

A Dilaton in Deformed Gross-Neveu Models

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Miransky Memorial, May 17, 2026, Hefei, China

I asked Claude PRO to “Please give me a detailed list of the accomplishments of the physicist Vladimir Miransky”.

Here is what it said:

Vladimir A. Miransky is a Ukrainian-Canadian theoretical physicist whose career has centered on non-perturbative dynamics in quantum field theory, especially dynamical symmetry breaking in gauge theories. Here is a detailed account of his principal accomplishments.

Miransky scaling (essential-singularity scaling). In the mid-1980s Miransky showed that in strong-coupling QED the dynamically generated fermion mass near the critical coupling does not follow a power-law (mean-field) behavior but instead a non-analytic essential singularity of the form $m \sim \Lambda \exp\left(-c/\sqrt{\alpha/\alpha_c - 1}\right)$. This "Miransky scaling" is the prototype of conformal/BKT-type scaling in gauge theories and has become a standard reference point in studies of near-conformal dynamics, walking technicolor, and the conformal window of QCD-like theories.

Dynamical chiral symmetry breaking in QED and QCD. Beginning in the late 1970s and through the 1980s (much of it with P. I.

Fomin, V. P. Gusynin, and Yu. A. Sitenko at the Bogolyubov Institute in Kiev), Miransky developed the Schwinger-Dyson/Bethe-Salpeter framework for dynamical chiral symmetry breaking in strongly coupled gauge theories. The Fomin-Gusynin-Miransky-Sitenko program established the existence of a critical coupling for chiral symmetry breaking in quenched QED and laid much of the technical groundwork that QCD-applications later built on.

Magnetic catalysis of chiral symmetry breaking. In a series of highly influential papers in the mid-1990s with V. P. Gusynin and I. A. Shovkovy, Miransky discovered that a constant external magnetic field is a universal catalyst of dynamical chiral symmetry breaking: it generates a fermion mass for arbitrarily weak attractive interaction, by effectively reducing the infrared dynamics to (1+1) dimensions through dominance of the lowest Landau level. "Magnetic catalysis" is now a textbook phenomenon and has been

studied extensively in NJL-type models, QED, QCD, graphene, and Dirac/Weyl semimetals. The Gusynin-Miransky-Shovkovy papers are among the most cited works in non-perturbative QFT of that era.

Applications to graphene and Dirac materials. With Gusynin, Sharapov, and Shovkovy, Miransky extended the magnetic-catalysis ideas to planar Dirac fermions in condensed-matter systems. This program provided one of the leading theoretical explanations of the additional quantum Hall plateaus observed in graphene in strong magnetic fields and predicted excitonic / chiral-symmetry-breaking-type instabilities in Dirac semimetals ? a body of work that helped seed the field of "relativistic" many-body physics in graphene. Walking technicolor and near-conformal gauge dynamics. Miransky's scaling analysis and his work (with Yamawaki and others) on gauge theories with many fermion flavours contributed directly to the "walking technicolor"

framework: gauge theories whose coupling runs very slowly over a large range of scales. This work is widely cited in beyond-Standard-Model phenomenology and in lattice studies of the conformal window. Color superconductivity and dense QCD. With Shovkovy and collaborators in the early 2000s, Miransky contributed to the theory of color superconductivity in dense quark matter, including studies of gapless phases, the role of neutrality constraints, and chromomagnetic instabilities ? issues that became central in the discussion of the QCD phase diagram and compact-star matter.

Gauged Nambu-Jona-Lasinio models and top-quark condensate scenarios. Together with Tanabashi and Yamawaki (and independently in related work with Bardeen and Hill), Miransky helped develop the "top-mode"/top-quark condensate approach to electroweak symmetry breaking, in which a four-fermion interaction among top quarks triggers dynamical electroweak symmetry

breaking. This was one of the early concrete realizations of compositeness ideas for the Higgs sector.

Monograph "Dynamical Symmetry Breaking in Quantum Field Theories" (World Scientific, 1993). Miransky's book remains a standard reference on non-perturbative methods (Schwinger-Dyson equations, ladder approximations, chiral symmetry breaking, anomalous dimensions in strongly coupled gauge theories) and has been used by two generations of graduate students and researchers. Institutional and mentoring contributions. Trained in Kyiv and long associated with the Bogolyubov Institute for Theoretical Physics of the National Academy of Sciences of Ukraine, Miransky later joined the University of Western Ontario in Canada, where he has been a professor in the Department of Applied Mathematics. He has mentored a number of students and postdocs (notably Gusynin and Shovkovy) who have themselves become leaders in non-perturbative QFT.

Awards and recognition.

He is a corresponding member of the National Academy of Sciences of Ukraine and a recipient of the Bogolyubov Prize of the NASU for his contributions to theoretical physics.

His papers on magnetic catalysis and on dynamical chiral symmetry breaking are among the most cited in their respective subfields.

Taken together, Miransky's career has had three particularly durable impacts: the recognition that strongly coupled gauge theories near criticality exhibit a distinctive essential-singularity (Miransky/BKT) scaling, the discovery that magnetic fields universally catalyze chiral symmetry breaking, and the extension of these relativistic-QFT ideas into condensed-matter Dirac systems such as graphene.

Then I asked Claude PRO “ Can you find for me some
downloadable photos of the physicist Vladimir Miransky?”

Gluonic use as the Ground State
in Cold Dense QCD

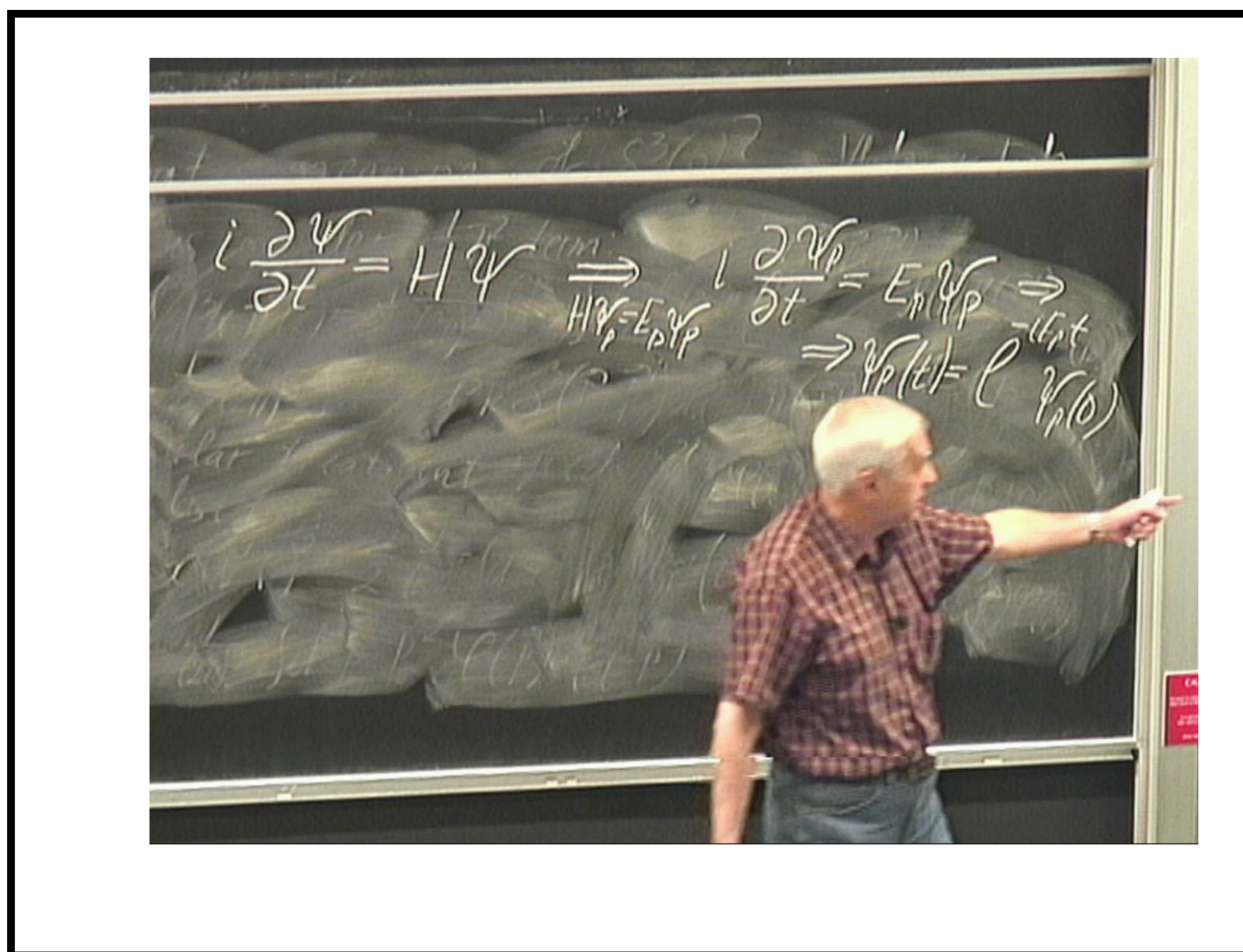
E. Gorbar, M. Hashimoto, and V.M.:
Phys. Lett. B 632 (2006) 305;
Phys. Rev. Lett. 96 (2006) 022005.

E. Gorbar, J. Jia, and V.M.,
Phys. Rev. D 73 (2006) 045001.

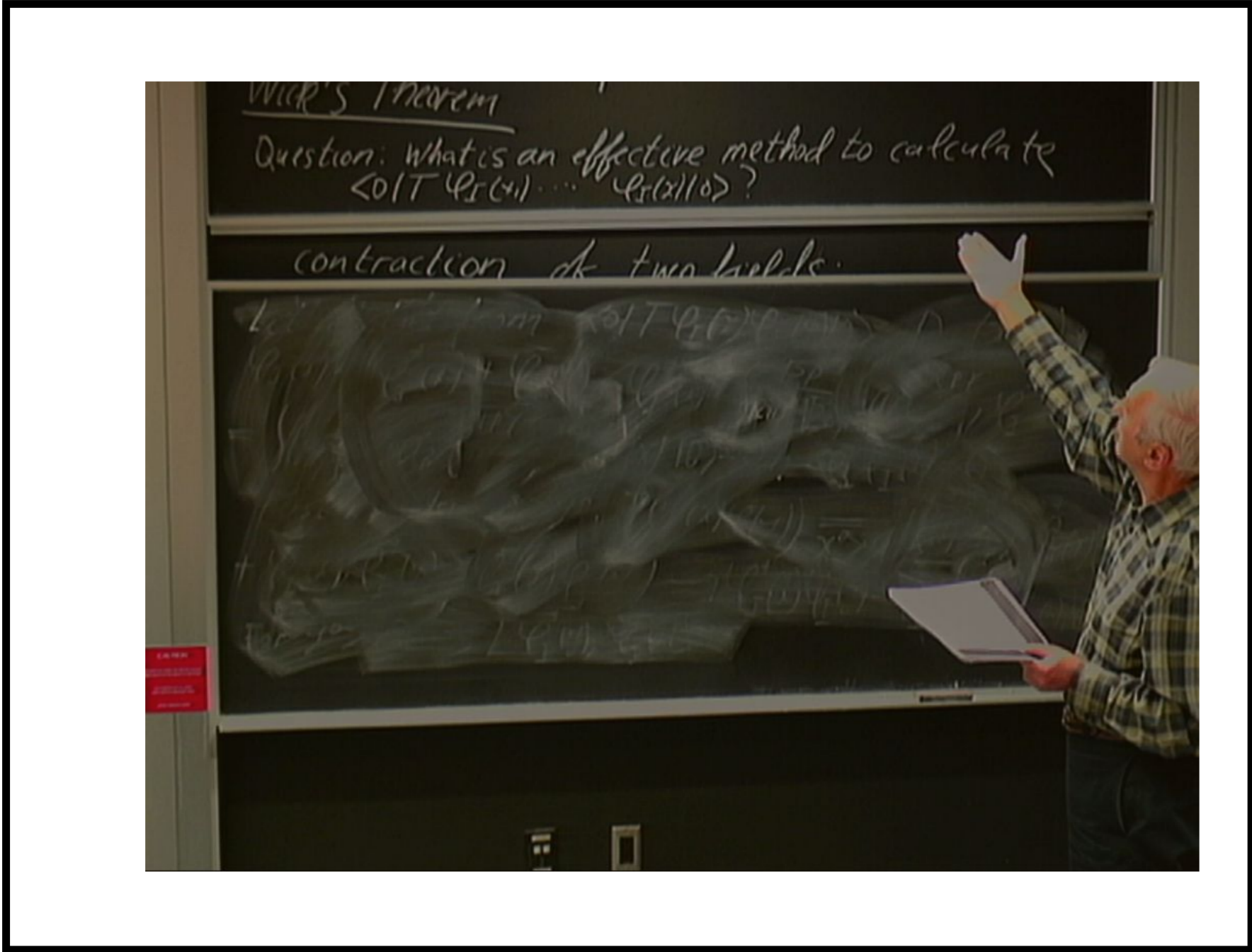
E. Gorbar, M. Hashimoto, V.M., and
I. Shovkovy, Phys. Rev. D 73 (2006) 111502(R)

$$n = K n_0, \quad K = 2-5, \quad n_0 \approx 0.17 \text{ fm}^{-3}$$

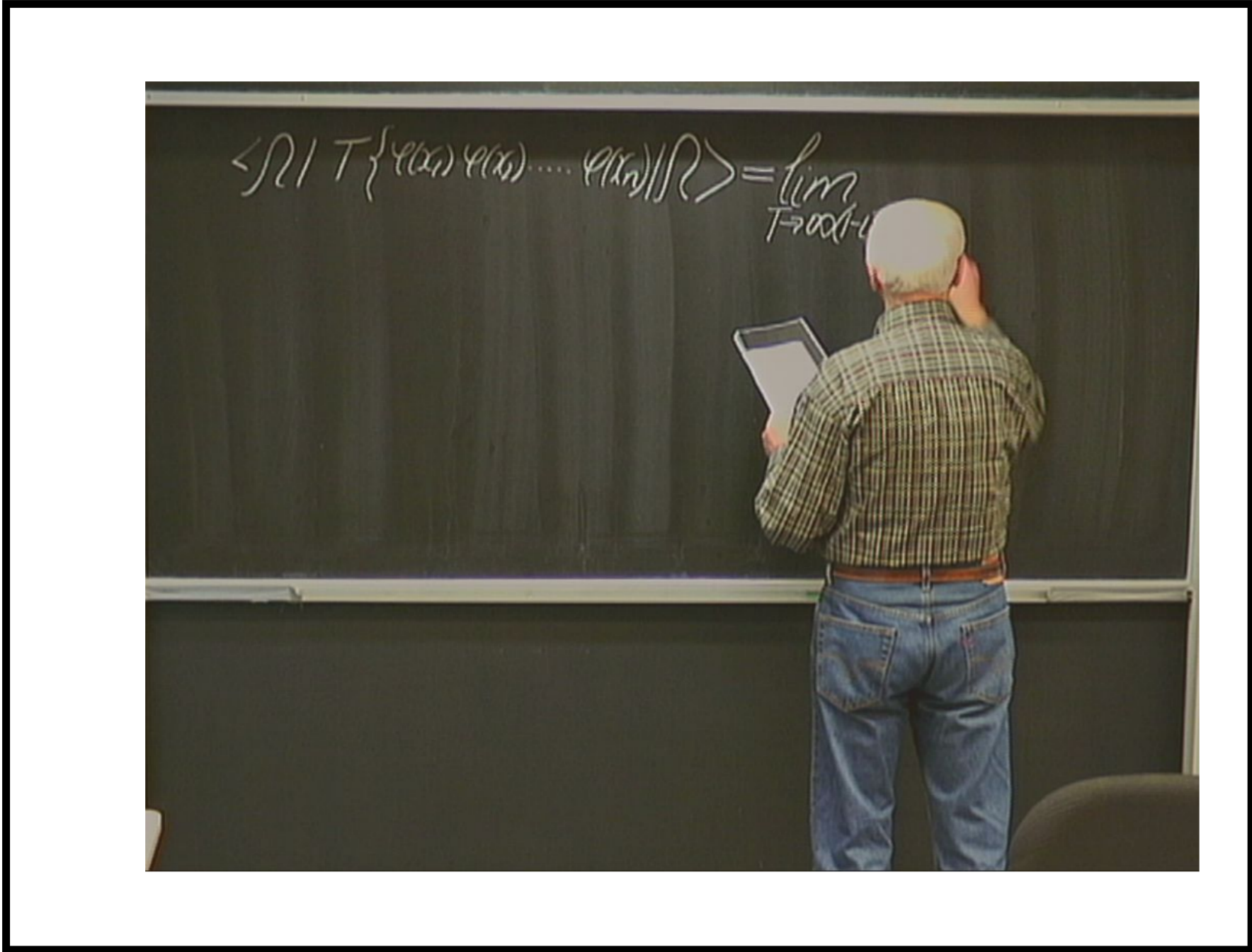
↑
nuclear density



International Conference on Symmetry Breaking Phenomena in Quantum Field Theory, Heifei 2026



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Outline

- Introduction
- 3D Gross Neveu model
- Parity violating deformation
Dynamical breaking of scale symmetry
- Gross-Neveu-Thirring model
- Broken scale symmetry and dilaton
- Thermal transport

G.W.S., R.A.Stewart, [arXiv:2402.09646 [hep-th]];
[arXiv:2402.09646 [hep-th]]; [arXiv:26??... [in progress]]

Introduction:

a metal object is cool to the touch

plastic or organic material feels warmer

what is the difference? thermal conductivity – κ

metal has phonons+conduction electrons which carry energy

insulator has only phonons, less carriers

phonons can be a good heat conductor in some rigid crystal structures, e.g. diamond

Boron-Arsenide – insulator with small phonon damping

material for cooling AI chips

relativistic system – no phonons

conductor – gapless fermions v.s. insulator – gapped fermions

Dirac semimetal – insulator phase transition

dynamical breaking of scale symmetry + dilaton

dilaton-mediated heat transport

3D Gross-Neveu Model :

$$\mathbf{S} = \int d^3x \left\{ -i\bar{\psi}\not{\partial}\psi + \frac{g}{2N}(\bar{\psi}\psi)^2 \right\}$$

Euclidean space, 2-component spinor, $O(2N)$ symmetry

$$\bar{\psi}\psi \equiv \sum_{a=1}^N \bar{\psi}_a(x)\psi_a(x)$$

not renormalizable in coupling constant expansion

renormalizable large N expansion

Hubbard-Stratonovic auxillary field

$$\mathbf{S} = \int d^3x \left\{ -i\bar{\psi}[\not{\partial} + \phi]\psi + \frac{N}{2g}\phi^2 \right\}$$

parity symmetry $(x^1, x^2, x^3)' = (-x^1, x^2, x^3)$

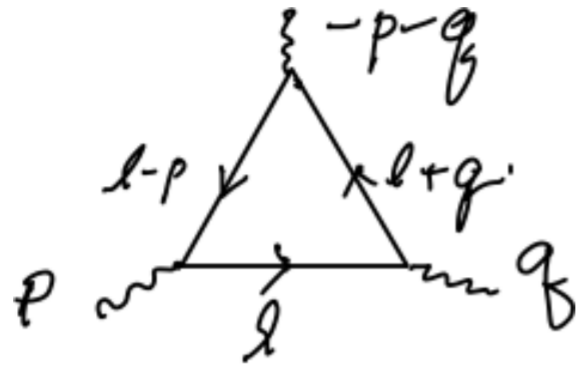
$\psi(x) \rightarrow \gamma^2\psi(x')$ $\phi(x) \rightarrow -\phi(x')$ $\langle\phi\rangle \sim \frac{1}{N}\langle\bar{\psi}\psi\rangle$ breaks P and T

3D Gross-Neveu Model at large N:

$$\mathbf{S} = \int d^3x \left\{ -i\bar{\psi}[\not{\partial} + \phi]\psi + \frac{N}{2g}\phi^2 \right\} \quad \text{integrate out fermions}$$

$$\mathbf{S}_{\text{eff}}[\phi] = \int d^3x \frac{N}{2g}\phi^2 - N\text{TR} \ln[\not{\partial} + \phi] + \mathcal{O}(1)$$

$$\mathbf{V}_{\text{eff}}[\langle\phi\rangle] = \frac{N}{2g}\langle\phi\rangle^2 + \frac{N}{6\pi}|\langle\phi\rangle|^3 + \mathcal{O}(1) \quad , \quad \frac{1}{g_{\text{crit}}} = 0$$



“The Gross-Neveu-Yukawa Archipelago”, R.S.Erramilli,
L.V.Iliesiu, P.Kravchuk, A.Liu, D.Poland, D.Simmons-Duffin,
JHEP 2023, 36 (2023).

Add a parity violating operator:

$$\mathbf{S} = \int d^3x \left\{ -i\bar{\psi}[\not{\partial} + \phi]\psi + \frac{N}{2g}\phi^2 \left[+ \frac{N\lambda}{3!}\phi^3 \right] \right\}$$

$$\mathbf{V}_{\text{eff}}[\langle\phi\rangle] = \frac{N}{2g}\langle\phi\rangle^2 + \frac{N}{6\pi}|\langle\phi\rangle|^3 + \frac{N\lambda}{3!}\langle\phi\rangle^3 + \dots$$

stability if $-\frac{1}{\pi} < \lambda < \frac{1}{\pi}$

$$\beta_{\frac{1}{g}} = \frac{1}{g} + \mathcal{O}(1/N), \quad \beta_{\lambda} = 0 + \mathcal{O}(1/N)$$

There is a line of UV fixed points $\frac{1}{g^*} = 0, -\frac{1}{\pi} \leq \lambda^* \leq \frac{1}{\pi}$

C.Cresswell-Hogg, D.Litim, [arXiv:2207.10115 [hep-th]].

Tune to the stability edge:

$$\mathbf{V}_{\text{eff}}[\langle\phi\rangle] = \frac{N}{2g} \langle\phi\rangle^2 + \frac{N}{6\pi} |\langle\phi\rangle|^3 + \frac{N\lambda}{3!} \langle\phi\rangle^3 + \dots$$

tune to stability edge $\lambda \rightarrow \frac{1}{\pi}$ and UV fixed point $\frac{1}{g} \rightarrow \frac{1}{g^*} = 0$

$$\mathbf{V}_{\text{eff}}[\langle\phi\rangle] = \begin{cases} \frac{N}{3\pi} \langle\phi\rangle^3 & \langle\phi\rangle > 0 \\ 0 & \langle\phi\rangle < 0 \end{cases}$$

any condensate $\langle\phi\rangle < 0$ – breaks scale invariance

charge gap – fermion mass $\sim \langle\phi\rangle$ – and massless dilaton

$$\langle\phi(-p)\phi(p)\rangle = \frac{1}{N} \frac{12\pi \langle\phi\rangle}{p^2} + \dots$$

Corrections to large N limit:

$$\Gamma = \int d^3x \left\{ \frac{N}{2g} \phi^2 + \frac{N\lambda}{3!} \phi^3 - i\bar{\psi}(\not{\partial} + \phi)\psi \right\} - \frac{N}{2} \text{Tr} \ln [\not{\partial} + \phi] \\ + \frac{1}{2} \text{Tr} \ln \left[\left(\frac{1}{g} + \lambda\phi(x) \right) \delta(x, y) + \Pi(x, y) \right] + \mathcal{O}(1/N)$$

$$\Pi(x, y) = (x | \frac{1}{\not{\partial} + \phi} | y)(y | \frac{1}{\not{\partial} + \phi} | x) + \frac{1}{N} \bar{\psi}(x)(x | \frac{1}{\not{\partial} + \phi} | y)\psi(y)$$

$$\beta_{\frac{1}{g}} = \frac{1}{g} + \dots, \quad \beta_{\lambda} = \frac{32}{\pi^2 N} (\lambda - 8\lambda^2) + \mathcal{O}(1/N^2)$$

UV fixed point $\frac{1}{g^*} = 0$, $\lambda^* = \pm \frac{1}{2\sqrt{2}}$

but stability is $|\lambda| \leq \frac{1}{\pi}$ and $\frac{1}{\pi} < \frac{1}{2\sqrt{2}}$

UNSTABLE ??????

In $3+\epsilon$ dimensions :

$$\Gamma = \int d^{3+\epsilon}x \left\{ \frac{N}{2g} \phi^2 + \frac{N\lambda}{3!} \phi^3 - i\bar{\psi}(\not{\partial} + \phi)\psi \right\} - \frac{N}{2} \text{Tr} \ln [\not{\partial} + \phi]$$

$$+ \frac{1}{2} \text{Tr} \ln \left[\left(\frac{1}{g} + \lambda\phi(x) \right) \delta(x, y) + \Pi(x, y) \right] + \mathcal{O}(1/N)$$

$$\Pi(x, y) = (x | \frac{1}{\not{\partial} + \phi} | y) (y | \frac{1}{\not{\partial} + \phi} | x) + \frac{1}{N} \bar{\psi}(x) (x | \frac{1}{\not{\partial} + \phi} | y) \psi(y)$$

$$\beta_{\frac{1}{g}} = \frac{1}{g} + \dots, \quad \beta_{\lambda} = -\epsilon\lambda + \frac{32}{\pi^2 N} (\lambda - 8\lambda^3) + \mathcal{O}(1/N^2)$$

UV fixed point

$$\frac{1}{g^*} = 0, \quad \lambda^* = \pm \frac{\sqrt{1 - \frac{\pi^2}{32} \epsilon N}}{\sqrt{8}}$$

Can be stable but needs $\epsilon \sim \frac{1}{N}$

3D Gross-Neveu-Thirring Model :

$$\mathbf{S} = \int d^3x \left\{ -i\bar{\psi}\not{\partial}\psi + \frac{g}{2N}(\bar{\psi}\psi)^2 - \frac{1}{2\eta}(\bar{\psi}\gamma^\mu\psi)^2 \right\}$$

Use scalar and vector Hubbard Stratonovic fields:

$$\mathbf{S} = \int d^3x \left\{ -i\bar{\psi}[\not{\partial} + i\mathbf{A} + \phi]\psi + \frac{N}{2g}\phi^2 + \frac{N\eta}{2}A_\mu A^\mu \right\}$$

Leading order at large N

$$\mathbf{V}_{\text{eff}}[\langle\phi\rangle] = \frac{N}{2g}\langle\phi\rangle^2 + \frac{N}{6\pi}|\langle\phi\rangle|^3 + \mathcal{O}(1) \quad , \quad \frac{1}{g_{\text{crit.}}} = 0$$

3D Gross-Neveu-Thirring Model :

Add parity violating operators

$$\mathbf{S} = \int d^3x \left\{ -i\bar{\psi}[\not{\partial} + i\not{A} + \phi]\psi + \frac{N}{2g}\phi^2 + \frac{N\eta}{2}A^2 \left[\frac{N\lambda}{3!}\phi^3 + i\frac{\kappa N}{4\pi}AdA \right] \right\}$$

$$\beta(\lambda, \kappa) = -\frac{1}{2\pi^2 N} \left[(8\lambda)^3 + \zeta(\kappa)(8\lambda) + \iota(\kappa) \right] + \mathcal{O}(1/N^2)$$

$$\zeta(\kappa) = -8 \frac{\left(\frac{\kappa}{2\pi}\right)^4 + 10\left(\frac{\kappa}{2\pi}\right)^2\left(\frac{1}{16}\right)^2 - 3\left(\frac{1}{16}\right)^4}{\left[\left(\frac{\kappa}{2\pi}\right)^2 + \left(\frac{1}{16}\right)^2\right]^2}$$

$$\iota(\kappa) = 4 \left(\frac{\kappa}{2\pi}\right) \left(\frac{1}{16}\right)^2 \frac{3\left(\frac{1}{16}\right)^2 - 5\left(\frac{\kappa}{2\pi}\right)^2}{\left[\left(\frac{\kappa}{2\pi}\right)^2 + \left(\frac{1}{16}\right)^2\right]^3}$$

\exists range of κ where $\lambda^* \leq 1/\pi$

\exists values of κ where λ^* is at the stability edge \rightarrow flat potential \rightarrow dynamical breaking of scale invariance with a massless dilaton.

Thermal conductivity κ :

In a clean, translation-invariant relativistic system the DC thermal conductivity is formally infinite (because the energy current is proportional to the conserved momentum density)

To get a finite κ_{xx} one needs a momentum-relaxation rate Γ (disorder, umklapp, lattice, bath). Then, in the hydrodynamic regime in $2+1D$,

$$\kappa_{xx} = s/\Gamma$$

where s is the entropy density. In $2 + 1D$, N massless fermions

$$s \sim NT^2, \quad \Gamma \sim T, \quad \rightarrow \kappa_{xx} \sim NT$$

In the dilaton phase, the fermions are frozen out and the entropy is carried by the dilaton alone. But the dilaton decay constant satisfies $f^2 \sim N$ (from large N counting of the effective action), so the dilaton effective action also contributes $s \sim NT^2$.

Conclusion :

There exist model quantum field theories with
ultraviolet fixed point
flat energy landscape
spontaneously broken scale symmetry
fermions are gapped,
there is a massless dilaton in the spectrum
dilaton mediated heat conductivity