Chris Pope at $35_v + 35_c$

M. J. Duff

Blackett Laboratory, Imperial College London
&
Hagler Fellow, Institute for Quantum Science and Engineering,
Texas A&M University

Cook's Branch Conservancy September 2023

$70 = 35_v + 35_c$

- Happy seventieth to Chris, but just like the scalars of $N = 8$ supergravity

$$70 = 35_v + 35_c$$

  his age is reducible* to 35 before arriving at A&M in 1988 and 35 after.
- I was privileged to collaborate with Chris in both eras which could equally well be called pre-brane and post-brane.
- *Three score years and ten* did not fit quite so well

First became aware of Chris:

- K3 as a gravitational instanton S. W. Hawking and C. N. Pope, "Symmetry Breaking by Instantons in Supergravity," Nucl. Phys. B **146**, 381-392 (1978)
- Spacetimes with no spin structure can still admit fermions if charged S. W. Hawking and C. N. Pope, "Generalized Spin Structures in Quantum Gravity," Phys. Lett. B **73**, 42-44 (1978)

- S^7 compactification of $N = 1, D = 11$ supergravity yields gauged $N = 8, D = 4$ supergravity plus a tower of massive states in reps of $OSp(4|8)$. M. J. Duff and C. N. Pope, "KALUZA-KLEIN SUPERGRAVITY AND THE SEVEN SPHERE," ICTP-82-83-07.

- $N = 8 \rightarrow N = 1$ by squashing S^7 but massless gravitino is not one of the 8 you started with M. A. Awada, M. J. Duff and C. N. Pope, "N=8 Supergravity Breaks Down to N=1," Phys. Rev. Lett. **50**, 294 (1983)

- $N = 1$ as a result of (weak) G_2 holonomy: $8 \rightarrow 1 + 7$

1980s Austin

- In 1982 Chris, Bengt Nilsson and I were all visitors to Steve Weinberg's group at UT Austin
- In my vote of thanks for Weinberg's lecture at Imperial in 2014, I recalled what a great time I had in Austin working with
  "Chris Pope and Bengt Nilsson"
- But Youtube subtitles read

Figure: Crisp Open Bank Nilsson

- Reversing the orientation of S^7 (skew-whiffing) yields $N = 0$.

- One may interpret squashing as a higgs and superhiggs effect and the Round ($N = 8$, $G = SO(8)$, Left squashed ($N = 1$, $G = SO(5) \times SO(3)$ and Right squashed ($N = 0$, $G = SO(5) \times SO(3)$ spheres as the corresponding vacua. Also a de-Higgsing as massive gravitino becomes massless. M. J. Duff, B. E. W. Nilsson and C. N. Pope, "Spontaneous Supersymmetry Breaking by the Squashed Seven Sphere," Phys. Rev. Lett. **50**, no.26, 2043-2046 (1983) [erratum: Phys. Rev. Lett. **51**, no.9, 846 (1983)]

- Recent: Role of singletons B. E. W. Nilsson and C. N. Pope,arXiv:2302.03842

1980s Austin

- Euclidean signature field configurations and their topological properties (Betti numbers, Euler numbers, Pontryagin numbers, holonomy, index theorems etc) which feature in gauge and gravitational instanton physics can lead a second life as internal manifolds appearing in the compactification of the extra dimensions in Lorentzian signature Kaluza-Klein theory.
- The first non-trivial example was provided by K3.
  M. J. Duff, B. E. W. Nilsson and C. N. Pope, "Compactification of $d = 11$ Supergravity on $K3 \times T^3$" Phys. Lett. B **129**, 39 (1983)

1980s Austin: Missed Opportunity

- Note number of supersymmetries surviving compactification determined by the *holonomy eg on* $K3 \times T^2$ *with* $H = SU(2)$

$$(N = 1, D = 10) \to (N = 2, D = 4)$$

- *We asked ourselves (and then the experts in the UT Math Department) whether there was 6-dimensional analogue* X^6 *with* $H = SU(3)$ *such that*

$$(N = 1, D = 10) \to (N = 1, D = 4)$$

and were told none was known.

- *"We do not know of any solutions with* $H = SU(3)$*"*
- *Calabi-Yau compactification appeared following year!*

1980s Imperial: Kaluza-Klein

- Vacuum stability M. J. Duff, B. E. W. Nilsson and C. N. Pope, "The Criterion for Vacuum Stability in Kaluza-Klein Supergravity," Phys. Lett. B **139**, 154-158 (1984)

- Consistent truncations M. J. Duff, B. E. W. Nilsson, C. N. Pope and N. P. Warner, "On the Consistency of the Kaluza-Klein Ansatz," Phys. Lett. B **149**, 90-94 (1984)

Figure: Things rapidly changing

Figure: Chris with Sue and Lesley

- Magnum opus M. J. Duff, B. E. W. Nilsson and C. N. Pope, "Kaluza-Klein Supergravity," Phys. Rept. **130**, 1-142 (1986)" Notwithstanding the interdisciplinary zealots

Figure: Death Valley

1988-1995 Branes and Texas A&M

- 1987: The D=11 supermembrane E. Bergshoeff, E. Sezgin and P. Townsend, Supermembranes and eleven dimensional supergravity, Phys. Lett. B189 (1987) 75.
- 1988/9: Dick Arnowitt hires Chris Pope, Dimitri Nanopoulos, Ergin Sezgin and me.
- We host STRINGS 1989 and STRINGS 1990
- 1988-1995 Branes were flourishing eg
  M. J. Duff, T. Inami, C. N. Pope, E. Sezgin and K. S. Stelle, "Semiclassical Quantization of the Supermembrane," Nucl. Phys. B **297** (1988), 515-538

- E. Bergshoeff, M. J. Duff, C. N. Pope and E. Sezgin, "Supersymmetric Supermembrane Vacua and Singletons," Phys. Lett. B **199** (1987), 69-74"

- E. Bergshoeff, M. J. Duff, C. N. Pope and E. Sezgin, "Compactifications of the Eleven-Dimensional Supermembrane," Phys. Lett. B **224** (1989), 71-78

- M. J. Duff, C. N. Pope and E. Sezgin, 'A Stable Supermembrane Vacuum With a Discrete Spectrum," Phys. Lett. B **225** (1989), 319-324
  but completely ignored by the string community.
  Hostile journal and NSF referee reports.

Michael Duff made the drive from Texas A&M to Austin to give us a review of membrane theory. In my wise-guy way I told him that I had only been joking when I invented supermembranes. To which he aptly replied "Many a true word is spoken in jest" an adage that apparently goes back to Chaucer. So be careful trading quips with Brits. And he was right about the physics, too.

Joseph Polchinski "Memories of a Theoretical Physicist" arXiv:1708.09093

- Fond memories of lunchtime conversations with Chris, Ergin and Hong Lu at the College Station Hilton and sometimes at the more down-market Golden Corral, an "all-you-can-eat" buffet that Chris would describe as "all-you-can-face"

1990s Type II A&M Theory

- "Supersymmetry without supersymmetry," Phys. Lett. B **409** (1997), 136-144

$$M \ on \ S^7 = IIA \ on \ CP^3$$

even though IIA supergravity on CP^3 has only $N = 6$. Missing states are D0-branes.

- M. J. Duff, H. Lu and C. N. Pope, "AdS(5) x S**5 untwisted," Nucl. Phys. B **532** (1998), 181-209

$$IIB \ on \ S^5 = IIA \ on \ CP^2 \times S^1$$

even though IIA supergravity on $CP^2 \times S^1$ has no fermions since CP^2 has no spin structure. Missing states are winding modes.

- M. Cvetic, M. J. Duff, J. T. Liu, H. Lu, C. N. Pope and K. S. Stelle, "Randall-Sundrum brane tensions," Nucl. Phys. B **605** (2001), 141-158
- Chris founder and first director of the Mitchell Institute

Summary

- 39 papers with Chris, among my best.
- Outstanding physicist. He has an amazing talent for going right to the root of a problem and, more often than not, solving it.
- Wicked sense of humour.
- Gracious host and excellent chef.
- $35_v + 35_c$ have been an honour and a privilege; looking forward to 35_s