BPS Cho–Maison magnetic monopole

Petr Beneš, Filip Blaschke

IEAP CTU in Prague

ICHEP 2020

Prague, July 30, 2020

Magnetic monopole in the Standard Model?

Two main paradigms for a field theoretical description of a magnetic monopole:

- 't Hooft–Polyakov monopole:
  - Traditional paradigm (1974)
  - Based on topology of the vacuum manifold G/H
  - In order that it exist, it must be $\pi_2(G/H) \neq \{1\}$
  - This is, however, not the case in SM: $\pi_2(SU(2) \times U(1)/U(1)) = \{1\}$
  - $\Rightarrow$ no 't Hooft–Polyakov monopole in SM!

✗

- Cho–Maison monopole:
  - Alternative paradigm (1996)
  - Desired non-trivial topology is found in the target space of the normalized Higgs field $H = \frac{1}{\sqrt{2}}(v + \sigma)\xi$, where $\xi^\dagger \xi = 1$
  - Set of all ξ form the complex projective space $\mathbb{C}\mathrm{P}^1$ (due to $U(1)_Y$ invariance)
  - But $\pi_2(\mathbb{C}\mathrm{P}^1) = \pi_2(S^2) = \mathbb{Z}$
  - $\Rightarrow$ Cho–Maison monopole can exist SM!

✓

Infinite monopole mass and the solution

Indeed, magnetic monopole solution can be found!

- But there's a problem: It has infinite mass!
- However, this can be cured by going beyond SM and modifying the $U(1)_Y$ kinetic term (Cho, Kim, Yoon, 1997) as

$$-\frac{1}{4}B_{\mu\nu}B^{\mu\nu} \quad \longrightarrow \quad -\frac{1}{4}\epsilon\, B_{\mu\nu}B^{\mu\nu}$$

  where ϵ is some positive function of $|H|^2$
- If $\epsilon(0) = 0$, the mass of the monopole comes out finite!

However, since ϵ is in principle arbitrary, is the monopole mass also arbitrary?

- This type of questions is solved by BPS limit of a given theory:
  - Equations of motions are of the first order
  - The solutions satisfy the lower energy (Bogomolny) bound
- For the 't Hooft–Polyakov monopole obtaining a BPS limit is easy
- What about the BPS limit of the Cho–Maison monopole?

The result

We derived a whole class of BPS theories that support Cho–Maison monopole:

- Turns out that, in contrast to 't Hooft–Polyakov monopole, it is not enough just to switch off the scalar potential, but also the gauge sector has to be non-trivially modified:

$$\mathcal{L}_{\mathrm{BPS}} = |D_\mu H|^2 - \frac{v^2}{4g^2|H|^2} h^2 \left(\mathrm{Tr}\left[F_{\mu\nu}^2\right] - \frac{2}{|H|^4} \mathrm{Tr}\left[F_{\mu\nu} H H^\dagger\right]^2 \right) - \frac{1}{4}\left(\frac{h'}{g|H|^2} \mathrm{Tr}\left[F_{\mu\nu} H H^\dagger\right] + \frac{f'}{g'} B_{\mu\nu} \right)^2$$

  where h, f' are some function of $|H|^2$

- We we able to find exact solutions
- Most importantly, we found the universal lower mass bound for the Cho–Maison monopole:

$$M \geq \frac{2\pi v}{g} \approx 2.37 \text{ TeV}$$

Based on:

P. B., F. Blaschke, PTEP 2018 (2018) no.7, 073B03, `arXiv:1711.04842`