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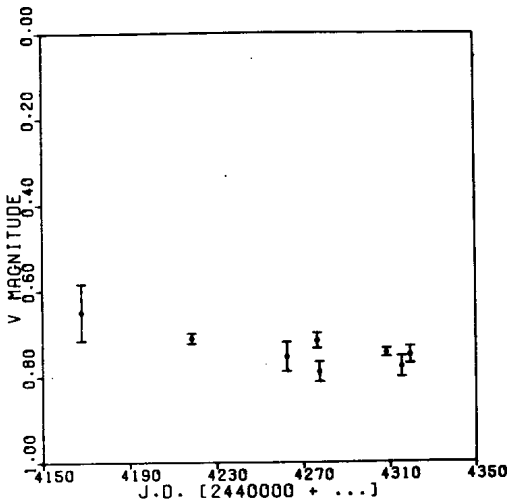
BV PHOTOMETRY OF BETELGEUSE OCT 1979 TO APR 1981

We present BV photometry of Betelgeuse (= α Ori = BS 2061) made by the author with a 15-cm f/6 Newtonian reflector in San Jose, California (latitude N 37° 15' 26" ; longitude W 121° 55' 43" ; elevation 70 meters above sea level). The photometer was designed and built by the author. It uses an uncooled RCA 931A photomultiplier tube, operated at -1000 volts, and standard UBV filters.

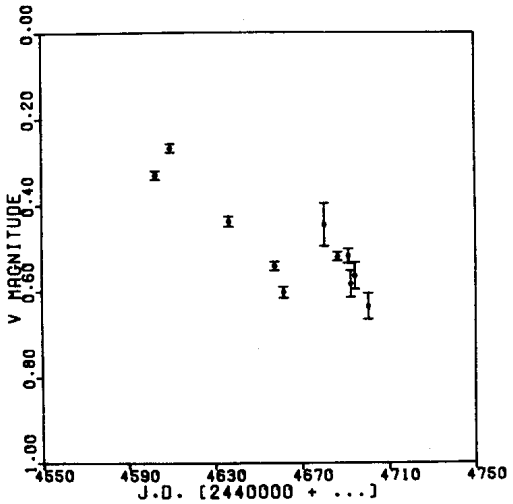
Table I gives 19 V magnitudes and 9 B-V colors for Betelgeuse. The 1979-1980 data generally represent two differential measurements of Betelgeuse with respect to the comparison star, which in all cases was γ Ori (= BS 1790), while the 1980-1981 data are averages of three differential measurements (except for JD 2444680, when only two measurements were made under poor seeing conditions). The column labeled ΔX in Table I is the difference in air mass between Betelgeuse and γ Ori. For γ Ori V = 1.64, B-V = -0.22 (Table 9 of Johnson et al. 1966). We often obtained the raw data directly from readings of the amplifier's ammeter, but some data were reduced from strip chart tracings. Dates for which strip chart data were taken are marked by an asterisk in Table I. The V magnitudes for the two seasons' data are plotted in Figures 1a and 1b.

We reduced the data according to the usual method of differential photometry (Equations 28a and 28b of Hardie 1962). This procedure gives differential values (ΔV, $\Delta(B-V)$); our final reduction step was simply to add these differential data to the V magnitude and B-V color of the comparison star.



1979-1980

Figure 1.a



1980-1981

Figure 1.b

Fig. 1 Standardized V photometry of Betelgeuse made by the author in two successive observing seasons. The data are taken from Table I. The error bars are one standard deviation errors based on the scatter of the raw differential measurements, using γ Ori as comparison star.

Table I

Photometry of Betelgeuse

Julian Date (2440000 +)	V		B-V		ΔX
4167.856	0.65	± 0.07			+0.20
4218.812	0.71	0.01			+0.03
4262.725	0.76	0.03			0.00
4276.694	0.72	0.02			-0.01
4277.731	0.79	0.02			-0.05
4308.677	0.75	0.01			-0.09
4315.708	0.78	0.02			-0.19
4319.693	0.75	0.02			-0.18
4602.767	0.33	0.01	1.89	± 0.02	+0.02
*4609.654	0.27	0.01	1.86	0.03	+0.17
*4636.678	0.44	0.01	1.85	0.01	+0.02
*4657.696	0.54	0.01	1.85	0.01	-0.05
4661.782	0.60	0.01	1.85	0.03	-0.28
*4680.661	0.45	0.05			-0.09
*4686.666	0.52	0.01	1.86	0.02	-0.13
*4691.679	0.52	0.01	1.84	0.01	-0.19
*4692.663	0.58	0.03	1.85	0.01	-0.16
*4694.674	0.57	0.03	1.87	0.01	-0.21
*4700.677	0.64	0.03			-0.22

For the 1979-1980 observations our transformation coefficient ε = -0.072 ± 0.011 . For the 1980-1981 observations with a different photomultiplier tube the appropriate transformation coefficients were ε = -0.050 ± 0.005, μ = 0.957 ± 0.007 . Though we directly measured B-V colors on half the nights, we used $\Delta(B-V)$ = 2.06 (from data in Table 9 of Johnson et al. 1966) to derive all our differential magnitudes (ΔV's) using Hardie's Equation 28a.

The data were reduced using mean atmospheric coefficients appropriate to our site of k_v = 0.52 mag/air mass and k'_{bv} = 0.37 mag/air mass. (We assumed k''_{bv} = -0.03 air mass^{-1}.)

In Table I the errors quoted are one standard deviation errors (of the mean) based on the scatter of the raw differential data. The data reduction terms were calculated to the nearest 0.001 mag, and the results in Table I are rounded off to the nearest 0.01 mag. Given the uncertainty of the transformation coefficients ε and μ and the effects of differential extinction

and reddening, the individual standardized magnitudes and colors have typical probable errors of about $\pm$ 0.03 mag. The relative data for each season (particularly when the strip chart recorder was used) would be accurate to $\pm$ 0.02 mag or better. Data obtained when Betelgeuse and γ Ori were near the meridian ($|\Delta X| < 0.05$) are to be considered the most reliable.

We find from the data in Table I that the B-V color of Betelgeuse was constant to $\pm$ 0.01 mag on 7 of the 9 nights it was measured; on the other two nights the data are only 0.04 and 0.02 mag redder -- probably not significant differences given the accuracy of the data. Averaging the values for all 9 nights gives $\langle B\text{-}V \rangle = 1.86$. For Betelgeuse, Johnson et al. (1966, Table 9) give $\langle B\text{-}V \rangle = 1.84$, but individual B-V values in their Table 4 range from 1.829 to 1.891 . Any difference between our mean color and theirs is most likely due to a slight error in our derived μ coefficient.

Figure 1a shows that the V magnitude of Betelgeuse was essentially constant in the winter of 1979-1980; excluding the first point we found $\langle V \rangle = 0.75$. Skillman (1981) measured Betelgeuse vs. γ Ori on 5 nights in January-March 1980 and found Betelgeuse constant to $\pm$ 0.02 mag. His data lead to $\langle V \rangle = 0.73$ and support our conclusions about the luminosity of Betelgeuse in the winter of 1979-1980.

Figure 1b clearly shows variations of up to half a magnitude in V with respect to the previous season's data. These data and the degree of variation compare well with the values given by Johnson et al. (1966, Table 4). They list eight V magnitudes which range from 0.726 to 0.320 . The degree of irregular variation and the associated time scale (a couple months) are typical of an SRc (semi-regular supergiant of late spectral class) variable star, as Betelgeuse is indeed classified (Kukarkin et al. 1969).

We encourage further monitoring of Betelgeuse with photometric equipment. Such photometry, combined with other types of data, will tell us useful things about Betelgeuse and other late-type stars. For example, from polarimetry

data Hayes (1981) finds evidence for the growth of a surface feature on Betelgeuse in the interval November 1980 to February 1981 (when we measured a half-magnitude brightening). From speckle interferometry data Goldberg et al. (1981) also found evidence for the growth of a surface feature at the same time. It is exciting that this type of activity on Betelgeuse was measured by three very different experiments.

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