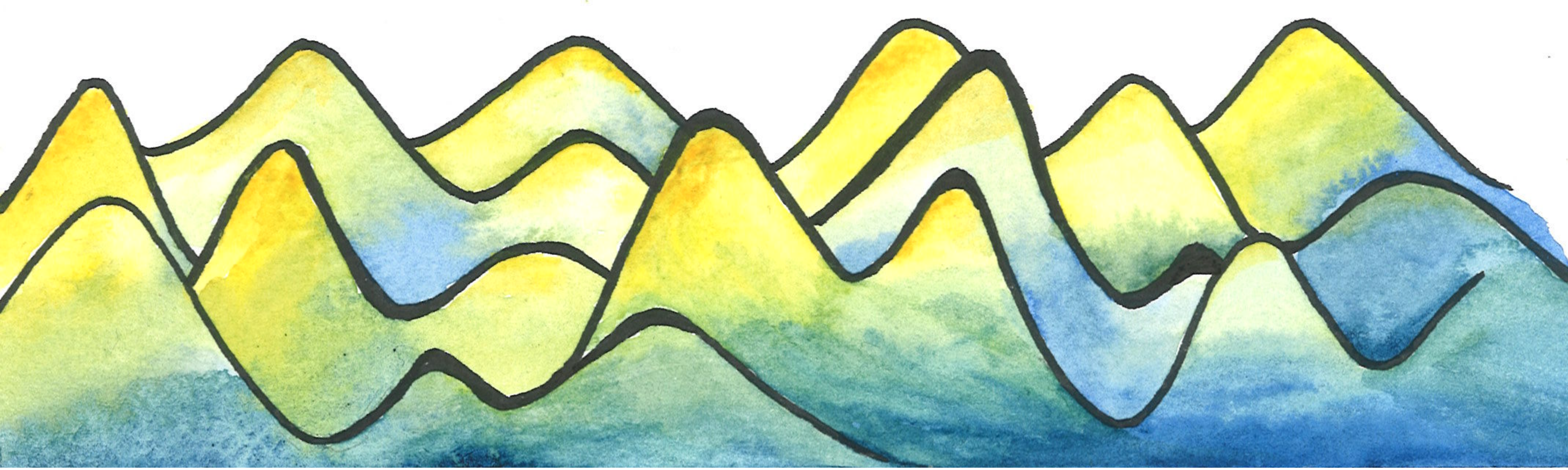
Universal predictions from inflation



Jonathan Frazer (DESY), David Marsh (DAMTP), Alexander Westphal (DESY), Marco Scalisi (DESY/ Leuven)

European Research Council

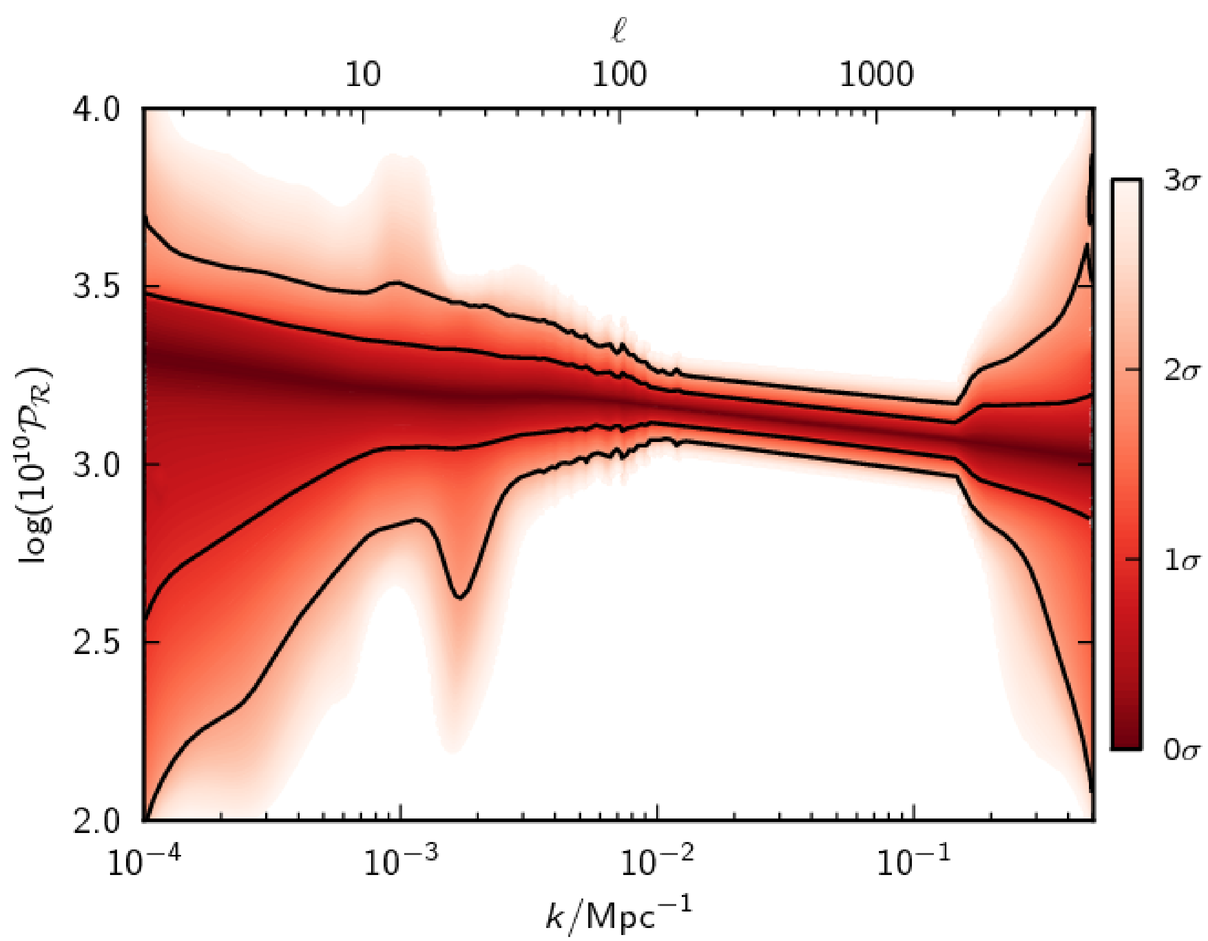
Primordial perturbations are very simple

The power spectrum of the primordial curvature perturbation can be parameterised by two numbers:
Amplitude A_s and tilt n_s.

$$P_\zeta(k) = A_s \left(\frac{k}{k_*}\right)^{n_s - 1}$$

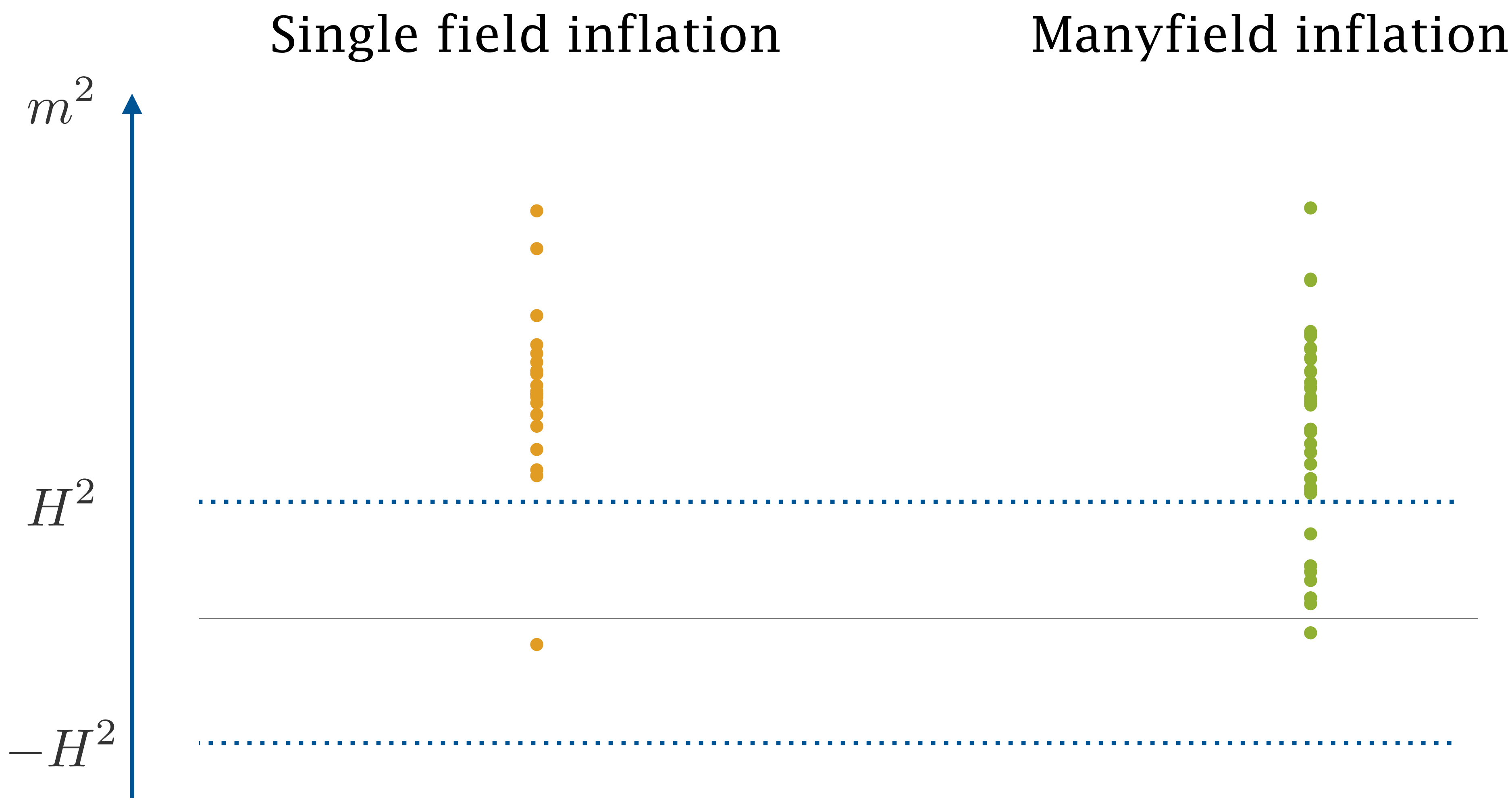
$$n_s|_{k_0} \equiv \left.\frac{\mathrm{d}\log P_\zeta}{\mathrm{d}\log k}\right|_{k_0} = 0.968 \pm 0.006$$

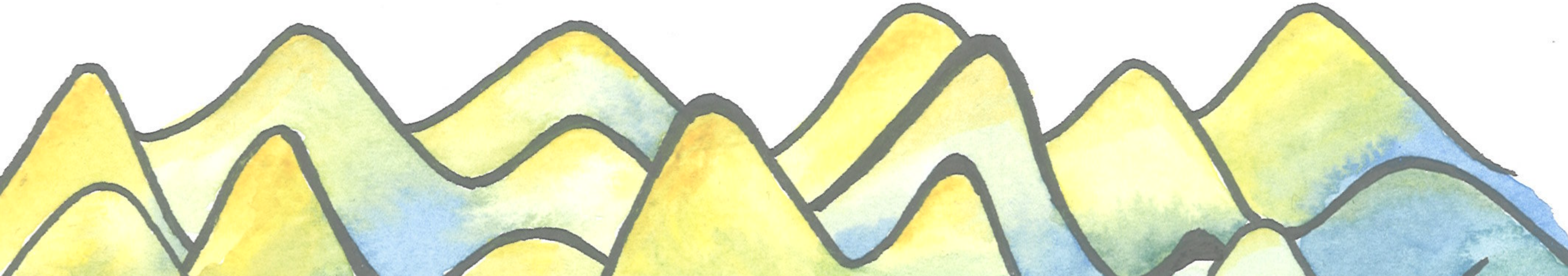
$$\alpha_s|_{k_0} \equiv \left.\frac{\mathrm{d}n_s}{\mathrm{d}\log k}\right|_{k_0} = -0.003 \pm 0.007$$



Planck 2015 results. XX:1502.02114

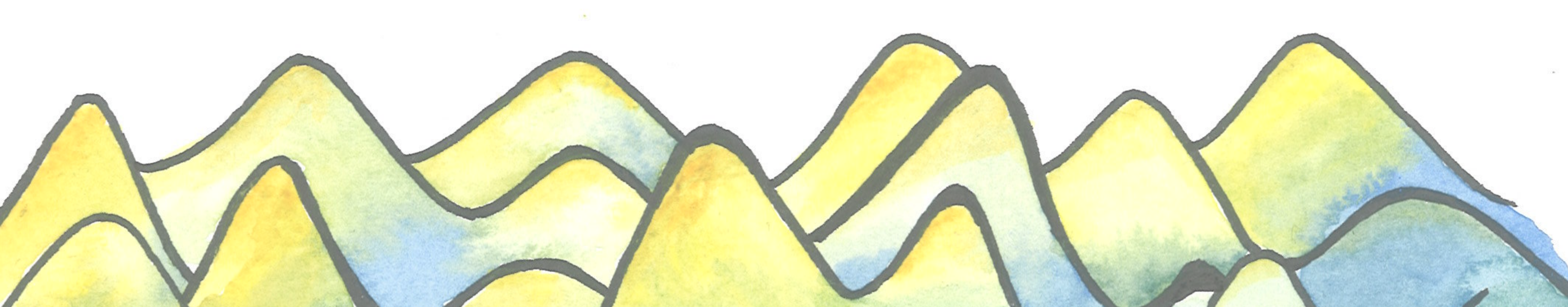
But inflation from fundamental physics might not be





Can complex inflationary physics give rise to simple observational signatures?

Emergent universality



Studying complicated models is complicated

Very little is known about inflation with many fields. Challenges:

1. Constructing the model: scaling problem *e.g.*

$$V = \Lambda_v^4 \sum_{k_{\min}}^{k_{\max}} \left[a_{\vec{k}} \cos\left(\vec{k}.\tilde{\phi}\right) + b_{\vec{k}} \sin\left(\vec{k}.\tilde{\phi}\right) \right] \qquad \tilde{\phi}^a \equiv \phi^a / \Lambda_{\rm h}$$

No. of terms ~ $(k_{\max}/k_{\min})^{N_f}$

2. Inflation is extremely rare.

(3. Computing observables: another scaling problem)

A random manyfield potential from RMT

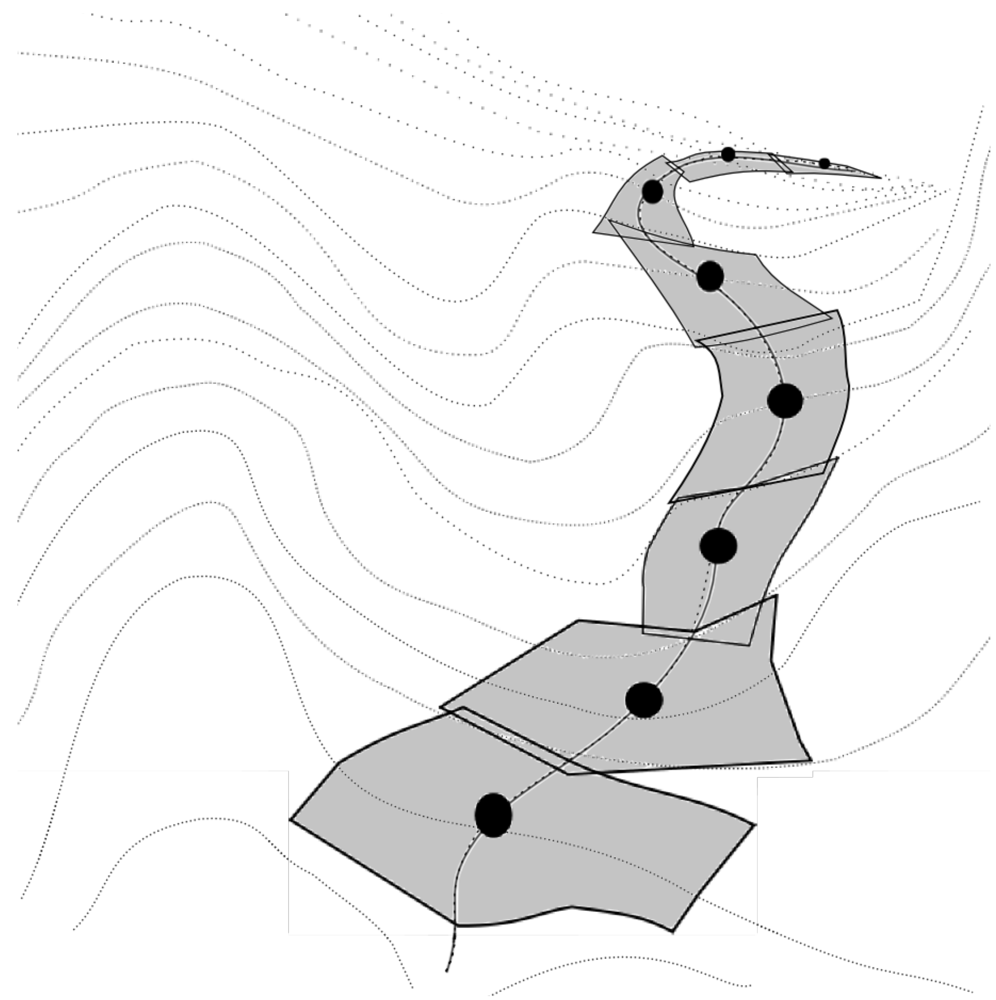
A local approach:

$$V\Big|_{p_0} = \Lambda_{\rm v}^4 \sqrt{N_f} \left(v_0|_{p_0} + v_a|_{p_0} \, \tilde{\phi}^a + \frac{1}{2} v_{ab}|_{p_0} \, \tilde{\phi}^a \tilde{\phi}^b \right)$$

$$v_0|_{p_1} = v_0|_{p_0} + v_a|_{p_0} \delta s^a$$

$$v_a|_{p_1} = v_a|_{p_0} + v_{ab}|_{p_0} \delta s^b$$

$$v_{ab}|_{p_1} = v_{ab}|_{p_0} + \delta v_{ab}|_{p_0 \to p_1}$$



$$\tilde{\phi}^a \equiv \phi^a / \Lambda_{\rm h}$$

Marsh, McAllister, Pajer and Wrase:1307.3559

Basics of Random Matrices

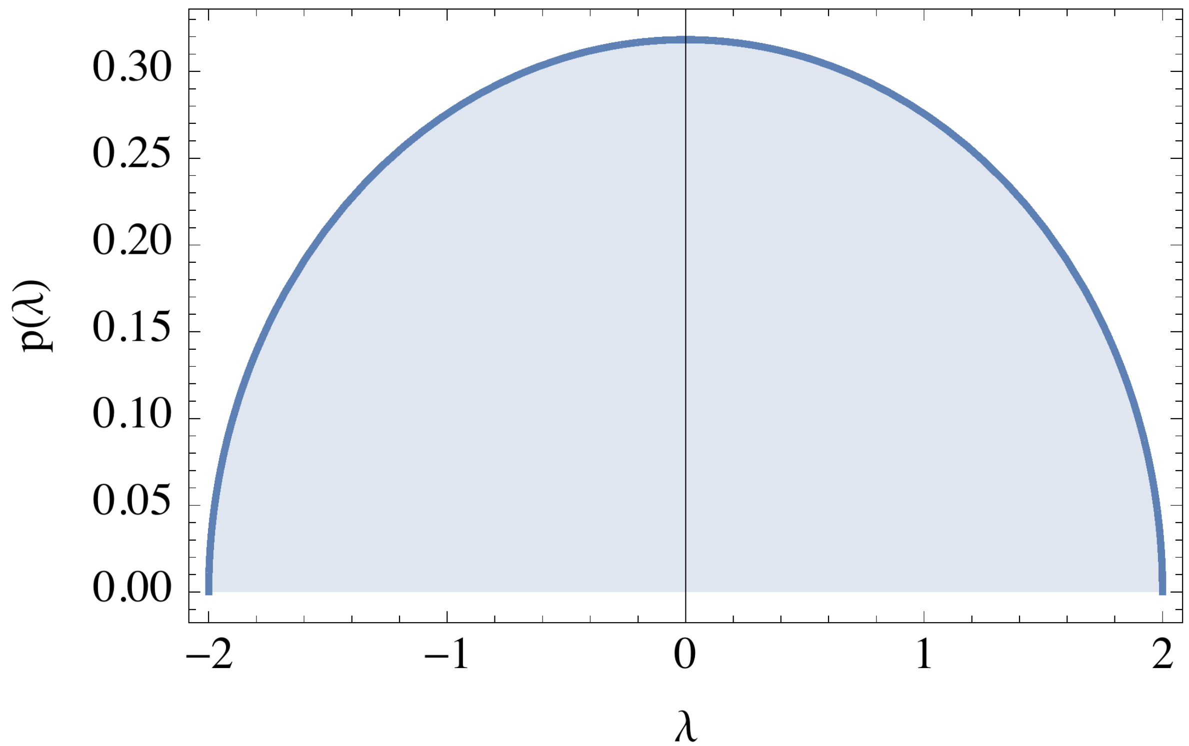
Any large matrix $M = M^\dagger$ with entries M_{ab} drawn from a random distribution (GOE)

$$p(\lambda_1, \ldots, \lambda_{N_f}) = Ce^{-\frac{1}{2}W}$$

$$W = \frac{1}{\sigma^2}\sum_{a=1}^{N_f}\lambda_a^2 - \sum_{a\neq b}\ln|\lambda_a - \lambda_b|$$

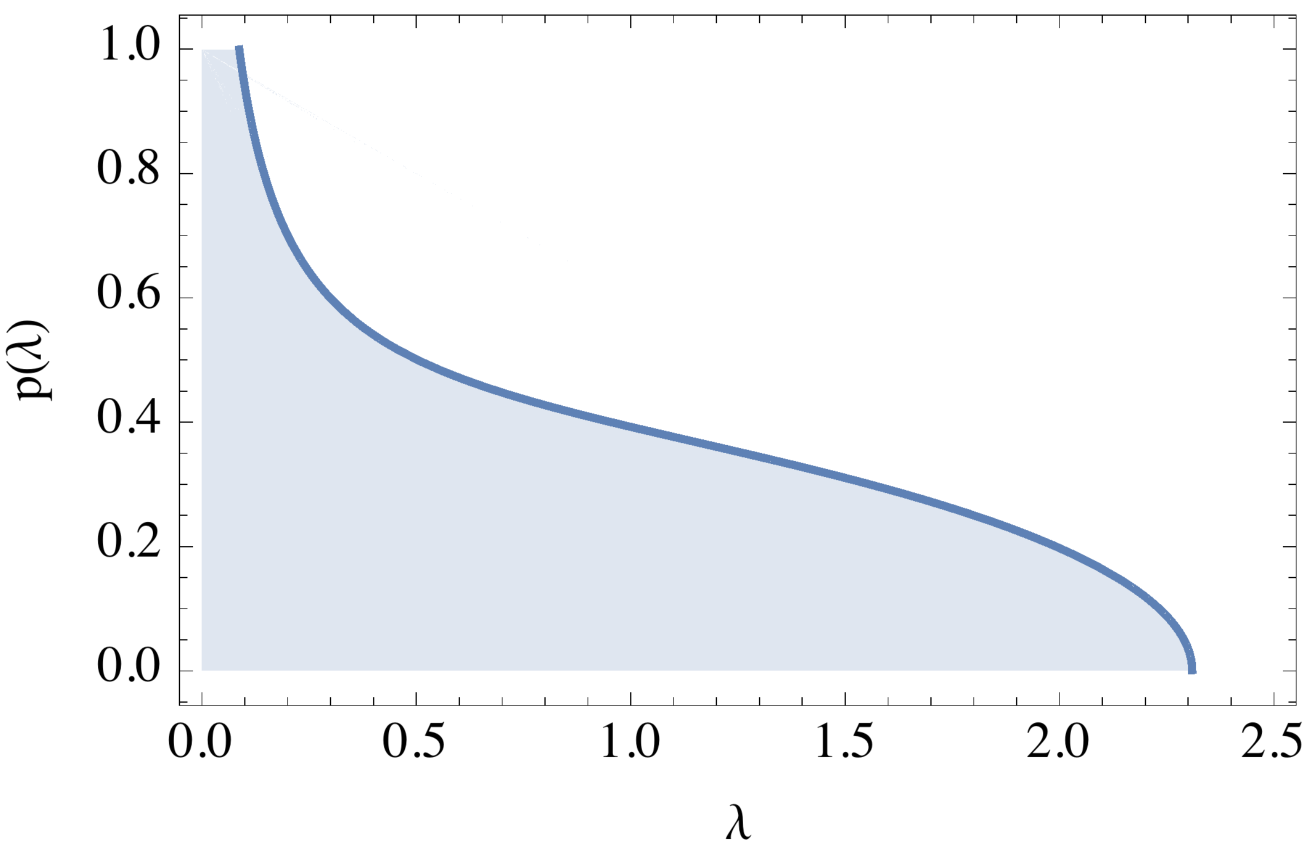
eigenvalue repulsion

Eigenvalues behave like a gas of charged particles in $\mathbb{R}^2$, confined to a line and subject to a quadratic potential



Wigner semi-circle

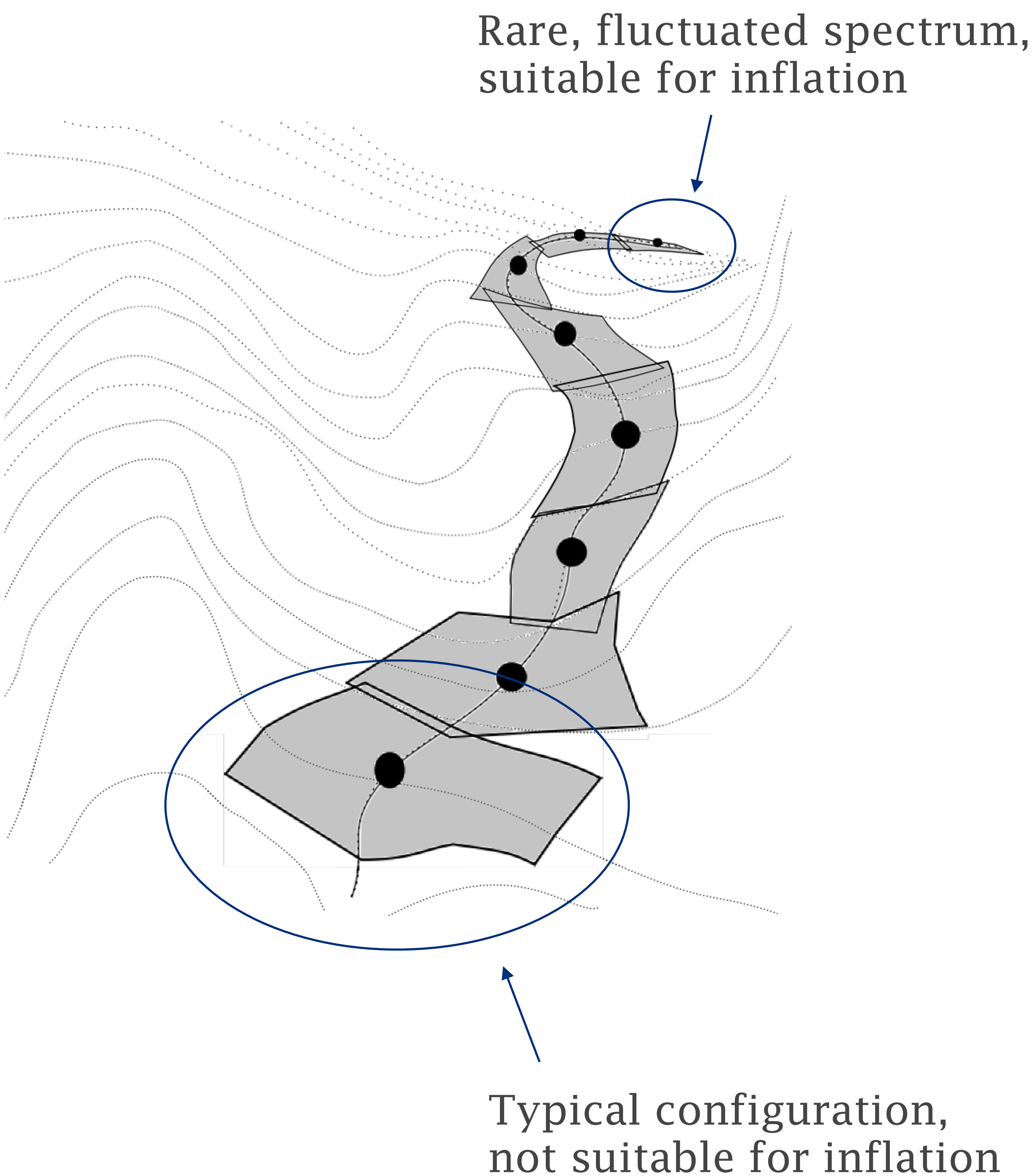
Basics of Random Matrices

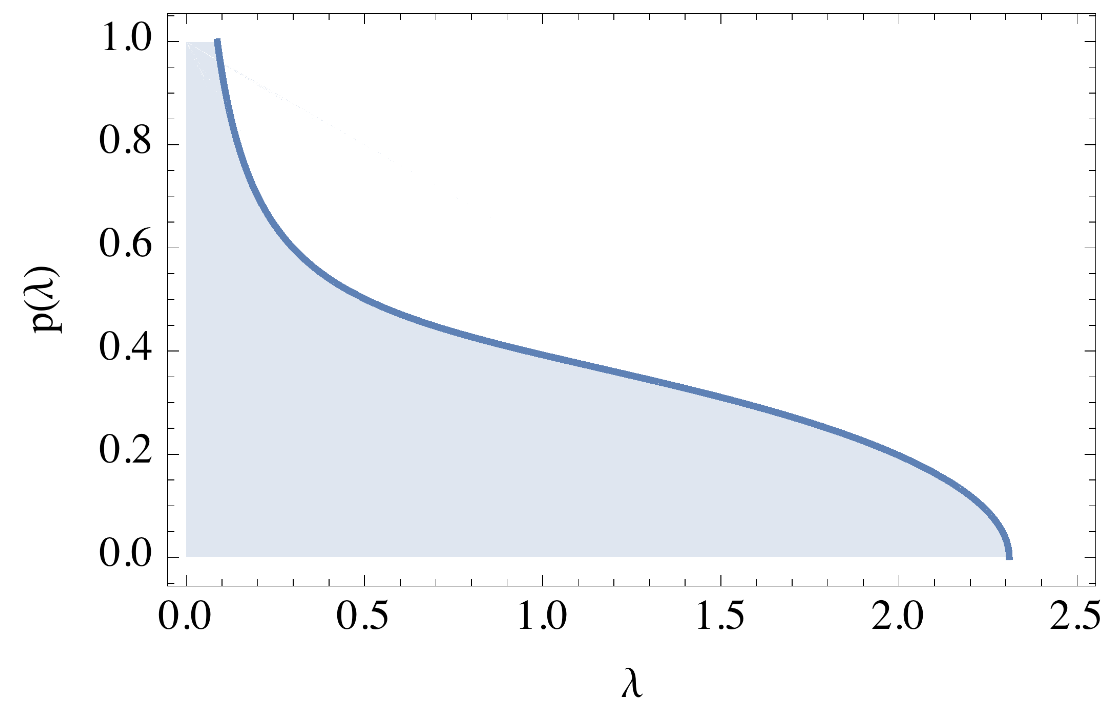


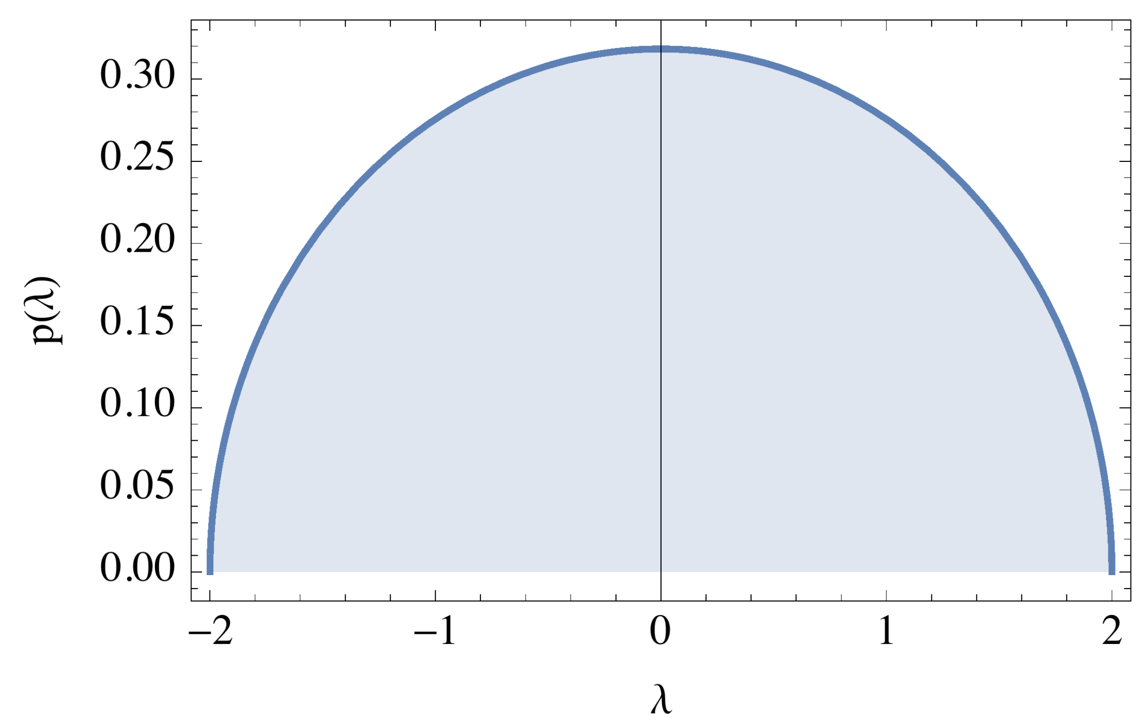
Atypical distribution of a GOE

D. S. Dean and S. N. Majumdar; cond-mat/0609651

A random manyfield potential from RMT







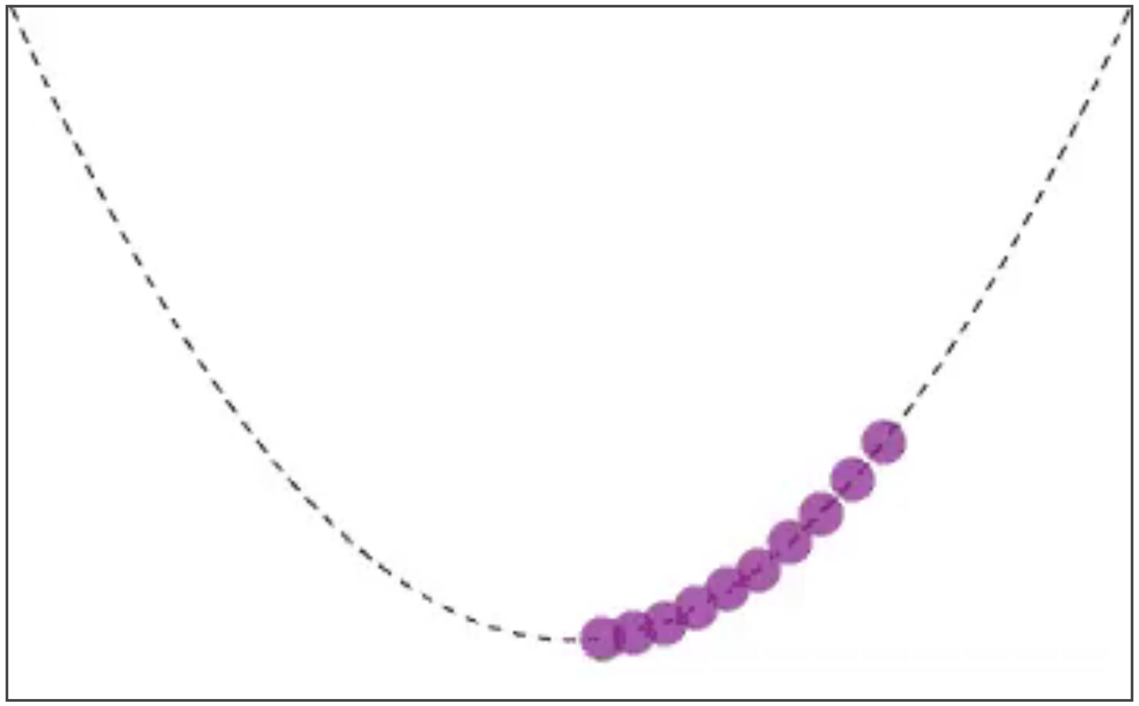
DYSON BROWNIAN MOTION

$$v_{ab}\big|_{p_1} = v_{ab}\big|_{p_0} + \delta v_{ab}\big|_{p_0 \to p_1}$$

$$\delta v_{ab} = \delta A_{ab} - v_{ab} \frac{||\delta \phi||}{\Lambda_h}$$

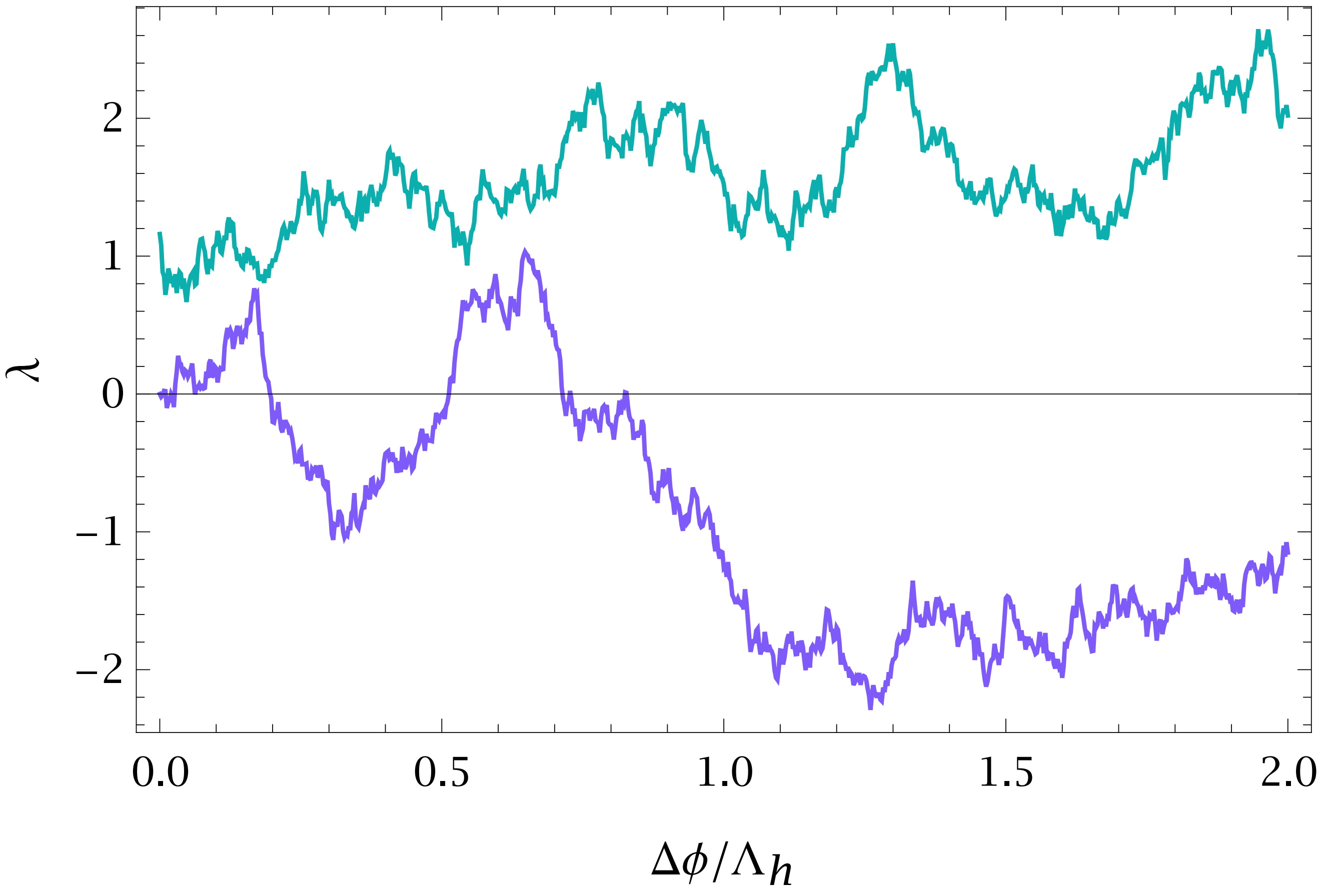
stochastic piece

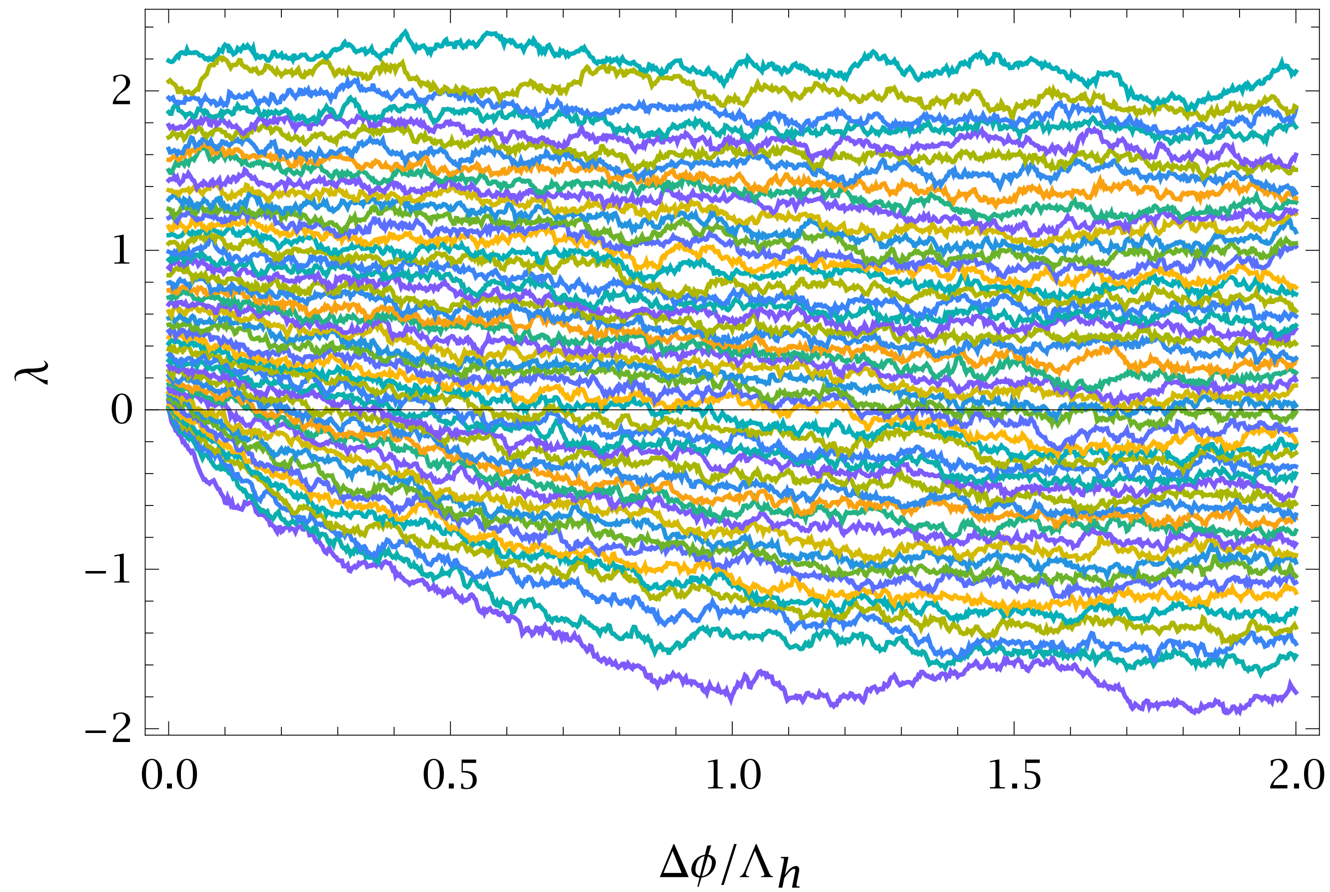
restoring force



Dyson 1962: "A Brownian-Motion Model for the Eigenvalues of a Random Matrix"

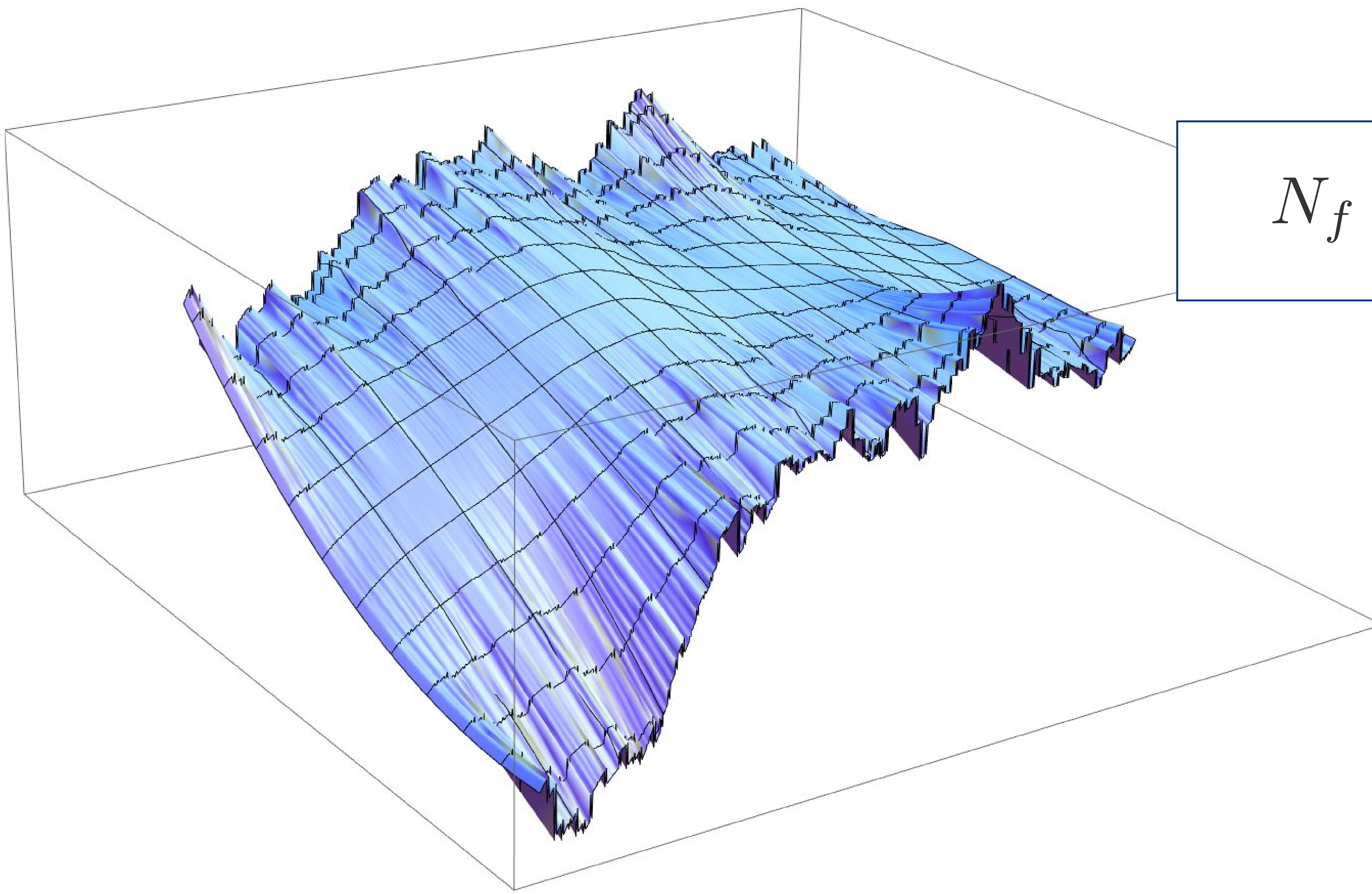
A random manyfield potential from RMT





Dias, Frazer, Marsh: 1604.05970, 1706.03774

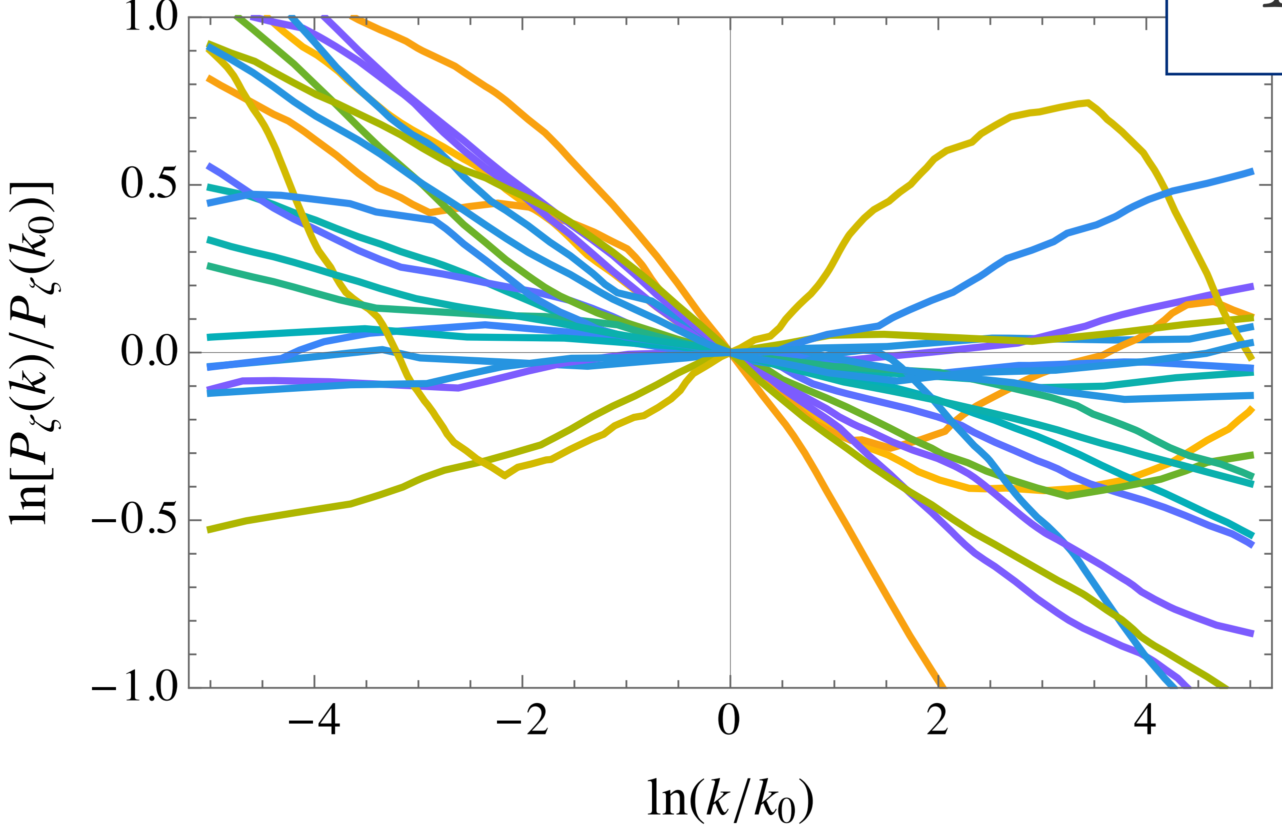
A random manyfield potential from RMT



$N_f = 2$

A random manyfield potential from RMT

$N_f = 2$



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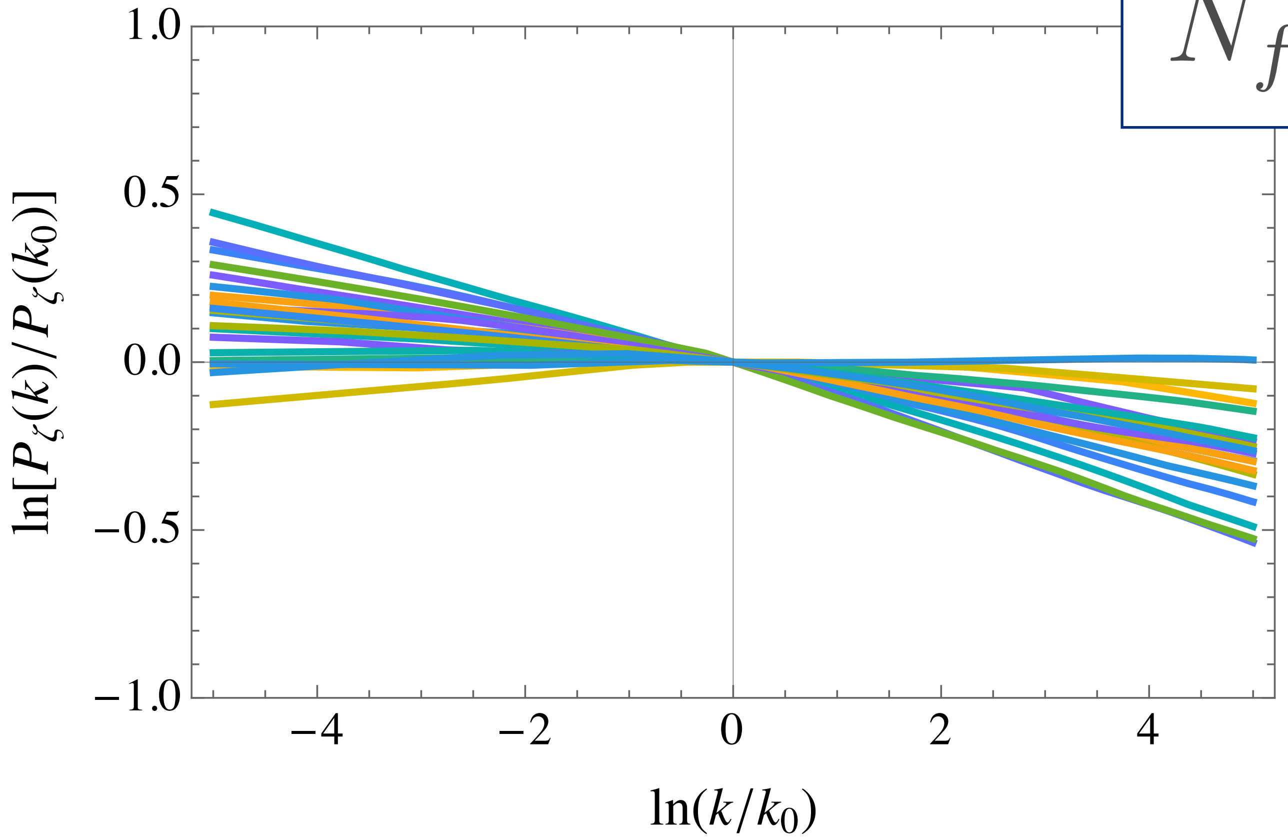
A random manyfield potential from RMT



$N_f = 100$

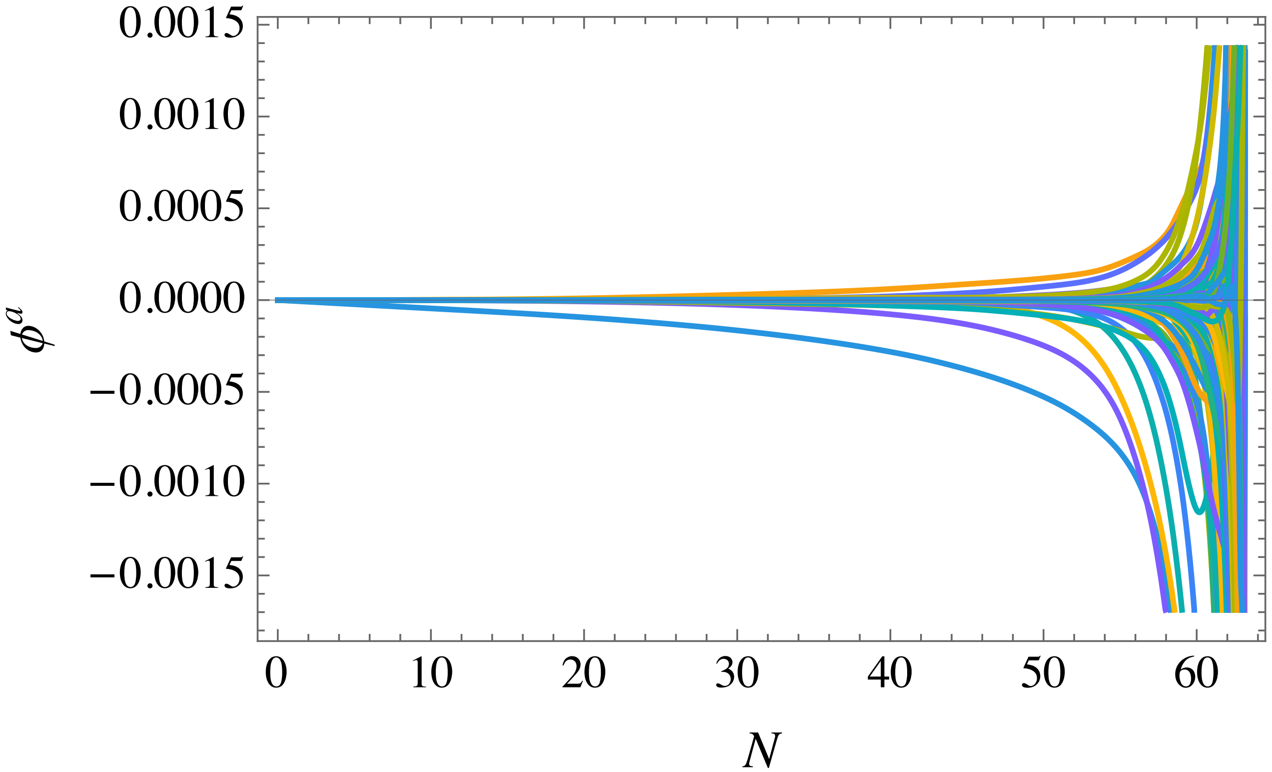
Dias, Frazer, Marsh: 1604.05970, 1706.03774

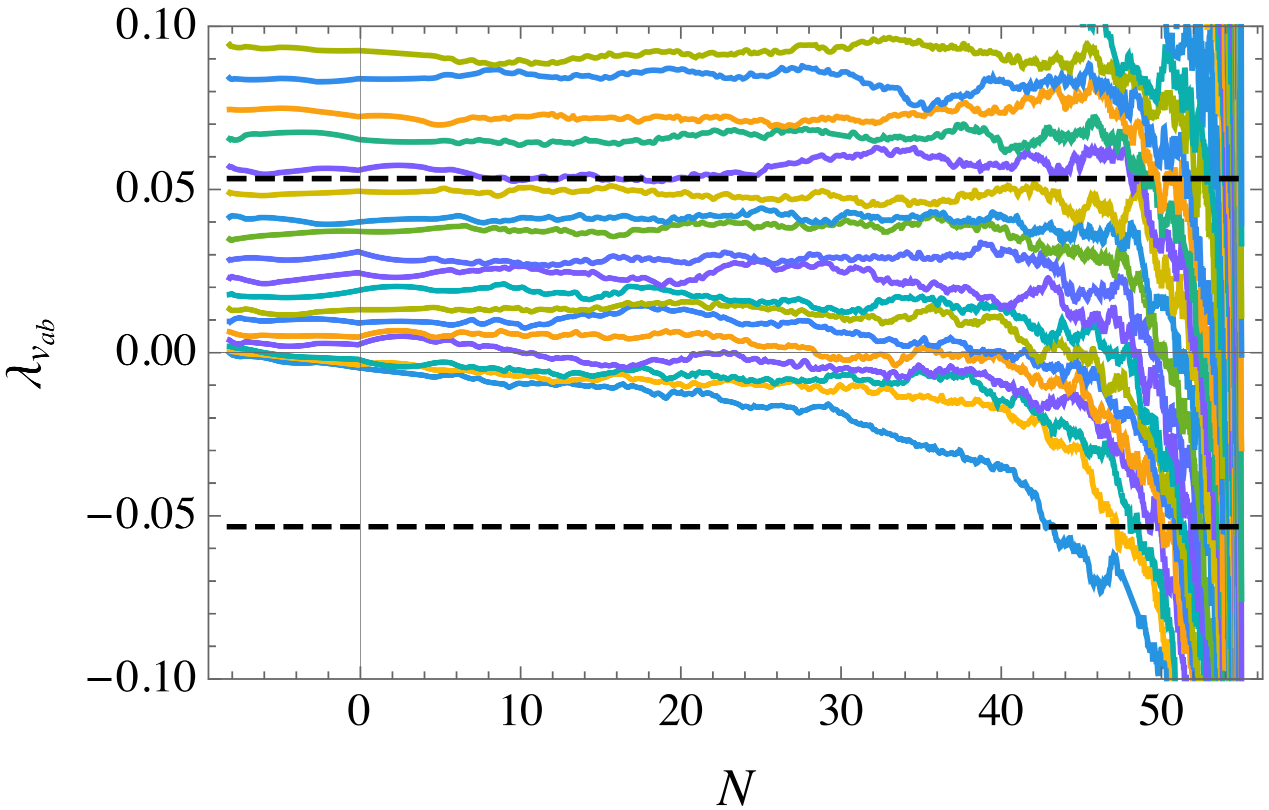
Sum-up:

- Can complex inflationary physics give rise to simple observational signatures?
- Phenomenological simplicity and universality can emerge from complex physics
- Random potentials give rise to simple observables in the large N limit
- Other mechanisms? Geometry of manifold?

A random manyfield potential from RMT

Inflation near a saddle point



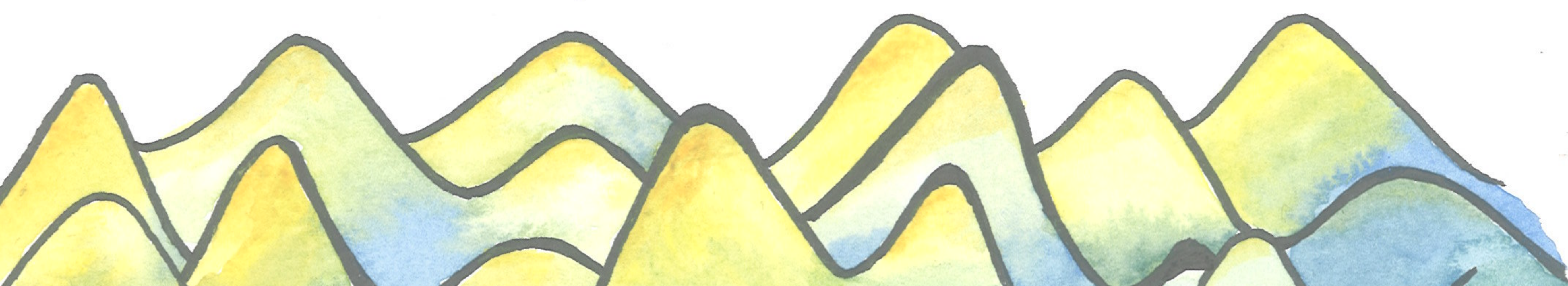


$$N_f = 100$$

Can complex inflationary physics give rise to simple observational signatures?

other mechanisms?

Geometry of manifold



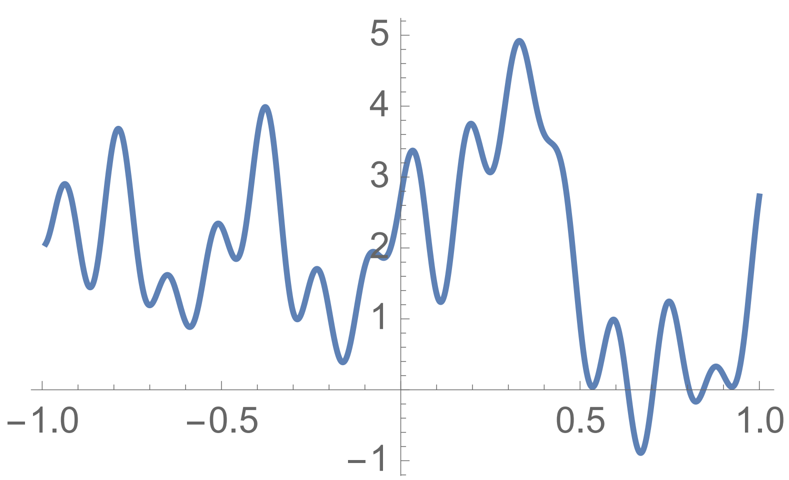
Geometry of the manifold

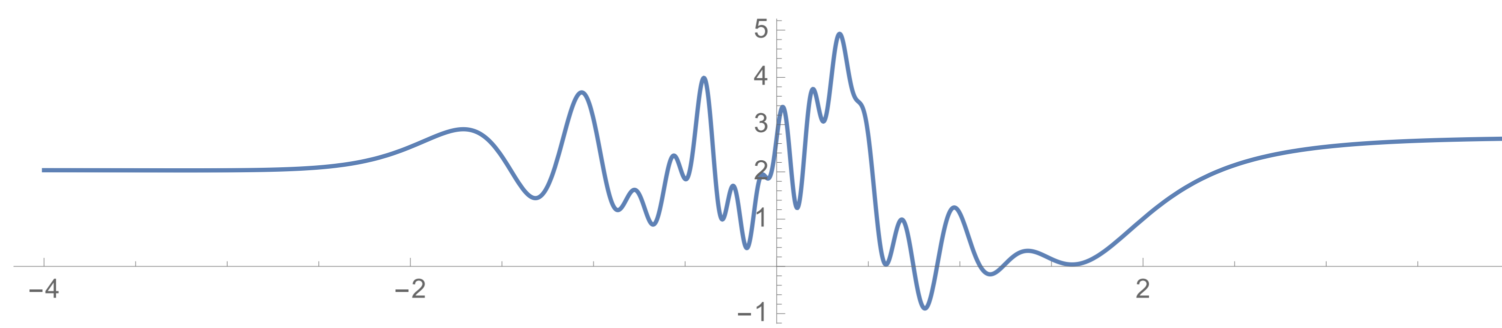
$$\mathcal{L}_{kin} = \frac{1}{2(1-c^2\phi^2)^2}(\partial\phi)^2$$

$$V = V_0 + V_1\phi + \cdots$$

$$\mathcal{L}_{kin} = (\partial\varphi)^2$$

$$V = V_0 + a_1 \tanh\left(\frac{c}{2}\varphi\right) + \cdots$$



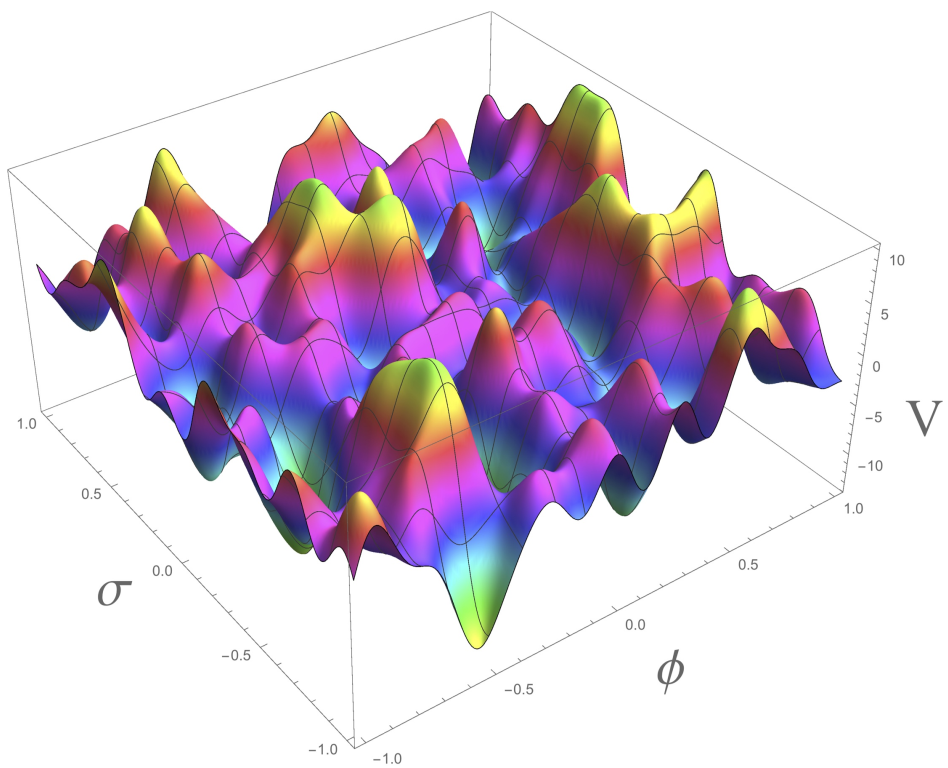


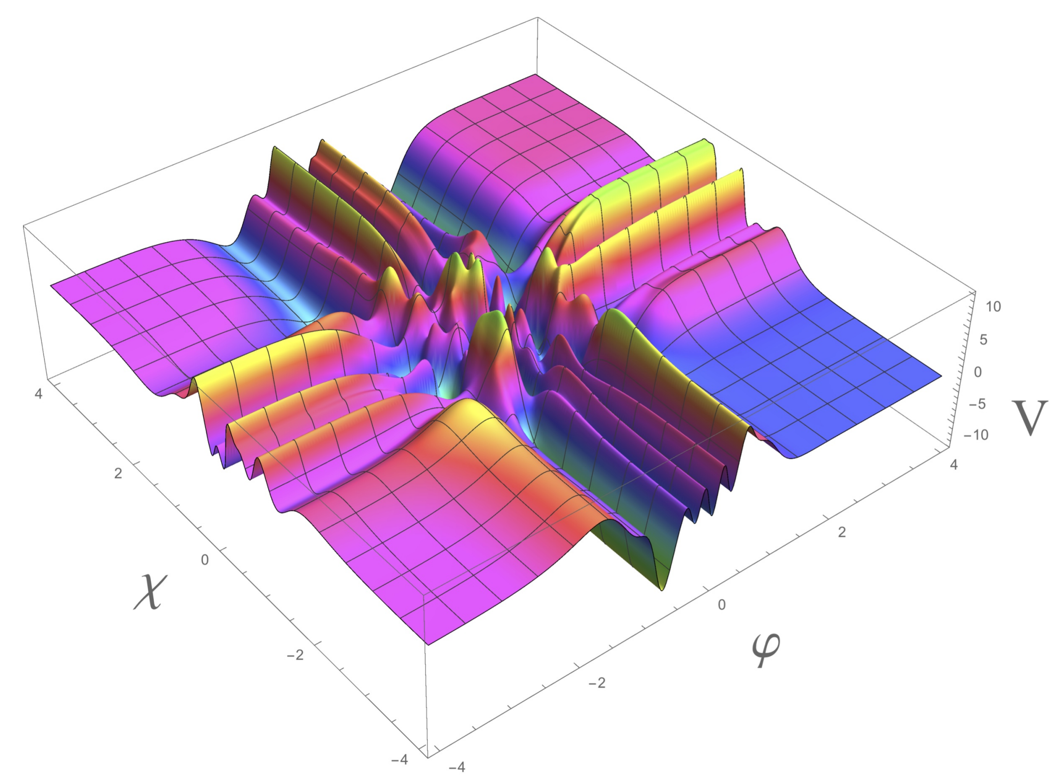
$$n_s = 1 - 2/N_e \qquad r = 8c^2/N_e^2$$

Geometry of the manifold

$$\mathcal{L}_{kin} = K_{ij}\partial\phi_i\partial\bar{\phi}_j = \sum \frac{1}{2(1-c_i^2\phi_i^2)}(\partial\phi_i)^2$$

$$K = -\sum \ln(1 - c_i\phi_i\bar{\phi}_i)$$





Geometry of the manifold

$$K = -\ln(1 - \sum c_i \phi_i \bar{\phi}_i) \longrightarrow$$

universal attractor, independent of the number of fields or c's