Title: Magnetohydrodynamics and Generalised Superfluids

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Abstract: Magnetohydrodynamics (MHD) describes the low-energy physics of electromagnetically conducting plasmas. In the conventional formulation of MHD, one introduces dynamical electromagnetic fields on top of the usual hydrodynamic setup by hand. In this talk, we will explore an alternate effective view of MHD purely based on symmetries, as a "string fluid" of magnetic field lines, without any assumption about the underlying microscopic field content. We will argue that MHD is described by a novel theory of superfluidity with a partially broken one-form symmetry. We will also discuss the implications of this broken symmetry for constructing hydrostatic partition functions describing MHD. The talk is based on [arXiv:1808.01939, arXiv:1811.04913].

MAGNETOHYDRODYNAMICS & GENERALISED SUPERFLUIDS

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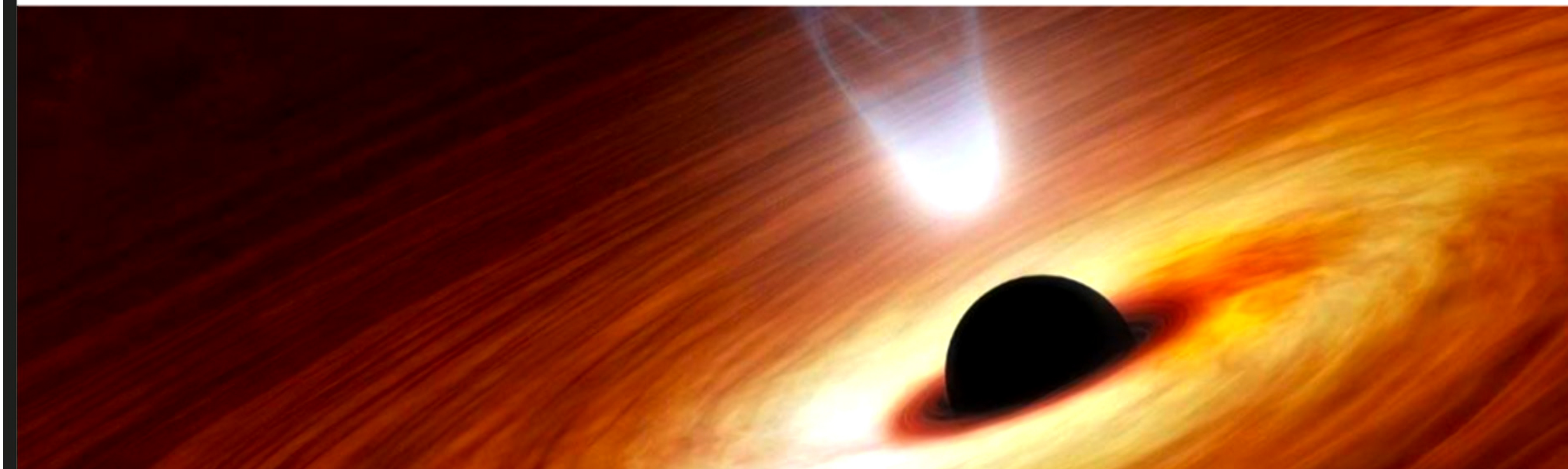

[1811.04913, 1808.01939] J Armas, AJ
[1803.00991] J Armas, J Gath, AJ, A V Pedersen

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INTRODUCTION

- Magnetohydrodynamics (MHD) describes the physics of electromagnetically conducting plasmas [1].
- Electric fields are screened in a plasma due to the presence of electrically charged particles. Dynamics is dominated by magnetic fields.
- MHD can be reformulated as a fluid with conserved string-like charges (magnetic field lines) [2].
- The string fluid formulation is structurally cleaner and is better suited for analytic and numerical implementations.

[1] Hernandez, Kovtun, [1703.08757].
[2] Schubring, [1412.3135]; Grozdanov, Hofman, Iqbal, [1610.07392].

OVERVIEW

- Although string fluids are phenomenologically consistent, there are inherent subtleties in their equilibrium structure — they do not admit a local thermal partition function.
- We motivate the introduction of a new non-hydrodynamic degree of freedom in string fluids, which is reminiscent of the "magnetic scalar potential" and fixes the equilibrium structure.
- The scalar field is also reminiscent of the condensate in superfluids due to spontaneous symmetry breaking. We argue that string fluids can be seen as a symmetry broken phase of a fluid with a "one-form" symmetry.

OUTLINE

- Relativistic Magnetohydrodynamics
- String Fluids
- Equilibrium Configurations
- Partial Breaking of One-Form Symmetry

J Armas, AJ, [1811.04913, 1808.01939].
J Armas, J Gath, AJ, A V Pedersen, [1803.00991].

RELATIVISTIC MAGNETO-HYDRODYNAMICS

Conventional Formulation

HYDRODYNAMICS AND ELECTROMAGNETISM

- Magnetohydrodynamics can be formulated as a charged fluid coupled to dynamical electromagnetic fields [1].
- The dynamical equations of MHD are the energy-momentum conservation

$$\partial_\mu T^{\mu\nu} = 0.$$

coupled to Maxwell's equations and electromagnetic Bianchi identity

$$J^\nu \equiv \partial_\mu F^{\mu\nu} + J^\nu_{\text{matter}} = 0, \qquad \epsilon^{\mu\nu\rho\sigma}\partial_\nu F_{\rho\sigma} = 0.$$

- The dynamical fields of MHD are

$$u^\mu \quad (u^\mu u_\mu = -1), \qquad T, \qquad \mu, \qquad E_\mu = F_{\mu\nu}u^\nu, \qquad B^\mu = \frac{1}{2}\epsilon^{\mu\nu\rho\sigma}u_\nu F_{\rho\sigma}.$$

[1] Hernandez, Kovtun, [1703.08757].

MHD CONSTITUTIVE RELATIONS

- A plasma is characterised by its constitutive relations

$$T^{\mu\nu}[u^\mu, T, \mu, E_\mu, B^\mu], \qquad J^\mu[u^\mu, T, \mu, E_\mu, B^\mu]\,.$$

- For instance, a plasma minimally coupled to electromagnetic fields via a conductivity term has constitutive relations

$$T^{\mu\nu} = \epsilon\, u^\mu u^\nu + P\, P^{\mu\nu} + \left(F^{\mu\rho} F^{\nu}{}_{\rho} - \frac{1}{4} F^{\rho\sigma} F_{\rho\sigma} \eta^{\mu\nu} \right), \qquad J^\mu = \partial_\nu F^{\nu\mu} + q\, u^\mu + \sigma \left(E^\mu - T P^{\mu\nu} \partial_\nu \frac{\mu}{T} \right),$$

$$P^{\mu\nu} = \eta^{\mu\nu} + u^\mu u^\nu, \qquad dP = s dT + q d\mu, \qquad \epsilon = sT + q\mu - P, \qquad \sigma \geq 0.$$

- They satisfy the second law of thermodynamics

$$S^\mu = s\, u^\mu - \frac{\mu}{T} \sigma \left(E^\mu - T P^{\mu\nu} \partial_\nu \frac{\mu}{T} \right), \qquad \partial_\mu S^\mu = \frac{\sigma}{T} \left(E^\mu - T P^{\mu\nu} \partial_\nu \frac{\mu}{T} \right) \left(E_\mu - T P_\mu{}^\rho \partial_\rho \frac{\mu}{T} \right) \geq 0.$$

NEUTRALITY AND ELECTRIC FIELD SCREENING

- Let us look at the Maxwell's equations

$$J^\mu = \partial_\nu F^{\nu\mu} + q\, u^\mu + \sigma \left(E^\mu - T P^{\mu\nu} \partial_\nu \frac{\mu}{T} \right) = 0.$$

- This can be solved within the derivative expansion to give

$$q(T,\mu) = u_\mu \partial_\nu F^{\nu\mu} = \mathcal{O}(\partial) \qquad \Longrightarrow \qquad \mu = \mu_0(T) + \mathcal{O}(\partial),$$

$$E^\mu = T P^{\mu\nu} \partial_\nu \frac{\mu}{T} - \frac{1}{\sigma} P^\mu{}_\rho \partial_\nu F^{\nu\rho} = \mathcal{O}(\partial)\,.$$

- At zeroth order in derivatives, the plasma is electromagnetically neutral and the electric fields are screened.

TAKING THE MAXWELL'S EQUATIONS ON-SHELL

- We can use Maxwell's equations to eliminate chemical potential and electric fields from the MHD constitutive relations

$$\mu = \mu_0(T) + \delta\mu[u^\mu, T, B^\mu], \qquad E^\mu = E^\mu[u^\mu, T, B^\mu]\,.$$

We will assume $\mu_0(T) = 0$ for the remainder of this talk.

- This reduces the dynamical variables to

$$u^\mu \quad (u^\mu u_\mu = -1), \qquad T, \qquad B^\mu\,.$$

- The dynamics is governed by

$$\partial_\mu T^{\mu\nu} = 0, \qquad \partial_\mu \star F^{\mu\nu} = 0,$$

$$T^{\mu\nu}[u^\mu, T, B^\mu], \qquad \star F^{\mu\nu}[u^\mu, T, B^\mu] = \frac{1}{2}\epsilon^{\mu\nu\rho\sigma}F_{\rho\sigma} = 2u^{[\mu}B^{\nu]} + \epsilon^{\mu\nu\rho\sigma}u_\rho E_\sigma[u^\mu, T, B^\mu]\,.$$

EFFECTIVE THEORY OF MAGNETIC FIELD LINES

- Due to neutrality and screening, chemical potential and electric fields are not independently dynamical in a plasma.
- The low energy dynamics of a plasma is dominated by magnetic fields in the electromagnetic sector, whose configurations are governed by the conservation of magnetic flux lines.
- Magnetohydrodynamics can be recast as a theory of fluids with added conserved string-like objects — magnetic field lines.
- Due to lesser number of dynamical variables and cleaner equations of motion, this formulation is better tractable for analytic and numerical implementations.

STRING FLUIDS

Reformulation of MHD

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STRING CHARGES AND ONE-FORM SYMMETRIES

- A zero-form global symmetry is characterised by a conserved one-form current

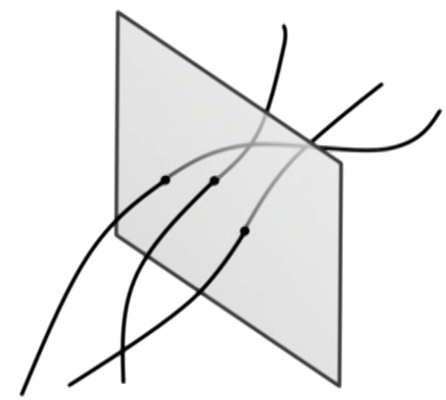
$$\partial_\mu J^\mu = 0, \qquad Q[\Sigma_3] = \int_{\Sigma_3} \star J^{(1)} .$$

The associated charge operator is conserved and counts the number of "charged particles" in a region of space.

- Correspondingly, a one-form symmetry is characterised by a conserved two-form current [1]

$$\partial_\mu J^{\mu\nu} = 0, \qquad Q[\Sigma_2] = \int_{\Sigma_2} \star J^{(2)} .$$

The charge operator counts the number of "charged strings" crossing through a surface and is conserved.



[1] Gaiotto, Kapustin, Seiberg, Willett [1412.5148].

FLUIDS WITH ONE-FORM SYMMETRY

- A one-form fluid is a fluid with a notion of conserved string charges.
- Dynamics of a one-form fluid is governed by the respective conservation equations

$$\partial_\mu T^{\mu\nu} = 0, \qquad \partial_\mu J^{\mu\nu} = 0.$$

The time-component of the one-form conservation equation lacks a time derivative and hence does not govern evolution. It instead imposes a constraint on the initial conditions.

- We can choose the required 7 degrees of freedom to be

$$u^\mu \;\; (u^\mu u_\mu = -1), \qquad T, \qquad h_\mu \;\; (h^\mu h_\mu = 1,\, u^\mu h_\mu = 0), \qquad \varpi\,.$$

These one-form fluids are called string fluids [1].

[1] Schubring, [1412.3135]; Grozdanov, Hofman, Iqbal, [1610.07392].

STRING FLUID CONSTITUTIVE RELATIONS

- A string fluid is characterised by its constitutive relations

$$T^{\mu\nu}[u^\mu, T, h_\mu, \varpi], \qquad J^{\mu\nu}[u^\mu, T, h_\mu, \varpi]\,.$$

- For example, we can have a string fluid with

$$T^{\mu\nu} = \epsilon\, u^\mu u^\nu + p\, P^{\mu\nu} - \varpi\rho\, h^\mu h^\nu, \qquad J^{\mu\nu} = 2\rho\, u^{[\mu}h^{\nu]} + \left(2r_\perp\, h^{[\mu}\Delta^{\nu]\rho}h^\sigma - r_\parallel\, \Delta^{\mu\rho}\Delta^{\nu\sigma}\right) f_{\rho\sigma}\,.$$

$$P^{\mu\nu} = \eta^{\mu\nu} + u^\mu u^\nu, \qquad \Delta^{\mu\nu} = \eta^{\mu\nu} + u^\mu u^\nu - h^\mu h^\nu, \qquad f_{\mu\nu} = 2T\,\partial_{[\mu}\left(\frac{\varpi h_{\nu]}}{T}\right),$$

$$dp = sdT + \rho d\varpi, \qquad \epsilon = sT + \rho\varpi - p, \qquad r_\perp \geq 0, \qquad r_\parallel \geq 0.$$

- They satisfy the second law of thermodynamics

$$S^\mu = s\, u^\mu + \frac{\varpi}{T} r_\perp \Delta^{\mu\rho}h^\sigma f_{\rho\sigma}, \qquad \partial_\mu S^\mu = \frac{1}{T}\left(r_\perp h^\mu h^\rho \Delta^{\nu\sigma} + \frac{1}{2} r_\parallel \Delta^{\mu\rho}\Delta^{\nu\sigma}\right) f_{\mu\nu} f_{\rho\sigma} \geq 0.$$

MHD AS A STRING FLUID

- MHD can be viewed as a string fluid with conserved magnetic field lines.

String	MHD
u^μ	$u^\mu - \frac{1}{\sigma(T)}\left(\frac{T^2 s(T)}{\epsilon(T)+P(T)+B^2}\right)2P^{\mu\rho}B^\sigma\partial_{[\rho}\left(\frac{B_{\sigma]}}{T}\right)$
T	T
h_μ	$\frac{B_\mu}{\lvert B \rvert}$
ϖ	$\lvert B \rvert$

String	MHD
$p(T,\varpi)$	$P(T)+\frac{1}{2}B^2$
$\epsilon(T,\varpi)$	$\epsilon(T)+\frac{1}{2}B^2$
$\rho(T,\varpi)$	$\lvert B \rvert$
$s(T,\varpi)$	$s(T)$
$r_\parallel(T,\varpi)$	$\frac{1}{\sigma(T)}$
$r_\perp(T,\varpi)$	$\frac{1}{\sigma(T)}\left(\frac{T s(T)}{\epsilon(T)+P(T)+B^2}\right)^2$

- Upon including the most generic constitutive relations, the mapping becomes one-to-one.

EQUILIBRIUM CONFIGURATIONS

and the Scalar Goldstone

EQUILIBRIUM PARTITION FUNCTIONS

- Equilibrium configurations in thermal field theory are described by a partition function

$$\mathcal{Z}[g_{\mu\nu}, A_\mu, b_{\mu\nu}],$$

which is a functional of time-independent background sources coupled to conserved currents.

- The partition function must be invariant under time-independent symmetry transformations of the background sources

$$\delta g_{\mu\nu} = L_{\chi(\mathbf{x})} g_{\mu\nu}, \qquad \delta A_\mu = L_{\chi(\mathbf{x})} A_\mu + \partial_\mu \Lambda(\mathbf{x}), \qquad \delta b_{\mu\nu} = L_{\chi(\mathbf{x})} b_{\mu\nu} + 2\partial_{[\mu}\Lambda_{\nu]}(\mathbf{x})\,.$$

- Due to the absence of gapless modes, in the hydrodynamic regime, the partition function is a local functional of background fields [1]

$$\mathcal{Z}[g_{\mu\nu}, A_\mu, b_{\mu\nu}] = \exp\left(-\frac{1}{T_0} \int d^3x \sqrt{-g}\, \mathcal{L}(g_{\mu\nu}, A_\mu, b_{\mu\nu}, \partial_\mu) \right).$$

[1] Banerjee, Bhattacharya, Bhattacharyya, Jain, Minwalla, Sharma [1203.3544]; Jensen, Kaminski, Kovtun, Meyer, Ritz, Yarom [1203.3556].

THE EQUILIBRIUM PATHOLOGY

- Equilibrium configurations of ordinary charged fluids are generated by the partition function

$$\mathcal{Z}[g_{\mu\nu}, A_\mu] = \exp\left(-\frac{1}{T_0}\int d^3x\sqrt{-g}\,\mathscr{L}(g_{\mu\nu}, A_\mu, \partial_\mu)\right) = \exp\left(-\frac{1}{T_0}\int d^3x\sqrt{-g}\,\mathscr{P}(g_{00}, A_0) + \mathcal{O}(\partial)\right),$$

  which leads to

$$u^\mu = \delta^\mu_0, \qquad T = T_0, \qquad \mu = \mu_0\,.$$

- Unlike zero-form fluids, no invariant zero-derivative scalars can be made out of $b_{\mu\nu}$

$$A_0 \to A_0 + \partial_0\Lambda(\mathbf{x}) = A_0, \qquad b_{0i} \to b_{0i} + \partial_0\Lambda_i(\mathbf{x}) - \partial_i\Lambda_0(\mathbf{x}) = b_{0i} - \partial_i\Lambda_0(\mathbf{x})\,.$$

- Therefore

$$\mathcal{Z}[g_{\mu\nu}, b_{\mu\nu}] = \exp\left(-\frac{1}{T_0}\int d^3x\sqrt{-g}\,\mathscr{L}(g_{\mu\nu}, b_{\mu\nu}, \partial_\mu)\right) = \exp\left(-\frac{1}{T_0}\int d^3x\sqrt{-g}\,\mathscr{P}(g_{00}) + \mathcal{O}(\partial)\right).$$

  This partition function does not generate string fluids.

A PARALLEL WITH SUPERFLUIDS

- Constitutive relations of a zero-form superfluid are like zero-form charged fluids, but in addition contain a superfluid velocity ξ_μ.
- Based on symmetry arguments, we could be tempted to write down a partition function

$$\mathcal{Z}[g_{\mu\nu}, A_\mu] = \exp\left(-\frac{1}{T_0}\int d^3x\sqrt{-g}\,\mathcal{L}(g_{\mu\nu}, A_\mu, \partial_\mu)\right) = \exp\left(-\frac{1}{T_0}\int d^3x\sqrt{-g}\,\mathcal{P}(g_{00}, A_0) + \mathcal{O}(\partial)\right).$$

This partition function generates zero-form charged fluids and not superfluids.

- However, superfluids have their zero-form symmetry spontaneously broken, leading to a non-hydrodynamic gap-less condensate. The appropriate partition function is given by [1]

$$\begin{aligned}\mathcal{Z}[g_{\mu\nu}, A_\mu] &= \int \mathcal{D}\phi \exp\left(-\frac{1}{T_0}\int d^3x\sqrt{-g}\,\mathcal{L}(g_{\mu\nu}, A_\mu, \partial_\mu; \phi)\right) \\ &= \int \mathcal{D}\phi \exp\left(-\frac{1}{T_0}\int d^3x\sqrt{-g}\,\mathcal{P}(g_{00}, A_0, (A_i + \partial_i\phi)^2) + \mathcal{O}(\partial)\right).\end{aligned}$$

[1] Bhattacharyya, Jain, Minwalla, Sharma [1206.6106].

FIXING STRING EQUILIBRIUM

- We propose that string fluids contain a non-hydrodynamic gap-less scalar field which controls the equilibrium configurations.
- Under a time-independent one-form background gauge transformation, the scalar field transforms as

$$\varphi(\mathbf{x}) \to \varphi(\mathbf{x}) - \frac{1}{T_0}\Lambda_0(\mathbf{x}) \,.$$

- The string fluid partition function is given by

$$\begin{aligned}\mathcal{Z}[g_{\mu\nu}, b_{\mu\nu}] &= \int \mathcal{D}\varphi \exp\left(-\frac{1}{T_0}\int d^3x\sqrt{-g}\,\mathcal{L}(g_{\mu\nu}, b_{\mu\nu}, \partial_\mu; \varphi)\right) \\ &= \int \mathcal{D}\varphi \exp\left(-\frac{1}{T_0}\int d^3x\sqrt{-g}\,\mathcal{P}(g_{00}, (b_{0i} - T_0\partial_i\varphi)^2) + \mathcal{O}(\partial)\right) .\end{aligned}$$

FIXING STRING EQUILIBRIUM

- Comparing with the string constitutive relations, we can find the equilibrium configuration

$$u^\mu = \delta_0^\mu, \qquad T = T_0, \qquad \varpi h_\mu = -T_0 \partial_\mu \varphi \,.$$

- The scalar field follows its classical non-linear equation of motion

$$\partial_k \left(\frac{\partial \mathscr{P}(\eta_{00}, (\partial_i \varphi)^2)}{\partial (\partial_i \varphi)^2} \partial^k \varphi \right) = \mathcal{O}(\partial) \,.$$

- Recalling the identification with minimally coupled MHD

$$\varpi = |B| + \mathcal{O}(\partial), \qquad h_\mu = \frac{B_\mu}{|B|} + \mathcal{O}(\partial) \qquad \Longrightarrow \qquad B_\mu = -T_0 \partial_\mu \varphi + \mathcal{O}(\partial) \,.$$

To leading order, the scalar field is equivalent to the magnetic scalar potential.

- The interpretation as magnetic scalar potential can be spoiled by non-minimal couplings and higher-derivative corrections in MHD.

CONSEQUENCES FOR MHD

- Equilibrium configurations of string fluids are controlled by one scalar differential equation, generated via a hydrostatic effective action.
- Ordinarily, to find equilibrium configurations of a plasma, one would need to simultaneously solve a set of 8 MHD equations (after removing Maxwell's).
- With the choice of variables suggested by string fluids and associated equilibrium partition functions, this reduces to a single equation to be solved for a single scalar field.
- Obtaining new analytic equilibrium solutions is crucial for numerical simulations, which use these as initial conditions for the full dynamical evolution.

PARTIAL BREAKING OF ONE-FORM SYMMETRIES

Origins of Scalar Goldstone

DEGREES OF FREEDOM

- The non-hydrodynamic scalar field in string fluids can be lifted out of equilibrium as

$$\varphi \to \varphi - \frac{1}{T_0}\Lambda_0 \qquad \longrightarrow \qquad \varphi \to \varphi - \frac{1}{T}u^\mu \Lambda_\mu \,.$$

- String fluid variables can be decomposed into hydrodynamic and non-hydrodynamic modes

$$\varpi h_\mu = -\, T_0 \partial_\mu \varphi \qquad \longrightarrow \qquad \varpi h_\mu = \mu_\mu - T\partial_\mu \varphi \,.$$

  μ_μ is a symmetry non-invariant one-form chemical potential that vanishes in equilibrium

$$\mu_\mu \to \mu_\mu - T\partial_\mu \left(\frac{1}{T}u^\nu \Lambda_\nu\right) .$$

- The local one-form fluid partition function, without involving the additional scalar field, generates a one-form fluid with degrees of freedom

$$u^\mu \quad (u^\mu u_\mu = -\,1), \qquad T, \qquad \mu_\mu \,.$$

  We interpret it as the "symmetry-unbroken" or "ordinary" phase of one-form fluids.

SUPERFLUID PHASES OF ONE-FORM FLUIDS

- In "string" phase of one-form fluids, the theory contains a non-hydrodynamic mode φ.
- This mode comes with its own equation of motion, which, within the hydrodynamic regime, can be shown to be [1]

$$u^\mu \partial_\mu \varphi = \frac{1}{T} u^\mu \mu_\mu \qquad \Longrightarrow \qquad u^\mu h_\mu = 0.$$

  This is reminiscent of the Josephson equation in zero-form superfluids: $u^\mu \partial_\mu \phi = \mu$.

- In the "symmetry-broken" or "superfluid" phase of one-form fluids, the theory contains a vector condensate

$$\varphi_\mu \to \varphi_\mu - \Lambda_\mu .$$

- Identifying $\varphi = u^\mu \varphi_\mu / T$, the "string" phase of one-form fluids can be understood as a phase where the one-form symmetry is partially-broken only along the direction of the fluid flow.

[1] AJ [1610.05797].

ORDER PARAMETERS

- We would like to identify certain order parameters to distinguish between the phases where the underlying one-form symmetry is intact or is partially/completely broken.
- In the zero-form case, vacuum expectation values of charged exponentials can serve as an order parameter

$$\left\langle \exp\left(i\phi(x)\right)\right\rangle, \qquad \phi \to \phi + \Lambda\,.$$

  If the expectation value is zero, the symmetry is unbroken, otherwise it is broken.

- For one-form symmetries, the charged operators are defined over spacelike loops

$$\left\langle \exp\left(i\int_C \varphi_\mu(x)\,dx^\mu\right)\right\rangle, \qquad \varphi_\mu \to \varphi_\mu + \Lambda_\mu\,.$$

  For large loops, the vacuum expectation value scales as the perimeter of the loop in the completely-broken phase, and the area of the loop otherwise.

ORDER PARAMETER FOR PARTIAL SYMMETRY BREAKING

- Large loop behaviour of these operators does not distinguish between the unbroken and partially-broken phases of the one-form symmetry.
- We need a preferred timelike vector to define an order parameter for the partially-broken phase.
- In equilibrium field theories, there is a natural notion of such a time. We can define an order parameter by integrating φ_μ along the euclidean thermal circle

$$\left\langle \exp\left(-\int_{S^1_\tau} \varphi_\mu(\mathbf{x})\, dx^\mu_E \right) \right\rangle = \left\langle \exp\left(\frac{i}{T_0} \varphi_0(\mathbf{x}) \right) \right\rangle, \qquad \varphi_\mu \to \varphi_\mu + \Lambda_\mu \,.$$

This vacuum expectation value being zero or non-zero should distinguish between partially-broken and unbroken phases in equilibrium.

ORDER PARAMETER FOR PARTIAL SYMMETRY BREAKING

- Generically, there is no notion of a preferred time out of equilibrium.
- However, within the regime of applicability of hydrodynamics as an effective field theory, the fluid velocity field provides a preferred time-like vector.
- We can generalise the equilibrium order parameter as

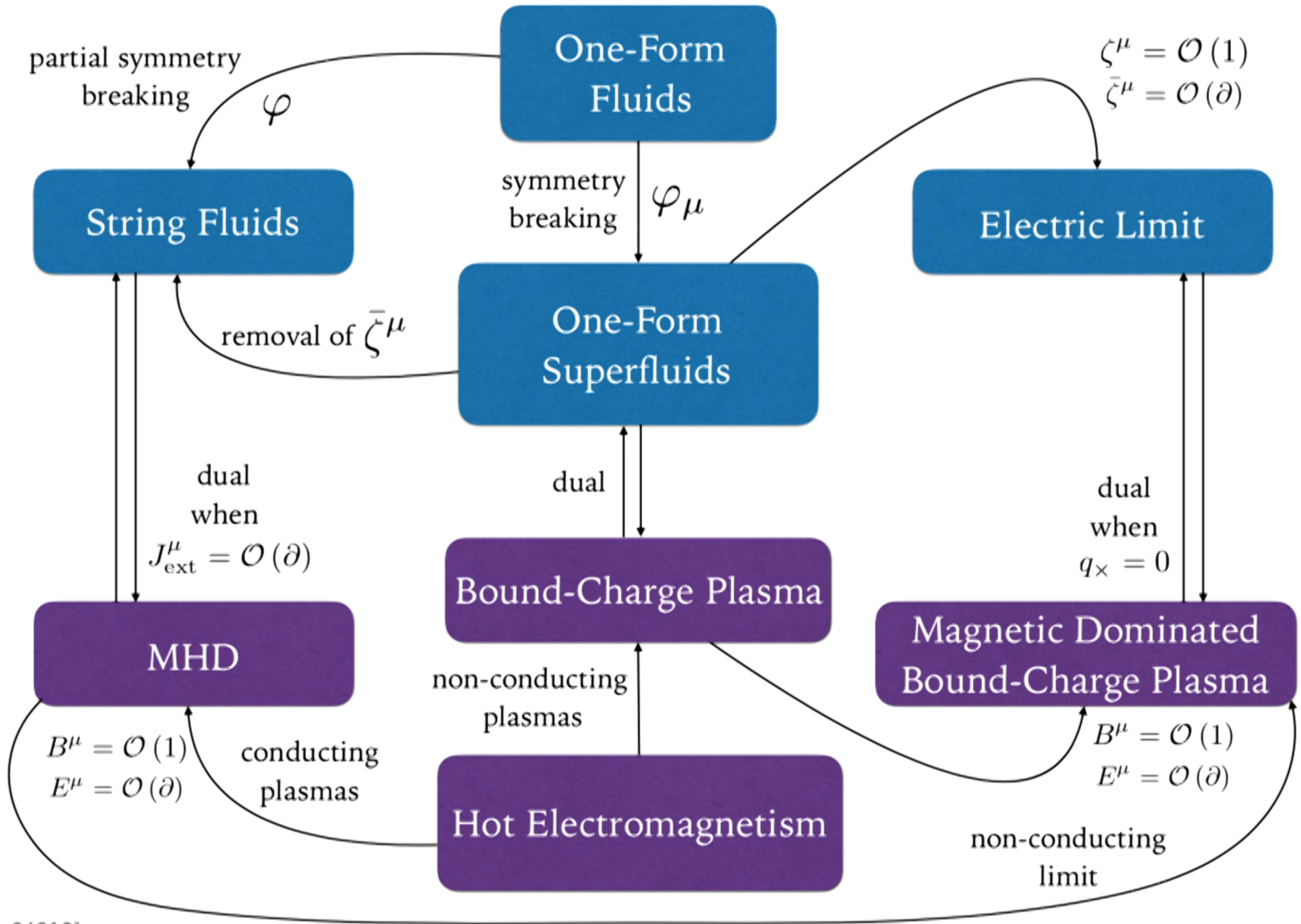
$$\left\langle \exp\left(\frac{i}{T_0}\varphi_0(\mathbf{x})\right)\right\rangle \quad \longrightarrow \quad \left\langle \exp\left(\frac{i}{T}u^\mu\varphi_\mu(x)\right)\right\rangle = \left\langle \exp\left(i\varphi(x)\right)\right\rangle .$$

- The viability of this order parameter can be tested by computing this expectation value in an effective action framework of MHD/string fluids [1].

[1] Glorioso, Son [1811.04879].

RECAP

- Magnetohydrodynamics can be effectively understood as a string fluid of dynamical magnetic field lines.
- String fluids have an underlying one-form symmetry, in addition to the usual Poincaré symmetries, with 7 hydrodynamic and 1 non-hydrodynamic degrees of freedom.
- In equilibrium, the hydrodynamic degrees of freedom are frozen and the configurations are governed by a Euclidean thermal field theory for the non-hydrodynamic field.
- The existence and symmetry-structure of the non-hydrodynamic field suggests that the underlying one-form symmetry is partially broken in string fluids along the direction of the fluid flow.



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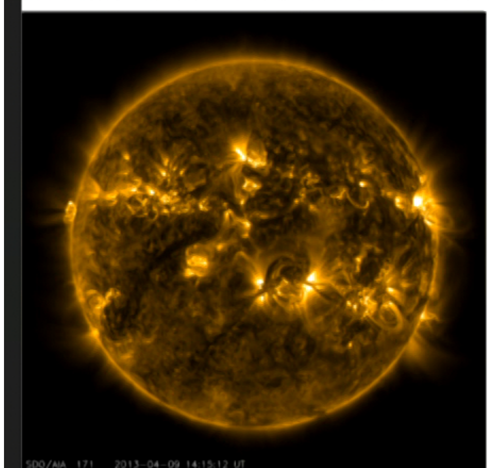

THANK YOU

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