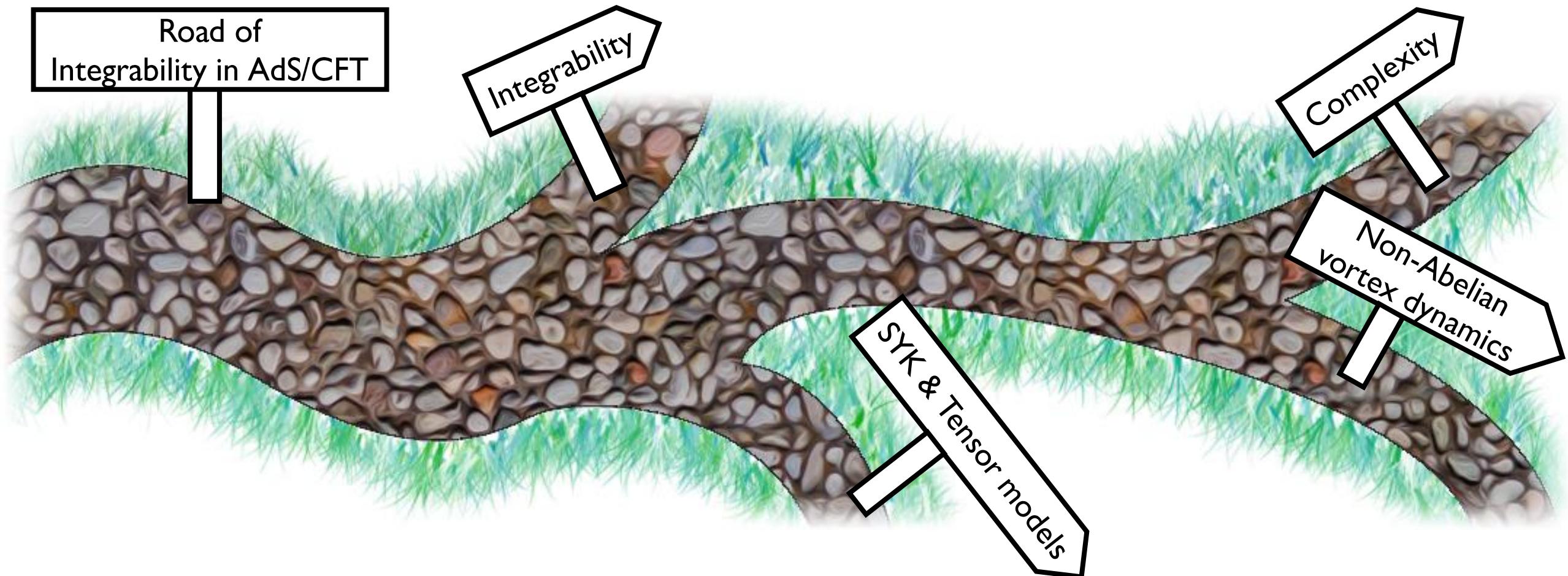






# Talk plan



*“... when a man is faced with alternatives he chooses one at the expense of the others.*

*In the almost unfathomable Ts’ui Pên, he chooses - simultaneously - all of them.”*

The Garden of Forking Paths – J. L. Borges

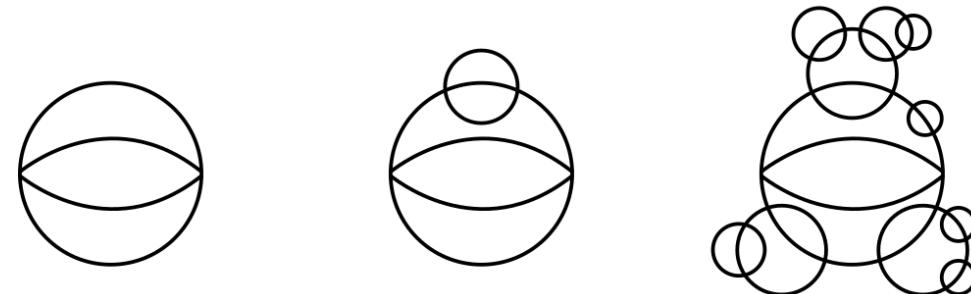


# SYK & Tensor models

A 0+1 dimensional model of  $N$  Dirac fermions:

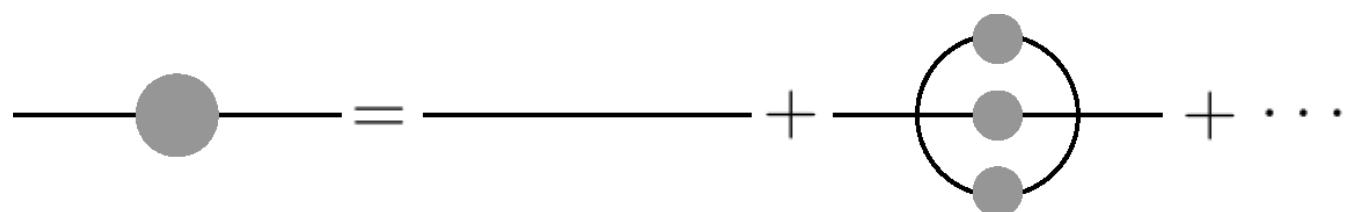
$$H_{\text{cSYK}} = J_{kl}^{ij} \chi_i^\dagger \chi_j^\dagger \chi^k \chi^l + m \chi_i^\dagger \chi^i$$

Averaging over disorder in the large- $N$  limit:



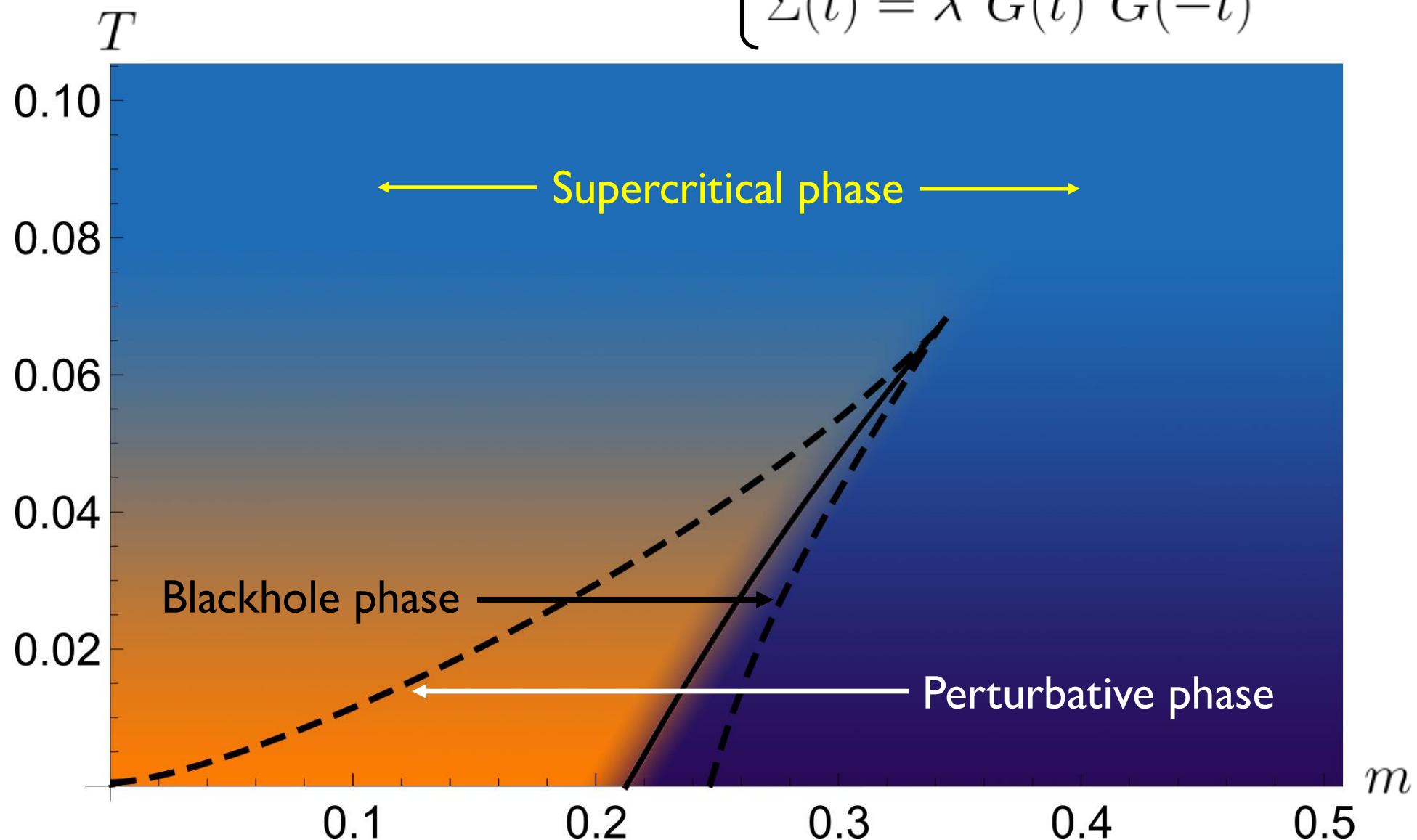
The two-point function can be recursively computed exactly

$$G(t) = \left\langle T \left( \chi^i(t) \chi_i^\dagger \right) \right\rangle_\beta$$

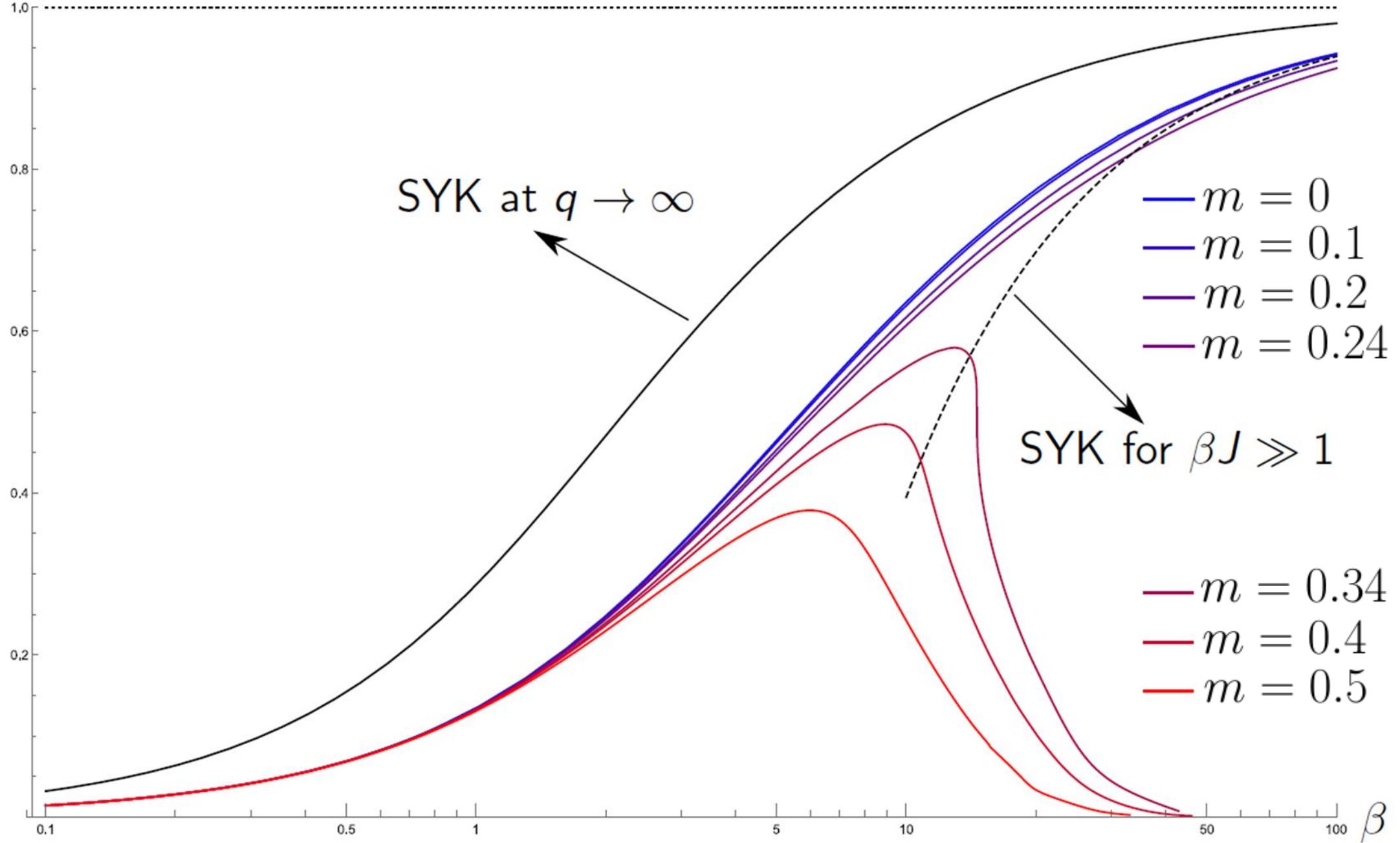


Schwinger-Dyson equations:

$$\begin{cases} G_k^{-1} = m - i\omega_k + \Sigma_k \\ \Sigma(t) = \lambda^2 G(t)^2 G(-t) \end{cases}$$

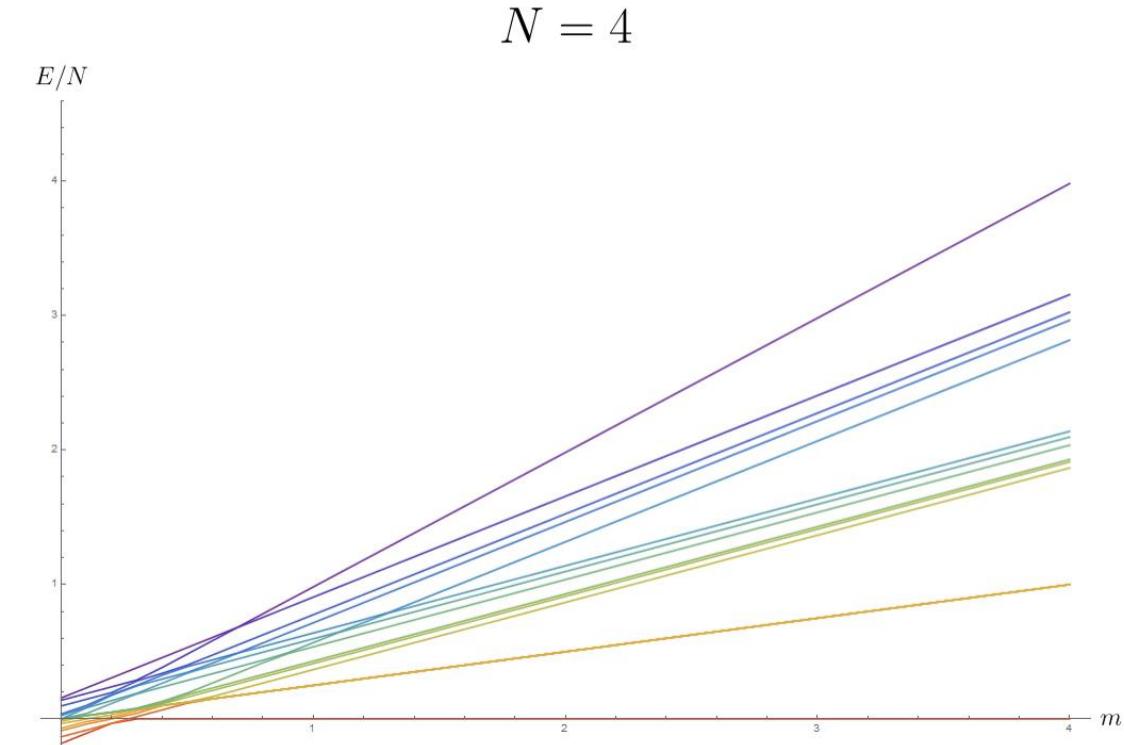
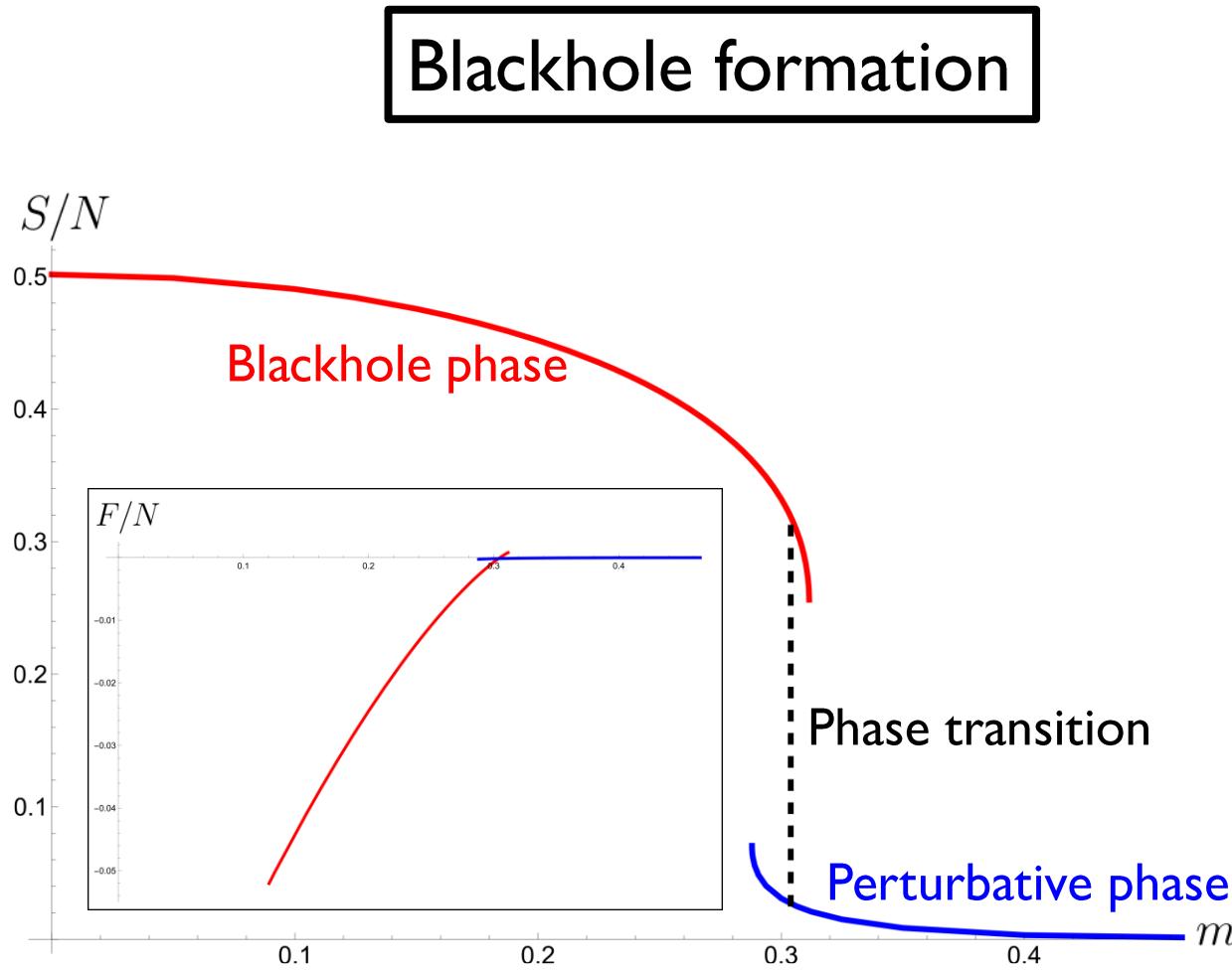


$$\frac{\lambda_L}{2\pi/\beta}$$





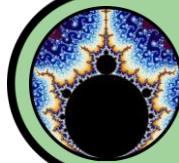
# SYK & Tensor models – Ongoing



**Direct diagonalization**

$$|\mathcal{H}| = 2^{48} = 281,474,976,710,656$$

(only 204 singlets)



# Complexity

Consider subregion of  $\text{AdS}_3$  Vaidya spacetime:

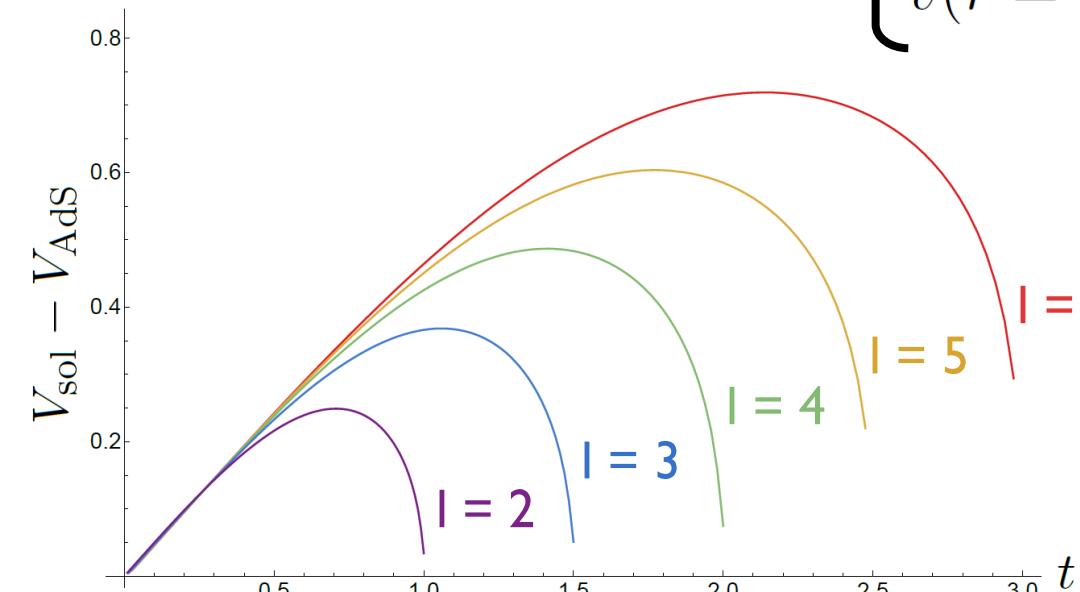
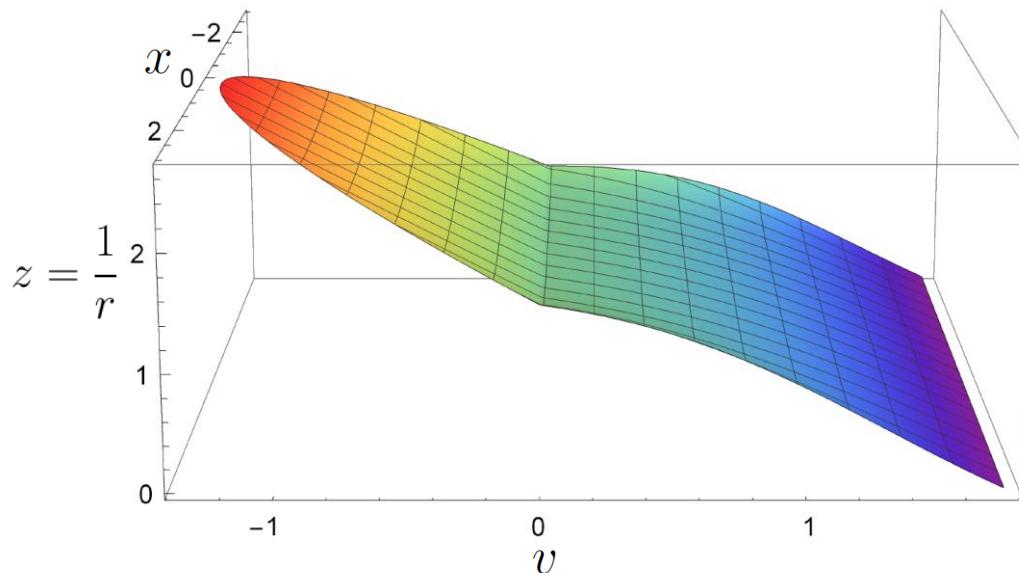
$$ds^2 = -r^2 f(v, r) dv^2 + 2 dv dr + r^2 dx^2$$

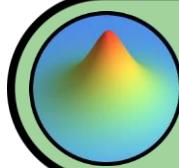
$$f = 1 - \frac{m(v)}{r^2}$$

$$m(v) = \frac{M}{2} \left( 1 + \tanh \frac{v}{\tilde{v}} \right)$$

HRT surface attached to a segment to 2+1 dimensions  Space-like geodesic with

$$\begin{cases} x(r = \infty) = \pm \frac{l}{2} \\ v(r = \infty) = t \end{cases}$$





# Non-Abelian vortex dynamics

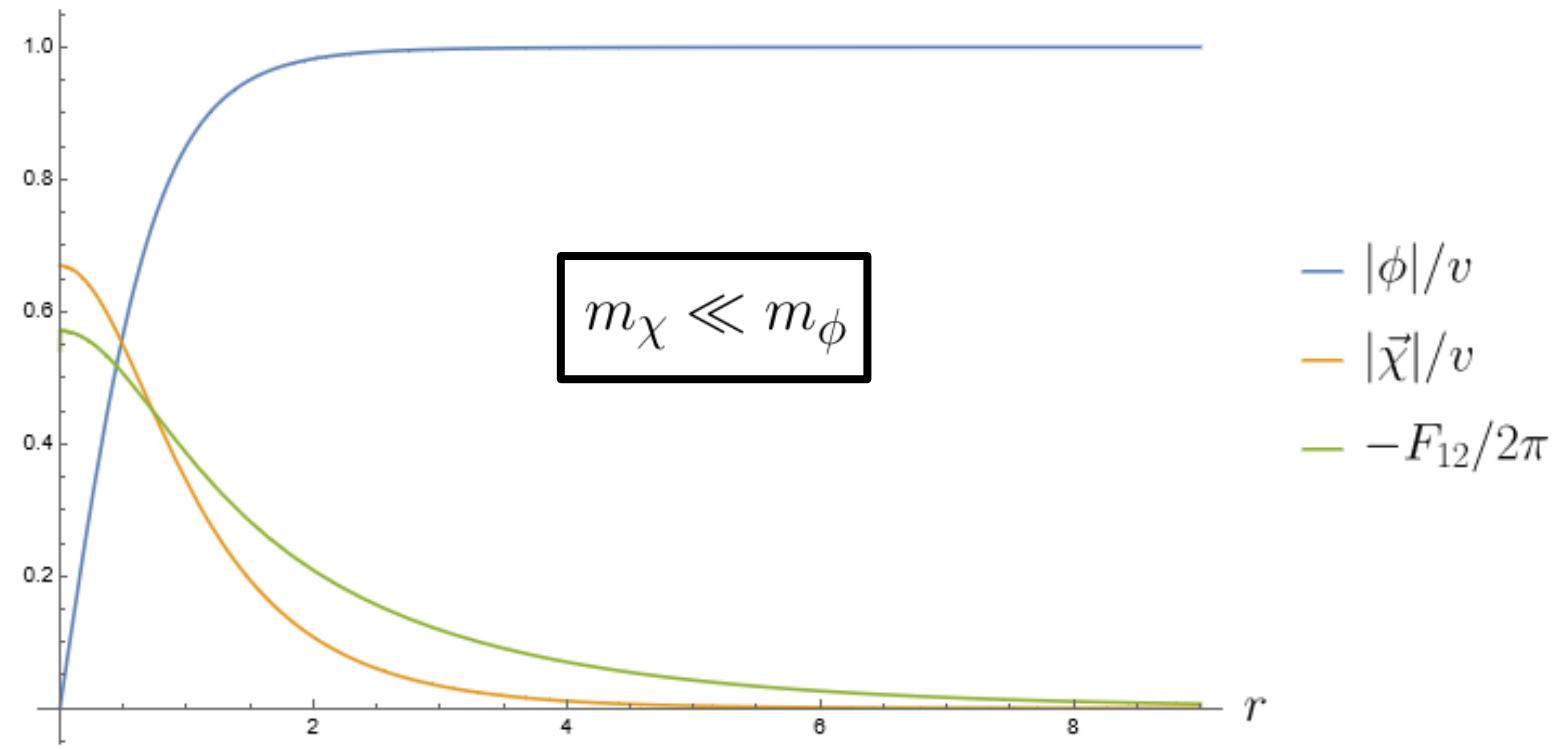
One of the simplest models having non-trivial vortices with internal orientational moduli:

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + D_\mu\phi(D^\mu\phi)^* + \partial_\mu\chi_a\partial^\mu\chi_a - V$$

$$V = \Omega^2\chi_a^2 + \lambda(|\phi|^2 + \chi_a^2 - v^2)^2$$

$$\begin{aligned}m_\phi^2 &= 4v^2\lambda \\m_\gamma^2 &= 2e^2v^2 \\m_\chi^2 &= \Omega^2\end{aligned}$$

$$\mathbb{R}^d \times \frac{SO(N)}{SO(N-1)} \simeq \mathbb{R}^d \times S^{N-1}$$



Full dynamical EOM (in Lorenz gauge) in  $d = 2$

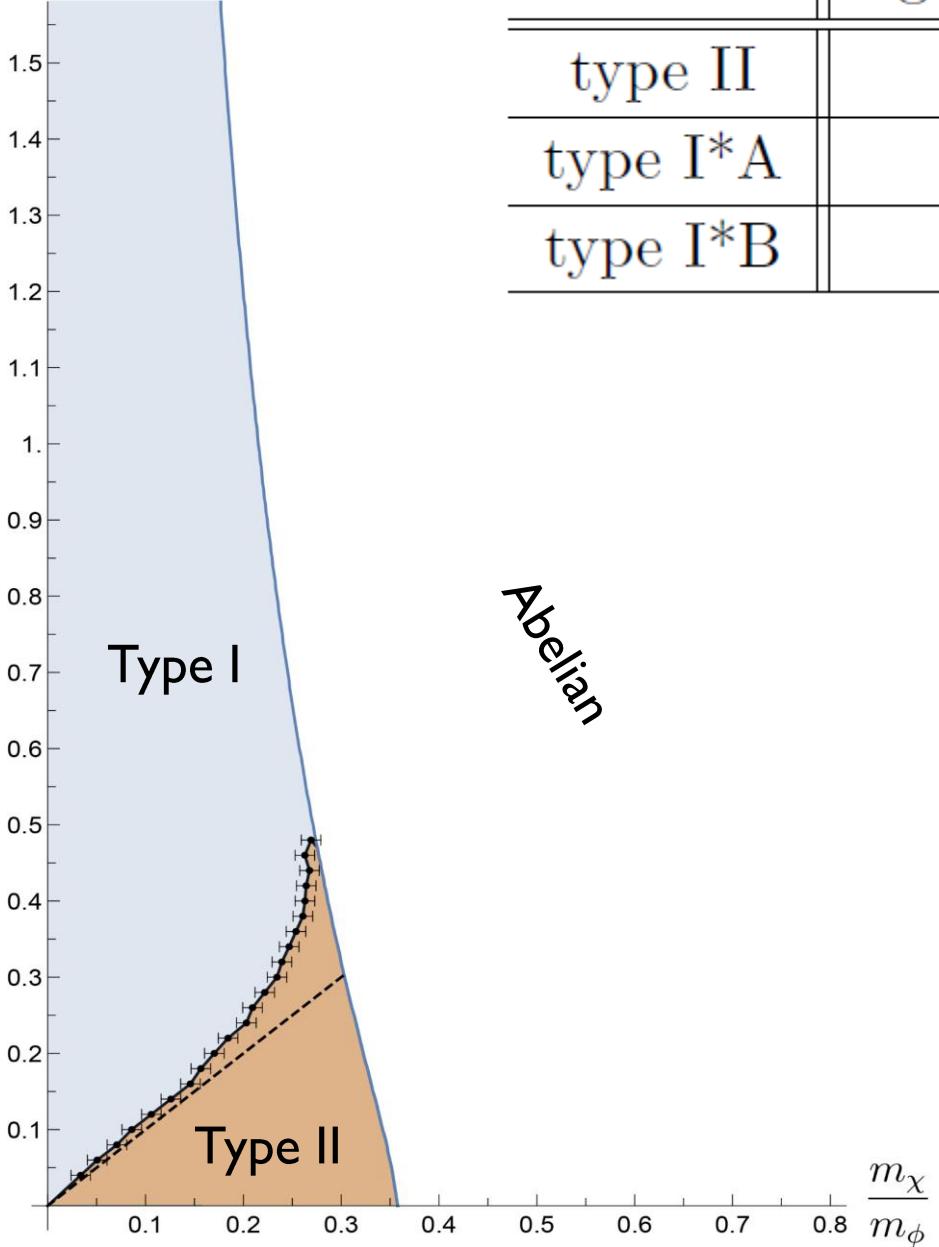
$$\begin{aligned} -\partial_\mu \partial^\mu \phi_r - 2\lambda(|\phi|^2 + \chi_i \chi^i - v^2) \phi_r + 2e A_\mu \partial^\mu \phi_i + e^2 A_\mu A^\mu \phi_r &= 0 \\ -\partial_\mu \partial^\mu \phi_i - 2\lambda(|\phi|^2 + \chi_i \chi^i - v^2) \phi_i - 2e A_\mu \partial^\mu \phi_r + e^2 A_\mu A^\mu \phi_i &= 0 \\ -\partial_\mu \partial^\mu \chi_i - 2\lambda(|\phi|^2 + \chi_i \chi^i - v^2) \chi_i - \Omega^2 \chi_i &= 0 \\ \partial_\mu \partial^\mu A_0 + 2e^2 |\phi|^2 A_0 + 2e (\phi_r \partial_t \phi_i - \phi_i \partial_t \phi_r) &= 0 \\ -\partial_\mu \partial^\mu A_x - 2e^2 |\phi|^2 A_x - 2e (\phi_r \partial_x \phi_i - \phi_i \partial_x \phi_r) &= 0 \\ -\partial_\mu \partial^\mu A_y - 2e^2 |\phi|^2 A_y - 2e (\phi_r \partial_y \phi_i - \phi_i \partial_y \phi_r) &= 0 \end{aligned}$$

### Procedure:

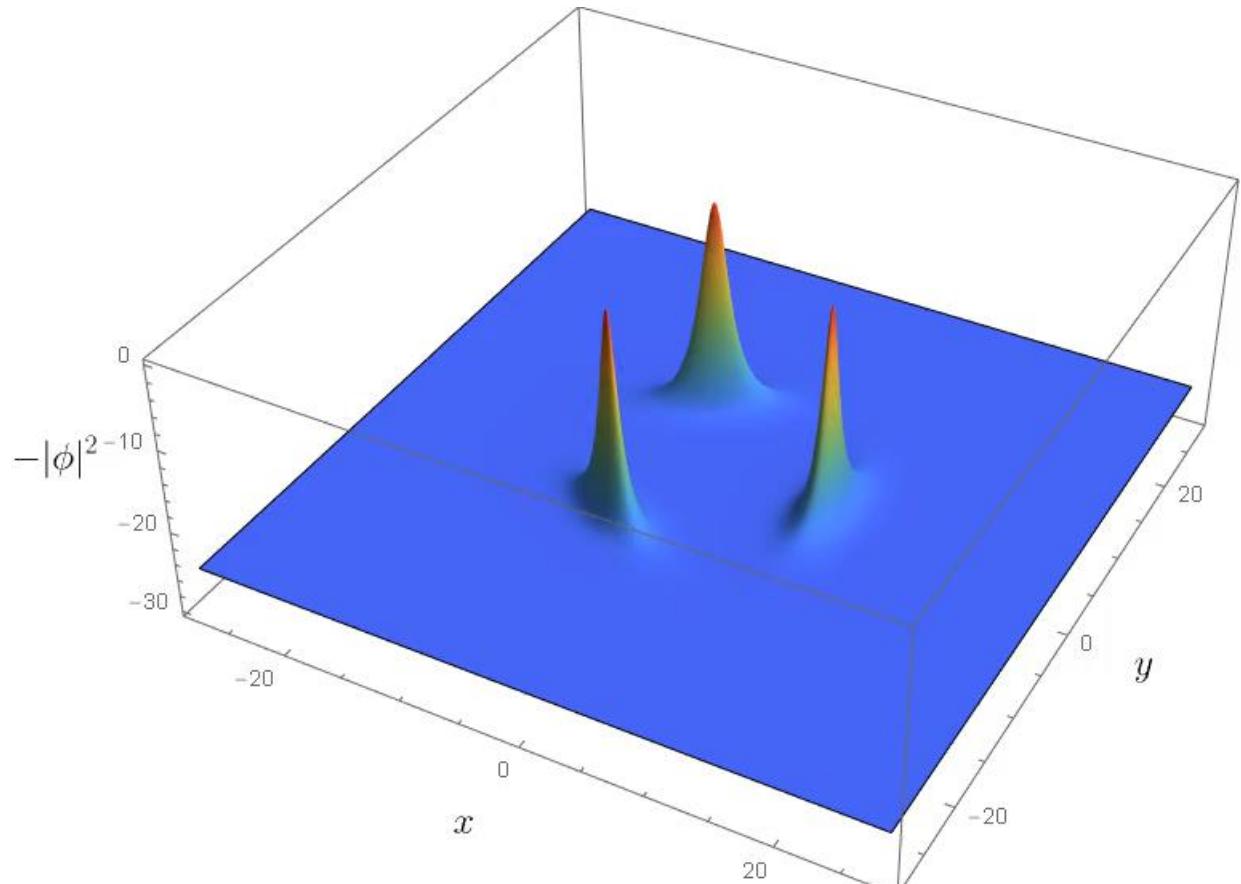
- Prepare an initial state à la Abrikosov
- Finite-element discretization
- Time-evolve using 4<sup>th</sup> order Runge-Kutta algorithm

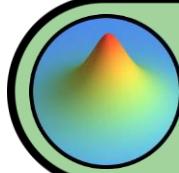
**GPU implementation to make the simulation time reasonable**

$$\frac{m_\gamma}{m_\phi}$$



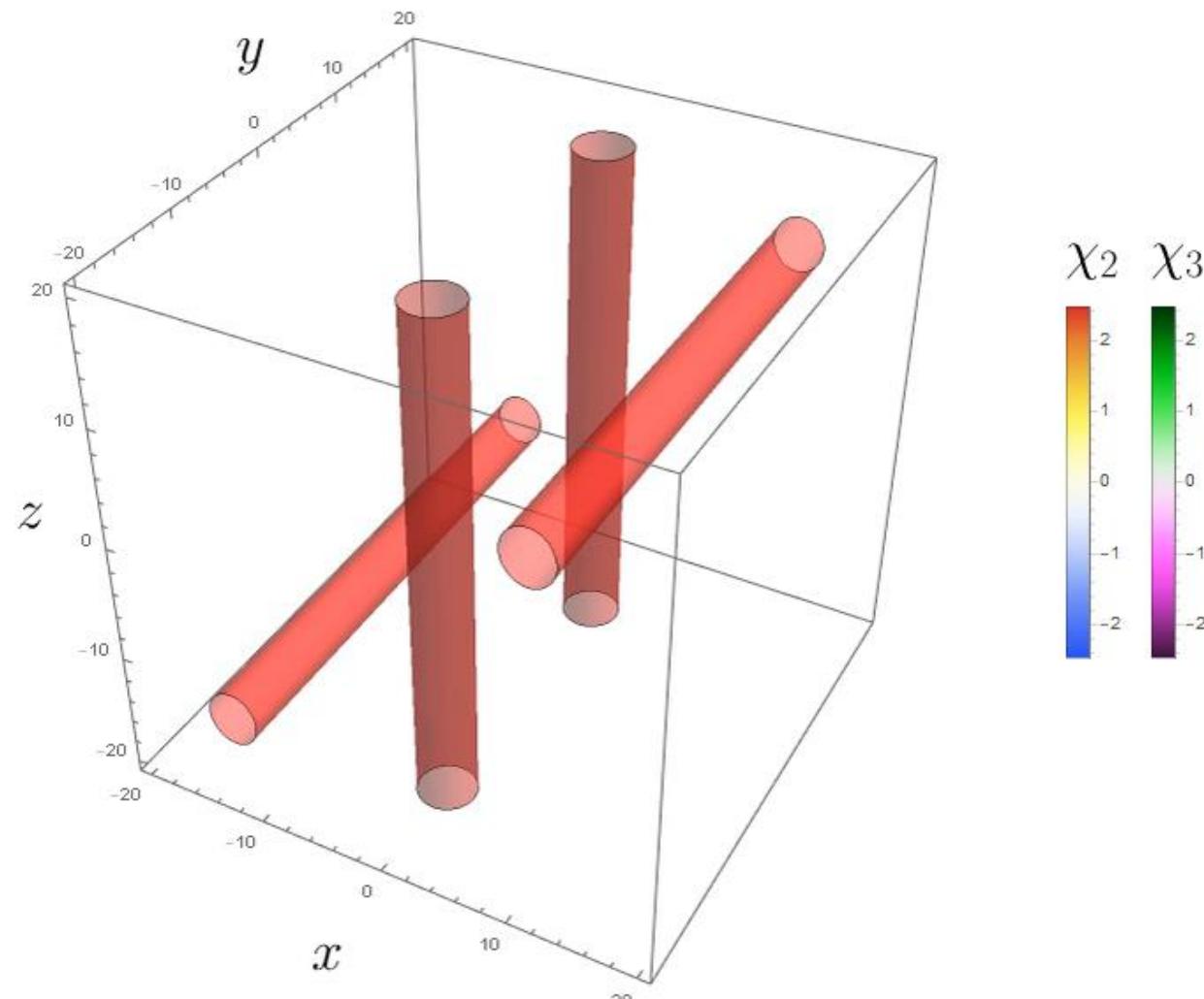
$\frac{m_\gamma}{m_\phi}$	v-v	lightest mass	parallel	orthogonal	anti-parallel
type II		$m_\gamma$	repulsion	repulsion	repulsion
type I* A		$m_\chi$	attraction	repulsion	repulsion
type I* B		$m_\chi$	attraction	attraction	repulsion





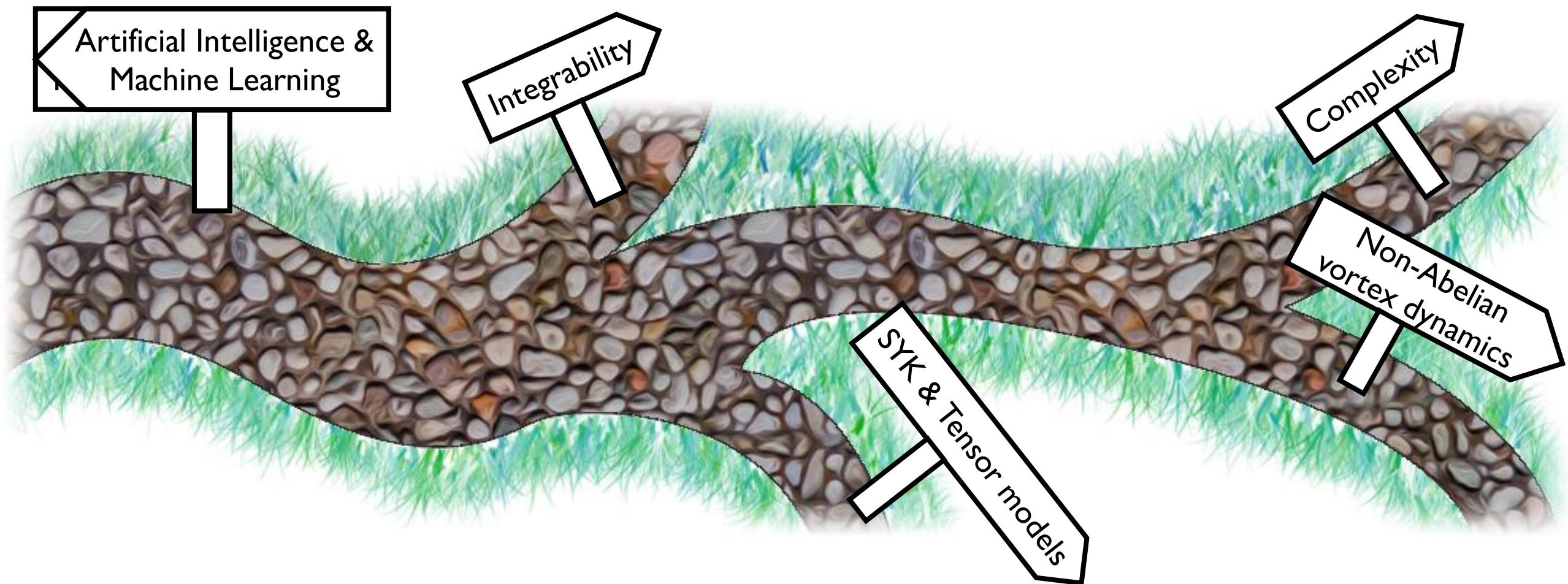
# Non-Abelian vortex dynamics - Ongoing

$t = 0.00$





# Conclusions



Thanks!