THE DETECTION OF COMPANION STARS TO THE CEPHEID VARIABLES ETA AQUILAE AND T MONOCEROTIS

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ABSTRACT

We have obtained ultraviolet spectra with IUE of the classical Cepheid variables η Aql and T Mon at several phases in their periods. For η Aql significant ultraviolet emission is detected at wavelengths less than 1600 Å, where little flux is expected from classical Cepheids. Furthermore, the emission at wavelengths less than about 1600 Å does not vary with phase. Comparison with model atmosphere flux distributions shows that the nonvariable emission is consistent with the flux expected from a main-sequence companion star with an effective temperature of about 9500 K (A0 V - A1 V). For T Mon a nonvarying component to the ultraviolet emission is observed for wavelengths less than about 2600 Å. Comparison with model atmosphere flux distributions suggests that the companion has an effective temperature of around 10,000 K (A0) and is near the main sequence.

INTRODUCTION AND OBSERVATIONS

Classical Cepheids are a major element in the determination of galactic and extragalactic distances. Thus determinations of their masses and absolute magnitudes are of considerable interest. One method for determining these properties is to study binary systems containing Cepheids. We report evidence here that the classical Cepheids η Aql and T Mon have companion stars.

As part of a program to study classical Cepheids with IUE, we obtained spectra of η Aql and T Mon on several days in 1979. All of the spectra were obtained at low resolution. Exposures were made in both the long and short wavelength cameras and with both the large and small apertures. Figures 1 and 2 show samples of the calibrated spectra at several different phases for η Aql and T Mon, respectively.

Examination of the spectra in figures 1 and 2 shows a number of interesting features. In both cases at short wavelengths (below 1600 Å in figure 1 and below 2000 Å in figure 2) the magnitude of the flux and its spectral distribution are clearly incompatible with the F or G type spectrum expected for a Cepheid. Only at longer wavelengths does the continuum flux increase with increasing wavelength as would be expected

for a Cepheid. Furthermore, only at longer wavelengths does the flux vary with phase, as expected for a Cepheid. For both stars the features pointed out above are seen in all of the spectra we have obtained, including those taken with the small aperture. Thus the source of the radiation must be within 1.5 arc sec of the two Cepheids. We therefore suggest that the features of the spectra presented in figures 1 and 2 indicate that η Aql and T Mon have early type companion stars.

ANALYSIS AND DISCUSSION

To determine accurately the characteristics of the companion stars, we have compared the observed flux at the Earth in the wavelength range of IUE with predicted fluxes from a series of stellar atmosphere models calculated by Kurucz (ref. 1). Each set of model atmosphere fluxes was reddened using published color excesses for the Cepheids. To reduce the contribution from the Cepheid, the models were fit to the data at the phase closest to minimum light. Further details on the model fits are presented elsewhere (refs. 2 and 3).

For η Aql the best fit was found for a model with an effective temperature of about 9500 K. For T Mon the best fit was for a model with an effective temperature of 10,000 K. Figures 3 and 4 show the data near minimum light, the best fit model fluxes, and fluxes for models with effective temperatures that bracket the best fit values for η Aql and T Mon, respectively. In both cases the agreement of the model fluxes with the observations is good in the region of the spectrum where the flux is due only to the companion and interstellar reddening is not a major problem.

If we assume that the companion stars are at the distance of the Cepheids, then we can use the observed ultraviolet flux to estimate the radius of the stars and hence their luminosity class. The radius is given by the expression $(R/d)^2 \pi F_\lambda = f_\lambda$, where R is the radius of the star, d is the distance to the star, F_λ is the surface flux at the star, and f_λ is the flux measured at the Earth, corrected for interstellar absorption. Following this procedure, we find radii for the companion stars of η Aql and T Mon of 2.2 $R_\odot$ and 7.4 $R_\odot$, respectively. Further details of the determination are given elsewhere (refs. 2 and 3). The radii determinations indicate that the companion star to η Aql is an A0 V to A1 V star, while the companion star to T Mon is an A0 III star.

The detection in the ultraviolet of companion stars to Cepheid variables could provide a valuable method for checking the period-luminosity relation. So far with IUE we have observed 6 classical Cepheids, two of which have companions. Pel (ref. 4) has estimated that at least 25% of all Cepheids are binaries. As our understanding of normal stars in the ultraviolet region of the spectrum improves, these companions to Cepheids could prove to be a new check on the period-luminosity relation.

REFERENCES

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4. Pel, J.W. 1978, Astr. Ap., 62, 75.

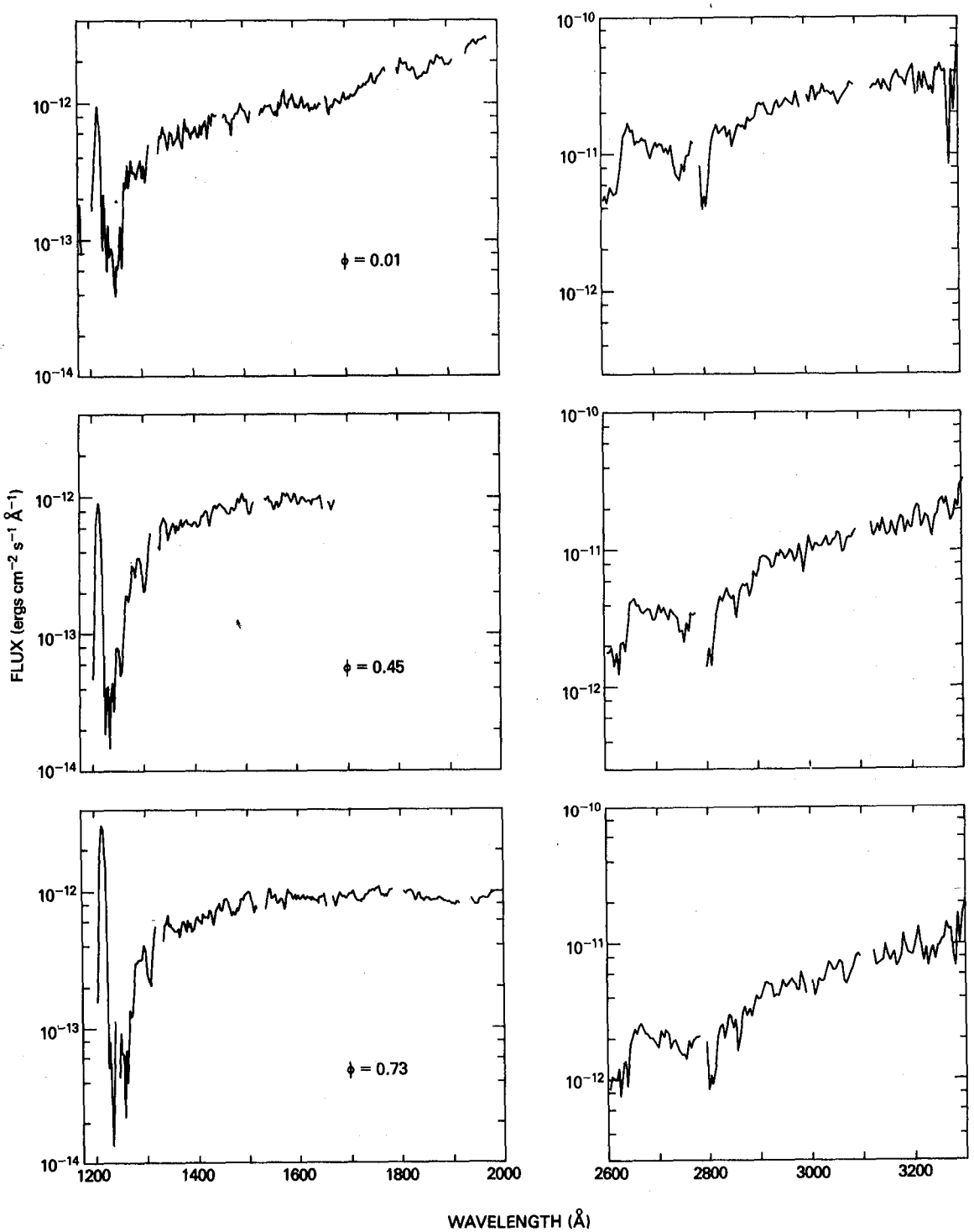

Figure 1. Low-dispersion short and long wavelength spectra in absolute flux units of η Aql at 3 phases in the 7.18 day period.

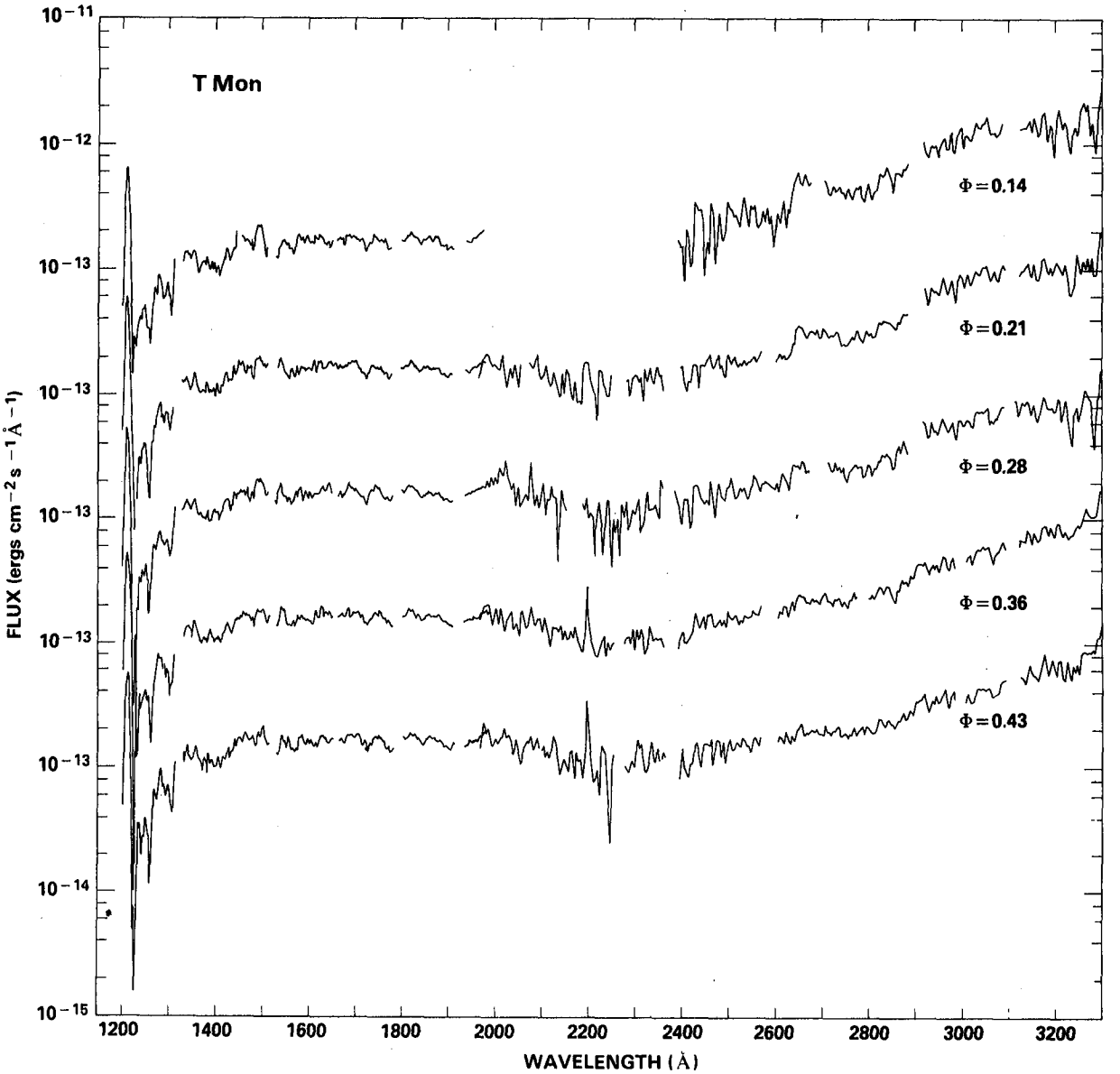

Figure 2. Low-dispersion short and long wavelength spectra of T Mon at 5 phases in the 27 day period. The ordinate for each spectrum has been displaced from the one above it by a factor of ten.

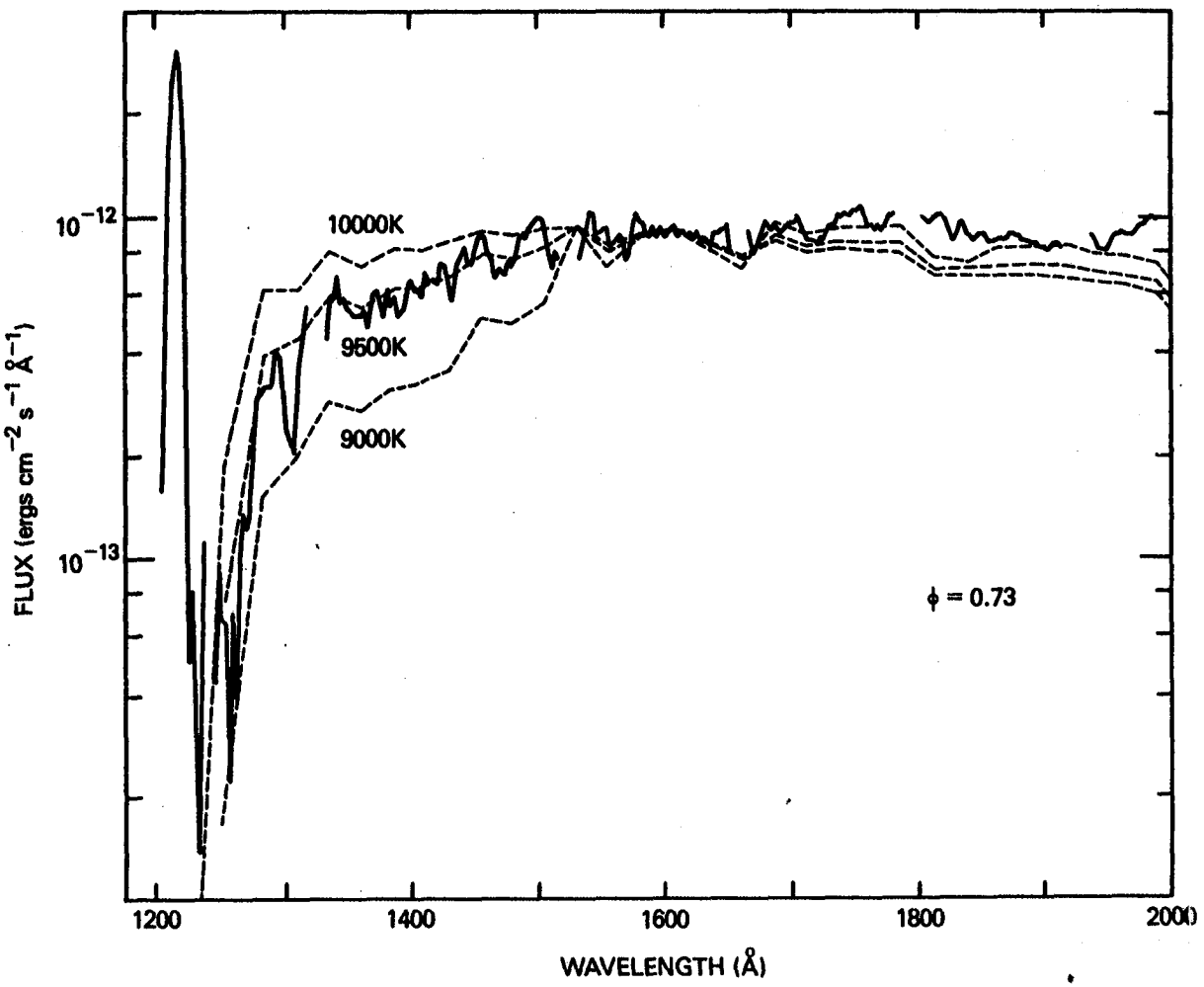

Figure 3. A comparison of the absolute flux distribution at the Earth for η Aql at phase 0.73 with reddened flux distributions from model atmospheres by Kurucz. The models have been adjusted to fit the data at 1600 Å.

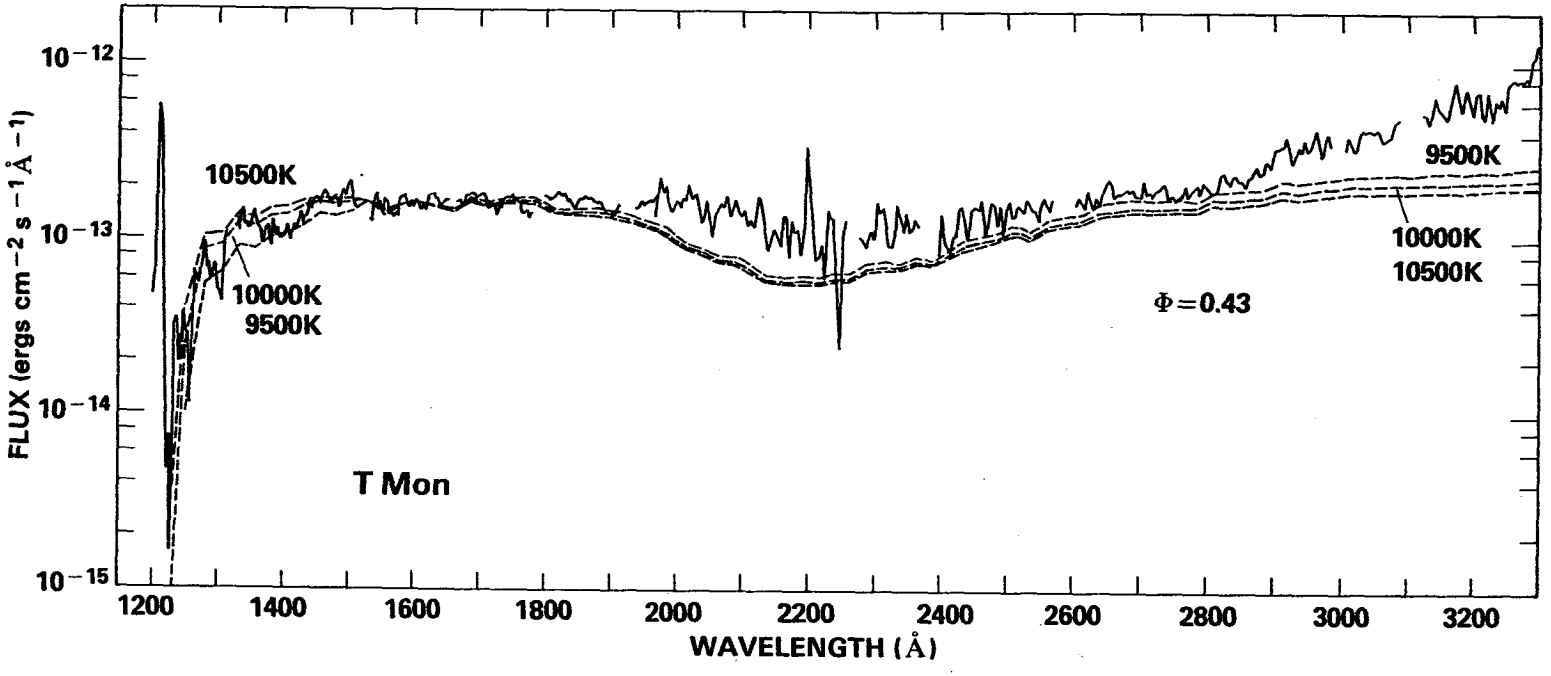

Figure 4. A comparison of the absolute flux distribution at the Earth for T Mon at phase 0.43 with reddened flux distributions from model atmospheres by Kurucz. The models have been adjusted to fit the data at 1600 Å.