Electroweak baryogenesis in a Two-Higgs-Doublet model

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Why Baryogenesis?

- Experimental evidence
  - Direct evidence: e.g. cosmic rays ($N_B/N_{\overline{B}} \sim 10^7$);
  - Cosmological arguments;
  - Observed baryon asymmetry of the Universe:

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  - baryon number violation;
  - C/CP violation;
  - thermal non-equilibrium.

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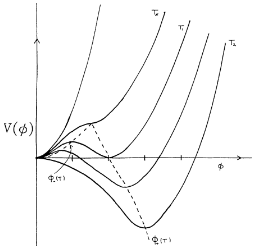
$$V_T = A(T^2 - T_0^2)\phi^2 - BT\phi^3 + \frac{\lambda_T}{4}\phi^4$$



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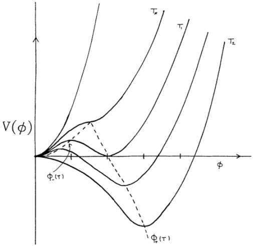

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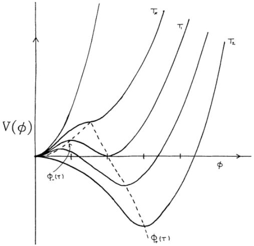
$B \sim \sum_{bosons} m_{boson}^3$



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- EW baryogenesis requires Beyond Standard Model physics.

Two-Higgs-Doublet model

- Two scalar doublets: $\Phi_1 = \begin{pmatrix} \phi_1^{\pm} \\ \phi_1^0 \end{pmatrix}, \quad \Phi_2 = \begin{pmatrix} \phi_2^{\pm} \\ \phi_2^0 \end{pmatrix}$
  - one of the simplest extensions of SM;
  - extra heavy bosons: $h^0, H^0, A^0, H^{\pm}$;
  - extra source of CP violation: explicit or spontaneous.
- Potential:

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\begin{aligned}
V_{tree}(\Phi_1, \Phi_2) = & - m_1^2 \Phi_1^\dagger \Phi_1 - m_2^2 \Phi_2^\dagger \Phi_2 - \frac{1}{2}\left(\mu^2 \Phi_1^\dagger \Phi_2 + H.c.\right) + \\
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Vacuum structure

- VEV's:

$$\langle \Phi_1 \rangle = \begin{pmatrix} 0 \\ v_1 \end{pmatrix}, \quad \langle \Phi_2 \rangle = \begin{pmatrix} u \\ v_2 e^{i\theta} \end{pmatrix} \quad (\tan\beta \equiv v_2/v_1)$$

- Three cases:
  - $u \neq 0 \Rightarrow U(1)_{em}$ is broken (not interesting!)
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- Do we live in a CP breaking or in an EW minimum?

Transitional CP violation

- If CP breaking, then θ is bounded by experiment.
- Difficulty: Tree level potential has at most two minima[2].
- Thus, CP breaking and EW minima never coexist.
- Transitional CP violation requires that loop and thermal corrections turn a CP breaking *saddle point* into a minimum.

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