SPECTROGRAPHIC OBSERVATIONS OF NOVA HERCULIS (1934) AND NOVA SERPENTIS (1909) WITH IDENTIFICATIONS OF [*Fe* v] AND [*Fe* III] IN NOVA PICTORIS (1925)*

P. SWINGS AND O. STRUVE

ABSTRACT

I. The velocities of expansion of Nova Herculis show a range of from 338 km/sec for [*O* II] to 256 km/sec for [*O* III]. This suggests stratification. The lines show curved outer components, with a faint indication of a central line in the case of $H\gamma$. Considerable change has taken place in the relative intensities of the emission lines since 1940. The continuous spectrum of the central star has decreased in brightness.

II. The forbidden spectra of [*Fe* v] and [*Fe* VI] are well developed in the present spectrum of Nova Serpentis. Although thirty-three years have elapsed since the outburst, the electron density in the nebulosity is still high, compared with most planetary nebulae.

III. Several unidentified lines measured by H. Spencer Jones in Nova Pictoris (1925) can now be attributed to [*Fe* v] and [*Fe* III].

I. THE SPECTRUM OF NOVA DQ HERCULIS (1934)

When the spectrum of Nova Herculis was last described two years ago,[1] its most interesting feature was the structure of the emission lines: each line consisted essentially of two components, with an approximate separation of 600 km/sec, which in terms of nebular expansion corresponded to a velocity of the order of 300 km/sec. The space between the two main components of each line was filled with fainter emission, which reached a maximum intensity in a third central component. The intensity distribution within the complex spectral lines was not exactly the same when the slit was located in different parts of the elongated image of the nebula. Under good seeing conditions, when the guiding was accurate, the two outer components were curved at the ends. Such a line structure must be due to the geometrical and kinematical characteristics of the nebular envelope; and it is interesting to examine how the effect appears now, after two additional years of evolution. The continuous nuclear spectrum, as observed at the McDonald Observatory in 1940, corresponded to a photographic magnitude estimated between 13 and 14; an accurate estimate of the brightness of the nucleus by Baade[2] gave $m_p = 13.35$. Hence, in 1940, the nucleus was still appreciably brighter than in the prenova stage ($m_p = 14.6$, according to Harvard observations). Finally, it is interesting to examine the variations in the physical conditions in the nebulosity brought about by the continued expansion of the excited gas and by the evolution of the exciting nucleus.

Spectrograms of Nova Herculis were obtained in July, 1942, at the McDonald Observatory, using the quartz prisms and the f/5 (dispersion 40 A/mm at λ 3930) and f/2 (dispersion 100 A/mm at λ 3930) cameras. During one f/5 exposure, the seeing was fairly good, and the guiding was made as accurately as possible. The object appeared definitely elongated, and the slit was placed east-west, hence at an angle of 45° with the major axis of the elliptical image. The average length of the lines on the spectrogram is 0.282 mm, corresponding to a length of 4".17; taking into account the spreading due to inaccurate guiding, the dimension of the nebula in position angle 45° was between 3" and 4".

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[1] Swings and Struve, *Ap. J.*, **92**, 295, 1940, and **94**, 296, 1941; Humason, *Pub. A.S.P.*, **52**, 369, 1940.

[2] *Pub. A.S.P.*, **52**, 386, 1940. Baade has recently given a new interpretation of the Mount Wilson observations of Nova Herculis (*Harvard Ann. Card*, No. 629).

The continuous spectrum is concentrated in a central strip; the corresponding photographic brightness of the nucleus is lower than in 1940, probably fainter than 14.0; the nucleus is slowly declining toward its prenova brightness.

As in 1940, each line consists of two outer components spaced at mid-length by about 600 km/sec, the corresponding interval being filled in with fainter emission; in $H\gamma$, a faint maximum appears in the center. The two outer components curve strongly at their ends. The complexity of several emissions, especially $H\delta$, N III 4640, and [O II] 3727 is due to blending. The outer components are not perfectly sharp, the spread in velocity which corresponds to their width being of the order of 100 km/sec. As in 1940, the violet component is slightly more intense than the red component. The separations between the intensity maxima of the outer components have been measured for several lines, and the results are given in Table 1; the images of N_1 and N_2 were too dense to be measured.

TABLE 1

SEPARATIONS OF THE OUTER COMPONENTS OF VARIOUS LINES IN NOVA HERCULIS

λ	Intensity	Identification	Separation (in Km/Sec)	Expansion Velocity (in Km/Sec)	λ	Intensity	Identification	Separation (in Km/Sec)	Expansion Velocity (in Km/Sec)
3726.2......	5	[O II]	676	338	4685.8......	7	He II	537	268
4340.5......	8	$H\gamma$	629	314	4363.2......	4	[O III]	511	256
4861.3......	12	$H\beta$	628	314					
4379.1......	4	N III	590	295	Mean....	....	....	....	297

For comparison, the following expansion velocities have been measured: by Merrill[3] in 1935: 290 km/sec (from emission lines of Fe II and O I); by Stratton[4] in 1939: 260 km/sec (from N_1); by Swings and Struve[1] in 1940: 269 km/sec (from eight lines, excluding N_1); and by Humason[1] in 1940: 300 km/sec (from $H\gamma$, $H\beta$, N_1 and N_2).

Table 1 shows a considerable range in the separations. While part of this is undoubtedly due to errors of measurement, it does not seem possible to account in this manner for the difference between the separation of $H\beta$ and $H\gamma$, on the one hand, and of [O III] 4363, on the other. Several sets of measures have given essentially the same result. A difference in the same sense appeared in our 1940 measurements. The range in expansion velocities suggests a stratified ring or shell structure for the outer nebulosity, each element moving outward with its own velocity. Stratification effects have been invoked for the interpretation of the wide range of ejection velocities in the Wolf-Rayet and P Cygni stars and in the early stages of novae; stratification, of course, is also well known in the case of planetary nebulae.

The curved outer components of the lines are not of uniform intensity. The curved tips are weak, and the middle sections of the lines are strong. In fact, our plates do not very clearly show that the outer components merge to form complete elliptical rings, like the ones described by Baade[2] from spectrograms obtained by Humason. But it is possible that our guiding was not good enough. A slight trailing along the slit will weaken the tips of the elliptical ring-images of the lines and tend to fill the inner parts of the ring with weak emission, while the central parts of the lines, being parallel to the slit, would not be affected. Hence, it is quite possible that the apparent faintness of the elliptical rings at their tips is not real.

The elements observed in the spectrum are essentially the same as in 1940: H (Balmer

[3] *Ap. J.*, **82**, 413, 1935.

[4] *Observatory*, **62**, 236, 1939.

series to H_{15}), *He* I, *He* II, *C* II, *C* III, [*O* II], *O* III, [*O* III], *N* II, *N* III (not excited by Bowen's fluorescence mechanism), [*Ne* III], [*Ne* V], and [*S* II]. But the relative intensities of the different emission lines have changed appreciably. These changes are summarized in Table 2. It is evident at once that the observed variations cannot be interpreted simply on the basis of a change in density and dilution in the expanding nebulosity. Some observations at first sight even appear to be contradictory. For example, the considerable decrease in intensity of [*Ne* III] and [*Ne* V] compared to *H* and [*O* II] suggests that the ionization of neon has decreased in the nebulosity; the ionization potentials of Ne^{+} and Ne^{+++} are 40.9 and 96.7 volts, respectively. Similarly, the intensity increase of the [*O* II] lines—which have an extremely low transition probability—is not solely due to a decrease in density, since the intensity ratio of the auroral (λ 4363) and nebular (N_1, N_2) transitions of [*O* III] has not decreased very much; the intensity increase of [*O* II] is probably due partly to a reduction in the ionization of O^{+}. Yet the *N* III lines have increased

TABLE 2

ESTIMATED LINE INTENSITIES IN NOVA HERCULIS IN 1940 AND IN 1942

λ	Element	Intensity		λ	Element	Intensity	
		1942	1940			1942	1940
3426	[*Ne* V]	0–1	3	4267	*C* II	2–3	3
3444	*O* III	1–0	3	4340	*H*γ	8	6
3587	[*Fe* VII]	0	1	4363	[*O* III]	4	4
3726	[*O* II]	5	6	4379	*N* III	4	3
3759	*O* III+[*Fe* VII]	3	6	4471	*He* I	1–0	2
3798	H_{10}	1	2	4515	*N* III	1–2	2
3835	H_9	1–2	3	4542	*He* II	1–0	2
3869	[*Ne* III]	1–2	6	4607	*N* II	1–0	2
3889	H_8+*He* I	3	6	4640	*N* III	10	6
3970	*H*ε+[*Ne* III]	4	7	4650	*C* III	2	2 bl.
4026	*He* I	1–0	1	4686	*He* II	7	5
4068	[*S* II]	2	4	4861	*H*β	12	8
4102	*H*δ+*N* III	10	7	4959	[*O* III]	20	15
4200	*He* II	1–0	2	5007	[*O* III]	30	25

in intensity. A recombination spectrum of *N* III requires the photo-ionization of N^{++}, whose ionization potential is 47.20 volts; hence, an increase of ionization of N^{++} is incompatible with a decrease in ionization of Ne^{+}, if we assume that the nucleus has not changed or even if we assume that the nucleus radiates like a black body of varying temperature. It is more likely that the *N* III lines are due to a fluorescence mechanism excited by the underlying radiation. Such a mechanism is very sensitive to a variation in the far ultraviolet absorption or emission lines of the underlying star. These spectral features of the underlying star may affect the fluorescence considerably, without affecting to a comparable extent the photo-ionization.

II. THE SPECTRUM OF NOVA RT SERPENTIS (1909)

The evolution of Nova Serpentis is very slow, and no very striking spectral changes were found in comparing our spectrograms of 1940[5] and 1942. But the forbidden spectra of [*Fe* V] and [*Fe* VI] have developed more completely and constitute now the main characteristics of the nebular spectrum of Nova Serpentis. Nova Serpentis is well worth investigating at regular intervals, since the forbidden spectra of [*Fe* III, V, VI, and VII] are

[5] Swings and Struve, *Ap. J.*, **92**, 295, 1940.

becoming more and more important for the discussion of high-excitation atmospheres and of novae. For [*Fe* VI], Nova Serpentis is at present an ideal object. Unlike AX Persei and CI Cygni, which also show, at times, the [*Fe* VI] spectrum,[6] Nova Serpentis is not complicated by late-type features in the visual region and has only an extremely weak continuous spectrum. On the other hand, Nova Serpentis possesses sharper lines than the nebular spectrum of Nova Pictoris which, in its latest stages, was also rich in [*Fe* VII] and [*Fe* VI].[7] Finally, the spectrum of Nova Serpentis is less complex than the spectra of

TABLE 3

LINES IN NOVA SERPENTIS (JULY 26, 1942)

Nova		Identification		Note	Nova		Identification		Note
λ	Int.	Element	λ		λ	Int.	Element	λ	
3346	2	[*Ne* V]	3345.8	......	4340.8	7	*H*γ	4340.5	......
3425.8	6	[*Ne* V]	3425.8	......	4363.0	6	[*O* III]	4363.2	......
3588	0	[*Fe* VII]	3586.3	1	4471.1	1	*He* I	4471.5	......
3663	1	[*Fe* VI]	3662.6	1	4541	0–1	*He* II	4541.6	......
3751	0n	{[*Fe* V]	3754.8	1	4639.6	1–2	*N* III	4640.6	......
		[*Fe* V]}	3744.	2	4657	0	[*Fe* III]	4658.2	1
3759.4	2	[*Fe* VII]	3759.4	1	4685.9	8	*He* II	4685.8	......
3770	1	{[*Fe* V]	3765.	2	4715.6	2	{[*Ne* IV]	4714.1	2, 5, 6
		H_{11}}	3770.6	......			*He* I}	4713.1	......
3783	1	[*Fe* V]	3784.2	1	4725.6	2	[*Ne* IV]	4719.7	2, 5, 6
3834.9	1	H_9	3835.4	......	4861.6	10	*H*β	4861.3	......
3839.6	1–0	[*Fe* V]	3839.3	1, 3	4959.2	3–4	[*O* III]	4958.9	......
3846.2	0–1	([*Fe* V]	3851)	2	4971.5	3n	{[*Fe* VI]	4970.	1
3868.7	8	[*Ne* III]	3868.7	......			[*Fe* VI]}	4974.	1
3890.2	4	{[*Fe* V]	3891.4	1, 4	5006.1	7	[*O* III]	5006.8	......
		He I	3888.6	......	5145.4	3	[*Fe* VI]	5147.	2
		H_8	3889.0	......	5161.0	1	[*Fe* VII]	5158.4	1
		[*Fe* VI]}	3891.4	1	5175.3	5	[*Fe* VI]	5177.	1
3894.2	1	[*Fe* V]	3895.4	1	5276.3	0	{[*Fe* VI]	5279.	2
3968.3	6	{[*Ne* III]	3967.5	......			[*Fe* VII]}	5274.1	1
		*H*ε}	3970.1	......	5309.6	3n	[*Ca* V]	5309.2	1
4024.9	0	{[*Fe* V]	4027.	2	5335.3	1–0	[*Fe* VI]	5336.	2
		He I}	4026.2	......	5411.8	2–3	*He* II	5411.6	......
4070.0	1	[*Fe* V]	4071.4	1	5426.0	2	{[*Fe* VI]	5430.	1
4100.8	5	{*H*δ	4101.7	......			[*Fe* VI]}	5424.	1
		N III	4097.3	......	5490.2	0–1	[*Fe* VI]	5486.	2
		N III}	4103.4	......	5574.0	0–1	[*O* I]	5577.3	7

NOTES

1. These wave lengths were obtained from measurements of AX Persei and CI Cygni.
2. Predicted wave lengths.
3. Blend of two [*Fe* V] lines
4. [*Fe* V] is the main contributor.
5. Separation difficult.
6. The forbidden $^2D-^2P$ transition of [*Ne* IV] consists essentially of two lines predicted at λ 4714.1 (transition probability, 0.78) and λ 4719.7 (transition probability, 1.07). These predicted wave lengths may be in error by several Angstrom units. The excitation potential of ^2P is unusually high for forbidden lines (7.7 volts). No other satisfactory identification could be found for the observed lines. On our 1940 spectrograms of lower dispersion the measured wave lengths were 4717.0 and 4728.1. See also J. C. Boyce, *M.N.*, **96**, 690, 1936.
7. Probably night-sky radiation.

[6] Swings and Struve, *Ap. J.*, **96**, 254, 1942. [7] Bowen and Edlén, *Nature*, **143**, 374, 1939.

planetary nebulae of high excitation showing *Fe* VI.[8] The only drawback is the faintness of Nova Serpentis, which, at the time of our last observation (July 26, 1942) was approximately of the fourteenth magnitude. Table 3 gives the wave lengths measured on a spectrogram having a dispersion of 100 A/mm at λ 3930.

Besides the lines of *H* and *He* II, the strongest emissions are the forbidden transitions of [*Ne* III], [*Ne* V], [*O* III], [*Fe* VI], [*Ca* V], [*Fe* V], and [*Fe* VII]. It is interesting to notice that, thirty-three years after the nova outburst, the auroral transition of [*O* III] 4363 is still stronger than N_2 and nearly as intense as N_1. Hence the density in the nebular envelope of Nova Serpentis must still be high, compared with most planetary nebulae; it must be similar to the density in other [*Fe* III, V, VI, or VII] nebulosities, such as AX Persei, CI Cygni, and similar objects. It is higher than in the planetary nebula IC 4997, which is characterized by strong λ 4363.

Table 3 shows several [*Fe* VI] lines which could not be detected in AX Persei or CI Cygni because of the presence of late-type features in these latter stars. The [*Fe* VI] spectrum is also better represented in Nova Serpentis than in Nova Pictoris and slightly better than in the planetary nebulae of high excitation.

III. IDENTIFICATION OF FORBIDDEN [*Fe* V] AND [*Fe* III] LINES IN THE SPECTRUM OF NOVA RR PICTORIS (1925)

Nova Pictoris is a remarkable representative of the slow nova type, and the evolution of its spectrum has been studied thoroughly by H. Spencer Jones.[9] When the spectrum was last described in 1934, the emission consisted mainly of lines which were attributed to [*Fe* VII] and [*Fe* VI] by Bowen and Edlén.[10] It may be expected that, at some earlier time, between the [*Fe* II] and the [*Fe* VI and VII] stages, the [*Fe* V] and [*Fe* III] spectra were also present. The attribution to [*Fe* III] of the line λ 4658 observed in various novae, including Nova Pictoris, was made by Edlén and Swings in 1939;[11] additional identifications will be given here. Moreover, the leading transitions of [*Fe* V] will also be identified. The importance of the spectra of [*Fe* III, V, VI, and VII] in the interpretation of nova spectra was emphasized by Edlén at the 1939 Paris Conference on novae and white dwarfs.[12]

[*Fe* V] LINES

As was mentioned by Edlén,[12] the identification of [*Fe* V] is difficult, because several of the predicted lines, which would be expected to be the most probable, fall very close to *H* or *He* I lines. Quite recently, Wyse[13] reached the conclusion that no identification of [*Fe* V] in nebulae could be considered as satisfactory. The situation was improved considerably when it was found last winter[14] that the high-excitation object AX Persei, which has very sharp lines, had reached a stage in which the [*Fe* V] spectrum was outstanding; it was possible to separate most of the [*Fe* V] lines from the *H* or the *He* I transitions and to estimate their relative intensities. It is on the basis of the results obtained in this way that the identifications of [*Fe* V] have been made possible in Nova Pictoris.

Transition $^5D - {}^3F$.—The strongest line is $^5D_4 - {}^3F_4$, whose predicted wave length is λ 3892 and whose wave length in AX Persei is λ 3891.4 (int. 4). An unidentified line was

[8] A. B. Wyse, *Lick Obs. Contr.*, Ser. II, No. 4; *Ap. J.*, **95**, 35, 1942.

[9] For the nebular stages of Nova Pictoris see *M.N.*, **91**, 777, 1931; **92**, 728, 1932; **94**, 35, 1933; and **94**, 816, 1934.

[10] *Loc. cit.*

[11] *Observatory*, **62**, 234, 1939.

[12] "Les novae et naines blanches," *Compt. rend. du colloque internat. d'ap. de 1939*, Paris: Hermann & Co., 1940. A copy of the proof of these *Proceedings* may be borrowed from the authors.

[13] *Loc. cit.*

[14] Swings and Struve, *Ap. J.*, **96**, 254, 1942.

found by Spencer Jones in the 1926 spectra at λ 3893.4 (int. 3); it was described as follows: "The λ 3893.4 line overlaps the *Hζ* band, appearing as a well-defined wing on its long wave-length side. It was first seen on the plate of 1926 March 20, but may have been present at an earlier date as the earlier plates of 1926 are too weak at *Hζ* to show it." The strongest transition, $^5D_3 - {}^3P_2$ of the second [*Fe* v] multiplet, has the predicted wave length λ 3896 and was observed in AX Persei at λ 3895.4 (int. 3). The line observed by Spencer Jones is a blend of these two [*Fe* v] lines. At later stages the line probably became lost in *Hζ*.

The second strongest line of the $^5D - {}^3F$ multiplet is $^5D_3 - {}^3F_3$, with predicted wave length λ 3839 and wave length in AX Persei λ 3839.3 (int. 2). Again, another [*Fe* v] line, $^5D_2 - {}^3P_2$, is practically coincident (predicted wave length λ 3838). A line was measured in Nova Pictoris at λ 3840.1 (int. 1) in 1926, λ 3839.8 in 1933, and λ 3841.3 in 1934 (blended with *Hη*, λ 3835.4, in 1934). It was described as follows:

The λ 3840.2 emission appears as a weak wing to the *Hη* band. Comparison with other hydrogen bands indicates that it is not a true wing but a weak overlapping band. The measured wave-length is based on the extent of the overlap and agrees closely with the wave-length, measured by Wright, of a line in the spectrum of BD+30°3639. It had probably strengthened in 1928, as the appearance of a wing was not shown, but the measured wave-length of *Hη* on both Cape and Johannesburg plates of that year shows the effect of a blend with a line of longer wave-length than *Hη*. Its origin is not known.

Transition $^5D - {}^3P$.—The (3–2) and (2–2) lines have been considered in the preceding paragraph. The $^5D_2 - {}^3P_1$ line has the predicted wave length of λ 4071 and was found in AX Persei at λ 4071.4 (int. 2). A line was measured in Nova Pictoris at the following wave lengths:

1925......λ 4068.6 (int. 6)	1928.....λ 4072.3 (int. 5)
1926......λ 4070.3 (int. 6)	1934.....λ 4071.3 (weak)

It was described as follows:

The emission at λ 4068.6 first appeared about 1925 October, at the same time as the forbidden iron bands. It is present in the spectra of η Carinae and of "iron" stars, such as BD−12°1500. The measured wave-length shows a general increase, and it appears probable that in the later stages another emission of greater wave-length emerges and blends with it.

The line measured in 1925 at λ 4068.6 is undoubtedly due to [*S* II]. The blending by [*Fe* v] appeared later and increased, hence giving rise to a gradual increase in wave length. Such a gradual shift in wave length cannot be due to the blending by the second, weak [*S* II] line at λ 4076.

Next comes $^5D_1 - {}^3P_0$, whose predicted wave length is λ 4181 and whose wave length in AX Persei is λ 4180.6 (int. 1). In 1926 a line was measured in Nova Pictoris at λ 4178.9 (int. 3) and was attributed to *Fe* II; in 1928 the measured wave lengths were λ 4181.0 (int. 3), and λ 4180.2 (int. 2). The line is described as follows:

The Fe^+, λ 4179, emission is weak in 1926 March and April, but subsequently strengthens. An emission of approximately the same wave-length is present in the spectrum in 1928, when metallic emissions have almost entirely disappeared. It would seem that another emission, at about λ 4180, appears about 1926 May; its origin is unknown.

The line λ 4180 is undoubtedly the $^5D_1 - {}^3P_0$ transition of [*Fe* v].

Finally, the last line of [*Fe* v], which is not hopelessly masked by *H* or *He* I and which is observed in AX Persei, is $^5D_0 - {}^3P_1$, predicted wave length, λ 4003, observed wave length in AX Persei, λ 4003.7 (int. 1–0). A line was measured in Nova Pictoris at λ 4004.9 (int. 0) in 1926 and λ 4005.1 (int. 3) in 1928. Its description is: "The emission at λ 4004.9 is weak and was suspected on several plates and measured only on that of October 4. The wave-length is very uncertain." This line is, at least partly, due to [*Fe* v]. Some doubt remains in this case, because the line measured at λ 4003.7 in AX Persei may not be entirely due to [*Fe* v]; a line is also present at the same wave length in CI Cygni, although [*Fe* v] is very faint in this latter star.

[*Fe* III] LINES

Transition $^5D - {}^3F$.—The strongest transition, $^5D_4 - {}^3F_4$, λ 4658, is identical with the line measured in Nova Pictoris at λ 4656.3 (int. 3 in 1926); this line was first detected in December, 1925. The transition $^5D_4 - {}^3F_3$, λ 4607, is partly responsible for the line measured at λ 4606.8 (int. 1 in 1926), described as follows: "λ 4606.8 is a weak and ill-defined emission which in 1928 was still present in the spectrum of the nova, with somewhat increased intensity." The fact that the line was still present in 1928, when λ 4658 had disappeared, means that some additional contributor must have existed. $^5D_4 - {}^3F_2$, λ 4573, may contribute to the line measured at λ 4570.1 (int. 1 in 1926), which was described as follows: "The emission at λ 4570 is a weak emission measured only on the plate of 1926 September 7 (a particularly good plate). The origin may be identical with that of a weak line at λ 4571.5 measured by Wright in the spectra of certain nebulae. It was not detected in 1928." Some other agent, such as *Mg* I or some as yet unidentified line, probably contributes, in addition to [*Fe* III]. Finally, $^5D_2 - {}^3F_3$, λ 4769.3, is probably identical with the line measured at λ 4771.2 (int. 0 in 1926) and described as follows: "The λ 4771.2 emission was measured on a few plates only. It is weak and ill-defined and the wave-length is somewhat uncertain. It was not detected in the 1928 spectrum."

Transition $^5D - {}^3P$.—The strongest transition $^5D_3 - {}^3P_2$ is predicted at λ 5270.3. A line was measured at λ 5271.4 (int. 2 in 1926) and attributed to [*Fe* II] with probably a blend with a line of unknown origin: "The [Fe^+] emission at λ 5273 also appears to be involved with another emission; a fairly strong line, at approximately the same wave-length, is present in 1931." The blend in the later stages (e.g., in 1931) was due to [*Fe* VI] and [*Fe* VII].

HYPOTHETICAL [*Fe* IV] LINE

An unidentified emission was measured at λ 5041.2 in 1926 and described as follows: "It is of moderate strength and is present on all the 1926 plates, but does not show on those of 1928 or 1931." This line is also present in the [Fe III] star RY Scuti[15] [λ 5040.1, int. 1), in AX Persei[15] (λ 5041.3, int. 1), in NGC 6572[13] (λ 5040.6, int. 0.7), in NGC 7027[13] (int. 1), and possibly in IC 418[13] and in the Orion Nebula.[13] It is possible that this line belongs to the forbidden $^4G - {}^4F$ transition of [*Fe* IV].[12]

McDONALD OBSERVATORY
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[15] Swings and Struve, *Ap. J.*, **91**, 546, 1940.