Chromo-electric and chromo-magnetic correlators at high temperature from gradient flow

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Outline

Background: Heavy Quark Diffusion

- Quark Gluon Plasmas can be probed in heavy ion collisions
- HQ momentum is changed by random kicks from the medium
  $\rightarrow$ Brownian motion: Follows Langevin dynamics

$$\dot{\mathbf{p}} - \eta \mathbf{p} = \mathbf{f}(t)$$

$$\langle f_i(t) \rangle = 0, \ \langle f_i(t') f_j(t) \rangle = \kappa \delta_{ij} \delta(t - t') \qquad \eta \approx \frac{\kappa}{2MT}\left(1 - \frac{5T}{2M}\right)$$

- Deriving from the force-force correlator in a Heavy Quark expansion:
  (Bouttefeux and Laine JHEP12(2020))

$$G_E = -\frac{\sum_i \mathrm{Tr}\langle U(\beta;\tau) g E_i(\tau) U(\tau;0) g E_i(0) \rangle}{3\mathrm{Tr}\langle U(\beta;0)\rangle}$$

$$G_B = \frac{\sum_i \mathrm{Tr}\langle U(\beta;\tau) g B_i(\tau) U(\tau;0) g B_i(0) \rangle}{3\mathrm{Tr}\langle U(\beta;0)\rangle}$$

Background: Heavy Quark Diffusion

- Spectral analysis:

$$G_{E/B}(\tau) = \int_0^\infty \frac{\mathrm{d}\omega}{\pi} \rho_{E/B}(\omega) \frac{\cosh\left(\frac{\beta}{2} - \tau\right)\omega}{\sinh\frac{\beta\omega}{2}}$$

$$\kappa_{E/B} = \lim_{\omega\to 0} \frac{2T\rho_{E/B}(\omega)}{\omega}$$

- Total heavy quark momentum coefficient:

$$\kappa_{\mathrm{tot}} \approx \kappa_E + \frac{2}{3}\langle \mathbf{v}^2 \rangle \kappa_B,\ \langle \mathbf{v}^2 \rangle \sim T/M$$

- Determination of G_E and G_B requires non-perturbative calculations

Outline

Discretization of G_E and G_B

- The chromo electric and magnetic correlators:

$$G_E(\tau) = -\frac{1}{3}\sum_{i=1}^{3}\frac{\langle \mathrm{ReTr}[U(\beta,\tau)E_i(\tau)U(\tau,0)E_i(0)]\rangle}{\langle \mathrm{ReTr}[U(\beta,0)]\rangle}$$

$$G_B(\tau) = \frac{1}{3}\sum_{i=1}^{3}\frac{\langle \mathrm{ReTr}[U(\beta,\tau)B_i(\tau)U(\tau,0)B_i(0)]\rangle}{\langle \mathrm{ReTr}[U(\beta,0)]\rangle}$$

- Discretising the E-field insertion:
  (Caron-Huot and Laine JHEP(2009))

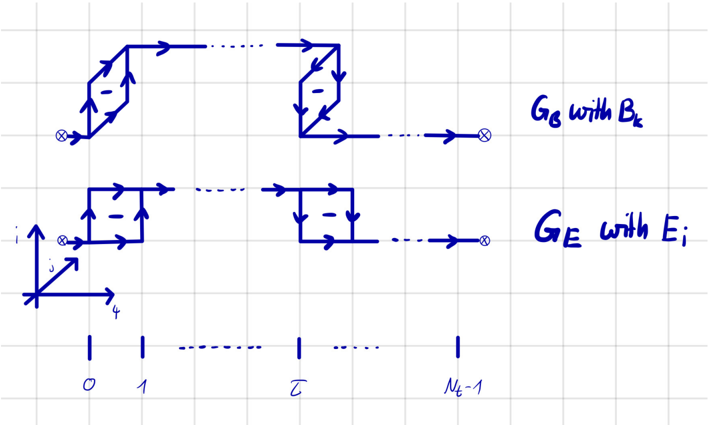
$$E_i(\tau,\mathbf{x}) = U_i(\tau,\mathbf{x})U_4(\tau,\mathbf{x}+a\hat{\mathbf{e}}_i) - U_4(\tau,\mathbf{x})U_i(\tau,\mathbf{x}+a\hat{\mathbf{e}}_4)$$

- Discretising the B-field insertion:

$$B_i(\tau,\mathbf{x}) = \epsilon_{ijk}U_j(\tau,\mathbf{x})U_k(\tau,\mathbf{x}+a\hat{\mathbf{e}}_j)$$

- Finite extent of E and B field requires "renormalization"

Discretization of G_E and G_B



Outline

Analysis: Lattice setup

- Using quenched lattices
- Lattice parameters:

N_s	N_t	β	N_{conf}
48	16	6.872	990
48	20	7.044	990
48	24	7.192	1500
56	28	7.321	1320

(a) $T = 1.5T_c$

N_s	N_t	β	N_{conf}
48	16	14.443	990
48	20	14.635	990
48	24	14.792	1500
56	28	14.925	1950
68	34	15.093	1170

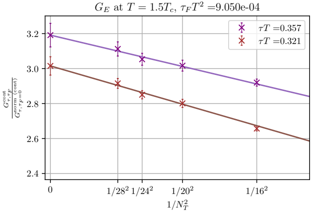
(b) $T = 10^4 T_c$

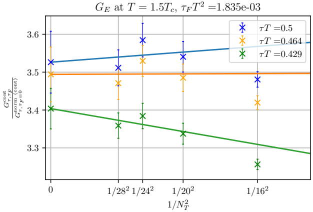
- Lattice configurations produced with heat bath and overrelaxation algorithm
- flowtime evolving with Symanzik flow, flow-time range:

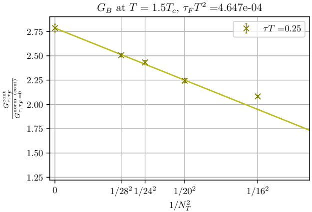
$$a \leq \sqrt{8\tau_F} \leq \frac{\tau - a}{3}$$

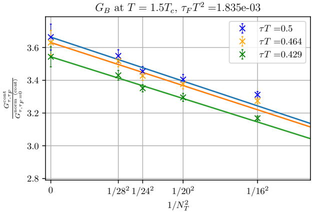
- Normalize the correlators with $G^{\text{norm}} = \frac{G^{\text{LO}}_{\text{latt}}(\tau,\tau_F)}{g^2 C_F} \rightarrow G^{\text{latt}}/G^{\text{norm}}$

Analysis: Continuum limit









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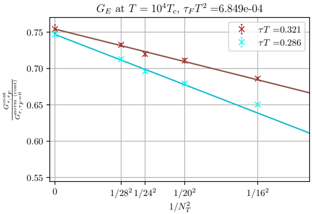
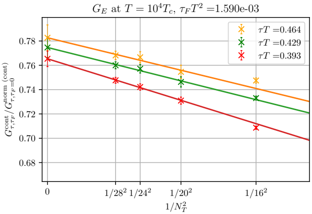
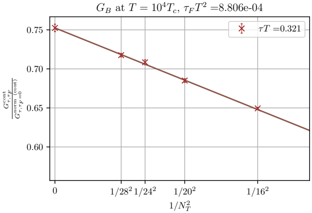
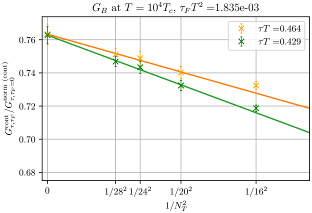
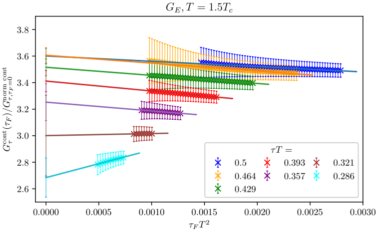


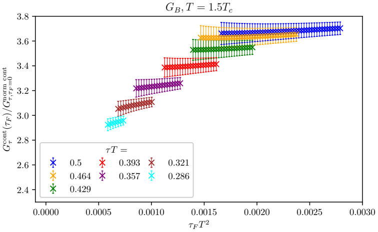






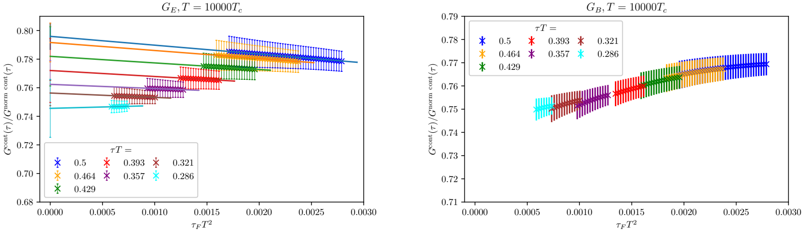
Analysis: Zero-flowtime limit $T = 1.5T_c$





- G_E: perform $\tau_F \to 0$ limit extrapolation
- G_B: no $\tau_F \to 0$ limit due to non-trivial anomalous dimension of G_B
  (Laine JHEP (2021))
- different behavior for G_E and G_B:
  G_E increases for $\tau_F \to 0$
  G_B decreases for $\tau_F \to 0$

Analysis: Zero-flowtime limit $T = 10^4 T_c$



- G_E: perform $\tau_F \to 0$ limit extrapolation
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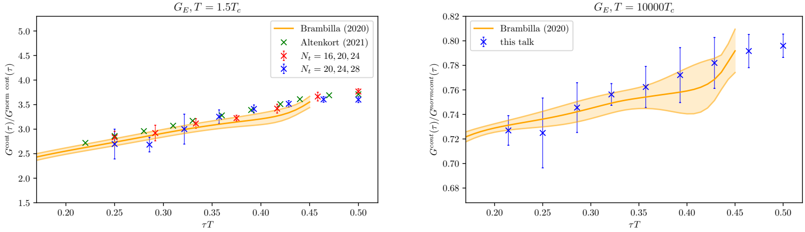
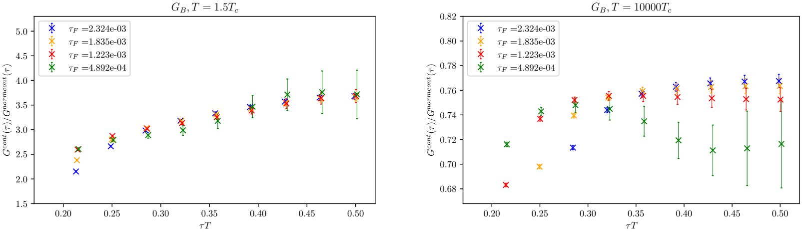
Results: G_E



(Altenkort et al. Physical Review D(2021)) (Brambilla et al. Physical Review D(2020))

- $\tau_F \to 0$ reproduces previous results for both, $T = 1.5Tc$ and $T = 10^4 T_c$

Results: G_B

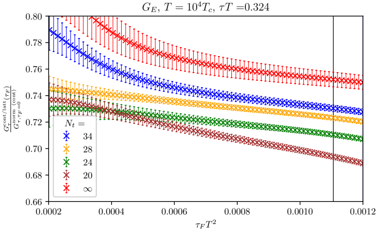


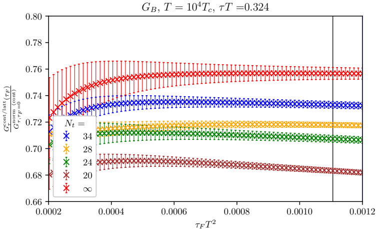
- complete new results for the Chromo-magnetic correlator
- G_B almost τ_F-independent for $\tau T \geq 0.25$ at $T = 1.5Tc$ and for $\tau \geq 0.3$ at $T = 10^4 Tc$

Thank you for your attention!

Analysis: Chromo magnetic correlator

- How does the Chromo magnetic correlator behave under gradient flow?

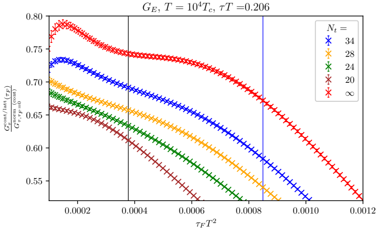


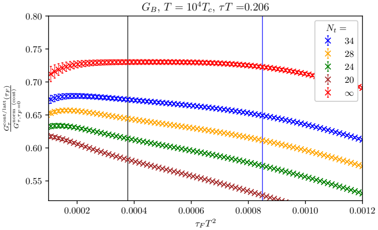


- Linear behaviour of the correlators up to the maximum flowtime limit
- G_B exhibits a wider flow-independent range

Analysis: Chromo magnetic correlator

- How does the Chromo magnetic correlator behave under gradient flow?





- G_E breaks down beyond the maximum flowtime limit
- G_B still exhibits a flow-independent range beyond the limit
- Different behaviour might be caused by the anomalous dimension of G_B
  (Mikko Laine JHEP (2021))