A NEW ANALYSIS OF THE ABUNDANCE STANDARDS ι HERCULIS AND τ SCORPII

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ABSTRACT. Recent continuum and line data in the far ultraviolet for ι Her (B3IV) and τ Sco (B0V) have been combined with published observations in the near uv and visible spectral regions and interpreted with the aid of the Kurucz (1979) line-blanketed model atmospheres. For ι Her and τ Sco, respectively, interpolated models of (T_{eff}/log g) 17500±500K/3.75±0.15, and 31500±1500K/4.3±0.2 fit the observed continua from 900 - 6500Å and the profiles of Hγ and Hδ. Adopting these models, solar abundances are suggested for both stars.

1. INTRODUCTION

Model atmospheres have successfully been employed to obtain effective temperatures, surface gravities, and elemental abundances for B stars now for about twenty years (cf. Underhill and Doazan 1982 for a review of techniques and results). Heretofore, however, except for a very few limited investigations only ground-based spectroscopic data have been analyzed using earlier blanketed or even unblanketed model atmospheres. Utilizing recently acquired continuum observations from the Voyager UVS, published high resolution line data from the Copernicus satellite, and line blanketed model atmospheres of Kurucz (1979), we have completed new abundance analyses for the sharp-lined B stars ι Her (B3IV) and τ Sco (B0V) and summarize some of the results in this paper. These efforts represent the initial steps of a more extensive recalibration of the temperature scale and abundances for B stars.

2. ANALYSIS OF THE CONTINUUM

The far uv continua (900 - 1700Å) of ι Her and τ Sco have been observed with the Voyager ultraviolet spectrometers (UVS) with a spectral resolution of about 20Å. We have combined these calibrated flux measurements with published near uv and visible data to provide uninterrupted continuous spectra from 900 - 6500Å. These observations are compared with our best fits to the Kurucz model continua in Figures 1 and 2.

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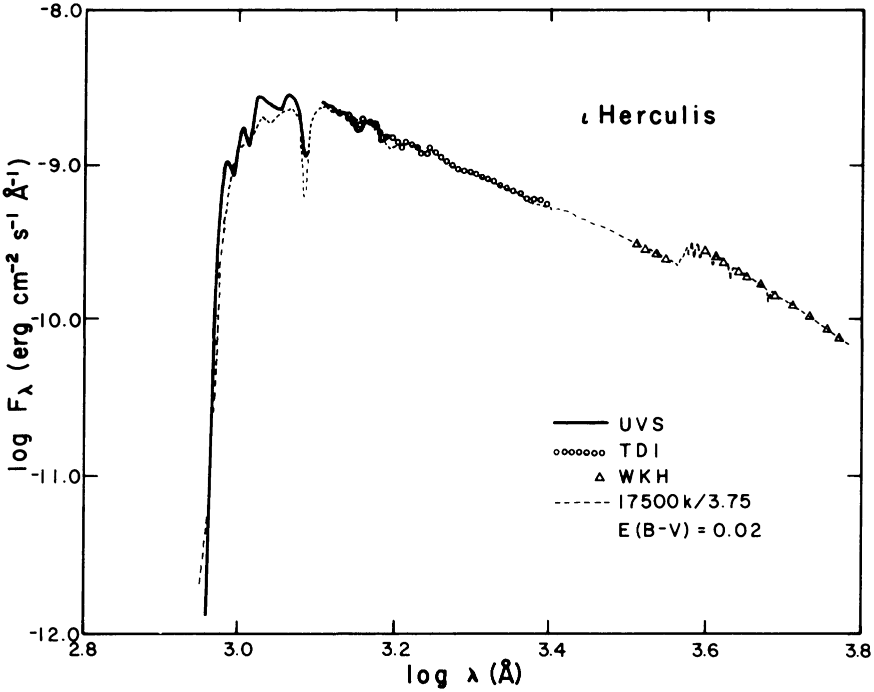

Fig. 1 - Combined Voyager, TD1, and ground-based (Breger 1976) flux data for ι Her compared with Kurucz model which produced the best fit.

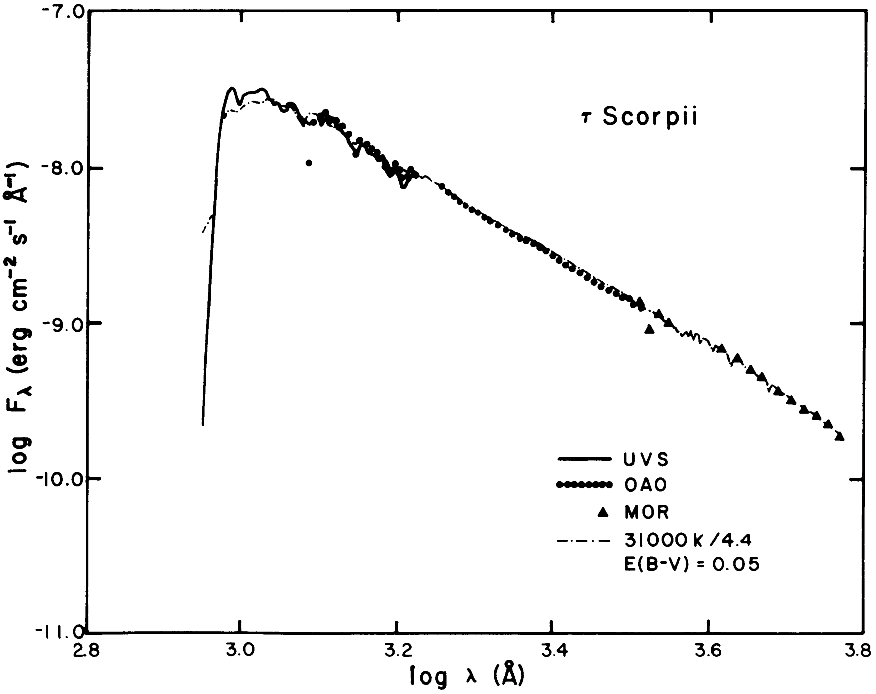

Fig. 2 - Same type of display as above but for τ Sco.

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For ι Her and τ Sco, respectively, we obtain values of T_{eff}, log g of 17500±500K, > 3.5, and 31000±2000K, 4.4±0.2. The Voyager observations place tight constraints on the adopted model atmospheres since for ι Her and τ Sco, respectively, about 45% and 70% of their total flux is emitted in the spectral region covered by the Voyager instrumentation. The continuum shortward of the flux maximum is fit as well as the Rayleigh-Jeans tail of the distribution. To correct the observations for a small amount of interstellar reddening, we employed the extinction curve (extrapolated to 900Å) published by Savage and Mathis (1979). Uncertainties in the reddening produce only small errors in T_{eff} (<1000K at 30000K, <500K at 17000K) since the flux level and distribution shortward of 1200Å is so strongly dependent on temperature. The far uv data suggest that log g $\geq$ 4.2 for τ Sco as the model continua show a striking increase in the flux level <1200Å with increasing gravity for a star near 30000K. This effect is not seen at 17000K, however. For both program stars, the observed flux between 900-1100Å is slightly larger than predicted by the models. It is premature to state whether this mismatch might be a result of errors in the calibration or model computations.

3. ANALYSIS OF THE LINE SPECTRA

The technique for analysis and a description of the UCLA spectrum systhesis code which was used are given in Peters (1976). The far uv data from the Copernicus satellite (Upson and Rogerson 1980 and Rogerson and Upson 1977) provide valuable supplements to older ground-based observations (Peters and Aller 1970, Hardorp and Scholz 1970) allowing us to improve the published chemical compositions as well as determine abundances for Ti, V, Cr, and Mn which do not display measurable lines in the visible spectrum. Surface gravities obtained by fitting observed profiles of Hγ and Hδ to theoretical profiles (Kurucz 1979) are in agreement with the values of log g suggested by the energy distributions. The abundance results are summarized in Table I. Details will be discussed elsewhere but, in general, a solar composition is suggested for both stars within the uncertainties of the observations and analysis. Ionization balance is acceptable. In ι Her, there was excellent agreement between the iron abundance suggested by the visible multiplet 118 and uv multiplet 1 (1130Å).

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TABLE I

THE CHEMICAL COMPOSITIONS OF ι Her[1] and τ Sco[2]

Ion	Number of Lines	Log N[3]	Number of Lines	Log N[3]	Log $N_{\odot}$[4]
	ι Her		τ Sco		
He I	9	10.90 ± .24	3	11.16 ± .13	10.8 ± .2
C II	32	8.42 ± .46	14	8.27 ± .46	8.62 ± .12
C III	1[5]	8.91	14	8.36 ± .33	
N II	28	7.89 ± .39	32	8.35 ± .42	7.94 ± .15
N III	...	...	14	8.38 ± .30	
O I	2[6]	8.99 ± .15	...	...	8.84 ± .07
O II	49	8.67 ± .44	75	8.69 ± .26	
O III	...	...	5	8.75 ± .30	
Ne I	10	8.64 ± .26			7.57 ± .12
Ne II	...	...	9	8.86 ± .37	
Mg II	7	7.34 ± .09	3	7.51 ± .19	7.60 ± .15
Al III	9	6.42 ± .24	...	...	6.52 ± .12
Si II	12	7.04 ± .47	...	...	7.65 ± .08
Si III	7	7.41 ± .44	13	7.51 ± .54	
Si IV	2	7.39 ± .06	7	7.34 ± .28	
P II	17	6.37 ± .55	...	...	5.50 ± .15
P III	3[7]	5.02 ± .60	...	...	
S II	67	7.17 ± .35	...	...	7.20 ± .15
S III	5	6.95 ± .36	9	7.09 ± .38	
Ar II	15	6.86 ± .59	3	8.17 ± .44	6.0 ± .2
Ca II	1[8]	6.16	...	...	6.35 ± .10
Ti III	9[7]	5.37 ± .55	5[7]	5.52 ± .63	5.05 ± .12
V III	14[7]	4.30 ± .83	3[7]	3.96 ± .66	4.02 ± .15
Cr III	9[7]	5.41 ± .63	3[7]	6.31 ± .75	5.71 ± .14
Mn III	8[7]	5.55 ± .40	4[7]	5.23 ± .13	5.42 ± .16
Fe II	15	6.82 ± .41	...	...	7.50 ± .08
Fe III	13[9]	7.50 ± .31	3	7.35 ± .18	

[1] T_{eff} = 17500K; log g = 3.75; ξ_T = 0 km s^{-1}

[2] T_{eff} = 31500K; log g = 4.3; ξ_T = 5 km s^{-1}

[3] N_H = 12.0

[4] Ross, J.E., and Aller, L.H. (1976)

[5] λ1247.38

[6] λλ1304, 1306

[7] All FUV lines

[8] K-line

[9] Includes multiplets 118 and 1 uv

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DISCUSSION

PETERS: I would like to make a few comments about the UV energy distributions we get from Voyager. Considering B-type MK standards, there is a striking functional dependence of the energy distribution of the star on the effective temperature, or spectral type of the star. (See Fig. 1) The energy distributions for neighboring subtypes are clearly separated. There are 1 1/2 orders of magnitude in the flux at about 1000 Å between a B0 star and a B7 star. Note also the short-wavelength cutoff of the energy distribution is also very dependent on the spectral type of the star. From either of these dependencies one can get the effective temperature.

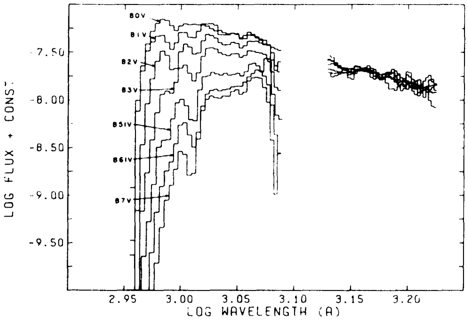

Fig. 1 - The fuv energy distributions (900 - 1700 Å) of selected B-type standard stars observed with the Voyager UVS and normalized from 1350 - 1450 Å.

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