

# Schwinger-Keldysh effective field theories

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with Kristan Jensen and Amos Yarom: 1701.07436

# Main question

How to reformulate fluid dynamics from first principles?

[ See also

M. Crossley, P. Glorioso, H. Liu, P. Gao;

F. Haehl, R. Loganayagam, M. Rangamani ]

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# The main ingredient

Fluid dynamics is a **thermal** system **out-of-equilibrium** → the **Schwinger-Keldysh** formalism is the natural setup

$$Z[A_1, A_2] = \text{Tr} (\mathcal{U}[A_1] \rho_{-\infty} \mathcal{U}^\dagger[A_2])$$

$\rho_{-\infty}$

$$= \int \mathcal{D}\xi_1 \mathcal{D}\xi_2 e^{iS_{eff}[\xi_1, \xi_2; A_1, A_2]}$$

Effective field theory logic:

- 1) Identify the relevant **infrared degrees of freedom**
- 2) Use the **symmetries** to constrain the effective action

# The symmetries

can be inferred from the microscopic definition

$$Z[A_1, A_2] = \text{Tr} (\mathcal{U}[A_1] \rho_{-\infty} \mathcal{U}^\dagger [A_2])$$

1) **Topological SK sector:**  $Z[A_1 = A_2 = A_r] = 1$

2) **Full KMS symmetry:**

$$Z[A_1(t_1), A_2(t_2)] = Z[A_1(-t_1), A_2(-t_2 - ib)]$$

3) **Topological KMS sector:**

$$Z[A_1(-t_1) = A_2(-t_2 - ib)] = 1$$

...

For thermal  
states only  
 $\rho_{-\infty} = e^{-b\mathcal{H}}$

$$\langle \mathcal{O}_1 - \mathcal{O}_2 \rangle = \frac{\delta Z}{\delta A_r} = 0$$

# Superspace implementation

2 topological sectors  $\rightarrow$  use **2 BRST-like symmetries**  $\{Q, \bar{Q}\} = -b\mathcal{H}$

The most general closed effective action is conveniently written in **superspace**

$$\mathbb{O} = \frac{\mathcal{R}}{2}(\mathcal{O}_1 + \mathcal{O}_2) + \theta\mathcal{O}_{\bar{g}} + \bar{\theta}\mathcal{O}_g + \bar{\theta}\theta\mathcal{A}(\mathcal{O}_1 - \mathcal{O}_2)$$

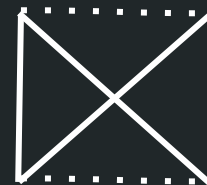
Full KMS symmetry ( **2** )

$$S_{eff} = \int d\sigma d\theta d\bar{\theta} \mathcal{L}(\mathbb{O}, \partial, iD_\theta, D_{\bar{\theta}}) + (\text{KMS-conjugate})$$

Topological Schwinger-Keldysh ( **1** ) and KMS symmetries ( **3** )

# Outlook

- Full classification of hydrodynamic transport and entropy current in superspace  
[work in progress with Kristan Jensen, Raja Marjeh and Amos Yarom]
- All time-ordered correlators are incorporated in this formalism. Applications to stochastic cosmology, condensed matter systems...
- Gravity counterpart  
[work in progress with Jan de Boer and Michal Heller]



# Thank you!

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and with Raja Marjeh: work in progress