ABSTRACTS OF REU FINAL REPORTS
The University of Toledo, Department of Physics & Astronomy
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(Faculty Mentor on parenthesis)

Astrophysics/Astronomy

William J. Dirienzo, *Extended Red Emission as a Function of Optical Depth in MBM 6, MBM 25, & MBM 32*, (A. N. Witt)

Extended Red Emission is a broad component of optical spectra observed in many interstellar clouds. It was first discovered about thirty years ago, yet it is still not completely understood. Through some process, carbon-rich clouds illuminated by ultraviolet light of sufficient energy emit this extra light which peaks in the red optical wavelength range. This paper describes a study of how the intensity of the ERE varies with optical depth of a cloud, and the photon conversion efficiency of the process. This study supports the idea of a two-stage process initiated by UV light between 120 and 250 nm. It is also shows that the number of ERE photons emitted is about 7% of the number of exciting UV photons illuminating the clouds, thus showing that the ERE carrier is abundant and should be incorporated more fully into comprehensive models of the interstellar medium. These results reaffirm earlier findings and show that current knowledge of the ERE is close to being able to describe it.

Adam Gray, *Optical Variability of Stars in the Large Magellanic Cloud*, (U. Vijh)

The majority of stars in the galaxy have constant properties for most of their lives; however, some stars vary constantly over a period of days, weeks, months, or even up to a year. Understanding how these variable stars are changing over time can help enhance the understanding of how stars in the universe evolve throughout their lifespan. By using both the infrared data collected from the nearby Large Magellanic Cloud by the SAGE survey, with two separate data epochs taken three months apart, and the optical data from the MACHO survey, with data taken from over eight years, more may be able to be understood about these varying stars.

Ryan Hupe, *Perturbations of Electronic Transitions of C_2 in the UV*, (:S. Federman)

Ultraviolet spectra of the D-X (0-0), F-X (0-0) and F-X (1-0) transitions of C_2 were obtained using the Hubble Space Telescope. These transitions have been analyzed in the past and the F-X (0-0) transition was found to consistently disagree with prediction in the $J<20$ levels. A study of the energy levels of the C_2 molecule suggests that the cause of these disagreements could be a perturbative state. The D-X (0-0) and F-X (1-0) bands were used to obtain information about the C2 column densities in interstellar clouds and oscillator strengths for the F-X bands. This information will be used to analyze the F-X (0-0) transitions and learn more about the perturbative state.

Shawn P. Witham, *Modeling Microturbulence in Stellar Atmospheres*, (L. Anderson-Huang)

Currently in the area of stellar atmospheric modeling, astronomers are able to accurately model atmospheres with observed spectral lines over all wavelengths with one area excepted: the width of the absorption lines. The theoretical line widths turn out more narrow than the observed absorption lines at any given temperature. This inconsistency can be resolved by using a distribution of velocities known as microturbulence. In current models, the values of microturbulent velocities are added ad hoc to compensate for the discrepancy in line widths. The objectives of this research project were to create a computer code that worked in three dimensions to model the microturbulent velocities by using first principle equations of motion of a radiating fluid. The computer simulations were successfully formed and tested for theoretical models of gray stellar atmospheres which gave radiatively driven microturbulent velocities as a function of height in the atmosphere.

Atomic/Molecular/Optical Physics

Hou Keong Lou, *Vacuum System Modeling of the UT-P/NIELS*, (T. Kvale)

Recent studies at the UT-P/NIELS (University of Toledo Positive/Negative Ion Energy Loss Spectrometer) accelerator facility focused on measurements of total cross sections of various interactions occurring in H+ + helium collisions in the energy region of 10- to 50-keV. In those measurements, the experimental data were observed to contain large background noise signals. These enhanced background signals were hypothesized to originate from collisions of scattered protons with residual gas molecules in the decelerator/energy analyzer region. A computer model of the vacuum system using Vaktrak (a program coded by Volker Ziemann) predicted a poor vacuum (~$2x10^{-5}$ Torr) around the analyzing magnet and the decelerator/energy analyzer. Measurements conducted of the vacuum in this region confirmed the results of the test, with measured base vacuum attaining a pressure of ~$3x10^{-5}$ Torr. The study indicated that the low vacuum was a result of low conductance from the diffusion pump responsible for producing the vacuum in this region and the decelerator/energy analyzer region. The vacuum system was redesigned to increase conductance in this region. According to the Vaktrak simulation, this change should result in the vacuum be improved by at least a factor of ten. The improved vacuum should reduce the background noise in the data, which will allow better signal to noise ratios in the ion energy loss measurements.

Joel Pendery, *Backscattering of Secondary Electrons to the Cathode in the Oblique Electric Field in Dielectric Barrier Discharge Systems Using Monte Carlo Simulation*, (V. Khudik & C. Theodosiou)

In contrast to electric field lines in gas discharge systems with bare electrodes, electric field lines in dielectric barrier discharge systems, where the cathode is covered with the dielectric layer, may cross the dielectric surface at an oblique angle. The secondary electrons emitted from this surface either return to the cathode due to collisions with background gas atoms or eventually escape from the region near the cathode. Using the diffusion P1-approximation to the kinetic equation for electrons, we have found analytically the electron escape factor k for different limiting cases. Monte-Carlo simulations of backscattering of electrons have been performed for noble gases and the dependence of the escape factor on the angle between the electric filed lines and the dielectric surface have been found. The analytical theory has been used to explain unexpected peculiarities in results of Monte-Carlo simulations.

Nicholas Reshetnikov, *The two-way bridge between transition lifetimes and dipole polarizability: A case study of Mg-like P (IV)*, (L. J. Curtis)

For atoms and ions with the ground state electron configuration of $ns^2\ {}^1S_0$, a remarkable approximation of the dipole polarizability can be made from just one transition lifetime measurement. Particularly, since the $ns^2\ {}^1S_0$ – $nsnp\ {}^1P_1^o$ intrashell transition dominates the total oscillator strength of transitions to the ground state, it in turn dominates the dipole polarizability of the ion. The oscillator strength serves as the quantum mechanical link between the two empirical quantities, allowing knowledge of both from a precise measurement of one. This relationship is especially useful for studying atoms for which precise measurements of either the lifetime or dipole polarizability are difficult or impossible to make. What is more, with just a few such precise measurements of either quantity, isoelectronic linearities can be exploited to interpolate to ions beyond empirical study. The Mg-like P (IV) ion, with two old and conflicting lifetime measurements and one precise dipole polarizability measurement, gave an excellent opportunity to test the two-way relationship. However, difficulty caused by cascading from higher energy states and blending from higher charged ions made the lifetime measure of 0.35(2) ns an unsatisfactory upper limit. If the blending can be removed by running the phosphorus beam at lower energies, the ANDC method can be used to decouple the cascades. Whether or not this attempt succeeds, the problems in precise lifetime determination of P (IV) underscore the usefulness of the two-way lifetime-dipole polarizability bridge and isoelectronic interpolation to sidestep empirical constraints on precise measurement.

Biological, Health, and Medical Physics

Lindsey Weber, *Functional MRI Data Acquisition in Amputee Pain Study*, (M. Dennis)

Over one million Americans have experienced the loss of a limb, yet little is understood about what specific areas of the brain are affected by amputation. As a result, clinical treatment of the chronic pain experienced by many amputees is currently based on symptoms alone, which has limited effectiveness. In a study using functional magnetic resonance imaging (fMRI), amputated subjects with variable pain will be scanned while continuously reporting the intensity of their pain; the data will be analyzed to find correlations between brain activity and pain level. This project focused on creating the method of data acquisition that will be used in the fMRI setting. One of the main tasks in this project included using LabVIEW 8.2 Student Edition software to import, manipulate and store the pain intensity data reported by amputee subjects. Other tasks included designing an MRI compatible electrical system and hardware interfacing with an NI USB-6008 analog/digital converter.

Condensed Matter Physics

Craig McClellan, *Accelerated Degradation of CdTe Solar Cells With Differing Semiconductor Film Thicknesses,* (A. Compaan)

CdTe solar cells are second generation thin film cells. The cells are composed of a soda lime superstrate, a TCO coating, CdS n-junction layer, a CdTe p-junction layer, and copper/gold back contacts. The accelerated lifetime of cells with differing thicknesses of CdTe and CdS were studied this summer. Controls were set aside for reference while test modules were soaked in a light stress simulator to accelerate degradation of the cell attributes. An IV system, with software to collect the J-V curve, measure the open circuit voltage, short circuit current, and calculate the efficiency, and fill factor, was used in the study. Degradations of those attributes were studied to investigate correlations between the different film thicknesses and the decay of the efficiency, Voc, Jsc, and Fill Factor. I found that modules with thinner layers of CdS (0.045 μm and below) had Voc degradation much greater than those with thicker layers of CdS. The addition of a layer of HRT promoted cell stability in cells with relatively thin layers of CdS that were not subjected to light soaking, yet did not seem to keep light soaked cells any more stable. Modules with thicker layers of both CdTe and CdS were more uniform and more stable. CdS thickness is very important in the stability of efficiency of a CdTe solar cell.

Mary Mills, *Simulating Thin Films: The Effects of a Rotating Substrate on Surface Morphology in Oblique-Incidence Epitaxial Growth,* (J. Amar)

The effects of substrate rotation during deposition on the surface morphology and roughness in oblique-incidence epitaxial growth are studied via kinetic Monte Carlo simulations, and compared with previous results obtained without rotation. In general, two main effects are observed. At high deposition angles rotation leads to a drastic change in the surface morphology. In particular, it leads to isotropic mounds and pyramids rather than the strongly anisotropic structures observed in the absence of rotation. At large angles, very regular pyramids are observed. Rotation also leads to a reduced surface roughness, although the surface roughness tends to increase with rotation rate. An explanation for these effects is given in terms of the effects of rotation rate on shadowing and coalescence. Some interesting effects at low rotation rate (less than 1 rev/ML) are also discussed. Our results are also compared with the case of deposition with fixed deposition angle but random azimuthal angle.

Grace Ong, *Sputter Deposition of Indium Iron Oxide Films for Photoelectrochemical Hydrogen Production,* (X. Deng, B. Ingler)

This project focuses on using indium and iron oxide to make a protective thin film for amorphous silicon based solar cells. From the work completed, the results indicate that samples should be made at 228°C, with 30W of indium and 100W of iron oxide, and a sputter deposition time of two hours. At 0.6V, the best sample displays a maximum photocurrent density of 50µA/cm2. Subsequently, an X-ray diffraction scan confirmed that it is indeed indium iron oxide that is being produced.

Randy Patton, *Modeling and Simulation of the p-n Junction And Optimized Design of Front Contact Grids for CIGS type Solar Cells,* (S. Marsillac)

. An understanding of the solar cell requires an understanding of the p-n Junction. Animations of various aspects of semiconductor phenomena (including the p-n junction) were created to aid in comprehension of semiconductor processes, and to increase information retention through the association of the mathematical description of these phenomena with a visual interpretation of the physical and chemical behavior of these devices. The front contact grid of a solar cell serves to reduce conductive losses in the cell. However, the grid itself will shade the cell beneath, resulting in shadowing and a decrease in power generation. An optimization process must therefore be applied, wherein both resistive losses and shadowing losses are minimized. Also analyzed were the effects of busbar shape on performance losses.

Jennifer Schanke, Ab-*Initio Modeling of the Slippery Hexagonal Solids* MoX_2 *(X = O, S, Se, Te),* (S. Khare)

This summer our group's objective was to calculate the theoretical values for various properties of materials from the MoX2 group (X = O, S, Se, Te) in the hexagonal P63/mmc space group. We wanted to discover if either material would act as a suitable lubricant for application to aerospace systems to increase the lifespan of the systems and to reduce the wear caused by friction. The first properties we calculated were the lattice constants for our materials using the ab-initio method. These were followed by the calculations of the elastic constants, whose values were extensively used to calculate the bulk modulus, shear modulus, Young's modulus, and Poisson's ratio of our materials. We are hoping to write a manuscript and publish our results in a research journal.

Ryan M Zeller, *Optical Thickness Monitoring System for High Vacuum Deposition Chamber*, (A.Compaan, J.Walker)

Groups at the University of Toledo studying CdTe/CdS based thin film photovoltaic solar cells require precise measurement and variation of film parameters to produce the most efficient cells possible. Controlling film thickness of the CdTe and CdS layers is essential to optimizing cell efficiency and desired cell characteristics. A non-destructive film thickness monitoring system for in-situ, real time chamber depositions in the AJA International Inc High Vacuum RF magnetron sputtering chamber was constructed. The monitoring system visualizes interference fringes of reflected laser light from front and back surfaces of the deposited film. Sample thickness is determined from known optical properties of the film material. Complications due to sample rotation during growth, background noise, and limitations from chamber geometry were overcome to achieve clear signal detection.

Physical Materials

Lindsay Sanzenbacher, *Two-Dimensional Crystallization of Microspheres by Drop-Drying*, (T. Bigioni)

When a drop of colloidal solution is dried on a substrate, nearly all of the particles are deposited at the drop's edge, a result of fluid flows inside the evaporating drop. The remaining particles typically form disordered deposits inside the drop's perimeter. My research studies the mechanism involved in the opposite effect, the formation of a uniform and highly-ordered monolayer array of colloidal spheres, namely, 800 nm polystyrene microspheres. For a monolayer to form, two key conditions must be achieved. First, the particles must be segregated from the bulk of the drop, and placed on the liquid-air interface. The interface must in turn be "sticky" enough to trap the particles long enough for them to crystallize into a two-dimensional array. This interfacial "stickiness" is due to favorable energetic conditions. The energetic factors that make this mechanism work are already well understood for large spheres, and thus, I have altered he kinetics of the system in various ways to bring the particles in contact with the liquid-air interface. This includes changing the rate of evaporation and drying the drop upside down. The effect that pinning has on the drop has also been studied. So far, I have succeeded in getting particles on the interface, but a highly-ordered monolayer has not yet been achieved. Further study of the methods that resulted in interfacial particles will be done to determine the best way to promote two-dimensional crystallization. Understanding these different effects will allow a more general method to be developed that can be used to form monolayers from a wide range of colloidal particles.