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This report covers the period October 1, 1996, to September 30, 1997. A much longer version, available at http://www.astro.wisc.edu or from the Department of Astronomy, contains a list of papers published in refereed journals or invited talks given at conferences, plus a list of papers submitted to refereed journals or in press. WIYN refers to the Wisconsin-Indiana- Yale-NOAO 3.5-m telescope on Kitt Peak.

1. PERSONNEL

Matthew Bershady joined the faculty as Assistant Professor. He was previously Assistant Professor at the Pennsylvania State University. His interests include distant galaxy kinematics, image structure, and luminosity functions, as well as instrumentation. Sparke was promoted to Professor. The other faculty are Professors Anderson, Cassinelli, Churchwell, Gallagher (Chair), Hoessel, Mathieu, Nordsieck, Reynolds, Savage, and Assistant Professor Wilcots. Professor Emeriti in frequent contact with the department are Bless, Code, Mathis, and Whitford. Percival has the rank of Scientist. Stephen Tufte and Mark Quigley joined the staff in postdoctoral research positions. Others on research appointments are Cohen, Percival, Sawyer (at WIYN), von Hippel (at WIYN), and Wakker. Four postdoctoral researchers resigned: Geoff Fox (to teach in England), Joni Johnson (at New Mexico State University), Menshing Han (to GSFC), and Kenneth Wood (to CfA).

Code continued to serve as the WIYN Observatory Scientist and is spending 1997-98 at NOAO in Tucson, AZ. Churchwell is the current chair of the Millimeter Array Advisory Committee advising the Director of NRAO. Gallagher was active in the Gemini 8-m telescopes project. Mathieu served as Chair of the Kitt Peak National Observatory Users Committee. Savage ended his three year position as a Councilor of the AAS and continued as a member of NASA's Origins Subcommittee. Percival continues to participate in the IAU Working Group ''Standards of Fundamental Astronomy.'' Steven Gibson completed the PhD degree and is now at the University of Calgary. Todd Tripp received the PhD and is now at the Department of Astrophysical Sciences in Princeton, NJ.

2. SOLAR SYSTEM

A UW team has studied comets Hale-Bopp, Hyakutake, and Wild 2 with narrow band images, interferometric imaging, spectropolarimetry, UV rocketry, and WIYN spectra. Continua and C I λ1657, H_2O^+, [O I] λ6300, Hβ, Hα, and C I λ9850 were imaged and spectra were obtained with the WIYN Multi-Object Spectrograph. Aurorae on Jupiter were studied in Hα.

3. STARS, OUTFLOWS, AND GALACTIC STRUCTURE

Mathieu and colleagues continued studying young binary systems by means of the HST Fine Guidance Sensor program, high-resolution NIR spectroscopy to explore circumstellar gas, high-resolution WIYN spectra in order to determine rotational velocities, and NIR photometry in order to study variability.

Hot star research has continued to be a major interest within the department. Cassinelli and his colleagues have continued working on magnetic fields in the winds of early type stars. Ignace, Cassinelli and Bjorkman have used the wind compressed zone model for the equatorial outflows from luminous stars. Ignace, Nordsieck and Cassinelli suggested that stellar magnetic fields can be studied by means of the Hanle effect, requiring polarization profiles of resonance lines that mostly lie in the far-UV region of the spectrum. Ignace and Cassinelli are obtaining Infrared Space Observatory (ISO) observations of Wolf Rayet stars in order to derive the velocity distribution from the line widths of IR recombination lines. Cohen, Cassinelli, and others continued their study of the X-ray and unexpectedly high EUV emission of the B stars ϵ and β CMa, as well as the X-ray emission from B stars in general. Conselice and Cassinelli are working on models for the formation of very massive stars. Hoffman, Nordsieck, and collaborators continue to study β Lyrae.

Acord, Walmsley (Arcetri), and Churchwell published an extensive analysis of several molecular line profiles toward the extraordinary outflow source G5.89, one of the most massive and energetic outflows yet detected. Shepherd, Churchwell, and Willner completed a high resolution study of the ON2-N massive star formation region. Churchwell pointed out several implications of large masses observed in outflows.

Research on stellar clusters has been active, including the WIYN Open Cluster Study, a detailed kinematic, astrometric, photometric, and abundance survey of a dozen open clusters over the next ten years. Anderson continued his monitoring of the Ca II H & K chromospheric emission in young clusters with WIYN. An unexpectedly low number of stars in NGC 2264 show significant activity. Dolan and Mathieu continued their program acquiring high-precision stellar radial velocities in clusters with the WIYN telescope and Multi-Object Spectrograph. Dolan's thesis will be a study of the λ,Orionis OB association, investigating the history of star formation and the initial mass function throughout the region. Mathieu and colleagues are studying 3 stars which lie 0.7 mag below the subgiant branch in the M67 color-magnitude diagram. von Hippel, with various colleagues, used HST observations to find white dwarfs in open clusters in order to intercompare white dwarf cooling ages with main sequence evolutionary ages. With others, he continues to classify stellar spectra automatically. Whitford has been in-

vestigating the structure of the inner disk of the Galaxy as shown by the distribution of OH/IR stars found in the Leiden-based survey of the equatorial belt.

4. INTERSTELLAR MEDIUM

Churchwell, and colleagues determined O/H, N/H, and S/H as a function of radial position in the galaxy, finding that all three elements decrease linearly with galactocentric radius with about the same gradient. There is little evidence for secondary production of N.

Faison, Churchwell, Hofner, and colleagues have recently completed an analysis of the mid-infrared (3 – 14 μm) spectra of ultracompact HII regions. Polycyclic Aromatic Hydrocarbon emissions and the 9.7 μm silicate feature were observed in many nebulae. Hofner and Churchwell detected hard X-ray emission from the W3 core. Faison is using the VLA and VLBA to map HI in absorption in front of 3C138 and other bright extragalactic compact radio sources.

Gibson and Nordsieck conducted a multiwavelength investigation of reflection nebulosity around the Pleiades cluster. Scattered light photometry was obtained at 2200 Å with the Wide-field Imaging Survey Polarimeter rocket flight and in the B filter with a Burrell Schmidt mosaic. A forward-scattering geometry is implied, and the grains are more forward-throwing at 2200 than 4400 Å. The HI 21cm line emission shows that the nebula is the result of an interstellar collision, with the smallest HI structure yet observed (0.04 pc).

Savage, Wakker, and colleagues have determined the metallicity and dust content of the high velocity cloud (HVC) towards NGC 3783. They conclude that this cloud has originated from the Magellanic Clouds. Savage and associates are studying highly ionized gas in Galactic HVCs toward bright extragalactic sources in order to determine ionization conditions. Maciejewski, D. Cox (Physics), and Shelton (GSFC) are investigating the W44 supernova remnant, which appears to evolve in a density gradient in a dense medium. Conduction and density gradients are both important for the structure. Mathis, with Torres-Peimbert and Peimbert (UNAM), investigated the effects of strong fluctuations in both temperature and density within planetary nebulae. Otte and Gallagher, with Scowen and Hester (ASU), studied the motion of the wisps in the Crab Nebula on HST images.

Reynolds, Tufte, Haffner, Quigley, and Hausen have used the Wisconsin Hα Mapper (WHAM), a Fabry-Perot interferometer operating on Kitt Peak, to observe weak [O I] 6300 in three directions in the warm ionized medium (WIM), as well as Hα emission towards high velocity cloud complexes. The group, with Heiles (Berkeley), investigates the Hα structure and kinematics in the Orion - Eridanus Superbubble. WHAM has also mapped the WIM [S II] 6716 and [N II] 6584 over part of the sky.

Wakker and van Woerden (Groningen) studied distances to HVC complexes H, C, and A, placing limits by observing foreground stars without comoving Mg II or Ca II. They bracketed the distance to complex A to place it in the galactic halo. Non-detections of the CO J = 1-0 line in the direction of HVC cores indicate that the observed HVCs are more distant than 2 kpc.

5. EXTRAGALACTIC

Bershady has continued working with students at Penn State University, focusing on constraining the $z > 3$ field galaxy luminosity function and understanding how to select such high redshift galaxies on the basis of color and image structure.

Erwin, Sparke, and Gallagher use WIYN to survey a sample of nearby early-type barred galaxies for double bars, especially secondary nuclear bars.

Gallagher and colleagues are studying Luminous Blue Variables and related objects in M31 and other nearby galaxies. Gallagher and Cole continued an HST program to characterize the properties of aging stellar populations in Magellanic Cloud star clusters and Local Group dwarf ellipticals. L. Mathews (SUNY Stony Brook) and Gallagher are considering extreme late-type spirals. Gallagher, with Hoessel and collaborators, obtained HST WFPC2 images to determine color-magnitude diagrams in nearby dwarf irregular galaxies; with Cole and others, Gallagher is conducting population studies using the WIYN telescope and facilities at the European Southern Observatory. Gallagher and colleagues are studying ''super star clusters'' in active regions in NGC 2903 and in M82. Hensler (Kiel) and Gallagher are combining theoretical and observational perspectives in chemo-dynamical models of galactic evolution. Gallagher and Homeier are using the HST and WIYN to study the star formation properties and history of NGC 7673, a clumpy, blue irregular that appears to be undergoing an interaction or merger.

Cole, Nordsieck, and Wood (CfA) began to model the distribution and optical properties of dust grains in the diffuse ISM of the LMC, using UV imaging polarimetry obtained with the WISP rocket. Conselice and Gallagher are studying small scale substructure in galaxies, especially in the Coma Cluster, and are investigating the core of NGC 6166 for structural irregularities. In collaboration with others, Conselice has worked on extragalactic dust by examining overlapping galactic images.

Howk and Savage have exploited the superb image quality provided by WIYN to examine the complex network of dusty filaments within NGC 891. Savage and colleagues have studied the associated and intervening O VI absorption line systems in the UV spectrum of a bright QSO, setting limits on physical conditions along the line of sight. Savage and Lu (CIT) are studying the Milky Way absorption by Mg II and Fe II toward QSOs in order to determine the sky covering factor of Galactic high velocity Mg II and Fe II absorption. Tripp (Princeton), Lu and Savage have obtained a high S/N GHRS spectrum of a bright quasar in order to study the relationship between galaxies and low column density, low redshift Ly-α clouds. A statistical analysis of the relationship between galaxies and Ly-α lines is underway.

von Hippel and colleagues are using HST photometry to detect intergalactic stars in the Virgo Cluster of galaxies. von Hippel, with a large number of collaborators, is using the KPNO and WIYN telescopes to search for and monitor gamma ray bursters.

Maciejewski and Sparke are investigating gas inflow to the centers of galaxies having small central bars within larger

kpc-scale bars. They were able to find orbits supporting each bar separately. They used a simple approach to study gas flow in a double-bar system. While on sabbatical at Groningen and Mt. Stromlo, Sparke observed polar ring galaxies in neutral hydrogen with the Australia Telescope Compact Array and investigated ionized gas in the rings with optical spectroscopy.

Wakker and colleagues have studied C^{+3} in the LMC. Kinematical differences between low- and high- ionization lines indicate that at least some C^{+3} is in coronal gas, but the distribution is not uniform.

Pisano, Wilcots, and Elmegreen (IBM) completed a WIYN and VLA study of the distribution and kinematics of HI in two late-type barred spiral galaxies, NGC 925 and NGC 1744. Pisano and Wilcots are using WIYN to measure the star formation rate and history. Wilcots and Miller (DTM) completed the first stage in a comprehensive study of the Local Group dwarf irregular, IC 10, using VLA HI maps and WIYN Hα images. Wilcots is continuing a similar study of IC 1613, another local dwarf irregular.

Wilcots, Gallagher, and others discovered a spectacularly complex distribution of gas surrounding NGC 4449, a nearby Magellanic irregular, and are continuing with VLA H I mosaics. Wilcots and Turnbull have detected small HI clouds around two Seyferts, Mrk 3 and NGC 6764. Wilcots and Molvig are mapping the distribution and kinematics of HI in and around NGC 672 and IC 1727, two late-type barred spirals. Wilcots and Baker are using WIYN to investigate the morphology and star formation history of barred Magellanic spirals. In a related study, Wilcots and collaborators are using the VLA and WIYN to investigate the effects of gravitational interactions on the asymmetries of Magellanic spirals and the physical properties of small HII regions in the LMC.

6. WIYN AND INSTRUMENTATION

The University of Wisconsin has a 26% share in the observing time of the 3.5-meter advanced technology telescope WIYN, now in routine operation and producing excellent high resolution optical images and spectral data. Its median point source image size was 0.8″. About 25% of the time it achieves 0.7″ or better and the best images are about 0.4″. This year the DensePak, a fiber optic bundle used for integral field spectroscopy, was commissioned, and the wavefront pipeline was completed. The consortium initiated development of a tip-tilt system correcting up to a 5 arcminute field of view. Percival continued his work on Progressive Image Transmission, with which very large images can be sent over very slow network connections.

Instrumentation efforts involve: **Cosmic Origins Spectrograph**, selected by NASA to be the HST replacement instrument for the 2002 HST orbital refurbishment mission (Savage, Co-I; J. Green (U. Colorado, P.I.) COS is $\sim$ 20 times more efficient than the Space Telescope Imaging Spectrograph and will be used on faint galactic and extragalactic objects. **Far- Ultraviolet Spectrographic Explorer** (FUSE; Savage, Co- I), a 912 – 1200 Å spectroscopy mission, is being prepared for launch in the fall of 1998. The **Hobby Eberly Spectrograph** (Bershady), a fiber integral field unit for the H.E. Telescope's Medium Resolution Spectrograph, will study the kinematics of galaxy disks. The **HPOL** (Half-wave Polarimeter) is used at both WIYN and the Pine Bluff Observatory for observations of comets and stars. Results can be seen at http://www.sal.wisc.edu/HPOL. **IR Fabry-Perot** (Reynolds and colleagues) is a spectrometer with a high throughput that achieves high spectral resolution of the 2 μm Brγ line. **SHS** (Spatial Heterodyne Spectrometer; Reynolds, colleagues from Physics, and others) is an UV Fourier transform spectrometer for observing faint line emissions. **WHAM** (The Wisconsin H-Alpha Mapper, Reynolds, PI) is at KPNO. The Hα sky survey began in January 1997 and should be completed in 1998. **WIYN**: Code, with others from the WIYN consortium including Gallagher, is leading development of a tip-tilt camera. **WISP** (The Wide-field Imaging Survey Polarimeter; Nordsieck, PI) is a suborbital rocket telescope that has obtained polarimetric UV images of comet Hale-Bopp, diffuse scattered light in the LMC, and the Pleiades reflection nebula.

7. OTHER EFFORTS

The department drastically modified its elementary curriculum. Complementing each lecture course is a computer-based lab in which students gain a deeper appreciation for science in a collaborative environment. Students and staff were involved in programs presenting astronomy to the public, discussing college access for high school students, and encouraging middle-school and high-school-aged girls in math and science. Throughout the summer, faculty, research scientists, and graduate students gave presentations in state parks throughout Wisconsin.

Lawler's group (Physics) measures branching ratios, radiative lifetimes and absorption oscillator strengths of astrophysical interest through a variety of experiments.

The extended version of this report lists 83 publications by staff members in refereed journals or from invited talks, and 42 more have been submitted to refereed journals or are in press.

John S. Mathis