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ARE THERE STARS EXCEPTIONALLY BRIGHT AT 1500 Å?

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ABSTRACT

Interstellar reddening at 1500 Å has been measured for more than a dozen stars. A few stars, including θ Ori, have apparently anomalous ultraviolet reddening. However, unreddened B stars also anomalously bright at 1500 Å by about 1.3 mag are shown probably to exist, and it is suggested that θ Ori may be one of these bright objects, reddened according to the same law that describes the reddening of other stars.

I. INTRODUCTION

Carruthers (1969*a*) and Bless and Savage (1969) showed that the star θ Ori is substantially brighter in the far-ultraviolet than expected on the basis of stellar models that have been reddened an appropriate amount in accord with the same reddening law that has emerged from the study of other stars. They concluded that an anomalous reddening law probably applied to θ Ori. Bless and Savage (1969) also showed that the star σ Sco apparently has a reddening similar to that of θ Ori.

We will describe briefly observations which show that unreddened stars too bright by about 1.3 mag may also exist. On the basis of this, we suggest that θ Ori may be one member of this new class of stars, reddened in accord with the same interstellar reddening law that applies to normal stars. A full presentation of the data will be given elsewhere.

II. OBSERVATIONS

A far-ultraviolet-sensitive electronographic Schmidt camera was flown on an Aerobee-150 rocket from White Sands Missile Range at 0205 MST on 1969 September 21. Wide-field photographs in the wavelength range 1230–2100 Å of the Orion and Monoceros regions were obtained, and have been discussed qualitatively (Henry and Carruthers 1969, 1970). The effective wavelength was about 1500 Å.

Densitometry of the star images gave numbers dependent on the brightness of the star. No calibration was available. A small systematic effect apparently due to imperfect focus, which varied across the field, was removed to give internal errors in the ultraviolet magnitudes of about 0.25 mag. The observed magnitudes were plotted against ultraviolet magnitudes derived from the stellar-atmosphere models of D. C. Morton and his co-workers (e.g., Van Citters and Morton 1970). For unreddened stars, a tight relationship was found which included main-sequence and giant stars. The least-squares fit to these data was used to obtain relative ultraviolet color excesses for all the stars. (These will be in error, by a constant, only if there is a far-ultraviolet absorption component

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that dims visually unreddened stars or if the models are in error by a constant amount independent of spectral class.)

III. DISCUSSION

In Figure 1, the far-ultraviolet color excess is shown plotted against the visual color excess $E(B - V)$. Most of the stars are unreddened and fall near the origin. The scatter near the origin is consistent with what is expected, judging by the consistency in the ultraviolet magnitudes measured in different photographs of the same star.

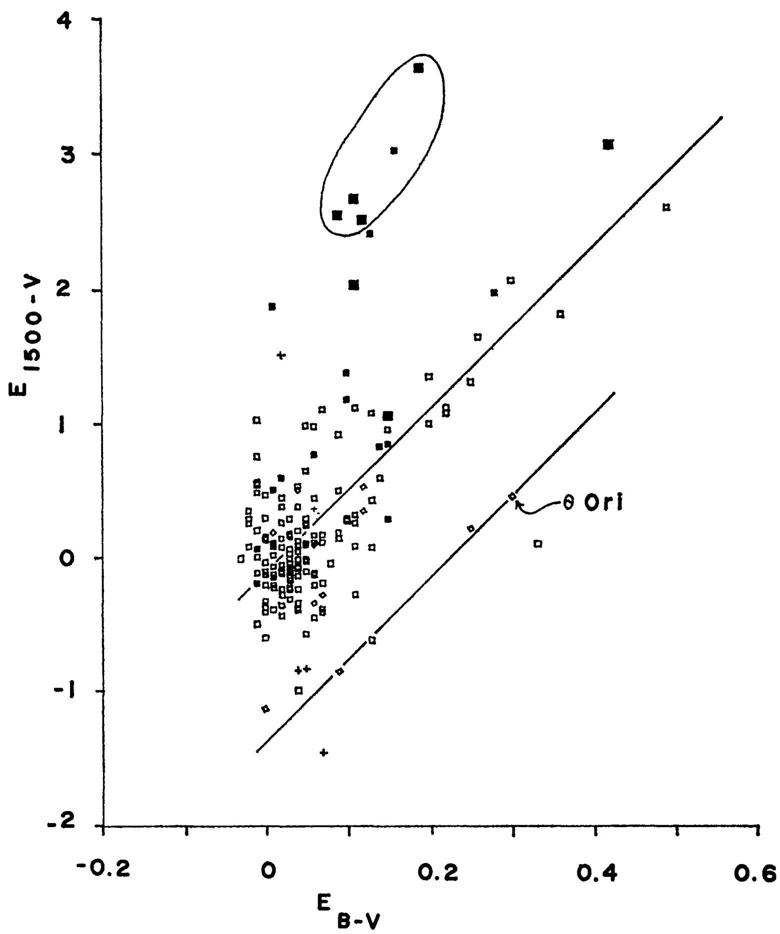

FIG. 1.—Ultraviolet color excess $E(m_{1500} - V)$ plotted against $E(B - V)$. The upper straight line is a conventional ultraviolet reddening law. A parallel line drawn through θ Ori also passes through a group of unreddened stars that appear to be 1.3 mag brighter than most main-sequence stars at 1500 Å relative to the visible. *Crosses*, stars for which doubt is possible regarding the data. *Small filled squares*, giants; *large filled squares*, supergiants. Diamonds represent groups of stars.

The upper straight line in the figure is a suggested interstellar reddening line of slope 6.0. This value is not inconsistent with values obtained by others. The line passes slightly below the origin, for the "unreddened" stars used in the calibration were not actually completely unreddened.

Supergiant stars (*large filled squares*) generally fall above the line; that is, they appear fainter at 1500 Å, relative to the visible, than do main-sequence stars. This is in agreement with previous observational evidence (Carruthers 1969*b*) and theoretical interpretations thereof (Mihalas 1970). A group of stars for which the calibration is especially uncertain are isolated in the figure. The giant stars (*small filled squares*) fall with the main-sequence stars or at least are only slightly fainter. (This will be discussed in more detail elsewhere.)

The most surprising group of anomalous points consists of nine objects that lie on a reddening line roughly parallel to the upper reddening line, but displaced from it by 1.3 mag. Data on these objects are given in Table 1. (For groups of stars, the data apply to the whole group.) Figure 1 suggests that θ Ori, instead of being reddened from the origin by a reddening line of lower slope, may be intrinsically similar to those essentially unreddened extra-bright objects that appear in the figure, and may be reddened in accord with a quite normal interstellar reddening law. The scatter for the unreddened stars is not small enough to exclude completely the possibility that the extra-bright unreddened stars are just part of the general scatter. This is difficult to test because of the deviations introduced by the reddening and by the presence of known and unrecognized giant stars. If ours is the correct interpretation of the figure, and if the data are not in error, then a class of objects exists that is about 1.3 mag brighter at 1500 Å, relative to the visible, than normal main-sequence stars. The extra ultraviolet flux is probably not due to

TABLE 1

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Name or HR	HD	Sp	V	$E(B-V)$	$E(m_{1500}-V)$
	36629, etc.	B5 V	6.71	0.25	+0.21
	36954, etc.	B3 V	6.60	0.09	−0.85
θ Ori...........	37020, etc.	B0.5 V	3.98	0.30	+0.45
	35502	B5 V	7.36	0.13	−0.62
	35882	B8 V	7.78	0.07	−1.45
	35899	B5 V	7.53	0.04	−0.99
1873...........	36779	B3 V	6.23	0.05	−0.83
	37526	B3 V	7.61	0.04	−0.84
	37903	B1.5 V	7.82	0.33	+0.10

strong emission lines, at least in the case of θ Ori, as spectra of this star do not show such lines (Carruthers 1969*a*). If, as the observations of Carruthers (1969*b*) imply, the models of Morton and his co-workers correctly predict the far-ultraviolet brightnesses of "normal" main-sequence B stars, then the present observations imply that some source of continuous opacity present in most B stars of Population I is absent in some. If, on the other hand, the "normal" B stars are appreciably fainter than the models predict (Opal *et al.* 1968), then it is necessary to assume that some additional source of opacity not included in the models is present in most B stars. The difference of 1.3 mag between the "normal" and "super-bright" stars is considerably greater than the difference in this wavelength range between the line-blanketed models of Morton *et al.* and models with no line blanketing.

IV. CONCLUSIONS

Data have been presented which suggest the existence of a small class of ultraviolet-bright stars. Such objects are difficult to interpret in terms of model atmospheres. Clearly, intensive observations of these objects, in the visible as well as in the ultraviolet, are greatly to be desired.

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