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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 beamline 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**


**GRANTS**


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

SCHOLARLY ACTIVITIES


- 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**


**INVITED TALKS AND POSTERS**


CONTRIBUTED TALKS AND POSTERS


OTHER SCHOLARLY ACTIVITIES

3. Served on 1 Ph.D. committee.
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\textsubscript{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 $\sim10^{17}$ Wcm$^{-2}$ focal intensity, the yield of $S^{13+}$ is $\sim1\%$ of the $S^{1+}$ 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) **Double Core-Hole Spectroscopy for Chemical Analysis with an Intense X-Ray Femtosecond Laser.**

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$_2$O and CO$_2$ to compare our previous results in N$_2$ with N$_2$O and compare our findings in CO with CO$_2$ to assess the validity of the method; i.e., even though single core hole ionization can not differentiate between CO and CO$_2$ or between N$_2$ and N$_2$O, 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) **Absolute Photodetachment Cross Section of H$^-$**

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:

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

PUBLICATIONS


**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).


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

INVITED TALKS


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


5. L. Fang, T. Osipov, B. Murphy, E. Kukk, and N. Berrah” Following dissociating N₂ molecules by probing them with femtosecond-range XFEL pulses” OSA conference, San Diego, August 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.


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


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:


Manuscript and Proposal Review:

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


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 $\text{Xe}$ and $\text{Xe@C}_6\text{0}$. The upper graph shows the present theoretical results for the free $\text{Xe}$ atom using the standard R-matrix method (red curve) and for $\text{Xe@C}_6\text{0}$ 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 $\text{Xe}$ atom (circular points and curve) and for $\text{Xe@C}_6^{+}\text{0}$ (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=1 cm\(^{-3}\)) 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 Fe\(^{26+}\). 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 Fe$^{26+}$. Lower panel: ratio of the calculated fractional abundances for the two densities.

**PUBLICATIONS**


**GRANTS**

**INVITED TALKS**


**CONTRIBUTED TALKS AND POSTERS**

**RESEARCH AND SCHOLARLY ACTIVITIES**

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

RESEARCH ABSTRACT

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

A Hasan\textsuperscript{1}, O Abu-Haija\textsuperscript{2}, J Harris\textsuperscript{3}, T Elkafrawy\textsuperscript{3}, A Kayani\textsuperscript{3}, and E Y Kamber\textsuperscript{3}

\textsuperscript{1}American University of Sharjah, P.O. Box: 26666 Sharjah, United Arab Emirates
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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\textsubscript{2}, H\textsubscript{2}O and CO\textsubscript{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\textsuperscript{2+} with N\textsubscript{2}, CO\textsubscript{2} and H\textsubscript{2}O 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\textsuperscript{2+}(2s\textsuperscript{2} 2p\textsuperscript{4} 3\textsuperscript{P}) and metastable states 2s\textsuperscript{2} 2p\textsuperscript{4} 1\textsuperscript{D} and 1\textsuperscript{S} of the incident Ne\textsuperscript{2+} ions; α, β, γ,...represent the ground and successive higher excited states of Ne\textsuperscript{+}; 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\textsuperscript{2+} - Ar collision system [5, 16] was used as a standard to calibrate the Q-scale for the Ne\textsuperscript{2+} - N\textsubscript{2}, CO\textsubscript{2} and H\textsubscript{2}O systems.

1. Translational energy-gain spectra: Figure 1 shows the translational energy-gain spectra for the formation of Ne\textsuperscript{+} ions from the reaction of the 50 eV Ne\textsuperscript{2+} ions with N\textsubscript{2}, CO\textsubscript{2} and H\textsubscript{2}O at 0° scattering angles. In Ne\textsuperscript{2+} - N\textsubscript{2} collisions, the observed collision spectrum is dominated by a peak due to capture from the metastable state 2p\textsuperscript{3} 1\textsuperscript{S} of Ne\textsuperscript{2+} into the 3s 4\textsuperscript{P} state of Ne\textsuperscript{+} product ions with production of N\textsubscript{2}\textsuperscript{+} in the ground state (X 2\textsuperscript{Σ}\textsubscript{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\textsuperscript{3} 1\textsuperscript{D} and 1\textsuperscript{S} of Ne\textsuperscript{2+} into the 2s2p\textsuperscript{6} 3\textsuperscript{S} and 3s 4\textsuperscript{P} states of Ne\textsuperscript{+} 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\textsuperscript{2+} - CO\textsubscript{2} collisions, the dominant peak corresponds to capture from the metastable state 2p\textsuperscript{3}\textsuperscript{1}S of Ne\textsuperscript{2+} into the 3s \textsuperscript{4}P, 2p\textsuperscript{6}\textsuperscript{2}S, and 3p \textsuperscript{4}P states of Ne\textsuperscript{+} product ions with production of CO\textsubscript{2}\textsuperscript{+} in the ground state (X \Sigma\textsubscript{g}\textsuperscript{+}), respectively, via reaction channels III\gamma X, III\beta X and III\delta X. There is also significant contribution from an unresolved reaction at \sim 5.2 eV, involving non-dissociative transfer ionization via II\alpha Y channel. The smaller peak at \sim 3 eV correlates with capture into the excited states of Ne\textsuperscript{+} ions from metastable states via reaction channels II\beta X, II\gamma X, II\delta X, and III\varepsilon X.

In Ne\textsuperscript{2+} - H\textsubscript{2}O collisions, three peaks are clearly seen, the strongest peak (channel III\delta X) is due to transfer excitation from the metastable state 2p\textsuperscript{3}\textsuperscript{1}S of Ne\textsuperscript{2+} into the 3s \textsuperscript{4}P state of Ne\textsuperscript{+} product ions with production of H\textsubscript{2}O\textsuperscript{+} in the excited state (A \textsuperscript{2}A\textsubscript{1}). The smallest peak at \sim 2.5 eV corresponds to capture into the 3s \textsuperscript{2}P state of Ne\textsuperscript{+} via the reaction channel II\delta A. The other peak at \sim 5.2 eV is due capture accompanied by the ionization of the target (channel II\alpha Y) with contributions from channels III\varepsilon X and II\beta X. Figure 1 also shows our calculated reaction windows for 50 eV Ne\textsuperscript{2+} - N\textsubscript{2}, CO\textsubscript{2} and H\textsubscript{2}O 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\textsuperscript{2+} ions from N\textsubscript{2}, CO\textsubscript{2} and H\textsubscript{2}O 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).](image-url)

2. Total cross sections: The measured total cross sections for single-electron capture by Ne\textsuperscript{2+} ions from CO\textsubscript{2} and H\textsubscript{2}O 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\(_2\)O 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:

State-selective electron capture in slow collisions Ne$q^+$ (q = 3 – 5) ions with H$_2$O

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 – Jordan
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State-selective single-electron capture process for slow collisions of Ne$q^+$ (q = 3 – 5) ions, produced in a recoil-ion source, with H$_2$O have been studied experimentally at laboratory impact energies between 15 and 300 keV (where q is the projectile charge state) and scattering angles between 0° and 60° by means of a differential energy-gain spectrometer [1].

For Ne$^{3+}$ - H$_2$O collisions, the dominant peak is due to capture into the 2p$^3$3p states. The structure at about 5.5 eV is energetically identifiable with capture into the excited states from the metastable states in the incident Ne$^{3+}$ ion beam. For Ne$^{4+}$ - H$_2$O 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.

In Ne$^{5+}$ - H$_2$O collisions, the observed collision spectrum is dominated by non-dissociative single-electron capture from the ground state incident Ne$^{5+}$ (2p$^2$ 3P) ions into the excited state 4d of Ne$^{4+}$ with production of H$_2$O$^+$ in the ground state (X $^2$B$_1$). 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


PUBLICATIONS


CONTRIBUTED TALKS AND POSTERS


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**


**In Press**


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.


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.


**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


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


**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, 16\textsuperscript{th} 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
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 $^3$He and $^4$He 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


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


GRANTS


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


**SCHOLARLY ACTIVITIES**

**Reviews**

**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

RESEARCH ABSTRACT
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 $\lambda$ 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 $\lambda$ 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.

![Graph](image-url)  
Fig.1 Spin-spin correlation function as a function of spin separation $r$ for an infinite spin - $\frac{1}{2}$ chain.
Fig. 2 Phase diagram of the spin -1 chain


PUBLICATIONS


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


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.


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. Al-Faify,1,2 T. Yoshitake,3 Y. Katamune,3 M. Bowden,4 M. Nandasiri,1,4 M. Ghantasala,5 D.C. Mancini,6 S. Thevuthasan4 and A. Kayani1

Affiliations

1Department of Physics, Western Michigan University, Kalamazoo MI 49008, USA
2Physics Department, King Khalid University, Abha, Saudi Arabia
3Department of Applied Science for Electronics and Materials, Kyushu University, Fukuoka, Japan 816-8580
4EMSL, Pacific Northwest National Laboratory, Richland, WA 99354, USA
5Department of Mechanical and Aeronautical Engineering, Western Michigan University, Kalamazoo MI 49008, USA
6Physical 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 sp² and sp³ 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


GRANTS

- Argonne national lab $20,000.00
- Environmental Molecular Sciences Laboratory (EMSL), PNNL materials proposal: approved and allocated
Explaining the Sr and Ba Scatter in Extremely Metal-Poor Stars

1National Astronomical Observatory, Mitaka, Tokyo, Japan
2Sonoma 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, T. Otuka, T. Kajino
1Nihon University, Chiyoda, Tokyo, Japan
2University of Tokyo, Hongo, Tokyo, Japan
3National 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, T. Kajino, T. Onaka
1Sonoma Center for Nuclear Astrophysics, Windsor, CA, USA
2National Astronomical Observatory, Mitaka, Tokyo, Japan
3University 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**


GRANTS


INVITED TALKS


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 $0s$-shell knockout processes. The model was applied to the $^{11}\text{B}(p,n)^{11}\text{C}$ and $^{11}\text{B}(p,p')^{11}\text{B}$ reactions, and good agreement with available data was obtained. The $(p,n)$ results are shown in Fig. 1. Successful $^{11}\text{B}(p,n)^{11}\text{C}$ calculations provide confidence in the model’s ability to predict cross sections to proton rich systems.

FIG. 1. Charge exchange cross sections for $^{11}\text{B}$ to the ground state and first excited state of $^{11}\text{C}$. 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

![Graph showing elastic proton scattering from $^{11}$B at 30.3 MeV. Solid line is the RCCSM calculation. Data are from Ref. [2].](image)

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, 0s-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 0s-shell hole components of the wave functions
FIG. 3. Elastic proton scattering from $^{11}\text{B}$ 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 0s 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 $^4\text{He}$ in Ref. [7], and are not sufficient to boost the calculated cross section into agreement with the data. However, like the 0s knockout contribution they effect the responses over the range of momentum transfer.

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

Calculations have also been performed for the inclusive reaction, $^{12}\text{C}(e,e'p)^{11}\text{B}(\text{g.s.})$, 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, $\phi_p = 90^\circ$. 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 $^{12}\text{C}(e,e'p)$ $^{11}\text{B}(1/2^-)$. The calculated values show the peculiar property of having a maximum around 18°. The ability of RCCSM calculations to describe $^{12}\text{C}(e,e'x)$ and $^{12}\text{C}(e,e'p)^{11}\text{B}$ 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 $^{12}\text{C}(e,e'p)^{11}\text{B}$ reaction. Open squares are the data of Ref. [8] to the $^{11}\text{B}$ ground state. Crosses are the RCCSM calculation to the $^{11}\text{B}$ ground state. Solid dots are the RCCSM calculation to the $^{11}\text{B}$ first excited state times ten.

“Hypernuclei and the Nijmegen ESC11 Potential”

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

The binding energies of $^{3}\Lambda\text{H}$, $^{4}\Lambda\text{H}(0^+)$, and $^{4}\Lambda\text{H}(1^+)$ 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 $\Lambda$ hypernuclei in MeV.

<table>
<thead>
<tr>
<th></th>
<th>$^{3}\Lambda\text{H}$</th>
<th>$^{4}\Lambda\text{H}(0^+)$</th>
<th>$^{4}\Lambda\text{H}(1^+)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td>0.57</td>
<td>3.34</td>
<td>3.09</td>
</tr>
<tr>
<td>Reduced $\Lambda\Sigma$ tensor</td>
<td>0.17</td>
<td>2.19</td>
<td>1.13</td>
</tr>
<tr>
<td>Exp.</td>
<td>0.13</td>
<td>2.20</td>
<td>1.15</td>
</tr>
</tbody>
</table>

PUBLICATIONS


GRANTS

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

RESEARCH ABSTRACT

HELIOS: The HELical Orbit Spectrometer

A. H. Wuosmaa1, B. B. Back2, S. I. Baker2, S. Bedoor1, S. J. Freeman3, C. R. Hoffman2, B. P. Kay2, J. C. Lighthall1,S. T. Marley1,2, K. E. Rehm2, J. E. Rohrer2, J. P. Schiffer2, D. V. Shetty1, A. W. Vann2, J. R. Winkelbauer4

1Western Michigan University, Kalamazoo MI, 49008-5252
2Argonne National Laboratory, Argonne IL, 60439
3Schuster Laboratory, University of Manchester.
4Michigan State University, East Lansing MI,

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 (θ<90°) rather than backward (θ<90°) angles in the laboratory. Such reactions include pickup reactions such as (d,3He) and (d,t). This configuration has now been used to study the 14,15C(d,3He)13,14B reaction (see below). Other projects underway include the commissioning of a cryogenic gas target for studies of reactions on 3He and 4He 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).


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.

<table>
<thead>
<tr>
<th>Beam</th>
<th>Target</th>
<th>Reaction</th>
<th>Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{28}\text{Si}$</td>
<td>CD$_2$</td>
<td>$^{28}\text{Si}(d,p)^{29}\text{Si}$</td>
<td>HELIOS commissioning</td>
</tr>
<tr>
<td>$^{12}\text{B}^*$</td>
<td>CD$_2$</td>
<td>$^{12}\text{B}(d,p)^{13}\text{B}$</td>
<td>RIB commissioning and nuclear structure of $^{13}\text{B}$</td>
</tr>
<tr>
<td>$^{17}\text{O}$</td>
<td>CD$_2$</td>
<td>$^{17}\text{O}(d,p)^{18}\text{O}$</td>
<td>Branching ratios of unbound states in $^{18}\text{O}$ for astrophysics</td>
</tr>
<tr>
<td>$^{13}\text{C}^*$</td>
<td>CD$_2$</td>
<td>$^{13}\text{C}(d,p)^{14}\text{C}$</td>
<td>Nuclear structure of $^{14}\text{C}$ and $^{14}\text{B}$</td>
</tr>
<tr>
<td>$^{190,136}\text{Xe}$</td>
<td>CD$_2$</td>
<td>$^{130,136}\text{Xe}(d,p)^{131,137}\text{Xe}$</td>
<td>Nuclear structure near $^{132}\text{Sn}$ and double-beta decay</td>
</tr>
<tr>
<td>$^{86}\text{Kr}$</td>
<td>CD$_2$</td>
<td>$^{86}\text{Kr}(d,p)^{87}\text{Kr}$</td>
<td>Nuclear structure of $^{87}\text{Kr}$</td>
</tr>
<tr>
<td>$^{14}\text{C}$</td>
<td>$^6\text{LiF}$</td>
<td>$^{14}\text{C}(^6\text{Li},d)^{18}\text{O}$</td>
<td>$^6\text{Li}$-transfer to cluster states in $^{18}\text{O}$, Nuclear structure of $^{13}\text{B}$</td>
</tr>
<tr>
<td>$^{19}\text{O}^*$</td>
<td>CD$_2$</td>
<td>$^{19}\text{O}(d,p)^{20}\text{O}$</td>
<td>Nuclear structure of $^{20}\text{O}$</td>
</tr>
<tr>
<td>$^{1}\text{H}$</td>
<td>$^{12}\text{C}$</td>
<td>$^{12}\text{C}(p,p')^{12}\text{C}(0^+_{2})$</td>
<td>Pair decay of the “Hoyle” state and $^{12}\text{C}$ nucleosynthesis</td>
</tr>
<tr>
<td>$^{28}\text{Si}$</td>
<td>CD$_2$</td>
<td>$^{28}\text{Si}(^3\text{He},^7\text{Al})$</td>
<td>Commissioning of forward-angle silicon array.</td>
</tr>
<tr>
<td>$^{13}\text{B}^*$</td>
<td>CD$_2$</td>
<td>$^{13}\text{B}(d,p)^{14}\text{B}$</td>
<td>Single-particle structure of $^{14}\text{B}$</td>
</tr>
</tbody>
</table>
Silicon-sensor development for a new HELIOS detector array.

A. H. Wuosmaa\textsuperscript{1}, S. Bedoor\textsuperscript{1}, J. C. Lighthall\textsuperscript{1}, B. B. Back\textsuperscript{2}, S. T. Marley\textsuperscript{1,2}

\textsuperscript{1}Department of Physics, Western Michigan University, Kalamazoo MI, 49008 USA
\textsuperscript{2}Physics Division, Argonne National Laboratory, Argonne IL 60439 USA

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 \textsuperscript{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.

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$^1$

$^1$Department of Physics, Western Michigan University, Kalamazoo MI, 49008 USA
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The nucleus $^{13}$B is the N=9 isotope 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 $\varpi (1s_{1/2})$ 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-amperees, and the production reaction was $^9$Be($^{14}$C,$^{13}$B)$^{10}$B. $^{13}$B Intensities of between 20 and 40x$10^4$ 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 $^{14,15}$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 recoiling $^{14,15}$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.

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

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

Figure 1. Experimental setup for studying $(d,^3\text{He})$ reactions in HELIOS.

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

PUBLICATIONS


**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


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


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.

**SCHOLARLY ACTIVITIES**

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
8. External Faculty Assessor, Australian National University.
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)


PUBLICATIONS (Other)


**GRANTS**


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.)

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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


**CONTRIBUTED TALKS AND POSTERS**


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


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**


**CONTRIBUTED TALKS AND POSTERS**


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.


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 Suburban Teenager Stars: the Off-cloud Young Population in the Orion OB1 Association, Cesar Briceño, Visiting Scientist, Astronomy Department University of Michigan, April 2, 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

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
El-Houssieny, Ehab
El-Houssieny, Mohamed
Elkafrawy, Tamer
Ganapathy, Subramanian
Gao, Xuan
Garratt, Elias
Hamam, Khalil
Harris, Justin
Kaur, Jagjit
Keerthisinghe, Darshika
Khatri, Raina
Khosravi Dehaghi,
Soroush
Koehler, Katrina
Kumara, Nuwan Sisira
Li, Chengyang
Mamudi, William
Marley, Scott

Graduate Students Cont.
McNeel, Daniel
Moore, Bryan
Nandasiri, Manjula
Peters, Alexander
Rai, Buddhi
Saleh, Mohammed
Stefanick, Trevor
Taibu, Rex
Towers, Sarah
VanGyseghem, Gaetan
Wickramarachchi,
Samanthi
Wickramarathna,
Madhushani
Yang, Jianqing