Curriculum Vitae

Melanie Becker

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Vordiplom in Physics at the Ruhr Universität
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Summer Student at DESY
Deutsches Elektronen Synchrotron
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Diplom in Physics (Cum Laude) at the
Rheinische Friedrich Wilhelms Universität
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Doctoral Thesis at the European Laboratory for
Particle Physics (CERN), Geneva,
Switzerland, August 1994
Advisor at CERN: Luis Alvarez Gaumé
Advisor at Bonn: Werner Nahm

POSITIONS HELD:	From September 1994 to September 1997 Postdoctoral Research Associate at the Physics Department of the University of California, Santa Barbara. From September 1997 to July 2000, Faculty Position as a Senior Research Fellow at California Institute of Technology Pasadena, CA 91125.
PRESENT POSITION:	Since July 2000, Assistant Professor Department of Physics University of Maryland College Park, MD 20742-4111.
TEACHING EXPERIENCE:	1994-1997 Teaching Assistant at UCSB. 1997-2000 Teaching Assistant at Caltech. 1998 Summer Undergraduate Research Advisor at Caltech. Fall of 2000, Physics 623 at UMD. Spring 2001, Physics 625 at UMD. Fall 2002, Introduction to String Theory and M-Theory" at UMD. Spring 2003, Physics 273 at UMD. Fall 2003, Physics 270 at UMD.
AWARDS:	Alfred Sloan Prize Fellowship in 2001, Graduierten Förderung Fellowship from Bonn University (1991).
ACTIVITIES:	Co-organizer of "String Theory at the Millennium", Conference at Caltech (2000).

Co-organizer of the "Mathematicians and Physicists Workshop on String Theory and Beyond" at UMD (2002).
Co-organizer of the RIT "String Theory and Math.", UMD (2003-).
Co-organizer of "String Geometry", conference in Utah, (2004).
Regular Referee of *Nuclear Physics* **B**,
Physical Review **D**, *Physics Letters* **B**,
International Journal of Modern Physics **A**,
Modern Physics Letters **A** and
Journal of High Energy Physics.

GRADUATE STUDENTS: Dragos Constantin, Anke Knauf and Ram Sriharsha.

Summary of research interests : String theory and mathematics

For a long time it has been known, that it is possible to compactify superstring theory on a warped geometry. This is a geometry, that is not a direct product of four-dimensional Minkowski space and an internal manifold. If the heterotic string is compactified on such a warped geometry, the resulting models in four dimensions have torsion. In [19] such an analysis was carried out for the first time for M-theory compactified on eight-manifolds. In this paper we worked out the consistency conditions following from supersymmetry and showed, that tensor fields of M-theory can have non-vanishing expectation values, while $\mathcal{N} = 2$ supersymmetry is preserved. Such an analysis has an easy generalization to F-theory compactifications on eight-manifolds and this has been done later on in the literature. The resulting low energy theory is then four dimensional, which makes it attractive from the phenomenological point of view.

Gukov, Vafa and Witten have subsequently shown, that the constraints derived in [19], can be obtained from two superpotentials appearing in three dimensions. As noticed by Giddings, Kachru and Polchinski, $\mathcal{N} = 2$ supersymmetry implies, that these superpotentials, together with the corresponding Kähler potentials combine into a scalar potential for the moduli fields. This is rather interesting, as it leads to non-vanishing expectation values for these fields. These expectation values have a one to one correspondence with the coupling constants of the standard model, so that compactifications of M-theory with non-vanishing fluxes may ultimately solve the 'moduli space' problem, which is one of the most important open problems in string theory. String theory will then be able to make definite predictions for the coupling constants of the standard model.

However, the compactifications considered in [19] are not the whole story. To obtain more realistic models, one should consider compactifications of the heterotic string on a non-Kähler, complex manifold with non-vanishing torsion (which is not Calabi-Yau). Such string theory compactification have never been considered in the physics literature in much detail. Not much is known about the mathematical properties of these manifolds either, so that this is an exciting territory for mathematics, as well as physics. String theorists need to understand these mathematical properties, in order to ultimately compute the coupling constants of the standard model, describing our four-dimensional world. This subject is one of my main current research areas. Together with K. Becker (an assistant professor at the University of Utah), K. Dasgupta (a postdoc at Stanford) and P. Green (a professor in the math. department at UMD) I have recently finished a paper on the subject [7] and our work will be significantly expanded in a future publication [2].

In one of my latest papers [6], we have explored the properties of the superpotential describing heterotic string theory compactifications on non-Kähler complex manifolds with torsion obtained in [7] and we have been able to show, that most of the moduli fields appearing in these more realistic models can be frozen, once non-vanishing expectation values for fluxes are taken into account. This is a rather interesting result from the phenomenological point of view and my present research will continue along this very promising direction. Several other aspects of compactifications with non-vanishing fluxes are being explored in [1,4,5].

There is a close connection between Riemannian manifolds of reduced holonomy and an area of mathematics known as calibrated geometry. This in fact became evident from our work [21], in which we found, that certain submanifolds, that we called 'supersymmetric cycles' are of vital importance in order to compute non-perturbative effects in the string coupling constant. These cycles correspond to, what mathematicians had known as 'calibrated submanifolds'. It became immediately clear, that in [21] we had discovered the role, that calibrated geometry is playing in the recent exciting developments of non-perturbative string theory. It may very well be, that the non-perturbative effects described in [21] play a role in solving the moduli space problem of string theory, as in certain type of compactifications non-perturbative corrections to the superpotential are expected to be present.

As was noticed by Gukov, Vafa and Witten and more generally conjectured by Gukov, the superpotential appearing in string theory and M-theory compactifications with non-vanishing fluxes is formulated in terms of calibrations. Together with my graduate student Dragos Constantin [8] I have proven Gukov's conjecture for certain string theory compactifications.

There are many other aspects of string theory and quantum gravity, that I am interested in and that I am working on. I will not be able to describe these here in detail. The subjects, that I find fascinating and in which I will be working on in the future are:

- ▹ Since string theory compactifications with fluxes are very promising candidates to solve the moduli space problem in string theory, it is time to consider realistic models for string theory phenomenology.
- ▹ Once the moduli space problem of string theory and the properties of the vacuum have been understood, we should be in the position to address one of the most important open problems in modern theoretical physics: the cosmological constant problem. Stabilizing the radial modulus of heterotic string compactifications, as we have recently done in [7], will be a crucial ingredient.
- ▹ I will continue working in the dual description of strongly coupled gauge theories in terms of weakly coupled supergravity theories. In this issue warped compactifications will be again the crucial ingredient. Confining gauge theories, which in principle can only be understood with complicated computer simulations, can be addressed in this way with a paper and pencil calculation. This is the direction, that we followed in [1]. Certainly, it should be interesting to see, if asymptotic freedom can be understood in this framework.
- ▹ Certainly along the way, I will return to calculations in Matrix theory, as this is the only renormalizable theory, known to describe M-theory. This theory is still in it's infancy and there are more open questions, than answers at this point.

Finally, I would like to present a short summary of my most relevant contributions to Superstring Theory and M-theory in the past

(1)In [17,16] we carried out the first calculation in M(atrix) theory at two loops and showed, that there is complete agreement between the super Yang-Mills theory and supergravity. This result strongly supported the M(atrix) model conjecture of Banks, Fischler, Shenker and Susskind.

(2) In [21,18] we evaluated non-perturbative corrections to the low energy effective action of Type II theories and showed, that these corrections can be described in terms of so called supersymmetric cycles. These supersymmetric cycles are known in the mathematics literature as calibrated submanifolds.

(3) In [19] we considered for the first time warped compactifications of M-theory on an eight manifold and derived the constraints imposed by supersymmetry on the fields of the theory. These compactifications are an active area of research for both physics and mathematics at this point, as it has been realized, that in many particular models they provide the solution to the moduli space problem of string theory. The coupling constants of the standard model can then ultimately be computed from string theory.

List of Publications

Melanie Becker

1. (with K. Becker and R. Sriharsha), *"PP-Waves, M-Theory and Fluxes"*, hep-th/0308014.
2. (with K. Becker, K. Dasgupta, P. Green and E. Sharpe), *"Compactifications of Heterotic Theory on Non-Kähler Complex Manifolds: II"*, UMD-PP-03-069, to appear.
3. (with K. Becker, J. H. Schwarz), *"From String Theory to M-theory: An Introduction for Graduate Students"*, in progress.

. (with D. Constantin, S. J. Gates, W. Merrell and J. Phillips), *"From 3D Supergravity to M-theory"*, UMD-PP-03-071, to appear.

5. (with A. Krause), *"M-theory and De Sitter Space"*, in progress.
6. (with K. Becker, K. Dasgupta and S. Prokushkin), *" Properties of Heterotic Vacua from Superpotentials"*, *Nucl. Phys.* **B 666** (2003) 144, hep-th/0304001.
7. (with K. Becker, K. Dasgupta and P. Green), *"Compactifications of Heterotic Theory on Non-Kähler Complex Manifolds: I"*, JHEP 0304:007, (2003), hep-th/0301161.
8. (with D. Constantin), *"A Note on Flux Induced Superpotentials in String Theory"*, JHEP 0308:015, (2003), hep-th/0210131.
9. (with K. Becker, M. Haack, J. Louis), *"Supersymmetry Breaking and Alpha-Prime Corrections To Flux Induced Potentials'*, JHEP 0206:060, (2002), hep-th/0204254.
10. (with K. Becker), *"Compactifying M-Theory to 4D"*, JHEP 0011:029, (2000), hep-th/0010282.

11. (with K. Becker), *"Fivebrane Gravitational Anomalies"*, *Nucl. Phys.* **B 577** (2000) 156, hep-th/9911138.

12. (with K. Becker), *"Instanton Action for Type II Hypermultiplets"*, *Nucl. Phys.* **B551** (1999) 102, hep-th/9901126.

13. (with K. Becker), *"Quantum Gravity Corrections for Schwarzschild Black Holes"*, *Phys. Rev.* **D60** (1999) 026003, hep-th/9810050.

14. (with K. Becker), *"Complete Solution for M(atrix) Theory at Two Loops"*, JHEP 9809:019, (1998), hep-th/9807182.

15. (with K. Becker), *"On Graviton Scattering Amplitudes in M-Theory"*, *Phys. Rev.* **D57** (1998) 6464, hep-th/9712238.

16. (together with K. Becker, J. Polchinski and A. Tseytlin), *"Higher Order Graviton Scattering in M(atrix) Theory"*, *Phys. Rev.* **D56** (1997) 3174, hep-th/9706072.

17. (with K. Becker), *"A Two-Loop Test of M(atrix) Theory"*, *Nucl. Phys.* **B506** (1997) 48, hep-th/9705091.

18. (with K. Becker, D. R. Morrison, H. Ooguri, Y. Oz and Z. Yin), *"Supersymmetric Cycles in Exceptional Holonomy Manifolds and Calabi-Yau 4-Folds"*, *Nucl. Phys.* **B480** (1996) 225, hep-th/9608116.

19. (with K. Becker), *"$\mathcal{M}$-Theory on Eight Manifolds"*, *Nucl. Phys.* **B477** (1996) 155, hep-th/9605053.

20. (with K. Becker), *"Boundaries in $\mathcal{M}$-Theory"*, *Nucl. Phys.* **B472** (1996) 221, hep-th/9602071.

21. (with K. Becker and A. Strominger), *"Fivebranes, Membranes and Non-Perturbative String Theory"*, *Nucl. Phys.* **B456** (1995) 130, hep-th/ 9507158.

22. (with K. Becker and A. Strominger), *"Three-Dimensional Supergravity and the Cosmological Constant"*, *Phys. Rev.* **D51** (1995) 6603, hep-th/9502107.

23. *"Non-Perturbative Approach to 2D Supergravity and Super-Virasoro Constraints"*, Thesis, CERN-TH-7173-94, March 1994, hep-th/9403129.

24. (with K. Becker) *'Interactions in the* $\mathrm{SL}(2,\mathbb{R})/\mathrm{U}(1)$ *Black Hole Background'*, *Nucl. Phys.* **B418** (1994) 206, hep-th/9310046.

25. (with K. Becker), *"Nonperturbative Solution of the Super-Virasoro Constraints"*, *Mod. Phys. Lett.* **A8** (1993) 1205, hep-th/9301017.

26. (with L. Alvarez Gaumé and K. Becker), *"SuperVirasoro Constraints and 2D Supergravity"*, talk given at the XIX International Colloquium on Group Theoretical Methods in Physics, Salamanca, Spain, 1992, preprint CERN-TH-6720/92.

27. (with L. Alvarez Gaumé, K. Becker, R. Emparan and J. Mañes), *"Double Scaling Limit of the SuperVirasoro Constraints"*, *Int. J. Mod. Phys.* **A8** (1993) 2297, hep-th/9207096.

28. (with L. Alvarez Gaumé and K. Becker), *"Superloop equations in the Double Scaling Limit"*, preprint CERN-TH-6575/92, July 1992.

29. "Landau-Ginzburg Theory, Mean Field Theory and Spin Systems in Imaginary Fields", Bonn-IR-91-16, Diplomarbeit, April 1991.