



Mathematics
Department

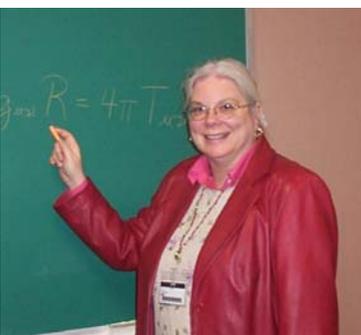
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Profile of the Month Prof. Deborah A. Konkowski

Deborah A. Konkowski is a Professor of Mathematics at USNA. Her research area is mathematical physics, primarily general relativity. Her research is focused on the nature of singularities in general relativistic spacetimes, spacetimes that model physical objects such as black holes and cosmic strings. She studies both classical and quantum singularities.

Recently, Prof. Konkowski has been studying the behavior of quantum mechanical particles in the vicinity of spacetime singularities. Traditionally singularities have been defined by the behavior of classical particles. Since there are no such particles, it is important to understand the nature of the singularities when real, quantum particles are used instead.



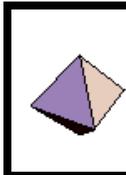
She collaborates on her research with Professor Thomas Helliwell at Harvey Mudd College. (Harvey Mudd is where Prof. Konkowski was an undergraduate student.) They like to include undergraduate students in their research projects. Some of these collaborations have resulted in published research articles. Two projects were done with undergraduates from Harvey Mudd and one with a midshipman, Cassidi Reese. This semester Prof. Konkowski has a Bowman Scholar, Midshipman Brian Ross, working with her on the classical and quantum singularities in the spacetime of a wiggly cosmic string.

Prof. Konkowski also likes to share her enthusiasm for Einstein's theory of general relativity with midshipmen by periodically offering a special topics course "Introduction to Mathematical General Relativity." Her students learn about special relativity and general relativity in this multimedia course. They learn about groups (the Lorentz transformations of special relativity form a group), tensors (these are generalizations of vectors), partial differential equations (the field equations of Einstein's general relativity are nonlinear partial differential equations), and the geometry and/or topology of the spacetimes. The course culminates with class projects where each student acts as a scientific detective and digs out the hidden structure (using techniques learned in the course) of an assigned spacetime metric.

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The symbol used on this current issue of Math News is one of the Platonic Solids. The Platonic solids, also called the regular solids or regular polyhedra, are convex polyhedra with equivalent faces composed of congruent convex regular polygons. There are exactly five such solids: the cube, dodecahedron, icosahedron, octahedron, and tetrahedron, as was proved by Euclid in the last proposition of the *Elements*. Ref. <http://mathworld.wolfram.com/PlatonicSolid.html> More on this in the next Math News Issue.



Math News

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Black Holes, Big Bangs and Cosmic Strings

By Prof. Konkowski General relativity is the best current description of the gravitational force, one of the four basic forces in nature. Einstein invented the theory of general relativity over a ten year period.

One hundred years ago Einstein, in 1905, put forth a revolutionary combination of time and space into a unified "space-time." This theory is called the special theory of relativity. It revolutionized our understanding of the physical world, an understanding in place since the time of Galileo and Newton.

Ten years later he revolutionized our understanding of gravity. In his theory of general relativity he described this force of nature in geometrical terms. No longer were we to think of the gravitational force between objects as some magical action at a distance, rather the gravitational force of an object could be thought of as the curvature of the space-time around the object, the space-time of special relativity. Einstein's theory is formulated as a set of partial differential equations. A differential equation is an equation

with derivatives in it and a partial differential equation has dependent variables that depend on more than one independent variable. The independent variables of relativity are just three spatial coordinates and one time coordinate. The dependent variables describe the curvature of space-time. When one solves Einstein's equations for a given situation, the result is a space-time "metric", a space-time distance relation. Everyone knows the Pythagorean relationship of $ds^2 = dx^2 + dy^2$ that gives the distance between two points on a flat two-dimensional plane; it is a "metric". In relativity a metric is generally four-dimensional and it describes a curved space-time.

All sorts of different objects with gravitational mass can be described by space-time metrics: planets, stars, black holes, cosmic strings, gravitational waves, and even models of the universe as a whole called cosmologies. The space-time metrics describe the curvature of the space-time, the gravitational effects of these objects.

Inside this issue:

Announcement for a terrific talk: Mathematics Department Midshipman-Faculty Colloquium, for a mathematically oriented general audience.

Black Holes, Big Bangs and Cosmic Strings

Mathematicians and physicists called relativists study the solutions of Einstein's equations. They look for new and different solutions. They study the mathematical and physical properties of the solutions. They look for singularities in the solutions – places where the solutions break down and no longer apply. They try to decide which mathematical solutions actually describe real physical objects as well as trying to derive solutions for known physical objects. Not all solutions to Einstein's equations are physically relevant. Let's consider several objects and their gravitational effects:

•*The Earth.* A daily reminder of the importance of relativity is the GPS navigational system. Without special and general relativistic corrections the accurate synchronization of the system would fail in less than a day.

•*Gravitational Waves.* Relativists predict that waves, similar to electromagnetic waves, are produced in gravitational interactions. Tantalizing indirect proof has been shown in a binary pulsar whose period is decreasing because of gravitational wave emission. Now, experimenters are trying for a direct detection using Michelson (!) interferometers in an experiment called LIGO (Laser Interferometer Gravitational (Wave) Observatory).

•*Black Holes.* Black holes are col-

lapsed stars so dense that even light cannot escape. The gravitational properties of these were predicted by relativists and have been observed by astronomers.

•*Big Bang Cosmologies.* Relativists have literally hundreds of different cosmological solutions that may describe the universe we live in. Astronomers are still matching the properties of our universe with the models and, thus far, the Big Bang models seem most promising.

•*Cosmic Strings.* Particle physicists predict that these very thin, limitless (infinitely long or loop-like) objects exist as relics from the early universe. Relativists have written space-time metrics to model the gravitational effects of these cosmic strings. Now, everyone is waiting to see if astronomers actually "see" cosmic strings through their gravitational signature.

To end one would be amiss to not mention the current research among mathematicians and physicists to improve, or even supplant, general relativity with a better theory, a theory that would naturally incorporate quantum mechanics, the other great invention of the 20th century. Many theories including string theory have been proposed. Only time will tell the outcome.

What is now proved was *once* only imagin'd.
WILLIAM BLAKE

Escher Math

The Mathematics Department Midshipman-Faculty Colloquium: Prof Doris Schattschneider will speak on "Ingenious mathematical amateurs: M.C. Escher (artist) and Marjorie Rice (homemaker)" at 1900 in Rickover 102 on Thursday February 3rd, 2005.

Jet Math

Excerpted from link (also on USNA sports site) on the upcoming Navy football bowl game in San Francisco: " ... Also, four F/A 18 Superhornet jets from Lemoore Naval Station near Fresno will do a flyover before the game. Sitting in the cockpit of one jet will be Brian Broadwater, Navy's quarterback in 1999. ..." Broadwater was a math major (Class of 01).

Athletic Math

Also, last month 3/c Mathematics Major Joshua Faucett ran the JFK 50-miler in just over 7 hrs, helping the Naval Academy team win the all-military trophy, in a major upset of the All-Marine team. Just a few weeks earlier he'd run the Marine Corps marathon in well under 3 hrs.

Psycho Math

A guy gets on a bus and starts threatening everybody: "I'll integrate you! I'll differentiate you!!!" So everybody gets scared and runs away. Only one person stays. The guy comes up to him and says: "Aren't you scared, I'll integrate you, I'll differentiate you!!!" And the other guy says: "No, I am not scared, I am **e to the power of x.**"

Almost Math

There are three kinds of people in the world: those who can count and those who can't.

Question of the Month

"Life is complex. It has real and imaginary components." - Tom Potter

What is the greatest prime such that 7 times the prime is less than 1000? E-mail your answer to Prof. Garcia smg@usna.edu. Among those with the right answer, a randomly chosen midshipman will get a fantastic math water bottle.

Answers for last issue puzzles: The father is 49, the wife is 36, the daughter 13, and the son is 9. MIDN 4/C Frank Sisto and MIDN 4/C Joseph A Murphy are last month's winners. By the way, an eightpenny nail is 2 and a half inches.