The Electroweak Sphaleron in a strong magnetic field

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Motivations

- Sphaleron has a magnetic dipole moment
- Magnetic field can lower sphaleron energy
- Could magnetic fields in e.g. heavy-ion collisions lower energy enough to make sphaleron observable?

Figure: Schematic cartoon of an Electroweak sphaleron
Strong magnetic fields in Electroweak Theory

- Constant magnetic field becomes unstable at
  \[ B_{\text{crit}}^{(1)} = \frac{m_W^2}{e} \]

- Stable solution becomes lattice of vortices.

- At second critical field
  \[ B_{\text{crit}}^{(2)} = \frac{m_H^2}{e} \]
  Higgs symmetry is restored.

- Expect sphaleron energy to be zero at this point, but what happens before then?
Our results

- Computed the sphaleron solution numerically in lattice Electroweak theory
- External field strength from $B_{\text{ext}} = 0$ to $B_{\text{ext}} = B_{\text{crit}}^{(2)}$
- Sphaleron becomes increasingly prolate for stronger fields.
- For $B_{\text{crit}}^{(1)} < B_{\text{ext}} < B_{\text{crit}}^{(2)}$ we have a sphaleron against an Ambjørn-Olesen vortex background.
Implications

- Critical field strength where sphaleron energy vanishes is

\[ B^{(2)}_{\text{crit}} = \frac{m^2_{\text{H}}}{e} \approx 5.2 \times 10^4 \text{ GeV} \approx 2.7 \times 10^{20} \text{ T} \]

- Magnetic fields in LHC heavy-ion collisions \( \sim 1 \text{ GeV}^2 \) and scale linearly with energy, so \( \sqrt{s} \sim 10^5 \text{ TeV} \) required.

- 10 TeV Pb-Pb collisions lower sphaleron energy by \( \sim 0.1\% \).

- Unsuppressed sphaleron production due to magnetic fields not feasible in foreseeable future.

- Potential cosmological/astrophysical sources:
  - Superconducting cosmic strings
  - Magnetically charged black holes
  - Inflation produced large scale magnetic fields