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This description covers the Department's activities from October 1, 2001, through September 30, 2002. It is condensed from a longer version at www.astro.wisc.edu that also lists published papers and invited reviews.

The Department continued its activities in the 11-m Southern African Large Telescope (SALT) project. UW is responsible for the design and construction of the Prime Focus Imaging Spectrograph (Nordsieck, PI), one of the major instruments. Churchwell was PI of the Space Infrared Telescope Facility (SIRTF) Legacy Science Project called GLIMPSE (Galactic Legacy Infrared Mid-Plane Survey Extraordinaire) to produce a near-infrared imaging survey of the inner Galactic plane. Other major thrusts include studies of star formation, extragalactic structure and evolution, and properties of highly ionized interstellar and intergalactic gas using far-ultraviolet spectra of QSOs and AGNs.

WIYN refers to the Wisconsin-Indiana-Yale-NOAO 3.5-m telescope on Kitt Peak.

1. PERSONNEL

The Department was saddened by the death of Emeritus Professor Albert E. Whitford (1905 – March 28, 2002), Chair of the Department from 1948 to 1958 and later Director of Lick Observatory.

Faculty are Professors Cassinelli, Churchwell, Gallagher, Hoessel, Mathieu, Nordsieck, Reynolds, Savage, and Sparke (Chair), Associate Professors Bershady and Wilcots, and Assistant Professors Barger and Lazarian. Percival is Scientist; Harris and Wakker, Associate Scientists; Burgh, Cho, Haffner, Ignace, and Indebetouw, Assistant Scientists. K. Stassun is a Hubble Postdoctoral Fellow and K. Johnson an NSF Postdoctoral Fellow. M. Orio is Visiting Associate Scientist. Helen Bryce and R. Safako joined the staff as Research Associate. Marc Verheijen accepted a postdoctoral position in Potsdam, Germany. Henry ''Chip'' Kobulnicky accepted a faculty position at the University of Wyoming. Philipp Richter is at the Arcetri Observatory in Florence. Dr. Sydney Barnes left to join the staff at Yale.

2. STARS, OUTFLOWS, AND GALACTIC STRUCTURE

Anderson, with Glinski (Tennessee Tech) found that red features in the nebulosity around HD44179 (the ''Red Rectangle'') are not likely to be associated with the Diffuse Interstellar Bands.

Cassinelli, Miller, and colleagues developed a ''Magnetically Torqued Disk'' model for Be star disks in which magnetic fields embedded within the star both add angular momentum to the outflow and direct it to the equator. Moeckel, Cho, and Cassinelli analyzed X-rays from bowshocks in stellar winds containing infalling clumps. Mendygral and Cassinelli used stellar atmosphere models to compute the uppermost luminosity for cool stars in the HR diagram. They found the boundary of the Eddington Limit (where the radiation pressure equals the inward force of gravity on the atmosphere) is well above the Humphreys Davidson empirical, observational limit.

Gallagher, Orio and Harbeck (MPI-A, Munich) observed the outburst of the peculiar variable V838 Mon. The structure of the nebula is consistent with a time-delayed reflection of the brightening of the central star. Using WFPC2, Halverson, Gallagher, and colleagues studied the moving wisps around the Crab pulsar.

Hoffman, with Nordsieck and Whitney (Sp. Sci. Inst.), modeled the polarization of binary star-disk systems, with application to the interacting binary β Lyr. Hoffman and Nordsieck continued their study of pre-main-sequence (PMS) binaries and suggest that that young binary systems do not show repeatable polarization behavior. More concerted efforts to observe complete cycles with more accurate polarimetric measurements are needed. Hoffman and Whitney are currently modeling the polarization of the luminous blue variable eta Car.

As part of the WIYN Open Cluster Study (WOCS), Barnes, Hole, Meibom, and Mathieu are acquiring high-precision stellar radial velocities in NGC 188, NGC 2264, and NGC 6819 with the WIYN telescope. Using high-resolution near-infrared spectroscopy (CO fundamental and overtone transitions) from the Keck Observatory, Mathieu and colleagues explored the circumstellar gas in both young binaries and single stars. Meibom, with Mathieu, is studying tidal interactions in close binaries. Stassun and Mathieu continued an observing program to discover and analyze new low-mass PMS eclipsing binary (EB) systems in order to test and calibrate PMS stellar evolutionary models. Stassun and colleagues are analyzing archival Chandra data to characterize the relationship between X-ray emission and stellar rotation among PMS stars in Orion.

3. THE INTERSTELLAR MEDIUM

Churchwell, with Watson, Sewilo and others, surveyed UltraCompact (UC) HII regions located in the inner Galaxy in order to resolve the ambiguity in distances arising from combining radial velocities and models of Galactic rotation. With the Arecibo telescope they observed H110α emission and H_2CO in absorption to establish the possible distances (near and far). They will observe as many UC HII regions in the GLIMPSE survey area as possible. Distances for 65 sources in the region $l = 30–70°$ have been determined. Observing time has been scheduled on the Green Bank Telescope to continue this program to complete the northern survey area $l = 10°$ to 30° and observations in the southern half of the GLIMPSE survey will be proposed. Churchwell and others have also used H I absorption line measurements to resolve distance ambiguities in the northern Galactic plane. Watson (Churchwell, PhD thesis supervisor) obtained CO and HCO^+ images of UC HII regions to determine the physical properties of their outflows, to determine if magnetohydrodynamic (MHD) entrainment is responsible for the

large mass contained in massive protostar bipolar outflows.

Sewilo, Churchwell, and others are studying hypercompact HII regions to determine their nature and evolutionary niche in the formation of massive stars. They are about 10 times smaller and ~100 times more dense than UC HII regions. Watson, Churchwell, and colleagues have used the BIMA array for a high spatial resolution study of CH_3CN in the W75N massive star formation region, both to isolate the source of the molecular emission and to determine physical properties of an apparently emerging massive protostar.

Fox, Savage, Wakker, Richter, and others are studying highly ionized gas in high velocity clouds (HVCs), especially Complex C. Absorption line profiles from the Far Ultraviolet Spectroscopic Explorer (FUSE) and Space Telescope Imaging Spectrograph (STIS) provide the kinematics of high and low ion absorption in different environments near the Galaxy. Fox, Savage, and others have found evidence for three distinct types of highly ionized gas in the ISM from absorption lines toward HD 116852, a star lying ~1.3 kpc from the Galactic plane in the inner Galaxy.

Gómez (with Cox and Benjamin from Physics) continues modeling the flow of the ISM into a spiral arm with a 3D MHD model. They expect to find observational signatures of non-circular and large scale vertical motions in the Milky Way and other spiral galaxies.

Halverson completed a master's thesis (Gallagher, supervisor) using WFPC2 images of the ''equatorial'' moving wisps around the Crab pulsar.

Lazarian, Cho, and students Yan and Esquivel are studying ISM turbulence from theoretical, numerical, and observational points of view. They have discovered a new regime of MHD turbulence. Cho, Lazarian & Vishniac (JHU) predicted and numerically confirmed that magnetic turbulence exhibits previously unknown properties, including high magnetic reconnection rates within the CNM (Cold Neutral Medium) that may be an important means of removing magnetic flux from molecular clouds. Cho, Lazarian, & Yan investigated compressible turbulence, finding new scaling relations that significantly change understanding of the dynamics of both cosmic rays and dust. Lazarian and colleagues studied turbulent cascade when the sources of turbulence are localized both in time and space. Lazarian continued to consider Velocity-Channel-Analysis (VCA), proposed earlier with Pogosyan (U Calgary), for extracting the underlying velocity and density statistics from observational data (e.g., H I). Turbulence determines the statistics of the Galactic emission on small scales. Cho & Lazarian provided predictions for synchrotron and dust emission and polarization acting as a foreground contaminant for Cosmic Microwave Background (CMB) studies.

Nordsieck's halfwave polarimeter (HPOL) on the 0.9m telescope at Pine Bluff Observatory is used to observe interacting binaries, Be stars, ISM probes, and other stars. Anderson, Weitenbeck (UW-Baraboo/Sauk County), and undergraduate Halstead make polarimetric observations in the region of NGC1502.

Hausen, Reynolds, and Haffner used the Wisconsin H-Alpha Mapper (WHAM) to measure the [O I] 6300/Hα intensity ratios in H II regions. They found ratios that are significantly lower than those in the fainter, lower density warm ionized medium (WIM). Haffner, Reynolds, and others carried out a comparison of the WHAM Hα survey with the Tenerife 10 and 15 GHz CMB maps. Galactic free-free emission is not the source of the dust-correlated microwave radiation. Emission from spinning dust grains is a possible source.

Savage, Wakker, Sembach (STScI) , Richter, Meade, and other members of the FUSE science team have completed their survey of O VI absorption in and near the Milky Way. Three major papers are now in press with ApJS: (1) the O VI catalog paper, Wakker *et al.* ''The FUSE Survey of O VI Absorption in and Near the Galaxy.'' (2) Savage *et al.*, ''Distribution and Kinematics of O VI in the Galactic Halo.,'' (3) Sembach *et al.*, ''Highly-Ionized High Velocity Gas in the Vicinity of the Galaxy.'' These report on O VI absorption (one of the best tracers of hot gas) toward 100 extragalactic objects and two distant halo stars. There is a widespread but highly irregular distribution of O VI in the thick disk. High velocity O VI absorption is detected along 65% of the lines of sight.

Richter, Wakker, Savage, and Sembach (STScI) used FUSE to study the distribution and properties of diffuse H_2 in intermediate-velocity clouds (IVCs) in the lower Galactic halo. In another study of H_2 in the Milky Way halo, Richter, Sembach & Howk detect a small, dense H_2 clump in the Galactic halo in direction of two LMC stars, most likely related to Tiny Scale Atomic Structures in the Cold Neutral Medium that have been previously found in H I absorption.

Madsen, Haffner, Reynolds, and colleagues used WHAM to search for weak Hα emission from ''compact'' high velocity clouds that may be dispersed throughout the Local Group. The detection of Hα from four of the five clouds indicated a flux of ionizing radiation that is greater than that of the expected metagalactic flux, suggesting that the clouds are likely located within the Milky Way's halo.

Mathis, Whitney, & Wood (U. St. Andrews, Scotland) investigated the effects of hierarchical clumping of dust (clumps within clumps) on analyses of observations of reflection nebulae. The clumping produces serious ambiguities in the determination of the mean grain albedo and phase function from nebular intensities.

4. EXTRAGALACTIC/COSMOLOGY

Barger and colleagues are making a census of the energy-producing galaxies and supermassive black holes in the Universe using observations at X-ray, optical, submillimeter, and radio wavelengths. She is involved in a follow-up study with ground-based telescopes of the Chandra Deep Field South and data for the North, as well as a moderately deep X-ray survey, with some new ground-based data, of the Lockman Hole. She and colleagues used gravitational lensing by clusters to determine the submillimeter properties of extremely red objects (EROs) and very red objects (VROs).

Bershady and others continued multiwavelength surveys of intermediate redshift luminous, compact, blue galaxies (LBGs), striving to determine evolution and internal kinematics. The PhD thesis of D. Andersen (supervisor, Bershady) showed that Hα emission-line echelle spectra can

constrain galactic inclinations down to 10-15°, contrary to standard lore. It is now possible to study the Tully-Fisher relation for many systems in order to analyze their photometric and kinematic structure and to measure the vertical component of velocities, leading to the surface mass-density of the disk. Bershady and colleagues are also involved in a new survey to make direct, kinematic estimates of the masses of galaxy disks and to conduct deep, multi-band optical imaging in order to to explore faint galaxy counts, the effects of large-scale structure on the counts, the reality of breaks in the counts slopes, and the implications of these breaks for the redshift distribution of the faint galaxy population. Hoessel, Bershady, and others are continuing their long-term, deep variability survey pointed at intermediate redshift clusters using WIYN.

Gallagher continued various collaborative studies of measuring chemical abundances in LMC red giant stars, stellar populations in the UMi dwarf spheroidal (dSph) galaxies, observations to detect ionized gas in the UMi and Dra dSphs with the WHAM group, and exploring how the dSphs might be shaped by initial conditions at the time of their formation. Imaging photometry has revealed large numbers of variable stars in the Leo A dIrr, constraining the mean star formation histories of nearby galaxies by their $V-I$ color distributions. A photometric investigation of early-type dwarf galaxies in the center of the Perseus galaxy cluster reveals metallicities and ages, suggesting that many such objects are remnants of larger systems. Other collaborations by Gallagher involve WFPC2 observations of the M83 nucleus, star clusters in NGC 7673, studies of properties of young stellar complexes and the nucleus of the UltraLuminous Infrared Galaxy, NGC 6240, and studies of super star clusters and the base of the M82 super wind. Ground-based telescopes, STIS, and IRTF are involved in these projects. The heating of the Diffuse Ionized Gas in halos of spirals and starburst galaxies and also optical rotation curves are being studied. Gallagher, Sparke, and others are analyzing WFPC2 and NIR images of the polar ring galaxies.

Hoessel, Bershady, and colleagues are continuing their long-term, deep variability survey pointed at intermediate redshift clusters using WIYN and the MiniMosaic CCD imager. Photometric reductions are yielding high-quality color-magnitude diagrams in the rest-frame vacuum UV, as well as photometric redshifts.

Savage, Richter, and colleagues are continuing their studies of O VI absorption line systems seen in the FUSE and STIS spectra of QSOs. Five QSOs have so far been observed in this program. The low redshift number density of O VI systems is very large; these highly ionized absorbers contain as much matter as galaxies at low redshift.

K. Johnson is currently studying the earliest stages of extragalactic star formation, ranging from individual ultracompact HII regions to super star clusters.

5. SALT, WIYN, AND INSTRUMENTS

SALT: Wisconsin leads the effort to build the Prime Focus Imaging Spectrograph, the primary first-light instrument (PFIS; Nordsieck, PI), The optical design has been streamlined and design of much of the mechanical system is underway. The SALT project is nearly on schedule and budget.

WIYN: Anderson completed the construction of an instrument interface, the ''CassIAS,'' for the f/13.6 modified Cassegrain focus that will provide acquisition, guiding and calibration functions for a variety of user instruments.

Star Tracker: In summer 2003, Percival, Jaehnig, Babler, and Harris will fly a low-cost star tracker that provides pitch, yaw, and roll control for sounding rockets, but can also do a full attitude determination.

Wisconsin H-alpha Mapper (WHAM; Reynolds and Haffner, PIs) has received additional funding from the NSF to probe the temperature, ionization state, and ionizing radiation field associated with warm ionized gas within the disk and halo of the Milky Way.

The Spatial Heterodyne Spectrometer was funded by the NSF (Roesler, Physics, PI, with Reynolds, Co-PI) to detect [O II] 3727 emission from warm ionized gas in the Galactic halo, providing information regarding possible variations in the electron temperature.

The Cosmic Origins Spectrograph: (COS: J Green (U. Colorado), PI) will be installed in the HST in 2004. Savage is a Co-I on the COS Science Team. COS is a high efficiency UV spectrograph that will be used for a wide range of studies of faint galactic and extragalactic objects.

6. OUTREACH

The Department was active in public outreach activities including an NSF-supported REU (Research Experiences for Undergraduates) program (Benjamin, Physics, PI), with faculty participation, efforts to recruit and train minorities in astronomy, and an ''Universe in the Park'' program (Wilcots) held throughout Wisconsin state parks.