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This description covers the Department's activities from October 1, 2002, through September 30, 2003. It is condensed from a longer version at www.astro.wisc.edu that also lists published papers and invited reviews.

The Department continued its activities in the Southern African Large Telescope (SALT) project. Nordsieck (PI) is responsible for the construction of the Prime Focus Imaging Spectrograph, one of the major instruments (see §6). Churchwell continued as PI of the GLIMPSE, Space Infrared Telescope Facility (SIRTF) Legacy Science project. It will produce a near-infrared imaging survey of the inner Galactic plane. Other major thrusts include studies of star formation, extragalactic structure and evolution, properties of interstellar and intergalactic gas, and studies of magnetized turbulence.

WIYN refers to the Wisconsin-Indiana-Yale-NOAO 3.5-m telescope on Kitt Peak. WHAM refers to the Wisconsin H-Alpha Mapper, a sensitive Fabry-Perot spectrometer operating on Kitt Peak.

1. PERSONNEL

Ellen Zweibel joined the faculty in January 2003 as Professor, with a joint appointment in Physics. She will pursue a research program in plasma astrophysics. Other faculty are Professors Anderson, Cassinelli, Churchwell, Gallagher, Hoessel, Mathieu, Nordsieck, Reynolds, Savage, and Sparke (Chair), Associate Professors Bershady and Wilcots, and Assistant Professors Barger and Lazarian. Bless and Mathis are Professors Emeriti residing in Madison. R. Benjamin is Assistant Professor in Madison and UW-Whitewater. Percival is Scientist; Wakker, Associate Scientist; Burgh, Haffner, and Indebetouw, Assistant Scientists. Former staff members now holding faculty positions are Harris (U. Washington), Stassun (Vanderbilt) and Ignace (East Tennessee State). Cho is Research Associate at CITA; F. Heitsch joined the staff of the IfAA in Munich; K. Johnson is an NSF Postdoctoral Fellow. N. Lehner, B. Pichardo and R. Safeko joined the staff; H. Bryce returned to Glasgow University. M. Orio is Visiting Associate Scientist. Marché served as Lecturer.

Asst. Prof. Amy Barger was awarded one of 15 five-year David and Lucile Packard Fellowships for Science and Engineering, as well as an NSF CAREER award. She was also awarded the Newton Lacy Pierce Prize of the AAS for outstanding observational research. Reynolds and Cox (Physics) were honored at the meeting ''How Does the Galaxy Work?: A Galactic Tertulia with Don Cox and Ron Reynolds,'' held in Granada, Spain. (A ''tertulia'' is a group informal discussion on a particular subject.)

2. SOLAR SYSTEM ASTRONOMY

Anderson and colleagues continued studying gases in several comets, especially water production rates and intensities of rotation-vibration bands of the NH_2 radical. Madsen, Reynolds, and Moseley (GSFC) are using WHAM to measure the Doppler shifts of a scattered solar Mg I line in Zodiacal light to determine the kinematics of interplanetary dust.

3. STARS AND OUTFLOWS

Cassinelli and colleagues have developed the Magnetically Torqued Disk (MTD) model for Be stars. The magnetic field from the star both torques the outflowing wind and channels it toward the equatorial region. The team is also studying X-rays in hot stars, especially τ Sco. It seems to have infalling clumps of material that might produce the emission from bow shocks.

Mathieu and students Hole and Meibom continued their program 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 velocity measurements of $\sim$3800 stars in five clusters. A team including Mathieu completed the first deep astrometry study of NGC 188. Mathieu, Meibom & Dolan completed their study of the binary eccentricity distribution in NGC 188. Comparison with other clusters clearly demonstrates ongoing main-sequence tidal circularization. Mathieu and collaborators identified a new breed of star, ''subsubgiants,'' that lie below the subgiant branch in the open cluster M67. Their low luminosities are puzzling. They may be the products of close stellar encounters involving binaries in the cluster environment. Using the Keck Observatory, Mathieu and colleagues observed CO fundamental and overtone transitions, extremely sensitive tracers of circumstellar gas in both young binaries and single stars. The emission region seems to include the equivalent of the terrestrial planet region of our solar system. Mathieu and Jensen completed their polarization study of young binary and multiple stars in order to determine the relative orientation of the circumstellar disks. Tidal torques are able to align the circumstellar disks in the wide binaries but not the circumbinary disks in multiple systems. Stassun and Mathieu completed their study of a pre-main-sequence (PMS) eclipsing binary system in Orion that provides an empirical calibration for, and test of, PMS stellar evolutionary models. They also completed a Chandra study of X-ray emission from PMS stars in Orion. Meibom's dissertation work involves studying tidal interactions in close binaries in several open clusters.

Indebetouw and K. Johnson identified a near-IR counterpart to a massive proto-star, one of only a few with evidence of a circumstellar accretion disk.

4. THE INTERSTELLAR MEDIUM

In a paper to appear in the ApJS, Haffner, Reynolds, Madsen, Jaehnig, and Percival, with Tufte (Lewis and Clark College) have summarized the WHAM northern sky Hα survey.

In addition to leading the GLIMPSE team, Churchwell has led programs centered on two main themes. The first is accurate distances and resolution of distance ambiguities of ~150 H II regions associated with massive star formation regions in the inner Galaxy, using H_2CO or HI 21 cm absorptions and H110α emission. This is preparation for the GLIMPSE program that will elucidate the structure of the inner Galaxy. The second theme is the physical nature of ultra- and hyper-compact H II regions and the physics of massive star formation. X-rays identify the ionizing stars in several ultracompact H II regions. WIYN provided infrared observations of jets, HH objects, massive protostars, and radio recombination line emissions. Colleagues included Gómez, Sewilo, and Indebetouw. Ignace and Churchwell have shown that a hierarchically clumped ionized circumstellar nebula can produce a power law flux density.

Lazarian, with Cho (now at CITA) and students Esquivel and Yan, investigated properties and implications of magnetic turbulence in interstellar gas. They continued studying a new regime of MHD turbulence that they had discovered earlier. It emerges in the partially ionized gas below the scale at which viscosity by neutrals damps hydrodynamic eddies. They investigated the resumption of the ionic cascade after the decoupling of neutrals and ions. They obtained properties of compressible MHD turbulence, including higher order statistics, and showed that fast modes are the primary agent for scattering cosmic rays and accelerating dust grains. They undertook analytical and numerical studies of the techniques that are used to compare MHD turbulence in computer simulations with observations of the ISM.

Gómez (thesis supervisor Cox, Physics) produced 3D simulations of the ISM flows in a spiral arm, including the magnetic field.

The WHAM group led by Reynolds is active. Haffner studied various emission lines from diffuse ionized features highlighted by the WHAM Northern Sky Survey, including the large, diffuse ionized region around the high-latitude B-star α Vir (Spica). Madsen and Reynolds have used WHAM to detect Hα and Hβ emission out to the tangent point in the inner Galaxy, characterizing the extinction along the lines of sight in the inner Galaxy for the first time with optical observations.

Savage, with local colleagues Lehner, Wakker, Meade, and Fox, plus others, used the Far Ultraviolet Spectroscopic Explorer (FUSE) and HST for a variety of projects. The team completed their survey of O VI absorption in and near the Milky Way in the spectra of extragalactic objects and two distant halo stars. The Milky Way's thick disk and hot halo are revealed. FUSE also observed H_2 absorption in many Galactic halo clouds. The team studied C IV, N V, and O VI surrounding the high-velocity cloud (HVC) Complex C. They found evidence for the production of these ions at the interfaces between the neutral HVC and the surrounding medium. They also considered the effect of non-solar relative elemental abundance patterns on the production of high ions in radiatively cooling gas flows. The team completed a FUSE survey of the local interstellar medium (LISM). The photoionization conditions vary significantly in the Local Bubble (LB) and the LISM. A FUSE and Space Telescope Imaging Spectrograph (STIS) survey of C II* absorption lines toward ~50 sightlines shows that cooling from [C II] seems to be different in high-velocity clouds as compared with lower velocity gas.

Zweibel is interested in the generation, evolution, and effects of galactic magnetic fields. With colleagues Heitsch and others, she studied magnetic reconnection, magnetic diffusion in a turbulent, weakly ionized medium, cosmic ray interaction with turbulence, shear flow instabilities in weakly ionized gas, and the far-IR emission from dust grains in a clumpy molecular cloud. She is also considering the evolution of magnetic fields on neutron stars.

5. EXTRAGALACTIC ASTRONOMY

Barger is making a census of the energy-producing galaxies and supermassive black holes in the Universe, using observations at X-ray, optical, submillimeter, and radio wavelengths. She led a team on a ground-based study of the X-ray sources detected in the deepest X-ray image of the sky ever taken. She and her collaborators have determined the evolution of the X-ray luminosity function. With student Steffen, along with others, she is using a wide-field, moderately deep Lockman Hole Chandra X-ray survey to learn about the X-ray sources that contribute the most to the X-ray background.

Bershady and colleagues have continued ground-based and HST surveys of intermediate redshift luminous compact blue galaxies (LBGs), focusing on the spatial distribution of spectroscopic properties as well as photometric estimates of the stellar masses. They make direct, kinematic estimates of the masses of galaxy disks. Using WIYN, Hoessel and Bershady continue their deep variability survey of intermediate redshift clusters. Glenn and Crawford are using these data for their thesis studies of the red-sequence galaxy population and cluster analogues of LBGs, respectively. Crawford and Bershady have successfully designed, purchased, calibrated, and commissioned a new narrow-band filter set as a follow-up to this broad-band cluster imaging survey.

Gallagher continued various collaborative studies of measuring properties of galaxies, especially dwarfs and their populations in clusters of galaxies. He and various colleagues studied star formation histories and other properties of many objects, including the ultraluminous merger starburst NGC 6240, the Seyfert galaxy Perseus A and the surrounding cluster material, the dwarf irregulars Sextans A and IC 1613, Virgo Cluster galaxies, and others. Gallagher, Madsen, Reynolds, and others used WHAM to search for warm ionized gas in the Draco and Ursa Minor dwarf spheroidal galaxies.

K. Johnson has continued her work studying the formation of extragalactic star clusters with observations in the infrared and radio regimes in order to examine the role of metal abundance in cluster formation and to gain insight into how the properties of massive star formation scale from individual ultracompact H II regions to super star clusters.

Savage and colleagues, using 0.1″ resolution HST images of the edge-on spiral galaxy NGC 4217, found extraplanar ($z > 0.4$ kpc) dust structures viewed in absorption against the background stellar light of the galaxy. This program will be extended to other objects. A team with Savage has analyzed high resolution FUSE and HST/STIS spectra of the IGM absorbers along the line of sight to the bright QSO PG 1259 +593 ($z_{em} = 0.478$), mainly to study the 10^5 to 10^6 K IGM. There are 8-16 O VI systems per unit redshift, suggesting that intergalactic O VI absorbers contain an important fraction of the baryonic mass in the low-redshift universe. A number of very broad Lyα lines are detected, some apparently revealing absorption by hot intergalactic HI.

The survey of early-type barred galaxies of Erwin (IAC) and Sparke shows that about a quarter have secondary bars. About the same fraction have inner disks. Sparke and other collaborators continued work on polar ring galaxies. Despite their curious nature, these objects closely follow the Tully-Fisher relation for normal disk systems, with deviations explained by the shape of the galaxy's dark halo. Pichardo and Sparke, collaborating with L. Aguilar, are studying the orbits that gas may follow in disks around the stars of an eccentric binary.

Pisano (CSIRO), Wilcots, and Wakker finished VLA and DRAO HI observations of two nearby galaxy groups selected to surround a background AGN, thereby sampling most phases of the intergalactic medium. No free-floating starless HI clouds were found. Wakker combed the FUSE sample for Lyman line absorption at velocities for the very nearby universe. HI is detected within 200 km/s and 400 kpc toward 19 of 24 nearby galaxies. In only 10 cases are the data sufficiently good to also check for OVI; in 9 it is found.

6. SALT, WIYN, AND INSTRUMENTS

SALT: The Southern African Large Telescope (SALT) is an 11-meter optical telescope modified from the Hobby-Eberly Telescope design, located in Sutherland, South Africa. It is on track for engineering first light at the end of 2003, with commissioning at the end of 2004. Nordsieck (PI) and Burgh are building the Prime Focus Imaging Spectrograph (PFIS), the primary first-light instrument. Most of the optics have now been fabricated. PFIS is currently scheduled to be shipped to South Africa in September 2004 to begin commissioning activities.

The GLIMPSE Legacy Science program on SIRTF (Churchwell, PI) Launched on 25 Aug. 2003, all SIRTF instruments seem to be performing close to expectations. GLIMPSE is a survey on both sides of the Galaxy center from $|b| = 10° - 65°, l = \pm 1°$. A summary of the GLIMPSE Legacy Science program is in Benjamin *et al.* (2003, PASP, 115, 953).

The WIYN Cassegrain Instrument Adapter System (Anderson, PI) is an interface providing acquisition, guiding and calibration at the modified, straight-through Cassegrain focus. It is available as a facility instrument.

The WIYN Bench Spectrograph upgrade (Bershady, PI) will make gains of factors of 3 in throughput. A successful preliminary design review has been concluded. The time scale is about two years.

The halfwave polarimeter (HPOL), Nordsieck, PI, resided on the 0.9 m telescope at Pine Bluff Observatory. HPOL obtained 164 observations of 89 distinct targets over the course of 75 nights during the period covered. Broadband polarimetric results of HPOL observations are at www.sal.wisc.edu/HPOL.

Star Tracker, Percival, PI. The ST5000 tracker provides pitch, yaw, and roll control for sounding rockets, but can also do a full attitude determination without gyros for both sounding rockets and satellites. On an air bearing test it delivered a performance superior to the current sounding rocket tracker. A final qualification flight will occur in January 2004.

Spatial Heterodyne Spectrometer. Reynolds and Jaehnig, with Roesler and Mierkiewicz (Physics) and Harlander (St. Cloud State), have successfully completed the testing of the SHS for the study of diffuse [O II] 372.7 nm emission at high Galactic latitudes.

The Cosmic Origins Spectrograph (COS) (J Green, U. Colorado, PI) Savage is Co-I on the science team. Installation on the HST has been delayed because of the Columbia shuttle re-entry disaster, but thermal-vacuum and science verification testing was successful.

7. MISCELLANEOUS

Linkages between astrophysical and laboratory plasmas will be strengthened by the establishment at UW of the Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas, involving senior scientists from UW, U. Chicago, Princeton, and other institutions. Zweibel is on the Steering Committee and a topical leader for studies in magnetic reconnection.

This summer, UW-Madison hosted its second REU (Research Experiences for Undergraduates) program (Benjamin, director). Fourteen students participated.

Mathieu and his colleagues launched the Center for Integration of Research, Teaching, and Learning (CIRTL) in January 2003. CIRTL, an NSF Center for Learning and Teaching, is a 5-yr project in collaboration with Michigan State University and Pennsylvania State University, with a mission to produce a future science, technology, engineering and mathematics college faculty that is effective in both research and teaching.