

University of Southern California
Space Sciences Center
Department of Physics and Astronomy
Los Angeles, California 90089

[S0002-7537(93)06531-X]

The following report covers activities from September 1999 through August 2000.

1. INTRODUCTION & PERSONNEL

Research in astronomy and the space sciences at USC is carried through in the Space Sciences Center and Department of Physics and Astronomy. Scientists whose research is reported below include: 1) Space Science Center: Dr. Darrell L. Judge, Professor and Director of the Space Sciences Center, Dr. C. Y. Robert Wu, Research Professor, Dr. Pradip Gangopadhyay, Dr. Howard S. Ogawa, & Dr. Geraldine J. Peters, Research Scientists, Dr. Fang-Zhong Chen, Postdoctoral Fellow, & Donald McMullin, Project Manager, and 2) Department of Physics & Astronomy: Dr. Werner Däppen & Melvin Daybell, Professors, Dr. Alan Nayfonov, Postdoctoral Fellow, Zhigang Gong, Tom Hung, Chia-Hsien Lin, & Ladislav Zejda, graduate students, and Dr. Gibson Reaves, Professor Emeritus.

2. RESEARCH

W. Däppen continued his research on using the sun as a plasma physics laboratory. To pursue this goal, he participates in state-of-the-art solar modeling and the analysis of helioseismic data. Helioseismology is the first accurate "experiment" that puts strong constraints on the thermodynamic quantities of the plasma of stellar interiors. His own contribution to the field [the Mihalas-Hummer-Däppen (MHD) equation of state] is currently being used in collaboration with several international solar and stellar modeling groups. His most recent attention is devoted to the subtle thermodynamic effects of excited states in atoms and ions of the solar interior. Such effects have indeed been detected by helioseismology, and they have to be taken into account in the determination of the helium abundance of the solar convection zone.

P. Gangopadhyay and D. E. Shemansky (USC department of Aerospace Engineering) continue their work on calculating the outer planetary upper atmosphere Lyman Alpha glow. The work is being carried out to resolve the discrepancy between the 15000 Rayleighs observed by Voyager spacecraft from the Jovian upper atmosphere and the maximum of 5000 Rayleighs that solar Lyman Alpha flux can generate. Preliminary calculations suggest that the discrepancy can be resolved if there is a thin layer of hot electrons in the upper atmosphere of Jupiter.

D. L. Judge, H. S. Ogawa, D. R. McMullin, P. Gangopadhyay, and M. Daybell have continued their work on solar EUV irradiance observations from sounding rockets, the Shuttle, and satellites like SOHO. Various instruments have been and are being utilized to obtain absolute solar EUV flux data. These include Rare Gas Ionization Cells (RGIC) to

obtain absolute integral irradiance in a wavelength region shortward of the ionization limit of the working gas used, Double Ionization Cells (HDIC) to obtain photoionization rates of Helium and Neon, Free Standing and Film Deposited Photodiodes to obtain absolute flux within the wavelength band pass of the metal filter used, an Optics Free Spectrometer (OFS) to obtain spectral irradiance data in the EUV and soft X-ray region, a low resolution (10 \AA) normal incidence spectrometer, and a solar EUV Monitor (SEM) to obtain absolute solar EUV irradiance that has been securing high quality data for four years aboard the SOHO spacecraft.

D. L. Judge, D. R. McMullin, and H. S. Ogawa are participating in a coordinated observation of the gravitational focusing cone of interstellar helium during the rise to solar maximum conditions. This will be a Joint Observation Project for SOHO together with ACE, EUVE, and Ulysses lead by the scientific team coordinator Eberhard Moebius, and will be the first comprehensive study of the interstellar parameters and the ionization of helium in the heliosphere. The campaign is scheduled for Nov–Dec 2000 when the Earth and all earth bound spacecraft pass through the interstellar focusing cone.

D. L. Judge, H. S. Ogawa, D. R. McMullin, P. Gangopadhyay and J. M. Pap have presented the entire SOHO CELIAS/SEM EUV database from January 1, 1996 (near SC23 minimum) to December 31, 1999. The SOHO CELIAS/SEM is a transmission grating spectrometer. The spectrometer continuously measures the full solar disk absolute solar flux within an 8 nm bandpass centered at the prominent and scientifically important He II 30.4 nm line (first order channel) as well as the absolute solar flux between 0.1 and 50 nm (central order channel). The central channel data also contain solar soft X-ray data. The 30.4 nm flux, the 0.1 to 50 nm flux and the extracted soft X-ray flux (0.1 to 5 nm) flux were presented and compared with the behavior of solar proxies.

D. L. Judge, D. R. McMullin, P. Gangopadhyay, H. S. Ogawa, F. M. Ipavich, A. B. Galvin, E. Moebius, P. Bochsler, P. Wurz, M. Hilchenbach, H. Gruenwaldt, D. Hovestadt, B. Klecker, and F. Gliem have published a paper on space weather observations using the SOHO CELIAS complement of instruments. The CELIAS particle and soft X-ray measurements have been used to examine examples of precursor information of CME events. They also discuss the usefulness of the CELIAS/SEM data for studying long term weather trends as well as short term storm data.

G. J. Peters continued her study of short-term wind and photospheric activity in Be stars in collaboration with D. Gies (Georgia State Univ.). A cross-correlation technique has been used to extract information on the nature of the photospheric line profile variability seen during 12 multi-wavelength campaigns involving the *IUE* spacecraft. Peters also continued her investigation of the long-term, apparent

yearly, cyclical variability in the winds of λ Eri and 66 Oph during the lifetime of the *IUE*. G. Peters began a study of the short-term micro-emission activity in the Be star π Aqr that lost its emission-line disk in the mid-1990s. Peters continued to serve as Editor-in-Chief of the *Be Star Newsletter*, a periodical published for the Working Group on Active B Stars of the IAU Division IV (Stars) in both paper (D. R. Gies, Georgia State University, technical editor) and electronic (<http://www.limber.org/benews/>, D. McDavid, technical editor) editions.

G. J. Peters continued to investigate the circumstellar material in Algol binary systems. Attention was directed toward the systems that contain early B primaries, especially those in which the gas stream strikes the mass gainer's photosphere tangentially or impacts at a shallow angle. It was found that the azimuthal distribution of the high temperature plasma (HTAR) and the amount and nature of the mass flow away from the system near phase 0.5 depend on the impact angle. Peters collaborated with R. Polidan (GSFC) and D. E. Lynch (Global Science & Tech.) in a study of apparent bipolar flows in V356 Sgr & TT Hya. They began an analysis of a series of spectra of V356 Sgr obtained with the FUSE spacecraft throughout the total eclipse of the primary. A high temperature plasma ($\sim 300,000$ K) is inferred from the O VI emission feature that dominates the spectrum. Peters presented a review talk on Algol binaries at the meeting "The Influence of Binaries on Stellar Population Studies" held in Brussels, Belgium, 21–25 August 2000.

G. J. Peters and J. Grigsby (Ball Aerospace) continued a study of the abundances of the Fe group elements in AV 304, a sharp-lined B0.5V star in the Small Magellanic Cloud, using spectra from HST/STIS. The abundances ranged from 0.5–1.0 dex below those observed in the sun. Peters & Grigsby also completed an investigation of the abundances of the Fe group elements in the ultrasharp-lined early B star ι Her using coadded high resolution *IUE* data, the Kurucz SYNTH code, and Kurucz model atmospheres.

Gibson Reaves continues his study of approximate methods in orbital dynamics. He is also involved in various volunteer academic activities at USC and elsewhere, including the local History of Astronomy Society. In March, Reaves received a USC Distinguished Emeriti Award.

C. Y. Robert Wu has continued his work with F. Z. Chen, T. Hung, and D. L. Judge and collaborators to obtain (1) temperature dependent cross sections of acetylene, methane, and ethylene in the UV region, (2) temperature-dependent cross sections of gaseous and liquid water and benzene in 160–180 nm region, and (3) ultrahigh resolution (FWHM = 0.0003 nm), high (555 K), and room (295 K) temperature absorption cross sections of N_2 and O_2 in the 83.4 nm, 91.7 nm, and 108.5 nm regions. Much of the above data have been analyzed and will be made available to the planetary and aeronomy communities. Our data have been applied in modeling various planetary atmospheres such as Earth, Saturn, Mars, Io, Titan, Jupiter, and Neptune.

Wu, F. Z. Chen, T. Hung, and D. L. Judge have continued their studies of fluorescence produced through photoexcitation of CO in the 28–100 eV region. They have observed, for the first time, fluorescence processes correlated with excited

electronic states of doubly- and triply-charged molecules. This observation was possible because the newest, brightest tunable synchrotron radiation source available at the Photon Factory, Tsukuba, Japan, was employed in the experiment. The O I and C I fluorescence excitation functions are useful in the modeling of dayglow in atmospheres of Venus and Mars. They also plan to examine the temperature effects on the absorption, dissociation, and ionization processes as the upper atmospheres of the mentioned planets are higher than the ambient temperature on the Earth's surface.

Wu, Chen, and P. Scoggins have continued their investigation of the absolute solar photon sputtering/desorption yields of CO_2 ices, H_2O ices, D_2O ices, and CH_4 clathrate hydrates in the inner valence and core electron regions using intense tunable VUV photon source provided by synchrotron radiation.

PUBLICATIONS

The publication list includes all papers published or submitted between 1999 September 1 & 2000 August 31 by permanent staff.

Baturin, V.A., **Däppen, W.**, Gough, D.O., & Vorontsov, S.V., 2000, "Seismology of the Solar Envelope: Sound-Speed Gradient in the Convection Zone," *MNRAS*, 316, 71.

Chen, F.Z., **Judge, D.L.**, & **Wu, C.Y.R.**, 2000, "Temperature-Dependent Photoabsorption Cross Sections of Allene and Methylacetylene in the UV Region," *J. Chem. Phys.*, 108, (in press).

Christensen-Dalsgaard, J., **Däppen, W.**, Dziembowski, W. A., & Guzik, J. A., 2000, "An Introduction to Helioseismology," in *Proc. Variable Stars as Important Astrophysical Tools*, ed. C. Ibanoglu (NATO Advanced Study Institute, Cesme, Turkey), (Dordrecht: Kluwer), 59.

Däppen, W., 2000, "Atoms and Molecules," in *Astrophysical Quantities, 4th Edition*, ed. A. Cox, (Springer-Verlag: New York), 27.

Däppen, W., 2000, "Solar Interior: Equation of State and Opacity," in *Encyclopedia of Astronomy and Astrophysics*, (Institute of Physics, Bristol), in press.

Däppen, W., 2000, "Stars: Thermodynamics," in *Encyclopedia of Astronomy and Astrophysics*, (Institute of Physics, Bristol), in press.

Däppen, W., & J.A. Guzik, J. A., 2000, "Astrophysical Opacity and Equation of State," in *Proc. Variable Stars as Important Astrophysical Tools*, ed. C. Ibanoglu (NATO Advanced Study Institute, Cesme, Turkey), (Dordrecht: Kluwer), 177.

Däppen, W., & **Nayfonov, A.**, 2000, "The Sun as an Equation-of-State Laboratory," *ApJS*, 135, 405.

Gong, Z.G., & **Däppen, W.**, 2000, "Upgrading the MHD Equation of State to Include Relativistic Electrons," in *The Impact of Large-scale Surveys on Pulsating Star Research*, eds. L. Szabados & D.W. Kurtz, (ASP Conference Series, Vol. 203), 388.

Gong, Z.G., **Däppen, W.**, & **Zejda, L.**, 2000, "MHD Equation of State with Relativistic Electrons," *ApJ*, in press.

Judge, D.L., **McMullin, D.R.**, & **Ogawa, H.S.**, 1999, "Absolute Solar 30.4 nm Flux from Sounding Rocket Obser-

- vations During the Solar Cycle 23 Minimum,” *Journal of Geophysical Research*, 104, 28321.
- Judge, D.L., McMullin, D.R., Gangopadhyay, P., Ogawa, H.S.,** Ipavich, F.M., Galvin, A.B., Moebius, E., Bochsler, P., Wurz, P., Hilchenbach, M., Gruenwaldt, H., Hovestadt, D., Klecker, B., & Gliem, F., 2000, “Space Weather Observations using the SOHO CELIAS Complement of Instruments,” *Journal of Geophysical Research*, (submitted.)
- Judge, D.L., Ogawa, H.S., McMullin, D.R., Gangopadhyay, P.,** & Pap, J.M., 2000, “The SOHO CELIAS/SEM EUV Database from SC23 Minimum to the Present,” *Advances Space Res.*, (submitted.)
- Lin, C.-H., & Däppen, W.,** 2000, “Investigating the Excitation of Acoustic Modes using Homomorphic Deconvolution,” *Sol. Phys.*, in press.
- Moebius, E., Litvinenko, Y., Gruenwaldt, H., Aellig, M.R., Bogdanov, A., Ipavich, F.M., Bochsler, P., Hilchenbach, M., **Judge, D.L.,** Klecker, B., Lee, M.A., & **Ogawa, H.S.,** 1999, “Direct Evidence of the Interstellar Gas Flow Velocity in the Pickup Ion Cut-Off as Observed with SOHO CELIAS CTOF,” *Journal of Geophysical Research Letters*, 26, 3181.
- Nayfonov, A., Däppen, W.,** Hummer, D. G., & Mihalas, D. M., 1999, “The MHD Equation of State with Post-Holtmark Microfield Distributions,” *ApJ*, 526, 451.
- Peters, G.J.,** 2000, “Long-Term Variability in the Winds of λ Eri and 66 Ophiuchi,” in *The Be Phenomenon in Early-Type Stars*, (IAU Colloq. 175), ed. M Smith, H. Henrichs, & J. Fabregat, (San Francisco: ASP Conf. Ser.), 212.
- Peters, G.J.,** 2000, “Stellar Astrophysics: Be Stars,” in *Encyclopedia of Astronomy and Astrophysics*, (Institute of Physics, Bristol), in press.
- Peters, G.J.,** 2000, “The Algol Binaries,” in *The Influence of Binaries on Stellar Population Studies*, ed. D. Vanbeveren, (Dordrecht: Kluwer), in press.
- Peters, G.J.,** & Gies, D.R., 2000, “Short-Term Wind and Photospheric Activity in Be Stars Deduced from Campaigns with the *IUE* Spacecraft,” in *The Be Phenomenon in Early-Type Stars*, (IAU Colloq. 175), ed. M Smith, H. Henrichs, & J. Fabregat, (San Francisco: ASP Conf. Ser.), 375.
- Peters, G.J.,** & Grigsby, J.A., 2000, “The Abundances of the Iron Group Elements in ι Herculis,” *ApJS*, submitted.
- Richards, M.T., Koubský, P., Šimon, V., **Peters, G.J.,** Hirata, R., Škoda, P., & Masuda, S., 2000, “A Multi-wavelength Study of Spectral Variations in the CX Draconis Binary,” *ApJ*, 531, 1003.
- Wu, C.Y.R., Chen, F.Z., & Judge, D.L.,** 2000, “Measurements of Temperature-Dependent Absorption Cross Sections of C_2H_2 in the VUV–FUV Region,” *Journal of Geophysical Research*, (submitted.)
- Wu, C.Y.R., & Chen, F.Z.,** 2000, “Temperature Dependent Photoabsorption Cross Section Measurements of Gas and Liquid C_6H_6 (Benzene) in the FUV Region,” *Journal of Geophysical Research*, (submitted.)
- Wu, C.Y.R., Hung, T., Judge, D.L.,** & Matsui, T., 2000, “High-Temperature High-Resolution Absorption Cross Section Measurements of O_2 in the 83.4 nm Region,” *Journal of Geophysical Research*, 103, 5329.
- Wu, C.Y.R., Hung, T., Judge, D.L.,** & Matsui, T., 2000, “High-Temperature High-Resolution Photoabsorption Cross Section Measurements of O_2 in the 108.5 nm Region,” *Journal of Geophysical Research*, (in press.)
- Wu, C.Y.R.,** Yang, B.W., **Chen, F.Z., Judge, D.L.,** Caldwell, J.J., & Trafton, L., 2000, “The High, Room, and Low Temperature Photoabsorption Cross Sections of SO_2 in the 208–295 nm Region, With Application to Io,” *Icarus*, 145, 289.

Geraldine J. Peters