Combined Ultraviolet Studies of Astronomical Sources

NASA Grant NAG5-87

Semiannual Progress Report No. 10

For the Period 1 February 1985 through 31 July 1985

Principal Investigators

Drs. A. K. Dupree; S. L. Baliunas; W. P. Blair;
L. W. Hartmann; J. P. Huchra; J. C. Raymond;
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August 1985

Prepared for
National Aeronautics and Space Administration
Greenbelt, MD 20771

Smithsonian Institution
Astrophysical Observatory
Cambridge, MA 02138

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Cygnus Loop

Three positions were observed; Miller's position 3 in High Dispersion, and two positions along the Hester, Parker and Dufour "spur" at Low Resolution. We confirm the hypothesis that resonant scattering within SNR filaments decreases the intensity of the C IV lines (Raymond et al., Ap. J., 246, 100). We find that the 'spur' shows less complete cooling and recombination toward its tip as predicted by Hester, Parker and Dufour, but we also find that the shock velocity is higher near the tip, complicating the interpretation of an interstellar cloud struck by the supernova blast wave. Both high and low dispersion optical observations of the IUE positions have been reduced, and we have found the explanation for the 'non-thermal' velocity broadening observed in the Cygnus Loop and the old supernova remnants.

Oxygen-Rich Supernova Remnants

High particle background limited the exposure on 1E0102-72 to 5 hours. Even so, broad C IV emission was detected, and the O IV]-Si IV blend at 1400Å and the O III] λ1664 line may have been detected as well. We will obtain longer exposures in combined ESA-NASA shifts with J. Danziger in September.

LMC Supernova Remnants

Observations are complete. We are presently reducing the complementary optical observations obtained at CTIO in November.

P Cygni Profiles in Dwarf Novae

IUE observations of HL CMa were obtained December 28-30, with simultaneous optical coverage December 29-30. We now have good coverage through the orbital period and through outburst maximum and decline. C. Mauche has extended the profile model calculations reported at the Sixth Year IUE conference (J. Raymond, p. 301). We find that the wind must be very strongly clumped, perhaps by shocks like those believed to account for O star X-ray emission. The wind must originate in the disk or accelerate very slowly if it originates near the dwarf. Results were presented at the Ninth North American Workshop on Cataclysmic Variables (Mauche and Raymond 1985; Raymond and Mauche 1985).

Soft X-ray Photoionization of Interstellar Gas

AM Her had faded to about 1/3 its normal brightness when the observation was obtained.

Spectral Variations in AM Her Stars

H0139-68 was observed through 5 orbital cycles on December 27. The data have been reduced and it appears to show an orbital phasing of the shortest wavelength continuum similar to that of AM Her. AM Her was observed about halfway between its maximum and minimum M states.

The Mass of Feige 24

The two exposures obtained imply a mass about 0.6 $M_{\odot}$. Further optical observations were obtained December 29. We are planning to use cross-correlation methods to improve the accuracy of the velocity measurement.

Atmospheric Inhomogeneities in Lambda Andromedae and FF Aquarii

In the chromospherically active G8 III-IV star Lambda And, the ultraviolet emission was sampled as part of an ongoing project to study the ultraviolet emission during the star's six year magnetic activity cycle. Our IUE spectra of Lambda And revealed the most energetic stellar flare and the first on a giant star observed in the ultraviolet (Baliunas et al. 1984 Ap. J., 282, 733). In the binary FF Aqr, the subdwarf O-type star was used to probe the atmosphere of its companion G8 III star during eclipse egress and ingress. Enhanced absorption in the spectrum lines of the subdwarf at phases just past emersion indicates an extended atmosphere well above the limb of the giant star. The magnetic mechanisms presumably heat the atmospheres of these stars in a similar fashion.

During our remaining shift in February 1985, we sampled the subdwarf O-star during ingress of the eclipse by the G-giant star. Our analysis shows that enhancements of the high-temperature lines (such as C IV) occurred. This strengthening of the absorption lines was also recorded previously by us during egress of the eclipse. We conclude that the atmosphere of the G-giant star is substantially extended. Significant densities at great heights above the stellar photosphere are required to produce the strong absorption enhancements. We are finishing the analysis, which includes all archival spectra, and preparing the paper for publication. A small flare is present in the archival spectra of FF Aqr, and analysis of the flare shows that while the flare is moderately luminous, the line ratios are similar to those in Lambda And.

Photometric and Spectroscopic Observations of Capella

Our recent photoelectric photometry of Capella (G5 III + F9 III) confirms the results of earlier photometric studies suggesting that the star is variable in light. Capella has been classified as an RS CVn variable, showing as it does bright chromospheric and coronal emission in addition to visible light modulation. The photometric brightness of Capella, however, appears to be correlated with increasing net Hα emission strength, evidenced in our photometry. This behavior is unlike "starspot" phenomena reported for the RS CVn binaries which show photometric faintness associated with increased chromospheric emission, presumably caused by visible darker spots with bright ultraviolet emissions from the spots and associated active regions. Therefore, we are monitoring the Hα absorption profile in high-resolution echelle spectra obtained at Oak Ridge Observatory. The Hα profile varies in shape according to the motion of the two orbiting stars. The profile shares contributions from both components. Our analysis of extant (archival) ultraviolet spectra shows that both components contribute to the ultraviolet emissions, which are the products of severe blending. The ultraviolet and Hα profiles thus behave similarly in their velocity changes. No ultraviolet flux variations have been recorded in the archival spectra, but they were obtained at times of little photometric change. The relative contributions of chromospheric and coronal emissions are in accord with the spectral types and our measured rational velocities of each stellar component. A paper is being prepared for publication.

α Ori

Observations of Alpha Orionis were obtained twice per month when the star was accessible to IUE. All of the spectra taken during 1984 to the spring of 1985 have been reduced and fluxes of the major emission lines and continuum bands extracted. The continuum at $\lambda\lambda$2950-3050 appears to follow the B magnitude variations, with approximately the same degree of modulation. This suggests that the photospheric temperature of Alpha Ori is not changing but that the light variations represent a geometric effect. The flux in the Mg II resonance lines show variability on a different time scale than the continuum. A first appraisal suggests that the blue wing of the emission line causes the variability, suggesting a change in the wind opacity, but this is under study. A new technique to determine radial velocities by constructing cross correlations between spectra is nearing completion. Potentially one can obtain substantially greater velocity resolution by this means. Values of ~ 2.5 km s^{-1} may be achieved beyond the IUE resolution of 25 km s^{-1}.

Metal Deficient Giant Stars

Both high and low dispersion spectra in the long wavelength region have been obtained of metal deficient field giant stars. In the coolest stars, chromospheric Mg II emission is detectable with surface fluxes comparable to those of Population I stars. These have been reported and published in the Third Cambridge Conference on Cool Stars, Stellar Systems, and the Sun, and the European IUE meeting in 1984. A paper is in preparation.

M67 Giants

Ken James and Graeme Smith had two IUE shifts for this project in October 1984 and both were successful. One spectrum was obtained on each shift with the LWP camera at low resolution. The target stars were two of the brightest red giants in M67, and both showed Mg II emission. The Mg II emission was strongest in the star with the greatest visual luminosity. This is the oldest open cluster in which IUE has been used to obtain ultraviolet spectra. Based on these observations, in the future we should be able to observe additional stars at fainter magnitude and intend applying for more time in the next round of IUE proposals. We are also in the process of obtaining spectra of the Ca II K line with ground-based telescopes at Mt. Hopkins and the Dominion Astrophysical Observatory. One of our targets has a strong asymmetric Ca II emission core.

High-Velocity Winds from Hybrid Stars

A paper entitled "On the Outer Atmospheres of Hybrid Stars" by Hartmann, Jordan, Brown, and Dupree will appear in Astrophysical Journal, Vol. 296, in press. In this paper we confirm that ι Aur and θ Her are hybrid stars, as suggested by Reimers, and show that γ Aql is still another member of the class. High-dispersion observations of the hybrid star α TrA confirm the large widths of the C IV emission lines, and provide a measurement of the electron density from the C II lines near 2325 angstroms. The emission line fluxes are used to derive emission measure distributions; assuming the density derived for α TrA is characteristic of all the hybrid stars, we explore some simple atmospheric models. The gas at temperatures of 2×10^5K probably has a scale height that is an appreciable fraction of the stellar radius. The Si III] and C III] line widths are probably dominated by turbulent broadening rather than expansion; the

magnitude of this broadening is such that turbulent motions, rather than thermal gas pressure, probably determines the extension of the outer envelope. Observations of the Mg II resonance line profiles show that the winds from the hybrid stars vary on timescales of a year or less. Very deep exposures of Mg II in α TrA show visible wind absorption extending out to 180 km s^{-1} relative to the photosphere. These data suggest that high-velocity mass loss is more common than previously realized.

Accretion Disk Parameters in Cataclysmic Variables - CVGWB

The observational goals of this program were to obtain IUE exposures (mostly SWP) of a number of intrinsically faint cataclysmic variables to determine continuum shapes and emission line fluxes in systems with low mass accretion rates. These observational goals have been met. Sucessful observations were made for VZ Scl, SW UMa and GD552, and these are of most interest to the designed program. An exposure on the faint CV AQ Eri was null, but the exposure had to be terminated at 240 minutes because of high background during the US 1 shift. During these higher background times, shorter exposures on the brighter objects BV Cen, WW Cet, PG 2300+166 and PG 1711+336 were obtained.

The analysis of these data is complex, involving the combining of available X-ray, optical and IR data when available and fitting models to the observed overall spectrum. This analysis is still in progress.

Chromospheric Emission of Late-Type Dwarfs in Visual Binaries - LDGDS

Stars in binaries are presumed to have been formed at the same time - they are coeval. Even without knowing absolute ages, this property enables some aspects of age-related phenomena to be studied. In particular, such stars should lie on isochrones in a diagram of chromospheric activity vs. mass.

Curiously, the less massive star of the system tends to exhibit greater atmospheric activity than the primary. There is no obvious explanation for this excess emission. Ca II H and K data generally show the same effect. A full analysis of the data is in progress.

Chromospheres and Transition Regions of Stars in the Ursa Major Group - CCGDS

The observations have been completed for this program. The Ursa Major Group is a small cluster of young stars in which the Sun is immersed. Members have been found by their similar space motions, but is this criterion sufficient to ensure that true members are selected?

The answer is no. There are a number of stars which resemble Ursa Major Group members, but which differ enough to be clearly distinguished as non-members. The only other alternative is that these stars are true UMaG members but that there is a much larger range of chromospheric emission strengths in UMaG than in a classical cluster like the Hyades.

This result has interesting implications for the kinematics of the Galaxy, and also perhaps for the dissolution of stellar associations.

Blue Galaxies

A single, two-shift observation of PSO 234 was made during this period. The existence of Lyα emission at the appropriate redshift was confirmed, but the emission was not extended as had been suggested by our first exposure. This indicates that a small amount of dust is probably responsible for the dimunition of Lyα emission in low metallicity blue galaxies.

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