University of Illinois
Department of Astronomy
Urbana, Illinois 61801

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This report covers activities of the department for the period 1 September 1999 - 31 August 2000.

1. PERSONNEL

During this report year the scientific staff consisted of the faculty: You-Hua Chu, Richard M. Crutcher (Chair), Hélene R. Dickel, John R. Dickel, Brian Fields, Charles Gammie, Icko Iben, Jr. (retired December 1999 as Distinguished Professor Emeritus), James B. Kaler, Fred K. Lamb, Susan A. Lamb, Kwok-Yung Lo, Peter McCullough, Margaret Meixner, Telemachos Ch. Mouschovias, Michael L. Norman, Edward C. Olson (emeritus), Sidney Rosen (emeritus), Ed Seidel, Stuart L. Shapiro, Larry L. Smarr, Lewis E. Snyder, Edmund C. Sutton, George W. Swenson (emeritus), Laird A. Thompson, William D. Watson, Ronald F. Webbink, Kenneth M. Yoss (emeritus); postdoctoral research associates: Alan Calder, Jose Miguel Girart, Robert Gruendl, Martin Guerrero, Damien Guillaume, Sungeun Kim, David Mehringer, Alexei Razoumov, Ronak Shah, Angela Speck, Scott Teare (resident at Mt. Wilson Observatory with UnISIS project), and research support staff: Rami Dass, Idan Ginsberg, Grant Miller, Raymond Plante, Ramprasad Rao, Harold Ravlin, and Douglas Roberts.

Research in theoretical astrophysics and general relativity and related areas was also carried out by members of the physics department: Thomas Baumgarte, G. Baym, V. J. Pandharipande, D. G. Ravenhall (emeritus), and Masara Shibata. The department hosted visits during the reporting year from Valentin Bujarrabal and Arancha Castro-Carrizo (Observatorio Astronomico Nacional, Spain), Adeline Caulet (France), Francis Lovas (NIST), Maria Jacqueline Vasconcelos (Universidade de Sao Paulo), and Dmitri Wiebe (Institute of Astronomy, Pyatnitskaya, Russia).

Twenty-six graduate students were enrolled during the 1999-2000 academic year and S.-Y. Liu, W. Manchester and J. Veal received Ph.D. degrees. Office support staff included Willa Hollis, Sandie Osterbur, and Deana Pettigrew under the guidance of the Administrative Assistant, Carol Stickrod.

During the past year, H. Dickel was a Visiting Astronomer at ASTRON (the Netherlands Foundation for Research in Astronomy) and a Visiting Professor at the Astronomical Institute ''Anton Pannekoek'' at the University of Amsterdam. J. Dickel was on sabbatical at ASTRON. L. Snyder was on sabbatical during Spring 2000.

2. FACILITIES

2.1 Campus Computation

The Astronomy Department has access to the facilities of the National Center for Supercomputing Applications (NCSA) at the University of Illinois, both through a national peer review allocation mechanism and a time allocation to the University of Illinois community. The major facility is a 1536-processor SGI Origin 2000 that provides up to about 0.8 teraflop of computer power. Other systems include an Intel 256-processor NT cluster and both IA-32 and IA-64 Linux clusters; the Linux clusters are currently being upgraded to provide 2 teraflops of computing power. Also available are advanced visualization systems such as a CAVE virtual environment and a multi-megapixel projector display wall.

2.2 Laboratory for Astronomical Imaging

The Laboratory for Astronomical Imaging (LAI) is a unit within the Astronomy Department through which the University of Illinois participates in the Berkeley-Illinois-Maryland Association (BIMA) Array consortium. Faculty personnel associated with the LAI were L. E. Snyder (director), R. M. Crutcher, H. Dickel, K.-Y. Lo (On leave as Director, ASIA, Taipei, Taiwan), M. Meixner, and E. C. Sutton. During this period, F. J. Lovas joined the LAI as visiting professor to update the Lovas List of Recommended Rest Frequencies for Observed Interstellar Molecular Microwave Transitions. R. Shah joined the LAI as a postdoctoral research associate. J. M. Girart continued on as a postdoctoral research associate. Graduate students during this period were P. Cortes, D. Fong, D. Friedel, S.-P. Lai, S.-Y. Liu, M. Lenigan, and A. Remijan. The senior research programmer was H. Ravlin and the LAI administrative secretary was D. Pettigrew. The BIMA Array scheduler was E. C. Sutton.

BIMA Array observing time is awarded on a competitive basis. Electronic observing proposal submission has been initiated. Information can be found on the WWW at http://www.astro.uiuc.edu/bima/call_for_proposals.html, http://www.astro.uiuc.edu/ bima/proposal/WhatsNew.html, and http://www.astro.uiuc.edu/bima/proposal/instructions.html.

2.2.1 The Combined Array for Research in Millimeter Astronomy, or CARMA

Plans are underway for combining the BIMA Array with the Caltech Owens Valley Array on a new high site with operations starting in 2004. The BIMA Array consists of ten 6-meter wide antennas and the Caltech array consists of six 10-meter wide antennas. CARMA, the array of combined telescopes, will be at least ten times more powerful than either of the original arrays.

2.3 Mt. Laguna Observatory

The UI Astronomy Department operates a 1-m telescope at Mt. Laguna Observatory jointly with San Diego State University. Operations during the past year were routine with little change in the instrumentation. Continuing in successful operation are (1) a 2048x2048 Loral CCD camera and (2) a

256x256 NICMOS-3 array camera, both of which continue to provide excellent wide-field imaging capabilities especially with the f/7.6 telescope secondary.

2.4 Optical Instrumentation

Progress continued toward the commissioning of the NSF-funded UnISIS project (University of Illinois Seeing Improvement System), a laser guided adaptive optics system being installed at the Mt. Wilson 100-inch telescope. Personnel currently involved in the project include L. Thompson (PI) and Scott Teare, research associate (resident at Mt. Wilson Observatory).

The projection of the 351 nm Rayleigh laser guide star is routine at 167 Hz (with the final aim of running the laser at 333 Hz). The laser guide star optical projection system transfers the laser light from the basement of the 100-inch telescope and up the Coude optics train for a final focus at 18 km altitude. Closed-loop performance of the adaptive optics system was demonstrated on natural stars, although no science data has been collected with this sub-system as the aim is to use the natural guide star system primarily to achieve closed-loop calibration of the laser guide star wave front signal. The major achievements in the past year includes: re-working of the 100-inch telescope aluminization chamber to increase the telescope's UV reflectivity, achieved 5 e- rms read-noise on the laser guide star wave front sensor, doubled the laser return flux by replacing a single-leg Pockels cell with a double-leg Pockels cell (electronic shutter for the laser guide star wave front sensor), successful detection of the laser guide star pupil image at the final wave front sensor.

2.5 Infrared Instrumentation

Teare is the PI for the development of a low resolution, near infrared, grism spectrometer for the Near-InfraRed IMaging (NIRIM) camera used at the Mount Laguna and Mount Wilson Observatories to be completed early in 2001.

3. RESEARCH

3.1 Stars

3.1.1 Binary Stars

E. Olson and P. Etzel (San Diego State) continued studying properties and accretion disks in long-period Algols. Using the Wilson Eclipsing Binary Computer Model (updated with ATLAS9 fluxes convolved with filter transmissions, Al reflections, atmospheric transmission and PMT response), simultaneous Iybv solutions were obtained for RX Gem. These solutions are free of third light. This binary is demonstrably semi-detached and yielded a fairly good photometric mass ratio. Absolute binary properties followed from our loser velocity curve. The ultraviolet solution yielded significant third light from disk Balmer continuum emission. Such light gives a new handle on disk properties, in addition to H-α emission profiles.

Olson upgraded opacities and integration routines in his non-LTE model of Algol accretion disks, and is exploring disk structure in RX Gem. Preliminary results account for both H-α emission profiles and disk continuum emission.

Using the upgraded Wilson program, new solutions were obtained for S Cnc and DN Ori. Slight underfillings of the loser Roche lobes were verified. A new solution (with improved ephemeris) was obtained for RW Per. Ultraviolet solutions of DN Ori and RW Per also contain disk Balmer emission, which will help in analysis of their disks.

The supersoft x-ray sources, first recognized as a class in the wake of ROSAT's discovery of a number of such sources in the Magellanic Clouds, are a very heterogeneous collection of objects having in common very hot white dwarfs. Besides symbiotic stars, recent novae, and the occasional planetary nebula, they include a number of cataclysmic-like binaries. Those of longer orbital period ($P > 9^{h}$) arise naturally from interacting binaries in which a main sequence or slightly evolved donor star of mass $\sim 1.5-2.3 M_{\odot}$ loses mass on a thermal time scale to its white dwarf companion. As shown by van den Heuvel, *et al.*, the characteristic mass transfer rate is high enough to fuel stable shell burning, without the white dwarf accumulating enough hydrogen to revert to the giant branch. However, there exist as well several much shorter-period supersoft sources which cannot accommodate such massive donors, and which must therefore arise from other circumstances. Webbink has found that, in fact, common cataclysmic variables, when they first begin mass transfer, pass through a relatively long ($\sim 10^{5}$yr) phase of stable shell burning, provided that the white dwarfs are of moderate mass ($0.75-0.85 M_{\odot}$), and they reach mass transfer in the orbital period range 3 to 5 hours, the orbital period range in fact occupied by the short-period supersoft sources.

The visual multiple 14 Aurigae contains five physical components: 14 Aur A is a single-lined spectroscopic binary, in which the visible component (KW Aur) is both an ellipsoidal variable and a δ Scuti variable; 14 Aur C is also a single-lined spectroscopic binary, and is coincident with the EUV source RE J0515+324, a hot white dwarf, which has proved to be a distant companion to the inner binary. Utilizing the fact that KW Aur is noticeably evolved, Webbink, in collaboration with a group headed by J. Holberg (Lunar & Planetary Lab, U. Arizona), has built a physical model of this quintuple system by treating it as a mini-star cluster. By simultaneously fitting the measured parallax, component magnitudes, colors, velocity amplitudes, and rotation velocities, as well as the white dwarf flux distribution and gravitational redshift, he has derived component masses for all five members, orbital inclinations for the two spectroscopic binaries, the chronological age of the multiple system, the cooling age of the white dwarf, and with it, the progenitor mass of the white dwarf. This solution not only provides a valuable new empirical point on the initial mass-final mass relation for white dwarfs, but strong constraints on models of high radial-overtone δ Scuti pulsators.

R. A. Downes (STScI), M. M. Shara (American Museum of Natural History) and Webbink have undertaken a third edition of the Catalog and Atlas of Cataclysmic Variables, incorporating >150 new objects since the second edition was compiled in 1996. This edition will be installed on the STScI web server, and updated regularly.

S. Shapiro and his group made considerable progress on

their study of the inspiral and coalescence of binary neutron stars and black holes in general relativity (see below).

3.1.2 Variable Stars

In the 1930's, D. Hoffleit (Yale) discovered several hundred variable stars of various types on Harvard patrol plates in several Milky Way fields. These discoveries were announced in the Harvard Bulletins (Nos. 874, 884, 887, 901, and 902), but few of these variables have been investigated further, for lack of either finding charts or accurate coordinates. With the generous assistance of Hoffleit, M. Hazen (Harvard) and Webbink have identified these Harvard Variables on the discovery plates, derived precise positions, and are now in the process of preparing these identifications for (belated!) publication.

3.1.3 Evolved Stars

M. Meixner, D. Fong, and E. Sutton, with V. Bujarrabal and A. Castro-Carrizo (OAN, Spain) and others have finished their ISO SWS and LWS study of low-excitation atomic gas in 24 evolved stars. The sample includes evolutionary phases from the asymptotic giant branch star to the planetary nebula phase. The results include spectrally resolved lines of [OI] 63 and 146 μm, [SiII] 35 μm, and [CII] 158 μm. These data are analyzed in the context of the photodissociation regions and shocked-gas regions which are created during the formation of planetary nebulae. They find that photodissociation, not shocks, is responsible for the chemical change from molecular to atomic gas in all these sources, except for AFGL 618, where both processes appear to contribute. The low-excitation atomic gas masses are estimated from the [CII] 158 μm line.

M. Meixner, D. Fong, E. Sutton, W. J. Welch (UC Berkeley) and K. Justtanont (Stockholm Obs.) have finished their BIMA CO J=1-0 imaging survey of 12 evolved stars. This BIMA survey will show what happens to the molecular gas when a planetary nebula forms and will complement their low-excitation atomic gas study with ISO. Preliminary results of the BIMA CO maps show holes in the CO emission in the planetary nebulae and some proto-planetary nebulae but not the AGB stars. These holes are created, in part, by the gradual photodissociation of the molecular gas by the central star as it evolves to hotter temperatures.

A. K. Speck, M. Meixner and G. R. Knapp (Princeton) have discovered parsec sized dust shells around two well-known proto-planetary nebulae, AFGL 2688 and AFGL 618, using the ISOPHOT. The infrared (120 and 180 μm) intensities do not fall off smoothly with radius as one would expect for constant or even steadily increasing mass-loss rates. Rather, AFGL 2688 and AFGL 618 both show enhanced emission at 150″ and 300″ and 160″ and 275″ , respectively. These ''periodic'' enhancements indicate episodic variations in the mass loss with time scales (few times 10^4 yrs) that appear to coincide with thermal pulses on the asymptotic giant branch (AGB).

T. Ueta and M. Meixner continue to improve the axially symmetric dust radiative transfer code. The code now handles grain size distributions and radial changes in dust grain composition. T. Ueta, M. Meixner and collaborators have used this code to model the circumstellar dust shells around several evolved stars. Their model of the enigmatic object, IRAS 18576+0341, suggests that it is a luminous blue variable. Their models of IRAS 17150-3224 and IRAS 17436+5003 suggest that the dichotomy of proto-planetary nebulae morphologies found by T. Ueta, M. Meixner and M. Bobrowsky (2000) is due to differences in mass loss histories. IRAS 17150-3224, which is a DUPLEX object, experienced an intensive mass loss (5×10^4 $M_\odot$ yr^{-1}) which created an optically thick dust shell. On the other hand IRAS 17436+5003, which is a SOLE object, experienced a less intensive mass loss (6×10^3 $M_\odot$ yr^{-1}) which created a relatively transparent dust shell.

3.1.4 Galactic Halo

Yoss, H. Detweiler (Illinois Wesleyan), G. Miller (Southwestern College, San Diego State University), and D. Bell (NOAO) obtained (B - V) and an Mg index for two fields in the direction of the NGP to V $\approx$19.5, using the University of Illinois 1-meter telescope at the Mt. Laguna Observatory. The Mg index measures the strength of the Mg H and Mgb absorption features, and G-K giants, dwarfs, and metal-abundant stars are clearly separated. Out of about 450 stars, most are dwarfs as expected, a few might be normal giants, but about six dozen appear to be metal-poor stars, both dwarfs and giants. The results are given in a paper entitled 'Detection of Metal-poor Stars in the Direction of the North Galactic Pole' which has been accepted for publication in the January 2001 issue of the Astronomical Journal. Spectra were obtained of a sample at KPNO in the spring of 2000 with the HYDRA positioner on the WIYN telescope, confirming the nature of the process.

K. A. Janes (Boston University), Miller, and Yoss continue their comprehensive photometric study of the well-known old open clusters, NGC 188, M67, NGC 6819 and NGC 7789, using the 1-meter telescope at Mt. Laguna Observatory. The primary goal of the program is to obtain highly precise (differential) magnitudes within the individual clusters that are also tied to the BVI photometric system, as defined by the Landolt standard stars, with high accuracy. In addition, they are monitoring several thousand stars in each of the clusters simultaneously in a search for small amplitude variable stars.

3.2 Diffuse Matter

3.2.1 Magnetic Fields

R. Crutcher continues his work on the measurement of magnetic fields in molecular clouds in order to improve our understanding of the role magnetic fields play in cloud evolution and in star formation. We made the first interferometric detection and mapping of linearly polarized spectral line emission due to the Goldreich-Kylafis effect. Our polarization maps of the CO $J=2-1$ line in the molecular outflow powered by the very young stellar system NGC 1333 IRAS 4A made it possible to define the direction of the magnetic field in the outflow. Comparison with theoretical predictions implies that the magnetic field is parallel to the polarization. Our data suggest that the deflection of the outflow may be

the result of the interaction between the outflow and the magnetic field. We also detect and map the linearly polarized dust continuum emission at 1.3 mm. The polarization map of the dust continuum is roughly consistent with an hourglass magnetic field morphology; i.e., it is in agreement with theoretical models of interstellar cloud contraction with a frozen-in magnetic field. The two techniques for mapping magnetic field morphologies agree. In general, the two techniques sample different column densities, and together they allow the study of magnetic field morphology over wider areas than either technique by itself would permit. We also completed the first published maps of magnetic fields in prestellar cores to test theoretical ideas about the way in which the magnetic field geometry affects the star formation process. The observations are JCMT-SCUBA maps of $\lambda 850 \mu$m thermal emission from dust. Linear polarizations at typically 10 or more independent positions in each of three objects, L1544, L183, and L43, were measured, and the geometries of the magnetic fields in the plane of the sky were mapped from the polarization directions. The observed polarizations in all three objects appear smooth and fairly uniform. In L1544 and L183 the mean magnetic fields are at an angle $\approx 30°$ to the minor axes of the cores. The L43 B-field appears to have been influenced in its southern half such that it is parallel to the wall of a cavity produced by a CO outflow from a nearby T Tauri star, while in the northern half the field appears less disturbed and has an angle 44° to the core minor axis. We conclude that no current model can explain these observations simultaneously with previous ISOCAM data. Finally, we report observations with the Arecibo telescope of the Zeeman effect in the 1665 and 1667 MHz lines of OH toward eight dark cloud cores. For L1544, the inferred line-of-sight magnetic field is $B_{los} = +11 \pm 2 \mu$G. The L1544 starless core has been observed to have infall motions; it may be very close to forming a star. $B_{los} \approx 11 \mu$G is consistent with the prediction of an ambipolar diffusion model computed specifically for this core before the Zeeman measurements were made; however, in order to obtain agreement with the data this model has B inclined by only 16° to the plane of the sky. Virial arguments show that unless the magnetic field is mainly in the plane of the sky, it is not important for support of the L1544 core.

Lai, Girart, Crutcher, and R. Rao (U. of Chicago) have conducted a survey of linear polarization in molecular cores at 1.3-mm wavelength using the BIMA array. They observe linear polarization from thermal dust emission and the CO J=2-1 line simultaneously. Significant dust polarization were detected toward W51 e1/e2, NGC 2024 FIR 5, NGC 1333 IRAS 4A, W49, DR21(OH) and IRAS 16293-2422. The observations achieve high resolutions up to 2 arcsec, which is more than 5 times better than most previous observations with single-dish telescopes. The improvement in angular resolution enables them to investigate detailed magnetic field structures at the scale of protostellar cores, and then assess the relative importance of the ordered field and the turbulent field, which provides an opportunity to test theoretical models and simulations of star formation.

3.2.2 Cosmic Rays

The history of cosmic rays in the Galaxy is encoded in the ''fossils'' of beryllium and boron, which are produced in collisions between cosmic rays and the interstellar medium (ISM). B. Fields, with K. Olive (Minnesota) and E. Vangioni-Flam and Michel Cassé (Institut d'Astrophysique, Paris) studied the Be and B evolution in the Galaxy, finding (2000) that the BeB-O trends demand that two sources of cosmic rays operated in the early Galaxy.

3.2.3 Interstellar Medium

P. R. McCullough and his colleagues J. Gaustad, D. Van Buren and W. Rosing have completed their robotic Hα survey of the southern-sky from Cerro Tololo Inter-American Observatory. The data are being analyzed to determine the structure of the warm ionized medium of the ISM and to provide a template for the free-free Galactic foreground emission that must be subtracted from the observations of the cosmic microwave background radiation such as will be made by the MAP and Planck satellites.

McCullough and Gary Swenson (ECE Dept. UIUC) used Meixner's near-IR camera at Mt. Laguna to observe over a steradian field of view the mesospheric OH lines that limit the sensitivity of near-IR observations from the ground. The OH emissions show the structure and dynamics of gravity waves in the upper atmosphere.

3.2.4 Planetary Nebulae

Y.-H. Chu, M. A. Guerrero, and R. Gruendl continue to study X-ray emission from planetary nebulae. They have completed a systematic archival study using the entire *ROSAT* data archive, the results have been published in an ApJS paper. They have obtained *Chandra* ACIS-S observations of NGC 6543 (the Cat's Eye Nebula) and NGC 7293 (the Helix Nebula). The diffuse X-ray emission from NGC 6543 is clearly resolved, showing the distribution of hot gas. Both NGC 6543 and NGC 7293 have a hard, point X-ray source at the central star; the origin is uncertain.

M. A. Guerrero, L. F. Miranda (IAA, Spain) and other researchers (IAC, IAA and CSIC, Spain, UNAM, México) have analyzed the spatial properties and kinematics of the collimated outflows in the planetary nebulae IC 4686, NGC 6891, K 3-35, and Hu 2-1. The results have been published in a series of four papers in MNRAS. It is reported the existence of systematic shifts of the radial velocities of the collimated outflows with respect to the radial velocity of the nebulae. This is interpreted as evidence of the orbital motion of the ejection source in a binary system.

M. A. Guerrero, A. Manchado and E. Villaver (IAC, Spain), R. Bachiller and E. Josselin (OAN, Spain), and P. García-Lario (ISO Data Centre, Spain) have analyzed the molecular content (H_2 and CO) of a sample of bipolar planetary nebulae. The results, published in one ApJS paper and one A&A paper, confirm that bipolar planetary nebulae are molecular-rich. It is found a correlation between different morphological subclasses and the $H_2/\mathrm{Br}\gamma$ ratio.

M. A. Guerrero, L. Stanghellini (STScI), and A. Manchado and E. Villaver (IAC, Spain) have performed a statistical analysis of a complete sample of Northern planetary

nebulae. This analysis confirms and strengthens some basic results on the chemical enrichment and spatial location distribution of the different morphological classes. Furthermore, the distribution of axial-ratio of elliptical planetary nebulae has been analyzed for the first time, and it is also found a correlation between morphological class and statistical distance. The results are reported in a paper to be published in the ApJ.

3.2.5 Supernova Remnants

J. Dickel, R. Strom (ASTRON) and D. Milne (ATNF) have been studying the radio characteristics of extended supernova remnants (SNRs). MSH $\sim$ 15−56 is a composite SNR with a shell of primarily swept-up material plus a central core presumably stimulated by an undetected pulsar. There are several peculiar differences between our radio and the x-ray emission of this object. The SNR MSH $\sim$ 14−63 has some characteristics of very young SNRs but other characteristics of older ones. The extended SNR G114.3+0.3 is a large shell with a pulsar at its center. They are completing the analysis of WSRT observations of this object and tentatively find no radio emission from the SNR directly associated with the pulsar.

Some other studies of supernova remnants include investigation of the structure of the largest pulsar-driven SNR known, G328.4+0.2, by B. Gaensler (MIT), J. Dickel, and A. J. Green (Sydney Uni.), a comparison of radio and x-ray emission from a complex of SNRs in the Small Magellanic Cloud, in order to distinguish several individual objects by J. Dickel and R. M. Williams (Goddard), analysis of the radio properties of the plerion SNR containing an x-ray pulsar, N 157B, by J. Lazendic (Sydney Uni.) and J. Dickel, and some overall analysis of SNRs with neutron stars of various types by J. Dickel, E. van der Swaluw (U. Utrecht), and Y. Gallant (U. Utrecht).

B. Dunne, R. Gruendl, and Y.-H. Chu have studied the ultraluminous supernova remnant MF16 in NGC 6946, using archival HST WFPC2 images and proprietary KPNO 4-m echelle spectra. They conclude that the high luminosity of this remnant is caused by the collision of the remnant with a circumstellar nebula. The results have been published in an AJ paper. They have also been studying the supernova remnants in M101, using archival *HST* WFPC2 images and new KPNO 4m echelle spectra. Some remnants reported previously are larger than usual. These new observations can be used to determine the real nature of these objects.

Y.-H. Chu, S.-P. Lai, and C.-H. Chen have completed a critical examination of the hypernova remnant candidate MF 83 in M101. The results are reported in a paper to be published in the ApJ. They are analyzing NGC 5471B, another hypernova remnant candidate in M101.

Y.-H. Chu, S. Van Dyk (IPAC), and R. Gruendl have obtained high-dispersion spectra for a number of young supernovae at distances up to 30 Mpc to study their ambient interstellar environments and to search for circumstellar nebulae. The data have been fully reduced. The results are being prepared for publication.

A supernova explosion very near the Earth would leave observable traces in the form of live radioactivity implanted in geological strata. Recently, live ^{60}Fe was observed in a deep-ocean crust. Fields and J. Ellis (CERN, Switzerland) found (1999) that the amount of ^{60}Fe was 2 orders of magnitude larger than the expected backgrounds. If the data are interpreted as a nearby supernova, it occurred within the past 5 Myr and within 30 pc of the Earth.

3.2.6 Circumstellar Nebulae

R. Gruendl, Y.-H. Chu, B. Dunne and S. Points have analyzed the Hα and [O III] emission from eight Galactic Wolf-Rayet ring nebulae. They find that in many cases the outermost edge of the [O III] emission leads the Hα emission. These offsets, when present, are due to the shock from the Wolf-Rayet bubble expanding into the circumstellar envelope. The details of the WR bubble morphology at Hα and [O III] can then be used to better understand the physical condition and evolutionary stage of the nebulae around Wolf-Rayet stars, as well as place constraints on the nature of the stellar progenitor and its mass loss history.

3.2.7 Astrochemistry

Liu, Snyder and D. M. Mehringer completed the BIMA Array observations for a survey of HCOOH in the molecular cores W3(OH), Orion IRc2, Sgr A-A, Sgr B2, G34.3+0.2, W51 M, DR21(OH), NGC 7538, IRS9, and IRS1.The best sources were Sgr B2(N-LMH), W51, and Orion (ApJ, submitted). As a follow-up to the formic acid survey, Remijan, Liu and Snyder started a survey of interstellar acetic acid sources that are coincident with formic acid sources.

Friedel, Snyder and B. E. Turner started a survey where spectral lines observed toward Sgr B2(N) with the BIMA Array are compared to the same spectral lines observed with the NRAO 12-m telescope.

3.2.8 Star Formation: Observations

H. R. Dickel, W. M. Goss (NRAO) and C. G. DePree (Agnes Scott College) completed the analysis of WSRT and VLA observations of the H_2CO absorption towards the UCHII regions C1 (ON 3) and C2 of W 58; a paper has been accepted by the Astronomical Journal. At a resolution of $\sim$0.1″, the continuum emission from W 58 C1 exhibits a core-halo structure with the core appearing as a ''broken shell.'' The H_2CO absorption at 2 cm is strongest ($\tau > 2$) towards the southwest, at the edge of the bright arc of continuum emission which suggests that the molecular gas might also be in a dense toroid around the UCHII similar to the situation found earlier towards W3(OH).

3.2.9 Molecular Clouds

R. Y. Shah is working with several collaborators to analyze the spatial distribution of deuterated molecules, namely NH_2D, DCO^+, and DCN. Shah and A. Wootten (NRAO) are concentrating on observations of nearby star-forming regions NGC 1333 with J. McMullin (NRAO) and Serpens with McMullin and J. Williams (U. of Florida). They are utilizing single-aperture data from the NRAO-12m and Caltech Submillimeter observatory, aperture synthesis data from the BIMA array. G. Sandell (NASA AMES), McMullin, and

Shah are using similar observing techniques to study massive star forming cores. Specifically, they are observing the massive young stellar object NGC 2023 for evidence of a disk. Shah and Wootten continue work with C. Carilli (NRAO) and K. Menten (MPfIR) on absorption lines of DCN and DCO^+ towards lensed quasar systems. They are attempting to measure the intervening column's deuterated molecule abundance as an estimator of the D/H ratio at redshifts near 1.

E. Sutton, A. Sobolev (Ural State U.), S. Ellingsen (U. Tasmania), D. Cragg (Monash U.), D. Mehringer, A. Ostrovskii (Ural State U.), and P. Godfrey (Monash U.) have finished a study of class II methanol masers in the molecular cloud W3(OH). Using the BIMA array they observed nine methanol transitions, all of which had been predicted as possible masers under conditions which were likely to occur in star-forming regions. They saw class II maser emission in three lines: $7_2 - 6_3$ A^-, $7_2 - 6_3$ A^+, and $3_1 - 4_0$ A^+. In these lines the maser emission appeared at a v_{LSR} of -43.1 km/s and originated from a region near the northern edge of the ultra-compact HII region in W3(OH). The remaining six lines did not show a narrow maser spike, although spatially extended emission was seen over a wider range of velocities. The masing region appears to be of high temperature ($\geqslant$110 K), high density (10^7 cm^{-3}), and high methanol abundance (10^{-6} $N(H_2)$). Broad line emission in all 9 lines also appears to be due to weak maser action, which is less strongly beamed along the line of sight.

Sobolev, Sutton, and I. Zinchenko (IAP, Novgorod) are also studying the kinematics and spatial distribution of CS, SO, SiO, HDO, and other chemical species throughout the W3(OH)/W3(H2O) region. There is a large amount of low excitation material overlying the entire region, but particularly extending to the southwest of W3(OH), as seen in the methanol $2_1 - 1_1$ E ($E_u = 28$ K) and $2_0 - 1_0$ E ($E_u = 20$ K) lines, among others. High excitation ($v_t=1$) lines of methanol are seen in the vicinity of both W3(OH) and W3(H2O), the latter of which seems to have a very high excitation temperature. We are particularly interested in what is happening in the vicinity of W3(H2O), also known as the TW object, in order to understand the morphology of the region, the nature of the TW object, and the impact of outflows and shocks on the overall cloud structure. $C^{34}S$ and methanol show strong evidence for a rotating disk around W3(OH). Both species are also present on larger scales, indicating a complex intermingling of low and high density material throughout the W3(OH)/W3(H2O) region. SiO emission, which is thought to trace shock excitation, is located primarily to the south of both sources. It is spatially extended and clumpy and appears to be outlining a region of interaction between a protostellar outflow and the ambient molecular cloud.

Sutton and collaborators W. McCutcheon (U. of British Columbia), G. Sandell (NRAO), H. Matthews (JAC Hilo, HI), T. Kuiper (JPL), W. Danchi (UC Berkeley), and T. Sato (Kwantlen U., British Columbia) have published a study of the spatial distribution of CO, CS, $H^{13}CO^+$, and continuum emission in the molecular cloud complex NGC 6334 in the vicinity of the sources I and I(N) (McCutcheon *et al.* 2000). They saw outflows from both sources and found evidence that I(N) is the younger of the two objects. An extensive spectral survey revealed that the more evolved source, I, has developed a rich chemical environment. The high abundances of complex molecules in general, and methyl-group molecules in particular, make NGC 6334 I comparable in many ways to the ''compact ridge'' region of the Orion-KL core. Chemical conditions of this sort are thought to be due to the evaporation of dust grain mantles in the vicinity of newly formed stars. Other signs of star formation in I include an ultra-compact H II region and H_2O, OH, and CH_3OH masers. The other source, I(N), has not yet reached this stage of evolution.

Using BIMA, Girart, Rao, and Crutcher analyzed the spectro-polarimetric data of IRC +10216, to search for linear polarization emission of molecular lines that theoretical models predict to be polarized: CS, SiS. The CS line shows marginal detection of polarized emission. These results are being written up for publication.

Girart, Viti, Williams (Univ. College London), Ho (CfA) and Estalella (Univ. Barcelona) are carrying out a comprehensive theoretical and observational study to elucidate the origin and properties of the quiescent emission clumps ahead of HH objects by, first, modeling their physical and chemical conditions (Viti & Williams 1999), and, second, by observing a number of the molecular lines predicted to be abundant enough to be detected. We carried out sensitive and high angular resolution multi-transitions BIMA and CSO observations. These observations will allow us to spatially resolve the emission. This is very important, since the chemical effects of the radiation is quite sensitive to the visual extinction between the HH object and the clump, i.e., it is expected a chemical differentiation with respect to the distance to HH 2. In addition we will be able to better determine their column densities and thus to refine the Viti & Williams model. Reduction of the data is almost completed.

Girart, Ho, Estalella and Rudolph (Harvey Mudd College) studied the HCO^+ emission in star forming regions with strong molecular outflow activity. We carried out LVG analysis of the multi-transition HCO^+ observations towards NGC 2264G. The ''anomalous'' $J=1\rightarrow0$ emission found seems to be due to absorption by cold, low density foreground gas in the same region. The analysis and results have been published in the Astrophysical Journal.

Girart and J. Acord (Syncretic Software) completed the reduction of the BIMA observations of the SiO $J=2\rightarrow1$ towards L1448. We measured proper motions of the extremely high velocity ''bullets'' from comparing with 1990 PdB maps of the same transition at a similar angular resolution. The analysis and results are being written up for publication.

Girart, Rodriguez and Curiel (Instituto de Astronomia, UNAM, Mexico) studied the radio continuum properties of the strong X-ray emitting YSO YLW 15. This is a remarkable object since it exhibits phenomena such as strong millimeter emission and association with a bipolar outflow that characterize extremely young stars, while at the same time presenting strong, time-variable X-ray emission that is ubiquitous and detected characteristically in more evolved objects. Our VLA observations reveal that YLW 15 is a subarcsecond radio binary, with one of the components spatially

extended and the other unresolved. We suggest that the components of the binary system may have different characteristics also at other wavelengths, as a result of different evolutionary status. The analysis and results have been accepted for publications to the Astrophysical Journal Letter.

Beltran (CfA), Ho, Estalella and Girart started a study of two intermediate-mass YSOs with a similar luminosity and located at a similar distance: a ''classical'' Herbig Ae/Be star and an embedded Herbig Ae/Be precursor YSO. Our goals are to determine the morphology of the circumstellar material around YSOs of intermediate-mass, and to study whether there is an evolutionary sequence of the circumstellar dusty structures similar to that found for low-mass stars. We carried out BIMA observations in order to: (1) map the dusty envelopes of the embedded sources, and (2) resolve-out the large structure in order to go inside the envelopes and map the central regions.

3.3 Cosmology

Norman has continued to study the formation of the first stars in the universe in collaboration with Tom Abel (CFA) and Greg Bryan (MIT). Using adaptive mesh refinement hydrodynamic cosmological simulations, we have found that primordial gas cools due to molecular hydrogen line radiation to a few hundred K in the cores of dark matter minihalos at redshifts of about 20. A single, massive, collapsing protostar forms via gravitational instability. A simulation with a spatial dynamic range of 10 billion resolves the structure of the protostar on scales down to 1/10 AU. We find a fully molecular core of one solar mass accreting an envelope of 100 solar masses in 10 thousand years.

Norman, in collaboration with N. Gnedin (Colorado) and J. Ostriker (Princeton), used cosmological hydrodynamic simulations to investigate the formation of galactic bulges within the framework of hierarchical clustering in a representative cold dark matter (CDM) cosmological model. We show that the largest objects forming at cosmological redshifts z 4 resemble observed bulges of spiral galaxies or moderate-sized ellipticals in their general properties, such as size, shape, and density profile. This is consistent with observational data indicating the existence of ''old'' bulges and ellipticals at more moderate redshifts. These bulges are gas dominated at redshift z=3, with high rates of star formation, and would appear to be good candidates for small blue galaxies seen in the Hubble Deep Field.

Norman and graduate student Wen-Ching Lin have studied the systematic errors in deriving the Hubble constant from observations of clusters of galaxies using the Sunyaev-Zeldovich effect and X-rays. Using a sample of numerically simulated X-ray clusters, we find that cluster asphericity and non-isothermality systematically overestimate the angular diameter distance of the cluster, and hence underestimate H0 by 20angle also contribute a large scatter to the derived H0 (+/- 15 km/s/Mpc), and thus we conclude this method is unlikely to yield precise measurements of H0. A paper describing these results is being prepared for submission to the ApJ. The cluster sample is available on the web at http://sca.ncsa.uiuc.edu.

3.4 Solar System

Comet LINEAR (C/1999 S4) was observed during its 2000 apparition in both line and continuum emission at 3 mm wavelength with the BIMA Array and the Owens Valley Array. Comet collaborators included Snyder & Remijan, Hogerheijde, de Pater, Wright, Hoffman, & Forster (Berkeley), Woodney (Lowell), A'Hearn (Maryland), Palmer (Chicago), Kuan & Huang (Taiwan Normal U.), and Blake, Kessler, Qi, & Liu (Caltech). We report a weak detection of HCN emission (LINEAR) with the BIMA Array in autocorrelation mode, in the three days prior to the comet's breakup on 2000 July 25. The antenna temperature of 3.5 mK in the 130″ beam suggests an outgassing rate a few percent of that of comet Hale-Bopp (C/1995 O1).

Teare and collaborators Dantowitz and Kozubal (Museum of Science, Boston) continued their high-angular resolution imaging work on the planet Mercury using the Mount Wilson Observatory 60-inch telescope. Their results (published in AJ) identify craters on a portion of Mercury not imaged during the Mariner spacecraft flybys in 1973-74.

3.5 Extragalactic Astronomy

3.5.1 Normal Galaxies

C.-H. Chen and Y.-H. Chu have been analyzing M101 giant HII regions NGC 5471 and NGC 5461, using HST WFPC2 images and KPNO 4-m echelle spectra. The HST continuum images are used to study the distribution and colors of OB associations and cluster within the giant HII regions. The colors of the clusters will be modeled to determine their ages. The goals for this project are to study the star formation history in very luminous giant H II regions and to determine whether globular clusters are formed in giant H II regions.

J. Dickel and L. Sjouwerman (JIVE) have been reducing some of the later high resolution VLA data at 8.4 GHz obtained over a period of six years on the central kpc of M31 by P. Crane (NRL), J. Cowan (U. Oklahoma), and J. Dickel. They are being used to carry out several objectives. First is to search for a radio emission from the remnant of a supernova that was observed to explode in 1885. The time required to produce enough particle acceleration and magnetic field enhancement to get observable synchrotron radiation from such objects is unknown and this candidate offers the best opportunity to find and monitor changes in the emission of young SNRs. By adding together 128 hours worth of data obtained over the 6 years, they have a tentative detection of a slightly extended source (about 2 pc across) with an integrated flux density of about 29 μJy at the apparent location of the SN. Three other new SNRs have also been found near the center of that galaxy. The data are also used to monitor M31* the variable black hole candidate in the very center of M31 for comparison with simultaneous x-ray observations by M. Garcia and F. Primini (CfA).

I. Barton (Ph.D. student) made excellent progress during the year analyzing a multi-wavelength set of visual wavelength images for population synthesis in two moderately nearby spiral galaxies: NGC 4258 and NGC 5055. Very high signal-to-noise images are available for these two galaxies at

the Mt. Laguna 1-m telescope in B, V, R, and ubvy colors. The aim is to analyze the stellar population changes as a function of radial distance from the galaxy nucleus in order to detect spatial variations in the galaxy mass-to-light ratios. These results are important in determining the nature of dark matter in spiral galaxies.

L. Thompson and M. Griffin (Ph.D. student) used the NICMOS-3 camera at the Mt. Laguna 1-m telescope to search for distant clusters of galaxies at near-IR wavelengths. The method seems to be a very promising extension of earlier work at visual wavelengths by Dalcanton (ApJ, 466, 92, 1996).

D. Goscha (PhD student) built a website, which contains several Mbytes of galaxy catalog data. The data itself were produced in its original form by Thompson and S. Gregory (University of New Mexico). While galaxy luminosity functions were derived by Thompson and Gregory from these data when they were first collected, the catalog data itself was never been published. The website provides finder charts as well as lists of galaxy position, morphology, ellipticity, magnitude, etc. Clusters in the catalog include A1656 (Coma), A2147 and A2151 (Hercules), A2197 and A2199 and several others. The website includes a simple search engine built using the PERL programming language to provide a convenient means for on-line catalog searching. An effort to analyze the ellipticity distribution of all S0 galaxies in this sample is being completed.

3.5.2 Large Magellanic Clouds

Chu and B. Wakker (U. Wisconsin) continue their Long Term Space Astrophysics program to investigate the physical structure and evolution of the interstellar medium (ISM), using the Large Magellanic Cloud (LMC) as an astrophysical laboratory. Specifically, they study the different phases of the ISM and their relationship with the underlying population of massive stars. They have been using X-ray data taken with the ROSAT and ASCA satellites to map and analyze the 10^6 K ionized gas, UV data taken by the HST STIS and to be taken by the FUSE satellite to analyze the 10^5 K ionized gas, and optical data taken with the CTIO telescopes to study the 10^4 K ionized gas structures and their stellar content. The interstellar structures they study include interstellar bubbles around single massive stars, supernova remnants (SNRs), superbubbles around OB associations, HII complexes, the giant HII region 30 Doradus, supergiant shells, and large-scale structures.

Y.-H. Chu, C.-H. Chen, *et al.* are using the HST WFPC2 images of LMC HII regions to search for small wind-blown bubbles in young HII regions, and SNR shocks in X-ray bright superbubbles. Six HII regions are included in this program: N11B, N30, N44, N51D, N63, and N180. No wind-blown bubbles are found in young HII regions. This can be explained if the interstellar medium is cloudy, and the evaporation of the cloudlets in a bubble interior quickly fills up the central cavity.

S. Points, Chu, and S. L. Snowden (NASA/GSFC) are examining the physical condition of the 10^6 K gas interior to the supergiant shell LMC 2. They have obtained ROSAT PSPC and HRI mosaics of LMC 2 to examine the distribution of hot gas and ROSAT PSPC and ASCA SIS spectra to study the physical conditions of the hot gas. The analysis has been completed and is being published in an ApJ paper. They have also been studying the diffuse hot gas in the entire LMC, cataloging the diffuse X-ray sources and correlating them with Hα features.

B. Dunne, Points and Chu have been studying the hot gas content of superbubbles in the LMC. Archival *ROSAT* PSPC data are used. They find that the X-ray luminosity is correlated only with the number of blue stars encompassed by the superbubble.

3.6 High-Energy Astrophysics and General Relativity

S. L. Shapiro and his group tackled a number of problems in theoretical astrophysics and general relativity theory. Although this work ranged over a wide variety of topics, much of the effort was focussed on gravitation physics, both Newtonian and relativistic. Some of the themes included the inspiral and coalescence of binary neutron stars and black holes and the associated generation of gravitational waves, the fallback of matter onto a black hole following a supernova explosion, and the effect of general relativity on the stability of a rapidly rotating neutron star against the formation of bars and r-modes. Some of the problems were treated analytically, others by means of large-scale computations. Important advances were achieved this past year, including the refinement (with research associate T. Baumgarte) of a new code to solve Einstein's field equations of general relativity, which appears to be stable for many dynamical timescales; the demonstration that differential rotation can support ''hypermassive'' neutron stars with significantly more rest mass than nonrotating or uniformly rotating stars (with T. Baumgarte and Visiting Research Professor M. Shibata); and the formulation of a mass current quadrupole radiation-reaction potential for numerical exploration of r-modes in a Newtonian hydrodynamics code (with research associate L. Rezzolla, M. Shibata and T. Baumgarte). Also, a recent calculation (with research associates S. Balberg and L. Zampieri and Professor M. Colpi of Milan) of the accretion luminosity from a black hole in SN 1997D suggests that proof or disproof of the presence of a central black hole in such a supernova remnant might be decided by direct observations by HST.

Shapiro trains and supervises, together with Professor F. K. Lamb, a talented undergraduate research team that works on forefront problems in theoretical astrophysics and general relativity. The team has recently written a paper with Shapiro that has appeared Phys. Rev. D. and deals with tidally induced collapse of a compact binary cluster in general relativity.

Gammie continued work on the theory of black hole accretion flows. With physics graduate student J. McKinney, Gammie developed a numerical model of axisymmetric viscous accretion flows. One of the main results of this work was that the global structure of the flow is sensitive to the inner boundary condition. The computations for this work were carried out on a Beowulf luster built this year by McKinney, undergraduates K. Obenschain and S. Olsson, and Gammie, and at the NCSA. Gammie, with J. Goodman

(Princeton) and undergraduate student E. Engelhard, continued work on the evolution of circumstellar disks; as part of this work, Gammie studied the nonlinear development of gravitational instability in disks. With E. Ostriker and J. Stone (UMCP), and astronomy graduate student Y.-T. Lin, Gammie continued work on the analysis of numerical models of star-forming molecular clouds. Gammie and Lin have studied the mass spectrum, relative alignment, and shapes of dense condensations (''clumps'') in the numerical models. All are consistent with observations.

3.6.1 Big Bang Nucleosynthesis

Big bang nucleosynthesis describes the production of the light elements in the early universe; the success and power of this theory rest on light elements observations. Fields (2000), with Olive, S. Ryan (Open U., England), T. Beers (Michigan State), and J. Norris (Australian National U.) showed how recent, high-precision Li data significantly improves the inferred primordial Li abundance, and thus sharpens our knowledge of the baryonic content of the universe.

3.6.2 Dark Matter

Recent observations of microlensing through the dark Galactic halo have been interpreted as evidence for a large population of halo white dwarfs. Fields, K. Freese (U. of Michigan), and D. Graff (Ohio State) found (1999) that that the creation of a white dwarf population is accompanied by the production of a very large, observable amount of carbon. The lack of such contamination strongly argues against a white dwarf interpretation of the microlensing events.

3.7 Code Development

Norman has released ZEUS-MP: a 3D, parallel, astrophysical fluid dynamics code. It is a message-passing parallel implementation of the ZEUS-3D code in wide use by the astronomical community. The code is available from the Laboratory for Computational Astrophysics website: http://lca.ncsa.uiuc.edu/lca_home_page.html.

Norman and undergraduate student Brian O'Shea, in collaboration with Greg Bryan (MIT), have incorporated a parameterized model for star formation and feedback (energy, metals) into their adaptive mesh refinement hydrodynamic code ENZO. The star formation model is based on the method of Cen and Ostriker, wherein a fraction of the gas in a cell which is Jeans unstable and cooling rapidly is converted into collisionless star particles which are evolved using N-body methods. We have carried out a series of tests varying the three adjustable parameters in the model, and found that the global star formation history in a CDM-dominated universe is rather insensitive to the star formation efficiency parameter, but more sensitive to the two feedback parameters. A paper describing this work is being prepared for submission to ApJ.

Shapiro and Baumgarte refined their new dynamical code to solve Einstein's field equations as general relativity in three spatial dimensions plus time. This code has been adopted by many groups around the world working in numerical relativity.

3.8 New Instruments

J. Dickel has participated in several working group discussions and more general meetings on the Low Frequency Array (LOFAR) being proposed by ASTRON, the U.S. Naval Research Lab, and Haystack Observatory. This new instrument will operate at the lowest radio frequencies observable from the surface of the earth and will greatly expand our knowledge in one of the least explored wavelength ranges available to astronomers. J. Dickel has contributed sections to the written document on the science case for this telescope and entered the discussion on how the science drives design considerations.

4. ASTRONOMICAL NOMENCLATURE

H. Dickel continues as President of the Working Group on Designations of the IAU Commission 5. The WG together with Commission 26 (Double and Multiple Stars) organized an electronic FORUM on the web re Designations of Stellar Companions (including extrasolar planets). The year long discussions culminated in a full day Multi-Commission Meeting (involving 10 commissions) at the IAU General Assembly in Manchester UK in August 2000. A type-C resolution resulted from this meeting and may be found at http://ad.usno.navy.mil/ad/wds/newwds.html.

5. PUBLIC SERVICE AND EDUCATION

The annual Icko Iben, Jr. Distinguished Lecture was presented in October by R. Kirshner of Harvard University on ''The Universe: Big, Old, Accelerating?''

J. Kaler continues his work in public education. The ''Little Book of Stars'' will be published by Copernicus Books (Springer NY) this fall, and ''Extreme Stars: At the Edge of Creation'' by Cambridge. Three other books on stellar astronomy are in various stages of development and various encyclopedia articles are awaiting publication. He has also written on astronomical topics for both ''Astronomy'' and ''Sky and Telescope.'' Kaler continues weekly sky news on ''Skylights'' (both emailed and on the web at http://www.astro.uiuc.edu/ kaler/skylights.html), and continues to expand the ''Star of the Week'' website (http://www.astro.uiuc.edu/kaler/sow/sow.html). Both sites have won several awards. New educational pages have been added on stars with newly discovered planets and on atmospheric optics. He also lectured extensively to both the public and to professional societies, the latter including the Great Lakes Planetarium Society, the Mid-Atlantic Planetarium Society, and the International Planetarium Society.

H. Dickel continues to be a Tour Speaker for the American Chemical Society.

Teare organized a workshop on photometry as part of this year's International Amateur-Professional Photoelectric Photometry symposium in Big Bear, CA and continues to serve as a Senior Astronomer with the Telescopes in Education Program at the Mount Wilson Observatory.

M. Meixner designed a new astronomy lab course called ''Observing the Sky'' which is targeted for introductory astronomy students who are not science majors. She taught it for the first time in Fall 1999.

The UI Astronomical Society continues to hold monthly open houses in the campus Observatory, a National Historic Landmark.

REFERENCES

Abel, T., Bryan, G. L., and Norman, M. L. 2000, ''The Formation and Fragmentation of Primordial Molecular Clouds,'' ApJ, 540, 39

Abel, T., Norman, M. L., and Madau, P. 2000, ''Photon-conserving Radiative Transfer Around Point Sources in Multidimensional Numerical Cosmology,'' ApJ, 523, 66

Balberg, S., Colpi, M., Shapiro, S. L., and Zampieri, L. 1999 ''Unveiling Black Holes in a Supernova Cauldron,'' Mercury, 28, 8

Balberg, S., Shapiro, S. L., and Zampieri, L. 2000, ''Black Hole Emergence in Supernovae,'' in Cosmic Explosions Proceedings of the 10th Annual October Astrophysics Conference in Maryland, College Park, Maryland, 11-13 October 1999, eds S. S. Holt and W. W. Zang (AIP Press) 147-150

Baumgarte, T. W. and Shapiro, S. L. 1999, ''Luminosity Versus Rotation in a Supermassive Star,'' ApJ, 526, 937

Baumgarte, T. W. and Shapiro, S. L. 1999, ''Evolution of Rotating Supermassive Stars to the Onset of Collapse,'' ApJ, 526, 941

Baumgarte, T. W., Hughes, S. A., and Shapiro, S. L. 1999, ''Evolving Einstein's Field Equations with Matter: The ''Hydro without Hydro'' Test, '' Phys. Rev. D, 60, 087501

Baumgarte, T. W., Hughes, S. A., Rezzolla, L., Shapiro, S. L., and Shibata, M. 1999, ''Implementing Fully Relativistic Hydrodynamics in Three Dimensions,'' General Relativity and Relativistic Astrophysics, Proceedings of the 8th Canadian Conference, eds. C. P. Burgess and R. C. Myers (AIP Conference Proceedings 493, Melville, New York), 53

Baumgarte, T. W., Shapiro, S. L., and Shibata, M. 2000, ''On the Maximum Mass of Differentially Rotating Neutron Stars,'' ApJL, 528, L29

Bobrowsky, M., Meixner, M., Axon, D., Hines, D. C., and Skinner, C. J. 1998, ''Imaging and Polarimetry of the Nebula around IRC+10216,'' AAS Meeting 193, abstract #69.15

Bobrowsky, M., Ueta, T., Greely, B., and Meixner, M. 2000, ''The Circumstellar Matter Around OH44.8-2.3,'' in Asymmetrical Planetary Nebulae II: From Origins to Microstructures, ASP Conference Series, eds. J. H. Kastner, N. Soker, and S. Rappaport, 199, 453

Bockelée-Morvan, D., Lis, D. C., Wink, J. E., Despois, D., Crovisier, J., Bachiller, R., Benford, D. J., Biver, N., Colom, P., Davies, J. K., Gérard, E., Germain, B., Houde, M., Mehringer, D., Moreno, R., Paubert, G., Phillips, T. G., and Rauer, H. 2000 ''New Molecules Found in Comet C/1995 O1 (Hale-Bopp): Investigating the Link Between Cometary and Interstellar Material,'' A&A, 353, 1101

Brandner, W., Grebel, E. K., Chu, Y.-H., Dottori, H., Brandl, B., Richling, S., Yorke, H. W., Points, S. D., and Zinnecker, H. 2000, ''HST/WFPC2 and VLT/ISSAC Observations of Proplyds in the Giant HII Region NGC3603,'' AJ, 119, 292-301

Chen, C.-H., Chu, Y.-H., Gruendl, R. A., and Points, S. D. 2000, ''HST WFPC2 Imaging of Shocks in Superbubbles,'' AJ, 119, 1317-1324

Chu, Y.-H. 1999, ''Morphology and Physical Structure of the Interstellar Medium,'' in Toward a New Millennium in Galaxy Morphology, eds. D. L. Block, I. Puerari, A. Stockton and D. Ferreira (Kluwer, Dordrecht), Ap&SS, 269, 441-458

Chu, Y.-H. 2000, ''Hot Gas in the Large Magellanic Cloud,'' Revista Mexicana de Astronomía y Astrofísica (Conference Series), 9, 262-269

Chu, Y.-H., Caulet, A., Dickel, J. R., Williams, R., Arias-Montano, L., Rosado, M., Ambrocio-Cruz, P., Laval, A., and Bomans, D. 1999, ''N63A: A Supernova Remnant in a Cloudy Medium,'' in New Views of the Magellanic Clouds, IAU Symposium 190, 143-144

Chu, Y.-H., Guerrero, M. A., and Gruendl, R. A. 2000, ''X-rays From Planetary Nebulae,'' in Asymmetrical Planetary Nebulae II: From Origins to Microstructures, 419-423

Chu, Y.-H., Kim, S., Points, S. D., Petre, R., and Snowden, S. L. 2000, ''RXJ050736-6847.8: A Large Supernova Remnant around an X-ray Binary in the Large Magellanic Cloud,'' AJ, 119, 2242-2247

Crovisier, J., Bockelée-Morvan, D., Colom, P., Biver, N., Despois, D., Lis, D., Benford, D.J., and Mehringer, D. 1999, ''The Composition of Ices in Comet C/1995 O1 (Hale-Bopp): Upper Limits on Undetected Species from Radio Spectroscopy,'' DPS, 31, 3202

Crutcher, R. M. and Troland, T. H. 2000, ''OH Zeeman Measurement of the Magnetic Field in the L1544 Core,'' ApJ, 537, L139

Dantowitz, R. F., Teare, S. W. and Kozubal, M. J. 2000, ''Ground-based High Resolution Imaging of Mercury,'' AJ, 119, 2455

Dickel, H. R. 2000, ''The Naming Game,'' series, Special to IAU Daily Newspaper ''Northern Lights,'' ed. J. Mason (XXIV IAU General Assembly in Manchester, UK) in issues No.s 2 through 10

Dickel, H. R. and Malkov, O. Y. 2000, ''New IAU Concepts of Binary/Multiple Star Designation,'' IAU Symposium 200 on The Formation of Binary Stars, held 10-15 April, 2000 in Potsdam, Germany, eds. Bo Reipurth and Hans Zinnecker, Poster Proceedings, 220

Dickel, H. R. and IAU TG Designations 2000, ''SMC 1 or What's in a Name?,'' IAU Symposium 190 on New Views of the Magellanic Clouds, eds. Y.-H. Chu, N. Suntzeff, J. E. Hesser, and D. A. Bohlender, (San Francisco, ASP), 17

Dickel, H. R., Spite, F., and IAU TG Designations 1999, ''Where is SMC1? A Cautionary Tale: Recommendations about Astronomical Objects Designation,'' in Galactic Evolution: Connecting the distant Universe with the local fossil record, Astrophys. & Space Science, 265, 567

Dickel, H. R., Williams, J. A., Upham, D. E., Welch, W. J., Wright, M. C. H., Wilson, T. L., Mauersberger, R., and Auer, L. H. 1999, ''W 49 A North: J=2-1 Lines of CS

and $C^{18}O$,'' AAS Meeting 194, BAAS 31, No. 4, abstract #109.02

Dickel, H. R., Williams, J. A., Upham, D. E., Welch, W. J., Wright, M. C. H., Wilson, T. L., and Mauersberger, R. 1999, ''Measurements of the J=2-1 Lines of CS and $C^{18}O$ toward the Star-Forming Region W 49 A North,'' ApJS, 125, 413

Dickel, H. R., Williams, J. A., Upham, D. E., Welch, W. J., Wright, M. C. H., Wilson, T. L., Mauersberger, R., and Auer, L. H. 2000, ''W 49 A North: J=2-1 Lines of CS and $C^{18}O$ - Collapse, Colliding Clouds, or ?,'' in Star Formation from the Small to Large Scale, Proceedings of the 33rd ESLAB Symposium, eds. F. Favata, A. Kaas, and A. Wilson, ESA SP-445, 359

Dickel, J. R. 1999, ''Radio Properties of Magellanic Cloud SNRs,'' in New Views of the Magellanic Clouds, eds. Chu *et al.*, IAU Symposium 190, 139-140

Dickel, J. R. 1999, ''What is 29 Doradus?,'' in New Views of the Magellanic Clouds, eds. Chu *et al.*, IAU Symposium 190, 581

Dickel, J. R. 1999, ''The Study of Shell Supernova Remnants with the Square Kilometer Array,'' in Perspectives on Radio Astronomy: Science with Large Antenna Arrays, ed. M. van Haarlem, 295-302

Duez, M. D., Engelhard, E. T., Fregeau, J. M., Huffenberger, K. M., and Shapiro, S. L. 1999, ''Binary–Induced Collapse of a Compact, Collisionless Cluster,'' Phys. Rev. D, 60, 104024

Dunne, B. C., Gruendl, R. A., and Chu, Y.-H. 2000, ''What Produced the Ultraluminous Supernova Remnant in NGC6946?,'' AJ, 119, 1172-1179

Fields, B. D. and Ellis, J. 1999, ''On Deep-Ocean ^{60}Fe as a Fossil of a Near-Earth Supernova,'' New Astronomy, 4, 419

Fields, B. D., Freese, K., and Graff, D. S. 2000, ''Chemical Abundance Constraints on White Dwarfs as Halo Dark Matter,'' ApJ, 534, 265

Fields, B. D., Olive, K. A., Vangioni-Flam, E., and Cassé, M. 2000, ''Testing Spallation Processes With Beryllium and Boron,'' ApJ, 540, 930

Fong, D., Meixner, M., Sutton, E. C., Welch, W. J., Bujarrabal, V., and Castro-Carrizo, A. 2000, ''High Resolution CO Observations of Evolved Stars Imaged with the BIMA Array and Some ISO Results,'' in Asymmetrical Planetary Nebulae II: From Origins to Microstructures, ASP Conference Series, 199, eds. J. H. Kastner, N. Soker, and S. Rappaport, 87-90

Frey, H. U., Mende, S. B., Arens, J. F., McCullough, P. R., and Swenson, G. R. 2000, ''Atmospheric Gravity Wave Signatures in the Infrared Hydroxyl OH Airglow,'' Geophys. Res. Lett., 27, 41-44

Girart, J. M., Crutcher, R. M., and Rao, R. 1999, ''Detection of Polarized CO Emission from the Molecular Outflow in NGC 1333 IRAS 4A,'' ApJ, 525, L109

Girart, J. M., Estalella, R., Ho, P. T. P., and Rudolph, A. L. 2000, ''A Multi-Transition HCO^+ Study in NGC 2264G: Anomalous Emission of the J=1-0 Line,'' ApJ, 539, 763

Goldman, J. and Swenson, G. W. Jr. 1999, ''Radio Wave Propagation Through Woods,'' IEEE Antennas and Propagation Magazine, 41, 34-36

Gorosabel, J., Castro-Tirado, A. J., Pedersen, H., Greiner, J., Thompson, D., Guerrero, M., Oscoz, A., Sabalisck, N., Villaver, E., and Lund, N. 1999, ''Optical and Near-infrared Observations of the GRB 970616 Error Box,'' A&AS, 138, 455-456

Gnedin, N. Y., Norman, M. L., and Ostriker, J. P. 2000, ''Formation of Galactic Bulges,'' ApJ, 540, 32

Grebel, E. K. and Chu, Y.-H. 2000, ''Hubble Space Telescope Photometry of Hodge 301: An ''old'' Star Cluster in 30 Doradus,'' AJ, 119, 787-799

Guerrero, M. A. 2000, ''The Kinematics of Point-Symmetric Planetary Nebulae: Observational Evidence of Precessing Outflows,'' in Asymmetrical Planetary Nebulae II: From Origins to Microstructures, 371-378

Guerrero, M. A. and Manchado, A. 1999, ''On the Chemical Abundances of Multiple-Shell Planetary Nebulae with Halos,'' ApJ, 522, 378-386

Guerrero, M. A., Chu, Y.-H., and Gruendl, R. A. 2000, ''ROSAT Observations of X-ray Emission from Planetary Nebulae,'' ApJS, 129, 295-313

Guerrero, M. A., Miranda, L. F., Manchado, A., and Vázquez, R. 2000, ''The Triple-Shell Structure and Collimated Outflows of the Planetary Nebula NGC 6891,'' MNRAS, 313, 1-7

Guerrero, M. A., Villaver, E., Manchado, A., García-Lario, P., and Prada, F. 2000, ''H_2 and Brγ Narrowband Imaging of Bipolar Planetary Nebulae,'' ApJS, 127, 125-140

Han, Z. and Webbink, R. F. 1999, ''Stability and Energetics of Mass Transfer in Double White Dwarfs,'' A&A, 349, L17-L20

Hofmeister, A. M., Rosen, L. J., and Speck, A. K. ''IR Spectra of Nano- and Macro-Crystals: the Overriding Importance of Optical Path,'' in Thermal Emission Spectroscopy and Analysis of Dust, Disks, and Regoliths, eds. M. L. Sitko, A. L. Sprague, and D. K. Lynch, Astronomical Society of the Pacific Conference Series, 196, 291-299

Iben, I. Jr. 1999, ''The Effects of Possible Binary and Tertiary Companions on the Behavior of Eta Carinae,'' in Eta Carinae at the Millenium, eds. J. Morse, R. Humphreys, and A. Damineli (San Francisco: ASP Conference Series), 367

Iben, I. Jr. 2000, ''On the Normalization of the Cepheid Period-Luminosity Relationship,'' in Variable Stars as Essential Astrophysical Tools, ed. C. Ibanoglu (Dordrecht: Kluwer), 437

Iben, I. Jr. 2000, ''Mass Transfer/Loss from AGB Stars in Close Binaries,'' in Asymmetrical Planetary Nebulae II: From Origins to Microstructures, eds. J. E. Kastner, N. Soker, and S. A. Rappaport (ASP; San Francisco), 107

Iben, I. Jr. 2000, ''Closing Remarks,'' in The Galactic Halo: From Globular Clusters to Field Stars, eds. A. Noels, P. Magain, D. Caro, E. Jehin, G. Parmentier, and A. Thoul (Liege: U. of Liege), 629

Iben, I. Jr. and Tutukov, A. V. 1999, ''On the Production by Triple Stars of Binary Blue Stragglers and Cataclysmic Variables, in ''The 11th European Workshop on White

Dwarfs, ASP Conf. Ser. 169, eds. J.-E. Solheim & E. G. Meivstas (San Francisco: ASP), 432

Josselin, E., Bachiller, R., Manchado, A., and Guerrero, M. A. 2000, ''CO Content of Bipolar Planetary Nebulae,'' A&A, 353, 363-370

Kaler, J. B. 2000, ''Ask Astro,'' ''Astronomy,'' continuing contributions: January, globular clusters

Kaler, J. B. 2000, ''Astronomy Update 1999,'' Proc. of the 35th Annual GLPA Conference, 19

Kaler, J. B. 2000, ''Three Astronomies,'' 1999 Armand N. Spitz Lecture, Proc. of the 33rd Annual GLPA Conference, 12, 2000, and The Planetarian, 12, 12

Kaler, J. B. 2000, ''De Schatkamer van de Sterren,'' Zenit, 27 (January), 4

Kaler, J. B. 2000, ''Sunlight,'' on the web at http://www.astro.uiuc.edu/ kaler/sow/atm/atm.html

Lai, S.-P. and Crutcher, R. M. 2000, ''33.8 GHz CCS Survey of Pre-Protostellar Cores,'' ApJS, 128, 271

Lazendic, J. S., Haynes, R. F., Dickel, J. R., Jones, P. A., White, G. L., and Costa, M. 1999, ''A New Investigation of the 30 Doradus Region with the Australia Telescope Compact Array,'' in New Views of the Magellanic Clouds, eds. Chu *et al.*, IAU Symposium 190, 251-253

Liu, S.-Y. and Snyder, L. E. 1999, ''Subarcsecond Resolution Observations of Sagittarius B2,'' ApJ, 523, 683

Lombardi, J. C., Rasio, F. A., Shapiro, S. L., and Sills, A. 1999, ''Tests of Spurious Transport in Smoothed Particle Hydrodynamics,'' J. Comp. Phys., 152, 687

Manchado, A., Villaver, E., Stanghellini, L., and Guerrero, M. A. 2000, ''The Morphological and Structural Classification of Planetary Nebulae,'' in Asymmetrical Planetary Nebulae II: From Origins to Microstructures, 17-25

Markovic, D. and Shapiro, S. L. 2000, ''Gravitational Collapse with a Cosmological Constant,'' Phys. Rev. D., 61, 084029

McCutcheon, W. H., Sandell, G., Matthews, H. E., Kuiper, T. B. H., Sutton, E. C., Danchi, W. C., and Sato, T. 2000, ''Star Formation in NGC 6334 I and I(N),'' MNRAS, 316, 152

Meixner, M. 2000, ''Properties of Proto-Planetary Nebulae,'' in Asymmetrical Planetary Nebulae II: From Origins to Microstructures, ASP Conference Series, eds. J. H. Kastner, M. Soker, and S. Rappaport, 199, 135

Meixner, M., Ueta, T., Dayal, A., Hora, J., Fazio, G., Hrivnak, B.J., Skinner, C. J., Hoffmann, W. F., and Deutsch, L. K. 1999, ''A Mid-Infrared Imaging Survey of Proto-Planetary Nebula Candidates,'' ApJS, 122, 221-242

Miranda, L. F., Fernández, M., Alcalá, J. M., Guerrero, M. A., Anglada, G., Gómez, Y., Torrelles, J. M., and Aaquist, O. B. 2000, ''High-Resolution Spectroscopy and Broadband Imaging of the Young Planetary Nebula K 3-35,'' MNRAS, 311, 748-754

Machacek, M. E., Bryan, G. L., Meiksin, A., Anninos, P., Thayer, D., Norman, M., and Zhang, Y. 2000, ''Hydrodynamical Simulations of the Ly alpha; Forest: Model Comparisons,'' ApJ, 532, 118

Norman, M. L. 2000, ''Introducing ZEUS-MP: A 3D, Parallel, Multiphysics Code for Astrophysical Fluid Dynamics,'' Revista Mexicana de Astronoma y Astrofsica (Serie de Conferencias), 9, 66-71

Norman, M., Daues, G., Nelson, E., Loken, C., Burns, J., Bryan, G., and Klypin, A. 2000, ''Simulated Cluster Archive: A Computational Catalog of X-ray Clusters in a Lamda-CDM Universe,'' in Large Scale Structure in the X-ray Universe, Proceedings of the 20-22 September 1999 Workshop, Santorini, Greece, eds. Plionis, M. & Georgantopoulos, I., Atlantisciences, Paris, France, 395

Pei, C. C., Liu, S.-Y., and Snyder, L. E. 2000, ''Identification of New Methanol Lines Toward Sagittarius B2,'' ApJ, 530, 800

Plante, R. L., Crutcher, R. M. and McGrath, R. E. 1999, ''The NCSA Astronomy Digital Image Library: From Data Archiving to Data Publishing,'' Future Generation Computer Systems, 16, 49

Points, S., Chu, Y.-H., Gruendl, R. A., Kim, S., Smith, R. C., Snowden, S., and Brandner, W. 1999, ''The Kinematic Structure of the Supergiant Shell LMC2,'' in New Views of the Magellanic Clouds, IAU Symposium 190, 156-157

Rasio, F. A. and Shapiro, S. L. 1999, ''Coalescence of Binary Neutron Stars,'' Classical and Quantum Gravity, 16, R1-R29

Rezzolla, L., Shibata, M., Asada, H., Baumgarte, T. W., and Shapiro, S. L. 1999, ''Constructing a Mass-Current Radiation–Reaction Force for Numerical Simulations,'' ApJ, 525, 935

Rezzolla, L., Lamb, F. K., and Shapiro, S. L. 2000, ''R-mode Oscillations in Rotating Magnetic Neutron Stars,'' ApJL, 531, L139

Ryan, S. G., Beers, T. C., Olive, K. A., Fields, B. D., and Norris, J. E. 2000, ''Primordial Lithium and Big Bang Nucleosynthesis,'' ApJL, 530, L57

Sarma, A. P., Troland, T. H., Roberts, D. A., and Crutcher, R. M. 2000, ''H I and OH Zeeman Effect Observations of NGC 6334,'' ApJ, 533, 271

Schilke, P., Mehringer, D. M., and Menten, K. M. 2000, ''A Submillimeter HCN Laser in IRC+10216,'' ApJ, 528, L37

Scowen, P., Chu, Y.-H., and Gruendl, R. A. 1999, ''A High Resolution Optical Summary of the Structure and Dynamics of 30 Doradus,'' in New Views of the Magellanic Clouds, IAU Symposium 190, 249-250

Shah, R. Y. and Wootten, A. 2000, ''Imaging at Radio through Sub-millimeter Wavelengths,'' ed. Jeff Mangum, in The Astronomical Society of the Pacific, Conference Series, 2000. The conference was held June 6-8, 1999, in Tucson, Arizona, E61

Shapiro, S. L. 1999, ''Black Holes and Gravitational Waves: Spacetime Engineering,'' in Numerical Astrophysics Proceedings of the International Conference on Numerical Astrophysics 1998 in Tokyo, Japan, 10-13 March 1998, eds. S. M. Miyama, K. Tomisaka, and T. Hanawa (Kluwer Academic Publishers, Dordrecht), 257

Shibata, M., Baumgarte, T. W., and Shapiro, S. L. 1999, ''Hydrodynamic Simulations of Coalescing Binary Stars: Stability Against Gravitational Collapse,'' in Numerical Astrophysics Proceedings of the International Conference on Numerical Astrophysics 1998 in Tokyo, Japan, 10-13

March 1998, eds. S. M. Miyama, K. Tomisaka, and T. Hanawa (Kluwer Academic Publishers, Dordrecht), 277

Shibata, M., Baumgarte, T. W., and Shapiro, S. L. 2000, ''Stability and Collapse of Rapidly Rotating, Supramassive Neutron Stars: 3D Simulations in General Relativity,'' Phys. Rev. D., 61, 044012

Sparks, W. M., Starrfield, S. G., Sion, E. M., Shore, S. N., Chanmugam, G., and Webbink, R. F. 2000, ''Cataclysmic and Symbiotic Variables),'' in Astrophysical Quantities, 4th Edition, ed. A. N. Cox (Berlin: Springer Verlag), 429-450

Speck, A. K., Barlow, M. J., and Skinner, C. J. ''Observations of the 11micron Silicon Carbide Feature in Carbon Star Shells,'' in IAU Symposium No. 177: The Carbon Star Phenomenon, ed. R. F. Wing, 578

Speck, A. K. and Hofmeister, A. M. 2000, ''Infrared Studies of Silicon Carbide,'' in Meteoritics & Planetary Science, 35 (Supplement), A150

Speck, A. K., Hofmeister, A. M., and Barlow, M. J. ''Silicon Carbide: The Problem with Laboratory Spectra,'' in Thermal Emission Spectroscopy and Analysis of Dust, Disks, and Regoliths, eds. M. L. Sitko, A. L. Sprague, and D. K. Lynch, Astronomical Society of the Pacific Conference Series, 196, 281-290

Speck, A. K., Hofmeister, A. M., Barlow, M. J., and Sylvester, R. J. 2000, ''Observational Evidence for Presolar Grains around Oxygen-rich Evolved Stars,'' in Meteoritics & Planetary Science, 35 (Supplement), A150

Speck, A. K., Meixner, M., and Knapp, G. R. 2000, ''Circumstellar Dust Around Post-AGB Stars,'' in ISO Beyond Point Sources: Studies of Extended Infrared Emission, eds. R. J. Laureijs, K. Leech and M. F. Kessler, ESA-SP 455, 83

Stone, J. M., Gammie, C. F., Balbus, S. A. and Hawley, J. F. 2000, ''Protostars and Planets IV,'' (Book - Tucson: University of Arizona Press, eds. Mannings, V., Boss, A. P., and Russell, S. S.), 589, 589

Swenson, G. W. Jr. 2000, ''Intragalactically Speaking,'' Scientific American, 283, 34-37

Teare, S. W. and Dantowitz, R. F. 2000, ''Twinkle-free Stars: Astronomical Imaging without Atmospheric Blurring,'' Mercury, 29(2), 28

Ueta, T., Meixner, M., and Bobrowsky, M. 2000, ''A Hubble Space Telescope Snapshot Survey of Proto-Planetary Nebula Candidates: Two Types of Axisymmetric Reflection Nebulosities,'' ApJ, 528, 861-884

Ueta, T., Meixner, M., and Bobrowsky, M. 2000, ''Dual Axisymmetry in Proto-planetary Nebula Reflection Nebulosities: Results from an HST Snapshot Survey of PPN Candidates,'' Asymmetrical Planetary Nebulae II: From Origins to Microstructures, ASP Conference Series, eds. J. H. Kastner, N. Soker, and S. Rappaport, 199, 195

Vazquez-Semadeni, E., Ostriker, E. C., Passot, T., Gammie, C. F. and Stone, J. M. 2000, ''Protostars and Planets IV,'' (Book - Tucson: University of Arizona Press, eds. Mannings, V., Boss, A. P., and Russell, S. S.), 3, 3

Veal, J. M., Snyder, L. E., Wright, M. C. H., Woodney, L., Palmer, P. Forster, J. R., de Pater, I., A'Hearn, M. F., and Kuan, Y.-J. 2000, ''An Interferometric Study of HCN in Comet Hale-Bopp (C/1995 O1),'' AJ, 119, 1498

Westpfahl, D. J., Bell, D. J., and Yoss, K. M. 1999, ''A List of Late-Type Stars in the Galactic Antirotation Direction,'' PASP, 111, 1169

Williams, R., Chu, Y.-H., Dickel, J., and Smith, R. C. 1999, ''Supernova Remnants in the Large Magellanic Cloud: A Multiwavelength Study of Energetics and Environments,'' in New Views of the Magellanic Clouds, IAU Symposium 190, 145-146

Williams, R. M., Petre, R., Chu, Y.-H., and Chen, C.-H. R. 2000, ''Resolving SNR 0540-6944 from LMC X-1 with Chandra,'' ApJ, 536, L27-L30

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D. Pettigrew