THE ASTROPHYSICAL JOURNAL, 291:L7–L10, 1985 April 1

ALPHA TRIANGULI AUSTRALIS (K2 II–III): HYBRID OR COMPOSITE?

T. R. AYRES[1]
Laboratory for Atmospheric and Space Physics, University of Colorado
Received 1984 April 30; accepted 1985 January 7

ABSTRACT

The prototype "hybrid-spectrum" giant, α Trianguli Australis, exhibits a far-ultraviolet continuum which is considerably bluer than would be expected of a star of its optical colors, suggesting the presence of a previously unrecognized companion. If the K type primary is as luminous as indicated by the widths of its Ca II and Hα lines, the companion could be an early F type dwarf that only recently has arrived on the main sequence. Indeed, the flux of C IV from α TrA—an important measure of "hybridness"—would not be inconsistent with that expected from a very young, chromospherically active F star.

Subject headings: stars: chromospheres — stars: late-type — ultraviolet: spectra

I. INTRODUCTION

A number of late-type giants and supergiants observed with the *International Ultraviolet Explorer* (*IUE*; Boggess *et al.* 1978) have been designated "hybrid" (Hartmann, Dupree, and Raymond 1980), owing to the coexistence in their spectra of circumstellar absorptions indicating mass loss, and high-excitation emissions indicating plasma as hot as 10^5 K. The signatures of cool winds and highly ionized species usually are not found together in the spectra of single giants (Linsky and Haisch 1979).

The hybrids are thought to represent a transition class between "coronal" stars (X-ray and C IV λ1550 emission) and "wind-dominated" stars (Mg II λ2800 circumstellar absorption): Hartmann, Dupree, and Raymond (1981) have proposed that the hybrid character of α Trianguli Australis (K2 II–III), in particular, can be explained by a warm (10^5 K) stellar wind that is intermediate in its properties between the fast, hot coronal wind of the Sun and the slow, cool chromospheric flows of the red supergiants like α Orionis.

However, in this *Letter* I present evidence that α TrA possesses a previously unrecognized companion of late spectral type which plausibly could be responsible for some aspects of the prototype hybrid spectrum, particularly the measured C IV emission.

II. OBSERVATIONS

Table 1 summarizes the optical properties of the stars and the far-ultraviolet spectra analyzed for this study. Details concerning the reduction of the *IUE* spectra to absolute flux can be found in Schiffer (1982).

Figure 1 contrasts the far-ultraviolet energy distribution of α TrA with those of Arcturus (α Bootis: K1 III) and Aldebaran (α Tauri: K5 III), two red giants whose $B - V$ colors bracket that of α TrA. The far-ultraviolet fluxes have been normalized to the apparent bolometric luminosities ($f_{\rm bol}$: see Ayres, Marstad, and Linsky 1981) to avoid prejudicing the comparison owing to uncertain distances and radii. With regard to its optical colors, α TrA clearly possesses an anomalously bright photospheric continuum in the interval 1800–2000 Å.

The anomalous ultraviolet continuum cannot be the result of a mistyping of α TrA owing to interstellar reddening. The differential extinction between the visual region (which determines $f_{\rm bol}$) and 1900 Å is 4.9 mag per magnitude of color excess $E(B - V)$ (Savage and Mathis 1979); therefore, if α TrA is dereddened to an earlier spectral type, the ultraviolet continuum will be *amplified* relative to $f_{\rm bol}$, and the anomaly will persist. Furthermore, based on the measured $U - B$ and $B - V$ colors, and standard color-color diagrams for giants and supergiants (e.g., Johnson 1966), the interstellar reddening toward α TrA probably does not exceed $E(B - V) = 0.1$ mag.

A more likely explanation for the "blue" continuum of α TrA is the existence of a previously unknown companion of earlier spectral type.

III. ANALYSIS

One can estimate the spectral type of the companion as follows:

The Wilson-Bappu Ca II K line magnitude and Kraft Hα magnitude of α TrA both indicate $M_v \approx -3.5$ (Zarro and Rodgers 1983), and therefore a distance of about 100 pc, if the visual absorption is small. For that distance, the bolometric luminosity of the K bright giant is about $2.5 \times 10^3\ L_\odot$, which implies a mass of 6 $M_\odot$ (in the post–main-sequence, core helium burning stage) and an age of 5×10^7 yr (see Iben 1972).

The companion cannot be evolved, because it therefore would be of comparable mass—and bolometric luminosity—to the K type primary, and its somewhat earlier spectral type would dominate the composite *UBV* colors. The proposed companion cannot be a hot white dwarf, because the blackbody temperature of a DB star needed to match the apparent

[1]Guest Investigator, *International Ultraviolet Explorer*.

TABLE 1

STELLAR PARAMETERS[a] AND *IUE* EXPOSURES

HD Number	Star Name	Spectral Type	V (mag)	$B - V$ (mag)	f_{bol}[b] (10^{-5} ergs cm^{-2} s^{-1})	SWP Image Number[c]	Exposure Time (minutes)
432.......	β Cas	F2 III–IV	+2.27	+0.34	0.30	24063H	7.5
29139	α Tau	K5 III	+0.85	+1.54	3.6	6679H[d]	400
39587	χ^1 Ori	G0 V	+4.41	+0.59	0.046	13643H	420
124897...	α Boo	K1 IIIb	−0.04	+1.23	4.9	11039H	420
						20044H	1290
150798...	α TrA	K2 IIb–IIIa	+1.92	+1.44	0.80	10903L[d]	40
						15494H[d]	1135

[a] From Hoffleit 1982, unless otherwise indicated.
[b] Based on Ayres, Marstad, and Linsky 1981.
[c] All exposures of 1150–2000 Å region through 10″ × 20″ aperture: H = high dispersion; L = low dispersion.
[d] From archives of *IUE*.

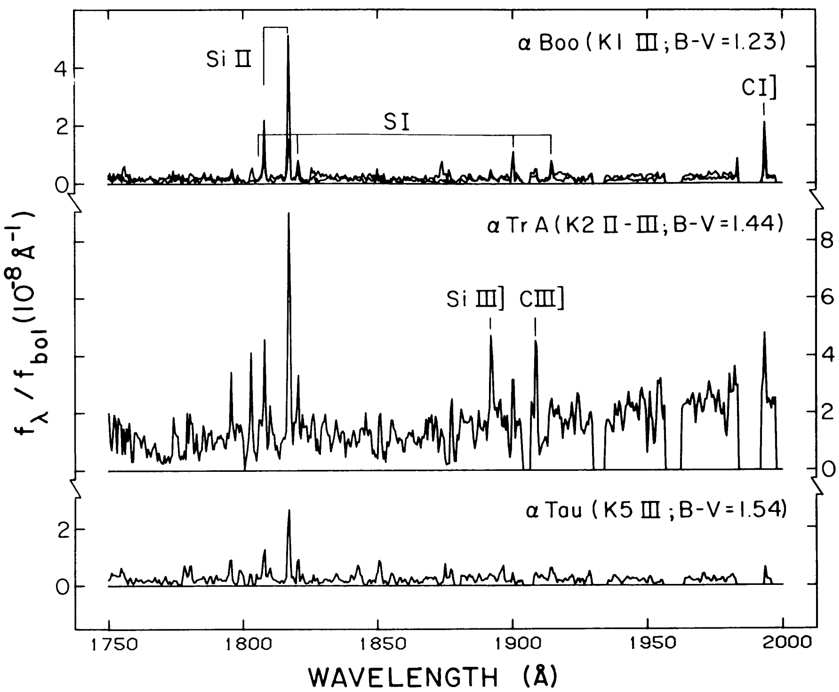

FIG. 1.—Comparison of far-ultraviolet energy distributions of K type giants. The tracings are high-dispersion (0.2 Å FWHM) *IUE* echelle spectra that have been filtered mildly, to remove bright spots and reseau marks, and smoothed to approximately 0.5 Å resolution. Most of the apparent structure is real, although not all of the defects in the original echellograms were removed successfully. The gaps in the long-wavelength portion of the diagram are caused by lack of overlap among the low orders of the echelle pattern. For α Boo, two spectra have been overlaid: The deeper of the two, SWP 20044, is overexposed in the emission lines but well exposed in the "continuum" regions; the other, SWP 11039, is well exposed in the emission lines but underexposed in the continuum. The monochromatic fluxes measured at Earth were divided by the stellar bolometric fluxes. In effect, the normalized fluxes represent far-ultraviolet "colors," characteristic of the stellar photosphere, which should be compatible with their optical counterparts. However, the 1800–2000 Å continuum of α TrA is too "blue" for its $B - V$.

continuum flux at 1990 Å (> 30,000 K) is not compatible with the steep decline of the UV continuum below 1800 Å. Therefore, the companion very likely is a main-sequence star.

On the main sequence, a good correlation exists between the luminosity of a star and its spectral type (or, equivalently, its $B - V$ color):

$$L_{bol} \approx 1.1 \times 10^{-2.3[(B-V)-0.6]} L_{\odot}, \qquad (1)$$

as derived from tables in Allen (1973). Furthermore, a good correlation exists between the photospheric f_{1990}/f_{bol} ratio of a main-sequence star and its $B - V$ color:

$$f_{1990}/f_{bol} \approx 1.5 \times 10^{-6-4.9[(B-V)-0.6]}\ \text{Å}^{-1}, \qquad (2)$$

as determined from *IUE* low-dispersion spectra of F0–G5 V stars from Heck *et al.* (1984), with bolometric fluxes based on the relation given by Ayres, Marstad, and Linsky (1981).

One can write the f_{1990}/f_{bol} ratio for the companion in terms of the estimated value of $f_{1990} = 1.6 \pm 0.2 \times 10^{-13}$

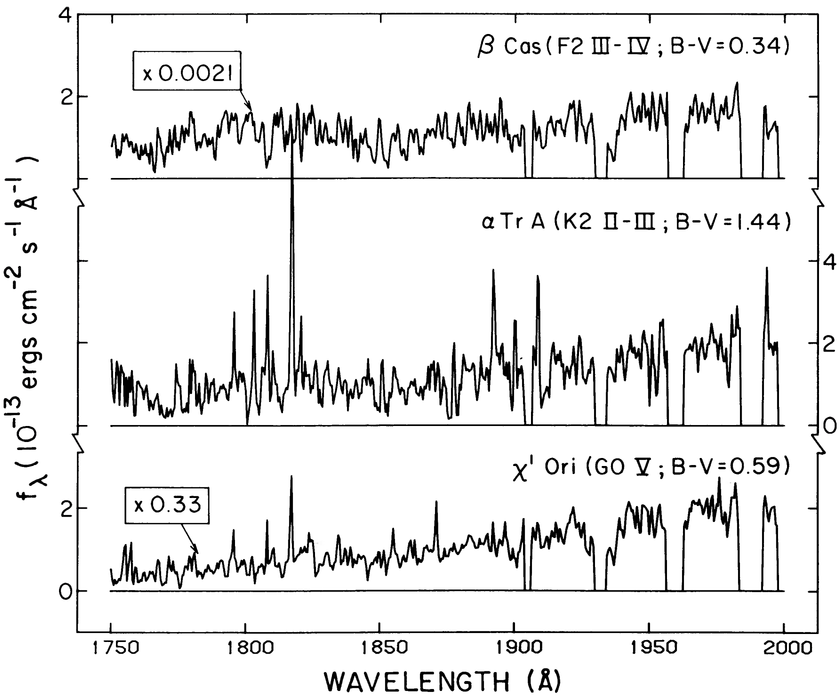

FIG. 2.—Comparison of the far-ultraviolet energy distribution of α TrA with those of representative F and G stars. The spectra of β Cas and χ^1 Ori were processed in the same manner as those of Fig. 1 and were normalized to the integrated flux of the α TrA spectrum in the interval 1925–1975 Å (the scale factors are provided at the left-hand side of the diagram). The normalization permits the *shapes* of the energy distributions to be compared. (The spectrum that would have the correct *photometric* amplitude in the 1800–2000 Å region for the assumed distance of α TrA [100 pc] would be an F3 V with $B - V = +0.39$ mag [see text].)

ergs cm^{-2} s^{-1} $Å^{-1}$ (from a 40 minute low-dispersion exposure of α TrA [SWP 10903]), and the luminosity of the companion (eq. [1]) diluted by the distance to α TrA:

$$f_{1990}/f_{\rm bol} \approx 4.6 \times 10^{-5+2.3[(B-V)-0.6]} \times (d/100\ {\rm pc})^2 \times 10^{8E(B-V)/2.5}\ Å^{-1}, \qquad (3)$$

where the final term dereddens the far-ultraviolet spectrum according to Savage and Mathis (1979). The relations given in equations (2) and (3) can be equated to yield the color of the companion:

$$(B - V) \approx 0.39 - 0.28 \log(d/100\ {\rm pc}) - 0.44E(B - V)\ {\rm mag}. \qquad (4)$$

If α TrA is at a distance of 100 pc, consistent with its Ca II and Hα luminosity classes, and if the reddening is small, then the companion has a $B - V$ color of about 0.39, which corresponds to F3 on the main sequence (Johnson 1966).

Figure 2 compares the far-ultraviolet energy distribution of α TrA with those of β Cassiopeia (F2 III–IV; $B - V = 0.34$) and χ^1 Orionis (G0 V; $B - V = 0.59$), two stars whose colors bracket that of the proposed companion. Aside from the numerous low- and moderate-excitation emissions that characterize a K type chromospheric spectrum (cf. Fig. 1), the general shape of the 1800–2000 Å continuum of α TrA is qualitatively compatible with that of a significantly earlier spectral type.

IV. DISCUSSION

Because the companion to α TrA very likely is an F type star which, owing to the youth of α TrA itself, only recently has arrived on the main sequence, one might wonder whether the high-excitation C IV emission of the α TrA spectrum might not be attributable partly, or entirely, to the companion. It is well known from studies of clusters that young main-sequence stars of late spectral type tend to be fast rotators with strongly enhanced ultraviolet emissions associated with intense chromospheric and coronal activity (e.g., Walter *et al.* 1984).

Walter *et al.* (1984) have measured the C IV fluxes of F dwarfs in the Ursa Major Stream, whose age (3×10^8 yr) is a factor of about 6 older than α TrA. One of the most active stars of their sample, 18 Bootis (HD 125451: F5 IV; $B - V = 0.38$; $v \sin i = 40$ km s^{-1}), is similar in color to the proposed companion. The $f_{\rm C\,IV}/f_{\rm bol}$ ratio of 18 Boo, 3×10^{-6}, would increase to about 1×10^{-5} if scaled to the age of α TrA according to the empirical relation, $f_{\rm C\,IV}/f_{\rm bol} \approx ({\rm age})^{-0.8}$, of Simon and Boesgaard (1984). Within factors of 2, that value is sufficient to explain the entire flux of C IV (several $\times 10^{-13}$ ergs cm^{-2} s^{-1}) from α TrA.

Accordingly, the companion might be entirely responsible for the C IV emission from the system, and the spectrum would then be merely composite—K giant low- and moderate-excitation emission lines plus F dwarf continuum and high-excitation emissions—not hybrid. Alternatively, the companion might not contribute significantly to the C IV flux, but the binary character of α TrA nonetheless might influence the magnetic activity of the primary, so that the otherwise wind-dominated spectrum exhibits some remnants of coronal activity.

An analogous situation is found among the Hyades K giants: The most "active" (with respect to C IV and X-ray emission) of the four—θ^1 Tauri (K0 III)—possesses an anomalous far-ultraviolet continuum which very likely is due to an F type companion (Baliunas, Hartmann, and Dupree 1983). Whether the companion contributes to the enhanced high-excitation emissions of θ^1 Tau directly, indirectly, or not at all cannot be resolved on the basis of existing observations, although the C IV and X-ray luminosities would not be unusual for an F star of the Hyades (e.g., Baliunas, Hartmann, and Dupree 1983).

Therefore, the implications of duplicity should be examined carefully in the case of α TrA, before conclusions based on the existence of 10^5 K plasma in the outer atmosphere of the K bright giant can be considered tenable.

I thank J. L. Linsky, F. Walter, and A. Brown for helpful discussions. I also thank the staff of the *IUE* Regional Data Analysis Facility in Boulder for their assistance in the reduction of the spectra. This study was supported by grant NAG5-199 from the National Aeronautics and Space Administration to the University of Colorado.

REFERENCES

Allen, C. W. 1973, *Astrophysical Quantities* (3d ed.; London: Athlone).
Ayres, T. R., Marstad, N. C., and Linsky, J. L. 1981, *Ap. J.*, **247**, 585.
Baliunas, S. L., Hartmann, L., and Dupree, A. K. 1983, *Ap. J.*, **271**, 672.
Boggess, A., *et al.* 1978, *Nature*, **275**, 377.
Hartmann, L., Dupree, A. K., and Raymond, J. C. 1980, *Ap. J.* (*Letters*), **236**, L143.
______. 1981, *Ap. J.*, **246**, 193.
Heck, A., Egret, D., Jaschek, M., and Jaschek, C. 1984, *IUE Low-Dispersion Spectra Reference Atlas. Part 1: Normal Stars* (ESA SP-1052).
Hoffleit, D. 1982, *Catalog of Bright Stars* (New Haven: Yale University Observatory).
Iben, I., Jr. 1972, in *IAU Colloquium 17*, *Age des Etoiles*, ed. G. Cayrel de Strobel and A. M. Delplace (Meudon: Observatoire de Paris), p. XI-1.
Johnson, H. L. 1966, *Ann. Rev. Astr. Ap.*, **4**, 193.
Linsky, J. L., and Haisch, B. M. 1979, *Ap. J.* (*Letters*), **229**, L27.
Savage, B. D., and Mathis, J. S. 1979, *Ann. Rev. Astr. Ap.*, **17**, 73.
Schiffer, F. H., III. 1982, Data Analysis Procedures for the International Ultraviolet Explorer Regional Data Analysis Facilities. Part I: Guidelines for Determining Wavelengths and Fluxes from Extracted Spectra (Computer Sciences Corporation TM-82/6207).
Simon, T., and Boesgaard, A. M. 1984, in *IAU Symposium 102*, *Solar and Stellar Magnetic Fields: Origins and Coronal Effects*, ed. J. O. Stenflo (Dordrecht: Reidel), p. 161.
Walter, F. M., Linsky, J. L., Simon, T., Golub, L., and Vaiana, G. S. 1984, *Ap. J.*, **281**, 815.
Zarro, D. M., and Rodgers, A. W. 1983, *Ap. J. Suppl.*, **53**, 815.

T. R. Ayres: Laboratory for Atmospheric and Space Physics, University of Colorado, Campus Box 392, Boulder, CO 80309