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LIGHT, COLOR, AND H-ALPHA LINE VARIATIONS OF RIGEL

Rigel (Beta Ori, HR 1713, HD 34085) is a luminous, blue supergiant ($M_V \approx -7$; B8 Ia) which is one of the brightest stars visible in the sky. Plaskett (1909) reported that Rigel varied in radial velocity by ≈ 8 km/s with a period of 21.9 days. Subsequent spectroscopic studies (e.g. Sanford 1948 and Crivellari et al. 1979) confirm the variability in velocity but indicate that the velocity variations are not periodic at least in a simple way. Photometry of Rigel carried out by Stebbins (1930) and Brodskaya (1950) show it to vary irregularly in brightness with a mean light range (at blue wavelengths) of ≈ 0.07 mag.

Photoelectric photometry of Rigel was carried out on 18 nights from September-December 1984. The observations were made with the 38 cm reflector of Villanova University which is equipped with a thermoelectrically cooled EMI 9658 photomultiplier. A description of the instrumentation is given elsewhere (e.g. Guinan et al. 1982). A pair of narrow and intermediate - band interference filters, centered near the rest wavelength of the Balmer H-alpha line, and intermediate - band blue (λ 4530) and yellow (λ 5500) filters were used. The H-alpha filter pair permits a measure of the net strength of the H-alpha line feature to be determined in the form of an alpha-index:

$$\text{alpha-index} = -2.5 \log (F_n/F_i) + \text{constant}$$

where F_n and F_i are the fluxes through the narrow and intermediate-band H-alpha filters, respectively. Observation of a number of standard stars permits the instrumental alpha-indices to be transformed to the Villanova alpha-system (Baliunas, Ciccone and Guinan 1975). Because of the extreme apparent brightness of Rigel ($m_V \approx +0.2$ mag.), a neutral density filter was employed, when observing the variable star. The neutral density filter reduces the light by 4.968 mag and 4.916 mag for the blue and yellow filters and by 4.889 for the H-alpha filter pair.

Differential photometry was made with respect to a fainter comparison star (HR 1704;V = +6.37; B5 V) which is within 20' of the variable star. The comparison star and adjacent sky-background measures were obtained without

the neutral density filter. Because of the angular proximity of the comparison and variable stars, the differential extinction corrections were insignificant. Typically, the observations were made once a night for about 45-60 minutes when the star was near the meridian. Nightly mean differential magnitudes were formed from the data and differential color and H-alpha indices were calculated. The yellow observations are plotted in Figure 1 along with the differential color index $\Delta(b-r)' = \Delta m(\lambda 4530) - \Delta m(\lambda 6600)$, and the differential alpha-index.

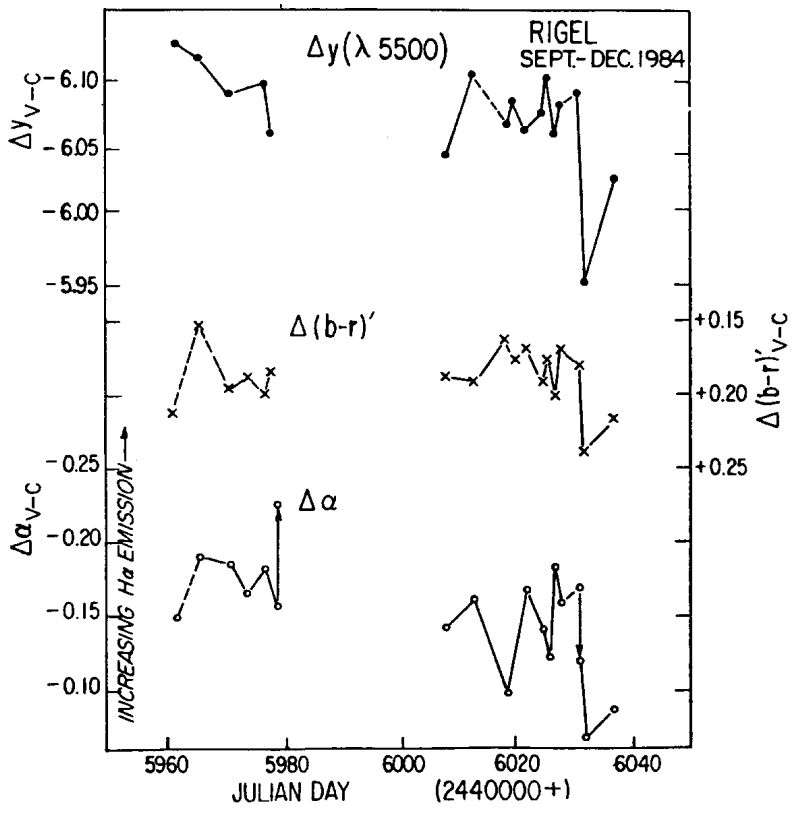

Figure 1: The photoelectric observations of Rigel made with respect to the comparison star, HR 1704, are plotted. The filled circles are the intermediate band yellow observations, the crosses are the differential $\Delta m\lambda 4530 - \Delta m\lambda 6600$ color indices, and the open circles are the differential alpha-indices. More negative values of the differential alpha index indicate increased net emission at H-alpha.

As shown in the figure, the yellow (5500) observations show irregular fluctuations in brightness on time-scales of one day to several days with a maximum range of light of $\approx$0.16 mag. The behavior of the star at blue and red wavelengths is similar to that at the yellow wavelength. Small variations in the Δ(b-r)' color index also occur with a maximum range of $\approx$0.05 mag., and having timescales of a few days. Generally the color changes show no definite correlation with the brightness variations. The relatively large negative values observed for the differential alpha index (Δalpha $\approx$-0.07 to -0.22) indicate that H-alpha emission is always present and that it is highly variable in strength. If the variable star had no H-alpha line emission, we estimate that the differential alpha-index (no H-alpha emiss.)$\approx$ +0.01 mag. Although the timescales of the variations in the alpha-index are similar to those of the brightness and color variations, there appear to be no definite correspondence among these quantities. Moreover, there is evidence that at least on two nights (JD 2445977 and JD 2446030) the level of H-alpha emission changed significantly over an interval of less than one hour. No corresponding variations in light or color were found to occur on these nights.

An abrupt decrease in brightness of about 0.13 mag. was observed over an interval of just one day (i.e. from JD 2446030.67 to JD 2446031.74). This event was accompanied by an increase in the color index of +0.06 mag. and an increase of +0.05 in the alpha index. Thus, during this time the star decreased in brightness while its color reddened and the net H-alpha emission line strength decreased. One possibility that explains these rapid changes is the ejection of gas from the star toward the observer. The cooler expanding gas temporarily obscures a portion of the star's photosphere, causing the net brightness to diminish, the color index to become redder, and the net H-alpha line absorption to become stronger.

In summary, the observed irregular variations in brightness, color and in the H-alpha line strength indicate the complex and unstable nature of Rigel's atmosphere. No periodicities were uncovered from the present data set in accord with the results of the modern radial velocity investigations and previous photometry. Moreover, there is evidence that the H-alpha line emission is variable on relatively short time scales. Further observations are planned and a more detailed discussion of the results will be presented elsewhere.

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