LOW COLOR TEMPERATURE VARIATIONS OVER THE COMMON ENVELOPE OF W URSAE MAJORIS AND THE CAUSE OF ITS W-TYPE LIGHT CURVE

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We discuss ultraviolet photometry of the eclipsing binary W Ursae Majoris obtained with the Groningen instruments on the Astronomical Netherlands Satellite (ANS). Fifty measurements of this star's brightness were obtained for each of the bandpasses at 2200, 2500, and 3300 Å. This new data is significantly more precise than Rucinski's OAO-2 photometry, enabling us to draw definitive conclusions about the distribution of brightness on the surface of W UMa. The ultraviolet light curves are generally similar in shape to those for optical passbands; the amplitudes are greater in the UV, while the depths of the primary and secondary eclipses are nearly equal at both 2200 and 2500 Å. We have analyzed the (2200 - 3300) color curve to determine how much the color temperature varies over the common envelope, concluding that any such temperature variations must be small. In terms of the traditional surface-brightness parameters for gravity darkening, temperature excess of the smaller component, and bolometric albedo, we find $\beta = 0.03 \pm 0.01$, $X = \Delta T/T = 0.000 \pm 0.009$, and $A_{bol} = 0.4 \pm 0.4$. Further, we conclude that the star is limb darkened considerably more at 2200 than at 3300 Å.

The new results strongly restrict the possible ways of giving W UMa a W-type light curve, i.e., one for which the eclipse of the smaller component is the deeper eclipse at optical wavelengths. They rule out the light curve model based on a general temperature excess which has been employed by a number of workers as well as the model featuring large gravity darkening espoused chiefly by R. E. Wilson. Also, we find no evidence for the high albedo or very low limb darkening needed by the light curve model of Anderson and Shu or for the temperature's being abnormally high in the region between the components as suggested by Berthier. Presently, the leading explanation of the ultraviolet and optical light variations seems to be a spot model in which at least 20% of the disc of the larger component would have to be covered with dark spots to give the W-type light curve observed at 'V'.

A full account of this work is being submitted to the Astrophysical Journal.

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DISCUSSION FOLLOWING EATON, WU AND RUCINSKI

Webbink: After seeing Andrea Dupree's UV spectra of some W UMa stars, I wonder how confident we can be that we are actually seeing continuum variations in your observations.

Rucinski: The rich emission spectrum becomes important at shorter wavelengths than used here but it will be necessary to carefully check the spectra for the presence of (variable) lines in the ANS bandpasses.

Shu: I would like to point out that in Lawrence Anderson and my light-curve paper, we suggested that spots on the primary were the most viable explanation for the W-type phenomenon. We even gave a speculative explanation of this expectation on the basis of the contact discontinuity theory.

Guinan: The light curve of W UMa appears to be unstable with changes occurring on time scales of days to years. Wouldn't this somewhat diminish the certainty of the determination of the gravity brightening exponent from an analysis of a single-epochal light curve?

Rucinski: It seems that the instabilities are caused by relatively dark spots with almost no influence on colors like the (2200-3300) color used in this analysis.

Geyer: The W UMa system TZ Boo is an extreme case for extreme light curve changes. My colleague Dr. Hoffmann has obtained a fine collection of light curves in UBV at the 42" Cassegrain reflector of Hoher List Observatory. They show not only the interchange of the depth of primary and secondary variations within a cycle of about 3.5 years, but also the color index is changing (Astron. Astrophys. Suppl., 33, 63).

Anderson: If those color observations were in the visible region, they may well show color variations at the same time your ultraviolet colors show none, since the spot appears black independent of λ for sufficiently short λ.

Rucinski then asked what wavelength bands Geyer observed, and he answered "UBV".

Budding: I would question whether your results are as clearly formed as they would appear to be. First, I think there may be some uncertainty about the relationship between color and effective temperature for these atmospheres. Second, in order to determine the gravities the actual geometric parameters have first to be known--presumably through the normal photometric solution, which I think would then be convoluted with what was assumed about gravity darkening.

Eaton: We used a flux-temperature scale based on the temperaturespectral type-bolometric correction scale of Johnson and on Wu's color-spectral class calibration for the ANS photometric system. As you suggest, this temperature scale could lead to slight systematic errors, but not to the extent of letting us fit the light wave with large gravity darkening or general temperature difference between components.

Rucinski: The geometry used was that obtained from the optical solution by Whelan, Worden, and Mochnacki (which is practically identical to solutions by other authors). The (2200-3300) color curve does not depend much on the geometry but is very sensitive to the distribution of temperature over the contact configuration.

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