Approaching Continuum Monopoles

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Confinement $\overset{??}{\simeq}$ dual superconductor

QCD vacuum - condensate of monopoles

$\langle M \rangle \neq 0$ $\quad$ $(\langle \mathcal{N} \rangle \neq 0)$

Dual Meisner effect - chromoelectric flux is squeezed into flux tubes

Color charges are linearly confined.

Simple & nice – but is it true?

Many questions:

1. If dual superconductor – expect spectrum of superconductor: light vector & scalar.

But the lightest vector glueball in YM: $m_{0^{--}} \sim 3$ GeV $\gg$ 1.5 GeV ($m_{0^{++}}$)

2. No gauge invariant definition of magnetic monopoles.

In fact in SU(2) Yang-Mills there is no observable magnetic charge.

The argument:

If magnetic charge q_M exists - it must be charge conjugation odd.

But in pure SU(2) Yang-Mills - C-parity is part of the gauge group.

Complete set of observables: eigenvalues of Wilson loops $W(L)$. C-parity:

$$W(L) \xrightarrow{C} W^*(L)$$

In SU(2) $W(L)$ has real eigenvalues!

Another way to see:

$$A_\mu^3 \to -A_\mu^3 \; ; \; W_\mu^+ \to W_\mu^-$$

rotation by π around first axis in color space.

Still - lattice is persistent - monopoles defined in specific gauges, but correlate well with confinement.

Continuum:

Start with Georgi-Glashow model - has conserved magnetic charge ('t Hooft)

$$J^M_\mu = \partial_\nu \left(\hat{\Phi}^a F^a_{\mu\nu} \right)$$

Then take $M_{Higgs} \to \infty$ in the confining phase (pure SU(2) limit)

What happens?

$\langle M \rangle = ?$ (likely $\neq 0$)

$\langle M(x) M(y) \rangle = ?$ - is it alive, or is it "frozen" $M(x) \simeq$ const

What is $M(x)$?

Roughly: $$M(x) = e^{i\int \lambda_i(x-y)\,\hat{\phi}^a(y)\,E_i^a(y)}$$

vector potential of Dirac monopole

$$[M(x), \hat{\phi}^a(y) B_i^a(y)] = i\,\frac{4\pi}{g}\,\frac{(x-y)^i}{(x-y)^3}\,M(x)$$

"creates" Coulomb magnetic field.

What is $\langle M(x)\rangle = ?$

$$\langle M(x)\rangle = \int dA\; e^{-S(YM) - i\int \lambda_i(\phi E_i)}$$

action with a "source"

At weak coupling is dominated by semiclassics.

Should have J_μ^μ almost such that $\partial_\mu J_\mu^\mu = 0$ - but not quite - it is conserved

Expect symmetric "dandelion":

$\sim J_\mu^\mu$

But action of dandelion bizarre:

$$S_d \sim \ln^3(\Lambda/\mu)$$

UV cutoff

IR cutoff

In fact best is not rotationally invariant

Dirac string

$$S = \frac{4\pi}{g^2} \# \ln \Lambda/\mu$$

2~3

will become Λ_{QCD}

Have to see about

$$\langle M(x)\, M^*(y) \rangle$$

but naively now expect

$$\sim \left(\frac{1}{|x-y|}\right)^{\frac{4\pi}{g^2}\mu}$$

So it is alive.

Interesting to see at finite T -

can set up the same calculation.

Does $\langle M \rangle$ "drive" the transition,

or does it "follow"?