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PHASE TRANSITIONS

EXAMPLE: STANDARD MODEL (AND ITS EXTENSIONS).

ϕ = HIGGS FIELD

$$V(\phi) = \lambda\left(\phi^{+}\phi - \frac{v^2}{2}\right)^2 \quad \Rightarrow \quad \langle \phi \rangle = \frac{v}{2}$$

IN VACUO

WHAT HAPPENS AT HIGH TEMPERATURE?

CONDENSED MATTER: LOW SYMMETRY AT LOW T

$\Downarrow$

HIGH SYMMETRY AT HIGH T

MELTING CRYSTAL $\Rightarrow$ RESTORATION OF TRANSLATIONAL SYMMETRY

SUPERCONDUCTIVITY: CONDENSATE OF Cooper pairs AT LOW T

$\Downarrow$

NO CONDENSATE AT HIGH T

"CONDENSATES EVAPORATE".

$\Downarrow$

EXPECT THAT $\langle \phi \rangle_T = 0$ IN STANDARD MODEL AT HIGH T

(SOMEWHAT SLOPPY, SEE BELOW).

SYMMETRY RESTORED AT HIGH T.

- AT FINITE T SYSTEM SITS AT MINIMUM OF <u>FREE ENERGY</u>, NOT ENERGY (NEGLECTING CHEMICAL POTENTIAL).

- EFFECTIVE POTENTIAL: SPECIFY VALUE OF Φ ("BY HANDS"), TAKE SYSTEM IN THERMAL EQUILIBRIUM W.R.T. ALL OTHER PARAMETERS (E.G. PARTICLE DISTRIBUTIONS ARE THERMAL)

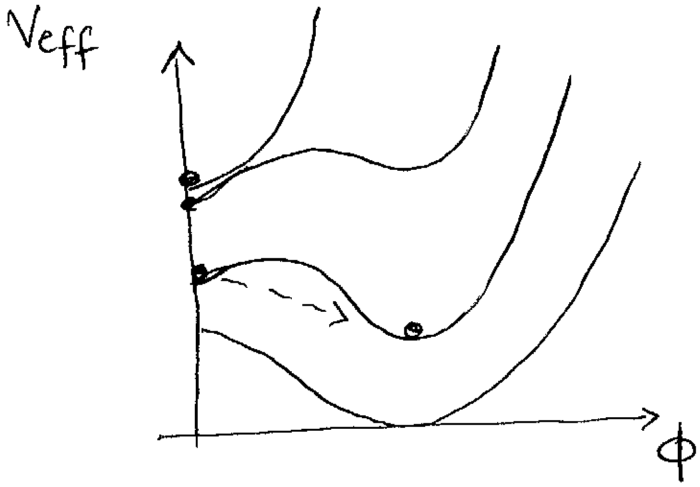
$V_{eff}(\Phi, T)$ = FREE ENERGY DENSITY AT GIVEN Φ

$$\Downarrow$$

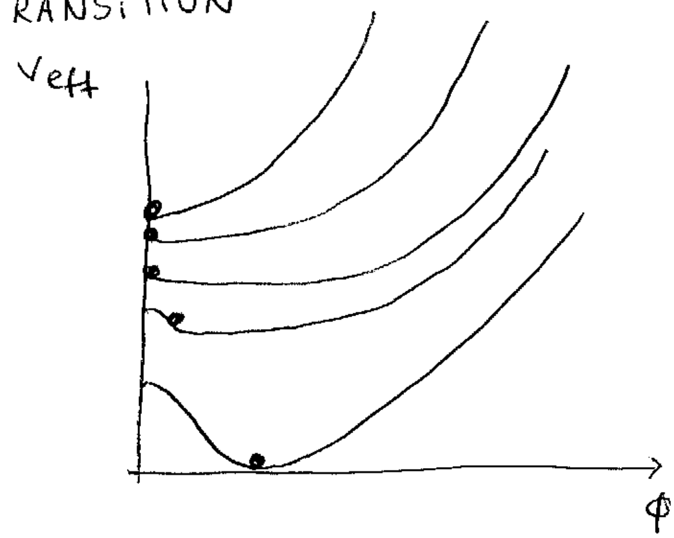
$\langle\phi\rangle_T$: minimum OF $V_{eff}(\Phi, T)$

<u>NB</u>: $V(\phi)$ AT $T=0$ <u>IS</u> EFF. POTENTIAL AT $T=0$: ENERY = FREE ENERGY AT ZERO T.

ORDER OF PHASE TRANSITION



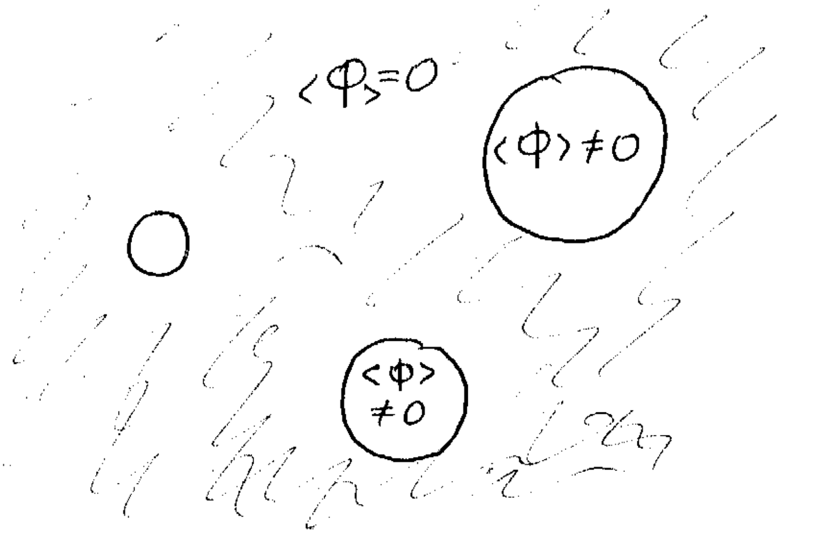
1ST ORDER



2nd ORDER

1ST ORDER: MOST INTERESTING FOR COSMOLOGY

OCCURS BY BUBBE NUCLEATION



MICROSCOPIC BUBBLES OF NEW PHASE SPONTANEOUSLY CREATED AND THEN EXPAND.

EFFICIENT IF ROUGHLY OF ORDER 1 BUBBLE CREATED IN HUBBLE VOLUME IN HUBBLE TIME.

THEN BUBBLES EXPAND TO SIZE ROUGHLY OF ORDER OF HUBBLE SIZE

$$H^{-1}(T_{EW}) = \frac{M_{Pl}^{*}}{T_{EW}^{2}} \sim \frac{10^{18}\,GeV}{10^{4}\,GeV^{2}} \sim 10^{14}\,GeV^{-1} \sim 1\,cm$$

BUBBLE GROWS FROM $R \sim T_{EW}^{-1} \sim (100\,GeV)^{-1} \sim 10^{-16}\,cm$ TO MACROSCOPIC SIZE OF ORDER $1\,cm$.

UNIVERSE BOILS

STRONGLY OUT-OF-THERMAL-EQUILIBRIUM, HENCE INTERESTING.

DOES THIS REALLY OCCUR?

NOT IN STANDARD MODEL, BUT IN SOME OF ITS EXTENSIONS.

WILL SOON HOPEFULLY KNOW FROM LHC !

TO SEE THIS: CALCULATE EFFECTIVE POTENTIAL.

* THERMODYNAMICS: FREE ENERGY DENSITY

$$f = \rho - Ts \qquad s = \text{entropy density}$$

1ST LAW (ZERO CHEMICAL POTENTIAL):

$$dE = -p\,dV + T\,dS \qquad E = \rho V, \quad S = sV$$

$$\Downarrow$$

$$V \cdot d\rho + \rho\,dV = -p\,dV + Ts\,dV + TV\,ds$$

$$\Downarrow$$

$$d\rho = T\,ds$$

$$\boxed{Ts = p + \rho} \implies \boxed{f = -p}$$

$$V_{eff}(T,\phi) = -\,p(T,\phi)$$

Need to calculate pressure

(NB: MINIMUM OF FREE ENERGY ; HIGHER PRESSURE WINS).

$$V_{eff}(T,\phi) = \lambda\left(\phi^2 - \frac{v^2}{2}\right)^2 + \text{TEMPERATURE CORRECTIONS}$$

$\Uparrow$ "TREE LEVEL"

$\Uparrow$ "LOOPS"

(NB: THERMAL LOOPS = TREE LEVEL FROM QFT VIEWPOINT PLASMA EFFECTS)

<u>ONE LOOP</u>: NEGLECT INTERACTIONS OF PARTICLES IN PLASMA,

IDEAL GAS APPROXIMATION

CALCULATE CONTRIBUTIONS OF <u>FREE</u> PARTICLES INTO <u>PRESSURE.</u>

WHY DEPENDS ON ϕ? BECAUSE MASSES DEPEND ON ϕ:

$$M_W(\phi) = \frac{g}{\sqrt{2}}\,\phi\,, \quad M_t = y_t \cdot \phi\,, \text{ etc.}$$

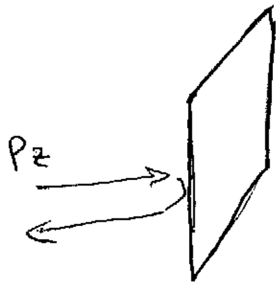
<u>One Lopp</u>: TEMPERATURE CORRECTIONS TO V_{eff} $= \sum_{\substack{\text{PARTICLE} \\ \text{spieces}}} (-p)$

$\uparrow$ pressure due to a particle spieces

PRESSURE: SINGLE PARTICLE SPIECES

$$p = \int_{p_z > 0} 2 p_z \cdot v_z \; f(\vec{p}) \, d^3 p$$

PRESSURE ON A WALL:



$2p_z$: MOMENTUM TRANSFER TO WALL

$v_z f(\vec{p})$: number OF PARTICLES OF MOMENTUM $\vec{p}$, HITTING WALL IN UNIT TIME PER UNIT AREA

$d^3p \cdot f(\vec{p})$: NUMBER DENSITY OF PARTICLES OF momentum $\vec{p}$

$$v_z = \frac{p_z}{E} \quad ; \quad \langle p_z^2 \rangle_{\text{ANGLES}} = \frac{1}{3} \vec{p}^{\,2}$$

$$p = \int \frac{1}{3} \frac{p^2}{E} f(p) \, d^3 p = 4\pi \int_0^\infty \frac{p^4 dp}{E} \cdot \frac{1}{(2\pi)^3} \frac{1}{e^{E/T} \mp 1}$$

$\Uparrow$ pressure

BOSE-EINSTEIN: BOSONS −

FERMI-DIRAC: FERMIONS +

$$E = \sqrt{p^2 + m^2(\phi)}$$

$$\Downarrow$$

ϕ larger than 0 $\Rightarrow$ E larger $\Rightarrow$ denominator in p larger $\Rightarrow$ pressure smaller $\Rightarrow$ V_{eff} larger

$\uparrow$ pressure integral

$$\boxed{V_{eff}(T,\phi) = \text{const} - \lambda\phi^2 v^2 + \lambda\phi^4 + \frac{T^2}{24}\alpha\,\phi^2 + \text{higher orders in } \phi}$$

α = COMBINATION OF COUPLINGS:

IF $m_i(\phi) = h_i\phi$, THEN

$$\alpha = \sum_{\text{BOSONS}} g_i h_i^2 + \sum_{\text{FERMIONS}} \frac{1}{2} g_i h_i^2$$

g_i = # OF SPIN STATES.

NB: LARGE CONTRIBUTION FROM t-quark IN SM.

SM: $\alpha = \frac{2}{v^2}\left(6M_W^2 + 3M_Z^2 + 6m_t^2\right)$

* Symmetry indeed restored at $T > T_c$

WHERE

$$\underbrace{\lambda v^2}_{\frac{m_H^2}{2}} = \frac{T_c^2}{24}\alpha$$

NUMERICALLY, SM: $T_c = 120\,\text{GeV} \cdot \left(\frac{m_H}{100\,\text{GeV}}\right)$

ORDER OF PHASE TRANSITION

If V_{eff} ANALYTIC IN ϕ^2

$\Downarrow$

$$\boxed{V_{eff} = \frac{\alpha}{24}(T^2 - T_c^2)\phi^2 + \lambda_{eff}\phi^4 + \ldots}$$

2nd ORDER.

BUT V_{eff} is <u>NOT</u> ANALYTIC IN ϕ^2

BOSONS

$$f = -p = -\frac{1}{3\cdot 2\pi^2}\int_0^\infty \frac{p^4\,dp}{E}\,\frac{1}{e^{+E/T}-1}$$

Infrared part: $E \ll T$ $\qquad \Lambda \ll T$

$$f \simeq -\frac{1}{3\cdot 2\pi^2}\int_0^\Lambda \frac{T p^4\,dp}{p^2 + m^2(\phi)}$$

TRY TO EXPAND IN $m^2(\phi)$

$$\simeq -\frac{1}{3\cdot 2\pi^2}\left[\text{const} - T\int_0^\Lambda m^2(\phi)\,dp + T\int_0^\Lambda m^4(\phi)\frac{dp}{p^2}\right]$$

DIVERGENT

Linear infrared "divergence" $\Rightarrow$ $\Leftarrow$ PAGE 1.30a

NEXT CONTRIBUTION is $-m^3(\Phi)\cdot T$

$\Downarrow$

$$\boxed{V_{eff} = \frac{\alpha}{24}(T^2 - T_c^2)\phi^2 - \gamma T\phi^3 + \lambda_{eff}\phi^4}$$

$$\gamma = \frac{1}{12\pi}\sum_{\text{BOSONS}} g_i |h_i|^3$$

NOTE NUMERICAL SUPPRESSION BY $(12\pi)^{-1}$

CALCULATING CUBIC TERM:

DIVIDE PRESSURE INTEGRAL INTO UV PART, $p > \Lambda$ AND IR PART, $p < \Lambda$, WHERE $\Lambda \ll T$, $\Lambda \gg m(\Phi)$

UV-PART : ANALYTIC IN ϕ^2

IR-PART

$$f_{IR} = -\frac{1}{3 \cdot 2\pi^2} \int_0^\Lambda \frac{T p^4\, dp}{p^2 + m^2(\Phi)}$$

$$= -\frac{T}{3 \cdot 2\pi^2} \int_0^\Lambda \Big[(p^2 + m^2_{(\Phi)})\, dp - 2 + \frac{m^4_{(\Phi)}}{p^2 + m^2(\Phi)} \Big] dp$$

ANALYTIC IN $m^2(\Phi)$, CALCULATED ALREADY

LAST TERM

$$-\frac{T m^4_{(\phi)}}{6\pi^2} \underbrace{\int_0^\Lambda \frac{dp}{p^2 + m^2_{(\Phi)}}}_{\frac{\pi}{2} \frac{1}{m(\Phi)}} = -\frac{T m^3(\Phi)}{12\pi}$$

AT $\Lambda \gg m(\Phi)$

$\Downarrow$

CUBIC TERM $\quad -\frac{T}{12\pi} m^3(\phi) = -\frac{T}{12\pi} h^3 \phi^3$

ON THE FACE OF IT:

FIRST ORDER PHASE TRANSITION

BUT: LIFE IS MORE COMPLICATED...

ON THE FACE OF IT: AT $T = T_c$

$$V_{eff} = -\gamma T_c \varphi^3 + \lambda_{eff} \phi^4 \qquad \lambda_{eff} \approx \lambda$$

$$\Downarrow$$

MINIMUM AT

$$\phi \simeq \frac{\gamma}{\lambda} T_c \qquad \text{RECALL } m_H \sim \sqrt{\lambda}\, v$$

HEAVY HIGGS $\Rightarrow$ LARGE λ $\Rightarrow$ SMALL Φ

BUT AT SMALL Φ PERTURBATION THEORY DOES NOT WORK

- INFRARED PROBLEM OF BOSONS AT HIGH T

  χ : BOSONIC FIELD, $m_\chi = h\phi$

  ITS DISTRIBUTION FUNCTION ~~AT~~ AT $E \ll T$

$$f(\vec{p}) \equiv \langle A^+(\vec{p}) A(\vec{p}) \rangle \simeq \frac{1}{e^{E/T} - 1} \simeq \frac{T}{E}$$

OCCUPATION # LARGE $\Rightarrow$ <u>CLASSICAL FIELD</u>

NB: IMPORTANT LESSON: QUANTUM BOSONIC FIELD BECOMES CLASSICAL FOR $|\vec{p}|, m \ll T$

CORRESPONDENCE

$$\text{ENERGY} = \int d^3p \sqrt{p^2+m^2}\langle A_p^+ A_p \rangle$$

$$= \frac{1}{2}\int d^3x \left[(\vec{\nabla}\chi)^2 + \dot{\chi}^2 + m^2\chi^2 \right) = \int d^3p\, (p^2+m^2)\, \chi_p^2$$

$$\chi_p^2 \sim \frac{\langle A_p^+ A_p \rangle}{E(p)} \sim \frac{T}{E^2}$$

FIELD FLUCTUATION

$$\langle \chi^2(\bar{x}) \rangle \sim \int d^3p\ \chi_p^2 \sim \int_0^\infty \frac{dp}{p}\ p^3 \chi_p^2$$

$$\Downarrow$$

FIELD FLUCTUATION AT MOMENTUM SCALE p

$$\langle \chi^2(\bar{x}) \rangle_p \sim p^3 \chi_p^2 \sim \frac{p^3 T}{E_p^2}$$

SELF-INTERACTION : $h^2 \chi^4$ [E.G. χ = W-BOSON $g^2 W\cdot W\cdot W\cdot W$; $m_W \sim g\phi$]

REQUIRE SELF-INTEACTION SMALL COMPARED TO FREE TERMS AT MOMENTUM SCALE $p \sim m_\chi$

$$1 \gg \frac{h^2 \langle \chi^2 \rangle^2}{m_\chi^2 \langle \chi^2 \rangle} \sim \frac{h^2 \langle \chi^2 \rangle}{m_\chi^2} \sim \frac{h^2 p^3 T}{m_\chi^2\, E_p^2} \sim \frac{h^2 T}{m_\chi}$$

PERTURBATION THEORY WORKS FOR

$$\boxed{m_\chi \gg h^2 T}$$

$$m_\chi = h\phi$$

$$\Downarrow$$

$$\boxed{\phi \gg h T}$$

RELATIVELY LARGE FIELDS ONLY

SM: $h \to g$, GAUGE COUPLING; $\chi = W$-field

Recall THAT AT CRITICAL TEMPERATURE

$$\phi \simeq \frac{\gamma}{\lambda} T$$

$$\gamma \simeq \frac{1}{12\pi} \cdot \frac{9 g^3}{2\sqrt{2}} \quad \text{(W, Z -CONTRIBUTIONS)}$$

$$\Downarrow \qquad \phi \gg g T$$

$$\Downarrow$$

$$\lambda \ll \frac{\gamma}{g} \sim g^2 \Leftrightarrow \boxed{m_H^2 \ll m_W^2}$$

TRUE FOR LIGHT HIGGS ONLY

CERTAINLY NOT TRUE FOR $m_H > 114$ GeV

"PHASE TRANSITION" NON-PERTURBATIVE.

IN FACT, NO PHASE TRANSITION AT ALL,

SMOOTH CROSSOVER (CF. LIQUID-VAPOR)

WHAT CAN MAKE PHASE TRANSITION STRONGLY FIRST ORDER?

NEW BOSONIC FIELD(S) STRONGLY ENOUGH COUPLED TO HIGGS FIELD.

NEW FIELD; COUPLES TO HIGGS WITH h_{NEW},
$m_{NEW} = h_{NEW} \cdot v$

RECALL

$$\phi(T_c) \simeq \frac{\gamma}{\lambda} T_c$$

$$\gamma = \frac{1}{12\pi} \sum_{BOSONS} g_i |h_i|^3 = \frac{1}{12\pi} \sum_{BOSONS} g_i \frac{m_i^3}{v^3}$$

g_i: # OF DEGREES OF FREEDOM

PERTURBATION THEORY VALID IF

$$\frac{\gamma}{\lambda} T_c = \phi(T_c) \gg h_i T_c \simeq \frac{m_i}{v} T_c$$

$$\Downarrow$$

WORKS IF

$$\lambda \ll \sum_{BOSONS} \frac{g_i}{12\pi} h_i^2$$

$$\Downarrow$$

$$m_H^2 \ll \frac{g_{NEW}}{12\pi} m_{NEW}^2$$

* NEED MANY DEGREES OF FREEDOM g_{NEW}
* LARGE COUPLING $h_{NEW} \Leftrightarrow$ LARGE MASS m_{NEW}

EXAMPLE: SCALAR TOP IN SUSY

* MAY HAVE "SOFT" (HIGGS-INDEPENDENT) MASS

$m_{\tilde{t},\mathrm{SOFT}}$ MUST BE SMALL (SMALLER THAN

ABOUT 100 GeV), OTHERWISE $\tilde{t}$ DECOUPLES FROM

PLASMA AT $T \sim T_c \sim 100$ GeV

* NUMBER OF DEGREES OF FREEDOM RATHER LARGE

$$g_{\tilde{t}_R} = \underset{\text{COLOR}}{3} \cdot \underset{\text{COMPLEX FIELD}}{2} = 6$$

* HIGGS-GIVEN MASS $m_{\tilde{t}} = 172$ GeV
($= m_t$)

$\Downarrow$

WITH NUMERICAL FACTORS (AND $\tan\beta$, ETC.) ACCOUNTED FOR,
SUFFICIENT TO MAKE PHASE TRANSITION
STRONGLY FIRST ORDER.

THIS WILL DEFINITELY BE SEEN AT LHC.

OTHER OPTIONS: LESS CLEAR

E.G. SINGLET SCALAR(S).

BARYON ASYMMETRY OF THE UNIVERSE.

QUANTITATIVE CHARACTERISTIC

$$\Delta_B = \frac{n_B - n_{\bar{B}}}{s}$$

STAYS CONSTANT IN TIME IF B IS CONSERVED AND EVOLUTION CLOSE TO ADIABATIC

RELATED TO $\eta_B = n_B / n_\gamma$ VIA NUMERICAL FACTOR (3 ν SPIECES)

$$\Delta_B = 0.14\, \eta_B$$

$$\Downarrow$$

$$\eta_B = 6.1 \cdot 10^{-10} \Longrightarrow \boxed{\Delta_B = 0.9 \cdot 10^{-10}}$$

EARLY UNIVERSE: $n_B - n_{\bar{B}} = \frac{1}{3}(n_q - n_{\bar{q}})$

$s \simeq (n_q + n_{\bar{q}})$

$$\Downarrow$$

$$\Delta_B \sim \frac{n_q - n_{\bar{q}}}{n_q + n_{\bar{q}}}$$

ONE EXTRA QUARK PER 10^{10} q-$\bar{q}$ PAIRS.

WHERE DID IT COME FROM?

1960's - 1970's : PREJUDICE

FROM 1980's : INFLATION

ASYMMETRY = 0 AT THE BEGINNING

GENERATED DURING EVOLUTION OF UNIVERSE.

SAKHAROV CONDITIONS

(1) BARYON NUMBER VIOLATION

(2) C- AND CP -VIOLATION

(3) THERMAL INEQUILIBRIUM

(2): C AND CP DISTINGUISH PARTICLES FROM ANTIPARTICLES

$\Downarrow$

IF CP OR C CONSERVED, PARTICLES AND ANTIPARTICLES BEHAVE IN THE SAME WAY

(3): THERMAL EQUILIBRIUM: ALL ASYMMETRIES GET WASHED OUT, IF QUANTUM NUMBERS ARE NOT CONSERVED.

(1) + (2) + (3) ~~[illegible]~~ SHOULD WORK TOGETHER, AT THE SAME TIME

QUALIFICATION: MAY FIRST GENERATE LEPTON NUMBER, IT WILL GET REPROCESSED INTO B.

Can baryon asymmetry be due to electroweak physics?

Baryon number is violated in electroweak interactions.

Non-perturbative effect

Hint: triangle anomaly in baryonic current B^{μ}:

$$\partial_{\mu}B^{\mu} = \left(\frac{1}{3}\right)_{B_q} \cdot 3_{colors} \cdot 3_{generations} \cdot \frac{g_W^2}{32\pi^2}\varepsilon^{\mu\nu\lambda\rho}F^a_{\mu\nu}F^a_{\lambda\rho}$$

$F^a_{\mu\nu}$: $SU(2)_W$ field strength; g_W: $SU(2)_W$ coupling

Likewise, each leptonic current $(n = e, \mu, \tau)$

$$\partial_{\mu}L^{\mu}_{n} = \frac{g_W^2}{32\pi^2} \cdot \varepsilon^{\mu\nu\lambda\rho}F^a_{\mu\nu}F^a_{\lambda\rho}$$

Large field fluctuations, $F^a_{\mu\nu} \propto g_W^{-1}$ may have

$$Q \equiv \int d^3x dt \; \frac{g_W^2}{32\pi^2} \cdot \varepsilon^{\mu\nu\lambda\rho} F^a_{\mu\nu} F^a_{\lambda\rho} \neq 0$$

Then

$$B_{fin} - B_{in} = \int d^3x dt \; \partial_\mu B^\mu = 3Q$$

Likewise

$$L_{n,\; fin} - L_{n,\; in} = Q$$

B is violated, $B - L$ is not.

How can baryon number be not conserved without explicit B-violating terms in Lagrangian?

Consider massless fermions in background gauge field $\vec{A}(\mathbf{x},t)$ (gauge $A_0 = 0$). Let $\vec{A}(\mathbf{x},t)$ start from vacuum value and end up in vacuum.
NB: This can be a fluctuation

Dirac equation

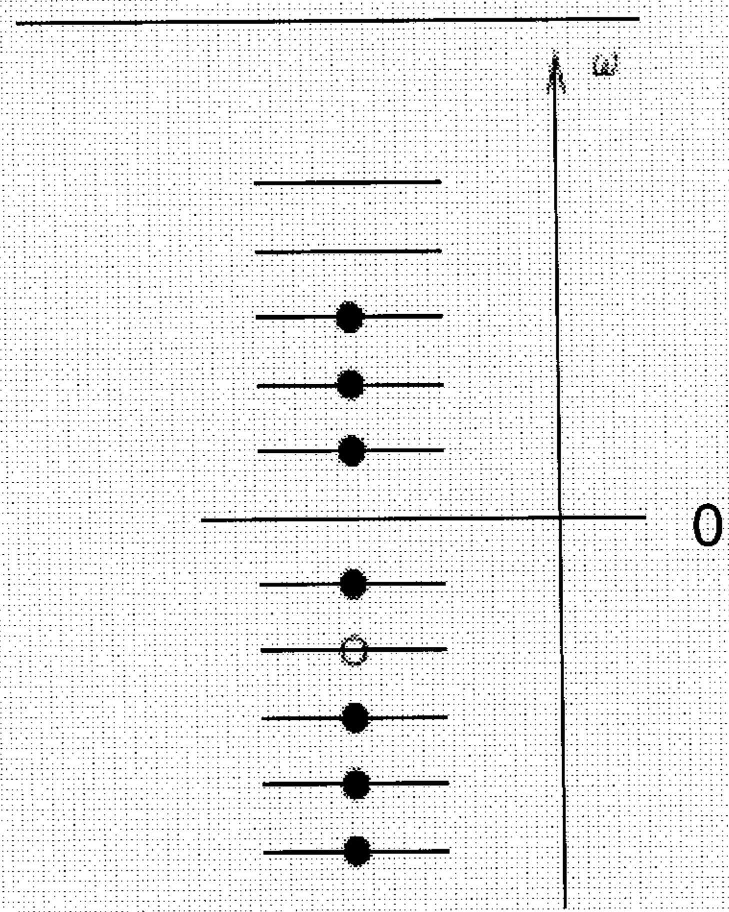
$$i\frac{\partial}{\partial t}\psi = i\gamma^0\vec{\gamma}(\vec{\partial} - ig\vec{A})\psi = H_{Dirac}(t)\psi$$

Suppose for the moment that $\vec{A}$ slowly varies in time. Then fermions sit on levels of instantaneous Hamiltonian,

$$H_{Dirac}(t)\psi_n = \omega_n(t)\psi_n$$

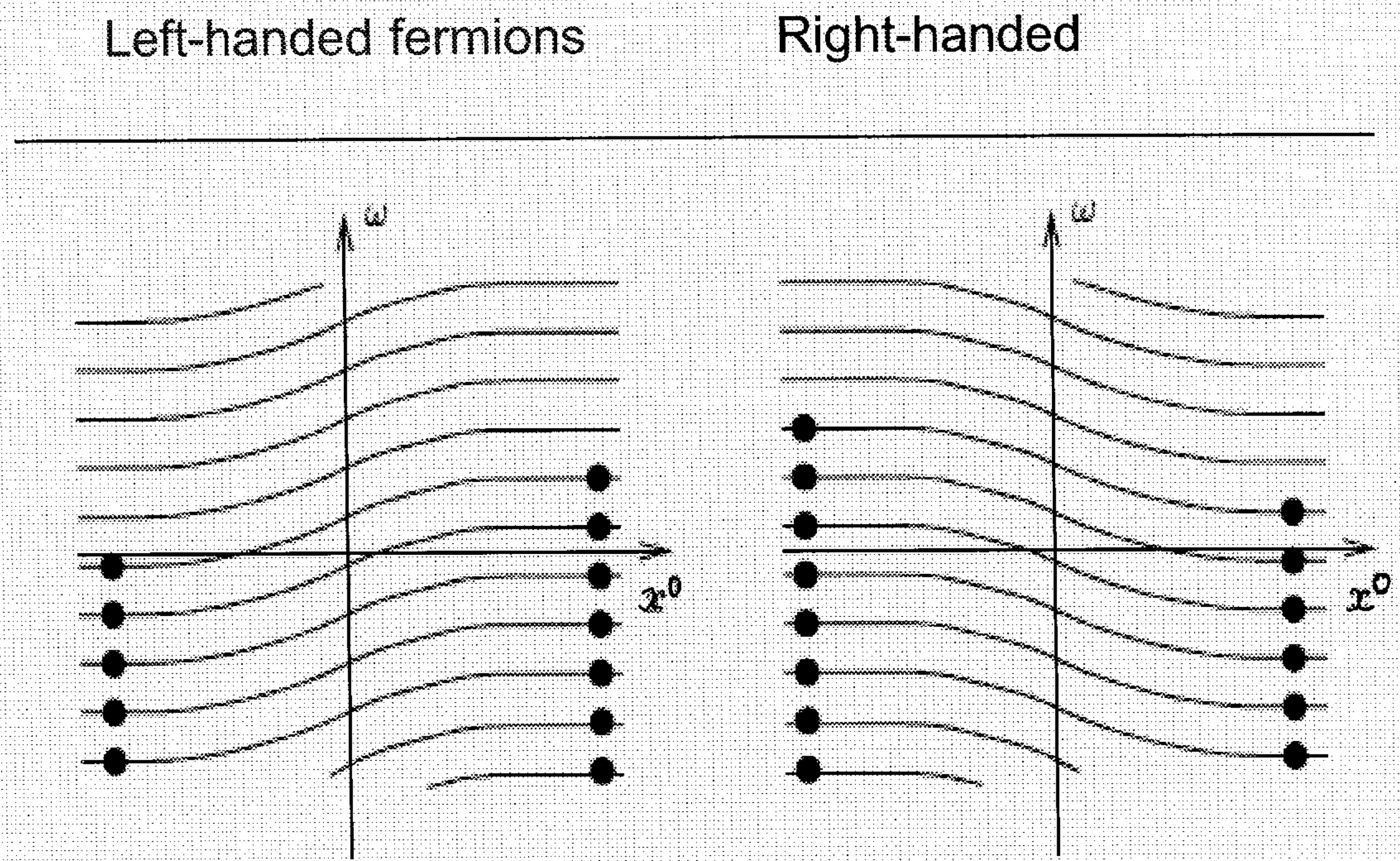
How do eigenvalues behave in time?

Dirac picture at $\vec{A} = 0$, $t \to \pm\infty$



TIME EVOLUTION OF LEVELS

IN SPECIAL (TOPOLOGICAL) GAUGE FIELDS



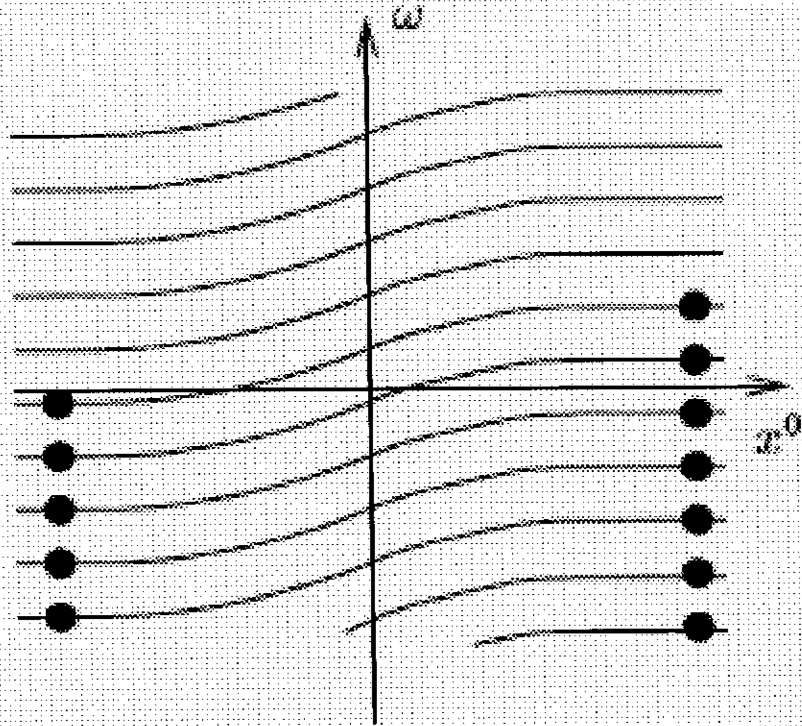
The case for QCD

$B = N_L + N_R$ is conserved, $Q^5 = N_L - N_R$ is not

1.43

If only left-handed fermions interact with gauge field,

then number of fermions is not conserved



The case for $SU(2)_W$

Fermion number of every doublet changes in the same way

1.44

NB: Non-Abelian gauge fields only (in 4 dimensions)

QCD: Violation of Q^5 is a fact.

In chiral limit $m_u, m_d, m_s \to 0$,
global symmetry is $SU(3)_L \times SU(3)_R \times U(1)_B$,
not symmetry of Lagrangian $SU(3)_L \times SU(3)_R \times U(1)_B \times U(1)_A$

Need large field fluctuations. At zero temprature their rate is suppressed by

$$e^{-\frac{16\pi^2}{g_W^2}} \sim 10^{-165}$$

High temperatures: large thermal fluctuations ("sphalerons").

B-violation rapid as compared to cosmological expansion at

$$\langle \phi \rangle_T < T$$

$\langle \phi \rangle_T$: Higgs expectation value at temperature T.

Possibility to generate baryon asymmetry at electroweak epoch, $T_{EW} \sim 100$ GeV ?

But Universe expands slowly. Expansion time

$$H^{-1} = \frac{M_{Pl}^*}{T_{EW}^2} \sim 10^{14}\ \text{GeV}^{-1} \sim 10^{-10}\ \text{s}$$

Too large to have deviations from thermal equilibrium?

THE ONLY WAY

FIRST ORDER EW PHASE TRANSITION

$\Rightarrow$ AFTER PHASE TRANSITION BARYON ASYMMETRY SHOULD NOT BE WASHED OUT

$$\Downarrow$$

$$\langle \phi \rangle_T > T \quad \text{AFTER PHASE TRANSITION}$$

[STRONGER THAN SIMPLY EXISTENCE OF 1ST ORDER PHASE TRANSITION]

$$\Downarrow$$

NEW BOSONS, STRONGLY INTERACT WITH HIGGS.

$$+$$

NEW SOURCE OF CP-VIOLATION

IF SO, THEN BARYON ASYMMETRY MAY BE GENERATED BY INTERACTIONS OF FERMIONS WITH BUBBLE WALLS.

GOOD CHANCE FOR LHC AND ILC.

IS THIS THE ONLY WAY TO GENERATE BARYON ASYMMETRY?

BY NO MEANS.

COMPETITOR: LEPTOGENESIS.

NB: ANY MECHANISM OF GENERATION OF BARYON ASYMMETRY AT HOT STAGE WOULD BE INCONSISTENT WITH BARYON ISOCURVATURE PERTURBATIONS.

SAME STORY AS WITH CDM.

NB: PUZZLE: $\Omega_{DM} \approx \Omega_B$. WHY? LOOKS LIKE COINCIDENCE.

TO CONCLUDE:

BOTH CDM AND BARYON ASYMMETRY MAY BE DUE TO PHYSICS AT 100 GEV SCALE. IF SO, WE WILL KNOW THAT IN OUR LIFETIME.

IF NOT, NEED A LOT OF LUCK.