A possible title?

THE ANOMALY STRUCTURE OF REGULARIZED SUPERGRAVITY

or

HOW TO CANCEL THE ANOMALIES
In (slow) progress

or

BRST INVARIANT PV REGULARIZATION OF SUSY YANG-MILLS AND SUGRA

BZ: “Everybody said you gave a good talk, but they didn’t understand it.”

BETTER
ADVENTURES IN PHYSICS WITH BRUNO
$N = 8$ SUGRA = T.O.E.? finite?

Gauged version: $O(8)$ gauge symmetry $\not\sim SU(3) \otimes SU(2) \otimes U(1)$
56 spin-$\frac{1}{2}$ states $\not\sim$ all SM quarks & leptons

$\implies$ Some SM particles are composite

Murray Gell-Mann, 1979
Ungauged version: $E(7, 7) \ni SU(8)$ global symmetry:
conjecture: $SU(8)$ gauge symmetry dynamically generated


Example: $CP^{n-1} \ni U(1)$ global symmetry in 2-d:
dynamically realized $U(1)$ gauge symmetry with composite gauge boson

A. d’Adda, P. Di Vecchia, M. Lüscher, 1979

EGMZ: ALL SM particles composite
Using “Veltman’s theorem”: (lunch in Annecy)
Effective low energy theory must be renormalizable (anomaly free), found
★ $SU(5)$ unique GUT group
★ 3 generations of quarks and leptons

+ real reps $\ni$ Higgs for breaking $SU(5) \rightarrow SM \rightarrow SU_c(3) \otimes U(1)$


Symmetry completion EGMZ: Particle spectrum represents SUSY & $SU(8)$.

Need reps of full symmetry of SUGRA.


Particular (reducible) rep of $E(7,7)$

2nd Shelter Island Conference, 1983

BZ: “expansion” vs “decontraction” of group (MKG vs MG-M & Y. Ne’eman)

+ CBA onslaught

General treatment of $U(1,1) \supset U(1)$ of $N = 4$ SUGRA


Some unintended consequences
# 1. 1980 Harvard Loeb lectures: 4th on EGMZ
Howard Georgi had two students:
  Lawrence Hall & John Hagelin (dating my cousin)
Dinner with JH and Holly       TM & TP
JH xeroxed all my transparencies

Shortly thereafter POSTER APPEARS

**Qualities of the Unified Field**
**Located in the Lagrangian of the Unified Field**

Original swallowed by strings? had full $N = 8$ Lagrangian + spectrum (not JH)
#2. 1996 White House council: 3 questions (that I remember)
so as not to embarrass President Clinton ?!

★ Did I have a nanny problem?
  “no” became “yes”

★ In 1993 I had written a letter to newspapers in support of SSC (125 women particle physicists; originally sent to women members of Congress (Year of the Woman) + Energy Secretary Hazel O’Leary).
  Stand by my letter. SSC should have been built

★ Haim Harari wrote in a Scientific American article on composite models: described EGMZ as “ambitious”, but “like other composite models... has serious flaws”
  We no longer believe in the model ourselves
# 3. An important result for physics!


“On the occasion of his 60th birthday, we wish to dedicate this paper to Andrei Sakharov, whose work in gravitational and particle physics has been a great inspiration to us.


Applications in string theory and black holes; c.f. Sergio Ferrara, BZ, their postdocs and students.

Renata Kallosh: “Noether-Gaillard-Zumino current” used in her attempt to prove N=8 SUGRA finite. Come full swing?
Original motivation: Can $SU(8)$ gauge symmetry be dynamically generated?
or Can there be massless vectors $\sim SU(8)$ adjoint?
Not if corresponding conserved current invariant under all local symmetries

S. Weinberg & E. Witten, 1980

To address this: constructed most general (linear in $F^2$) Lagrangian with electromagnetic duality: $E \leftrightarrow H \quad F \leftrightarrow \tilde{F}$
Symmetry of EOM’s, not Lagrangian
E.g. Free em field: $L = \frac{1}{2}(E^2 - H^2) = -\frac{1}{4}F^2 = +\frac{1}{4}\tilde{F}^2$ not invariant
But $F^a_{\mu\nu} = \partial_\mu A^a_\nu - \partial_\nu A^a_\mu \implies \partial^\mu \tilde{F}^a_{\mu\nu} = 0$, and, defining $G^a_{\mu\nu}$ by $\tilde{G}^a_{\mu\nu} = 2\partial L/\partial F^a_{\mu\nu}$ ($\rightarrow -F^a_{\mu\nu}$ for free fields) $\implies \partial^\mu \tilde{G}^a_{\mu\nu} = 0$ from EOM for $A^a_\mu$

Invariance under EOM’s (including matter) requires

$$\delta \begin{pmatrix} F \\ G \end{pmatrix} = X \begin{pmatrix} F \\ G \end{pmatrix}, \quad X = X^*$$

$$X = \begin{pmatrix} A & B \\ C & D \end{pmatrix}, \quad C = C^T, \quad B = B^T, \quad D = -A^T$$

$X$ rep of $Sp(2n, R)$ for $n$ fields $F^a$, $a = 1, \ldots n$
★ Found form of $\delta \mathcal{L}$ under duality transformation
★ Found general form of Lagrangian
★ Scalars valued on coset space $Sp(2n, R)/[U(n) = \text{maximal compact subgroup}]$, or subgroup thereof, e.g. $E(7, 7)/SU(8)$ in $N = 8$ SUGRA
★ Found conserved currents (NGZ current).

Not invariant under local transformations:
\[ A \to A + \partial \lambda, \quad B \to B + \partial \lambda' \quad \text{where} \quad G_{\mu \nu} = \partial_\mu B_\nu - \partial_\nu B_\mu \]

But $Q = \int d^3x J_0 = \text{generator of } E(7, 7)$ is invariant

Lot’s of other applications

Viewpoint of EGMZ at time:
no evidence of SUSY partners; scale of SUSY breaking high

^ 

Still

Maybe rethink?

Mary K and the seven dwarfs

P. Binétruy

JP to MKG, LBL theory common room: Minimal gravity coupling to scalars

$$\mathcal{L}(h, \phi) = \frac{1}{2} \sum_{i=1}^{n} g^\mu\nu \partial_\mu \phi^i \partial_\nu \phi^i \implies$$

$$\implies m_0 \to \infty \ \forall \text{scalars, e.g. GWS Higgs}$$

[Diagram showing scalar fields]

ANS: $\mathcal{L}(h, \phi)$ invariant under $SO(n)$ up to other couplings

Let $\langle \phi_1 \rangle \neq 0$: $SO(n) \to SO(n - 1)$ left with $n - 1$ Goldstone bosons.

An office in Aspen: “Dwarfs” generalized to SUGRA: in general $m_0 \sim m_3/2$.

Can suppress masses of scalars that are GB’s of SUSY-breaking sector $\implies$ much larger $m_3/2$ allowed
Baltimore, April 1988

January 10-11 2005 Symposium in Honor of Julius Wess
on the Occasion of his 70th Birthday

November 6-7 2008 Memorial Conference in Honor of Julius Wess

Supersymmetry and superstring phenomenology


Memorial volume in honor of Julius Wess
Early history of SUSY in physics and math

Golfand, Volkov, WZ, Witten, Candelas et al., Seiberg, Akulov, Witten

# of papers found in Spires under “topic supersymmetry”

“prehistory” (including 2-d SUSY) = pre WZ 1974: M. Shifman, Golfand Memorial Volume
★ ABC’s of SM & MSSM: $f \rightarrow \tilde{f}$, $g \rightarrow \tilde{g}$, $H \rightarrow \tilde{H} \times 2$
★ Rudiments of string landscape heterotic $E_8^2$ example with CY compactification 
é la Candelas et al. orbifolds
★ SUSY and dark matter
★ Hidden sector needed for SSB: no $m_{\tilde{q}} < m_u$  
> Dimopoulos & Georgi
★ SUSY breaking example: gaugino condensation with Kähler stabilization of dilaton  
> P. Binétruy, MKG & Y-Y Wu + students
★ Measured soft parameters (at LHC??) + RGE probe high scale physics  
> e.g. M. Peskin review

Ended on optimistic note re SUSY at LHC Enthusiastically shared by Julius

But hedged our bets!
Winter & Spring 1982: Bruno lectures on SUSY & SUGRA

Attended by grad students, UCB faculty, LBNL staff

Lecture notes preliminary version available at


http://www-theory.lbl.gov/ZuminoSUGRAnotes.pdf