# Holographic Brownian Motion & Dissipation

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Ongoing work with Bala Sathiapalan

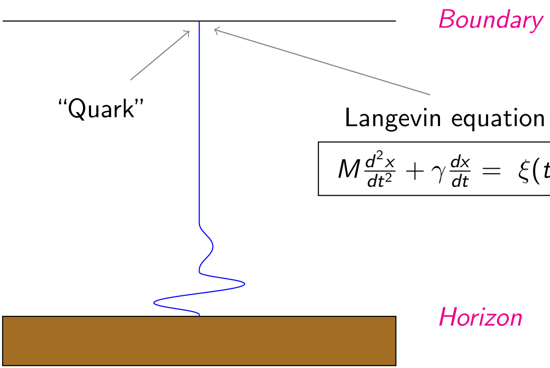
*For a heavy quark in a strongly coupled $\mathcal{N} = 4$ super Yang-Mills plasma,*

$$\text{Dissipation at } T = 0$$

$$\neq$$

$$\text{Dissipation at } T \to 0$$

# Set-up




$$M\frac{d^2x}{dt^2} + \gamma\frac{dx}{dt} = \xi(t)$$

[J. de Boer et al; Son & Teaney]

- *Generalized* Langevin equation (in frequency space)

$$\left[-M\,\omega^2 + G_R(\omega)\right]x(\omega) = \xi(\omega)$$

# Retarded Green's Function

- For small frequency

$$G_R(\omega) = -i\gamma\ \omega - \Delta M\ \omega^2 - i\rho\ \omega^3 + \dots$$

- Dimensional analysis

$$G_R(\omega) \sim [M]^3 \quad \Rightarrow \quad \begin{cases} \gamma \sim \mathrm{T}^2 \\ \Delta M \sim \mathrm{T} \\ \rho \sim \mathrm{T}^0 \end{cases}$$

- At zero temperature : $G_R(\omega) = -i\rho\ \omega^3 \quad \leftrightsquigarrow \quad$ Dissipative!

# An Example : Brownian Motion in 1+1 Dimensions

- Retarded propagator

$$G_R(\omega) = -\frac{\mu\ \omega}{2\pi} \frac{(\omega^2 + 4\pi^2 T^2)}{(\omega + i\frac{\mu}{\sqrt{\lambda}})}$$

*[PB & B. Sathiapalan]*

[Nucl. Phys. **B 884** (2014) 74-105]

- Viscous drag

$$\gamma = 2\sqrt{\lambda}\pi T^2$$

- Higher order "dissipation coefficient"

$$\rho = \frac{\sqrt{\lambda}}{2\pi} - \frac{2(\sqrt{\lambda})^3 \pi T^2}{\mu^2}$$

# Zero temperature dissipation

**The effect is physical**

- ✓ It is finite and therefore no need to renormalize by adding counterterms.

- ✓ It cannot be renormalized away in the boundary theory by any hermitian counter term.

- ✓ Quark moving at constant velocity doesn't feel any drag at $T=0$.

- Explanation : This zero temperature dissipation is due to radiation of accelerated charged particle. Remarkably the dissipation in this highly non-linear boundary theory is given by simple radiation reaction formula in classical electrodynamics!

# A phase transition at T= 0?

**Dissipation as T $\to 0$**

- Calculating $G_R(\omega)$ in $AdS_5$-Schwarzschild black hole bulk geometry

$$\rho = \frac{(\pi - \log 4)}{4} \frac{\sqrt{\lambda}}{2\pi}$$

**Dissipation at T$= 0$**

- Calculating $G_R(\omega)$ in pure $AdS_5$ bulk geometry

$$\rho = \frac{\sqrt{\lambda}}{2\pi}$$

- **Conclusion :** Possibly due to deconfinement transition at T$= 0$.

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thank you!