

The 15th Annual

# Keck Northeast Astronomy Consortium

Undergraduate Symposium  
on Research in Astronomy

October 29-30, 2004

*hosted by*

***Colgate University***

*and including*

***\* Haverford College \* Middlebury College \****  
***\* Swarthmore College \* Vassar College \* Wellesley College \****  
***\* Wesleyan University \* Williams College \****

# **2004 KNAC Undergraduate Symposium on Research in Astronomy @ Colgate University**

## **Schedule of Events**

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### **Friday, October 29, 2004 White Eagle, The Grove**

5:00 - 7:00 p.m.	Check-in, White Eagle Lodge
6:00 - 7:00 p.m.	Reception & Symposium Registration, White Eagle Lodge
7:00 - 8:30 p.m.	Dinner, White Eagle Lodge
8:30 p.m. - ??	Party, White Eagle Teepee and Game Room

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### **Saturday, October 30, 2004 Colgate University, Lathrop Hall 209**

7:00 - 8:30 a.m.	Breakfast, White Eagle Lodge
9:00 - 10:30 a.m.	Session I: The Solar System
10:30 - 11:15 a.m.	Session II: Poster Papers & Coffee Break
11:15 - 12:25 p.m.	Session III: Stars and Extrasolar Planetary Systems
12:25 - 1:30 p.m.	Lunch and Poster Viewing, Lathrop Hall 158 and Academic Quad
1:30 - 2:45 p.m.	Session IV: Stellar Collisions and Pulsars
2:45 - 3:00 p.m.	Coffee Break
3:00 - 4:30 p.m.	Session V: Galaxies and Quasars
4:30 p.m.	Adjourn

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# KNAC Symposium Schedule

Colgate University \*\*\* Saturday, October 30, 2004 \*\*\* Lathrop Hall 209

## Session I: The Solar System

9:00 - 10:30

*Chair: Jay Pasachoff*

Melissa Rice, "Radar Imaging of Mercury"

Kayla Gaydosh, "From Venus with Love: The Transit of Venus 8 June 2004"

Trisha Hutchins and Rebecca Mickol, "Visual Spectroscopy of Planetary Satellites"

Eliza Blair, "Fun in the Sun: High-Resolution Solar Spectroscopy at Middlebury College"

One-minute summaries of Poster Papers (see Session II)

## Session II: Poster Papers

10:30 - 11:15

*Chairs: Kim McLeod and David Cohen*

Supreet K. Sidhu, "Dark Slope Streaks on Mars: Formation, Changes, and Fading"

Rachel A. Hock, Merideth Frey and Stephanie Rounds, "Highly Accurate Positions of Saturn's Satellites from Hubble Space Telescope Observations"

David Butts and Kamen Kozarev, "Solar Limb Spicules from the Swedish Solar Telescope and TRACE"

Christine M. Simpson, "Motions of Water Masers toward Class I Protostar YLW16A"

Victoria Swisher, "High-resolution X-ray Spectroscopy of the Accreting Weak-line T Tauri Star DoAr 21"

Katie Schlesinger, "A Multi-Faceted Approach to Identifying Young Stars"

Peter Robinson, "Searching for Past Outbursts of Recurrent Novae"

Matt Rosenfeld, "Stellar Evolution and Hydrodynamics of Low-Mass Population II Stars"

Richard Bi, "Put It On Your Fridge - Integrating Magnetic Fields into SPH"

Zach Proulx, "Modeling Red Giant Stars in Stellar Collisions"

Lauren Willis, "Combining Weak Lensing Using Polarization Alignment Breaking with a Multiply Imaged Quasar"

## Session III: Stars and Extrasolar Planetary Systems

11:15 -12:25

*Chair: Bill Herbst*

Brad Melius, "Visual Spectroscopy of Stars and Nebulae"

Scott Fleming, "The XO Project: Searching For Transiting Extrasolar Planets"

Michael Kuhn and Ellen Foster, "Spectrographic Classification of Photometric Planet Candidate Stars"

Saurav Dhital, "A Closer Look at Two PMS T Tauri Stars: HMW 15 & HBC 338"

## Session IV: Stellar Collisions and Pulsars

1:30 - 2:45

*Chair: Fronefield Crawford III*

Matt Rosenfeld and Zach Proulx, "Make It, Then Break It: The Story of Stellar Evolution and Stellar Collisions"

Richard Bi, "Put It On Your Fridge - Integrating Magnetic Fields into SPH"

Gabe Roxby, "Search for Radio Pulsations from PSR J0537-6910"

Steve Gilhool, "Search for Giant Pulses in EGRET Error Boxes"

## Session V: Galaxies and Quasars

3:00 - 4:30

*Chairs: Debbie Elmegreen and Frank Winkler*

Megan Roscioli, "Morphologies of Mid-Infrared Galaxies"

Emily McNeil, "Quantitative Asymmetry in the COSMOS Field"

Stephanie B. Wortel, "Looking into the Past: Extending the Known Variability of the Quasars 3C 273 and 3C 279"

Douglas Rubin and Meredith Schaffer, "Protogalaxies: Analysis of High Redshift Galaxies in the Hubble Ultra Deep Field"

Rebecca A. Stoll, "Quasar Host Galaxies at High Redshift"

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# ABSTRACTS

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## **Put It On Your Fridge - Integrating Magnetic Fields into SPH**

Richard Bi, Vassar College '06

*Advisor: James Lombardi, Vassar College*

We have successfully integrated magnetic fields into a one-dimensional Smoothed Particle Hydrodynamics (SPH) code, producing a Smoothed Particle Magnetohydrodynamics (SPMHD) code. To demonstrate that the SPMHD code is functional and accurate, we performed a variety of tests, including shock tube tests commonly presented in MHD literatures. A shock tube test involves two fluids that have substantial discontinuities in their physical variables (density, pressure, initial velocity, and magnetic fields) across a planar interface. The physical variables are then evolved through time. The results of the tests were positive and followed closely the exact numerical solutions, demonstrating that our code is able to handle the discontinuities given and resolve all shocks. The code also yields good conservation of total energy and momentum. Magnetic fields were then incorporated into our current three-dimensional SPH code, which we use to model stellar collisions. We have begun simulations with the new three-dimensional SPMHD code to test the effects of magnetic fields on the transport of angular momentum during collisions. Preliminary results indicate that while and after two stars merge, the presence of magnetic fields has an effect on the rotational profile and the ejecta of the collision product. Besides further testing and analysis, improvements to the three-dimensional code need to be made before conclusions can be drawn.

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## **Fun in the Sun: High-Resolution Solar Spectroscopy at Middlebury College**

Eliza Blair, Swarthmore College '07

*advisor: Stephen J. Ratcliff, Middlebury College*

Over the course of ten weeks between June 7 and August 13, 2004, a homemade spectrometer was refurbished and used to take spectra of the sun. Two different detectors were used: a Creative Labs Webcam Pro eX and an FLI Maxcam ME2. The webcam, which had a lower resolution but the ability to take measurements in color, was used to photograph interesting sections and take color panoramas of wide areas of the solar spectrum. The Maxcam, which had a far higher sensitivity and resolution, was used to take monochrome measurements. This setup was used to explore two main areas of undergraduate solar research: the Doppler effect between the east and west limbs of the sun, and the Zeeman effect in sunspots; also, the feasibility of using an average, inexpensive webcam for astrospectroscopy purposes was investigated.

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## **Solar Limb Spicules from the Swedish Solar Telescope and TRACE**

David Butts, Williams College '06

Kamen Kozarev, Williams College '05

*advisor: Jay M. Pasachoff, Williams College*

We studied spicules on the solar limb with simultaneous observations from the Swedish Solar Telescope on La Palma, Canary Islands, and NASA's Transition Region and Coronal Explorer spacecraft (TRACE). In La Palma, we used Lockheed Martin's Solar Optical Universal Polarimeter (SOUP). We are working on determining the properties, especially the distributions of velocities and of heights, of the spicules using co-aligned visible-light observations from the ground and ultraviolet observations from space. We are using a specially written IDL code to obtain these velocities.

Butts, Joseph Gangestad, and Pasachoff observed at La Palma in May 2004; Kozarev joined Butts during the summer and is continuing on the work as his senior thesis. We thank Bart De Pontieu of Lockheed Martin Solar and Astrophysics Laboratory for his collaboration in La Palma and Daniel B. Seaton '01 for his assistance with programs relevant to TRACE. The spicule studies at Williams are supported by a TRACE Guest Investigator grant from NASA. The Swedish Solar Telescope is operated on the island of La Palma by the Royal Swedish Academy of Sciences in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias.

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## **A Closer Look at Two PMS T Tauri Stars: HMW 15 & HBC 338**

Saurav Dhital, Swarthmore College '06  
*advisor: William Herbst, Wesleyan University*

While continuing the study of rotational periods of PMS T Tauri stars in various, nearby clusters, we discovered two stars behaving unusually. HMW 15, in the young star-forming cluster IC 348, came out of an apparent eclipse, which had lasted 3.5 years (if proved, it would be the longest known eclipse), and was expected to remain at its brightest for some time. Instead, recent observations show the star experiencing short-time variations in magnitude, which cannot be explained by the eclipse model. We also report an apparent change in the rotational period of HBC 338, in nearby NGC 1333. Such a change in period has not been seen in T Tauri stars. This might be due to differential rotation, a phenomenon previously undetected and thought to be non-existent among T Tauri stars.

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## **The XO Project: Searching For Transiting Extrasolar Planets**

Scott Fleming, Vassar College '05  
*Advisor: Peter McCullough, STScI*

The XO Project is an automated, wide-field photometric survey in search of transiting extrasolar planets. Last summer was spent developing a data reduction pipeline that can be run through the Sun Grid Engine. Our code uses the Box Least Squares Method for period finding, and after collecting data for a little over a year now, we have our first transit candidates. This summer was spent creating "Wanted Posters" for each candidate containing information on the candidates and their parent stars. Using these posters, some spectral-type follow-up was performed with Vassar College collaborators on some of the candidates. Data from recently observed fields were also reduced and analyzed to find additional candidates.

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## **From Venus with Love: The Transit of Venus 8 June 2004**

Kayla Gaydosh, Bryn Mawr College '05  
*Advisor: Jay M. Pasachoff, Williams College*

For the first time in 122 years, a transit of Venus occurred on June 8th 2004. The Williams College Transit of Venus Expedition Team observed the transit at the Aristotelian University of Thessaloniki, Greece, using our Apogee CCD camera on their 20-cm f/15 refractor. Historically, Venus transits were the most accurate method for determining the Astronomical Unit. However, the infamous "Black Drop" effect during the second and third contacts with the solar limb hindered precise calculations. Using the reduced ground-based imagery, investigation of the black drop provides insight to the limitations of the historical observations as well as the point-spread function of the telescopes and the solar limb darkening. I made movies from a sequence of these images to illustrate the "Black Drop" effect. The TRACE satellite made space-based images, which show little or no "Black Drop" effect. I worked with the images in collaboration with Glenn Schneider of the University of Arizona, processing them and making a movie in IDL centered on Venus instead of the sun. I carried out aperture photometry of the circum-Cytherean atmosphere for preliminary analysis as a basis for extra-solar planet research, since a transit of Venus is a close-up proxy for extra-solar planet transits that are being increasingly observed.

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## **Search for Giant Pulses in EGRET Error Boxes**

Steve Gilhool, Vassar College '05  
*Adviser: Fronefield Crawford III, Haverford College*

In this paper, we discuss a search for pulsars in the error boxes of 56 unidentified gamma-ray sources from the 3<sup>rd</sup> EGRET catalog which could be previously undetected energetic pulsars. In particular, we are searching for pulsars that periodically emit giant pulses. Detection of giant pulses is a secondary way to detect radio pulsars and may pick up candidates missed by a standard Fourier transform search. Pulsars in the known population that have been observed to emit giant pulses have unique properties, so any pulsars discovered in our search would be particularly interesting and provide valuable information about these phenomena and their connection.

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## **Highly Accurate Positions of Saturn's Satellites from Hubble Space Telescope Observations**

Rachel A. Hock, Wellesley College '07  
Merideth Frey, Wellesley College '07  
Stephanie Rounds, Wellesley College '07  
*Advisor: Richard French, Wellesley College*

The gravitational forces exerted by the inner satellites of Saturn directly affect the dynamics of the planet's giant ring system, causing the scalloped edges and small density waves seen in the image below. New images from the Cassini-Huygens spacecraft show these dramatic effects due to resonances between ring particles and the satellites. Our work this summer concentrated on using over 400 images taken by the Hubble Space Telescope (HST) from September 1996 to March 2004 to calculate within a few hundredths of an arcsecond the ephemerides or position in the sky relative to Saturn for eleven of Saturn's moons. By having accurate orbits, the subtle variations in the rings can be better understood. After considerable work spent correcting for the geometric distortions present in the images, we have achieved results accurate to about 0.02". Our work reveals that in some cases JPL's ephemerides show systematic errors. The current ephemerides are calculated using observations from Earth-based telescopes and the Voyager probes which are not as accurate as our measurements. Our results will be provided to JPL to be incorporated into the database that is used to calculate the orbits of Saturn's satellites. These new orbits will be useful for the planning of observations for the Cassini mission and for detailed dynamical studies of the interactions of Saturn's moons and rings. (Supported by the Massachusetts Space Grant Consortium.)

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## **Visual Spectroscopy of Planetary Satellites**

Trisha Hutchins, Colgate University '05  
Rebecca Mickol, Colgate University '07  
*Advisor: Thomas J. Balonek, Colgate University*

Spectroscopy has proven to be a useful technique in the field of astronomy, allowing for the identification of the composition of celestial bodies. The goal of our project was to test the capabilities of the Colgate University system (16-inch Ferson Newtonian/Cassegrain telescope, Optomechanics spectroscope and Photometrics Star1 CCD) and to develop calibration and analysis methods for solar system spectroscopy. We used the imaging program ImageJ and the spectroscopy program VisualSpec to calibrate and analyze the spectra (range ~4000 to 8000 Å). Flux calibration was done using observed spectra of several bright stars, including the solar-type G2 star Beta Draco, and the spectral library within VisualSpec. We report the results of our observations of the giant planet Jupiter, the Galilean moons (Io, Europa, Ganymede and Callisto), three lunar craters (Archimedes, Plato, Tycho) and two lunar maria (Serenitatis, Imbrium).

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## **Spectrographic Classification of Photometric Planet Candidate Stars**

Michael Kuhn, Swarthmore College '07  
Ellen Foster, Vassar College '07  
*advisor: Fred Chromey, Vassar College*

During June and July 2004, we used the Vassar College 32-inch telescope to make spectroscopic observations of three 10th through 12th magnitude stars with potential transiting exoplanets. These stars were selected by wide-field CCD monitoring by the Space Telescope Science Institute XO group, which selects stars with periodic decreases of about 1%. The comparison of the program stars' spectra to standard spectra taken with the same telescope allows us to classify the candidate stars as an F2V, F8V, and F9IV-V with a  $\pm 1$  error in spectral type and a +1 error in luminosity class. The stars were classified using spectral features between 4000 and 9000 Angstroms. From our analysis, none of these stars are giants and none of them show evidence of being a binary system, making them good planet candidates for further observation.

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## **Quantitative Asymmetry in the COSMOS Field**

Emily McNeil, Middlebury College '06

*advisor: Charles Liu, CUNY, College of Staten Island*

The COSMOS project is an international collaboration sharing the largest single allotment of Hubble Space Telescope time ever. The data include photometric and spectroscopic data from an equatorial, two-degree<sup>2</sup> field—the largest ever covered by the HST. The COSMOS project is an invaluable resource because of the wealth of data allowing scientists to explore underlying relationships on an enormous time and distance scale. In this paper we calculate the asymmetry coefficients of 91 galaxies in the COSMOS field using a method adapted from Abraham (1996). The asymmetry coefficient is one of many quantifiable indicators of morphology—a quality that promises a better understanding of the processes that make galaxies look the way that they do. The value was measured in two bands, g and i, allowing us to compare the shape to the color. We found that galaxies are more asymmetric in the g-band than in the i-band, which supports our expectation that late-type galaxies are bluer. Additionally, we compared the ratio of asymmetries in both bands to a color index. The relation indicates that redder galaxies are more asymmetric in the g-band than in the i-band, whereas bluer galaxies appear relatively more asymmetric in the i-band than in the g-band. (This research was funded by the NSF as part of the Research Experiences for Undergraduates program at AMNH.)

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## **Visual Spectroscopy of Stars and Nebulae**

Brad Melius, Colgate University '06

*Advisor: Thomas J. Balonek, Colgate University*

Using Colgate's Optomechanics Model 10C Grating Spectrograph and Photometrics Star 1 CCD electronic camera attached to our 16-inch Ferson telescope, we took spectra of various stars and nebula over four nights at the beginning of the summer. The goal of the project was to test the capabilities of our system and generate spectra correctly calibrated for wavelength and relative flux. To analyze these spectra we utilized a program called Visual Spec, designed for amateur astronomers to study the visual portion of the spectrum. We generated calibrated spectra of bright stars and nebula and compared our results with spectra obtained previously by other astronomers.

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## **Modeling Red Giant Stars in Stellar Collisions**

Zach Proulx, Vassar College '07

*Advisor: James Lombardi, Vassar College*

We enhance a three-dimensional Smoothed Particle Hydrodynamics (SPH) code to simulate and analyze collisions involving red giant stars that occur in globular clusters and galactic nuclei. The red giant is modeled as a point-mass core surrounded by a gaseous envelope represented by SPH particles. The SPH particles interact through hydrodynamic and gravitational forces, while the core point contributes gravitational forces alone. We simulate stellar collisions between a 0.95 solar mass red giant star and a 0.97 solar mass main sequence star. Collision products involving red giant stars have implications for the formation of so-called super-blue stragglers, stars in the galactic core visible only in the infrared that are not yet fully understood. We vary the relative velocity and periastron separation of initial orbit for each collision. The collisions range from head-on to grazing, and our results show core knock-outs, main sequence fly-bys, binary and common envelope systems, and bound systems that lead to mergers. Collaborators at Northwestern University, Natasha Ivanova and Fred Rasio, will utilize a stellar evolution code to evolve our red giant collision products, allowing us to compare our models with observations of super-blue stragglers.

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## **Radar Imaging of Mercury**

Melissa Rice, Wellesley College '04  
*Advisor: John Harmon, Arecibo Observatory*

Radar images of the entire Mercurian surface have been created using the Arecibo S-band radar (wavelength 12.6cm) and the long code delay-Doppler method. We have mapped the locations of midlatitude radar-bright craters across all longitudes, and in the Mariner-10 imaged hemisphere we find several disagreements between the features that appear freshest in the unpolarized radar images and those that have been classified as most recent in the USGS geologic maps. All USGS c5 craters correspond to bright features in our same-circular polarized radar images; however, several c-1 and c2 craters have radar-bright deposits as well. In our radar maps of the Skinakas Basin region of the Mariner-10 unimaged hemisphere, we find little agreement between the proposed basin rim locations and the radar features. We have mapped the south polar region using new data from April 2004 with a sub-Earth latitude of 4.5S, this being our first chance to view the south pole since the Arecibo telescope upgrade. We confirm the locations of features seen in the pre-upgrade maps and we identify 15 new “ice” features extending to latitudes as low as 73S. All south polar features have circular polarization inversions (average  $c=1.38$ ) that are consistent with volume scattering off cold-trapped volatiles. We also present a preliminary analysis of our August 2004 observations, including new radar images of “Feature C” (the strongest echo feature in the Mariner-10 unimaged hemisphere) and of the north polar region. (This research was funded by the NSF as part of the Research Experiences for Undergraduates program.)

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## **Searching for Past Outbursts of Recurrent Novae**

Peter Robinson, Vassar '06 (interning at Maria Mitchell Observatory, Nantucket)  
*Advisor: Geoff Clayton and Brad Schaefer, Louisiana State University*

Recurrent Novae (RNe) are currently one of the leading candidates for systems that are Type Ia Supernovae (SNe) progenitors. Given the importance of Type Ia SNe as “Standard Candles” for cosmology, it is important to know as much as possible about these systems, especially in order to calculate how the expected lower metallicity affects the peak luminosity in very distant (early Universe) Type Ia SNe. In the summer of 2004, a search for past outbursts of three known RNe, CI Aql, V1017 SGR, and V3890 SGR, was conducted using the digitized plates at the Maria Mitchell Observatory on Nantucket, MA. The plates cover the years 1913-1995. It was hoped that the search would refine the outburst frequency for these systems. No eruptions were discovered, but the rich coverage of the plates significantly reduce the likelihood of V1017 Sgr having an outburst between 1958 and 1995. Furthermore, V3890 SGR was observed to have short term variability during quiescence, with the B magnitude randomly varying between 15.4 and fainter than 16.7 (the plate limit). In addition to the RNe outburst search, BS Sgr and V1016 Sgr, classical Novae (CNe) that are RNe candidates were subjected to a search for unknown past outbursts. No such outbursts were found.

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## **Morphologies of Mid-Infrared Galaxies**

Megan Roscioli, Haverford College '05  
*Advisor: Pauline Barmby, Harvard-Smithsonian Center for Astrophysics*

We combine data from the Infrared Array Camera on the Spitzer Space Telescope, WFPC2 on the Hubble Space Telescope, and the DEEP redshift surveys to examine the morphologies of infrared-bright galaxies in the Groth Strip. Our sample includes 778 galaxies with redshifts up to  $z \sim 1.7$ . We examine the IRAC colors as a function of redshift for different morphological types, parameterized by the optical bulge/disk ratio. While the general agreement with galaxy template predictions is good, the IRAC colors are not precise enough to serve as primary indicators of morphological type for galaxies at high redshifts. A few galaxies with high bulge fractions have surprisingly red IR colors but appear to be a heterogeneous group. We compute bolometric IR luminosities and examine the properties of the LIRGs ( $L(\text{IR}) > 10^{10} L(\text{solar})$ ), which we find are not restricted to any redshift or bulge fraction.

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## **Stellar Evolution and Hydrodynamics of Low-Mass Population II Stars**

Matt Rosenfeld, Vassar College '07  
*Advisor: James Lombardi, Vassar College*

In our ongoing quest to form a comprehensive model of a star cluster that incorporates stellar dynamics, evolution, and hydrodynamics, we have made significant progress in the areas of stellar evolution and hydrodynamics. We utilized two codes: TYCHO for stellar evolution and Smooth Particle Hydrodynamics (SPH) for stellar collisions. TYCHO was originally developed by David Arnett from the University of Arizona to model aging stars. The code has since evolved into a more comprehensive, open source, general stellar evolution code. Our SPH code was originally developed by Fred Rasio, and has undergone major changes since then to include radiation pressure and more accurate numerical techniques. We used TYCHO to generate models of so-called population II stars, that is, stars that formed during the early stages of the universe and are now found in globular clusters. We have also developed a web-interface for TYCHO to facilitate collaborations and allow for more general use (<http://urania.vassar.edu/cgi-bin/astro/tycho/tycho.pl>). Using the TYCHO code, we evolved a 0.6 solar mass population II star and a 0.8 solar mass population II star. We monitored the time these stars spent on the main sequence by observing the helium abundance in the core, and compared the chemical composition profiles with those from similar calculations in the literature. Then, using the SPH code, we relaxed and collided these two stars without magnetic fields. Once magnetic fields are added to the SPH code (Lombardi and Bi, in preparation), we will be able to examine how magnetic fields affect the rotation of collision products.

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## **Make It, Then Break It: The Story of Stellar Evolution and Stellar Collisions**

Matt Rosenfeld, Vassar College '07  
Zach Proulx, Vassar College '07  
*Advisor: James Lombardi, Vassar College*

We enhanced our three-dimensional Smoothed Particle Hydrodynamics (SPH) and Tycho stellar evolution codes. This summer we considered both red giant and low-mass population II stars. We worked with our Tycho stellar evolution code (originally developed by David Arnett at the University of Arizona) to model low-mass population II stars for collisions in our SPH code. We also enhanced our SPH code to model and simulate collisions involving red giant stars.

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## **Search for Radio Pulsations from PSR J0537-6910**

Gabe Roxby, Wesleyan University '06  
*Advisor: Fronefield Crawford III, Haverford College*

The X-ray pulsar PSR J0537-6910 is an exciting pulsar to study, owing to its very fast spin period (16 ms), its tendency to undergo occasional glitches in its otherwise regular spin behavior, its young age (~5 kyr), and its location in the Large Magellanic Cloud. Soon after its discovery in X-rays, data were taken to determine if PSR J0537-6910 was also visible as a radio pulsar. No radio pulsations were detected in that search. We report on a more recent radio search for pulsations in a new observation with increased sensitivity. No radio pulsations were detected in this second search, and we report a 1400 MHz radio luminosity upper limit from the search of 50 mJy kpc<sup>2</sup>. This limit is below the luminosity of several young pulsars, but since the majority of pulsars less than 10 kyr old have 1400 MHz luminosities below this, no strict conclusions can be made regarding whether PSR J0537-6910 is in fact a radio emitter.

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## **Protogalaxies: Analysis of High Redshift Galaxies in the Hubble Ultra Deep Field**

Douglas Rubin, Wesleyan University '06  
Meredith Schaffer, Vassar College '07  
*Advisor: Debra Elmegreen, Vassar College*

Using the Hubble Ultra Deep Field survey images, we study the morphological properties of 357 galaxies (59 spirals, 112 doubles, 108 chains, and 78 clump clusters) in a redshift range of  $z \sim 1-4$ . We determine the galaxies' magnitudes, surface brightnesses, colors, sizes and masses of their star forming regions. The results are compared to previous studies and theoretical models, from which we extrapolate the eventual maturation of our galaxies into present-day spirals.

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## **A Multi-Faceted Approach to Identifying Young Stars**

Katie Schlesinger, Swarthmore College '05  
*advisor: Eric Jensen, Swarthmore College*

As planets and stars are hypothesized to develop concurrently, we search for inchoate planetary systems in the regions about young stars. We developed a system for identifying these young stars, known as T Tauris, combining spectral analysis, x-ray luminosity, and location upon a Hertzsprung-Russell diagram. We use high lithium abundance as a signifier of youth, as lithium is destroyed through convective processes. This approximate age is cross correlated with the stars' locations upon a Hertzsprung-Russell diagram. Lastly, we combine this information with 2MASS and ROSAT x-ray data to further confirm that these stars are of T Tauri age. Our system to evaluate stellar age will prove useful in the future, as it provides a clear method to finding good locations for further planetary research. We present our multifaceted methodology for identifying young stars and the theory behind it.

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## **Dark Slope Streaks on Mars: Formation, Changes, and Fading**

Supreet K. Sidhu, Swarthmore College '05  
*advisors: Cynthia B. Phillips and Christopher F. Chyba, The SETI Institute*

Dark slope streaks are among the youngest and most dynamic features on the surface of Mars today. Satellite images show new streaks appearing in as little as three months, while older streaks slowly fade away. Two major classes of models have been proposed to explain how streaks form: dry models that do not require the presence of liquid water and wet models that do. We have piloted an image ratioing technique that will allow us to systematically detect and describe changes in streaks over time, perhaps yielding clues to discriminate between the wet and dry models. If slope streaks do indicate liquid water, they will have major significance in the search for life on Mars and may be important targets for future NASA missions.

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## **Motions of Water Masers toward Class I Protostar YLW16A**

Christine M. Simpson, Wellesley College '05  
*Advisor: M. J. Claussen, NRAO*

We present three epochs of phase referenced VLBA observations of water masers toward Class I protostar YLW16A, which is located in the  $\rho$  Ophiuchus cloud. We determine absolute positions of the strongest maser and show that the absolute motion is due to the parallax, global motion of the cloud, and the proper motion of the maser itself. Assuming the  $\rho$  Ophiuchus cloud is 150 pc distant, and estimating the global motion of the cloud via Hipparcos stellar proper motions, we estimate the proper motion of the strong maser reference feature to be  $6.2 \pm 3.5$  km s<sup>-1</sup>. Combined with the radial velocity of this feature, we find the space motion to be  $14.8 \pm 3.5$  km s<sup>-1</sup> and the angle of inclination to the plane of the sky to be  $65^\circ \pm 12^\circ$ . We also track the motion of a weaker maser between epochs. Our research was funded by the National Radio Astronomy Observatory, which is a facility of the National Science Foundation.

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## **Quasar Host Galaxies at High Redshift**

Rebecca A. Stoll, Wellesley College '06  
*Advisor: Kim McLeod, Wellesley College*

Understanding how quasars evolve with the galaxies that house them has important ramifications for our understanding of galaxy formation. Host galaxies have previously been isolated and characterized for nearby quasars. In this work, we extend the search to quasars at  $z=4$  using data collected in January 2004 on the Magellan I 6.5m telescope at the Las Campanas Observatory in Chile. We analyzed 3654 near-infrared images representing 16.5hrs of exposure time taken over four nights on six different quasars. The data for each quasar were processed to correct for nonlinear detector response, pixel-to-pixel variations, and optical distortions, and combined to make one final image for each quasar. By using field stars as models of a point of light observed through out atmosphere by our telescope and detector, we were able to remove the bright central source to reveal...in most cases, nothing. For two of the objects, however, residuals after subtraction suggest the presence of hosts. Preliminary analysis suggests these hosts are more luminous than an average galaxy today. Our results are marginally consistent with the model in which large galaxies form through mergers of smaller galaxies.

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## **High-resolution X-ray Spectroscopy of the Accreting Weak-line T Tauri Star DoAr 21**

Victoria Swisher, Swarthmore College '06  
*advisors: David Cohen and Eric Jensen, Swarthmore College*

The mechanisms producing X-rays for stellar objects are still unknown, despite knowledge that young stars have more X-rays and that a disk around the star can contribute to total X-ray emission. How these processes affect X-ray emission is a problem that astrophysicists are currently trying to unravel. We obtained a 94 ks observation using the HETG and METG from the Chandra X-ray telescope of the K0 pre-main-sequence star DoAr 21. We fitted Gaussian models to our data enabled us to determine that the emission lines were not broad, indicating that the X-rays we detected came from the star itself and not its accretion disk. These Gaussian models also yielded amplitudes of emission lines, which were further used in density diagnostics that gave mid-range density values with high error bars. Two-temperature thermal models were used to ascertain the temperatures of the X-ray emitting plasma, which were 17 MK and 64 MK. DoAr 21 also experienced a flare during our observation that caused its brightness to increase by a factor of three. We determined that the temperature increased by a factor of two during the flare by applying the two-temperature model used for the entire observation to the quiescent and flare spectra.

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## **Combining Weak Lensing Using Polarization Alignment Breaking with a Multiply Imaged Quasar**

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A gravitational lens bends the light from a source, distorting the morphology. Further, if the lens is sufficiently strong, this distortion can produce multiple images of the original source. With multiple images that have a known time delay, one can calculate Hubble's constant. However, there is some difficulty in doing so because one needs to accurately describe the mass distribution of the lens system. One such source is 0957+561, a gravitationally lensed quasar, with two resolvable images, one of which has an extended, polarized jet. Unlike the morphology, the intrinsic polarization of the jet is unchanged by gravitational lensing. We can therefore predict the deviation of the polarization from the observed morphology of the jet due to weak lensing. Combining this with the amount of mass that must be interior to the two images, which we calculate using strong lensing, we can discover if any mass profiles provide a better fit to the data, and therefore constrain the large scale mass distribution. This technique of using both strong and weak lensing can be applied to any source with multiple images and a jet with adequate polarization. We present the theory of this technique and data from 0957+561.

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## **Looking into the Past: Extending the Known Variability of the Quasars 3C 273 and 3C 279**

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We continue an ongoing program of acquiring optical observations of several quasars at the Colgate University Foggy Bottom Observatory, including 3C 273 and 3C 279, while introducing archival data from Mt. Lemmon Observatory from the mid- to late-1980s to extend our temporal coverage. Upon conclusion, this process will result in the compilation of twenty years of optical observations for a half dozen quasars, constituting the most complete twenty-year light curves ever for these objects. Preliminary reductions of this summer's images and of the Mt. Lemmon Observatory data set reveal activity previously unknown from 1985-1988 for 3C 273 and trends of activity at least a year earlier than previously believed for 3C 279. Preliminary results for these two quasars are encouraging for the reduction of other quasars in the program, serving as an example of how useful creating these complete twenty-year histories can be toward finding patterns in quasar activity.

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