This description covers the Department’s activities from October 1, 1999, through September 30, 2000. It is condensed from a version at www.astro.wisc.edu that also lists published papers and invited reviews.

During the past year, the Astronomy Department at UW-Madison has been active in a wide range of observational and theoretical research programs. We have joined the 10-m Southern African Large Telescope (SALT) consortium. The telescope is modified from the Hobby-Eberly telescope but will have a larger corrected field of view (8’’) with better image quality, larger pupil, and an enlarged prime-focus instrument payload. First light is expected in 2003.

We are especially pleased that Dr. Amy Barger has accepted a position as Assistant Professor, to begin her duties in August 2001. She is currently the Hubble Fellow/Chandra Fellow at Large at the Institute of Astronomy, University of Hawaii.

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

1. PERSONNEL

The faculty consists of Professors Anderson (Chair), Cassinelli, Churchwell, Gallagher, Hoessel, Mathieu, Nordsieck, Reynolds, Savage, and Spake, Associate Professor Bershady (promoted from Assistant Professor), and Assistant Professors Barger, Lazarian and Wilcots. Percival is Scientist; Harris and Wakker are Associate Scientists. Assistant Scientists are Barnes (McKinney Assistant Scientist), Kobulnicky (Hubble Fellow), and Quigley. M. Orio is Visiting Associate Scientist. Dr. Philipp Richter joined the staff as Assistant Scientist. He will work with Savage on data from the Far Ultraviolet spectrograph (FUSE) satellite relating to gas in the interstellar and intergalactic medium. Dr. Jungyeon Cho arrived to work with Lazarian as Assistant Scientist. Dolan, Haffner, and Stasson are Research Associates.


2. STARS, OUTFLOWS, AND GALACTIC STRUCTURE

Barnes continued his work on the rotation rates of late-type stars. His theoretical work with Sofia (Yale), and Pinsonneault (Yale) suggests that the majority of the stars in young open clusters have undergone disk interactions with a time-scale of the order of 1 Myr in their early stages. He is actively comparing these models with observations of stellar rotation periods in clusters that are a few to several hundred Myr old. He is also investigating the angular momentum distribution and transport in stellar interiors.

Cassinelli and Miller worked on a variety of problems associated with hot stars. The X-ray line emission of Zeta Puppis and δ Ori, observed with the High-Energy Transmission Grating Spectrometer on the Chandra satellite, serve as diagnostics of the temperature and density of the gas. With Waldron (Emergent Information Technologies), Cassinelli carried out a study of the properties of the X-ray sources in Zeta Ori, and (with John Brown, Glasgow) investigated the transfer of angular momentum to the disks around Be stars. Ignace (U. Iowa), Quigley, Babler and Cassinelli are analyzing the profiles of recombination and forbidden lines in the ISO spectra of Wolf Rayet stars to investigate the velocity and ionization structure in the winds of the stars.

Churchwell continued collaborative observational programs to study the properties of galactic massive star formation regions (MSFRs). Projects included a C17O (1-0, 2-1, 3-2) and C18O (2-1) survey towards 16 MSFRs. The gravitational energy of most clumps is about the same as the bulk kinetic energy inferred from line widths. With several collaborators, Churchwell imaged 24 MSFRs at 350 μm in order to detect precursors of Ultracompact H II regions. One third of the submm components had precisely the properties expected prior to the formation of a UC HII region: no detected ionized gas, but having maser emission. Churchwell, Watson, Pankonin (NSF), and Bieging (U. Arizona) are observing CH3CN emission toward MSFRs using the Heinrich Hertz telescope of the Submillimeter Observatory, as well as the Berkeley Illinois Millimeter Array. Sewilo analyzed high dynamic range VLA continuum images of G5.89 obtained over a 10 year period and confirmed its angular expansion rate.

Mathieu and collaborators Barnes, Dolan, and Meibom continued their program acquiring high-precision stellar radial velocities in clusters with the WYIN telescope and Multi-Object Spectrograph. They have orbital solutions for many binaries in NGC 188 and observations in M35, NGC 2264, and NGC 6819. Dolan’s PhD thesis (Mathieu, supervisor) was using optical photometry and multi-object spectroscopy for lithium absorption to identify pre-main sequence stars in the region around λ Ori, and to determine the star formation history in the region. Mathieu and collaborators have determined orbital masses of pre-main-sequence binaries for comparing with theoretical tracks; CO emission also provides information about the geometry and physical conditions in the circumbinary disks.

Hoffman and Nordsieck used the Space Telescope Imaging Spectrograph on the Hubble Space Telescope to search for Doppler signatures of a bipolar outflow in the interacting eclipsing binary star β Lyrae. They seek to confirm their previously-published polarimetric evidence for such an outflow and to investigate its size and composition. With Pol-
3. INTERSTELLAR MEDIUM

Lazarian worked with Pogosyan (CITA) on obtaining the statistics of turbulence from observations, with Vishniac (JHU) on turbulent reconnection, and with De Gouveia Dal Pino (Univ. of Sao Paulo) on the acceleration of ultrahigh energy cosmic rays during reconnection events. With B. Draine (Princeton), Lazarian obtained measures of polarization for dipole radiation from tiny rotating grains (PAHs), important for the Galactic emission in the range of 10-100 GHz.

Nordsieck and Doane are analyzing data from the fourth sounding rocket flight of the Wide-Field Imaging Survey Polarimeter (WISP) which obtained polarimetric images of the Galactic reflection nebulosity near M81 and M82 with a resolution of 1’ through a broadband filter centered at 1750 Å.

The reduction of the Wisconsin H-alpha Mapper (WHAM) survey of the diffuse interstellar Hα for δ > -30° has been completed by Haffner and Reynolds, who have begun a collaboration with Tufft (Lewis and Clark College) to study optical emission lines from High Velocity Clouds. Haffner, with Jenkins, Tripp (Princeton), Roesler (UW-Physics), and Reynolds has begun comparing Space Telescope Imaging Spectrograph (STIS) UV observations of the Si II absorption line with WHAM Hα. Reynolds, Haffner, Madsen, Mathis, and Wood (CfA) have begun to explore absorption and scattering in the diffuse interstellar medium by comparing radiation transfer models with observed Hα and Hβ intensities and line profiles from WHAM.

Savage, with Fabian, Richter, Wakker, Sembach (JHU), Howk (JHU), Tripp (Princeton) and members of the Far Ultraviolet Spectroscopic Explorer (FUSE) scientific team are pursuing a variety of programs of UV-related spectroscopy. These include the galactic ISM absorption lines recorded in QSOs. The spectra are being used to study abundances, physical conditions, and kinematics of neutral, warm ionized and hot ionized gas extending many kiloparsecs away from the Galactic plane, including intermediate- and high-velocity clouds. Wakker continued his investigation into the distances and metallicities of these clouds.

Mathis continues to investigate the ionization properties of the diffuse ionized gas in the Galaxy by means of photo-ionization models as well as interstellar elemental depletions and abundances.

4. EXTRAGALACTIC ASTRONOMY

Bershady has completed a follow-up imaging survey with WIYN of intermediate redshift spiral galaxies with optical rotation-curves obtained at Palomar and Lick (with Haynes and Giovanelli (Cornell), Mihos (Case Western), and Koo (UC Santa Cruz) to study the outlying galaxies in the Tully-Fisher (rotation speed-luminosity) correlation. Bershady, Gallagher, Sparke, and Wilcots (alphabetical) have continued a collaboration to explore the kinematics and evolution of galaxies. One project, with D. Andersen (Penn State), is determining the intrinsic ellipticity of nearby galaxy disks. Bershady, Conselice, Jangren (Penn State), Koo (UCSC), and Guzman (Yale) completed development of quantitative indices of galaxy morphology that include rotational asymmetry, image concentration, size, surface-brightness, and multi-band color. Bershady and Conselice are currently analyzing recent NICMOS observations with the Hubble Deep Field in collaboration with Dickinson (STScI). Hoessel, Bershady, Saha (NOAO), and Majewski (Virginia) have begun a long-term, deep variability survey of intermediate redshift clusters using the WIYN telescope and the MiniMosaic CCD imager.

Gallagher and various colleagues investigated a variety of the properties of galaxies, and clusters. These included studies of the star formation history, abundances, ages, masses, and evolution. Various approaches include color-magnitude diagrams using the WFPC2 camera on the HST, spectroscopy, and deep ground-based photometry. Objects under investigation are Local Group dwarf galaxies, star cluster in M82 and other galaxies, several starburst galaxies, faint Local Group dwarf galaxies, and superthin edge-on galaxies. One project involves the responses of low mass disk galaxies to mild perturbations; sometimes the starburst is quite strong. Another is exploring the evolution of gravitational instabilities in perturbed, gas-rich disks through observations of evolutionary sequences of starbursts with guidance from theoretical models. Conselice, with Gallagher and Wyse (JHU) as supervisors, is pursuing a PhD thesis on populations of dwarf galaxies in clusters of galaxies. The goal is understanding the origins and astrophysical implications of large numbers of dwarf elliptical galaxies in clusters. Otte (working with Gallagher and Reynolds) is obtaining observations with WIYN and the 2.1m telescope on Kitt Peak to test the hypothesis of an additional heating mechanism in the diffuse ionized gas of galaxies. With Wilcots, she is measuring the Hα velocities and line widths in several galaxies.

Kobulnicky completed a 21-cm and optical emission line kinematic study of local spiral and irregular galaxies with Gebhardt (UCSC). With Koo (UCSD), Kobulnicky conducted near infrared spectroscopic observations of two high-redshift galaxies near z = 2.9 using the Keck II telescope. With Woosley and Fryer at UCSC, Kobulnicky is continuing to monitor the radial velocities in Cygnus OB2 association in order to detect companion stars and measure their mass distribution. Kobulnicky and Pisano have described Arecibo 21
cm HI measurements of unusually blue, compact, nearby galaxies. These may be analogs of compact starbursting galaxies observed in the Hubble Deep Field.

Madsen and Reynolds performed a deep search for Hα emission beyond the outer edge of the H I disk of M31. No emission was detected down to a limit of 0.03 Rayleighs, corresponding to an emission measure of 0.08 cm⁻⁶ pc⁻¹.

Savage, Richter, Tripp (Princeton), Jenkins (Princeton), Sembach (JHU), and Howk (JHU) are studying the intergalactic absorption lines found in FUSE and STIS spectra of bright low redshift QSOs. These UV spectra have been supplemented with WIYN observations of the redshifts of galaxies brighter than $B \sim 19$. A major goal is to determine the physical conditions in intervening O VI systems found at low redshift that may harbor a major fraction of the baryons at low redshift. Howk and Savage are using the HST to image edge-on galaxies to search for dusty interstellar clouds in the disk-halo interface of spiral galaxies. This follows a WIYN imaging program that revealed that spiral galaxies like NGC 891 commonly have dust structures, possibly the sites of star formation, extending 0.5 to 1.5 kpc into the halos.

Sparke supervised the PhD thesis of Peter Erwin on a survey of early-type barred galaxies with the WIYN telescope, searching for signs of inner bars and other central structures. These turn out to be surprisingly common. Noordermeer and Sparke investigated the kinematics of a model for lopsided galaxies consisting of a disk lying off-center in a dark halo and orbiting the halo center. They searched for families of stable, closed, non-crossing orbits that the gas should follow. Several models showed strong lopsided gas kinematics. Late-type galaxies, which are dominated by dark matter, show lopsided gas more frequently than early-types. Sparke also worked with colleagues on optical observations and H I mapping of polar ring galaxy system, II Zw 70/71.

5. INSTRUMENTATION AND OBSERVATORIES

5.1 SALT and WIYN Instrumentation

Bershady and Andersen (Penn State; CIC exchange student at UW) concluded primary construction of an NSF-funded funded fiber integral field unit (‘‘6-Pak’’) for WIYN. The cable will be completed and installed on WIYN during the upcoming year. Bershady is developing a throughput enhancement of the WIYN Bench Spectrograph. A second integral field unit cable for the Hobby-Eberly Telescope’s Medium Resolution Spectrograph awaits installation.

Wisconsin will lead the effort to contribute the first major SALT facility-class instrument, the Prime Focus Imaging Spectrograph. Nordsieck (PI) is working on its design. It will specialize in very high throughput with low and medium spectral resolution (R = 500 - 13000), plus spectropolarimetry from 3200 to 9000 Å.

5.2 Other instruments

Several instrumentation advances were developed at the UW. These included the Progressive Image Transmission (Percival) for large images with a remote engineering data system targeted for low-bandwidth connections. Percival, K. Jaehnig, D. Michalski, and S. Gabelt finished the design of the advanced star tracker, the ST5000, that provides pitch, yaw, and roll control for sounding rockets. It can also do a full attitude determination without gyros for both sounding rockets and satellites. The WISP flight of Nordsieck (see §3), its first test, was a complete success. The instrument is being considered as a replacement for the Ball “STRAP” star tracker that has been standard for sounding rockets since the 1970’s. Nordsieck’s halfwave polarimeter (HPOL) observed interacting binaries, Be stars, ISM probes, AG Dra, Ae/Be stars, and LRV stars from both the Pine Bluff Observatory and WIYN. Broadband polarimetric results are listed on the website: www.sal.wisc.edu/HPOL. Nordsieck, Jaehnig, and Harris are continuing development of the Far-Ultraviolet SpectroPolarimeter (FUSP), a sounding rocket payload that will obtain spectropolarimetry from 1050 - 1500 Å, the first below 1300 Å. FUSP will quantitatively constrain the geometry and dynamics of hot stellar systems as well as the strength and geometry of the magnetic field. Harlander (St Cloud State), Roesler (Physics Dept), and Reynolds have continued the development of a Spatial Heterodyne Spectrometer for observations of faint diffuse [O II] 3727 emission from the warm ionized component of the interstellar medium.

The Cosmic Origins Spectrograph (COS) will be installed on the Hubble Space Telescope in 2003. Savage is a Co-Investigator on the COS science team (J. Green, U. Colorado, PI). COS will operate from 1150 to 3200 Å at a spectral resolution of 22,000.

6. TEACHING AND OUTREACH

The “Universe in the Park” program takes place in state parks throughout Wisconsin during the summer and fall camping seasons. It consists of talks and slide shows, question sessions, and providing the general public a chance to view astronomical objects through portable telescopes. During the 2000 season there were 43 sessions in 27 state parks, involving several members of the faculty, staff, and students, both graduate and undergraduate.