IUE OBSERVATIONS OF THE 1982-84 ECLIPSE OF EPSILON AURIGAE

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INTRODUCTION

We summarize the major characteristics in the ultraviolet of the 1982-84 eclipse of Eps Aur as observed with IUE by various workers. This star can be observed over the entire IUE wavelength range, from 1200 to 3200 A, in low dispersion, allowing eclipse light curves to be obtained in broadband regions, but due to its steep spectral gradient and the sensitivities of IUE cameras, high resolution exposures adequately cover only the regions from 1700-1900 and 2400-3200 A. In many ways, the UV data confirms or expands upon interpretations of the system made from observations in other wavelength regions, but in other respects the system remains as enigmatic as before.

OBSERVATIONS

The flux from an late-A, early-F supergiant like Eps Aur drops over 2 orders of magnitude from 3200 to 1200 A. Thus it is necessary to take multiple exposures of different length to adequately cover all wavelengths. For Eps Aur in low dispersion, typically 2 exposures with each camera are needed, ranging from 7 sec to 20 minutes. In high dispersion, two LWR images with an exposure ratio of 4 are needed to optimize exposure levels in the continuum and at Mg II; for the SWP, a full shift exposure only extends to about 1700 A. Unfortunately this precludes studying astrophysically interesting high temperature lines such as C IV and Si IV if they are present.

The characteristics in low dispersion can be summarized as follows:

1. The eclipse light curve in the near UV generally follows that found in the optical region. During totality, the eclipse depth slowly increases up to third contact. The minor fluctuations in light seen optically are increasingly exaggerated in the UV from 3200 A down to about 1500 A. Shortward of this, the fluctuations become smaller in amplitude. The fluctuations occur predominantly prior to mid-totality.

2. The eclipse depth is dependent upon wavelength, increasing somewhat in depth from 3200 A to 1600 A then becoming shallower such that at 1200 A it is only 0.2 mag. deep.

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3. Two extraordinary brightenings were seen in the UV near first and third contacts. The occurrance at first contact has caused various IUE observers to find different depths of eclipse because different reference spectra were used. The brightening seen optically at mid-totality is also visible in the UV, the degree being in the same ratio as the optical/UV depth.

4. The 2200 A depression characteristic of interstellar grain absorption is consistent with published values of E(B-V) $\simeq$0.35. There is no detectable change in the dip during the eclipse.

5. Compared to other A-F supergiants, there is a UV excess shortward of 1400 A. The line spectrum, however, does not match that of a middle-B type star, and subtracting a hot continuum does not adequately explain the shallowness of the eclipse from 1400 to 1500 A.

6. The only strong emission line seen is that of O I 1304. It fluctuates by a factor of 2 during the eclipse, but too little out-of-eclipse data is available to say if this behavior is eclipse dependent.

The observations at high dispersion are more difficult to study because of the wealth of overlapping lines at IUE's resolution. Some early results are:

1. P-Cyg profiles in the Mg II doublet were revealed in the central core as the continuum faded. The profile remained essentially unaltered throughout the eclipse, the absorption core being shifted -13 km/s. During ingress, the Mg II line wings dropped more rapidly than the continuum and during egress recovered more slowly.

2. It is difficult to distinguish multiple velocity components in the UV, but some structure is reported. The radial velocity curve of the photospheric lines is nearly constant up to mid-totality, becomes more negative by about 45 km/s up to third contact, then returns to the velocity value expected from the orbital motion of the primary at the end of the eclipse.

3. The low-excitation lines of Fe II, Mn II and Cr II have stationary components that appear to be the tops of emission lines filling in the absorption cores of the stellar lines. At the constant velocity phases, they are appear on the redward side of the corresponding absorption lines.

DISCUSSION

As would be expected from the pre-eclipse observations that the UV energy distribution is still mainly dominated by the primary, the eclipse data mimics in many ways the behavior seen in the optical region. The downward slope of the light curve during totality, the superimposed light fluctuations, and the radial velocity curve are consistent with previous observations; the Mg II emission has counterparts in other regions, such as in H alpha, and is consistent with Ca II measurements. The IUE observations, however, do shed some light when interpreting this behavior.

The UV fluctuations have been interpreted as being due to aperiodic Cepheid-like pulsation of the primary (Ake and Simon 1984) or as structure in the occulting body (holes or tunnels, Parthasarathy and Lambert 1983, Boehm et al 1984). We feel the fact that variations are enhanced with decreasing wavelength down to 1500 A favors the pulsation explanation. Schimdt and Parsons (1982) find that in Cepheids a 0.5 mag. amplitude in V translates to amplitudes up to 5 mag. at 1600 A because of the extreme temperature sensitivity of the UV continuum and ionization edges in F supergiants. The strength of the O I emission in Eps Aur is also consistent with the shock-induced O I emission in Cepheids.

The opacity of the occulting body is mainly continuous (Chapman et al 1983) as most of the absorption lines in high dispersion do not change in depth nor do different lines appear during the eclipse. Some lines, however, are reported to show some structure taken to be evidence of multiple components (Ferluga and Hack 1984) and others seem to be filled in by emission peaks (Castelli et al 1982). Furthermore interstellar or circumstellar components are seen in low-excitation lines of Mg I, Mg II, Fe II, etc.

The radial velocity curve in the UV derived from the photospheric lines is somewhat consistent with that reported in the past with other eclipses. The lines are found to be blueshifted after mid-totality, but prior to mid-totality no corresponding large redshift is seen (Ake and Simon 1985).

The constancy of the Mg II emission (Altner et al 1984) and deduced emission of other low-excitation lines is characteristic of the Zeta Aur systems where a hot secondary interacts with the wind from the cooler primary and excites the circumsystem material. In these systems, when the continuum from the hot star is reduced during an eclipse, the emission lines appear with redshifted peaks due to scattering of the hot star photons off the receding gas in the wind from the primary. In Eps Aur, the "emission peaks", which remain constant as the overlying absorption deepens during the eclipse, are found on the redward side of the corresponding absorption components much as in the Zeta Aur systems.

Perhaps the most intriguing aspect of the IUE observations is the shape of the far UV energy distribution and the eclipse light curve since they provide new insight into the nature of the system. The 2200A depression does not change during the eclipse indicating that the occulting body is not composed of the types of grains typically found in the interstellar medium (Boehm et al 1984, Ake and Simon 1984). Moreover, the absence of additional line absorption implies that the occulting body is also devoid of a significant amount of gaseous material. Finally we note that the UV excess shortward of 1400 A, as reported by Hack and Sevelli (1979), is suggestive that a hot secondary has been detected, but it cannot be definitively stated to be that of a hot star (Parthasarathy and Lambert 1983, Ake and Simon 1984). The final test of the location of this added UV source will be observations at the predicted time of the next secondary eclipse.

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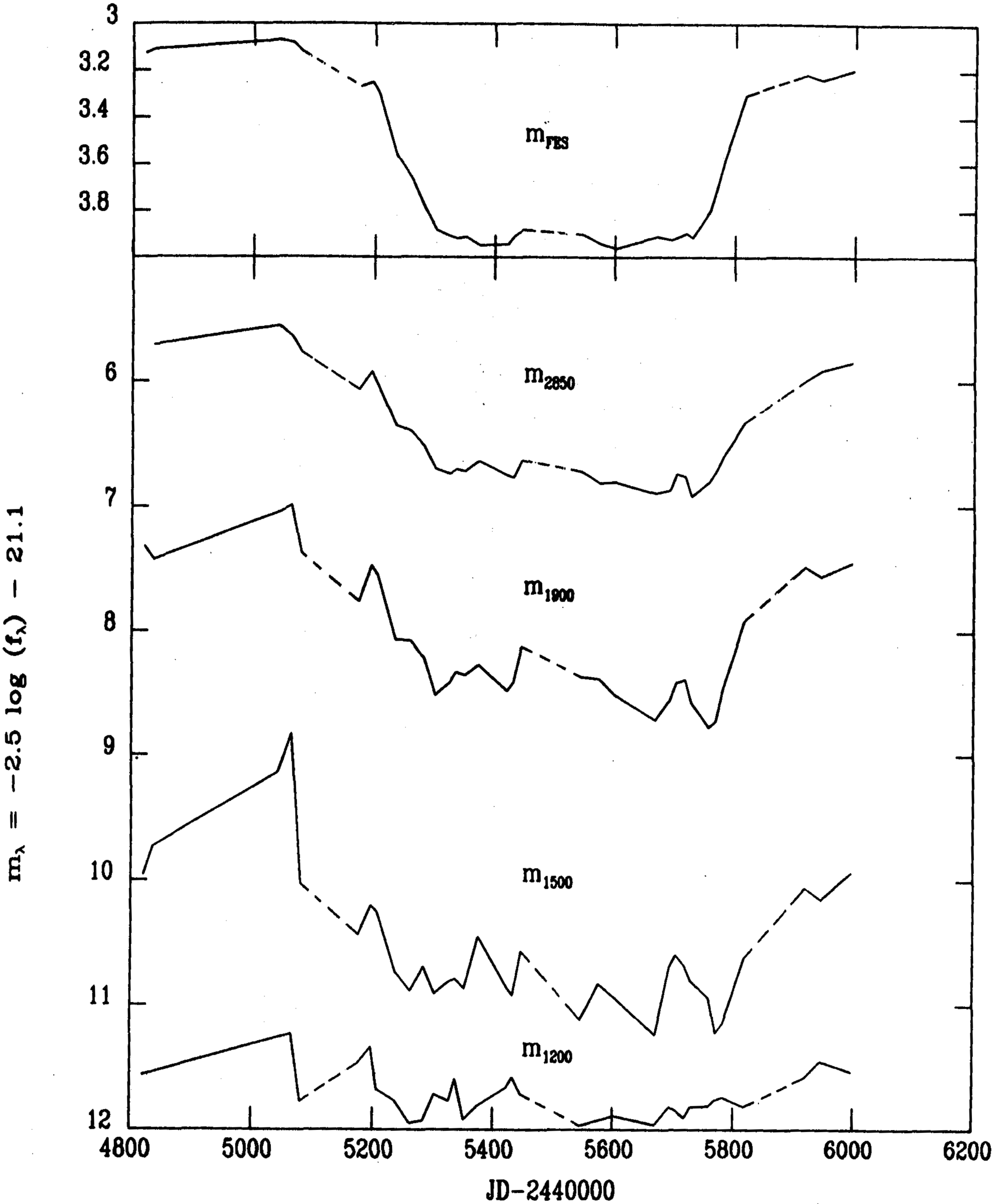

Figure 1. (Ake) Eclipse light curves for ϵ Aur as measured by IUE's Fine Error Sensor (transformed to V magnitudes) and ultraviolet regions centered at 2850, 1900, 1500 and 1260 A (converted to magnitudes on an energy scale where m_λ=0 is 3.64 x 10^{-9} ergs/cm^2/sec/A). Dotted lines indicate unobserved dates due to ϵ Aur's proximity to the Sun.