The University of Toledo
Ritter Astrophysical Research Center
Toledo, Ohio 43606

[S0002-7537(98)07201-1]

This report covers the period 1 July 1996 to 30 June 1997.

1. PERSONNEL

During the report period, Karen S. Bjorkman joined the permanent staff as Assistant Professor of Astronomy, and Jon E. Bjorkman accepted a position as Research Assistant Professor. Anatoly Miroshnichenko began a postdoctoral research associateship, working with K. Bjorkman on data from WUPPE. Otherwise, the permanent staff was unchanged.

During the fall of 1996, Morrison was on leave at the Astronomical Institute ''Anton Pannekoek,'' University of Amsterdam, The Netherlands.

Students involved in astronomical research were: undergraduate Greg Madsen; and graduate students Brian Abbott, Bruce Cantor, Brian Friedmann, Karl Gordon, David Knauth, Ivaylo Mihaylov, Christopher Mulliss, Jens Petersohn, Tracy Smith, Larissa Spiker, ZhongYuan Xue, and Janos Zsargó. Visiting undergraduate students Eric Higgs and Dan Yelle (Xavier Univ. and the Univ. of Pittsburgh, respectively) were supported by the NSF REU program.

2. OBSERVATORY

The 1200×800-pixel CCD camera system that was received from Wright Instruments Ltd. in November 1992 provided another trouble-free year for the échelle spectrograph with the 1-m telescope. During the report period, a total of 515 stellar, planetary, and cometary spectra were obtained on 81 nights. Most of the stellar observations were made with the standard Hα grating setting, where the spectral coverage consists of 9 disjoint 70-Å regions in the yellow and red, and with a wide slit that yields a spectral resolving power $R \simeq 26{,}000$. During the period 1997 February to July, however, the slit was set to give $R \simeq 60{,}000$. Information on objects observed with the 1-m telescope since the fall of 1993 and on the number and quality of spectra of each one can be found in Gordon (1996).

3. RESEARCH

3.1 Stellar Astrophysics

Continuing spectroscopic monitoring programs at Ritter Observatory that are not described below concern: binary stars, hypergiant stars, BA supergiant stars, Herbig Ae/Be stars, A-type shell stars, and UU Herculis-type stars.

K. Bjorkman continued her analysis of data obtained with the WUPPE instrument aboard the Astro-2 space shuttle mission. These data are among the first ultraviolet spectropolarimetric observations of classical Be stars and of Herbig Ae/Be stars ever obtained. The UV observations are combined with optical observations for complete spectropolarimetry from 1450 Å to 1.05 μm. For the classical Be stars, the effects of spectral type and rotation rate on the polarimetric spectrum are being investigated. A. Miroshnichenko is working with Bjorkman on analyzing the data on the Herbig Ae/Be stars and also on the classical Be stars. Supporting high-resolution optical spectra of the WUPPE stars were obtained by Morrison, Gordon, and Mulliss with the Ritter échelle spectrograph, and these data will be included in the analysis.

With K. Wood (Harvard CfA), Bjorkman and Bjorkman developed techniques for using continuum spectropolarimetry to diagnose the structure of circumstellar disks around classical Be stars. From observations with the Halfwave Polarimeter (HPOL) at the Pine Bluff Observatory (PBO), they were able to show that the disk structure can be well constrained by the polarization data. These techniques are now being applied to additional stars, with M. Putman (U. Wisconsin and Australian National U.) also involved in that analysis.

In collaboration with A. Quirrenbach (Max-Planck Inst.), Bjorkman and Bjorkman combined spectropolarimetry from PBO with interferometry from the USNO MrkIII interferometer for seven Be stars, and were able to demonstrate definite evidence for disks that are constrained to be quite thin. The combination of interferometry and spectropolarimetry is shown to be useful for obtaining detailed information about the nature of circumstellar disks.

K. Bjorkman continued a spectropolarimetric survey of Herbig Ae/Be and T Tauri stars in the optical, using the HPOL instrument at PBO and at the WIYN observatory at Kitt Peak. Additional observations were obtained during a WIYN run with K. Nordsieck (U. Wisconsin) in December 1996, and analysis of these data is underway. Other work on the Herbig Ae/Be stars by K. Bjorkman includes collaboration with C. Grady (Eureka Scientific) and M. Sitko (U. Cincinnati) to investigate the nature of the circumstellar envelopes of these stars by means of ultraviolet, optical, and infrared spectroscopy and UV and optical spectropolarimetry.

Spiker and K. Bjorkman have begun to revisit the question of mass-loss rates of B stars. Recent X-ray and EUV results, combined with new theories for axisymmetric envelopes around rotating stars, have suggested that current estimates of mass-loss rates from B stars may be low. Using the new results and true axisymmetric models, together with newly reprocessed *IUE* archival data, Spiker and Bjorkman are deriving new mass-loss rates for comparison with older published values.

Miroshnichenko and K. Bjorkman studied spectropolarimetric data obtained by the Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE) aboard the *Astro-2* space mission in March 1995. They found that the Herbig Ae/Be star AB Aur displays a position angle flip by nearly 90° in the UV region while another pre-main-sequence candidate, HD 50138, does not. The results indicate that both objects have non-spherical circumstellar envelopes. That of AB Aur

has a lower density contrast between the equatorial and polar regions than that of HD 50138.

In collaboration with M. Elitzur (Univ. of Kentucky) and Ž. Ivezić (Princeton Univ.), Miroshnichenko carried out modeling of spectral energy distributions (SED) of a sample of 13 galactic B[e] stars in a range from 0.3 to 100 μm. They found that the dust density distributions can be roughly described as $\propto r^{-3/2}$ in the inner shell, and by a somewhat flatter decline in the outer regions. However, the SEDs differ significantly within the group, possibly reflecting different evolutionary states of individual stars.

Miroshnichenko studied high-resolution spectra of MWC 314, an LBV candidate recently discovered by him, in collaboration with L. Houziaux, I. Frémat (Univ. Mons, Belgium), E. Chentsov, and V. Klochkova (Special Astrophys. Observ. of the Russian Acad. Sci.). They calculated profiles of Balmer emission lines and that of He I λ 6678, using two different radiation transfer computer codes. They calculated the Balmer line profiles using an axisymmetric model of the stellar wind and the Sobolev approximation to determine hydrogen level populations. The comoving-frame method in a spherical envelope was used for the helium line. The main parameters of the star and its wind have been determined to be: $T_{\rm eff}=25000$K, $R^{*}=50R_{\odot}$, $\dot{M}=4\times10^{-5}M_{\odot}$ yr^{-1}, $v_{\infty}=500$ km s^{-1}.

Morrison continued to study Ritter échelle spectra of the Herbig Ae/Be star HD 163296 and the candidate Herbig Ae/Be star HD 50138.

Under the supervision of Morrison, Mulliss began a major study of time variability in B- and A-type supergiants, as seen in Ritter échelle spectra. Particularly of interest are the stars HR 1035, HR 1040, and α Cyg. The radial velocities and equivalent widths of photospheric lines and the strengths of absorption and emission components in Hα are being searched for periodicities, and photospheric precursors to certain dramatic increases in Hα absorption equivalent widths (''high-velocity absorption events;'' Kaufer *et al.* 1996) are sought.

Mulliss re-analyzed his radial-velocity observations of ι Her, a well-studied B3 IV star that exhibits photometric, radial-velocity, and line-profile variability. When the data set is subdivided, the star is found to switch among several different pulsation modes, a result that is consistent with the discrepant periodicities have been reported in the literature. The new analysis shows that the conclusion of the presence of mode switching is robust with respect to different ways of subdividing the data set.

Anderson and Xue continued the calculation of non-LTE model atmospheres from the early B-star range into the mid- and late-B range of temperatures (from 30000 K to 22000 K). These atmospheres have new and extended model ions for the II, III and IV ions of C, N, O, Ne, Al, and Si, with representations for all allowed transitions between states with principal quantum numbers less than 7 built on the first two or three parent excitations. The models also include distribution function representations for the transitions in III and IV ions of Sc–Ni. They are able to produce high-resolution emergent spectra for direct comparison with observations, which should allow the analysis of the possible influence of turbulence gradients.

In collaboration with K. Wood (CfA), J. Bjorkman continued to develop Monte Carlo simulation techniques for 3-D radiative transfer. Methods have now been developed for determining the 3-D radiative equilibrium temperature distribution within dusty environments. These methods have been applied to a study of dust formation in the disks around B[e] stars. Preliminary results indicate that the Wind-Compressed Disk Model (Bjorkman and Cassinelli 1993) can explain the formation of disks around B[e] stars and that these disks are sufficiently dense to explain the formation of dust in their outflow.

J. Bjorkman is also developing methods for calculating line profiles in aspherical circumstellar envelopes for determinations of the mass-loss rates from hot stars (in collaboration with K. Bjorkman). As part of this program, Mihaylov is developing a Monte Carlo line synthesis code for calculating UV resonance line profiles in complex aspherical, nonmonotonic velocity fields in the outflows from hot stars.

J. Bjorkman is also continuing his theoretical work with Abbott on the winds from rotating stars. Numerical models of rapidly rotating stellar winds indicate that there may be multiple critical points in the wind. Since these critical points determine the mass loss rate, the wind could have more than one solution for the outflow. If so, the winds of rapidly rotating stars may have multiple outflow rates, and the star may switch between the different solutions, producing time variability of the emergent spectrum. Using the topological analysis methods developed by Bjorkman (1995), Abbott is classifying all the critical points of rotating line-driven winds, determining their location, and finding which outflow solutions are allowed.

Other collaborations include investigating the magnetic field structure of Wind-Compressed Zone models with R. Ignace (Univ. Glasgow) and J. Cassinelli (Univ. Wisconsin), and determining the effects of gravitational microlensing of extended sources (J. Simmons and I. Coleman, Univ. Glasgow). Our preliminary work indicates that microlensing an AGB star would produce observable polarization signatures that would aid in diagnosing both the properties of the lensing object and the properties of the extended circumstellar envelope. Similarly, microlensing of stars with circumstellar disks would provide a valuable probe of the disk structure.

3.2 Interstellar Matter

Gordon, Witt and Friedmann reported the first successful detection of extended red emission (ERE) in the diffuse ISM of the Galaxy, covering galactic latitudes from $|b|=20°$ to $|b|=60°$ with a total sky area $>1100\square°$. In this study, background photometry in *B* and *R* done with *Pioneer 10* and *11* at heliocentric distances greater than 3.3 AU was combined with precision star counts extending to $m=20$ to derive the intensity distribution and color of the diffuse galactic background radiation. In the *R*-band, the ERE is found to be about as intense as the scattered diffuse radiation, and it is found to be well correlated with N(H I) and the line-of-sight far-IR thermal emission from galactic dust. On the basis of these correlations, a photon conversion efficiency of

$(10 \pm 3)\%$ was determined, assuming that all dust absorption in the 912 – 5500 Å range is caused by the ERE photoluminescent agent. This efficiency estimate is a lower limit because there are several other likely contributors to the absorption.

Petersohn and Witt completed a radiative transfer study of far-UV (1600 Å) background radiation measured by the Dynamic Explorer (DE)-1 satellite. A significant fraction of the background was attributed to diffuse (scattered) galactic light. The most likely solution for the albedo and phase function asymmetry parameter are $a = 0.57 \pm 0.15$ and $g = 0.89 \pm 0.05$. An uncorrelated background component, most likely due to extragalactic light, was found to amount to 400 ± 150 photons s^{-1} $Å^{-1}$ cm^{-2} sr^{-1}.

Witt and Gordon continued their radiative transfer work on clumpy scattering media by completing a large series of galaxy models with doubly exponential disks and bulges, with arbitrary bulge/disk ratios. Models with identical amounts of dust, with either homogeneous or clumpy distributions, were studied in order to quantify the effects of clumpiness on observable galactic parameters such as surface brightness gradients, color gradients, total apparent luminosity, and IR surface brightness profiles. A subset of these models was used in a collaboration with L. Kuchinski (OSU) in which the optical depth perpendicular to the disk of a set of highly inclined spiral galaxies was found. These results, which indicate that typical central optical depths are of order 1–2, are important in the ongoing debate as to whether galactic disks are opaque or not.

In collaboration with Madsen and P. Grosbol (ESO), Witt employed these same models to estimate the dust masses of disk galaxies, comparing the observed $V-K$ color distributions across the disks of these objects with predicted $V-K$ excesses for models with known dust masses. The dust masses were found to be larger than corresponding dust masses derived from observed IRAS 100-μm fluxes by factors of 5–7 for homogeneous models and by factors of 7–10 for clumpy models.

Gordon, Calzetti, and Witt employed similar models to study the characteristics of dust in starburst galaxies. In such systems, the dust has mainly a screen-like geometry, surrounding the starburst regions, while dust internal to such regions has been removed either by radiation pressure or by grain destruction. The wavelength dependence of extinction in such systems is most like that in the SMC, with no observable 2175-Å feature. Witt, Gordon, and Rh. Evans (U. Chicago) have been collaborating on a program of imaging photopolarimetry of NGC 7023 and other reflection nebulae at visible and near-IR wavelengths. Their aim is the determination of the near-IR albedo of the nebular dust and the degree of clumpiness of the nebular material.

Federman, Knauth, D. Lambert (U. Texas), and B-G Andersson (JPL) studied the photodissociation region (PDR) associated with NGC 7023, which is illuminated by the star HD 200775. They measured absorption from atomic species (Na I, K I, Ca II) and molecules (CH, CH^+, C_2, and CN) in order to extract the physical conditions in the PDR in front of the star. Chemical models of the foreground gas successfully reproduced the observations only when the extinction curve for this sight line was adopted. Future models of the radio and infrared emission from the PDR in the molecular cloud need to take the local extinction into account. The chemical models, however, were not able to reproduce the observed column of CN. Measurements of CN and HCN emission at radio wavelengths show that CN/HCN increases toward the star; an extra contribution to the CN abundance from the molecular cloud is needed to bring the modeling results of the foreground gas into agreement with the observations.

An analysis by Federman, D. E. Welty (U. Chicago), and J. Cardelli (Villanova) revealed the amount of CH produced in the non-equilibrium processes leading to the synthesis of CH^+ in cloud envelopes. They combined estimates of density and temperature from the excitation of neutral carbon within the three fine-structure levels of the ground electronic state with measurements of the total amount of CH and upper limits for C_2 and CN toward 23 Ori and β^1 Sco. The results from C I excitation suggest rather low densities. The upper limits for C_2 and CN constrain the amount of CH associated with the equilibrium chemistry for these species: $CH \rightarrow C_2 \rightarrow CN$. The remainder of the observed CH column is assumed to be produced along with CH^+. For both directions, the column of CH is approximately 40% of the CH^+ column. The analysis is being applied to a larger sample of sight lines.

Federman, Knauth, Lambert, Y. Sheffer (U. Texas), Cardelli, and U. Sofia (Villanova) completed their measurements on the $^{11}B/^{10}B$ ratio in diffuse interstellar clouds. The data for the sight lines toward κ Ori and ζ Oph are consistent with the results presented last year for the gas toward δ Sco. The interstellar ratio does not vary to within the precision of the measurements (20%) and is consistent with the meteoritic ratio of ~ 4. The results can be understood with models of Galactic nucleosynthesis for light elements — namely, spallation involving cosmic ray protons on interstellar CNO, enhanced amounts of cosmic ray CNO nuclei on interstellar protons, and neutrinos from a supernova on ^{12}C nuclei in the stellar envelope is required to explain the observations for the solar system and interstellar space.

3.3 Planetary System Astrophysics

On six nights during the first half of 1997 April, Knauth and Mulliss obtained spectra at $R = 60{,}000$ of Comet C/1995 O1 (Hale-Bopp) with the échelle spectrograph on the 1-m telescope. With the collaboration of Morrison, analysis of these spectra is underway. Two principal aims of the study are to compare the strengths of the unidentified lines with those in the group's spectra of Comet Hyakutake and to search for heretofore unnoticed splitting of these lines.

James continued as PI of a *Hubble Space Telescope* program in which Mars has been monitored with WFPC2, STIS, and NICMOS during all periods in which it has been observable since 1990. Observations acquired during Cycle 6 have reinforced our earlier conclusion that the atmosphere of Mars has recently been significantly more cloudy near aphelion than had been previously believed. Coupled with microwave CO spectra obtained by Clancy (SSI), these data suggest that this process may play an important role in the global water cycle. Images of Mars acquired during the fall of 1996 re-

vealed significant dust storm activity in the north polar region of the planet. In June, 1997, a significant dust storm in Valles Marineris was discovered as part of *HST* observations supporting Pathfinder.

M. Wolff and Cantor are using a weak CO_2 band to monitor the global opacity and atmospheric temperature on Mars. Use of the Ritter échelle spectrograph with $R = 60{,}000$ allows determination of equivalent widths of individual lines in the 8689 Å band. These widths are sensitive to atmospheric aerosols and to atmospheric temperature. Between 1997 February and July, spectra were obtained on 16 nights. An atmospheric model which takes account of variations in surface reflectance, elevation, and seasonal effects is being developed.

Bruce Cantor, with the help of Higgs and Yelle, analyzed the regression of the north polar cap of Mars using both WFPC1 and WFPC2 images from four Martian years. Cantor compares these regressions during the four spring seasons observed by *HST* to each other and to the historical data base in order to constrain interannual variations.

James is a Participating Scientist and member of the MOC (Mars Observer Camera) Team on the Mars Global Surveyor Mission. Preliminary planning for the mapping phases of the mission has taken place during the past year. In addition, James is a Co-I for the MARCI camera for the 1998 Mars Surveyor Orbiter and has been involved in filter selection and calibration.

3.4 Laboratory Astrophysics

Curtis, Ellis, and Matulioniene have collaborated with T. Brage of the Univ. of Lund to develop a method for incorporating the relativistic J dependence of the Dirac radial wave function into the specification of oscillator strengths from measured lifetime and energy level data. They have used this method to improve the accuracy of the oscillator strengths deduced from their earlier measurements of the $6p^2 - 6p7s$ transitions in Bi II. Henderson, Curtis, Matulioniene, Ellis and Theodosiou have made measurements of the lifetimes of the $6p$, $6d$, $7s$, $7p$ and $5f$ levels in Tl III. In addition, they have combined these and earlier lifetime measurements for other ions in this isoelectronic sequence with theoretical estimates of other, weaker, processes to obtain values for the electric dipole polarizabilities of Au I, Hg II, Tl III, Pb IV, and Bi V, which permit the prediction of the wavelengths of high Rydberg transitions in these ions. In collaboration with G. Wahlgren of the Univ. of Lund, Henderson, Matulioniene, Curtis and Ellis have made measurements and theoretical calculations of the lifetime of the $5d^46s - 5d^46p$ 2204 Å line in W II, which is needed for synthetic spectrum calculations.

Witt, X. Deng (Univ. Toledo), D. Furton (Rhode Island Coll.), Smith, and Friedmann have begun a laboratory study of hydrogenated amorphous carbon with Si and other impurities. The aim is to find likely materials for grain mantles that exhibit photoluminescence matching the ERE both in spectral characteristics and in efficiency. Much of the initial effort was directed toward establishing an experimental facility capable of measuring the conversion efficiency of photoluminescent materials. A series of films with a wide range of C/Si ratios was produced with the local plasma-enhanced chemical vapor deposition system. Through collaborations with X. Chen (Tencor Corp.) and Th. Henning (Univ. Jena), independent measurements of the indices of refraction were obtained for these films, while their optical and photoluminescent characteristics were determined locally. Work is also progressing toward the study of the near-IR emission characteristics of these solids under conditions resembling those of interstellar environments.

3.5 High-Energy Astrophysics

Iwamoto continued collaboration with researchers in Kyoto and Chiba Inst. Tech. on dynamical weak processes associated with the formation of meson condensation inside neutron stars.

In collaboration with the groups in Tokyo and Montana State, Iwamoto studied the effects of axion emission on the thermal evolution of neutron stars. Three types of equations of state with nucleon superfluidity are considered, in comparison with the observational data, to obtain limits on the axion parameters within the KSVZ and DFSZ axion models.

4. INSTRUCTION

4.1 Academic

Undergraduate astronomy enrollments for the four academic quarters covered by the report period were as follows. In our general education courses, the annual total was 1137 for the three introductory lecture courses and 151 for the laboratory. The more advanced (300-level) general-education courses had a total enrollment of 16. The junior/senior-level course entitled, ''Astronomy in the Planetarium,'' had an enrollment of 8, and the honors course entitled, ''Mars: A Science & Popular History,'' had an enrollment of 16. In graduate courses and advanced undergraduate courses for science majors, the total enrollment was 54.

4.2 Public

K. Bjorkman participated in the Quantum Leap program, making several presentations about physics fundamentals to groups of Girl Scouts from across the nation. She also gave presentations on astronomy at state parks in Wisconsin under the auspices of the ''Universe in the Park'' program, which she developed while at the University of Wisconsin.

Undergraduate Assistants to Anderson and Mak for public education were Dawn Mulliss, Jeff Potter, and Dan Carmany. Programs written and presented for the public at Ritter Planetarium were (authors in parentheses):

1. *Planet Quest* (D. Mulliss and J. Potter)
2. *The Old Lights of Holiday Nights* (Anderson and Mak)
3. *Santa's Secret Star* (Mak)
4. *Winter Skies* (Mak)
5. *So You want to be an Astronomer?* (Mak)
6. *Spring Skies over Toledo* (Mak)
7. *Women in Asronomy* (D. Mulliss)

The total attendance for all programming conducted under the auspices of Ritter Planetarium and Brooks Observatory

tied the all-time high of 25,500 for the year. Monthly public observing nights with the Ritter 1-meter telescope and weekend evening viewings with the facilities of the Brooks Observatory usually attracted 50 to 100 people per event. In all, approximately 8000 attended observing sessions during the course of the year, including nearly 5000 for our eight clear nights of observing Comet Hale-Bopp.

During the report period, we conducted over 20 Astronomy Merit Badge programs for Boy Scouts, in which more than 325 scouts received their badges. We also conducted 15 Girl Scout Space Exploration Ribbon programs which allowed roughly 300 scouts to receive their ribbons. We also conducted several public workshops on amateur astronomy and telescope use and care, as well as two in-service workshops for area schools.

Planetarium Staff attended three meetings, delivering two papers.

5. MISCELLANEOUS

5.1 Participation in meetings

Witt and K. Bjorkman participated in the workshop on small telescopes at the Toronto AAS meeting in January. At the Workshop on B[e] stars (June 1997, Paris, France), J. Bjorkman gave an invited talk and Miroshnichenko presented an invited talk and four contributed posters. Iwamoto presented papers at: the Joint April Meeting of the APS and the AAPT with the Canadian Association of Physicists and the Sociedad Mexicana de Fisica (CAM '97) in Washington D.C.; and at the 1997 Spring Meeting of the Ohio Section of the APS. James presented papers at the MGS Workshop on Polar Processes, LASP, Boulder, CO and the DPS Meeting, Cambridge, MA.

5.2 Visiting lectureships

J. Bjorkman was invited to lecture at the ninth annual summer school of the European Astrophysical Doctoral Network held in Brussels, Belgium. He presented a course on circumstellar disks and laboratory exercises on excess IR emission in hot stars. He also presented colloquia at the University of Glasgow, the University of Amsterdam, and Michigan State University. Federman presented a Colloquium/Seminar at Michigan State University, and Morrison presented a colloquium at the University of Amsterdam.

5.3 Service

K. Bjorkman continued to serve as a member of the Publications Board of the AAS, and Morrison continued to serve on the V. M. Slipher Committee on Public Education in Astronomy. J. Bjorkman was elected to a three-year term on the IAU Working Group on Active B stars. He was also elected to the scientific organizing committee for a meeting to be held in June, 1999 in Alicante, Spain on ''The Be Phenomenon in Early Type Stars'' (IAU Sponsorship is being sought).

5.4 Awards and Research Support

We gratefully acknowledge NASA LTSA grants to J. Bjorkman, Federman, and Witt; NASA grants to K. Bjorkman and to Federman and Schectman; STScI grants to Federman and James; and an NSF grant to Iwamoto. K. Bjorkman and J. Bjorkman acknowledge support from subcontracts from the Univ. of Wisconsin. James received support from JPL as Participating Scientist on the MOC team of MGS and as Co-I on the MARCI (Mars Color Imager) camera on Mars Surveyor '98.

Iwamoto wishes to acknowledge the Yukawa Institute for Theoretical Physics and the Department of Physics, Kyoto Univ. for support during his visits, and Morrison is grateful for visitor support from the Astronomical Institute ''Anton Pannekoek,'' Univ. of Amsterdam.

PUBLICATIONS

External collaborators are listed in parentheses.

Reports, Theses, and Abstracts

(Coleman, I.J., Simmons, J.F.L., Newsam, A.M.), & Bjorkman, J.E. 1997, ''Microlensing, Polarisation, and the Analysis of Stellar Envelopes,'' in press

Curtis, L.J. 1996, ''Lifetime and Energy Level Measurements and Systematizations,'' in Program & Abstracts, XVI Atomic Physics Program Contractors' Workshop of the DoE, Office Basic Energy Sci., Div. Chem. Sci., Technical Report of the California State Univ. at Fullerton

Curtis, L.J. 1996, ''Semiempirical Studies of Atomic Structure,'' in Summaries FY 1996 — Research in the Chemical Sciences, DoE/NBM-1098, Office of Scientific & Technical Information, Oak Ridge TN, p 81

Friedmann, B.C., Witt, A.N., Gordon, K.D., (Schild, R.E., Bohlin, R.C., & Stecher, T.P.) 1996, ''Large Angle Scattering in the UV: IC63,'' BAAS, 189, 1607

Gordon, K.D. 1997, Detection of Extended Red Emission in the Diffuse Interstellar Medium, Ph.D. Thesis, Univ. of Toledo

Gordon, K.D. & Witt, A.N. 1996, ''Search for Extended Red Emission in the Diffuse ISM,'' BAAS, 189, 1604

(Grady, C.A., Pérez, M.R.), & Bjorkman, K.S. 1996, ''Transient Accretion Events in Herbig Ae/Be Star Spectra: The Evidence for Infalling Planetesimals in HD 100546 (B9e),'' in From Stardust to Planetesimals, M.E. Kress, A.G.G.M. Tielens & Y.J. Pendleton eds., NASA CP3343, p. 27

(Grady, C.A., Pérez, M.R.), Bjorkman, K.S., (Sitko, M.L., Russell, R.W., Lynch, D.K., & Hanner, M.S.) 1997, ''The Beta Pictoris Phenomenon in the Herbig Ae Star HR 5999,'' BAAS, 28, 1337

Irving, R.E., Maniak, S.T., (Hellborg, R.,) & Curtis, L.J. 1996, ''Postfoil Ion Beam Divergence Calculations Utilizing the Tabulations of Sigmund and Winterbon,'' Bull. Am. Phys. Soc., 42, 1083

Iwamoto, N., (Qin, L., Tsuruta, S., & Nomoto, K.) 1997, ''Axion Limits from Neutron Star Cooling,'' Bull. Am. Phys. Soc., 42, 1109

Iwamoto, N. 1997, ''The Role of Nucleon-Nucleon Scattering on the Transport Coefficients of Neutron Star Matter,'' Bull. Am. Phys. Soc., 42, 1484
James, P.B. 1996, ''Apogee and Perigee,'' MacMillan Encyclopedia of Physics, J.S. Rigden ed., p. 45
James, P.B. 1996, ''Johannes Kepler,'' MacMillan Encyclopedia of Physics, J.S. Rigden ed., p. 811
James, P.B. 1996, ''Kepler's Laws,'' MacMillan Encyclopedia of Physics, J.S. Rigden ed., p. 812
James, P.B. 1996, ''Planetary Magnetism,'' MacMillan Encyclopedia of Physics, J.S. Rigden ed., p. 1200
James, P.B. 1996, ''Space,'' MacMillan Encyclopedia of Physics, J.S. Rigden ed., p. 1468
James, P.B. 1996, ''Space and Time,'' MacMillan Encyclopedia of Physics, J.S. Rigden ed., p. 1470
James, P.B. 1996, ''Van Allen Radiation Belts,'' MacMillan Encyclopedia of Physics, J.S. Rigden ed., p. 1663
(Kuchinski, L.E., Terndrup, D.M.), Witt, A.N., & Gordon, K.D. 1996, ''The Impact of Dust on Photometric Studies of Spiral Galaxies,'' BAAS, 189, 2201
Madsen, G.J., Witt, A.N., Gordon, K.D., & (Grosbol, P.) 1996, ''Dust Mass Determination in Disk Galaxies,'' BAAS, 189, 1707
Petersohn, J.K. 1997, Modeling the Diffuse Galactic Light: Scattering Properties of Galactic Dust, M. S. Thesis, Univ. of Toledo
(Schulte-Ladbeck, R.E., Schmid, H.M., Meade, M.R., Harries, T.J., Lupie, O.L.), & Bjorkman, K.S. 1997, ''Six Years of Spectroscopic and Spectropolarimetric Monitoring of AG Car,'' in Luminous Blue Variables - Massive Stars in Transition, eds. A. Nota & H.J.G.L.M. Lamers, ASP Conf. Ser., in press
(Snow, T.P.) & Witt, A.N. 1996, ''Revised Depletion and New Constraints on Interstellar Dust Composition,'' in From Stardust to Planetesimals, M.E. Kress, A.G.G.M. Tielens & Y.J. Pendleton eds., NASA CP3343, p. 87
Witt, A.N., Ryutov, D., & (Furton, D.G.) 1996, ''HAC: Band Gap, Photoluminescence and Optical/Near-IR Absorption,'' in From Stardust to Planetesimals, M.E. Kress, A.G.G.M. Tielens & Y.J. Pendleton eds., NASA CP3343, p. 105

Publications

(Anderson, C.M., Weitenbeck, A.J., Code, A.D., Nordsieck, K.H., Meade, M.R., Babler, B.L., Zellner, N.E.B.), Bjorkman, K.S., (Fox, G.K., Johnson, J.J., Sanders, W.T., Lupie, O.L., Edgar, R.J., Clayton, G.C.) 1996, ''Ultraviolet Interstellar Polarization of Galactic Starlight I. Observations by the Wisconsin Ultraviolet Photo-Polarimeter Experiment,'' AJ, 112, 2726
(Bell, J.F. III, Wolff, M.J.), James, P.B., (Clancy, R.T., Lee, S.W., & Martin, L.J.) 1997, ''Mars Surface Mineralogy from Hubble Space Telescope Imaging during 1994-1995: Observations, Calibration, and Initial Results,'' Journal of Geophysical Research, 102, 9109
Bjorkman, J.E. 1998, ''Wind-Compressed Disks and Dust Formation in B[e] Stars'' in Proceedings of the Workshop on B[e] Stars held June 9–12, 1997, in Paris France, ed. C. Jaschek & A.M. Hubert (Dordrecht: Kluwer), in press
Bjorkman, J.E. 1997, ''Circumstellar Disks'' in Stellar Atmospheres: Theory and Observations, European Astrophysical Doctoral Network IXth Predoctoral School, ed. J.-P. deGreve (Berlin: Springer), in press
(Clancy, R.T., Grossman, A.W., Wolff, M.J.), James, P.B., (Rudy, D.J., Billawala, Y.N., Sandor, B.J., Lee, S.W., & Muhleman, D.O.) 1996, ''Water Vapor Saturation at Low Altitudes around Mars Aphelion: A Key to Mars Climate?'' Icarus, 122, 36
(Clancy, R.T., Wolff, M.J.), James, P.B., (Smith, E., Billiwala, Y.N., Lee, S.W., & Callan, M.) 1996, ''Mars Ozone Measurements near the 1995 Aphelion: Hubble Space Telescope Ultraviolet Spectroscopy with the Faint Object Spectrograph,'' Journal of Geophysical Research, 101, 12,777
(Clayton, G.C.), Bjorkman, K.S., (Nordsieck, K.H., Zellner, N.E.B., & Schulte-Ladbeck, R.E.) 1997, ''Evidence for a Bipolar Geometry in R Coronae Borealis?,'' ApJ, 476, 870
Curtis, L.J., Deck, R.T., & Ellis, D.G. 1997, ''Limitations on the Precision of Atomic Meanlife Measurements,'' Phys. Lett. A, 230, 330
Curtis, L.J., Ellis, D.G., Matulioniene, R., & (Brage, T.) 1997, ''Relativistic Empirical Specification of Transition Probabilities from Measured Lifetime and Energy Level Data,'' Phys Scripta, in press
Federman, S.R., & (Cardelli, J.A.) 1996, ''Atomic and Molecular Data for Interstellar Studies: a Status Report,'' in 5th International Colloquium on Atomic Spectra and Oscillator Strengths for Astrophysical and Laboratory Plasmas, Phys Scripta, T65, 158
Federman, S.R., Knauth, D.C., (Lambert, D.L., & Andersson, B-G) 1997, ''Probing the Photodissociation Region toward HD 200775,'' ApJ, in press
Federman, S.R., (Menningen, K.L.,), Lee, W., & (Stoll, J.B.) 1997, ''Relative Band Oscillator Strengths for Carbon Monoxide: $A^1\Pi - X^1\Sigma^+$ Transitions,'' ApJ, 477, L61
Federman, S.R., (Welty, D.E., & Cardelli, J.A.) 1997, ''The Amount of CH Produced during CH^+ Synthesis in Interstellar Clouds,'' ApJ, 481, 795
(Fox, G.K., Code, A.D., Anderson, C.M., Babler, B.L.), Bjorkman, K.S., (Edgar, R.J., Johnson, J.J., Lupie, O.L., Meade, M.R., Sanders, W.T., Weitenbeck, A.J., & Zellner, N.E.B.) 1997, ''Solar System Observations by the Wisconsin Ultraviolet Photo-Polarimeter Experiment. II. The First Linear Ultraviolet Spectropolarimetry of Io,'' AJ, 113, 1158
(Fox, G.K., Code, A.D., Anderson, C.M., Babler, B.L.), Bjorkman, K.S., (Edgar, R.J., Johnson, J.J., Lupie, O.L., Meade, M.R., Nordsieck, K.H., Sanders, W.T., Weitenbeck, A.J., & Zellner, N.E.B.) 1997, ''Solar System Observations by the Wisconsin Ultraviolet Photo-Polarimeter Experiment. I. The First Ultraviolet Linear Spectropolarimetry of Mars,'' AJ, 113, 1152
Gordon, K.D., (Calzetti, D.), & Witt, A.N. 1997, ''Dust in Starburst Galaxies,'' ApJ, 487, 625
Gordon, K.D. & Mulliss, C.L. 1997, ''ζ^2 Coronae Borealis, a Spectroscopic Triple System Including an Asynchronous Close Binary,'' PASP, 109, 221

(Grady, C.A., Pérez, M.R., Talavera, A.,) Bjorkman, K.S., (de Winter, D., Thé, P.S., Molster, F.J., van den Ancker, M.E., Sitko, M.L.), Morrison, N.D., Beaver, M.L., (McCollum, B., & Castelaz, M.W.) 1996, ''The β Pictoris Phenomenon Among Herbig Ae/Be Stars. UV and Optical High Dispersion Spectra,'' A&AS, 120, 157

(Grady, C.A., Pérez, M.R.), Bjorkman, K.S., (Sitko, M.L., & de Winter, D.) 1996, ''Extrasolar Comets near Young Beta Pic Analogs,'' in Star Formation, Near and Far, ed. S.S. Holt & L.G. Mundy, AIP, in press

(Grady, C.A., Sitko, M.L.,) Bjorkman, K.S., (Pérez, M.R., Lynch, D.K., Russell, R.W., & Hanner, M.S.) 1997, ''The Star-Grazing Extra-Solar Comets in the HD 100546 System,'' ApJ, 483, 449

Henderson, M. & Curtis, L.J. 1996, ''Lifetime Measurements in Tl II,'' J. Phys. B: Atomic, Molec. Opt. Phys. 29, L629

Henderson M., Curtis, L.J., Ellis, D.G., Irving, R.E., & (Wahlgren, G.M.) 1996, ''Lifetimes and Oscillator Strengths for the $6p7s^3P_{0,1}$ Levels in Bi II,'' ApJ, 473, 565

Henderson, M., Curtis, L.J., Matulioniene, R., Ellis, D.G., & Li, Y. 1997, ''Lifetimes of the $3p^5 4s^3P_1$, $^1P_1$, and $3p^5 3d^3P_1$ Levels in K II,'' Phys. Rev. A, 55, 2723

Henderson, M., Curtis, L.J., Matulioniene, R., Ellis, D.G., & Theodosiou, C.E. 1997, ''Lifetime Measurements in Tl III and the Determination of the Ground State Dipole Polarizabilities for Au I - Bi V, Phys. Rev. A 56, 1872

James, P.B., (Bell, J.F. III, Clancy, R.T., Lee, S.W., Martin, L.J., & Wolff, M.J.) 1996, ''Hubble Space Telescope Synoptic Imaging of Mars: 1995 Opposition Observations,'' Journal of Geophysical Research, 101, 18,883

James, P.B., (Clancy, R.T., Lee, S.W., Martin, L.J., & Bell J.) 1996, ''Seasonal Recession of Martian South Polar Cap: 1992 HST Observations,'' Icarus, 123, 87

(Johnson, J.J., Anderson, C.M.), Bjorkman, K.S., (Code, A.D., Fox, G.K., Weitenbeck, A.J., Sanders, W.T., Babler, B.L., Meade, M.R., Zellner, N.E.B., Edgar, R.J., Magalhães, A.M., Clayton, G.C., Schulte-Ladbeck, R.E., & Lupie, O.L.) 1997, ''Ultraviolet Spectropolarimetry of Three Classical Novae Early in Outburst: Evidence for Aspherical Shells,'' AJ, 113, 2200

(Lambert, D.L., Sheffer, Y.), Federman, S.R., (Cardelli, J.A., Sofia, U.J.), & Knauth, D.C. 1997, ''The $^{11}B/^{10}B$ Ratio of Local Diffuse Interstellar Clouds,'' ApJ, in press

Morrison, N.D., Knauth, D.C., Mulliss, C.L., & Lee, W. 1996, ''High-Resolution Optical Spectra of the Head of Comet C/1996 B2 (Hyakutake),'' PASP, 109, 676

(Muto, T., Tatsumi, T.), & Iwamoto, N. 1997, ''Nonequilibrium Processes in Kaon Condensation,'' Australian J. Phys. 50, 13

(Muto, T., Tanaka, T., Fujii, H., Tatsumi, T.), & Iwamoto, N. 1997, ''Nonequilibrium Weak Processes in Kaon Condensation and Dynamical Evolution of Neutron Stars'' in Proceeding of the 14th International Conference on Particles and Nuclei, edited by C. E. Carlson & J. J. Domingo (World Scientific, Singapore), p. 481

(Quirrenbach, A.), Bjorkman, K.S., Bjorkman, J.E., (Hummel, C.A., Buscher, D.F., Armstrong, J.T., Mozurkewich, D., Elias, N.M. II, & Babler, B.L.) 1997, ''Constraints on the Geometry of Circumstellar Envelopes: Optical Interferometric and Spectropolarimetric Observations of Seven Be Stars,'' ApJ, 479, 477

(Snow, T.P.) & Witt, A.N. 1996, ''Interstellar Depletions Updated: Where All the Atoms Went,'' ApJ, 468, L65

(Tran, H.D, Filippenko, A.V., Schmidt, G.D.), Bjorkman, K.S., (Jannuzi, B.T., & Smith, P.S.) 1997, ''Probing the Geometry and Circumstellar Environment of SN1993J in M81,'' PASP, 109, 489

Witt, A.N., Friedmann, B.C., & (Sasseen, T.P.) 1997, ''Radiative Transfer Analysis of Far-Ultraviolet Background Observations Obtained with the Far Ultraviolet Space Telescope,'' ApJ, 481, 809

(Wolff, M.J., Lee, S.W., Clancy, R.T., Martin, L.J., Bell, J.F. III), & James, P.B. 1997, ''1995 Observations of Martian Dust Storms Using the Hubble Space Telescope,'' Journal of Geophysical Research, 102, 1679

(Wood, K.), Bjorkman, K.S. & Bjorkman, J.E., 1997 ''Deriving the Geometry of Be Star Circumstellar Envelopes from Continuum Spectropolarimetry I. The Case of Zeta Tauri,'' ApJ, 477, 926

Zsargó, J., Federman, S.R., & (Cardelli, J.A.) 1997, ''Atomic Physics with the Goddard High Resolution Spectrograph on the *Hubble Space Telescope*. III. Oscillator Strengths for Neutral Carbon,'' ApJ, 484, 820

REFERENCES

Bjorkman, J.E. & Cassinelli, J.P. 1993, ApJ, 409, 429

Bjorkman, J.E. 1995, ApJ, 453, 369

Gordon, K.D. 1996, http://www.physics.utoledo.edu /www/ritter/archive/archive.html

Kaufer, A. *et al.* 1996, A&A, 314, 599

Nancy D. Morrison