The University of Wisconsin-Madison

Department of Astronomy

Madison, WI 53706

As in the past, the Astronomy Department at UW-Madison has been active in a wide range of observational and theoretical research programs. We are playing a major role in the Southern African Large Telescope (SALT) consortium that is constructing a 10-meter optical telescope located at the Southern African Astronomical Observatory site in Sutherland, South Africa. Our efforts are described in §6 below.

Another major thrust of the department comes from the award of one of the six Legacy Science programs of the Space Infrared Telescope Facility (SIRTF), an 0.85-m telescope in solar orbit, to be launched in late 2002 or early 2003. The UW project, called GLIMPSE (Galactic Legacy Infrared Mid-Plane Survey Extraordinaire), has Churchwell as PI with a team of 15 scientists from 7 institutions. It will be responsible for imaging the inner 2/3 of the Galactic plane with a spatial resolution of $\sim 2''$, down to the confusion limit, with images in the $3-8$ μm region. The survey will require 400 hours of telescope time.

1 Personnel

Dr. Amy Barger assumed her position as Assistant Professor in August 2001. Previously she was the Hubble Fellow/Chandra Fellow at Large at the Institute of Astronomy, University of Hawaii. She is the recipient of the 2001 Annie Jump Cannon Award of the AAS for her contributions to astronomy.

In June, Prof. Linda Sparke became Chair, succeeding Anderson. Other faculty are Professors Cassinelli, Churchwell, Gallagher, Hoessel, Mathieu, Nordsieck, Reynolds, and Savage, Associate Professors Bershady and Wilcots (promoted to the rank during the year), and Assistant Professors Barger and Lazarian. Bless and Mathis are Professors Emeriti residing in Madison.

Percival is Scientist and Associate Director of the Space Astronomy Laboratory as well as Project Manager for the Prime Focus Imaging Spectrograph on SALT. Harris and Wakker are Associate Scientists.

Dr. Eric Burgh joined the staff as Assistant Scientist after completing his graduate work at the Johns Hopkins University. He will work with Nordsieck as the Instrument Scientist for the Prime Focus Imaging Spectrograph for the SALT. Dr. Marc Verheijen arrived in March after a 3 month stay in Bangalore, India, from the NRAO in Socorro where he held a Jansky Fellowship. He will work with Bershady on galaxy kinematics with the new SparsePak instrument on WIYN and with Wilcots on the evolution of the gas content in galaxy clusters using the VLA and the Giant Meter Radio Telescope (in India). In September 2001, Dr. Remy Indebetouw joined the staff as Assistant Scientist to work with the SIRTF Legacy team GLIMPSE (Churchwell, PI; see below). His primary responsibilities will be to lead the effort to plan early observations to validate the GLIMPSE observing strategy and to establish data validation criteria and implement them as data arrive. Other Assistant Scientists are Drs. Sidney Barnes (McKinney Assistant Scientist), Jungyeon Cho, Matt Haffner, Henry "Chip" Kobulnicky, Mark Quigley (who in September, 2001, accepted another position at UW), and Philipp Richter. M. Orio is Visiting Associate Scientist. Dr. James Lattis served as Lecturer during the academic year. Kobulnicky finished his Hubble Fellowship and joined the GLIMPSE and SALT Prime Focus Imaging Spectrograph teams (Churchwell and Nordsieck, resp., PIs), and was awarded a 5-year NASA Long-Term Space Astrophysics (LTSA) grant to study how matter lost in galactic winds from starforming drives galaxy evolution.

Many scientists visited during the year, including Prof. David Meyer (Northwestern), who spent his sabbatical year in residence. David James, a post-doctoral fellow from St Andrews, Scotland,

visited Mathieu's WIYN Open Cluster Study group from March-September.

Four students received the PhD degree. Dr. Chris Conselice (Gallagher, supervisor) worked on the kinematics and evolution of dwarf elliptical galaxies in the Virgo Cluster. He is now at CalTech. Dr. Birgit Otte, now at JHU, investigated emission line ratios in edge-on spiral galaxies (Reynolds, supervisor). Dr. D. J. Pisano, now NSF Fellow at CSIRO Australia Telescope National Facility, had a thesis entitled "The Formation and Evolution of Isolated Galaxies" (Wilcots, supervisor). He began an NSF International Fellowship at the Australia Telescope National Facility. D. Andersen (Penn State CIC exchange student, in residence at UW; Bershady, supervisor) worked on spectroscopy of nearly face-on disks. He is now at the Max-Planck-Institut für Astronomie (Heidelberg).

Churchwell continued to serve on the Visitors Committee for Arecibo Observatory, besides being PI of the SIRTF Galactic Legacy Science program GLIMPSE. Gallagher continued as Chair of the International Board of the Gemini Observatory. He was appointed as Director of the Astronomy and Astrophysics Antarctic Research Institute; this organization provides organization and oversight for various research University of Wisconsin-Madison polar research programs, including the currently operating AMANDA and planned IceCube high energy neutrino observatories.

Mathieu was President of the WIYN Board of Directors as well as Associate Director, National Institute of Science Education. He continued as Director of the College Level 1 Institute within NISE. All of the CL-1 products are at
www.wcer.wisc.edu/nise/cl1/.

Savage continued as a member of the Space Telescope Institute Council and the AAS Nominations Committee.

Percival continued his participation in the IAU Working Group on Astronomical Standard's initiative called SOFA: "Standards of Fundamental Astronomy." The goal of this effort is to produce a set of basic software that implement commonly-used formulae and standard models in fundamental astronomy.

Wilcots served on the National Radio Astronomy Observatory's Users Committee, the NRAO's Program Advisory Committee, the AAS Committee on Employment, and chaired the WIYN Scientific Advisory Committee. Wilcots continues to direct the Universe in the Park program which finished its sixth successful season in 2001. The program visited 29 different state parks throughout Wisconsin and held 47 sessions from May to October. Both of these are new records. Estimates are that that nearly 3000 people participated in Universe in the Park this season. Wilcots also directs the department's efforts towards the ancillary benefits associated with the SALT telescope project.

The monograph "Galaxies in the Universe: an Introduction", by Sparke and Gallagher, was published by Cambridge University Press in October 2000. This advanced undergraduate text provides a modern perspective on observational and theoretical aspects of galaxies, as well as their development within our expanding Universe. Errata are listed at www.astro.wisc.edu/ sparke/book.

2 The Solar System

Reynolds, Haffner, and colleagues from UW Physics and elsewhere carried out a study of Hα emission from the earth's geocorona using spectra collected during the Wisconsin H-alpha Mapper (WHAM) sky survey. They concluded that continued observations with WHAM could be used to monitor changes in the earth's global methane production, a primary greenhouse warming gas.

Reynolds, Anderson, Harris, and colleagues from Physics and elsewhere obtained WHAM and also WIYN observations of comet Hale-Bopp (C/1995 O1) in the λ6300 [O I] lines and estimated the rate of production of water molecules from the nucleus.

3 Stars, Outflows, and Galactic Structure

Anderson, Harris, and Scherb (UW Physics) continue their program of observations of solar system objects. The electron density diagnostic [S II] λ6717, 6731 has been extensively mapped in the Jupiter/Io torus using the WIYN Densepak, providing simultaneous measures of intensity, velocity, and line ratio (density). Such comets as become available, e.g. Linear WM-1, are also on the program.

Anderson and Glinski (Tenn. Tech) used the WIYN Densepak to obtain moderate resolution spectra of the emission features near 5800Å in the Red

Rectangle Nebula surrounding HD 44179. The results suggest that the currently popular idea that these bands are the same as the diffuse interstellar bands in the same general wavelength range is not correct.

Cassinelli and student Miller have analyzed the high-resolution Chandra X-ray spectra of the hot stars ζ Puppis (O4f) and δ Orionis (O9.5 & B0.5 III), collaborating with MacFarlane (Prism Computational Sciences), Waldron (Emergent Information Technologies), and Cohen (Swarthmore). Cassinelli has also worked with Waldron in interpreting the Chandra high resolution spectrum of ζ Ori (O9.5 Ia). They used forbidden, intercombination, and resonance lines of helium-like ions as diagnostics of the radial distribution of the various ions. The Doppler-broadened emission line profiles reveal the temperature structure of the gas. The X-ray line spectra differ in several ways from predictions. There seems to be an extra source of X-rays arising from the base, possibly located in magnetic loop structures.

Cassinelli, Nordsieck, and R. Ignace (U. Iowa) have continued their work using the UV Hanle effect as a diagnostic of magnetic fields in hot stars. They should be able to detect fields of less than 100 Gauss using high resolution polarization observations of strong UV lines in the winds. Ignace, Cassinelli, Quigley and Babler studied the Infrared Space Observatory spectra of Wolf Rayet stars, especially the velocity laws and filling factor in the winds. The IR continuum of these stars is formed in the wind. The dominant continuum opacity, free-free absorption, increases with wavelength, so optical depth unity, and thus the radius of the line formation, moves outward with increasing wavelength. Because recombination lines of He II have larger widths, the velocity law can be obtained. They estimate that the filling factor is about only 1/50.

Mathieu and colleagues Barnes, Dolan, and Meibom continued acquiring high-precision stellar radial velocities with the WIYN telescope and Multi-Object Spectrograph. As part of the WIYN Open Cluster Study (WOCS), they have obtained 5612 velocity measurements of 511 stars in NGC 188, 4097 measurements of 1116 stars in M35, 2021 measurements of 354 stars in NGC 2264, and 3694 measurements of 940 stars in NGC 6819. Additional spectroscopic binary orbits are steadily being found in each cluster, with orbital solutions for nearly 70 binaries in NGC 188, the most extensively observed. As a post-doctoral scientist, Dolan developed and commissioned a java-based database allowing flexible access to all WOCS data.

Mathieu, Carr (NRL), and Najita (NOAO) continued a program at the Keck Observatory of high-resolution near-infrared spectroscopy (CO fundamental and overtone transitions) in order to explore the circumstellar gas in both young binaries and single stars. The CO transitions are extremely sensitive tracers of disk gas. In order to study the history of disk dispersal to later stellar ages, they have expanded their program from binaries to single stars.

Mathieu, Rhode (Yale), and Herbst (Wesleyan) completed their $v \sin i$ study of low-mass Trapezium stars. They found strong evidence that the period light variations of T Tauri stars are caused by spot modulation as the star rotates. There were no significant differences in the $v \sin i$ distributions of the periodic and control samples, indicating that there are no evident biases in the periodic sample. Surprisingly, for stars with known period the mean value of $\sin i$ is significantly lower than expected for a random distribution of stellar rotation axes. They find evidence at the 3σ level that the radii of stars on similar mass tracks are decreasing as the stars move closer to the ZAMS.

Stassun and Mathieu continued their study of pre-main-sequence (PMS) eclipsing binary stars to derive empirical masses, to be used to test and calibrate PMS stellar evolution models. Multiband photometric monitoring of several eclipsing binary candidates in the Orion star-forming regions was carried out with the CTIO 0.9-m, and spectroscopic monitoring with WIYN and the Hobby Eberly Telescope high-resolution spectrograph. They also continued their survey of PMS spectroscopic binary stars in Orion with the WIYN multi-object spectrograph. The aim of this program is to characterize the frequency of close binary systems and to study the relationship between binarity and early stellar angular momentum evolution.

Barnes has continued to work on stellar evolution, with an emphasis on the rotational evolution of stars. He assisted colleagues in completing and publishing the newest version of the Yale

Isochrones. These include the latest physics and begin at the stellar birthline, facilitating comparison with very young clusters. He investigated the rotational consequences of disk- locking of young stars and the rotation rates of the host stars of extrasolar planets.

Stassun, M. van den Berg (Utrecht), Mathieu, and F. Verbunt (Utrecht) completed their studies of the photometric variability of stars in the old open cluster M67. Photometric variability in the cluster occurs in only 3% of the nearly 1000 stars studied and is strongly correlated with binarity. They discovered a contact binary (W UMa) system, bringing the total known to four. This work also led to a detailed study of the blue straggler triple system S 1082.

James (St. Andrews, but in residence at Madison), working with Mathieu and Barnes, focussed on the M7 and M34 open clusters. These two clusters are especially important because of their intermediate ages (about 250 Myr) and differing metallicities. These clusters will define the angular momentum evolution on the main-sequence at ages in between those of the well-studied Pleiades (100 Myr) and Hyades (600 – 700 Myr) clusters, and will begin to characterize cluster-to-cluster differences for coeval systems. James reduced and analyzed an M7 BVIc photometric dataset over the central 1 degree of the cluster. A subset of photometric members lying close to the nominal main sequence were observed at WIYN. The resultant radial velocities, the existing spectral type data, and the BVIc photometry will allow the WOCS team to construct a catalogue of cluster members for follow-up spectroscopy for Li abundances and photometric monitoring studies. James also analyzed a large data set of differential photometry for rotation period determinations in the M34 cluster. Barnes and James are in the process of constructing light curves for M34 photometric members.

Stassun and Mathieu received a Chandra archival research grant with M. Barsony (Space Science Institute) and G. Basri (UC Berkeley) to study the rotation-activity connection among low-mass PMS stars in Orion.

Stassun, with Wood (St. Andrews) and Whitney (Space Science Institute), studied the photometric variability of the embedded young star HH30. A tentative period in the scattered light curve indicates extremely slow rotation of the central star. HST archival observations of HH30 are being modeled via Monte Carlo radiative transfer codes to study magnetically channeled accretion of circumstellar disk material onto the central star. Stassun and Whitney continued their HST archival research project to model the 3-D scattered light morphologies of protostars in the Taurus molecular cloud.

Hoffman, Nordsieck, and Whitney continue to investigate the characteristics of their Monte Carlo radiative transfer model for binary star-disk systems and its use in reproducing the observed flux and polarization curves of β Lyrae. Recent improvements include the use of ellipsoidal volumes to represent Roche-lobe-filling stars. Hoffman and Nordsieck have analyzed their polarimetric observations, taken with HPOL at WIYN, of the PMS binary stars BM Ori and MWC 1080. They estimate the contribution from interstellar polarization and the behavior of the intrinsic polarization for each. They collaborated with J. Meyer (undergrad) on a spectropolarimetric study of the peculiar B[e] star MWC 349A. Observations with HPOL at WIYN confirm previous estimates of the orientation of a circumstellar disk in the system, and suggest that a nearby star is not a companion as previously thought. These results lend support to the classification of MWC 349A as a PMS B[e] star.

Orio, with colleagues, is studying pointed XMM-Newton observations for Nova LMC 1995 (a supersoft X-ray source and a candidate type Ia supernova progenitor) and the behavior of post-outburst novae observed with Chandra. She is using ROSAT archival data, supplemented with data of Einstein, ASCA, Chandra and XMM-Newton, to study the long term variability in intensity and spectrum of X-ray sources, especially cataclysmic variables and low mass X-ray binaries. The sample includes many unidentified sources with interesting variations on time scales of days, months and years. Orio is also considering the long term behavior of classical novae at quiescence, in order to clarify several aspects of the secular evolution of these objects. There is an ongoing program of optical identification and monitoring of Low Mass X-Ray Binaries and cataclysmic variables that are X-ray sources. This program is carried on with ESO telescopes and mainly with the WIYN telescope. Some of the supersoft sources have huge asymmetric ion-

ization nebulae around them. These nebulae can be detected at WIYN.

4 The Interstellar Medium (ISM)

The Wisconsin H-alpha Mapper (WHAM) Northern Sky Survey total intensity map (Reynolds, PI) has been made available to the community at the web site http://www.astro.wisc.edu/wham/. The survey provides the first view of the large scale distribution and kinematics of the diffuse interstellar Hα north of declination $-30^{\rm o}$.

Churchwell, with Bieging (U. Ariz), Pankonin (NSF), and student Watson, continued to try to detect and determine the properties of precursors of Ultracompact HII regions using CH_4CN line emission. A survey of over 20 known massive star formation regions using the Sub-Millimeter Observatory on Mt. Graham has revealed compact and apparently optically thick CH_4CN emission toward a large fraction of the sample surveyed. The BIMA and OVRO arrays will provide higher resolution interferometric observations.

Hollis (GSFC) and Churchwell used previously published molecular line data from the Orion and Sgr B2 molecular clouds to show that the formation of complex interstellar molecules is consistent with formation from chemical groups such as OH, CH, CHl_2, CH_3, CN, NH_2, and HCO that were initially formed on grain surfaces and subsequently released into the interstellar medium.

In an effort to resolve the distance ambiguities of ultracompact HII regions in the inner Galaxy, Churchwell (with Araya and Hofner, U. Puerto Rico, and Kurtz, UNAM) used the Arecibo 300m telescope to measure the H110α line in emission and the 6 cm H_2CO line toward 21 ultracompact HII regions. The H_2CO line was observed in absorption against the HII regions, and the near/far distance ambiguity was resolved. The success of this pilot program has prompted proposing a much more extensive survey to resolve the distances to all detectable massive star formation regions in the inner Galaxy with the the GBT and Arecibo telescopes. One motivation for these surveys is to prepare for the SIRTF/GLIMPSE imaging survey of the inner Galactic plane.

Student Marta Sewilo, working with Churchwell, is measuring the angular expansion rates of G5.89 and G34.26 using VLA continuum images obtained over a 10 year period. She will also be heavily involved in the determination of kinematic distances of ultracompact HII regions using the GBT and Arecibo. C. Watson's thesis topic will be the outflows associated with massive star formation, especially the origin of the large masses in the outflows. He has played a key role in writing an automated observing command program for the SIRTF Legacy project.

Lazarian, Cho, and students Yan and Esquivel investigated properties and consequencies of the ISM turbulence from theoretical, numerical, and observational points of view. They cooperated with E. Vishniac (JHU) in theoretical studies of MHD turbulence and obtained new results on turbulence cascade in partially ionized gas, on coupling of different MHD modes, on cosmic ray scattering, and on acceleration of cosmic rays. Lazarian continued work with Pogosyan (Univ. Edmonton) on obtaining velocity and density statistics of turbulence from observational data, concentrating on the effects of absorption. This work will open a new avenue for dealing with turbulence not only in HI, but also in CO and other molecular species for which absorption is important. The application of earlier results to the Small Magellanic Cloud HI (with S. Stanimirovic, Arecibo) revealed a Kolmogorov-type cascade from size of the whole galaxy down to the resolution limit. With De Gouveia Dal Pino (Univ. Sao Paolo), Lazarian obtained constraints on the acceleration of ultra high energy cosmic rays during reconnection events. With French collaborators, he worked on the statistics of starlight polarization, important for CMB studies.

Reynolds, Haffner, Hausen, and Tufte used WHAM to characterize the kinematics and emission measure of the diffuse ionized gas toward the Lockman Window (an area of low H I emission) and toward the high latitude O star HD 93521. They found that the ionized gas is kinematically associated with the H I, but that the H II and the H I toward HD 93521 do not appear to be mixed into partially ionized clouds, as had been suggested by Spitzer and Fitzpatrick. With Sterling, they used WHAM to detect for the first time the temperature sensitive [N II] λ5755 in the diffuse ISM. Their observations indicate that the electron temperature of low density ionized gas is 2000 K higher than that

in the higher density, classical H II regions. This has provided additional support for the presence of a supplemental heating source within the low density gas. The WHAM sky survey data found evidence for an enormous superbubble that appears to have blown out into the halo above the Cas OB6 association in the Perseus arm. This finding has provided support for the idea that at least some of the ionizing radiation from O stars is able to travel long distances through the Galactic disk via large cavities that are devoid of H I. The WHAM sky survey created the first Hα map of a high latitude intermediate velocity cloud, the "K Complex". The ionized gas traces the H I quite well spatially and kinematically over the 600 square degree complex.

Savage, Wakker, Sembach (STSCI), Richter, Meade, and other members of the FUSE science team have nearly completed their survey of O VI absorption in the Milky Way halo seen toward 85 extragalactic objects. High velocity O VI absorption is detected along 65% of the lines of sight, at both positive and negative radial velocities. Milky Way thick disk O VI absorption reveals a widespread but highly irregular distribution of O VI, implying substantial amounts of gas with T $\sim$3 10^5 K in the Milky Way halo. There is a slight excess of high-latitude O VI to the North compared to the South, but observations are not well described by simple plane parallel models of patchy O VI absorbing structures. The observed profiles are far wider than thermal. The Galactic gas parcels containing O VI are moving both toward and away from the plane with roughly equal frequency. A combination of models involving the radiative cooling of hot gas in a Galactic fountain flow ($\sim$ $2M_\odot$/yr for each side of the disk) and the turbulent mixing of warm and hot gases appears to be required to explain the highly ionized gas found in the halo.

Andrew Fox, in collaboration with Savage, Richter, student Fabian, Meyer (NWU), Lauroesch (NWU), and Sembach (STScI), is studying high resolution spectra from FUSE and STIS of the highly ionized interstellar gas ((Si IV, C IV, N V and O VI) toward HD 116852, a halo star at a distance of 4.8 kpc. They find evidence for three distinct types of absorbing gas along this sight line. The study is being extended to several other sight lines in the low halo that probe features such as Radio Loop IV and the Perseus spiral arm. A principal goal of this study is to investigate the relationship between O VI and the other high ions present in the Galactic halo.

Richter focussed on FUSE observations of neutral and molecular gas in Intermediate-and High Velocity Clouds. He detected a widespread diffuse molecular gas phase in the lower Milky Way halo. He also used the WIYN DensePak for complementing observations of quasar fields.

Wakker completed a literature survey on high- and intermediate-velocity clouds that showed the diversity of HVCs. Some are distant ($d > 4$ kpc) and metal poor ($Z < 0.1Z_\odot$), other are nearby ($\sim$1 kpc from the Galactic plane) and metal rich ($Z \sim 0.5-1Z_\odot$), while still others are tidal debris ($d \sim$50 kpc, $Z \sim 0.25Z_\odot$).

Gómez (with Benjamin and Cox, Physics) concluded the development of a new model for the free electron distribution in the galaxy, based on a compilation of the published values for the dispersion measure of the pulsars with an independent distance determination. Gómez and Cox are now studying the flow of the galactic ISM into a spiral perturbation, paying special attention to substructure generated in the gaseous arms and vertical motion induced by this flow. Among other things, they expect to find how the non-axisymmetric rotation curve influences the measured distances of the ISM components.

Mathis, with Whitney and Wood, is considering the fractal nature of interstellar clouds. The models have a heirarchical structure on large and small scales. The radiative transport in such models differs considerably from single scale clumpy models. The importance of cloud structure is shown by the depletion patterns of heavy ions within the ISM. Mathis and Wakker are considering H I emission as a diagnostic of clumping over large angular scales. Mathis was involved in the interpretations of ISO fine-structure line observations of ultracompact H II regions.

5 Extragalactic/ cosmology

Barger is obtaining a more complete census of the energy-producing galaxies and supermassive black holes in the Universe. Using X-ray, submillimeter, and radio wavelengths, she has studied galaxies and AGN that were previously hid-

den by dust and gas. With the Chandra X-ray Observatory, she has detected obscured supermassive black holes at the centers of galaxies. This work was done principally in collaboration with Cowie (Hawaii), Brandt, Garmire, and Mushotzky (GSFC), Hornschemeier (Penn State), and Bautz (MIT). She led the study that made the first optical observations of sources found in deep Chandra data, discovering two new populations: one associated with normal galaxies and another associated with optically faint galaxies. She also deduced that about 5% of optically bright galaxies are X-ray active at any time and thus that black hole activity lasts for about half a billion years. Barger found that about 30% of black hole activity has occurred since the Universe was half its present age. By combining X-ray, optical, and radio data, she was able to estimate the accretion history of the Universe. To further determine the nature of the X-ray sources, Barger and student Steffen are analyzing spectroscopic data obtained with HYDRA on WIYN of sources in a wide-area Lockman Hole field to be targeted with Chandra. This study will be complementary to forthcoming far-infrared observations of the region with the Space Infrared Telescope Facility. Barger is Co-I on the Chandra Deep Field North survey (Brandt of Penn State is PI) that is obtaining a 2 million second exposure and will be the deepest X-ray image ever taken. It is expected to resolve fully the X-ray background into its constituent sources. Barger and Cowie (Hawaii) will be doing the optical and submillimeter follow-up on this field. Barger and student Hedrick are doing a submillimeter study of extremely red objects that are gravitationally lensed by three rich Abell clusters. These objects may be extremely dusty objects or high redshift ellipticals. The objective is to determine their contribution to the submillimeter extragalactic background light. Barger is also examining the submillimeter properties of faint radio sources.

Bershady has continued HST STIS, NICMOS and WFPC surveys of intermediate redshift compact, luminous, blue narrow-emission-line galaxies in collaboration with Guzman (U. Florida) and Koo (UC Santa Cruz). They are trying to determine the current state and future evolution of these sources, and in particular if these galaxies can fade to become part of today's spheroidal galaxy population. As part of a related study, Bershady continues to study the Tully-Fisher relation for intermediate redshift galaxies with collaborators Haynes and Giovanelli (Cornell), Mihos (Case Western) and Koo. Recent results indicates that sources outlying the canonical rotation speed-luminosity relation are preferentially disturbed systems – as determined either from their image structure or velocity fields.

Andersen completed his Ph.D. research (Bershady, supervisor) on WIYN imaging and DensePak spectroscopy of nearly face-on disks. He found that disks are intrinsically elliptic at the 5-10% level and determined how these properties contribute to the scatter in the observed Tully-Fisher relation.

Bershady, Verheijen, Andersen, Wilcots, and Swaters (JHU) are involved with commissioning science with the new SparsePak fiber integral field unit on WIYN (see Instrumentation, below). Their science objectives are to measure the mass of galaxy disks by direct determination of the stellar velocity ellipsoid, and to probe the ionized gas velocity fields in late-type and low-surface-brightness systems. Preliminary results indicate much lower disks masses than previously assumed.

Gallagher's research centers on defining and understanding physical processes responsible for the evolution of galaxies, with an emphasis on lower mass systems. These are common and include the satellites of the Milky Way, allowing detailed studies to be made. A project to define the star formation history of the Large Magellanic Cloud (LMC) from studies of field star color-magnitude diagrams (CMDs) and metal abundances is making good progress with Smecker-Hane (UC Irvine) and Cole (UMass). The LMC bar is younger than the disk, probably appearing as a distinct component 4-6 Gyr ago. A related WFPC2 project led by Wyse (JHU) measured a normal field star mass function down to 0.4 $M_{\odot}$ in the Ursa Minor dwarf spheroidal. Studies of Local Group dwarf galaxy stellar populations continue, with an analysis of deep IC 1613 and Sex A WFPC2 V and I filter observations partially completed under the leadership of Saha and Dolphin (NOAO), Skillman (Minnesota), and Dohm-Palmer (U. Michigan). VLT spectroscopy (with Tolstoy [Groningen] and others) of the IR CaII triplet in three nearby dwarfs provides a glimpse of chemical enrichment patterns. The senior thesis project of A. Maxham

(now U. Illinois), based on CMDs from VLT imaging by Tolstoy et al., gives further evidence for the ubiquity of radial age/metal gradients in the Cetus and Aquarius dwarfs. Even small galaxies are not simple one-zone systems. They have experienced considerable post-formation evolution.

For his Ph.D. thesis (Gallagher, supervisor), Conselice inquired into the nature and origins of ubiquitous spheroidal dwarfs in clusters, primarily with the WIYN telescope. The kinematics of dwarf ellipticals in the Virgo cluster of galaxies are consistent with most dwarfs entering the cluster after the formation of the E-galaxy core. Complementary photometric investigations of the dwarf populations in the core of the Perseus cluster indicate a wide range in color of fainter dwarfs, consistent with such galaxies being remnants of larger field systems that were partially disrupted by interactions as they became part of the cluster. This program also yielded spectacular WIYN images of the system of ionized filaments and young stars associated with the central Perseus cluster galaxy NGC 1275. A survey of Virgo dEs for HI 21-cm line emission, with K. O'Neil (NAIC), showed that the expected transition cluster-field dwarfs seem to exist. However, the cluster dwarf origins problem is not solved. New Keck observations by M. Geha et al. (Lick) prove that Virgo dwarfs are not rotationally flattened, as would be expected if they are stripped remnants of field spirals.

Gallagher continues studies of small field galaxies, including an analysis of major axis kinematics with Matthews (CfA). These are dark matter-dominated systems with normal (i.e., high) specific angular momentum content. New WFPC2 images of HI-rich galaxies detected by HIPASS (H I Parkes All Sky Survey) allowed for the first time a measure of stellar population properties in this class of object. This program was led by Knezek (WIYN) and involved M. Disney et al. at Cardiff.

Gallagher's other work on the evolution of field galaxies focuses on the nature of their starbursts. What types of processes trigger such events, and what are the evolutionary implications for the resulting stellar populations? In agreement with other investigations, his project, with Matthews (CfA), Conselice, and graduate student Homeier, shows that a range of interactions, including minor collisions, can produce starbursts, especially in gas-rich extreme late-type field systems.

Gallagher, with Calzetti (STScI) and her colleagues, is exploring processes within starbursts. Smith (UC London) and Gallagher analyzed echelle spectra from the Herschel Telescope as well as WFPC2 images of the luminous, 60 Myr old super star cluster M82-F. The data strongly suggest a deficiency of lower mass stars in this cluster. Another puzzle in M82 comes from the de Grijs et al. WFPC2 and NICMOS survey of the post-starburst "B-region" in M82, where colors indicate the presence of compact clusters with ages of about 1 Gyr. Further studies of the M82 star clusters to determine the ages and spatial patterns are planned with a combination of HST and ground-based observations. The lifetimes of "clusters of star clusters" and the "starbursts clumps" are key factors for understanding the evolution of starbursts. Cluster ages within the favorably oriented starburst clumps of NGC 7673, being charted by Gallagher and Homeier from WFPC2 imaging, should be extended to other starbursts soon. This work builds on studies of cluster age patterns in the smaller scale starburst galaxy NGC 1569, and less extreme (or more advanced) case in NGC 4449, carried out by Gallagher in collaboration with Hunter (Lowell) and colleagues. This program contrasts with observations of starburst regions within the centers of galaxies that is led by Calzetti and her STScI group. WFPC2 results on the M83 starburst arc will be followed by a similar investigation of the hot spot nucleus of NGC 2903.

Hoessel, Bershady, Saha (NOAO), Majewski (Virginia), and Glenn (UW) have begun a long-term, deep variability survey of intermediate redshift clusters using the WIYN telescope with the MiniMosaic CCD imager. Second-epoch observations were achieved for 75% of the target fields. Photometric reductions are yielding high-quality color-magnitude diagrams for galaxies in the rest-frame vacuum ultra-violet.

Reynolds, Haffner, and Madsen used WHAM to carry out a deep search for Hα emission in the plane of M 31. They detected faint emission out to the edge of the H I disk, which extends to a radius twice that of the stellar disk. Their observations set an upper limit of 1.6×10^4 photons cm^{-2} s^{-1} on the intergalactic ionizing flux within the Local Group. They found no evidence for an ionized gaseous disk

extending beyond the H I disk.

Otte, Gallagher, and Reynolds observed the [O II] 3727/Hα line ratio in a number of edge-on spiral galaxies and found evidence that the observed variations in the line ratio are due at least in part to variations in the temperature of the emitting gas. This suggests the existence of an additional heat source within the diffuse ionized gas that overwhelms photoionization heating at densities $n < 0.1$ cm^{-3}.

Savage, Richter, Tripp (Princeton), Sembach (STScI), Howk (JHU), and Jenkins (Princeton) are pursuing a program with the Far Ultraviolet Spectroscopic Explorer (FUSE) and the Space Telescope Imaging Spectrograph (STIS) to determine the physical conditions and number density of the recently discovered low redshift intervening O VI absorption line systems seen in the spectra of QSOs. Five QSOs have been observed so far. At low redshift, these highly ionized absorbers apparently contain as much matter as galaxies. Six more QSOs will be observed with HST during 2002, and four of them with FUSE. The line of sight to PG 1259+593 is receiving special attention, since it provides information about abundances and physical conditions in the high velocity cloud Complex C as well as the IGM.

To understand the origin of the O VI systems, one must determine if the absorbers are associated with galaxies, galaxy groups, or other structures along the line of sight to each QSO. Fox and Savage have initiated a program with the WIYN 0.9m and 3.5m telescopes to determine the redshifts of galaxies in the fields of the QSOs being studied by FUSE and STIS as part of the intervening O VI absorption line program described above. Their work suggests that the O VI systems are either associated with the halos of individual galaxies or with gas in the large scale structures traced by galaxies.

Sparke and Erwin (Inst. Canarias) have been preparing 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; about a quarter of the galaxies have secondary bars and about the same fraction have inner disks. NGC 2681 may be the clearest example yet of a galaxy with three concentric bars. Inner bars appear to be oriented randomly with respect to the outer bar, and to have no association with active nuclei. Gaseous star-forming nuclear rings are also common, especially among the S0 galaxies in the sample. Three S0 galaxies appear to have purely stellar nuclear rings, with no evidence for dust or recent star formation.

Sparke and Gallagher participated in the Hubble Heritage Project's high-resolution multicolor imaging of the polar ring galaxy, NGC 4650A, with WFPC2. The unusual disk-ring structure of polar ring systems may be the remnant of a huge galactic collision, probably at least a billion years ago. They are investigating if the polar material represents the shredded remains of a young gas-rich galaxy, rather than being originally the disk of a normal spiral into which the central body has fallen.

Andrea Cox (Beloit College) spent the summer at UW-Madison. She and Sparke analyzed radio observations of polar ring galaxies to show that these are no more likely to contain an active nucleus than are normal elliptical or SO galaxies. Star formation is probably the source of the radio emission, but these are not starburst galaxies; their modest rates of starbirth will require several gigayears to exhaust the available cool gas.

Wilcots continues to focus on understanding the distribution and kinematics of H I in the environment of galaxies and the symbiotic relationship between star formation, the evolution of massive stars, and the evolution of the interstellar medium in galaxies. Nathaniel Doane has begun working on a PhD thesis seeking equivalents to the Local Bubble (the region surrounding the Sun filled with relatively low-density ISM) in other spiral galaxies.

Using WIYN, Wilcots and Thurow studied the ionized gas in the star-forming irregular galaxy NGC 4214. Their results indicate that stellar winds and steep density gradients in the cool ISM are the main drivers of the observed outflows of ionized gas. Similar work continues on Local Group dIrrs IC 1613 and IC 10. They joined with Bothun (U. Oregon) on a Fabry-Perot study of the ionized gas in NGC 1569. Wilcots & Hunter (Lowell) continue their investigation of extended H I around nearby irregular galaxies. VLA and HIPASS (H I Parkes All Sky Survey) data show that while the Local Group irregular Sextans A does have a very extended H I disk, it is incredibly smooth, suggesting that Sextans A has yet to suffer any external pertur-

bation.

Wilcots, Zabludoff (Arizona), van Gorkom (Columbia), and Mulchaey (OCIW) continue their study of the H I content of poor groups of galaxies. Results from the VLA suggest an absence of a population of intergalactic H I clouds in these groups and that the H I mass function in poor groups is extremely flat. Work continues on mapping a number of groups across the evolutionary sequence with both the VLA and the Australia Telescope Compact Array. Wilcots and Pisano, Fabian, Wakker, and Kern are searching for H I counterparts to O VI absorbtion line systems in groups of galaxies using both the VLA and the Dominion Radio Astrophysical Observatory in Penticton, B.C. A collaboration with Muehle and Klein (U. Bonn, Germany) continues work on understanding the complex relationship between massive stars and the ISM in the post-starburst galaxy NGC 1569. The high resolution H I data indicate that the recent starburst may have been triggered by a recent merger with a small gas rich system, the tidal remains of which are still visible around NGC 1569.

Undergraduates working with Wilcots include Prescott, mapping the distribution and kinematics of H I in the interacting pair of late type galaxies IC 1727 and NGC 672; Kern, working on H I in groups of galaxies; Gaal, investigating the distribution and kinematics of H I in the Magellanic spiral NGC 1507; and Swetz, modeling the mass distribution of NGC 4449.

In collaboration with David Koo (UC Santa Cruz), Kobulnicky published a spectroscopic chemical and dynamical study of high-redshift galaxies. With K. Johnson (U. Colorado), he continued investigation of the youngest phases of massive star cluster formation, and with Pisano and Bershady he completed a study comparing the 21-cm neutral hydrogen and ionized gas kinematics.

Verheijen, in collaboration with Van Gorkom (Columbia), Wilcots, Dwarakanath, and Poggianti (Raman Inst), obtained deep HI images with the VLA of galaxy cluster Abell 2192 at a redshift of 0.2. Several galaxies were detected, setting a new distance record for an observed HI emission line. These VLA data will be combined with Giant Meter Radio Telescope (in India) observations for increased sensitivity. Supplemental WIYN-Hydra spectroscopy showed a clear separation in redshift between the star forming emission line galaxies and those without emission lines, suggesting that a gas-rich clump of galaxies is falling into the main body of this cluster. The ultimate goal of this study is to understand the evolution of the cold gas content and stellar populations of gas rich galaxies falling into a cluster's gravitational potential well. Verheijen, Zwaan (U. Melborne), and Van Dokkum (Caltech) analyzed deep H I imaging VLA data of Abell 1689 at a redshift of 0.18. No direct detections of galaxies were obtained and follow-up optical spectroscopy with WIYN-Hydra will be needed to pursue a statistical detection strategy.

Verheijen, Bershady and Andersen have been analyzing the commissioning data of the new SparsePak instrument on WIYN. As a first result, the vertical stellar velocity dispersion of a nearly face-on galaxy disk has been measured at 3.5 disk scale lengths from the center. Hα velocity fields have been derived for spiral galaxies with a wide range in central disk surface brightness, significantly increasing the possibilities for studying the kinematics of low surface brightness disks.

6 WIYN, SALT, and Instruments

The Department is continuing in its international partnership in the Southern African Large Telescope (SALT). UW is the second largest partner in the consortium, after the government of South Africa. SALT, an 11-meter optical telescope modified from the Hobby-Eberly Telescope (U. Texas and collaborators) design, is located at the SAAO site in Sutherland, South Africa, but it will have a larger corrected field of view (8′), better image quality, larger pupil (11m), and an enlarged prime-focus instrument payload. Ground-breaking occurred September 1, 2000. First light is expected in 2003/2004.

UW's prime responsibility for the SALT project is the design and construction of the Prime Focus Imaging Spectrograph (Nordsieck, PI). It will specialize in very high throughput, low and medium resolution (R = 500 - 13000) spectroscopy and spectropolarimetry from 3200 to 9000Å, using an articulated camera and Volume Phase Holographic gratings and a double-etalon Fabry-Perot system. With a peak efficiency above 65% and a 3200Å efficiency above 30%, it will be unique among, or su-

perior to, existing instruments on 8-10m telescopes in the UV, in medium resolution spectroscopy, in Fabry-Perot spectroscopy, and in spectropolarimetry. Important components are being developed at Rutgers and the South African Astronomical Observatory. The instrument will be commissioned in 2004.

Anderson is the Wisconsin PI for the construction of the Cassegrain Instrument Adapter System for the WIYN Telescope, which will provide routine access for integral field devices as well as user instruments to the Cassegrain f/13.5 focus. It provides acquisition and guiding signals as well as calibration source beams. It is expected to be integrated into the WIYN system in the first half of 2002.

Bershady and Andersen have completed and installed an NSF-funded fiber integral field unit ("SparsePak") for WIYN, built at Wisconsin. The instrument is currently in commissioning phase, with observations and analyis being conducted by Veheijen, former undergraduate Harker, Bershady and Wilcots. A second integrated field unit cable ("HexPak") for the Hobby Eberly Telescope's Medium Resolution Spectrograph is completed and awaits installation. These instruments are unique in their high delivered etendue (7-10 m^2 $arcsec^2$) and spectral resolutions (up to R = 21,000). They are designed for study of the dynamics of spiral disks of external galaxies.

Under the guidance of Mathieu, the WIYN Observatory, in collaboration with a suite of partners, took over operation of the Kitt Peak 0.9m telescope. A complete renovation of the telescope drive and control system is coming to completion in Fall 2001. The telescope will be dedicated to wide-field imaging with a 2048^2 CCD and the KPNO Mosaic camera, with emphases on time-dependent astrophysics and undergraduate and graduate research programs.

An advanced low-cost star tracker, the ST5000, was built by Percival, Jaehnig, Michalski, and Gabelt of the Space Astronomy Lab. It provides pitch, yaw, and roll control for sounding rockets, and can also do a full attitude determination, without gyros, from the positions of a few stars for both sounding rockets and satellites in only a few seconds. The attitude determination algorithm was tested successfully in a rooftop test, and the unit will be flown on a sounding rocket payload in December 2001.

Nordsieck's halfwave polarimeter (HPOL) was on the 0.9m telescope at Pine Bluff Observatory. HPOL obtained 256 observations of 101 distinct targets over the course of 96 nights between Oct 1, 2000 and Sept 30, 2001. Specific areas of interest are interacting binaries, Be stars, ISM probes, AG Dra, AeBe stars, and LRV stars. Broadband polarimetric results of HPOL observations are listed on the HPOL website: www.sal.wisc.edu/HPOL.

Savage is a Co-Investigator on the Science Team of the Cosmic Origins Spectrograph (COS), to be installed in the Hubble Space Telescope in 2004 (J. Green, U. Colorado, PI.) COS is a high efficiency spectrograph designed to operate between 1150 and 3200 Å with a spectral resolution of $\sim$20,000. In the far-UV, COS is $\sim$15 times more efficient than the Space Telescope Imaging Spectrograph. COS will be used for a wide range of studies of faint galactic and extragalactic objects. Savage's studies with COS will emphasize the highly ionized gas found in QSO absorption line systems. Similar O VI absorption line systems at low redshift may contain as much matter as the entire local population of galaxies.

7 Publications

This section contains only publications in refereed journals and invited review papers at meetings.

Allen, L.E., Myers, P.C., Di Francesco, J., Mathieu, R.D., Chen, H. & Young, E., 2001, "HST/NICMOS Imaging Survey of the Ophiucus (Lynds 1688) Cluster", AJ, in press

Andersen, D.R., Bershady, M.A., Sparke, L.S., Gallagher, J.S., & Wilcots, E.M. 2001, "A Measurement of Disk Ellipticity in Nearby Spiral Galaxies", ApJ, 551, 131

Araya, E., Hofner, P., Churchwell, E., Kurtz, S. 2001, "Arecibo Observations of Formaldehyde and Radio Recombination Lines Toward Ultracompact HII Regions", ApJ, in press

Barger, A. J., 2001, "The XRB and the Census of Quasars", in Proceedings of the 20th Texas Symposium on Relativistic Astrophysics, Austin, TX, eds. H. Martel, J.C. Wheeler, American Institute of Physics Press, in press

Barger, A. J., with 7 other authors, 2001, "Su-

permassive Black Hole Accretion History Inferred from a Large Sample of Chandra Hard X-ray Sources", AJ, in press

Barger, A. J., with 5 other authors, 2001, "The Submillimeter Properties of the 1 Ms Chandra Deep Field North X-ray Sample", ApJ, 560, L23

Barger, A. J., L.L. Cowie, R.F. Mushotzky, E.A. Richards, 2001, "The Nature of the Hard X-ray Background Sources: Optical, Near-infrared, Submillimeter, and Radio Properties", AJ, 121, 662

Barnes, S.A., 2001, "An assessment of the rotation rates of the host stars of extra-solar planets" ApJ, accepted (astro-ph/0107350)

Barnes, S.A., Sofia, S. & Pinsonneault, M.H., 2001, "Disk-locking and the presence of slow rotators in young star clusters" ApJ, 548, 1071

Bershady, M. A., Jangren, A., Conselice, C. J. 2000, "Structural and Photometric Classification of Galaxies – I. Calibration Based on a Nearby Galaxy Sample," AJ, 119, 2645

Bershady, M. A. 2000, "Galaxy Form and Spectral-Type: A Physical Framework for Measuring Evolution," Astrophysics & Space Science, 269, 183

Bland-Hawthorn, J. & Reynolds, R.J. 2001, "Gas in Galaxies", in Encyclopedia of Astronomy and Astrophysics, ed. P. G. Murdin (IOP Publishing & Macmillan:London)

Bluhm, H., de Boer, K. S., Marggraf, O., Richter, P. 2001, "ORFEUS echelle spectra: Molecular hydrogen in disk, IVC, and HVC gas in front of the LMC", A&A, 367, 299

Bouche, N., Lowenthal, J.D., Charlton, J.C., Bershady, M.A., Churchill, C.W., Steidel, C.C. 2001, "H-alpha Imaging with HST + NICMOS of an Elusive Damped Ly-alpha Cloud at z = 0.6," ApJ, 550, 585

Brandt, D. M., with 16 other authors including A.J. Barger, 2001. "The Chandra Deep Field North Survey. V. 1 Ms Source Catalogs", AJ, in press

Brandt, J.C., with 17 co-authors including Savage, B.D. 2001, "Goddard High Resolution Spectrograph Observations of NGC 4151", AJ, 121, 2999

Brandt, J. C., with 17 co-authors including Savage, B. D. 2001, "AB Dor in '94. I. Hubble Space Telescope Goddard High Resolution Spectrograph Observations of the Quiescent Chromosphere of an Active Star" AJ, 121, 2173

Carr, J.S., Mathieu, R.D., & Najita, J.R., 2001, "Evidence for Residual Material in Accretion Disk Gaps: CO Fundamental Emission from the T Tauri Spectroscopic Binary DQ Tau", ApJ, 551, 454

Cassinelli, J.P., Ignace R., & Nordsieck K.H. 2001, "Determination of Magnetic Fields in the Winds of Hot Stars using the Hanle Effect", to appear in *Magnetic Fields Across the HR Diagram*, ASP conference series, eds G. Mathys, S.K. Solanki, & D. T. Wickramisinghe (San Francisco, ASP)

Cassinelli, J.P. 2001, "Observable Effects of Magnetic Fields on Hot Stars", to appear in *Magnetic Fields Across the HR Diagram"* ASP conference series, eds G. Mathys, S.K. Solanki, & D. T. Wickramisinghe (San Francisco, ASP)

Cassinelli, J. P., Miller N.A., Waldron, W. L., MacFarlane, J.J., & Cohen, D. H. 2001, "Chandra Detection of Doppler Shifted X-ray Line Profiles from the Wind of ζ Puppis (O4f)", ApJ, 554, L55

Chapman, S. C., E.A. Richards, G.F. Lewis, G. Wilson, & A.J. Barger, 2001, "The Nature of the Bright Submillimeter Galaxy Population: A Radio Pre-selected Sample with $I > 25$", ApJ, 547, L147

Cho, J., Lazarian, A., & Vishniac, E. 2001, "Simulations of MHD turbulence in a strongly magnetized medium", ApJ, in press

Clayton, G.C., Wolff, M.J., Nordsieck, K.H., & Babler B. L. 2001, "Interstellar Polarization in M31", PASP, submitted

Cole, A. A., Smecker-Hane, T. A., & Gallagher, J. S. 2000, "The Metallicity Distribution of red Giants in the Large Magellanic Cloud," AJ, 120, 1808

Conselice, C. J., Bershady, M. A., Jangren, A. 2000, "The Symmetry of Galaxies: Physical Morphology for nearby and High Redshift Galaxies," ApJ, 529, 886

Conselice, C. J., Bershady, M. A.; Gallagher, J. S., III, 2000, "Physical morphology and triggers of starburst galaxies", A&A, 354, L21

Conselice, C. J., Gallagher, J. S., & Wyse, R. F. G. 2001, "Dynamics and the Origin of Low-Mass Galaxies in the Virgo Cluster," ApJ, 559, 791

Conselice, C. J., Gallagher, J. S., & Wyse, R. F. G. 2001, "On the Nature of the NGC 1275 System", AJ, in press

Cowie, L. L., A.J. Barger, with 10 other authors, 2001, "Detecting High Redshift Evolved Gal-

axies as the Hosts of Optically Faint Hard X-ray Sources", ApJ, 551, L9

Cox, A. L., & Sparke, L. S. 2001, "Radio-Continuum Emission in Polar-Ring Galaxies", AJ, submitted

Cox, A. L., Sparke, L.S., Watson, A. L., & van Moorsel, G. 2001, "Stars and Gas in the Galaxy Pair II Zw 70/71", AJ, 121, 692

Crawford, C. S., with 6 co-authors including A.J. Barger. 2001, "Multiwavelength Observations of Serendipitous Chandra X-ray Sources in the Field of A2390", MNRAS, submitted

de Gouveia Dal Pino, E., & Lazarian, A. 2001, "Constraints on Ultra-High-Energy Cosmic Ray Acceleration in Accretion-Induced Collapse Pulsars", ApJ, in press

de Grijs, R., O'Connell, R. W., & Gallagher, J. S. 2001, "The Fossil Starburst in M82," AJ, 121, 768

Dickinson, M., with 13 co-authors including Bershady, M. A. & Conselice, C. 2000, "The Unusual Infrared Object HDF-N J123656.3+621322," ApJ, 531, 624

Dolan, C.J., & Mathieu, R.D., 2001, "The Spatial Distribution of the λ Orionis Pre-Main-Sequence Population", AJ, 121, 2124

Dolan, C.J., & Mathieu, R.D., 2001, "A Photometric Study of the Young Stellar Population throughout the λ Orionis Star-Forming Region", AJ, in press

Dolphin, A. E., with 8 co-authors including Gallagher, J. S., & Hoessel, J. G. 2001, "Deep HST Imaging of IC 1613. I. Variable Stars and Distance," ApJ, 550, 554

Erwin, P., Sparke, L. S., Vega Beltran, J. C., & Beckman, J. 2002, "Double Bars, Inner Disks, and Nuclear Rings in Barred Galaxies", in "The central kpc of starbursts and AGN", ASP Conf Ser, in press

Fosalba, P., Lazarian, A., Tauber, J., & Prunet, S., 2001, "Statistical properties of Galactic starlight polarization", ApJ, in press

Gallagher, J. S. & Grebel, E. K. 2001, "Extragalactic Star Clusters: Speculations on the Future," in IAU Symp. 207, "Extragalactic Star Clusters," eds. E. K. Grebel, D. Geisler, & D. Minniti (ASP, San Francisco), in press

Gallagher, J. S. & Matthews, L. D. 2001, "Star Formation Modes in Low-Mass Disk Galaxies," in "Modes of Star Formation and the Origin of Field Star Populations", ASP Conf Ser, eds. E. Grebel, W. Brandner, in press

Gallagher, J. S., Sparke, L. S., Matthews, L. D., Frattare, L. M., English, J., Kinney, A. L., Iodice, E., & Arnaboldi, M. 2001, "Wide Field Planetary Camera 2 Observations of the 'Polar Ring' Galaxy NGC 4650A," ApJ, in press

Gelatt, A. E., Hunter, D. A., & Gallagher, J. S. 2001, "The Star Clusters in the Irregular Galaxy NGC 4449," PASP, 113, 142

Gomez-Reves, G., Benjamin, R., & Cox, D. P. 2001, "A reexamination of the distribution of galactic free electrons", AJ, 122, 908

Greiner, J., with 8 other authors including M. Orio. 2001, "BZ Cam during its 1999/2000 optical low state", A&A, 376, 1031

Greiner, J., Schwarz, S., Zharikov, M., & Orio, M. 2000, "RX J1420.4+5334 - another tidal disruption event?", A&A, 362, L25

Greiner, J., Orio, M., & Schwartz, R. 2000, "RXJ0537-7034: The Shortest period Supersoft X-ray Source", A&A, 355, 1041

Haffner, L.M. 2001, "The Wisconsin H-Alpha Mapper Northern Sky Survey", in "Tetons 4: Galactic Structure, Stars, and the Interstellar Medium", ASP Conference Series Vol. 231, eds., C. E. Woodward, M. D. Biscay, and J. M. Shull, p. 345

Haffner, L.M., Reynolds, R.J., & Tufte, S.L. 2001, "A Map of the Ionized Component of the Intermediate Velocity Cloud Complex K", ApJ 556, L33

Handler, G., with 11 other authors including D. James, "The First Member of Two Classes of Pulsating Star: HD 209295", MNRAS, submitted

Harris, J., Calzetti, D., Gallagher, J. S., Conselice, C. J., Smith, D. A. 2001, "Young Clusters in the Nuclear Starburst of M 83," ApJS, in press

Hausen, N. R., Reynolds, R. J., Haffner, L. M., & Tufte, S. L. 2002, "Interstellar H-alpha Line Profiles toward HD 93521 and the Lockman Window", ApJ, in press

Hollis, J. M., & Churchwell, E. 2001, "Functional Molecular Groups on Interstellar Grains", ApJ, 551, 803

Hornschemeier, A. E., with 17 co-authors including A.J. Barger, 2001, "The Chandra Deep Survey of the Hubble Deep Field North Area: II. Results from the Caltech Faint Field Galaxy Redshift Survey Area", ApJ, 554, 742

Howk, J.C., & Savage, B.D. "The Multiphase Halo of NGC 891: WIYN H-alpha and BVI Imaging" 2000, AJ, 119, 644

Howk, J.C., Sembach, K. R., & Savage, B. D. "The Abundance of Interstellar Boron" 2000, ApJ, 543, 278

Howk, J. C., with 5 co-authors including Savage, B. D. 2002, "The Global Content, Distribution and Kinematics of Interstellar O VI in the LMC", ApJ, submitted

Hunter, D. A., O'Connell, R. W., Gallagher, J. S., & Smecker-Hane, T. A. 2000, "The Star Clusters in the Starburst Irregular Galaxy NGC 1569," AJ, 120, 2383

Ignace, R., Cassinelli, J. P., Quigley, M., & Babler, B. 2001 "Terminal Speeds and Ion Fractions from [Ca IV] 3.21 μm Lines in Three Single WN Stars", ApJ, 558, 771

Iodice, E., Arnaboldi, M., De Lucia, G., Gallagher, J. S., Sparke, L. S., & Freeman, K. C. 2001, "The puzzle of the polar structure in NGC 4650A," AJ, in press

James, D., with 6 other authors. 2001, "WASP - A Photometer for Planet-Hunting", MNRAS, submitted.

Jaxon E.G., Guerrero M.A., Howk J.C., Chu Y.-H., Wakker B.P., 2001, "Spectroscopic classification of 42 LMC OB stars: selection of probes for the hot gaseous halo of the LMC", PASP, 113, 1130

Johnson, K. E., Kobulnicky, H. A., Massey, P., & Conti, P. 2001, "A Sample of Clusters of Extragalactic Ultracompact H II Regions", ApJ, 559, 864

Kobulnicky, H. A., & Koo, D. C. 2000, "Near-Infrared Spectroscopy of Two Galaxies at z=2.3 and z=2.9: New Probes of Chemical and Dynamical Evolution at High Redshift", ApJ, 545, 712

Lazarian, A. 2001, "Polarization of Microwave Emission from Dust", ASP, in press

Lazarian, A., & Pogosyan, D., Vazquez-Semadeni, E., Pichardo, B. 2001, "Emissivity statistics in turbulent compressible magnetohydrodynamic flows and the density-velocity correlation", ApJ, 555, 130

Lozinskaya, T.A., Moiseev, A.V., Afanas'ev, V.L., Wilcots, E.M., & Goss, W.M. 2001, "Interstellar Medium Surrounding the WO Star in the Galaxy IC 1613: New Optical and Radio Observations", ARep, 45, 417

Lyke, J. E., with 19 other authors including M. Orio, 2001, "ISO-SWS Observations of V1425 Aquilae (Nova Aquilae 1995)", AJ, in press

Madsen, G. J., Reynolds, R. J., Haffner, L. M., Tufte, S. L., & Maloney, P. R. 2001, "Observations of the Extended Distribution of Ionized Hydrogen in the Plane of M31", ApJ Letters, in press

Maciejewski, W., Turben, P. J., Sparke, L. S., & Stone, J. M. 2002, "Gas Inflow in Barred Galaxies - Effects of Secondary Bars", MNRAS, in press

Martín-Hernández, N.L., Mathis, J. S., Churchwell, E., with 9 other authors, 2001, "ISO Spectroscopy of compact H II regions in the Galaxy: Ionization Structure and Elemental Abundance Gradient", A&A, in press

Mallouris, C., with 12 co-authors, including B. D. Savage. 2001, "Far Ultraviolet Spectroscopic Explorer Observations of Interstellar Gas toward the Small Magellanic Cloud Star Sk 108", ApJ, 558, 133

Matheson, T., with 17 co-authors including Bershady, M. A. 2000, "Optical Spectroscopy of Supernova 1993J During Its First 2500 Days," AJ, 120, 1487

Miller, N.A., Cassinelli, J.P., Waldron, W.L., MacFarlane, J.J., & Cohen, D.H. 2001, "An Emission Line Analysis of the Chandra Spectrum of the Hot Star δ Ori", ApJ, submitted

Miller, N.A., 2001, "Recent Progress in Understanding the X-ray Sources in Hot Star Winds", in "Stellar Coronae in the Chandra and XMM-Newton Era", Eds Favata, F., & Drake, J. Noordwijk, The Netherlands, ASP Conference Series

Moos, H. W., with 15 co-authors including Savage, B. D. 2002, "Abundances of Deuterium, Oxygen, and Nitrogen in the Local Interstellar Medium: First Results from FUSE", ApJ, submitted

Morgenthaler, J. P., with 8 co-authors including Anderson, C. M., & Harris, W. M. 2001, "Large Aperture [O I] Photometry of Comet Hale-Bopp: Implications for the Photochemistry of OH", submitted

Murphy, E. M., with 9 co-authors including Savage,B. D. 2000, " FUSE Spectroscopy of High-Velocity Cloud Complex C", ApJ, 538, L35

Noordermeer, E., Sparke, L. S., & Levine, S. E. 2001, "The Kinematics of Lopsided Galaxies", MNRAS, in press

Nordsieck, K. H. 2001, "New Circumstellar

Magnetic Field Diagnostics", to appear in "Magnetic Fields Across the HR Diagram", ASP conference series, Eds G. Mathys, S.K. Solanki, & D. T. Wickramisinghe (San Francisco, ASP)

Nossal, S. Roesler, F.L., Reynolds, R.J., Haffner, L.M., Tufte, S., Bishop, J., & Percival, J. 2001. "Geocoronal Balmer-alpha Intensity Measurements Using the WHAM Fabry-Perot Facility", JGR 106, 5605

Oegerle, W.R., with 7 co-authors including Savage, B.D. 2000. "FUSE Observations of the Galactic and Intergalactic Medium Towards H1821+643", ApJ, 538, L23

Orio, M., with 6 co- authors. 2001, "The X-ray emission from Nova V382 Velorum: II. The supersoft component observed with BeppoSAX", ApJ, submitted

Orio, M., Covington, J., & Ogelman, H. 2001 - "The observations of classical and recurrent novae in the ROSAT data base", A&A, 373, 542

Orio, M., with 9 co-authors. 2001, "The X-ray emission from Nova V382 Velorum: I. The hard X-ray emission observed with BeppoSAX", MNRAS, 326, L13

Oskinova, L. M., Ignace, R., Brown, J. C., & Cassinelli, J. P. 2001, "Modeling X-ray Variability in the Structured Atmospheres of Hot Stars", A&A, 373, 1009

Otte, B., Reynolds, R. J., Gallagher, J. S. 2001, "Emission Line Ratios and Variations in Temperature and Ionization State in the Diffuse Ionized Gas of Five Edge-on Galaxies", ApJ, submitted

Otte, B., Reynolds, R. J., Gallagher, J. S., & Ferguson, A. M. N. 2001, "Searching for additional heating - [OII] emission in the diffuse ionized gas of NGC891, NGC4631 and NGC3079," ApJ, in press

Pankonin, V., Churchwell, E., Watson, C., Bieging, J. 2001, "A Search for the Earliest Stages of Massive Protostars", ApJ, in press

Peeters, E., Churchwell, E., Mathis, J. S., with 10 other authors, 2001, "An ISO Spectral Catalogue of Compact HII Regions", A&A, in press

Pisano, D. J., Kobulnicky, H., Guzmán, R., Gallego, J., & Bershady, M.A. 2001, "The Gas Content and Kinematics of Nearby Blue Compact Galaxies: Implications for Studies at Intermediate and High Redshift", AJ, 122, 1194

Platais, I., with 7 co-authors including S. A. Barnes, 2001, "WIYN Open Cluster Study. VII. NGC 2451A and the Hipparcos Distance Scale", AJ, 122, 1486

Pisano, D.J., & Wilcots, E.M. 2000, "Companions and Interactions in the NGC 6946 System", MNRAS, 319, 821

Proffitt C. R., & Quigley M. F. 2001, "Boron Abundances in Early B Stars: Results from the B III Resonance Line in IUE Data", ApJ, 548, 429

Quigley, M. F., Cassinelli, J. P., & Ignace R. 2001, "Constraints from IR data on the Velocity Law and Clumpiness in the wind of WR 136", ApJ, submitted

Reynolds, R.J. 2002, "The Galaxy's Atmosphere", Scientific American, in press

Reynolds, R.J. & Haffner, L.M. 2001, "Mapping the Galactic Free-Free Foreground via Interstellar H-alpha Emission", proceedings of IAU Symp. No. 201, "New Cosmological Data and the Values of the Fundamental Parameters", eds. A. Lasenby and A. Wilkinson, in press

Reynolds, R.J., Sterling, N., Haffner, L.M., & Tufte, S.L. 2001, "Detection of [N II] 5755 Emission from Low density Ionized Interstellar Gas", ApJ 548, L221

Reynolds, R. J., Sterling, N. C., & Haffner, L. M. 2001, "Detection of a Large Arc of Ionized Hydrogen Far Above the Cas OB6 Association: A Superbubble Blowout into the Galactic Halo?", ApJ 558, L101

Rhode, K.L., Herbst, W. & Mathieu, R.D., 2001, "Rotational Velocities of Pre-Main-Sequence Stars in the Orion Nebula Cluster", ApJ, in press

Richter, P. 2001, "Molecular Gas in the Galactic Halo and Beyond", in "Gaseous Matter in Galaxies and the Intergalactic Space", eds. R. Ferlet et al., PASP Conference Series, in press, astro-ph 0109191

Richter, P., Savage, B.D., Wakker, B.P., Sembach, K.R., Kalberla, P.M.W. 2001, "The FUSE Spectrum of PG 0804+761: A Study of Atomic and Molecular Gas in the Lower Galactic Halo and Beyond", ApJ, 549, 281

Richter, P., with 7 co-authors including Wakker, B., & Savage, B. D.. 2001, "The Diversity of High- and Intermediate-Velocity Clouds: Complex C versus IV Arch", ApJ, 558, 133

Richter, P., with 7 co-authors including Wakker, B.P. & Savage, B.D. 2001, "The Diversity of High-

and Intermediate-Velocity Clouds: Complex C versus IV Arch", ApJ, 559, 318

Richter, P., Sembach, K.R., Wakker, B.P., Savage, B.D. 2001c, "Molecular Hydrogen in High-Velocity Clouds", submitted to ApJ Letters

Savage, B.D. 2001, "Ultraviolet Absorption Line Studies of the Galactic Interstellar Medium with the Goddard High Resolution Spectrograph", in "A Decade of HST Science ", (Cambridge: Cambridge Univ. Press) , in press

Savage, B.D. 2002, "Early Ultraviolet Spectroscopy from Space", in "The Century of Space Science", eds. J. Bleeker, J. Beiss, M.C.E. Huber (Dordrecht: Kluwer Academic Press), in press

Savage, B.D., et al. 2000, "FUSE Observations of O VI Absorption in the Galactic Halo", ApJ, 538, L27

Savage, B. D., Meade, M., & Sembach, K. R. 2001, "IUE Observations of the Moderately and Highly Ionized Interstellar Medium Toward 164 Early Type Stars", ApJS, in press

Savage, B.D., Sembach, K.R., Tripp, T.M., Richter, P. 2001, "FUSE and STIS Observations of Intervening O VI Absorption Line Systems in the Spectrum of PG 0953+415", ApJ, in press

Savage, B.D., Sembach, K.R., & Howk, J. C. 2001, "STIS and GHRS Observations of Warm and Hot Gas Overlying the Scutum Supershell", ApJ, 547, 907

Savage, B.D. , Wakker, B. et al. 2000, "The Hubble Space Telescope Quasar Absorption Line Key Project XV. Milky Way Absorption Lines", ApJS, 129, 563

Sembach, K.R., Savage, B.D., et al. 2000, "FUSE Observations of O VI Absorption in High Velocity Clouds", ApJ, 538, L31

Sembach, K. R., Howk, J. C., Savage, B. D., Shull, J. M. 2001, "FUSE Observations of Atomic Abundances and Molecular Hydrogen in the Leading Arm of the Magellanic Stream", AJ, 121, 992

Sembach, K. R., Howk, J. C., Savage, B. D., Shull, J. M. & Oegerle, W. R. 2001, " Far Ultraviolet Spectroscopy of the Intergalactic and Interstellar Absorption Toward 3C 273", ApJ, Nov 10 issue

Shelton, R. L. with 24 co-authors including Savage, B. D. 2001, "Observations of O VI Emission from the Diffuse Interstellar Medium", ApJ, 560, 730

Shull, J. M. with 9 co-authors including Savage, B. D. 2000, "FUSE Observations of Diffuse Interstellar Molecular Hydrogen", ApJ, 538, L73

Shull, J.M. with 8 co-authors including Savage, B.D. 2000, " FUSE Observations of the Low Redshift Ly b Forest", ApJ, 538, L13

Smecker-Hane, T. A., Cole, A. A., Gallagher, J. S. 2001,"The Star Formation History of the Large Magellanic Cloud," ApJ, in press

Smith, L. J. & Gallagher, J. S. 2001, "M82-F: A Doomed Super Star Cluster?", MNRAS, 326, 1027

Snow, T.P. with 12 co-authors including Savage, B.D. 2000, " FUSE Observations of H2 in the Translucent Interstellar Cloud Toward HD 73882", ApJ, 538, L65

Sparke, L. S. 2001, "What can polar rings tell us about the shapes of dark matter halos?", 2001, in "Yale Dark Halos" meeting, ASP Conf Ser, in press

Stanimirovic, S., & Lazarian, A. 2001, "Velocity and density spectra of the Small Magellanic Cloud", 551, L53

Stassun, K.G., Mathieu, R.D., Vrba, F.J., & Henden, A. 2001, "A 10 Micron Search for Truncated Disks Among Pre-Main-Sequence Stars with Photometric Rotation Periods," AJ, 121, 1003

Stassun, K. G., van den Berg, M., Mathieu, R.D., & Verbunt, F., 2001, "Photometric Variability in the Open Cluster M67. II. General Survey", A&A, in press

Steffen, A., Mathieu, R.D., with 6 co-authors. 2001, "A Dynamical Mass Constraint for Pre-Main-Sequence Tracks: The Binary NTT 045251+3016", AJ, 122, 997

Sterling, N., Savage, B.D., Richter, P., Fabian, D., Sembach, K.R. 2001, "FUSE Observations of O VI Overlying the Scutum Supershell", ApJ, in press

Tolstoy, E., Irwin M. J., Cole, A. A., Pasquini, L., Gilmozzi, R., & Gallagher, J. S. 2001, "Using the Ca II Triplet to Trace Abundance Variations in Individual Red Giant Branch stars in Three Nearby Galaxies," MNRAS, 327, 918

Trentham, N., Tully, R.B., & Verheijen, M.A.W., 2001, "The anomalous properties of Markarian 1460", MNRAS, 325, 1275

Trentham, N., Tully, R.B., & Verheijen, M. A. W., 2001, "The Ursa Major cluster of galaxies - III. Optical observations of dwarf galaxies and the lu-

minosity function down to M(R)=-11", MNRAS, 325, 385

Tripp, T. M., & Savage, B.D. 2000, "O VI and Multicomponent HI Absorption Associated with a Galaxy Group in the Direction of PG0953+415: Physical Conditions and Baryonic Content", ApJ, 542, 42

Tripp, T. M., Savage, B.D. & Jenkins, E. B. 2000, "Intervening O VI Quasar Absorption Systems at Low Redshift: A Significant Baryon Reservoir", ApJ, 534, L1

Tully, R.B., Somerville, R.S., Trentham, N., & Verheijen, M.A.W., 2001, "Squelched Galaxies and Dark Halos", ApJ, submitted

Tumlinson, J., with 21 co-authors including Savage, B. D. 2002, "A FUSE Survey of Interstellar Molecular Hydrogen in the Small and Large Magellanic Clouds", ApJ, in press

Van den Berg, M., Orosz, J., Verbunt, F., & Stassun, K. 2001, "The blue straggler S 1082: A triple system in the old open cluster M 67," A&A, 375, 375

Van den Berg, M., Stassun, K., Verbunt, F., & Mathieu, R.D. 2001, "Photometric Variability in the Old Open Cluster M67. I. X-ray Sources," A&A, accepted

Verheijen, M.A.W., 2001, "The Ursa Major cluster of galaxies - V. HI Rotation Curve Shapes and the Tully-Fisher Relations", ApJ, in press

Verheijen, M.A.W., & Sancisi, R., 2001, "The Ursa Major cluster of galaxies - IV. HI synthesis observations", A&A, 370, 765

Wakker B.P., & Mathis J.S., 2000, "Dependence of gas phase abundances in the ISM on column density", ApJ, 544, L107

Waldron, W. L., & Cassinelli, J. P., 2001, "Chandra Discovers a Very High Density X-ray Plasma on the O-star ζ Orionis", ApJ, 548, L45

Wilcots, E.M., & Thurow, J.C. 2001, "WIYN Integral Field Unit Study of the Kinematics of the Ionized Gas in NGC 4214", ApJ, 555, 758

Wilcots, E.M., Zabludoff, A., van Gorkom, J., & Mulchaey, J. 2001, "The H I Content of Poor Groups of Galaxies I: NGC 2563 and NGC 5846", ApJ, submitted

Wilson, G. L., L. L. Cowie, A. J. Barger, & D. J. Burke. 2001, "Star Formation History Since z=1 as Inferred from Rest-frame Ultraviolet Luminosity Density Evolution", AJ, submitted

Wood, K., Wolk, S.J., Stanek, K.Z., Leussis, G., Stassun, K.G., Wolff, M., & Whitney, B. 2000, "Optical Variability of the T Tauri Star HH 30 IRS," ApJ, L542, 21

Yi, S., with 6 co-authors including S. A. Barnes, 2001, "Towards better age estimates for stellar populations: the Y^2 isochrones for Solar mixture" ApJ, accepted (astro-ph/0104292)

Zinnecker, H. & Mathieu, R.D., 2001, eds., Proceedings of IAU Symposium 200 "The Formation of Binary Stars" (ASP: San Francisco)

Zwaan, M.A., Van Dokkum, P.G., & Verheijen, M.A.W., 2001, "Hydrogen 21-Centimeter Emission from a Galaxy at Cosmological Distance", Science, 293, 1800