

Fourth Annual  
Department of Physics Undergraduate Research Symposium



**Upgrades for the Extremely Fast Tracker in the Collider Detector at Fermilab**

*Jason Agne*

**Neutron Electric Dipole Moment Project:  
 $^3\text{He}$  Polarization Experiment**

*Danielle Chandler*

**Spatial Resolution Enhancement Techniques in Pump-Probe Confocal Microscopy**

*Bryant Chhun*

**Quantum Interference Effects in Forked Superconducting Nanowires**

*Robert Colby*

**Improving the Biomolecular Ruler: Measurements of the Steady-State Anisotropies of the Alexa 488 and Alexa 568 Fluorescent Dyes**

*John Eichorst*

**Solution of the BTK Problem with a Position-Dependent Effective Mass**

*Justin Elenewski*

**Chiral Liquid Crystals in Suspensions of *Salmonella* Flagella**

*Zach Hensel*

**Experimentally Testing the Interstitialcy Theory of Condensed Matter**

*Anthony Karmis*

**Diffusion Monte Carlo Method in Few Electron Systems**

*Wingho Ko*

**Investigation of the Formation of Tidal Features Through Numerical Simulations of Galaxy Mergers**

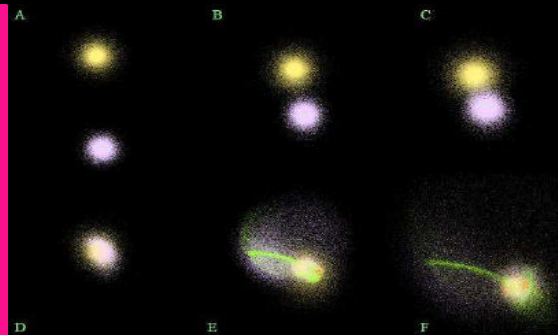
*Irina Marinova*

**Point-Contact Spectroscopy of the Two-Band Superconductor  $\text{MgB}_2$**

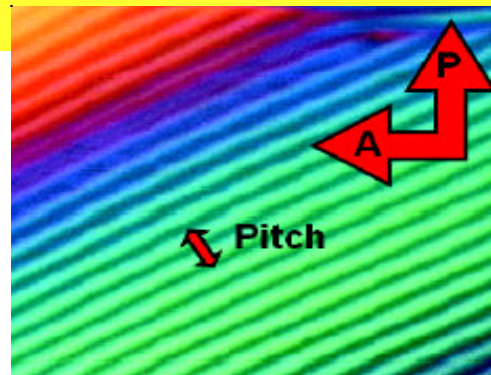
*Karen Parkinson*

**The Evolution of Dark Matter Halos in Simulations of Galaxy Collisions and Mergers**

*Jonathon Van Schelt*



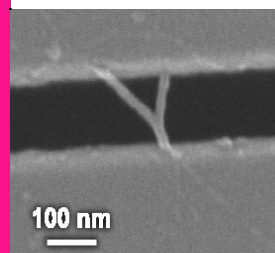
The Undergraduate Research Symposium showcases the Senior Thesis projects from the Class of 2005. Twelve students will present the results of their research projects during a 15-minute presentation, followed by a question and answer period.



January 28, 2005

1:00-5:30 p.m.

141 Loomis Lab of Physics



*Undergraduate physics students who are currently participating in (or have an interest in) undergraduate research are encouraged to attend.*



## Undergraduate Research Symposium January 28, 2005

<b>Time</b>	<b>Student</b>	<b>Title</b>	<b>Advisor</b>
<b>1:00</b>	Jason Agne	Upgrades for the Extremely Fast Tracker in the Collider Detector at Fermilab	Kevin Pitts
<b>1:20</b>	Danielle Chandler	Neutron Electric Dipole Moment Project: <sup>3</sup> He Polarization Experiment	Jen-Chieh Peng
<b>1:40</b>	Bryant Chhun	Spatial Resolution Enhancement Techniques in Pump-Probe Confocal Microscopy	Enrico Gratton
<b>2:00</b>	Robert Colby	Quantum Interference Effects in Forked Superconducting Nanowires	Alexey Bezryadin
<b>2:20</b>	John Eichorst	Improving the Biomolecular Ruler: Measurements of the Steady-State Anisotropies of the Alexa 488 and Alexa 568 Fluorescent Dyes	Robert Clegg
<b>2:40</b>	Justin Elenewski	Solution of the BTK Problem with a Position Dependent Effective Mass	Anthony Leggett
<b>3:00</b>	<b>Coffee Break</b>		
<b>3:20</b>	Zach Hensel	Chiral Liquid Crystals in Suspensions of Salmonella Flagella	Zvonimir Dogic (Harvard)
<b>3:40</b>	Anthony Karmis	Experimentally Testing the Interstitialcy Theory of Condensed Matter	Andrew Granato
<b>4:00</b>	Wingho Ko	Diffusion Monte Carlo Method in Few Electron Systems	Richard Martin
<b>4:20</b>	Irina Marinova	Investigation of the Formation of Tidal Features Through Numerical Simulations of Galaxy Mergers	Susan Lamb
<b>4:40</b>	Karen Parkinson	Point-Contact Spectroscopy of the Two-Band Superconductor MgB <sub>2</sub>	Laura Greene
<b>5:00</b>	Jonathon Van Schelt	The Evolution of Dark Matter Halos in Simulations of Galaxy Collisions and Mergers	Susan Lamb

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**Jason Agne**

Upgrades for the Extremely Fast Tracker in the Collider Detector at Fermilab

This talk will describe research aimed at upgrading the efficiencies of the outdated components of the CDF Tevatron, where the heaviest quark, the top quark, was discovered. Charged track information is crucial to the CDF physics program, and hundreds of different physics analyses rely heavily upon the very efficient operation of the CDF's trigger system, referred to as the eXtremely fast Tracker (XFT). Computer simulations were performed to determine the most effective upgrades to the XFT. Upgrades to the XFT should improve the efficiency with which charged track events, which are produced in every proton-antiproton interaction, are detected for subsequent analysis.

**Danielle Chandler**

Neutron Electric Dipole Moment Project:  $^3\text{He}$  Polarization Experiment

The  $^3\text{He}$  polarization relaxation time experiment is a necessary feasibility experiment for the Neutron Electric Dipole Moment Project. The goal of the experiment is to determine how long polarized  $^3\text{He}$  will retain its polarization under the conditions defined by the Neutron Electric Dipole Moment experiment. This talk describes preliminary  $^3\text{He}$  polarization relaxation time measurements performed at room temperature.

**Bryant Chhun**

Spatial Resolution Enhancement Techniques in Pump-Probe Confocal Microscopy

The diffraction resolution limit in far-field light microscopy can be overcome using stimulated emission techniques. Stimulated emission quenches excited molecules at the edge of the focal spot, which produces an effective focal spot smaller than that limited by diffraction alone. Stefan Hell showed spot sizes with a lateral width of 28 nm, demonstrating that  $\lambda/25$  resolution could be achieved. We intend to reproduce Hell's results by modifying his apparatus to take advantage of supercontinuum generation. Additional techniques will be tested with the goal of further reducing fluorescent spot sizes.

**Bob Colby**

Quantum Interference Effects in Forked Superconducting Nanowires

This talk will describe efforts to develop nanometer-scale superconducting loops, the goal of which is to investigate superconductivity in nanometer-scale structures. Superconducting loops with a radius approaching the order of the superconducting coherence length were fabricated by sputter coating a suspended nanoscale template with a thin film of MoGe. The template was first created by depositing fluorinated carbon nanotubes in solution across a 100-nm wide trench, and then searching for naturally-occurring, suspended Y-shaped

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nanotube bundles. The procedure was improved by combining nanotube bases with carbon platforms drawn by electron beam deposition with a scanning electron microscope. Carbon platforms grown in this method can be drawn in a nearly arbitrary shape, including symmetric, closed loops suspended across the 100-nm trench, without the use of carbon nanotubes. Loops created by these methods should allow measurements of Little-Parks oscillations in loops with a radius approaching the superconducting coherence length, corresponding to the divergent regime in the Little-Parks description.

### **John Eichorst**

Improving the Biomolecular Ruler: Measurements of the Steady-State Anisotropies of the Alexa 488 and Alexa 568 Fluorescent Dyes

Alexa dyes are extremely high yield and durable dyes that offer the possibility for extremely interesting applications in the fields of biology and biochemistry. Specifically, the Alexa 488 and Alexa 568 dyes participate in a near-field interaction that is a consequence of their light absorption and emission characteristics. When this interaction occurs between dye molecules and a substrate to which they are bound, physical information about the substrate itself, on length scales of tens of angstroms, can be obtained by looking at the energy transfer efficiency. This talk describes steady state anisotropy measurements on the Alexa 488 and Alexa 568 fluorescent dyes. Anisotropy measurements reveal how these dyes depolarize an incident polarized light beam, and this depolarization factor reflects the physical properties of the dyes. By varying the solvent viscosity of each dye, the depolarization factor of each dye—and the associated physical properties of the dye—can be studied. The goal of these studies is to make the use of these dyes more widespread and accurate in research applications.

### **Justin Elenewski**

Solution of the Blonder-Tinkham-Klapwijk Problem with a Position Dependent Effective Mass

This talk will describe a research project to assess the applicability of the Deutscher model to point-contact spectroscopy at a normal metal/heavy fermion superconductor (N/HFS) interface. The Schroedinger equation with a spatially-varying mass was analyzed for plane wave scattering at a delta-function potential barrier. While the two- and three-dimensional cases present complicated, nonlinear partial differential equations, the one-dimensional case is shown to be exactly solvable using an analytical technique developed by Alhaidari. The resulting solutions are applied to the quasiclassical Blonder-Tinkham-Klapwijk (BTK) scattering problem, restricted to the case of an isotropic s-wave order parameter due to the 1-dimensional nature of the solutions. The tunneling conductance obtained through this method corresponds to a renormalization of the BTK effective barrier potential,  $Z$ , allowing the parameters of this model to be correlated with the

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conductance spectrum of the superconducting/normal metal (S/N) contact. Contrary to the claims of Deutscher and Nozieres, it is demonstrated that this model is incapable of generating the observed low-bias conductance behavior in N/HFS contacts.

### **Zach Hensel**

#### Chiral Liquid Crystals in Suspensions of *Salmonella* Flagella

A chiral liquid crystal phase, dubbed the helical nematic phase, has been observed in concentrated colloidal suspensions of *Salmonella* flagella. As described in this talk, analysis of this phase with fluorescence and polarization microscopy shows an intrinsic link between the properties of this phase and the helical parameters of wild-type *Salmonella* flagella. Individual filaments are observed to diffuse in a rotational, screw-like fashion. The existence of left- and right-handed twist through the crystalline tactoids suggests a possible twisted nematic superstructure.

### **Anthony Karmis**

#### Experimentally Testing the Interstitialcy Theory of Condensed Matter

The interstitialcy theory of condensed matter is the only theory to give a unified treatment of matter in the solid (both crystal and amorphous) and liquid states. In this theory, amorphous solids are treated as crystals with point defects, and the transition to the liquid state is described in terms of the production of defects. The theory also makes predictions about the equilibrium and kinetic properties of amorphous solids. This talk describes experimental efforts to test the interstitialcy theory by measuring the thermal conductivity of amorphous samples.

### **Wing Ho Ko**

#### Diffusion Monte Carlo Method in Few Electron Systems

This talk describes efforts to implement the diffusion Monte Carlo (DMC) method for calculating the energy of the ground-state hydrogen ( $H_2$ ) molecule and the lowest-energy triplet state of the Hooke's atom. These results are compared with essentially exact numerical results or analytic solutions in the literature. Several subtleties associated with DMC calculations, including those pertaining to the choice of the trial wavefunction, to the implementation of the fixed-node approximation, and to time-step errors, have been investigated and will be discussed. The energy estimates given by the DMC method are in good agreement with the values in the literature. The time-step errors in the  $H_2$  molecule also show a dependence on step size, in agreement with the literature.

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**Irina Marinova****Investigation of the Formation of Tidal Features Through Numerical Simulations of Galaxy Mergers**

The common belief is that galaxies are formed hierarchically, i.e., larger galactic structures are built up from smaller ones. Hierarchical structure formation is complicated, however, by the possible production of dwarf galaxies in collisions of larger galaxies. Observationally, dwarf galaxies seem to be associated with tidal tails. However, this may be an observational selection effect. Consequently, it is of interest to investigate the conditions under which dwarf galaxies might be formed in galactic collisions and mergers. This talk describes a numerical investigation of the possible formation of tidal dwarf galaxies. The primary focus of this study is on interactions in systems containing a disk galaxy, because these galaxies can provide the needed seed material for the dwarf, and because gas and stars can be pulled from the edge of the disk to form the long tidal tails associated observationally with tidal dwarfs. The collisions were studied using N-body/smoothed-particle-hydrodynamics (SPH) techniques. The disk models are identical and consist of a stellar disk and bulge, a gaseous disk, and a spheroidal dark matter halo. The collision parameter space is explored by varying the initial collision geometry. The collision simulations are test runs without gas. In three out of the four simulations, prominent tidal tails are formed.

**Karen Parkinson****Point-Contact Spectroscopy of the Two-Band Superconductor MgB<sub>2</sub>**

One of the outstanding questions concerning the superconductor MgB<sub>2</sub> is the effect of increased interband scattering on the two-band superconductivity in this material. Increased interband scattering is predicted to result in a suppression of the superconducting transition temperature,  $T_c$ , and a merging of the two gaps into a single gap. This talk describes an investigation of the effects of increased interband scattering on MgB<sub>2</sub> thin films. The films were damaged with <sup>4</sup>He<sup>+</sup> ion-irradiation, and then transport and point-contact spectroscopy (PCS) studies of the superconducting properties were performed. The ion-irradiation fluences used in these studies ranged from  $1 \times 10^{15}$  to  $1 \times 10^{17}$  ions/cm<sup>2</sup>. From the resistivity versus temperature measurements, it was observed that  $T_c$  decreases almost linearly with both fluence and resistivity at 40 K. For a sample irradiated with a fluence of  $1 \times 10^{16}$  ions/cm<sup>2</sup>,  $T_c$  decreased from 39.3 K to 36.3 K and the resistivity at 40 K increased from  $\rho = 3.45 \mu\Omega\text{cm}$  to  $16.1 \mu\Omega\text{cm}$ . The dynamic conductance data shows that the two gaps tend to merge with increasing interband scattering, that is, the superconducting gap ratio  $R = 2\Delta/k_B T_c$  increases from  $R = 1.43$  to  $R = 1.76$  for the small superconducting gap in MgB<sub>2</sub> and decreases from  $R = 4.13$  to  $R = 3.90$  for the large superconducting gap in MgB<sub>2</sub>.

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**Jon Van Schelt****The Evolution of Dark Matter Halos in Simulations of Galaxy Collisions and Mergers**

Galactic dark matter halos are affected greatly in collisions and mergers of galaxies. In order to follow this adequately in numerical simulations, much higher resolution is required than is generally available in large-scale structure simulations. It is very important to investigate the results of collisions and mergers on individual pairs of galactic dark matter halos. We have been investigating the results of collisions between comparable mass galaxies by simulating collisions and mergers of galaxies using N-body techniques. The luminous matter will also have an effect on the eventual density distribution of the various galactic components so a representation of the disk and bulge is included. The initial simulations are of galaxies approaching at near escape velocity with small impact parameters that leads to slightly off-center collisions. Results show that by a time of 1.75 Gyr a central high-density region has formed in the dark matter halo with a radius of approximately 80 kpc, scaling our results to the Milky Way. Most of the dark matter remains in the region occupied by luminous matter throughout the simulation, but a small amount is spread to very large radii and would be lost to the overall potential in a cluster.

For more information about the Undergraduate Research Symposium contact:  
Dr. Lance Cooper (slcooper@uiuc.edu) or Toni Pitts (tpitts@uiuc.edu)

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