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OUTBURSTS OF THE Be STAR ω ORIONIS DURING 1987 - 1989

The bright Be star ω Orionis (HR 1934; m_v = +4.50 mag; B3 IIIe; vsini= 160 kms^{-1}) was the subject of photoelectric observations at the Villanova University Observatory since 1981. A discussion of the properties of the star have been given in Guinan and Hayes (1984), Sonnenborn et al. (1988) and references therein. The photometric observations of ω Orionis reported here were conducted on 25 nights from 1987 October through 1989 April using the 38-cm reflector. The photoelectric photometer is equipped with a thermoelectrically cooled (-20C) EMI 9658 photomultiplier and a microprocessor-controlled integrating system (McCook and Maloney 1979). A pair of Hα intermediate- and narrow-band filters and two intermediate-band filters centered at λ4530 and λ5500 were used. The characteristics of the filters have been given previously by Guinan and Wacker (1985).

The observing sequence was the usual pattern of *sky - comparison - variable - comparison - sky* with each observation lasting 20 seconds. The stars were typically observed for about 45 minutes each night. The comparison star was 38 Ori (HR 1839; A2 V; m_v = +5.36), and 32 Ori (HR 1839; B5 V; m_v= +4.20) served as the check star. The effects of differential atmospheric extinction were removed, using seasonal mean extinction coefficients or directly determined extinction coefficients when the star was observed at high airmass. At a level of $^{+}$0.008 mag, no significant light variations were detected between the comparison and check stars on the several nights in which both stars were observed.

Nightly mean differential magnitudes were computed from the data. Also the differential color index, $\Delta(b-r)'$ was formed from the intermediate-band blue (λ4530) and red (λ6600) differential magnitudes and is given by: $\Delta(b-r)'_{v-c} = \Delta m_{\lambda 4530} - \Delta m_{\lambda 6600}$. The (b - r) color index is similar to the (B - R) or (B - V) color indices of the UBVRI system. The differential α-index was also formed from the Hα narrow- and intermediate-band observations and transformed to the standard Villanova α-system (see Baliunas et. al., 1975). The α-index provides a measure of the net strength of the Balmer Hα feature. Figure 1 shows a plot of the intermediate-band λ6600 observations and the $\Delta(b-r)'$ and $\Delta\alpha$ indices.

As shown in the figure, monitoring of the star began in Fall 1987 on JD 2447094 (October 12 UT 1987) with the star 0.1 mag brighter (in red) than the quiescent brightness level. The

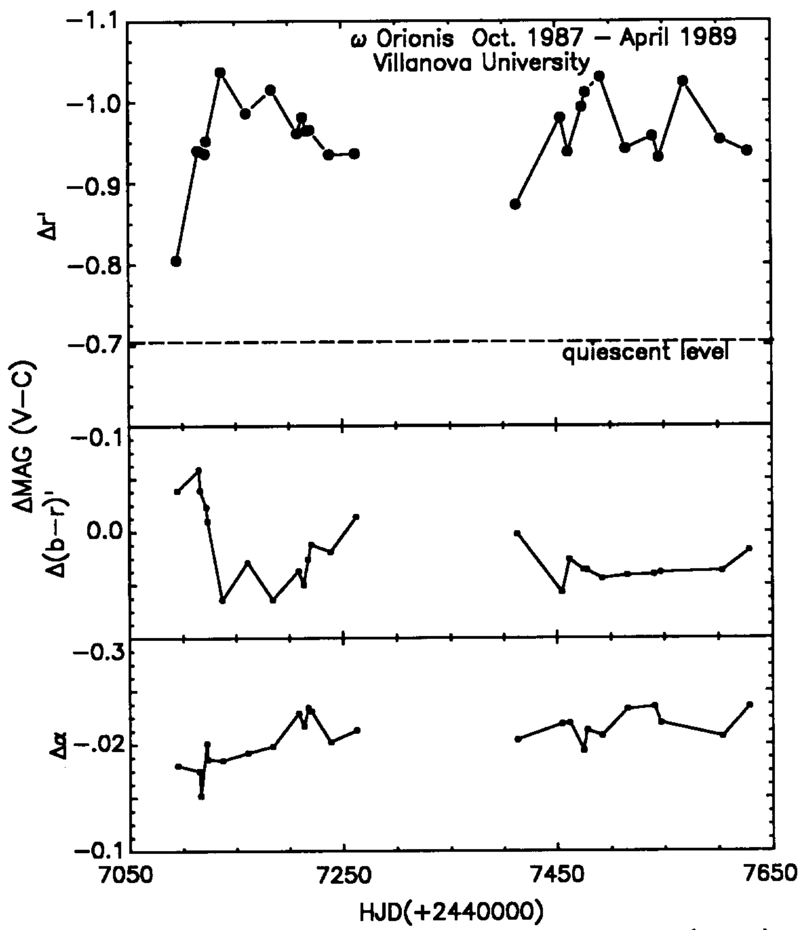

Figure 1. A plot of the nightly mean differential red (λ6600) magnitudes, (b – r) – colors, and α–indices of ω Ori is shown. The light level when the star is quiescent is indicated in the upper panel. A numerical decrease in the α–index indicates an increase in Hα emission.

quiescent brightness level was determined over the last 6 years of observations ($<\Delta r>_q$= -0.71 mag). Its brightness then increased during the next several weeks to a maximum value of Δr = -1.04 mag. After JD 7136 (December 7 UT 1987) the brightness of the star then decreased irregularly over the next four months to the end of the spring 1988 observing season. Several months later in September 1988 when observations resumed, the brightness of ω Ori was 0.06 mag fainter than the last observation of the previous season, but still 0.16 mag brighter than its quiescent value. After JD 7412 the brightness of the star increased until it achieved maximum brightness (Δr = -1.02 mag) on JD 7491 (November 26 UT 1988).

The brightness then decreased by about 0.09 mag until on JD 7569 (February 11 UT 1988) when a secondary event apparently occurred and the star's brightness increased (Δr = -1.02 mag). Afterwards the brightness of the star decreased slowly through the end of April 1989. From our data the two major outbursts were separated by 11 months. Observations made at Villanova since 1981 show a recurrence of outbursts with a mean interval of 10 months. However, the duration of the outburst observed in 1988/89 was longer and more complex than previous events monitored at Villanova, possibly because this outburst consisted of two separate events.

The $\Delta(b-r)'$ color index is plotted in the middle panel of Figure 1. It is apparent from the figure that there is a good correlation between the brightness and the color index in the sense that during the light maximum the star is reddest and when it is faintest the star is bluest. This indicates that the relative light augmentation is greater in red than in blue. If we assume that the increase in brightness of ω Orionis is due to a mass ejection episode, then the observed color change during the outburst indicates that the ejected gas is initially optically thick and cooler than the star's photosphere.

In the lower panel of Figure 1 the differential α-index is shown. From the definition of the $\Delta\alpha$-index, a numerically smaller value indicates a relative increase in the Hα emission line strength or a relative decrease in the absorption line strength. A value of the $\Delta\alpha$ = -0.10 corresponds to no net Hα emission for a star of the same spectral class of ω Ori. For the 1987/88 event as the brightness of the star increases there is no corresponding significant change in the $\Delta\alpha$-index. However, after maximum brightness the $\Delta\alpha$-index gradually decreases (indicating increased Hα emission) reaching a minimum value 70-90 days later. For the 1988/89 event the increase in Hα emission after the outburst is not as well defined possibly because of a second event taking place 100 days after the initial outburst. The apparent phase lag of the peak in the net Hα emission occurring 2-3 months after an outburst is apparent in the data obtained from prior years. Since in the envelope models for Be stars (e.g. Poekert and Marlborough 1978) the Hα emission arises further out in the envelope than does the continuum emission, it therefore may not be to surprising to see a temporal lag in the Hα emission. The increase in the net Hα emission a few months after the initial outburst could be caused by the thinning out of the ejected gas and a decrease in its optical depth with time.

These observations appear to be generally consistent with current models of Be stars (c.f. Underhill and Doazan 1982). The most interesting result of our long-term monitoring program is the 8-11 month interval seen between major outbursts. However, the mechanism producing the apparent cyclic recurrence of outbursts in ω Orionis still needs to be investigated theoretically.

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