The Photon:

Spotlight

On Alumnus Keith Josten

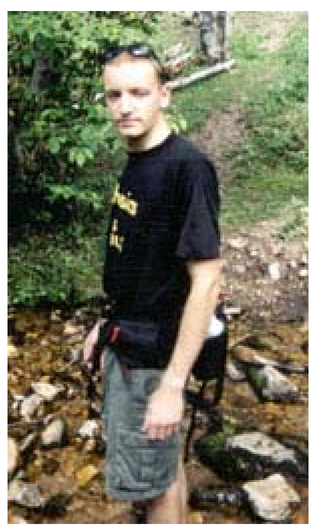
UM physics alumnus **Keith Josten** may have received his B.S. degree just two years ago, but he sure has gotten around! He's worked in the Lecture-Demo Lab (UM), Magneto-Optics Lab (UM), the Laboratory for High Energy Astrophysics (LHEA) (NASA-Goddard) and the Laboratory for Gravitation (UM). Find out more below!

by Keith Josten, Class of 1999

I got a lot out of my undergraduate experience here in the Physics Department at Maryland. While my coursework and private pursuits taught me most of what I know about the subject of physics, I found my various work experiences to be of equal if not greater importance to my college education. Along with teaching me various aspects of the fields of engineering and astronomy, they provided me with a good glimpse of what a career in physics research would be like.

I came here after completing my first two years of college at a community college up in Pennsylvania. Knowing how work oriented I am, I knew that it would be critical to my education to get a job in physics as soon as I got here. So I did the smart thing and came down here before the semester started and poked my head around to find a job.

The first opportunity I found was to work as a night manager in the Lecture-Demonstration Laboratory. This was the perfect job for a newcomer to the department because I had the opportunity to work with and meet most of the teaching faculty here in the department while playing with some fun and informative demonstrations. By the end of the year, I had been in direct contact with at least 15 professors in the department and knew a little bit about each one of them and what types of research they were interested in. Having this knowledge became quite valuable when I went to look for a more research oriented position, which I found the following semester. That fall I began working in **Dr. Dennis Drew's** Magneto-Optics lab. I was initially employed as a lab rat, filling gas cylinders and organizing the lab.



Keith sports his Physics-is-Phun ware while hiking in New Mexico

I suppose my performance impressed Dr. Drew because he soon came to me with the suggestion that I apply for the Senior Summer Scholarship, which is

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On String Theory

In the last century, we have seen emerge two very accurate and beautiful theories in physics: quantum field theory and classical general relativity. Quantum electrodynamics allowed us to compute, for example, the magnetic moment of the electron, which has been verified experimentally to a very high precision. General relativity predicted the deflection of light by the sun and has changed fundamentally our notion of space and time.

However, if the try to unify both theories to describe gravity at short distances, we run into divergences or "problems" that cannot be resolved with the conventional renormalization techniques of quantum field theory. The presence of these non-renormalizable divergences suggests that general relativity is only a valid description up to some energy scale beyond which new physics appears: a high energy theory.

Superstring theory is our most promising candidate to be such a high energy theory for gravity, as it regularizes the divergences found in a quantum field theory of gravity. The basic idea of string theory is very simple: different elementary particles instead of being pointlike objects are different vibrational modes of a string.

quantized we can associate a spin 1 particle to this field, the so called photon. Similarly, when gravity is quantized there appears a spin 2 particle, which is called the graviton.

Small Internal Manifold: In superstring theory it is assumed that the ten dimensional space-time in which the string lives is of the form M_10=Minkowski_4 \times K_6, where Minkowski_4 is our four-dimensional world. Six of the 10D coordinates are curled up on a small internal manifold K_6. This is known as Kaluza-Klein compactification.

M-Theory: M-Theory is a quantum theory of gravity that lives in eleven dimensions from which the different types of superstring theories that live in ten dimensions can be obtained. The name is deliberately ambiguous, reflecting the unknown nature of the theory. M has variously been suggested to stand for membrane, matrix, mother and mystery.

Matrix theory: A quantum mechanical system with matrix degrees of freedom and 32 supercharges, obtained by dimensional reduction of d=10 supersymmetric U(N) Yang-Mills theory. In the large N limit

Figure 1

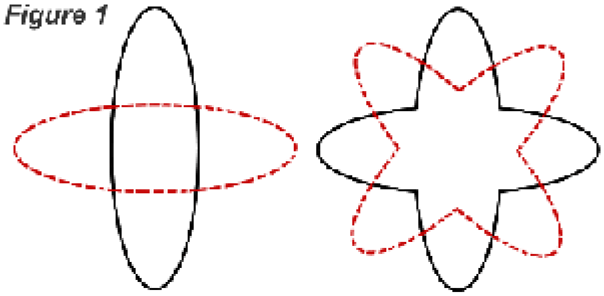

Illustration by Reka Shanmugavel

A string can vibrate in different resonant patterns. Each pattern corresponds to a different elementary particle.

The typical size of a string is pretty small. It is of the order of the Planck length (which is 1.6×10^{-33} centimeter). To an external observer, the string will effectively appear as a pointlike object. Moreover, the spectrum of a closed string contains a massless spin-2 particle. In 1974, Scherk and Schwarz interpreted this particle as the graviton, the field quantum of gravitation. Superstring theories are only consistent if they live in ten space-time dimensions as otherwise their spectrum includes negative norm states.

this is conjectured to be M-theory.

Supersymmetric: Supersymmetry is a symmetry whose charge transforms as a spinor, which relates the masses and couplings of fermions and bosons.

Two loop order: Used in Feynman diagrams, two loop order means that the Feynman diagram contained two loops, which is a specific order in the perturbation theory.

Non-perturbative: Superstring perturbation theory can be defined in terms of Feynman diagrams like in ordinary field theory. This perturbation theory is defined in terms of the string coupling constant. A non-perturbative formulation of string theory is non-perturbative in the string coupling constant and cannot come from such a Feynman diagram expansion.

The four-dimensional world in which we live can be obtained by compactifying six dimensions on a small internal manifold. The particle spectrum of the four-dimensional theory is then determined by the topology of the internal manifold.

We used to believe that there are five different types of superstring theories that live in ten dimensions. However, in recent times it has been realized, starting with the work of E. Witten, C.Hull and P. Townsend, that these theories can be obtained by compactification from an eleven-dimensional theory that has been called M-theory.

Figure 2

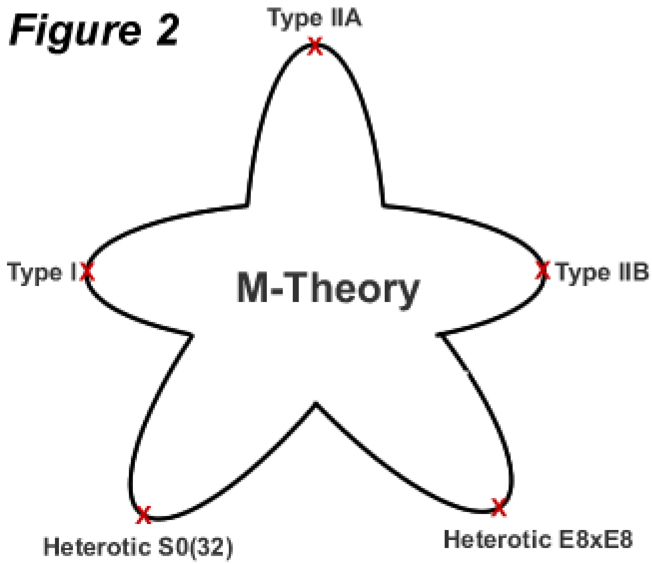

Illustration by Reka Shanmugavel

The five consistent ten-dimensional Superstring theories can be derived from M-theory.

It is known that at large distances M-theory is described by eleven-dimensional supergravity. However, for many years, people did not know how to describe M-theory at short distances. This situation changed in the summer of 1996, when Banks, Fischler, Shenker and Susskind made the claim that M-theory in the infinite momentum frame can be described in terms of Matrix theory. This is a gauge theory in one dimension describing supersymmetric pointlike objects--the so-called Dirichlet zero branes first discovered by J.Polchinski.

In collaboration with K. Becker, J. Polchinski and A. Tseytlin, I have shown that graviton scattering amplitudes of M-theory can be calculated in terms of this simple quantum mechanical model. Our calculation was done for up to two loop order in the gauge coupling constant and provided an important test of the Matrix model conjecture. In general, one will be able to compute quantum gravity corrections in M-theory by computing 1/N-corrections in the gauge theory, where N denotes the number of Dirichlet zero branes. Very little is known about such corrections at this point and only time and hard work will be able to provide the answer.

Matrix theory was the first example of a series of beautiful models where a duality between gauge theory and quantum gravity emerged. Recently it has been claimed that four-dimensional confining supersymmetric gauge theories can be described in the dual picture as a warped compactification of M-theory to four-dimensional Minkowski space.

The ultimate goal of this approach is to understand four-dimensional quantum gauge theories which have similar properties as QCD in terms of string theory with 1/N as the string coupling constant. The supergravity duals of four-dimensional confining gauge theories are severely restricted by supersymmetry as I have shown in a series of papers in collaboration with K. Becker. It shall be one of my goals for the near future to see if properties of the gauge theory, such as the glueball masses or Wilson loop correlation functions, can be determined from M-theory.

From a different perspective such warped compactifications of M-theory are of interest as these compactifications may provide a supersymmetric realization of the extra large dimension scenario that has been proposed by Randall and Sundrum.

There are many important problems that have to be solved, if we would like to apply string theory to describe our four-dimensional world. It is largely believed that the key to many of these problems may lie in a non-perturbative formulation such as M-theory.

M-theory provides a unified picture of the five existing consistent superstring theories that live in ten dimensions. Furthermore, it combines gravity with quantum mechanics and at the same time it has a structure that is rich enough to explain the symmetries appearing in the standard model. Given the extremely rapid development of this theory, we are rather optimistic that many of the problems of string theory will be soon understood and that M-theory will be able to explain the properties of the four-dimensional world in which we live.

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a university scholarship that pays undergraduate students to work for a summer on a research project. My project was to design and build an optically-pumped far-infrared laser for Dr. Drew's lab. To do so, I first had to learn about optically-pumped far-infrared lasers. Then I had to learn how to design and draw scientific apparatus using a CAD program. And finally, I had to design and draw the parts for the laser, see to it that they were manufactured according to specifications, and assemble the finished pieces.

Needless to say, this all ended up taking much more than a summer. Dr. Drew continued to finance the project through my senior year and into the summer following my graduation, when I finally completed assembling and began testing the laser. In the spring semester of my senior year, while I was still working on the laser for Dr. Drew, my astronomy major presented me with the opportunity to work at the Laboratory for High Energy Astrophysics (LHEA) at Goddard Space Flight Center (GSFC) on an independent research project.

For this project, I analyzed data from the Rossi X-ray Timing Explorer (RXTE) satellite to study a curious anomaly in the spectrum of a well known X-ray binary system called SS433. Even though I stayed on part time for the summer after my graduation, the results of this study were inconclusive. However much progress was made on the study and I anticipate my progress will be used in future explorations of this anomaly.

As I approached graduation, I was sure that I did not want to go to graduate school right away, so I started networking for a job. I found a few leads, one at the National Institute of Standards and Technology (NIST), one at Johns Hopkins University Applied Physics Lab (JHUAPL), one at the National Institute of Health (NIH), and one here in the physics department in the Laboratory for Gravitation. I took the job here at the university because of my interest in gravity research.

I work in **Dr. Ho Jung Paik's** Laboratory for Gravitation as a faculty research technician. My main job is to design, produce, and otherwise technically assist in the production of gravity experiments. I'm currently involved in two of the projects we have going on at the lab. My first priority is to design and produce a superconducting angular accelorometer that is to be used in an experiment that will search for evidence of a force called the spin-mass coupling force. For quite a while now, our understanding of the physical universe has led us to believe that there are four fundamental forces in nature which govern all physical processes in the universe; electromagnetism, gravity, the strong force, and the weak force. Modern physics has been able to show that the electromagnetic, strong, and weak forces are all related, however the gravitational force still remains a mystery. Recently, a theory known as String Theory has suggested that there might be a fifth force, a spin-mass coupling force, that would relate the electromagnetic force to gravity. Should this be true, we would be able to relate all of the forces in nature, arriving at a much better understanding of how the universe works, which is the ultimate goal of physics. What our accelorometer will do is try to detect this spin-mass coupling force. It will do this by setting up favorable conditions in which the spin-mass coupling force will be large enough to move a test body far enough so that the movement can be sensed using superconducting technology.

The other project that I work with is being conducted at Louisiana State University (LSU). I provide Superconducting QUantum Interference Device (SQUID) support for the bar gravity wave detector that is currently in operation down in Louisiana. SQUID sensors are basically very sensitive magnetic field detectors. They are used widely in research and development for very weak electromagnetic signal detection.

My job is to test and install the SQUID microchips on mounts that can be readily used by the gravity wave detector. I'm hoping to have two operational SQUIDs prepared for LSU's gravity wave detector and have the spin-mass accelorometer assembled before I leave in August to attend graduate school at Penn State University. I have recently been admitted into the Aerospace Engineering department there, where I will pursue my master's degree studying rocket propulsion.

I'm glad that I made my decision to work in gravity research because I see now that I would not want to spend my life doing this. My experience at the Laboratory for Gravitation allowed me to get a good glimpse of what that life would be like on a daily basis, and that made me rethink what I wanted to do with my life. I had wanted to be an experimental physicist and study gravity, but I've realized over the past several years that what I want to do is contribute to man's exploration of space. By experiencing a broad range of work in my undergraduate and post-undergraduate career, I've realized that my natural talent tends to lean more towards the engineering side of things, which is why I've chosen to pursue an engineering degree in graduate school. I appreciate the preparation I received in the physics department at Maryland and look forward to continuing to reap its benefits.

• See Keith's profile

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