

New Faculty

(JULY 2005)

Jan Egedal-Pedersen

*Assistant Professor of Physics, Division of Atomic, Biological, Condensed Matter
& Plasma Physics*

RESEARCH INTERESTS

Plasmas—the ionized gas in lightning bolts, tube lights, and most of interstellar space—are excellent conductors of electrical currents. Plasmas interact strongly with electric and magnetic fields and are generally “frozen” to magnetic field lines. However, the plasma can occasionally and rapidly break free and allow the magnetic field to change topology. This process is called magnetic reconnection and occurs in such diverse environments as the sun, the Earth’s magnetotail, and in magnetic fusion devices. As examples, magnetic reconnection is responsible for coronal mass ejections (the most powerful explosions in our solar system) and the aurora borealis. An outstanding problem in reconnection theory is the discrepancy between the theoretical time scale predicted for magnetic reconnection and the much shorter observed time scale.



The physics of magnetic reconnection has been studied analytically and numerically for the past five decades. Although significant progress has been obtained, the equations governing the plasma behavior are so complex that experimental data is required to determine the circumstance under which the often competing mechanisms dominate the physics. Professor Egedal’s research group is providing direct experimental observation of the reconnection dynamics inside the Versatile Toroidal Facility (VTF), which is a large basic plasma physics device located at the Plasma Science and Fusion Center at MIT. This ongoing research has led to the discovery of a new paradigm for reconnection where the process is catalyzed by the properties of the individual electron trajectories. This new theory is now successfully applied to the interpretation of *in situ* measurements of reconnection obtained by spacecrafts in the Earth’s magnetotail.

BIOGRAPHICAL SKETCH

Jan Egedal-Pedersen obtained his Master of Science from the Technical University of Denmark in 1994. He then attended Oxford University, where his Ph.D. research concentrated on the properties and measurements of fast ions in the

world's largest nuclear fusion experiment, JET (Joint European Torus). During this period he was supported as a Madam Curie Fellow under the European Human Mobility Program. In 1998, Egedal-Pedersen became a Post-doctoral Fellow at the Plasma Science and Fusion Center at MIT. In 2000, he was promoted to Research Scientist, managing the VTF research program on magnetic reconnection.

For a list of Prof. Egedal's selected publications, please visit his faculty web page at web.mit.edu/physics/facultyandstaff/index.html.

Joseph A. Formaggio

Assistant Professor of Physics, Division of Experimental Nuclear & Particle Physics

RESEARCH INTERESTS

An astonishing culmination of discoveries taking place over the last decade has led to a revolution in our understanding of neutrinos—one of nature's most elusive particles. Whereas just ten years ago it was commonly accepted that

neutrinos were massless particles, a number of key experiments have shown that concept was incorrect. Experiments studying neutrinos from atmospheric, solar, and reactor sources have shown conclusively that neutrinos change flavor and, as a consequence, have a very small but finite mass. This serves to remind us that the Standard Model of nuclear and particle physics is incomplete. Knowledge of the neutrino mass can provide direction as how to extend that model.

Professor Formaggio's research is focused upon exploring the properties of neutrinos through three areas of experimental research:

- **SNO:** Located in a nickel mine deep underneath the Northern Ontario soil, the Sudbury Neutrino Observatory (SNO) has been studying neutrinos produced in the solar core. In 2001, SNO helped solve the so-called "solar neutrino problem," by proving that neutrinos produced in the solar core undergo flavor transformation, a unique signature of neutrinos possessing a finite mass. The SNO continues to accumulate data to this day and to make important contributions to our understanding of neutrinos and solar physics.
- **KATRIN:** The scale of neutrino masses still remains an open question that is of great importance for many areas of physics, including particle physics and cosmology. A direct measurement of the neutrino mass would therefore provide independent and valuable input to our understanding of the universe and how it evolves over time. Formaggio is currently involved in the



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construction of KATRIN, a next-generation tritium beta decay experiment geared at directly measuring the neutrino mass down to fractions of an electron volts.

- Braidwood: Studying how neutrinos of a certain species can transform into other types of neutrinos—a phenomenon known as neutrino oscillations—can provide a unique window into understanding why the universe we live in today is dominated by matter. Formaggio is also involved in the design of the Braidwood experiment, which uses neutrinos created in reactor cores to make high-precision measurements of neutrino oscillations.

BIOGRAPHICAL SKETCH

Joseph Formaggio received his B.S. in physics at Yale University in 1996. Thereafter, he received his Ph.D. in physics from Columbia University, where he did his dissertation on neutrino physics by analyzing data taken at the NuTeV experiment located at the Fermi National Laboratory. His research focused on searches for exotic particles predicted by certain theoretical extensions of the Standard Model of particle physics. In 2001, he joined the SNO as a postdoctoral fellow at the University of Washington, where he was later appointed to research assistant professor. Formaggio lives with his wife, Jaymi, and his two children, Joshua and Coby.

For a list of Prof. Formaggio's selected publications, please visit his faculty web page at web.mit.edu/physics/facultyandstaff/index.html.

Steven Nahn

Assistant Professor of Physics, Division of Experimental Nuclear & Particle Physics

RESEARCH INTERESTS

Professor Steven Nahn is pursuing the understanding of the fundamental building blocks of nature and how they interact. The theory of how quarks and leptons behave is called the Standard Model for good reason, having been thoroughly confirmed in the last 30 years of experimentation in high energy physics. However, there are still fundamental questions yet to be answered, such as:

- What is the origin of mass, and what is responsible for the differences in the masses of the quarks and leptons?
- What is behind the observed asymmetry between matter and antimatter in the universe?
- What is the nature of this dark matter and dark energy which pervade our universe, yet have not been directly observed?

These “big questions” underlie the experiments Nahn has partaken in, studying the physics of W and Z bosons with the L3 experiment at CERN and the bottom quark at the CDF (Collider Detector at Fermilab) experiment.

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His current focus is the CMS (Compact Muon Solenoid) experiment at CERN, which is particularly interesting as it will cross a new threshold in collision energy, opening a new window on particle physics. Combining precision experimental data with the latest theory indicates that the collision energy at CERN’s Large Hadron Collider (LHC), where CMS operates, will be sufficient to expose predicted but not yet observed particles—some incorporated within the framework of the Standard Model and others which extend the theory past its current bounds. As such, the LHC represents a watershed in particle physics, where the theoretical understanding of “how the world works” will be sharpened by experiment, whether or not new particles are actually observed.

BIOGRAPHICAL SKETCH

Steve Nahn was born on October 24th, 1968, in Trier, Germany, and grew up as the seventh of eight children in Madison, Wisconsin. He received a B.S. in physics with Honors and math from the University of Wisconsin. From there, he attended graduate school at MIT, working with Professors Becker, Fisher, and Ting on the L3 experiment at CERN, eventually receiving his Ph.D. for the analysis of W Boson Pair Production. For several years prior to his return to MIT, Nahn was a research scientist at Yale University, overseeing the data acquisition and operation of the world’s largest operating silicon detector, while studying the properties of the bottom quark as a member of the CDF Collaboration. Nahn is married and has two children.

For a list of Prof. Nahn’s selected publications, please visit his faculty web page at web.mit.edu/physics/facultyandstaff/index.html.

Marin Soljačić

*Assistant Professor of Physics, Division of Atomic, Biological, Condensed Matter
& Plasma Physics*

RESEARCH INTERESTS

Technological advances of the past decade have enabled the control of the material structure at length-scales smaller than the wavelength of light. This enabled the creation of new materials, *e.g.*, photonic bandgap crystals, or various surface plasmon systems, whose optical properties are dramatically different than those of any naturally occurring material. For example, nanostructured materials which display diffraction-less propagation of light, exhibit negative refraction, or support very slow propagation of light, have all been demonstrated. Professor Soljačić's interests are in exploring the new and exciting physical phenomena supported by these materials. The unique properties of these new materials have already enabled a wide range of very important applications, *e.g.*, in medicine, telecommunications, defense, etc., and are expected to do so even more in the future.



Professor Soljačić is also interested in various topics in nonlinear optical physics. Maxwell's equations as presented in most undergraduate text books are linear. However, all materials in nature are nonlinear (including vacuum), and sure enough, at high light intensities, optical phenomena become nonlinear, displaying a wide range of rich and beautiful behavior. For example, almost every general non-linear dynamics phenomenon, *e.g.*, solitons, pattern formation, fractals, etc., can now be studied in optical material systems.

BIOGRAPHICAL SKETCH

Marin Soljačić received his Bs.E. degree in physics and electrical engineering from MIT in 1996, and earned his Ph.D. in physics at Princeton University in 2000. In September 2000, he was named an MIT Pappalardo Fellow in Physics, and in 2003 was appointed a Principal Research Scientist in the Research Laboratory of Electronics at MIT. He is the recipient of the 2005 Adolph Lomb medal from the Optical Society of America.

For a list of Prof. Soljačić's selected publications, please visit his faculty web page at web.mit.edu/physics/facultyandstaff/index.html.

Enectalí (“Tali”) Figueroa-Feliciano

Assistant Professor of Physics, Division of Astrophysics

RESEARCH INTERESTS

Professor Figueroa’s research interests revolve around the development of high-energy-resolution imaging spectrometers for ground and space-borne applications in experimental astrophysics and cosmology.

Cryogenic thermal detectors (bolometers and microcalorimeters) are broadband, non-dispersive, highly sensitive detectors that are being developed for astronomical observations from the microwave to the gamma-ray bands. The science targets for these detectors include (among others): the Cosmic Microwave Background (CMB) polarization, the Sunyaev-Zeldovich effect of clusters of galaxies on the CMB, mapping of molecular and dust clouds, timing studies of pulsars, understanding the environment near the event horizon of black holes, and tracing the elemental abundances and velocity structure of supernovae remnants, galaxies, and clusters. They also have many applications outside astrophysics, including materials analysis, quantum cryptography, and security/defense.

Professor Figueroa pioneered the development of position-sensitive detectors that will provide an order of magnitude more pixels (and thus larger field of view) than traditional single-pixel X-ray microcalorimeters. His broader interests include cosmology, clusters of galaxies, dark matter detection, superconductivity and the study of phase transitions, phonon propagation modes in thin films, quantum electronics, and building spaceflight hardware.



H. Williams

BIOGRAPHICAL SKETCH

Enectalí Figueroa-Feliciano received a B.S. degree in mechanical engineering from the University of Puerto Rico at Mayagüez in 1995. He earned his M.S. and Ph.D. in physics at Stanford University, working with Professors Blas Cabrera and Arthur B. C. Walker. Upon graduation from Stanford in 2001, he became an astrophysicist at the NASA Goddard Space Flight Center. He is the microcalorimeter lead for the Generation-X Vision Mission, a member of the Constellation-X facility science team, Suzaku Observatory science working group, and X-ray Quantum Calorimeter (XQC) sounding rocket team. He has received several NASA awards for the development and demonstration of position-sensitive X-ray microcalorimeters. He joined the physics faculty at MIT in January 2006.

For a list of Prof. Figueroa’s selected publications, please visit his faculty web page at web.mit.edu/physics/facultyandstaff/index.html.

Joshua Winn

Assistant Professor of Physics, Division of Astrophysics

RESEARCH INTERESTS

Planet formation is a venerable physics problem, dating back to Kant and Laplace, who argued that the solar system formed from a spinning disk of gas and dust. Yet it was only in 1995 that astronomers began finding planets around other Sun-like stars (“extrasolar planets”). At last, it has become possible to learn whether our solar system is typical, or unusual, in the context of our entire galaxy.



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This topic is interesting on many levels. As a physicist, one wants to understand how matter accumulates into planets, and what is the full range of possible outcomes. Some of the newfound planetary systems have striking unanticipated properties: planets on very eccentric orbits, and giant planets hugging their stars much closer than Mercury does the Sun. From a technological point of view, planet detection is a chal-

lenging problem that motivates fascinating and ambitious solutions. And finally, it would be wonderful to make even slight progress on the age-old question of whether there are other planets capable of supporting life.

Professor Winn’s research involves observations of young stars and extrasolar planetary systems with optical telescopes—especially the Magellan 6.5 Meter telescopes in Chili—and theoretical model building. His recent work includes high-precision photometry of planetary transits (when planets pass in front of their parent stars); measurements of the alignment between an extrasolar planetary orbit and the rotation axis of its parent star; and theoretical models for the anomalously large planet HD 209458b, and for the peculiar eclipses of the young star KH 15D.

In addition, Winn is interested in cosmology and galaxy structure. He has used radio observations to detect gravitational lenses, and searches for special cases of lensing in which one can learn about the centers of galaxies, including the supermassive black holes that reside there. He is interested in new techniques and technologies for radio interferometry that will enable further progress in these areas.

BIOGRAPHICAL SKETCH

Josh Winn is from Deerfield, Illinois. He graduated from MIT in 1994 with S.B. and S.M. degrees in physics. After spending a year as a Fulbright Scholar at Cambridge University, he returned to MIT as a Hertz Fellow. While in graduate school, he worked in medical physics, condensed matter physics, and astrophysics, and wrote for the science section of *The Economist*. He earned a Ph.D. in physics in 2001, and subsequently held NSF and NASA postdoctoral fellowships at the Harvard-Smithsonian Center for Astrophysics. He began as an Assistant Professor of Physics at MIT in January 2006.

For a list of Prof. Winn's selected publications, please visit his faculty web page at web.mit.edu/physics/facultyandstaff/index.html.



Robert A. Simcoe

Assistant Professor of Physics, Division of Astrophysics

RESEARCH INTERESTS

Rob Simcoe maintains strong interests in both the development of optical/infrared instrumentation for ground-based astronomical observatories, and the observation of galaxies and intergalactic matter at the epoch when the universe was ~10–20% of its present age.

In particular, he has worked to improve characterizations of the spatial distribution of elements heavier than Hydrogen and Helium at early times. In the wake of the Big Bang, the universe is thought to have been primarily composed of H and He, with nearly all large-scale production of heavier elements taking place through nuclear fusion in the cores of the first stars. When these stars ended their lifetimes, they exploded as supernovae and polluted intergalactic space with newly formed chemicals.

By studying the strength and spatial variation of intergalactic oxygen and carbon at early epochs, Simcoe has been working toward an understanding of when and where the first stars in the universe were formed. Further work in



correlating the locations of early galaxies with heavy elements in the nearby intergalactic medium is also leading to some of the first direct physical characterizations of the cycle of galaxy formation, supernova feedback, and chemical enrichment during the peak era of star formation over cosmic time.

BIOGRAPHICAL SKETCH

Robert A. Simcoe recently completed a three-year Pappalardo Fellowship in Physics at MIT. He specializes in observational astrophysics, with particular emphasis on the chemistry of galaxies and intergalactic matter in the early universe. An amateur astronomer and telescope maker from his youth, Simcoe went on to earn his A.B. in astrophysical sciences from Princeton in 1997, and his Ph.D. in astronomy from Caltech in 2003. He remains active in the application of new technologies toward instrumentation for large ground-based telescopes—including the twin 6.5 Meter Magellan telescopes in the Chilean Andes, where he carries out most of his observations. Simcoe joined the MIT Physics faculty as an Assistant Professor in the fall of 2006.

For a list of Prof. Simcoe's selected publications, please visit his faculty web page at web.mit.edu/physics/facultyandstaff/index.html.