THE SPECTRUM OF NOVA DQ HERCULIS (1934) IN 1947 AND 1949*

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ABSTRACT

Spectrograms of Nova DQ Herculis obtained in 1947 and 1949 reveal striking changes in the spectrum of the nebulosity since 1942. The mean velocity of expansion remains the same as in previous years.

The latest published descriptions of Nova DQ Herculis[1] were based on spectrograms obtained in 1942. The main emphasis had been placed on the structure of the shell as revealed by the spectral lines. In combination with the remarkable direct photographs obtained by Baade, the excellent Mount Wilson spectrograms studied by Humason determined the emitting atoms giving rise to the luminosity of the various parts of the postnova (nucleus, general nebulosity, pairs of condensations on the major and minor axes). The range of velocities within the shell was found to be from 222 to 396 km/sec, a figure in agreement with the early observations of the main absorption components in 1934 and 1935. The McDonald observations were in general agreement with the Mount Wilson results.

Spectrograms of the nova were obtained on October 14 and 17, 1947, and on June 9 and 17, 1949, at the McDonald Observatory. The two 1947 spectrograms were taken with the Cassegrain spectrograph (glass prisms and $f/1$ camera; quartz prisms and $f/2$ camera), while the three 1949 spectrograms were obtained at the prime focus (grating spectrograph: $f/0.65$ camera). In all cases the slit passed through the nucleus in an east-west direction, at an angle of 45° with the axis of the shell. The visual magnitude of the nova, measured photoelectrically by Dr. John Irwin on June 23, 1949, was 14.4. On account of the faintness of the object, only low-dispersion instruments could be used. The nucleus appears to have very nearly returned to its preoutburst brightness ($m_p = 14.6$, according to Harvard observations).

The continuous spectrum of the nucleus, which appears on the 1947 and 1949 spectrograms, is intense in the violet and ultraviolet, hence corresponding to an early type. On the 1949 material obtained with 103*a*-E emulsion, the continuum starts around λ 4800 and extends into the ultraviolet to the limit of transparency of the solid Schmidt camera. Some weak continuous background also appears in the red.

The lines which reveal the best structure on our 1949 spectrograms are $H\gamma$ and the intense $H\alpha$ + [N II] group. In $H\gamma$ the shortward component is slightly stronger than the longward. It is precarious to derive velocities of expansion from the double line at $H\alpha$, since the longward component is heavily blended by the shortward component of λ 6584 [N II]. However, the two [N II] lines may be safely combined. The results obtained for the mean velocity of expansion are:

In 1947:	For $H\epsilon$,	330 km/sec ;
	For $H8 + He$ I,	346 km/sec .
In 1949:	For [N II],	293 km/sec ;
	For $H\gamma$,	320 km/sec .

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[1] M. L. Humason, *Pub. A.S.P.*, **55**, 74, 1943; W. Baade, *Pub. A.S.P.*, **54**, 244, 1942; P. Swings and O. Struve, *Ap. J.*, **96**, 468, 1942. For earlier investigations see references contained in these papers.

The previously published results are:

Humason (1942): For [*N* II], 326 (±10) km/sec;

For $H\gamma$, 310 km/sec (mean for hydrogen, 314 km/sec);

Swings and Struve (1942): For $H\gamma$, 314 km/sec.

All these figures are in excellent agreement, considering the low dispersion of our 1947 and 1949 material. The recent spectrograms do not enable a precise determination of the

TABLE 1

ESTIMATED LINE INTENSITIES IN NOVA DQ HERCULIS IN 1940, 1942, 1947, AND 1949

λ	Element	1949	1947	1942	1940
3426	[*Ne* V]	*	0?	0–1	3
3444	*O* III	*	0–1	1–0	3
3587	[*Fe* VII]	*	0	0	1
3726	[*O* II]	15	8	5	6
3759	*O* III+[*Fe* VII]	5	3	3	6
3771	*H* 11	2	....	....	2
3798	*H* 10	3	2	1	2
3835	*H* 9	5	2	1–2	3
3869	[*Ne* III]	0–1	1	1–2	6
3889	*H* 8+*He* I	7	3	3	6
3970	$H\epsilon$+[*Ne* III]	8†	4†	4	7
4026	*He* I	3	1	1–0	1
4069	[*S* II]+(*O* II)	8	3	2	4
4076	[*S* II]	3	....	....	2
4102	$H\delta$+*N* III	20n‡	10n‡	10	7
4200	*He* II	0	1	1–0	2
4267	*C* II	5	4	2–3	3
4340	$H\gamma$	10	8	8	6
4363	[*O* III]	6	4	4	4
4379	*N* III	7	5	4	3
4471	*He* I	3	1	1–0	2
4515	*N* III	?	1	1–2	2
4542	*He* II	0	1	1–0	2
4607	*N* II	1	?	1–0	2
4640	*N* III	11	10	10	6
4650	*C* III	5	2?	2	2bl
4686	*He* II	12	8	7	5
4861	$H\beta$	10	12	12	8
4959	[*O* III]	2	10	20	15
5007	[*O* III]	6	15	30	25
5177	[*Fe* VII]	....	1	§	1
5276	[*Fe* VII]	....	1–0	§	1
5412	*He* II	....	1–2	§	2
5679	*N* II	....	2	§	3
5756	[*N* II]	0–1	1–2	§	6
5801	*C* IV	....	1	§	1
5876	*He* I	2	3	§	4
6300	[*O* I]	2	‖	§	5
6364	[*O* I]	1	‖	§	3
6548	[*N* II]	10	‖	§	9
6563	$H\alpha$	40	‖	§	10
6584	[*N* II]	20	‖	§	12

* Region not covered on the 1949 spectrograms.
† Contribution of [*Ne* III] minor.
‡ Major contribution of *N* III.
§ Region not covered on the 1942 spectrograms.
‖ Region not covered on the 1947 spectrograms.

ranges in velocities, such as had been obtained in 1942 by measuring the outer and inner edges of the spectral lines. It may only be said that the range in 1949 is of the same order as in 1942.

Table 1 describes the variations in relative intensities of the emission lines arising in the nebulosity, from 1940 to 1949. These variations are brought about in the spectrum by the continued expansion of the excited gas and by the evolution of the exciting nucleus. On the 1949 spectrograms a few weak emission lines, not listed in Table 1, are due to *N* II and *O* II.

The most striking feature is the considerable intensity decrease of N_1 and N_2. While these [*O* III] lines were the strongest of the whole spectrum (with the possible exception of $H\alpha$) in 1940 and 1942, they have become weak in 1949. Line N_1, which used to be stronger than $H\beta$, has now become weaker. One gathers the impression that, contrary to expectations, λ 4363 [*O* III] has gained (or at least not declined) in intensity relative to N_1 and N_2. [*Ne* III] has practically disappeared. The [*Fe* VII] lines in the visual region are not observed on our 1949 spectrograms. At this point of view Nova Herculis differs radically from two other slow novae—Nova RT Serpentis (1909) and Nova RR Pictoris (1925). On the other hand, [*O* II] has gained in intensity relative to [*O* III] and *O* III lines, and even to the Balmer series. The line *N* III is very strong; it is not entirely excited by Bowen's fluorescence mechanism, since λ 4379 *N* III is present and since the fluorescence line of *O* III at λ 3759 is not strong.

The present spectrograms integrate over regions of the nebulosity which may have different physical conditions. Even so, it seems that the observed variations cannot be explained simply on the basis of a change in density and dilution in the expanding nebulosity. The intensity decrease of [*Ne* III] (and of [*Ne* V] in 1947) indicates a decrease in the ionization of neon. The intensity increase of [*O* II] and the decrease of [*O* III] also point toward an ionization decrease of oxygen. If the intense *N* III spectrum is emitted in a recombination process, the N^{++} ions must be photoionized to a considerable extent, which seems to be in contradiction to the situation concerning oxygen and neon. The second ionization potential of neon is 40.9 volts, the second of oxygen is 34.94 volts, and the third of nitrogen is 47.20 volts. The corresponding wave lengths are:

For neon: $(Ne^{+} \rightarrow Ne^{++})$, λ 301.7 A

For oxygen: $(O^{+} \rightarrow O^{++})$, λ 353.2 A

For nitrogen: $(N^{++} \rightarrow N^{+++})$, λ 261.4 A

The observations may be understood if we assume that the far ultraviolet exciting radiation of the nucleus differs considerably from the black body. This departure could bring about an irregular distribution among the stages of ionization, such as that discussed by Bowen and Swings.[2] It is also possible that fluorescence excitation by the underlying radiation plays an important role in the emission. Such a mechanism would be affected considerably by the far ultraviolet absorption or emission features of the exciting nuclear spectrum.

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[2] *Ap. J.*, **92**, 105, 1947.