The University of Toledo
Ritter Astrophysical Research Center
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This report covers the period 1 July 1999 to 30 June 2000.

1. PERSONNEL

During the report period, James and Morrison were on sabbatical leave. Iwamoto resigned his position at the university. K. Bjorkman was promoted to Associate Professor and granted tenure at the university; otherwise, the permanent staff was unchanged. Miroshnichenko continued as a postdoctoral research associate working with K. Bjorkman, and J. Bjorkman continued as Research Assistant Professor.

Students involved in astronomical research were: Adam Kowalski of Ottawa Hills High School; undergraduates Will Fischer, Amanda Gault, Darren Hojnacki, and Goldie Summers; and graduate students Jennifer Benson, Boncho Bonev, Bruce Cantor, David Knauth, Ivaylo Mihaylov, Kaike Pan, Kathy Shan, Tracy Smith, Larissa Spiker, John Wisniewski, and János Zsargó.

Visiting NSF-REU undergraduate students were, during the summer of 1999, Nikole Howard (Worcester Poly.), and Kyle Westfall (U. Virginia) and, during the summer of 2000, Gregory Mack (Ohio Wesleyan) and Althea Moorhead (U. of Arizona). David Horne was a visiting exchange student from the University of Hertfordshire, England, during the year, and Alex Carciofi of the U. of Sao Paolo (Brazil) worked with J. Bjorkman during the spring and summer of 2000.

2. OBSERVATORY

An upgrade of the control system for the Wright Instruments Ltd. CCD cameras on the échelle and the Low-Dispersion Spectrograph (LDS) was undertaken. Software drivers and hardware interfaces for controlling the CCD's with a new Linux platform were developed with the assistance of Burmeister, Ambalanath, and Knauth. Upgrades to the telescope control system encoder interface were also developed by Burmeister. At the end of the report period, both systems were in their initial checkout phases.

Because of the upgrade, no stellar spectra were acquired from early April 2000 through the end of the report period. During the 250 nights when the spectrographs were operable during the year, 492 stellar spectra were obtained with the échelle and 193 with the LDS on a total of 94 nights used. The échelle 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 report period, the Ritter observing team consisted of K. Bjorkman, Fischer, Knauth, Miroshnichenko, and Morrison.

3. RESEARCH

3.1 Stellar Astrophysics

Ritter Obs. continued its long-term spectroscopic monitoring programs on hot supergiant stars, Herbig Ae/Be stars, classical Be and shell stars, and binary stars. A cooperative observing program with S. J. Adelman (The Citadel) on A-type supergiant stars was begun. Adelman is obtaining precise differential photometry on the *uvby* system with the Five College Automated Photometric Telescope to complement radial velocities and Hα profiles from Ritter high-resolution spectroscopy. Morrison is analyzing the first season's radial velocities of Deneb.

The summer of 1999 saw the first extensive use of the two spectrographs operating in parallel, as Ritter Obs. carried out its monitoring programs with the échelle spectrograph while using the LDS to participate in a multi-observatory spectroscopic campaign on WR 137. The Ritter observing team obtained 71 observations of the star in the 5300–6000 Å region with a resolution of 3 Å and a signal-to-noise ratio in excess of 200. This WC 7+O 9 star (=HD 192641) is a prime candidate to have a large-scale structured wind. High-precision spectropolarimetry of this star shows a pronounced signature of global wind flattening, and rotationally-modulated variability on a time scale of a few days is being sought. A. F. J. Moffat and S. V. Marchenko (U. Montréal) coordinated the campaign and are analyzing the data.

Spiker and K. Bjorkman continued their reinvestigation of the mass-loss rates of B stars. Spiker's M. S. thesis concluded that photospheric line blanketing can be responsible for a number of significant features in the wind line profiles, and so should be considered when measuring wind velocities and estimating mass-loss rates. Results from several sample cases showed that, when photospheric effects were taken into account in the modeling, estimated mass-loss rates could be as much as a factor of five times higher than previously estimated.

K. Bjorkman and Wisniewski have carried out a detailed study of the interstellar polarization along the line of sight to the classical Be star π Aqr. Using spectropolarimetry, they determined the interstellar polarization component much more accurately than has been done previously. Removal of the interstellar component is a critical first step in analyzing spectropolarimetric variability; π Aqr showed interesting behavior in 1989–1999. Wisniewksi has begun work on the interpretation of the intrinsic polarimetric variations.

K. Bjorkman, in collaboration with Miroshnichenko, continued the analysis of ultraviolet spectropolarimetric observations of Oe/Be, B[e], and Herbig Ae/Be stars obtained with the WUPPE instrument aboard the Astro-2 Space Shuttle mission. The UV observations are combined with contemporaneous optical observations for complete spectropolarimetric coverage from 1450 Å to 1.05 μm.

With K. Wood (Harvard CfA), Bjorkman and Bjorkman

have developed techniques for using continuum spectropolarimetry to constrain the structure of circumstellar disks around classical Be stars. From optical observations obtained with the Halfwave Polarimeter (HPOL) at the Pine Bluff Observatory (PBO), they demonstrated the efficacy of the technique. Recent work in this collaboration includes refinement of methods for estimating the average disk temperatures of Oe/Be stars from the polarization data. Work by Summers and K. Bjorkman indicates that such temperatures may also be derived from optical data of high enough resolution and signal-to-noise ratio. Average disk temperatures determined in this way are about 75% of the stellar effective temperature for the four stars that they have studied in detail to date.

K. Bjorkman, in collaboration with M. Meade (U. Wisconsin), continued to work on an atlas of spectropolarimetric observations of Be stars based on 1989–1994 observations from PBO. Meade has significantly updated the atlas web pages over the past year. A preliminary version of the web-based portion of the atlas was presented at IAU Colloquium 175 in July 1999. Wisniewski has begun to analyze the database for an investigation of the nature of variability in Be star polarization and its implications for disk models. Work on the web pages for the second volume of the atlas, which will cover observations from 1995 to 2000, has also begun.

D. McDavid (Limber Obs.), K. Bjorkman, J. Bjorkman, and A. T. Okazaki (Hokkai-Gakuen U.), continued to investigate whether contemporaneous observations of Hα V/R spectral variations and polarization levels in classical Be stars can be used to test models of disk variations. In particular, predictions of the one-armed spiral density wave model are being tested for the stars ζ Tau and 48 Lib, using data from Ritter, Limber Obs., PBO, and the literature. G. Summers assisted with data analysis for this project.

In collaboration with R. Gray (Appalachian State U.), V. Klochkova and E. Chentsov (Special Astrophys. Obs., Russia), and P. Garcia-Lario and J. Perea Calder (ESA, Spain), Miroshnichenko and K. Bjorkman completed a study of the Herbig Ae candidate star IP Per. The evolutionary state of this star has been controversial due to different surface gravity estimates. The study used low- and high-resolution spectroscopy to determine the star's fundamental parameters. It turned out that the atmospheric metal abundance is about 40% that of the Sun. It was shown that the star has a later spectral type (A7) than previously thought (A3). It has a nearly zero-age main-sequence luminosity; thus it is most likely a young object.

This same group, together with three other groups from the Fesenkov Astrophys. Institute (Kazakhstan), Aerospace Corp., and Pulkovo Obs., completed an extensive study of two recently recognized B[e] stars, AS 78 and MWC 657. Diverse optical and near-IR photometric and spectroscopic observations obtained in 1993–2000 were analyzed. Photometric variations with a period of 86 days and an amplitude of 0.6 mag. (optical region) were detected for MWC 657. The fundamental parameters of AS 78 were estimated from modeling the Balmer line profiles and the spectral energy distribution. Evidence that these objects are binary systems containing a B-type intermediate-luminosity star and a gaseous disk around the less luminous component was presented.

Miroshnichenko and K. Bjorkman, with H. Levato and M. Grosso (Complejo El Leoncito, Argentina), made the first high-resolution spectroscopic and multiwavelength photometric observations of two B[e] stars, HD 85567 and Hen 3-140. Fundamental parameters of both stars were estimated. A large near-IR excess was reported for Hen 3-140 for the first time. The stars seem to be members of a small group of similar objects, whose peculiarities might be due to their binary nature.

Miroshnichenko, K. Bjorkman, and McDavid continued an investigation of the classical Be star π Aqr, which is currently in a quasi-normal star phase. An emission component of the Hα line was detected, and regular variations with a period 84.273 ± 0.004 day and an amplitude of 224.0 ± 0.4 km s^{-1} were found. Preliminary suggestions are that these variations are due to variable mass transfer in a contact binary system, whose characteristics have been estimated.

Miroshnichenko and K. Bjorkman obtained IR photometry of 10 Be stars with gaseous disks, 10 Be stars with traces of circumstellar dust, and several B[e] and Herbig Ae/Be stars at the 3-meter NASA Infrared Telescope Facility (Hawaii). Nine out of the 10 Be stars with anomalous far-IR excesses were detected at 10 μm. The analysis, which is aimed at investigating the nature and properties of the circumstellar dust in evolved main-sequence stars, is in progress.

Miroshnichenko and K. Bjorkman, with V. Krugov (Main Astron. Obs., Ukraine) analyzed high-resolution observations of the bright Be stars γ Cas and ζ Tau obtained in 1993–2000 at Ritter Obs. and at the Terskol station of the Main Astronomical Obs. The radial velocity of the central peak of Hα in ζ Tau seems to follow the binary orbital motion (period 132.9 days) on top of the long-term variations (period 1518 days). In γ Cas, this peak shows a constant trend toward negative velocities since 1993, which is opposite to the behavior of other emission lines.

The Ritter observing team obtained high- and low-resolution spectra of the bright nova V1494 Aql during its early decline stage. The transition of the Hα profile from single-peaked to a double-peaked profile and the broadening of Hα with time were observed. Systems of absorption lines at about -1000 and -2000 km s^{-1} were found in the high-resolution data. The Hα profile variations were interpreted in terms of the geometry of the expanding envelope. The interstellar extinction and the distance to the nova were estimated.

In collaboration with K. Nordsieck (U. Wisconsin), Wisniewski continued to investigate the circumstellar environments of LBVs and cLBVs. UV and visible spectropolarimetric data on the LBV P Cyg, obtained with the WUPPE instrument on the Astro-1 and Astro-2 shuttle missions and by the HPOL instrument at PBO and WIYN, are being analyzed. Preliminary analysis of the polarized flux shows a lack of a Balmer and a Paschen jump, an enhancement in the Fe III line at 1800 Å, and an enhancement of the absorption components of the optical P Cygni lines. Based upon these

findings, constraints on the inhomogeneity of the star's wind are being developed.

J. Bjorkman continued to develop 3-D radiative transfer techniques using Monte Carlo simulation with K. Wood (SAO), Mihaylov, and Carciofi. As part of his Ph.D. thesis research, Mihaylov is developing techniques for using weighted photons (photon packets with unequal energy). We now have developed a general technique for determining unbiased estimators for the variance of any measured quantity, and we are currently investigating which weighting techniques are the most efficient.

Carciofi is extending our Monte Carlo radiation transfer methods in order to determine the radiative equilibrium temperatures for dust grains of different size and chemical composition in the winds from both cool and hot stars. In general, we find that the SED is relatively insensitive to the grain size distribution, except for cases with intermediate optical depths. For mixtures of grains, we find that the more refractory grains can shield the less refractory ones, allowing them to condense closer to the star than one would expect based on single-temperature grain models. Finally, we find that isotropic scattering can be a poor approximation when calculating the SED. In particular, the forward throwing nature of dust grains can significantly increase the UV continuum when it is dominated by the scattered light.

J. Bjorkman continued to work on the hydrodynamic structure of rotating stellar winds with Zsargó and Moorhead. Zsargó has been investigating the dynamics of dense clumps that form within the stellar wind. Howk *et al.* (2000) found, in a 1-D model, that some of these clumps fall back onto the stellar surface. Zsargó added the effects of rotation and extended this model to calculate 3-D clump trajectories. In specialized circumstances, these clumps can fall onto the equatorial plane, possibly creating a disk. However, the vast majority of clumps escape outward or fall directly onto the star. Thus, the mass flux of clumps into the disk is quite small and is probably not an effective source of material for the dense disks observed around Be stars.

Moorhead investigated the 1-D equatorial solutions of a rotating stellar wind. She extended our previous method for determining the full solution topology of line-driven stellar winds to include the effects of both rotation and the finite solid angle of the stellar radiation source. In general, we find that the finite disk effect doubles the number of critical points in the wind. At high rotation rates, the inner critical point disappears and a new set of critical points appears at large radii. Interestingly, it appears that the inner and outer critical point solutions may both exist simultaneously, offering a potential mechanism for the wind to switch discontinuously between states of high and low mass loss.

Other collaborative work included: determining the geometry and temperature structure of the infalling envelopes of pre-main-sequence stars with B. Whitney (Space Science Inst.) and determining the effects of gravitational microlensing of extended sources with R. Ignace (U. Iowa) and J. Simmons (U. Glasgow).

3.2 Solar Astronomy

B. Komitov (Inst. of Astronomy, Bulgarian Acad. of Sciences) and B. Bonev examined the conditions for violation of the rule of Gnevyshev-Ohl, which states that even-numbered 11-year solar cycles are followed by higher-amplitude odd-numbered ones. This regularity has been valid for the last 150 years, but it is very likely to be broken in the current 11-year cycle, No. 23. Using the Schove series of indirect data, which includes the main macro-characteristics of the 11-year cycles and is continuous since the end of the third century, Komitov and Bonev showed that the main factor for violation of the rule of Gnevyshev-Ohl is a very high maximum of the even-numbered 11-year cycle (maximum annual mean Wolf numbers exceeding 130). The analysis implies the current solar maximum to be lower than that of cycle 22, as observed.

Bonev continued his work, started at Bowling Green State U., on consistency between independent indirect data sets for solar activity, the reliability of the quasi-two century and the Gleissberg solar cycles, and their connection with the 2400-year cycle previously found in radiocarbon data.

3.3 Interstellar Matter

Frisch *et al.* (1999) found that interstellar grains traversing the solar system exhibit a size distribution which extends well beyond the largest sizes contemplated by current models for grains in the diffuse interstellar medium. Prompted by this finding, Witt, in collaboration with R. Smith (CfA) and E. Dwek (GSFC), investigated whether these larger interstellar grains exist in the ISM on Galactic distance scales as well. Observations of the halo of scattered X-rays surrounding Nova Cygni 1992 were analyzed, since the intensity and profile of X-ray halos are exceptionally sensitive to the largest grains along the line of sight. The results confirm that the size distribution of interstellar grains found in the solar system provides the best match to the available X-ray halo data. Analysis of additional halo data from the growing *Chandra* archive is planned.

In collaboration with K. Gordon (U. Ariz.) and M. Cohen (UC-Berkeley), Witt continued work on mapping the brightness and distribution of the extended red emission (ERE) over the sky at $|b|>25°$. The data employed consist of B,R surface photometry of the integrated sky light by *Pioneer 10* and *11* from locations more than 3.3 AU from the Sun and avoid measurable contributions from the zodiacal light. The stellar contributions are removed from the *Pioneer* data by means of existing stellar photometric data and Cohen's SKY model. The residual diffuse radiation exhibits clear evidence for the presence of ERE in the Galactic cirrus at high and intermediate galactic latitudes.

In collaboration with K. Gordon and an observer team headed by R. Rudy (Aerospace Corp.), Witt investigated the spectral range 0.9–2.5 μm for the presence of possible additional photoluminescence bands in reflection nebulae exhibiting ERE. Two new broad emission features, centered at 1.15 and 1.50 μm, were discovered. The first conincides with a band predicted for silicon nanoparticles, further strengthening the identification of the ERE with photoluminescence

by this family of nanoparticles. The band at 1.5 μm was identified as a luminescence feature produced by iron disilicide grains.

Knauth, Federman, D. Lambert (U. of Texas), and P. Crane (NASA HQ and Dartmouth) are studying the variation in the ^{7}Li/^{6}Li ratio in interstellar clouds in order to enhance understanding of light element nucleosynthesis. In the Galaxy today, ^{7}Li is believed to be produced via cosmic-ray spallation, where cosmic ray protons break apart interstellar C, N, and O nuclei, and via reactions occurring in red giant stars. The ^{6}Li nucleus is synthesized solely by cosmic-ray spallation. They reported the discovery of clouds toward *o* Per with a ^{7}Li/^{6}Li ratio of about 2, as expected from cosmic ray reactions, a value that contrasts with a ratio of 12 measured for the solar system and the diffuse cloud toward ζ Per. The sight line toward *o* Per passes close to a nearby site of massive star formation (IC 348) which may be the source of the cosmic rays. However, in order to go from a ratio of 12 to one of ≈ 2, a significant amount of newly synthesized Li is needed, and an enhanced abundance of Li should also be seen. This is not the case; the Li/H abundance and the K/Li abundance ratio are similar along the two sight lines. Observations of Li I in additional sight lines through the cloud in Perseus are now being analyzed to help clarify the measurements for *o* and ζ Per.

Another facet of this research, a collaboration with Lambert, involves planned observations of the ^{11}B/^{10}B ratio with *HST* for the same set of stars. The objective of the project is to determine whether or not the clouds with the atypical Li isotopic ratio also show an unusual boron isotopic ratio. While both ^{11}B and ^{10}B are thought to arise from cosmic-ray spallation, ^{11}B may also be synthesized by spallation of neutrinos on ^{12}C in a Type II supernova, the ν process. These observations will place constraints on the poorly known neutrino reaction.

Zsargó, under the supervision of Federman, completed his Ph. D. research, which aims for tighter constraints on models of CH^+ production in diffuse interstellar clouds. The general consensus is that CH^+ is produced by the reaction $C^+ + H_2 \rightarrow CH^+ + H$, which is endothermic by 0.3 eV. The source for the energy remains hotly debated; suggested sources include hydrodynamic and magneto-hydrodynamic shocks, intermittency arising from turbulence, and Alfvénic waves. Zsargó first analyzed *HST* spectra of interstellar C I in clouds showing CH^+ and sometimes CH absorption, but with no detectable amounts of C_2 or CN, and showed that the relative populations among fine structure levels in the electronic ground state of C I indicate low gas densities for these clouds. Simple chemical models based on the low densities suggest that nearly all the CH observed toward his sample of stars arises from the synthesis of CH^+ under non-thermal conditions. He found that ion-drift velocities resulting from the passage of a magneto-hydrodynamic wave drive the non-thermal reactions leading to CH. The same conclusion applies to the directions with measured CO abundances. In the past, CH and CO production in these sight lines were thought to be from reactions occurring at the observed low kinetic temperatures.

3.4 Planetary System Astrophysics

James is a Participating Scientist for Mars Global Surveyor and is a member of the MOC (Mars Orbiter Camera) Team. He was also a co-I on the imaging experiment on the Mars Climate Orbiter, which was lost during this year. During the report period, he studied the seasonal recession of the Martian south polar cap using data acquired by the MOC wide-angle and narrow-angle cameras. His observations of Martian clouds in the polar regions were used in a collaborative study of polar meteorology with J. Hollingsworth of NASA Ames.

In his Ph. D. thesis research, Cantor used MOC wide-angle mapping images to study the distribution and properties of dust storms on Mars. The effect of atmospheric dust on the seasonal sublimation of the CO_2 polar caps is the subject of a theoretical study being undertaken by Bonev using various radiative transfer models, with the aim of improved understanding of interannual variability in seasonal cycles on Mars. Shan has nearly completed a study of the seasonal variation of clouds in the Tharsis region of Mars using the *HST* mapping images, and Horne completed a similar study of dust and condensate clouds in the Hellas region. Benson used *HST* images to study cloud motions. Mars observations by *HST* did not take place during the year just past but will resume early in the next year.

Bonev, in collaboration with Komitov, used previously reported data to obtain new empirical two-variable power laws describing the variability of the Haser scale lengths of cometary CN and its parent molecule. A good estimate of these parameters is important for obtaining the production rates of CN and its parent with the simplest but still widely used density distribution model of cometary atmospheres. The scale lengths also provide first constraints on the parameter spaces of more complicated models. In addition to the heliocentric distance, the 10.7-cm solar radio flux is used as an independent variable in order to account for solar activity effects. The two-variable description reduces the error bars and avoids improper systematics found in the behavior of the one-variable fits with only the heliocentric distance.

3.5 Laboratory Astrophysics

Graduate students involved in theoretical and accelerator-based atomic physics research included Murray Henderson, Rasa Matulioniene, and Henry Povolny.

Curtis has undertaken a combined isoelectronic and homologous study of branching fractions for ground term transitions of the form $ns^2np^2 - ns^2nsn's$. Accurate values for the relative intensities for the 13 transitions within this multiplet have been determined for the $n=3$ sequence in Si I–Ar V, for the $n=4$ sequence in Ge I–Br IV, for the $n=5$ sequence in Sn I–Cs VI, and for the $n=6$ sequence in Pb I–Bi II. The method utilizes singlet-triplet mixing amplitudes determined empirically from spectroscopic data. For the neutrals, the transitions occur in the visible, and experimental branching fraction measurements exist for comparison. They provided tests which demonstrated the high accuracy of the method and motivated its extension to ions, for which the transitions occur in the UV.

Curtis and Ellis collaborated with Matulioniene and C. Froese Fischer (Vanderbilt U.) in a combined theoretical and semiempirical study of the transition probabilities of the $5s^2-5s5p$ resonance and intercombination lines in the Cd isoelectronic sequence. Through a combination of multiconfiguration Dirac-Hartree-Fock calculations, determinations of intermediate coupling amplitudes from measured spectroscopic energy level data, and semiempirical linearizations of measured lifetime data, accurate determinations were made for these transitions for Cd I–Ho XX.

Schectman, Cheng, Curtis, Federman, Fritts, and Irving measured lifetimes and branching fractions for levels arising from the $5s^25d$ and $5s^24f$ configurations in Sn II. The result confirms and improves the precision of the value of the oscillator strength assumed by Sofia *et al.* (1999), who found an interstellar tin abundance greater than solar in low-density sight lines and suggested that it is due to *s*-process enhancement.

T. Smith and Witt, in collaboration with D. Furton (Rhode Island Coll.), continued laboratory studies of carbon- and silicon-based grain analogs, with the main goal being the identification of candidates for the interstellar ERE process. Many materials, such as hydrogenated amorphous carbon, hydrogenated carbon-silicon alloys, silicon carbide, and nanodiamonds, can be eliminated on the basis of their luminescence behavior under UV illumination. Silicon nanoparticles continue to satisfy the growing body of observational constraints better than any other material investigated so far.

Federman, Cheng, Fritts, Knauth, and K. Menningen and K. Fulk (U. of Wisconsin at Whitewater) used the Synchrotron Radiation Center of the U. of Wisconsin at Madison in an experiment to determine oscillator strengths in CO. Particular attention was given to transitions involving the ground electronic state *X* and the upper *B*, *C*, and *E* states because available measurements differ by as much as a factor of 2. These transitions are seen in interstellar spectra acquired with the *Far Ultraviolet Spectroscopic Explorer* (*FUSE*) and are important for theoretical models of CO photodissociation in interstellar clouds and circumstellar envelopes. Our results removed the discrepancy that existed between earlier absorption experiments and those based on electron-impact excitation.

4. INSTRUCTION

4.1 Academic

Spiker received the M.S. degree in physics, Matulioniene received the Ph. D. in physics for atomic physics research, and Cantor and Smith received the Ph. D. in physics for research in astrophysics.

In 1997 September, The University of Toledo changed from a quarter to a semester academic calendar. Therefore, for comparison with earlier enrollment figures, the following numbers should be multiplied by 1.5. Undergraduate astronomy enrollments for the summer quarter and the two semesters covered by the report period were as follows. In our general education courses, the annual total was 1223 for the three introductory lecture courses and 101 for the laboratory. The more advanced general-education courses had a total enrollment of 43. In graduate courses and advanced undergraduate courses for science majors, the total enrollment was 32.

4.2 Public

K. Bjorkman participated in outreach programs to local schools and served as a mentor to several high school students interested in astronomy. In the summer of 1999, she was a scientist participant in the U. of Toledo TAPESTRIES program, which is designed to improve science education in the K-6 classroom. Anderson-Huang, K. Bjorkman, and Witt participated in Project ASTRO.

Undergraduate Assistants to Anderson and Mak at the Ritter Planetarium-Brooks Observatory were Will Fischer, Meredith Gray, and Kristine Van Tilburg. We note the retirement of the Planetarium Secretary, Mrs. Darlene Tyson.

During the report period, the Ritter Planetarium presented fourteen unique public planetarium programs, twelve from our library and two newly produced. The new, in-house productions were: ''The Weather Out There'' (author Gray) and ''Bringing the Heavens Home'' (author Mak). We continued to upgrade our library of K–12 programs and activities. We are now offering K–12 groups the option of double features at a reduced price per program, usually combining a live program and a taped multi-media program. They have been very well received. During the report period, approximately 300 Boy Scouts and 175 Girl Scouts completed the Boy Scouts' Astronomy Merit Badge program and the Girl Scouts' Space Exploration Ribbon program, respectively.

Approximately five thousand people attended weekend evening viewings or tours of Brooks Obs. and the Ritter 1-m telescope. The total attendance for all programming conducted under the auspices of Ritter Planetarium and Brooks Observatory was 26,000, slightly less than last year.

As usual, the planetarium staff attended various local, state, and regional meetings and conferences.

5. MISCELLANEOUS

5.1 Participation in Meetings

Witt presented an invited lecture, ''Overview of Grain Models,'' at IAU Symposium No. 197, held on Cheju Island in South Korea, Aug. 1999.

K. Bjorkman gave an invited review talk at IAU Colloquium 175: The Be Phenomenon in Early-Type Stars, held in Alicante, Spain, in June/July 1999. She also presented 3 poster papers at this meeting, and was co-author on 2 others. She gave an invited talk at a Topical Session entitled ''Small, Networked, and Robotic Telescopes'' at the January 2000 meeting of the AAS.

Posters at the June 2000 AAS meeting in Rochester, NY were presented by J. and K. Bjorkman, Summers, Miroshnichenko, Fischer, Federman, Knauth, and Zsargó. Federman organized a Topical Session entitled ''High-resolution Spectroscopy at Visible and Ultraviolet Wavelengths'' for this meeting.

Knauth attended IAU Symposium 198, The Light Elements and Their Evolution. Cheng and Schectman attended the DAMOP (Division of Atomic, Molecular, and Optical

Physics) meeting of the APS in Storrs, CT. Bonev presented two posters at the 31st Meeting of the AAS Solar Physics Division, Lake Tahoe, Nevada.

5.2 Visiting Lectureships

Morrison gave a colloquium at the U. of Wisconsin during her 8-week visit there. K. Bjorkman presented invited colloquia at the U. of Montréal and Georgia State U.; J. Bjorkman presented colloquia at the U. of Minnesota and the U. of Delaware; and Witt presented invited seminars at the U. of Louisville and the U. of Chicago.

5.3 Service

Morrison continued to serve on the V. M. Slipher Committee on Public Education in Astronomy. J. Bjorkman continued to serve on the Organizing Committee of the IAU Working Group on Active B stars. Federman was elected chair of the *FUSE* Observers Advisory Council. In December 1999, K. Bjorkman completed her 4-year term as a member of the Publications Board of the AAS. She also served as a judge for the Bok Award, which is given by the AAS and ASP, and for a separate award given by the IAPPP at the Intel International Science and Engineering Fair (ISEF) held in Detroit in May 2000.

5.4 Awards and Research Support

Morrison is grateful to the Brittingham Foundation at the U. of Wisconsin for expense support during her visit. Participation in research by Benson, Fischer, and Summers was supported by an NSF-REU grant to the Department of Physics and Astronomy. Carciofi was sponsored by a FAPESP grant from the Brazilian government. K. Bjorkman is a Cottrell Scholar of the Research Corporation, and gratefully acknowledges this support. We gratefully acknowledge: an NSF grant to J. Bjorkman; NASA LTSA grants to J. Bjorkman, K. Bjorkman, Federman, and Witt; *FUSE* and STScI grants to Federman; various NASA grants to Witt; a NASA ADP grant to K. Bjorkman; and a NASA grant to Federman, Schectman, and Cheng.

PUBLICATIONS

External collaborators are listed in parentheses.

Reports, Theses, and Abstracts

Bjorkman, J.E. & Zsargó, J. 2000, ''Decoupling of Dense Clumps and Disk Formation in Hot Star Winds,'' BAAS, 32, 682

Bjorkman, K.S. 1999, ''Flexible Observing and Monitoring Programs with Small, Dedicated Telescopes,'' BAAS, 31, 1553

Bjorkman, K.S., Miroshnichenko, A.S., (& Krugov, V.D.) 1999, ''Long-term High-Resolution Spectroscopy of γ Cas, ζ Tau, and π Aqr,'' BAAS, 32, 681

Bonev, B. 2000, ''Periodogram Analysis of the Zurich and Schove Series. Stability of the Quasi-Century and Quasi-Two Century Solar Cycles,'' BAAS, 32, 829

Cantor, B. 2000, ''Martian Dust Storms: 1999 MOC Observations,'' Ph.D. dissertation, U. of Toledo

Cheng, S., Federman, S.R., (Menningen, K.M., Fritts, M.), Knauth, D.C., & (Fulk, K.) 2000, ''Oscillator Strengths for $B-X$, $C-X$, and $E-X$ Transitions in Carbon Monoxide,'' DAMOP, R9.98

Federman, S.R. 2000, ''Isotopic Abundances in the Interstellar Medium,'' BAAS, 32, 730

Fischer, W.J. & Morrison, N.D. 2000, ''Double-Peaked H Alpha Emission in the A-Type Supergiant HD 223960,'' BAAS, 32, 683

Knauth, D.C., Federman, S.R., & (Lambert, D.L.) 1999, ''Physical Conditions in the Photodissociation Regions of Two Reflection Nebulae: NGC 2023 and vdB 102,'' BAAS, 31, 1243

Knauth, D.C., Federman, S.R., (Lambert, D.L., & Crane, P.) 2000, ''Lithium Isotope Ratios for Interstellar Clouds toward ζ and *o* Persei,'' BAAS, 32, 738

(Komitov, B.) & Bonev, B. 2000, ''The Violations of the Rule of Gnevyshev-Ohl in the Schove Series. Does the Current 11-year Cycle No. 23 Indicate a New Centurial Solar Minimum?'' BAAS, 32, 832

(Markova, N.), Morrison, N.D., (Kolka, I., & de Groot, M.) 2000, ''Long-Term Spectral and Photometric Variability of P Cygni,'' in A. S. P. Conf. Ser., 204, Thermal and Ionization Aspects of Flows from Hot Stars, ed. H. Lamers & A. Sapar, p. 111

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