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This report covers the period October 1, 1997, to September 30, 1998. A longer version, available at http://www.astro.wisc.edu or from the Department of Astronomy, contains a list of papers published or in press in refereed journals and invited talks given at conferences. WIYN 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 Assistant Professors Bershady and Wilcots. Professor Emeriti in frequent contact with the Department are Bless, Code (now primarily in Tucson), Mathis, and Whitford. Percival has the rank of Scientist. Harris, Quigley, Tufte, and Wakker hold research research positions. David Cohen completed his postdoctoral position and moved to the Bartol Institute at the University of Delaware; he remains a Visiting Scientist. Ted von Hippel resigned his research appointment with us at WIYN to join the Gemini Project in Hawaii. Dr. J. MacFarlane, Prism Computational Sciences, Inc, was appointed as an Honorary Fellow. Jerry Acord received his Ph.D. in Spring 1997 and is in a postdoctoral position at the U. Illinois associated with BIMA. Witold Maciejewski defended his Ph.D. thesis in fall 1998, and holds a postdoctoral position at the Max Planck Institute for Astronomy in Heidelberg.

Code continues as the WIYN Observatory Scientist based at NOAO in Tucson, AZ. Churchwell currently chairs the Millimeter Array Advisory Committee, advising the Director of NRAO on scientific issues. Gallagher is on the international Board of the Gemini 8-m Telescopes Project. Mathieu served as Chair of the Kitt Peak National Observatory Users Committee and WIYN Science Advisory Committee; he, Gallagher, and UW-Madison Provost Wiley are on the WIYN Board. Savage rotated off NASA's Origins Subcommittee, was appointed to the Committee for Astronomy and Astrophysics of the National Research Council, and also joined NASA's UV-Optical Space Astronomy Working Group. Percival continues to participate in the IAU Working Group ''Standards of Fundamental Astronomy.''

2. SOLAR SYSTEM

A UW team including Anderson, Harris, Nordsieck, Scherb, Roesler & Reynolds has studied comets Hyakutake, Hale-Bopp and Wild 2 with narrow band images, interferometric imaging, both ground based optical and rocket borne UV spectropolarimetry, and WIYN Telescope Multi-Object Spectroscopy. The WISP sounding rocket package obtained both images and polarization maps of Hale-Bopp in a UV continuum band and in the λ1657 line of CI. The WIYN MOS was used on Hale-Bopp with the distributed fiber Hydra positioner to sample the one degree scale distribution and with an integral field device known as Densepak to sample spectral variation on the scale of a few arc seconds. The main program of the MOS concentrated on the λλ6100-6400 region at a resolution of 15,000. This region contains emission features of [OI] λ6300, λ6363, H_20^+ and NH2. From these data both atom/molecule production rates and flow velocities have been extracted. Of particular interest is the acceleration of the H_2O^+ as it couples to the Solar wind. Observations were made at both high and low heliocentric latitudes between which there is a factor of ~ 2 difference in the kinetic energy density of the Solar wind. Differences in the confinement and acceleration of the H_2O^+ plasma are obvious and are being subjected to analysis by full 3-D MHD and chemical network computations.

The WIYN Solar system program under the direction of Anderson is now concentrating on the plasma environment of the Jupiter/Io system. Measurements of the mass loading of the Jovian magnetosphere by newly formed ions such as S^+, and the growth and decay of emissions during eclipse ingress/egress events are being studied with the MOS integral field capability.

3. STARS, OUTFLOWS, AND GALACTIC STRUCTURE

Churchwell and coworkers are researching massive star formation and early evolution. Acord, Walmsley, & Churchwell studied the molecular cloud core and the molecular outflow associated with G5.89-0.39 using SiO. Acord, Churchwell, & Wood measured the angular expansion rate of G5.89 to be 4 ± 1 mas from which they inferred $D=2$ kpc. Churchwell noticed that many bipolar molecular outflows contain more mass than the protostar and argued that the outflow consists of deflected accreting matter.

Hofner (NAIC) & Churchwell made the first detection of hard X-ray emission from the massive star formation complex W3, probably from the hot, wind-shocked cavity interior to the UC HII region observed with the VLA. The FeXXV line at 6.7 keV is also seen from this volume. Shepherd (Caltech), Churchwell & coworkers continued high resolution observations of massive outflows from massive star formation regions. The analysis of the ON2-N region has been completed and the study of G192 has been submitted.

Dolan's thesis study with Mathieu of the λ Ori star-forming region has surveyed more >500 pre-main-sequence candidates in a 1-degree field around λ Ori with WIYN for lithium absorption. They find 72 pre-main sequence stars versus 3 T Tauri stars in earlier surveys. These stars have inferred ages of <1 million years, less than that of the OB stars, suggesting triggered star formation. The newly discovered stars do not show diagnostics of actively accreting disks, despite their youth, possibly due to their proximity to massive stars. The survey will be extended to the B35 cloud in the molecular ring around λ Ori and an intermediate region.

Stassun, Mathieu, Mazeh (Tel Aviv) & Vrba (USNO) reported first results from their survey for photometric variability of stars within a roughly 1°×2° region around the Trapezium. Light curves of ~ 5000 stars produced rotation periods for >200 stars. The period distribution is not bimodal, and there are no correlations of disk accretion diagnostics with period. Some stars are rotating very near breakup, their angular momentum evolution during subsequent contraction to the main sequence is particularly interesting. No significant difference is found in the $v \sin i$ distribution of the Trapezium region with that in the Pleiades for similar mass stars, despite an age difference of nearly two orders of magnitude.

Mathieu, Lattanzi (Torino), & Zinnecker (Wurzburg) used HST FGS observations to obtain a relative astrometric orbit of the pre-main-sequence single-lined spectroscopic binary 045251+3016, despite its projected separation of only tens of milliarcseconds. Efforts are underway to derive the absolute orbits and system physical parameters. Mathieu, Carr (NRL) & Najita (CfA) continued a program of high-resolution near-infrared spectroscopy (CO fundamental and overtone transitions) to explore the circumstellar gas in several young binaries.

Erwin & Sparke made a theoretical study of circumstellar disk stability in close binary star systems. The results are applicable to understanding the formation of planetary systems in disks within around binary stars and to the orbits of small bodies in the solar system.

Mathieu, Jensen (Swarthmore) & Fuller (Manchester) began a program of sensitive 800μ observations of pre-main-sequence binaries with separations of 1 AU to 100 AU with the JCMT/SCUBA . Such binaries had not been detected at millimeter wavelengths, suggesting disk clearing or destruction. The sensitivity of SCUBA permits searches for truncated circumstellar disks in these systems, so we can see whether protoplanetary disks can survive in close binaries.

Stassun & Wood(CfA) made multiwavelength optical/IR models to predict photopolarimetric signatures of magnetic accretion. They find the degree of polarization inversely proportional to magnitude (P large when fainter), as observed in a few sources.

Hot star research is a major interest for Cassinelli & Nordsieck, and also involves Meade, MacFarlane and Whitney (Prism CS) & Gallagher. Cassinelli & Miller presented several new model calculations for B[e] stars in terms of luminous magnetic rotators at the June 1998 hot stars meeting in Heidelberg. Cassinelli organized a session on theoretical interpretations of the great eruption at the η Car meeting in Montana in July, 1998. He suggested that during the 1840-1860 ''great event'' the star was in the ''cool apex region'' of the HR diagram where it could easily be destabilized by the near perihelion passage of the long period binary companion; this model is being further developed.

R. Ignace (Glasgow, Scotland), Cassinelli & Nordsieck completed a second paper on the use of the Hanle effect to determine the magnetic field strengths and configurations from FUV resonance line profiles. Simulations of the observations with Nordsieck's FUSP rocket experiment have also been computed, showing that fields of 10 to 1000 Gauss can be measured from Hanle effect observations. Quigley, Cohen & Cassinelli are analyzing ISO observations of the continuum of near main sequence B stars to determine if heating of the outer atmospheres of B stars is responsible for the large EUV excesses found in EUVE and ORFEUS-SPAS II observations of ϵ CMa (B2 II) and β CMa (B1 II-III).

Nordsieck's halfwave polarimeter (HPOL) resided entirely on the 36'' telescope at Pine Bluff Observatory (PBO) this past year. HPOL obtained 205 observations of 85 distinct targets over 99 nights between Oct 3 1997 and Sept 16 1998. HPOL observes a wide range of objects, specific areas of interests are: P Cyg, AG Dra, Be stars, AeBe stars, interacting binaries (primarily β Lyr and V356 Sgr), LVR stars (primarily α Ori, α Her, R Leo, V CVn, g Her, μ Cep), and ISM probes. Broadband polarimetric results of HPOL observations are listed on the HPOL website (http://www.sal.wisc.edu/HPOL). J. Hoffman's Ph.D. thesis exploration of interacting binaries through the analysis of spectropolarimetric observations is progressing with the publication of a paper on β Lyr and modeling of radiative transfer effects within such systems with Whitney (Prism CS) & Wood (CfA).

von Hippel in collaboration with C. Sneden (U Texas) is extending his work on automated stellar classification (Bailer-Jones, Irwin, & von Hippel to derive detailed atmospheric abundances for a new survey of low metallicity stars.

Cole's thesis study with Gallagher is of low-mass He-burning stars in post-red giant evolutionary phases. Research results include understanding age-metallicity effects in LMC red clump stars. Work is in progress to analyze Strömgren photometry reaching to the red clump in the LMC, as a means to obtain metallicity distributions, and to use WIYN observations of Galactic open clusters to develop an improved calibration of the IR Ca II triplet strength as a metallicity diagnostic in the red clump.

von Hippel & Gilmore (Cambridge) are studying HST observations of white dwarfs in open clusters, to intercompare white dwarf cooling ages with main sequence stellar evolutionary ages. This work is meant to calibrate stellar evolutionary ages and put the age of the Galactic disk and halo on the same scale. The WIYN Open Cluster Study (WOCS) collaboration continues to obtain photometry (von Hippel & Sarajedini (NOAO)) and high-precision stellar radial velocities (Dolan & Mathieu) as part of their effort to build to build a detailed kinematic, astrometric, photometric, and abundance survey of a dozen open clusters. 3902 high-resolution spectra of 433 stars (V<17) have been taken in NGC 188 with a precisions of 0.4 km/sec. Nearly 100 velocity variables have been identified, with orbital solutions obtained for 33. Observations have also exist for ~ 400 stars in the open cluster M35, ~ 300 stars in the very young cluster NGC 2264, and 380 stars in the intermediate-age cluster NGC 6819.

4. INTERSTELLAR MEDIUM

The WHAM Hα survey was completed. 37,000 spectra have been obtained on a 0.98°×0.85° (l×b) grid above declination −30° provide the first detailed picture of the distribution and kinematics of the diffuse interstellar H II through

the Hα line, comparable to that of the H I obtained through the 21 cm line. WHAM is located on Kitt Peak and operated remotely from Madison.

Reynolds, Hausen, Tufte, & Haffner detected [O I] λ 6300 emission from the diffuse interstellar medium. The intensity of the emission relative to Hα implies that most of the Hα emission from the diffuse interstellar medium originates from regions in which the hydrogen is nearly fully ionized, rather than from partially ionized H I clouds or layers of H II on the surfaces of H I clouds. Haffner, Reynolds, & Tufte discovered faint, very long Hα filaments in the interstellar medium. One filament stretches 80 degrees across the sky, reaching a latitude of 50 degrees before arching toward the Galactic plane near the CMa OB association. The origins of these filaments are not known. Tufte, Reynolds, & Haffner reported the detection of very weak Hα emission from high velocity H I clouds in the M, A, and C complexes located in the Galactic halo. This emission suggests that these clouds are bathed in an ionizing radiation field of about 2 x 10^5 photons cm^{-2} s^{-1}. The origin of this radiation is not yet clear; one possibility is Lyman continuum photons escaping the Galactic disk.

Haffner (PhD thesis) is completing an initial study of [N II]/[S II]/Hα line intensity ratios in the diffuse interstellar medium within a 1000 square degree region, $123<l<164$, $-35<b<-5$. Results suggest that variations in line intensity ratios probe changes in the temperature and ionization state of the emitting gas. There appear to be systematic trends in the electron temperature and in the ionization state of sulfur related to both distance from the Galactic midplane and to the proximity of known sources of ionization. Wood (CfA) is working with Reynolds in applying his 3-D radiative transfer models to investigate the role of light scattered by dust in the WHAM Hα maps. The goal of this project is to determine how much of the diffuse emission is from the warm ionized medium versus scattered light form HII regions.

Wakker, Howk, Chu & Bomans (Illinois) used the GHRS on HST to detect CIV absorption in the LMC away from regions where CIV could have been locally produced by shocks or photo-ionization. Combined with the presence in these directions of kinematical differences between low- and high-ionization lines, this result indicates that at least some of the C+3 in the LMC is in coronal gas. We argue that photo-ionization is not likely to be a major contributor to the CIV column density through the LMC halo, and conclude that the CIV shows the presence of hot halo gas in the LMC.

Faison, Churchwell, and collaborators obtained intermediate resolution spectra in the 2-13 μ window toward $\sim$ 20 ultra-compact (UC) HII regions. Models of the observed spectra predict that ionizing stars of UC HII regions make evacuated dust cavities $\sim$ 10 times larger than the dust sublimation radii. Churchwell with Cesaroni *et al.* observed 3 massive star formation regions with sub-arcsec resolution in the NH_3(4,4) line, confirming high temperatures and densities inferred from lower resolution observations. They resolved the problem that the luminosity derived from temperatures and angular diameters measured from NH_3 lines, assuming spherical symmetry, was >5 times that found from integrated FIR fluxes by showing the spherical model was wrong. This result has important implications for the nature of molecular cloud cores which produce massive stars.

Sembach (JHU), Savage, Lu (CIT) & Murphy (JHU) are studying highly ionized gas detected in Galactic high velocity clouds toward bright extragalactic sources. High velocity C IV absorption has been seen along 3 of the 10 extragalactic sight lines sampled at 15 km s^{-1} resolution with the Goddard High Resolution Spectrograph (GHRS), not including the directions to the LMC and SMC. The sky covering factor of highly ionized HVCs appears to be roughly similar to that for H I-HVCs. The C IV-HVCs have ionization properties consistent with photoionization by the extragalactic background radiation. The clouds are probably low density, large, and mostly ionized regions located well beyond the neutral gas layer of the Milky Way.

Using a combination of HI, H-alpha, SII absorption and [SII] emission data in the direction of the Seyfert galaxy Markarian 290, Wakker *et al.* found that the high-velocity cloud (HVC) complex C has a true metallicity of 0.06 $\pm 0.014^{+0.014}_{-0.007}$ times the solar metallicity. Assuming the gas is in pressure equilibrium with hot halo gas, the cloud is probably less distant than 25 kpc. A lower distance limit of 5 kpc was determined by van Woerden *et al.* The mass of the object is 2×10^6 $(D/5kpc)^2$ solar masses. We estimate that it represents 0.06(D/5kpc) solar masses/year of low-metallicity gas falling on the Galaxy. The HVC may be a present-day analogue of the damped Ly-alpha absorbers seen in QSO spectra.

Wakker, Savage, Oosterloo & Putman used the Australia Telescope Compact Array (ATCA) and Parkes to observe the HI fine structure in the core of HVC#187, HVC287+240 +22. Lu *et al.* derived a sulfur abundance a sulphur abundance of 0.25 times solar for the HVC, and argued that the HVC originated in the same process that created the Magellanic Stream. The HI data show structure down to the lowest-measurable scale ($\sim$ arcmin); several concentrations appear to be unresolved. A linear feature seen at the highest resolution can no longer be discerned at >4 arcmin resolution. The volume density and pressure are estimated to be $\sim$ 30/R/D(kpc)r cm^{-3} and 18000/R/D(kpc)r K cm^{-3}, respectively, where R is the resolution and D(kpc) the unknown distance.

Howk & Savage used archival data from GHRS to study the warm ionized medium of the Galaxy in absorption. UV absorption lines allowed measurements of relative amounts of the ions Al III and S III along sightlines to 6 stars in the Galactic disk and halo. Using the photoionization code CLOUDY they showed that the derived column densities of Al III and S III imply the abundance of Al relative to S in the ionized medium of the Galaxy is significantly below the solar system relative abundances of these elements. They interpreted this result as evidence for dust in H II regions and the warm ionized medium of the Galaxy. Howk, Savage, & Fabian are studying the gas-phase abundances and physical conditions of the warm neutral medium along the sightline to the star μ Col. This star is the GHRS radiometric calibration standard thus its best-observed early type star. This large archival dataset allowed Howk *et al.* to accurately derive the

abundances of the most important species for studying depletion in interstellar dust grains.

Heiles (Berkeley), Haffner, & Reynolds investigated the Orion-Eridanus Supperbubble by combining the new WHAM survey data for the region with 21 cm, IR, and X-ray maps to explore the bubble's structure and kinematics and the relationships between the various temperature and ionization phases of the gas. There is a clear onion-skin structure with H I on the outside followed by warm H II and then hot H II toward the interior. Callaway & Savage are developing a comprehensive study of a Galactic Supershell. Observations in HI 21 cm, Hα, X-ray, and infrared emission, as well as optical and UV absorption toward high latitude halo stars demonstrate that: 1) A large HI bubble surrounds a region of hot, X-ray emitting gas; 2) This bubble of hot gas, also seen in Hα emission, appears to extend to large vertical heights; 3) Energetic phenomena and related objects in the region include HII regions, supernova remnants, and several O and B stars; 4) Optical and UV absorption seen along sight lines toward high latitude stars demonstrate the presence of ionized species at the same kinematic distance as the shell. Hot gas from within the supershell evidently has been ejected to large vertical distances, providing observational evidence of the mechanism whereby gas is heated near the Galactic plane and circulated into the Galactic halo.

Weitenbeck & Anderson continued making polarimetric observations in the vicinity of NGC1502 as a long term project to study the ISM in that direction.

5. EXTRAGALACTIC

Cole & Nordsieck made a polarimetric study of the diffuse galactic light of the LMC at 2150 Å, from the flight of the Wisconsin Imaging Polarimeter on a sounding rocket. The diffuse light is polarized at the 5–20% level, showing that scattered light contributes $\approx$ 10% of the diffuse galactic light. Together with Wood (CfA), they used the UV polarization map to determine the inclination of the LMC disk and the phase function asymmetry for scattering by interstellar dust grains.

Cole & Gallagher are working with T. Smecker-Hane (UC-Irvine) to obtain deep optical color-magnitude diagrams of field stars in the Large Magellanic Cloud from images taken with WFPC2, NICMOS and at CTIO. The CMDs will be used to determine the complete star-formation history of the LMC over the past 12 Gyr.

Wakker, Howk, Chu & Bomans (Illinois) used the GHRS on HST to detect CIV absorption in the LMC away from regions where CIV could have been locally produced by shocks or photo-ionization. Combined with the presence in these directions of kinematical differences between low- and high-ionization lines, this result indicates that some of the C+3 in the LMC is in coronal gas. They argue that photo-ionization is not likely to be a major contributor to the CIV column density through the LMC halo, and conclude that the CIV arises in hot halo gas in the LMC.

Conselice, Gallagher, Homeier, & Calzetti and Kinney (STScI) are mapping nearby starburst galaxies in the NIR with the LCO 2.5 m telescope, optical imaging from LCO, KPNO and WIYN, and HST UV images. The group is investigating the nature of the ISM of these galaxies, and devising methods for determining the contribution of starbursting regions to the overall light production in blue starburst galaxies. Conselice and R. Evans (U. Chicago/Yerkes Obs.) have been improving the 1 m reflector at Yerkes Observatory. They are using it and WIYN, to image overlapping galaxies as a way to determine the dust content and hence opacity of galaxies among Hubble types. Cole & Gallagher found that stars younger than 10 Gyr are not required to explain the ultraviolet upturn in the nucleus of M32. At 1600 Å and 5500 Å, the nucleus of M32 is unresolved with WFPC2.

Gallagher, Cole, & Hoessel are working closely with Tolstoy and others in interpreting WFPC2 color-magnitude diagrams of 5 Local Group dwarf irregular (dI) galaxies as part of the Skillman (P.I., Minnesota) HST project. Efforts here concentrate on understanding properties of intermediate age stellar components, especially in the Leo A and Peg dIs. The Peg project, led by Gallagher, showed most of its stars probably formed more than 2 Gyr ago, while the Tolstoy-led Leo A study shows stars with ages $\sim$ 1 Gyr dominate. The Skillman HST project results indicate a wide range of star formation histories among structurally similar dI galaxies. This project continues at Wisconsin with the analysis of new WFPC2 GTO observations of IC1613 led by Hoessel and ground-based explorations of other nearby dwarfs.

Gallagher is collaborating on several studies of dwarf galaxies, including the HI distribution in the Magellanic system NGC 4449 led by Hunter (Lowell), stellar populations in the Ursa Minor dSph from HST observations with Wyse (JHU) & Gilmore (Cambridge), and a census of planetary nebulae in the dE NGC 147 from WIYN data. He completed a photometric study of transition dwarf galaxies with Knezek & Sembach (JHU) and is working with Hensler (Kiel) on theoretical chemo-dynamical models for dwarf galaxy evolution. In a related program, J. Davies (now JHU) completed his UW senior thesis on a search for dSph companions of M31 in collaboration with Armandroff (NOAO) & colleagues.

Howk & Savage are imaging dust and ionized gas in the disk-halo interfaces in nearby edge-on spiral galaxies with WIYN. The superb quality images reveal complex dusty filaments stretching to $\sim$ 2 kpc from the midplane in NGC 891 and several other spirals; these have $>10^5$ solar masses and require $>10^{52}$ ergs to reach their observed heights. Howk & Savage are analyzing the connection between the high-z dust structures and the thick layers of diffuse ionized gas seen in these galaxies. Models of these processes are being explored with Wood (CfA). Gallagher's collaboration with A. Ferguson (Cambridge) & Wyse (JHU) to investigate HII regions in outer disks of spirals continues. Recent results include initial tests of dependences of star formation rates on galactic parameters and local conditions, and O and N abundance determinations.

Maciejewski's Ph.D. thesis directed by Sparke investigated stellar orbits in doubly barred galaxies. He showed that families of orbits exist which could be building blocks for long-lived, self-consistent, double bars. The results were also applied to gas inflows in such systems. Erwin is completing a thesis study with Sparke of nuclear structures in barred

galaxies using observations from WIYN and the HST. Levine (USNO) & Sparke continued their numerical modeling of lopsided disk galaxies.

Matthews (SUNY-Stony Brook, now NRAO) completed her thesis with Gallagher on properties of extreme late-type spiral galaxies. A paper on WFPC2 imaging their galactic nuclei with Watson (UNAM), Krist (STScI), & the WFPC2 team is in progress, as is a study of the Tully-Fisher parameters for these galaxies with van Driel (Meudon). Work on the structures of ''superthin'' disk galaxies is also in progress. Many extreme late type spirals appear to have experienced relatively little evolution in terms of their dynamics and stellar populations.

Pisano & Wilcots completed the first stage of a study of the extended environment around truly isolated galaxies. Using the VLA they found that 2 of 6 ''isolated'' galaxies each have two extremely gas-rich dwarf companions. The dynamical time scales of these systems suggest that the companions will be accreted within 1 Gyr and will provide a large infusion of fuel to drive future star formation.

Wilcots & Miller (Leiden) completed a study of the HI kinematics and distribution in the Local Group starburst, IC 10. Their HI data and images obtained with WIYN suggest that the galaxy has processed only half of its disk and that the collective power of the stellar winds has removed the vast majority of the gas from the western side of the galaxy. The HI velocity field suggests that the galaxy is currently accreting a great deal of gas from its extended envelope, which may be driving the starburst; IC 10 might be a galaxy that is still in the process of formation. Wilcots & Turnbull (UW undergrad) mapped the HI in two Seyferts, Mrk 1126 and NGC 6764; both have HI envelopes extending some 3-5 times farther than the starlight. Mrk 1126 also appears to have a small HI-rich companion.

Wilcots continues a study of the role of interactions in the evolution of barred Magellanic spirals. His VLA observations for a sample of 20 systems thought to be currently interacting suggest that only half of these actually are interacting with nearby neighbors. Wilcots & Molvig (UW undergrad) studied the distribution and kinematics of HI in and around the NGC 672/IC 1727 system of interacting galaxies. They found that both galaxies are embedded in a large envelope of recently stripped gas. The interaction has yet to dramatically affect the morphology or star formation characteristics of either galaxy.

Gallagher, Homeier, Watson (UNAM), Conselice & the WFPC2 Team are studying nearby luminous blue galaxies. Optical and UV structures derived from WFPC2 images demonstrate patchy, intense star formation, while WIYN-based velocity field measurements and wide field imaging suggest these galaxies are have been moderately disturbed by mergers or minor interactions. Future goals include a better understanding of the evolution and stellar content of such galaxies. Wilcots & Martin (STScI) also began a WIYN Densepak study of the kinematics of diffuse ionized gas in nearby star-forming irregular galaxies.

Gallagher & L. J. Smith (UCL) studied the stellar contents of clusters F and L in the M82 starburst galaxy. Their modeling of WHT spectra for cluster F indicate that it has an age of 60 Myr and is an example of an ultra-luminous super star cluster. Gallagher is also collaborating with R. O'Connell and R. de Grijs (UVa) in the analysis of WFPC2 and NICMOS images of the edge of the starburst zone in M82 with the goal of studying properties of the population of dense star clusters.

von Hippel, H. Ferguson (STScI), & Tanvir (IoA, Cambridge) are following up their discovery of intergalactic red giant stars in the Virgo Cluster with HST optical and infrared photometry in order to measure the abundances and spatial distribution of the intergalactic stars. Conselice, Gallagher & Wyse (JHU) are studying tidal effects and dwarf galaxy populations in nearby rich clusters. A new morphological system was developed to describe the types of interactions and tidal features seen in nearby clusters and compact groupings of objects, galaxy aggregates, were discovered in the Coma cluster. These consist of a central disk system surrounded by luminous condensations, and further observations are planned to reveal their physical natures.

Bershady and Haynes & Giovanelli (Cornell) are surveying rotation-curves intermediate redshift spiral galaxies at Palomar and WIYN. They use the Tully-Fisher (TF) relation to measure evolution in galaxy M/L as a function of redshift. Preliminary results from $\sim$ 40 galaxies to $z<0.4$ suggests little change in the TF relation, but a strong color-dependence is seen in the zero-point of the B-band TF relation. Larger samples are needed to see if this dependence changes with redshift. A careful understanding of the measurement systematics related to TF parameters is critical: Bershady and Mihos (Case Western) are modeling observations to assess systematics and develop a protocol for their removal from real data.

Bershady, Koo (Santa Cruz), Guzman (Yale) & Jangren (Penn State) are investigating the nature and evolution of an enigmatic luminous, compact narrow emission-line galaxies (CNELGs) that appear at intermediate and high redshifts. Optical sizes, structure and color gradients are measured from WFPC-2 images, combined with Keck optical emission-line widths. They estimate that these galaxies, observed 5-10 Gyr in the past, could fade to resemble today's nearby spheroidals. Further refinement is needed in the details of the photometric fading and reddening, as well as possible kinematic and morphological evolution. Bershady led new efforts to obtain new NIR observations in the K band with the KPNO 4 m in H band with HST/NICMOS. A preliminary analysis of the kinematic and photometric mass estimates indicate they are roughly comparable.

Conselice & Bershady developed a new analysis of faint galaxy image asymmetry, based on Conselice's image-rotation method. They find that image rotational asymmetry (IRA) is even more tightly correlated with rest-frame galaxy color than in Conselice's original analysis. The dependence and departures from this correlation as a function of look-back time is being studied in the HDF with optical and NIR NICMOS images. Bershady is collaborating in imaging the entirety of the HDF using NICMOS. Conselice is analyzing these new data with his asymmetry algorithm. Preliminary results indicate a much larger degree of asymmetry for a given color at higher redshift, indicative of a higher degree

of merging and interaction for a given star formation rate.

Bershady is also addressing the selection of high redshift galaxies via multi-color and surface-brightness techniques to complement direct counts. Results from his deep K band observations from Keck, with Lowenthal (U.Mass) & Koo (Lick), show that the counts do not roll over, as previously believed, but that there is a deficit of old, red galaxies at $1 < z < 5$. A substantial population of compact, moderately luminous sources appears at intermediate redshift in the K band. Bershady's long term variability survey of extended sources in SA 57, with Kron (Chicago) & Trevese (U. Rome), indicates a rise in the number of Seyfert nuclei at intermediate redshift, but less dramatically than previously claimed for low luminosity AGN. It is not clear yet if these AGN are somehow related to the profusion of compact, blue galaxies in the field; none of the CNELGs studied by Bershady and collaborators are variable. A connection could exist through a secondary phenomenon; i.e. an increase in the merger and interaction rates at higher redshift.

Savage is a member of the HST QSO Absorption Line key project team, which released its 3rd catalog of QSO absorption lines, including 2594 absorption lines from the UV spectra of 66 QSOs. Results from the 3 catalogs are: total number of detected absorption lines is 3283, including: 1089 Ly-α lines, 20 extensive metal line systems, 103 C IV systems, and 42 O VI systems. These data support a variety of investigations of gaseous systems in the near-by Universe; e.g., the redshift evolution of the Ly-α forest and metal line systems and associations between QSO absorbers and galaxies. Savage & Wakker are using the combined catalogs to study Galactic Mg II and Fe II toward the QSOs to determine the sky covering factor of Galactic high velocity absorption. The Milky Way lines provide important examples of the absorption properties of a zero redshift galaxy for comparison with absorption seen at higher redshift in QSO metal line systems.

Tripp (Princeton), Lu (CIT) & Savage have completed their study of the of low redshift Ly-α absorbers in the UV spectra of H1821+643 ($z = 0.287$) and PG1116+215 ($z = 0.177$) obtained by the GHRS. The spectra have 3σ limiting equivalent widths of ~ 50 mÅ. Toward H 1821+643 26 Ly-α lines are seen, and toward PG1116+216 they detect 13 Ly-α lines. Combining these results with those toward 3C 273 implies a low redshift intergalactic Ly-α line density of 106 ± 16 lines per unit redshift for rest equivalent widths > 50 mÅ. UV and WIYN observatory galaxy redshifts in the 1deg fields centered on the quasars have been combined to study relationships between absorbers and galaxies. 17 galaxy-absorber pairs within projected distances of 1 Mpc with velocity separations of < 350 km s^{-1} are found. The results are consistent with the hypothesis that many of the low redshift Ly-α absorption lines trace the overall gas distributions in the large scale structures of galaxies, rather than the gaseous halos of individual galaxies. The study will be extended to one more quasar (PKS 0953+415) with observations to be obtained by STIS in early 1999.

6. WIYN AND INSTRUMENTATION

The University of Wisconsin has a 26% share in the observing time of the 3.5-meter WIYN telescope, that produces excellent high resolution optical images and spectroscopy. 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 fast tip-tilt system, correcting up to a 5 arcminute field of view. Percival continued his work on remote observing and his Progressive Image Transmission System, which allows very large images to be sent over slow network connections.

Savage continues as a Co-I on the Cosmic Origins Spectrograph, being prepared as a replacement instrument for the 2003 HST orbital refurbishment mission. COS is $\sim$ 20 times more efficient than the Space Telescope Imaging Spectrograph in the FUV, and will be used on faint objects. Savage is also a Co-I in the Far Ultraviolet Spectrographic Explorer (FUSE; a 912–1200 Å spectroscopy mission, being prepared for launch in February 1999).

Bershady continues his work on fiber integral field units for the Hobby Eberly Telescope's Medium Resolution Spectrograph, to be used to study the kinematics of galaxy disks. Conselice, Sawyer (WIYN), and P. Smith (NOAO) investigated the irradiance profile of the fibers coming from the Hydra multi-object spectrograph on WIYN. They found the irradiance pattern to be effected by imperfections in the fibers creating a output light pattern larger than what would be expected.

The HPOL (Halfwave 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). The Spatial Heterodyne Spectrometer (SHS; Reynolds, colleagues from Physics, and others) is a rocket-launched UV Fourier transform spectrometer for observing faint line emissions.

Percival, Nordsieck, Babler, Harris, and Bonomo developed a prototype low-cost star tracker with embedded support for Progressive Image Transmission. This device can provide 3-axis attitude updates as well as providing a low-bandwidth imaging capability. The device will fly as a tag-along on an upcoming sounding rocket mission.

7. OTHER EFFORTS

Sparke is completing an advanced undergraduate textbook on the astrophysics of galaxies, co-authored with Gallagher. Publication is planned by Cambridge University Press in 1999. That year should also see the publication of a book on stellar atmospheres by Cassinelli and Lamers (Utrecht).

Mathieu is Director of the College Level 1 Institute of the National Institute of Science Education on the Madison campus. The essential goal of these Institutes is to synthesize present knowledge student learning and disseminate it to practitioners. The first Institute is focusing on alternative means of classroom assessment, with the primary product being the Field-tested Learning Assessment Guide (FLAG). The FLAG is a user-friendly web site which will meet the user's needs, and provide a complete tutorial package for classroom use.

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