Fluctuating condensate

What is there beyond a homogeneous condensate and Higgs particles?

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Plan

Condensate

classical ↔ quantum

B-E: elementary particles, ideal gas

BCS: composite particles with intrinsic scale

Interactive system: - macroscopically populated states
- one or several states?
- scale dependent picture
- two fluid description + corrections
- **neither quantum nor classical**

In what follows: few remarks on - interactive elementary bosons
- QCD

Condensate

UV. $\leftrightarrow$ IR.

ϕ^4 scalar model: $\phi(x) \to \Phi + \phi(x)$

Φ: - drops out from derivatives, it is a **local** coupling constant only

- but if treated as a collective coordinate:

  - $d = 2$: finite contribution at finite volume,
  - $d = 1$ finite contribution in the thermodynamical limit
  - $d > 2$: itself has no contribution
    diagnostic relevance only: to reflect the IR dynamics of modes $\{\phi(p)|0 < p < \epsilon\}$ which are highly **non-local**

Condensate

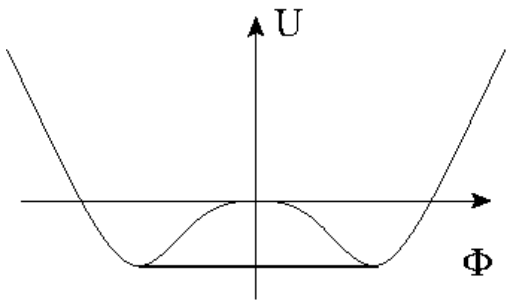
strongly coupled $\leftrightarrow$ weakly coupled

lattice regularization: continuum limit $\equiv$ critical point: $\xi = \dfrac{m}{a} \to \infty$

non-perturbative critical phenomena $\Longrightarrow$non-perturbative IR modes?

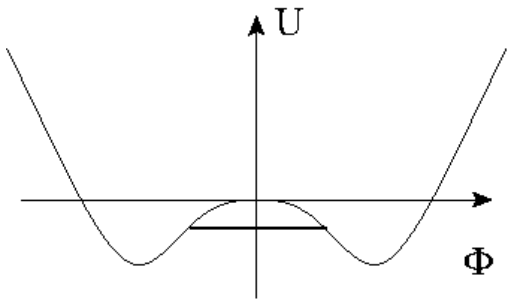
weak: Lüscher, Weiss (1987-89) ren. pert. exp. works in both phases

strong: Maxwell-cut (ignored by L-W)
half of the vacuum fluctuations lack restoring force

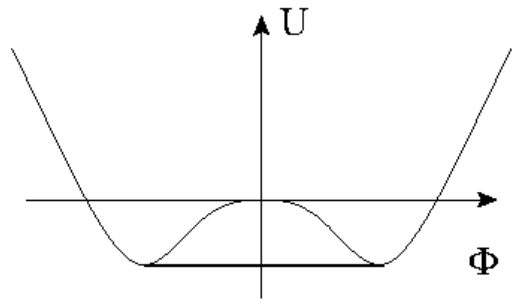


Condensate

Maxwell-cut



$n = 1$



$n > 1$

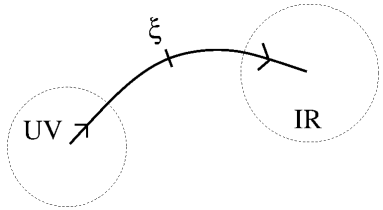
- Spinodal instability of $n = 1$ extends as in the case of $n > 1$
- Takes place for $0 < p < k_{cr}$
- Unexpected soft modes in SSB (even for discrete symmetry)

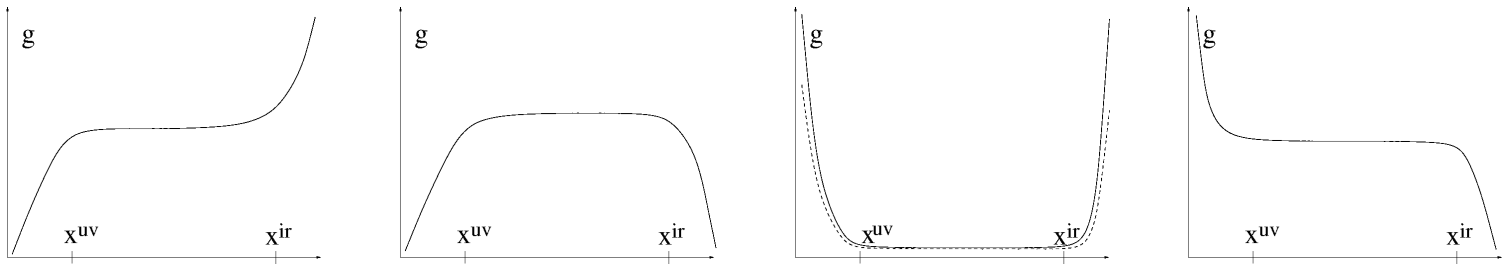
(Alexandre, Branchina, J. P. 1999)

UV-IR interplay

Global Renormalization Group

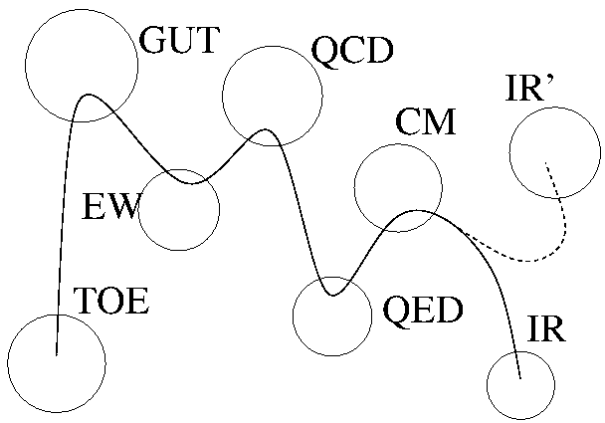
Two classification schemes
for operators: UV and IR
IR: possible non-locality!





r-r	r-ir	ir-r	ir-ir
m	screened charge	$(\bar{\psi}\psi)^2$	$(\bar{\psi}\psi)^3$

TOE:



UV-IR interplay

Condensate in ϕ^4 model

Symmetric phase:

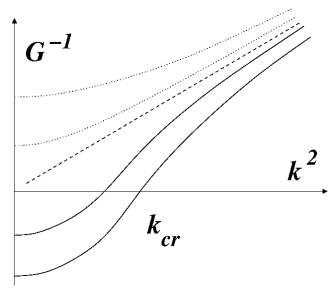
Mass gap: no IR evolution $\Longrightarrow$IR triviality

the only relevant operator (mass) is Gaussian

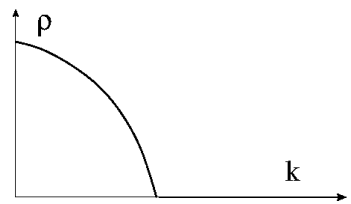
Symmetry broken phase:

- condensate Φ at $p = 0$

- at which scale does it start in RG?



- tree-level RG: saddle points of blocking $\phi_{saddl}(x) = \rho_p \cos(px+\theta_p)$

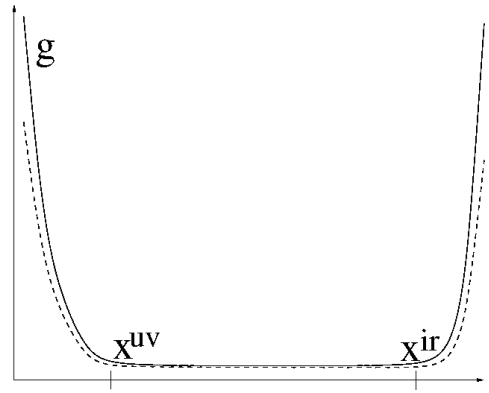


- **soft Goldstones modes** from SSB of external symmetries ($n = 1$!) (domain walls in the mixed, spinodal phase)
- **dynamical Maxwell-cut**: degenerate action for modes $p < k_{cr}$

UV-IR interplay

RG microscope

Microscope: IR sensitivity on UV irrelevant parameters



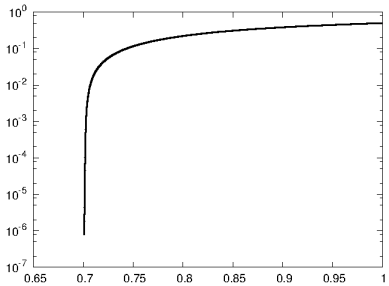
Hybrid, UV-IR parametrization of theories,

- $\Phi = \sqrt{\frac{-m_B^2}{g_B}}$, or $\sqrt{\frac{m_R^2}{g_G}}$?
- Φ: **new free parameter in SM?**

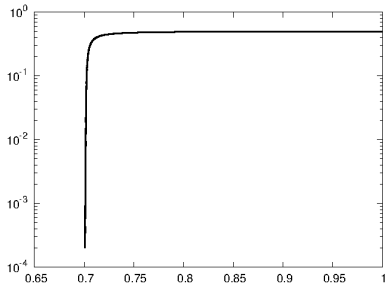
UV-IR interplay

Quantum censorship

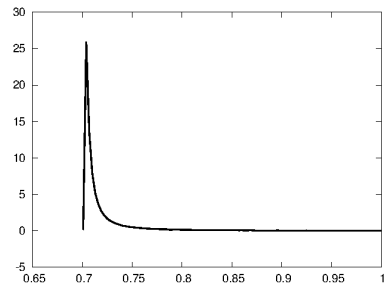
Numerical integration of the functional RG equation:
high degree of degeneracy found by lowering the cutoff at $k = k_{cr} > 0$
(Nagy, Pangon, J. P., Sailer, 2010)



$g_2\phi^2$



$g_4\phi^4$



$g_6\phi^6$

No reliable analytical or numerical method for $k < k_{cr}$
Two scenarios:
- degeneracy remains ← **classical physics**
- degeneracy splits ← **quantum censorship**:
  decoherence: strongly coupled quantum modes
  instead of semiclassical limit

QCD

Color condensate

Unbroken $SU(3)$ $\Longrightarrow$inhomogeneous condensate $\Longrightarrow$spinodal phase

Metallurgy: no sound wave in certain alloys in the mixed phase

Zero modes: domain walls

Plane wave $\Longrightarrow$recoil of the wall $\Longrightarrow$dissipation

Mechanism of gluon confinement

Need of functional RG for real time, but the problems are
- gauge invariance
- strong mass-shell singularities: no BN-KLN resummation
  pinching singularities from
  the empty bag model and
  the spaghetti vacuum model

Summary

1. Condensate supports non-local, strongly coupled phenomena
2. **SSB:**
   - 2.1 Condensation takes place in a finite scale window
   - 2.2 Soft modes due to broken space-time symmetries (domain walls)
   - 2.3 Dynamical Maxwell-cut
   - 2.4 No reliable method
   - 2.5 No reliable relation between UV and IR parameters
   - 2.6 New free parameter of SM?
3. **Gluon confinement:** strong dissipation by domain walls