RR TELESCOPII IN 1953 AND 1954, AND THE DEVELOPMENT OF SLOW NOVAE

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Summary

Recent developments in the emission spectrum of RR Tel include the emergence of C IV, [A IV], [K IV], [Fe IV], [Fe V]. A special search for the hitherto unknown [Fe IV] lines proved successful in the light of Edlén's independent predictions from laboratory data. Fe II lines have faded steadily relative to [Fe II].

The rate of development towards higher stages of ionization is compared with that of other slow novae. Time intervals between corresponding stages of RR Pic, RR Tel, RT Ser and η Car are found to be approximately in the ratios 1 : 6 : 17 : 220. One result of this comparison is to give some grounds for supposing that η Car brightened from a pre-nova state not very long before Halley's observation in 1677.

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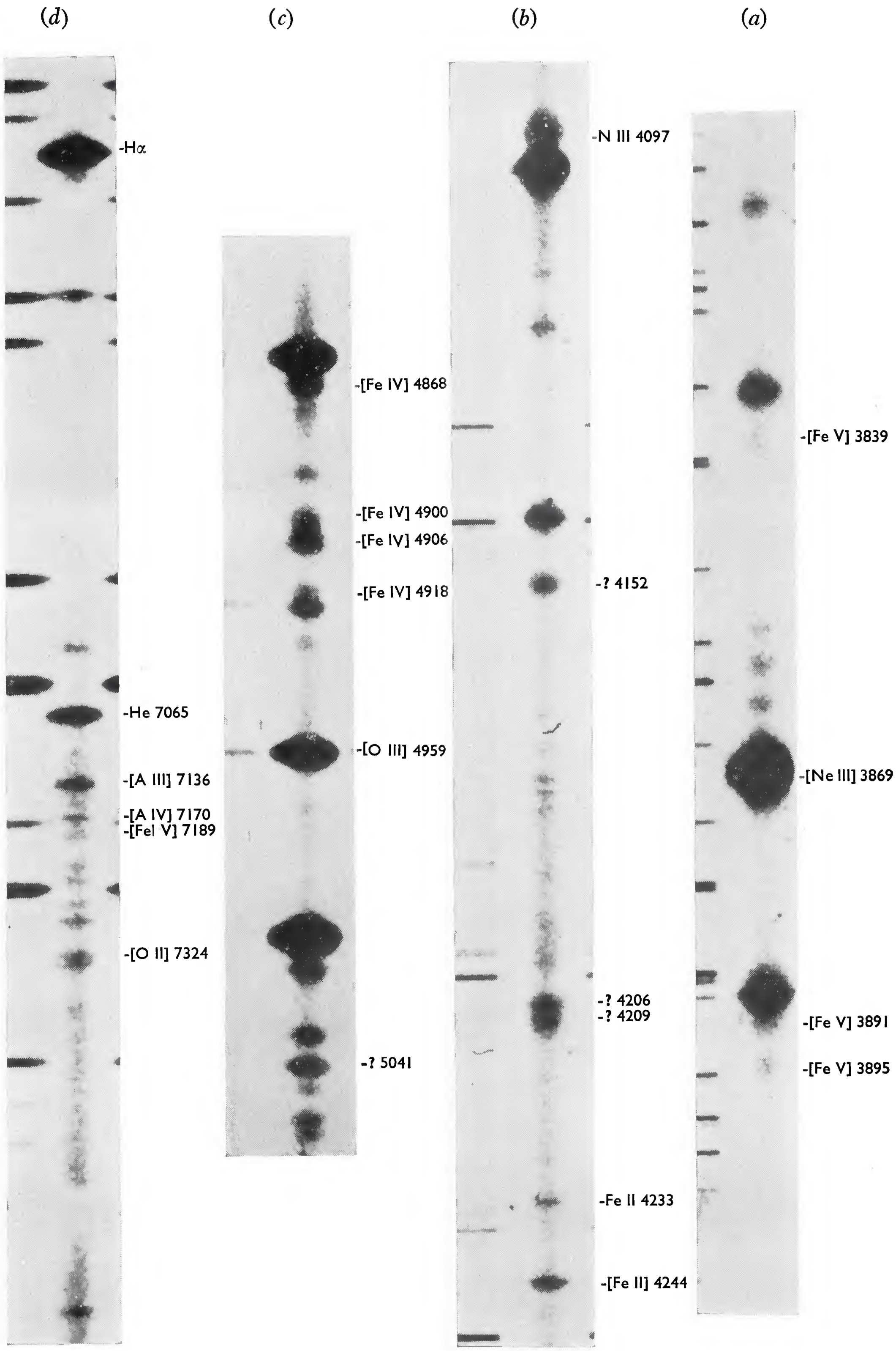
1. Radcliffe spectra of the interesting slow nova RR Tel, covering the period 1949–1952, have been described in two previous communications.* It will be recalled that the star, which had been known since 1908 to be variable ($12^{m}\cdot 5$ to 16^{m}), rose sharply to 7th magnitude in late 1944, remaining fairly constant until 1949, since when a gradual decline to about 9th magnitude has set in. In 1949 June to August a fairly rapid transition was recorded on low-dispersion Radcliffe spectra (Paper I) from absorption (H, Ti II) to emission (H, Fe II). The much more detailed Cassegrain spectra of 1951–52 showed an emission spectrum of advanced Eta Carinae type (Paper II); between 1951 August and 1952 May there was a marked strengthening of broad bands due to [O III] and [Ne III].

The present paper is concerned with identifications of lines in spectra of RR Tel obtained in 1953 and 1954 with the two-prism Cassegrain spectrograph attached to the Radcliffe reflector. In addition, one useful spectrum (120 A/mm) extending beyond the Balmer limit to 3300 A was secured in 1954 with the Newtonian spectrograph, which, equipped with an aluminized plane grating, is now freed from all glass absorption.

Table I lists the observational material secured during the period. Not all the plates have been measured, but if the plate was used in the present study the last column of the table shows the region covered by the measures. Dr D. Koelbloed of the Amsterdam Institute obtained some further material in 1954 for the purpose of a spectrophotometric study which will give valuable quantitative information concerning the physical state of the object. One of his plates

* A. D. Thackeray, *M.N.*, **110**, 45, 1950; **113**, 211, 1953. These papers are hereafter referred to as Papers I, II respectively.



RR Telescopii in 1954.

(*a*), (*b*), (*c*), *July* 26.

(*d*) *July* 3.

A. D. Thackeray, RR Telescopii in 1953 and 1954, and the development of slow novae (taken for the infra-red region) is included in Table I, and the writer is deeply indebted to Dr Koelbloed for the use of this plate. The other plates in the table, and all the measures, are by the writer.

TABLE I

Observations of RR Tel 1953–54

Plate	Date	Emulsion	Exposure (min)	Region measured (A)
c 1341	1953 March 20	103aO	32	
c 1342	1953 March 20	103aF	50	
c 1457	1953 May 13	103aF	80	4630–6793
c 1547	1953 June 24	103aO	60	3869–5042
c 1579	1953 July 2	103aF	270	4630–7065
c 1599	1953 July 20	I N	270	6563–8750
c 1649	1953 Aug. 15	103aF	90	
b 1663	1953 Aug. 22	103aO	120	
b 1719	1953 Sept. 22	103aF	136	4026–6793
c 1898	1954 March 28	103aB	30	
c 1915	1954 April 5	103aB	72	4529–6371
c 1955	1954 May 10	103aB	63	4861–6371
c 2023	1954 June 16	103aB	1	
c 2023	1954 June 16		3	
c 2023	1954 June 16		10	
c 2023	1954 June 16		180	3704–6371
c 2040	1954 July 3	II N	240	6563–8860
c 2040	1954 July 3		12	
c 2041	1954 July 3	103 U	20	
b 2106	1954 July 26	103aB	260	3691–6371
c 2165*	1954 Sept. 8	103 U	124	6678–7378
c 2196	1954 Oct. 5	103aB	70	
G T 2†	1954 Oct. 24	R 55	120	3343–4101

* Observation by D. Koelbloed.
† Newtonian spectrogram.

2. Since the majority of the 250 lines observed in 1953–54 appear already in Table V of Paper II, no useful purpose is served by giving anew a complete table of wave-lengths and identifications. Table II therefore presents a selected list of measured lines, which omits, for instance, the large number of familiar lines due to [Fe II] and Fe II. The criteria for inclusion in Table II have been:

(i) Unidentified lines.
(ii) Lines not observed prior to 1953.
(iii) Lines which have clearly strengthened since 1952.
(iv) A few representative lines, previously observed, to serve as an indication of the intensity-scale; e.g. the Balmer lines in the ultra-violet, [O II] 7324, [O III] 4959, etc.

The arrangement of the table is as in Paper II, an asterisk implying a footnote at the end of the table. The identifications are as before based primarily on Mrs Moore-Sitterly's *Revised Multiplet Table*. In addition, the writer is deeply indebted to Professor B. Edlén for communicating, prior to publication, information concerning wave-lengths of permitted lines due to C, N, O in various stages of ionization, and also to Dr R. Velasco for similar communication concerning Ni III. Professor Edlén has also very kindly communicated information about [Fe IV] (see below).

TABLE II

Selected lines in RR Tel, 1953 and 1954

Wave-length (A)	1953 Int.	1953 n	1954 Int.	1954 n	Identification						
3343			3s	1	Ne III	2F	42·9				
3478			4N	1	N IV	1	78·7				
3490:			2N	1	N IV	1	83·0, 84·9				*
3632·6			?1n	1							
47·0			?1n	1							
91·5			0·5	2	H		91·56				
3697·0			1n	2	H		97·15				
3703·8			3n	2	H		03·85				
11·9			3n	2	H		11·97				
14·8			1n	1							
21·8			6	2	H		21·94,	S III	2F	21·1	*
34·4			4	2	H		34·37				
50·1			3	1	H		50·15				
54·8			1n	1	?Fe V	3F	55·5				
57·6			1·5n	2	?O III	2	59·9, 57·2				
70·6			6n	2	H		70·60				
81·8:			?0·5	1	?Fe V	3F	82·9				
3797·9			8	2	H		97·90,	S III	2F	96·7	
3819·7			5n	2	He		19·6,	Fe V	3F	20·2	
35·4			12	2	H		35·39				
39·6			1·5N	1	Fe V	3F	38·9,	Fe V	1F	38·1	
59·31			3n	2				He II		58·07	
91·65:			2N:	2	Fe V	3F	91·8				*
3895·75			2N	2	Fe V	1F	95·7				
3954·4			1	1	?Fe III	120	54·38				*
4071·84			4N	2	Fe V	1F	71·5				
4097·3	4n	2	12	1	N III	1	97·31				*
4152·46	4	2	8n	2							*
4181·3			1·5n	1	Fe V	1F	81·3				
4206·62:	6	2	10n	2							*
09·04:	4	2	7n	2							*
33·23	3	2	3	2	Fe II	27	33·17				
4244·15	8	2	10	2	Fe II	21F	43·98, 44·81				
4379·08			2?d	2	N III	17	79·09				
4510·3:			3N	2	K IV	2F	11·0				
29·55	1N	2	2	2	?Mn IV	2F	28·3				
4571·24	3	2	4	3							*
4634·37	4	4	10	3	N III	2	34·16				
40·89	10	4	18	3	N III	2	40·6, 41·9				
49·46	1·5n	4	3n	3	C III	1	49 (blend)				
4658·22	9	4	10	3	Fe III	3F	58·1				
4713·22	10	4	12	3	A IV	1F	11·4	He	12	13·2	
4740·50	4	4	6	4	A IV	1F	40·3				
4861·4	70	4	70	4	H		61·3				
4868·2:	4:	4	8:	4	Fe IV	F					*
4900·2	2	4	8	4	Fe IV	F					
06·2	6	4	12	4	Fe IV	F					
18·1	?1	3	4	4	Fe IV	F					
30·8	1n	2	2n	4	?Fe III	1F	30·5				*
4958·79	40	4	50	4	O III	1F	58·91				
5033·27	4	4	10	4							
41·55	8	4	15	4				Si II	5	41·1	
56·2	3	3	6	4	Si II	5	56·1				
5060·3	1·5	2	4	4	Fe III	1F	60·3				

TABLE II (*continued*)

Wave-length (A)	1953 Int.	n	1954 Int.	n	Identification						
5071·0			0·5	1	?Cr IV	4F	71·6				
5084·0:	?1	1	1N	4	?Fe III	1F	84·8				
5147·9			1n?d	3							
5191·9	1	2	4	4	A III	3F	91·4				
5215·0			1n	2							
33·9	6	3	16	4				Fe II	49	34·6	*
5288·6	2	3	6	4							
5305·1:			1n	1							
5323·9			1·5	4	?Cl IV	3F	22·2				
5412·4	2N	3	5W	4	He II	2	11·5				
5494·1	1	2	1·5	4				Fe II	17F	95·8	*
5518·6	1	3	3	4	Cl III	1F	17·2				
35·2	1	2	1	1	Cl III	1F	37·7	Fe II	55	34·9	
44·2			?0·5	1							
52·4			?0·5	1	?Cr III	2F	50·3				
67·9			?0·5	1							
77·8	?1	1	2	3	?O I	3F	77·45				
5592·1			2	3	O III	5	92·4				
5666·6	?1n	1	0·5	2	N II	3	66·6				
5679·8	2n	2	2	3	N II	3	79·6	?Fe VI	1F	78·0	*
5783·6			1·5	3	?Cr III	1F	85·4	?Mn VI	2F	83·4	
5799·7	4n	3	7W	4	C IV	1	01·5				
5813·3:	1n	2	2n	2	C IV	1	12·1				
20·7	?1	1	3	4							
34·8			1	1							
53·9			?0·5	1							
5860·6			?0·5	1							
5904·5:			1	2	?Mn VI	2F	07·1				
5911·3	1	3	4	4							*
6047			1	1							
6101·9			5	4	K IV	1F	01·1				
6312·2	10	3	10	4	S III	3F	10·2				*
6731:	?1	1			?S II	2F	31·3				
6793·2	3	4	2:	2	K IV	1F	94·8				*
6997	?1	1	4	2	?Ti III	3F	91·8	?A V	1F	06·3	
7065	20	2	35	2	He I	10	65·2				
7101:	0·5	2	0·5	1							
36	10	1	15	2	A III	1F	35·8				
55			2	2	Fe II	14F	55·1	?Ti III	3F	52·8	
71	2	1	5	2	A IV	2F	69·0	He II		77·5	*
7189	?0	1	3n	2	Fe IV	F					
7207			?0·5	1							
21	?0	1	3	2	Fe IV	F					
38			3	2	A IV	2F	36·0				
62			2	2	A IV	2F	63·3				
7281	4	1	6	2	He I	45	81·3				
7324	8	1	10	2	O II	2F	(blend)	A IV	2F	32·0	*
7378			1n	2	C IV			Ni II	2F	77·9	*
7749	4	1	8	1	A III	1F	51·0				
7816	?0	1	?1	1	He I	69	16·2				
7923			1n	1							
8046			1n	1	Cl IV	1F	46·1				
8361	2	1	?1n	1	He I	68	61·8				
8446	10	1	10	1	?O I	4	46·5				

NOTES TO TABLE II

3490 On the Newtonian spectrogram (120 A/mm) this strong very diffuse feature is barely resolved from 3478 and the measured wave-length is very uncertain.

3721·8 The contribution of [S III] to this line is indicated by comparing its intensity with those of neighbouring Balmer lines.

3891·65 (Plate 2 (*a*)). Wave-length and intensity uncertain owing to proximity of H 3889.

3954·4 Identification very uncertain.

4097·3 Strengthened from 1953 to 1954; well resolved from Hδ (Plate 2 (*b*)). Not recorded in Paper II but, like N III 4640, was probably present, very diffuse, blended with the wing of Hδ.

4152·46 (Plate 2 (*b*)). Unidentified. Observed also in η Car. The ascription to [Co II] in Paper II is now ruled out by the subsequent behaviour in RR Tel.

4206·62, 4209·04 Unidentified. Observed in RR Pic as a single line 4207. Assuming the two lines to have a common origin the separation may provide a clue to the identification.

4571·24 Can scarcely be due to Mg I at this stage of ionization.

4868·2 (Plate 2 (*c*)). Wave-length and intensity uncertain owing to proximity of Hβ. Identification with [Fe IV] due to Edlén (private communication).

4930·8 Probably due to Fe III (1*F*). [O III] 4931·8 should be several thousand times fainter than the nebulium pair.

5233·9 Fe II must be a minor contributor. This unidentified line appeared in RR Pic.

5494·1 Mainly unidentified; this line is too strong for Fe II 17 *F*, and the wave-length disagrees.

5679·8 The absence of 5177 shows that the contribution of [Fe VI] must be small.

5911 Observed in N Her.

6312·2 As in Paper II the wave-length disagrees from the prediction for [S III] but there can be little doubt of the correctness of the identification.

6793·2 The lower intensity recorded in 1954 is a result of the insensitivity of the emulsion used. In 1953 103aF emulsion recorded this line well, but not the other [K IV] line at 6101.

7171 In 1953 this line was regarded as too strong for [A IV]. In 1954 it appears stronger than the other [A IV] lines; probably He II 7177 contributes.

7324 (Plate 2 (*d*)). Just resolved but measured as a single line.

7378 Probably due to C IV as observed in planetary nebulae (see Swings and Jose, *P.A.S.P.*, **61**, 181, 1949) with [Ni II] as a minor contributor.

3. *Representation of elements*

H	The Balmer series is represented from Hα to H 18 (3691). A continuum appears on the Newtonian spectrogram extending well beyond the series limit. The Paschen series is recorded from 8863 to 8500 A. The stronger lines have very wide faint wings—see Hβ on Plate 2 (*c*).
He I	New lines due to this element appear at 7816, 7281, 8361.
He II	4686 still appears as a very strong wide band and 5412 is also strongly winged.
C II	4267 is weakly present.
C III	4650 has been increasing in intensity since 1951.
C IV	5801, 5812, a well resolved pair despite strong wings, became quite a prominent feature in 1954. 5801 appeared weakly in 1952 but was regarded as unidentified in Paper II. 7378 appears weakly.
N II	Weakly present; multiplet 3.
[N II]	Still prominent.

N III	Multiplets 1, 2, 17. The 4640 group appeared as a very diffuse, unresolved band in 1952 (much stronger than in 1951); in 1953–54 all N III lines appeared much sharper, with 4634, 4640 and 4097, Hδ as well resolved pairs.
N IV	The strong multiplet 1 is the chief feature in the far ultra-violet. The very broad band (4048 to 4064) recorded as probably due to N IV in 1952 has disappeared. This feature probably has the same origin as the broad N III bands.
O I	The line 8446, apparently excited by Ly β (Bowen, *P.A.S.P.*, **59**, 196), appears strongly in 1953 and 1954. These infra-red plates are much better exposed than those of Paper II, and O I 8446 seems to have weakened relative to [O II] 7324, in agreement with the general trend of increasing ionization.
[O I]	6300, 6363 are still prominent. In addition, the auroral line 5577 appears to be weakly present.
[O II]	The pair at 7324 is prominent, but the 3727 pair cannot be detected even on the Newtonian spectrogram. No permitted lines are observed.
O III	Possibly represented by the one line 3757.
[O III]	5007, 4959 and 4363 are still very broad bands.
[F II], [F III], [F IV]	Not found.
[Ne III]	3869, 3967 present as very strong bands, like [O III], (Plate 2 (*a*)). 3343 appears on the Newtonian spectrogram (1954).
[Ne IV]	Multiplet 1*F*, with uncertain wave-lengths near 4720, is apparently absent but might be expected to appear soon.
Mg I	The continued presence of the line 4571·2, attributed doubtfully to Mg I in Paper I, means that some other identification should now be sought.
Mg II	4481 still appears weakly in 1954.
Si II	Represented by multiplets 1, 2, ?4, 5.
Si III, IV	Not found, rather surprisingly in view of the presence of Si II.
[S II]	Represented by 1*F* and ?2*F*. The weakness or absence of 6717, 6731 closely parallels the weakness or absence of [O II] 3727.
[S III]	6312 (3*F*) persists; 3797, 3721 (2*F*) are both blended with H lines, but appear to be present judging by the Balmer decrement.
[Cl III]	5517, 5537 (1*F*) were recorded in 1953 and 1954.
[Cl IV]	A line measured four times in 1954 at 5323·9 may be due to multiplet 3*F* (5322·2). 8046 (1*F*) was measured once.
[A III]	Represented by 1*F*, 3*F*. The strengthening of these lines is one of the outstanding features of recent developments. In Paper II 7135 (1*F*) was weakly recorded.
[A IV]	Represented by 1*F*, 2*F*. 4740 was recorded weakly as an unidentified line in 1952.

[K IV] Represented by 6101, 6793 (1*F*) and 4511 (2*F*). Only 6793 was found in 1953.

Ca, Sc, V Not found.

[Ti III] Doubtfully represented by 6992, 7153 (3*F*), but the wave-lengths are discrepant.

[Cr III] Doubtfully represented by weak 5783 (1*F*) and 5552 (2*F*) with discrepant wave-lengths.

[Cr IV] Doubtfully represented in 1954 by a very weak line once measured at 5071 (4*F*).

[Mn IV] Possibly represented by 4529 (2*F*) which increased in intensity from 1953 to 1954. This line is analogous to 4658 of [Fe III]. The next strongest line is blended with Mg II 4481.

[Mn VI] Very doubtfully represented by two members of 2*F*, but 1*F* should appear too.

Fe II, [Fe II] Still represented by very numerous lines. The permitted lines have faded considerably. The progressive change in ratio between permitted and forbidden lines is well illustrated by the lines 4233, 4244 whose intensities for each year since 1949 are as follows:

		1949	1950	1951	1952	1953	1954
Fe II	4233	4	4	8	6	3	3
[Fe II]	4244	...	2	6	7	8	10

The absolute intensities are not of course strictly comparable from year to year; the intensities for 1949–50, dependent only on Newtonian spectra, should certainly be increased for comparison with later years.

Fe III A line at 3954 is very doubtfully ascribed to this ion, but the more familiar line 4419 does not appear.

[Fe III] Still represented by multiplets 1*F*, 3*F*.

[Fe IV] A special search for the multiplets in green and infra-red, predicted by Edlén* without precise wave-lengths, was conducted in 1953 and 1954. A number of unidentified lines, found in 1953, were listed as possibly due to this ion.† I am much indebted to Professor Edlén for communicating privately that the following lines in RR Tel can be definitely ascribed to [Fe IV] according to the independent analysis of his laboratory data:

Observed wave-length	Int. (1954)
4868·2	8:
4900·2	8
4906·2	12
4918·1	4
7189	3n
7221	3

* B. Edlén, Paris Colloquium on Novae and White Dwarfs, 1939.
† A. D. Thackeray, *The Observatory*, **74**, 90, 1954.

The lines 4868 and 4906 suffer from blending with $H\beta$ and Fe II respectively (Plate 2 (*c*)). The other strong line 4900 has been observed in η Car (Paper II) and in other objects. RR Tel, with its sharp lines and continued brightness, is by far the best object in the sky for the astrophysical study of [Fe IV] lines.

[Fe V] Members of multiplets 1*F*, 3*F* appeared weakly in 1954. All lines observed are listed in Table II, (Plate 2 (*a*)).

[Fe VI], [Fe VII] Not found. N II 5679 masks [Fe VI] 5678.

[Co II] The line at 4152 (Plate 2 (*b*)), previously observed in η Car and RR Tel, and tentatively ascribed in Paper II to [Co II] on the ground of good agreement in wave-length and of relatively high transition probability in the region studied, must now be regarded as unidentified in both objects. The increase in strength in 1953 and 1954 points to an ion of higher ionization potential.

[Ni II] The few lines previously recorded have faded. In 1954, 4201 alone was once recorded weakly.

Ni III No coincidence with lines in RR Tel could be found with Velasco's unpublished laboratory lines due to this ion. The identification of some lines with [Ni III] or [Ni IV] however remains an interesting possibility.

The strongest unidentified lines are 4152, 4206, 4209, 5033, 5041, 5233, 5288.

4. *Summary of developments in* 1953–54.—The chief characteristic of the development of RR Tel since spectroscopic observations began in 1949 has been a gradual increase in the state of ionization. In 1953–54 this is exemplified well by the emergence of C IV, [Fe IV], [Fe V], [A III], [A IV], [Cl IV], [K IV]; there has been no very marked change in individual lines like the emergence of strong broad bands of [O III] and [Ne III] which occurred between the 1951 and 1952 seasons.

A second feature is the fading of Fe II permitted relative to forbidden lines (see preceding section). In this connection it is worth emphasizing the continued presence of Si II lines but non-appearance of Si III and Si IV. The permitted lines of higher stages of ionization which have recently appeared are confined to the light elements C, N, etc. The absence of Si II 4128, 4130 suggests dilution of radiation.

Thirdly, there is a striking difference in character between lines of low and high stage of ionization or excitation. Fe II lines are sharp, while lines such as [Fe V], [K IV] 4511 are quite diffuse. (See Plate 2 (*a*, *b*) for comparison of Fe II and [Fe V]). Among the stronger lines, the series of increasing diffuseness is continued by C IV 5801, [O III] and [Ne III] and the broadest band of all, He II 4686. Thus diffuseness appears to be correlated with both increasing ionization and excitation potential.

5. *Rate of development compared with other slow novae.*—It is well known that different novae tend to show roughly the same sequence of spectroscopic developments, but that the rate of development varies markedly. McLaughlin*, in particular, has derived quantitative relationships between the rates of development and of decline in light and the absorption velocities of novae.

* D. B. McLaughlin, *Ap. J.*, **85**, 362, 1937; **91**, 369, 1940; **95**, 428, 1942.

Sufficient spectroscopic observations of RR Tel during the nebular stage have now been accumulated to permit a fair comparison with the corresponding stages of the well-observed slow nova RR Pic.* The observations of spectroscopic changes in RT Ser and η Car are very scanty, but nevertheless an attempt to compare these other two slow novae with RR Tel is of some interest.

The comparison of stages of spectroscopic development can be supplemented by two points on the light-curves. In the cases of RR Pic, RR Tel and RT Ser it is known that the epoch of maximum light was preceded by a steep rise some months or years earlier; between these dates the light-curves are fairly flat at a magnitude or so fainter than the brightest maximum. The preliminary rise of RR Pic was not actually observed, but must have occurred between 1925 January 13 and April 13.† η Car was at its brightest known maximum in 1843 and is known to have fluctuated between 2nd and 4th magnitude from 1677 to 1830.

The main object of the accompanying Table III is to compare the various developments during the nebular stages. Consequently the zero-point of the time scale is chosen to coincide with the "Eta Carinae" stage ([Fe II] predominant), although in η Car itself this stage seems to have persisted without much change for at least 40 years. Many adopted stages correspond to marginal appearances of various states of ionization, especially of Fe. The dates of marginal appearance are of course subject to very great uncertainty, especially when comparing spectra taken with widely different spectrographs. It must be remembered too that the marginal appearance of any emission line will depend upon the strength of any continuous spectrum; however, the continuum is usually very weak in these objects at the corresponding phases. The marginal appearance of [Fe III] in η Car is given as 1951, since this ion is well represented in Table II of Paper II, while Gaviola's observations‡ from 1944 to 1951·2 do not include lines such as 4734, 4754 and there is no certain evidence of the ion at all in earlier years.

As was pointed out in Section 3, the development of RR Tel has involved the more rapid fading of Fe II than of [Fe II] lines. The ratio of permitted to forbidden line intensities (e.g. 4233/4244) seems to vary considerably from nova to nova at the same stage of ionization. No doubt this ratio is an indication of a more complex set of physical conditions than the criteria of development used in Table III.

The last column of Table III gives an average time-sequence, based on all four objects, for the development of the various stages, in arbitrary units.

In Fig. 1 the data of Table III are plotted with RR Pic used as a basic comparison. It will be seen that there is a roughly linear relationship between the rates of development of all four novae, surprisingly close considering the uncertainties of the dates. The slopes of the straight lines drawn through the points correspond to the following time-scales for corresponding stages of development of the four novae:

RR Pic	RR Tel	RT Ser	η Car
1·0	6	17	220

The above figures are necessarily rough, their probable errors being of the order of 25 per cent.

* H. Spencer Jones, *Ann. Cape Obs.*, X, pt. 9, 1931.
† H. Shapley, *H.B.*, 823, 1925.
‡ E. Gaviola, *Ap. J.*, **118**, 234, 1953.

TABLE III

Development of four slow novae

Stage	RR Pic	Δt (days)	RR Tel	Δt (yrs)	RT Ser†	Δt (yrs)	η Car	Δt (yrs)	Δt (Arbitrary units)
Preliminary rise	1925 Jan. 13	−284 }	1944·9	−5·8	1909	−19			−7
	1925 Apr. 13	−194 }							
Maximum	1925 June 10	−136	1948·5 :	−2·2 :	1920	− 8	1843	−77 :	−3
cF absorption (Ti II !)	1925 Sept. 10	− 44	1949·4	−1·3			1893‡	−27 :	−1
η Car	1925 Oct. 24	0	1950·7	0	1928	0	1900 − 1940	0 :	0
[Fe III] m.a.	1925 Dec. 1 :	+ 38 :	1951·5	0·8	1931	+ 3	1951	+31 :	+1
[O III] m.a.	1926 Feb. 1 :	+100 :	1951·5	+0·8					+1·5
He II flash	1926 Mar. 15	+142	1952·4	1·7					+2·5
[Fe IV] m.a.	1926 Apr. 28	+186	1953·3	+2·6					+3·5
[Fe V] m.a.			1954·3	+3·6					
[Fe VI] m.a.	1926 June 4	*+223			1940	+12			+5
[Fe VII] m.a.	1926 Sept. 7	*+318			1942	+14			+6

* From Spencer Jones (*op. cit.*, Table XLIV, page 134 1). The marginal appearances are taken from [Fe VI] 5146, [Fe VII] 5720. The stronger lines 5177, 6085 are liable to blending with Fe II and [Ca V] respectively at earlier dates.

† Data for RT Ser are taken from S. & C. P. Gaposchkin, *Variable Stars*, pp. 263, 264, and Struve and Swings, *Ap. J.*, **92**, 295, 1940; **96**, 471, 1942.

‡ B. J. Bok (*P.A.*, **38**, 399, 1930). In 1893 η Car was nearly a magnitude brighter than in preceding years, and it is not entirely certain that a bright-line spectrum may not have been prominent earlier. In 1886, however, the spectrum was observed visually to be continuous plus absorption lines (Clerke, *The Observatory*, **11**, 429, 1888).

It is of interest to note that since McLaughlin found that N. Lac 1936 developed at 16 times the rate of RR Pic, this rate corresponds to about 3500 times that of η Car. However, no close parallelism can be expected between the developments of the fastest and the slowest novae; it is the slow novae like RR Tel that seem to exhibit the purest examples of sequences of increasing ionization.

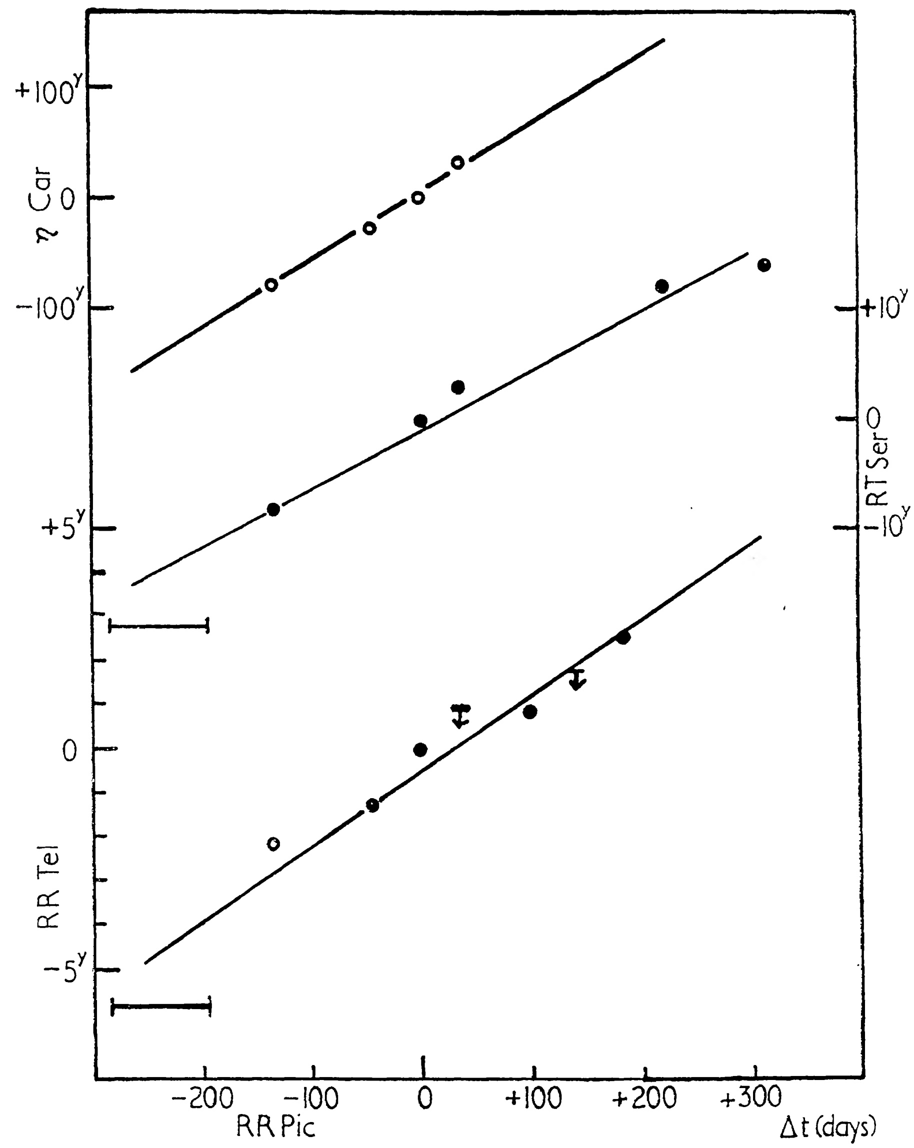


FIG. 1.—*Epochs of corresponding stages of development of RR Pic (abscissae) and η Car (top), RT Ser (middle), RR Tel (bottom).*

The close relationships exhibited in Fig. 1 suggest that extrapolations of the lines may be attempted without falling into the realm of pure speculation. Thus, by extrapolating the line for RR Tel we find that the marginal appearance of [Fe VI] and [Fe VII] may be expected at about 1954·8 and 1955·8 respectively. No sign of [Fe VI] 5177 could be detected on the last plate of that region (1954·76) but its appearance in the near future followed by [Fe VII] may be confidently expected.

Extrapolation of the line for η Car suggests that the [O III] lines should appear about 1980. As was pointed out in Paper II, however, the lines of oxygen in η Car seem to be surprisingly weak. It will therefore be of special interest to see whether the [O III] lines do follow the pattern of development suggested by other novae.

The first two entries in Table III refer to points on the light-curves and their relation to the other entries is probably insecure. Nevertheless it is of interest to attempt to estimate from them when a preliminary rise of η Carinae may have occurred. A straightforward application of the relative time-scales suggests a date between 1670 and 1710, with an uncertainty of about half a century. Halley's observation in 1677, when the star was ranked as 4th magnitude, is usually accepted as the first record, and one might therefore suppose that a preliminary rise from pre-nova state occurred shortly before. However, Bayer's *Uranometria* (1603) apparently recorded the star as 2nd magnitude on second-hand evidence.* As pointed out by Innes†, the star was probably fainter than 4th magnitude in Ptolemy's time, for it was not included in the *Almagest*. Any records of the star prior to 1677 would be valuable in this connection and the problem seems to deserve the attention of historians of astronomy.

* Quoted by Agnes Clerke, *Problems in Astrophysics*, p. 371, 1903.

† *Ann. Cape Obs.*, IX (not XI as sometimes quoted), 75B.

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ADDENDUM

Note added in proof. I am deeply indebted to Dr A. Armitage who has supplied the following information concerning the history of Eta Carinae, based on Muller and Hartwig, *Geschichte u. Lit. des Lichtwechsels*, Leipzig, 1918, 1920.

The non-inclusion of Eta Carinae in the oldest Catalogues (Ptolemy, etc.) allows no conclusions to be drawn in view of the fact that bright stars such as μ Argus (10° farther north) are not included. The earliest records of the region of Eta, depending on observations in India at the end of the sixteenth century, are included in Bayer's and v. Houtmanns' charts. v. Houtmanns' (1603) does not show the star, while he includes p, q, s, μ Car, whence Eta can hardly have been brighter than 5^m. Bayer (1603) includes a group of some seven stars, designated d, of 4th magnitude; the modern Eta may have belonged to this group, but Bayer's Eta Argus, of 2nd magnitude, is certainly not Eta Car.

Lacaille (1757) assigns 2nd magnitude to his Eta Argus, with an accurate position which clearly identifies it with the modern Eta Car.

One may conclude that the star must have brightened at some time between 1600 and 1757, but that the richness of the Milky Way region renders naked-eye records practically unusable for estimating the extent of the brightening.