Exceptional Confinement and Deconfinement in G(2) Gauge Theory

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- The exceptional group G(2)
- Confinement and deconfinement in G(2) Yang-Mills theory
- Higgsing G(2) to SU(3)
- Deconfinement and Size of the Gauge group
- Not so grand unification

K. Holland, P. Minkowski, M. Pepe, U.-J. W., Nucl. Phys. B668 (2003) 207

The Exceptional Group G(2)

Group embeddings: $SO(7) \supset G(2) \supset SU(3)$

Constraints: $\Omega_{ab}\Omega_{ac} = \delta_{bc}$, $T_{abc} = T_{def}\Omega_{da}\Omega_{eb}\Omega_{fc}$

$$T_{127} = T_{154} = T_{163} = T_{235} = T_{264} = T_{374} = T_{576} = 1$$

Fundamental representation: $\{7\} = \{3\} \oplus \{\bar{3}\} \oplus \{1\}$

Adjoint representation: $\{14\} = \{8\} \oplus \{3\} \oplus \{\bar{3}\}$

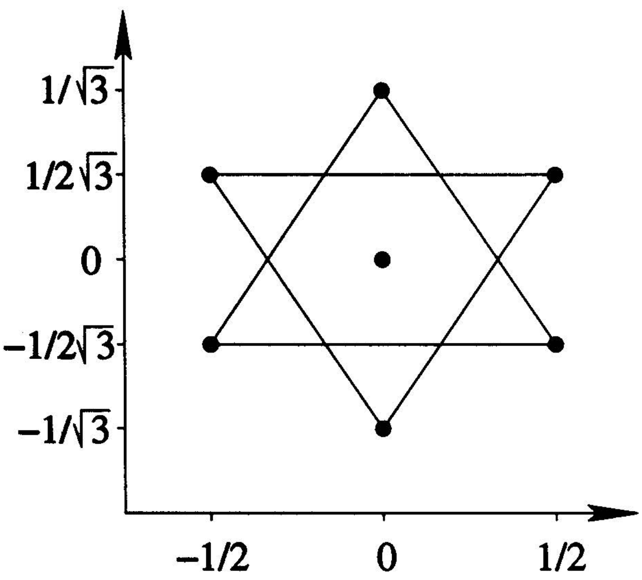
Center: G(2) has no triality

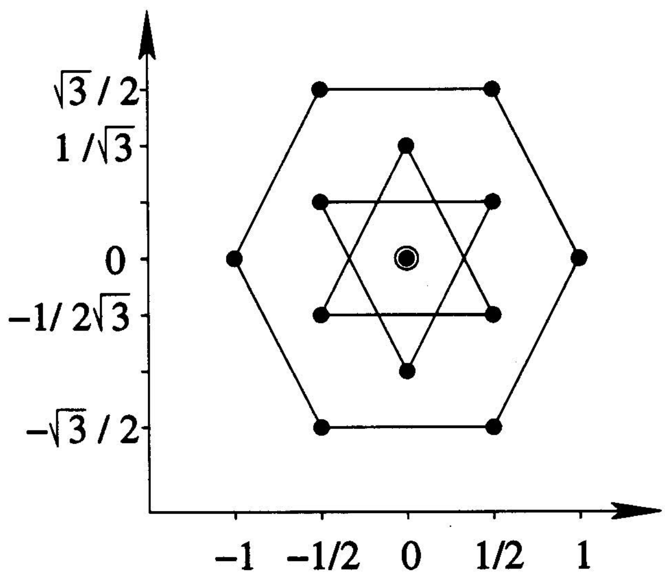
Reductions: $\{7\} \otimes \{7\} = \{1\} \oplus \{7\} \oplus \{14\} \oplus \{27\}$ ⇒ Mesons

$\{7\} \otimes \{7\} \otimes \{7\} = \{1\} \oplus 4\{7\} \oplus 2\{14\} \oplus 3\{27\} \oplus 2\{64\} \oplus \{77\}$ ⇒ Baryons

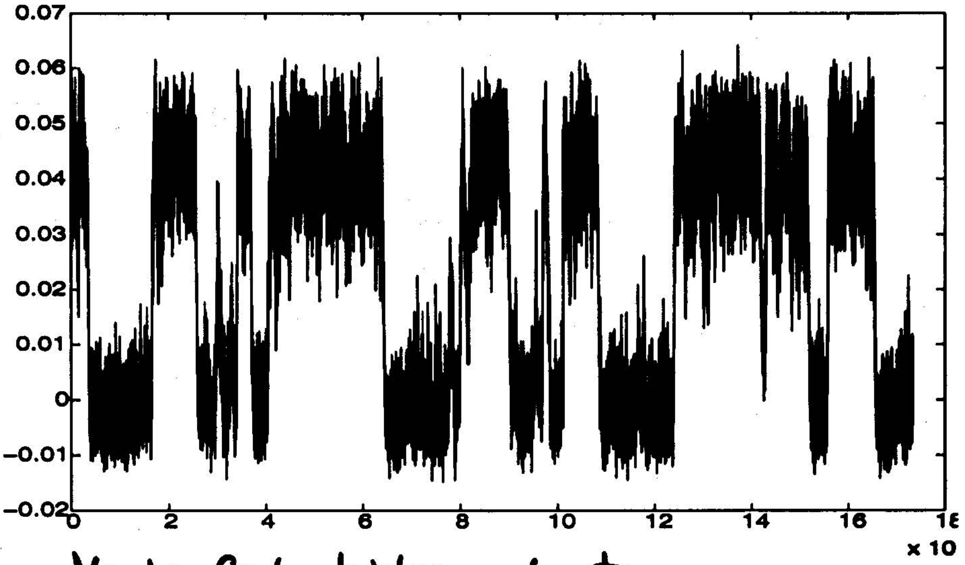
$\{14\} \otimes \{14\} \otimes \{14\} = \{1\} \oplus \{7\} \oplus 5\{14\} \oplus 3\{27\} \oplus 2\{64\} \oplus 4\{77\} \oplus 3\{77'\}$ ⇒

Three G(2) "gluons" can screen a quark ⇒ string breaking

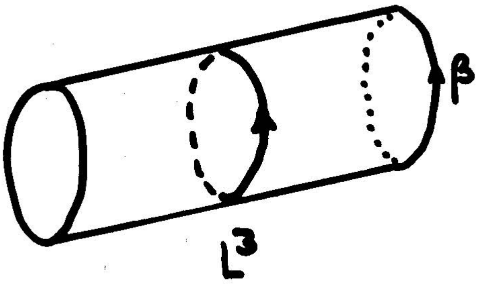




Deconfinement in G(2) Yang-Mills Theory

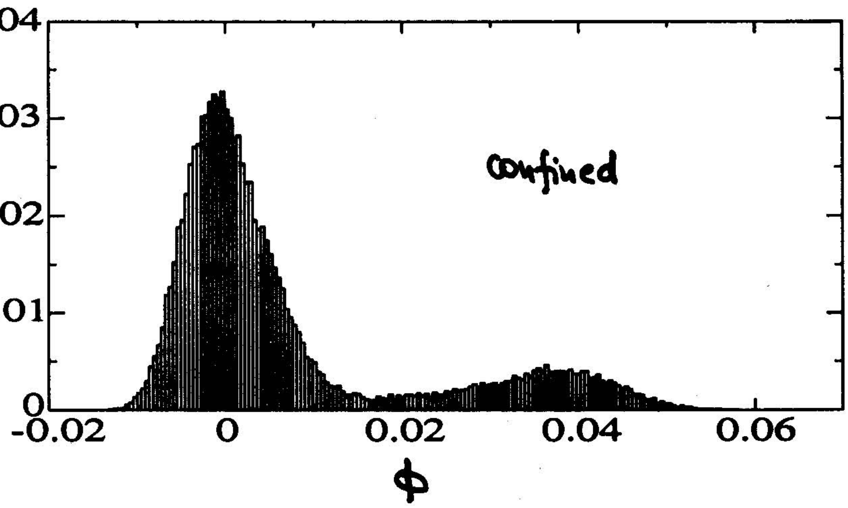


Monte Carlo history of Φ



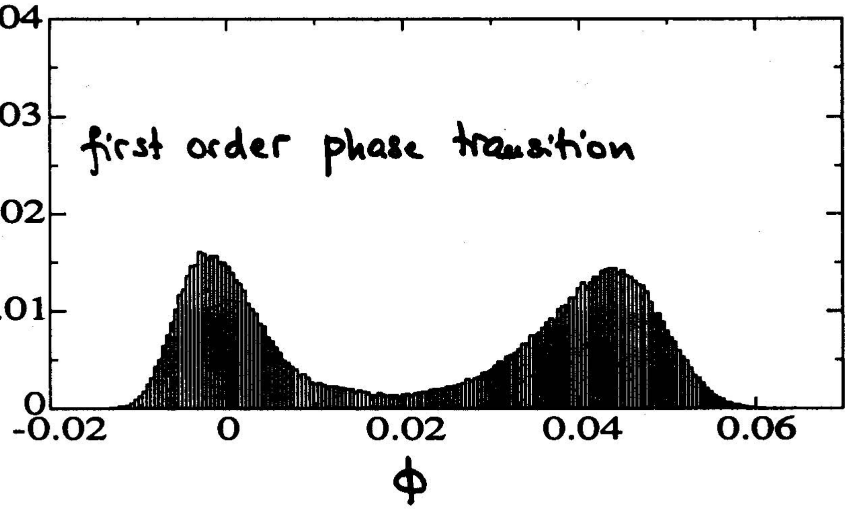
Polyakov loop:

$$\Phi(\vec{x}) = \mathrm{Tr}\, \mathcal{P} \exp \int_0^\beta dt\, A_0(\vec{x},t)$$



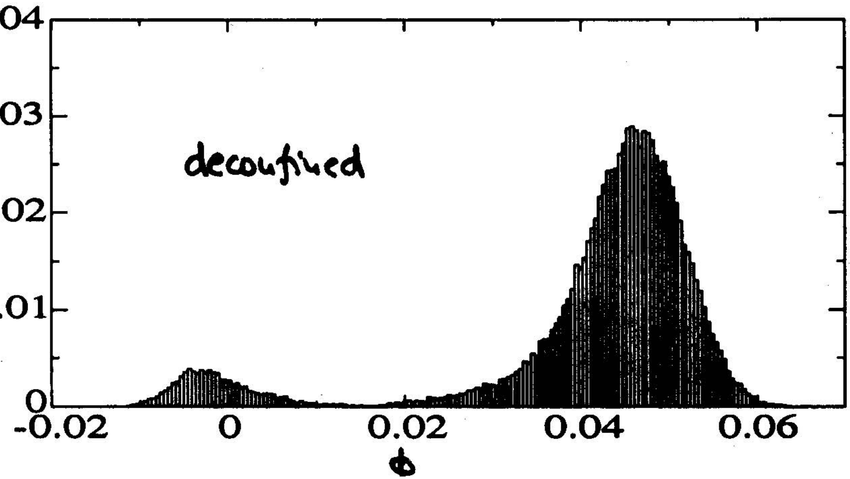
Free energy of a static quark:

$$\langle \Phi \rangle \sim \exp(-\beta F)$$



Although the center is trivial, G(2) Yang-Mills theory still has a first order phase transition.

M. Pepe, POS LAT 2005, 017



Higgsing G(2) to SU(3)

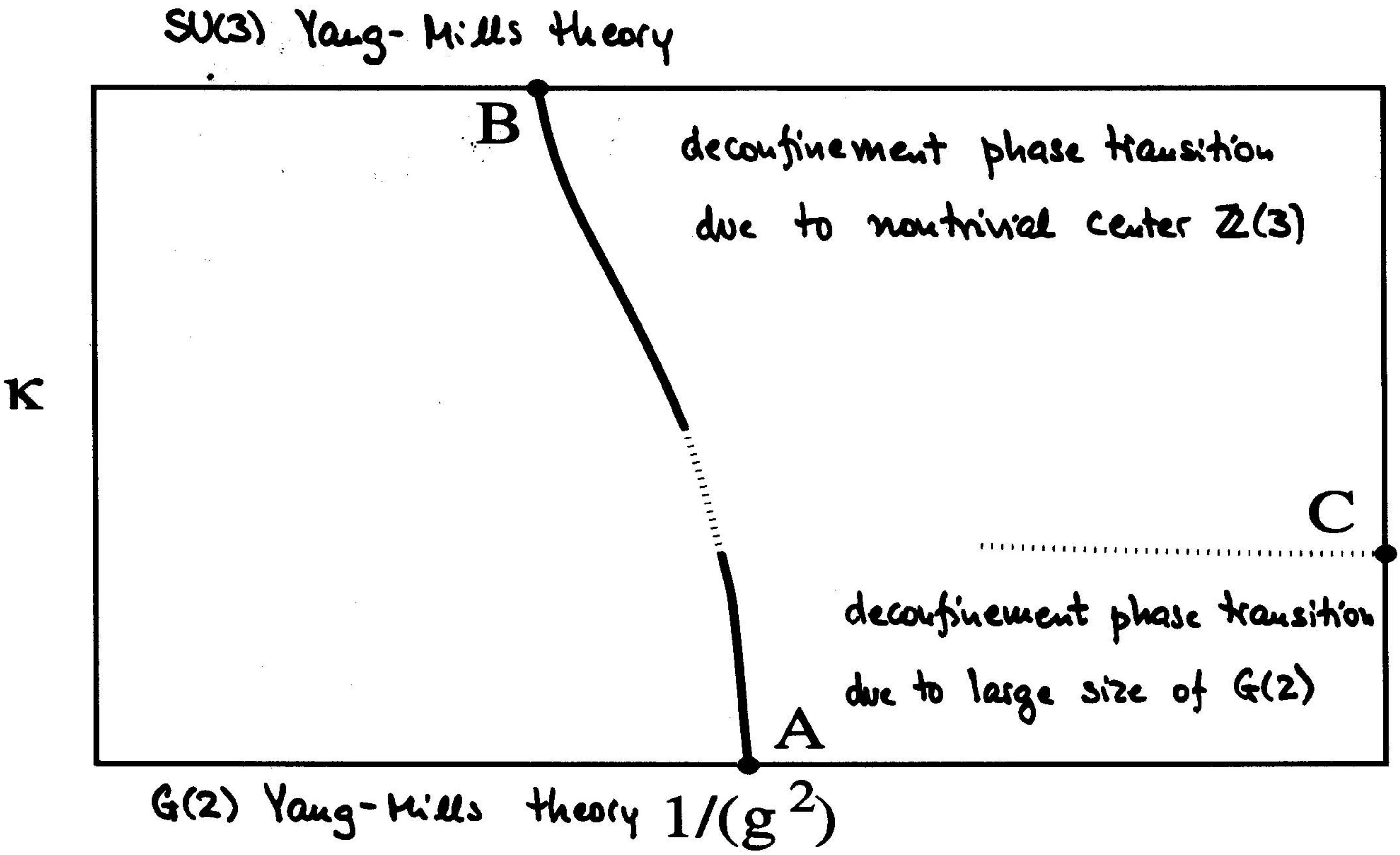
G(2) gauge-Higgs model with fundamental Higgs {7} :

$$S[A_\mu, \chi] = \int d^4x \left\{ \frac{1}{2g^2} \mathrm{Tr}\, F_{\mu\nu} F_{\mu\nu} + D_\mu \chi D_\mu \chi + V(\chi) \right\}$$

Mexican hat potential : $V(\chi) = \lambda(\chi^2 - v^2)^2$

Spontaneous symmetry breaking : $SO(7) \to SO(6)$
6 Goldstone bosons

Gauging of $G(2) \subset SO(7)$: $G(2) \to SU(3)$
6 additional "gluons" pick up a mass



Not so Grand Unification

Standard Model with $N_c = 3$:

$$\begin{pmatrix} u_L \\ d_L \end{pmatrix}, u_R, d_R, \begin{pmatrix} u_L \\ d_L \end{pmatrix}, u_R, d_R, \begin{pmatrix} u_L \\ d_L \end{pmatrix}, u_R, d_R, \begin{pmatrix} \nu_L \\ e_L \end{pmatrix}; \nu_R, e_R$$

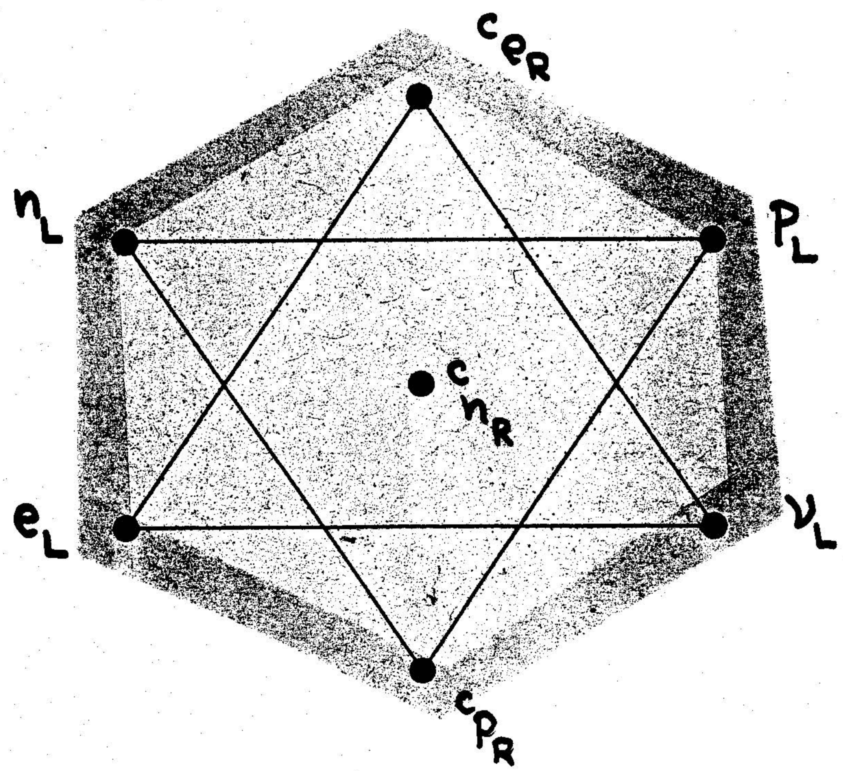
fits into $\{16\}$ of $SO(10) \supset SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$

Non-Standard Model with $N_c = 1$:

$$\begin{pmatrix} p_L \\ n_L \end{pmatrix}, p_R, n_R, \begin{pmatrix} \nu_L \\ e_L \end{pmatrix}, e_R, \nu_R$$

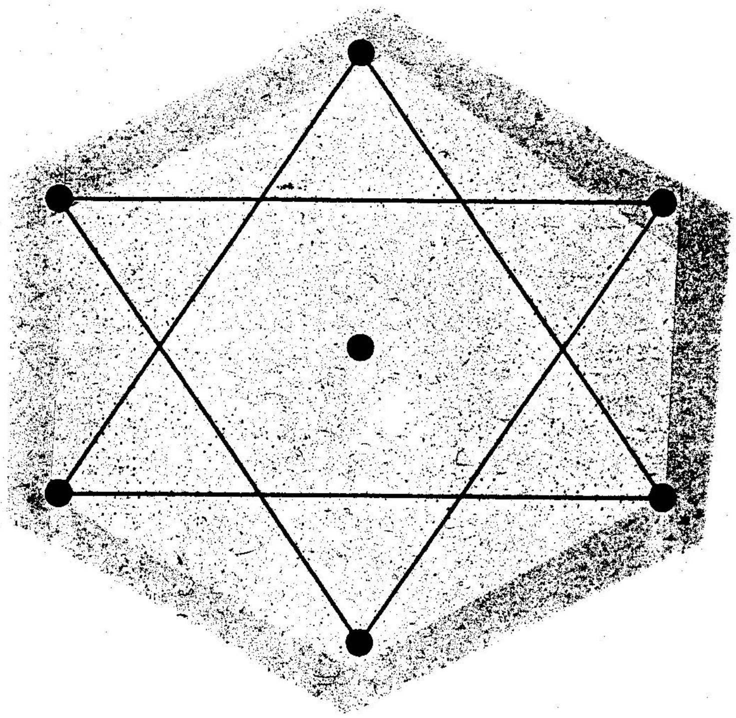
fits into $\{7\}$ of $G(2) \supset SU(2)_L \otimes U(1)_Y$

or into $\{8\}$ of $SO(7) \supset SU(2)_L \otimes U(1)_Y \otimes U(1)_{B-L}$



Not a grand idea, because $G(2)$ and $SO(7)$ have no chiral representations $\Rightarrow$ fermion masses run to GUT scale.

Is G(2) realized in Nature ?



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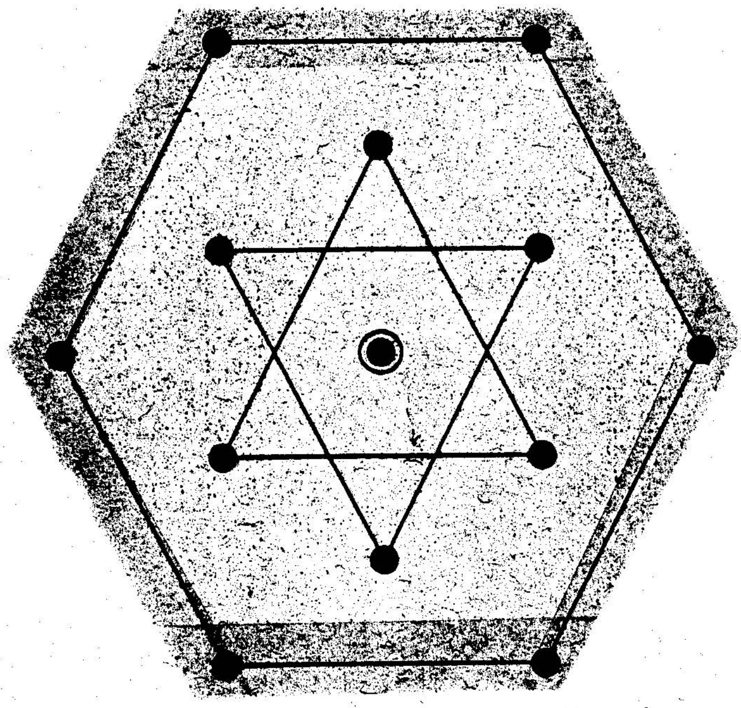

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