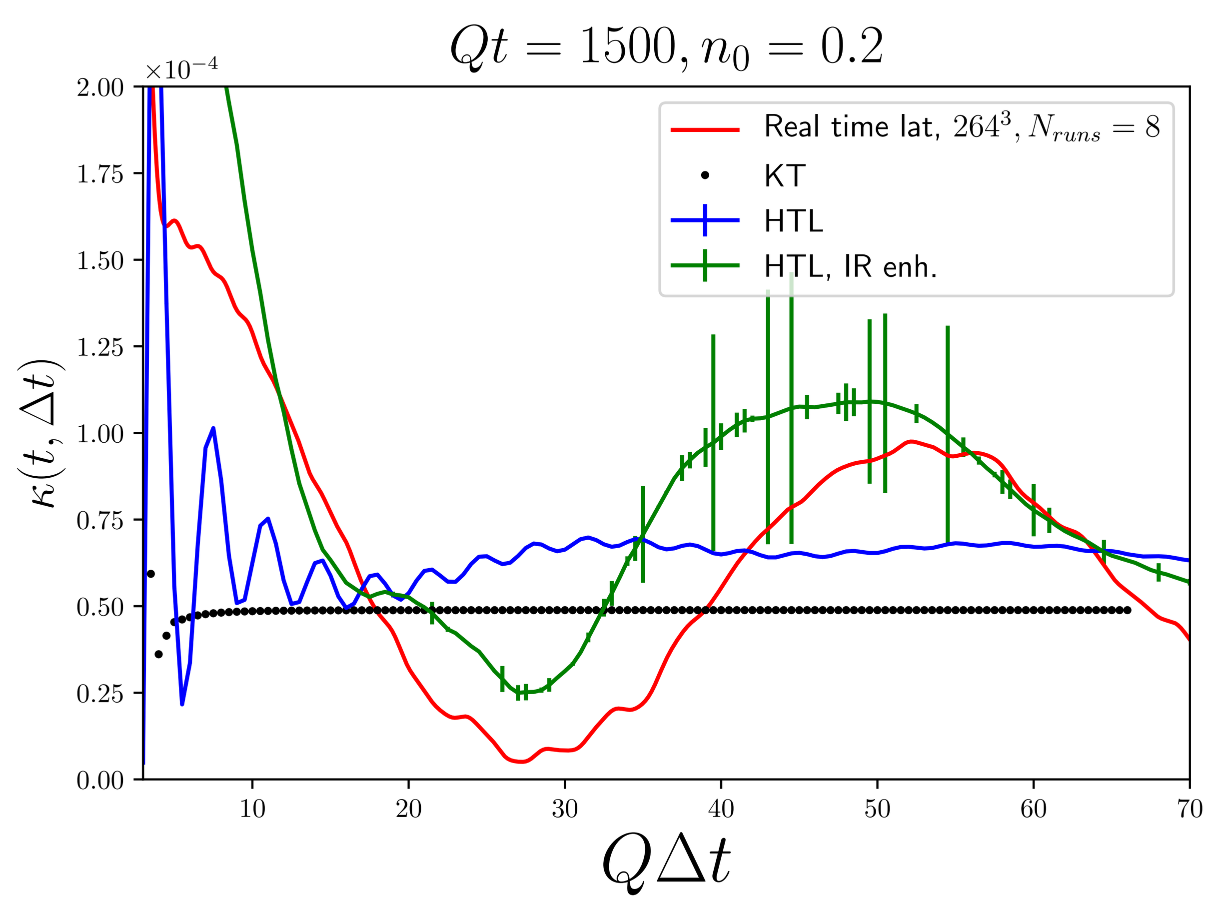
Results: Time dependence and IR enhancement

Dependence on time t of $\kappa(t) = \lim_{\Delta t\to\infty}\kappa(t,\Delta t)$



- At large t our gauge field configuration is that of a universal attractor where the physical scales evolve as powerlaws in t. We extract the powerlaw of κ so that we can compare the exponent and coefficient to other physical scales, such as m_D, T_*, Λ.
- Preliminary: HTL method close to real time lattice extraction, KT method is a factor ~ 2 smaller.
- Real time lattice datapoints obtained by averaging the Δt dependence.

Dependence on size of the integration window Δt



- HTL curve corresponds to unenhanced $\ddot{F}$. HTL IR enh. corresponds to the enhanced (extracted from data) $\ddot{F}$.
- KT curve corresponds to the generalization of (2).

Conclusions

- We measure the heavy quark momentum diffusion coefficient κ far from equilibrium. κ follows an approximate $t^{-1/2}$ power law (preliminary). This is consistent with HTL ($t^{-5/7}\times$ logarithmic correction). Including the IR enhancement improves the agreement with the transient time behavior.
- We find that the IR enhancement of the *gauge-fixed* $\ddot{F}$ leads to an observable modification of the *gauge-invariant* signal in $\kappa(t,\Delta t)$. Oscillations in finite $\tilde{t}$ have a similar frequency as the plasmon frequency.

References

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