WHAT'S HOT IN... PHYSICS , November/December 2009

M-Theory Progress Sparks New Interest in String Theory

by Simon Mitton

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The Physics Top Ten captures the spirit of a great revival of interest in branes and string theory, following a lengthy absence of the subject from the ratings. Hot Papers #3, #4, and #6 demonstrate a surge of activity in M2-brane theory, which has sparked a flurry of papers.

What's string theory all about? The short answer is that it combines general relativity and quantum mechanics in a quest to find a quantum theory of gravity. The theory is geometrical: strings are one-dimensional objects which we perceive as electrons and quarks. Higher-dimensional objects are branes, a word derived from membrane. From the point of view of being accessible to curious non-specialists, the theory is heavy duty in terms of its mathematical formulation and its technical language, which is a barrier to a wider understanding of the theory.

String theory is multifaceted in the sense that its mathematical landscapes are richly varied, and only a small class of its constructs appear to connect to reality. Historically, theoretical physics has been strongly driven by the quest for unification and simplification, although at the new frontiers it may not seem like that. Maxwell's electromagnetic theory combined electricity and magnetism. In that spirit, string theorists search for the Theory of Everything, while their critics dismiss the efforts as a theory of nothing, on the grounds that it has never made a testable prediction.

Jonathan Bagger

Neil Lambert

In 1995 string theorists grazing at a smorgasbord of tasty options identified 11-dimensional M theory as the bedrock on which to anchor their constructs. The interest stems from the fact that M theory has the maximum possible amount of supersymmetry in three dimensions. But there's more: M-theory has duality, meaning that quantities thought to be separate are in fact linked through the mathematics. Duality is a powerful concept in theoretical physics. M-branes are mysterious objects, and little is known apart from the special case of a single M-brane. That's quite a contrast with D-branes, where a description in terms of open strings has driven great progress in string theory and gauge theory.

In 1997 Juan Maldacena, a co-author of Hot Paper #3, made a conceptual breakthrough with the conjecture that a string theory defined in one space is equivalent to a quantum field theory without gravity defined on the boundary of the space. This duality set in motion many new lines of research in quantum gravity. M-theory has a known gravitational dual, which is the first step towards understanding M2-branes at singularities (such as black holes).

Although the dynamics of a single M-brane are well understood, very little is known about the interactions of multiple M2-branes. That problem is addressed in Hot Paper #4, in which Jonathan Bagger and Neil Lambert construct a supersymmetric field theory in three dimensions that is consistent with all the symmetries expected of a multiple M2-brane theory. This paper immediately attracted the attention of other string theorists who have carried out computations using the algebraic framework developed by Bagger and Lambert. [View a Research Front Map titled: "Bagger-Lambert Theory"].

Paper #4 motivated the research of Ofer Aharony and colleagues that is reported in Hot Paper #3, which examines M2-branes in flat space. For *Science Watch* from Thomson Reuters, Professor Aharony offered the following comment on the technical aspects of the paper: "Our work led to many generalizations of M2-branes in other backgrounds. Integrable structures have been found that may eventually lead to a solution of the theory of M-branes." The highly supersymmetric three-dimensional conformal field theories examined in the paper are interesting for various reasons.

In Hot Paper #6, Bagger and Lambert offer some comments on various physical aspects of the multiple M2-brane set-up proposed in #4. They have tested the model further, and conclude that it meets all expectations for M-theory. In terms of what the model may lead to, they state "the most pressing open issue is obtaining an infinite class of three algebras that can represent an arbitrary number of M2-branes."

Elsewhere in the Physics Top Ten, the papers on observational cosmology (#1, #2, #5, and #10) continue to attract a large following. Due to the mandatory two-year "retirement" age for Hot Papers, this is the last time we shall see #2, which has been continuously in the Top Ten for virtually all two years of its eligibility, registering 1,608 citations. The new #1, in fact, replaces #2 as the key reference on the cosmological interpretation of WMAP results.

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Physics Top 10 Papers

Rank	Paper	Citations This Period (May-Jun 09)	Rank Last Period (Mar-Apr 09)
1	E. Komatsu, *et al.*, "Five-year Wilkinson Microwave Anisotropy Probe observations: Cosmological interpretation," *Astrophys. J. Suppl. Ser.*, 180(2): 330-76, February 2009. [14 institutions worldwide] *406EI	143	4
2	D.N. Spergel, *et al.*, "Three-year *Wilkinson Microwave Anisotropy Probe* (*WMAP*) observations: Implications for cosmology," Astrophys. *J. Suppl. Ser.*, 170(2): 377-408, June 2007. [13 U.S. and Canadian institutions] *178TD	121	1
3	O. Aharony, *et al.*, "N = 6 superconformal Chern-Simons-matter theories, M2-branes and their gravity duals," *J. High Energy Phys.*, 10: no. 091, October 2008. [Weizmann Inst., Rehovot, Israel; Inst. Adv. Study, Princeton, NJ; Technion, Haifa, Israel; Rutgers U., Piscataway, NJ] *370JT	66	†
4	J. Bagger, N. Lambert, "Gauge symmetry and supersymmetry of multiple M2-branes," *Phys. Rev. D*, 77(6): no. 065008, 15 March 2008. [Johns Hopkins U., Baltimore, MD; King's Coll. London, U.K.] *282CF	54	†
5	J. Dunkley, *et al.*, "Five-year *Wilkinson Microwave Anisotropy Probe* observations: Likelihoods and parameters from the *WMAP* data," *Astrophys. J. Suppl. Ser.*, 180(2): 306-29, February 2009. [14 U.S. and Canadian institutions] *406EI	54	†
6	J. Bagger, N. Lambert, " Comments on multiple M2-branes," *J. High Energy Phys.*, 2: no. 105, February 2008. [Johns Hopkins U., Baltimore; King's Coll. London, U.K.] *285GD	50	†
7	J.Y. Kim, *et al.*, "Efficient tandem polymer solar cells fabricated by all-solution processing," *Science*, 317(5835): 222-5, 13 July 2007. [U. Calif., Santa Barbara; Gwangju Inst. Sci. Tech., Korea] *189DC	47	5
8	X.H. Chen, *et al.*, " Superconductivity at 43K in $SmFeAsO_{1-x}F_x$," *Nature*, 453(7196): 761-2, 5 June 2008. [U. Sci. & Tech., Hefei, China] *308UK	45	2
9	Z.A. Ren, *et al.*, "Superconductivity at 55 K in iron-based F-doped layered quaternary compound $Sm[O_{1-x}F_x]FeAs$," *Chinese Phys. Lett.*, 25(6): 2215-6, June 2008. [Chinese Acad. Sci, Beijing] *306MN	41	3
10	J.K. Adelman-McCarthy, *et al.*, "The Sixth Data Release of the Sloan Digital Sky Survey," *Astrophys. J. Suppl. Ser.*, 175(2): 297-313, April 2008. [84 institutions worldwide] *327WN	39	6

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