Could the Higgs' field be a Ginzburg-Landau–type order parameter ?

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- 8. QFT calculations with the classic G-L–Higgs

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The Beauty of Standard Model :

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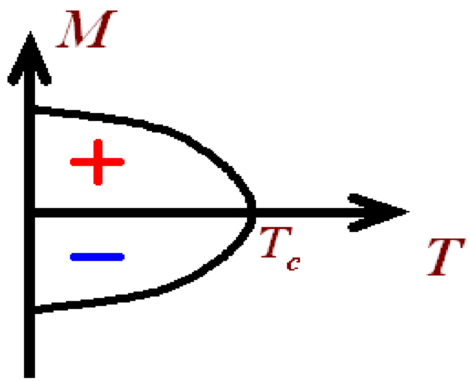
The SM weak features :

- Cabbibo-Kobayashi-Maskawa mixing,
- Higgs trick destroys all the SM elegancy

Order parameter [Landau 1937]. E.g., in magnetics:



- add a weak field δH_+
- tend $V \to \infty$
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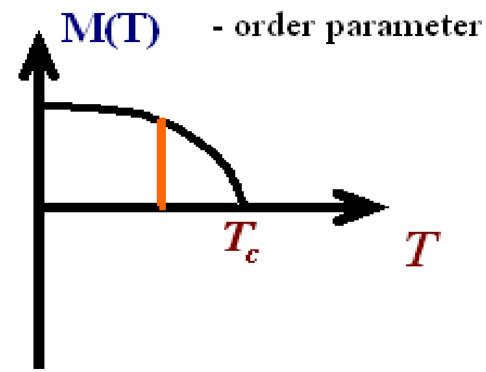

Ferromagnetism in a finite volume V.

In the thermodynamic limit

2. Order Parameter, Phase transition, Symmetry Breaking

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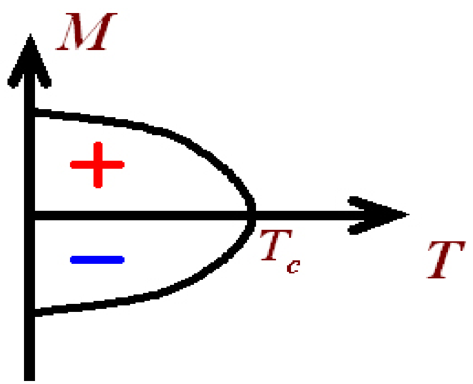

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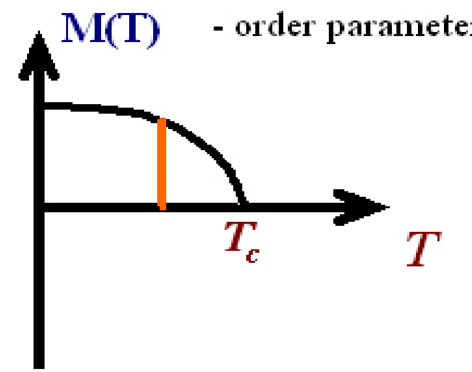

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Correlation function: (c-function !)

$$K_{\sigma\sigma}(\mathbf{r}) =< \sigma(\mathbf{0})\sigma(\mathbf{r}) > - < \sigma(\mathbf{0}) >< \sigma(\mathbf{r}) >$$

$$K_{\sigma\sigma}(\mathbf{r} \to \infty) = \begin{cases} 0, & T > T_c \\ M^2(T), & T < T_c \end{cases}$$

3. Landau-Ginzburg Ψ in Superconductivity

In Ginzburg-Landau [1950] SuperConductivity, $\Psi(r)$ – an auxiliary function for system of electrons; it is $\Psi = |\Psi| e^{i\Phi}$ = 2-component (complex) order parameter for SC transition;

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$$F = F_n + \int \left(\frac{\hbar}{2m^*} |\vec{\nabla} \Psi(r)|^2 + a|\Psi(r)|^2 + b|\Psi(r)|^4 \right) dV$$

with $a \sim T - T_c$, $b \approx$ const, m^* – effective mass.
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SC current $j_\alpha = \frac{e^* \hbar}{m^*} |\Psi|^2 \nabla_\alpha \Phi$, $e*$ – effectve charge.
Later(1959), Gor'kov found: $m^* = 2m, e^* = 2e$, $|\Psi|^2 = n_s/2$.

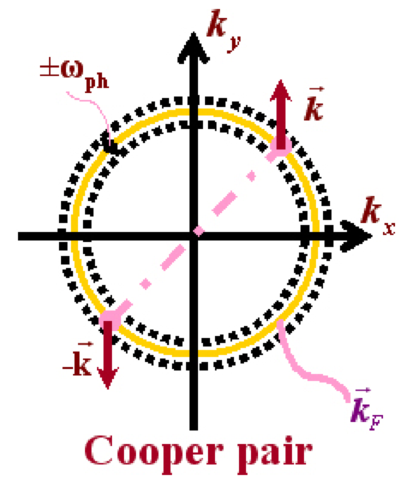
3a. BSC-Bogoliubov SuperConductivity

BCS phenomenologic model:

$$H = \sum_{\vec{k},\sigma} \varepsilon_{\vec{k}}\, c^{+}_{\vec{k}\sigma} c_{\vec{k}\sigma} + \sum_{\vec{k},\vec{k}'} V_{\vec{k},\vec{k}'}\, c^{+}_{\vec{k}\uparrow} c^{+}_{-\vec{k}\downarrow} c_{-\vec{k}'\downarrow} c_{\vec{k}'\uparrow}\,,$$

- eff. Cooper pairs (antipodes) attraction

$\varepsilon_{\vec{k}} = \frac{\vec{k}^2}{2m} - \varepsilon_F$ - electron energy above ε_F



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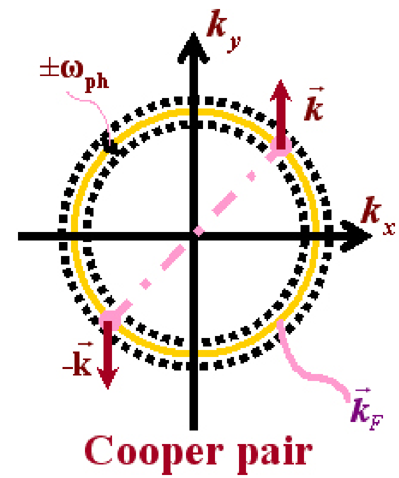

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Effective electron-electron attraction in the vicinity of Fermi surface

$$V(\vec{k},\vec{k}') = \begin{cases} -V_C, & |\varepsilon_{\vec{k}} - \varepsilon_{\vec{k}'}| < \omega_{ph} \\ 0, & |\varepsilon_{\vec{k}} - \varepsilon_{\vec{k}'}| > \omega_{ph} \end{cases}$$

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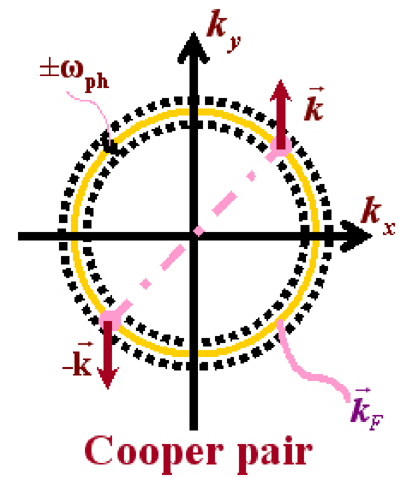

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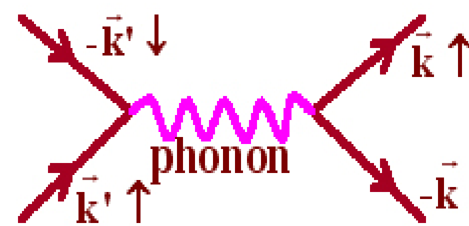
BCS antipode attraction follows from Bogoliubov micro-theory with explicit electron-phonon interaction $H_{Fr}; V_C = g^2_{Fr}$



3b. Semi-Phenomenological BSC theory

Variational BCS wave function

$|\Psi_{BCS}>=\prod_{\vec{k}}(u_{\vec{k}}+v_{\vec{k}}c^{+}_{\vec{k}\uparrow}c^{+}_{-\vec{k}\downarrow})|0>; \quad c_{\vec{k}\sigma}|0>=0.$

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- LG order parameter$=$ Quasi-average of Cooper pair condensate: $\boxed{< c^{+}_{\vec{k}\uparrow} c^{+}_{-\vec{k}\downarrow} >= \Psi(\vec{k})}$ [Gor'kov (1959)]
- Energy gap: $|\Psi(\vec{k})| = \frac{\triangle_{\vec{k}}}{2E_{\vec{k}}}, \quad \triangle_0 \approx exp\left(-\frac{1}{\lambda}\right); \quad \lambda = N_0 V_C.$
- SC temperature $T_c = 1.14\, \omega_{ph}\, exp\left(-\frac{1}{\lambda}\right); \quad 2\triangle_0 = 3.52 T_c$

Hence, L-G Ψ —physical, but not quantum !

Phase symm. breaking: $\tilde{c}^{+}_{\vec{k}\sigma} = e^{i\phi} c^{+}_{\vec{k}\sigma} \Rightarrow \tilde{\Psi}(\vec{k}) = e^{2i\phi}\Psi(\vec{k})$

4. Fizz-bottle and Phase-Gauge symmetries

Higgs Lagrangian is 4-dim replica of L-G Hamiltonian

$$a|\Psi(r)|^2 + b|\Psi(r)|^4 \Rightarrow V(\Phi) = -\frac{m^2}{2}\Phi^2 + g\,(\Phi^2)^2\,;\ \Phi^2 = \Phi_1^2 + \Phi_2^2$$

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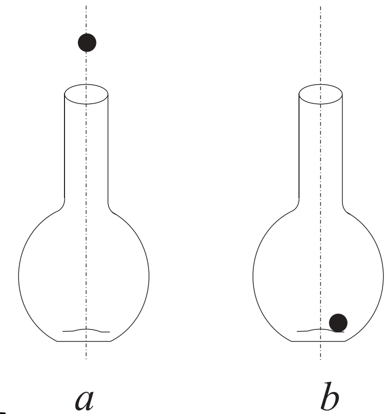

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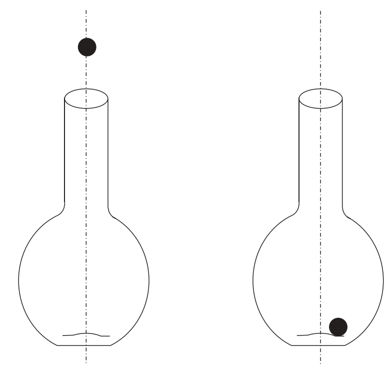

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In 2nd-quantized microscopical picture, the symmetry is a phase symmetry $c \to e^{-i\alpha}c,\ c^* \to e^{i\alpha}c^*$ responsible for No. of particles conservation. It is broken in the $|\Psi_{BCS}>$ structure and in Bogoliubov (u, v) transformation (ascending to his theory of Superfluidity 1946).

5. Andrej portrait $\sim$ 35-40 years ago

- 1. Славнов-Фаддеев, “Массивные и безмасовые поля Янга-Миллса” ТМФ т.3: 18, 1970 CI = 37
- 2. Slavnov, “Invariant regularization of nonlinear chiral theories” Nucl.Phys. B31: 301,1971. Cited 6 2 times
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- ...
- 11. Belokurov-Kazakov-Shirkov-Slavnov-Vladimirov "UV behaviour of spontaneously broken gauge theories" Phys.Lett.B47:359,1973. В Дубне отмечали Славнов-33
- 12. Белокуров-Владимиров-Казаков - СЛАВНОВ - Ширков, "УФ поведение в присутствии неабелевых калибровочных полей" ТМФ 19 :149,1974

  – UV behaviour of YM-fieds with fermions and scalars

6. Some Slavnov's XXI thoughts

- 133. Slavnov, "Renormalizable EW model without fundamental scalar mesons." hep-th/0601125 CI= 8
- 135. Славнов, "Механизм Хиггса как коллективный эффект, обусловленный лишними измерениями" ТМФ 148: 339,(2006). hep-th/0604052 CI= 9
- 136. Slavnov, "Higgs mechanism as a collective effect". In "Yalta 2006, New trends in HEP", pp253-260

7. Higgs field – just G-L order parameter ?

Quests :

- 1 – Issue of renormalizability with G-L–Higgs
- 2 – Underlying physical basis for G-L-Higgs ?
- 3 – Experimental evidence pro/contra G-L-H ?

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Temporary answers :

- 1 = Possible; see recent attempts
- 2 = Unknown at the moment. Probably new level of matter – certainly outside the SM
- 3 = Current data: neither “pro”, nor “contra”

8. QFT calculations with classic G-L–Higgs

In parallel to current fashionable calculation with quantum Higgs, make computation of physical processes with classic GL-Higgs.

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In parallel to current fashionable calculation with quantum Higgs, make computation of physical processes with classic GL-Higgs. To this goal –

- In Feynman rules, change quantum Higgs field to the classic one;
- To sweep "renormalization garbage" under the rug, use some of the XXI-Slavnov ideas or just invariant regularization, like Pauli-Villars one;
- Take regulator mass M_{reg} large enough to guarantee the carpet "being fixed on the place" during (at least) next decade.

8a. The 2-dim carpet for SM with classic G-L-Higgs

As a UV regulator for calculation in the presence of classic G-L-Higgs field, one can formally use procedure of compactification, by reducing physical 4-dim manifold to, e.g., 2-dim one.

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The small-distance "2-merization" (Arefeva+Volovich '93-'94) can be nicely realized in mom-picture

$$d^4p \longrightarrow \tilde{d^4}p = \frac{d^4p}{1+p^2/\wp^2}\,; \qquad \wp = \text{compactification scale}$$

with additional bonus (at scales $p \gtrsim \wp$) for protagonists of 2-dim soluble models.

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Andrej, don't lose the time, the 8th decade could happen to be crucial !

Сентенция великого физика

“Как правило, свой возраст по мере течения лет люди воспринимают всё с большей печалью. Но в его возрастании есть большие преимущества, способствующие приобретению творческой личностью истинного счастья и успокоения. Необходимо только знать и помнить, что развитие человека проходит по стадиям:

1. Первая — до 25–30 лет — это животное состояние. Человек думает, главным образом, о своих страстях и практически ничего не создает.

Сентенция великого физика, 2

2. Вторая — до 55 лет — смешанное состояние, ибо приходится думать то об удовлетворении своих желаний, то о полезной деятельности.
3. Третья – до 80 лет – по-настоящему человеческое состояние, когда в душе не бушуют страсти и успеваешь много и плодотворно работать, чтобы что-то оставить после себя.

Сентенция великого физика, 3

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