ABSTRACTS OF REU FINAL REPORTS

The University of Toledo, Department of Physics & Astronomy
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(Faculty Mentor on parenthesis)

Astrophysics/Astronomy

Jakub Prchilk, *A Spectroscopic Study of CepOB3b,* (Tom Allen, Dr. Tom Megeath)

Spectra for ~1900 sources were classified in theCep OB3b region of the sky. Cep OB3b is an excellent location for the studying Young Stellar Objects. It is one of two clusters, the other being the ONC, nearby (<1kpc), young (< 5 Myr), and rich (>1000 stars). The MMT Telescope was used with the Hectospec instrument attached. The spectra obtained from the MMT is being used to determine the age and properties of YSOs in Cep OB3b. Also, probable new members of the cluster have been identified by searching the spectral features of CaII, Li, and Halpha in the objects being observed. These features indicate stellar youth and accretion.. Approximately 600 of the stars observed were known members of CepOB3b by either infrared excess or x-ray detection. However, this spectroscopic analysis showed that of the ~1300 spectra captured that were not known members of CepOB3b there were 22 with Lithium detections. Lithium being an indicator of stellar youth allows us to add these YSOs to the CepOB3b catalog.

Kristen Garofoli, *Recent Chandra observations of the starburst galaxy NGC 4449 have discovered several black hole x-ray binaries which are located within or near very young star clusters,* (Rupali Chandar)

Here we present the results from a suite of N-body simulations of N = 16, 384 (~ 6000 M?) star clusters through the first 10 Myr of their lives in order to determine whether such systems are capable of forming from purely dynamically means in such clusters. These simulations span a wide range of initial size and density profiles, both with and without primordial mass segregation, testing both realistic systems and extreme cases in order to find under what circumstances tight binaries are able to form within this limited timeframe. Clusters without primordial mass segregation are found to only be able to dynamically produce binaries this quickly when they are extremely compact and concentrated. The introduction of a large degree of primordial mass segregation, however, greatly increases the rapidity with which the binary systems form. Yet even in those cases the number of binaries formed are quite small, and are found to often not be good candidate x-ray binaries. The relative fraction of those found still within their parent cluster versus ejected from it also appear to be inconsistent with the observations. This leads us to conclude that x-ray binaries do not form dynamically in clusters of this size, and are likely instead the result of primordial binaries present from the cluster?s birth.

Marina Kounkel, *WFC3 Imaging of Protostars in the Orion Molecular Clouds*, (Thomas Megeath)

The Orion molecular clouds contain the largest sample of protostars within 500 pc of the Sun. As part of our survey, we have used WFC3 imaging at 1.6 um to observe 124 fields in Orion containing previously confirmed protostars.The focus of this survey was to identify companions around the protostars at distances as small as 100 AU at the

distance of Orion. By combining the WFC3 imaging with a Spitzer Space Telescope survey of the Orion clouds, as well as NICMOS and IRTF imaging, we determine the density of candidate YSOs as a function of distance from each of the targeted protostars. We also look at scattered light from the individual protostars.

Philip McDonald, *MBM6, (Adolf Witt)*

In this paper we present the results of studying the interstellar cloud MBM6. Using optical data obtained by ground-based telescopes located in New Mexico we were able to produce an optical SED through surface brightness differential photometry. Other observations were available in the form of infrared data from the Spitzer Space Telescope. These IR data were used to determine the dust temperatures and optical depths in different parts of MBM 6 along with determining the polycyclic aromatic hydrocarbons (PAH) mass fraction. From these data we found evidence of extended red emission (ERE) in the optical SED. The temperatures of the dust grains were found to be in the range from 14 K to 17 K, which is lower then the temperature of average interstellar dust (17.8 K) found by the Planck satellite. From the IR data we also found that the PAH mass fraction was considerably higher in the southern section of the cloud. When compared to published models of dust emission by Draine & Li (2007) we find that the PAH mass fraction of this southern section lay between 2.5%-4.6% while the rest of the cloud is below .47%. The southern portion of MBM 6 containing the higher PAH mass fraction is also a region of small optical depth; furthermore it faces away from the plane of the Milky Way, which is contrary to what is expected.

Pattilyn McLaughlin, *The Distance to LDN 1780,* (Adolf Witt)

It was hypothesized in Franco's 1989 paper that if the interstellar cloud LDN 1780 was a part of the cloud complex LDN 134, then its distance would be approximately 110 ± 10 pc. This paper will prove that LDN 1780 is indeed a part of this complex. Since the distance to a cloud cannot be directly determined through trigonometric or spectrophotoscopic parallax due to the nature of its brightness, stars directly in front of and behind the cloud were examined. Spectrophotoscopic parallax was used to determine the distances to 130 stars and therefore determining the distance to LDN 1780 by plotting these distances against their extinction due to the cloud. In order to find the magnitude of these stars at the V band, photometry was performed using a program called DS 9 with an add-on called Funtools. Counts from the program were then converted into fluxes and plotted against the wavelength of the respective filter. Absolute magnitude was determined by comparing stellar SEDs to Kurucz (1993) stellar atmosphere models corrected for extinction. The number of magnitudes of extinction for each star was then found by using a map produced by Ridderstadt (2006) and the IPAC 100 micron emission map. Once these three variables were found we were able to calculate the distances to these stars and then plot them. LDN 1780 was located where there occurred a sharp jump from 0 magnitudes of extinction to extinctions greater than 1 on the "Distance vs. Av" map. Using these techniques we found LDN 1780 to be located at a distance of approximately 103 ± 5pc.

Anthony Passero, *Spectroscopic Data Reduction Using Spextool,* (Karen Bjorkman)

The underlying mechanics of circumstellar disks are not well-understood, due to the complexity of the systems in which most of these disks arise. Observing these disks in a relatively simple systems, such as circumstellar disks around Be stars, is the key to understanding more complicated systems. Additionally, the infrared spectral region offers unique insight into understanding these disks. I reduced spectroscopic data taken from the NASA Infrared Telescope Facility in Hawaii, which covers near-infrared wavelengths. Spextool is the program used for this reduction, necessary for its ability to reduce the cross-dispersed data from the SpeX instrument, on-board the IRTF. The data promise to be useful for observing emission lines present in circumstellar disks, and ultimately for learning about the structure and time-evolution of these disks.

Brandon Saner, *How Globular CLusters Can Help Us Understand the Origins of the Galaxies* **,** (Rupali Chandar)

My summer research experience was both enlightening and intimidating. I learned as much as I discovered I have yet to learn, and I met a lot of interesting and intelligent individuals in my department. I really had no idea what it would be like going into it, but I think that overall I picked up some essential tools and set the foundations for building the necessary experience and relationships for continuing on in this field. Since I plan on going on to get a master's degree and PhD in astrophysics, the fact that I am involved with current research, gaining that exclusive view of the subject from the non-classroom, non-textbook side, and building a list of accomplishments will be great for getting accepted into the graduate and doctoral programs that will be best for me. I was thrilled that I got to participate in the research programs this summer, my freshman year, as it will definitely set me up to be as attractive as possible to future institutions. My goal of becoming a professor of physical science at a university will be made much more easily attainable this way.

Frances Schmidt, *Class I Protostar Mass Accretion***, (**Will Fischer)

Class II stars have been studied in much greater detail that Class I stars. Class II sources are known to accrete matter from the inner disk to the star along funnel flows that trace magnetic field lines in a process called magnetospheric accretion. Hydrogen emission lines form in these funnel flows. The strengths of these hydrogen lines are proportional to the rate of mass flow (Muzerolle et al. 1998, AJ, 116, 2695). Current star-formation theory predicts that Class I sources have higher mass accretion rates than do Class II sources. If this is correct, and the magnetospheric accretion model holds true for Class I objects, then their hydrogen lines should be stronger than those of the Class II objects. Using a sample of spectra obtained from SpeX on NASA's Infrared Telescope Facility, we analyzed Paschen Beta and Brackett Gamma emission lines of 32 Class I protostars in Orion and 19 Class II stars in Taurus and Auriga. We found the equivalent width and flux for each Paschen Beta and Brackett Gamma detection, and the upper limits for these values in each case of non-detection. We determined the reddening of each source by comparing its (J-H) and (H-K) colors to the Class II locus (Meyer et al. 1997, AJ, 114, 288), and then corrected the line fluxes for reddening and distance (420 pc) to obtain line luminosities. After comparing Class II luminosities to the Class I luminosities, we concluded that they were surprisingly similar. This indicates either that Class I sources accrete matter more slowly than was previously believed, or that the

accretion flow in Class I and Class II objects differs in a way that reduces the Class I line fluxes.

Dhruv Sengar, *Chemical Study of Diffuse Interstellar Clouds,* (Steve Federman)

Space is vast and mainly empty, yet there are molecules in large quantity. In some regions there are clumps of CO, CN, CH, etc. Diffuse molecular clouds are regions of space that have relatively low density of gas and dust, but still reveal the presence of molecules. Diffuse clouds are not visible; the main way that they can be seen is by the light of the stars that pass through them. Analysis of chemical abundances helps us determine the densities in the clouds. Ultraviolet radiation breaks apart molecules, but the dust in space scatters the radiation. The goal of this project was to determine the optical depth of the dust at 1000Å (τ_{uv}). Using the optical depth, I will then be able to find density using chemical analyses.

Atomic/Molecular/Optical Physics

Tyler Fronk, *Ion Implantation in CdTe Solar Cells***,** (Rick Irving and Thomas Kvale)

The effects of doping cadmium telluride (CdTe) solar cells with Phosphorous (P+) ions at different doping concentrations are explored. The goal was to create an electron reflector near the back surface that would prevent back surface recombination and therefore increase open circuit voltage and efficiency. Photoluminescence data will be shown detailing the problems with damage caused by ion implantation and further areas of experimentation will be discussed.

Luke Kwiatkowski, *Theoretical Calculations of Atomic Polarizabilities,* (David Ellis, Larry Curtis, Rick Irving)

Using the calculus of variations to minimize the energy of an atom in a uniform electric field, an expression for the electric dipole polarizability can be found as a function of electrons' radial coordinate. Minimizing the energy leads to a differential equation that must be solved numerically. Approximations to this solution were found which yield good results but more time will be needed to find an efficient way to solve the differential equation. This will provide a convenient way to calculate polarizabilities using multiconfiguration atomic wavefunctions, and will provide insight into the behavior of electrons in atom under the influence of an applied field.

Biological, Health, and Medical Physics

:**Jacob Buenger**, *MRI Research,* (Micheal Dennis)

This summer I joined a research team that involved several projects regarding the structure and function of the cerebral cortex of the brain. The evaluation of the grey matter of the cerebral cortex was performed using Magnetic Resonance Imaging (MRI). MRI images the brain by using very strong magnetic fields and radio waves at resonant frequencies to obtain signals from hydrogen nuclei. The structure of the grey matter of the brain was evaluated using the Freesurfer software package which measures the grey matter thickness over thousands of vertices and reports the average thickness for each area of the brain. The principle project that I worked on was the Amputee Project, which

looked to identify cortical areas where cortical thickness is related to depression, pain, anxiety, or other amputation-related factors. The subjects were given questionnaires and had MRI images taken of their brains. There were 10 amputees and 15 controls. My role in this project consisted of data entry from the questionnaires, running correlations, and analyzing results. We found correlations between the thickness and questionnaires in several different areas of the brain. Our next step is to continue recruiting subjects and looking at other types of analyzes.

Olivia Eggenberger, *Thermoluminescent Dosimetry System Calibration***,** (E. Ishmael Parsai)

This paper describes the process involved in calibrating a thermoluminescent dosimetry system. Each TLD was given an element correction coefficient (ECC) to eliminate variation and the reader was given a reader calibration factor (RCF) to convert a reading in nC to a dose value in cGy. The ECCs are unit less numbers around 1 and the final RCF value is 20.31 cGy/nC. When tested, the percent error for the TLDs with buildup was 2.4% and the percent error for the TLDs without buildup was 26.97%. The larger percent error was due to the unpredictability of radiation dosage without buildup and so it was more acceptable.

Condensed Matter Physics

Josiah Aultman, *Indium oxide and cobalt oxide thin films on amorphous-silicon solar cells for hydrogen production,* (William B. Ingler Jr.)

This paper focuses on depositing indium oxide and cobalt oxide as thin film semiconductors or TCCRs (transparent, conductive and corrosion resistant) on amorphous-silicon solar cells, used for hydrogen production. We found that depositing the cobalt oxide at a higher power of about 100 W and the indium oxide at a lower power of around 30 W is going to produce the greatest current density. However, the higher the powers the transparencies of the films tend to decrease as well. Adding about .6 sccm of $Ar/1\%O_2$ optimized the current density and also slightly increased the transparency. As we decreased sputtering time from 15 to 10 minutes, the current density and transparency of the film both seemed to increase. Making depositions at 200°C gave us the best results although we did not diverge from it often. We were able to draw a few conclusions from the data we gathered, but more research could be done in order to determine more exact values for these parameters.

Nathan Callahan, *Simulation of diffusion of nanoparticle clusters on an interface,* (Jacques Amar)

The diffusion behavior of clusters of nanoparticles confined to an interface is studied. The relationship between the size of the cluster and the diffusion coefficient is investigated. A simulation is run using molecular dynamics with brownian kicks and langevan damping. The diffusion coefficient was seen to decrease inversely proportionally to the size.

Ammaarah El-Amin, *The effects of a thin Molybdenum Oxide (MoOx) layer inserted between the CdTe absorber layer and various metal back electrodes of CdTe solar cells*, (Micheal Heben)

The effects of a thin Molybdenum Oxide (MoOx) layer inserted between the CdTe absorber layer and various metal back electrodes of CdTe solar cells were studied. The current-voltage (I-V) characteristics of the cells were compared with those of CdTe solar cells without this MoOx layer. Experimental results show a decrease in efficiency for the cells with the MoOx layer, in contrast to expectations based on published reports. [ref] However, the results are inconclusive because the MoOx was unevenly deposited and several of the cells with the MoOx layer were shunted. Consequently, the properties of MoOx as back contact merits further investigation. As a secondary finding of this project, we determined that, on average, a Mo/Al/Cr back contact produced slightly higher efficiency cells than a standard Cr/Al/Cr contact.

Chad L. McElvany, *Determination of Energy Band-Edge Locations for PbS Semiconducting Quantum Dots Using Cyclic Voltammetry***,** (Randy J. Ellingson)

Colloidal semiconductor quantum dots (QDs) offer a promising route to serve as light-absorbing materials in inexpensive, efficient photovoltaic solar cells. Evaluating the conduction band and valence band edge positions of QDs and QD-based thin films from cyclic voltammetry (CV) measurements is a relatively new technique, and has been applied to just a few QD materials. Reports in the literature often fail to address important aspects of the CV data, sometimes omitting analysis of the anodic peak and/or omitting band gap energy analysis (instead relying solely on the optical assessment of the band gap). I attempted to locate the conduction and valence band edge positions from cathodic *and* anodic peaks in the CV plots, and relate them to the optical band gap; a size-dependent trend emerges. The optical band gap (Eg) of lead sulfide QD solutions were obtained through spectrophotometric analysis and compared to plots of Current vs. Potential acquired from CV experiments performed upon QD-based thin film samples. The QD thin films were fabricated using a layer-by-layer (LbL) method, by dipping a 1" x 1" glass substrate, coated with a transparent conducting thin film of ITO (indium-doped tin oxide), into a solution of oleic acid capped QDs in hexane solvent, followed by a dip into a solution of acetonitrile containing 1,2-ethanedithiol (EDT); approximately 20 cycles of this deposition process resulted in a film thickness of ~100 nm. Noticeable degradation of the PbS QD-based thin films was observed after several cycles, so the presented data was limited to the first or second cycle.

Lawrence Moses, *A study of CdCl2 treatment on CdS/CdTe Solar Cells***,** (Alvin Compaan)

CdS/CdTe solar cells are a rapidly-growing sector of the photovoltaics industry. A CdCl2 treatment improves the quality and performance of CdS/CdTe cells. In this study, we seek to understand how the length of treatment time affects the photoluminescence of a CdS/CdTe cell. We first created a CdS/CdTe cell through RF sputtering. We then cut the sample into 6 pieces. One piece was left untreated, and the remaining 5 were treated for different lengths of time. These samples were mounted into a cryo-stat chamber and their PL spectrum were measured both film side and junction side. Then we measured the power dependence of the peaks of some of our samples. Finally, we measured the temperature dependence of a sample. Our results are shown.

Logan Stagg, *Study of Cuprous Oxide thin Films for Use as Photovoltaic absorber Layers*, (Alvin Compaan, Kristopher Wieland)

With a bandgap of 2eV, cuprous oxide is of interest as an absorber layer in multijunction solar cells. Cuprous oxide thin films are deposited by reactive magnetron sputtering. Parameters including RF Power, substrate temperature and deposition pressure are varied. Films are analyzed using Raman spectroscopy, x-ray diffraction and UV-Vis transmission. After optimization of sputtering conditions, complete devices are made using CdS and Cu2O.