The Quiescent and Flaring EUV Spectrum of Algol

and its Relationship to Other Active Coronae

EUV Spectroscopy of Bright Hyades Coronae: 71 Tauri and Theta 1 Tauri

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1. Summary

This program involves analysis and interpretation of EUVE spectromter observations of the active stars Algol (β Per) and 71 Tauri. The EUVE satellite spectrometers observed the prototype eclipsing binary Algol over nearly 1.5 orbital periods. Effective exposure times were 100 ksec and 89 ksec in the short wave (70-180 Å) and medium wave (140-370 Å) channels. High temperature (up to 20 MK) Fe XVI-XXIV emission lines are clearly detected in the overall spectrum. In addition, a quiescent continuum is present which increases towards shorter wavelengths. Using synthesized spectra of optically thin line and continuum emission folded through the instrumental response, we have examined constraints on the [Fe/H] coronal abundance in Algol. We find that the coronal Fe is underabundant by factors of $\approx$2–4 relative to solar photospheric values, unless an unreasonably large quantity of coronal plasma at T > 30 MK is present in the quiescent spectrum. The latter possibility is, however, inconsistent with available X-ray data. Lightcurves of the high temperature EUV lines compared to line emission at He II 304 A show considerable differences, with much deeper minima present in the He II line during *both* primary and secondary eclipses. Toward the end of the observation a moderate flare lasting $\sim$6 hours was detected in the high temperature Fe emission lines.

The 71 Tau observation, for about the same exposure time, revealed only a handful of weak emission lines; however, the strongest lines were also those of Fe XXIII/XX, suggesting a hot coronal plasma. No obvious flaring or other variation was present in the 71 Tau Deep Survey lightcurve.

2. Technical Progress

Over the course of this project, the following work was accomplished:

(1) At the outset, because the wavelength solution and processing parameters had been changed since the original observations we processed, both the Algol and the 71 Tau data were reprocessed using the IRAF "cep" task.

(2) In addition, it was found that, for the Algol observation, a roll angle change about 1/4 of the way into the observation caused a non-negligible positional shift of the

pointing direction, as verified by time-resolved examination of the deep survey images. This in turn required an aspect correction which shifted the latter 3/4 of the observation by ≈ 20 " resulting in a sharpened "core" of the spectral lines in the SW and MW spectra.

(3) The resulting QPOE files were further time-filtered using the maximum ADC counts as a criterion to remove periods of high detector background.

(4) For Algol, the QPOE file was time filtered into quiescent and flaring periods.

(5) For both Algol and 71 Tau, the spectra were extracted using the IRAF APALL procedure.

(6) The euvcombine task was used to provide spectra corrected for the detector effective area.

(7) Lines were identified and fluxes estimated using both IRAF gaussian fitting procedures and the ICUR procedure in IDL.

(8) Rough differential emission measures for the Algol quiescent and flaring spectra were estimated by the "Pottasch" technique.

(9) A simple attempt to fit the Algol spectrum using a synthesized spectrum derived from a power-law type DEM failed to reproduce the short-wavelength contunuum flux observed in Algol. Therefore, a set of IDL routines was developed to both synthesize the overall spectra and perfrom least squares fitting. In developing this software, we incorporated the latest Fe line data from Brickhouse, Raymond and Smith (1994), as all of the lines observed (except for He II 304, which we did not fit) were from highly ionized Fe. The program also folded both the predicted line and continuum emission through the various spectrometer response functions. The DEM was parameterized as a log function using a sum of terms of Chebyshev polynomials of orders 3 to 14 (selectable). In general, the models with the higher order polynomials produced solutions with an "oscillatory" DEM which was unphysical. Another free paramter in the models was the line-to-continuum ratio, or 1/[Fe abundance]: since the continuum is produced primarily by H-He free-free radiation

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for the high temperatures ($\sim 10^7$ K) seen in Algol, the line-to-continuum ratio is directly related to the coronal abundance. The results of our fitting procedure are described in detail in the attached preprint: the principal result is that the Algol corona is likely to be 2–4 times underabundant in Fe relative to standard "solar" photospheric abundances.

(10) Light curves were derived for the summed SW spectrum and the He II 304 Å line in the MW spectrum. These are shown in Fig. 1. The 304 Å light curve shows evidence of strong eclipses at both primary and secondary optical minima. This suggests that the 304 Åradiation is coming from either a region between the primary and the secondary, or, in an accretion "hot spot" nearer the primary star. The SW summed spectrum does not show strong eclipses, suggesting that, as expected, the high temperature Fe lines are produced in the corona of the K star secondary, but must extend beyond the K star disk.

(11) For 71 Tau, there was not much analysis to be done except to extract the spectrum as described and derive line fluxes. In addition, the spectrum was re-extracted using a package developed by T. Ayres of CASA/U. Col., which seemed to be able to produce a better S/N ratio for weak spectra (see Fig 2). A paper on 71 Tau is currently in progress.

3. Presentations and Publications

- "EUVE Observations of Algol," R. Stern, CEA Colloquium, May 1994.

- "High Temperature Line and Continuum Emission in Algol," R.A. Stern, J.R. Lemen (Lockheed Palo Alto Research Lab), J.P. Pye (U. Leicester), J.H.M.M. Schmitt (MPE/Garching)presented at the HEAD/AAS meeting, Napa, CA, November, 1994

- "EUVE Observations of Algol: Detection of a Continuum and Implications for the Coronal [Fe/H] Abundance," R.A. Stern, J.R. Lemen, J.H.M.M. Schmitt, and J.P. Pye, 1994, Ap.J. (Letters), submitted.

- "EUVE Observations of Algol," R.A. Stern, J.R. Lemen, J.H.M.M. Schmitt, and J.P. Pye, 1994, B.A.A.S. for 185th AAS Meeting, Tucson.
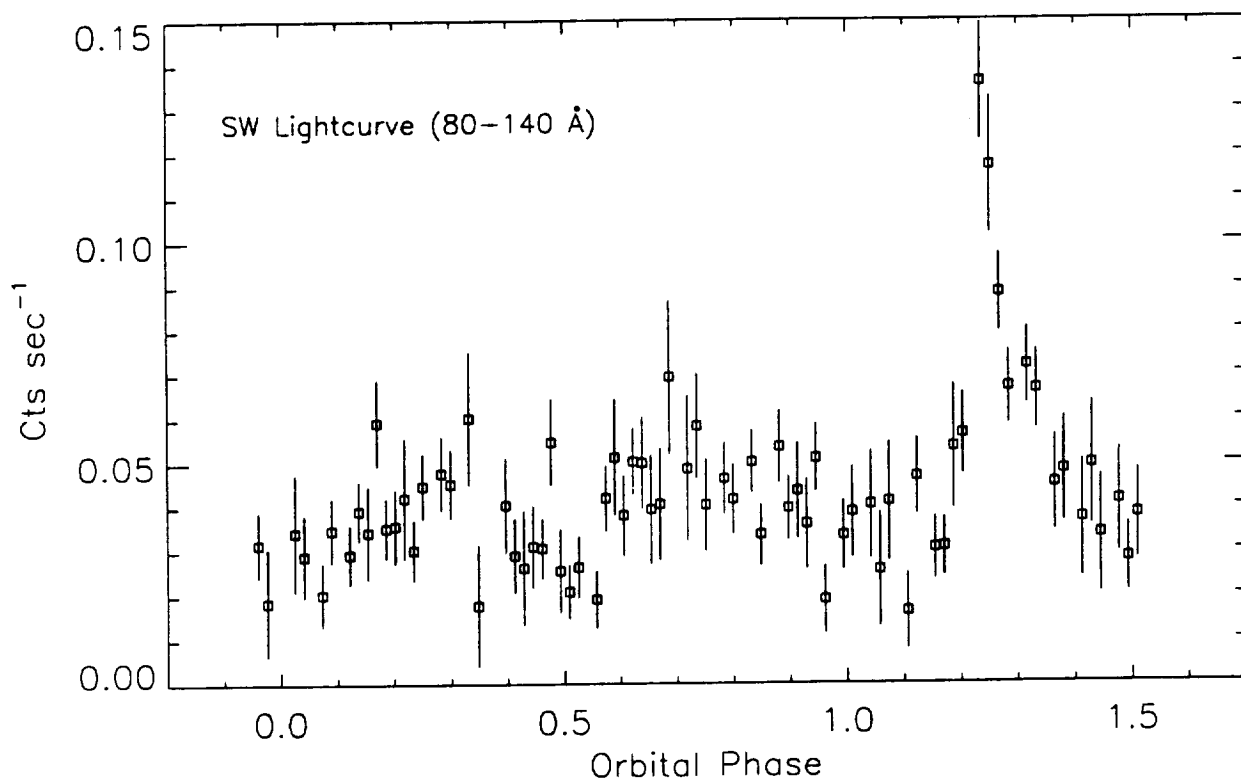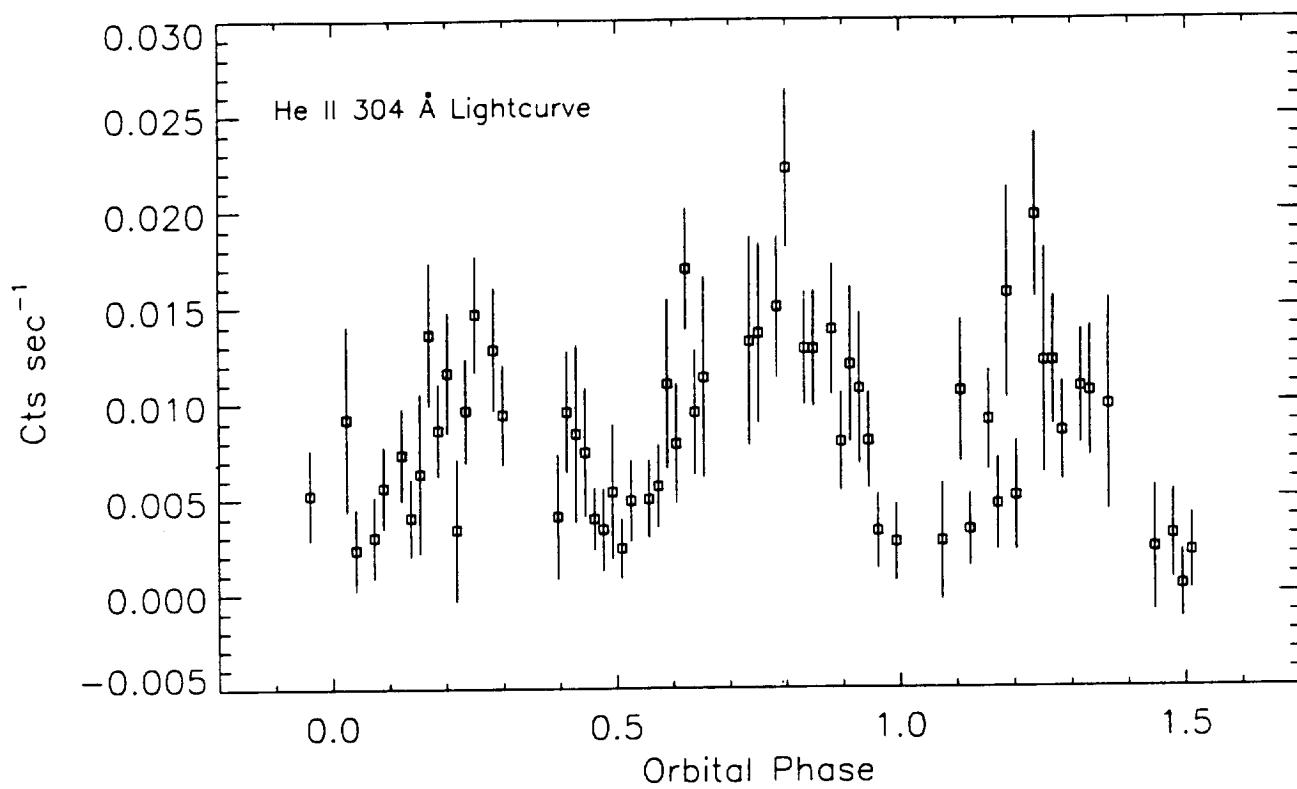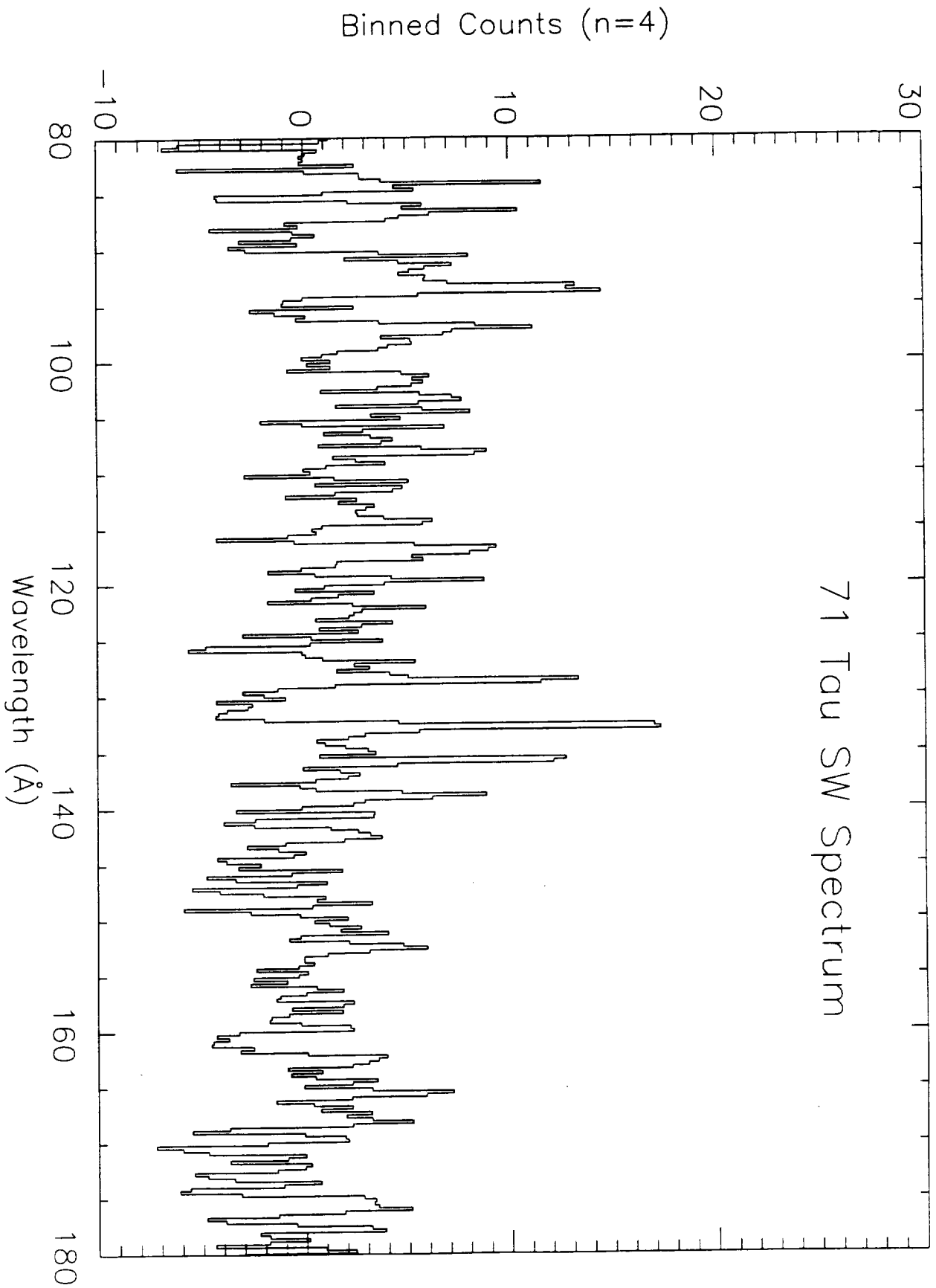
FIG 1

Binned Counts (n=4)

71 Tau SW Spectrum

Wavelength (Å)

FIG 2

EUVE Observations of Algol: Detection of a Continuum and Implications for the Coronal [Fe/H] Abundance

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1.

Abstract

We report results from the first extreme ultraviolet spectrum of the prototype eclipsing binary Algol (β Per), obtained with the spectrometers on the Extreme Ultraviolet Explorer (EUVE). The Algol spectrum in the 80–350Å range is dominated by emission lines of Fe XVI–XXIV, and the He II 304 Å line. The Fe emission is characteristic of high temperature plasma at temperatures up to at least log T $\sim$ 7.3 K. We have successfully fit the observed quiescent spectrum using a continuous emission measure distribution with the bulk of the emitting material at log T > 6.5. We are able to adequately model both the coronal lines and continuum data with a cosmic abundance plasma, but only if Algol's quiescent corona is dominated by material at log T > 7.5, which is physically ruled out by prior X-ray observations of the quiescent Algol spectrum. Since the coronal [Fe/H] abundance is the principal determinant of the line-to-continuum ratio in the EUV, allowing the abundance to be a free parameter results in models with a range of best fit abundances $\approx$ 15–35% of solar photospheric [Fe/H]. Since Algol's photospheric [Fe/H] appears to be near-solar, the anomalous EUV line-to-continuum ratio could either be the result of element segregation in the coronal formation process, or other, less likely mechanisms that may enhance the continuum with respect to the lines.

Subject headings: ultraviolet: stars, stars: coronae, binaries: eclipsing

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1. INTRODUCTION

The prototypical eclipsing binary Algol (β Per) has continued to puzzle and intrigue astronomers for at least 200 years. Recently, some of this attention has focused upon the properties of Algol as a source of X-ray emission from $> 10^7$ K plasmas (Schnopper *et al.* 1976, Harnden *et al.* 1976, White *et al.* 1978, Swank *et al.* 1981, White *et al.* 1986, van den Oord and Mewe 1989, Stern *et al.* 1992, Ottman 1994, Antunes, Nagase, and White 1994). The X-ray emission was initially interpreted as coming from shocked accreting material from the K2 IV component (Algol B) onto the B8 V component (Algol A). Subsequent data revealed, however, that Algol exhibited many of the X-ray characteristics of the RS CVn systems, including the occurence of large flares with a temperature-emission measure history resembling scaled up solar flares (White *et al.* 1986, van den Oord and Mewe 1989, Stern *et al.* 1992). The flare data also revealed the presence of an unresolved complex of line emission near 6.7 keV, which was identified with Fe XXV/XXVI emission characteristic of plasma temperatures $\gtrsim$ 15 MK. Although EXOSAT flare observations of the line-to-continuum ratio for this complex suggested near-solar abundances (White *et al.* 1986), GINGA observations of a longer duration flare revealed a line-to-continuum ratio that varied significantly from theoretically predicted models for a solar-abundance plasma (Stern *et al.* 1992). Since the X-ray continuum at such high temperatures is produced primarily by H and He bremsstrahlung, the line-to-continuum ratio should be a measure of [Fe/H] abundance. Alternatively, some radiative transfer effect such as resonance scattering might be affecting the line-to-continuum ratio: this was pointed out in the case of an even larger X-ray flare on UX Ari by Tsuru *et al.* (1989), although such an effect was insufficient to produce the 4:1 variations in equivalent width seen in successive UX Ari flares. ASCA observations of Antunes, Nagase and White (1994) suggest a quiescent Algol coronal Fe abundance of $\approx$ 1/3 solar; however, this interpretation is based upon a simple model of the

Algol corona with only two isothermal plasma components.

The relationship between photospheric and coronal abundances is a currently active field of solar research (e.g. Meyer 1985), and may be an important indicator of how coronal material is heated and transported from lower-lying, more dense material. For very active stellar coronae such as Algol's, where coronal heating is many orders of mangnitude greater than in the Sun, abundance differences are likely to provide even more important clues to the coronal heating process.

With the launch of the Extreme Ultraviolet Explorer (EUVE) in 1992, it is now possible to observe active stellar coronae and resolve individual EUV emission lines from active coronae which are produced at temperatures ranging from $< 10^6$ K to $10^{7.3}$ K. We therefore undertook a study of the Algol system with EUVE in an attempt to better understand the temperature distribution of coronal material, and, if possible, to study abundance effects in the corona. Since Algol is an eclipsing system of period 2.87 d, the variability of Algol EUV emission as a function of orbital phase was also investigated in this observation: these results will be discussed elsewhere. In this *Letter* we focus upon the quiescent EUV spectrum of Algol and the [Fe/H] coronal abundance as indicated by the line-to-continuum ratio.

2. Observations and Spectral Extractions

β Per was observed by the EUVE spectrometer (see Bowyer and Malina 1991 for a complete description of the EUVE spectrometer and spacecraft) from 1993 Oct 30 2038 UT to 1993 Nov 4 0944 UT. After selecting out periods of source occultations and regions of high internal detector background, the net exposure time was $\approx$ 100 ksec for the EUVE shortwave (SW) spectrometer, and slightly lower in the medium (MW) and longwave (LW) channels. Line emission from β Per was detected well above background in all three

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spectrometer bands, SW (70-190 Å), MW (140-380Å) and LW (280-760 Å). This letter will concentrate on the SW and MW observations: the LW observations consist primarily of detections also made in the MW band (e.g. He II 304 Å) or second order flux from shorter wavelengths. The overall duration of the observation covered nearly 1.5 orbital periods of the Algol system. Toward the end of the observation, a moderate EUV flare which lasted ≈ 6 hours was detected in the SW spectrum. Analysis of the overall light curve and the flare will be discussed in a subsequent publication.

During the observation, a reconfiguration of the EUVE spacecraft's attitude resulting in a roll angle change required that the spectrometer data be corrected for an ≈ 20 " aspect shift. This was achieved by cross-correlating the images of Algol in the Deep Survey telescope before and after the roll angle change, and resulted in a modest improvement in the spatial and spectral resolution for the observation. The observation was then split up into two time intervals: one of 82 ksec effective exposure covering the quiescent Algol spectrum, and one of 11 ksec exposure covering the initial phases of the EUV flare. In this letter we discuss the results from the quiescent data only. The quiescent spectra were extracted from the spectrometer images using IRAF and the EUV reduction software (Version 1.4) with the NOAO/APALL package. Some subsequent analysis of the extracted spectra was performed with routines written in IDL.

2.1. Line Identifications and Fluxes

In Figure 1 we show the raw extracted spectra in the SW and MW spectrometers from the quiescent period. Line identifications were fairly unambiguous and were confirmed using the Brickhouse, Raymond, and Smith (1994) Fe line list. In the SW and MW bands, the spectrum is dominated by emission lines from highly ionized Fe XVI-XXIV. The line fluxes were determined by fitting gaussian profiles and a linear continuum to the data with the

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IRAF "fitprofs" routine in the NOAO/ONEDSPEC package. In addition, a check of the derived line fluxes was performed using the ICUR procedure (walter 1992) in IDL, which fits a gaussian profile with a background that may contain quadratic terms. In general, the fluxes derived for the stronger lines agreed to within 20%. The fluxes were corrected for interstellar absorption assuming an H column density of 2×10^{18} cm^{-2}, with a He/H ratio of 0.1, and no ionized He. The assumed total H column is consistent with the 27 pc distance to Algol and the upper limit to the H I column derived from the Na I measurements of Welsh *et al.* (1990) of 2.5×10^{18} cm^{-2}. A list of the lines detected, their observed and predicted wavelengths (from Brickhouse *et al.* 1994), and the observed and corrected fluxes at earth are given in Table 1. Note that a wavelength correction of $\approx +0.26$ Å for the SW spectrum is indicated by the results of the Table 1 and was used in the analysis which follows below. For the MW spectrum, the wavelength shifts are not uniform, but are $\lesssim 1$ Å, and given the sparse MW spectrum, do not result in any line ID ambiguities.

2.2. The EUV Continuum

In the SW band, an apparent continuum is present in both the raw extracted spectrum and the after the spectrum has been corrected for instrumental effective area. We are confident that this is not an instrumental effect, for the following reasons: (1) in the 2-dimensional spectrometer image, the SW continuum is clearly present against adjacent detector background on either side of the dispersed spetrum, thus it is not due to any scattering of *diffuse* radiation, (2) although there are various sources of scattered light in the EUV spectrometers (EUVE G.O. Program Handbook 1994, M. Abbott, private communication) none are strong enough to produce the characteristic continuum we observe. In particular, the contribution from scattered 304 or 504 Å radiation in Algol's spectrum is insignificant at ≈ 100 Å. Also, although Algol has a strong UV continuum,

ϵ CMa (Sp type B2 Iab, V=1.5) with an even stronger UV continuum, failed to produce any evidence of scattered UV continuum in the SW spectrometer (J. Vallerga, private communication). Finally, (3), higher energy X-rays (40-80 Å) might appear in the 2nd order spectrum. However, this is ruled out because the peak 2nd order effective area at 50 Å, for example, is only a few % of the 1st order effective area at 100 Å. Hence the continuum would have to rise by a factor of 30 or more between 100 and 50 Å to produce approximately the same flux as expected in 1st order. This is an order of magnitude more than predicted for free-free bremsstrahlung, the principal component of the continuum.

3. Analysis

3.1. Spectral Synthesis with Variable Continuum

One principal goal of our analysis was to determine the temperature distribution of coronal plasma between log T $\approx$ 5.5-8.0, i.e. the differential emission measure (DEM). In an attempt to fit both the line fluxes and the continuum, we proceeded to synthesize the observed spectrum using an optically thin plasma emission spectrum folded through a gaussian profile. We took the line emissivities from Brickhouse *et al.* (1994), with the continuum emissivities and emissivities of other elements' lines from the Mewe *et al.* (1985, 1987) plasma code. In both cases the Allen (1973) solar photospheric abundances were initially used. Although such an intermingling of data could, in some cases, lead to errors, in our situation virtually all the emission lines which determine the DEM are from Fe, and the continuum emissivity comes almost entirely H+ or He++ bremsstrahlung. Since H and He are completely ionized in the corona, the only uncertainty in the continuum calculation comes from the use of the approximations in the Mewe *et al.* (1987) paper. As a check, we have compared the continuum emissivities with those calculated for log T=7.2 by Landini and Monsignori-Fossi (1990), and find them in good agreement.

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For all temperatures between log T = 5.0 and 8.0 at intervals of 0.1 in Δ log T, we separately computed the line and continuum emisivities for the EUV spectrometer bands, and folded the input spectra through the gaussian spectral response of the spectrometers, with the gaussian widths given by the EGO 1.8 reference data set. The spectra were initially binned into 0.067 Å bins for the SW and 0.13 Å bins for the MW spectrometer. A table of the predicted continuum and line spectra for a constant 10^{50} volume emission measure ($n_e^2 * V$) at each log T was then generated. Using this table, the EUVE quiescent Algol SW and MW spectra were simultaneously fit using a continuous differential emission measure (DEM) model. The model was parameterized by a sum of terms of an Nth-order Chebyshev polynomial in log EM–log T (see Lemen, Schrijver, and Mewe 1986). The use of the Chebyshev polynomial sum has the advantage that any arbitrary functional form for the DEM can be approximated as the number of terms in the polynomial is increased. Also, the Chebyshev polynmials form an orthogonal set of functions: i.e., the coefficients of the polynomials (the fitted parameters) are uncorrelated and therefore may be fit independently. An IDL routine incorporating a modified form of the CURFIT algorithm (Bevington 1969?) was employed to perform the actual least-sqaures minimization. The EUVE spectra were re-binned by a factor of 4 (to 0.27 and 0.52 Å) in order to reach a sufficient number ($>$ 10–15 cts) in the background bins (the model spectra were re-binned accordingly). The data points were weighted by their Poisson errors (signal + background counts).

In addition to the coefficients of the Chebyshev polynomials, we allowed for a variable ratio of the continuum normalization relative to the predicted value for a solar abundance plasma. We performed model fits beginning with a flat DEM distribution for summed Chebyshev polynomials of maximum order 3 to 14. In all cases, the functional form constrained by the Chebyshev expansion was spline-interpolated to Δ log T =0.1 and then the entire DEM function was integrated with the plasma emissivity table. As expected, increasing the number of terms simply increased the apparent structure in the DEM

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function. The best fits for these fits yielded a range of Fe abundances from 20–40% of the Allen values (17–34% of the Anders and Grevesse 1989 values, hereafter AG). At a 99% confidence level, we are able to exclude all models with an Fe abundance $< 15\%$ (AG), although we cannot statistically eliminate models with a normal solar abundance. The results of our spectral synthesis are shown in Figure 2, where we plot the observed SW spectrum and the best fit model with 6 terms in the polynomial expandsion, with an Fe abundance of 27% (AG). For this fit, the expected solar abundance continuum value is shown as a dashed line in the figure. In fact, by fixing the continuum normalization at the value expected for a solar abundance plasma, we are also able to obtain good fits which do not look significantly different from the fitted spectrum in Figure 2. However, the DEM then is required to have most of the emitting plasma at temperatures with $\log T > 7.5$. This is shown in Figure 3, where we plot the DEM (for a sum of up to a 6th-order Chebyshev polynomial), with varying values of the efective Fe abundance. Only for a ratio of $\lesssim 40\%$ of solar does the DEM stop rising for $\log T \gtrsim 7.5$.

4. DISCUSSION

4.1. Interpreting the Line-to-Continuum Ratio

It is clear from the analysis of the DEM for Algol that the formal fits allow for large variations in the shape of the DEM curve at $\log T > 7.5$. If there are substantial amounts of plasma at these high temperatures, then the continuum flux may be produced primarily by free-free radiation at these temperatures. The spectral slope of the continuum in the EUV is not sufficiently well determined as to allow a temperature determination from the continuum alone. However, we believe that it is very unlikely that large amounts of very hot plasma ($> 3 \times 10^7$ K) in the *quiescent* spectrum of Algol are present. In particular,

prior measurements of X-ray emission in the Algol quisecent spectrum (White *et al.* 1983, White *et al.* 1986, Stern *et al.* 1992, Ottman *et al.* 1994, Antunes *et al.* 1994) demonstrate a lack of coronal emission measure for $\log T \gtrsim 7.3$. While such measurements are subject to the usual criticisms of lack of spectral resolution, and the assumption of 1 or 2 T models, all of them (the EXOSAT, GINGA and ASCA observations in particular) would be quite sensitive to plasma at temperatures exceeding 10 MK, and in fact, would yield best fit temperatures of up to 50–100 MK if indeed the quiescent Algol spectrum was dominated by such hot plasma.[3]

Little hard data are presently available on the photospheric [Fe/H] abundance of Algol A or B. Algol B is difficult to observe even during primary eclipse, and was only detected spectroscopically in optical lines of Na I by Tomkin and Lambert (1978). Most analyses of optical or ultraviolet data (e.g. Richards 1993?, Cugier and Molaro 1983) aassume solar abundances. There is strong evidence that C is depleted relative to Solar abundance in Algol A (Cugier and Hardorp 1988, Tomkin *et al.* 1993), but less than expected from CNO process modeling, perhaps due to mixing.

There are hints from the X-ray region that either an enhanced continuum or a depletion of Fe could exist in the flaring corona of Algol B. Although White *et al.* (1986)'s observation of Algol with *EXOSAT* was consistent with a solar abundance plasma, Stern *et al.* (1992) found evidence for a variable Fe XXV/XXVI line-to-continuum ratio during a large X-ray flare seen with the *GINGA* satellite. One possible interpretation of the latter result is a variation in the coronal Fe abundance during flares. Although the *GINGA* Fe line variations suggested that the apparent Fe abundance was declining during the flare decay phase relative to the rise phase, which was nearly at Solar abundances, it is also possible

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[3]in the case of flaring plasma, GINGA is certainly capable of measuring flare temperatures up to 70MK - see Stern *et al.* 1992

to interpret this data as a return to lower-than Solar abundances after an enhancement in the apparent Fe abundance during the early flare stages. If so, Algol's non flaring coronal abundance would have been about 1/3 of Solar. This consistent with the line-to-continuum determination of the Fe abundance reported in this Letter. It is also intriguing that the coronal Fe/H abundance derived in the ASCA X-ray spectra of Antunes *et al.* (1994) is $\approx$ 30-37% of AG. However, these abundances were derived using a very simplified EM model for the Algol corona: i.e. 2 isothermal components with variable abundances. Obviously, application of the DEM derived using the EUVE data to the ASCA results will be necessary to accurately constrain the apparent abundance data.

There may be alternative explanations for the unxepected line-to-continuum ratio in the Algol EUVE spectra. In particular, Schrijver, Mewe and van den Oord (1994) have suggested resonance scattering in an inhomogeneous corona as a possible way to increase the apparent line-to-continuum ratio. We point out, however, that, with this hypothesis, reductions of more than a factor of two at line center are difficult to achieve, and significant variations between resonance and non-resonance lines (i.e. such as some of the density-sensitive Fe XXI lines) should be apparent, which is not the case for the Algol spectrum. Another possible explanation is the presence of unresolved, weak line emission which is not accounted for in the current plasma codes. However, such emission would have to carefully mimic the gradual rise in the continuum seen at shorter wavelengths, and would also have to be distributed broadly in wavelength.

It is also possible that a non-thermal continuum is dominating the thermal plasma continuum, as proposed for anomalous GINGA line-to-continuum Fe line ratio in the case of a large flare on AB Dor (Vilhu *et al.* 1993). However, this requires that the emissivity of the non-thermal component overwhelm the thermal component, an unlikely situation except in the case of the impulsive phase in flares. In addition, the power-law slope of a typical solar hard X-ray burst of $\gamma \sim$3–5 ($I(E) = AE^{-\gamma}$ photon cm^{-2} s^{-1} keV^{-1}; Gary 1985) produces

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an increasing flux in photons cm^{-2} s^{-1} $Å^{-1}$ at *longer* wavelengths, with a power-law slope of $(+)1-3$.

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Figure Captions

Figure 1. Algol quiescent count spectra for the shortwave (SW) and medium wave (MW) EUVE spectrometers. Spectra are summed over 4 bins.

Figure 2. Observed flux (dot-dash line) and best fit model (small squares) using synthesized spectrum for the quiescent SW data. $N_{chebyshev} = 6$ terms, and Fe/H (Anders-Grevesse) = 0.27. The continuum predicted by a solar-abundance plasma with the same DEM is shown as a dashed line. Roman numerals indicate Fe ionization stages.

Figure 3. Differential emission measure for best-fit models with [Fe/H] fixed at various values from 0.16–1.0. Squares show the fitted points for the Chebyshev polynomial sum (N=6) for the case Fe/H = 0.33. Smooth lines are spline fits (with $\Delta \log T = 0.1$).

TABLE 1
Quiescent EUV Line Fluxes

λ_{obs}	λ_{pred}	Line ID	Flux(nc)[a,d]	Flux(ic)[b,d]	L_{EUV} (corr)[c]
		SW Spectrometer			
93.72	93.92	Fe XVIII	3.7	3.9	0.75
102.02	102.22	Fe XXI	2.1	2.1	0.38
103.83	103.94	Fe XVIII	1.4	1.1	0.23
108.13	108.37	Fe XIX	3.5	3.0	0.57
110.24	110.63	Fe XX	0.7	⋯	0.1
114.22	114.41	Fe XX	1.3	1.4	0.22
116.89	117.17	Fe XXII	8.1	10.	1.5
118.46	118.66	Fe XX	1.7	1.9	0.29
119.72	120.00	Fe XIX	0.8	⋯	0.1
121.48	121.83	Fe XX[e]	4.4	4.7	0.75
128.50	128.73	Fe XXI	9.3	10.	1.5
132.60	132.85	Fe XXIII[f]	32.	31.	4.8
135.55	135.78	Fe XX	9.0	8.4	1.3
		MW Spectrometer			
192.37	192.09	Fe XXIV	24.	25.	3.1
285.08	284.15	Fe XV	⋯	1.9	0.31
304.63	303.78	He II	180.	184.	33.
335.82	335.41	Fe XVI	8.7	10.	2.1

[a] flux derived using IRAF ncfit

[b] flux derived using IDL icur

[c] EUV luminosity in line (10^{28} erg s^{-1})corrected for ISM absorption with $N_H = 2 \times 10^{18}$ cm^{-2}

[d] fluxes in 10^{-4} photons cm^{-2} s^{-1} at earth
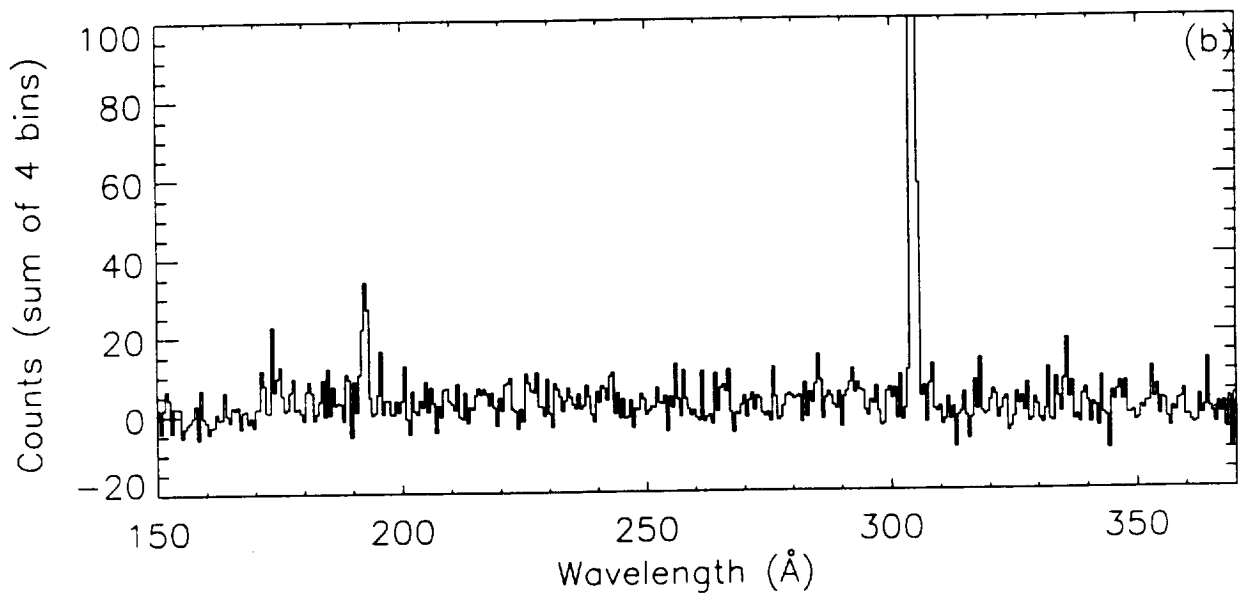
[e] blend with weaker Fe XXI 121.21

[f] blend with Fe XX 132.85

FIG 1

photons cm^{-2} s^{-1} Å^{-1}

Wavelength (Å)

Observations
Model
Solar Abundance Continuum

XVIII
XXVIII
XIX
XX
XXI/XXII
XX
XXI
XXII
XXIII/XX

FIG 2

FIG. 3

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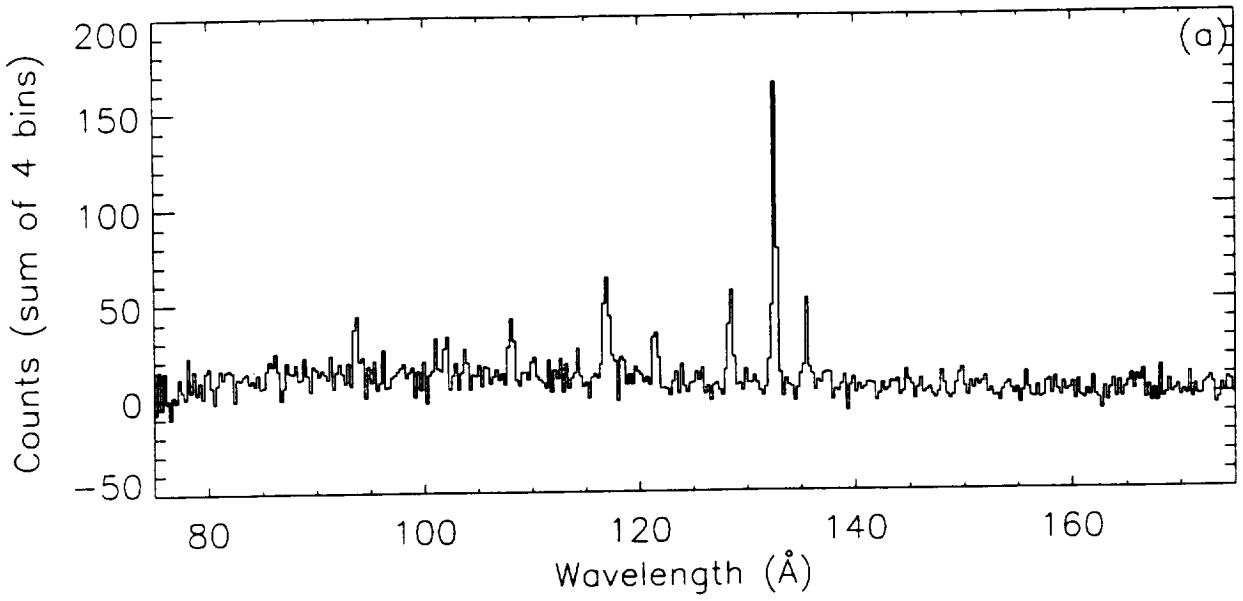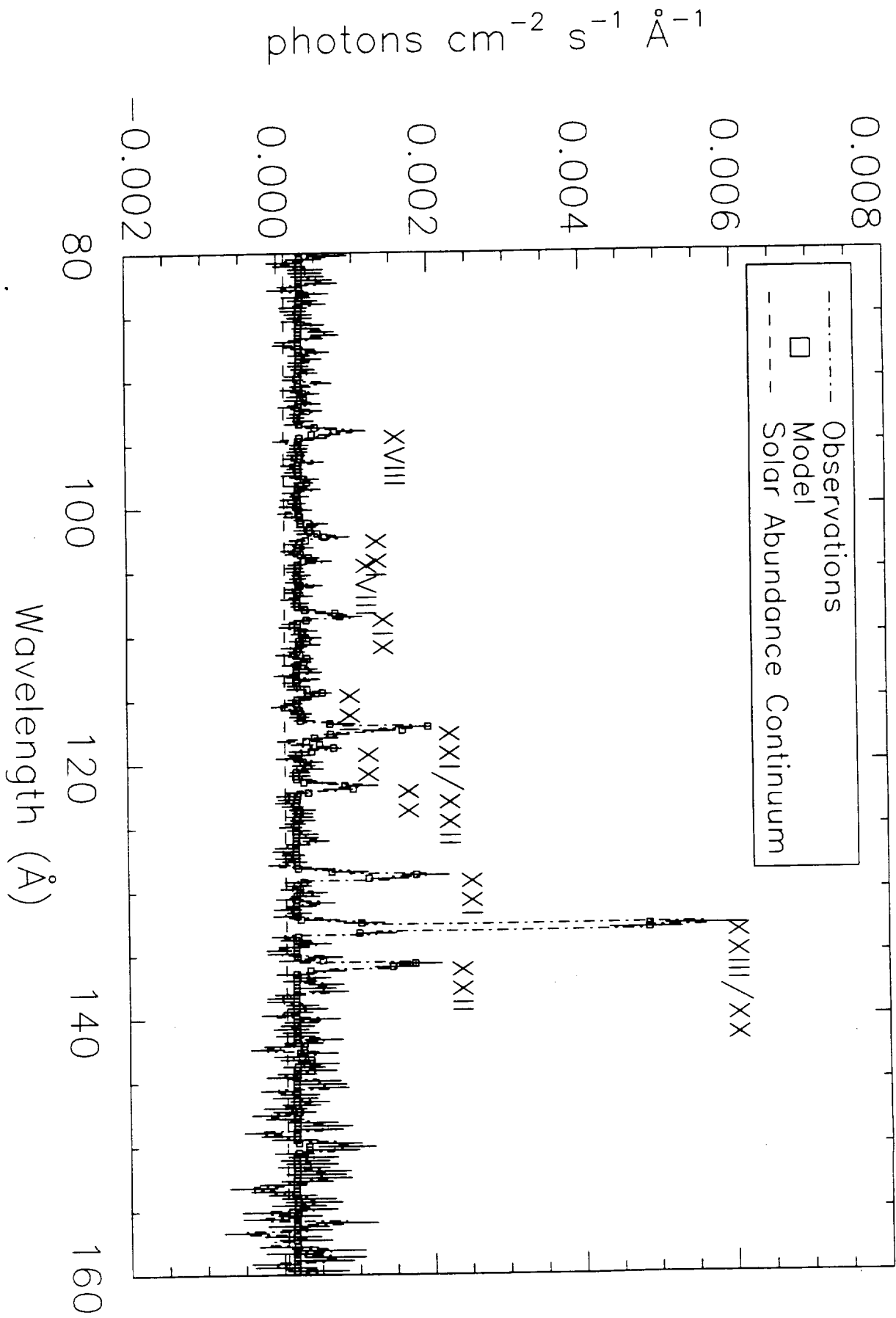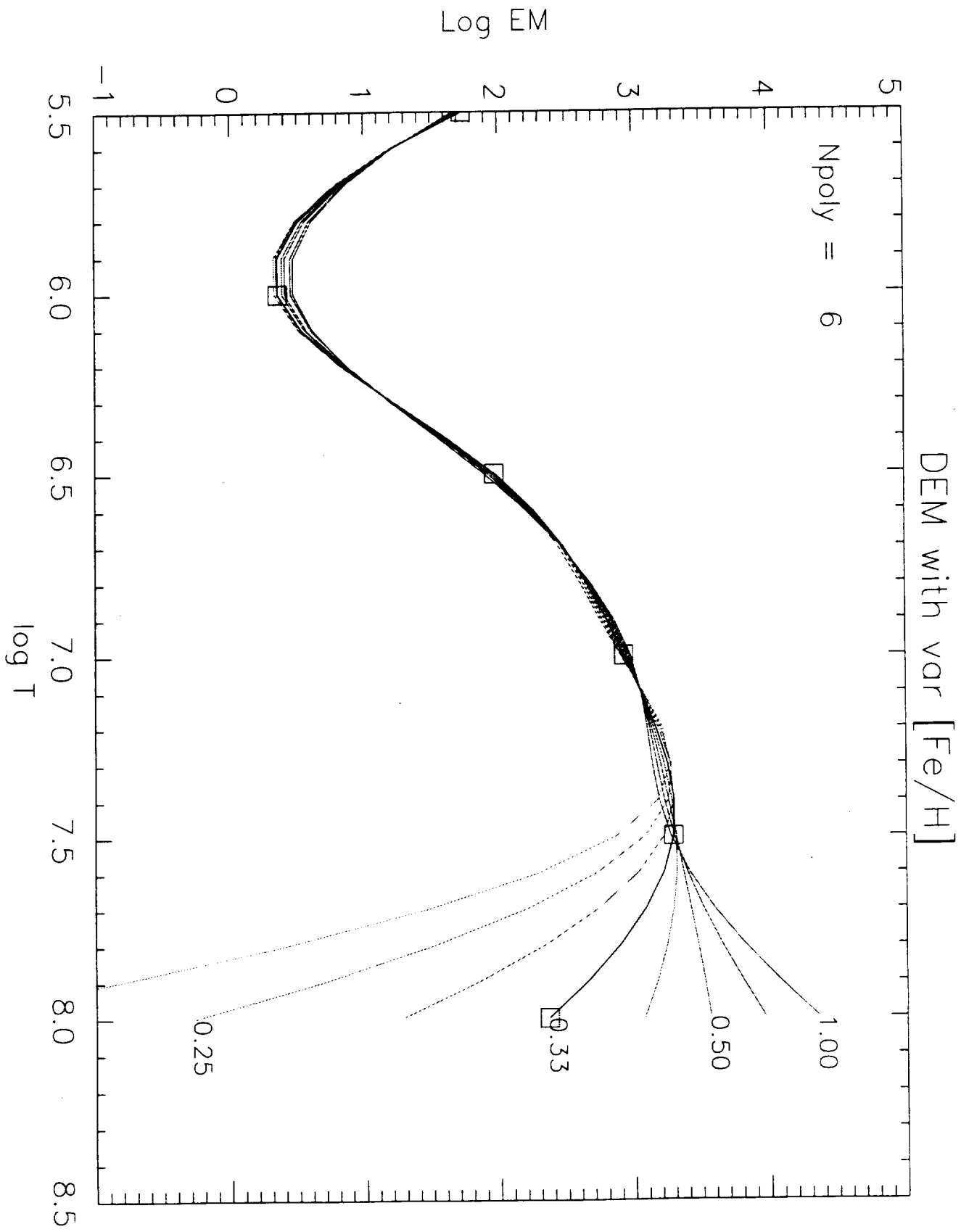
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16. ABSTRACT

This program involves analysis and interpretation of EUVE spectromter observations of the active stars Algol (β Per) and 71 Tauri. The EUVE satellite spectrometers observed the prototype eclipsing binary Algol over nearly 1.5 orbital periods. Effective exposure times were 100 ksec and 89 ksec in the short wave (70-180 \AA) and medium wave (140-370 \AA) channels. High temperature (up to 20 MK) Fe XVI-XXIV emission lines are clearly detected in the overall spectrum. In addition, a quiescent continuum is present which increases towards shorter wavelengths. Using synthesized spectra of optically thin line and continuum emission folded through the instrumental response, we have examined constraints on the [Fe/H] coronal abundance in Algol. We find that the coronal Fe is underabundant by factors of ≈ 2--4 relative to solar photospheric values, unless an unreasonably large quantity of coronal plasma at T $>$ 30 MK is present in the quiescent spectrum. The latter possibility is, however, inconsistent with available X-ray data. Lightcurves of the high temperature EUV lines compared to line emission at He II 304 A show considerable differences, with much deeper minima present in the He II line during {\it both} primary and secondary eclipses. Toward the end of the observation a moderate flare lasting ~ 6 hours was detected in the high temperature Fe emission lines.

The 71 Tau observation, for about the same exposure time, revealed only a handful of weak emission lines; however, the strongest lines were also those of Fe XXIII/XX, suggesting a hot coronal plasma. No obvious flaring or other variation was present in the 71 Tau Deep Survey lightcurve.

17. KEY WORDS

Extreme ultraviolet; Stellar coronae

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