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# PHOTOMETRY OF ZETA AURIGAE DURING THE 1977 AND 1979–80 ECLIPSES

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**ABSTRACT**

*UBV* photometry of Zeta Aurigae during the 1977 and 1979–80 eclipses is presented. From an analysis of the available photometry, it is concluded that the long term intrinsic variation in the brightness of the late-type super giant companion, as claimed by various investigators, is far from certain.

**Key words:** eclipsing binaries; Zeta Aurigae—*UBV* photometry—variable stars

## Introduction

The well known eclipsing binary system Zeta Aurigae, which consists of a K-type supergiant and a B-type main sequence star, has been the subject of intensive photometric and spectroscopic studies by several investigators (Wright 1970). Roach and Wood (1952) have shown that the duration of the effects of the eclipse strongly depends on the wavelength region of observation, the duration being longer at shorter wavelengths. The light loss from the early-type main sequence star has been attributed to extinction by the extended atmosphere of the late-type supergiant rather than due to occulation by an opaque body. Recently, IUE observations in the far ultraviolet show that the effects of the atmosphere of the K-type supergiant on the radiation from the B-type main sequence star can be seen spectroscopically even about seventy days prior to the detection of the effects of the eclipse photometrically (Chapman 1980). Contradictory suggestions regarding the variation of the radius of the late type companion have been made by different authors. Larsson-Leander (1961) suggested a gradual decrease of the radius of the supergiant from the variation in the depths of eclipses. However, from an analysis of the duration of totality of the eclipses, Kiyokawa (1967) proposed a gradual increase of the radius of the star, whereas Saijo and Saito (1978) prefer a periodic nonradial pulsation of the supergiant. Intrinsic variations in the brightness of the late-type companion have been reported in the literature (Larsson-Leander 1961, Bappu *et al.* 1965, Kiyokawa *et al.* 1972).

In this paper we present the results of photoelectric photometry of Zeta Aurigae in the Standard *UBV* system obtained during the 1977 and 1979-80 eclipses. The available narrow band and *UBV* photometry is analysed to see the nature of the intrinsic variations of the late type supergiant quoted in the literature.

## Observations

During the 1977 eclipse, Zeta Aurigae was observed on 29 nights before ingress, three nights during the early part of the ingress, and seven nights inside totality. Poor weather conditions and the large hour angle of the star prevented observations both during and after the egress. During the 1979-80 eclipse, the star could be observed on one night in the early period of the ingress, nine nights inside totality, three nights during the later part of the egress, and ten nights outside the eclipse after the egress. Observations could not be obtained before and during the ingress because of bad weather conditions.

Observations were made through standard UBV filters with the 34-cm Cassegrain reflector of the Kavalur Observatory. An unrefrigerated 1P21 photomultiplier together with a conventional d.c. set up, consisting of a d.c. amplifier and a strip chart recorder, was used throughout. However, a part of the 1979-80 observations were recorded on a pulse counting system. All measurements were made differentially with respect to the primary comparison Lambda Aurigae. As a secondary comparison, Two Aurigae was also observed. From the atmospheric extinction free magnitudes, obtained using the appropriate mean values of extinction coefficients, the magnitude and colour differences (in the sense, Zeta Aurigae - Lambda Aurigae) were determined. These, in turn, were transformed to the standard *UBV* system of Johnson and Morgan (Johnson 1963). Separate transformation coefficients were used for the 1977 and 1979-80 observations. The observational results are summarised in Tables 1, 2, and 3.

**Table 1.** Differential magnitude and colours of Two Aurigae

| | Present study | | Nicolet |
|---|---|---|---|
| | 1977 | 1979–80 | (1978) |
| $\Delta V$ | +0.061±0.019 | +0.065±0.003 | +0.07 |
| $\Delta(B-V)$ | +0.785±0.016 | +0.790±0.004 | +0.76 |
| $\Delta(U-B)$ | +1.378±0.029 | +1.439±0.003 | +1.46 |

Table 1 gives the differential magnitude and colours of Two Aurigae with respect to Lambda Aurigae obtained by us (in the sense, Two Aurigae - Lambda Aurigae). Similar values derived from the catalogue of Nicolet (1978) are also given for a comparison with our results The $\Delta V$ and $\Delta(B-V)$ values of the two determinations and the $\Delta(U-B)$ values obtained during the 1979-80 observing run agree well with those derived from the catalogue. The disparity of about $0^m.05$ in the $\Delta(U-B)$ values is probably due to the less accurate determination of the slope of the $(U-B)$ calibration in 1977.

The differential magnitudes of Zeta Aurigae in *UBV* obtained during the 1977 and 1979-80 eclipses are given in Tables 2 and 3. Each value given in the Tables is a mean of 2.3 independent measurements. Figs. 1 and 2 are plots of these.

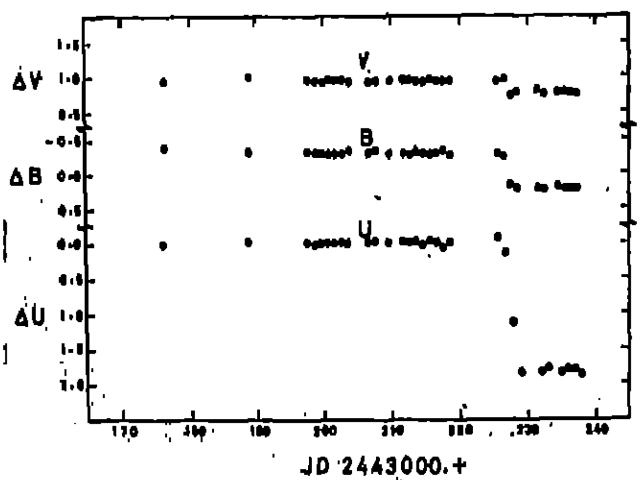


Fig. 1. *UBV* light curves of Zeta Aurigae during the 1977 eclipse

**Table 2.** Differential *UBV* magnitudes of Zeta Aurigae during 1977 eclipse.

| JD | $\Delta U$ | $\Delta B$ | $\Delta V$ |
|---|---|---|---|
| 2443000.+ | | | |
| 145.348 | −0.014 | −0.350 | −0.958 |
| 149.285 | −0.043 | −0.364 | −0.978 |
| 150.226 | −0.072 | −0.355 | −1.012 |
| 152.247 | +0.033 | −0.341 | −0.983 |
| 153.186 | +0.022 | −0.327 | −0.970 |
| 154.256 | +0.047 | −0.315 | −0.991 |
| 156.118 | −0.012 | −0.319 | −0.988 |
| 157.084 | +0.034 | −0.318 | −0.983 |
| 165.220 | +0.009 | −0.329 | −1.018 |
| 176.234 | −0.001 | −0.384 | −0.950 |
| 189.078 | +0.031 | −0.332 | −1.024 |
| 197.986 | +0.015 | −0.344 | −0.988 |
| 199.183 | −0.002 | −0.321 | −0.972 |
| 200.178 | +0.009 | −0.302 | −0.953 |
| 201.187 | +0.018 | −0.295 | −0.997 |
| 202.159 | +0.017 | −0.317 | −0.981 |
| 203.131 | +0.022 | −0.306 | −0.990 |
| 204.203 | +0.003 | −0.365 | −0.965 |
| 207.116 | +0.011 | −0.323 | −0.965 |
| 208.122 | +0.021 | −0.272 | −0.978 |
| 210.147 | +0.014 | −0.315 | −0.987 |
| 212.137 | +0.025 | −0.325 | −0.993 |
| 213.148 | +0.019 | −0.302 | −0.990 |
| 214.174 | +0.039 | −0.355 | −0.984 |
| 215.176 | −0.016 | −0.332 | −0.965 |
| 216.145 | +0.047 | −0.320 | −1.018 |
| 217.142 | +0.014 | −0.337 | −0.985 |
| 218.144 | −0.070 | −0.371 | −0.988 |
| 219.153 | +0.011 | −0.308 | −0.988 |
| 226.088 | +0.073 | −0.317 | −0 988 |
| 227.108 | +0.137 | −0.277 | −1.014 |
| 228.165 | +1.130 | +0.153 | −0.779 |
| 229.094 | +1.846 | +0.182 | −0.815 |
| 232.012 | +1.861 | +0.212 | −0.854 |
| 233 098 | +1.793 | +0.217 | −0.794 |
| 235.682 | +1.852 | +0.175 | −0.823 |
| 236.090 | +1.806 | +0.205 | −0.830 |
| 237.076 | +1.820 | +0.200 | −0.821 |
| 238.086 | +1.897 | +0.199 | −0.807 |

## Discussion

No meaningful deductions of the times of contact or the duration of totality can be made due to the scantiness of the observations. The mean depths of the 1977 eclipse are $1^m.831$ in *U*, $0^m.529$ in *B*, $0^m.163$ in *V* while that of the 1979-80 eclipse are $1^m.952$ in *U*, $0^m.509$ in *B*, and $0^m.134$ in *V*. The depths of the two eclipses in *V* and *B* agree well with each other and are close to those of the 1963-64 eclipse. The depth of the 1979-80 eclipse in *U* is also close to the 1963-64 eclipse value, whereas that of the 1977 eclipse differs by $\sim 0^m.1$ (See Table 4). We suspect the likelihood of an error in (*U—B*) transformation of 1977, since the Δ (*U—B*) values of Two Aurigae and Lambda Aurigae obtained during the two observing runs also differ by a similar quantity.

Table 3. Differential *UBV* magnitudes of Zeta Aurigae during 1979-80 eclipse

| JD | Δ*U* | Δ*B* | Δ*V* |
|---|---|---|---|
| 2444000.+ | | | |
| 199.331 | +0.315 | −0.228 | −0.957 |
| 199.462 | +0.311 | −0.254 | −0.944 |
| 206.367 | +1.964 | +0 175 | −0.884 |
| 208.387 | +2 007 | +0.231 | −0.830 |
| 209.370 | +2.031 | +0.227 | −0.825 |
| 210.371 | +2.015 | +0.290 | −0.828 |
| 225.374 | +1.924 | +0 218 | −0.821 |
| 226.317 | +1.869 | +0.216 | −0 815 |
| 229.326 | +1.951 | +0.147 | −0.808 |
| 230.335 | +1.920 | +0.211 | −0.767 |
| 237.361 | +1.981 | +0.210 | −0.809 |
| 238.319 | +1.851 | +0.166 | −0.822 |
| 239.139 | +0.565 | −0.166 | −0.805 |
| 239.146 | +0.538 | −0.186 | −0.825 |
| 239.225 | +0.466 | −0.201 | −0.928 |
| 239.276 | +0.419 | −0.219 | −0.940 |
| 239.367 | +0.364 | −0.236 | −0.937 |
| 239.401 | +0.335 | −0.233 | −0.934 |
| 240.085 | +0.182 | −0 264 | −0.947 |
| 240.157 | +0.180 | −0.262 | −0.947 |
| 240.188 | +0.163 | −0.263 | −0.927 |
| 240.272 | +0.146 | −0.285 | −0.951 |
| 240.347 | +0.141 | −0.269 | −0 933 |
| 241.150 | +0.092 | −0.280 | −0.924 |
| 241.269 | +0.088 | −0.296 | −0.940 |
| 241.326 | +0.090 | −0.273 | −0.958 |
| 244.331 | +0.022 | −0.293 | −0.951 |
| 245.280 | +0.035 | −0.278 | −0.944 |
| 249.231 | −0.066 | −0.293 | −0.976 |
| 251.296 | +0.014 | −0.274 | −0.935 |
| 254.304 | −0.018 | −0 306 | −0.968 |
| 258.304 | +0.022 | −0.289 | −0.936 |
| 262.269 | −0.022 | −0.328 | −0.982 |
| 264.267 | −0.023 | −0.311 | −0.966 |
| 266.264 | +0.016 | −0.274 | −0.941 |
| 269.280 | +0.006 | −0.305 | −0.948 |

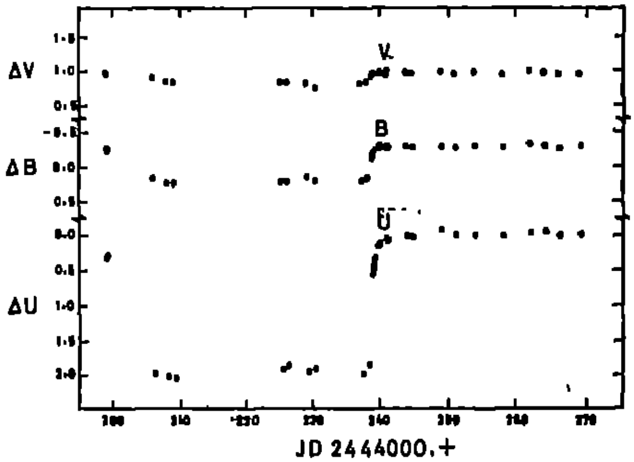


Fig. 2. *UBV* light curves of Zeta Aurigae during the 1979–80 eclipse

Based on the observed differences in the depths of eclipses various authors have concluded that the K-type supergiant is intrinsically variable (Larsson-Leander 1961, Bappu *et al.* 1965, Kiyokawa *et al.* 1972). To have an idea about the nature of the variation and the time scales involved, we have compiled the depths of eclipses published so far. The details are given in Table 4. Observations in the *UBV* system only are included. It is evident from the Table that there is no consistency in the depths (for the same eclipse) quoted by several investigators. The inconsistency in the observational results seems mainly due to the errors involved in the transformation to *UCV*. It is, therefore, difficult to establish conclusively the variability of the late type supergiant companion unless more accurate observations are forthcoming. The various problems in combining results obtained in different photometric systems have already been discussed, in detail, by Roach and Wood (1952). Since observations in narrow band filters do not have the problems associated with the transformation, a comparision of depths of eclipses obtained in interference filters by different investigators would be more meaningful. Depths of eclipses obtained through interference filters along with their respective peak wavelengths, available in the literature, are given in Table 5 and are plotted in Fig. 3. There is good consistency in the depths of eclipses observed by different authors. Hence, long term intrinsic variations in the brightness of the late type supergiant, as claimed by the various investigators based on the observed differences in the depths of eclipses in *UBV*, is far from certain. But this does not rule out the possibility of short period fluctuations of the type observed by

Table 4. Depths of eclipses observed in *UBV*

| Eclipse | U | B | V | Reference |
|---|---|---|---|---|
| 1955-56 | 1.930 | 0.510 | 0.120 | Grant and Abt (1959) |
| | 2.000 | 0.540 | 0.140 | Popper (1961) |
| | — | 0.549 | 0.146 | Larsson-Leander (1961) |
| 1958 | — | 0.529 | 0.120 | Larsson-Leander (1961) |
| 1963-64 | 1.970 | 0.540 | 0.116 | O'Connell (1964) |
| | 1.930 | 0.540 | 0.150 | Shao (1964) |
| | 1.871 | 0.505 | 0.124 | van Genderen (1964) |
| | — | 0.580 | 0.160 | Bappu *et al* (1965) |
| | 1.964 | 0.560 | 0.154 | Kiyokawa (1967) |
| 1971-72 | 2.216 | 0.622 | 0.191 | Kiyokawa *et al.* (1972) |
| | 1.930 | 0.500 | 0.110 | Sanwal *et al* (1973) |
| | 2.108 | 0.584 | 0.170 | Lovell and Hall (1973) |
| 1977 | 1.831 | 0.529 | 0.163 | Present study |
| 1979-80 | 1.952 | 0.509 | 0.134 | Present study |
| Mean | 1.973 ± 0.072 | 0.543 ± 0.023 | 0.143 ± 0.016 | |

Table 5 Depths of eclipses observed through interference filters

| Eclipse | Wavelength (Å) | Depth of eclipse (mag) | Reference |
|---|---|---|---|
| 1955-56 | 3860 | 1.868 | |
| | 4250 | 0.960 | |
| | 4930 | 0.226 | Wood and Blitzstein (1957) |
| | 5250 | 0.203 | |
| 1963-64 | 3529 | 2.009 | |
| | 3850 | 1.891 | O'Connell (1964) |
| | 4229 | 0.951 | |
| 1963-64 | 3540 | 2.024 | |
| | 3855 | 1.903 | Kondo and Harris (1964) |
| | 4240 | 0.947 | |
| 1963-64 | 3930 | 1.694 | |
| | 4730 | 0.330 | Fracastoro and Catalano (1965) |
| | 5540 | 0.128 | |
| | 6450 | 0.060 | |
| 1971-72 | 3552 | 2.124* | |
| | 4243 | 0.919 | Kiyokawa and Kitamura (1973) |
| | 5012 | 0.236 | |
| 1977 | 3500 | 2.074 | |
| | 4170 | 1.049 | Saito *et al* (1978) |
| | 5080 | 0.264 | |

* Depth was incorrectly evaluated by the authors as 2.266

Bappu *et al.* (1965) during totality and which needs to be examined by the methods of monochromatic photometry on future occasions.

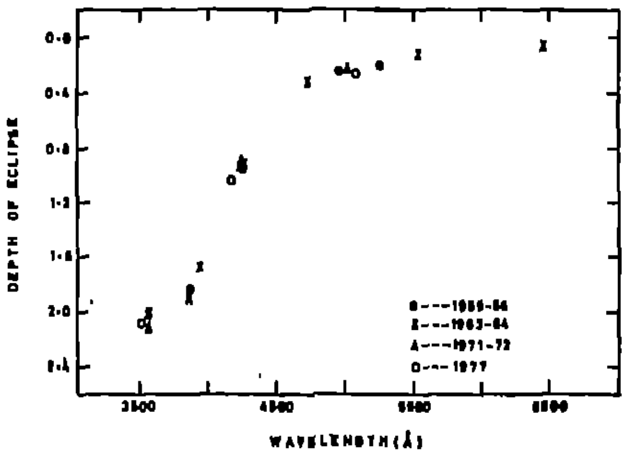


Fig. 3. Variation of the depth of eclipse with wavelength

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