Effective field theory for dissipative photons from higher-form symmetries

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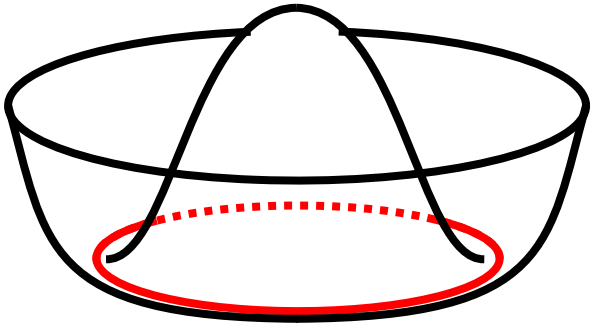
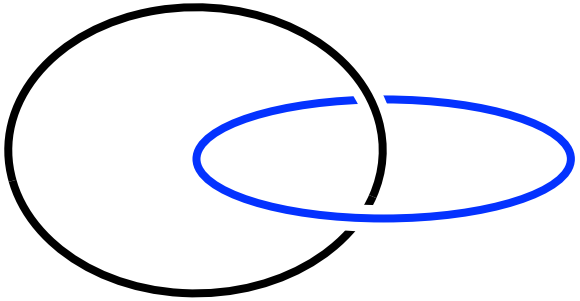




Symmetry provides universal understanding of physics.

Conventional Global Symmetry

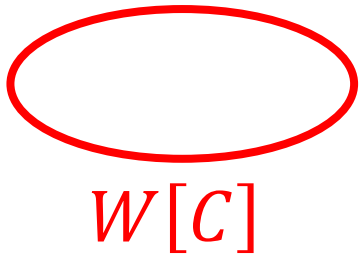
Charged particles

Chiral symmetry breaking

$$\mathrm{SU(2)_L} \times \mathrm{SU(2)_R} \longrightarrow \mathrm{SU(2)_V}$$

Gapless pions

Higher-Form Symmetry Gaiotto et al, JHEP 02 (2015) 172.



Charged loops (for 1-form)

Electric 1-form symmetry breaking

$$\mathrm{U(1)_e} \longrightarrow \mathbf{1}$$

Gapless photons

Higher-Form Symmetry × Non-equilibrium

- How does higher-form symmetry arise out of equilibrium?
- What dissipative effects are consistent with the symmetry?

Real-time dynamics of QFT —— **S**chwinger–**K**eldysh formalism

Our Work

✓ Established symmetry-based construction of SK-action

$$\mathcal{L}_{\text{eff}}[A_r, A_a] = \mathcal{L}_{\text{Maxwell}} + \mathcal{L}_{\text{diss}} + \mathcal{L}_{\text{noise}} + (\text{higher derivative terms})$$

✓ Successfully described photon-dissipation in insulators

$$\text{Gauss's law: } \boldsymbol{\nabla} \cdot \epsilon(\boldsymbol{E} - \tau \dot{\boldsymbol{E}} + \boldsymbol{\xi}) = 0$$

τ : relaxation time
$\boldsymbol{\xi}$: thermal noise

✓ Organized dissipative processes

$$s^{\mu}[A_r] = -\beta \left(T^{0\mu}_{\text{EM}} + A^0_r \frac{\delta I_{\text{eff}}}{\delta A_{a,\mu}} \right) \Bigg|_{A_a = 0}$$

entropy production
$\partial_\mu s^\mu \geq 0$

Thank You!