

# Formal Particle Theory in the UK

Prof Nick Dorey  
Prof Jerome Gauntlett

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- ★ Science Overview
- ★ Quality and Size
- ★ Resources

Based on consultation with community

THEN.....

## The Standard Model

Local, Renormalisable, Relativistic QFT

↓ Spin 1

Non-Abelian Gauge Theory

$$U(1) \times SU(2) \times SU(3)$$

- Theoretical Milestones,
  - Yang-Mills equation (1954)
  - Higgs Mechanism (1964)
  - Renormalisability (1972)
  - Asymptotic freedom (1973)

NOW.....

## Outstanding Problems

- Standard Model
  - Quark Confinement, Mass Gap
  - High Temperature/Density  
Cosmology, RHIC
  - Efficient Calculation Methods  
LHC Backgrounds
- Beyond Standard Model
  - Electroweak Symmetry Breaking  
Hierarchy Problem
  - Dark Matter/Dark Energy
  - Unification of Gravity with Standard Model  
Quantum Spacetime

## QUANTUM GRAVITY

- Energy Scale:  $M_{\text{Pl}} \simeq 10^{19}$  GeV  
⇒ Far beyond reach of experiment.
- Strong theoretical constraints:
  - Theory must be unitary,  
finite/renormalisable and reduce to GR  
at low energy,

Only candidate (so far): **String Theory**

- UK scientists made huge contributions to understanding,
  - Non-perturbative Dualities,  
$$\begin{array}{ccc} \text{Theory A} & \equiv & \text{Theory B} \\ \text{@ strong coupling} & & \text{@ weak coupling} \end{array}$$
  - Branes - higher dimensional extended objects,

- Can pose (and sometimes answer) sharp theoretical questions concerning,
  - Black hole thermodynamics  
Statistical Mechanical interpretation using branes!
  - Resolution of spacetime singularities
  - Fundamental nature of spacetime at  $\ell \sim 1/M_{\text{Pl}}$

# STRING THEORY

- String Phenomenology,
  - Long-term goal: Detailed predictions for particle physics and cosmology
  - “Top-Down” and “Bottom Up” approaches to model, building:  
[SUSY](#), [extra dimensions](#), [brane worlds](#)
- String-inspired interdisciplinary progress:
  - Perturbative QCD [on-shell methods](#)
  - AdS/CFT: Strongly-coupled gauge theory and condensed matter
  - Mathematics: especially Geometry - world leading

## QFT

- Present understanding of Gauge Theory limited,
  - Perturbation Theory  
Divergent Series!
  - Lattice Simulation
- Unsolved Problems in QCD,
  - Proof of confinement, mass gap  
Clay Millenium Prize
  - First principles calculations of hadron masses, S-matrix Analytic approach?
  - Behaviour at high temperature/density  
Cosmology, RHIC

## RECENT PROGRESS

AdS/CFT Correspondence, (1997)

Non – Abelian  
Gauge Theory  $\equiv$  String Theory

- New Perspectives on Strongly-Coupled Gauge Theory,
  - Quarks confined by flux tubes  $\equiv$  Strings
  - AdS black hole successfully used to model RHIC thermal plasma
- New Perspectives on Gravity,
  - Unitary description of black hole evaporation.
  - Warped brane worlds/extra dimensions.

Exciting time in Theoretical Physics!

## QUALITY AND SIZE

- Theoretical Particle Physics in the UK has an extraordinary tradition, especially in Formal Theory: enormous progress in Standard Model, black holes, string theory, supersymmetry, dualities etc.
- Is currently doing very high impact work e.g. in Formal Theory second only to the US. Particularly good at Big discoveries.
- Continues to appoint top international People:  
  
2005: 120 F.T.E.  
  
2008: 155 F.T.E.  
  
About 40% Formal Theory
- Excellent for recruiting and inspring UGs into Physics

## RESOURCES

### Rolling Grant RA Support

- 2005: 34 PDRAs
- 2008: 34 PDRAs (+9 SPG)
- 2011: 21 PDRAs (+4SPG?)

40% cuts!!

A ratio of 0.3 RA's per FTE on Rolling Grants would correspond to having 45RA's. *Minimum* required to exploit scientific resources.

In addition: AFs cut.

## Travel Support

Average: 0.5K - 1K per yer per FTE and RA.

Academics funding their own travel expenses.

Basic amount needed 1.5K - 2K per year

Shouldn't be tied to RA support.

## FEC Support

Average amount of FEC support is about 20% for FTE.

Amount needed: perhaps 60% - or at least as much as in other areas of science and/or other STFC subjects.

## CONCLUSION

International Review of UK Physics and Astronomy Research 2005:

“As stated in the 2000 report, the UK has a long history of excellence and leadership in string theory and general relativity. However, there are signs that this position is under threat....”

There has been significant recent investment by UK universities into this area.

Current funding leaves the subject in crisis:

- Won't exploit fantastic scientific potential of UK community
- Will have a serious negative impact on the subject: strongly anticipate that we will lose staff, especially the best.

UK Formal Particle Theory is high impact science, is great value and needs urgent help!