and $\omega''e = 1006$ cm.$^{-1}$, and the triplet separations, it appears that *the new system must involve at least one* $^3\Pi$ *state of the normal* TiO *molecule*. It seems likely that the lower level of the transition is the known $X^3\Pi$ state, and that this is actually the ground state of the molecule. The upper level might be a singlet level (intercombination system) or a previously unobserved triplet level. The latter case is the more probable, and the weakness of the system in emission might be explained if the absorption took place to, say, a $^3\Sigma$ level situated above another $^3\Sigma$ level lying so low that the corresponding bands have wave-lengths too long to have been observed up to now.

The plates used in this investigation were taken with the 200-inch and 100-inch reflectors at the Mount Wilson and Palomar observatories and were made available by the kindness of Drs Bowen and Merrill. The work was supported in part from funds granted to the Ohio State University by the Research Foundation for aid in fundamental research.

19. SUR LA TEMPERATURE DES ETOILES R ET N

Par R. Bouigue

Des mesures spectrophotométriques effectuées aux Observatoires de Haute Provence et de Toulouse ont permis d'établir une relation entre l'intensité des raies D du sodium et la température de vibration déduite des quatre séquences suivantes: séquences +4 et +5 pour CN (syst. rouge) et séquences −1 et −2 pour C² (syst. de Swan). Ces deux quantités et la considération de l'intensité de la bande 6260 A. constituent trois critères de classification situés dans une zone spectrale relativement étroite (5400–6800 A.) et toujours observable, ces critères montrent que la classe des étoiles carbonnées se divise en trois sous-classes distinctes qui se raccordent aux environs de C 6.

20. THE VIOLET AND ULTRA-VIOLET REGIONS OF THE SPECTRA OF THE N-TYPE STARS

By P Swings, A. McKellar and K. N. Rao

Introduction

The violet and ultra-violet regions of the spectra of the cool carbon stars are notoriously difficult to photograph. This is so particularly for the late N-type stars with which the present paper deals. The spectra of R-type and early N-type stars can be photographed down to λ3500 by exposures several times as long as for M-type stars of comparable class. However, the later N-type spectra fall so rapidly in intensity from λ4400 and so even more extremely from λ4100 to shorter wave-lengths that the spectra of the brightest stars have not been recorded below λ3900.

The earlier investigators (e.g. Shane, 1920) were well aware that the extreme decrease in intensity toward the violet was much more than expected from a source at the temperature indicated for late N-type stars, but observations did not reveal the source of opacity. In 1947 Shajn and Struve photographed the spectrum of UU Aur (N 3) to about λ3900 and by comparing it with an M-type spectrum advanced reasons for supposing the source of extra opacity in the violet and ultra-violet to be at least partly molecular absorptions.

In 1948 McKellar described a survey of the spectra of several N-type stars in the λ4000 region, and noted that a well-marked group of absorption bands occurred in the spectrum of Y CVn. The strongest band was at λ4053, and the group was tentatively identified with the λ4050 group first produced in the laboratory by Herzberg and long known in emission in cometary spectra.

To digress for a moment on the subject of the λ4050 bands, when they were produced in the laboratory in 1942, there appeared good reasons for attributing them to CH_2.

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However, more recent investigations at Liége by Rosen, Monfils, and Etienne, confirmed and extended by Douglas at Ottawa, have shown that the carrier molecule does not contain hydrogen and therefore cannot be CH_2. The most likely although not the certain emitter is the triatomic carbon molecule C_3. The most recent evidence from cometary spectra (Jose and Swings, Comet 1948–I) indicating that the λ4050 group arises from a polyatomic molecule which is not parent to CH does not contradict the suggested C_3 identification. Thus, as related to the present topic, the situation regarding the λ4050 bands is that the identification of their emitter is still not definitely settled but is possibly C_3 and that while there seems no doubt that the cometary and laboratory bands are the same, the identity of these with the group in the spectrum of Y CVn is provisional and not certain.

In the light of the above we may summarize the aims of the present work as the following:

(i) To explore the spectra of the late N-type stars as far into the ultra-violet as possible.

(ii) To try to identify any new absorption features found in the hope that they might provide clues to the source of high opacity and also to the identification of the bands found in the λ4100–3900 region in the spectrum of Y CVn.

The Observations

Observations were made using the 82-inch telescope at the McDonald Observatory by P Swings and K. N. Rao in April and May, 1949, and at the Dominion Astrophysical Observatory by A. McKellar from 1947 to 1950. The stars observed were the brightest of type N available, and included RY Dra (N4p), Y CVn (N3), X Cnc (N3), U Hya (N2), VY UMa (Na), 19 Psc (NO), RS Cyg (NOpe), and Z Psc (NO), UX Dra (NO). Spectra of some M-type stars were obtained for comparison purposes; these included 56 Leo (M), B.D. 6°2620 (M3), and B.D. 9°1633 (M). Certain of the spectra photographed at the McDonald Observatory are, to the extent of our knowledge, the best yet obtained of the violet region of the spectra of late N-type stars.

Of necessity, most of the plates were obtained with the lowest dispersion available, and even so exposures were of the order of several hours.

Of the spectrograms photographed at the McDonald Observatory, one of Y CVn extends farther into the ultra-violet than any yet obtained of a late N-type star, and several spectrograms of moderate dispersion of the stars Y CVn and RY Dra show the λλ3900–4100 region with superior resolution.

Results

In a short paper such as this, it is possible only to summarize the main results. Several slides will serve to show some of the spectrograms obtained and to illustrate the basis for certain conclusions.

Fig. 1 shows low-dispersion spectrograms of U Hya, X Cnc, and RY Dra in the λ4100 to λ3900 region with the spectrum of the early N-type star VY UMa for comparison. It is seen that the λ4053 group of bands to which reference was made in the introduction and which dominates the spectrum of Y CVn in this wave-length region is also the main series of absorption features in the other late N-type spectra photographed. Indeed, for RY Drac, the spaces between bands are so narrow that they simulate emission lines. These bands do not occur in early N-type spectra.

Fig. 2 shows reproductions of higher dispersion plates of the same region of the spectra of Y CVn and RY Dra. In the upper of these spectra the bands in the λ4053 group are indicated. In the two lower plates, the regions between the bands (the 'apparent' emissions at λλ4010, 3982, 2958, 3948 and 3924) are readily seen.

In view of their similarity to emission lines possible identifications as such were checked; it seems quite certain, however, that they are narrow bands of stellar radiation between absorption bands.

Fig. 3 shows three spectrograms, the upper one being that of Y CVn extending farthest into the ultra-violet and the middle and lower spectra being M-type and early N-type spectra obtained, for comparison, with the same quartz spectrograph. Among the interesting points are (*a*) measurable features have been found in the late N-type spectrum down to about λ3400: (*b*) careful comparison shows that the spectrum of Y CVn from λ4100 to λ3400 bears no resemblance in detail either to early N-type spectra or to M-type spectra of comparable class. (This is illustrated on the figure.) (*c*) In the ultra-violet several groups of 'apparent' emissions occur (including λλ3754, 3742, 3730; λλ3690, 3671, 3654, 3643, 3636; and 3568, 3558, 3550, 3541.) Like the similar features near λ4000, these are undoubtedly not emission lines but narrow regions between wide and deep absorption bands, centred at about λλ3790, 3700, 3595, 3480, and 3420. These absorption bands constitute an interesting part of the new observational material found in the present investigation.

With the discovery of the new ultra-violet bands came the problem of the identification of the molecule responsible for them. A search through the data on known band systems did not reveal any promising identification.

Our attention was then directed to the λ4050 region which seemed to have a fundamental place in the problem of the ultra-violet opacity of late N-type atmospheres, both because of the very rapid drop in intensity below λ4100 and the strength of the λ4053 and related bands. A detailed comparison of this region of the spectra of the several late N-type stars with the laboratory and cometary λ4050 group of bands strengthened the previously tentative conclusion that the bands in the N-type spectra are probably the same as in the other two sources, but this is still not certain. In any case, as noted earlier, the emitter of the λ4050 group is not known, although astronomical considerations as well as the experiments of Douglas show that the molecule must contain carbon and may be C_3.

The third group of unidentified bands in late N-type spectra, namely the blue-green red-degraded bands (main heads at λλ4977, 4876, 4640, 4541, 4352), was considered in relation to the other groups at the shorter wave-lengths. The most recent suggestion as to their origin had been that they might arise from hydrides. More recent spectrograms obtained at Victoria with fairly high dispersion have shown, however, no detectable open structure and so the likelihood of a hydride origin is considered remote. One of us (P Swings) in examining the wave-numbers of the main bands of the three unidentified groups (blue-green, λ4050 and ultra-violet) found a remarkable set of wave-number coincidences between the λ4053 band and the main unidentified bands to the longer and shorter wave-lengths.

At first we were inclined to think that these coincidences were significant and suggestive of a common origin for all three groups of bands, but various difficulties in this interpretation forced its abandonment.

One interesting observational result was provided by the star U Hydrae (N3). While Sanford's atlas (*Ap. J* **111**, 262, 1950) showed the blue-green unidentified bands not present in the spectrum of U Hydrae, various Victoria spectrograms showed the bands to be quite strong. It appears that the bands are sometimes present and sometimes not, and that there is no definite relation between their presence and the brightness of this irregular variable star. Further investigation, for which McDonald, Mount Wilson, and Victoria plates were made available, showed that when the blue-green bands were not present, the spectrum of U Hydrae resembled an early N-type star in the violet, and the λ4053 bands were not present. When the blue-green bands were present, however, the λ4053 bands were also present and the intensity of the spectrum in the far violet decreased as for late N-type spectra. Therefore, the occurrence of the blue-green bands, the λ4053 group, and the sharp increase in far-violet opacity can definitely be linked together. This does not solve the problem of the identification of any of the three sets of bands.

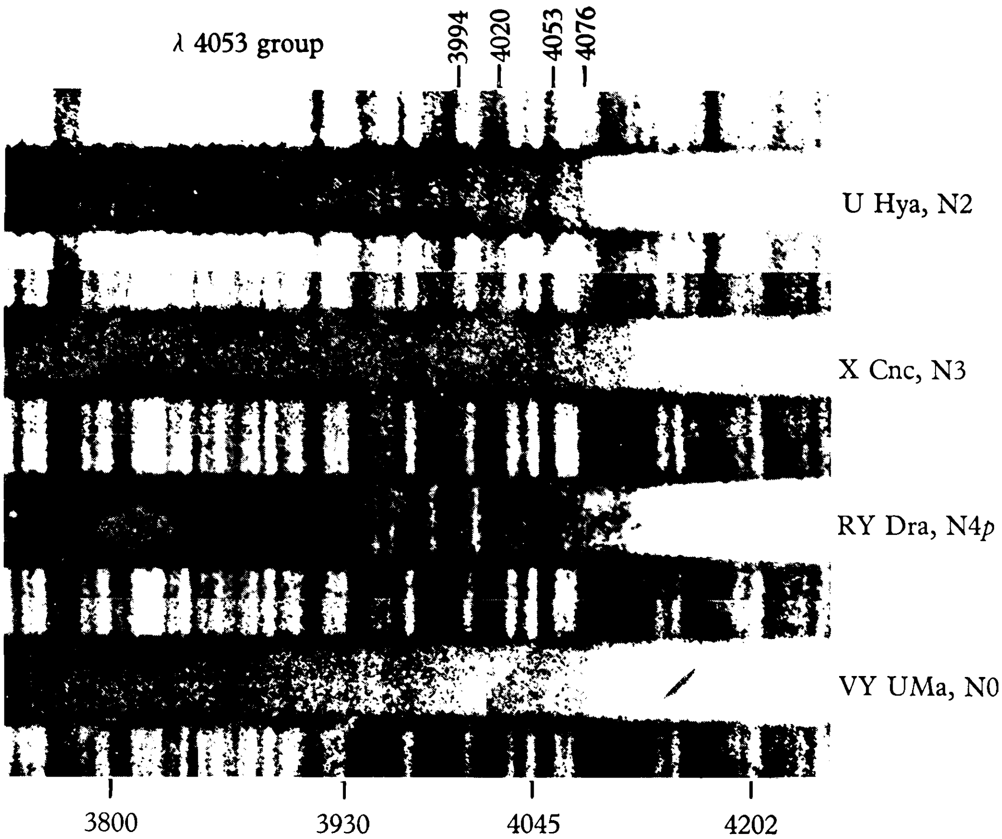

Fig. 1.

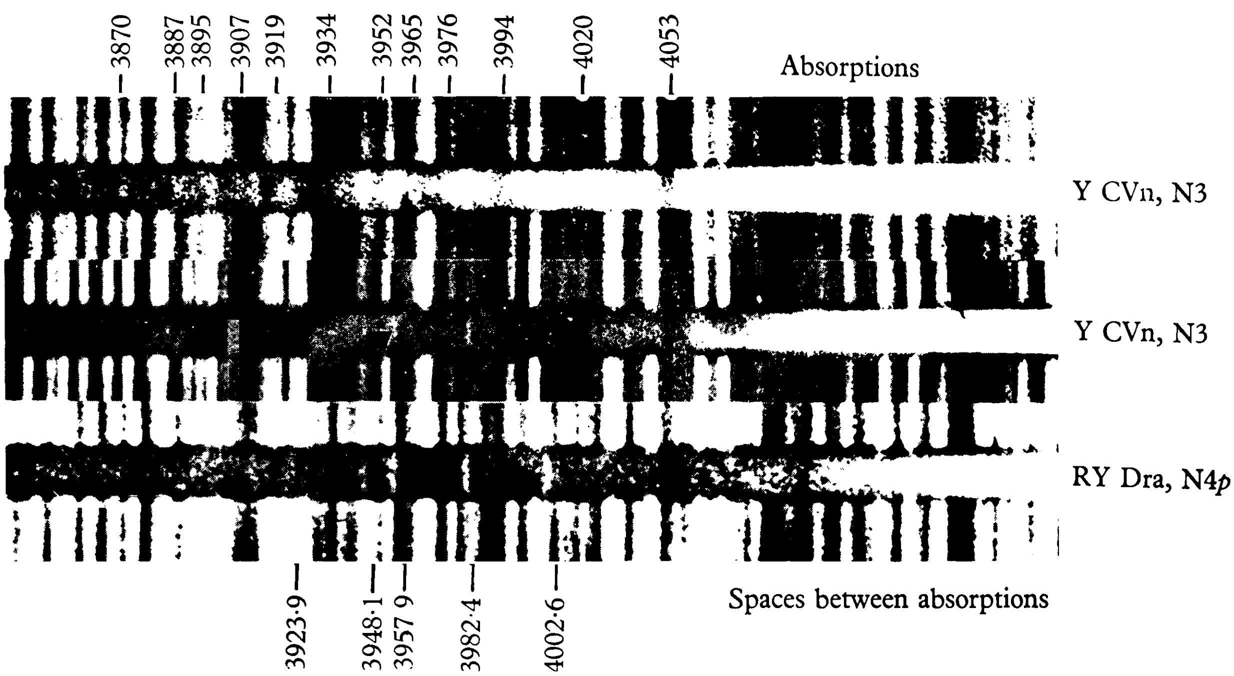

Fig. 2.

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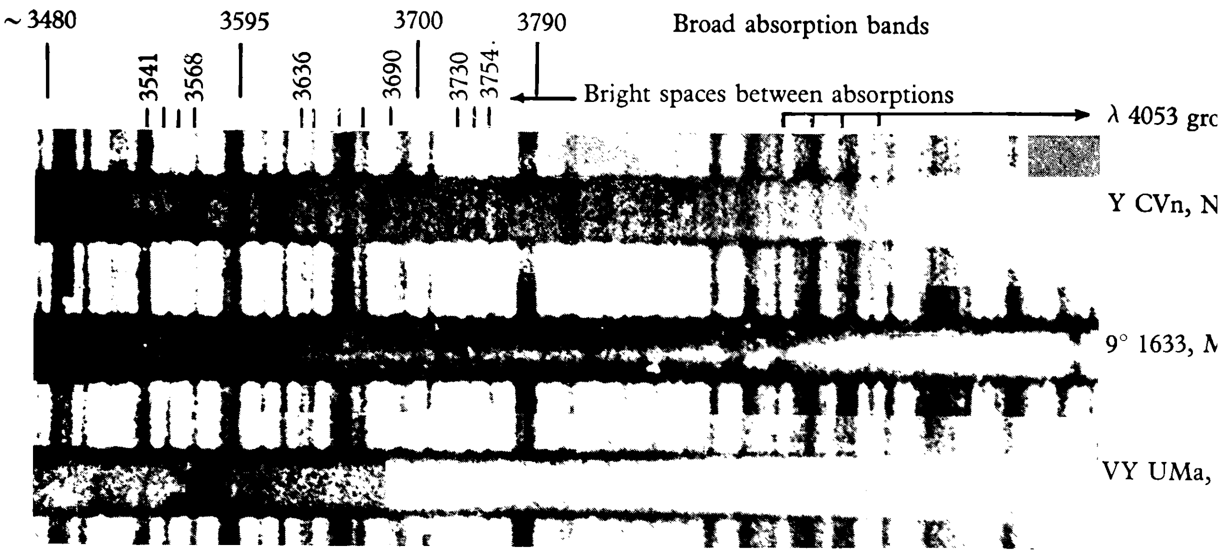

Fig. 3.

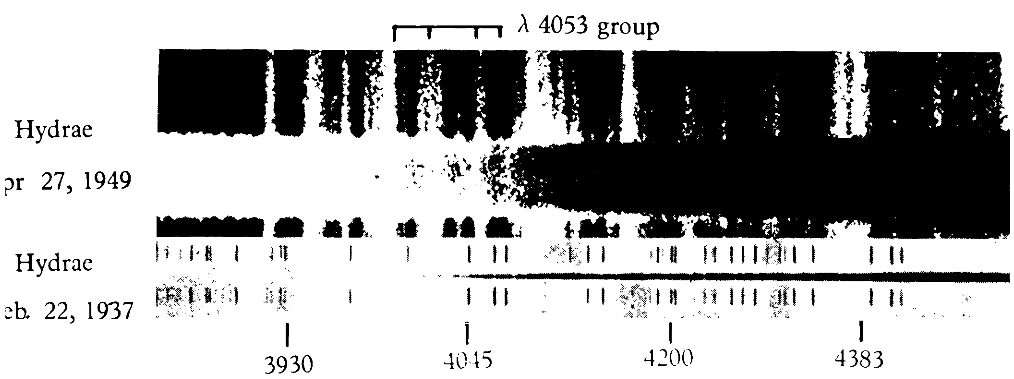

Fig. 4.

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It does, however, show that the change occurring in the N-type atmosphere, making the spectral-type later, causes absorption in both blue-green and λ4053 bands and strongly suggests that the increased opacity in the far-violet is molecular in origin.

Fig. 4 shows the far-violet spectrum of U Hydrae on two occasions. The upper spectrogram, showing the λ4053 group, resembles that of a late N-type star, while the lower one is like that of an early N-type star.

In summary we may say:

(1) The λ4053 group of bands and the associated great drop in intensity shortward of λ4100 occur together for all the several late N-type stellar spectra studied.

(2) A series of wide deep absorptions was found in the ultra-violet region (λ3800 to λ3400) of the one spectrogram of Y CVn extending into this region.

(3) The likelihood of the identity of the λ4053 group of bands with the λ4050 laboratory and cometary bands is somewhat strengthened by the new data, but cannot yet be regarded as certain.

(4) It was not possible to identify the molecule responsible for the ultra-violet bands but it is felt that all three unidentified sets of bands may arise from polyatomic molecules.

(5) The behaviour in the spectrum of U Hydrae of the blue-green bands, the λ4053 group, and the rapid decrease in intensity in the far-violet region tend to support the idea that the great opacity in the violet region of the late N-type stars arises from absorption by molecules.

21. THE SPECTRUM OF η CARINAE

By A. D. THACKERAY

The spectrum of η Carinae as recorded by the two-prism Cassegrain spectrograph of the Radcliffe Observatory in the range 3677–8863 A. consists of over 300 rather sharp bright lines, of which the identified lines are distributed among the elements as follows:

Table 1

Element	No. of emission lines	Maximum Intensity	Element	No. of emission lines	Maximum Intensity
H	19	1000:	Ca II	0	—
He	7	45	Sc II	?1	6:
[N II]	3	30	Ti II	21	4
O I	?1	(6)	V II	10	1
[Ne III]	2	4	Cr II	20	5
Na I	1	18	[Cr II]	3	(4)
Mg I	2	6−	Fe II	91	50
Mg II	1	1	[Fe II]	82	60
Si II	5	10−	Fe III	1	6:
[P II]	1	(2)	[Fe III]	3	5
[S II]	2	12	Ni II	5	6:
[S III]	?1	10	[Ni II]	8	18
			[Cu II]	1	1·5
			Total	291	

[Ni II] is rather prominent, especially in the infra-red. The lines do not agree in wavelength with the R.M.T. values, but the discrepancy has been cleared up by a recent revision of energy levels. One line at 6312·5 could be attributed to [S III] by assuming that a similar revision of energy levels is required for this ion.

Calcium H and K appear in absorption displaced by −475 km./sec., without emission

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