

University of Colorado, Boulder
Center for Astrophysics and Space Astronomy
Boulder, Colorado 80309-0389
<http://casa.colorado.edu>

[S0002-7537(99)04901-X]

1. INTRODUCTION: ASTROPHYSICS AT THE UNIVERSITY OF COLORADO, BOULDER

The astronomy and astrophysics program at the University of Colorado exists within the structure of the Astrophysical and Planetary Sciences Department (APS), with its affiliated units – the Center for Astrophysics and Space Astronomy (CASA), the Joint Institute for Laboratory Astrophysics (JILA), and the Laboratory for Atmospheric and Space Physics (LASP). Previous Observatory Reports provide details on the organizational arrangement.

The APS Department offers an academic program leading to the PhD degree in a variety of areas of astrophysics and planetary sciences. Students obtain basic theoretical knowledge common to these related fields, before specializing. Faculty have active research programs funded by NASA, NSF, and DOE.

In this report, we emphasize new developments and recent publications specifically within CASA and its membership. In astrophysics, particular strengths of CASA lie in hot and cool stars, interstellar and intergalactic matter, high-energy astrophysics, solar physics and UV/Xray/IR/sub-mm instrumentation.

2. SCIENTIFIC DEVELOPMENTS

2.1 Instrumentation

Colorado's hardware role in the Far Ultraviolet Spectroscopic Explorer [FUSE] has concluded with delivery of the spectrograph to Johns Hopkins in February 1998. The mission is scheduled for launch in spring 1999. Dr. James Green, P.I. of the Colorado hardware effort, is a member of the FUSE Science Working Group, together with CASA astronomers Drs. Cash, Linsky, Shull, and Snow. Pre-launch efforts are focussing on development of software tools to analyze the expected flood of far-UV spectra.

As FUSE ramped down, the CASA hardware team began work on the Cosmic Origins Spectrograph (COS), to be installed in NASA's Hubble Space Telescope in 2003. The powerful ultraviolet instrument will be built jointly with Ball Aerospace and Technologies Corp. in Boulder. COS will bring the diagnostic power of UV spectroscopy to bear on such fundamental issues as the ionization and baryon content of the intergalactic medium and the origin of large-scale structure in the Universe; the ages, dynamics, and chemical enrichment of galaxies; and stellar and planetary origins. COS will build on the legacies of Copernicus, IUE, GHRS, FOS, STIS, and FUSE, giving HST the greatest possible grasp of faint UV targets, ensuring that Hubble maintains a powerful UV spectroscopic capability through the end of its mission.

CASA also hosted, in August 1998, a workshop to discuss the future of space-based optical and ultraviolet astronomy. The meeting was organized by Drs. Morse and Shull, and

was well-attended by members of the UV/Optical community. The general consensus was that the next step beyond Hubble, which concludes its mission in 2010, should be a 4-6 m class instrument, whose enhanced resolution and sensitivity could probe well beyond the current HST horizon. Such a mission would strongly complement the largely-IR NGST, particularly if it could be deployed in the same time-frame.

2.2 Space Astronomy

CASA astronomers continue intensive use of NASA spacecraft. In 1998, there were awards from the Hubble Space Telescope (HST), Extreme Ultraviolet Explorer (EUVE), ASCA, X-ray Timing Explorer (XTE), ROSAT, and SOHO. Grants were received from other NASA programs including Astrophysics Theory, Data Analysis and Long-Term Programs, and Space Physics.

2.3 Groundbased Astronomy

CASA scientists continue to make extensive use of National groundbased optical and radio facilities for solar, stellar, interstellar, and extragalactic research. Efforts continue to secure a partnership in a new optical telescope, in order to enhance teaching and research efforts within the APS Department, as well as the affiliated organizations.

3. SELECTED INDIVIDUAL RESEARCH

Tom Ayres is involved in a number of ongoing observational projects with the solar IR spectrograph at the McMath-Pierce telescope, the new Phoenix nighttime IR spectrometer, and HST/STIS ultraviolet spectroscopy of R CrB stars and the archetype red giant Arcturus. He also is analyzing extensive solar data sets from the SOHO/Sumer UV imaging spectrometer; has collaborated on the interpretation of ORFEUS far-UV measurements of A-stars at the edge of the coronal activity zone; and is studying a remarkable EUV flare event that was detected by EUVE on the otherwise unremarkable G giant Mu Velorum. During summer 1998, Ayres collaborated on a proposal for an imaging EUV spectrometer for the upcoming Japanese Solar-B mission. He chairs the National Solar Observatory Users Committee, and serves in a group that is charting the future of the National Observatories. Ayres is involved in the newly-created Astrobiology Center at Colorado; he specializes in the evaluation of the ionizing radiation and coronal wind from the young Sun, both of which can play key roles in the evolution of primordial planetary atmospheres. Ayres continues to serve as Assoc. Director of CASA, and is supervising (together with Alex Brown) 3rd-year graduate student Rachel Osten.

Jeff Bennett this year completed two major, multi-year education projects with the publication of two college-level textbooks: (1) *Using and Understanding Mathematics* (with William L. Briggs) represents a new approach to liberal arts mathematics, often called quantitative reasoning. The text

was published in August to strong reviews, and is already in use at more than 60 colleges and universities. (2) The Cosmic Perspective (with Megan Donahue, Nicholas Schneider, and Mark Voit) is a new textbook for introductory astronomy that takes a “big picture” approach that the authors developed during their past 17 years of teaching. The book will be used in courses beginning in 1999, and is coming out with very strong pre-publication reviews. Both textbooks are published by Addison Wesley. In addition to the publication of the two books, Bennett continued his work as Co-PI on the Voyage project to build a scale model solar system on the National Mall; the project is jointly sponsored by NASA, the Smithsonian Institution, and the Challenger Center for Space Science Education. He also continues to teach for the U. of Colorado’s Honors Program.

Brad Gibson is an active member of the HST Key Project on the Extragalactic Distance Scale, whose goal is the resolution of the long-standing controversy over the Hubble Constant. Type Ia supernovae are recognized as the best available standard candle out in the Hubble Flow, and Gibson is leading the team in its pursuit of the Hubble Constant through supernovae. Parallel to this optical HST work, Gibson is involved with a NICMOS study of many of the HST Key Project’s galaxies, in an attempt to better separate the degenerate effect of metallicity and reddening upon the inferred galactic distance moduli. Gibson is supervising the PhD research of 2nd-year graduate student Mary Putman (The Australian National University). Their discovery of a leading arm to the Magellanic Stream (published in Nature in Aug 1998) provides unequivocal evidence for a tidal origin to the Stream, in contrast with the ram pressure model, its major competitor over the past decade. Gibson and Putman continue to pursue their more general program of High-Velocity Cloud research, including high-resolution mapping with the ATCA, emission line studies at the AAT and WHHT, and future metallicity determinations with awarded GI time on FUSE.

I.R. Little-Marenin continued her investigations of the dust characteristics of circumstellar dust grains. She and P. Benson studied the variability of water maser emission from circumstellar shells. She presented papers on the timevariability of the dust in Miras and on the timevariability of the 22 GHz water maser line in VX UMa and V778 Cyg at the ESO workshop on Cyclic Variability held at Garching, Germany in 1997 October. In late October 1997, she spent a week working with the group of J. Hron at the University of Vienna on problems of circumstellar shells. In June of 1998, she and her husband presented the results of five years of teaching workshops on astronomy to college teachers at the AAS meeting in San Diego.

Jon Morse continued research on processes in the interstellar medium, including HST studies of protostellar jets, oxygen-rich supernova remnants, Eta Carinae, a new planetary nebula in the globular cluster NGC 6441, and the extended line-emitting region of the Seyfert galaxy NGC 5252. See recent papers and HST images at Web site <http://casa.colorado.edu/~morsey/>. Morse has recently completed the 30,000 spectra Synthetic Template Grid based on Kurucz model atmospheres for use as templates in the CfA Stellar

Velocity program. Spectra cover the wavelength range 5145-5230Å. The grid spans a large range of stellar parameters: $T_{\text{eff}}=3500$ to 13000 K in 250 K steps, $\log g = 0.5$ to 5.0 in steps of 0.5, $[M/H] = +0.5$ to -4.0 in steps of 0.5, and 22 v_{ini} ’s ranging from 1 to 140 km/s.

Morse is the Project Scientist for the Cosmic Origins Spectrograph (COS) for the Hubble Space Telescope. He is responsible for coordinating and executing the COS GTO science program, and interfacing with both hardware and software engineers to ensure that the science goals can be met by the instrument design.

Morse co-organized three conferences in 1998: “Eta Carinae at the Millennium” held during 19-23 July at the 320 Guest Ranch in Gallatin Gateway, Montana; “Ultraviolet-Optical Space Astronomy Beyond HST” held during 5-7 August at the Regal Harvest House, Boulder, Colorado; and “Young Supernova Remnant Workshop” held during 11-13 October at NCAR, Boulder, Colorado. Morse is editing the proceedings of the first two meetings for the ASP.

Michael Shull’s interests lie in studies of interstellar and intergalactic matter, supernova remnants, and active galaxies. His research group carries out theoretical studies in these areas, as well as space observations with the Hubble Space Telescope and science planning for upcoming missions: the Far Ultraviolet Spectroscopic Explorer (FUSE 1999) and the Cosmic Origins Spectrograph (COS-2003) on the Hubble Space Telescope (HST). Shull and colleagues will be involved in several key FUSE studies of D/H, O VI, molecular hydrogen, and the He II Gunn-Peterson effect. Recent theoretical projects (with Mark Fardal and Mark Giroux) include radiative-transfer modeling of the metagalactic ionizing background from quasars and starburst galaxies, with applications to intergalactic metallicities, the He II Gunn-Peterson effect, and the processes of reionization and x-ray preheating of the high- z intergalactic medium. Ralph Sutherland (ANU) and Shull completed comprehensive models of OB associations, deriving their yields of ionizing radiation, hot gas, and heavy elements from modern evolutionary tracks, stellar atmospheres, and massive-star nucleosynthesis. Shull, Massimo Ricotti, and Jim Dove are studying the propagation and escape of ionizing photons from star-forming regions in disk and dwarf irregular galaxies. Ricotti, Ellen Zweibel, and Shull are studying the turbulent mixing of hot and cold interstellar gas, including thermal conduction and radiative cooling.

On the observational side, Jason Tumlinson, Shull, Mark Giroux, and John Stocke analyzed HST/GHRS spectra of QSO absorption-line systems toward 3C 232. They derived a lower limit on the low- z ionizing background, consistent with theoretical calculations (Shull, Roberts, Giroux 1998), from FeI/FeII and MgI/MgII ratios. In a long-term HST project (GHRS and STIS), Stocke, Steve Penton, and Shull are studying the distribution, metallicity, and baryon content of low- z Lyman-alpha absorbers toward QSOs behind cosmic voids. Shull wrote reviews on this subject for the 1997 Paris IGM conference and the 1998 Melbourne H I workshop. A recent paper (Shull *et al.* 1998) on the PKS 2155-304 sightline identified strong Ly-alpha absorbers at $cz =$

17,000 km/s with extended gas in a small group of large H I galaxies. The metallicity of these clouds appears to be quite low (< 0.003 solar) suggesting a primordial nature. During the past year, Shull edited the proceedings of a NASA-sponsored ORIGINS conference (Estes Park, CO) and initiated studies of a UV-Optical working group to provide suggestions for a possible successor to Hubble Space Telescope in UV - Optical space astronomy.

Beverly Smith, in collaboration with Suzanne Madden (Saclay, France), has used the Infrared Space Observatory (ISO) to study the mid-infrared emission features from 'macromolecules' in the interstellar medium of 'normal' galaxies. Before ISO, these features were only detectable in luminous 'starburst' galaxies. With ISO, it is now possible to see them in galaxies like the Milky Way. Using ISO, she has mapped these features in the nearby spiral galaxies NGC 7331 (a good analog of the Milky Way) and NGC 4736. These results show that these macromolecules are excited by the relatively quiescent post-starburst stellar populations in the bulges of these galaxies, and yet are not destroyed in the circumnuclear rings of star formation in these galaxies (Smith 1998; Smith and Madden 1998). These results provide strong constraints on theoretical models of these dust grains.

Beverly Smith and Suzanne Madden (Saclay, France) have also used ISO to search for 'hidden' molecular gas in low mass Virgo Cluster spiral galaxies via the 158 micron CII line. They found two galaxies with very weak 2.6mm CO (1 - 0) emission (the standard tracer of molecular gas) but strong CII emission, implying that the standard Galactic conversion factor does not hold in low mass spiral galaxies.

With Curt Struck (Iowa State), Beverly Smith has been conducting an optical, 21 cm HI, and CO (1 - 0) survey of extragalactic tails and bridges, to study the gas properties and star formation rates in these features. In this study, they have made the first detection of CO in an extragalactic tail (Smith *et al.* 1998). Beverly Smith has also collaborated with Shardha Jogee and Jeff Kenney (Yale) in an OVRO CO (1 - 0) and optical study of the starburst bubble in NGC 2782 (Jogee *et al.* 1998), and, in collaboration with Fritz Benedict (Texas) and his group, has investigated star formation in the inner ring of the barred galaxy NGC 4314 using the Hubble Space Telescope (Benedict *et al.* 1998).

With Paul Harvey (Texas) and his team, Beverly Smith has used Kuiper Airborne Observatory data to investigate variability in the Galactic star forming region SSV 13 in NGC 1333 (Harvey *et al.* 1998).

Ted Snow was active in several research areas: laboratory studies of the chemistry of large organic molecular ions; measurements and the interpretation of interstellar abundances and depletions; observational studies of the diffuse interstellar bands; and comparisons between interplanetary and interstellar grains.

The laboratory work, led by V. Bierbaum of Chemistry at Colorado and described preliminarily in last year's report, revealed that small PAH cations such as ionized naphthalene and ionized pyrene are not likely to be abundant in the diffuse interstellar medium because they react quickly with hydrogen atoms to produce protonated forms. The relevance of

this work, reported in a series of papers by Le Page *et al.* (J. American Chem. Soc., 119, 8373, 1997; J. American Chem. Soc., in press; International J. Mass Spectrometry, in press) and by Snow *et al.* (Nature, 391, 259, 1998) is that these species appear now to be ruled out as viable candidates as carriers of the diffuse interstellar bands. Larger PAH cations, or carbon chain molecules, are still possibilities, to be explored in future experiments.

Work done with J. Bally and E. Zweibel (both at Colorado) has shown that the traditional method of inferring interstellar dust composition from depletions (based on the difference between an assumed reference abundance and observed interstellar gas-phase abundances of the elements) may be invalid. Studies of interstellar dust show that there is probably more solid material in space than is consistent with standard depletion measures, and we suggest that the underlying assumption that stars represent the composition of the interstellar medium is wrong. Instead it appears likely that chemical fractionation may occur during star formation, thus allowing for a greater abundance of solid refractory material in interstellar space than is reflected in stellar composition measurements. If this thesis is correct, there may be a large and previously unexpected population of large interstellar grains. This work is being prepared for publication as of late 1998.

New observations of the diffuse interstellar band at 4430A (Snow, Boyd, and Massey, Pub. Astr. Soc. Pacific, in press) show that this band, the strongest of all the diffuse bands, becomes saturated in very heavily-reddened lines of sight. These first CCD-based observations of the band also reveal a general stability of the band profile, a lack of asymmetry, and a lack of emission wings, all supportive of a molecular origin. A second study (Snow, in preparation) shows that the 4430A feature lacks fine structure that might be attributed to molecular rotational and vibrational lines.

Finally, the comparison between observations of interstellar silicates and embedded grains within interplanetary particles suggests that the inclusions in the interplanetary grains (called GEMS, for Glass with Embedded Metals and Sulfides) may be the long sought-after interstellar silicate particles. This work, based primarily on the infrared spectra in the 10-micron region and being done in collaboration with J. P. Bradley of MVA, Inc, is being prepared for publication in the *Astrophysical Journal* (Bradley *et al.* 1999).

4. PERSONNEL CHANGES DURING 1998

New Faculty: Dr. Nick Gnedin (University of California-Berkeley)

New Research Associates: Dr. Jim Dove (University of Wyoming); Dr. Brad Gibson (Mt. Stromlo Observatory); Dr. Bo Reipurth (European Southern Observatory); Dr. Beverly Smith (California Institute of Technology/JPL)

Research Associate Departures: Dr. David Devine (NASA-Goddard)

CASA Visiting Scientists: Dr. Wendy Bauer (Wellesley College); Dr. Elizabeth Griffin (Oxford, England); Dr. Rob Fesen (Dartmouth)

New Graduate Students: Jason Tumlinson.

New Staff: Monica Digeronimo, Benjamin Reed.

5. PUBLICATIONS DURING 1997/98

- Abraham, R., Yee, H., **Ellingson, E.**, Carlberg, R., and Gravel, P. 1998, "The CNOC Cluster Redshift Survey Catalogs. V. MS 1224.7+2007 and MS 1512.4+3647," *ApJS*, 116, 231.
- Alcock, C., **Morse, J.** *et al.* 1997, "MACHO Alert 95-30: First Real-Time Observations of Extended Source Effects in Gravitational Microlensing," *ApJ*, 491, 436.
- Ayres, T., Brown, A., Harper, G., Bennett, P., Linsky, J.,** Carpenter, K., and Robinson, D. 1997, "Digging Deeper in the Coronal Graveyard," *ApJ*, 491, 876.
- Ayres, T.,** Simon, T., Stern, R., Drake, S., Wood, B., and **Brown, A.** 1998, "The Coronae of Moderate Mass Giants in the Hertzsprung Gap and the Clump," *ApJ*, 496, 428.
- Bally, J.,** Testi, L., Sargent, A., and Carlstrom, J. 1998, "Disk Mass Limits and Lifetimes of Externally Irradiated Young Stellar Objects Embedded in the Orion Nebula," *AJ*, 116, 854.
- Bally, J.,** Sutherland, R., **Devine, D.**, and Johnstone, D. 1998, "Externally Illuminated Young Stellar Environments in the Orion Nebula: Hubble Space Telescope Planetary Camera and Ultraviolet Observations," *AJ*, 116, 293.
- Balogh, M., Schade, D., Morris, S., Yee, H., Carlberg, R., and **Ellingson, E.** 1998, "The Dependence of Cluster Galaxy Star Formation Rates on the Global Environment," *ApJL*, 504, L75.
- Begelman, M.** 1998, "Instability of Toroidal Magnetic Field in Jets and Plerions," *ApJ*, 493, 291.
- Bender, P.** and **Hils, D.** 1997, "Confusion Noise Level Due to Galactic and Extragalactic Binaries," *Class. Quant Grav (Special Issue)*, 14, 1439.
- Benedict, G., Howell, A., Jorgensen, I., **Smith, B.**, and Kenney, J. 1998, "HST Surface Photometry of NGC 4314 - History of Star Formation in a Nuclear Ring," *BAAS*, 192, 6610.
- Bland-Hawthorn, J., Veilleux, S., Cecil, G., Putman, M., Gibson, B., and **Maloney, P.** 1998, "The Smith Cloud: H I Associated with the Sgr Dwarf?," *MNRAS*, 299, 611.
- Boroson, B., Blair, W., Davidsen, A., Vrtilik, S., Raymond, J., Long, K., and **McCray, R.** 1997, "Hopkins Ultraviolet Telescope Observations of Hercules X-1," *ApJ*, 491, 903.
- Brandt, J.** *et al.* **Linsky, J.** *et al.* 1998, "An Ultraviolet Spectral Atlas of 10 Lacertae Obtained With the Goddard High Resolution Spectrograph on the Hubble Space Telescope," *AJ*, 116, 941.
- Brummell, N.,** Hurlburt, N., and **Toomre, J.** 1998, "Turbulent Compressible Convection with Rotation. II. Mean Flows and Differential Rotation," *ApJ*, 493, 955.
- Chen, H., **Bally, J.,** O'Dell, C., McCaughrean, M., Thompson, R., Rieke, M., Schneider, G., and Young, E. 1998, "2.12 Micron Molecular Hydrogen Emission from Circumstellar Disks Embedded in the Orion Nebula," *ApJL*, 492, L173.
- Chiueh, T., Li, Z., and **Begelman, M.** 1998, "A Critical Analysis of Ideal Magnetohydrodynamic Models for Crab-Like Pulsar Winds," *ApJ*, 505, 835.
- Conti, P.** 1997, "B[e] Stars: What are They and Why are They at This Workshop?," in *Luminous Blue Variables: Massive Stars in Transition*, eds. A. Nota and H. Lamers, ASP Conf.Ser., 120, 161.
- Conti, P.** 1998, "Main Sequence O Stars and Starburst Galaxies," in *The Scientific Impact of the Goddard High Resolution Spectrograph*, eds. J. Brandt, C. Peterson and T. Ake, ASP Conf.Ser., 143, 55.
- Dekel, A., Bond, R., Bouchet, F., Coles, P., Durrer, R., Gottlober, K., **Hamilton, A.**, and Mo, H. 1997, "Formation of Large Scale Structure," in *The Evolution of the Universe*, eds. G. Borner and S. Gottlober, 224.
- de Kool, M., Li, H., and **McCray, R.** 1998, "Thermal Evolution of the Envelope of SN 1987A," *ApJ*, 503, 857.
- Devine, D., Bally, J., Reipurth, B.,** and Heathcote, S. 1997, "Kinematics and Evolution of the Giant HH 34 Complex," *AJ*, 114, 2095.
- Donahue, M., Voit, M., Gioia, I., Luppino, G., Hughes, J., and **Stoake, J.** 1998, "A Very Hot, High Redshift Cluster of Galaxies: More Trouble for $\Omega_0 = 1$," *ApJ*, 502, 550.
- Dove, J.,** Wilms, J., **Nowak, M.,** Vaughan, B., and **Begelman, M.** 1998, "RXTE Observation of Cygnus X-1: I. Spectral Analysis," *MNRAS*, 298, 729.
- Drake, R., Carroll, J., Estabrook, K., Glendinning, S., Remington, B., Wallace, R., and **McCray, R.** 1998, "Development of a Laboratory Environment to Test Models of Supernova Remnant Formation," *ApJL*, 500, L157.
- Drake, R., *et al.*, and **McCray, R.** 1998, "Observation of Forward Shocks and Stagnated Ejecta Driven by High-Energy-Density Plasma Flow," *PRL*, 81, 2068.
- Dring, A., **Linsky, J.,** Murthy, J., Henry, R., Moos, W., Vidal-Madjar, A., Audouze, J., and Landsman, W. 1997, "Lyman-Alpha Absorption and the D/H Ratio in the Local Interstellar Medium," *ApJ*, 488, 760.
- Ellingson, E.,** Yee, H., Abraham, R., Morris, S., and Smecker-Hane, T. 1997, "The CNOC Cluster Redshift Survey Catalogs III. MS 1621.5+2640 and MS 0302.7+1658," *ApJS*, 113, 1.
- Ellingson, E.,** Yee, H., Abraham, R., Morris, S., and Carlberg, R. 1998, "The CNOC Cluster Redshift Survey Catalogs. VI. MS 0015.9+1609 and MS 0451.5-0305," *ApJS*, 116, 247.
- Fan, Y., **Zweibel, E.,** and Lantz, S. 1998, "Two-Dimensional Simulations of Buoyantly Rising, Interacting Magnetic Flux Tubes," *ApJ*, 493, 480.
- Fan, Y., **Zweibel, E.,** Linton, M., and Fisher, G. 1998, "The Rise of Kink-Unstable Magnetic Flux Tubes in the Solar Convection Zone," *ApJL*, 505, L59.
- Fardal, M., Giroux, M.,** and **Shull, J.M.** 1998, "The High-Redshift He II Gunn-Peterson Effect: Implications and Future Prospects," *AJ*, 115, 2206.
- Folkner, W., Hechler, F., Sweetser, T., Vincent, M., and **Bender, P.** 1997, "LISA Orbit Selection and Stability," *Class. Quant Grav (Special Issue)*, 14, 1405.
- Gerin, M., Phillips, T., Keene, J., **Betz, A.,** and **Boreiko, R.** 1998, "CO, CI and CII Observations of NGC 7023," *ApJ*, 500, 329.
- Gough, D., Merryfield, W., and **Toomre, J.** 1998, "Phase Inversion: Inferring Solar Subphotospheric Flow and Other Asphericity from the Distortion of Acoustic Waves," *ApJ*, 501, 882.

- Green, J., Morse, J.,** and COS Instrument Definition Team 1998, "The Cosmic Origins Spectrograph: A 2002 Replacement Instrument for the Hubble Space Telescope," in *Ultraviolet Astrophysics Beyond the IUE Final Archive*, p. 805.
- Güdel, M., Guinan, E., and **Skinner, S.** 1998, "The X-ray Sun in Time: A Study of the Long-Term Evolution of Coronae of Solar-Type Stars," *ApJ*, 483, 947.
- Hamilton, A.** 1998, "Linear Redshift Distortions: A Review," in *Large-Scale Structure*, ed. D. Hamilton, 185.
- Hanson, M., Howarth, I., and **Conti, P.** 1997, "The Young Massive Stellar Objects of M17," *ApJ*, 489, 698.
- Harvanek, M., Stocke, J., Morse, J.,** and Rhee, G. 1997, "High Dynamic Range VLA Observations of the Gravitationally Lensed Quasar 0957+561," *AJ*, 114, 2240.
- Harvey, P., **Smith, B.,** DiFrancesco, J., and Colome, C. 1998, "Far-Infrared Constraints on Structure and Variability of SSV 13 in NGC 1333," *ApJ*, 499, 294.
- Heap, S. *et al.*, **Linsky, J.** and *et al.* 1998, "UV Spectral Dating of Stars and Galaxies," *ApJL*, 492, L131.
- Heinz, S.** and **Begelman, M.** 1997, "Analysis of the Synchrotron Emission from the M87 Jet," *ApJ*, 490, 653.
- Heinz, S., Reynolds, C.,** and **Begelman, M.** 1998, "X-ray Signatures of Evolving Radio Galaxies," *ApJ*, 501, 126.
- Jacoby, G., **Morse, J.,** Fulton, L., Kwitter, K., and Henry, R. 1997, "Planetary Nebulae in the Globular Clusters Pal 6 and NGC 6441," *AJ*, 114, 2611.
- Jogee, S., Kenney, J., and **Smith, B.** 1998, "The Remarkable Starburst-Driven Outflow in NGC 2782," *ApJ*, 494, L185.
- Johnstone, D., Hollenbach, D., and **Bally, J.** 1998, "Photoevaporation of Disks and Clumps By Nearby Massive Stars: Application to Disk Destruction in the Orion Nebula," *ApJ*, 499, 758.
- Jones, T., *et al.* and **McCray, R.** 1998, "10(51) Ergs: The Evolution of Shell Supernova Remnants," *PASP*, 110, 125.
- Kimble, R., *et al.*, **Linsky, J.,** and Valenti, J. 1998, "The On-Orbit Performance of the Space Telescope Imaging Spectrograph," *ApJL*, 492, L83.
- Kosovichev, A., *et al.*, and **Toomre, J.** 1997, "Structure and Rotation of the Solar Interior: Initial Results from the MDI Medium-1 Program," *SolPhys*, 170, 43.
- Krelowski, J., Schmidt, M., and **Snow, T.** 1997, "Groupings of Strong and Weak Diffuse Interstellar Bands Formed by Common Carriers," *PASP*, 109, 1135.
- Lacy, C., Fekel, F., Mathieu, R., Morrell, N., **Morse, J.,** Torres, G., and Willmarth, D. 1997, "The Spectroscopic Orbit of π Ceti," *AJ*, 113, 1088.
- Linsky, J.,** Wood, B., **Brown, A.,** and **Osten, R.** 1998, "Dissecting Capella's Coronae - GHRS Spectra of the Fe XXII 1354 and He II 1640 Lines from Each of the Capella Stars," *ApJ*, 492, 767.
- Linsky, J., Harper, G., Bennett, P., Brown, A.,** and Valenti, J. 1998, "A Critical Evaluation of Mass Loss Rates and Wind Properties of Evolved Late-Type Stars," in *Cyclical Variability in Stellar Winds*, eds. L. Kaper and A. Fullerton, 30.
- Linsky, J.,** Wilson, T., and Rood, R. 1998, "Summary of Working Group VI: Local Interstellar Medium," in *Primordial Nuclei and Their Galactic Evolution*, *Space SciRev*, 84, 309.
- Little, S., Little-Marenin, I.,** and **Garmany, C.** 1998, "Report on Astronomy Workshops for College Teachers: 1993-1997," *BAAS*, 192, 8001.
- Little-Marenin, I.** and **Little, S.** 1997, "What Types of Dust Exist in the Circumstellar of Miras?" *JAAVSO*, 25, 80.
- Maloney, P.** and **Begelman, M.** 1997, "The Origin of Warped, Precessing Accretion Disks in X-ray Binaries," *ApJL*, 491, L43.
- Maloney, P., Begelman, M.,** and **Nowak, M.** 1998, "Radiation-Driven Warping.II.Non-Isothermal Disks," *ApJ*, 504, 77.
- Marti, J., Rodriguez, L., and **Reipurth, B.** 1998, "Proper Motions of the Inner Condensations in the Hh 80-81 Thermal Radio Jet," *ApJ*, 502, 337.
- McCaughrean, M.J., Chen, H., **Bally, J.,** Erickson, E., Thompson, R., Rieke, M., Schneider, G., Stolovy, S., and Young, E. 1998, "High-Resolution Near-Infrared Imaging of the Orion 114-426 Silhouette Disk," *ApJL*, 492, L157.
- Michael, E., **McCray, R.,** Kazimierz, J., Borkowski, K., Pun, J., and Sonneborn, G. 1998, "High Velocity Lyman-Alpha Emission From SNR 1987A," *ApJL*, 492, L143.
- Morse, J.,** Blair, W., and Raymond, J. 1997, "HST Observations of Oxygen-Rich Supernova Remnants in the Magellanic Clouds," in *Tex-Mex 6*, eds. R. Dufour and M. Peimbert, *RMA*, 7, 21.
- Morse, J.,** Cecil, G., Wilson, A., and Tsvetanov, Z. 1998, "Inclined Gas Disks in the Lenticular Seyfert Galaxy NGC 5252," *ApJ*, 505, 159.
- Morse, J., Green, J.,** Ebbets, D., **Andrews, J.,** Heap, S., Leatherer, C., **Linsky, J.,** Savage, B., **Shull, M., Snow, T.,** Stern, A., **Stocke, J.,** and **Wilkinson, E.** 1998, "Performance Overview and Science Goals of the Cosmic Origins Spectrograph for the Hubble Space Telescope," *SPIE*, 3356, 361.
- O'Dell, C., Hartigan, P., **Bally, J.,** and **Morse, J.** 1998, "High Velocity Features in the Orion Nebula," *AJ*, 114, 2016.
- Osten, R., Brown, A.,** and **Ayres, T.** 1997, "Flaring on RS CVn Systems: Results from EUVE Photometry," in *Cool Stars, Stellar Systems, and the Sun*, eds. R. Donahue and J. Bookbinder, 1540.
- Osten, R.** and Saar, S. 1998, "Physical Properties of Active Stars and Stellar Systems," *MNRAS*, 295, 257.
- Padoan, P., Juvela, M., **Bally, J.,** and Nordlund, A. 1998, "Synthetic Molecular Clouds From Supersonic MHD and Non-LTE Radiative Transfer Calculations," *ApJ*, 504, 300.
- Raymond, J., Blair, W., Long, K., Vancura, O., Edgar, R., **Morse, J.,** Hartigan, P., and Sanders, W. 1997, "The Ultraviolet Spectrum of a Face-on Shock Wave in the Vela Supernova Remnant," *ApJ*, 482, 881.
- Reipurth, B., Bally, J.,** and **Devine, D.** 1997, "Giant Herbig-Haro Flows," *AJ*, 114, 2708.
- Reipurth, B.** and Aspin, C. 1997, "Infrared Spectroscopy of

- Herbig-Haro Energy Sources,” *AJ*, 114, 2700.
- Reynolds, C.** and **Begelman, M.** 1997, “Iron Fluorescence from within the Innermost Stable Orbit of Black Hole Accretion Disks,” *ApJ*, 488, 109.
- Robinson, R. *et al.* and **Linsky, J.** 1998, “The Goddard High Resolution Spectrograph: Post-COSTAR Characteristics,” *PASP*, 110, 68.
- Saar, S., Huovelin, J., **Osten, R.**, and Shcherbakov, A. 1997, “He I D3 Absorption and Its Relation to Rotation and Activity in G and K Dwarfs,” *AAP*, 326, 741.
- Schachter, J., Fiore, F., Elvis, M., Mathur, S., Wilson, A., **Morse, J.**, Awaki, H., and Iwasawa, K. 1998, “NGC 7582: The Prototype Narrow Line X-ray Galaxy,” *ApJL*, 503, L123.
- Schou, J. *et al.*, and **Toomre, J.** 1998, “Helioseismic Studies of Differential Rotation in the Solar Envelope by the Solar Oscillations Investigation Using the Michelson Doppler Image,” *ApJ*, 505, 390.
- Shull, M.** 1997, “The Nature of the Low-Redshift Lyman-Alpha Clouds,” in *Structure and Evolution of the IGM from QSO Absorption Lines*, eds. P. Petitjean and S. Charlot, 101.
- Shull, M.** 1997, “Structure and Evolution of the Intergalactic Medium: Conference Summary,” in *Structure and Evolution of the IGM from QSO Absorption Lines*, eds. P. Petitjean and S. Charlot, 361.
- Sikora, M., Madejski, G., and **Begelman, M.** 1997, “Variability, Power, and Pair Content of AGN Jets,” in *Relativistic Jets in AGNs*, eds. M. Ostrowski, M. Sikora, G. Madejski, and M. Begelman, 287.
- Simon, T. and **Ayres, T.** 1998, “High-Excitation Emission Lines in the Far-Ultraviolet Spectrum of the Late A Star α Cephei,” *ApJL*, 500, L37.
- Skinner, S.**, Itoh, M., and Nagase, F. 1998, “A Search for X-ray Evidence of a Compact Companion to the Unusual Wolf-Rayet Star HD50896 (EZ cMa),” *New Astr.*, 3, 37.
- Sloan, G., **Little-Marenin, I.**, and Price, S. 1998, “The Carbon-Rich Dust Sequence: Infrared Spectral Classification of Carbon Stars,” *AJ*, 115, 809.
- Smith, B.** and Madden, S. 1997, “Interstellar Gas in Low Mass Virgo Cluster Spiral Galaxies,” *AJ*, 114, 138.
- Smith, B.**, Struck, C., and Pogge, R. 1997, “Atomic Hydrogen and Star Formation in the Bridge/Ring Interacting Galaxy Pair NGC 7714/7715 (Arp 284),” *ApJ*, 483, 754.
- Smith, B.** 1998, “ISOCAM Mid-Infrared Imaging of the Quiescent Spiral Galaxy NGC 7331,” *ApJ*, 500, 181.
- Snow, T.**, Le Page, V., Keheyan, Y., and **Bierbaum, V.** 1997, “Laboratory Studies of PAH Cations of Astrophysical Interest,” *NatL*, 391, 259.
- Snow, T.**, Hanson, M., Black, J., van Dishoeck, E., Crutcher, R., and Lutz, B. 1998, “Carbon and Oxygen Depletion and Extinction in the Translucent Cloud Toward HD 24534,” *ApJL*, 496, L113.
- Sonneborn, G., Pun, C., Kimble, R., Gull, T., Lundqvist, P., **McCray, R.**, Plait, P., Boggess, A., Bowers, C., Danks, A., Grady, J., Heap, S., Kraemer, S., Lindler, D., Loiacono, J., Maran, S., Moos, H., and Woodgate, B. 1998, “Spatially Resolved STIS Spectroscopy of SN 1987A: Evidence for Shock Interaction with Circumstellar Gas,” *ApJL*, 492, L139.
- Spina, A., **Toomre, J.**, and Knobloch, E. 1998, “Confined States in Large-Aspect-Ratio Thermosolutal Convection,” *JPhys E* 57, 524.
- Stoeke, J.** and **Rector, T.** 1997, “An Excess of Mg II Absorbers in BL Lac Objects,” *ApJL*, 489, L17.
- Stoeke, J.**, **Penton, S.**, **Harvanek, M.**, Neely, W., and Blades, J.C. 1998, “HST Spectra of 3C279: A Lyman Limit System at Low Redshift,” *AJ*, 115, 451.
- Tegmark, M., **Hamilton, A.**, Strauss, M., Vogeley, M., and Szalay, A. 1998, “Measuring The Galaxy Power Spectrum with Future Redshift Surveys,” *ApJ*, 499, 555.
- Tegmark, M. and **Hamilton, A.** 1998, “Uncorrelated Measurements of the CMB Power Spectrum,” in *Relativistic Astrophysics*, eds. A. Olinto, J. Frieman and D. Schramm, 270.
- Tobias, S., **Brummel, N.**, Clune, T., and **Toomre, J.** 1998, “Pumping of Magnetic Fields by Turbulent Penetrative Convection,” *ApJL*, 502, L177.
- Tsuboi, Y. *et al.* and **Skinner, S.** 1998, “ASCA Detection of a Super-Hot 100 Million K X-ray Flare on the Weak-Lined T Tauri Star V773 Tauri,” *ApJ*, 503, 894.
- Tumlinson, J.**, Hartigan, P., **Morse, J.**, and Raymond, J. 1998, “HST/FOS Spectroscopy of HH47A: Shock Velocity, Magnetic Fields, and Secondary Shock Structure,” in *TexMex 6*, eds. R. Dufour and M. Peimbert, RMA, 7, 21.
- Vrtilek, S., Boroson, B., Cheng, F., **McCray, R.**, and Nagase, F. 1997, “Simultaneous Hubble Space Telescope and ASCA Observations of LMC X-4: X-ray Ionization Effects on a Stellar Wind,” *ApJ*, 490, 377.
- Wagoner, R., Lehr, D., Silbergleit, A., **Nowak, M.**, and **Begelman, M.** 1998, “Relativistic Diskoseismology: Search for a Definitive Black Hole Signature,” in *Relativistic Astrophysics*, eds. A. Olinto, J. Frieman, and D. Schramm, 758.
- Walborn, N., Danks, A., Sembach, K., Bohlin, R., Jenkins, E., Gull, T., Lindler, D., Fegans, J., Hulbert, S., **Linsky, J.**, Hutchings, J., and Joseph C. 1998, “Space Telescope Imaging Spectrograph Observations of the Interstellar Velocity Structure and Chemical Composition Toward the Carina Nebula,” *ApJL*, 492, L169.
- Wanders, I., Peterson, B., Alloin, D., **Ayres, T.**, and **Shull, M.** *et al.* 1997, “Steps Toward Determination of the Size and Structure of the Broad-Line Region in Active Galactic Nuclei. XI. Intensive Monitoring of the Ultraviolet Spectrum of NGC 7469,” *ApJS*, 113, 69.
- Wood, B. and **Linsky, J.** 1998, “The Local ISM and its Interaction with the Winds of Nearby Late-Type Stars,” *ApJ*, 492, 788.
- Yee, H., **Ellingson, E.**, Morris, S., Abraham, R., and Carlberg, R. 1998, “The CNOC Cluster Redshift Survey Catalogs. IV. MS 1358.4+6245 and MS 1008.1-1224,” *ApJS*, 116, 211.
- Zweibel, E.** 1998, “Fragmentation Instability of Molecular Clouds,” *ApJ*, 499, 746.
- Zweibel, E.** 1998, “Fast Reconnection of Weak Magnetic Fields,” *PhysPlasmas*, 5, 247.