TABLE I

VARIATIONS OF VELOCITY IN FIVE Ne VARIABLES

Star	Visual Magnitude	Period Days	Velocity Range km/sec	Phase after Maximum Light: Minimum Velocity	Maximum Velocity	Bright $H\alpha$ Absent
R Lep ...	6.0–10.4	443	+ 25 to + 37	0.35	0.85	0.35 to 0.68
UV Aur ...	7.9–10.1	395	− 9 + 4	0.35	0.95	0.33 0.61
V Oph ...	6.9–10.8	300	− 42 − 35	0.25	0.85	0.33 0.56
V CrB ...	6.9–12.4	362	−124 −107	0.00	0.60	0.44 ?
U Cyg ...	6.1–11.8	457	+ 2 + 20	0.30	0.95	0.32 0.67

doubted. The exact shapes of the velocity curves cannot be determined yet but they will not depart greatly from that of a sine curve.

On the average, minimum velocity precedes minimum light by 0.25 P and maximum velocity precedes maximum light by 0.10 P, except for V Coronae Borealis, in which minimum velocity is near maximum light and maximum velocity near minimum light. The large negative velocity of V Coronae Borealis also is exceptional.

The average values of the magnitude range, the period, and the velocity range for the five variables are, 4.3 mag., 391 days, and 13 km/sec, respectively. No correlations of velocity range with magnitude range or with period were found.

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THE INFRARED SPECTRUM OF P CYGNI

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The spectral region of P Cygni from $H\alpha$ to λ 8900 has been examined by P. W. Merrill[1] on spectrograms of dispersion 33 and 65 A/mm, obtained with a plane-grating spectrograph attached at the Cassegrain focus of the 100-inch telescope. Mer-

[1] *Mt. Wilson Contr.*, No. 486; *Ap. J.*, **79**, 183, 1934.

rill observed that the Paschen lines have both bright and dark components, that λ 8446 *O* I is bright and more intense than any other line in this part of the spectrum, and that the *He* I lines λλ 6678, 7065, and 7281 are present in emission.

Coudé spectrograms extending to about λ 8600, taken by R. F. Sanford on July 19 and October 11, 1943, were generously loaned to me for examination. They were obtained with the 32-inch camera, dispersion 20.8 A/mm, on the Eastman IV N emulsion; their quality is exquisite. A few lines appearing on these plates and not previously described by Merrill will be discussed in this note.

The infrared lines of *O* I are fairly strong as already mentioned by Merrill; the observations are summarized in Table I.

TABLE I

INFRARED EMISSION LINES OF *O* I IN P CYGNI

Laboratory			P Cygni	
λ	Intensity	Multiplet Designation	Intensity in Emission	Intensity in Absorption
8446.76..... 8446.35.....	23 25	$(^4S)3s^3S^0-(^4S)3p^3P$	2	0
8232.99..... 8230.01..... 8227.64..... 8221.84.....	13 10 11 15	$(^2D)3s^3D^0-(^2D)3p^3D$	0	–
7775.40..... 7774.18..... 7771.96.....	25 26 27	$(^4S)3s^5S^0_2-(^4S)3p^5P$	3	3
7254.47..... 7254.19.....	17 15	$(^4S)3p^3P-(^4S)5s^3S^0$	0?	–

The $(^4S)3p^5P-(^4S)4d^5D^0$ multiplet at λλ 6155.99, 6156.78, 6158.19, often observed in novae, is absent in P Cygni. In Rigel, also, the infrared absorption lines of *O* I are much stronger than the λ 6156 group. In P Cygni the lines of *O* I do not show any selectivity of the type exhibited by *Si* III;[2] the emission spectrum

[2] Swings and Struve, *Pub. A.S.P.*, **52**, 392, 1940.

of *O* I is rather similar to the spectrum obtained in a laboratory discharge. The ionization potential of oxygen is only 13.55 volts, and the *O* I lines observed in P Cygni are thus mainly due to a recombination mechanism. The situation would be entirely different in shell stars of lower excitation, such as certain novae in the *O* I emission stages. In such stars selectivities among lines may be expected.[3] It would be interesting to study the changes in the *O* I spectrum in the infrared and visual region in the course of the evolution of a nova.

The striking faintness of λ 4267 *C* II ($3d^2D - 4f^2F^0$) in P Cygni has often been mentioned. In normal B stars (absorption) and in late WC stars (emission), λ 4267 is a very intense line. On the other hand the $3s^2S - 3p^2P^0$ transition (λ 6578.03, λ 6582.85) is quite conspicuous in emission in P Cygni. To determine whether this emission is abnormally strong relative to λ 4267 would require photometric measurements. The red doublet is also very intense in absorption in Rigel; thus the fact that λ 4267 is usually considered the characteristic stellar line of *C* II may simply be due to its location in the violet region. The transition $3p^2P^0 - 3d^2D$ (λ 7231.12, λ 7236.19) that connects the upper level of the red doublet with the lower level of λ 4267 is definitely present in emission, although weak and possibly present in absorption. Its observation is rendered difficult by strong atmospheric lines, but microphotometric tracings leave no doubt about its presence. The intensity of the infrared linking transition is intermediate between those of the strong $3s^2S - 3p^2P^0$ and weak $3d^2D - 4f^2F^0$ transitions.

The average excitation in P Cygni is not favorable to a study of *C* III. The $3p^1P^0 - 3d^1D$ transition (λ 5696) is faintly present in emission, whereas there is hardly any trace in emission of the multiplet $3s^3S - 3p^3P^0$ (λλ 4647.40, 4650.16, 4651.35) which is stronger than λ 5696 in WC stars or in the laboratory. Hence P Cygni resembles certain Of stars, such as HD 192639,[4] as far

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[3] For a thorough term analysis of the *O* I spectrum from λ 13163.7 to λ 2876.3, see B. Edlén, *Kungl. Svenska Vetenskapsakademien Handlingar,* 3d ser., **20,** No. 10, May 1943.

[4] Swings and Struve, *Pub. A.S.P.,* **52,** 394, 1940.

as *C* III is concerned. The predicted wave length of the $3s^1S - 3p^1P^0$ transition is λ 8499.7, but unfortunately this is too near to the Paschen line P16 to permit detection of a faint *C* III emission. This predicted *C* III line at λ 8500 should be strong in WC stars and in shell stars of excitation higher than P Cygni.

The additional information obtained from the infrared spectrum of P Cygni fits well in the general picture of the mechanisms of excitation of emission lines in the shells surrounding stars of early type. Recombination, collisional excitation, and fluorescence are all active for all elements, but their relative importance varies widely. In a shell such as that of P Cygni the emission lines of *O* I are mainly produced by recombination; but this would not necessarily be the case in a cooler shell. On the other hand, elements of high ionization potential such as *Fe* III or *C* III are probably mainly excited by fluorescence in P Cygni. For elements of intermediate ionization potential, electron collisions are an efficient mechanism. In many Be stars with shells revealing *Fe* II lines, the predominance of low-level lines of *Fe* II is very pronounced and is probably a result of the collisional excitation by electrons of fairly low temperature.

These considerations serve to emphasize again the great caution that one should use when trying to estimate abundances of elements in shell stars, including novae, on the basis of the observed emission lines. This is especially true for carbon, nitrogen, and oxygen which, in recent years, have been so often considered on account of the adopted division of the Wolf-Rayet stars. One should also use great caution when estimating abundances from the intensities of the stellar absorption lines in which anomalies may be produced by physical agents such as dilution or fluorescence, combined with mechanical agents such as ejection, rotation, or turbulence.

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