# Dark Monopoles in GUTs

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## Introduction

- One of the consequences of Grand Unified Theories (GUTs) is that they have topological magnetic monopoles.
- In general, these monopoles have a magnetic charge in the abelian subalgebra of the unbroken group $G_v$.
- In this work, however, we construct monopoles with **vanishing abelian magnetic charge**, so that they do not interact with the $U(1)_{em}$ electromagnetic field.

## Dark Monopoles Construction

- We consider that the gauge group is $G = SU(n)$ and that it is broken down to $G_v = [SU(p) \times SU(n-p) \times U(1)]/Z$ by a Higgs field $\phi$ (adjoint representation) with a vacuum of the form $\phi_0 = v\frac{\lambda_p.H}{|\lambda_p.H|}$, where $\lambda_p$ is a fundamental weight of the Lie algebra $L(G)$.
- Our ansatz is constructed using an $SO(3)$ subgroup of $G$, whose generators are called the **monopole generators,** $\boldsymbol{M_i}$ $(\boldsymbol{i = 1, 2, 3})$, which are given by a linear combination of step operators of $L(G)$.
- Their mass possess **lower** and **upper bounds** (similar to the 't Hooft-Polyakov monopole).
- They have a purely **non-abelian magnetic flux**. The magnetic charge is conserved, quantized and it follows from an **asymptotic symmetry** of the field configuration.
- Regarding stability, we found unstable modes.

## Conclusions

- We expect that our construction can be **generalized to other gauge groups**.
- These Dark Monopoles must exist in some GUTs and we analyzed the SU(5) case in details.
- The cosmological implications of these monopoles are still an open question.

We have found magnetic monopole solutions (in GUTs) whose magnetic field **is not** in the direction of **electromagnetism**.

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## Some Technical Notes

- Ansatz:

$$W_i(\mathbf{r}) = -\frac{[1-u(r)]}{er}\epsilon_{ijk} n^j M_k \,,$$

$$\phi(\mathbf{r}) = vS + \frac{2v}{\sqrt{6}|\lambda_p|}\sqrt{\frac{4\pi}{5}}\, f(r) \sum_{m=-2}^{2} Y_{2m}^{*}\, Q_m \,,$$

where

$$M_3 = 2T_2^{ij} \,,$$
$$M_1 = 2T_2^{jk} \,,$$
$$M_2 = 2T_2^{ki} \,,$$

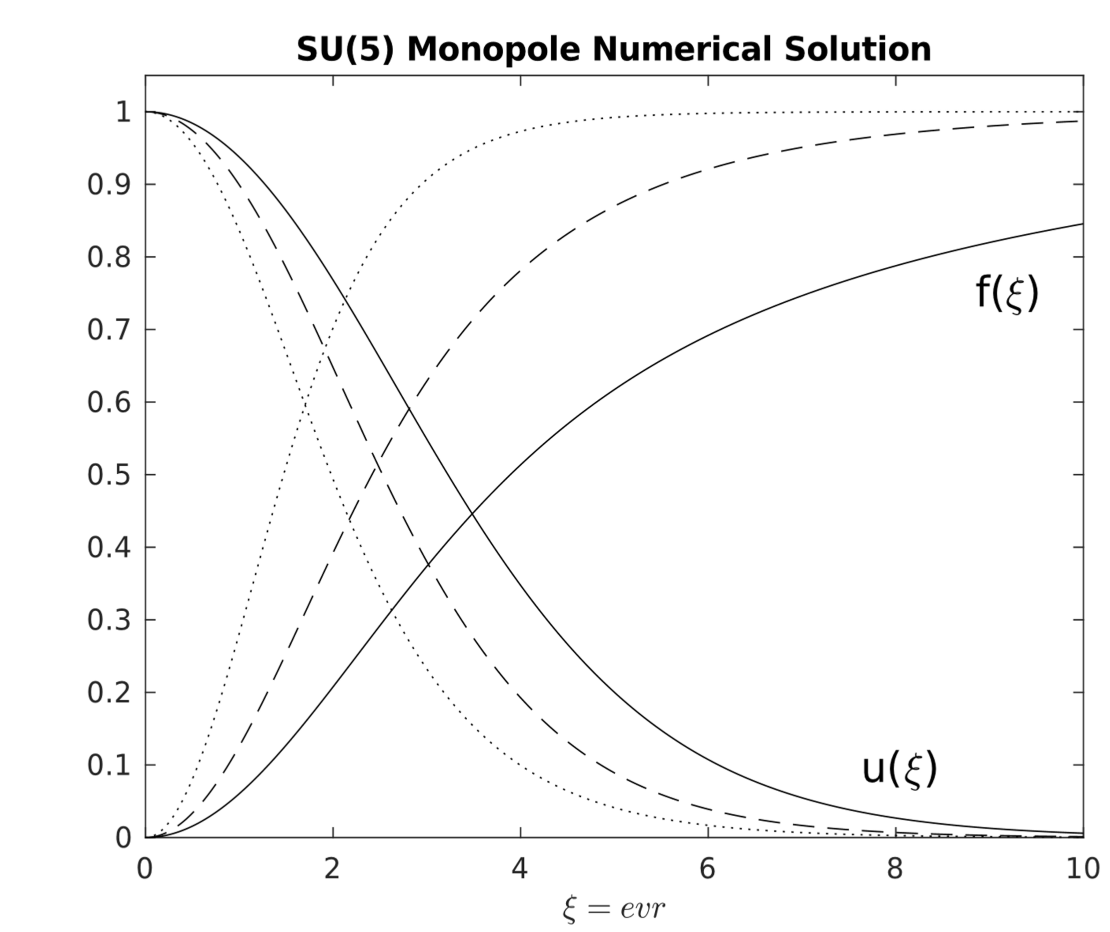
with $2T_2^{ij} = -i\left(E_{ij} - E_{ji}\right)$ while the $E_{ij}$ are the step operators associated with the root $\alpha_{ij}$. Moreover, $Q_m$ form a quintuplet under the $su(2)$ algebra of $M_i$, while $S$ is a singlet. In addition, $n^i = {x^i}/{r}$.

- Asymptotic Magnetic Field:

$$B_i(r \to \infty) = -\frac{n^i}{er^2}\, n^a M_a \,.$$

That is, the magnetic field only takes values in the direction of some step operators s.t. $Tr(B_i\phi) = 0$.

Numerical Solution for the radial equations $f(r)$ and $u(r)$ for the $SU(5)$ case:




- Monopole Mass:

$$M = \frac{4\pi v}{e}\,\tilde{E}(\lambda/e^2),$$

where $\tilde{E}(\lambda/e^2)$ is a monotonically increasing function of $\lambda/e^2$. In the $SU(5)$ case, we obtained that:

$$\tilde{E}(0) = 1.294,$$
$$\tilde{E}(\lambda \to \infty) = 3.262.$$

- Magnetic Charge: $Q_M = -8\pi/e$.

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