Mathematics and Physics of Branes in String and M -Theory
3 January – 29 June 2012
Isaac Newton Institute Final Report

Background and Theme

The Mathematics and Physics of Branes in String and M-theory (BSM) programme was organized to stimulate collaborative research in the light of recent developments in the study of branes in M-theory.

String Theory and its strongly coupled limit, M-theory, are currently the leading candidates for a complete quantum theory of all known fundamental forces in nature. In addition their study has sparked off remarkable new ideas in pure mathematics. The Newton Institute has previously hosted three related programmes: “Geometry and Gravity” (1994), “M-theory” (2002) ”Strong Fields, Integrability and Strings” (2007). Given the recent advances, the time was right for another Newton Institute programme in the area.

The themes of the programme were identified to be:

- **String/M-theoretic geometry:** properties of compactifications, classifications of solutions, dualities and their uses e.g. T-folds and U-folds, fermionic T-dualities and the incorporation of p-form fields to give novel effective geometries.
- **String/M-theoretic novel algebraic structures:** Three-algebras, duality groups and higher exceptional groups such as E_{10} and E_{11}
- **Brane physics:** Quantisation of branes, field theories for multiple branes and their intersections. Attempts to define a fundamental theory of membranes.
- **Applications to strongly coupled field theory:** The use of brane physics and the associated gauge/gravity duality for applications to strongly coupled systems such as nonperturbative quantum field theories and condensed matter systems etc
- **Applications to particle physics:** The role of string compactifications in string phenomenology, brane constructions of the Standard Model and the combination with supersymmetry breaking.
- **Applications to Cosmology:** The dynamics of branes in order to study early universe cosmology.

Structure:

The programme was divided into a five month section on relatively formal theoretical issues which was organized by Berman, Lambert and Mukhi, followed by a one month segment on applications to elementary particle phenomenology organized by Conlon and Quevedo. The former focused on the first three themes and the later the last two themes, as listed above. However it is important to note that the two teams made great efforts to coordinate their activities so as to ensure a smooth programme. Furthermore there is no sharp boundary between these themes and so elements of all of them were present at various times throughout the programme.

During the programme roughly 4-5 seminars were organized per week, except during the workshops when there were several talks each day. The regular seminars were concentrated in the middle of the week with the aim of leaving two days free from seminars. The programme also had a teleconference talk given by Edward Witten of the IAS Princeton, broadcast over the internet.

The programme had the following 5 workshops:

BSMW01: **Mathematical Aspects of String and M-Theory**

This workshop was held at the start of the programme and focused on some of the most formal aspects of String/M-Theory. A particularly strong theme of this meeting was that of generalized geometry (generalized beyond the notion introduced by Hitchin) which arises via U-duality and is expected to play an important role in String/M-theory as it reflects a radically new view of spacetime. Higher spin gravity, flux compactifications and the Moonshine programme in mathematics were some of the other themes.

BSMW02: Recent Advances in Scattering Amplitudes

This workshop was set up to capitalize on the striking recent advances on performing amplitude calculations in quantum field theory without using the traditional but increasingly intractable technique of Feynman diagrams. This is currently a very active field with deep relations to twistor theory and other topics in pure mathematics (such as symbols and motives).

BSMW03: Condensed Matter, Black Holes and Holography

One of the more surprising advances in the study of branes in String/M-theory is that, through the AdS/CFT correspondence, there are potentially important applications to other areas of physics such as Condensed Matter, where new techniques are needed to understand strongly coupled systems. This workshop was run as a pedagogical international school with lecture courses describing these new techniques. The focus ranged from quantum matter and topological phases to the gravity-fluid dynamics correspondence. This activity was particularly unique in that it brought formal String/M-theorists together with Condensed Matter theorists. It proved to be very popular and was attended by approximately 120 participants.

BSMW04: Branes and Black Holes (Satellite Meeting at King's College London)

The Satellite meeting was held in King's College London and focused on the role that branes in String/M-theory have to play in understanding black holes in quantum gravity. The meeting brought together internationally leading scientists and covered a diverse selection of topics, notably black hole entropy and microstates, deSitter gravity, flows and stability, and topological strings.

BSMW05: String Phenomenology 2012

The final workshop was the annual international conference on String Phenomenology which had 135 participants from the United Kingdom, Europe, the United States and Asia. This is the main annual conference on phenomenological aspects of string theory and this was the eleventh incarnation. In addition to the plenary talks, there were a large number of parallel talks by students and junior researchers attending. Topics discussed included construction of string vacua, string cosmology and implications of LHC results.

Outcome and Achievements

We believe that the programme was very successful and attracted 181 participants to the Institute, as well as additional participants to the workshops and satellite meetings. The feedback forms that we obtained are very supportive of the programme with only occasional minor suggestions for improvement.

Many international participants of programme also used the Isaac Newton Institute scheme to travel to other UK institutions to give seminars.

Although it is too early to tell, we believe that the programme has had a significant effect on the advancement of String/M-Theory. This has led to a consolidation of ideas and perspectives in various topics which will shape the future research activities of a large portion of the international community. In particular the following topics were discussed at length by an international cross-section of active researchers:

- Doubled field theory and applications to generalized geometry
- Algebraic structures such as Lie-crossed modules and gerbes underlying the 6-dimensional (2,0) theory
- Localization techniques in field theories on spheres in a variety of dimensions
- Black hole entropy and modular forms
- Scattering amplitudes and twistorial techniques in a variety of dimensions
- Construction and properties of string vacua

The programme brought together researchers at all stages in their careers, from all over the world, and led to many discussions and collaborations. A list of known papers which acknowledge the programme is given below.

Papers of the BSM Programme

1. arXiv:1208.3562 **Dark Radiation in Large Volume Models,** Michele Cicoli, Joseph P. Conlon, Fernando Quevedo
2. arXiv:1208.0020 **Duality Invariant M-theory: Gauged supergravities and Scherk-Schwarz reductions** David S. Berman, Edvard T. Musaev, Daniel C. Thompson
3. arXiv:1208.0261 **M-theory and Type IIA Flux Compactifications** Jock McOrist, Savdeep Sethi
4. arXiv:1207.2766 **Fluxbranes: Moduli Stabilisation and Inflation** Arthur Hebecker, Sebastian C. Kraus, Moritz Kuntzler, Dieter Lust, Timo Weigand
5. arXiv:1207.1103 **Superpotential De-sequestering in String Models** Marcus Berg, Joseph P. Conlon, David Marsh, Lukas Witkowski
6. arXiv:1207.1095 **Non-Abelian Self-Dual String Solutions** Chong-Sun Chu, Sheng-Lan Ko, Pichet Vanichchapongjaroen
7. arXiv:1207.0317 **A Statistical Approach to Multifield Inflation: Many-field Perturbations Beyond Slow Roll** Liam McAllister, Sebastian Renaux-Patel, Gang Xu
8. arXiv:1206.6697 **Two-loop RGEs with Dirac gaugino masses** Mark Goodsell
9. arXiv:1206.6781 **5-dim Superconformal Index with Enhanced En Global Symmetry** Hee-Cheol Kim, Sung-Soo Kim, Kimyeong Lee
10. arXiv:1206.6775 **AMSB and the Logic of Spontaneous SUSY Breaking** Shanta de Alwis
11. arXiv:1206.6699 **Periodic Arrays of M2-Branes** Imtak Jeon, Neil Lambert, Paul Richmond
12. arXiv:1206.5815 **GLSMs for non-Kahler Geometries** Allan Adams, Ethan Dyer, Jaehoon Lee
13. arXiv:1206.5697 **Supersymmetric Domain Walls** Eric A. Bergshoeff, Axel Kleinschmidt, Fabio Riccioni
14. arXiv:1206.5643 **Note on non-Abelian two-form gauge fields** Pei-Ming Ho, Yutaka Matsuo
15. arXiv:1206.5237 **D-Branes at del Pezzo Singularities: Global Embeddings and Moduli Stabilisation** Michele Cicoli, Sven Krippendorf, Christoph Mayrhofer, Fernando Quevedo, Roberto Valandro
16. arXiv:1206.4719 **Strange Metals in One Spatial Dimension** Rajesh Gopakumar, Akikazu Hashimoto, Igor R. Klebanov, Subir Sachdev, Kareljan Schoutens
17. arXiv:1206.3581 **On the Temperature Dependence of the Shear Viscosity and Holography** Sera Cremonini, Umut Gursoy, Phillip Szepietowski

18. arXiv:1206.3503 **5d quivers and their AdS(6) duals** Oren Bergman, Diego Rodriguez-Gomez
19. arXiv:1205.5606 **One-loop renormalization and the S-matrix** Yu-tin Huang, David A. McGady, Cheng Peng
20. arXiv:1205.5303 **Holographic duals of Boundary CFTs** Marco Chiodaroli, Eric D'Hoker, Michael Gutperle
21. arXiv:1205.4647 **A worldsheet extension of O(d,d;Z)** Costas Bachas, Ilka Brunner, Daniel Roggenkamp
22. arXiv:1205.4243 **Covariant actions for models with non-linear twisted self-duality** Paolo Pasti, Dmitri Sorokin, Mario Tonin
23. arXiv:1205.3108 **Non-Abelian Tensor Multiplet Equations from Twistor Space** Christian Saemann, Martin Wolf
24. arXiv:1205.2472 **Triality in Minimal Model Holography** Matthias R. Gaberdiel, Rajesh Gopakumar
25. arXiv:1205.2277 **Off-Shell Hodge Dualities in Linearised Gravity and E11** Nicolas Boulanger, Paul P. Cook, Dmitry Ponomarev
26. arXiv:1205.0069 **Superconformal Index with Duality Domain Wall** Dongmin Gang, Eunkyung Koh, Kimyeong Lee
27. arXiv:1204.6685 **Magnetic Domains** Derek Harland, Sam Palmer, Christian Saemann
28. arXiv:1204.3895 **Vortices and 3 dimensional dualities** Hee-Cheol Kim, Jungmin Kim, Seok Kim, Kanghoon Lee
29. arXiv:1204.3043 **Eisenstein series for infinite-dimensional U-duality groups** Philipp Fleig, Axel Kleinschmidt
30. arXiv:1204.2779 **Umbral Moonshine** Miranda C. N. Cheng, John F. R. Duncan, Jeffrey A. Harvey
31. arXiv:1204.1979 **Non-Geometric Fluxes in Supergravity and Double Field Theory** David Andriot, Olaf Hohm, Magdalena Larfors, Dieter Lust, Peter Patalong
32. arXiv:1204.2167 **(1,0) superconformal theories in six dimensions and Killing spinor equations** Mehmet Akyol, George Papadopoulos
33. arXiv:1204.2217 **A supersymmetric holographic dual of a fractional topological insulator** Martin Ammon, Michael Gutperle
34. arXiv:1204.1280 **The large N limit of M2-branes on Lens spaces** Luis F. Alday, Martin Fluder, James Sparks
35. arXiv:1203.6357 **Argyres-Douglas Loci, Singularity Structures and Wall-Crossings in Pure N=2 Gauge Theories with Classical Gauge Groups** Jihye Seo, Keshav Dasgupta
36. arXiv:1203.5784 **Quivers, YBE and 3-manifolds** Masahito Yamazaki
37. arXiv:1203.5757 **M-brane Models from Non-Abelian Gerbes** Sam Palmer, Christian Saemann
38. arXiv:1203.3546 **Membranes in M-theory** Jonathan Bagger, Neil Lambert, Sunil Mukhi, Constantinos Papageorgakis
39. arXiv:1203.3561 **The Kerr/CFT correspondence and its extensions: a comprehensive review** Geoffrey Compère
40. arXiv:1203.1617 **Integrable Wilson loops** Nadav Drukker

41. arXiv:1203.0015 **Higher Spin Black Holes from CFT** Matthias R. Gaberdiel, Thomas Hartman, Kewang Jin
42. arXiv:1202.3692 **A R^4 non-renormalisation theorem in N=4 supergravity** Piotr Tourkine, Pierre Vanhove
43. arXiv:1202.3416 **Self-duality of the D1-D5 near-horizon** Eoin Ó Colgáin
44. arXiv:1202.3060 **A geometric action for non-geometric fluxes** David Andriot, Olaf Hohm, Magdalena Larfors, Dieter Lust, Peter Patalong
45. arXiv:1202.1501 **On "New Massive" 4D Gravity** Eric A. Bergshoeff, J. J. Fernandez-Melgarejo, Jan Rosseel, Paul K. Townsend