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How generic is cosmic string formation in SUSY GUTs ?

by

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Genericity of cosmic strings in SUSY GUTs

- 1. Theoretical Framework
- 2. Ingredients of our model
- 3. Elements of group theory
- 4. A known example :

$$SO(10) \rightarrow SU(4)_C \times SU(2)_L \times SU(2)_R \rightarrow SM\,(\times Z_2)$$

- Conclusions

1. Theoretical Framework

- Grand Unified Theories + Supersymmetry
- QFT in 4D + renormalisable

PARTICLE PHYSICS

+

COSMOLOGY

⇨ Are cosmic strings generic **?**

2. Ingredients of our model

- Particle physics needs :
  - Proton life-time measurments (Super-Kamiokande)

$$\tau_P(p \to e^+\pi^0) > 5.0\times 10^{33}\, ans$$

This implies :

- Supersymmetry (M_{GUT})
- Z_2 of R-parity unbroken at low energy

- The quantum numbers of known particles under $SU(3)_C$ x $SU(2)_L$ x $U(1)_Y$.

This implies :

- To know how to embed the SM in G_{GUT}.

- Cosmology imposes :
  - Measurments of oscilations of solar and atmospheric neutrinos [Super-Kamiokande, 1998], ...

  We need to give a mass to neutrinos (via SEE-SAW)

  - Measurments of matter/antimatter asymmetry [BBN, WMAP]

$$Y_B = \left(\frac{n_B - n_{\bar{B}}}{n_S} \right) \approx (8.7 \pm 0.4) \times 10^{-11}$$

  We need a mechanism of Baryogenesis (via LEPTOGENESIS)

  It requires

$$U(1)_{B-L} \subset G_{GUT} \quad \text{and} \quad \not{B-L} \quad \text{at} \quad M_{GUT}$$

  - Solution to problems of Standard Model of Cosmology :
    - The monopole problem
    - The flatness problem
    - The horizon problem

  } Inflation (HYBRID)

  See talk of M. Sakellariadou

3. Elements of group theory

- G_{GUT} = ?

Lie groups

SU(n+1) — SO(2n+1) — ~~Sp(2n)~~ — SO(2n) — 5 exceptional gp :

4 infinite families (SU(n+1), SO(2n+1), Sp(2n), SO(2n))

~~G_2~~, ~~F_4~~, E_6, ~~E_7~~, ~~E_8~~

- Constraints on these groups :
  - Unification means only 1 coupling constant

    ➡ simple group (or semi-simple with an additionnal discrete symmetry)
  - Minimal Rank = 4 so that $G_{SM} \subset G_{GUT}$.
  - Complex fermionic representations (to keep the nature of the electro-weak interactions). We are left with SO(4l+2), SU(l) and E_6.

- Anomaly free fermionic representation :

SO(6), E_6, SO(4l+2), but SU(l) ?

- Maximal rank = 8. Reasons :
  - Higher order groups would lead to already studied SSBs.
  - Predictability of the model
  - M-theory gives no constraint (10^5)

Conclusion :

- SU(5), SU(6), SU(7), SU(8), SU(9)
- SO(10), SO(14)
- E_6

This includes « Flipped SU(5) », $[SU(3)]^3$, ...

An example : SO(10)

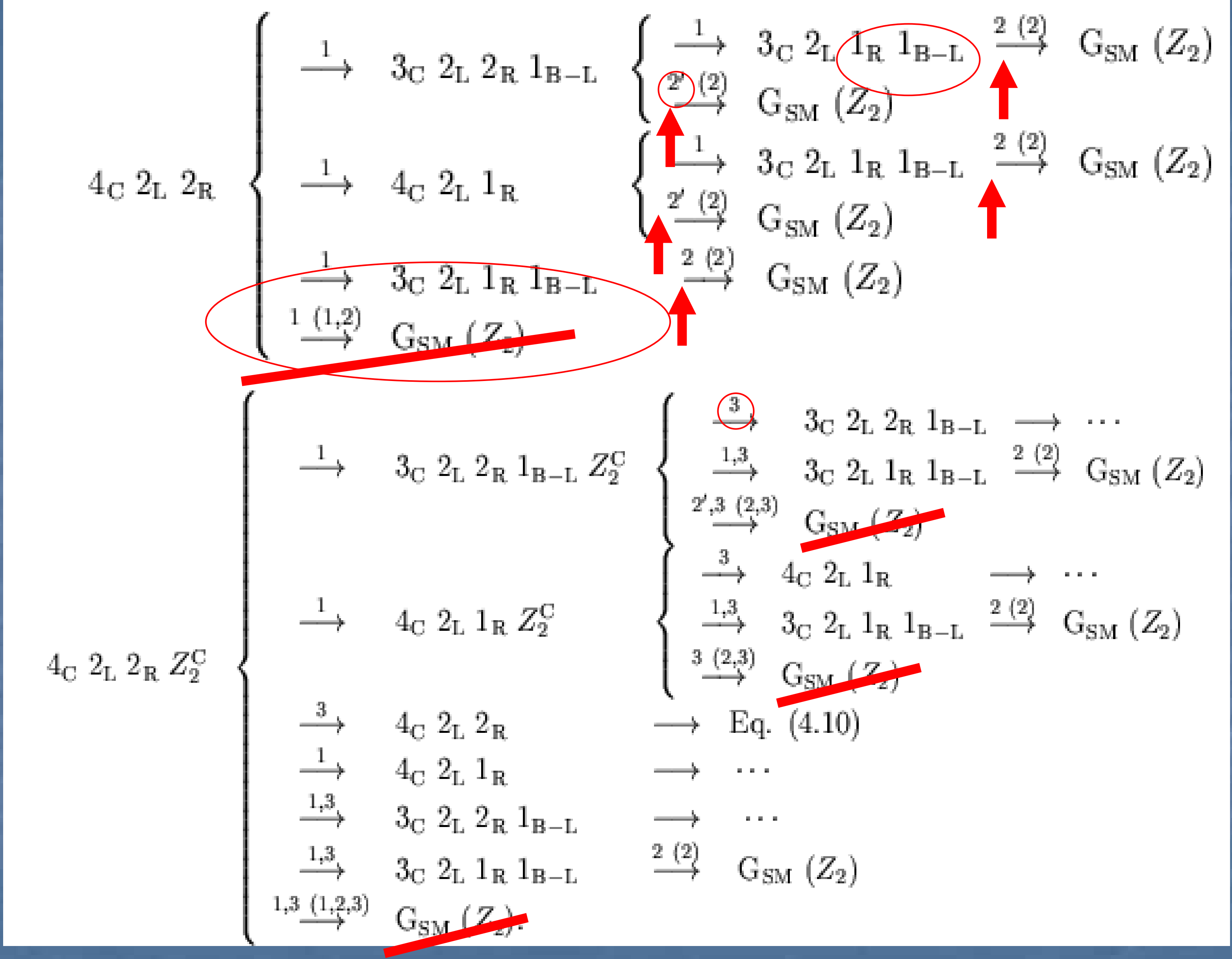
2 maximal regular sub-groups :

- SU(5) x U(1)
- SU(4) x SU(2) x SU(2)

Focus on the Pati-Salam group : $SU(4)_C x SU(2)_L x SU(2)_R$

- $U(1)_{B-L}$ included in $SU(4)_C$
- Mass spectrum for neutrinos
- Baryogenesis
- All the fermions belong to only 1 representation, the **16**. No need for additional fermions.
- Note : there is a discrete symmetry in SO(10) : D-parity (charge conjugation) Z_2^C.
- Embedding of the SM : $Y/2 = - I_R^3 + (B-L)/2$

$$Y/2 = I_R^3 + (B-L)/2$$



1: monopoles   2: topological strings

2': embedded strings   3: domain walls

↑ INFLATION

$$
\mathrm{SO}(10)\left\{
\begin{array}{cccc}
\xrightarrow{1} & 4_{\mathrm{C}}\ 2_{\mathrm{L}}\ 2_{\mathrm{R}} & \longrightarrow & \\
\xrightarrow{1,2} & 4_{\mathrm{C}}\ 2_{\mathrm{L}}\ 2_{\mathrm{R}}\ Z_2^{\mathrm{C}} & \longrightarrow & \\
\xrightarrow{1,2} & 4_{\mathrm{C}}\ 2_{\mathrm{L}}\ 1_{\mathrm{R}}\ Z_2^{\mathrm{C}} & \longrightarrow & \cdots \\
\xrightarrow{1} & 4_{\mathrm{C}}\ 2_{\mathrm{L}}\ 1_{\mathrm{R}} & \longrightarrow & \cdots \\
\xrightarrow{1,2} & 3_{\mathrm{C}}\ 2_{\mathrm{L}}\ 2_{\mathrm{R}}\ 1_{\mathrm{B-L}}\ Z_2^{\mathrm{C}} & \longrightarrow & \cdots \\
\xrightarrow{1} & 3_{\mathrm{C}}\ 2_{\mathrm{L}}\ 2_{\mathrm{R}}\ 1_{\mathrm{B-L}} & \longrightarrow & \cdots \\
\xrightarrow{1} & 3_{\mathrm{C}}\ 2_{\mathrm{L}}\ 1_{\mathrm{R}}\ 1_{\mathrm{B-L}} & \xrightarrow{2\ (2)} & \mathrm{G_{SM}}\ (Z_2) \\
\xrightarrow{1\ (1,2)} & \mathrm{G_{SM}}\ (Z_2) & &
\end{array}
\right.
$$

Conclusion for SO(10) via PS and via SU(5) x U(1):

- 68 schemes compatible with cosmology
  - 34 schemes with string formation and $G_{SM} x Z_2$
  - 21 schemes with string formation and G_{SM}
  - 13 schemes with embedded string formation and G_{SM}

Results for other groups

- SU(5) does not work :
  - Incompatible with proton life-time (even in SUSY case)
  - Unavoidable monopole problem

- SU(6) and SU(7) do not contain B-L
- For E_6, 1268 compatible schemes
  - 664 with string formation and $G_{SM} x Z_2$
  - 422 with string formation and G_{SM}
  - 170 with embedded string formation and G_{SM}
  - 12 with embedded string formation and $G_{SM} x Z_2$
  - Conclusion : 534 schemes OK with successfull leptogenesis.
    All of them end up with cosmic strings.
- For higher rank groups ... idem

Discussion

Restrictions of our work :

- SUSY GUTs
- Hybrid inflation model
- Baryogenesis via leptogenesis
- B-L broken at the end of inflation

Conclusions

- What did we learn ?
  - Cosmic strings seem to be GENERIC. Their formation appears at the end of inflation.

    → Study their properties

  - Cosmology can give information about particle physics at GUT scale.

  - What is their energy, their implication in the CMB?

    See next talk

More details in

Jeannerot, Rocher, Sakellariadou, Phys. Rev. D**68**, 103514 (2003)