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This report covers the period 1 July 1997 to 30 June 1998.

1. PERSONNEL

During the report period, Anatoly Miroshnichenko completed a one-year postdoctoral research visit with K. Bjorkman and returned to his position at Pulkovo Observatory. Min Yan, from Harvard U., began a postdoctoral fellowship with Federman. The permanent staff was unchanged.

Students involved in astronomical research were: undergraduates Danielle Anderson, Will Fischer, and Greg Madsen; and graduate students Brian Abbott, Bruce Cantor, Brian Friedmann, David Knauth, Ivaylo Mihaylov, Christopher Mulliss, Patrick Ouellette, Kaike Pan, Tracy Smith, Larissa Spiker, ZhongYuan Xue, and Janos Zsargó. Visiting NSF REU undergraduate students were Jennifer Benson (Buena Vista Univ. Iowa) and Eric Higgs (Xavier Univ.).

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 690 stellar spectra were obtained on 92 nights. Most of the 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 $R \simeq 26{,}000$.

3. RESEARCH

3.1 Stellar Astrophysics

Continuing spectroscopic monitoring programs at Ritter Observatory that are not described below concern: binary stars, Herbig Ae/Be stars, A-type shell stars, and UU Herculis-type stars. In support of the XMEGA collaboration, led by M. F. Corcoran (NASA/Goddard), Ritter Obs. obtained high-resolution spectra of ι Ori concurrent with ASCA observations of the system at both periastron and apastron.

K. Bjorkman continued her analysis of ultraviolet spectropolarimetric observations of Oe/Be and Herbig Ae/Be stars obtained with WUPPE aboard the Astro-2 space shuttle mission. The UV observations are combined with contemporaneous optical observations for complete spectropolarimetric coverage from 1450 Å to 1.05μm. For the classical Be stars, the effects of spectral type and rotation rate on the polarimetric spectrum are being investigated. According to a recent analysis of the data for HD 50138, a B[e] star, the spectropolarimetry indicates that electron scattering rather than dust must be responsible for producing most of the polarization.

Miroshnichenko worked with K. Bjorkman to analyze the data on the Herbig Ae/Be stars, and is also involved in the analysis of data on the classical Be stars. Supporting high-resolution optical spectra of the WUPPE stars were made by Morrison, Mulliss, Smith, and Knauth, using the fiber-fed échelle spectrograph at Ritter Observatory, and these data are also being included in the analysis. Two papers on these results have been published.

With K. Wood (Harvard CfA), Bjorkman & Bjorkman developed techniques for analyzing the structure of circumstellar disks around classical Be stars using continuum spectropolarimetry. From observations obtained with the Half-wave Polarimeter (HPOL) at the Pine Bluff Obs. (PBO), they were able to show that the disk structure can be well constrained by the polarization data. Recent work in this collaboration includes the development of a method for estimating the disk temperatures of Oe/Be stars from the polarization line blanketing in the UV. This technique is now being applied to WUPPE observations of Oe/Be stars.

K. Bjorkman continued a spectropolarimetric survey of Herbig Ae/Be and T Tauri stars in the optical using the HPOL at PBO and at the WIYN observatory on Kitt Peak. Other work on the Herbig Ae/Be stars by K. Bjorkman includes an ongoing collaboration with C. Grady (Eureka Scientific) and M. Sitko (U. Cincinnati) to investigate the nature of the circumstellar envelopes around these stars using ultraviolet, optical, and infrared spectroscopy and UV and optical spectropolarimetry.

K. Bjorkman, in collaboration with M. Meade and B. Babler (U. Wisconsin), is developing an atlas of spectropolarimetric observations of Be stars based on 5 years of data from PBO. Web pages are under development containing summaries of the complete data set, to supplement the published catalog when it is completed.

K. Bjorkman, in collaboration with D. McDavid (Limber Obs.), Benson, and J. Bjorkman, has begun 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, the predictions of the one-armed spiral density wave model are being compared with data from Ritter and from PBO.

Spiker and K. Bjorkman continued their project on mass-loss rates of B stars, using results from the ionization study underway by Abbott and J. Bjorkman. A good understanding of the ionization structure is crucial for an accurate estimate of the mass-loss rate. Efforts to account for the underlying photospheric line profiles are also being included. The underlying photosphere can have a significant effect on the wind-line profiles and can mimic wind-related features.

K. Bjorkman, in collaboration with J. Hoffman and K. Nordsieck (U. Wisconsin) and with Mulliss, is investigating the circumstellar material in the interacting binary system β Lyrae, using spectropolarimetric data from PBO and high-resolution spectroscopic data from Ritter. Clear dependences on the binary phase appear in both the Hα line profile and the level of the broadband polarization.

In summer and fall 1997, Miroshnichenko, Mulliss,

Bjorkman, and Morrison carried out high-resolution spectroscopy, at the Ritter 1-m telescope, of six recently identified early-type stars with infrared excesses. As a result, two new classical Be stars (HD 4881 and HD 5839) and three objects in transition between the pre-main-sequence and main-sequence evolutionary stages (HD 32509, HD 184761, and HD 224648) were identified. The sixth object, HD 179218, a Herbig Ae/Be candidate star, was found to display significant variations of the Hα line profile, which are similar to those of classical Be stars. These observations were supported by optical spectropolarimetry at PBO.

In collaboration with Y. Frémat and L. Houziaux (Univ. Mons, Belgium), I. Andrillat (Univ. Montpellier, France), and E. Chentsov and V. Klochkova (Special Astrophysical Obs., Russia) Miroshnichenko studied the first high-resolution spectra ever obtained of two recently identified early-type stars with infrared excesses, MWC 314 and AS 314. More than 400 emission lines, 63 photospheric lines (not observed previously), and 60 diffuse interstellar bands have been found in the spectrum of MWC 314. The absence of the oxygen photospheric lines in the spectrum, which has also been reported for the LBVs AG Car and HR Car, implies a N/O overabundance and indicates that MWC 314 is a highly evolved massive star. Its distance, 3 kpc, was estimated from the radial velocities of the emission lines of singly ionized metals and corresponds to a luminosity of nearly $10^{6.2} L_{\odot}$, one of the largest in the Galaxy.

The spectrum of AS 314 contains a strong Hα emission line (W_{λ} = 14 Å) with a narrow P Cyg profile (100 km s^{-1}). Many weak Fe II emission lines as well as a few Fe I and forbidden lines were also found. The IR excess implies the presence of circumstellar dust and is similar to that of AG and HR Car. This may indicate that the star experienced a matter ejection event in the past rather than steady-state mass loss. Both objects have been suggested to be candidate LBVs in quiescence.

With K. Wood (CfA), J. Bjorkman is continuing to develop techniques for Monte Carlo simulation of 3-D radiative transfer. One application of this work is the determination of the radiative equilibrium temperature and the corresponding spectral energy distribution of the radiation emitted by 3-D dusty environments. In particular, these methods are being applied to the temperature structure of the infalling envelopes and protostellar disks around young stellar objects, such as T Tauri stars and Herbig Ae/Be stars.

J. Bjorkman is also developing methods for calculating line profiles in aspherical circumstellar envelopes that will be used for determining the mass-loss rates of hot stars (in collaboration with K. Bjorkman). As part of this program, Mihailov is developing a Monte Carlo line synthesis code that will be capable of calculating UV resonance line profiles for complex aspherical, non-monotonic velocity fields in the outflows from hot stars. To determine accurate line profiles, it is also necessary to determine the ionization distribution within the stellar wind. B. Abbott has modified J. MacFarlane's (Univ. Wisconsin) spherically symmetric non-LTE ionization code to use the density and velocity of the wind-compressed disk model of a rotating stellar wind. These 2-D ionization fractions are being used by the Monte Carlo line profile code to calculate the line profiles for rotating winds.

Other collaborative projects include examining line-driven outflows near the Eddington limit with J. Cassinelli (Univ. Wisconsin) and M. Elitzur (Univ. Kentucky), investigating whether the wind-compressed disk model can explain the properties of the mid-plane ring observed around SN1987A with A. Frank and T. Collins (Univ. Rochester), calculating the magnetic field structure of wind-compressed zone models with R. Ignace (Univ. Glasgow) and J. Cassinelli, and determining the effects of gravitational microlensing of extended sources with R. Ignace, M. Hendry, and J. Simmons (Univ. Glasgow). Our preliminary work indicates that microlensing an AGB star would produce observable spectroscopic line profile and linear polarization signatures that will aid in diagnosing the properties of both the lensing object and the extended circumstellar envelope.

Mulliss continued his Ph. D. thesis research on spectroscopic variability in the early A-type supergiant stars α Cyg and HR 1040. During the summer and early fall of 1997, α Cyg was monitored intensively at Ritter, with a median time between spectra of less than two days. During this time interval, three striking, blueshifted absorption enhancements in Hα occurred at a spacing of about 40 days. Under investigation is the hypothesis that these events represent a stellar wind disturbance that is phase-locked to the surface of the star, with the 40-day interval being a simple fraction of the star's rotation period. Working with Morrison, Fischer began a study of time variability in the radial velocities, equivalent widths, and Hα profile of the A3 Ia^{+}-type hypergiant star 6 Cas. This star is a Galactic analog to the most optically luminous stars in external galaxies, for which the wind momentum-luminosity relation has been proposed as a distance indicator.

In aid of a collaboration with N. Markova (National Obs., Bulgaria), Morrison measured Hα equivalent widths in all 33 Ritter échelle spectra of the star P Cygni obtained from 1994 through 1998. The study, which includes data from several observatories, reduced in a uniform manner, aims to elucidate the long-term behavior of mass loss in this star.

Anderson-Huang has joined a large-scale group effort, centered in Uppsala, Sweden under the guidance of B. Gustafsson, to understand the radiative transfer through convecting atmospheres in Sun-like stars.

Pan and Tan (Yunnan Obs., P. R. China) continued their project on stellar rotation. They measured rotational velocities of hundreds of stars, and studied rotational synchronization and orbital circularization mechanisms in early-type close binary systems. They found that, for most of the binaries, the dynamical tidal theory is substantially compatible with observational data. However, they also argued that other mechanisms (such as magnetic braking) must be employed in explaining synchronization and circularization in Am and Fm binaries, and in understanding the circular orbits of systems whose components have not both been synchronized yet.

3.2 Interstellar Matter

Yan, with J. Bjorkman and Federman, modeled recent measurements with the *Infrared Space Observatory* of the

planetary nebula NGC 7027. The main emphasis was on reproducing pure rotational line emission from CO, CH, CH^+, and OH at mid-infrared wavelengths with a thermal/chemical model of the neutral envelope. The near-infrared emission from rovibrational lines of H_2 were also considered. Most of the molecular emission arises from the dense photodissociation region within the nebula, but some of the CO emission comes from gas shocked by the fast-moving stellar wind. A paper describing this work has been submitted to ApJ.

Witt and collaborators continued the study of photoluminescence by interstellar grains, the process believed to be responsible for extended red emission (ERE) in numerous nebulae as well as in the diffuse ISM of the Galaxy. Jointly with Gordon (LSU) and Furton (Rhode Island Coll.), Witt developed a model for the source of the ERE in terms of photoluminescence by silicon nanoparticles (SNP). Quantum confinement in SNP causes high-efficiency photoluminescence with a range of spectra closely matching those of the ERE in astronomical sources. SNP are thought to form in oxygen-rich mass outflows from stars through the nucleation of SiO. In collaboration with V. Zubko (Technion, Israel) and Smith, Witt subsequently explored the extinction contributions from a population of SNP sufficiently abundant to produce the ERE observed in the diffuse ISM. Based on Mie calculations with size-dependent optical constants, SNP are found to produce an unstructured continuous absorption at $\lambda < 300$ nm. Witt, Gordon, and M. Cohen (UC Berkeley) are continuing the mapping, begun with Gordon's Ph. D. thesis, of the ERE in the diffuse medium of the Galaxy at $|b| > 20°$. They are using the all-sky surface photometry in *B* and *R* done at heliocentric distances > 3.3 AU by Pioneer 10 and 11, together with detailed star counts to $m = 19$, to derive intensities of the diffuse galactic (scattered) light (DGL) in *B* and the sum of DGL and ERE in *R*.

In their program to study radiative transfer in dusty media, Witt, Gordon, and Friedmann continued their modeling of radiative transfer in the reflection nebula IC 63, which is illuminated at large scattering angles by the star γ Cas. The goal is to constrain further the dependence of the scattering phase function on wavelength throughout the UV. Witt, Gordon, and Madsen (now at U. Wisc) further explored the transfer of stellar radiation in clumpy media with particular application to disk galaxies. Madsen completed an honors thesis on the determination of dust masses in disk galaxies from optical and near-IR digital images, based on these models.

3.3 Planetary System Astrophysics

James continues as PI of an *HST* program to monitor Mars, which has been active during all periods in which Mars has been observable since 1990. During the most recent year, STIS and NICMOS were used to study the Martian atmosphere and surface, respectively. Analyses of images and spectra acquired in 1997 continue to show 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 collaborator T. Clancy (SSI), these data suggest that the cloudiness may play an important role in the global water cycle. M. Wolff and other team members have analyzed images of Mars acquired during 1996–97 to find significant dust activity near the receding north polar cap. FOS spectra have been used to study the distribution and time dependence of ozone on Mars.

Cantor, with the help of Higgs, has been analyzing an extensive set of observations of the north polar cap of Mars using both WFPC1 and WFPC2. Cantor compared the cap regressions seen during the four spring seasons observed by *HST* to each other and to the historical data base. In addition, he has made some important observations concerning the temporal variation of the albedo of the north polar frost.

James is also a Participating Scientist and member of the MOC (Mars Observer Camera) Team on the *Mars Global Surveyor* mission. He participated in the data analysis of the aerobraking images acquired during the fall of 1997 and is currently using the MOC data to study the behaviors of the polar caps. James is a co-investigator of the MARCI camera experiment on the Mars Climate Orbiter, which will be launched late in 1998. He most recently was involved in camera calibrations at LASP in Boulder, CO.

3.4 Laboratory Astrophysics

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

Irving, Henderson, Ellis, and Curtis collaborated with Zou, Hellborg, and Martinson at the Univ. of Lund in the measurement of lifetimes of doubly-excited $2p3l$ levels in B II. While the cosmic abundance of boron is extremely low, it plays an important role in nucleosynthesis. Moreover, because these doubly-excited levels decay primarily radiatively, they also provide a separate test of that portion of theory that is then applicable to the isoelectronic levels in Be I, in which radiation and autoionization channels compete. Curtis has made a study of branching fractions in neutral Si, Ge, Sn and Pb. By utilizing measured spectroscopic data to specify the intermediate coupling coefficients and test for the presence of configuration mixing, he has made accurate semiempirical estimates that can be compared with the measured arc data of Corliss and Bozman (CB). The results indicate that, although the CB values for transition probabilities and oscillator strengths contain absolute and relative errors, branching fractions deduced from the same upper level using the CB compilation can be quite reliable. Henderson, Irving, Matulioniene, Curtis, and Ellis collaborated with Wahlgren and Brage of the Univ. of Lund in a determination of lifetimes and oscillator strengths for Ta II, W II, and Re II. Schectman, Povolny, and Curtis have completed a remeasurement and reevaluation of the lifetimes and transition probabilities in Si II. Irving, Henderson, and Curtis collaborated with Martinson of the Univ. of Lund in precision measurements of the resonance transition in Be I and B II.

Federman continued his work on oscillator strengths for S I lines through a collaboration involving E. Biémont and H.-P. Garnir (Univ. of Liège) and Z.S. Li and S. Svanberg (Lund Inst. of Technology). Federman converted his astronomically derived oscillator strengths into upper-state lifetimes for comparison with measurements on high-lying lev-

els acquired at Lund and with theoretical calculations for lifetimes and branching fractions performed at Liège. Overall, the correspondence between astronomical and experimental lifetimes is excellent; discrepancies may exist only for the weakest, least well-characterized lines in interstellar spectra.

From interstellar spectra acquired with the Goddard High Resolution Spectrograph on *HST*, Zsargó and Federman obtained accurate sets of self-consistent relative oscillator strengths for ultraviolet transitions in Co II and Ni II. As with our earlier studies on lines in S I and C I, the measured equivalent widths for a series of lines were placed on a single curve of growth by adjusting the line oscillator strengths. Lifetime measurements by K.L. Mullman and J.E. Lawler (Univ. of Wisconsin) allowed us to place the astronomical results for Co II on an absolute scale. A recently completed large-scale theoretical effort derived oscillator strengths in good agreement with our combined set of empirical ones. As a result of this work, we were able to derive accurate interstellar cobalt abundances toward ρ Oph A and ζ Oph. These abundances are larger than once thought, yielding a weaker correspondence between the amount of an element incorporated in interstellar grains and the condensation temperature for compounds containing that element. An implication of our finding is that the paths to grain formation continue to elude us. Experiments are now being conducted at Toledo, Wisconsin, and Denison that will place the relative oscillator strengths for Ni II on an absolute scale.

In collaboration with X. Deng (Univ. of Toledo), D. Furton (Rhode Island Coll.) and Smith and Friedmann, Witt has begun to set up a laboratory for the study of photoluminescence in likely interstellar grain analog materials. A particular goal is the measurement of absolute photoluminescence efficiencies for comparison with values derived from astronomical data. This year's work concentrated on the production and study of hydrogenated amorphous carbon-silicon alloys in order to investigate whether they are capable of high-efficiency photoluminescence at longer wavelengths than is pure hydrogenated amorphous carbon. This expectation was confirmed, but it was also found that a strong 4.6-μm Si–H stretch feature is an ever-present characteristic of C-Si alloys. The fact that this feature is not observed in the diffuse ISM suggests that hydrogenated amorphous C-Si alloys are not a likely component of interstellar dust in spite of their attractive photoluminescence properties. Subsequent work was therefore directed at the study of silicon nanoparticles, whose oxygen-passivated surfaces may contribute to the interstellar 10-μm ''silicate'' absorption feature and whose photoluminescence properties are even more in line with astronomical data.

Witt and collaborators investigated the photoluminescence in one of Mayo Greenberg's EUREKA samples, an organic refractory residue derived through the photolysis of a cosmic mixture of ices with subsequent exposure to solar UV radiation aboard an ESA long-term space exposure satellite. This sample, while luminescing strongly, did not exhibit the wavelength characteristics of ERE. However, it did absorb in the C–H stretch band at 3.4 μm, creating a near-perfect match to the interstellar feature observed at that wavelength.

4. INSTRUCTION

4.1 Academic

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 1001 for the three introductory lecture courses and 97 for the laboratory. The more advanced (3000-level) general-education courses had a total enrollment of 8. In graduate courses and advanced undergraduate courses for science majors, the total enrollment was 26.

The M. S. degree in physics was awarded to Cantor and Xue.

4.2 Public

Undergraduate assistants to Anderson-Huang and Mak for public education at the Ritter Planetarium-Brooks Observatory were Dawn Mulliss, Jeff Potter, Jamie Huston, Will Fischer, and Jeff Fisler. Potter accepted a position at the Alexander Brest Planetarium in Jacksonville, Florida.

During the report period, the Ritter Planetarium presented a record fifteen unique public planetarium programs, including the following shows written in-house (authors in parentheses):

Summer Skies over Toledo (Mak)
Where Have All the Martians Gone (Mak)
The Fall Skies over Toledo (Mak and D. Mulliss)
The Winter Skies over Toledo (D. Mulliss and Mak)
Lightyears Away (Mak)
The Spring Skies over Toledo (D. Mulliss and Mak)
Native American Skylore (Mak)

Total attendance for all programming conducted under the auspices of Ritter Planetarium and Brooks Observatory reached an all-time high of 27,500 for the year. The results of a new advertising and public relations campaign exceeded last year's Comet Hale-Bopp draw. Our normal program of monthly public observing nights with the Ritter 1-meter telescope and weekend evening viewings with the facilities of the Brooks Observatory drew approximately five thousand people.

Visiting school groups may now choose from twenty programs, some live, some taped. While these programs cover all aspects of astronomy, each begins with a live tour of the night sky and ends with an interactive question and answer session. In recent years we have seen our ''traditional service area'' increase from about a 30-mile radius to well over a 60-mile radius.

We streamlined our Boy Scouts' Astronomy Merit Badge program and the Girl Scouts' Space Exploration Ribbon program. Each three-hour program is now offered monthly. During the report period, approximately 220 Boy Scouts and 265 Girl Scouts completed the program. Mak conducted a well-attended, five-part workshop on amateur astronomy. Participants learned how to use star charts, how to buy, use,

and care for telescopes, and how to go beyond the basics of looking at the Moon and planets.

The Resource Room, our lending facility for area teachers, continues to grow, albeit more slowly than we had hoped. Our focus is on collecting and developing materials (reference, audio-visual, manipulative, etc.) specifically related to our programs. The planetarium staff continued to attend local, state, and regional conferences.

The University College of The University of Toledo awarded a B.S. degree in Planetarium Sciences to D. Mulliss. The individualized program relied heavily on course work in physics, astronomy, geology, education, theater, art, and field experience at the Ritter Planetarium-Brooks Observatory.

5. MISCELLANEOUS

5.1 Participation in Meetings

Anderson-Huang was invited to review the present understanding of the solar chromosphere-corona transition region at the ISSI Workshop *Solar Composition and Its Evolution—From Core to Corona* in Bern in January. Mulliss attended a national meeting of the APS.

J. Bjorkman was invited to the Guillermo Haro Workshop in Tonantzintla, Mexico (July, 1997). K. Bjorkman, J. Bjorkman, Miroshnichenko, Morrison, and Mulliss presented posters at the AAS meeting in Washington, DC (Jan., 1998). At IAU Colloquium 169 in Heidelberg, Germany (June, 1998), J. Bjorkman gave an invited talk, Miroshnichenko and K. Bjorkman presented oral papers, and Morrison presented two poster papers in co-authorship with Mulliss. James attended: Mars Telescopic Observations Workshop, Tucson, AZ (Oct., 1997); the DPS meeting in Boston, MA (July, 1997); the MGS Workshop on Atmospheres, LASP, Pasadena, CA in (May, 1998); and several MOC and MARCI team meetings.

Federman, Witt, Friedmann, and Smith attended the Space Science Laboratory Astrophysics Workshop at CfA, Cambridge, MA (April 1998). Witt attended the workshop *Interstellar Dust in the Solar System* at ISSI, Bern, Switzerland (Oct. 1997) and the meeting *Astrophysics with IR Surveys: A prelude to SIRTF* at Pasadena, CA (June 1998).

5.2 Visiting Lectureships

Federman presented Colloquia/Seminars at the Univ. of Michigan and Case Western Reserve Univ. He gave a public lecture at the Cleveland Museum of Natural History in its series ''Frontiers in Astronomy.'' K. Bjorkman gave an invited talk at Michigan State Univ., as part of the Astronomy Seminars series, in March 1998. J. Bjorkman presented colloquia at the University of Wisconsin, the University of Kentucky, and the University of Glasgow.

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 is serving a three-year term on the Organizing Committee of the IAU Working Group on Active B stars. He is also a member of the scientific organizing committee for IAU Colloquium 175 (June, 1999 in Alicante, Spain), *The Be Phenomenon in Early Type Stars*. Witt served on NASA's UV, Visible, & Gravitational Astrophysics proposal review panel in July, 1997.

5.4 Awards and Research Support

We gratefully acknowledge NASA LTSA grants to Federman, J. Bjorkman, and Witt; two NASA grants to K. Bjorkman, two to Witt, and one to Federman and Schectman; an STScI grant to James; and an NSF grant to Iwamoto. James received support from JPL to serve as Participating Scientist on the MOC team of Mars Global Surveyor and as Co-I on MARCI (Mars Color Imager) camera on Mars Surveyor '98. Morrison received grants from the Fund for Astrophysical Research, Inc., and from the Small Grants Program of the American Astronomical Society (NASA funds). Participation in research by Benson, Fischer, and Higgs was supported by an NSF-REU grant to the Department of Physics and Astronomy.

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