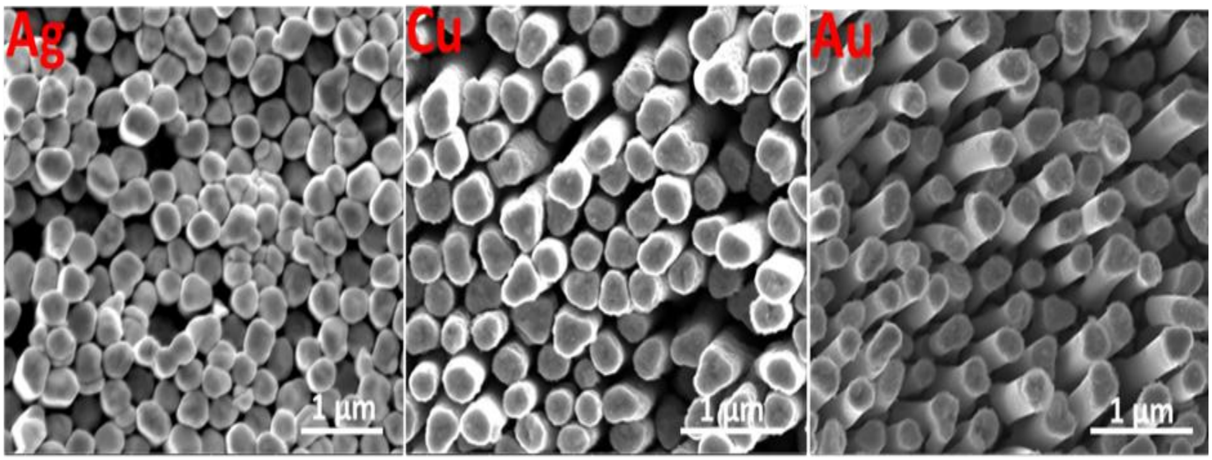
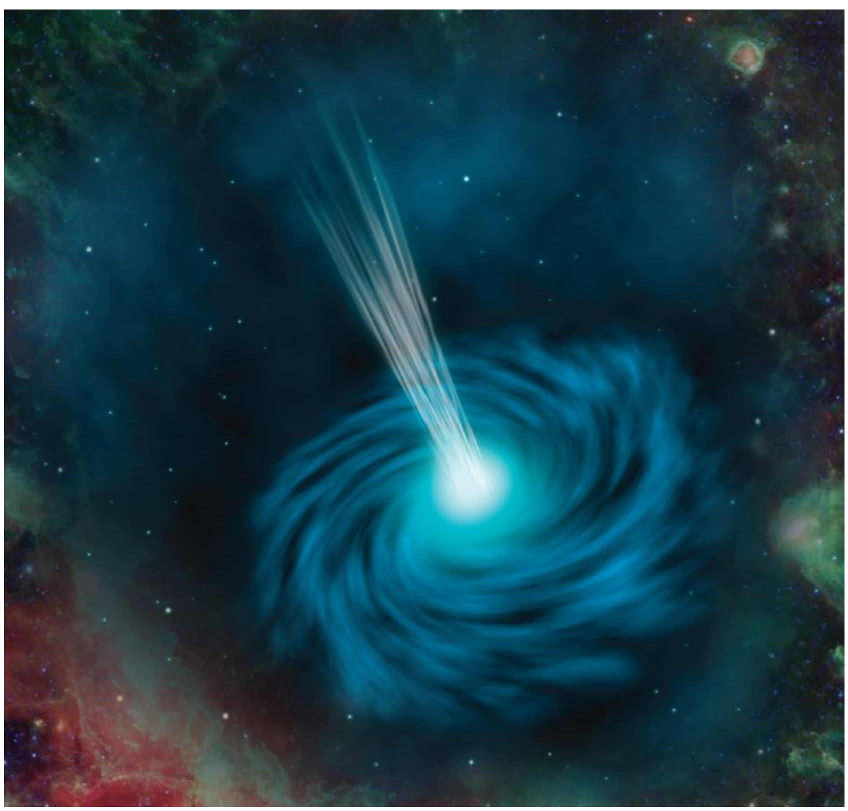
Research Report

WESTERN MICHIGAN UNIVERSITY
College of Arts and Sciences
Department of Physics

January 1, 2012 – December 31, 2012





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1 COVER DESIGNS

The top picture illustrates a nano sized rod (approx. diameter 250 nm) of Silver, Copper and Gold grown via DC electro-deposition process. This work is part of research done in Nanotechnology which is a field that deals with the manufacturing nanoscale devices. The field has grown exponentially in the last few years, owing to the industrial need for smaller, faster and more efficient devices. These devices find applications in diverse fields such as medicine, semiconductor physics, molecular biology, computing and energy materials (see details in A. Kayani's contribution).

The bottom picture illustrates a model that describes what can be used to estimate the bulk polarization of large rotating meteoroids in the magnetic field of a neutron star. The results of this model are applicable to the Supernova Neutrino Amino Acid Processing model, which describes one way in which the amino acids could have achieved chirality. In this model, meteoroids carrying molecules necessary for life interact with the strong magnetic fields of neutron stars, which alter molecular formation to favor a specific molecular handedness (see details in M. Famiano's contribution).

2 INTRODUCTION

The department is very pleased to present its 41st annual report summarizing the research activities of the members of the Department of Physics at Western Michigan University.

This report includes summaries of research performed in the department as well as at national and international laboratories, observatories, and other facilities. These include Michigan State University, Argonne National Laboratories, Lawrence Berkeley National Laboratory, and SLAC National Laboratory. During the period January 1 – December 31, 2012, our department graduated three Ph.D. students and three masters students. Faculty published 48 articles and presented 38 invited talks at national and international conferences as well as seminars and colloquia. They contributed 66 presentations or posters to scientific meetings, and secured about $2,426,400 in research grants that came to WMU. Furthermore, the faculty contributed about 76 scholarly activities, such as serving as a member or chair on national and international science advisory committees, on users executive committees, on program committees for divisional American Physical Society conferences, on a beam-line advisory group for national facilities, on research proposal review panels, as a senior editor for a scientific journal, as referees of publications, as organizers of national and international conferences, and in activities promoting diversity (see report for details).

Special thanks go to Mrs. Katie Easley for her dedicated assistance in the preparation and presentation of this document.

Nora Berrah
Editor

3 ASTRONOMY

3.1 Manuel Bautista

RESEARCH GROUP

Ehab ElHoussieny

Vanessa Fivet

Thomas Gorczyca

Kirk Korista

RESEARCH ABSTRACT

I study astrophysical plasma and their spectra, including atomic and molecular processes, radiative transfer, and hydrodynamics. These plasmas, in the context of different kinds of astronomical objects, respond to the mechanical, thermal, and radiative energy, thus it is through understanding of these plasmas that we decipher how the universe operates. Objects like Eta Carinae, where dense shells of episodic ejections create an opaque nebula where mostly low ionization iron-peak species are seen and non-equilibrium photo-chemical reactions lead to the formation of molecules and grains. Galactic winds in Active Galactic Nuclei, that are thought to regulate the evolution of their super-massive Black Holes and the whole galaxy, and exhibit rich spectra that extends from the infrared to X-rays. Up to the photosphere of Sun-like stars where despite enormous gas pressures the intense radiation fields cause atoms to depart from local thermodynamic equilibrium and difficult our understanding of stellar structure and composition.

My research combines large quantum mechanical computations of atomic parameters using massive parallel computers, like the TITAN supercomputer at the Oak Ridge National Laboratory, with the analysis of observations from space and ground-based observatories like the Hubble Space Telescope, Spitzer, Chandra, and VLT.

This year, my group has worked on two main projects. The first project is a systematic study of the spectra of low ionization iron-peak species and the construction of spectral models for these systems. These ions are crucial in the study of a great variety of galactic and extragalactic objects. The models will be benchmarked and applied in the analysis of spectra of Eta Carinae taken with the Hubble Space Telescope and high-resolution ground based observations of Quasar outflows. This work is being funded by NASA (Astronomy and Physics Research and Analysis program).

The second project is a study of photoionized plasmas when the ionizing radiation varies with time. Photoionization modelling is an important technique in the study of various kinds of astronomical systems. These models commonly assume steady-state conditions owing to constant ionizing sources. However, flux variability is characteristic in many objects. Our work demonstrates that time-dependent ionization leads to non-equilibrium conditions and dynamical effects that need to be taken into account. This is a novel area of research and is the topic of the Ph.D. dissertation of Mr. El-Houssieny.

PUBLICATIONS

1. “NLTE analysis of Sr lines in spectra of late-type stars with new R-matrix atomic data”, Bergemann, M., Hansen, C.J., Bautista, M., Ruchti, G.., 2012, Astron. and Astrophys. 546, 90

2. “Atomic decay data for modeling K lines of iron peak and light odd-Z elements “ Palmeri, P., Quinet, P., Mendoza, C., Bautista, M.A., Garcia, J., Witthoeft, M.C., Kallman, T.R., 2012, Astron. and Astrophys. 543, 44

3. “BAL Outflow Contribution to AGN Feedback: Frequency of S IV Outflows in the SDSS”, Dunn, J.P., Arav, N., Aoki, K., Wilkins, A., Laughlin, C., Edmonds, D., Bautista, M., 2012, The Astrophys. J. 750, 143

4. “Radiation damping in the photoionization of Fe^{14+}“, Hasoglu, M.F., Gorczyca, T.W., Bautista, M.A., Felfli, Z., Manson, S.T., 2012, Phys. Rev. A 85, 0701

GRANTS

1. NASA Astronomy and Physics Research and Analysis, “The Coolest Iron-Peak Species in Astrophysics”, PI M.A. Bautista. Period: 11/02/10 – 11/01/2013. Supplemental award amount: $173,221. Cumulative award amount: $490,628

2. Discovery and Dissemination Award (CDD) from the College of Arts and Sciences Western Michigan University. Award amount: $1000

3. Instructional Development Grant from the Office of Faculty Development Western Michigan University. Award amount: $3200

INVITED TALKS

1. “Broad Absorption Line Plasma Outflows from Quasars. Feedback from Accreting Supermassive Black Holes” Seminar Series of the Department of Physics of the University of Notre Dame, February 2012, South Bend, IN

2. “Accurate Spectral Modeling of Fe II. A Long Standing Problem in Astrophysics”. Meeting of the American Astronomical Society Laboratory Astrophysics Division, June 2012, Anchorage, Alaska

SCHOLARLY ACTIVITIES

- Referee of The Astrophysical Journal, Astronomy & Astrophysics, The Astrophysical Journal, and Journal of Physics B

- Courses Taught: Selected Topics (PHYS 5980), and Intro. Modern Physics (PHYS 3090), Elementary Physics (PHYS 1070)

- Supervisor of postdoctoral researcher Dr. Vanessa Fivet.

- Undergraduate Advisor

- Research supervisor of three undergraduate students.

- Advisor of two graduate students
- Reviewer for the NASA Postdoctoral Program

- Panel reviewer for the NASA Solar and Heliophysics Program

- Representative of the Department to the Awards and Special Project of the Graduate Students College

- Member of the Undergraduate Committee and the Future of the Department Committee of the Department of Physics

- Coordinator of a project to reform the Intro. Modern Physics laboratories (PHYS 3100)

- Coordinator of a project to reform the Elementary Physics Laboratory (PHYS 1080)

- Training of Professors from Sichuan University, China, on "Integrating Research into the Classroom". Haenicke Institute for Global Education, Western Michigan University, Jul 2012

3.2 Kirk Korista

RESEARCH GROUP

Manuel Bautista and Thomas Gorczyca

RESEARCH ABSTRACT

My research lies in the modeling and interpretation of rest-frame UV-optical-IR spectra of Active Galactic Nuclei (AGN). Photoionization modeling and reverberation mapping are two analysis tools used to determine physical conditions within the broad emission line region (BELR) – which contain gas clouds deep within the gravitational potential well of the supermassive black holes (SMBH) which power AGN. The proximity of these photoionized gas clouds to the SMBH makes our understanding of this region critical to our determinations of the masses of these black holes, which apparently co-evolved with the stellar content of galaxies over cosmic time.

PUBLICATIONS

1. Goad, M.R., **Korista, K.T.**, & Ruff, A.J., The broad emission-line region: the confluence of the outer accretion disc with the inner edge of the dusty torus, *Monthly Notices of the Royal Astronomical Society*, 426, 3086-3111, 2012.
2. Ruff, Andrea J., Floyd, David J.E., Webster, Rachel L., **Korista, Kirk T.**, & Landt, Hermine, New Constraints on the Quasar Broad Emission Line Region, *The Astrophysical Journal*, 754, 18-29, 2012.
3. Abdel-Naby, Sh.A., Nikolić, D., **Gorczyca, T.W.**, **Korista, K.T.**, & Badnell, N.R., Dielectronic recombination data for dynamic finite-density plasmas. XIV. The aluminum isoelectronic sequence, *Astronomy & Astrophysics*, 537, 40-51, 2012.

INVITED TALKS AND POSTERS

1. **Korista, K.T.**, & Goad, M.R., "The BLR – where the accretion disk meets the dust torus I: geometry and kinematics" (invited talk), Workshop: Improving Black Hole Masses in AGN, DARK Cosmology Centre, Niels Bohr Institute, University of Copenhagen, July 2-13, 2012.
2. Goad, M.R., & **Korista, K.T.**, "The BLR – where the accretion disk meets dusty torus II: line-continuum reverberation" (invited talk), Workshop: Improving Black Hole Masses in AGN, DARK Cosmology Centre, Niels Bohr Institute, University of Copenhagen, July 2-13, 2012.

CONTRIBUTED TALKS AND POSTERS

1. Ruff, Andrea J., Floyd, David J. E., **Korista, Kirk T.**, Webster, Rachel L., Porter, Ryan L., & Ferland, Gary J., Near infrared hydrogen emission line ratios as diagnostics of the broad emission line region, *Journal of Physics Conference Series*, 272, 2012.

OTHER SCHOLARLY ACTIVITIES

1. Reviewer for Monthly Notices of the Royal Astronomical Society.
2. Reviewer for the Astrophysical Journal.
3. Served on 1 Ph.D. committee.

4 ATOMIC and MOLECULAR PHYSICS

4.1 Nora Berrah

RESEARCH GROUP

Probing Complexity using the LCLS and the ALS

Soroush Dehaghi, Li Fang, Brendan Murphy, Timur Osipov, Rene Bilodeau, and Nora Berrah*

RESEARCH ABSTRACT

The research program objective is to investigate *fundamental interactions between photons and gas-phase systems* to advance our understanding of correlated and many body phenomena. Our research investigations focus on probing multi-electron interactions in order to understand and ultimately control energy transfer processes from electromagnetic radiation. Most of our work is carried out in a strong partnership with theorists.

Our current interests include: 1) The study of non linear and strong field phenomena in the x-ray regime using the linac coherent light source (LCLS), the most powerful ultra-fast x-ray free electron laser (FEL) facility at the SLAC National Laboratory. Our investigations focus on probing physical and chemical processes that happen on ultrafast time scales. This is achieved by examining both electronic and nuclear dynamics subsequent to the interaction of molecules and clusters with LCLS pulses of various intensity and pulse duration. 2) The study of correlated processes in select anions with vuv-soft x-rays from the Advanced Light Source (ALS) at Lawrence Berkeley Laboratory.

A) Multiphoton Ionization as a clock to Reveal Molecular Dynamics with Intense Short X-ray Free Electron Laser Pulses

We investigated molecular dynamics of multiple ionization in N_2 through multiple core-level photoabsorption and subsequent Auger decay processes induced by intense, short x-ray free electron laser pulses. The timing dynamics of the photoabsorption and dissociation processes is mapped onto the kinetic energy of the fragments. Measurements of the latter allow us to map out the average internuclear separation for every molecular photoionization sequence step and obtain the average time interval between the photoabsorption events. Using multiphoton ionization as a tool of the multiple-pulse pump-probe scheme, we demonstrate the modification of the ionization dynamics as we vary the x-ray laser pulse duration (Pub 1).

B) Multiphoton *L*-shell ionization of H2S using intense x-ray pulses from a free-electron laser

Sequential multiphoton *L*-shell ionization of hydrogen sulfide exposed to intense femtosecond pulses of 1.25-keV x rays has been observed via photoelectron, Auger electron, and ion time-of-flight spectroscopies. Monte Carlo simulations based on relativistic Dirac-Hartree-Slater calculations of Auger decay rates in sulfur with single and double *L*-shell vacancies accurately model the observed spectra. While single-vacancy-only calculations are surprisingly accurate even at the high x-ray intensity used in the experiment, calculations including double-vacancy states improve on yield estimates of highly charged sulfur ions. In the most intense part of the x-ray focal volume, an average molecule absorbs more than five photons, producing multiple *L*-shell vacancies in 17% of photoionization events according to simulation. For 280-fs pulse duration and ~10^{17} Wcm^{-2} focal intensity, the yield of S^{13+} is ~1% of the S^{3+} yield, in good agreement with simulations. An overabundance of S^{12+}, and S^{14+} observed in the experimental ion spectra is not predicted by either single-vacancy or double-vacancy calculations (Pub 2).

C) <u>Double Core-Hole Spectroscopy for Chemical Analysis with an Intense X-Ray Femtosecond Laser.</u>

Theory predicted that double-core hole (DCH) spectroscopy can provide a new powerful means of differentiating between similar chemical systems with a sensitivity not hitherto possible [a,b]. Although double core-hole ionization on a single site (ssDCH) in molecules was recently measured with double and single photon absorption, double core holes with single vacancies on two different sites (tsDCH), allowing unambiguous chemical analysis, had remained elusive. We were able however to report for the first time the direct observation of tsDCH, produced via sequential two-photon absorption, using short, intense x-ray pulses from the Linac Coherent Light Source (LCLS) Free-Electron Laser (FEL) and compare it with theoretical modeling in the case of CO. The observation of DCH states, which exhibit a unique signature, and agreement with theory proved the feasibility of the method. We also carried out experiments on N_2O and CO_2 to compare our previous results in N_2 with N_2O and compare our findings in CO with CO_2 to assess the validity of the method; ie, even though single core hole ionization can not differentiate between CO and CO_2 or between N_2 and N_2O, could tsDCH, measured via two photon photoelectron spectroscopy, allow the differentiation between similar chemical environment? Our results demonstrated that this methodology is indeed successful (Pub.7). Our findings exploited the ultrashort pulse duration of the FEL to eject two core electrons on a time scale comparable to that of Auger decay and demonstrate possible future x-ray control of physical inner-shell processes.

D) <u>Absolute Photodetachment Cross Section of H^-</u>

We have measured the absolute photodetachment cross section of H^- at both the ALS and also at the SOLEIL facility in France to test the calculations by Yip et al. [c] which cover a photon energy range between 12-45 eV. This experiment is very important from a fundamental point of view since it represents the three-body Coulomb breakup problem. It is "unique" because of the greater importance of the electron repulsion relative to the Coulomb attraction of the electrons to the nucleus when Z=1. Thus the atomic properties of H^- are more sensitive to electron correlation effects when compared to Helium for example [c]. Furthermore, there is no experimental data available to test published calculations [c]. Measuring the absolute photodetachment cross section of H^- is important because H^- is responsible for a large part for the opacity of stellar atmospheres, including our own sun. Thus it is relevant to understand fundamentally the interaction of the H^- ions with the vuv/x-rays produced by our sun by simulating this experiment in the laboratory. We used the SOLEIL facility in France in order to access the low photon energy (12-20 eV, not easily accessible at the ALS). We have however used the ALS BL 10 undulator at zero order in combination with filters to access the low photon energy range. The data are presently being analyzed to determine if the latter experiment is not contaminated with higher order effects.

References:
[a] L. S. Cederbaum, et al., J. Chem. phys. 85, 6513-6523 (1986).
[b] R. Santra et.al, . Phys. Rev. Lett. 103, 013002-013005 (2009).
[c] F. L. Yip, D. A. Horner, C. W. McCurdy, and T. N. Rescigno, Phys. Rev. A 75, 042715 (2007).

* *National and International Collaborations (Germany, Finland, Sweden, Japan, Italy) are included in the list of authors in our publications list.*

PUBLICATIONS

1. L. Fang, T. Osipov, B. Murphy, F. Tarantelli, E. Kukk, J.P. Cryan, M. Glownia, P.H. Bucksbaum, R.N. Coffee, M. Chen, C. Buth, and N. Berrah, "Multiphoton Ionization as a Clock to Reveal Molecular Dynamics with Intense Short X-ray Free Electron Laser Pulses", Phys. Rev. Lett., **109**, 263001 (2012).

2. B. F. Murphy, L. Fang, M.-H. Chen, J. D. Bozek, E. Kukk, E. P. Kanter, M. Messerschmidt, T. Osipov, and N. Berrah," Multiphoton L-Shell Ionization of H2S using Intense X-ray Pulses from the LCLS Free Electron Laser" Phys. Rev. A 86, 053423 (2012).

3. B.F. Murphy, L. Fang, T.Y. Osipov, M. Hoener, and N. Berrah, "Intense X-ray FEL-Molecule Physics: Highly Charged Ions" the American Institute of Physics (AIP) Conference Proceedings of ICAPiP, **1438**, 249 (2012).

4. T.Y. Osipov, L. Fang, B.F. Murphy, M. Hoener, and N. Berrah, "X-Ray FEL Induced Double Core-Hole and High Charge State Production", Journal of Physics: Conference Series **388,** 012030, (2012).

5. James P. Cryan, J. M. Glownia, Andreasson, A. Belkacem, N. Berrah, C. I. Blaga, C. Bostedt, J. Bozek, N. A. Cherepkov, L. F. DiMauro, L. Fang, O. Gessner, M. Guehr, J. Hajdu, M. P. Hertlein, M. Hoener, O. Kornilovy, J. P. Marangos, A. M. March, B. K. McFarland, H. Merdji, M. Messerschmidt, V. Petrovic, C. Raman, D. Ray, D. Reis, S. K. Semenov, M. Trigo, J. L. White, W. White, L. Young,P. H. Bucksbaum, and R. N. Coffee, **"**Molecular frame Auger electron energy spectrum from N_2" J. Phys. B: At. Mol. Opt. Phys. **45**, 055601 (2012).

6. H. Thomas, A. Helal, K. Hoffmann, N. Kandadai, J. Keto, J. Andreasson, B. Iwan, M. Seibert, N. Timneanu, J. Hajdu, M. Adolph, T. Gorkhover, D. Rupp, S. Schorb, T. Möller, G. Doumy, L.F. DiMauro, M. Hoener, B. Murphy, N. Berrah, M. Messerschmidt, J. Bozek, C.

Bostedt and T. Ditmire, “Explosions of Xe-clusters in ultra-intense femtosecond x-ray pulses from the LCLS Free Electron Laser”, Phys. Rev. Lett. **108**, 133401 (2012).

7. P. Salen, P. van der Meulen, H.T. Schmidt, R.D. Thomas, M. Larsson, R. Feifel, M.N. Piancastelli, L. Fang, B. Murphy, T. Osipov, N. Berrah, E. Kukk, K. Ueda, J.D. Bozek, C. Bostedt, S. Wada’ R. Richter, V. Feyer and K.C. Prince, “X-ray FEL-induced Two-Site Double Core-Hole Formation for Chemical Analysis”, Phys. Rev. Lett. PRL **108**, 153003 (2012).

8. Christian Buth, Ji-Cai Liu, Mau Hsiung Chen, L. Fang, M. Hoener, N. Berrah, “Ultrafast absorption of intense x rays by nitrogen molecules”, J. Chem. Phys.**136**, 214310 (2012).

9. V. S. Petrović, M. Siano, J.L. White, N. Berrah, C. Bostedt, J. D. Bozek, D. Broege, M. Chalfin, R. N. Coffee, J. Cryan, L. Fang, J. P. Farrell, L. J Frasinski, J. M. Glownia, M. Gühr, M. Hoener, D.M. P. Holland, J. Kim, J. P. Marangos[3], T. Martinez, B. K. McFarland, R. S. Minns, S. Miyabe, S. Schorb, R. J. Sension, L. S. Spector, R. Squibb, H. Tao, J. G. Underwood, and P. H. Bucksbaum, “Transient X-ray fragmentation: Probing a prototypical photoinduced ring opening”, Phys. Rev. Lett. **108**, 253006, (2012).

10. R.C. Bilodeau, N.D. Gibson, C.W. Walter, A. Aguilar, N. Berrah, “Inner-shell photodetachment: Shape and Feshbach resonances of anions”, Journal of Electron Spectroscopy and Related Phenomena **185** 219– 225 (2012).

11. B. Rudek, S. Kil Son, L. Foucar, S. W. Epp, B. Erk, R. Hartmann, M. Adolph, R. Andritschke, A. Aquila, N. Berrah, et al.“Ultra-Efficient Ionization of Heavy Atoms by Intense X-Ray Free-Electron Laser Pulses”(In press, Nature Photonics).

GRANTS

1. Principal Investigator: Department of Energy, Office of Science, BES, Division of Chemical Sciences, Geosciences and Biosciences grant. Project title: Probing Complexity using the ALS and the LCLS. Funded $ 600,000 between March 2011-2014.

2. Principal Investigator: Department of Energy, Office of Science, BES, Division of Chemical Sciences, Geosciences and Biosciences grant. Project title: Advanced Instrumentation for Ultrafast Science at the LCLS. Funded $ 3,000,000 between September 2009-2013.

3. Two Beamtime granted at the x-ray free electron laser, LCLS at Stanford National Laboratory (SLAC).

4. Dedicated “Approved Program” Beamtime granted at ALS, Lawrence Berkeley National Laboratory, Berkeley, CA, 2013-2016.

5. Funding from the Advanced Light Source, ~$36,000.

6. Contributing to the project "Empowering Women in North Africa to be Leader in Science and Technology through Career Advancement Opportunities, P.I. Geri Richmond (UO). Funded $236,158 with the University of Oregon contributing $137,252 and the Ocean and International Environmental Scientific Affairs of the Department of State contributing $98,906. Sept 2012-2013.

INVITED TALKS

1. "Probing Fundamental Processes Related to Plasmas Physics using the LCLS X-ray FEL", Workshop in Paris VI, "2012 Journee Plasmas/Plasma Day", Paris, France, January 18, 2012.

2. "Molecular Physics with X-FEL" Plenary talk, 2012 EGAS conference, European Group on Atomic Systems, Goteborg (Sweden), July 9-13, 2012.

3. "Probing Molecules from Within using X-FEL", Seminar, Commissariat a l'Energie Atomique (CEA)", Paris, France, January 26, 2012,

4. "Ionizing Matter with Intense X-rays from the LCLS", Seminar at the LCLS, SLAC, Stanford University, CA, May 16, 2012.

5. "Preparing an LCLS experiment", Seminar for the Machine Control Center, LCLS, Stanford University, SLAC, CA, May 16, 2012.

6. "Ionizing clusters with LCLS radiation", Seminar, Universite Paris VI, Jussieu, Paris, France May 31, 2012.

7. "AMO physics with Free Electron Lasers", Seminar, The GANIL Accelerator facility, CAEN, Basse Normandie, France, July 4, 2012.

8. "Probing matter from within using x-ray free electron lasers", Conference for Undergraduate Women in Physical Sciences (WoPhyS'12) at the University of Nebraska in Lincoln, October 2012.

CONTRIBUTED TALKS AND POSTERS

1. N. Berrah, "Probing Fundamental Processes Related to Plasmas Physics using the LCLS X-ray FEL", Workshop in Paris VI, "2012 Journee Plasmas", Paris, France, January 18, 2012.

2. R. C. Bilodeau, M. Hoener, S. Schippers, A. Muller, R. Phameuf, D. Gibsson, W. Walter, A. Aguilar, N. Berrah, " Enhanced single-photon detachment in anion of C_{60} and observation of scaling law", Bull. Am. Phys. Soc. http://meetings.aps.org/link/BAPS.2012.DAMOP.Q1.18, June 4-8, 2012.

3. N.D. Gibson, C.W. Walter, D.J. Matyas, A.N. Lebovitz, Y.-G. Li, R.M. Alton, S.E. Lou, R.C. Bilodeau, N. Berrah, A. Aguilar, D. Hanstorp, « Inner-shell photodetachment from O^-

‘, Bull. Am. Phs. Soc. http://meetings.aps.org/link/BAPS.2012.DAMOP.K1.23, June 4-8, 2012.

4. B. Murphy, SPIE X-ray FEL Instrumentation Conference, “A mirror-based soft x-ray split-and-delay system for femtosecond pump-probe experiments at LCLS” San Diego, CA August 2012.

5. L. Fang, T. Osipov, B. Murphy, E. Kukk, and N. Berrah” Following dissociating N_2 molecules by probing them with femtosecond-range XFEL pulses” OSA conference, San Diego, August 2012.

6. N. Berrah, “Probing Matter from Within using Ultra-Intense and Ultra-Fast X-Rays from the LCLS Free Electron Laser”, EGAS International conference, Goteborg, Sweden, July 2012.

7. M. Mucke, V. Zhaunerchyk, L.J. Frasinski, R.J. Squibb, M. Siano, J.H.D. Eland, L. Foucar, K. Motomura, T. Osipov, L. Fang, B. Murphy, N. Berrah, P. Linusson, P.v.d. Meulen, P. Salén, R.D. Thomas, M. Larsson, M.N. Piancastelli, M. Glownia, J. Cryan, R. Coffee, C. Bostedt, J. Bozek, S. Schorb, M. Messerschmidt, O. Takahashi, S. Mondal, S. Wada, K. Ueda, R. Richter, K. Prince and R. Feifel, “Investigation of molecular double core holes using a correlation spectroscopy technique” XFEL conference, Hamburg, Germany, July 2012.

SCHOLARLY ACTIVITIES

Professional Society Service & Science Advocacy, Planning and Evaluation:

1. Member, Basic Energy Sciences Advisory Committee (BESAC), Office of Science, Department of Energy, 2002-2013.

2. Member, Committee of Visitors (COV) Review Panel for the Scientific User Facilities Division within the Office of Basic Energy Sciences, April 2013.

3. Member, APS Nominating Committee, 2013-2015.

4. Member, Executive Committee, Division of Laser Science (DLS), APS, 2010-1013

5. Member, Science Advisory Committee, Advanced Light Source (ALS), Lawrence Berkeley National Laboratory (LBNL), 2007-2013.

6. Member, Users Executive Committee, Linac Coherent Light Source (LCLS), SLAC National Acceleratory Laboratory, 2012-2015.

7. *Promoting Diversity;* Member, COACh Advisory Board for Gender Equity in STEM fields, 2009-2013.

8. Member, American-Algerian Foundation for Culture, Education, Science and Technology, 2010-

Promoting Diversity-Contribution in Outreach/Mentoring of Women to Promote, Retain and Increase the Number of Women in Physics nationally and internationally.

1. Present seminars to give a role model/mentorship during focused women conferences in STEM fields

2. International Gender equity in STEM fields: Organizing, with Prof. Geri Richmond (U. Oregon), workshops on coaching women in North Africa to build successful careers in the STEM fields. Three workshops were planned in Tunisia, Algeria and Morocco with US State Department and UO funds.

Conference Organization and Leadership:

1. Organizer, session on Physics with Ultrafast X-rays, Frontiers in Optics 2012/Laser Science XXVIII conference, Rochester, NY, 2012.

2. Member, International Committee, Gordon Research Conference on Photoions, Photoionization and Photodetachment, 2012.

3. Member, International Committee, Many Particle Spectroscopy Conference, Sendai, Japan, 2010-2014.

Manuscript and Proposal Review:

1. Reviewer of four proposals for DOE, Basic Energy Sciences.

2. Manuscript reviewer for many physics journals (Phys. Rev. Lett., Phys. Rev. A, J. Chem. Phys.)

3. Editor, Physics Department, Annual Research Report, 2010-

4. Member, Graduate Committee Admissions, 1993-1996,’99-2012

4.2 Thomas W. Gorczyca

RESEARCH GROUP

Priyanka Chakraborti, Laurentiu Dumitriu, Jagjit Kaur, and Gaetan VanGyseghem.

RESEARCH ABSTRACT

Photoionization of Endohedral Atoms Using R-matrix Methods: Application to Xe@C60

It is demonstrated that the effect of a static cage potential on the photoionization of endohedrally-enclosed atoms can be incorporated into standard R-matrix calculations using one of two independent methods. For photoionization processes occurring entirely within the fullerene, the outer-region solutions can be modified by the additional cage potential to yield phase-shifted Coulomb functions that are matched to the inner-region R-matrix. Alternatively, if the cage potential is contained within the R-matrix "box", it can be directly incorporated into the formalism via simple one-electron integral contributions to the Hamiltonian, yielding a modified R-matrix itself. Both methods are applied to the photoionization of Xe@C60 in the vicinity of the giant 4d-> kf shape resonance, and are found to be in excellent agreement with each other (see Fig. 1). Furthermore, good agreement with recent experimental results is obtained (see Fig. 1), validating the present approach and demonstrating that the full power of the many-electron, multi-channel, open-shell capabilities of the R-matrix method can be brought to bear on the photoionization of confined-atom systems in general.

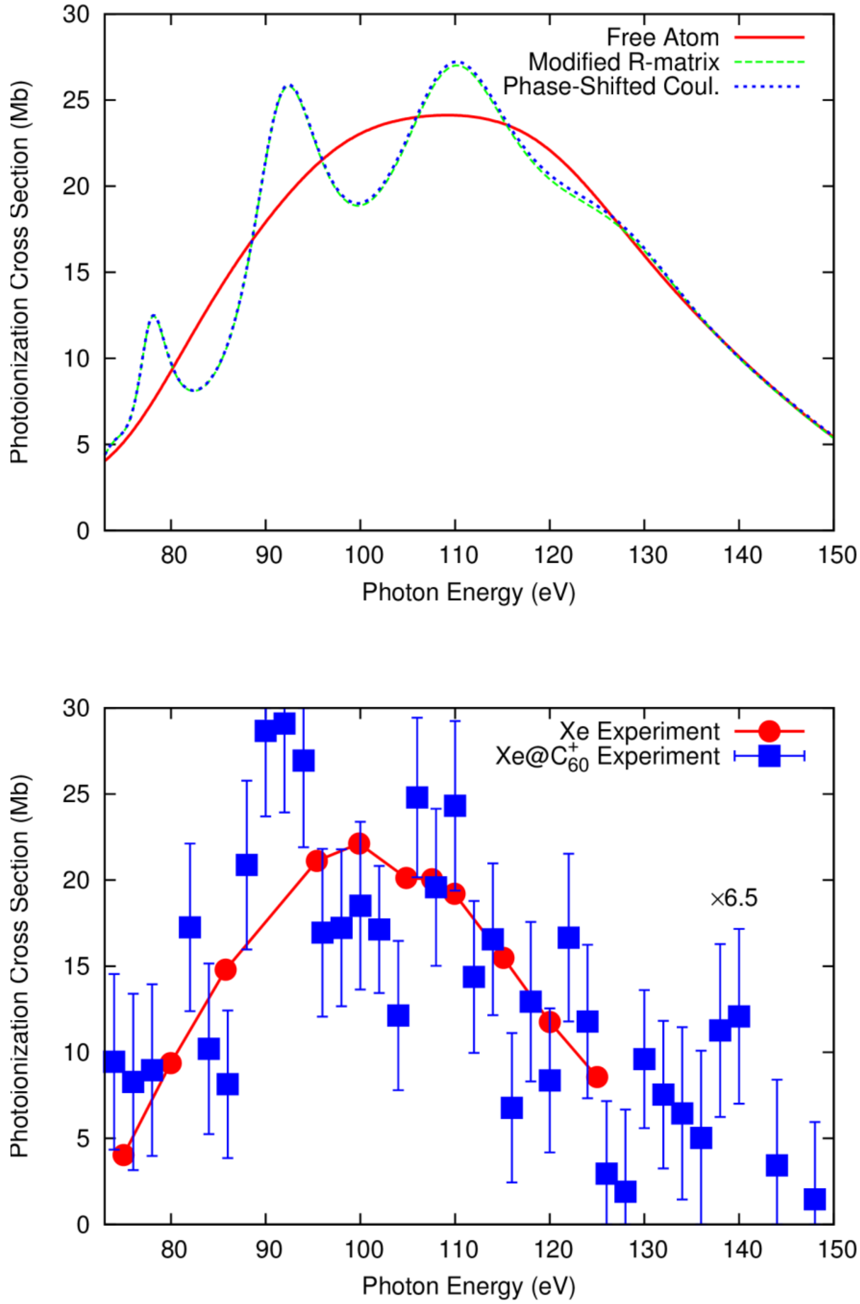

Fig. 1 Total photoionization cross section of Xe and Xe@C_{60}. The upper graph shows the present theoretical results for the free Xe atom using the standard R-matrix method (red curve) and for Xe@C_{60} using the modified R-matrix (green dashed curve) and phase-shifted Coulomb (blue dotted curve, barely distinguishable from the green dashed curve) methods. All theoretical results used the length form of the dipole operator. The lower graph shows the experimental results for the free Xe atom (circular points and curve) and for Xe@C^{+}_{60} (square points and error bars) multiplied by 6.5 to superimpose the oscillations onto the free atom case.

Suppression of Dielectronic Recombination Due to Finite Density Effects

D. Nikolic, T. W. Gorczyca, K. T. Korista, G. Ferland, N. R. Badnell

We have developed a general model for determining density-dependent effective dielectronic recombination (DR) rate coefficients in order to explore finite-density effects on the ionization balance of plasmas. Our model consists of multiplying highly-accurate zero-density DR rate coefficients, which have been produced from state-of-the-art theoretical calculations with experimental benchmarking, by a suppression factor. The suppression factor is based-upon detailed collision-radiative calculations for a wide range of ions at various densities and temperatures, and a general formula is then developed as a function of isoelectronic sequence, charge, density, and temperature. These density-dependent effective DR rate coefficients are then used in the plasma simulation code Cloudy to compute ionization balance curves for both collisionally ionized and photoionized plasmas at very low (ne=1cm-3) and finite (ne=1010 cm-3) densities (see Figs. 1 and 2). We find that the denser case is significantly more ionized due to suppression of DR, warranting further studies of density effects on DR by extensive detailed collisional-radiative calculations. This is expected to impact the predictions of the ionization balance in denser cosmic gases such as those found in nova and supernova shells, accretion disks, and the broad emission line regions in active galactic nuclei.

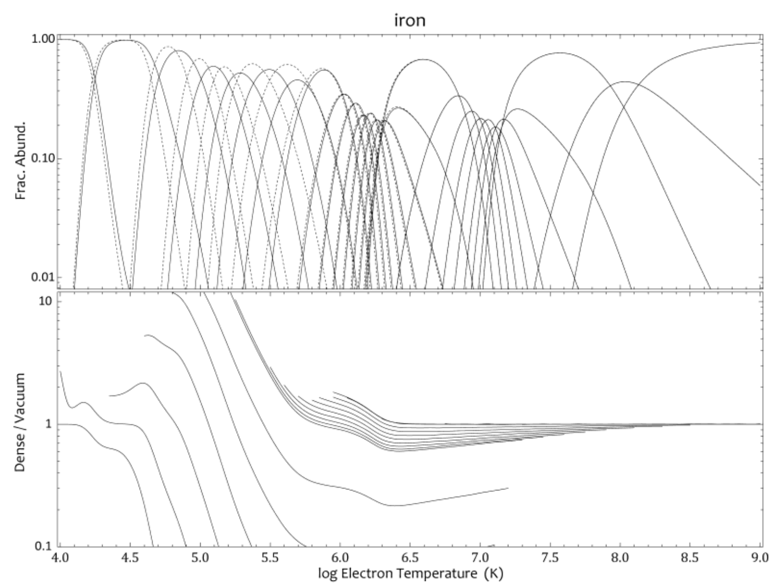

Fig. 1 Upper panel: collisional ionization fractional abundance vs. electron temperature for all ionization stages of Fe. The solid curves correspond to a density of 1 cm-3 and the dashed curves correspond to a density of 1010 cm-3. From left to right, the curves range from Fe+ to Fe26+. Lower panel: ratio of the calculated fractional abundances for the two densities.

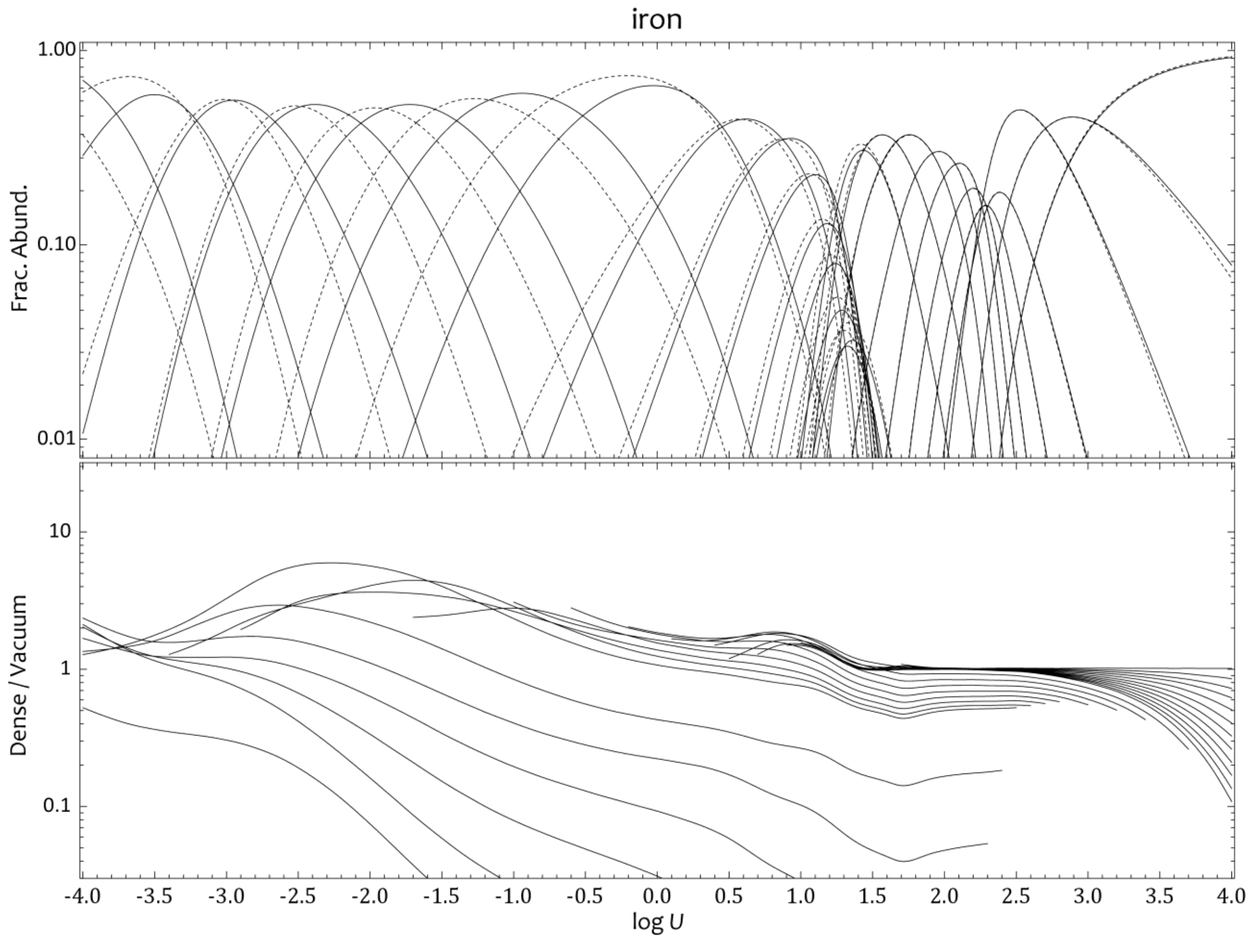

Fig. 2 Upper panel: photoionization fractional abundance vs. the ionization parameter U for all ionization stages of Fe. The solid curves correspond to a density of 1 cm-3 and the dashed curves correspond to a density of 1010 cm-3. From left to right, the curves range from from Fe+ to Fe26+. Lower panel: ratio of the calculated fractional abundances for the two densities.

PUBLICATIONS

1. D. Nikoli'c, T. W. Gorczyca, K. T. Korista, G. Ferland, and N. R. Badnell, Suppression of Dielectronic Recombination Due to Finite Density Effects, Astrophys. J., in press (2012).

2. M. F. Hasoglu, H. L. Zhou, T. W. Gorczyca, and S. T. Manson, Photoionization of Confined Ca in a Spherical Potential Well, Phys. Rev. A in press (2012).

3. T. W. Gorczyca, M. F. Hasoglu, and S. T. Manson, Photoionization *of Endohedral Atoms Using R-matrix Methods: Application to Xe@C_{60}*, Phys. Rev. A 86, 033204 (2012).

4. M. F. Hasoglu, T. W. Gorczyca, M. A. Bautista, Z. Felfli, and S. T. Manson, *Radiation Damping in the Photoionization of* Fe^{14+}*,* Phys. Rev. A 85, 040701(R) (2012).

5. Sh. A. Abdel-Naby, D. Nikoli'c, T. W. Gorczyca, and N. R. Badnell, *Dielectronic Recombination Data for Dynamic Finite-Density Plasmas: XIV. The Aluminum Isoelectronic Sequence*, Astronomy and Astrophysics 537, A40 (2012).

GRANTS

1. T. W. Gorczyca (PI) and K. T. Korista, NASA Astrophysics Research and Analysis Program, for project entitled *Improved Simulations of Astrophysical Plasmas: Computation of New Atomic Data*, funded $280,000 for period 4/1/2011-3/31/2014.

INVITED TALKS

1. T. W. Gorczyca, *DR Calculations of M-Shell Ions*, 2012 ADAS Workshop, Le Commissariat à l'Energie Atomique (CEA), Cadarache, France, September 24, 2012.

2. T. W. Gorczyca, *DR/Innershell Atomic Modeling*, AtomDB Work Week and Workshop 2012, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, August 10, 2012.

CONTRIBUTED TALKS AND POSTERS

1. M. F. Hasoglu, T. W. Gorczyca, M. A. Bautista, Z. Felfli, and S. T. Manson, *Radiation Damping in the Photoionization of* Fe^{14+}, The 43rd Annual Meeting of the Division of Atomic, Molecular, and Optical Physics, Orange County, California, June 4-8 (2012).

RESEARCH AND SCHOLARLY ACTIVITIES

1. Reviewer for Physical Review Letters, Physical Review A, Journal of Physics B, The Astrophysics Journal, Astronomy and Astrophysics, Atomic Data and Nuclear Data Tables, NSF, DoE, and NASA.

2. Department of Physics Newsletter Editor.

3. Department of Physics Colloquium Coordinator.

4. Graduate Committee Member.

5. Qualifying Committee Member.

6. College GAPDAC representative.

7. Committee chair for graduate students Priyanka Chakraborti and Laurentiu Dumitriu.

8. Committee member for graduate students Buddhi Man Rai, Tamer Elkafrawy, Chengyang Li, Samanthi Wickramarachchi, Darshika Keerthisinghe, Ehab El-Houssieny.

4.3 Emanuel Kamber

<u>**RESEARCH ABSTRACT**</u>

Single-electron capture collisions of ground and metastable Ne^{2+} ions with molecular gases

A Hasan[1], O Abu-Haija[2], J Harris[3], T Elkafrawy[3], **A Kayani[3]**, and **E Y Kamber[3]**

[1] American University of Sharjah, P.O. Box: 26666 Sharjah, United Arab Emirates
[2] Physics Department, Tafila Technical University, P. O. Box 179, Zip Code 66110. Tafila, Jordan
[3] Physics Department, Western Michigan University, Kalamazoo, MI 49008-5252, USA

A detailed understanding of single-electron capture processes in slow collisions of doubly-charged ions with molecules has been the goal of many experimental studies [1 - 3]. These processes have become extremely important in many research areas such as fusion plasma, astrophysics and atmospheric science, and the design of controlled thermonuclear fusion devices. In addition, N_2, H_2O and CO_2 molecules are important components of many planetary atmospheres, and are also found in the earth's atmosphere.
In the present work, state-selective differential cross sections for single-electron capture process in low-energy collisions of Ne^{2+} with N_2, CO_2 and H_2O in the laboratory impact energy range of 50 to 400 eV and 0° scattering angles have been studied using a differential energy-gain spectrometer. The experimental apparatus and measuring procedure have been previously described in detail by Abu-Haija *et al.* [3].

The observed reaction channels are labeled according to the notation previously used by Kamber *et al.* [4]. The designations I, II, and III represent, respectively, the ground Ne^{2+} ($2s^2\ 2p^4\ {}^3P$) and metastable states $2s^2\ 2p^4\ {}^1D$ and ${}^1S$ of the incident Ne^{2+} ions; α, β, γ,..represent the ground and successive higher excited states of Ne^+ ion; X, A, B,.. represent the ground and higher excited states of the target product; Y represents the target double ionization. To identify the reaction channels involved, the energy-gain spectra for Ne^{2+} - Ar collision system [5, 16] was used as a standard to calibrate the *Q*-scale for the Ne^{2+} - N_2, CO_2 and H_2O systems.

1. *Translational energy-gain spectra:* Figure 1 shows the translational energy-gain spectra for the formation of Ne^+ ions from the reaction of the 50 eV Ne^{2+} ions with N_2, CO_2 and H_2O at 0° scattering angles. In Ne^{2+} - N_2 collisions, the observed collision spectrum is dominated by a peak due to capture from the metastable state $2p^3\ {}^1S$ of Ne^{2+} into the 3s ${}^4P$ state of Ne^+ product ions with production of N_2^+ in the ground state ($X\ {}^2\Sigma_g^+$) via reaction channel IIIγX, with contributions from reaction channels IIIβX, IIIδX, and the transfer excitation channels IIIγA and IIαG. The broad peak, centered at Q = 1 eV, is due to capture from the metastable states $2p^3\ {}^1D$ and ${}^1S$ of Ne^{2+} into the $2s2p^6\ {}^2S$ and 3s ${}^4P$ states of Ne^+ via IIβX, IIγX, and IIIγX. Comparison with the

high resolution results of Okuno *et al.* [2] at 1200 eV shows good agreement with the present measurements.

In Ne^{2+} - CO_2 collisions, the dominant peak corresponds to capture from the metastable state $2p^3$ ^1S of Ne^{2+} into the 3s ^4P, $2p^6$ ^2S, and 3p ^4P states of Ne^+ product ions with production of CO_2^+ in the ground state ($X\ \Sigma_g^+$), respectively, via reaction channels IIIγX, IIIβX and IIIδX. There is also significant contribution from an unresolved reaction at ~ 5.2 eV, involving non-dissociative transfer ionization via IIαY channel. The smaller peak at ~ 3 eV correlates with capture into the excited states of Ne^+ ions from metastable states via reaction channels IIβX, IIγX, IIδX, and IIIεX.

In Ne^{2+} - H_2O collisions, three peaks are clearly seen, the strongest peak (channel IIIδX) is due to transfer excitation from the metastable state $2p^3$ ^1S of Ne^{2+} into the 3s ^2P state of Ne^+ product ions with production of H_2O^+ in the excited state ($\tilde{A}$ $^2A_1$). The smallest peak at ~ 2.5 eV corresponds to capture into the 3s ^2P state of Ne^+ via the reaction channel IIδA. The other peak at ~ 5.2 eV is due capture accompanied by the ionization of the target (channel IIαY) with contributions from channels IIIεX and IIβX. Figure 1 also shows our calculated reaction windows for 50 eV Ne^{2+} - N_2, CO_2 and H_2O collisions, using both the LZ [7] and the ECOB models [8]. Calculated peak-values have been normalized to our observed peak-values in the energy spectra. The reaction windows favor reaction channels with smaller Q-values compared to the dominant channels.

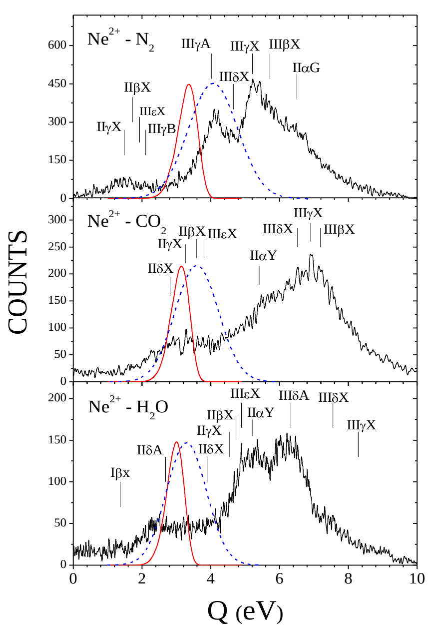

Figure 1. Translational energy-gain spectra for single-electron capture by 50 eV Ne^{2+} ions from N_2, CO_2 and H_2O at 0° scattering angles. Also shown are reaction windows calculated on the basis of the LZ model (solid curves) and the ECOB model (dashed curves).

2. *Total cross sections*: The measured total cross sections for single-electron capture by Ne^{2+} ions from CO_2 and H_2O are shown in Figure 2 together with the LZ [7] and COB [9] models. The absolute uncertainty is estimated to be in the order of 25% and only relative errors are displayed in Figure 2.
The total cross sections slowly increase with the collision energy. This can be understood from the reaction window, which gets broader with increasing energy, and therefore capture channels

with large Q-values get an increasing probability. In the absence of a full quantal calculation that requires the consideration of a large number of couplings and curve crossing between the potential energy curves associated with the quasi-molecule formed in the collisions, we have calculated cross-sections for single-electron capture using the LZ and COB models for a qualitatively explanation of our measurements. Furthermore, these comparisons are also useful to check the validity of these models describing the collision systems. Our measured cross sections are in poor accord with these theoretical calculations and are at least a factor of 7-9 smaller than these models.

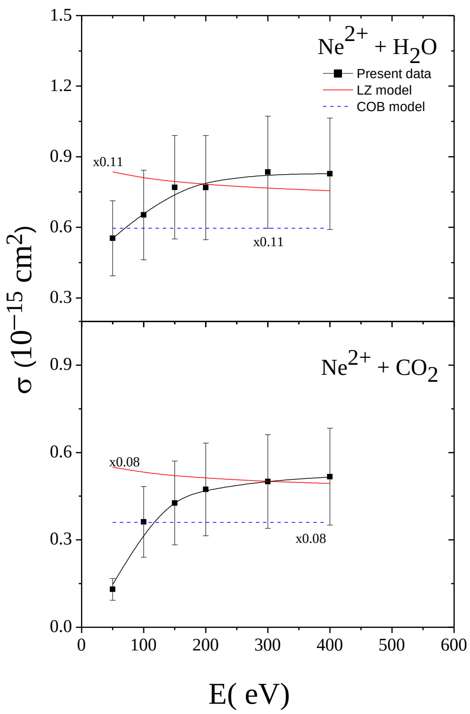

Figure 2. Total cross sections for single-electron capture by Ne^{2+} ions from H_2O and CO_2. The scaling factors of the theoretical calculations are also shown. Smooth lines are drawn to guide the eye.

The total cross sections slowly increase with the collision energy. This can be understood from the reaction window, which gets broader with increasing energy, and therefore capture channels with large Q-values get an increasing probability. In the absence of a full quantal calculation that requires the consideration of a large number of couplings and curve crossing between the potential energy curves associated with the quasi-molecule formed in the collisions, we have calculated cross-sections for single-electron capture using the LZ and COB models for a qualitatively explanation of our measurements. Furthermore, these comparisons are also useful to check the validity of these models describing the collision systems. Our measured cross sections are in poor accord with these theoretical calculations and are at least a factor of 7-9 smaller than these models.

References:

[1] Kamber E Y, Jonathan P, Brenton A G and Beynon J H 1987 *J. Phys.B: At. Mol. Phys.* **20** 4129

[2] Okuno K, Fukuroda A, Kobayashi N and Kaneko Y 1989 *J. Phys. Soc. Japan* **58** 1590

[3] Abu-Haija O, Kamber E Y, Ferguson S M and Stolterfoht N 2005 *Phys. Rev.* A **72** 42701

[4] Kamber E Y, Mathur D and Hasted J B 1982 *J. Phys.B: At. Mol. Phys.***15** 263
[5] Kahlert H J and Huber B A 1984 *Z. Phys*. A **317** 139
[6] Harper S M, Hu Wan-Ping and Price S D 2002 *J. Phys.B: At. Mol. Phys* **35** 4409
[7] Olson R E and Salop A 1976 *Phys. Rev.* A **14** 579
[8] Niehaus A 1986 *J. Phys.B: At. Mol. Phys* **19** 2925
[9] Ryufuku H, Sasaki K and Watababe T 1980 *Phys. Rev.* A **21** 745

State-selective electron capture in slow collisions Ne^{q+} (q = 3 – 5) ions with H_2O

E. Y. Kamber[1], O. Abu-Haija[2], A. Hasan[3], and **A. Kayani**[1]

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[2] Physics Department, Tafila Technical University, P. O. Box 179, Zip Code 66110 – Jordon
[3] American University of Sharjah, P.O. Box: 26666 Sharjah, United Arab Emirates

State-selective single-electron capture process for slow collisions of Ne^{q+} (q = 3 – 5) ions, produced in a recoil-ion source, with H_2O have been studied experimentally at laboratory impact energies between 15 and 300 qeV (where q is the projectile charge state) and scattering angles between 0^o and 6^o by means of a differential energy-gain spectrometer [1].
For Ne^{3+} - H_2O collisions, the dominant peak is due to capture into the $2p^33p$ states. The structure at about 5.5 eV is energetically identifiable with capture into the excited states from the metastable states in the incident Ne^{3+} ion beam. For Ne^{4+} - H_2O collisions, the dominant reaction channel correlates with capture into the excited state 3d′ of the Ne^{3+} ion from the ground state incident Ne^{4+} ($2p^2$ ^3P) ions. The structure on the lower-energy side of the dominant peak corresponds to capture into 4s and 4p states.

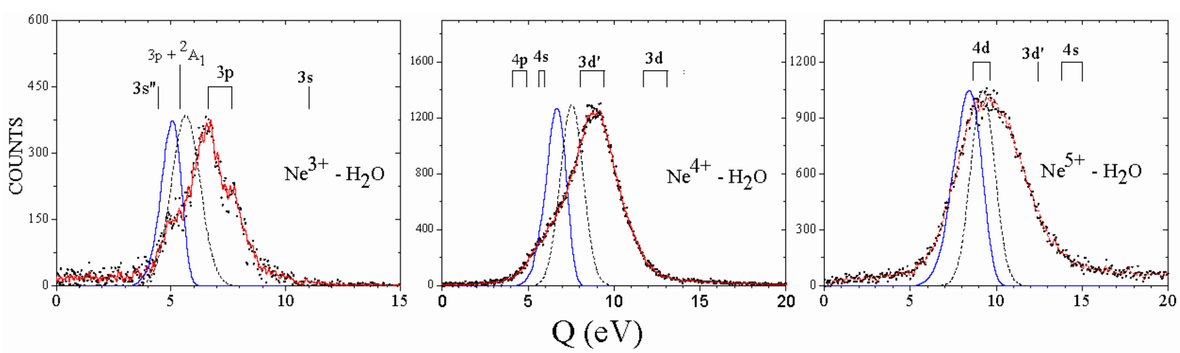

Figure 1: Translational energy-gain spectra for single-electron capture by 25 qeV Ne^{q+} (q = 3 – 5) ions from H_2O. Also shown are reaction windows calculated on the basis of LZ model (full curve) and the ECOB model (broken curve).

In Ne^{5+} - H_2O collisions, the observed collision spectrum is dominated by non-dissociative single-electron capture from the ground state incident Ne^{5+} (2p ^2P) ions into the excited state 4d of Ne^{4+} with production of H_2O^+ in the ground state (X $^2B_1$). The spectra are interpreted qualitatively in terms of the reaction windows, which are calculated using the Landau-Zener model and the extended version of the classical over-the barriers model [1]. The energy dependence of total cross-sections for single- and double-electron capture are also measured and found to slowly increase with increasing impact energies. The measured cross sections are compared with the theoretical results based on the multi-channel Landau-Zener model.

References

[1] O. Abu-Haija, E. Y. Kamber, S. M. Ferguson, and N. Stolterfoht, Phys. Rev. A **72,** 42701 (2005).
[2] T. E. Cravens, Science, **296**, 1042 (2002).

PUBLICATIONS

1. "Single-electron Capture Collisions of Ground and Metastable Ne^{2+} ions with Molecular Gases," A. Hasan, O. Abu-Haija, J. Harris, T. Elkafrawy**, A. Kayani,** and **E.Y. Kamber**, Physica Scripta T in press.

CONTRIBUTED TALKS AND POSTERS

1. "Single-electron Capture Collisions of Ground and Metastable Ne^{2+} ions with Molecular Gases," A. Hasan, O. Abu-Haija, J. Harris, T. Elkafrawy**, A. Kayani,** and **E.Y. Kamber**, 16th International Conference on the Physics of Highly Charged Ions, September 2 – 7, 2012, Heidelberg. Germany.

2. "State-Selective Electron Capture in Slow Collisions of Ne^{q+} (q = 3 – 5) ions with H_2O," **E. Y. Kamber**, O. Abu-Haija, A. Hasan, and **A. Kayani**, 16th International Conference on the Physics of Highly Charged Ions, September 2 – 7, 2012, Heidelberg. Germany.

4.4 John A. Tanis

RESEARCH ABSTRACT

Dr. Tanis is active in the field of atomic collision physics, investigating fundamental interactions that occur in collisions between atomic particles, as well as atomic interactions that occur in charged particles interactions with insulating surface. Major emphases of this work at present are: (1) investigation of the transmission and guiding properties of fast electrons and ions through insulating nano- and micro-capillaries, a phenomenon that, in addition to its fundamental interest, has several potential applications in the fields of science, medicine, and technology, and (2) studies of detailed collision dynamics in processes of x-ray emission associated with charge-changing processes, specifically radiative double electron capture (RDEC). In the first case, the work with capillaries lies at the intersection of atomic physics and materials science, while the latter project involves pure atomic physics.

Notably, Prof. Tanis was on sabbatical leave during the 2011-12 academic year at the GANIL facility in Caen, France where he collaborated with Dr. Amine Cassimi. This work involved the transmission of slow and medium speed highly charged ions through micrometer-sized glass capillaries of both tapered and conical shapes. Results of this work provide a complement to the work at WMU on fast electron transmission through similar tapered glass capillaries.

Notable accomplishments in the past year have included the work of the work of Samanthi Wickramarachchi (Ph.D. student) on fast electron transmission through tapered-glass macrocapillaries resulting in two manuscripts, an invited talk, and two posters at international conferences, the work of Darshika Keerthisinghe (Ph.D. student) on fast electron transmission through polyethylene terephthalate (PET or Mylar) nanocapillary foils resulting in two manuscripts, an invited talk, and a poster at international conferences, the work of Asma Ayyad (Ph.D. student) on fast ion transmission through single-glass macrocapillaries resulting in a manuscript and a poster at an international conference, and the work of Tamer Elkafrawy (Ph.D. student) on x-ray projectile-ion coincidences to give information on capture and loss processes associated with x-ray emission resulting in two manuscripts, two talks, and a poster at three conferences. Significantly, Tamer Elkafrawy received his Ph.D. from the university at the December 2012 commencement, with Prof. Tanis serving as the chairperson of the dissertation committee for the thesis defense. Also, Ms. Wickramarachchi and Ms. Ayyad spent the month of May 2012 in Caen to participate in the beam time and to gain experience in working at a large laboratory environment like that at GANIL. All of these accomplishments contributed greatly to the success of the research group during the past year.

These various studies are carried out with collaborators at WMU and other laboratories, nationally and internationally, including collaborators from Germany, France, Hungary, Japan, and Poland. Dr. Tanis' research has been supported extensively by the U.S. Department of Energy, the National Science Foundation, and the Research Corporation. Several graduate, undergraduate, and high school students have been involved in this research over the years and, to date, eight students have received the Ph.D. degree under his supervision, with three more currently in progress.

Students who have been involved in the work covered by the period of this research report and their areas of specialty are as follows:

Asma Ayyad – Ph.D. (in progress), materials science/atomic physics
Tamer Elkafrawy – Ph.D. (completed, December 2012), atomic physics
Darshika Keerthisinghe – Ph.D. (in progress), materials science/atomic physics
Samanthi Wickramarachchi – Ph.D. (in progress), materials science/atomic physics
Chun-Lin Zhou (Univ. of Caen) – Ph.D. (completed, July 2012), materials science/atomic physics

The various activities associated with Dr. Tanis' research including publications, presentations (invited talks and contributed), proposals and grants, scholarly activities, and Ph.D. and M.A. theses and committees for the period of this report are listed below.

M.A. THESES AND Ph.D. DISSERTATIONS

Dr. Tanis served as the chairperson of the Ph.D. dissertation committees of the following individual:

Mr. Tamer Elkafrawy– Ph.D. (completed, December 2012), atomic physics

PUBLICATIONS

1. A. Simon, **J. A. Tanis**, T. Elkafrawy and A. Warczak, *Radiative double electron capture (RDEC) in ion-atom collisions,* J. Phys.: Conf. Series **388**, 012034 (2012).

2. **J. A. Tanis**, *Charged-particle transmission through insulating capillaries*, McGraw-Hill 2013 Yearbook (2012).

3. A. Cassimi, T. Ikeda, L. Maunoury, C. L. Zhou, S. Guillous, A. Mery, H. Lebius, A. Benyagoub, C. Grygiel, H. Khemliche, P. Roncin, H. Merabet, **J. A. Tanis** and Y. Yamazaki, *Unexpected dynamics of charge evolution in glass capillaries for 230 keV* Xe^{23+} *ions*, Phys. Rev. A **86**, 062902 (2012).

In Press

1. B. S. Dassanayake, D. Keerthisinghe, S. Wickramarachchi, A. Ayyad, S. Das, N. Stolterfoht and **J. A. Tanis**, *Temporal evolution of electron transmission through insulating PET nanocapillaries,* Nucl. Instrum. Meth. Phys. Res. (2013), in press.

2. D. Keerthisinghe, B. S. Dassanayake, S. Wickramarachchi, A. Ayyad, N. Stolterfoht and **J. A. Tanis**, *Transmission and Guiding of Fast Electrons through Insulating PET Nanocapillaries*, AIP Conference Proceedings, accepted.

3. T. Elkafrawy, A. Warczak, A. Simon and **J. A. Tanis**, *Evidence for Radiative Double Electron Capture (RDEC) in* F^{9+} *on Carbon Collisions*, AIP Conference Proceedings, accepted.

4. Asma M. Ayyad, B. S. Dassanayake, D. Keerthisinghe, T. Ikeda, A. Kayani and **J. A. Tanis**, *Transmission of fast highly charged ions through single and tapered glass capillaries*, Phys. Scr. (2013), accepted.

5. T. Elkafrawy, A. Warczak, A. Simon, and **J. A. Tanis**, *Single photon emission correlated to double electron capture by bare ions: background processes*, Phys. Scr. (2013), accepted.

6. S. J. Wickramarachchi, D. Keerthisinghe, B. S. Dassanayake, T. Ikeda, **J. A. Tanis**, *Dependence of electron transmission on charge deposited in tapered glass macrocapillaries at a tilt angle of* 5.0^o, Phys. Scr. (2013), accepted.

7. N. Winters, A. Warczak, **J. A. Tanis**, T. Gassner, A. Gumberidze, C. Kozhuharov, S. Hagmann, P. M. Hillenbrand, N. Petridis, R. Reuschl, M. Schwemlein, R. Strzalka, D. Sierpowski, U. Spillmann, S. Trotsenko, G. Weber, D. F. A. Winters, Z. Yin, and Th. Stöhlker, *A study of radiative double electron capture in bare chromium ions at the ESR*, Phys. Scr. (2013), accepted.

8. D. Keerthisinghe, B. S. Dassanayake, S. Wickramarachchi, N. Stolterfoht, and **J. A. Tanis**, *Charge deposition dependence and energy loss of electrons transmitted through insulating pet nanocapillaries*, Nucl. Instrum. Meth. Phys. Res. (2013), accepted.

9. S. J. Wickramarachchi, T. Ikeda, D. Keerthisinghe, B. S. Dassanayake, **J. A. Tanis**, *Angular dependence of electron transmission through a microsized tapered glass capillary*, Nucl. Instrum. Meth. Phys. Res. (2013), accepted.

GRANTS

1. October 1, 2011 – June 30, 2012: *Ions lourds et nanotechnologie (Heavy ions and nanotechnology)*, A. Cassimi and **J. A. Tanis**, **PIs**, Conseil Régional De Basse-Normandie, Soutien aux Chaires d'Excellence, Requested: 53,940 Euros ; Awarded: 53,940 Euros (about $70,100). This grant supported my sabbatical in Caen, France.

2. July 1, 2012 – June 30, 2015: , *Electron And Ion Interactions With Nano- And Microcapillaries* **J. A. Tanis, PI**, A. N. Kayani, Co-PI, National Science Foundation, Atomic and Molecular Physics Program, Requested $557,495; declined.

INVITED TALKS (underlined indicates person giving talk)

1. **T. Elkafrawy**, A. Simon, A. Warczak, and J. A. Tanis, *Evidence for radiative double electron capture (RDEC) in* F^{9+} *on carbon collisions*, 22nd International Conference on the Application of Accelerators in Research and Industry, Fort Worth, Texas, August 2012.

2. **D. Keerthisinghe**, B. S. Dassanayake, S. Wickramarachchi, A. Ayyad, N. Stolterfoht and J. A. Tanis, 22nd International Conference on the Application of Accelerators in Research and Industry, Fort Worth, Texas, August 2012.

3. **S. J. Wickramarachchi**, B. S. Dassanayake, D. Keerthisinghe, T. Ikeda and J. A. Tanis, 22nd International Conference on the Application of Accelerators in Research and Industry, Fort Worth, Texas, August 2012

CONTRIBUTED TALKS AND POSTERS

1. **T. Elkafrawy**, **J. A. Tanis**, A. Simon, and A. Warczak, *Radiative double electron capture (RDEC) in collisions of bare fluorine ions with carbon foils,* Division of Atomic, Molecular, and Optical Meeting of the American Physical Society, Anaheim, CA, June 2012, BAPS.2012.DAMOP.D1.60

2. **D. Keethisinghe**, B. S. Dassanayake, **S. Wickramarachchi**, **A. Ayyad**, N. Stolterfoht and **J. A. Tanis**, *Transmission of fast electrons through PET nanocapillaries,* 21st Conference on the Application of Accelerators in Research and Industry, Fort Worth, TX, August 2012, Program and Schedule, TUE-AP03-5.

3. **S. J. Wickramarachchi**, B. S. Dassanayake, **D. Keerthisinghe**, T. Ikeda and **J. A. Tanis**, Dynamics of electron transmission through a micro-size tapered glass capillary, 21st Conference on the Application of Accelerators in Research and Industry, Fort Worth, TX, August 2012, Program and Schedule, TUE-AP03-4.

4. **T. Elkafrawy**, A. Simon, A. Warczak, and **J. A. Tanis**, *Evidence for Radiative Double Electron Capture (RDEC) in F^{9+} on Carbon Collisions,* 21st Conference on the Application of Accelerators in Research and Industry, Fort Worth, TX, August 2012, Program and Schedule.

5. N. Winters, A. Warczak, **J. A. Tanis**, A. Gumberidze, S. Hagmann, P.M. Hillenbrand, R. Reuschl, M. Schwemlein, D. Sierpowski, U. Spillmann, R. Strzalka, S. Trotsenko, G. Weber, D.F.A. Winters, Y. Zhong and Th. Stöhlker, *A Study of Radiative Double Electron Capture in Bare Chromium Ions at the ESR,* 16th International Conference on the Physics of Highly Charged Ions (HCI 2012), Heidelberg, Germany, September 2012, Book of Abstracts, A-b33.

6. **S. J. Wickramarachchi**, B. S. Dassanayake, **D. Keerthisinghe**, T. Ikeda, **J. A. Tanis**, *Dependence of Electron Transmission on Charge Deposited in Tapered Glass Macrocapillaries,* 16th International Conference on the Physics of Highly Charged Ions (HCI 2012), Heidelberg, Germany, September 2012, Book of Abstracts, A-c13.

7. C. L. Zhou, S. Guillous, J. Rangama, A. Méry, W. Iskander, E. Sezestre, **S. Wickramarchchi**, **A. Ayyad**, T. Ikeda, **J. A. Tanis**, A. Cassimi, *Fabrication of a Slow HCI Nanobeam with an Insulating Tapered Glass Capillary,* 16th International Conference on the Physics of Highly Charged Ions (HCI 2012), Heidelberg, Germany, September 2012, Book

of Abstracts, A-c19.

8. C. L. Zhou, **J. A. Tanis**, A. Benyagoub, C. Grygiel, H. Lebius, A. Mery, I. Monnet, J-M. Ramillon, F. Ropars, T. Madi, T. Ikeda, Y. Yamazaki, H. Khemliche, P. Roncin, M. Simon, A. Mueller, M. Doebeli, and A. Cassimi, *Transmission of 27 keV Ar^{9+} in Tapered and Conical Insulating Glass Macro-capillaries*, 16th International Conference on the Physics of Highly Charged Ions (HCI 2012), Heidelberg, Germany, September 2012, Book of Abstracts, A-c20.

9. **A. M. Ayyad**, B. S. Dassanayake, **D. Keerthisinghe**, **S. Wickramarachchi**, **A. Kayani**, and **J. A. Tanis**, *Interaction between Fast Highly Charged Ions and a Single Glass Macrocapillary*, 16th International Conference on the Physics of Highly Charged Ions (HCI 2012), Heidelberg, Germany, September 2012, Book of Abstracts, B-c01.

10. **T. Elkafrawy**, A. Simon, A. Warczak, and **J. A. Tanis**, *Single Photon Emission Correlated to Double Electron Capture by Bare Ions*, 16th International Conference on the Physics of Highly Charged Ions (HCI 2012), Heidelberg, Germany, September 2012, Book of Abstracts, B-b11.

11. **D. Keerthisinghe**, B. S. Dassanayake, **S. Wickramarachchi**, **A. Ayyad**, N. Stolterfoht and **J. A. Tanis**, *Energy and time dependence of guided electrons through PET nanocapillaries*, 19th International Workshop on Inelastic Ion-Surface Collisions (IISC-19), Frauenchiemsee, Germany, September 2012, Book of Abstracts.

12. **S. J. Wickramarachchi**, B. S. Dassanayake, **D. Keerthisinghe**, T. Ikeda and **J. A. Tanis**, *Energy Dependence Associated with Electron Transmission through a Micro-Sized Tapered Glass Capillary*, 19th International Workshop on Inelastic Ion-Surface Collisions (IISC-19), Frauenchiemsee, Germany, September 2012, Book of Abstracts.

SCHOLARLY ACTIVITIES

1. On sabbatical leave at the GANIL facility in Caen, France during the 2011-12 academic year.

2. Member of the Program Committee for the *Division of Atomic, Molecular, and Optical Physics* of the American Physical Society, 2011-2012.

3. Member of the International Advisory Board, *16th International Conference on the Physics of Highly Charged Ions (HCI 2012)*, Heidelberg, Germany, 2010-12.

4. Member of SPARC (Stored Particle Atomic Physics Collaboration) Advisory Board at GSI, Darmstadt, Germany, 2007 - ???

5. Refereed a total of 10 papers as follows:

   Physical Review Letters – 4
   Physical Review A – 1
   Nuclear Instruments and Methods in Physics Research – 1
   Physica Scripta – 1

Chinese Physics Letters – 1
AIP Conference Proceedings – 1
AIP Advances – 1

6. Dr. Tanis serves or has served as the chairperson of the Ph.D. thesis committees of the following individuals:

   Mr. Tamer Elkafrawy– Ph.D. (completed, December 2012), atomic physics
   Asma Ayyad – Ph.D. (in progress), materials science/atomic physics
   Samanthi Wickramarachchi – Ph.D. (in progress), materials science/atomic physics
   Darshika Keerthisinghe – Ph.D. (in progress), materials science/atomic physics

   Dr. Tanis has served or is serving on the Ph.D. dissertation committees of the following individuals in a chairing role:

   Ms. Priyanka Chakraborti – Ph.D. (in progress), atomic physics
   Mr. Elias Garratt – Ph. D. (in progress), condensed matter
   Mr. Manjula Nandasiri – Ph. D. (in progress), condensed matter
   Mr. Chun-Lin Zou (Univ. of Caen) – Ph.D. (completed, December 2012), atomic physics/materials science

5 CONDENSED MATTER PHYSICS

5.1 Clement Burns

RESEARCH GROUP

Professor: Clement Burns
Ph. D. Students: Xuan Gao, Khalil Hamam, Chengyang Li, Jianqing Yang
Postdoctoral Worker: Mohammad Al-Amar
Undergraduates: Danniel Ulrey, Joshua Hampton (Kalamazoo College)

RESEARCH ABSTRACT

This group has activities in two main areas, x-ray synchrotron studies of highly correlated systems and laboratory studies of energy related materials, especially novel types of low cost solar cells.

Work in X-ray synchrotron studies
Experiments were conducted at the Advanced Photon Source (APS) at Argonne National Laboratory in Illinois.

Synchrotron Experiments - summary

1. Further development of polarization analysis for scattered x-rays for inelastic studies of highly correlated systems.
2. Low temperature (down to 0.05K) diffraction studies of quantum crystals, mainly studies of solid ^3He and ^4He in restricted geometries.
3. Studies of the quantum phase transition in chromium metal under pressure.

Ongoing Laboratory work at Western Michigan University

1. Studies of fundamental properties of organic semiconductors relevant for low cost solar cells.
2. Creation of thin film organic solar cells.
3. Design and construction of a low temperature (0.05 K) refrigerator for studies of correlated systems.

PUBLICATIONS

1. J. Park, B.-G. Cho, K. D. Kim, J. Koo, H. Jang, K.-T. Ko, J.-H. Park, K.-B. Lee, J.-Y. Kim, D. R. Lee, C. A. Burns, S. S. A. Seo and H. N. Lee, "Oxygen-Vacancy-Induced Orbital Reconstruction of Ti Ions at the Interface of $LaAlO_3/SrTiO_3$ Heterostructures: A Resonant Soft-X-Ray Scattering Study", accepted by Physical Review Letters.

2. Yu. V. Shvyd'ko, J. P. Hill, C. A. Burns, D. S. Coburn, B. Brajuskovic, D. Casa, K. Goetze, T. Gog, R. Khachatryan, J.-H. Kim, C. N. Kodituwakku, M. Ramanathan, T. Roberts, A. Said, H. Sinn, D. Shu, S. Stoupin, T. Toellner, M. Upton, M. Wieczorek, H. Yava, "MERIX -

next generation medium energy resolution inelastic x-ray scattering instrument at the APS", accepted by the Journal of Electron Spectroscopy and Related Phenomena.

3. Mohammad M. AL-Amar, Khalil J.Hamam, Gellert Mezei, Ramakrishna Guda, Nasser M. Hamdan, Clement A. Burns, "A new method to improve the lifetime stability of small molecule bilayer heterojunction organic solar cells", accepted by Solar Energy Materials & Solar Cells.

GRANTS

1. National Science Foundation, Division of Materials Research, "Collaborative Proposal: Synchrotron x-ray scattering experiments on solid helium". $91,982 from Sept. 15, 2008 – August 31, 2012.

2. U. S. Department of Energy, Basic Energy Sciences Program – Materials Science, "X-ray Studies of Highly Correlated Systems". Granted $300,000 from Jan. 4, 2009 – May 31, 2012.

3. U. S. Department of Energy, Basic Energy Sciences Program – Materials Science "Resonant Inelastic X-ray Scattering Studies with Polarization Analysis". Granted $300,000 for three year period June 1, 2012 – May 31, 2015.

4. Received $80,487 to help support a graduate student carrying out research at the Advanced Photon Source at Argonne National Laboratory, Jan. 1, 2010 - December 31, 2012.

CONTRIBUTED TALKS AND POSTERS

1. "Evidence for a BCC to HCP Phase Transition for Solid Helium in Porous Vycor Glass at 100 bar and 800 mK." L. B. Lurio, S. Bera, J. Maloney, N. Mulders, Z. Cheng, M. H. W. Chan, C. A. Burns and Z Zhang, APS March Meeting Boston, MA 2012.

2. Chengyang Li, Clement Burns, Ayman Said, and Xuan Gao, "Phonon Spectrum of Chromium at High Pressure", Advanced Photon Source Users' Meeting Poster, Argonne National Laboratory, Argonne, IL, May 7-9, 2012.

3. Xuan Gao, Clement Burns, Diego Casa, Mary Upton, Jungho Kim, Thomas Gog, and Chengyang Li, "X-ray Analyzers for Polarization Measurements in Resonant Inelastic X-ray Scattering", Advanced Photon Source Users' Meeting Poster, Argonne National Laboratory, Argonne, IL, May 7-9, 2012.

4. Anthony Nacci, Khalil Hamam, Clement Burns, "Researching New Materials for Thin Film Solar Cells", Howard Hughes Medical Institute Summer Research Poster Presentation, Western Michigan University, August 9, 2012.

SCHOLARLY ACTIVITIES

Reviews

Reviewed one paper for the Journal of Synchrotron Radiation and one book for The American Association for the Advancement of Science, in Science Books and Films.

External committees

1. Member of the Beamline Advisory Group for Sectors 9 and 30 at the Advanced Photon Source at Argonne National Laboratory.

2. Chair of the Beamline Advisory Team for the High Resolution Inelastic X-ray Scattering Beamline at the National Synchrotron Light Source II (NSLS-II) facility. This beamline is one of six original beamlines chosen for the $900 million dollar NSLS-II project.

5.2 Sung Chung

<u>RESEARCH ABSTRACT</u>

Entanglement Perturbation Theory for Antiferromagnetic Heisenberg Spin Chains

Lihua Wang [1,2] and **Sung Chung**[1,3]

[1] Western Michigan University, Kalamazoo, Michigan 49008
[2] Computational Condensed-Matter Physics Laboratory, RIKEN, Saitama, Japan
[3] Asia Pacific Center for Theoretical Physics, Pohang, South Korea

A recently developed many-body method, entanglement perturbation theory (EPT) [1-4], is used to study the antiferromagnetic Heisenberg spin chains with z-axis anisotropy λ and magnetic field. To demonstrate the accuracy, we first apply EPT to the isotropic spin 1/2 antiferromagnetic Heisenberg model, and find that EPT successfully reproduces the exact Bethe Ansatz results for the ground state energy, the local magnetization, and the spin correlation functions [5-7]. In particular, EPT confirms for the first time the asymptotic behavior of the spin correlation functions predicted by the conformal field theory, which realizes only for lattice separations larger than 1000 [8], see Fig.1. Next, turning on the z-axis anisotropy and the magnetic field, the 2-spin and 4-spin correlation functions are calculated, and the results are successfully compared with those obtained by Bosonization [9] and density matrix renormalization group methods [10]. Finally, for the spin-1 antiferromagnetic Heisenberg model, the ground state phase diagram in λ space is determined with help of the Roomany-Wyld RG finite-size-scaling [11]. The results are in good agreement with those obtained by the level-spectroscopy method [12], see Fig.2.

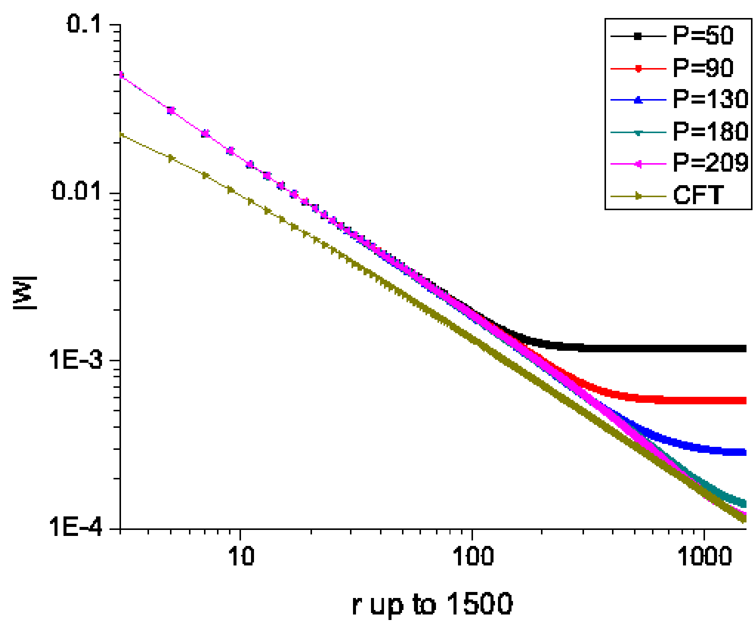

Fig.1 Spin-spin correlation function as a function of spin separation *r* for an infinite spin - ½ chain.

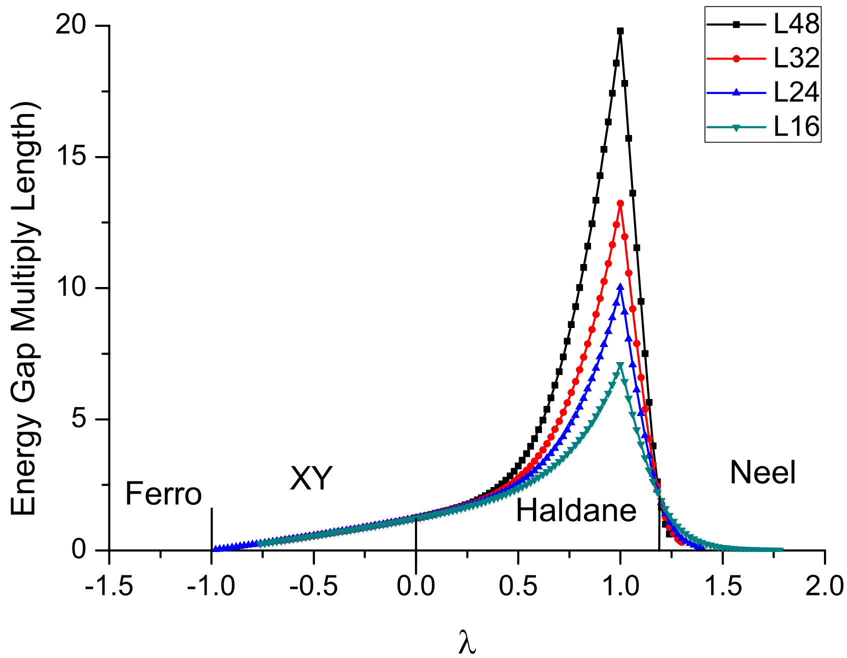

Fig.2 Phase diagram of the spin -1 chain

[1] S.G. Chung, Phys. Lett. A 359, 707 (2006).
[2] S.G. Chung, Phys. Lett. A 361, 396 (2007).
[3] S.G. Chung, K. Ueda, Phys. Lett. A 372, 4845 (2008).
[4] S.G.Chung and L.Wang. Phys. Lett. A, 373, 2277 (2009).
[5] M.Karbach, K.Hu, and G.Muller, cond-mat/9809163 v1 10 sep 1998.
[6] J.Sato, M.Shiroishi, and M.Takahashi, Nuclear Physics B729, 441 (2005).
[7] L.Wang and S.G.Chung. J. Phys. Soc. Japan, in press.
[8] I. Affleck, J. Phys. A: Math. Gen. 31, 4573 (1998).
[9] T.Hikihara and A.Furusaki, Phys. Rev. B 69, 064427 (2004).
[10] S.R. White, D.A. Huse, Phys. Rev. B 48, 3844 (1993).
[11] H.H.Roomany and H.W.Wyld, Phys. Rev. D 21, 3341(1993).
[12] W.Chen, K.Hida, and B.C.Sanctuary, Phys. Rev. B 67,104401 (2003).

PUBLICATIONS

1. L. Wang and S.G. Chung, ***Entanglement perturbation theory for antiferromagnetic Heisenberg spin chains***, Journal of the Physical Society of Japan, in press

GRANTS

1. ***To develop a novel many-body method,*** requesting NSF supercomputer at the University of Texas, 10,000 SUs granted.

CONTRIBUTED TALKS AND POSTERS

1. ***Entanglement perturbation theory: idea, recent progress, and prospect for quantum chemistry***, at the Institute for Solid State Physics, University of Tokyo, Tokyo Japan on May 15, 2012.

2. ***Entanglement perturbation theory: idea, recent progress, and prospect for quantum chemistry***, at Institute for Nano-Life Science, Yokohama City University, Kanagawa Japan on May 17, 2012.

3. ***Entanglement perturbation theory: idea, recent progress, and prospect for quantum chemistry***, at the Physics Department, Aoyama Gakuin University, Tokyo Japan on May 18, 2012.

4. ***Entanglement perturbation theory: idea, recent progress, and prospect for quantum chemistry***, Condensed Matter Theory seminar at the Kyoto University, Kyoto Japan on May 23, 2012.

5. ***Entanglement perturbation theory: idea, recent progress, and prospect for quantum chemistry,*** Chemistry seminar at Pohang University of Science and Technology (Postech), Pohang Korea on May 30, 2012.

6. ***Entanglement perturbation theory: idea, recent progress, and prospect for quantum chemistry,*** Chemistry seminar at the Kyoto University, Kyoto Japan on June 27, 2012.

SCHOLARLY ACTIVITIES

1. I served as an external reviewer for the promotion of Dr. Hiroshi Matsuoka at the Physics Department, the Illinois State University, Normal Illinois.

2. As a JSPS fellow (Japan Society for Promotion of Science, Japanese-government funded agency), I received $20,000 fellowship for a 2 month stay, May 1 – June 30, 2012, at the Physics Department, the Kyoto University, Kyoto Japan.

5.3 Asghar Kayani

RESEARCH GROUP

Students:

Dr. Salem Al-Faify	– Graduated summer 2011
Mr. Amila Dissanayake	– Ph.D. student
Mr. Elias J. Garratt	– Expected Graduation spring 2013 with Ph.D.
Mr. Nandasiri Manjula	– Expected Graduation spring 2013 with Ph.D.
Mr. Subramanian Ganapathy	– Expected Graduation spring 2013 with Ph.D.
Mr. Rex Taibu	– Graduated 2012 with M.A. degree
Mr. George Tecos	– Graduated 2011 with M.A. degree

RESEARCH ABSTRACT

1) Effect of chromium underlayer on the properties of nano-crystalline diamond films,
E. Garratt,[1] S. AlFaify,[1,2] T. Yoshitake,[3] Y. Katamune,[3] M. Bowden,[4] M. Nandasiri,[1,4] M. Ghantasala,[5] D.C. Mancini,[6] S. Thevuthasan[4] and A. Kayani[1]

Affiliations

[1]*Department of Physics, Western Michigan University, Kalamazoo MI 49008, USA*
[2]*Physics Department, King Khalid University, Abha, Saudi Arabia*
[3]*Department of Applied Science for Electronics and Materials, Kyushu University, Fukuoka, Japan 816-8580*
[4]*EMSL, Pacific Northwest National Laboratory, Richland, WA 99354, USA*
[5]*Department of Mechanical and Aeronautical Engineering, Western Michigan University, Kalamazoo MI 49008, USA*
[6]*Physical Sciences and Engineering, Argonne National Laboratory, Argonne, IL 60439, USA*

This paper investigated the effect of chromium underlayer on the structure, microstructure and composition of the nano-crystalline diamond films. Nano-crystalline diamond thin films were deposited at high temperature in microwave-induced plasma diluted with nitrogen, on single crystal silicon substrate with a thin film of chromium as an underlayer. Characterization of the film was implemented using non-Rutherford backscattering spectrometry, Raman spectroscopy, near-edge x-ray absorption fine structure, x-ray diffraction and atomic force microscopy. Nanoindentation studies showed that the films deposited on chromium underlayer have higher hardness values compared to those deposited on silicon without an underlayer. Diamond and graphitic phases of the films evaluated by x-ray and optical spectroscopic analysis determined consistency between sp^2 and sp^3 phases of carbon in chromium sample to that of diamond grown on silicon. Diffusion of chromium was observed using ion beam analysis which was correlated with the formation of chromium complexes by x-ray diffraction.

PUBLICATIONS

1. **Effect of chromium underlayer on the properties of nano-crystalline diamond films,** E. Garratt, S. AlFaify, T. Yoshitake, Y. Katamune, M. Bowden, M. Nandasiri, M. Ghantasala, D.C. Mancini, S. Thevuthasan and A. Kayani, Appl. Phys. Lett, 102, 011913 (2013)

GRANTS

- Argonne national lab $20,000.00
- Environmental Molecular Sciences Laboratory (EMSL), PNNL materials proposal: approved and allocated

6 NUCLEAR PHYSICS

6.1 *Michael Famiano*

RESEARCH ABSTRACT

Explaining the Sr and Ba Scatter in Extremely Metal-Poor Stars

M.A. Famiano, W. Aoki,[1] T. Suda,[1] T. Kajino,[1] R.N. Boyd[2]
[1]National Astronomical Observatory, Mitaka, Tokyo, Japan
[2]Sonoma Center for Astrophysics, Windsor, CA, USA

Recent data compilations of abundances of Strontium and Barium in extremely metal poor stars show that an apparent cutoff is observed for [Sr/Ba] at [Fe/H]<-3.6 and large fluctuations for [Fe/H]>-3.6 with a clear upper bound depending on metallicity. We study the factors that place upper limits on the logarithmic ratio [Sr/Ba]. A model is developed in which the collapses of type II supernovae are found to reproduce many of the features seen in the data. This model is consistent with galactic chemical evolution constraints of light-element enrichment in metal-poor stars. Effects of turbulence in an explosive site have also been simulated, and are found to be important in explaining the large scatter observed in the [Sr/Ba] data.

Applications of Recent Shell-Model Calculations for fp-Shell Nuclei to Type Ia Supernovae and X-Ray Bursts

M.A. Famiano, T. Suzuki,[1] T. Otuka,[2] T. Kajino[3]
[1]Nihon University, Chiyoda, Tokyo, Japan
[2]University of Tokyo, Hongo, Tokyo, Japan
[3]National Astronomical Observatory, Mitaka, Tokyo, Japan

Recent shell-model calculations for the fp-shell nuclei have indicated a reduction in some of the GT strengths by a factor of several times. In particular, the GT- strengths for 56Ni have been shown to be reduced by a significant amount for Ex<4 MeV for the GXP1F parameter set when compared to the widely-used KBF parameter set. The match between the GXP1F results and experiment lends credence to the possibility that the GT- strength functions are much lower for the fp-shell nuclei than previously thought. This can have significant implications in two astrophysical scenarios. One is the production of 56Ni in Type Ia supernovae, and the other is the effect on the light curves of x-ray bursts, both of which are studied using two different shell-model results. Differences in the observable results of both astrophysical scenarios are shown.

Model for Determining Amino Acid Chirality in the Supernova Neutrino Processing Model

M.A. Famiano, R.N. Boyd,[1] T. Kajino,[2] T. Onaka[3]
[1]Sonoma Center for Nuclear Astrophysics, Windsor, CA, USA
[2]National Astronomical Observatory, Mitaka, Tokyo, Japan
[3]University of Tokyo, Hongo, Tokyo, Japan

A model is described that can be used to estimate the bulk polarization of large rotating meteoroids in the magnetic field of a neutron star. The results of this model are applicable to the Supernova Neutrino Amino Acid Processing model, which describes one way in which the amino acids could have achieved chirality.

PUBLICATIONS

1. ***Double Isobaric Analog of ^{11}Li in ^{11}B***, R. J. Charity, L. G. Sobotka, K. Hagino, D. Bazin, M. A. Famiano, A. Gade, S. Hudan, S. A. Komarov, Jenny Lee, S. P. Lobastov, S. M. Lukyanov, W. G. Lynch, C. Metelko, M. Mocko, A. M. Rogers, H. Sagawa, A. Sanetullaev, M. B. Tsang, M. S. Wallace, M. J. van Goethem, & A. H. Wuosmaa, Phys. Rev. C 86, 041307 (2012).

2. ***Time of Flight Mass Measurements of Exotic Nuclei***, M. Matos, A. Estrade, H. Schatz, D. Bazin, M. Famiano, A. Gade, S. George, W.G. Lynch, Z. Meisel, M. Portillo, A. Rogers, D. Shapira, A. Stolz, M. Wallace, & J. Yurkon, Nuc. Instr. Meth. in Phys. Res. A, 696, 171 (2012).

3. ***Tracking Saddle-to-Scission Dynamics Using N/Z in Projectile Breakup Reactions***, S. Hudan, A. B. McIntosh, R. T. de Souza, S. Bianchin, J. Black, A. Chbihi, M. Famiano, M. O. Frageau, J. Gauthier, D. Mercier, J. Moisan, C. J. Metelko, R. Roy, C. Schwarz, W. Trautmann, and R. Yanez, Phys. Rev. C 86, 021603 (2012).

4. ***Isospin Observables from Fragment Energy Spectra***, T.X. Liu, W. G. Lynch, R. H. Showalter, M. B. Tsang, X. D. Liu, W. P. Tan, M. J. van Goethem, G. Verde, A. Wagner, H. F. Xi, H. S. Xu, M. A. Famiano, R. T. de Souza, V. E. Viola, R. J. Charity, & L. G. Sobotka, Phys. Rev. C 86, 024605 (2012).

5. ***Probing Elastic and Inelastic Breakup Contributions to Intermediate-Energy Two-Proton Removal Reactions***, K. Wimmer, D. Bazin, A. Gade, J. A. Tostevin, T. Baugher, Z. Chajecki, D. Coupland, M. A. Famiano, T. K. Ghosh, G. F. Grinyer, R. Hodges, M. E. Howard, M. Kilburn, W. G. Lynch, B. Manning, K. Meierbachtol, P. Quarterman, A. Ratkiewicz, A. Sanetullaev, S. R. Stroberg, M. B. Tsang, D. Weisshaar, J. Winkelbauer, R. Winkler, & M. Youngs, Phys. Rev. C 85, 051603 (2012).

6. ***Near- and Sub-Barrier Fusion of ^{20}O Incident Ions With ^{12}C Target Nuclei***, M. J. Rudolph, Z. Q. Gosser, K. Brown, S. Hudan, R. T. de Souza, A. Chbihi, B. Jacquot, M. Famiano, J. F. Liang, D. Shapira, & D. Mercier, Phys. Rev. C 85, 024605 (2012).

7. ***Angular Dependence in Proton-Proton Correlation Functions in Central ^{40}Ca+^{40}Ca and ^{48}Ca+^{48}Ca Reactions***, V. Henzl, M. A. Kilburn, Z. Chajecki, D. Henzlova, W. G. Lynch, D. Brown, A. Chbihi, D. D. S. Coupland, P. Danielewicz, R. T. deSouza, M. Famiano, C. Herlitzius, S. Hudan, Jenny Lee, S. Lukyanov, A. M. Rogers, A. Sanetullaev, L. G. Sobotka, Z. Y. Sun, M. B. Tsang, A. Vander Molen, G. Verde, M. S. Wallace, & M. Youngs, Phys. Rev. C 85, 014606 (2012).

8. ***The r-Process in Metal Poor Stars and Black Hole Formation***, R.N. Boyd, M.A. Famiano, B.S. Meyer, Y. Motizuki, T. Kajino, & I.U. Roederer, ApJ 744, L14 (2012).

GRANTS

Nuclear Structure Studies of Nuclei of Astrophysical Relevance, NSF Nuclear Physics Program. Amount: $240,000 August 2012 - August 2013.

INVITED TALKS

1. **The r-Process in Core Collapse Models and Explanation of Scatter in Sr and Ba Abundances in Metal-Poor Stars**, Invited Astronomy Colloquium, Sendai University, December 11, 2012.
2. **Experimental Investigations of the Nuclear Equation-of-State**, Invited Nuclear Physics Colloquium, Sendai University, December 12, 2012.
3. **Model for Determining Amino Acid Chirality in the Supernova Neutrino Processing Model**, ***NAOJ Astrobiology Workshop***, National Astronomical Observatory, Mitaka, Japan, November 23 - 24, 2012.
4. **Heavy Element Production in r-Process Collapse Scenarios**, Nuclear Physics Seminar, The University of Tokyo, November 4, 2012.
5. **Black Hole Formation and Constraints on the r-Process and Galactic Chemical Evolution**, ***Workshop on Element Genesis and Cosmic Chemical Evolution***, Wako, Saitama, Japan, October 2012.
6. **Observational Constraints of Computational Nuclear Astrophysic**s, National Astronomical Observatory Colloquium, Mitaka, Tokyo, Japan, July 4, 2012.
7. **Neutrino Effects in r-Process Nucleosynthesis and Black Hole Formation**, The 2nd Dogae Nuclear Physics and Nuclear Astrophysics Workshop, Kangwon-do, Korea, August 1-4, 2012.
8. **Cosmology, Science, and Religion**, Public Lecture at the Tokyo Chapter of the WMU Alumni Association, Tokyo, Japan, June 5, 2012.

SCHOLARLY ACTIVITIES

- NSCL User's Executive Committee, Chair
- NUFO FRIB Representative
- Michitoshi Soga Japan Center Advisory Committee

6.2 Dean Halderson

RESEARCH ABSTRACT

"Nucleon Induced Reaction with the Extended Recoil Corrected Continuum Shell Model"

Dean Halderson, Department of Physics, Western Michigan University, Kalamazoo, MI

The recoil corrected continuum shell model (RCCSM) has been extended to include core states with $1\hbar\omega$ excitations. This extension allows one to include 0*s*-shell knockout processes. The model was applied to the $^{11}B(p,n)^{11}C$ and $^{11}B(p,p')^{11}B$ reactions, and good agreement with available data was obtained. The (*p,n*) results are shown in Fig. 1. Successful $^{11}B(p,n)^{11}C$ calculations provide confidence in the model's ability to predict cross sections to proton rich systems.

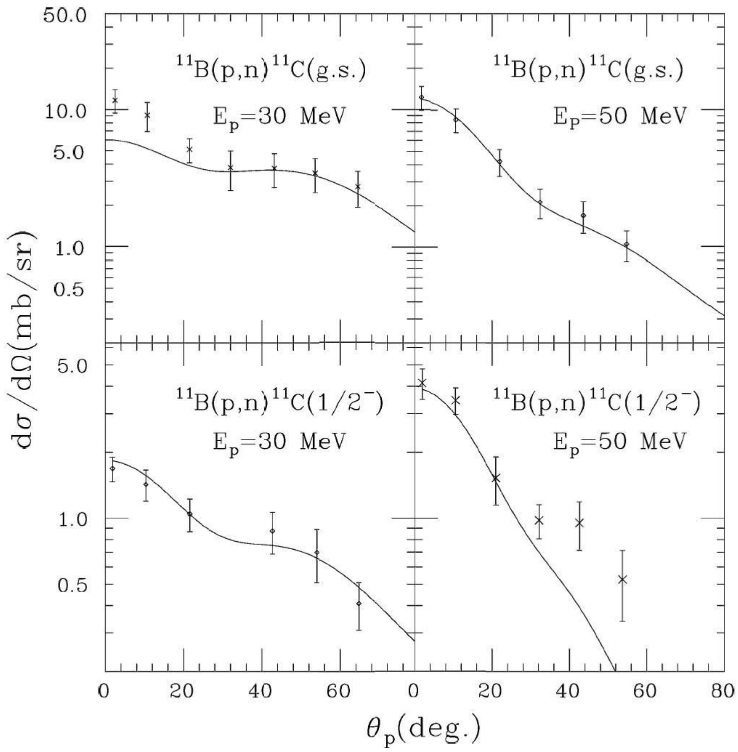

FIG. 1. Charge exchange cross sections for ^{11}B to the ground state and first excited state of ^{11}C. The solid lines are from calculations. The data is from Ref. [1]

The calculated elastic proton scattering cross section at 30.3 MeV agrees well with the data as shown in Fig. 2. In fact the quality of the fit is similar to the optical model fit of Ref. [2]. At 155 MeV the cross section gives the appearance that the target size is somewhat too small as shown in Fig. 3. The modest agreement at 155 MeV is not of

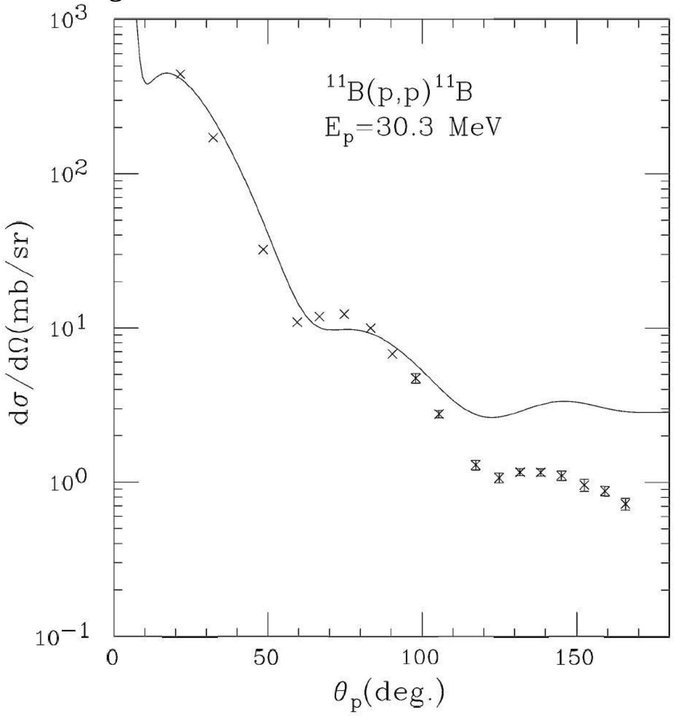

FIG. 2. Elastic proton scattering from ^{11}B at 30.3 MeV. Solid line is the RCCSM calculation. Data are from Ref. [2].

concern since knockout reactions show less sensitivity to the interaction at high energy transfer. Therefore, the RCCSM is one model that will provide satisfactory agreement with many nucleon induced reactions over a large energy range and should be appropriate for use in knockout reactions.

"Inclusive and Exclusive Electron Scattering from ^{12}C"

Dean Halderson, Department of Physics, Western Michigan University, Kalamazoo, MI

The extended version of the RCCSM has been applied to electron scattering. Calculations were performed for ^{12}C(*e*,*e'x*) and ^{12}C(*e*,*e'p*)^{11}B(g.s.) in the quasi-elastic region. The agreement with measured cross sections was good at low momentum transfer. At high *q*, the calculated cross sections were smaller than the data [4], and dissection of the cross sections into longitudinal and transverse responses indicated that the weakness was in the transverse response as shown in Fig. 5. A possible explanation for this lack of strength is the neglect of recoil terms.

The contribution to the responses from coupled channels, 0*s*-shell hole components of the wave functions, and meson exchange currents can be seen in Figs. 5 and 6. Elimination of the contribution of channels that couple to the exit channel reduces the longitudinal response by 23% at q = 300 MeV/c, but only 2% at q = 550 MeV/c as shown by the dashes lines in Fig. 5 Elimination of the 0*s*-shell hole components of the wave functions

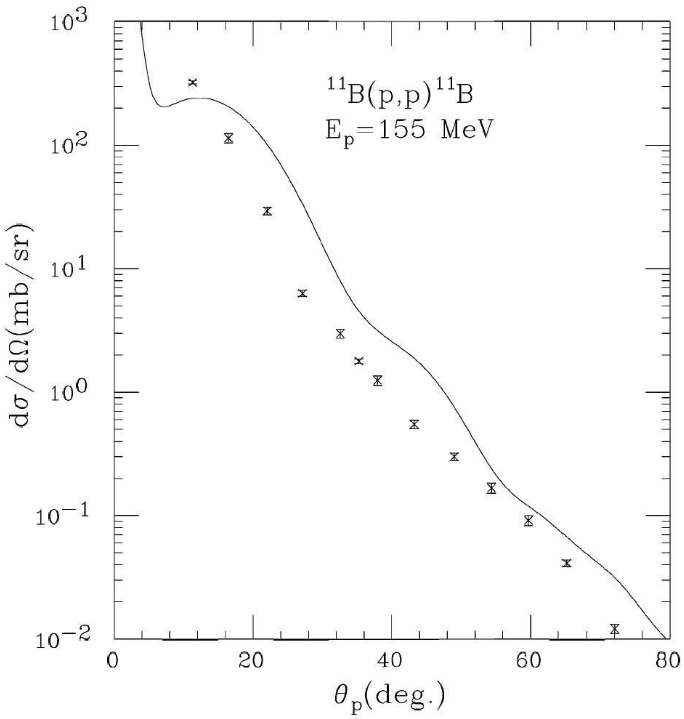

FIG. 3. Elastic proton scattering from ^{11}B at 155 MeV. Solid line is the RCCSM calculation. Data are from Ref. [3].

is shown as dotted lines in Fig. 5. The inclusion of 0*s* shell knockout is less significant, but its contribution persists throughout the range of momentum transfer. The contribution of MEC, as shown in Fig. 6, is smaller than those calculated for ^{4}He in Ref. [7], and are not sufficient to boost the calculated cross section into agreement with the data. However, like the 0*s* knockout contribution they effect the responses over the range of momentum transfer.

Appearing at an energy of $106/A^{1/3}$ MeV is the high energy octupole resonance. It contributes a significant amount of strength to the longitudinal response at q = 300 MeV/c. Both the coupled channels and resonance contributions would be missing from optical model calculations.

Calculations have also been performed for the inclusive reaction, ^{12}C(*e*,*e'p*)^{11}B(g.s.), in the quasi-elastic region. Shown in Fig. 6 are the data of Ref. [6] as open squares. These data have a missing momentum range between 181.5 and 304.8 MeV/c, an energy transfer of 60 MeV, and a momentum transfer of 104.4 MeV/c. The proton direction is out of the scattering plane, φ_p = 90º. The lab proton energy ranges from 39.5 to 42.5 MeV. The calculations with single-particle operators are represented by ×. The calculation agrees well with the data except at higher angles where the calculated values decline smoothly and the data drops below them. Relativistic distorted wave impulse

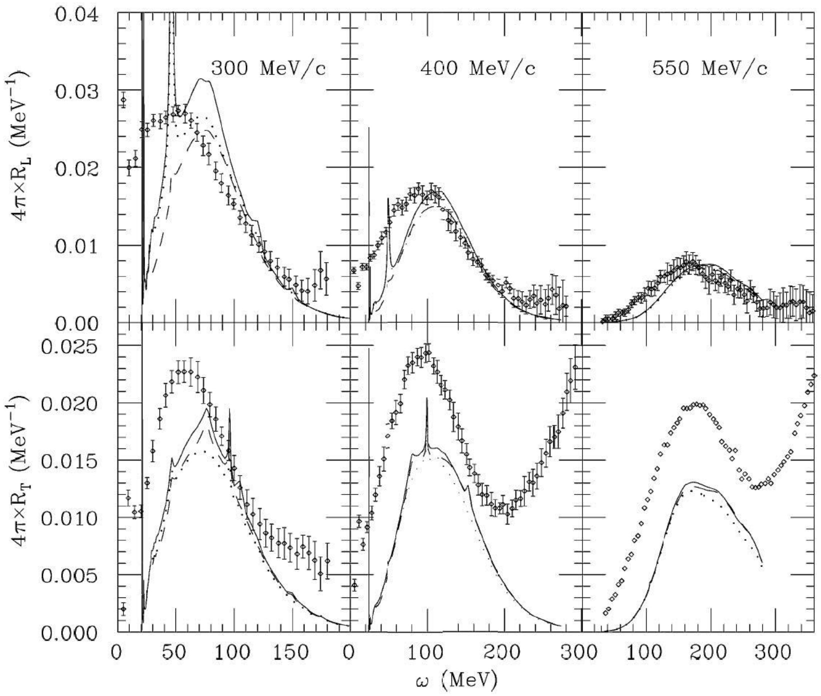

FIG. 4. Longitudinal and transverse responses extracted from the data of Ref. [4]. Solid lines are responses calculated with single-particle operators. Dashes lines omit contributions from coupled channels. Dotted lines omit contributions from 0s hole components.

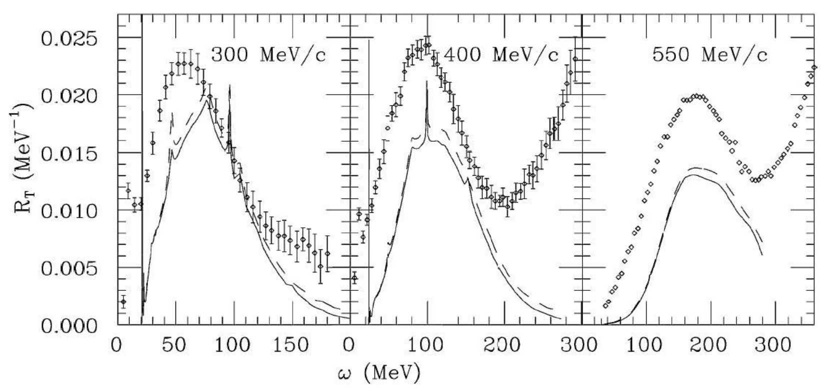

FIG. 5. The transverse responses extracted from the data of Ref. [4]. Solid lines are responses calculated with single-particle operators. Dashes lines include meson exchange currents.

approximation calculations reported in Ref. [6] have a similar shape, but require a considerable normalization. Also shown as solid dots are ten times the calculated values for ^{12}C(*e*,*e'p*) ^{11}B(1/2$^-$). The calculated values show the peculiar property of having a maximum around 18º. The ability of RCCSM calculations to describe ^{12}C(*e*,*e'x*) and ^{12}C(*e*,*e'p*)^{11}B reactions at and below 300 MeV/c indicates that they should provide useful predictions for other knockout reactions in this momentum transfer region.

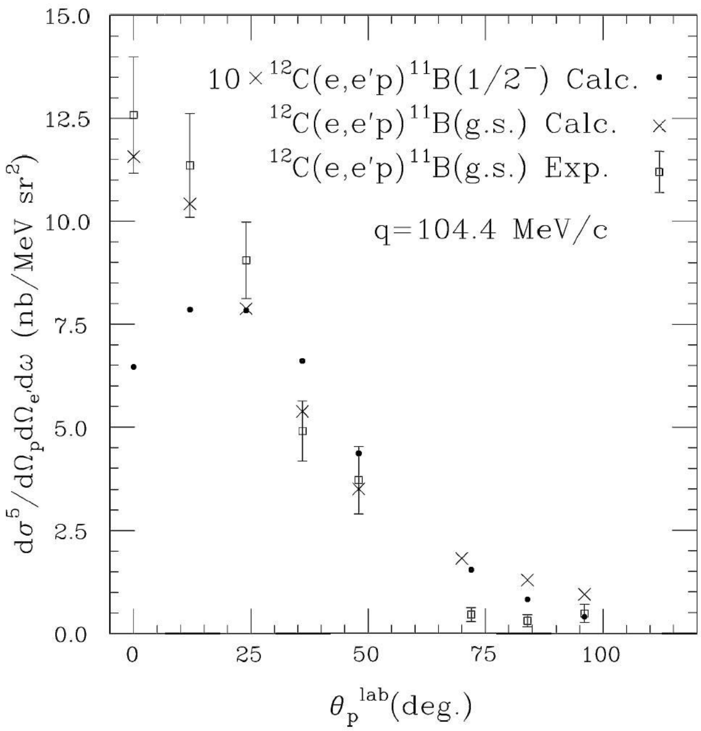

FIG. 6. The inclusive ^{12}C(*e,e'p*)^{11}B reaction. Open squares are the data of Ref. [8] to the ^{11}B ground state. Crosses are the RCCSM calculation to the ^{11}B ground state. Solid dots are the RCCSM calculation to the ^{11}B first excited state times ten.

"Hypernuclei and the Nijmegen ESC11 Potential"

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The binding energies of ${}^{3}_{\Lambda}$H, ${}^{4}_{\Lambda}$H(0^+), and ${}^{4}_{\Lambda}$H(1^+) have been calculated with the latest version of the Nijmegen baryon-baryon potential.[6] The results are shown in Table I with the full potential and with the $\Lambda\Sigma$ tensor coupling reduced by 10%. Clearly the modified tensor interaction is preferred for the light hypernuclei. The Nijmegen group is presently investigating whether such a modification can be accommodated by their model.

Table I. Binding energies of the 0s-shell Λ hypernuclei in MeV.

	${}^{3}_{\Lambda}$H	${}^{4}_{\Lambda}$H(0^+)	${}^{4}_{\Lambda}$H(1^+)
Full	0.57	3.34	3.09
Reduced $\Lambda\Sigma$ tensor	0.17	2.19	1.13
Exp.	0.13	2.20	1.15

[1]A. S. Clough, C. J. Batty, B. E. Bonner, and L. E. Williams, Nucl. Phys. A **143**, 385 (1970).
[2] J. Lowe, Nucl. Phys. A **162**, 438 (1971).
[3] B. Gepffrion, N. Marty, B. Tatischeff, and A. Willis, Nucl. Phys. A **116**, 209 (1968).
[4]P. Barreau and *et al*., Nucl. Phys. A **402**, 515 (1983).
[5] D. Halderson, Phys. Rev. C **53**, 2978 (1996).
[6] T. Tamae and *et. al*, Phys. Rev. C **80**, 064601 (2009).
[7] Th. A.Rijken, private communication.

PUBLICATIONS

1. **J. Grineviciute** and **D. Halderson**, "Relativistic R-matrix and continuum shell model," Phys. Rev. C **85**, 054617 (2012).

GRANTS

D. Halderson, National Science Foundation Grant, 2009-2012, $24,420

6.3 Alan Wuosmaa

<u>RESEARCH ABSTRACT</u>

HELIOS: The <u>HELI</u>cal <u>O</u>rbit <u>S</u>pectrometer

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The HELIOS device at Argonne National Laboratory continues to be a mainstay in our experimental program. It is a novel spectrometer, based on a large-volume high-field magnetic solenoid, designed to study nucleon transfer and other reactions in inverse kinematics. A detailed technical description of the device and its capabilities are contained in Refs. [1,2]. Briefly, HELIOS uses a uniform magnetic field produced by the solenoid to transport particles from the target, positioned on the solenoid/beam axis, to a linear array of position-sensitive silicon detectors also placed on the axis. This arrangement provides significantly improved resolution the center-of-mass frame for reactions in inverse kinematics, as well as straightforward determination of particle species and suppression of unwanted backgrounds. HELIOS plays a prominent role in the future Strategic Plan for the ATLAS facility, as it is well matched to the ongoing CARIBU radioactive beam source development project.

The basic HELIOS device is mature in most respects, and to date many experiments have been conducted, primarily to study neutron-transfer using the (*d,p*) reaction. In addition to experiments with light radioactive beams [3-5] and heavy stable beams [6,7]. A number of development projects are underway to widen the scope of the experimental program, some of them described here. These include first physics measurements conducted with unstable beams in forward kinematics, where the charged particles of interest are emitted at forward (□<90^{o}) rather than backward (□<90^{o}) angles in the laboratory. Such reactions include pickup reactions such as (d,^{3}He) and (d,t). This configuration has now been used to study the ^{14,15}C(d,^{3}He)^{13,14}B reaction (see below). Other projects underway include the commissioning of a cryogenic gas target for studies of reactions on ^{3}He and ^{4}He targets, and the installation of a large avalanche detector/Bragg ionization chamber for the detection of heavy residues produced in reactions with CARIBU beams.

Finally, an important upgrade of the apparatus involves the construction and instrumentation of a new silicon-detector array. The existing array, always considered a prototype device has served the device well. The sensors, however, which were reclaimed from an prior application, are reaching 20 years old and beginning to malfunction. To improve the silicon-array performance, as well as to extend the acceptance and efficiency, a new silicon-detector array is being constructed with a new type of silicon detector. The WMU group is responsible for overseeing the design and fabrication of the new silicon sensors (see below).

[1] A. H. Wuosmaa *et al.*, Nucl. Instr. and Meth. in Phys. Res. A **580**, 1290 (2007).
[2] J. C. Lighthall *et al*., Nucl. Instr. and Meth. in Phys. Res. A **622**, 97 (2010).
[3] B. B. Back *et al.*, Physical Review Letters **104**, 132501 (2010).
[4] A. H. Wuosmaa *et al.*, Physical Review Letters **105**, 132501 (2010).
[5] C. R. Hoffman *et al.*, Phys. Rev. C **85**, 054318 (2012).
[6] B. P. Kaye *et al.*, Phys. Rev. C **84**, 024325 (2011).
[7] D. Sharp *et al*., Phys.Rev. C **87**, 014312 (2013).

Table 1. Beams, reactions, and physics topics for experiment conducted with HELIOS from August 2008 to December 2011. Beams indicated by “*” are short-lived nuclei produced with the In-Flight method.

Beam	Target	Reaction	Physics
^{28}Si	CD_2	^{28}Si(d,p)^{29}Si	HELIOS commissioning
^{12}B*	CD_2	^{12}B(d,p)^{13}B	RIB commissioning and nuclear structure of ^{13}B
^{17}O	CD_2	^{17}O(d,p)^{18}O	Branching ratios of unbound states in ^{18}O for astrophysics
^{15}C*	CD_2	^{15}C(d,p)^{16}C ^{15}C($d,^{3}$He)^{14}B	Nuclear structure of ^{16}C and ^{14}B
^{130,136}Xe	CD_2	^{130,136}Xe(d,p)^{131,137}Xe	Nuclear structure near ^{132}Sn and double-beta decay
^{86}Kr	CD_2	^{86}Kr(d,p)^{87}Kr	Nuclear structure of ^{87}Kr
^{14}C	^{6}LiF	^{14}C(^{6}Li,d)^{18}O	□-transfer to cluster states in ^{18}O, Nuclear structure of ^{13}B
^{19}O*	CD_2	^{19}O(d,p)^{20}O	Nuclear structure of ^{20}O
^{1}H	^{12}C	^{12}C(p,p')^{12}C(0^{+}_{2})	Pair decay of the “Hoyle” state and ^{12}C nucleosynthesis
^{28}Si	CD_2	^{28}Si($d,^{3}$He)^{27}Al	Commissioning of forward-angle silicon array.
^{13}B*	CD_2	^{13}B(d,p)^{14}B	Single-particle structure of ^{14}B

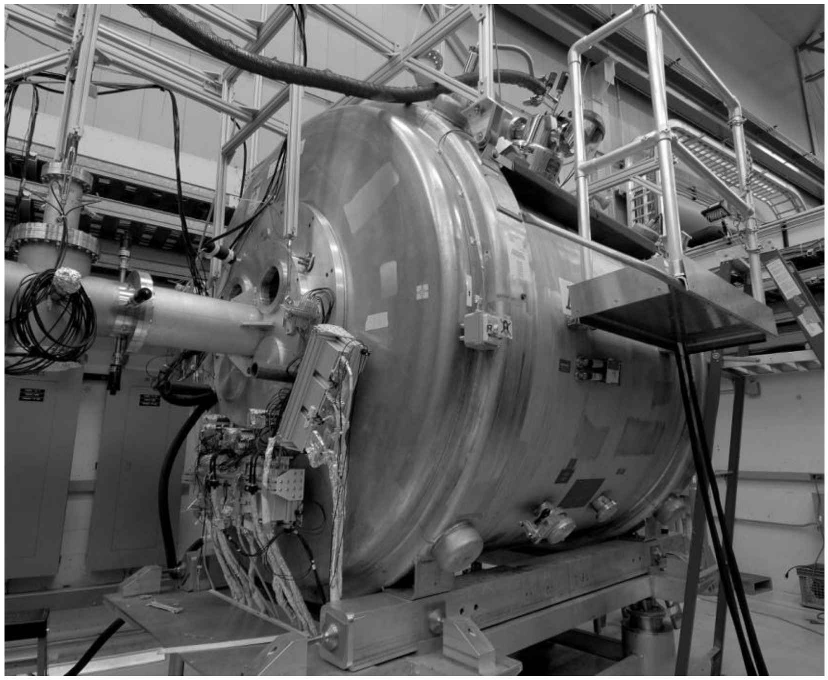

Figure 1. HELIOS at the ATLAS facility at Argonne National Laboratory

Silicon-sensor development for a new HELIOS detector array.

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We are currently working with the firm, Micron Semiconductor, in the UK, to develop a new type of position-sensitive silicon detector to be used in the HELIOS silicon-detector array. Like the existing silicon sensors, these detectors must be able to stop relatively high-energy (<15 MeV) protons, have excellent energy, and position resolution. One difficulty with the existing silicon sensors is that the resistive division used in those devices is continuous, and subject to non-linear effects on the charge collection that make them difficult to calibrate in both energy and position. The new design that we are pursuing attempts address this problem by making the position readout discrete, rather than continuous, while retaining the basic functionality of charge-division to provide position sensitivity. To do this, the active area of the detector is divided into 50 1mm wide segments, connected through a resistor chain that can be read out on the two ends. A comparison of the charge collected on the two ends provides the position sensitivity, and the total particle energy is obtained by measuring the total charge deposited in the device from an Ohmic contact on the back of the detector. Figure 1 shows a photograph of one of the new prototype detectors, and Figure 2 shows a plot of particle energy versus position obtained from that device for alpha particles emitted by a ^{228}Th source. Both energy and position response are very linear, and the resolution in energy and position are adequate for use in the new HELIOS array. Following additional testing and final prototyping, 60 new sensors will be fabricated and installed in the new array fixture being fabricated at ANL.

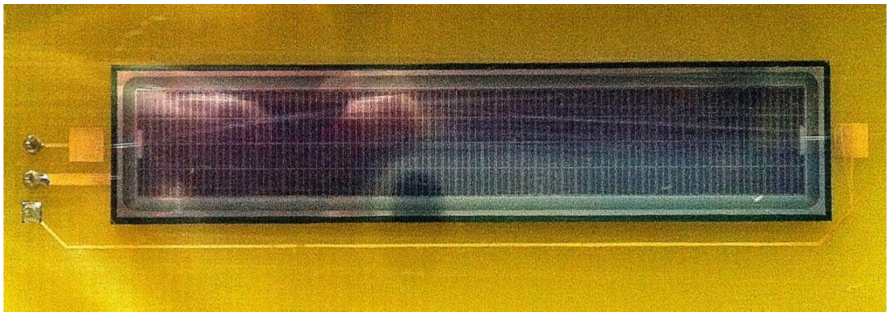

Figure 1. Photograph of new HELIOS prototype silicon sensor.

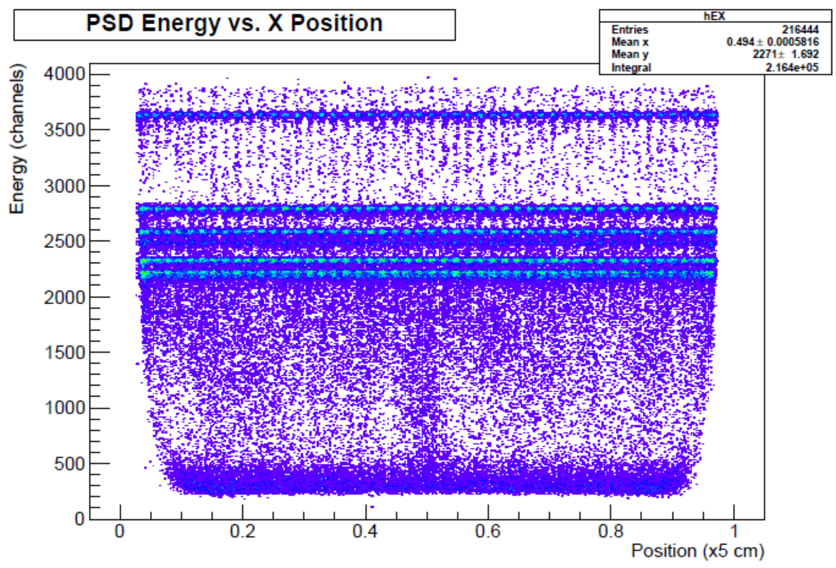

Figure 2. Particle energy versus detector position for alpha particles from a ^{228}Th source, obtained using the new HELIOS detector prototype.

The ^{13}B(*d*,*p*)^{14}B reaction and single-neutron states in ^{14}B.

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The nucleus ^{13}B is the N=9 isotone with the largest N/Z ratio whose ground state is still particle bound. It is an ideal nucleus to study *sd*-shell single-particle properties at and beyond the limits of stability, however detailed knowledge of the structure of ^{14}B is very limited [1]. Due to the $1s_{1/2}$ - $0d_{5/2}$ orbital inversion observed in light neutron-rich nuclei near the *p*-shell closure for neutrons, the wave function of the ground state of ^{14}B is likely dominated by a □($1s_{1/2}$) configuration. This property and the very small neutron binding energy (0.969 MeV) make ^{14}B a good example of a halo nucleus where the neutron wave function extends to a much larger radius than what would normally be thought of as the nuclear surface. The single-neutron properties of ^{14}B can be well studied through the ^{13}B(*d,p*)^{14}B reaction. Without radioactive beams, this measurement would be impossible as the "target" nucleus ^{13}B has a half-life of only 17.33 ms.

We have conducted a measurement of ^{13}B(*d,p*)^{14}B in inverse kinematics, with a ^{13}B beam incident on a solid target containing deuterium (^{2}H) using HELIOS[2,3] at Argonne National Laboratory. This measurement required the development of a ^{13}B beam with the in-flight facility which had not been done previously, and was carried out using a new technique utilizing a ^{9}Be production foil instead of the usual cryogenic gas target. The primary beam was ^{14}C with an intensity of approximately 80 to 100 particle-nano-amperes, and the production reaction was ^{9}Be(^{14}C,^{13}B)^{10}B. ^{13}B Intensities of between 20 and 40x10^{4} particles per second were obtained, with a ^{13}B energy of approximately 204 MeV. Protons were detected at angles greater than 90 degrees in the laboratory in the HELIOS silicon-detector array in coincidence with recoiling ^{14,13}B ions detected in a forward array of silicon particle-detector telescopes. While the data are still being analyzed, transitions to known, and several previously unknown states in ^{14}B were observed. Fig. 1 shows an excitation-energy spectrum for ^{14}B, where the solid (open) histograms correspond to events obtained in coincidence with ^{14}B(^{13}B). The ^{13}B data represent states in ^{14}B that are unbound with respect to neutron emission. Figure 2 shows angular distributions for the lowest four narrow states, with spin and parity $(2,1,3,4)^{-}$, with reaction-model calculations showing the angular distributions expected from the Distorted-Wave Born Approximation (DWBA) (left panel). For the ground (2^{-}) and first-excited (1^{-}) states, both l=0 and 2 transitions are allowed. The corresponding relative spectroscopic factors are shown on the right panel of figure 2, and are presented in comparison with the results of shell-model calculations done using the WBT interaction. The agreement in the spectroscopic factors is very good, although the agreement is only fair for excitation energies. A manuscript describing these results is currently under preparation.

[1] *Energy Levels of Light Nuclei, TUNL Nuclear Data Evaluation Project*, http://www.tunl.duke.edu/nucldata/index.shtml.
[2] A. H. Wuosmaa *et al.*, Nucl. Instr. and Meth. in Phys. Res. A **580**, 1290 (2007).
[3] J. C. Lighthall *et al.*, Nucl. Instr. and Meth. in Phys. Res. A **622**, 97 (2010).

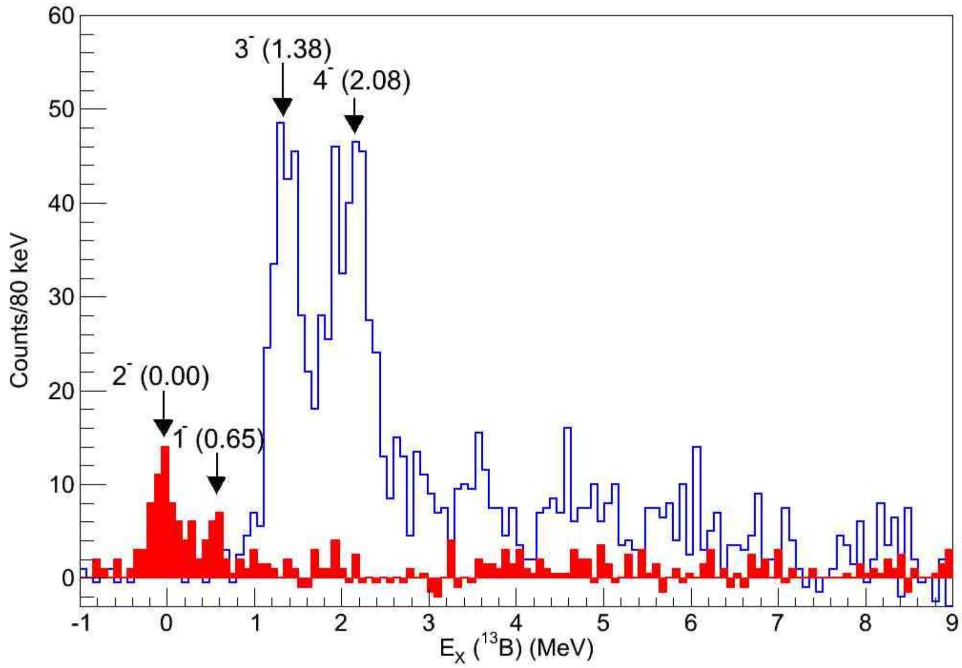

Figure 1. Preliminary excitation-energy spectrum for ^{14}B from the ^{13}B(d,p)^{14}B reaction. The red solid and blue open histograms correspond to events from neutron bound, and neutron unbound states in ^{14}B, respectively.

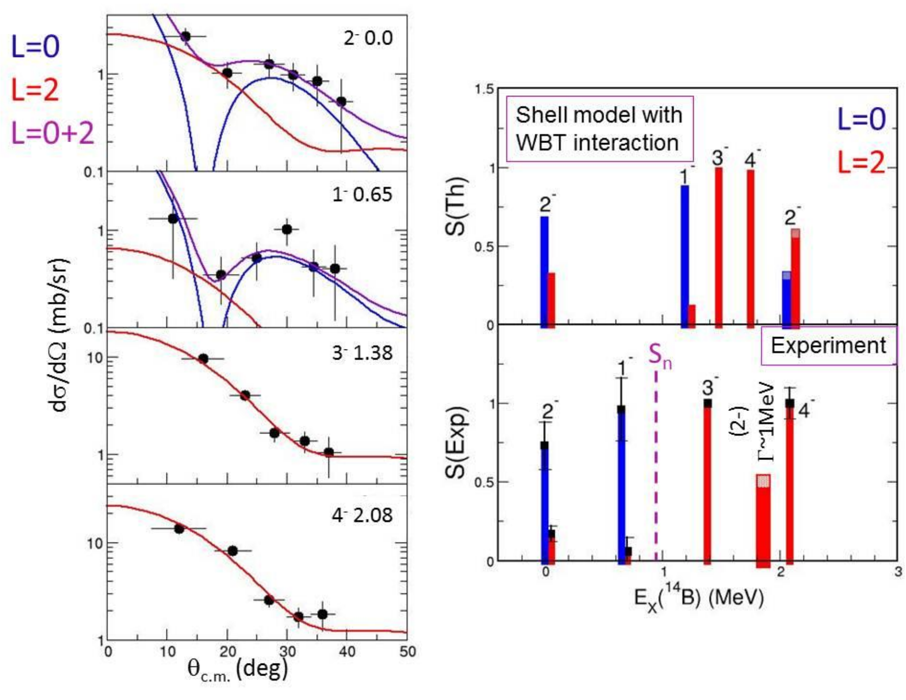

Figure 2. (Left panel) Angular distributions for four narrow states populated in the ^{13}B(d,p)^{14}B reaction. The curves represent the results of DWBA calculations described in the text. (Right panel) l=0 and 2 spectroscopic factors obtained from the current measurement (bottom) and from shell-model calculations (top).

The ^{14,15}C(d,^{3}He)^{13,14}B reactions and single-neutron states in ^{14}B.

S. Bedoor[1], A. H. Wuosmaa[1], M. Alcorta[2], P. F. Bertone[2], B. B. Back[2], S. Baker[2], B. A. Brown[3], C. M. Deibel[2,4], C. R. Hoffman[3], H. Iwasaki[3], B. P. Kay[2], **J. C. Lighthall**[1,2], A. O. Macchiavelli[4], **S. T. Marley**[1,2], R. C. Pardo[2], K. E. Rehm[2], J. P. Schiffer[2], **D. V. Shetty**[1]

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To complement our studies of single-neutron states in ^{14}B done with the ^{13}B(d,p)^{14}B reaction, we have also studied the isotopes ^{13,14}B populated with proton removal with the (d,^{3}He) reaction in inverse kinematics with the HELIOS spectrometer [1,2]. In ^{14}B, the proton-pickup reaction populates neutron states that have large overlap with the ^{15}C target nucleus whose ground-state wave function is that of a single $1s_{1/2}$ neutron. Also, new data are obtained for the ^{14}C(d,^{3}He)^{13}B reaction which has been studied only once before in normal kinematics [1] . In that older measurement, transitions to states in ^{13}B were largely obscured by those from (d,^{3}He) reactions on the 60% ^{12}C impurity in the ^{14}C target; in HELIOS this difficulty is eliminated by using a ^{14}C beam and doing the experiment in inverse kinematics.

The experiment was done using HELIOS, with the silicon-detector array in the new down-stream configuration, with ^{13,14}B recoils detected in a silicon-detector telescope positioned between the target and the silicon-detector array, as illustrated in Fig. 1. Data are still being analyzed, however preliminary results are very interesting. The (d,^{3}He), as well as (d,□) and (d,t) proton, deuteron, and neutron-pickup reactions have all been observed for the ^{14}C beam. On-line data extracted for the ^{14}C(d,^{3}He)^{13}B reaction appear in the left panel of Figure 2. Some of these reactions are being studied now for the first time. The data set for the ^{15}C beam is also being examined and clear evidence for the ^{15}C(d,^{3}He)^{14}B ground-state transition has been observed, with indications of strength for higher excited states (right panel of Figure 2). The data are still under analysis, and will complete the set of data for the dissertation studies of WMU graduate student Shadi Bedoor.

[1] A. H. Wuosmaa *et al.*, Nucl. Instr. and Meth. in Phys. Res. A **580**, 1290 (2007).
[2] J. C. Lighthall *et al.*, Nucl. Instr. and Meth. in Phys. Res. A **622**, 97 (2010).

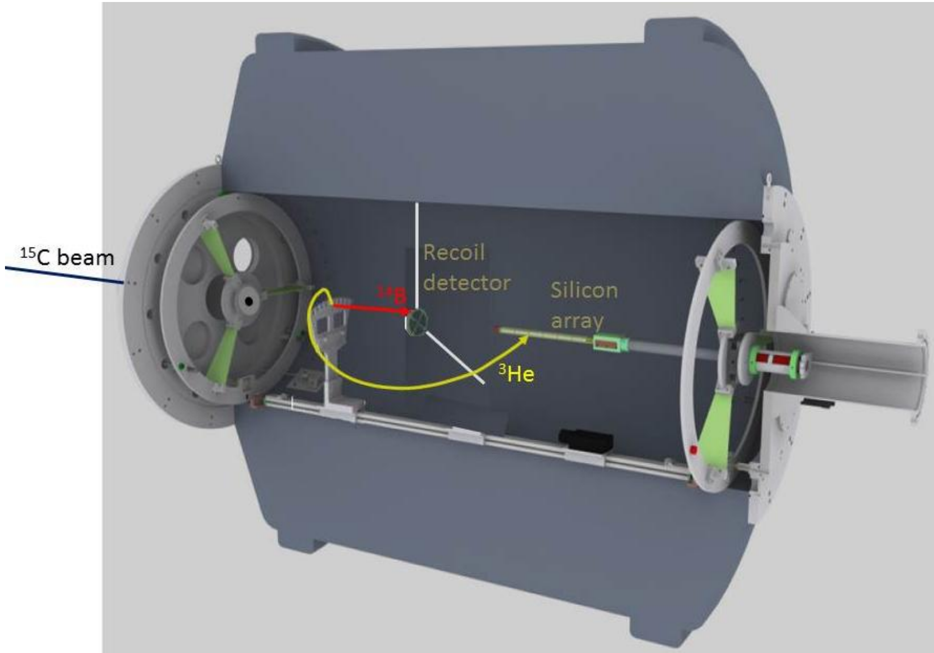

Figure1. Experimental setup for studying (d,^{3}He) reactions in HELIOS.

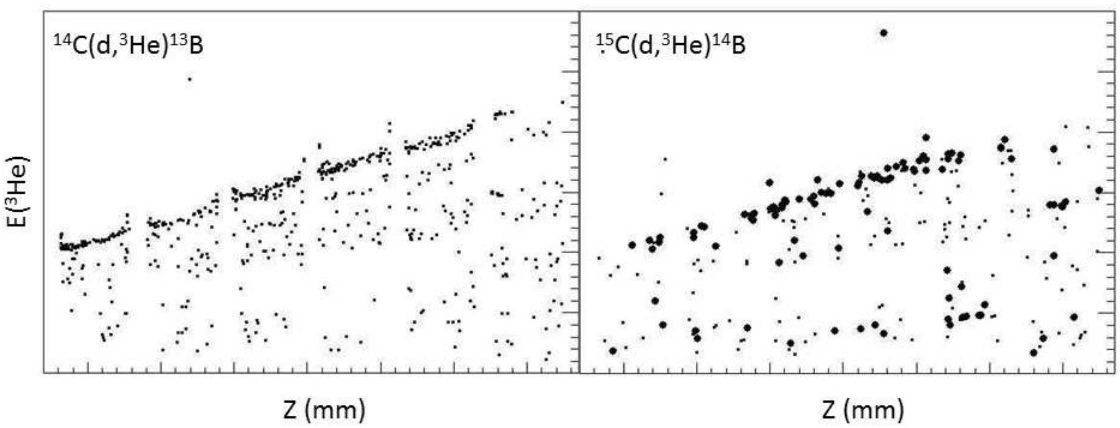

Figure **2.** On-line energy-position correlation plots for the ^{14}C(d,^{3}He)^{13}B (left) and ^{15}C(d,^{3}He)^{14}B (right) reactions. The prominent diagonal features correspond to the ground-state transitions for each reaction.

PUBLICATIONS

1. **Neutron single-particle strength outside the N=50 core**, D.K.Sharp, B.P.Kay, J.S.Thomas, S.J.Freeman, J.P.Schiffer, B.B.Back, S.Bedoor, T.Bloxham, J.A.Clark, C.M.Deibel, C.R.Hoffman, A.M.Howard, **J.C.Lighthall**, **S.T.Marley**, A.J.Mitchell, T.Otsuka, P.D.Parker, K.E.Rehm, D.V.Shetty, **A.H.Wuosmaa**. Phys.Rev. C **87**, 014312 (2013).

2. **Double isobaric analog of ^{11}Li in ^{11}B**, R.J.Charity, L.G.Sobotka, K.Hagino, D.Bazin, M.A.Famiano, A.Gade, S.Hudan, S.A.Komarov, Jenny Lee, S.P.Lobastov, S.M.Lukyanov, W.G.Lynch, C.Metelko, M.Mocko, A.M.Rogers, H.Sagawa, A.Sanetullaev, M.B.Tsang, M.S.Wallace, M.J.van Goethem, **A.H.Wuosmaa**. Phys.Rev. C **86**, 041307 (2012).

3. **High-spin spectrum of 24Mg studied through multiparticle angular correlations,** E.S.Diffenderfer, L.T.Baby, D.Santiago-Gonzalez, N.Ahsan, A.Rojas, A.Volya, I.Wiedenhover, **A.H.Wuosmaa**, M.P.Carpenter, R.V.F.Janssens, C.J.Lister, M.Devlin, D.G.Sarantites, L.G.Sobotka, Y.Utsuno, M.Horoi. 2012DI04 Phys.Rev. C **85**, 034311 (2012).

4. **Democratic Decay of ^{6}Be Exposed by Correlations**, I.A.Egorova, R.J.Charity, L.V.Grigorenko, Z.Chajecki, D.Coupland, J.M.Elson, T.K.Ghosh, M.E.Howard, H.Iwasaki, M.Kilburn, Jenny Lee, W.G.Lynch, J.Manfredi, **S.T.Marley**, A.Sanetullaev, R.Shane, **D.V.Shetty**, L.G.Sobotka, M.B.Tsang, J.Winkelbauer, **A.H.Wuosmaa**, M.Youngs, M.V.Zhukov, Phys.Rev.Lett. **109**, 202502 (2012)

5. **Experimental study of the ^{19}O(d, p)^{20}O reaction in inverse kinematics**, C.R.Hoffman, B.B.Back, B.P.Kay, J.P.Schiffer, M.Alcorta, S.I.Baker, S.Bedoor, P.F.Bertone, J.A.Clark, C.M.Deibel, B.DiGiovine, S.J.Freeman, J.P.Greene, **J.C.Lighthall**, **S.T.Marley**, R.C.Pardo, K.E.Rehm, A.Rojas, D.Santiago-Gonzalez, D.K.Sharp, **D.V.Shetty**, J.S.Thomas, I.Wiedenhover, **A.H.Wuosmaa**. Phys.Rev. C **85**, 054318 (2012).

6. **α decay of the excited states in ^{12}C at 7.65 and 9.64 MeV**, J.Manfredi, R.J.Charity, K.Mercurio, R.Shane, L.G.Sobotka, **A.H.Wuosmaa**, A.Banu, L.Trache, R.E.Tribble. Phys.Rev. C **85**, 037603 (2012).

GRANTS

1. **Study of exotic light nuclei with few nucleon transfer reactions**
Department of Energy Office of Nuclear Physics,
$551,000 over 2010-2013
A. H. Wuosmaa, Principal Investigator
Awarded; Active

2. **Study of exotic light nuclei with few nucleon transfer reactions**
Department of Energy Office of Nuclear Physics,
$650,495 over 2013-2016
A. H. Wuosmaa, Principal Investigator
Submitted

INVITED TALKS

1. **Recent experimental results from HELIOS. A. H. Wuosmaa**, Plenary talk at the 11th International Conference on Nucleus-Nucleus Collisions (NN2012), San Antonio, TX, May 2012.

CONTRIBUTED TALKS

1. **Neutron sd-shell excitations in exotic nuclei near N=8**. **A. H. Wuosmaa**, Direct Reactions with Exotic Beams Workshop 2012 (DREB 2012), Pisa, Italy, March 2012.

2. **Structure of ^{9}C from the ^{10}C(d,t)^{9}C reaction and the reliability of ab-initio transfer form factors**. **S.T. Marley**, **A.H. Wuosmaa**, **S. Bedoor**, **J.C. Lighthall**, **D.V. Shetty**, M. Alcorta, P.F. Bertone, J.A. Clark, C.M. Deibel, C.L. Jiang, T. Palchan-Hazan,R.C. Pardo, K.E. Rehm, A.M. Rogers, C. Ugalde, R.B. Wiringa, Nuclear Structure 2012, Argonne National Laboratory, Argonne IL, August 2012.

3. **Study of the ^{13}B(d,p)^{14}B reaction in inverse kinematics with HELIOS**. **S. Bedoor**, **A. H. Wuosmaa**, **J. C. Lighthall**, M. Alcorta , B. B. Back, P. F. Bertone, B. A. Brown, C. M. Deibel , S. T. Marley, K. E. Rehm, A. M. Rogers, J. P. Schiffer, **D. V. Shetty**, Nuclear Structure 2012, Argonne National Laboratory, Argonne IL, August 2012.

4. **Stucture of ^{9}C from the d(^{10}C,t)^{9}C Reaction and the Reliability of Ab-Initio Transfer Form Factors S.T. Marley**, **A.H. Wuosmaa**, **S. Bedoor**, **J.C. Lighthall**, **D.V. Shetty**, M. Alcorta, P.F. Bertone, J.A. Clark, C.L. Jiang, T. Palchan-Hazan, R.C. Pardo, K.E. Rehm, A.M. Rogers, R.B. Wiringa, C.M. Deibel, C. Ugalde, Fall Meeting of the American Physical Society Division of Nuclear Physics, Newport Beach CA, October 2012 (DNP 2012).

5. **Study of ^{13}B(d,p)^{14}B Reaction in Inverse Kinematics with HELIOS S. Bedoor**, **A.H. Wuosmaa**, **J.C. Lighthall**, **S.T. Marley**, **D.V. Shetty**, M. Alcorta, B.B. Back, P.F. Bertone, K.E. Rehm, A.M. Rogers, J.P. Schiffer, B.A. Brown, C.M. Deibel, Fall Meeting of the American Physical Society Division of Nuclear Physics, Newport Beach CA, October 2012 (DNP 2012).

6. **Alpha-decay of exited states in ^{12}C** Juan Manfredi, Robert Charity, Kevin Mercurio, Rebecca Sane, Lee Sobotka, **Alan Wuosmaa**, Adriana Banu, Livius Trache, Robert Tribble, Fall Meeting of the American Physical Society Division of Nuclear Physics, Newport Beach CA, October 2012 (DNP 2012).

SEMINARS AND COLLOQUIA

1. **Lecture Series on *"Probing Exotic Nuclear Structure with Transfer Reactions,"* A. H. Wuosmaa,** Institut fur Kern und Stralphysik, KU Leuven, Leuven Belgium, April 2012.

2. **The Study of the Structure of ^{9}C at ATLAS**, **S. T. Marley**, Seminar, Physics Department, Indiana University South Bend, 2012.

3. **The Study of the Structure of ^{9}C at ATLAS**, **S. T. Marley,** Heavy-Ion discussion group, Physics Division Argonne National Laboratory, 2012.

4. **Historical and Philosophical Implications of Relativity and Quantum Mechanics**, **A. H. Wuosmaa**, Invited talk at the Western Michigan University Philosophy Club, Western Michigan University, December 2012.

<u>SCHOLARLY ACTIVITIES</u>

1. Member: FRIB Users Organization Executive Committee,
2. Member, ATLAS Users Executive Committee (Chair)
3. Co-convener: FRIB working group on Solenoidal Spectrometers.
4. Member: Michigan State University National Superconducting Cyclotron Laboratory Program Advisory Committee,
5. Member: ATLAS Program Advisory Committee
6. Grant reviewer for: the U. S. Department of Energy, Office of Nuclear Physics and SBIR/STTR Program, the U. S. National Science Foundation, the U. K. Science and Technologies Facilities Council (STFC), The Natural Sciences Engineering and Research Council (NSERC) of Canada, The South African National Research Foundation (NRF).
7. Referee for the Journals: Physical Review Letters, Physical Review C, Physics Letters B, European Journal of Physics.
8. External Faculty Assessor, Australian National University.
9. Western Michigan University Research Policies Council.
10. Served as the chairperson of the Ph.D. thesis committee of Scott Marley (completed, June 2012).

PHYSICS EDUCATION

7.1 *Charles Henderson*

M.A. THESES AND Ph.D. DISSERTATIONS

William Mamudi, 2012, M.A. committee chair, Summer II 2012
Trevor Stefanick, 2012, M.A. committee chair, Fall 2012

PUBLICATIONS (Journal Articles or Book Chapters)

1. Beach**,** A. L., **Henderson, C.**, & Finkelstein, N. (2012). Facilitating Change in Undergraduate STEM Education. *Change: The Magazine of Higher Learning*, **44** (6), 52–59.

2. **Henderson**, C., Beach, A., & Finkelstein, N. (2012). Promoting High Quality Teaching Practices in Higher Education: Lessons Learned from the USA. In W. Bienkowski, J. C. Brada, & G. Stanley (Eds.), *The University in the Age of Globalization*. New York, NY: Palgrave Macmillan.

3. **Henderson, C.**, Dancy, M., & Niewiadomska-Bugaj, M. (2012). The Use of Research-Based Instructional Strategies in Introductory Physics: Where do Faculty Leave the Innovation-Decision Process?. *Physical Review Special Topics - Physics Education Research,* 8 (2), 020104.

4. **Henderson, C.**, Beach, A., & Finkelstein, N. D. (2012). Four Categories of Change Strategies for Transforming Undergraduate Instruction. In P. Tynjälä, M.-L. Stenström, & M. Saarnivaara (Eds.), *Transitions and Transformations in Learning and Education* (pp. 223-246). Dordrecht, Netherlands: Springer. doi:10.1007/978-94-007-2312-2

5. Petcovic, H., Fynewever, H., **Henderson, C.**, Mutambuki, J., & Barney, J. (2012) Faculty Grading of Quantitative Problems: A Mismatch between Values and Practice, *Research in Science Education*.

6. **Henderson**, C., Fynewever, H., Petcovic, H., & Bierema, A. (2012). Identifying the Impact of National ATE Centers on Their Host Institutions: An exploratory study. *Community College Review*, **40** (1) 3-24.

PUBLICATIONS (Other)

1. **Henderson, C.**, & Beichner, R. (2012). Physical Review Special Topics – Physics Education Research: A brief history and future directions. *American Physical Society Forum on Education Newsletter*, Fall 2012, 4–6.
2. **Henderson, C.** (2012). Editorial: Physical Review in Physics Education Research 2.0. *Physical Review Special Topics - Physics Education Research*, **8** (2), 1–2. doi:10.1103/PhysRevSTPER.8.020001

3. **Henderson, C.** (2012). Evaluation of the Physics and Astronomy New Faculty Workshop, A white paper prepared for the Workshop on the Role of Scientific Societies in STEM Faculty Workshops, Washington, DC, May 3, 2012.
4. **Henderson, C.**, Cole, R., Froyd, J., & Khatri, R. (2012). Five Claims about Effective Propagation, A white paper prepared for January 30-31, 2012 meetings with NSF TUES Program Directors.
5. **Turpen, C.**, **Henderson, C.**, & Dancy, M. (2012) Faculty Perspectives about Instructor and Institutional Assessments of Teaching Effectiveness, *Proceedings of the 2011 Physics Education Research Conference*.
6. **Henderson, C.**, **Barthelemy, R.**, Finkelstein, N., & Mestre, J. (2012) Physics Education Research Funding Census, *Proceedings of the 2011 Physics Education Research Conference*.
7. Yerushalmi, E., **Henderson, C.**, **Mamudi, W.**, Singh, C., & Lin, S-Y (2012). The Group Administered Interactive Questionnaire: An Alternative to Individual Interviews, *Proceedings of the 2011 Physics Education Research Conference*.
8. Lin, S-Y., Singh, C., **Mamudi, W.**, **Henderson, C.**, & Yerushalmi, E. (2012) TA-Designed vs. Research-Oriented Problem Solutions, *Proceedings of the 2011 Physics Education Research Conference*.
9. Dancy, M., & **Henderson, C.** (2012) Experiences of New Faculty Implementing Research-Based Instructional Strategies, *Proceedings of the 2011 Physics Education Research Conference*.
10. Lee, M., Dancy, M., **Henderson, C.**, & Brewe, E. (2012) Success and Constraints in the Enactment of a Reform, *Proceedings of the 2011 Physics Education Research Conference*.

GRANTS

1. PI (with A. Beach, T. Greene, M. Grunert, and S. Stapleton, Co-PIs), “WIDER: EAGER: Evidence-based Instructional Practices at WMU: An Examination of Instructor Practices, Institutional Climate, and Social Networks.”, NSF#1256505, $299,536 awarded for the period 9/15/12 to 8/31/14.

2. PI, “Collaborative Research: Sustainable Diffusion of Research-Based Instructional Strategies: A Rich Case Study of SCALE-UP”, NSF#1223564, $190,852 awarded for the period 9/1/12 to 8/31/15. (This is one of three collaborative proposals, with total project funding of $599,991. Collaborating PIs are M. Dancy, University of Colorado Boulder, and B. Beichner, North Carolina State University.)

3. PI “Collaborative Research: Increasing the Impact of TUES Projects through Effective Propagation Strategies: A How-To Guide for PIs”, NSF#1122446, $456,208 awarded for the period 1/1/12 to 12/31/15. (This is the lead of three collaborative proposals, with total project funding of $764,880. Collaborating PIs are R. Cole, University of Iowa, and J. Froyd, Texas Engineering Experiment Station.)

4. PI "Assessing the Impact of the Iowa State HHMI Project", subcontract to Iowa State HHMI proposal, $114,216 awarded for the period 11/14/10 to 8/31/14.

5. Co-PI (with M. Borrego, PI, and M. Prince, Co-PI) "Collaborative Research: Use and Knowledge of Research-Based Instructional Strategies (RBIS) in Engineering Science Courses", NSF#1037671, $150,001 awarded for the period 9/1/10 to 8/31/12.

6. Co-PI (with M. Dancy, PI) "Collaborative Research: From Dissemination to Adoption: A Study of the Instructional Change Process in Faculty Most Likely to Succeed", NSF #1022186 and #1022806 , $249,998 awarded for the period 8/15/10 to 7/31/13

7. PI (with M. Dancy, co-PI), "Understanding Instructor Practices and Attitudes Towards the Use of Research-Based Instructional Strategies In Introductory College Physics", NSF, $331,143 awarded for the period 1/1/08 to 12/31/12.

INVITED TALKS

1. **Henderson, C.** "Writing for Academic Journals" Invited Panelist, American Association of Physics Teachers 2012 Summer Meeting, Philadelphia, PA, July 30, 2012.

2. **Henderson**, C. "The Challenges of Spreading and Sustaining Research-Based Instruction in Undergraduate STEM", Distinguished Lecture, American Society of Engineering Education National Meeting, San Antonio, TX, June 13, 2012.

3. Dancy, M. & **Henderson, C.** "Educational Transformation in STEM: Why has it been limited and how can it be accelerated?" Invited talk, Transforming Research in Undergraduate STEM Education Conference, Saint Paul, MN, June 5, 2012.

4. **Henderson, C.** "Evaluation of the Physics and Astronomy New Faculty Workshops", Invited presentation, Workshop on the Role of Scientific Societies in STEM Faculty Workshops, Washington, DC, May 3, 2012.

5. **Henderson, C.** "The Challenges of Spreading and Sustaining Research-Based Instruction in Undergraduate Physics", Physics Colloquium, Ball State University, Muncie, IN, March 29, 2012.

6. **Henderson, C.** "Promoting and supporting Pedagogical Change in Higher Education", fourth public lecture of the Interactive Teaching and Learning Project, University of Jyväskylä, Jyväskylä, Finland, March 13, 2012.

7. **Henderson, C.** "Developing Teaching in Higher Education", invited commentator, project symposium consisting of six research presentations with comments by C. Henderson, University of Jyväskylä, Jyväskylä, Finland, March 13, 2012.

8. **Henderson, C.** “The Challenges of Spreading and Sustaining Research-Based Instruction in Undergraduate Physics”, Physics Colloquium, Rochester Institute of Technology, Rochester, NY, February 14, 2012.

CONTRIBUTED TALKS AND POSTERS

1. **Khatri, R., Henderson, C.**, Cole, R., & Froyd, J. “Change is Hard: Improving the Propagation of Educational Innovations”, Contributed Talk, American Association of Physics Teachers 2012 Summer Meeting, Philadelphia, PA, August 1, 2012.
2. Dancy, M. & **Henderson, C.** “Pedagogical Practices of New Faculty Following Participation in an Intensive Physics Education Focused Workshop”, Contributed Talk, American Association of Physics Teachers 2012 Summer Meeting, Philadelphia, PA, August 1, 2012.
3. **Henderson, C.** & Quardokus, K. “Department-Level Instructional Change: Complexity Leadership Theory and Social Networks”, Contributed Talk, American Association of Physics Teachers 2012 Summer Meeting, Philadelphia, PA, August 1, 2012.
4. Barthelemy, R., **Henderson, C.,** & Grunert, M. “The Experiences of Women in Physics Education Research Graduate Programs”, Contributed Talk, American Association of Physics Teachers 2012 Summer Meeting, Philadelphia, PA, July 31, 2012.
5. **Mamudi, W., Henderson, C.**, Lin, S-Y., & Yerushalmi, E. “Instructor’s Goals for Using Example Solutions in Introductory Physics”, Contributed Talk, American Association of Physics Teachers 2012 Summer Meeting, Philadelphia, PA, July 31, 2012.
6. **Khatri, R., Henderson, C**., Cole, R., & Froyd, J. “Principal Investigator and Program Director Views of Successful Propagation”, Contributed Poster, 2012 Physics Education Research Conference, Philadelphia, PA, August 1, 2012.
7. **Henderson, C.** & Quardokus, K. “Department-Level Change Initiatives: Using Social Network Analysis to Understand the Hidden Structure of Academic Departments”, Contributed Poster, 2012 Physics Education Research Conference, Philadelphia, PA, August 1, 2012.
8. Barthelemey, R., Grunert, M., & **Henderson, C.** “The Graduate Research Field Choice of Women in Academic Physics and Astronomy: A Pilot Study”, Contributed Poster, 2012 Physics Education Research Conference, Philadelphia, PA, August 1, 2012.
9. Dancy, M. & **Henderson, C.** “Toward Sustained and Effective Reform: A Study of the Change Process in 15 Faculty” contributed poster, Transforming Research in Undergraduate STEM Education Conference, Saint Paul, MN, June 4, 2012.
10. Cutler, S., Borrego, M., Froyd, J., **Henderson, C.**, & Prince, M. “Collaborative Research: Use and Knowledge of Research Based Instructional Strategies (RBIS) in Engineering Science Courses”, poster presented at the 2012 NSF-EFRI Grantees Conference, Arlington, VA, March 7, 2012.
11. **Henderson, C.**, Dancy, M., & **Turpen, C.** "The Challenges of Assessing Teaching Effectiveness: Strategies for PER to Influence Practice", contributed talk, American Association of Physics Teachers 2012 Winter Meeting, Ontario, CA, February 7, 2012.

SCHOLARLY ACTIVITIES

1. WMU Emerging Scholar Award, September 2012.

2. Senior Editor, *Physical Review Special Topics – Physics Education Research*, April 2012 to present.

3. Member, National Research Council (NRC) Committee on Undergraduate Physics Education Research and Implementation, January 2011 to June 2013.

4. Chair, AAAS Workshop on the Measurement of Teaching Practices, December 17-29, 2012. Editor, Physics Education Research Section, *American Journal of Physics*, November 2009 to present.

5. Member, Editorial Board, Physics Education Research Users Guide, Spring 2012 to present.

6. Member, American Association of Physics Teachers Publications Committee, April 2012 to present.

7. Editor, Getting Started in Physics Education Research, a peer reviewed volume for *Reviews in Physics Education Research*, Fall 2007 to Fall 2013 (lead editor, with K. Harper, co-editor).

8. Senator, Physics Representative to WMU Faculty Senate, Fall 2004 to Spring 2013.

9. Member, WMU Grade and Program Dismissal Appeal Committee (GAPDAC)

10. Board Member, Michigan section of the American Association of Physics Teachers, Spring 2006-Spring 2012.

11. External Evaluator, Physics and Astronomy New Faculty Workshop.

12. Twelve scholarly reviews: The Physics Teacher, External review of an application for tenure and promotion, Fulbright Specialists Program, National Science Foundation TUES Program, Proceedings of the Physics Education Research Conference, Tertiary Education Management, Journal of Chemical Education

7.2 David Schuster

RESEARCH ABSTRACT

Several research projects in Physics & Science Education continued during 2012 and three new projects started, in collaboration with colleagues and graduate students. Research, development and instruction were all involved, in line with our approach of integrating aspects of science education that complement each other, namely: research, instructional design, materials development, and implementation.

The projects are outlined below.

Research projects

1. Experimental Comparison of Inquiry and Direct Instruction in Science

The research itself is completed, and we are preparing two papers for journal submission in addition to one already published. The project was originally funded $1.9 Million by the NSF's IERI program, with a later $100,000 supplement. The principle investigators are W.W. Cobern (PI), D.G. Schuster, and B. Applegate, with graduate students A. Undreiu and B. Adams. The project compared the efficacy of 'inquiry-based' vs. 'direct' instructional approaches to developing conceptual understanding of important science topics at the middle school grades. Instructional units developed for the project were: ii. Force and Motion, and ii. Light, Climate and the Seasons. This experimental comparatively study involving the development of parallel teaching modules in the two instructional modes, aligned assessment instruments, teacher preparation, and implementation in classrooms by experienced middle school teachers in a summer program. There were two years of development and piloting, followed by four years of field trials. After two years of field trials, teachers switched instructional modes to control for any teacher effect. The journal articles currently in preparation report on: i. the complete project, findings and implications, and ii. The development of instruction and assessment as basis for the research and as exemplar instructional units. Dissemination during the project has been via refereed journal article, international and national conferences and proceedings.

2. Assessing pedagogical content knowledge of inquiry science teaching

This project was awarded $400,000 by the NSF in the Assessing Student Achievement program, as well as an international supplement of $40,000, and during 2012 we obtained an additional extension and $35,000 supplement. The grant project continues through March 2013. David Schuster is PI, with W. W. Cobern as Co-PI. The project develops and tests new types of assessment items and instruments, to probe pre-and in-service teachers' pedagogical content knowledge (PCK) of how to teach science by inquiry, and to identify their actual teaching orientations, along a spectrum where we usefully characterize orientations as direct didactic, direct active, guided inquiry or open discovery, with activity-mania also being common but of different nature. Assessment items involve case-based vignettes of actual classroom topic-teaching situations along with realistic response options corresponding to common teaching practices. An assessment item typology was devised and new item types and formats include 'Spectrum MCQ' and 'Likert testlet' formats. We worked with teachers to devise realistic classroom vignettes and teaching options, then guided by the typology created sets of items in various topic areas and grade levels. We have over 60 reviewed and refined items; and have been producing 40 more to make a total of 100 available on the web as a resource for science teacher education. These can be used individually as formative assessment during teacher preparation courses, or summatively as compiled instruments. We have constructed 4 ‘Forms’ of 16 items each with some overlap. These instruments are versions of what we call the Pedagogy of Science Teaching Test (POSTT). The assessment went through an earlier stage of detailed dissection of individual items by focus groups and expert panelists, leading to item refinement or replacement. During 2012 the Science and Mathematics Program Improvement group (SAMPI) conducted a field test involving classroom teaching and the relation to teaching orientations identified by the assessment instrument. Experienced SAMPI evaluators observed the teaching practices of twelve teachers at district schools, using a lesson observation protocol designed specifically for the project, observing three lessons per teacher, plus interviews. A POSTT-Field teaching orientation instrument was administered to the teachers after the observations and teachers were interviewed on both their own teaching and their responses to the instrument. There is continuing interest in the project as indicated by approaches from teacher education faculty at other institutions and willingness to collaborate by using the instruments and sharing resulting data.

3. *Cognition in physics problem solving*

This is ongoing unfunded research into the reasoning processes and knowledge schemata involved in physics problem solving, for both experts and novices. Part of it is being done in collaboration with doctoral student Adriana Undreiu. The cognitive process and compiled knowledge revealed are far more complex and extensive than is represented by the ‘model solutions’ that teachers and textbooks present to students as a final-product polished solutions. Thus for example, we find that principle-based reasoning, case-based reasoning, experiential-intuitive reasoning, analogy-based reasoning and everyday heuristics are all play roles, for both novices and experts, especially when they encounter unfamiliar problems. There is a strong interplay between reasoning modes and the knowledge elements of an individual’s existing schemata in the domain, which are better developed for experts. We have been studying cognition in solving optics problems (reflection and refraction), which forms Ms. Undreiu’s dissertation research, and is in an advanced stage of completion, and conducting a similar study for problems involving acceleration in curved motions. Dissemination thus far has been by national and international conference presentation and proceedings.

4. *An inquiry approach to refraction and its relation to the historical discovery of the refraction law*

This project develops an inquiry-based approach to the teaching of refraction, including a diagrammatic formulation of the law without formal trigonometry, and relates this to the historical development of the law of refraction. We implement the approach in the Physics 1800 course for pre-service teachers. The project has thus far been reported at the International History, Philosophy and Science Teaching conference in Thessaloniki, Greece, in 2011, and in 2012 year at the summer AAPT meeting in Omaha, Nebraska, and the World Conference on Physics Education in Istanbul, Turkey.

5. *Integration of a formative assessment system into physics instructional design, and a comparison of the effects of formative and summative assessment in dynamics instruction.*

This is a new research project in conjunction with graduate Chaiphat Plybour and will form his Ph.D. dissertation research. Formative assessment (Assessment for Learning) is potentially one of the most effective of all instructional strategies to improve science learning. The main purpose of formative assessment is to enhance learning along the way, contrasting with conventional summative assessment as used mainly for grading and ranking students. A central feature of formative assessment is timely feedback during learning, giving students the opportunity to improve, while at the same time enabling teachers to adjust their instruction to learners' needs. Formative assessment needs to be systemic, i.e. designed into the topic from the start as part of regular course operations, rather than being an 'add-on'. Our project has five elements: describing the central features of formative assessment; formulating principles for integrating it into topic instruction; doing so for a dynamics unit; implementing in teaching; and finally comparing the effectiveness of formative and summative assessment systems for concept learning. During 2012 we produced initial versions of the first three aspects, and in Fall implemented formative system in teaching the conceptual dynamics part of Physics 1800 for pre-service teachers. Two sections of the course served as the treatment and control groups; one experiencing strongly formative assessment, the other conventional summative assessment, both taught by the same instructor. Learning gains were assessed by pre- and post-tests, and initial analyses indicate that the formative treatment produces greater learning gains and more favorable course evaluations. The project will continue with further analyses, refined methods and extension to kinematic problems.

6. Ambiguous meanings of the concepts "weight" and "weightlessness" in textbooks, and an instructional approach distinguishing two physical constructs and addressing semantic issues.

This is a new research project with graduate student Rex Taibu and will form his Ph.D. dissertation research. The concept of "weight" and it possible meanings can be ambiguous and confusing. There are two distinct physical constructs involved: the gravitational force on an object, and the contact force of interaction with a measuring scale. Unfortunately, both of these are given the same name "weight", which also seems to imply it is a property of the object itself. In the static situation in an inertial frame, both constructs both give the same value. In a dynamic situation in an accelerating frame (such as an elevator or orbiting spaceship), the two constructs lead to different values for "weight". The physics is clear but the varied and ambiguous usage of the term weight in textbooks and teaching causes confusion. The purpose of this project is to characterize textbook and teaching approaches, disentangle semantic confusions in weight definitions, and advocate an approach making the two physical constructs explicit and distinct. Thus far we have clarified the constructs and started characterizing physics textbook treatments, finding that different books 'adopt' alternative definitions and may not address the semantic issues.

7. Graduate student difficulties understanding dynamics in rotating reference frames

This is a new research project with graduate student David Cassidy and will also form his Ph.D. dissertation research. We are investigating student difficulties in understanding dynamics in rotating reference frames, including the concept of 'fictitious' centrifugal and Coriolis forces, and the relationship between conceptual understanding and mathematical formalism. Thus far Cassidy has carried out a pilot study involving structured problem-solving interviews with six graduate students who have completed advanced undergraduate and graduate level courses in classical mechanics. Student knowledge and thinking was probed during think-aloud problem solving, while tackling basic problems involving the motion of an object seem from inertial and rotating frame perspectives. Student conceptual grasp was much weaker than anticipated for students who had passed advanced mechanics courses. These initial findings will inform the subsequent design of the project, which will also lead to the development of an instructional approach to the topic of dynamics in rotating frames.

PUBLICATIONS

1. David Schuster. *Discovering the Law of Refraction: An Inquiry Approach with a Counterpart in the History of Physics.* World Conference on Physics Education, Istanbul, Turkey, July 2012, Paper in WCPE conference CD.

2. David Schuster, William Cobern, Betty Adams, Brandy Skjold, Kelly Sparks, Amy Bentz. *Case-based Assessment of Science Teaching Orientations.* American Educational Research Association National Conference, Vancouver, British Columbia, Canada, April 2012, Paper in AERA conference CD.

CONTRIBUTED TALKS AND POSTERS

1. David Schuster, Betty Adams, Bill Cobern, and Brandy Skjold. *Assessing Pedagogical Content Knowledge of Inquiry Science Instruction Part 1: Operational Models.* American Association of Physics Teachers National Meeting, Philadelphia, Pennsylvania, August 2012

2. Betty Adams, David Schuster, Bill Cobern, and Brandy Skjold. *Assessing Pedagogical Content Knowledge of Inquiry Science Instruction Part 2: Case-based Instruments.* American Association of Physics Teachers National Meeting, Philadelphia, Pennsylvania, August 2012.

3. David Schuster, David Cassidy, and Betty Adams, Life *and Laws in a Rotating Reference Frame.* Michigan Section of the American Association of Physics Teachers Spring Meeting, Grand Valley State University, Allendale, Michigan, April 2012.

4. David Cassidy. David Schuster, and Betty Adams. *But Only When I'm Moving .... Darn it, Coriolis!* Michigan Section of the American Association of Physics Teachers Spring Meeting, Grand Valley State University, Allendale, Michigan, April 2012.

5. David Schuster, Betty Adams, and Adriana Undreiu. *An Innovative Inquiry-Narrative Approach to Teaching Sunlight, Climate and Seasons.* National Science Teachers Association Conference, Indianapolis, Indiana, March 2012.

6. David Schuster, William Cobern, Betty Adams, Brandy Skjold, Kelly Sparks, Amy Bentz. *Assessing Pedagogical Content Knowledge of Inquiry Science Instruction*. Association of Science Teacher Educators National Conference, Clearwater Beach, Florida, January 2012.

8 Research and Public Lectures at WMU

The Department of Physics sponsors lectures on physics research intended mainly for graduate students and faculty. These talks inform faculty and students at Western of research efforts here and at other institutions as well as acquaint visiting speakers with our research and academic programs at Western. The Department of Physics also sponsors public lectures on physics topics of general interest. These talks are intended for faculty, physics graduate students, physics undergraduate students, and non-physicists. The research and public lectures are listed below.

The Department of Physics sponsors lectures on physics research intended mainly for graduate students and faculty. These talks inform faculty and students at Western of research efforts here and at other institutions as well as acquaint visiting speakers with our research and academic programs at Western. The Department of Physics also sponsors public lectures on physics topics of general interest. These talks are intended for faculty, physics graduate students, physics undergraduate students, and non-physicists. The research and public lectures are listed below.

1. Sub-structures in the Halo of the Milky Way, Kathy Vivas, CIDA-Venezuela/University of Michigan, January 23, 2012

2. Magnetic Shape Memory Smart Materials and High Energy Efficiency, Pnina Ari-Gur, Professor Mechanical and Aeronautical Engineering, Western Michigan University, February 6, 2012

3. Recent Progress Towards a Quantum Computer, Alvin Rosenthal, Professor, Department of Physics, Western Michigan University, March 12, 2012

4. Physics Learning and Classroom Practice: Clinical and Classroom-Based Studies of Physics Cognition, Jose P. Mestre, Departments of Physics, and Educational Psychology, University of Illinois at Urbana-Champaign, March 19, 2012

5. Lessons from Suburbian Teenager Stars: the Off-cloud Young Population in the Orion OB1 Association, Cesar Briceño, Visiting Scientist, Astronomy Department University of Michigan, April 2, 2012

6. The Late Evolution of Intermediate Mass Stars: Jets and Magnetic Fields, Nikta Amiri, Leiden Observatory, The Netherlands, April 9, 2012

7. "Inelastic X-ray Scattering at APS", Diego Casa, Beamline Scientist, Argonne National Laboratory, Complex Materials Consortium, September 10, 2012

8. "Aromatic Molecules: A Playground for Probing Electron Correlations", Ralf Wehlitz Senior Scientist, Synchrotron Radiation Center, University of Wisconsin at Madison, September 17, 2012

9. "No Lectures=More Learning: An Experience in Studio Physics Teaching of Elementary Physics at the WMU Department of Physics", Manuel A. Bautista, Associate Professor, Western Michigan University, October 8, 2012

10. Transmission of Slow Highly-Stripped Heavy Ions through Insulating Capillaries or (My Experiences on Sabbatical in Caen, France), John Tanis, Professor, Western Michigan University, November 12, 2012

11. "Blowing Up Matter from Within using Ultra-Intense and Ultra-Short X-Ray Laser Pulses", Nora Berrah, Professor, Western Michigan University, November 26, 2012

9 PERSONNEL January 1 - December 31, 2012

Faculty
Bautista, Manuel
Berrah, Nora
Burns, Clement
Chung, Sung
Famiano, Michael
Gorczyca, Thomas
Halderson, Dean
Henderson, Charles
Kaldon, Philip (Part Time)
Kamber, Emanuel
Kayani, Asghar
Korista, Kirk (Chair)
McGurn, Arthur
Miller, Mark (Part Time)
Pancella, Paul
Paulius, Lisa (Asst. chair)
Rosenthal, Alvin
Schuster, David
Tanis, John
Wuosmaa, Alan
Wyman, Max

Faculty Emeriti
Bernstein, Eugene
Hardie, Gerald
Kaul, Dean
Soga, Michitoshi
Poel, Robert
Shamu, Robert

Staff
Easley, Katie
Gaudio, Benjamin
Hoffmann, Chris
Johnson, Cathy
Kern, Allan
Krum, Lori
Welch, Rick

Research Associates
Bilodeau, René
Fang, Li
Fivet, Vanessa
Lighthall, Jonathan
Murphy, Brendan
Osipov, Timur
Shetty, Dinesh

Graduate Students
Alasmari, Aeshah
Almeshal, Abdelkareem
Ayyad, Asmá
Bandara, Amila
Barthelemy, Ramon
Bedoor, Shadi
Bokari, Eiman
Carpino, J. Fiore
Chakraborti, Priyanka
Chapman, Tricia
Dissanayake, Amila
Dumitriu, Laurentiu
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