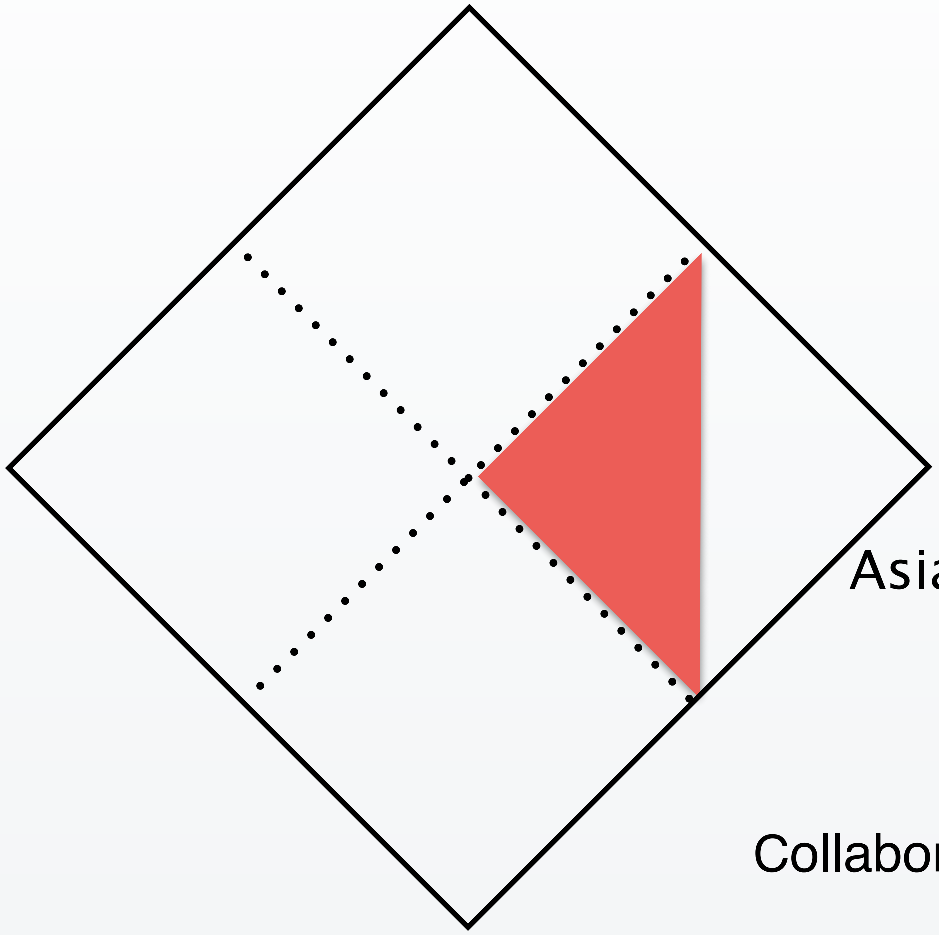
Rindler Fluid and Its Properties

— with Weak Momentum Relaxation



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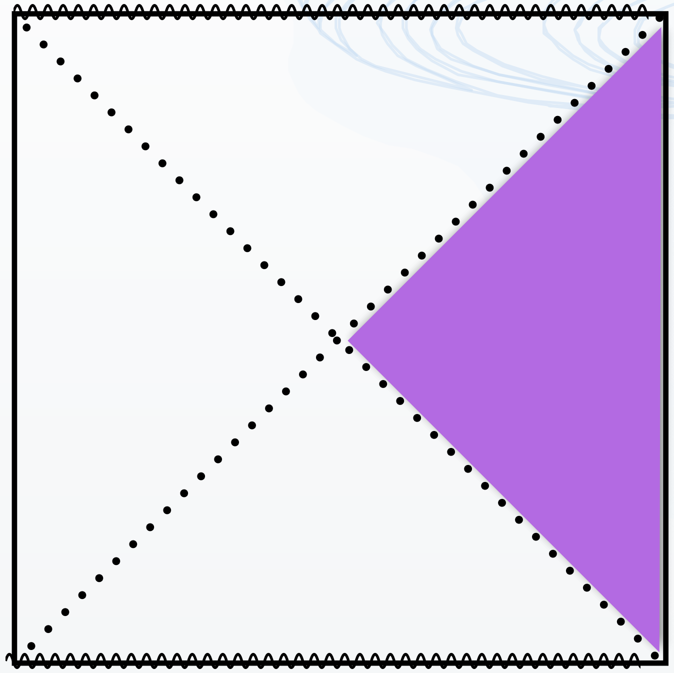


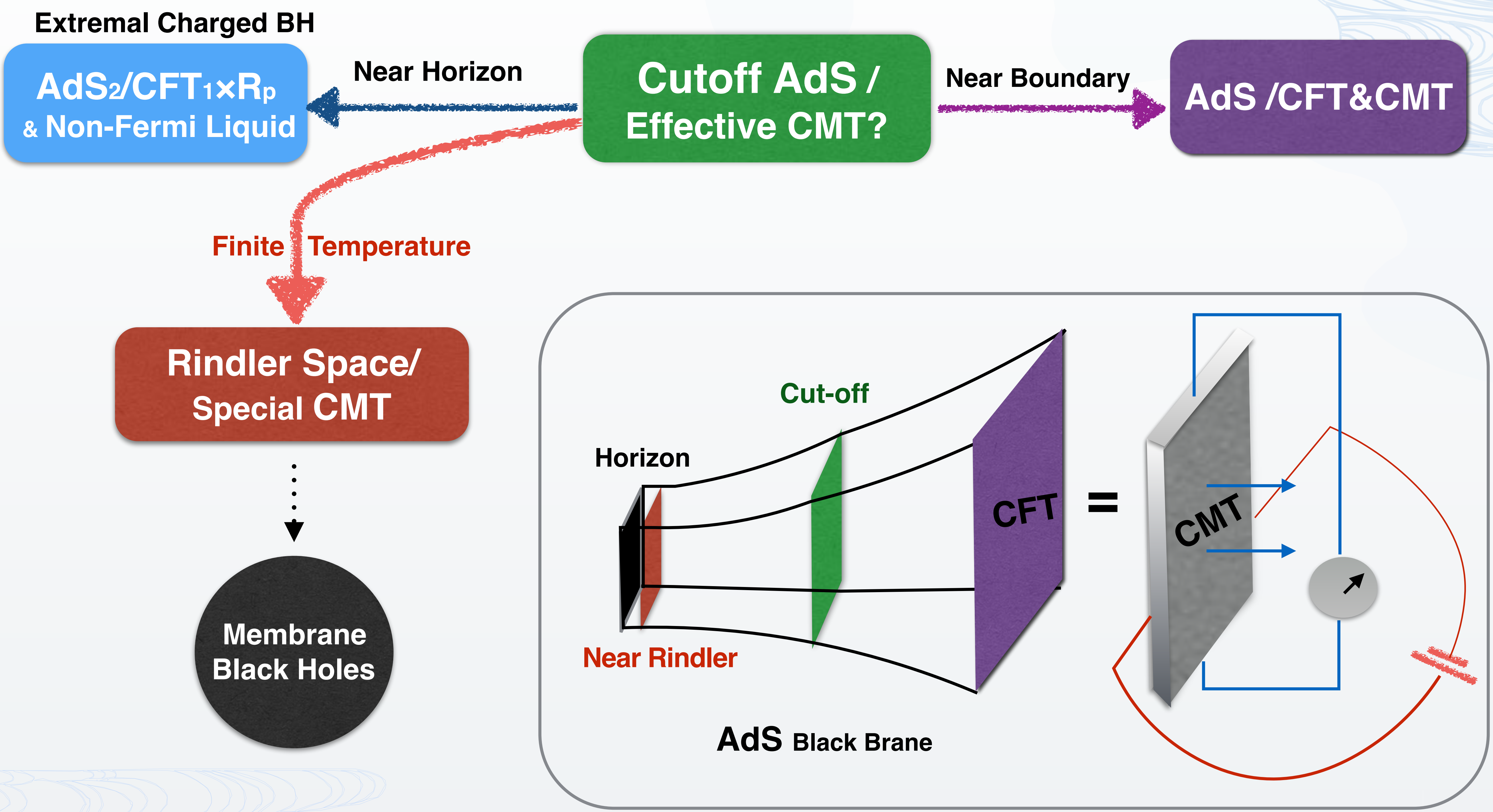
Based on 1705.05078
Collaborators: S. Khimphun, B. H. Lee, C.Y. Park

What is Rindler Fluid?

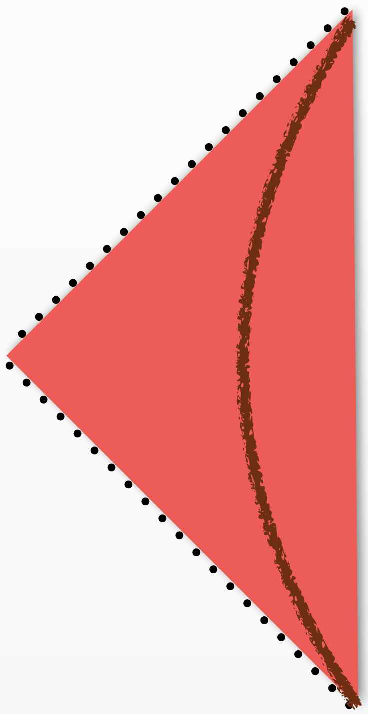
Fluid dual to Rindler spacetime

Navier-Stokes Equations: Bredberg, Keeler, Lysov, Strominger [10',11']
Fluid/Gravity Expansion: Compere, McFadden, Skenderis, Taylor [11',12']
Entropy Current and Constraint: Chirco, Eling, Liberati, Meyer, Oz [12',13']
AdS/Rindler Correspondence: Caldarelli, Camps, Goutéraux, Skenderis [12',13']
Comparison with AdS/Fluid: Matsuo, Natsuume, Ohta, Okamura [12',13']
Recurrence Relation and Petrov type Cai, Li, Yang, Zhang [13',14']

Main Motivations



Rindler Fluid with Weak Momentum Relaxation



$$S_0 = \frac{1}{16\pi G_{p+2}}\int \mathrm{d}^{p+2}x\sqrt{-g}\left[R - \frac{1}{2}\sum_{\mathcal{I}=1}^{p}(\partial\phi_{\mathcal{I}})^2\right] - \frac{1}{8\pi G_{p+2}}\int \mathrm{d}^{p+1}x\sqrt{-\gamma}K.$$

$$\mathrm{d}s^2_{p+2} = -2\kappa_0(r-r_0)\mathrm{d}t^2 + 2\mathrm{d}t\mathrm{d}r + \delta_{ij}\mathrm{d}x^i\mathrm{d}x^j$$
$$-\frac{p}{4}(r-r_0)(r-r_c)k^2\mathrm{d}t^2 - \frac{(r-r_c)}{2\kappa_0}k^2\delta_{ij}\mathrm{d}x^i\mathrm{d}x^j + O(k^4),$$
$$\phi_{\mathcal{I}} = kx_{\mathcal{I}}, \quad x_{\mathcal{I}} = x_i = x_1, x_2, ..., x_p\,.$$

Ward Identity $\quad \partial_t\langle T^t{}_i\rangle + \partial_i\mathbb{p}_k = -\bar{\tau}_0^{-1}\langle T^t{}_i\rangle - (\ell_0)k^2\partial_t v_i + \cdots\,. \quad \bar{\tau}_0^{-1} = \frac{k^2 s_k}{4\pi(\mathbb{e}_k + \mathbb{p}_k)}.$

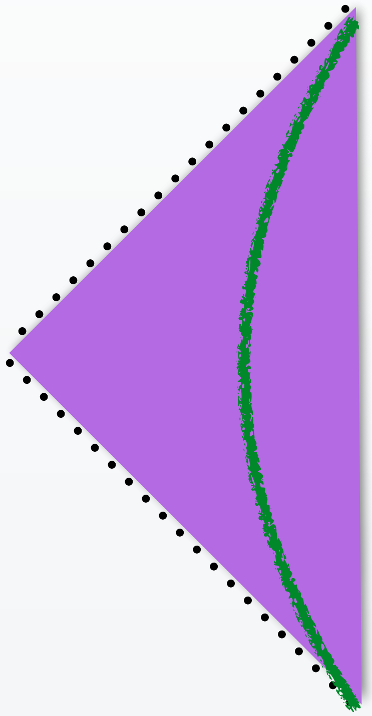
Thermal Conductivity $\quad \bar{\kappa}_\omega = \frac{1}{1-\mathbb{i}\omega\tau_0}\frac{4\pi s_k T_k}{k^2}, \quad \tau_0^{-1} = \frac{k^2}{4\pi T_k}\left[1 - \frac{(\ell_0)T_0}{s_0}\frac{k^2}{T_0^2}\right] + O(k^6)$

Correction to Relaxation Rate $\quad \ell_0 = -\frac{2}{\mathbb{p}} - \delta\ell_0 = -\frac{1}{\mathbb{p}}, \quad \xi_0 \equiv \frac{\ell_0 T_0}{s_0} = -1$

"Momentum relaxation from the fluid/gravity correspondence" Blake[15']

"hydrodynamic of transports with momentum relaxation" Hartnoll, Kovtun, Muller, Sachdev[07']

Cutoff AdS Fluid with Weak Momentum Relaxation



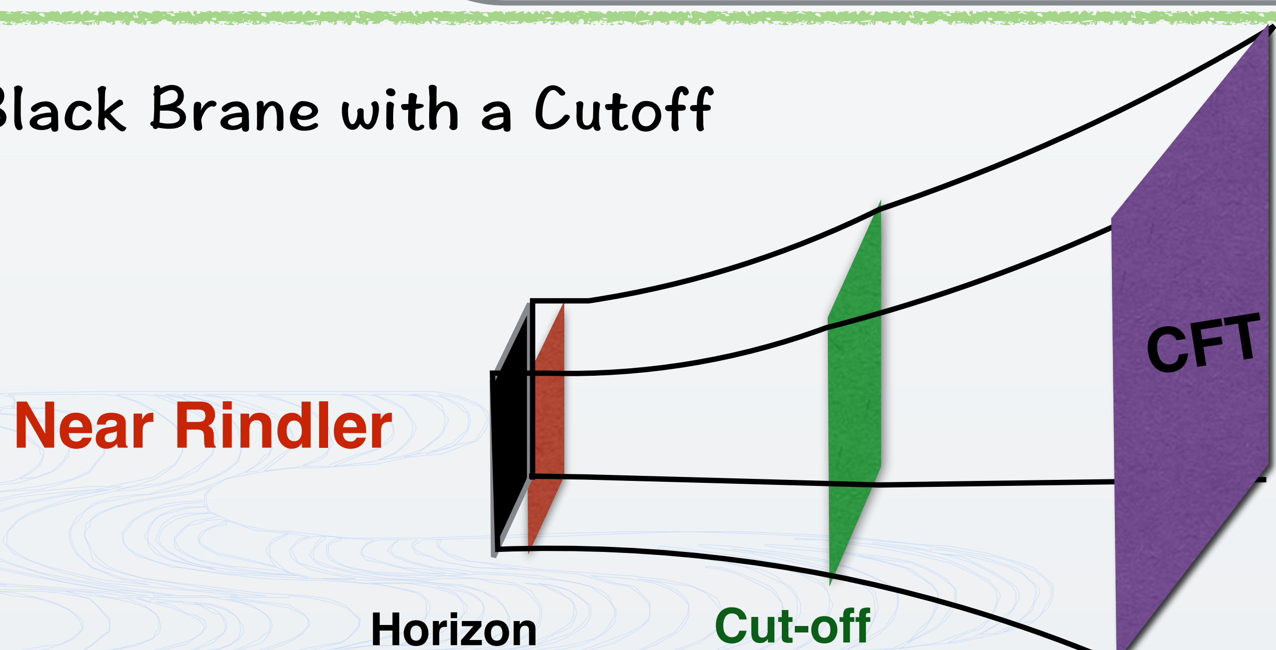
Ward Identity

$$\partial_t \langle \mathcal{T}^t{}_i \rangle + \partial_i \tilde{\mathcal{P}} = -\tilde{\tau}_c^{-1} \langle \mathcal{T}^t{}_i \rangle - \ell_c k^2 \partial_t v_i + \cdots , \quad \tilde{\tau}_c^{-1} = \frac{k^2 \tilde{s}_c}{4\pi(\tilde{\mathcal{E}} + \tilde{\mathcal{P}})}.$$

Thermal Conductivity

$$\tilde{\kappa}_\omega = \frac{1}{1 - \mathrm{i}\omega\tau_c} \frac{4\pi \tilde{s}_c \tilde{T}_c}{k^2}, \qquad \tau_c^{-1} = \frac{k^2}{4\pi \tilde{T}_c} \left[1 - \frac{\ell_c T_c}{s_c} \frac{k^2}{T_c^2} \right] + O(k^6).$$

AdS Black Brane with a Cutoff



Correction to Relaxation Rate

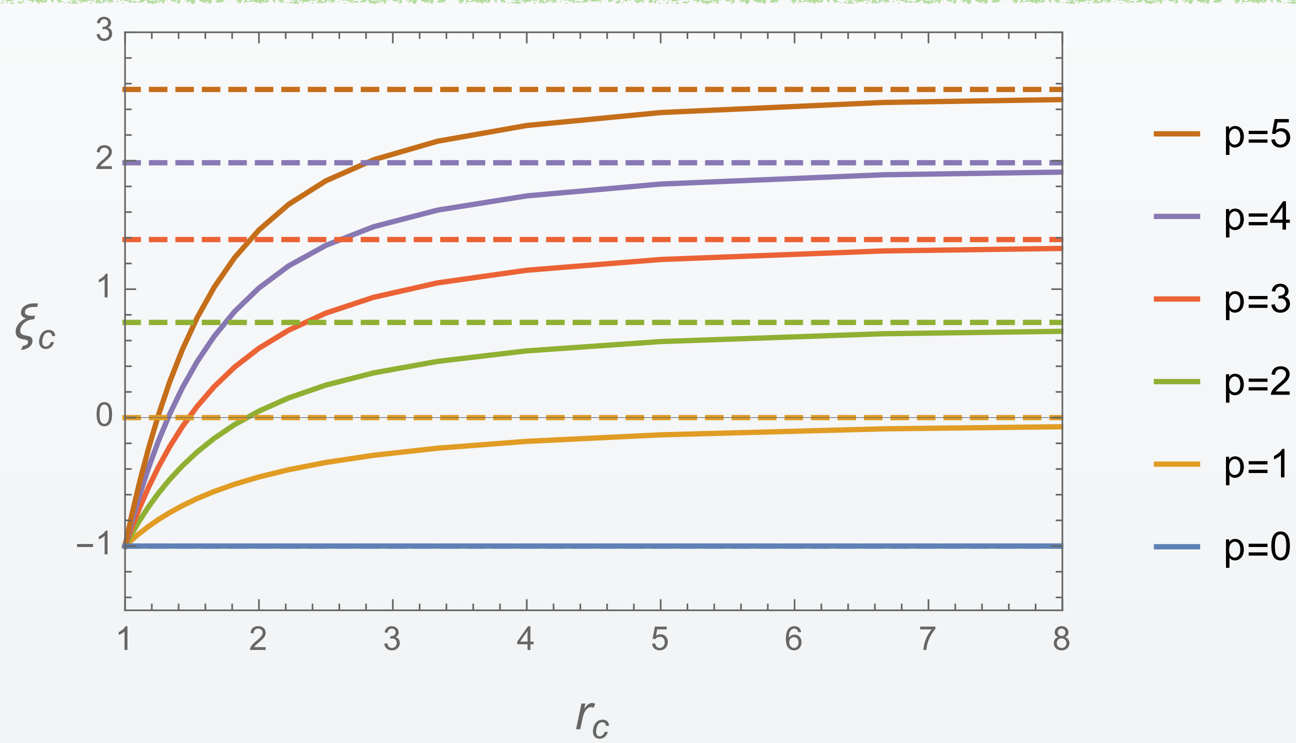
$$\xi_c \equiv \frac{\ell_c T_c}{s_c} = (p+1) \left[\tilde{\tau}_p(r_c) - \frac{r_c \tilde{\tau}_p'(r_c)}{(p-1)} \right],$$

$$\tilde{\tau}_p(r) \equiv \int_{r_0}^{r} \frac{\mathrm{d}\tilde{r}\, r_0^2}{\tilde{r}^3 f(\tilde{r})} \left(1 - \frac{r_0^{p-1}}{\tilde{r}^{p-1}} \right).$$

RG Flow From Conformal Fluid to Rindler Fluid

Rindler Fluid ← Near Horizon — **Cutoff AdS/Fluid** — Near Boundary → **AdS/CFT Fluid**

$$\lim_{r_c \to r_0} \xi_c = -1, \qquad \xi_c \equiv \frac{\ell_c T_c}{s_c} = (p+1)\left[\tilde{\tau}_p(r_c) - \frac{r_c \tilde{\tau}_p'(r_c)}{(p-1)}\right], \qquad \lim_{r_c \to \infty} \xi_c = (p+1)\tilde{\tau}_p(\infty),$$



$$\tilde{\tau}_p(r) \equiv \int_{r_0}^{r} \frac{d\tilde{r}\, r_0^2}{\tilde{r}^3 f(\tilde{r})} \left(1 - \frac{r_0^{p-1}}{\tilde{r}^{p-1}}\right).$$

$$\tilde{\tau}_3(\infty) = \ln 2/2$$

$$\tilde{\tau}_2(\infty) = (9\ln 3 - \sqrt{3}\pi)/18$$

AdS/Rindler Correspondence?

Key Coefficient in 2nd Order Fluid

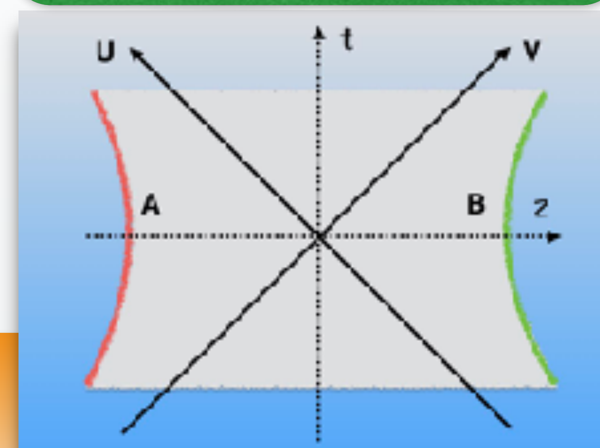
$$T_{\mu\nu} = P(\eta_{\mu\nu} + d u_\mu u_\nu) - 2\eta\sigma_{\mu\nu} - 2\eta\tau_\omega\left[u^\lambda \mathcal{D}_\lambda \sigma_{\mu\nu} + \omega_\mu{}^\lambda \sigma_{\lambda\nu} + \omega_\nu{}^\lambda \sigma_{\mu\lambda}\right]$$
$$+ 2\eta b\left[u^\lambda \mathcal{D}_\lambda \sigma_{\mu\nu} + \sigma_\mu{}^\lambda \sigma_{\lambda\nu} - \frac{\sigma_{\alpha\beta}\sigma^{\alpha\beta}}{d-1} P_{\mu\nu}\right]$$

On-going and Relevant Topics

Charged Rindler Fluid
Chaos and Butterfly V?

Khimphun, Lee, Park, Zhang, 1711.***??

Holography in Rindler Frame

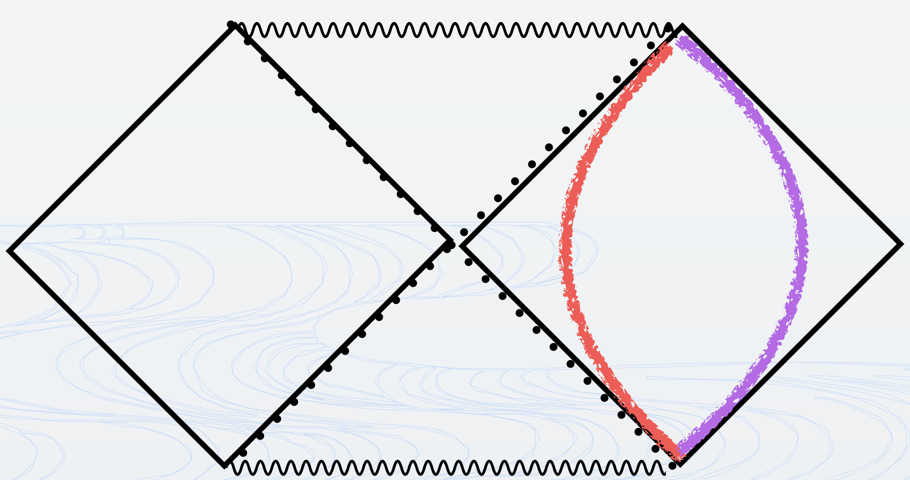


NAdS_2/SYK Models
WorldSheet Horizon?

Cai, Ruan, Yang, Zhang, 1709.06297

Schwarzschild Black Hole
Membranes/Soft Hairs?

Cai, Ruan, Zhang, 1609.01056



Holographic EPR Pair
Bell's Measurement?

Chen, Sun, Zhang, 1612.09513

Thanks for All Your Attention!