The 17th annual

Keck Northeast Astronomy Consortium Undergraduate Research Symposium At Vassar College

Schedule of Papers, 2006 October 7

Session 1 Room 207, Sanders Physics Lab 9:00-10:35

1.1. Polarization of Extragalactic Radio Sources

Chris Dieck, Wesleyan University
Advisor: Prof. Bruce Partridge, Haverford College

Observations of the cosmic microwave background (CMB) continue to become more accurate and precise as time advances. We are now at a point where measurements of the polarization of the CMB are possible, which would allow testing of the theory of inflation. As these more precise measurements become possible, contamination from foreground objects becomes more of a concern for background observations. In an effort to control for these foreground objects, we observed the polarization of 42 rising spectrum radio galaxies up to 43.1 GHz. We find relationships between the flux density and the polarization percentage and characteristic changes in the polarization percentage with changes in frequency.

1.2 (M). The Effects of Interactions on Galaxy Evolution in the Early Universe

Thomas Ferguson, Vassar College '07,
Brendan Mullan, Colgate University '07
Advisor: Prof. Debra Elmegreen, Vassar College

We have studied interacting galaxies out to an redshift of ~1.3, corresponding to a lookback time of ~7 billion years, using data from the GEMS and GOODS sky surveys taken by the Advanced Camera for Surveys (ACS) on the Hubble Space Telescope (HST). Of the 10,000 galaxies included in this survey, we concentrated on a subset of pairs of interacting galaxies – 51 "antennae" and 76 "shrimps" - and how the interactions affect galactic evolution through changing morphologies and star formation. We have determined several optical properties of the galaxies, including integrated

colors, magnitudes, linear sizes of tidal tails, fractional tail luminosities, tail surface brightness, clump masses and ages, and disk scale lengths.

1.3. A New Search for Planetary Nebulae in the Small Magellanic Cloud

Joseph W. Coish, Haverford College '09
Advisor: Dr. P. Frank Winkler, Middlebury College

This project examined the Small Magellanic Cloud to discover new planetary nebulae (PNe) in order to refine previously published planetary nebula luminosity functions (PNLF). We identified 34 new planetary nebulae candidates and confirmed 91 from previous searched. We then calculated magnitudes for all the PNe in three emission-lines, Ha (6563 Å), [S II] (6716, 6731 Å), and [O III] (5007 Å). Using the magnitudes in the [O III] emission line, we created a new planetary nebula luminosity function.

1.4. A Study of the Globular Cluster System of the Spiral Galaxy NGC 7331

Aaron Larner, Wesleyan University
Advisor: Katherine Rhode, Wesleyan University

Studying entire globular cluster systems (as opposed to single globular clusters) can teach us a great deal about galaxy structure and formation. For this project, I used wide-field CCD images to study the globular cluster (GC) system of the spiral galaxy NGC 7331. Previously, many studies have been done on GC systems of elliptical galaxies, but very few have been done on spiral galaxies. Our goals were to determine some important quantities about this particular GC system (such as total number and specific frequency of clusters) and compare them to what we know about the GC systems of other spiral galaxies.

1.5 Redshift Effects on the Spectroscopic Properties of Active Galaxies

Kelly Wallenstein, Wellesley College
Advisor: Prof. Ed Moran, Wesleyan University

Unraveling the mystery of the origin of the X-ray background requires an accurate understanding of the background's contributing sources; in particular, the nuclei of active galaxies. While active galaxies known as Seyfert 2s display many of the X-ray characteristics expected for the dominant contributors to the hard X-ray background, optical observations of faint X-ray sources suggest that distant Seyfert 2s are rare. It is hypothesized that the distinguishing spectral features of distant Seyfert 2 nuclei are obscured by host-galaxy emission, which is significant in ground-based observations of highly redshifted sources. Previous simulations using local Seyfert 2s revealed an apparent "transformation" of Seyfert 2s into normal galaxies when light was collected from the entire galaxy. This study aims to determine the amount of extranuclear light necessary for these apparent transformations to

occur or, equivalently, the redshifts at which distant Seyfert 2s might begin to resemble normal galaxies.

1.6 Host Galaxies of X-shaped Radio Sources

Alessondra Springmann, Wellesley College '07
Advisor: Dr. C. C. Cheung, Kavli Institute for Particle Astrophysics and Cosmology, Stanford Linear Accelerator Center/Stanford University

Within radio galaxies, an active galactic nucleus (AGN) powers a pair of collimated jets of relativistic particles, forming a pair of giant lobes at the end of the jets and thus giving a characteristic double-lobed appearance. Approximately 12 radio galaxies have an "X"-shaped morphology: in these, two pairs of lobes appear to originate from the galactic center, producing a distinctive X-shape. Two main mechanisms have been proposed to explain the X-shape morphology: one being through the merger of a binary supermassive black hole system and the second being that the radio jets are expanding into an asymmetric medium. By analyzing radio host galaxy shapes, we probe the distribution of the stellar mass to compare the differing model expectations regarding the distribution of the surrounding gas and stellar material about the AGN.

Session 2 Room 207, Sanders Physics Lab 10:50-12:10

2.1. Optical Monitoring of Quasar 3C 345 and Exponential Outbursts

Peter C. Shively, Colgate University '08
Advisor: Professor Thomas Balonek, Colgate University

Over the past eighteen years, roughly 4000 images of 3C 345 have been taken at Colgate University's Foggy Bottom Observatory. An optical light curve of these data illustrates numerous significant outbursts occurring over this period. The data have been previously found, by Gibbons (2000), to fit the same equations used by Valtaoja et al. (1999) for the exponential rise and decay of quasar variability in radio data. Our further study of the variations indicates that several underlying multi-year variations, called outbursts, seem to exist in the optical 3C 345 data upon which are superposed short (weeks to months) flares. While the presence of the outbursts in radio total flux variations and VLBI maps tell us a good deal about the intrinsic nature of the underlying quasar, it is still largely unknown whether this type of analysis will prove as successful for optical elements.

2.2. (M). Multiband Optical Monitoring of Four Blazars

Trevor David ’09, Vassar College, and Amanda Zangari ’08, Wellesley College
Advisor: Fred Chromey, Vassar College

We observed the four blazars 3C 279, 3C 345, BL Lacertae and 3C 454.3 over the course of several weeks with Vassar’s 32-inch telescope and FLI CCD camera. These distant galaxies are believed to have supermassive black holes at their centers, around which matter accretes and is heated by friction. This mechanism, often referred to as an Active Galactic Nucleus (AGN), can cause rapid and enormous changes in luminosity. We observed in the B,V, and R filters, in order to see if there is a correlation between the AGN,s brightness and its color. We used NOAO’s IRAF package for data reduction as well as to perform photometry on the reduced CCD images. We observed no appreciable microvariability or rapid flares in brightness on the intra-night timescale but did observe several incidences of moderate variability on the inter-night timescale. We will compare our results with simultaneous observations made at Colgate University’s Foggy Bottom Observatory.

2.3. 147/157 GHz Methanol Line Ratios in Regions of Star Formation

Jenna Lemonias ’08, Vassar College
Advisor: Dr. Vladimir Strelnitski, Maria Mitchell Observatory

We present the results of the observations of two masing rotational lines of methanol, 9_0-8_1 A+ at 147 GHz and 7_{-1}-6_0 E at 157 GHz, in eight galactic sources: DR21N, DR21(OH), NGC7538M, NGC7538S, NGC7538W, NGC7538(IRS9), W75N, and W75N(OFF). Observations were carried out with the ARO 12-m radio telescope at Kitt Peak, AZ. The 147 GHz line was detected in all the sources except W75N(OFF). The 157 GHz line was detected in DR21(OH) and W75N. All the positive detections are the first detections for these sources. For the two sources where both lines were detected, the 147/157 peak intensity ratio varies in broad limits, from ≈1.4 to ≥35. In other sources only a lower limit of this ratio could be determined, and it is, typically, ≥1-8. Preliminary analysis of the available statistical equilibrium calculations of methanol level populations allows us to suppose that the 147/157 ratio is a steep function of the gas density in the masing condensation. If this hypothesis is correct, the 147/157 line ratio can become a sensitive probe of gas density in Class I methanol masers. More statistical equilibrium calculations are needed to confirm or reject this hypothesis.

2.4. HI 21-cm and OH 18-cm Arecibo Observations of (Ultra)Luminous Infrared Galaxies

María Ximena Fernández, Vassar College '07
Drs. T. Ghosh, E. Momjian, C. Salter, Arecibo Observatory

We present HI 21-cm and OH 18-cm spectral line analysis of eighty-five luminous infrared galaxies from the 2 Jy IRAS-NVSS sample observed with the 305 m Arecibo Radio Telescope. We detected HI in 82 galaxies (16 new detections), and OH in 7 galaxies (5 new detections). In some cases, the HI spectra showed the classic single-peak or double horn distributions, while the majority exhibited distorted features indicating they are in interacting/merging systems. IRAS 23327+2913 is discussed in greater detail since both HI emission and OH megamasing activity are new detections, and its spectra display features that indicate the presence of two nuclei at the beginning stages of interaction. This study hopes to contribute to the current understanding of the differences between LIRGs with AGN and those with pure starburst.

2.5. Evidence for Inverted Spectrum 20GHz Emission in the Galactic Plane

Jonathan Pober, Haverford College '07
Advisor: Prof. Stephen Boughn, Haverford College

A comparison of a 19GHz full-sky map with the WMAP satellite K band (23GHz) map indicates that the bulk of the 20GHz emission in the Galactic plane has an inverted (rising) spectrum with spectral index $\alpha \sim 0.3$. While such a spectrum is inconsistent with synchrotron ($\alpha \sim -0.7$) and Bremsstrahlung ($\alpha \sim -0.1$) emission, it is consistent with various models of electric dipole emission from thermally excited spinning dust grains, as well as models of magnetic dipole emission from ferromagnetic grains. A few regions in the plane, e.g., the Cygnus arm, appear to have spectra with even larger α. At Galactic latitudes between $b_{II} = 7^{\circ}$ and 20°, the spectrum steepens to $\alpha \sim -0.3$. A low signal to noise of the 19GHz map precludes a detailed map of spectral index.

Poster Session Room 100-101, Sanders Physics Lab 12:10-1:40

P1. Coronal Observations at the 2006 Solar Eclipse

Megan Bruck, Williams College
Advisor: Prof. Jay M. Pasachoff, Williams College

Williams College coordinated an eclipse expedition, headed by Professsor Jay Pasachoff, to the Greek island of Kastellorizo, located just 2 kilometers southwest of Turkey, for the total eclipse of March 29, 2006. Three principal observations of the corona were conducted: one of them was high-time-resolution (10 Hz) observations in the coronal green line looking at coronal loops; another was similar observations in the coronal red line; both are to determine among theories of coronal heating and continue earlier reports of excess Fourier power in the 1 Hz range. As we knew from SOHO observations from the day before the eclipse, an active region was stationed right on the east limb and it gave us very suitable loops to study, with pointing in agreement with TRACE. A third set of observations used a very narrow-band filter (Fabry-Perot), with 1/6 angstrom resolution, to make velocity (Doppler) images and obtain emission line profiles of the same coronal loops.

P2. Optical Variability of the Blazar 1510-08 and Comparison to the X-ray

Talia Sepersky, Wellesley College ‘08
Advisor: Prof. Thomas Balonek, Colgate University

The blazar 1510-08 (z=0.361, Liller & Liller 1975) was imaged in the R filter on 105 nights ranging from June 17, 2003, to July 25, 2006, at Colgate University’s Foggy Bottom Observatory. These images were reduced using Colgate-specific scripts in IRAF. Analysis of these data led to the creation of a light curve, which displays evidence of a significant increase in brightness in the summer of 2004, and a smaller event in 2006. When combined with 165 nights of data taken from 1995 to summer 2003, the optical data were compared with the X-ray curve compiled from data taken over the same time range. The comparison revealed that the two optical outbursts in 2004 and 2006 have apparently corresponding outbursts in the X-ray, as well as other features that appear to match up between the two graphs. However, other features in the optical do not match up to X-ray data taken at the same time.

P3. Optical Variability of Blazar 3C 279 and Comparison with X-ray Variability

Kathryn Fallows, Colgate University '08
Advisor: Prof. Thomas Balonek, Colgate University

The blazar 3C 279 was observed through an R filter at Colgate University's Foggy Bottom Observatory and four years of archived images were reduced. These new results were plotted with previously reduced data to create an eighteen year light curve. This updated light curve shows that following a flare in 2001, its maximum brightness in the history of observation at Colgate, 3C 279 fell to its minimum observed brightness in 2003. Since then its brightness has continued to increase. The optical data were also plotted with corresponding X-ray data. Comparisons of the optical with the X-ray light curve show possible correlations, though recent optical data appear undersampled, making correlation difficult.

P4. Lithium Depletion in Late-Type Members of the Beta Pictoris Moving Group

Jennifer Yee, Swarthmore College '07
Advisor: Prof. Eric Jensen, Swarthmore College

We present a study of lithium depletion in twelve late-type members of the coeval, ~12 Myr old Beta Pictoris Moving Group (BPMG). We have compared the empirical data from this survey to isochrone predictions by Baraffe et al. (1998), D'Antona & Mazzitelli (1997, 1998), and Siess, Dufour, & Forestini (2000). Significantly more lithium depletion was observed in the sample than is predicted for a group of this age, suggesting a problem with theories describing PMS lithium depletion. In addition, we compared our results to the work of Song, Bessell, & Zuckerman (2002) on HIP112312. In contrast to that work, we did not observe the lithium depletion boundary of the BPMG, even though the sample extended to stars as late as M4.5, further underscoring the gap between age estimates from lithium depletion and those from theoretical evolutionary tracks.

P5. A Survey of Young Stars in the Solar Neighborhood

Blair E. Reaser, Swarthmore College '07
Advisor: Prof. Eric L. N. Jensen, Swarthmore College

In order to improve our understanding of stellar evolution and planet formation, we are finishing a survey of young, low mass stars in the solar neighborhood. As part of our survey, spectra were taken of candidates selected based on criteria that avoided a bias toward or against objects with circumstellar disks. Since lithium abundance is an indicator of youth, the equivalent width of the Li I line in each object's spectrum was compared with the equivalent widths of the lithium lines of stars in clusters with known ages, in order to verify the youth of the stars in our sample. We identified 26 stars as young with this analysis, five of which are newly identified as young. Once we had established the youth of our candidates, their galactic space motions were calculated and plotted with respect to the average space motions of known moving groups. None of our young candidates has galactic space motions consistent with membership in known moving groups, nor do they indicate the existence of any new moving groups.

P6. Formaldehyde Emission from Protostellar Region L1448IRS3

Claire Davy, Bryn Mawr College
Advisor: Dr. Jeff Mangum, NRAO

Accurate measurements of temperature and density are essential in determining whether there are stars forming in a protostellar region and, if so, what the behavior and characteristics of these protostars might be. Formaldehyde is a good molecular probe for this because of its unique properties. Using formaldehyde emission data from the BIMA interferometer and the IRAM 30 meter radio telescope, I made a temperature map of the L1448IRS3 protostellar region. A simulation program called RATRAN, which uses Monte Carlo methods to simulate the radiative transfer and molecular excitation effects in a cloud, made it possible to model the formaldehyde emission from L1448IRS3.

Session 3 Room 207, Sanders Physics Lab 1:40-3:15

3.1. Gamma Ray Channeling Through Curved Structures

Seth Cohen, Wesleyan University
Advisor: Dr. Derek Tournear, Los Alamos

The channeling and focusing of gamma rays with energies of ~100 keV to several MeV is important in the development and advancement of medical, astronomical, and military technologies. We have developed a way to channel gamma rays through curved, layered structures that use the rays' shallow grazing angle to concentrate incident photons onto small-area detectors. In our experimental setup, collimated gamma rays are channeled through a curved crystal consisting of alternating layers of 40-nm-thick gold and 4-micron-thick polymer. The channeled rays are focused onto a detector, where specific-energy photons are counted. Our experiments confirmed that channeling does occur in both straight- and curved-crystal structures. The successful implementation of this technology would give a factor of ~100 improvement in angular resolution over other developing technologies, and more than an order of magnitude improvement in sensitivity over any current technology. Applications include safer and more efficient detection and removal of tumors, nuclear materials detection, and development of gamma-ray telescopes.

3.2. Mapping the Resonant Modes of the Axion Dark Matter eXperiment Microwave Cavity

Karl Twelker, Middlebury College '07
Steve Asztalos, Lawrence Livermore National Laboratory

The Axion Dark Matter eXperiment (ADMX) uses a tunable microwave cavity to detect axion decays from the theorized cosmic halo of dark matter axions. Because the axion mass is unknown, the cavity must search over a broad range of frequencies, each corresponding to a specific axion mass. The experiment will use the TM010 mode of the cavity, so a mode map that relates the frequency of this mode (and others) to the tuning rod position is essential. In order to produce this mode map, we stimulated the modes of the cavity and measured the spectra, finding each peak of the resonant modes, then plotted these peak frequencies against the rotation angle of the tuning rods.

3.3 (M). ELSA: An Integrated Semi-Automated Nebular Abundance Package

Jesse S. Levitt ’08, Williams College, Peter J. J. O’Malley ‘08, Haverford College and Peter G. R. Nunns ‘08, Williams College
Advisor: Prof. Karen B. Kwitter, Williams College

We present a new release of ELSA, a program for analyzing the emission line spectrum of objects such as planetary nebulae. ELSA features advanced routines that correct for interstellar reddening and contamination from coincident emission lines, as well as convergence loops for calculating nebular temperatures and densities and a five-level atom model for determining ionic and elemental abundances. ELSA also provides a complete, streamlined data flow capable of accommodating spectroscopic flux measurements in many different stages and outputting data in many forms, including LaTeX tables.

3.4 X-Ray Emission From Clump Bow Shocks In Massive Star Wind Flows

Alex Burke ‘07, Vassar College

Recent observations have shown that the emission profiles of massive stars such as Zeta Pup and Zeta Ori have unusually hard x-ray emissions, and the x-ray line profiles tend to be symmetrical and only slightly blueshifted. We suggest a possible explanation for this: in the highly supersonic stellar winds that form around a massive star, locally denser regions of the wind form axially symmetric bow shock structures. We treat these denser regions as rigid spherical “clumps’ and assume that they exist randomly around the star. The bow shock shape is parabolic, with temperatures along the shock in excess of 10^6 K, decreasing from a maximum temperature at the shock head. Taking into account stellar occultation, clump occultation, and optical depth parameters, we simulate the line profiles resulting from emission along the shock. We reasonably reproduce the main features of the observed line profiles, though some parameters, such as the speed of the clumps, remain unclear at this time.

3.5. Chandra Spectroscopy of the Hot Star beta Cru and the Discovery of a Pre-Main Sequence Companion

Michael Kuhn '07, Swarthmore College
Advisor: Prof. David Cohen, Swarthmore College

Using a 75,000 s Chandra X-Ray Observatory observation, we examined x-ray emission from the B0.5III star beta Cru and a newly discovered companion. The stars are separated by 4" and the secondary has about 3 times fewer counts than the primary. The flux contrast must be much greater in the optical, though, or the companion would have been discovered earlier. The HETG spectrograph was used to produce a dispersed spectrum in which individual line profiles of the primary were resolved. We found that the lines show slight broadening, suggesting an origin in a slow stellar wind rather than a corona. The secondary has a harder spectral energy distribution than the primary, which is best fit by a 2 temperature model with 9 and 23 million K components, making it a probable PMS star. The secondary is also more variable then the primary, consistent with thex-ray flaring seen in PMS stars.

3.6. Photometric Analysis of Pulsed Accretion in the Spectroscopic Binary UZ Tau E

Matthew Richardson, Fisk University
Advisor David Cohen, Swarthmore College

UZ Tau E is a binary system located within the UZ Tauri system. It has been classified as a M1 Classical T Tauri Star (CTTS) with a strong Hα emission and strong excess and continuum emission in the infrared and sub-millimeter wavelengths. Another important characteristic of UZ Tau E is that it is surrounded by a circumbinary disk composed of gas and dust. Theoretical prediction produced by Artymowicz and Lubow state that over time a circumbinary disk will experience gravitational perturbations, caused by an eccentric binary system, which should result in accretion that is in sync with the orbit of the binary system. Such pulsed accretion might be determined through a photometric analysis of the periodic photometric variations of such a system. The purpose of this research is to determine how the stars of UZ Tau E are interacting with the circumbinary disk that surrounds them. Our findings, based on a photometric analysis of photometric data spanning more than three years, give a good indication that the system is indeed experiencing pulsed accretion.

Session 4 Room 207, Sanders Physics Lab 3:35-4:55

4.1. Simulations of Exoplanet Spectroscopy with JWST

Matt Johnson ’07, Wesleyan University
Advisor: Dr. Jeff Valenti, Space Telescope Science Institute

We conducted several simulations to investigate the feasibility of obtaining spectroscopy of extrasolar planets using the Near-Infrared Spectrograph (NIRSpec) on the James Webb Space Telescope (JWST). NASA's Kepler Mission, which is scheduled for launch in 2008, expects to find a wealth of both Jupiter-mass and Earth-mass planets transiting their host stars which could serve as candidates for NIRSpec observations when JWST launches. Using current published specifications of NIRSpec and models of star and planet spectra, we determined lower magnitude bounds for which spectral features can be resolved for planets around host stars of various spectral classes. We also investigated other parameters, such as transit length and orbital period, and their effects on the signal to noise and quality of the simulated spectra.

4.2. Rotation Periods of T Tauri stars in NGC 1333

David Vollbach ‘07, Vassar College
Advisor: Prof. William Herbst, Wesleyan University

Observations of NGC 1333 were conducted over the course of 6 winters at the Van Vleck Observatory. Photometric analyses of 76 stars across 2 fields of view were able to determine rotation periods for 11 of these stars. A method for combining periodograms from all 6 years of observations by multiplication proved very successful in reducing noise and clearly expressing periods.

4.3. Determining the Periods of Stars in IC 348 Using Eight Seasons of Data

Eric Scheid, WPI
Advisor: William Herbst, Wesleyan University

Over the summer of 2006, data reduction of 151 stars in the young cluster IC 348 was performed to determine the rotation periods of the stars. A new method was developed to determine periods using all eight seasons of data collected at the Van Vleck Observatory. This multiplying method proved quite effective at determining periods; a total of 50 periods were found, with 10 being reported for the first time at the Van Vleck Observatory.

4.4 Observation of Spicules in TRACE 1216 Å and 171 Å Filters

Rangga Budoyo, Wesleyan University
Advisor: Prof. Jay Pasachoff, Williams College

Our work during summer 2006 was a continuation of an ongoing solar project in observing spicules in multiple wavelengths. I modified an existing IDL routine, followspicule, so that we can measure spicules in 171 Å (coronal line) data from the Transition Region and Coronal Explorer (TRACE). Further modification is still required to be able to do a reliable measurement. Also, using the original followspicule, I measured 28 spicules in 1216 Å data from the 2005 TRACE observations. The results show that spicules in this wavelength have similar height and interpolated velocity distributions to spicules in 1600 Å, but they have a much smaller measured velocity distribution.

4.5(M). Quantifying Properties of Saturn's Rings through Wavelet Analysis of Density Waves

Kathryn Stack, Williams College '08
Rebekah Dawson, Wellesley College '09
Advisor: Prof. Richard French, Wellesley College

Spiral density waves, the result of orbital resonance, are the fingerprints of the gravitational interaction between Saturn's moons and the water ice particles that compose its rings. We analyzed a number of density waves observed in Cassini radio occultations with wavelets, a mathematical technique ideal for processing localized oscillations of changing frequency. At various radii in Saturn's A Ring and Cassini Division, we calculated background surface densities and quantified particle damping. These properties can be used by ring dynamicists to better model Saturn's fascinating ring system.