

ERG 2026

Exact Renormalization Group

1-5 Sep 2026

University of Sussex, UK



GONG SHOW

Poster session lightning-talk slides

[P1] David Dullaway

Following fixed points through gravitational higher-curvature theory space: functional RG tests at fourth and sixth order

[P2] Stijn Hennissen

Constructing UV-critical hypersurfaces using machine learning

[P3] Edwyn Tecedor

Resurgence in Ward–Schwinger–Dyson Equations for QED

[P4] Dominik Chudy & Jan Herre

Many-body correlations in Floquet steady-states: Frequency-resolved renormalization group of the driven Anderson impurity

[P5] Fabrizio Chicconi & Luca Parente

Weyl Gauged Gravity

[P6] Juan Fernandez Molinero

One symmetry, multiple avatars: $U(1)$ in Asymptotically Safe Gravity

[P7] Iason Vakondios

Multicritical fixed points from functional renormalisation

[P8] Vatsalya Vaibhav

Can the Radiation Era be Extended all the way to the Bang?

[P9] Gabriel Weigert

Resurgence and FRG Perspectives in Strong-Field QED

[P10] Moritz Gessner

On the Structure of the Fermion Sector in the Asymptotically Safe Standard Model

[P11] Jorge Ibañez

Conformal Invariance Constraints in the Functional Renormalization Group

[P12] Ana García-Page

Chiral Quantum Phase Transition in Moiré Dirac Materials at finite density

[P13] Nahzaan Riyaz

Probing Conformal Windows with Perturbation Theory

[P14] Carter Goldman

Spatial Coarse-Graining Impedes the Ability to Classify Message-Passing Algorithms

[P15] Paul Philip Sprenger

Gauge-Invariant and Background-Independent Quantum Gravity

[P16] Yaniss Rabahi

Universal Thermodynamics of Two-Dimensional Bose Gas: a Non-Perturbative Renormalization Group Approach

[P17] Lidia Marino

On black-hole scalarization: strong breaking of black-hole uniqueness and constraints from asymptotically safe gravity

[P18] Rowan Packer

Scalar Matter in Lorentzian Quantum Gravity

[P19] Oskar Stachowiak

Two-Component Bose Mixtures: Mean-Field Theory and Functional Renormalisation Group

[P20] Max Fornoville

Critical behavior of isotropic magnets with screened dipolar interactions

[P21] Johannes Pöplau

Negative diffusion in the Functional Renormalization Group flow for the Quark-Diquark Model

[P22] Konrad Kockler

Self-consistent quark-meson spectral functions

[P23] Patrick Niekamp

Analytically continued FRG for dissipative open quantum systems

[P24] Carlos Pastor Marcos

Cosmology from asymptotically safe Proca theories

[P25] Freddie Matthew King

Symmetry breaking in the Nambu-Jona-Lasinio Model using the FRG

[P26] Lovro Šaravanja

Probability distribution of order parameter in $O(N)$ models

[P27] Tim Lukas Eckert

Spontaneous symmetry breaking in a relativistic Yukawa theory with Luttinger fermions

[P29] Gregorio Tibone

Scaling regimes of shallow water turbulence

[P30] Kanta Masuki

Generative diffusion model with inverse renormalization group flows

[P31] Yunxin Ye

Mass scale hierarchies in a Yukawa model with Luttinger and Dirac fermions from self-organized criticality

[P32] Alvaro Pastor Gutierrez

Non-perturbative news from the conformal window

[P33] Taichi Tanaka

Non-Renormalization of π_1 -Characters under Finite ERG Transformations on Multiply Connected Configuration Spaces

[P34] Francesco Ferrarin

A tale of scales in Asymptotically Safe Quantum Gravity

[P35] Justin Mauldin

The moat regime under magnetic fields

[P36] Rory Phipps

Computing the Bubble Nucleation Rate with Functional Renormalisation Group Methods

POSTER PRIZES

Three Best Poster Prizes

Sponsored by EPL

- **Best poster — by public voting**
vote for your top three
- **Best 1-minute gong show presentation**
vote for your top three
- **Best poster — selected by panel**

Horizontal scans across higher-curvature operators give further support to the Asymptotic Safety conjecture

K&L: general $f(\text{Riemann})$ gravity | MSB PRICE: one running coupling per curvature order

UV-ATTRACTIVE DIRECTIONS AT R^2 / QG

3

fourth order

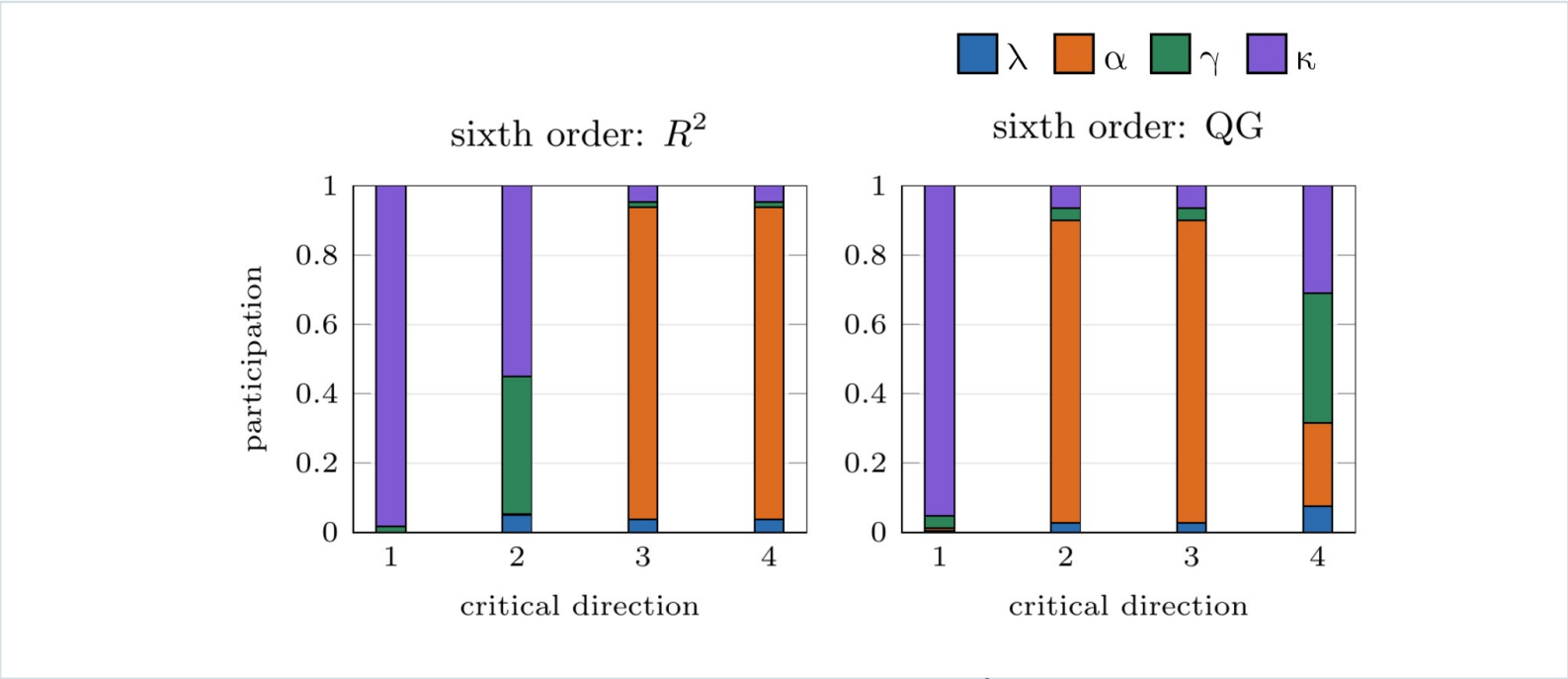
HOMOTOPY

3

sixth order

New sixth-order eigendirection

95–99% κ · UV-repulsive

Same principal branch, tracked continuously.
Evidence—not proof—of a stabilising 3D projected critical surface.

Sixth-order eigendirection participation at R^2 and QG

COME TO THE POSTER FOR

QUADRATIC BENCHMARK

Regulator + operator robustness

CUBIC EXTENSION

Folds, detours + branch tracking

WIDER THEORY SPACE

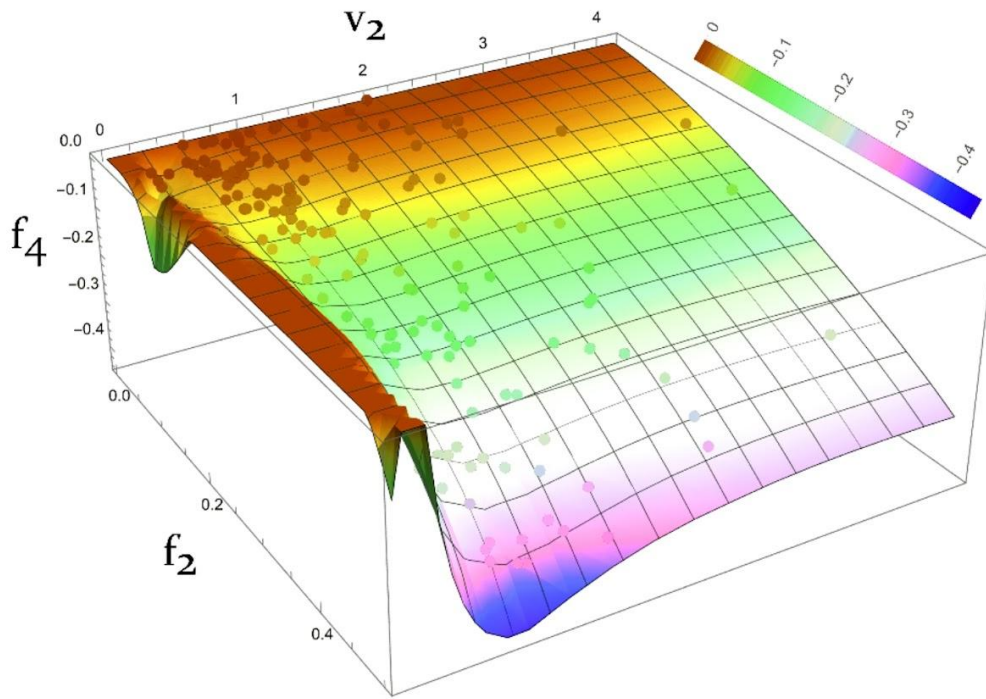
Alternative roots—none as robust as P

Constructing UV- critical Hypersurfaces using Machine Learning

Stijn Hennissen

Radboud University
Nijmegen, Netherlands

Collaboration with F. Saueressig and A.
Silva



- ❖ Hypersurface approximation by neural network adapted to FRG flow equations
- ❖ Simplest model already efficiently constructs physically interesting regions
- ❖ Conclusion: It is worth developping a more advanced model architecture!
- ❖ Beyond the paper: Rigorous functional analysis treatment

Which QED truncations control Borel singularities?

Edwyn Tecedor

LPTHE • Sorbonne Université • CNRS • IPSA

1 Ward closure in QED

$$\Gamma^\mu = A\gamma^\mu + B\frac{p^\mu \not{p}}{p^2}, \quad B = 2DA$$

Two tensor structures must match.

Here $A(a, L) = G^{-1}(a, L)$, with $S^{-1}(p) = \not{p} G^{-1}(a, L)$.

2 Tensorial Mellin reduction

$$\mathcal{M}^\mu(x, y) = \mathcal{S}(x, y) \left[H_C(x, y) \gamma^\mu + H_L(x, y) \frac{r^\mu \not{r}}{r^2} \right]$$

The QED numerator produces two reduced Mellin coefficients.

Poles: $x = 1, \quad y = 1, \quad x+y = -2, \quad x = -2, \quad x = 2$

3 Ward test

$$\Delta(x, y) = H_L(x, y) - 2H_C(x, y) \neq 0$$

Not a Ward violation: a truncation diagnostic.

At linear order, $f_z = -2\gamma \Rightarrow$ multiplication by $-2x$

$$G(a, L) = 1 - \sum_{n \geq 1} \gamma_n(a) L^n, \quad L = \log(p^2/\mu^2).$$

Why this matters

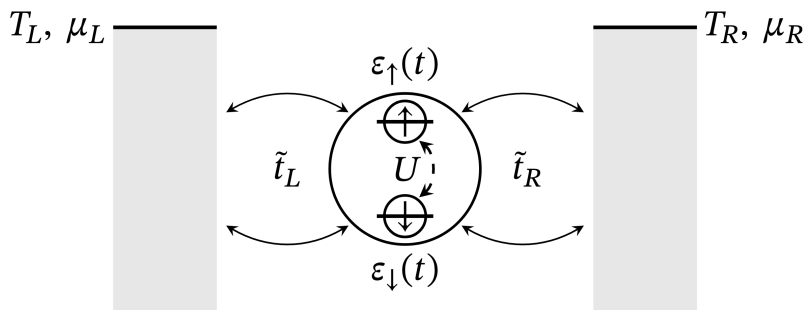
$$(\partial_L - \beta_0 \xi) \hat{G} = \hat{\gamma} + \hat{\gamma} \star \hat{G} + \hat{\beta}' \star (\xi \hat{G})$$

Resurgence asks which missing WSD terms change the leading Borel singularities, and which only enter at higher orders.

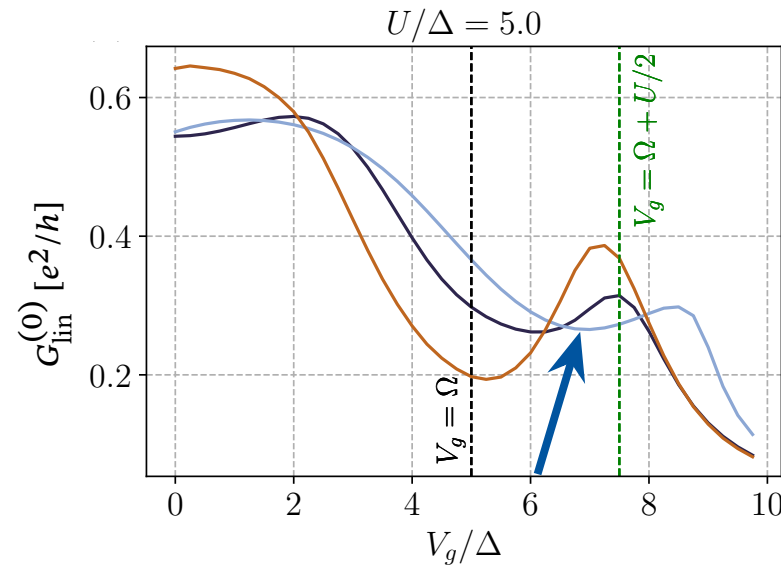
Come to the poster: QED Mellin coefficients, Ward closure and Borel-plane RG

Towards understanding driven many-body steady-states

Floquet steady-state functional RG for the driven Anderson impurity

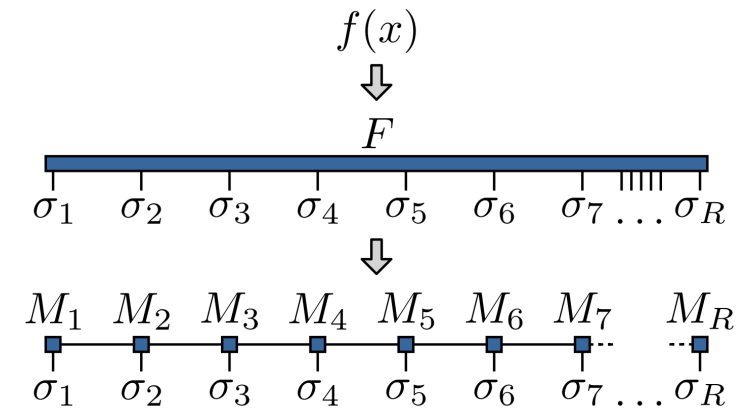


Drive one correlated impurity:
 $\varepsilon(t) = V_g + A \cos \Omega t$



FRG · 2PT · GW

Sidebands follow the **Hubbard bands**
to $V_g = \Omega + U/2$, not the Kondo peak.



Beyond quantum dots: **memory** is
the limit → vertex compressed as
low-rank tensor train.

WEYL GAUGED GRAVITY

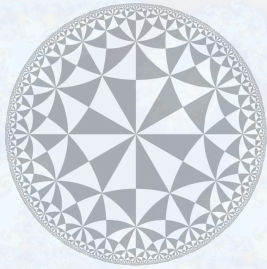
What if Scale Invariance is the fundamental approach to Quantum Gravity?

Weyl Geometry

$$\begin{cases} g'_{\mu\nu} = \Omega^2 g_{\mu\nu} \\ S'_\mu = S_\mu - \partial_\mu \ln(\Omega) \end{cases}$$

$$\Omega = e^{2\sigma(x)} > 0$$

Scale Invariance



Weyl Gauged Gravity

$$\mathcal{L}_{\text{WG}} = \frac{1}{2\lambda} \hat{C}^2 + \frac{1}{\xi} \hat{R}^2 + \frac{1}{4\alpha^2} W^2$$

S_μ decoupling

$$\mathcal{L}_{\text{WG}} \xrightarrow{\text{low energy}} \mathcal{L}_{\text{EH}}$$

Renormalizability &
Possible AF



Interplay with SM



Radboud
Universiteit
Nijmegen

“Towards recovering effective universality in AS gauge-gravity systems”

Nikhef

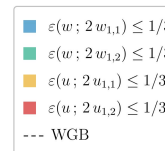
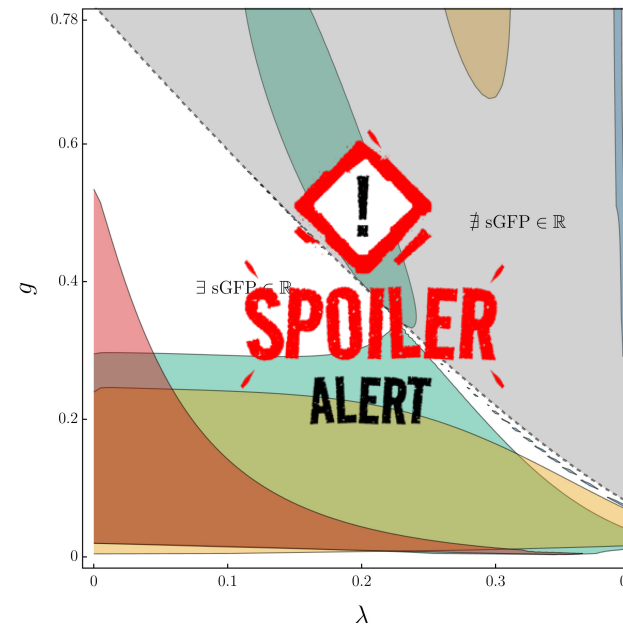
$$\Gamma_k = \dots + \frac{1}{4} \int d^4x \sqrt{g} F_{\mu\nu} F^{\mu\nu} \\ + \frac{w}{8k^4} \int d^4x \sqrt{g} (F_{\mu\nu} F^{\mu\nu})^2 \\ + \frac{u}{8k^4} \int d^4x \sqrt{g} (F^\mu{}_\nu F^\nu{}_\rho F^\rho{}_\sigma F^\sigma{}_\mu)$$

$$w \sqrt{g} (F_{\mu\nu} F^{\mu\nu})^2 \sim w (F^2)^2 + w h (F^2)^2 + \mathcal{O}(h^2)$$

$\beta_w \approx \beta_w$

Measure

$$\varepsilon(c_i; c_j) = \left| \frac{\Delta\beta_{c_i} - \Delta\beta_{c_j}}{\Delta\beta_{c_i} + \Delta\beta_{c_j}} \right|_*$$



Come and talk to me!

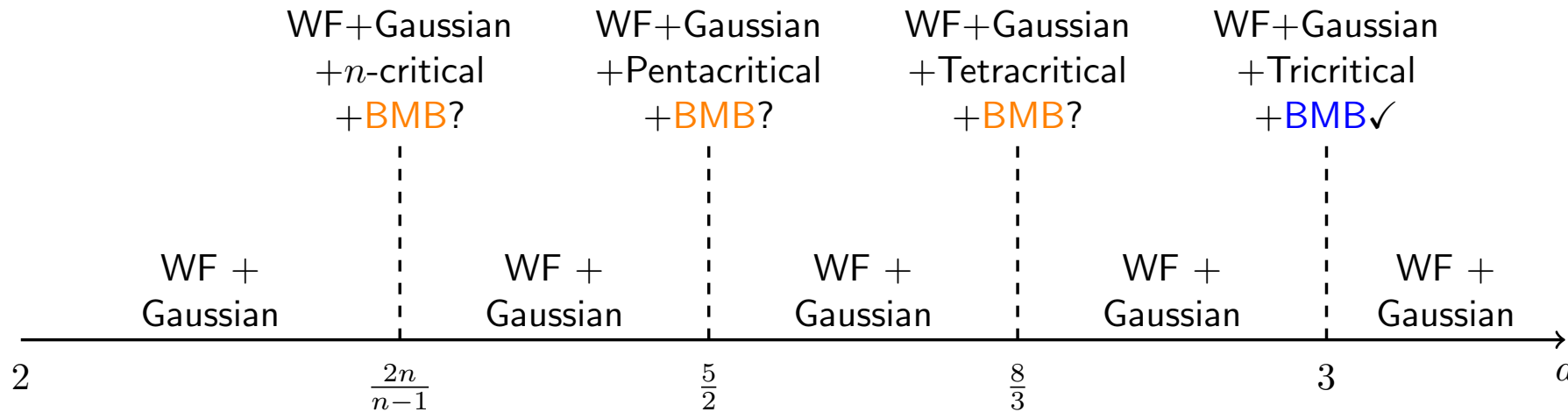
Juan Fernandez Molinero

juan.fernandezmolinero@ru.nl

work with Frank Saueressig, Marc Schiffer
and Marieke Postma.

Multi-criticality and BMB phenomena of scalar fields in lower dimensions

- ▶ What is the structure of the multicritical fixed points in lower dimensions?
- ▶ What is the fate of the Bardeen-Moshe-Bander phenomenon?



Find me at the poster session

Iason Vakondios — University of Patras

Daniel Litim — University of Sussex



UNIVERSITY OF
PATRAS
ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΑΤΡΩΝ

US
University of Sussex

Dark Matter Production in Quadratic Gravity!

Can We Extend Radiation Era to the Big Bang?

Vatsalya Vaibhav
With
Latham Boyle and Neil Turok

Can the radiation era extend back to the Big Bang? Rethinking dark matter production and graviton thermalization in quadratic gravity

Latham Boyle,^{1,2} Neil Turok,^{1,2} and Vatsalya Vaibhav¹

¹*Higgs Centre for Theoretical Physics, James Clerk Maxwell Building, Edinburgh EH9 3FD, UK*

²*Perimeter Institute for Theoretical Physics, Waterloo, Ontario N2L 2Y5, Canada*

Naive estimates based on Einstein gravity with Lagrangian $\frac{1}{2}M_{Pl}^2(R - 2\Lambda)$ suggest that, if the radiation era extended back to the Big Bang (*i.e.* as far back as the classical spacetime background makes sense), this would result in an over-production of dark matter and a relic cosmic background of thermal gravitons. Here we revisit these conclusions in quadratic gravity, the minimal renormalizable completion of Einstein gravity, whose Lagrangian also includes the terms $\frac{1}{6}f_0^{-2}R^2 - \frac{1}{2}f_2^{-2}C^2$. Assuming the radiation era *does* extend back to the bang, we find a novel constraint relating the coefficient f_2 and the dark matter mass m_{dm} , needed to obtain the correct dark matter abundance. This is an elegant gravitational production mechanism for dark matter (*e.g.* stable right-handed neutrinos). Moreover, the presence or absence of the relic graviton background (detectable by forthcoming CMB experiments via its small imprint on N_{eff}) will place new constraints on f_0, f_2 .





Functional Perspectives in Strong-Field QED

Gabriel Weigert

Holger Gies

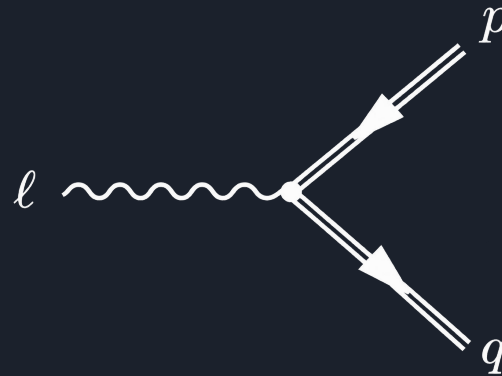
Friedrich-Schiller-Universität Jena

QED under perturbative control

Ritus–Narozhny conjecture:

$$g = \alpha\chi^{2/3}$$

Euclidean calculations $\longrightarrow$ relevant Minkowski strong-field physics





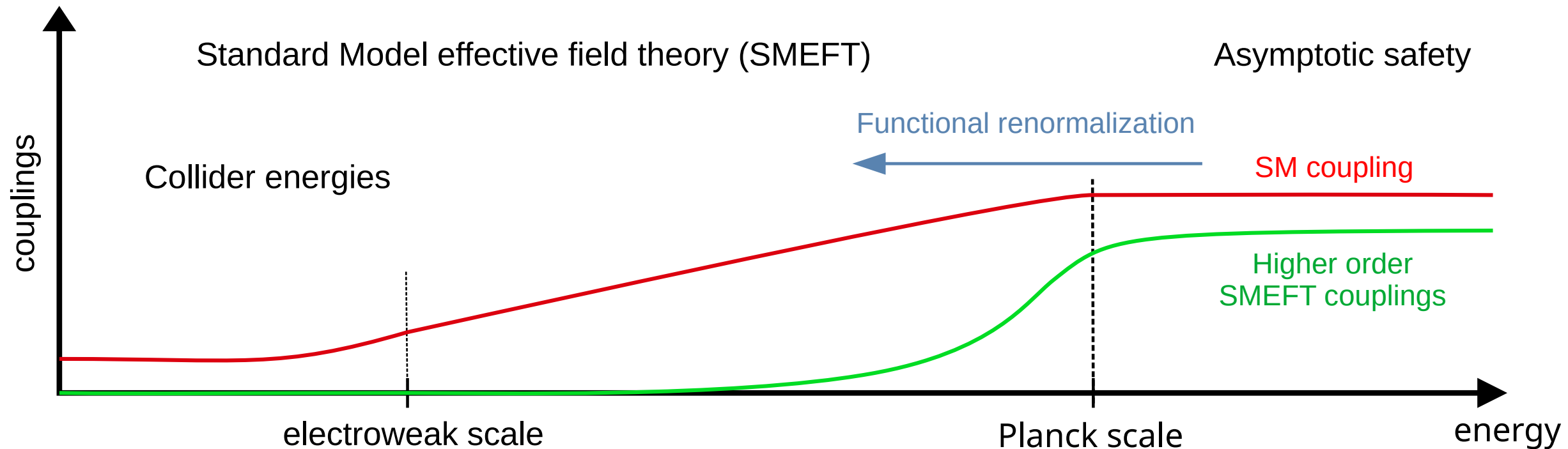
The Fermion Sector of the SMEFT from Asymptotic Safety

Astrid Eichhorn, Moritz Gessner and Shouryya Ray

arxiv:2607.18398

- Use the FRG to flow from asymptotically safe UV fixed point to experimental scales

$$S_{\text{SMEFT}} = S_{\text{SM}} + \sum_{D>4} \sum_i \frac{c_i}{\Lambda_{\text{UV}}^{D-4}} \int d^4x O_{i,D} \supset (\psi^\dagger \bar{\sigma}^\mu \psi)(\psi^\dagger \bar{\sigma}_\mu \psi) \text{ with } \text{SU}(2)_L \times \text{U}(1)_Y \text{ Weyl fermions}$$



Conformal Invariance Constraints in the Functional Renormalization Group

Jorge Ibañez · Gonzalo De Polsi · Matthieu Tissier

1

Critical regime

Interactions occur at all scales.

2

Functional RG

Fluctuations are integrated scale by scale.

3

Derivative expansion

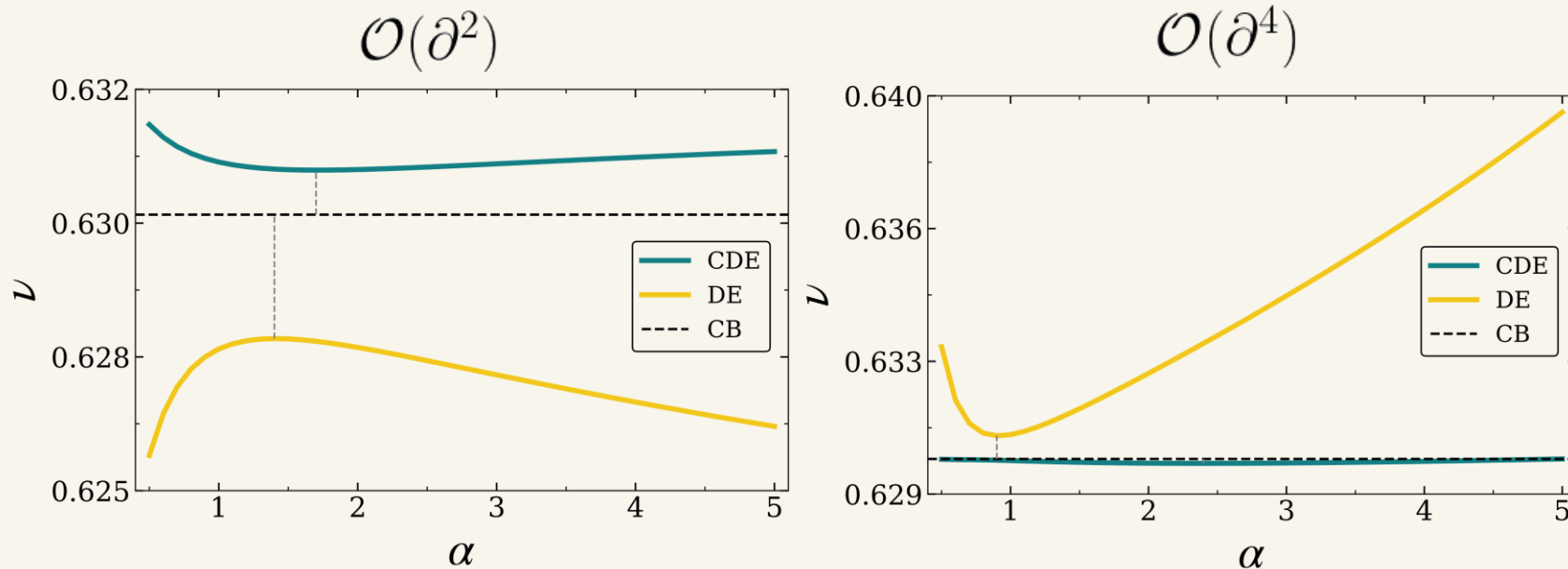
A practical truncation, but regulator dependent.

4

Conformal constraints

Scale and conformal symmetry are imposed at the fixed point.

CONFORMAL DERIVATIVE EXPANSION



$$\begin{array}{ccc} \text{DE} & & \text{CDE} \\ \boxed{\mathcal{D}\Gamma_k^{(n,m)} = 0} & \implies & \boxed{\begin{array}{l} \mathcal{D}\Gamma_k^{(n,m)} = 0 \\ \mathcal{C}_\mu \Gamma_k^{(n,m)} = 0 \end{array}} \\ n \leq N & & n+m \leq C \end{array}$$

- Improved critical-exponent accuracy
- Excellent regulator stability

Chiral Quantum Phase Transition in Moiré Dirac Materials at *finite density*

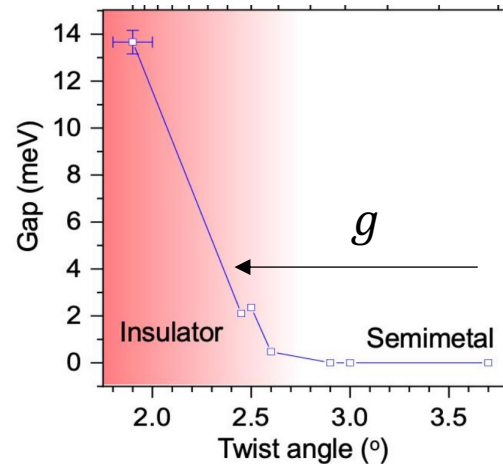
MAX PLANCK INSTITUTE FOR
SOLID STATE RESEARCH



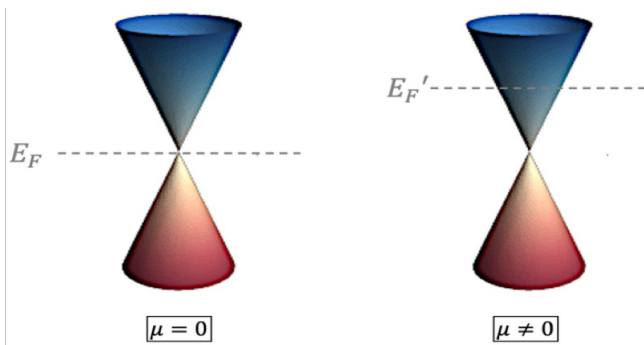
A. García-Page, F. Rennecke, K. Fraboulet, L. Classen



Technische Universität München



Adapted from Ma, L., *et al.*
arXiv:2412.07150 (retrieved 04.03.2026)



$$S[\{\bar{\psi}, \psi\}] = \int d^d r \left\{ [\bar{\psi}(\not{\partial} - \mu \hat{\gamma}_0)]\psi - \frac{g}{2N_f}(\bar{\psi}\psi)^2 \right\}$$

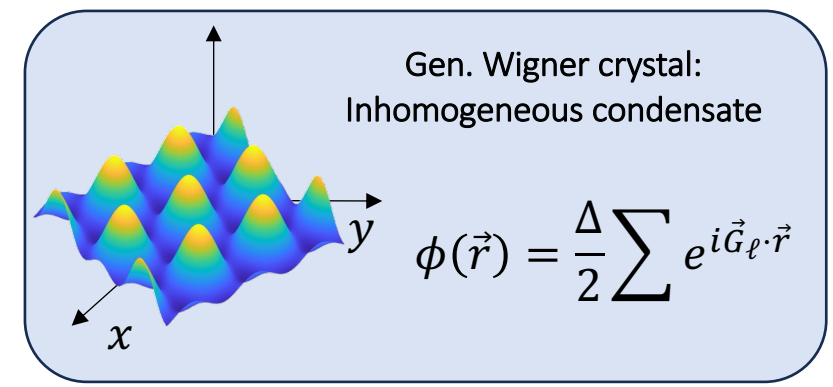
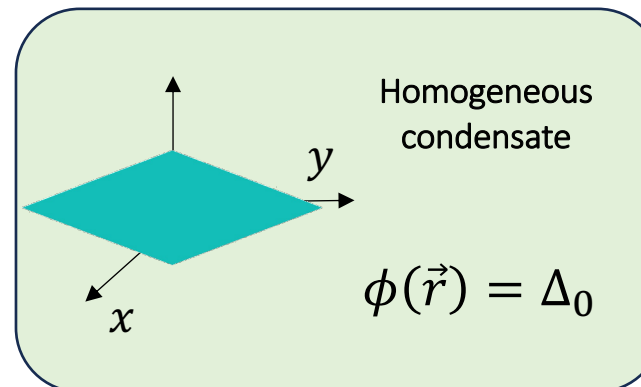
fRG

Study of homogeneous phase

Mean-field theory

Homogeneous and
inhomogeneous phases?

$$S[\phi] = \frac{1}{2g} \int d^d r \phi^2(r) - N_f \text{Tr} \left[\log(i\not{\partial} - \mu \hat{\gamma}_0) + \hat{\phi} \right]$$



Spatial Coarse-Graining Impedes the Ability to Classify Message-Passing Algorithms

Carter M. Goldman, Ryan Singh, Christopher L. Buckley

University of Sussex

INTRODUCTION

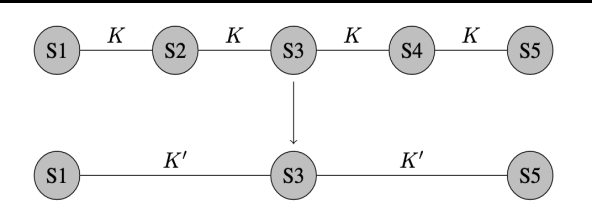
- Supporters of the Bayesian Brain Hypothesis argue that the brain maintains a generative model of the environment and inverts this model to infer the states of the world.
- Message-passing is one class of algorithms that performs this computation tractably. While there is some evidence that the brain uses specific forms of message-passing, such as mean-field variational inference, other algorithms remain plausible candidates but have yet to be thoroughly considered.
- In this study, we investigate the measurement requirements for comparing message-passing algorithms as alternative explanations of data.
- We examine how the spatial precision of neural recordings would affect the ability to determine which message-passing algorithm the brain implements.

METHODS

- We performed mean-field (MF) message-passing and Thouless-Anderson-Palmer (TAP) message-passing on a probabilistic graphical model with 5 binary nodes.
- Using the renormalization group, we calculated an effective energy function for this model after decimating 2 nodes (see figure below).
- We then used this effective energy function to attempt to infer the form of the message-passing algorithm performed on the original model.

$$m_i = \sigma \left(\sum_j J_{ij} m_j \right) \quad \text{MF}$$
$$m_i = \sigma \left(\sum_j [2J_{ij} m_j + 4J_{ij}^2 (1 - 2m_i) m_j (1 - m_j)] \right) \quad \text{TAP}$$

Spatial coarse-graining procedure



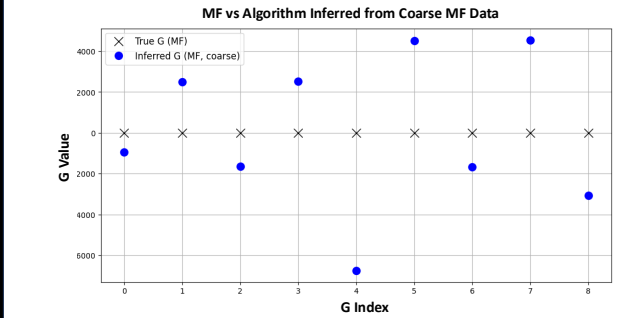
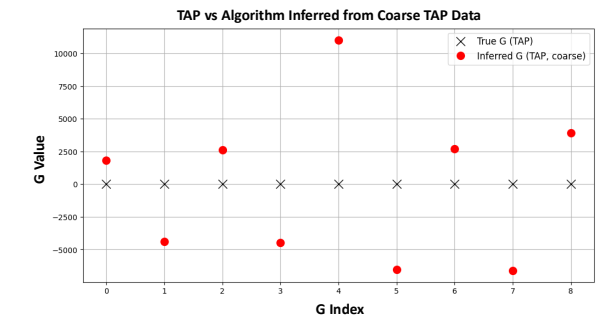
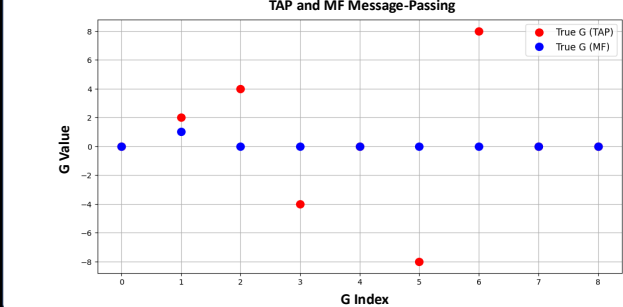
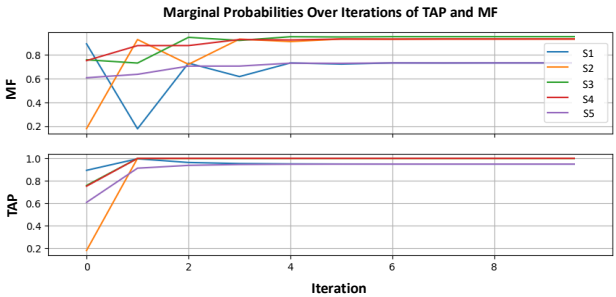
REFERENCES

Delemau, A., Herzet, C., & Daudet, L. (2012). Boltzmann machine and mean-field approximation for structured sparse decompositions. *IEEE Transactions on Signal Processing*, 60(7), 3425-3438.

R. Goldstein and James S Walker. Thermodynamic functions and critical properties from a cluster-decimation approximation. *Journal of Physics A: Mathematical and General*, 18(8):1275, 1985.

Rajkumar Vasudeva Raju, Zhe Li, Scott Linderman, and Xaq Pilikow. Inferring inference. *arXiv preprint arXiv:2310.03186*, 2023.

RESULTS



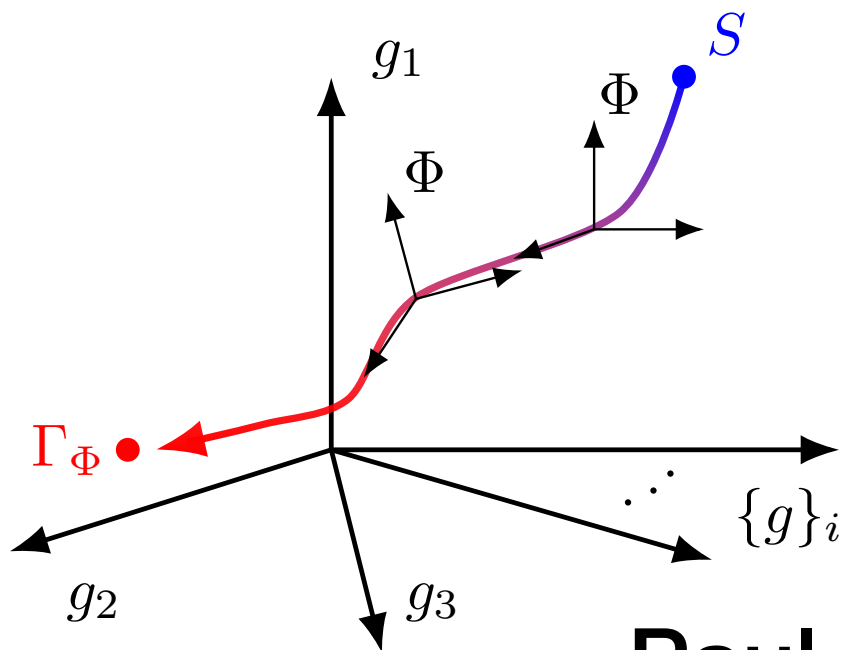
RESULTS

- The true and inferred message-passing algorithms are shown above as a vector G :
$$m_i = \sigma \left(\sum_{a,b,c} G_{a,b,c} J_{i,j}^a m_i^b m_j^c \right)$$
- Spatial coarse-graining prevented us from inferring the true algorithms used to generate the data.
- Both algorithms inferred from the coarse data included higher order terms in the update.
- However, only TAP includes higher-order terms, which serve to account for the covariance between nodes without modeling covariance explicitly.

DISCUSSION

- For the specific class of algorithms considered, it appears that **fine-grained measurements may be necessary to draw conclusions about how the brain could implement Bayesian inference through message-passing.**
- However, it may still be possible to distinguish MF and TAP.
- Future studies should examine alternative models, message-passing algorithms, and ways to coarse-grain data that align with neural recording technology currently available.
- For instance, researchers could attempt to recover message-passing algorithms using the average of neighboring nodes in a lattice-shaped Boltzmann machine, analogous to EEG recordings.

How do you construct a diffeomorphism-invariant flow in quantum gravity?



Paul. P. Sprenger

Diffeomorphism-Invariant Approach to Asymptotically Safe Quantum Gravity

F. Ihssen, B. Knorr, S. Mezger, J. M. Pawłowski, Paul P. Sprenger

Institute for Theoretical Physics, Heidelberg University · sprenger@thphys.uni-heidelberg.de



THE QUESTION

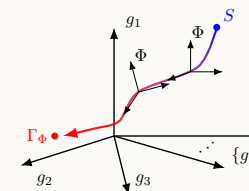
How do you account for diffeomorphism invariance in metric quantum gravity?

01 Motivation

- regulator in the ERGE breaks diffeomorphism symmetry
- how to construct a diffeomorphism-invariant flow?
- preserve the correct relevance counting of operators
- computational accessibility via heat kernel methods [1]

02 Flowing Fields Absorb Breaking

absorb the breaking of the regulator-induced terms with a field reparameterization [2]

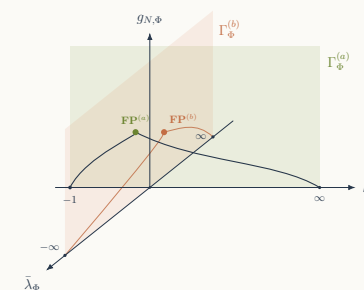


⇒ gauge-invariant flow equation

$$\partial_t \Gamma_\Phi[g] = \frac{1}{2} \text{Tr} \left[\frac{1}{\Gamma_\Phi^{(2)}[g] + R_k[g]} \partial_t R_k[g] \right] + F_\Phi[g].$$

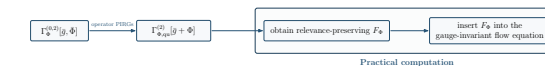
- F_Φ acts as a driving force
- restores the correct relevance of operators
- rectifies the changes from $\sqrt{g} R_k[g] \rightarrow \sqrt{g} \tilde{R}_k[g]$

03 Two Invariant Actions



04 How to Compute the Correction

Workflow

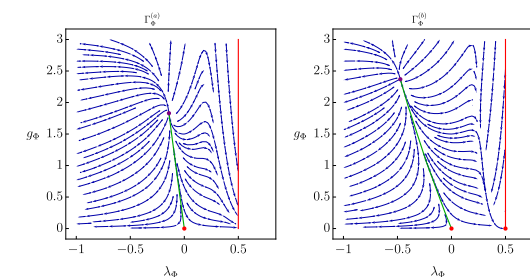


Extracting the diffeomorphism-invariant terms

$$\Rightarrow \partial_t \Gamma_\Phi[g] = -\text{Tr} \left[G \partial_t R_k G \frac{\delta}{\delta g} \left(\Gamma_{\text{inv}}[g] + (S_{\text{gauge}}) \right) \right].$$

05 Results

- rectified breaking terms for the cosmological constant $\Rightarrow \partial_t \lambda_\Phi$



06 Outlook

- rectify terms for $\sqrt{g} R$ to obtain the correct $\partial_t g_N, \Phi$
- de Sitter phase possible? (nature of $\lambda_\Phi = 1/2$ singularity)
- stability of gravity-matter systems: minimally coupled scalars and fermions (WIP)
- include all relevant operators: $\sqrt{g} R^2, \sqrt{g} C^2$ (?)

07 Ask me about

the different effective actions $\Gamma[g, h]$ vs. $\Gamma_\Phi[g, \phi_i]$ vs. $\Gamma_\Phi[g]$

how to use different strategies to get an error estimate on the results

the role of the $\lambda = 1/2$ singularity

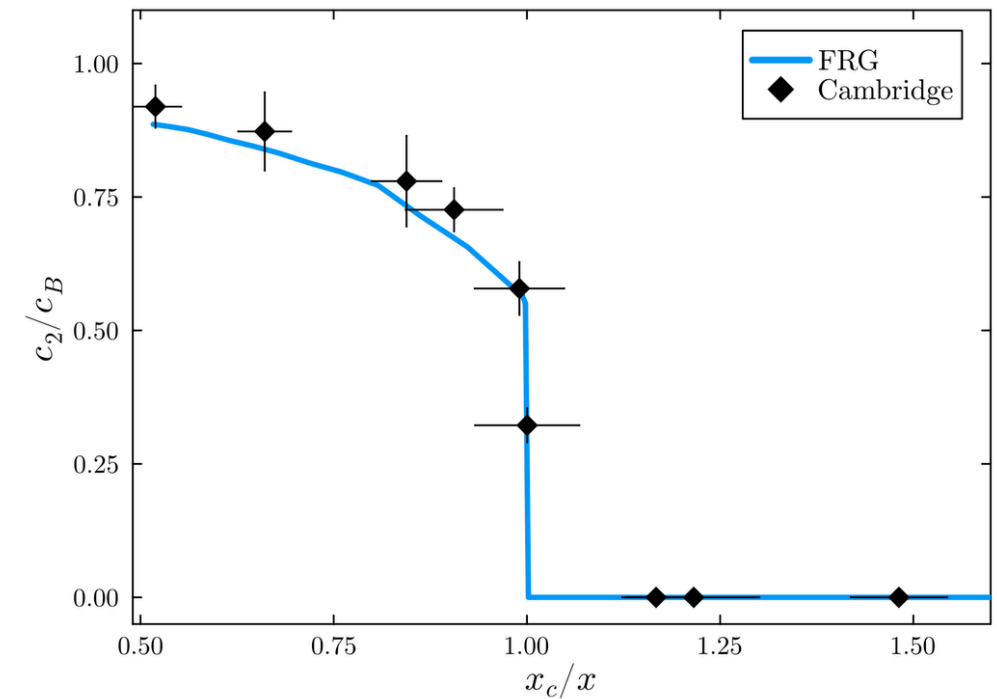
how the (modified) Nielsen and (modified) Slavnov-Taylor identities come into play

Universal Thermodynamics of the Two-Dimensional Bose Gas: a Non-Perturbative Renormalization Group Approach

Yaniss Rabahi (University of Lille, France), Ivan Balog, Adam Rançon.

- High-precision approach based on a second-order derivative expansion
- Equation of state, superfluid density, and BKT transition across interaction regimes
- ERG as a gold standard for characterizing the 2D Bose superfluid

Second sound velocity: hallmark of superfluidity



Thank you for your attention

Spontaneous black-hole scalarization in asymptotically safe quantum gravity

Pedro Fernandes Astrid Eichhorn Gustavo De Brito Lidia Marino

UV

Asymptotically safe
quantum gravity



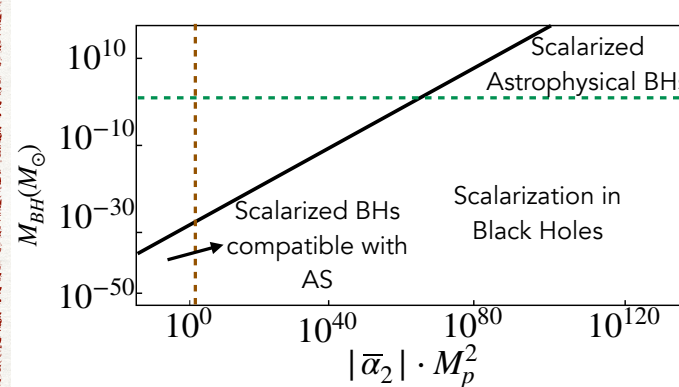
Scalar Gauss -
Bonnet Gravity



Phenomenological
interest

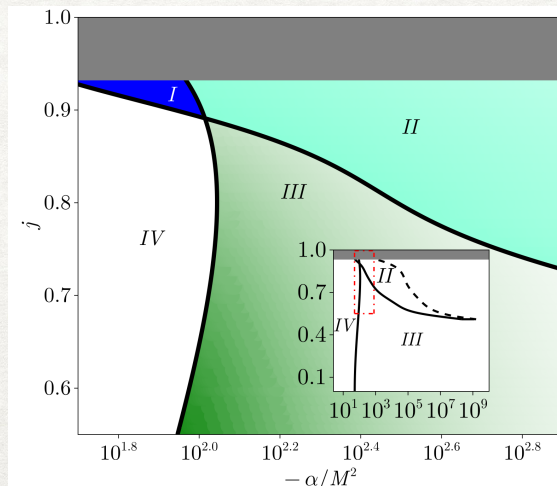
IR

Not compatible with asymptotic safety



[arXiv:26~]

Strong breaking of black hole uniqueness



[arXiv:2603.05064]

Example on how quantum gravity
theories can discriminate between
different modified gravity models

Together, they can reduce the
freedom in both directions!

Example on how phenomenology
can discriminate between different
quantum gravity theories

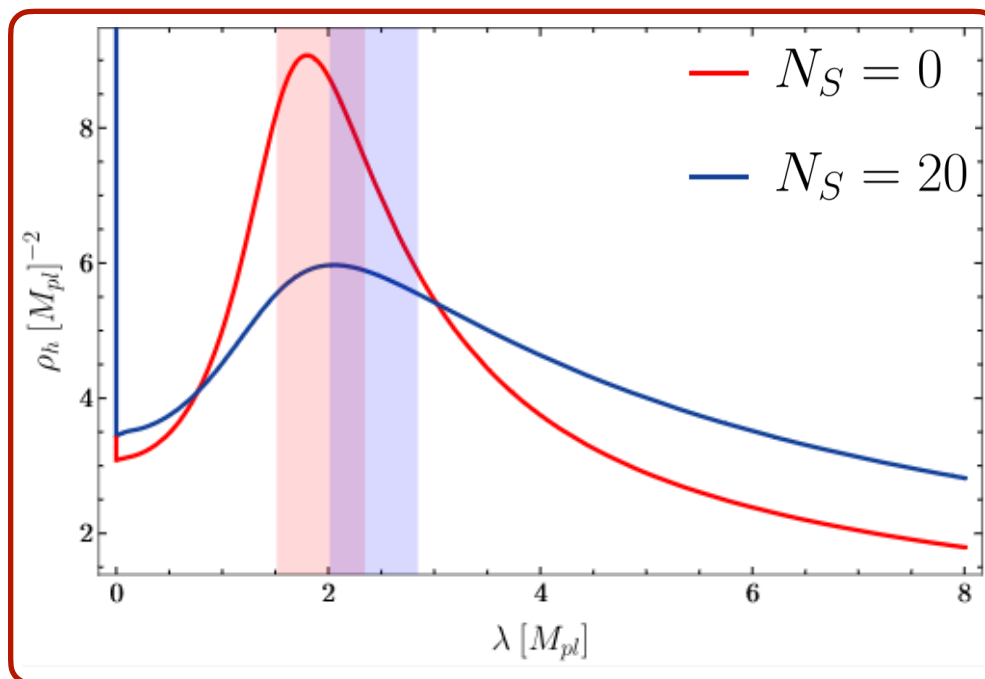
Scalar Matter in Lorentzian Quantum Gravity

Rowan Packer

- The spectral-fRG provides direct access to real-time/ Lorentzian objects such as the *graviton spectral function*

$$\rho_h(\lambda) = \frac{1}{Z_h} \left[2\pi\delta(\lambda^2 - m_h^2) + \theta(\lambda^2 - 4m_h^2)f_{h,\text{grav}} + \theta(\lambda^2 - 4k^2)f_{h,\text{scalar}} \right]$$

*Transverse
Traceless
graviton
spectral
function*



- Asymptotic safety in the Lorentzian signature must be compatible with *matter*:

$$\partial_t \Gamma_k^{(hh)} = \text{[Diagram: Solid loop with a cross]} + N_S \text{[Diagram: Dashed loop with a cross]} \quad \text{Incorporating Scalar matter!}$$

- Scalar matter makes a *positive* contribution
- The spectral function remains positive - compatible with *unitarity*



Two-Component Bose Mixtures: Mean-Field Theory and Functional Renormalisation Group

Oskar Stachowiak Paweł Jakubczyk
Institute of Theoretical Physics, University of Warsaw, Warsaw, Poland

The Wetterich equation

$$\partial_k \Gamma_k[\phi] = \frac{1}{2} \text{Tr} \left[\left(\Gamma_k^{(2)}[\phi] + R_k \right)^{-1} \partial_k R_k \right].$$

3D Quantum LPA

LPA with field expansion

$$\Gamma_k = \int d\tau \int d^d x \sum_{i=1}^2 \phi_i^* \left(\partial_\tau - \frac{\nabla^2}{2m} \right) \phi_i + U_k(\rho_1, \rho_2)$$

Field expansion of U

$$U_k(\rho_1, \rho_2) = \sum_{i=1}^2 \frac{\lambda_{i,k}}{8} (\rho_i - \kappa_{i,k})^2 + \frac{\lambda_{12,k}}{4} (\rho_1 - \kappa_{1,k})(\rho_2 - \kappa_{2,k}), \quad \rho_i = |\phi_i|^2.$$

Questions

- Stability of the phase diagram
- Critical Exponents
- Mass-imbalanced and interaction-imbalanced mixtures
- Miscibility Condition beyond mean-field theory

2D, classical DE(2)

DE(2) with field expansion. Defining $\rho_i = |\phi_i|^2$ and $\mathbf{j}_i = \phi_i^* \nabla \phi_i - \phi_i \nabla \phi_i^*$,

$$\Gamma_k = \int_x d^d x \left[U_k(\rho_1, \rho_2) + \sum_{i=1}^2 \left(\frac{Z_{i,k}}{2} |\nabla \phi_i|^2 + \frac{Y_{i,k}}{8} (\nabla \rho_i)^2 \right) + \frac{Y_{12,k}}{4} \nabla \rho_1 \cdot \nabla \rho_2 - \frac{W_{12,k}}{4} \mathbf{j}_1 \cdot \mathbf{j}_2 \right],$$

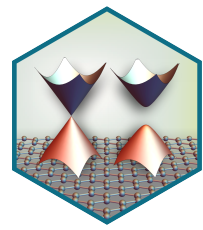
Field expansion of U

$$U_k(\rho_1, \rho_2) = \sum_{i=1}^2 \frac{\lambda_{i,k}}{8} (\rho_i - \kappa_{i,k})^2 + \frac{\lambda_{12,k}}{4} (\rho_1 - \kappa_{1,k})(\rho_2 - \kappa_{2,k}), \quad \rho_i = |\phi_i|^2.$$

Questions

- BKT fixed pint
- Critical Exponents
- Super-fluid drag

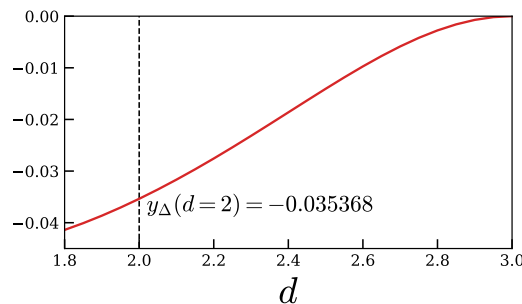
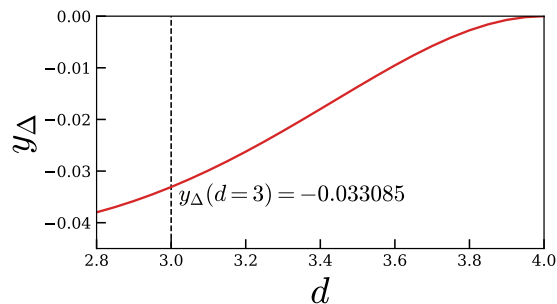
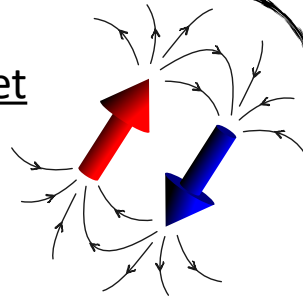
Critical behavior of isotropic magnets with screened dipolar interactions



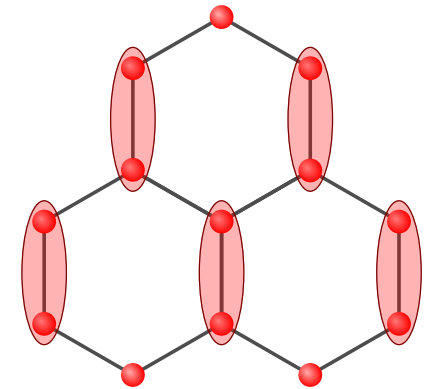
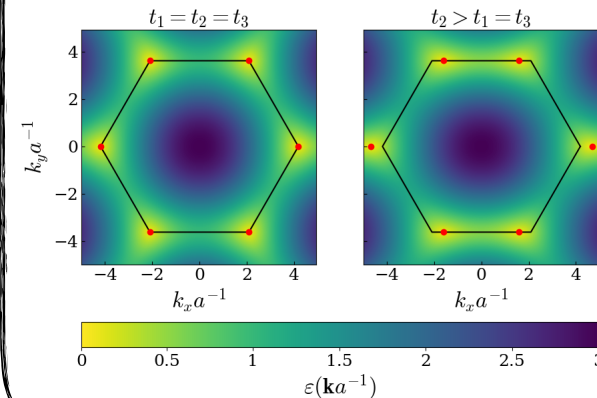
Max Fornoville^{1,2}, K. Fraboulet¹, M. M. Scherer³, L. Classen^{1,2}

$$\mathcal{L} = \frac{1}{2}(\partial_i \phi_j)^2 + \boxed{\frac{\Delta}{2}(\partial_i \phi_i)^2} + \frac{1}{2}m^2 \phi_i^2 + \frac{\lambda}{4}(\phi_i^2)^2$$

Simplest example: Dipolar antiferromagnet



Outlook: Electronic nematicity in Dirac fermion systems



NEGATIVE DIFFUSION IN THE FRG FLOW: HYPERDIFFUSION SOLUTION FOR THE QDM

Johannes POEPLAU¹, Ashutosh DASH¹ & Dirk H. RISCHKE^{1,2}

¹ Institute for Theoretical Physics, Goethe University, Max-von-Laue-Str. 1, D-60438 Frankfurt am Main, Germany
² Helmholtz Research Academy Hesse for FAIR, Campus Riedberg, Max-von-Laue-Str. 12, D-60438 Frankfurt am Main, Germany

I. Abstract

- The low energy sector of strong-interaction matter is described by effective models, which emerge from gluon dynamics. First-principles QCD calculations capture this e.g. via dynamical hadronization. Therefore first-principle calculations require a good understanding of the low energy models.
- A previous study¹ solved the QDM and encountered **strong oscillations** during the flow of the derivative of the effective potential.
- We show that these oscillations are a model feature, which can be traced back to a **negative diffusion coefficient** during the flow.
- Advection-Diffusion equations with **negative diffusion are ill-posed and require specialized methods**, as e.g. adding a regularization term, which converts the flow equations into a well-posed equation.

II. Quark-Diquark Model in the FRG

- Lagrangian of the Quark-Diquark Model (QDM) with a 2SC color superconducting phase²

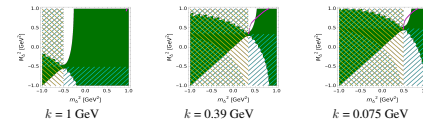
$$\mathcal{L} = \bar{\psi} (\not{\partial} - \gamma^0 \mu) \psi + \frac{\hbar}{2} \left(\Delta_a^* \bar{\psi}^T e^T \tau^2 C \gamma^5 \psi + \Delta_a \bar{\psi} e^T \tau^2 C \gamma^5 \bar{\psi}^T \right) + \frac{1}{2} (\partial_\mu - 2\mu \delta_{\mu 0}) \Delta^* (\partial^\mu + 2\mu \delta^{\mu 0}) \Delta + U(\Delta^* \Delta).$$
- LPA Flow Equation for the effective potential with the Litim Regulator:
$$\partial U = Q + F + S, \quad Q = -\frac{k^5}{12\pi^2} \sum_{\pm} \left(1 \pm \frac{8\mu^2}{\chi D} \right) \frac{\coth(\xi_{\pm}/2T)}{\xi_{\pm}},$$

$$\xi_{\pm} = \xi_{\pm}(m_{\Delta}^2, M_{\Delta}^2, \mu), \quad M_{\Delta}^2 = \partial_{\Delta}^2 U, \quad m_{\Delta}^2 = \frac{\partial_{\Delta} U}{\Delta}.$$
- $\xi_{\pm}$ depends on m_{Δ}^2 , M_{Δ}^2 and μ in a non-trivial way.
- It was found³ that the flow equation for the effective potential can be written in the form of a conservative advection-diffusion equation by taking a Δ derivative and writing it in terms of $u = \partial_{\Delta} U$:

$$\partial u(\Delta) = \frac{d}{d\Delta} Q(\Delta, u, \partial_{\Delta} u) + \frac{d}{d\Delta} F(\Delta, u) + S(\Delta).$$

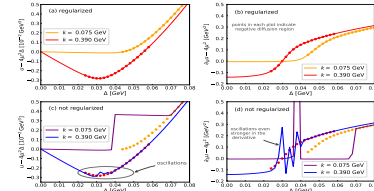
- Q acts as a diffusion term – applying the derivative w.r.t. Δ on Q results in the diffusion coefficient D .

$$\frac{dQ}{d\Delta} = D \partial_{\Delta}^2 u + E \partial_{\Delta} u + G, \quad D = \frac{\partial Q}{\partial(\partial_{\Delta} u)}.$$



- In the green region, the diffusion coefficient is positive and the hashed regions indicate the regions excluded by convexity restoration. **A white, non-hashed region exists, in which the diffusion is negative. This region is not excluded by convexity restoration.**

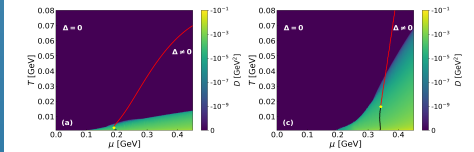
IV. Negative Diffusion



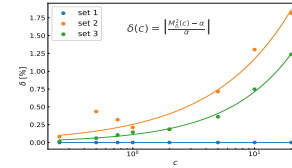
- Negative diffusion can be understood by considering the heat equation with a constant diffusion coefficient for the Fourier transformed $u(\Delta) = \sum_q c_q e^{i q \Delta}$, for a single mode c_q

$$\partial_t c_q = -D q^2 c_q$$
- For a **negative D** , all modes c_q will **grow exponentially**, causing the problem to be ill-posed.
- This **exponential growth** can be **regularized by introducing a hyperdiffusion-like term** $C \partial_{\Delta}^4 u$, which damps the high q modes⁴

$$\partial_t c_q = -D q^2 c_q - C q^4 c_q.$$
- With the regularization, the oscillations, during the flow, vanish.



- Negative diffusion occurs in high- μ low- T region and grows with the Yukawa coupling: (a) compared to (c).



- The regularization term can be systematically removed with a fit:
$$M_c^2(c) = \alpha + \beta \sqrt{c}.$$

References

- [1] J. Stoll, N. Zorbach, and J. Braun, arXiv:2510.01066
- [2] F. R. Santos, The Phase Diagram of QCD at High Densities
- [3] E. Grossi and N. Wink, arXiv:1903.09503
- [4] T. Wielecki, Shocks in nonlinear diffusion, Applied Mathematics Letters 8, 27 (1995)

Based on

arxiv:2608.20196



V. Applications

- Models with complex scalar field and a chemical potential
- Especially truncations in these models which require higher derivatives of u , e.g. LPA'
- high density, low temperature sector of QCD (2SC, CFL phases)

Contact: poeplau@itp.uni-frankfurt.de

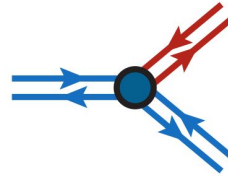
Multi-scattering processes and spectral properties of low-energy QCD

Konrad Kockler - Institut für Theoretische Physik, Universität Heidelberg

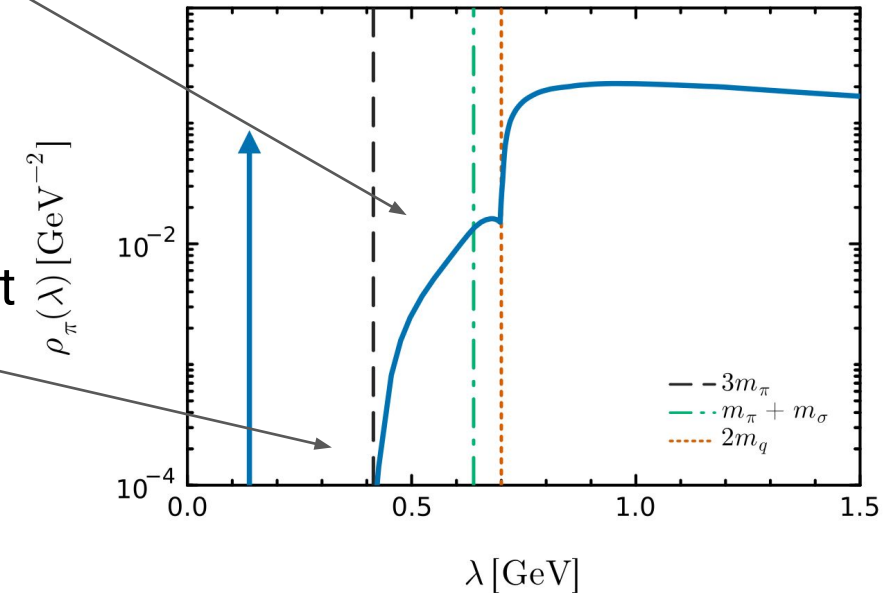
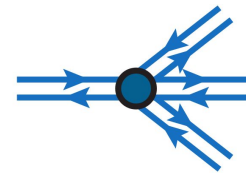
quark and meson
spectral functions:

- direct real-time
- Lorentz invariant
- RG-self-consistent

broadened sigma onsets



Lowest $\pi \rightarrow 3\pi$ scattering onset



Qualitatively new behaviour due to
feedback of momentum dependence

Analytically continued FRG for dissipative open quantum systems

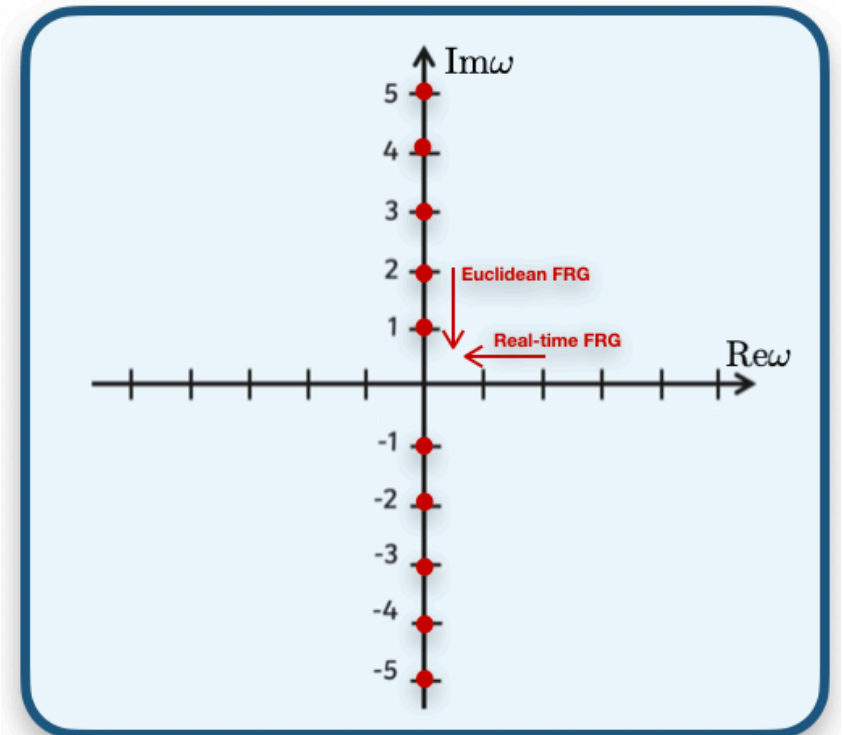
Authors: Patrick Niekamp, Johannes Roth, Lorenz von Smekal

- **Goal:** Investigate an Euclidean approach to critical dynamics
- Open system: Euclidean formulation of dissipation

$$\Gamma_k^{(2),E}(\omega_n, \mathbf{p}) = \omega_n^2 + \mathbf{p}^2 + \gamma_k |\omega_n| + m_k^2,$$

- Analytically continued Euclidean computations can be favorable to real-time

$$\Gamma_k^{(2),R}(\omega, 0) = - \lim_{\epsilon \rightarrow 0} \Gamma_k^{(2),E}(\omega_n \rightarrow -i(\omega + i\epsilon), 0)$$



Cosmology from Asymptotically Safe Proca Theories



Carlos Pastor-Marcos ft. L. Heisenberg, Á. Pastor-Gutiérrez, J. M. Pawłowski, M. Reichert

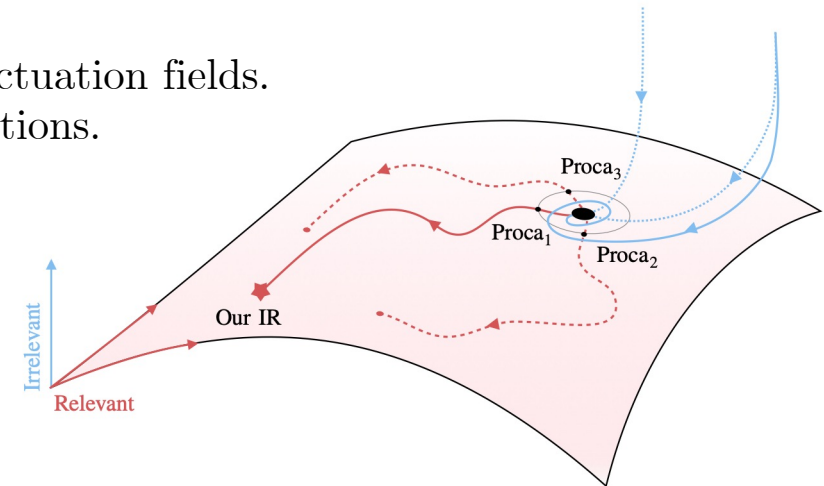
THE GOAL

“Study the UV completion of EFTs for Cosmology — We start with V-T QFTs”
– *Or how to constrain the set of possible IR scenarios from UV-informed EFTs* –

How: Within **Asymptotic Safety**! Using a vertex expansion in the fluctuation fields.
We solve for **6 coupled flows**, including cubic and quartic self-interactions.

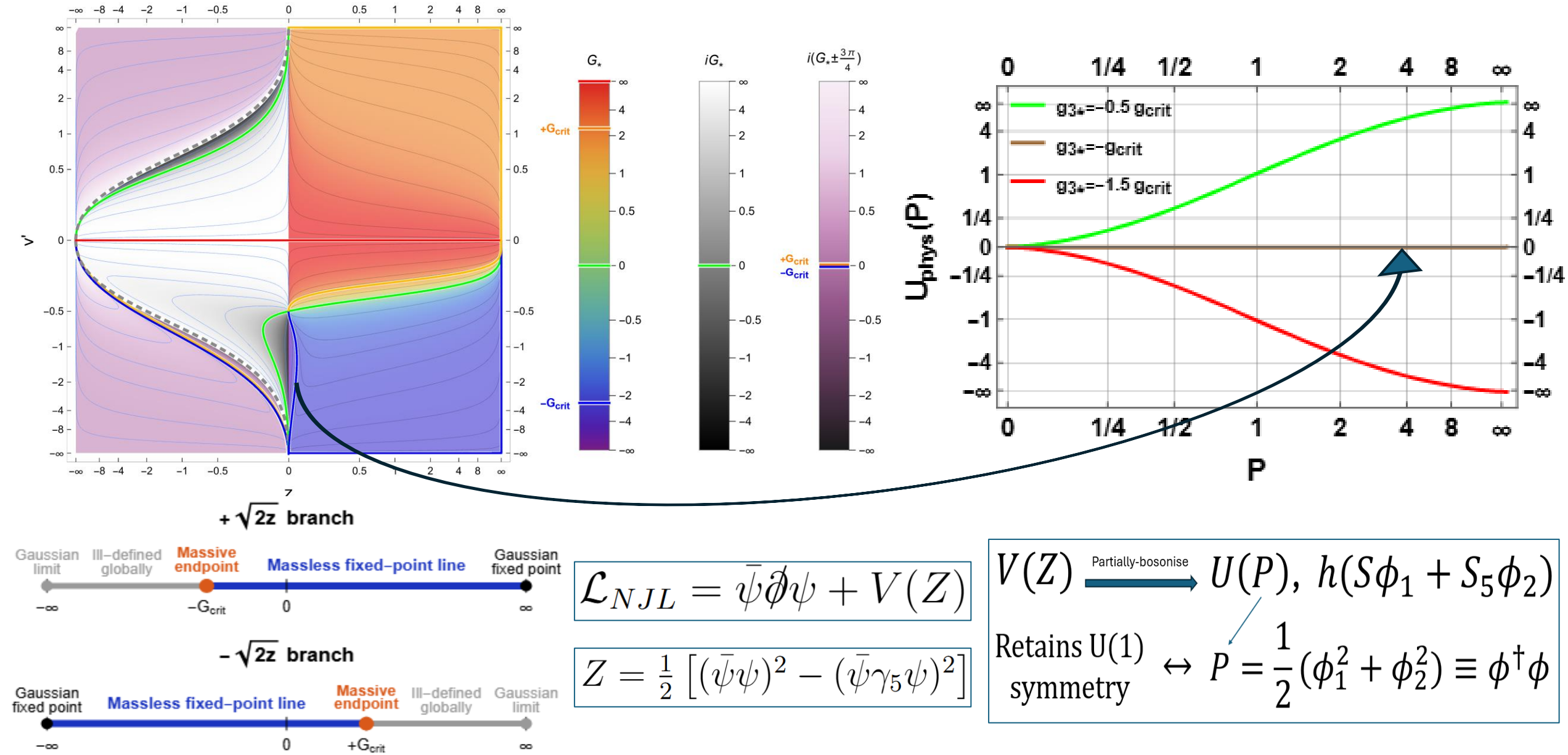
Why: Proca theories are **massive V-T theories** with **many applications in cosmology**! E.g., modelling dark energy, late-time cosmic acceleration, growth of structure...

The findings: A **very rich fixed point structure**! Evidence for non-perturbative renormalisability of V-T theories.



A connection btw. Quantum Gravity & Cosmology!!

Line of Fixed Points in a 3D NJL-type Model



Probability distribution of order parameter in $O(N)$ models

Ivan Balog, Adam Rançon, Bertrand Delamotte and Lovro Šaravanja



Objective

We want to find:

$$P(s) \propto \int \mathcal{D}S \delta(s - \frac{1}{L^d} \sum_x S_x) e^{-H[S]}$$

FRG method

Introducing effective probability action:

$$\Gamma_{M,k}[\phi] + \ln P_J(s) = \sum_x J(x)\phi(x) - \frac{M^2}{2} \left(s - \frac{1}{L^d} \sum_x \phi(x) \right)^2 - \sum_{x,y} \frac{1}{2} \phi(x) R_k(x-y) \phi(y)$$

Obtaining flow equation:

$$\partial_k \Gamma_{M,k}[\phi] = \frac{1}{2} \sum_{x,y} \partial_k R_{M,k}(x,y) \left(\Gamma_{M,k}^{(2)} + R_{M,k} \right)^{-1}(y,x)$$

Real effective probability distribution is given by: $\Gamma_k[\phi] = \lim_{M \rightarrow \infty} \Gamma_{M,k}[\phi]$
LPA ansatz:

$$\Gamma_{M,k}[\phi] = \int_x \frac{(\nabla \phi(x))^2}{2} + I_{M,k} \left[\frac{\phi(x)^2}{2} \right]$$

For $N \rightarrow \infty$ LPA approximation is exact and furthermore it is possible to find analytical solution for flow equations.

Analytical solution for $N \rightarrow \infty$

In limit $N \rightarrow \infty$ flow for probability potential reduces to:

$$\partial_k I_k[\rho] = \frac{N}{2L^d} \sum_{q \neq 0} \frac{\partial_k R_k(q^2)}{q^2 + R_k(q^2) + I'_k[\rho]}$$

Solution to probability potential can be given in form:

$$L^d I[\rho]/N = \int_0^{\frac{L^{d-2}}{N} \rho} d\alpha F^{-1}[\alpha + \Delta]$$

where Δ is parameter dependent on distance from criticality (at criticality it is equal to 0), while function F is given by:

$$F[\alpha] := -\frac{1}{2} \int_0^\infty du \left(e^{-u\alpha} \theta(u)^d - u^{d/2} \right)$$

MC simulation and comparison with FRG

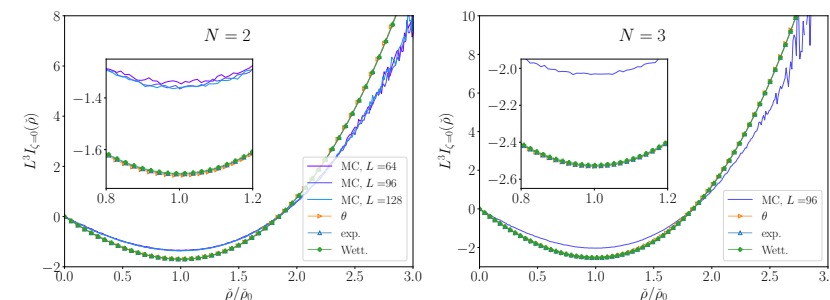


Figure 1: Comparison of MC data for different sample sizes and LPA approximation for different regulators, at criticality

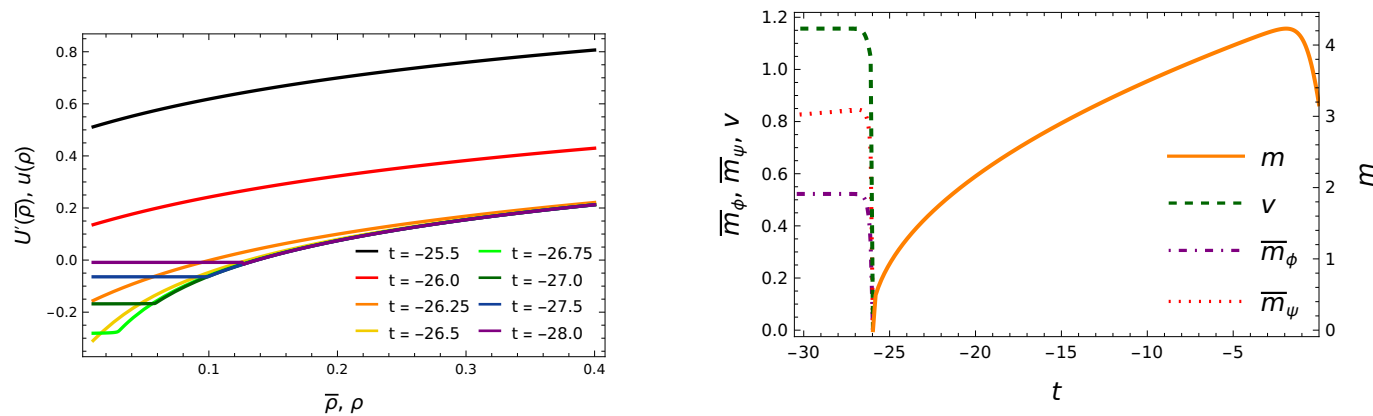
Naturalness with Relativistic Luttinger Fermions

Tim Eckert and Holger Gies

Luttinger–Yukawa model

$$\Gamma_k = \int d^4x \left[-Z_\psi \bar{\psi} G_{\mu\nu} \partial^\mu \partial^\nu \psi + \frac{Z_\phi}{2} \partial_\mu \phi \partial^\mu \phi - h \phi \bar{\psi} \gamma_{11} \psi + U(\bar{\rho}) \right]$$

Natural flow from symmetric to broken regime



Naturalness: marginal mass parameter $\rightarrow$ no fine-tuning

Self-organized criticality

Scaling regimes of shallow water waves

Gregorio Tibone^{1,2,†}, Olivier Coquand³, Giorgio Krstulovic¹, Léonie Canet²

1) INPHYNI, Université Côte d'Azur and CNRS

2) LPMC, Université Grenoble Alpes and CNRS

3) LAMPS, Université de Perpignan

† gregorio.tibone@univ-cotedazur.fr

Dispersive shallow water equations

$$\begin{cases} \partial_t h = -\partial^i(hu^i) \\ \partial_t u^j = -u^i \partial^i u^j - g \partial^j h + \nu \Delta u^j + \boxed{\frac{h_0^2}{3} \Delta \partial_t u^j} + F^j \end{cases}$$

Different observed scaling regimes

High Re

Low Ds

$$E_p^h \sim p^{-2}$$

Low Re

High Ds

$$E_p^h \sim p^{-\frac{4}{3}}$$

Analytical
results?

Functional Renormalization
Group

Wave Turbulence



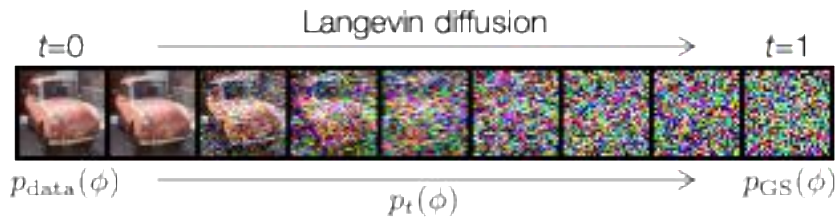
Generative Modeling with Inverse Renormalization Group Flows

Kanta Masuki and Yuto Ashida, The University of Tokyo



Cf. Stable Diffusion, 2025

■ Generative modeling (diffusion model, flow matching, etc.)



Machine Learning technique to generate complex data
Use probability flow connecting “UV” data distribution to noise distribution

Main Challenges: high computational cost

- Noise schedules are important but are determined heuristically
- Computational cost grows rapidly with system size (=image size) L

■ Generative modeling based on the exact RG flow

(Conceptual figure)



Effective theory in the Polchinski RG

We construct generative model that uses probability flow in the exact RG, i.e., $p_\Lambda[\phi] \propto e^{-S_\Lambda[\phi]}$.

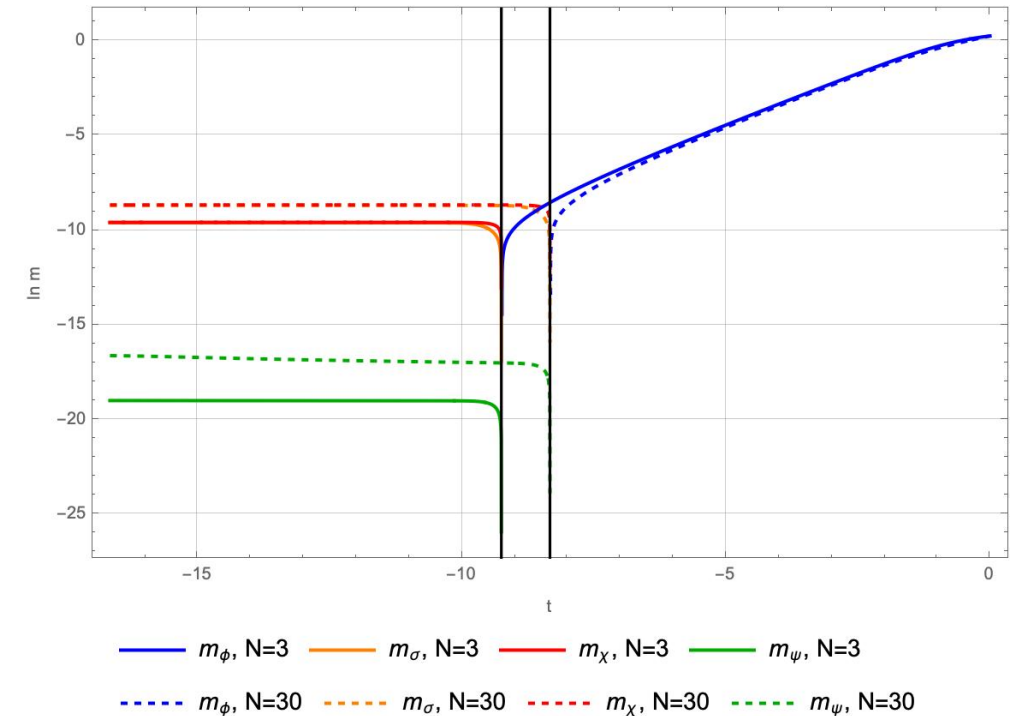
- ✓ Based on the inverse RG flow, the models create data from outline to detail.
- ✓ Noise schedules are determined by the RG theory, which improves efficiency/quality
- ✓ The quasi-locality and scale separation of the RG enable scalable computational cost.

Luttinger-Dirac-Yukawa model

$$\begin{aligned} \Gamma_k = \int d^4x & \left[-Z_{\chi,k} \bar{\chi} G_{\mu\nu} \partial_\mu \partial_\nu \chi + Z_{\psi,k} \bar{\psi} i \gamma_\mu D_\mu \psi \right. \\ & + \frac{Z_{\phi,k}}{2} \partial_\mu \phi \partial_\mu \phi + U_k(\phi) \\ & - h_{\chi,k} \phi \bar{\chi} \gamma_{11} \chi + i h_{\psi,k} \phi \bar{\psi} \psi \\ & \left. + \frac{1}{4} F_{\mu\nu}^i F_{\mu\nu}^i + \frac{1}{2\alpha} (\partial_\mu A_i^\mu)^2 + \bar{\eta}^i \partial^\mu \nabla_\mu^{ij} \eta^j \right] \end{aligned}$$

- ▶ Luttinger fermions χ + Dirac fermions ψ , both Yukawa-coupled to a dynamical scalar ϕ
- ▶ Dirac sector coupled to $SU(N)$ gauge fields (treated perturbatively, one-loop β_g)

Seesaw-type mechanism

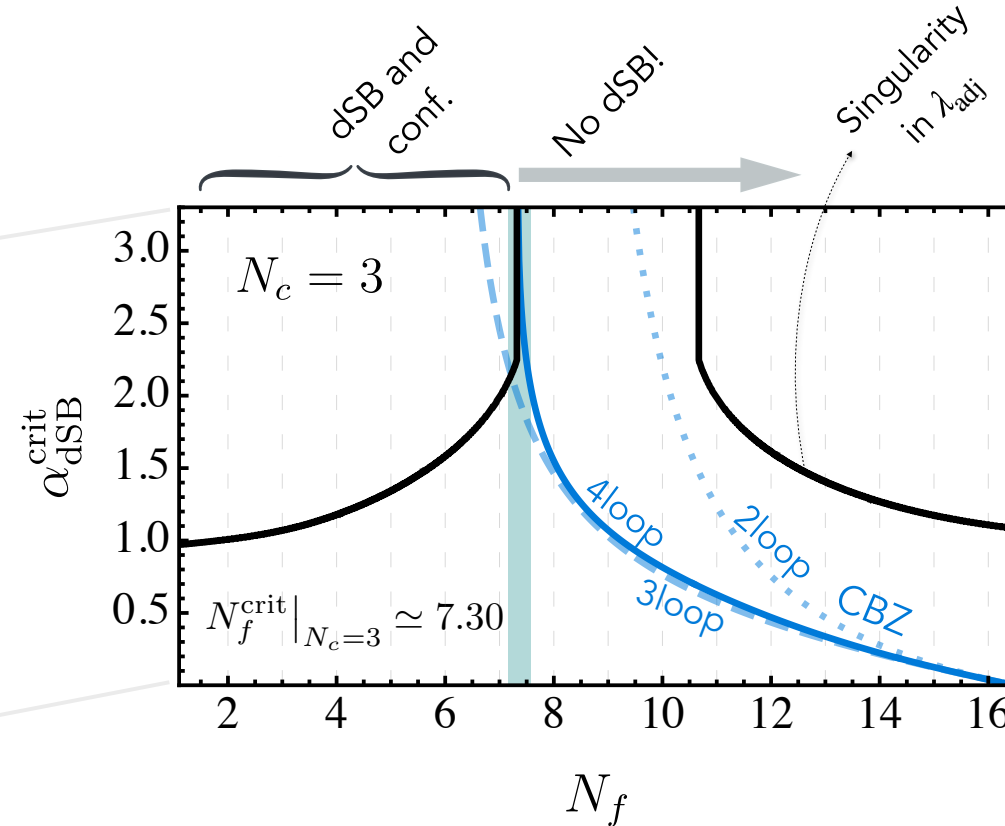
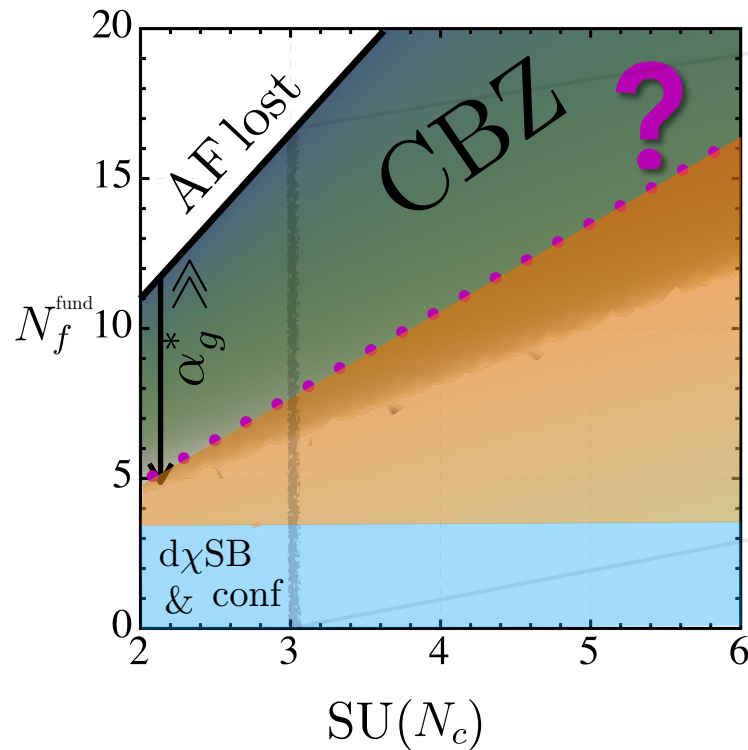


$$m_\psi \ll m_{\sigma,\chi} \sim \Lambda_F \ll \Lambda_{UV}$$

Mass hierarchies without fine tuning!

Nonperturbative News From the Conformal Window

Álvaro Pastor Gutiérrez



Full bosonisation: momentum dependencies and high-order chiral invariants

Self-consistent fRG prediction of a dSB free phase

Nonperturbative dynamics at the boundary: no walking nor Miransky/BKT

Symmetric mass gaps and confinement wo/ dSB?

Non-Renormalization of π_1 -Characters under Finite ERG Transformations on Multiply Connected Configuration Spaces

Satoshi Ohya¹

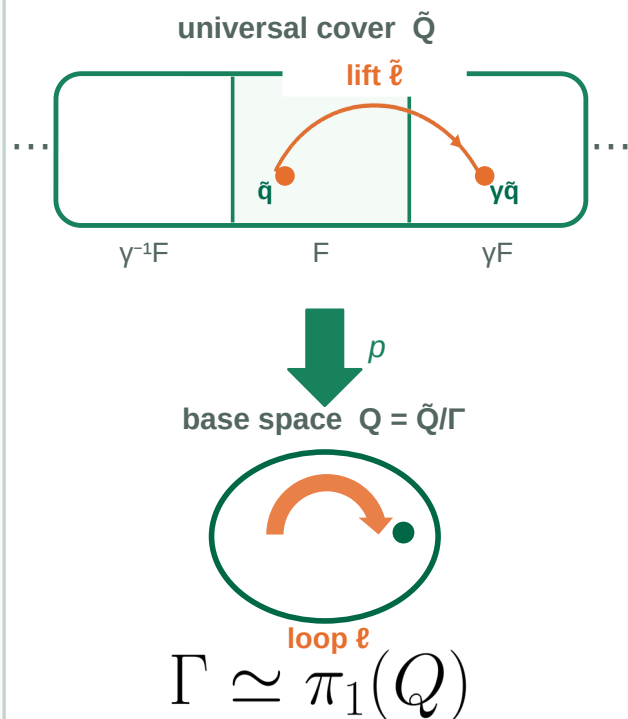
Taichi Tanaka²

¹ Institute of Quantum Science

² Graduate School of Science and Technology

Nihon University

1 LIFT THE TOPOLOGY



2 CONSTRUCT THE FINITE KERNEL

Dowker covering-space sum

Every lift of the endpoint contributes once.

$$R_{\Lambda, \Lambda'}[\phi, \phi'] = \sum_{\gamma \in \Gamma} D(\gamma) \tilde{R}_{\Lambda, \Lambda'}[\tilde{\phi}, \gamma \tilde{\phi}']$$

$D(\gamma)$: global π_1 -character

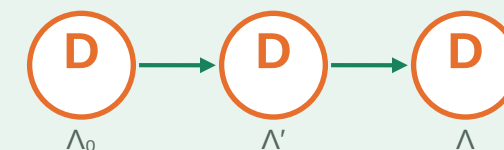
$\tilde{R}$ local finite ERG kernel on the universal cover

D global boundary condition carried by the winding sector

Composition law + simultaneous deck invariance

3 CHARACTER AND LEVEL

One character, two consequences



$$D_{\Lambda, \Lambda_0}(\gamma) = D_{\Lambda', \Lambda_0}(\gamma)$$

non-renormalization

With lift-independent normalization $D(\gamma)=1$:

$$D(\gamma[\ell]) = e^{iI(\ell)} = 1 \implies I(\ell) \in 2\pi\mathbb{Z}$$

level quantization

APPLICATIONS

d-dimensional nonlinear $O(d+2)$ σ model

$$D(n) = e^{i2\pi kn}$$

WZW level k

3d $SU(N)$ Yang-Mills

Chern-Simons level

Explicit universal-cover kernel still faces the Gribov-Singer problem.

A tale of scales in Asymptotically Safe Quantum Gravity

What if ASQG is not fundamental?

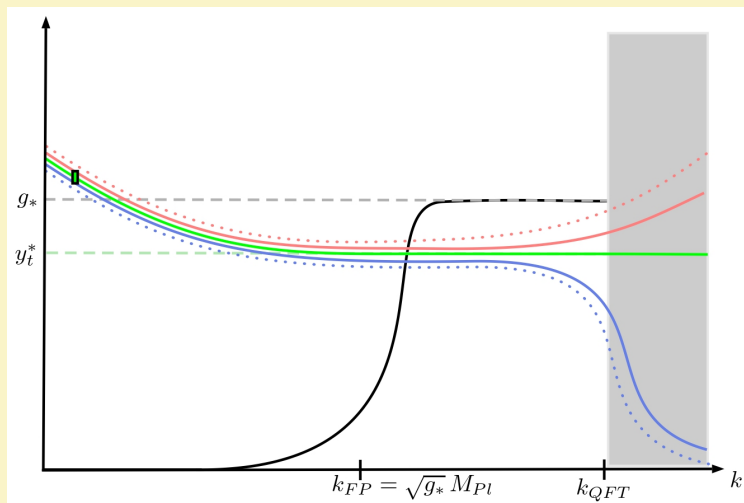
Can it arise as an effective description of a more fundamental theory? Can we constrain the QG scale using low-energy observables?

1707.01107 Eichhorn, Held

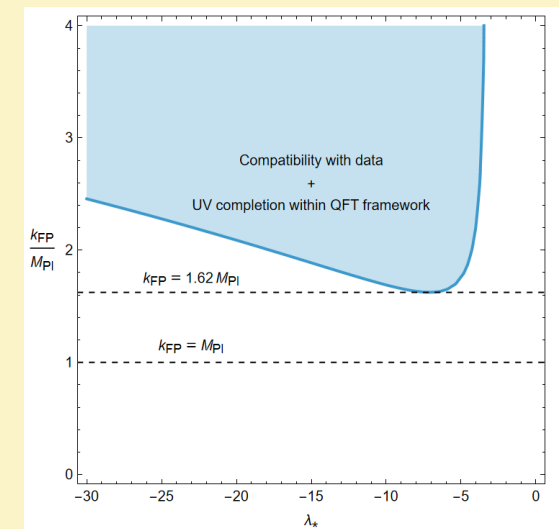
The top-quark mass provides a powerful constraint.

We identify the **fixed point scale**, a meaningful QG scale in AS, and we study its interplay between other relevant scales

UV completion and compatibility with experiments require that this scale be at least Planckian, ruling out weakly-coupled string embeddings



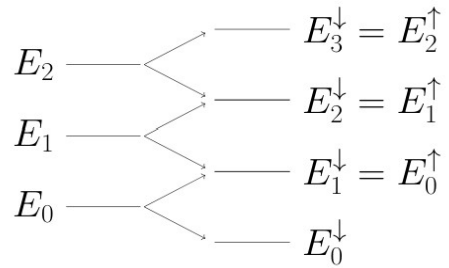
- And more...
- relation to species scale?
 - "bumps" as signatures of ASQG?



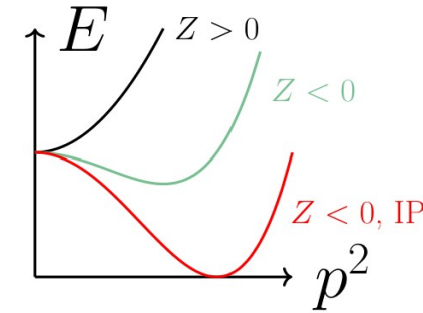
The moat regime under magnetic fields

Justin L.P. Mauldin, Kristina Totic, Johannes Pöplau and Dirk H. Rischke

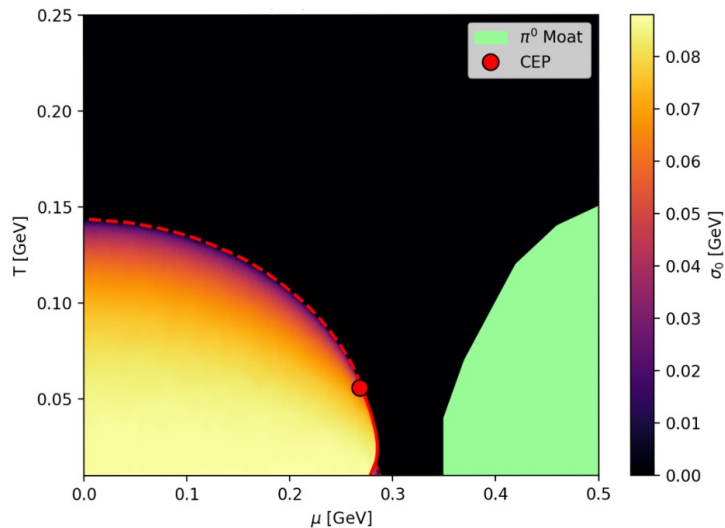
Particles are restricted to Landau levels
→ dim. Reduction and (inverse-) magnetic catalysis



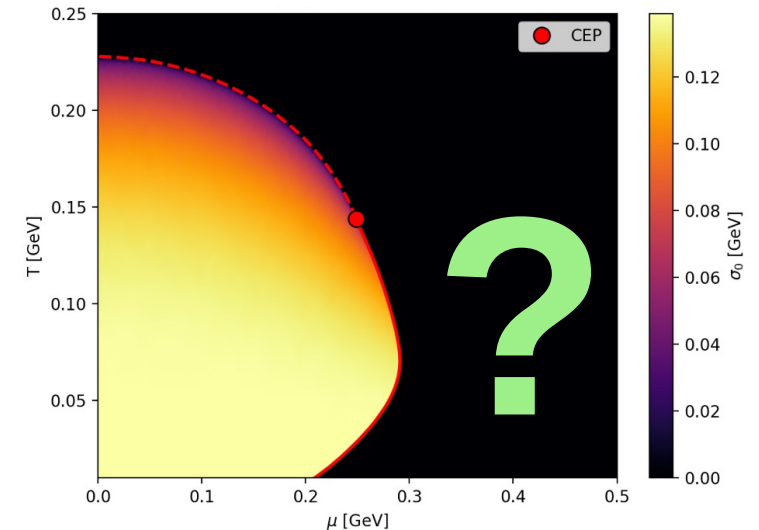
In the moat regime a particles ground state is at finite momentum



$B = 0$



$B > 0$



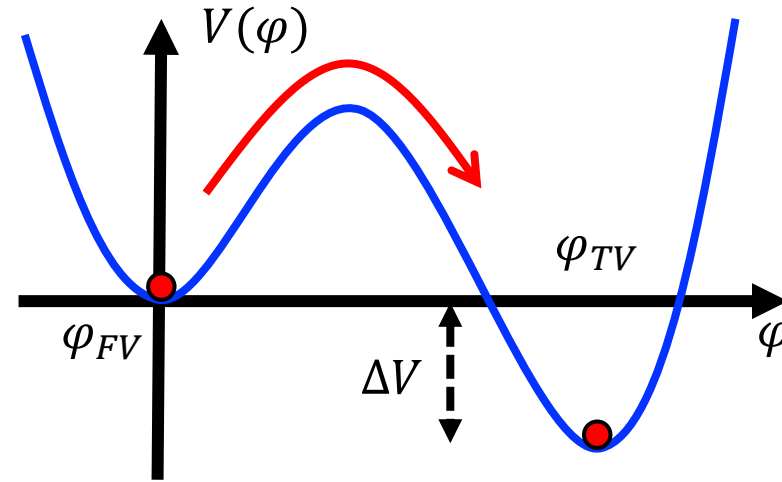
Computing the Bubble Nucleation Rate with Functional RG Methods

Authors: Rory Phipps, Stephan Huber, and Manuel Reichert

The rate of bubble nucleation controls the shape of the GW spectrum from a first-order thermal phase transition.

How can we use the fRG in practice to obtain the nucleation rate?

What questions can this help us answer?



Come and have a chat to find out more!