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Combined Ultraviolet Studies of Astronomical Sources

NASA Grant NAG5-87

Semiannual Report No. 3

For the Period 1 August 1981 through 31 January 1982

Principal Investigators

Drs. A. K. Dupree; M. S. Giampapa; J. P. Huchra;
R. W. Noyes; L. W. Hartmann; J. C. Raymond

March 1982

Prepared for
National Aeronautics and Space Administration
Greenbelt, MD 20771

Smithsonian Institution
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Supernova Remnants

IUE observations of a non-radiative shock at the edge of the Cygnus Loop, together with complementary optical observations, were presented at the 159th meeting of the AAS. These observations seem to answer the old question of electron-ion equilibration in shock fronts. The probable detection of O III] λ1666 and strong upper limits on C III] and C IV lines from the SNR in NGC4449 yield limits on the abundance ratio and on the precursor mass. These results were presented at the 159th AAS meeting. A paper on the distance to Tycho's supernova remnant based on IUE and optical interstellar lines is being prepared by J. Black and J. Raymond.

Stellar Flares

Preliminary analysis of the flare on EQ Peg detected by IUE and the Z-machine at Mt. Hopkins suggests that this was more like a surge than a solar flare in that the emission measure distribution was strongly peaked at about 10^5 K.

Local Interstellar Medium

Two of the four allocated shifts for study of the local interstellar medium have been used. The most surprising result is detection of C IV interstellar absorption towards a star only 40 pc. away.

Hot Galaxies

IUE spectra at the irregular galaxies N4214 and N4670 are dominated by O stars. In N4214, the C IV line is in P Cygni. These UV spectra show no strong emission lines although the optical spectra are dominated by recombination lines. The Hβ luminosity and the UV flux are generated by several hundred O stars. The

IUE spectrum of MK 36 also shows no emission lines but very weak absorption. It is very blue, still rising shortward of Ly α. The UV to IR energy distribution is almost Rayleigh-Jeans, leaving little room for evolved red stars in any spectral region.

Mass Loss from Stars

In November 1981 we obtained a new high-dispersion SWP spectrum for the hybrid atmosphere star α TrA in which we were able to expose for 19 hours by taking advantage of a low-background shift 2. It was already known that the high-temperature emission lines in this star were very wide; C IV λ1548,1550 widths were estimated to be ~ 200 km s^{-1}, and the optically thin Si III λ1892 and C II λ1909 lines exhibit FWHM ~ 100 km s^{-1}. With the longer exposure we estimate a C IV line width which is even larger than before, ~ 230 km s^{-1}. In addition, we have detected several new lines which went unobserved in our previous 8 hour exposures. The N V λ1238 line is detected weakly, exhibiting a FWHM ~ 150-190 km s^{-1}. Broad He II λ1640 is found, with a width of at least 60 km s^{-1}, Si IV λ1393 is detected with width ~ 140 km s^{-1}. Redshifted C II λ1335 is also observed, with a relatively narrow line width. The observation of lines from ions of different excitation enables us to obtain a more comprehensive picture of atmospheric dynamics and its relationship to mass loss than previously possible. Modeling of these data is presently underway.

Contact Binaries

All of the observations of W UMa type stars have been reduced and the phase dependence of chromospheric emissions evaluated. Both the short and long period system show a modulation of chromospheric flux that is similar to the optical modulation with two minima per orbital period. However, in several systems the depth of primary and secondary minima is reversed from the optically determined depths indi-

cating a distinctly different atmospheric structure between the components. Generally the surface fluxes of ultraviolet emissions are comparable to those of solar active regions, but in the longest period systems (such as Epsilon CrA and S Ant) the transition region fluxes of 10^6 K material are surprisingly large - several hundred times the solar surface flux - a fact which may be related to the evolutionary structure of a dwarf atmosphere. X-rays from these systems appear low - both suggesting that the interaction between the components may accelerate the effects of a stellar wind.

In one system, Epsilon CrA, we have discovered the heretofore undetected secondary component by its extreme (500 km s^{-1}) velocity variation found in the Mg II line at orbital elongations. Such systems present the unique opportunity to evaluate the rotation-activity correlation that was apparent from our very first IUE studies.

Many of these results were presented in preliminary form at the Santa Cruz Summer Workshop on *Cataclysmic Variables and Related Objects.*

Double Quasars

Observations were completed consisting of two long exposures made in May and December 1981 corresponding to the alignment of the Long Wavelength Large Aperture with both components. These observations were made in collaboration with R. Wilson and P. Gondhalekhar in the U.K. The deconvolution of the spectra of the two components is non-trivial since they are separated by about 6 seconds of arc on the sky. A scheme has been devised at the CfA Reduction Facility that uses the point spread function determined by a standard star, and the position of the two quasar spectra derived from average fluxes, to fix four of the six parameters necessary to establish the two gaussian profiles of the spectra perpendicular to the dispersion. Then an iterative scheme requiring a minimum of χ^2 was used to obtain the flux in each spectrum. Our preliminary result from the May 1981 data

indicates a ratio which is different from the near simultaneous VLA measurement and may indicate the presence of spectral variations in one component.

The Transition Regions and Coronae of Solar-Type Stars

Observations for this program were obtained with the IUE satellite during April 1 to 3, 1981 and January 3 to 4, 1982. To date, 4 of the 5 observing shifts allocated to this program have been utilized. The remaining shift is scheduled for March 2, 1982. The observations consist of SWP and LWR images acquired in the low dispersion mode through the large aperture. The data thus far acquired have been reduced and we are presently combining the results with existing X-ray data from HEAO-B in order to develop theoretical models for the outer atmospheres of these stars. An important preliminary result from this program is the following: the observed UV and X-ray emission are most compatible with the existence of young, compact, high-pressure coronal loop structures in the atmospheres of active-chromosphere, late-type stars. We presented this result at the Annual UCL Astronomy Colloquium, 14-17 September 1981. We are currently in the process of extending this preliminary result and we will present a paper on this program at the IUE Symposium during April 1982.

High Dispersion, Long Wavelength Studies of T Tauri Stars

The IUE observations for this program have been successfully obtained. We have also acquired high resolution (uncalibrated) Ca II K line profiles for the targets in our program with the Mt. Hopkins 60 inch telescope and echelle spectrograph. We are now reducing the high dispersion IUE data and we have presented (preliminary) calibrated Mg II h and k line profiles at the AAS meeting in Boulder during January 1982 (Giampapa *et al.* 1981, *B.A.A.S.*, 13, 811). We have initiated some exploratory atmospheric model calculations with the PANDORA radiative transfer code. Furthermore, these IUE observations have revealed the existence of chro-

mospheric line profile variability in T Tauri stars. Thus, additional high dispersion IUE spectra will be required to discern the range of physical conditions that may exist in single T Tauri stars.

Ultraviolet Studies of Evolved Chromospheres and Coronae in Giants in the Praesepe Cluster

Ana sis of ultraviolet spectra of evolved stars in open clusters will provide important information on the evolution of chromospheres and coronae in cool stars. V.ith IUE, we have been comparing chromospheric and coronal emissions in the K0 III stars in the Praesepe cluster, thought to be several hundred million years old. We are complementing the ultraviolet data with ground-based spectra of the chromospheric Ca II K emission cores. While the remainder of our IUE observations are scheduled for mid-March, our earlier UV data combined with the optical spectra suggest there is a spread of chromospheric activity among these ostensibly similar, coeval, giants. This suggests that a "hidden parameter", apart from effective temperature and stellar gravity, controls the atmospheric emissions. Our earlier IUE observations of K0 III stars in the Hyades cluster, whose stars are about twice as old as those in Praesepe, revealed a similar disparity between these homogeneous giants. A comparison of the ultraviolet emission in the giants in the Hyades and Praesepe clusters may reveal the parameter governing the strength of chromospheric and coronal emissions for these evolved stars.

VV Cephei

The analysis of a large quantity of IUE data on VV Cephei (45 LWR images and 36 SWP images) continues. Progress made during late 1981 as a result of the visit of Dr. A. V. Holm includes: (1) the extension of the UV light curve to include the most recent low-dispersion data, (2) measurement of equivalent widths of prominent emission features such as Fe II λ1786 Å, (3) comparison of absorption line

profiles of the hot secondary star with those of standard B-type stars, and (4) the identification of numerous Fe II multiplets of rather high excitation potential in the high-dispersion spectra.

The absorption line profile of C II λ1335 Å in VV Cep is very similar to that of ζ Dra (B6 III), suggesting that the spectral type of the secondary may be late Be. The UV spectrum of the secondary is still strongly masked by overlying absorption due to the M-star atmosphere even 4 years after eclipse, and further analysis will be required to establish the nature of the secondary.

Several sequences of absorption lines arising in the lowest two doublet states of Fe II, *viz.* a^2G and a^2H, have been identified in the 1750-2000 Å region of the VV Cep spectra. These states have excitation potentials of 2.00 and 2.55 eV, respectively, and their populations may be useful in probing the structure of the extended cool atmosphere.

Some of the recent results on VV Cep have been presented by W. Hagen at the North American Workshop on Symbiotic Stars in Boulder during June 1981.

Active Regions on Solar-Type Dwarfs as a Function of Rotation and Age

In October 1981, sequences of observations were obtained, spaced at several-day intervals, recording chromospheric and transition zone emission from lower main sequence stars. The stars were selected from a group of stars under joint study by SAO and Mt. Wilson scientists to determine their rotational modulation, and were observed simultaneously with H-K photometry from Mt. Wilson. One star, HD206860 (G0, 4.7-day rotation period), was experiencing large rotational modulation at the time and showed significant enhancements of upper chromospheric and transition zone lines in the ultraviolet, correlated with H-K flux. Data for this and four other stars observed are currently under analysis.

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Observations and Theory of Mass Loss in Late-Type Stars. L. Hartmann in Proc. NATO Advanced Study Institute on Solar Phenomena in Stars and Stellar Systems, ed. R. M. Bonnet and A. K. Dupree, (D. Reidel), p. 331.

Chromospheres and Coronae in Binary Systems. A. K. Dupree in Proc. NATO Advanced Study Institute on Solar Phenomena in Stars and Stellar Systems, ed. R. M. Bonnet and A. K. Dupree, (D. Reidel), p. 407.

On the Relationship Between Coronae and Mass Loss in Late-Type Stars. L. Hartmann, A. K. Dupree, and J. Raymond, *Astrophys. J.*, **246**, 193.

Mass Loss from Cool Stars. A. K. Dupree in Effects of Mass Loss on Stellar Evolution (IAU Colloq. No. 59), ed. C. Chiosi and R. Stalio, (D. Reidel), p. 87.

Coordinated X-ray, Ultraviolet and Optical Observations of AM Her, U Gem and SS Cyg. G. Fabbiano, L. Hartmann, J. Raymond, J. Steiner, G. Branduardi-Raymont, and T. Matilsky, *Astrophys. J.*, **243**, 911.

Ultraviolet Emission of the Vela Supernova Remnant and the Cygnus Loop. J. C. Raymond, J. H. Black, A. K. Dupree, L. Hartmann, and R. S. Wolff, *Astrophys. J.*, **246**, 100.

Short-Timescale Variability of Chromospheric Ca II in Late-Type Stars. S. L. Baliunas, L. Hartmann, A. H. Vaughan, W. Liller, and A. K. Dupree, *Astrophys. J.*, **246**, 473.

IUE Ultraviolet and Optical Chromospheric Studies of Late-Type Giants in the Hyades Cluster. S. L. Baliunas, L. Hartmann, and A. K. Dupree, in *The Universe at Ultraviolet Wavelengths - The First Two Years of IUE*, (ed. R. D. Chapman) NASA Conference Publication 2171, p. 325.

IUE Ultraviolet Observations of W UMa Stars. A. K. Dupree and S. Preston, in *The Universe at Ultraviolet Wavelengths - The First Two Years of IUE*, (ed. R. D. Chapman) NASA Conference Publication 2171, p. 333.

The Astrophysical Interest of EUV Observations of Extra-Solar Objects. A. K. Dupree, *Space Science Reviews*, **29**, 479.

IUE Observations of Pre-Main Sequence Stars. I. Mg II and Ca II Resonance Line Fluxes for T Tauri Stars. M. S. Giampapa, N. Calvet, C. L. Imhoff, and L. V. Kuhi, *Astrophys. J.*, **251**, 113 (Dec. 1981 issue).

Ultraviolet Observation of a Non-Radiative Shock Wave. J. C. Raymond, R. Fesen, and T. R. Gull, *BAAS*, **13**, 887.

X-ray, Optical and UV Observations of the Supernova Remnant in NGC4449. W. P. Blair, J. C. Raymond, R. Kirshner, and P. F. Winkler, *BAAS*, **13**, 795.

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Ultraviolet and Optical Spectrum Studies of λ Andromedae: Evidence for Atmospheric Inhomogeneities. S. L. Baliunas and A. K. Dupree, *Astrophys. J.*, in press.

Ultraviolet Observations of Stellar Chromospheric Activity. L. Hartmann, A. K. Dupree, and J. C. Raymond, *Astrophys. J.*, **252**, 214.

Ultraviolet Spectra of the LMC X-ray Transient A0538-66. J. C. Raymond, *Astrophys. J.*, in press.

Stellar Activity, A. K. Dupree in Proceedings of the Second Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun, (eds. M. S. Giampapa and L. Golub), SAO Special Report 392, in press.

Observations of Cataclysmic Variables with IUE. L. Hartmann and J. C. Raymond, in *The Universe at Ultraviolet Wavelengths - The First Two Years of IUE*, (ed. R. D. Chapman) NASA Conference Publication 2171, p. 495.

Coordinated IUE, Einstein and Optical Observations of Accreting Degenerate Dwarfs. G. Fabbiano, J. E. Steiner, L. Hartmann, and J. C. Raymond, in *The Universe at Ultraviolet Wavelengths - The First Two Years of IUE*, (ed. R. D. Chapman) NASA Conference Publication 2171, p. 501.

IUE Observations of Supernova Remnants. J. C. Raymond, in *The Universe at Ultraviolet Wavelengths - The First Two Years of IUE*, (ed. R. D. Chapman) NASA Conference Publication 2171, p. 595.

High Resolution, Absolute Flux Profiles of the Mg II h and k Lines for T Tauri Stars. M. S. Giampapa, C. Morossi, M. Ramella, and C. L. Imhoff, *BAAS*, **13**, 811.

Far Ultraviolet and X-ray Evidence Concerning the Chromospheres and Coronae of the T Tauri Stars, in Proceedings of the Second Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun, (eds. M. S. Giampapa and L. Golub), SAO Special Report 392, in press