2008 SAO Summer Intern Project Abstracts

Using Ultraviolet Spectroscopic Data to Test Solar Coronal Models

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Solar coronal and solar wind models are becoming more sophisticated as they are developed with realistic physics that describe the heating and acceleration processes in the corona. In the past these models have been tested by comparing their outputs with solar wind data (densities, temperatures, and outflow velocities) measured at 1 AU. In this paper we use spectroscopic data from the SOHO Ultraviolet Coronagraph Spectrometer (UVCS) to compare with the outputs of a specific solar coronal model. The model selected was the Solar Corona component from the Michigan SpaceWeather Modeling Framework (SWMF). Specifically we use the observed $1/e$ profile line widths of HI Lyα to compare with the plasma temperatures predicted by the model. The comparisons are made in the corona at heights between $1.5R_{\odot}$ and $3.5R_{\odot}$ during the solar minimum of Cycle 23. We find that there are areas where the model can be improved, especially in the coronal hole regions over the poles of the Sun. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

Quantifying Dark Matter Substructure via Gravitational Lensing

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We construct a method for placing upper and lower bounds on the mass of substructure in a gravitationally lensed quasar system exhibiting anomalous image fluxes. The source of the flux anomaly is considered to be a mass clump within the shear and convergence field of a singular isothermal ellipsoid lens galaxy. The clump is modeled as a singular isothermal ellipsoid and the quasar source as an ellipse orientable with respect to the ellipticity orientation of the perturbing clump. We find the minimum substructure mass needed to adjust the flux anomaly and the maximum substructure mass which can adjust the flux anomaly without perturbing the image positions, fluxes, and time delay ratios of the entire lensing system. We apply the model to the system B1422+231 and find that the effects of an elliptical source and perturbing clump are to decrease the mass lower bound found previously for the circular case. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

Optical Spectroscopy of the recurrent nova RS Ophiuchi: outburst and quiescence

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The recurrent nova RS Ophiuchi was well studied at all wavelengths after the 2006 outburst; we present an investigation of the evolution of the nebula in RS Oph from the quiescent period before the 2006 outburst through the current quiescent period. We use optical spectroscopy of the nebula and measure equivalent widths and fluxes of the emission lines of the H Balmer series, HeIλ5875, 6875, 4471, 7281, 7065, HeIIλ4686, O and Fe lines. The detailed time coverage of this data allows us to study the evolution of the nebula on long time-scales, before and after outburst. We find that the temperature and emitting volume of the nebula increase after the outburst, as expected, and by JD2454200 (April 9, 2007) RS Oph resumes quiescence values for EW of all the emission lines measured. From comparing the light curve for Hα to models created by Hachisu et al. (2007) we suggest that the emission of this line comes from both the nebula and an accretion disk. We use the flux ratio of Hα to Hβ to constrain the density of the nebula to 10^{6-7} cm^{-3} . We also compare theoretical predictions of the white dwarf and nebula temperature evolution with our measurements and find good agreements. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

Properties and Evolution of Young Stellar Clusters in Orion

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Giant molecular clouds (GMCs) provide an excellent environment for studying star formation, one of the most fundamental evolutionary paths in astronomy. The Orion Giant Molecular Cloud complex as our nearest GMC has consequently become a region of interest in the field. Recent sky surveys in the infrared have provided more photometry than previously available for the region, opening the door to more exploration of and precise science with the cloud. In this report we focus on a region in the south of the Orion GMC, Lynds 1641 (L1641). Data from the Two Micron All Sky Survey (2MASS) and the Spitzer Space telecope are used to classify 802 stars in this region and place them in HR diagrams by region and young stellar object (YSO) class. Using models for stellar evolution to estimate age and mass, we take a look at trends present between YSO class and age, age and location in L1641, as well as accretion properties of these young stellar objects. We find that YSO class follows a clear age sequence as previously observed. We estimate the age of the southern region of L1641 as the oldest, and the age of the northern region as the youngest, though there is some contamination from an older group of foreground stars. We also supply evidence that accretion becomes weaker with age. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

X-ray Abundance and Temperature Structure of Nearby Ellipticals: First Results from a Complete Sample Observed by Chandra and XMM-Newton

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We present initial results from a representative, statistically complete sample of 26 nearby ellipticals observed with XMM-Newton and Chandra. We examine the gas properties of these systems, focusing on global metal abundances and the temperature and abundance structure of the gas. By limiting the sample to moderate luminosity, non-group or cluster dominant ellipticals, we hoped to avoid biasing our results. Data were gathered from various sources, including our own analysis and the literature. For a subset of the sample, we present radial spectral profiles. Temperature and abundance profiles of well studied systems were investigated to determine how features of the profiles corresponded to the structural and environmental aspects of the systems. This understanding was then applied to poorly known systems to draw conclusions about their properties. In the temperature profiles, we find correlations between central rises and recent AGN activity and between outer rises and surrounding hot ambient gas. In the abundance profiles, which are less well understood, we find that a central dip in the profile seems to correspond with evidence of AGN outbursts. Comparing global abundances to optical and luminosity properties, we find no correlation between these properties even for our gas poor systems. On the other hand, we also found excellent correlation between X-ray and optical abundances. These results imply that the abundances of our galaxies are primarily supplied by internal sources and very little dilution or stripping of the abundance has occurred in our systems. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

PRELIMINARY MODELING OF ORION SOURCE I: ACCRETION AND OUTFLOW WITHIN $10-1000$ AU OF A FORMING HIGH-MASS STAR

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Radio Source I in the Orion BN/KL region is the nearest example of a high-mass young stellar object (YSO), and one of only a few star-forming sources known to power both H_2O and SiO masers. The masers enable mapping of the structure and dynamical evolution of material within $10-1000$ AU of a high-mass YSO in unprecedented detail (~ 0.1 AU resolution), and provide strong evidence for a compact disk and outflow. In this poster, we present examples of the dataset that we have used to inform preliminary geometric and dynamical models of Source I. We show a comparison of simple models aimed at establishing the YSO geometry, that include treatments of maser (un)saturation, and varying density and velocity fields. Finally, we discuss the implications of our results for high-mass star formation in general.

Shock Speed, Cosmic Ray Pressure, and Gas Temperature in the Cygnus Loop

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Upper limits on the shock speeds can be combined with post-shock temperatures to obtain upper limits on the ratio of cosmic ray to gas pressure (P_{CR}/P_G) behind the shocks. We constrain shock speed limits from proper motions and distance estimates, and we derive temperatures from X-ray spectra. The Palomar Observatory Sky Survey (POSS) observed faint Hα emission stretching around the Cygnus Loop supernova remnant over epochs separated by 39.1 years. We measured proper motions of 18 non-radiative filaments and derived shock velocity limits based on a limit to the Cygnus Loop distance of 576 ± 61 pc given by Blair et al. for a background star. The PSPC instrument on-board *ROSAT* observed the X-ray emission of the post-shock gas along the perimeter of the Cygnus Loop, and we measure post-shock electron temperatures from spectral fits. Proper motions range from 2".7 to 5".4 over the POSS epochs and post-shock temperatures range from $kT \sim 100-200$ eV. Our preliminary analysis suggests a cosmic ray to post-shock gas pressure consistent with zero, and in some positions P_{CR} is formally smaller than zero. We conclude that the distance to the Cygnus Loop is close to the upper limit given by the distance to the background star and that either the electron temperatures are lower than those measured from *ROSAT* PSPC X-ray spectral fits or an additional heat input for the electrons, possibly due to thermal conduction, is required. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

A Fluid Model of the Centaurus A Jet

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Using Chandra ACIS-I exposures, we have constrained the pressure of the jet in Centaurus A over distances of $125-3900$ kpc ($7-220$ arcsec) from the nucleus. A fluid model of the jet was used to study its velocity, momentum flux, and mass flow rate. Observed jet properties are found to be inconsistent with purely adiabatic flow, so we have included mass injection and the associated dissipation in our models. Allowing the entrainment of stellar mass loss alone, if the power of the jet is constant, we are able to make consistent models for this overconstrained flow. Simulations with the model favor initial jet speeds in the first 100 pc (5.6 arcsec) from the nucleus at approximately $0.75c$ and mass densities ($10^{-4}-10^{-3}$) times lower than the external densities. The stellar matter injection dominates the mass of the jet, roughly tripling the mass flux of the jet by approximately 3600 pc (200 arcsec) from the nucleus. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

Binarity in the Pleiades Cluster, a Progress Report

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In an effort to understand the orbital eccentricity versus period relation and other properties of binary stars in the Pleiades cluster, we are carrying out a spectroscopic survey in the cluster with the facilities at the Harvard-Smithsonian Center for Astrophysics. An additional goal is to provide targets for astrometric observation by SIM, in the context of a Key Project to determine the mass-luminosity relation in the cluster. Over the past 25 years we have collected more than 2500 echelle spectra of 262 objects in the Pleiades area. For each star we have determined the effective temperature and projected rotational velocity using cross-correlation techniques. Our radial velocities have allowed us to obtain orbital solutions for 19 spectroscopic binaries so far, of which 6 are new. We have also detected the secondary components of several previously known single-lined binaries, converting them into double-lined. Altogether we have 25 binaries with orbits that are confirmed members of the cluster. These have been used to establish the tidal circularization period, and to compare with the predictions of tidal theory. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

Spectral Classification and Analysis of Serendipitously Detected X-ray Sources and Their Optical Counterparts

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The Chandra Multiwavelength Project (ChaMP) has constructed a database of $\sim$ 6800 X-ray sources serendipitously detected by Chandra imaging and matched to optical counterparts with high confidence. We present new optical spectral classifications for 147 X-ray bright ($f_X \sim 10^{-14}$ - 10^{-12} ergs s^{-1}) ChaMP sources based primarily on observations with the FAST Spectrograph on the Tillinghast 60" Telescope at Mt. Hopkins. 45 of these sources are identified as M stars with Hα emission and are combined with existing stellar spectra in the ChaMP database, creating a final sample size of 121 emitting M stars, to analyze the correlation between $L_{H\alpha}/L_{bol}$ and L_X/L_{bol}. Analysis by Covey et al. (2008) of $\sim$ 40 M stars in a similar sample found evidence for a turnover in the $L_{H\alpha}/L_{bol}$ vs. L_X/L_{bol} relationship near $L_X/L_{bol} \sim 3 \times 10^{-4}$. Our expanded sample nearly triples the size of the sample analyzed by Covey et al. (2008) and shows no evidence of a turnover in the $L_{H\alpha}/L_{bol}$ vs. L_X/L_{bol} relationship. However, our analysis does corroborate the existence of a plateau at $L_{H\alpha}/L_{bol} \sim 10^{-3}$ and suggests a sample bias towards flaring stars. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.