INTER ACTIONS

DEPARTMENT OF PHYSICS 2009

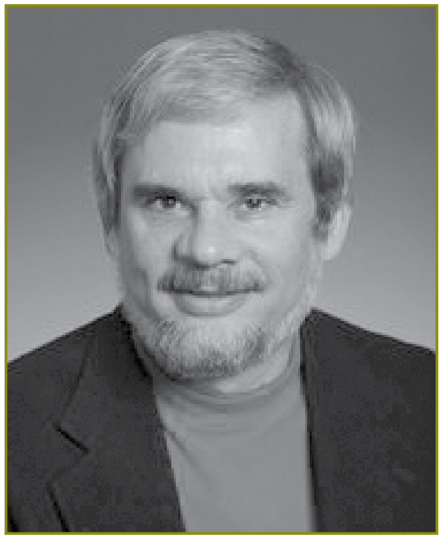
Physics
Carnegie Mellon

New Department Head, New Faculty, New Web Site, and More

Since the last edition of Interactions, Fred Gilman has become Dean of the Mellon College of Science and I took his place as the Head of the Department of Physics. In spite of the current challenging economic conditions, the department continues to benefit from the momentum established during Fred's nine years of leadership as department head.

Our Biological Physics Initiative evolved from concept to reality as we hired four new faculty members in this area over the past four years. These new colleagues have joined up with members of our condensed matter group to build a thriving community that is attracting both undergraduate and graduate students. They've also attracted funding from the National Institutes of Health, the National Science Foundation, and the American Health Assistance Foundation. New courses have been created that cut across department boundaries. It's exciting to see this research thrust reach maturity. You can read about the research of our most recent hire, Dr. Alex Evilevitch, in the article he wrote for this edition of *Interactions*, "Physical Virology: Matching Genome Length and Virus Size".

During the preparation for our 2007 advisory board review, the department developed a proposal to expand our existing astrophysics program. This proposal was endorsed by the board and has morphed into the Bruce and Astrid McWilliams Center for Cosmology.



Gregg Franklin

The Center joins research efforts in astrophysics and particle physics and partners with computer science, statistics, and other disciplines. Come visit us and you'll see that the eighth floor of Wean Hall has been transformed with carpeting on the floors, new lighting in the ceiling, and flat screen monitors on the walls. There are a few less cinder blocks in Wean Hall; a wall was removed to create an open interaction area with comfortable chairs, white boards, and, of course, a coffee machine. But it is the people that really count. We're pleased that Dr. Hy Trac will soon be joining us as a new assistant professor. Dr. Trac is currently a postdoctoral fellow at the Harvard-Smithsonian Center for Astrophysics and is known for his use of numerical simulations to study the role of dark matter in the early universe. The Center's search committee is aggressively interviewing candidates to fill two new physics department faculty positions. In addition, Drs. Dan Whalen and Aravind Natarajan are joining us as the first McWilliams Postdoctoral Fellows. The formation and rapid growth of the Center has been made possible by the much appreciated support of Bruce and Astrid McWilliams and a strong commitment from the Carnegie Mellon administration.

You can learn more about our Biological Physics group and our Cosmology Initiative by exploring our new Web site, www.cmu.edu/physics.

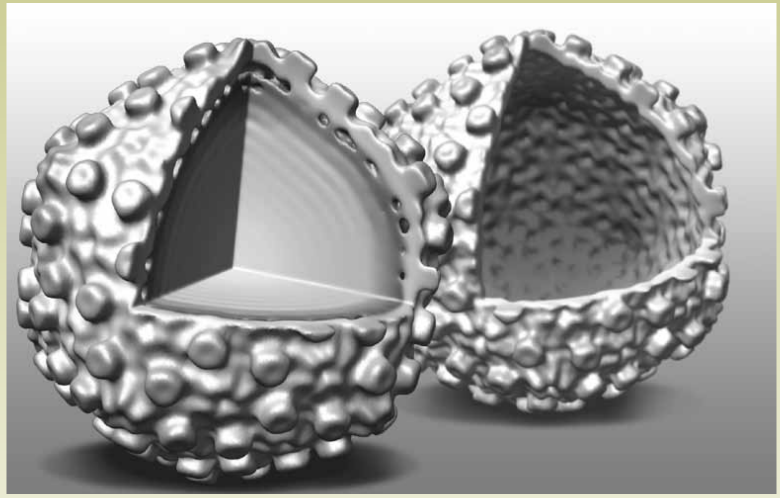
You can learn more about our Biological Physics group and our Cosmology Initiative by exploring our new Web site, www.cmu.edu/physics. Just click on "Research" and follow the links to see what our research groups are doing. We've updated our photos, so if you click on "People", you might find that some of our faculty members have aged a bit (not me, though).

Our undergraduate program continues to thrive under the direction of Profs. Steve Garoff and Kunal Ghosh with typical class sizes of 30 and more. A recent American Institute of Physics report summarizing graduation statistics showed that, out of 762 physics degree granting institutions, only 17 departments conferred more bachelor degrees in physics than our department

(Continued on page 4)

Physical Virology: Matching Genome Length and Virus Size

Viruses are simple lifeless entities that cannot reproduce on their own and therefore depend on host cells to provide them with the necessary life support mechanisms. Simplified, all viruses consist of a protein shell (capsid) that protects the viral genome (DNA or RNA). To infect, the viral genome must enter the cell, where it hijacks the host cell's machinery and synthesizes multiple copies of virions. This can lead to cell lysis, which is a lethal event.



Cryo electron microscopy single particle reconstruction of bacteriophage lambda with and without DNA.

Viruses present a major threat to human health and welfare. The extent of this threat becomes obvious if one considers the morbidity and mortality caused by the human immunodeficiency virus (HIV), hepatitis virus, influenza as well as threats from severe acute respiratory syndrome (SARS), avian influenza virus (H5N1), and swine influenza (H1N1). Aside from vaccination, current anti-viral strategies either target the receptors through which viruses enter host cells, or target specific enzymes that are critical to viral replication. The main limitation of these kinds of anti-viral agents is that they are highly 'specialized', as they target specific events in individual viruses' life-cycles. Thus, their use is limited to a specific virus or a small group of viruses. Furthermore, viruses frequently undergo mutations that alter the target sites. Therefore, there is a growing need to develop less specialized viral intervention strategies that will enable targeting a broad range of viruses with little susceptibility to mutation. For instance, drugs that directly interfere with the assembly of the viral capsid and/or packaging of the viral DNA into the capsid could provide a "broad spectrum" anti-viral agent.

Alex Evilevitch, who joined the Department of Physics' Biological Physics' team in June 2009, leads a Physical Virology group. It is a rather new field that seeks to define the physical mechanisms controlling virus development. This knowledge can provide information essential to the rational design of new anti-viral strategies with less specificity for a limited number of viruses. Furthermore, biological and physical simplicity relative to other biological systems have made viruses an attractive physical model system to study fundamental properties of DNA compaction and translocation as well as protein self-assembly using viral capsids.

Pressurized Viruses

The majority of viruses possess spherical, icosahedral protein capsids with radii varying between 10 and 100 nm and with thicknesses of few nm corresponding to single protein layer. Viral capsids contain genomes that are tens of microns in contour length. Sufficient genome encapsidation implies that the virus must be stable enough to withstand internal forces exerted by its packaged genome and external forces from its environment. Yet, it must be unstable enough to rapidly release its genome in the cell during infection. Thus, there must exist a unique match between a virus' genome length and capsid size and strength that is adjusted to the biological and physical properties of the host cell. Evilevitch's research group investigates fundamental physical principles that control viral encapsidation and genome release.

The future challenges for physical virology will be to develop systematic biophysical studies that will test and verify analytical and numerical models for capsid assembly, structure, stability, and function.

Bacterial viruses (phage) provide ideal experimental systems to define the correlation between genome and capsid dimensions since they can be genetically modified and assembled both in vivo and in vitro to form mutants with varying capsid size as well as packaged DNA length. Consider, for example, the case of phage lambda, one of the most thoroughly investigated bacterial viruses. Its genome is a single molecule of double-stranded (ds) DNA, with a length of 48,500 base pairs, i.e., about 17,000 nm in contour length. The volume associated with packing this amount of DNA at crystalline density is significantly larger than the volume available inside the viral capsid, whose dimension (radius) is only about 30 nm. This results in small spacings between DNA strands, corresponding to strongly repulsive interactions between neighboring portions of DNA, and implies, in turn, a high degree of stress inside the capsid. One measure of this overall stress is the average pressure exerted on the inside walls of the capsid by the confined DNA. It is precisely this pressure that is responsible for inserting the genome into the host bacterial cell. Evilevitch and co-workers have discovered a way to determine this pressure and found that in one phage lambda capsid it is 40 atm, a pressure equivalent to that at a depth of 1200 ft. in the ocean. The studies illustrate key physical requirements for viral infectivity. Internal genome pressure is required for phage and many other dsDNA viruses (e.g. Human Herpes Simplex Virus) to be able to infect by passive ejection of its genome.

Mechanical Properties of Viral Shells

Survival success of viruses hinges in their ability to take control over hosts' cellular machineries and to withstand physical conditions to which they are exposed. The latter is critically dependent on factors such as genome density and capsid strength. Atomic Force Microscopy (AFM) nanoindentation studies of viral capsids conducted in the group, reveal unique mechanical properties for different classes of viruses, which can in turn be directly related to a virion's life cycle. The AFM tip can apply force on a single viral particle in order to obtain real-time, force-distance curves, as the nanometer size tip of the cantilever scans the specimen surface. With the help of AFM, one can learn whether capsid strength limits the extent to which viral shell can be pressurized, which must in turn be correlated with the maximum force that a DNA packaging motor can exert. Based on these studies, Evilevitch proposed an evolutionary energy optimization that determines the genome length of wild type DNA viruses, since they can survive twice the external mechanical stress compared to their shorter genome mutants.

The future challenges for physical virology will be to develop systematic biophysical studies that will test and verify analytical and numerical models for capsid assembly, structure, stability, and function. Further, these studies must be extended to the eukaryotic dsDNA viruses, the physical dimensions of which suggest that genome pressure is also a crucial factor for their development. This research will be conducted in close collaboration between the group at CMU and the University of Pittsburgh Medical School.

2008-09 Faculty News Briefs

Luc Berger's 1986 Prediction Confirmed by Recent Experiment

Luc Berger

Twenty-three years ago Carnegie Mellon physics professor Luc Berger published a paper in *Physical Review B* about domain walls in magnetic materials. In it, he proposed that a continuous rotation of the magnetic moment of the wall would cause a DC voltage to appear across the thickness of the wall. Remarkably, despite the complexity of such a system, the ratio of voltage to rate of rotation was predicted to be simply the ratio of two fundamental constants of physics, h/e: Planck's constant over the electron charge. Recent experiments by Yang et al., at the University of Texas, Austin, have now verified Berger's 1986 prediction. The sample is an iron-nickel nanowire. The measured voltage across a wall in the nanowire is found to agree within 10% with the expected value. This work appeared in the February 13, 2009 issue of *Physical Review Letters*. Bryan Josephson shared the 1973 Nobel Prize in physics for his 1962 prediction of a voltage in superconducting junctions, which obeys a mathematically similar relation. But Berger's effect involves a different kind of physics, based on electron spin, rather than charge. This is a fast-growing field, called spintronics.

More Faculty News:

- Roy Briere was named the APS Outstanding Referee for 2009
- Tiziana Di Matteo received the 2008 Carnegie Science Center Award of Excellence (Emerging Female Scientist)
- Sara Majetich was honored as Distinguished Lecturer by the University of Toronto, Department of Electrical and Computer Engineering
- Curtis Meyer received the 2008 William H. and Frances S. Ryan Award for Meritorious Teaching
- Ira Rothstein was named a Fellow of the American Physical Society
- Michael Widom was named a Fellow of the American Association for the Advancement of Science

Alumnus Jared Rinehimer Shares Thoughts on Switch From Physics to Law School

Jared Rinehimer

When I first discussed with anyone the possibility of attending law school, I almost invariably received one response: "Why would you want to do that?" Most continued by questioning why I would make such a large jump to what they considered a grossly different field. Naturally, I began to wonder if these topics were really as far off as the students I had consulted in both fields would have led me to believe.

In science, we prize our commitment to logical thought, peer scrutiny, and the power of observation and evidence. It is not a stretch to admit that law also values these principles. The Law School Admission Test, for instance, is an examination centered on logic, with a considerable portion of the exam consisting of logic puzzles and examining the validity of arguments. Scrutiny exists in the modern day appeals process. Evidence and observation are important in many litigations and criminal cases. Even one of the pioneers of the case law teaching method, Christopher Columbus Langdell, professed that law should be treated as a "science".

Personally, I believe a science education (and especially one at an institution such as Carnegie Mellon) is a very effective preparation for a legal career. Besides the stated similarities above, there is a manner of thinking that is learned through the course of a scientific education which is broadly applicable. Many students seem to begin schooling by only wanting to know the answers. Their only drive is to understand enough to answer the specific problem at hand, get the answer correct, and move on. It is difficult for many science students to progress significantly in their programs without crossing this barrier. While knowledge is certainly important, what helps often is the ability to generalize and reason so as to solve new problems and modify existing methods. Mathematical reasoning with consistent definitions enables scientists to use clear communicative methods to describe what they mean, and also gives a realm for which to build up abilities for complex logical thought. In both undergraduate and graduate school, many of the physics students are often wrong, be it on homework sets, exams, or just thoughts about course material. This enables us to work together and look past our own egos, and to realize that complete understanding is more important than initial reaction. All of these traits are valuable anywhere, and are particularly valuable in a legal setting.

This isn't to say that all scientists should be going to law school. Nor is it true that no other field adequately prepares students for law. What does seem clear is that the two fields are not as far from each other as many would like to believe. It should not be, and is not, mutually exclusive for one to be both a scientist and a lawyer. I am certainly not the first from Carnegie Mellon to think of this (see www.cmu.edu/mcs/magazine/pdf/SC-v1n1-web2.pdf, pp. 18), and I certainly won't be the last. I am thoroughly grateful that I am lucky to attend schools where advisers and mentors have realized this fact long before I did.

Jared Rinehimer graduated in 2007 with a B.S. in physics, and was the 2007 recipient of the Richard E. Cutkosky Award. He is currently working on his Ph.D. in physics at the University of Washington. He has been accepted to Harvard Law School.

New Department Head

(Continued from page 1)

in 2008. I believe our ability to attract students into our program is directly linked to the quality of our program. While our courses continue to serve as the foundation of our undergraduate education, we believe meta-curricular activities are an integral part of the undergraduate experience. Department sponsored activities include social and academic events such as banquets, barbeques, and an annual poster session. Our students are also active in our Physics Students Advisory Council (SAC), the Society of Physics Students (SPS), the Carnegie Mellon Rocket Command, the Physics and Philosophy Club, and the Astronomy Club. Many of our students also participate in Carnegie Mellon's Student Pugwash. I understand that there are also non-department sponsored events organized by the students, such as Physics Phi days. (You may remember the Panther Hollow Inn located down Forbes Avenue.) Most of our students also find time to participate in undergraduate research; approximately 90% of our students have research or internship experience by the time they graduate.

I'll confess that we're hoping that this *Interactions* newsletter will arouse your curiosity and motivate you to visit our Web site at www.cmu.edu/physics. Even better, stop by to visit us if you can or send us email at physics@andrew.cmu.edu.

Logo design by physics graduate student Chip Hogg

Degrees Granted in 2008

Doctor of Philosophy in Physics

Dec-07

Alexander Fore
Zebulun Krahn
Shu Nie
Michael Williams

May-08

Kwangzoo Chung
Sandeep Gaan
Seamus Riordan
Vladimir Stojanovic

Aug-08

Michael McCracken

Master of Science in Physics

May-08

Bora Akgun
Tristan Bereau
Ryan Booth
Chien-Yi Chen
Eric Evarts
Haw Zan Goh
Yueh-Feng Liu
Duff Neill
Siddharth Shenoy
Nishtha Srivastava

Bachelor of Arts in Physics

Dec-07

Oliver Han

Bachelor of Science in Physics

Dec-07

Noel Berman
Joseph Slade IV

May-08

Stephen Brunner
Christopher Brust
Daniel Carmody
Jonathan Eckel
Kate Eckerle
Jerome McHale
Federico Pineda
Jonathan Stahlman
Brian Tice
Holt Wilkins

Aug-08

Justin Pye

Bachelor of Science in Physics with an additional major in Computer Science

Dec-07

Levi Boyles

Bachelor of Science in Physics with an additional major in Statistics

May-08

Gregory Hallenbeck

Bachelor of Science in Physics with an additional major in International Relations

May-08

Alexander Rutgers

Bachelor of Science in Physics with a minor in Computer Science

May-08

Nicholas Dobbs

Bachelor of Science in Physics with a minor in Engineering Studies

May-08

Gregory Zborowski

Bachelor of Science in Physics with minors in Engineering Studies and Biomedical Engineering

May-08

Heeyong Kang

Bachelor of Science in Physics with a minor in French and Francophone Studies

May-08

Seda Avetisian

Bachelor of Science in Physics with minors in German and Mathematical Sciences

May-08

Nathan Morrison

Bachelor of Science in Physics with a minor in Mathematical Sciences

May-08

Gregory Peim
Joshua Schiffrin

Bachelor of Science in Physics with a minor in Psychology

May-08

Christof Schoenborn

Bachelor of Science in Physics with an Astrophysics track

May-08

Joshua Ilany
Stephen Schweizer
Anja Weyant

Bachelor of Science in Physics with an Astrophysics track with a minor in French and Francophone Studies

May-08

Hayley Finley

Bachelor of Science in Physics with a Biological Physics track

May-08

Laurel Farmer

Bachelor of Science in Physics with a Computational Physics track

May-08

David Huston
Garrett Mitchell

Double Degree

Bachelor of Science in Electrical and Computer Engineering and Bachelor of Science in Physics

May-08

Ryan Comes

Bachelor of Science in Computer Science and Bachelor of Science in Physics

May-08

Kevin Costello

Bachelor of Science in Physics and Bachelor of Science in Mathematical Sciences (Mathematics)

May-08

Antonio Russo

Aug-08

David Baker

Bachelor of Science in Physics and Bachelor of Arts in Japanese

May-08

Dorothy Holland-Minkley

Minor in Physics

Dec-07

Yan Yin Ho
Evan Hoke
Jeffrey Jagoda
Daniel Pencoske

May-08

Joseph Arizpe
John Bauman
Samuel Burnett
Jason Cohen
Kyle Comer
Mizel Kjukic
Jeffrey Grafton
Carl Lecompte
Justin Li
Paul McKenney
Helder Roche
Martin Rosenberg
Michael Sanphy
Samantha Spath

Aug-08

Joshua Godick

Degrees Granted in 2008 Continued

Honors

Noel Berman
College Honors

Stephen Brunner
University Honors
College Honors

Daniel Carmody
University Honors
College Honors
Phi Kappa Phi
Phi Beta Kappa

Ryan Comes
University Honors
College Honors
Phi Beta Kappa

Kevin Costello
University Honors

Kate Eckerle
University Honors
Phi Kappa Phi
Phi Beta Kappa

Laurel Farmer
University Honors

Hayley Finley
College Honors

Gregory Hallenbeck
University Honors
Phi Beta Kappa

Dorothy Holland-Minkley
University Honors
Phi Beta Kappa

Nathan Morrison
University Honors
College Honors
Phi Kappa Phi
Phi Beta Kappa

Federico Pineda
University Honors
College Honors

Antonio Russo
University Honors
College Honors
Phi Kappa Phi
Phi Beta Kappa

Joshua Schiffrin
University Honors
Phi Kappa Phi
Phi Beta Kappa

Jonathan Stahlman
University Honors
College Honors
Phi Beta Kappa

Brian George Tice
University Honors
College Honors

Anja Weyant
University Honors
College Honors

Holt Wilkins
College Honors

Richard E. Cutkosky Award
Jonathan Stahlman

Degrees Granted in 2009

Doctor of Philosophy in Physics
Aug-09
Gabriel Altay
Haijun Gong
Jianjun Pan
Yuli Wei

Master of Science in Physics
May-08
Christopher Brust
Colin Degraf
Megan Friend
Qi Fu
Weihua Hu
Chang-You Lin
Jonathan Lind
Samuel Rauhala
Xi Tan
Chik Him Wong
Cem Yolcu

Bachelor of Science in Physics
May-09
Ian Anderson
Kara Berke
Kevin Cleary
Harry Frank
Stephen Head
Aaron Hernley
Avishek Kumar
Brian Mason
Kenji Oman
Cara Palermo
David Stone

Aug-09
Henry Ermer
Sibel Guler

Bachelor of Science in Physics with an additional major in Computer Science
May-09
Michael Rosenman

Bachelor of Science in Physics with an additional major in Philosophy
May-09
Brian Pollack

Bachelor of Science in Physics with an additional major in Professional Writing
May-09
Jun Xian Leong

Bachelor of Science in Physics with a minor in Chemistry
May-09
Eumbeom Kim

Bachelor of Science in Physics with a minor in Mathematical Sciences
May-09
Kelly Duncan

Aug-09
Omar Shams

Bachelor of Science in Physics with an Astrophysics track
May-09
Blake Coughenour
Derrick McKee

Bachelor of Science in Physics with an Astrophysics track with an additional major in Statistics
May-09
Rebecca Reesman

Bachelor of Science in Physics with an Astrophysics track with a minor in Mathematical Sciences
May-09
Fiona Ding

Bachelor of Science in Physics with a Biological Physics track
May-09
Henry Wladkowski III

Bachelor of Science and Arts in Physics and Drama
May-09
Tamar Shavit

Degrees Granted in 2009 Continued

Bachelor of Science in Electrical and Computer Engineering with an additional major in Physics

May-09

Thomas Bolds

Bachelor of Arts in Philosophy with an additional major in Physics

May-09

Michael Whiston

Bachelor of Science in Physical Sciences (Student Defined Major) with a minor in Physics

Dec-08

Shawn Knight

Bachelor of Science in Applied Computational Science (Student Defined Major)

May-09

Christopher Eldred

Double Degree

Bachelor of Science in Computer Science and Bachelor of Science in Physics

May-09

Alan Lundin

Bachelor of Science in Physics with a Computational Physics track and Bachelor of Science in Computer Science with a minor in Mathematical Sciences

Dec-08

Keehwan Park

Minor in Physics

Dec-08

Alexandra Beck
Howard Kim
Shawn Knight
Randyka Pudjoprawoto

May-09

Nicola Alfeo
John Bauman
Jonathan Coens
Brian Coltin
Debtirtho Ghosh
Sam Kaplan
Kevin Lin
Anna Olson
Nicholas Roche
Carolyn Sawyer
Jocelyn Sunseri
Alex Volkovitsky
Charles Wesley

Honors

Ian Anderson
University Honors

David Baker
University Honors

Fiona Ding
Sigma Xi

Christopher Eldred
University Honors
College Honors
Phi Kappa Phi
Phi Beta Kappa

Avishek Kumar
College Honors
Sigma Xi

Brian Pollack
University Honors

Alan Lundin
University Honors

Rebecca Reesman
College Honors
ACS Scholar

Michael Rosenman
University Honors
College Honors
Phi Kappa Phi
Phi Beta Kappa
Sigma Xi

Tamar Shavit
University Honors

David Stone
University Honors
College Honors

Michael Whiston
University Honors
College Honors
Phi Beta Kappa
Sigma Xi
ACS Scholar

Richard E. Cutkosky Award

Michael Rosenman

Tell us about yourself!

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Department of Physics
Carnegie Mellon University
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INTERACTIONS

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Produced by the Communications Design Group and the Physics Department, December 2009, 10-264.