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THE SPECTRUM OF R CORONAE AUSTRALIS

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SUMARIO

El espectro de R CrA presenta peculiaridades que hacen muy difícil clasificarlo en el sistema MK. La línea K de Ca II y las líneas de hidrógeno dan un tipo espectral A5, aproximadamente. La estrella muestra algunas características de envolvente (shell) con Ti II muy intenso, en particular las líneas λλ3759-61. Hay emisiones en H-alfa y otras líneas de Balmer. También las líneas de Fe II muestran una emisión débil. Todo junto nos hace clasificar al espectro de R CrA como una A5pe. La velocidad radial derivada de todas las líneas en absorción bien identificadas es −28 km/seg. en buen acuerdo con el valor publicado en el Catálogo General de Velocidades Radiales de Wilson.

ABSTRACT

The spectrum of R Cra cannot be classified uniquely in the MK system. However, the K-line of Ca II and some hydrogen lines indicate a spectral type earlier than A7, perhaps A5. Shell characteristics, with extremely strong Ti II (specially λλ3759-61) are observed. Emissions are present at H-alpha and other Balmer lines. The Fe II-lines show weak emissions. Altogether the spectrum of R CrA can be described, approximately, as an A5pe. A radial velocity of −28 km/sec. is derived from all well-identified absorption lines. This value agrees well with that given in Wilson's General Catalogue of Stellar Radial Velocities.

Introduction

R Coronae Australis is imbedded in the cone-shaped nebula NGC 6729. A brief description of the spectra of both the star and the nebula is given by Greenstein (1948).

Eight T Tauri-like objects, including one flare star (Hardy and Mendoza, 1969), are located in a rather small area centered on NGC 6729. Probably all these objects belong to the same stellar association.

The observations

One of us (E.E.M.V.) observed R CrA photometrically and spectroscopically. The multicolor photometry covers the wavelength range from 0.36 to 5.0 microns. The results of this photometry are given elsewhere (Mendoza 1968, 1969). Spectra were obtained in the blue and red spectral region. One spectrum on a IIa-0 emulsion was obtained with the Cassegrain spectrograph attached to the 60-inch of the Cerro Tololo Inter-American Observatory, in March 1968. A reproduction of this spectrum is shown in Figure 1. Two red spectra were obtained with the nebular spectrograph

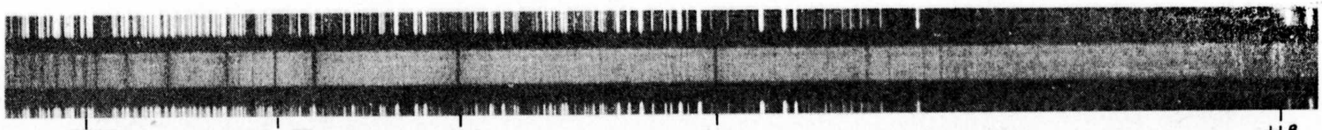

Fig. 1.—*The blue spectrum of R CrA. Original dispersion 78 Å/mm.*

attached to the 60-inch telescope of the Observatorio Astronomico of the University of Cordoba in August 1968. The dispersion of the blue spectrum is 78 Å/mm and that of the red plates is 240 Å/mm. The emulsion used in the latter case was 103a-F. Three objective prism plates, again on IIa-0 emulsion, were obtained with the Curtis Schmidt telescope on Cerro Tololo in March 1968. The dispersion of the objetive prism spectra is 180 Å/mm at H-gamma.

The spectra

For the blue spectrogram obtained on Cerro Tololo on March 30, 1968, a slit of 1″ width and 27″ length was used. The slit extended in the E-W direction. With the indicated slit position the nebula should contribute little to the spectrum. Some contamination of the spectrum by the nebula may have ocurred, though, since the star was trailed along the slit during the exposure. A contamination, if it exists at all, should not be serious since the surface brightness of the nebula is low.

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The appearance of the spectrum is highly peculiar. No unique type in the MK system can be assigned to it. The spectrum may briefly be described as follows:

Hydrogen

H-beta shows two emission components, separated by about 390 km/sec, and superimposed on a wide and shallow absorption component. The latter is about 80 Å wide.

H-gamma and H-delta consist of two emission components, and a shallow and wide absorption component with a sharp central core. The emission components are separated by about 400 km/sec. The absorption core appears to be displaced to the red by about 10 km/sec with respect to the center of the shallow absorption line.

H-epsilon and the higher lines of the Balmer series present the same wide and shallow absorption lines and a sharp asymmetric core, flanked by two emissions, of which the violet wing is better visible.

The last Balmer line visible is $n = 20$. Beyond the Balmer limit, the continuum is not very much depressed; in fact the continuum appears to be remarkably strong. This has already been noted in other T Tauri-like objects (see, per example, Haro and Herbig, 1955).

H-alpha is present in the two red spectrograms obtained at Cordoba Observatory as a strong, somewhat sharp and single emission line. The continuum around H-alpha is very weak in both spectra.

Helium

The only line visible is λ4471 of the ^3D series. The line is weak and shallow. On the microphotometer tracing it shows three absorption peaks. Two of them can be attributted to Ti II, so that λ4471 is extremely weak if present at all. The remainder is very probably due to light from the nebula, which entered the slit during the guiding. HeI λ4026 is not present; a line at λ3819 does not correspond to helium.

Magnesium

λ4481 is very strong and comparable to H-gamma. It has a violet emission component. The strength of λ4481 is difficult to understand since it does not seem to be an abundance effect, because other Mg II lines are absent, except λ4390.

Silicon

λλ4128-30 is very weak; λλ3856-58-62 are visible and slightly stronger than λλ4128-30.

Calcium

Ca II is represented by the H and K lines. Both are sharp and have a violet emission component. Ca I is represented by a weak 4226 line.

Titanium

Lines of this element are greatly enhanced, specially those of Ti II at λλ3759-61 which are as strong as the nearby Balmer lines. A great many lines of this element are present as in supergiant stars. But this, most likely, is not due to electron pressure, since Fe II is not similarly enhanced.

Iron

From neutral iron only the strongest lines from M.43 (λλ4071 + 4046) are well visible. Fe II is represented by the strongest lines from M.27 (λλ4233-4351-4173), M.28 (λ4178), M.37 (λ4515) and M.38 (λλ4583-4549-4522). Practically all of them show violet emission which is roughly proportional to the intensity of the absorption line. The Fe II lines are not enhanced similarly to those of Ti II.

Other elements

Of other elements, Sc II (λ4246) and Sr II (λ4077 and 4215) are weakly present.

Radial Velocity

The radial velocity was derived from all well-identified absorption lines and the result is -28 ± 3 km/sec, in agreement with the value given in Wilson's catalogue (1953), namely

—36 km/sec. The behavior of the different elements was analysed, but due to the various emission features which accompany the hydrogen, calcium and ionized iron lines, these lines give biased results. The least disturbed lines are those of Ti II; the average velocity from fourteen lines is —28 km/sec, which coincides with the average obtained from all absorption lines. It can be added that in the spectral region covered there is no progressive change of the velocity of the central absorptions of the Balmer lines with their transition number.

Objective prism plates

The Schmidt plates were secured on three different nights, March 24, 25 and 26, 1968. No spectral changes during these nights were recorded. These objective prism spectra show strong continuum and very weak lines. H-beta can be seen in emission. Altogether the spectral type can be described as an Ape, in agreement with the spectral type obtained from the slit spectrogram.

Discussion

Considering together the peculiarities described —narrow cores and broad wings in the hydrogen lines; enhanced Ti II, strong Balmer continuum— one arrives at the conclusion that the best explanation is provided by an early A type star surrounded by a shell. It is impossible to be more specific about the underlying object, since we do not see features which can be attributed with certainty to the star, besides the broad hydrogen lines. The shell spectrum corresponds approximately to that of an A5 II or A5 I star. The absence of the expected dilution effect for λ4481 and the preferential strengthening of Ti II, as compared with Fe II, do not contradict previous information on shell spectra, because Pleione showed similar behavior at some phase (Underhill, 1961).

As we pointed out earlier, the center of the broad Balmer lines lies about 10 km/sec to the violet of the absorption cores, so that the shell does not seem to be in a rapid state of motion.

If one compares the present description with earlier ones, one finds some discrepancies. The spectrum was classified by Greenstein and Aller (1947) as cA5, by Hubble (1921) as Gpec. and by Joy (1945) as F5. FeII is reported to be in emission. One probable explanation for the late type is the existence of a group of strong Ti II lines in the region of λ4300, which when examined at low-dispersion probably appeared as a faint G-band (they are not seen in our low dispersion spectra). Joy adds that few absorption lines can be distinguished and that helium is not present. Herbig (1960) in a note states that (in 1946) "it showed H and Fe emission upon an absorption spectrum featured by strong Balmer lines together with weaker lines of He I, Ca II, and perhaps Mg II". This last remark points toward a noticeable change, since now Mg II is very strong.

Conclusion

The spectrum of R CrA cannot be classified uniquely; however, the K and hydrogen lines indicate a spectral type earlier than A7, perhaps A5. Shell characteristics, with extremely strong Ti II (specially λλ3759-61) are observed. Emissions are present at H-alpha and other Balmer lines and also the Fe II lines show weak emissions. The spectrum can be described, approximately, as an A5pe.

It is interesting to point out that R CrA and R Mon both are imbedded in two conical nebulae NGC 6729 and NGC 2261, respectively. Both have strong circumstellar infrared emission and probably both have Ape spectral types (Mendoza 1968, 1969).

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