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This report covers the period October 1, 1998, to September 30, 1999. It is a very brief summary of a much longer version available at <http://www.astro.wisc.edu> or from the Department of Astronomy, 475 N. Charter St., Madison WI 53706. The long report has detailed information on individual research programs and lists of collaborators in each project. The long version also has a list of 125 papers published, submitted, or in press in refereed journals, including invited conference talks.

1. PERSONNEL

The faculty consists of Professors Anderson (Chair), Cassinelli, Churchwell, Gallagher, Hoessel, Mathieu, Nordsieck, Reynolds, Savage, and Sparke, and Assistant Professors Bershady, Lazarian, and Wilcots. Percival served as Scientist. Emeriti Professors who reside in Madison are Bless, Code (mainly based in Tucson), Mathis, and Whitford. Postdoctoral fellows were Harris, Quigley, Haffner, & Wakker. S. Barnes, from Lowell Observatory, came as the "McKinney Assistant Scientist." H. Koblunicky arrived as a Hubble Fellow from UC-Santa Cruz. Dr. Alex Lazarian joined the staff as Assistant Professor in September, 1999. He is interested in magnetic reconnection in the interstellar medium (ISM), dynamos, dust-grain alignment, statistics of interstellar turbulence, and cosmic rays.

A. Cole completed his Ph.D. thesis on red clump stars as stellar population diagnostics and moved to a postdoctoral position at the Univ. of Massachusetts. M. Haffner received the Ph.D. degree for his work with the Wisconsin H α Mapper (WHAM) project and joined the WHAM team in January in a postdoctoral position. S. Tufté left his postdoctoral position with the WHAM team in July to begin his duties as Asst. Professor in the Department of Physics at Lewis and Clark College in Portland, OR. C. Howk received the Ph.D. degree with a thesis on extraplanar dust in nearby edge-on galaxies. In April, 1999, he joined the research staff of The Johns Hopkins University, pursuing UV studies with the Far Ultraviolet Spectroscopic Explorer project. M. Faison (Beloit College) defended his Ph.D. thesis on small scale (a few AU) structure in the ISM.

Cassinelli was on leave in the fall of 1998 for two months at the High Altitude Observatory of NCAR, and for two months at the Physics and Astronomy Department of the University of Glasgow, Scotland. Churchwell continues to serve as the Chair of the Scientific Advisory Committee for the Atacama Large Millimeter Array (ALMA) project. He has also joined the Visitors Committee for NAIC (Arecibo Observatory) and the Program Advisory Committee of the Director of NRAO. Wilcots served on the ALMA Advisory Committee. Gallagher continued as a member of the International Gemini 8-m Telescopes Project and WIYN Telescope Boards and is involved in MAXAT, studies of extremely

large-aperture ground-based telescopes. Mathieu served on the Astronomy and Astrophysics Survey - UVOIR from Space Panel, on the WIYN Board, and on the WIYN Scientific Advisory Committee (Chair). He is Associate Director, National Institute of Science Education, and is Director of its College Level 1 Institute. Savage continued as a member of the Committee for Astronomy and Astrophysics of the National Research Council and joined the Space Telescope Institute Council of AURA. Savage was a member of the Public Policy and Education Panel of the Astronomy and Astrophysics Decade Survey and of the NASA UV-Optical Space Astronomy Working Group. Percival continued his participation in the IAU Working Group on Astronomical Standard's initiative "Standards of Fundamental Astronomy."

2. STARS, OUTFLOWS, AND GALACTIC STRUCTURE

Anderson continued monitoring the Ca II K line in stars in various galactic clusters in order to find secular variations in their chromospheric activities. Barnes has been working on the structure and evolution of G, K, & M stars by comparing rotating stellar with observations of photometrically determined rotation periods of stars in young open clusters. Cassinelli, with many collaborators, has considered theory and observations of hot stars in several aspects: magnetic buoyancy in the outer radiative zone, dynamos, polarimetric variability, spectropolarimetry, X-ray and extreme ultraviolet emission, and *Infrared Space Observatory* observations. Nordsieck, Cassinelli, and others are exploring using the Hanle effect (polarization arising from scattering of resonance lines in a magnetic field) as a diagnostic for the physical conditions in hot star atmospheres. Stassun and Mathieu, with others, studied disk-regulated rotation among low-mass pre-main-sequence (PMS) stars and have found that stellar rotation periods do not correlate with the presence of near-IR excess-emission signatures of disks. A large fraction of slowly rotating PMS stars lack near-IR excesses, implying that some 40% of all young, low-mass, PMS stars do not have disks capable of regulating stellar rotation. This is a major observational challenge to existing PMS rotational evolution models. Dolan & Mathieu are finding that the PMS stars in the λ Orionis star-forming region fall on a remarkably narrow locus in the H-R diagram with an inferred average age on the order of 1 million years. This age is less than that of the OB stars, suggesting triggered star formation. Remarkably, the ages of the low-mass stars seem independent of the distance from λ Ori, even for stars up to 30 pc away. Many of the stars do not show diagnostics of actively accreting disks.

Hoffman and Nordsieck have observations of the interacting binary star β Lyrae (including future HST work) and have developed capabilities of theoretically modeling radiative transfer in it and in binary systems in general. Investi-

gations of binary stars were also carried on, with others, by Mathieu (circumstellar gas; masses of PMS binaries to test current modeling) and Stassun (modeling circumstellar disks). A goal is to determine the masses of MS stars in order to test current PMS stellar evolution models. Churchwell, with C. Watson and others, continued investigations of massive star formation regions and may have found the long sought precursors to ultracompact H II regions. Churchwell continues work on measuring the angular expansion rates of UC H II regions and is interested in using methyl cyanide as a possible tracer of emerging massive protostars. Churchwell and Code have obtained deep images of massive star formation regions to obtain information on the absorbing natal cloud. As part of the WIYN Open Cluster Study, Dolan, Meibom, and Mathieu continued acquiring high-precision stellar radial velocities with the WIYN telescope and discovering extensive spectroscopic binary populations. Code and others completed an HST study of the central stars in four high excitation planetary nebulae.

3. INTERSTELLAR MATTER

The Wisconsin H-Alpha Mapper (WHAM) $H\alpha$ survey (Reynolds, Haffner, Tufte, Quigley, and colleagues) has been completed, and the data (spectra and maps) will become available in early 2000. Reynolds, Haffner and Tufte surveyed Galactic $H\alpha$, [N II], and [S II] emission using WHAM, including the Perseus Arm plus an interesting line of sight at high latitude. An additional source of heat apparently dominates over photoionization heating in low density plasma. Mathis modeled the diffuse emission and confirmed that result. Radiation transfer models of Wood (CfA) and Reynolds reproduce the overall characteristics of the observed $H\alpha$ background.

Savage, Fabian and others are studying the galactic ISM absorption lines in a Space Telescope Imaging Spectrograph (STIS) spectrum of bright QSOs over the region from 1150 to 1750 Å. They obtain insights about the relationship between the low and high ionization absorption for complete paths through halo gas. They also have used archival HST data to study the gas-phase abundances and physical conditions of the cold and warm neutral gas towards the low-halo star μ Columbae, with interesting results regarding the composition of grains. Savage, Wakker, and the QSO absorption line Key Project team determined the Milky Way absorption toward 83 QSOs. The Milky Way lines provide important examples of the range of absorption properties of a zero redshift (current epoch) galaxy for comparison with absorption seen at higher redshift in QSO metal line systems. The study revealed a systematic difference in H I column densities compared with those from 21 cm emission. High velocity Mg II covers a large fraction of the sky. A UW team has used 21 cm, $H\alpha$, X-ray, IRAS, and IUE observations to study the properties of the Scutum Supershell in order to study the ejection of hot gas into the halo by shells and supershells. Wakker and others continued investigating the distances and metallicities of high- and intermediate velocity clouds. They have shown that Complex C represents infall of low-metallicity gas at a rate that can solve the long-standing G-dwarf problem.

4. EXTRAGALACTIC

Extragalactic research is the largest single focus of the UW astronomy faculty, including Bershadly, Gallagher, Hoessel, Savage, Sparke, and Wilcots, along with their students Cole, Conselice, Erwin, Homeier, Pisano, and many outside collaborators. They have used the WIYN telescope, among others, extensively.

Bershadly is involved in a rotation-curve survey of intermediate redshift spiral galaxies, in developing quantitative indices of galaxy morphology, and analyzing Hubble Deep Field images. Bershadly, Gallagher, Sparke, and Wilcots have a project to determine the kinematics and evolution of galaxies, including the intrinsic ellipticity of nearby galaxy disks.

Gallagher continued to develop quantitative methods for measuring star formation histories of galaxies, mainly with WFPC2 on the HST. His team's study of the LMC suggests an enhancement during the last 2-4 Gyr in the LMC star formation rate and differences in the evolutionary history between the LMC bar and disk. He is investigating stellar population mixes and ages in dense super star clusters, as well as analyzing bright clumps in the starburst galaxy M82 and in the starburst zone of the low mass galaxy NGC 1569. He is collaborating with Mathews (NRAO) in studies of the structure and evolution of low mass spiral-like "extreme late-type" galaxies seen as "superthin" galaxies. He, Conselice, & Homeier are investigating star clusters in the luminous clumps within the starburst galaxy NGC 7673, as well as the emission line properties and the stellar content and structures of nearby UV-bright starbursts. Cole's Ph.D. thesis explored the age and chemical abundances of the red clump stars as a tracer of past star formation. Groups including Gallagher, Hoessel, and others analyzed WFPC2 resolved star photometry in several Local Group dwarf irregular galaxies (especially IC 1613 and the Ursa Minor dwarf spheroidal galaxy). Gallagher and collaborators were involved in determining the stellar content of regions close to ionized gas filaments along the outer edges of the Cen A radio lobe. He is collaborating with groups which are determining the stellar populations in the enigmatic And IV dwarf and measuring abundances of H II regions located beyond the R_{25} optical boundaries of spiral galaxies. Conselice is working on a Ph.D. thesis with Gallagher, with Wyse (JHU) as collaborator, to study small scale stellar objects and features in clusters of galaxies.

Pisano continued his thesis with Wilcots on isolated galaxies to assess the state of continuing galaxy formation in the local universe. They found previously unknown companions around roughly 15% of their sample galaxies and signatures of recent interactions around another 15%. Wilcots, Pisano, and others continued their WIYN observations of a NGC 925, a late-type barred spiral, in order to examine its global star formation and stellar properties. Many signs of large-scale asymmetries have been found in this probably typical galaxy. Wilcots is collaborating on two major studies of the neutral gas content of loose groups of galaxies: surveying the H I content of galaxies in a sample of active, intermediate, and quiescent loose groups and completely mapping the H I distribution in groups of galaxies using the Very Large Ar-

ray. Wilcots and others made the first detection of H I associated with the newly discovered Cas 1 dwarf galaxy in the IC 342 group, and used the VLA to measure the H I content in low surface brightness galaxies in the M81 group.

Sparke and students continued investigating the dynamics of galaxies, especially galactic bars. Erwin has completed his survey of inner bars and other central structures in early-type barred galaxies. These turn out to be surprisingly common; about a quarter of the galaxies have secondary bars and about the same fraction have inner disks. Maciejewski and Sparke investigated stellar orbits in galaxies with small central bars within larger structures. They have shown that a stable flow of gas on a set of closed loops is possible. Noordermeer (now at Utrecht) 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. Sparke and colleagues have collected and analyzed H I data for galaxies from the Nançay radio telescope.

Cole and Nordsieck produced UV polarimetric images for the LMC with the Wide-field Imaging Survey Polarimeter (WISP) and placed important constraints on the scattering properties of the dust. It scatters very efficiently and is very forward-throwing in its phase function.

Savage and others are continuing to study low redshift Ly α absorbers in the UV spectra of QSOs (along with information from WIYN), providing information on Ly α and metal line systems. The occasional detection of O VI metal line systems bears on the possibility that a significant fraction of the baryons at low redshift may exist in a hot phase of the intergalactic matter. Howk (now at JHU) and Savage have continued to use the superb image quality provided by WIYN to study dust and ionized gas in nearby edge-on spiral galaxies, especially NGC 891.

5. INSTRUMENTATION

There is an active program to development instruments for both ground-based and space observations. Bershadsky has continued an NSF-funded funded instrumentation program to build an Integral Field Unit (IFU) for the Hobby Eberly Telescope's Medium Resolution Spectrograph. He is working on a redesign of part of the WIYN Bench Spectrograph. Nordsieck and Harris continued the flight series of the Wide-Field Imaging Survey Polarimeter in a successful fourth flight targeting faint mid-latitude Galactic clouds. A new UV polarimetric imager is being designed. They continue the development of the Far-Ultraviolet SpectroPolarimeter, a sub-orbital rocket payload that will obtain the first spectropola-

rimetry from 1050 to 1500 Å with a resolution of R=1800. Percival & Baranowski developed a remote observing package with Progressive Image Transmission for efficient transmission of large images. Percival and others successfully flew a prototype low-cost star tracker on a sounding rocket.

Savage is a Co-Investigator for the Far-Ultraviolet Spectrographic Explorer operating in the 905 to 1185 Å region at a spectral resolution of 30,000. Savage will study the distribution and kinematics of interstellar hot gas in order to gain insights about its origin(s). He is on the science team of the Cosmic Origins Spectrograph, to operate on the HST from 1150 to 3200 Å at a spectral resolution of 22,000. It will be used for a wide range of spectroscopic studies of faint galactic and extragalactic objects.

6. OTHER ACTIVITIES

Anderson continued his interests in the Jupiter/Io system with observations of the [S II] emission with WIYN. The goal is to determine the mass loading and dynamics of the Jovian plasma torus.

UW gives graduate students a limited amount of queue observing on WIYN for their own research programs conducted independently of faculty. Student projects on star formation and photoevaporation on the face of an interstellar cloud, Wolf-Rayet nebulae, and low surface brightness galaxies were conducted.

Fabian and others used archival GHRS data to confirm the theoretical branching ratio and oscillator strength for the weak Mg II 3s-4p doublet at 1240Å. Laboratory measurements of astrophysical interests were carried out in the Physics Department under Prof. J. Lawler, in an active program to measure atomic parameters for Ni II, Ho I, Ho II, Lu I, Lu II, Dy I, Dy II, Lu I, and Lu II.

M. Orio & H. Ögelman of Physics have a long term X-ray project on classical novae. Orio studied supersoft X-ray sources and galactic black hole candidates in optical wavelengths, discovering a low mass supersoft X-ray system, prototype of a new class of objects. Ögelman and collaborators completed a study of the jet of the Vela pulsar and for the first time detected gamma radiation from the pulsar PSR B1055-52.

There is strong astrophysical activity in other groups of Physics, including the theory of the interstellar medium, X-ray instrumentation, optical instrumentation, neutrino astrophysics, and the physics of turbulence.

John S. Mathis

