THE PRESENT SPECTRAL CHARACTERISTICS OF SIXTEEN OLD NOVAE*

M. L. HUMASON

ABSTRACT

Spectra of sixteen old novae have been observed with a small-dispersion spectrograph. Observations have been made in the fields of two others in an effort to identify them by their spectra. Visual magnitudes of the observed objects range from 10.0 to 16.5. Charts of all the fields are given for the benefit of other observers.

Most of the objects have a strong continuous spectrum extending well into the violet, in which neither absorption nor emission lines can be seen. They have therefore been classified as O Con, since the extension into the violet corresponds to that of O-type stars, or possibly of early B stars. When emission lines have been observed, the stars have been classified as O Em.

In the search for Nova B Cassiopeiae (1572), Baade observed an interesting faint blue star on a color plate of the region. Its photographic magnitude is 17.0, its spectrum A0n. As the mean absolute magnitude for stars of this type is roughly +1.0, the distance modulus, uncorrected for space absorption, is 16.0, thus indicating a distance of the order of 16,000 parsecs in a direction 125° from that of the galactic center. It is not assumed that this star is the nova.

Spectral types of four stars observed in the field of Nova Vulpeculae (1670) indicate that this nova has not yet been rediscovered. One of these objects is the faint variable star found by W. H. Steavenson.

With the exception of T Coronae, all the novae observed are blue and probably correspond in temperature with the O or early B stars. T Coronae may also be blue if it is the companion of a red star.

The density of Nova Persei (1901) in its present state is of the order of 220 ⊙. The corresponding value for Nova Aquilae (1918) is 70 ⊙. For eleven novae whose distances are not so reliably known, a mean density has been determined by using $M_{max} = -7.0$, the mean M of galactic novae at maximum, from which their present mean M is obtained by adding the mean of their amplitudes. The resulting mean density of this group is 60 ⊙.

During the past several years spectrograms of sixteen old novae have been obtained. In addition, stars in the fields of two other novae have been observed, in an effort to identify them by their spectra. The instrument used is the 100-inch Cassegrain nebular spectrograph, which has a dispersion of 500 A/mm at $H\gamma$. Visual magnitudes are used throughout this paper unless otherwise stated.

The mean magnitude of the novae observed is about 14.0. Whenever the object was bright enough, its spectrum was widened by allowing the star to drift along the slit. While most of the spectra are narrow and the dispersion small, the observations give for the first

* *Contributions from the Mount Wilson Observatory, Carnegie Institution of Washington,* No. 596.

time an indication of the present spectral characteristics of these objects.

Of the eighteen objects observed, fifteen are thought to be correctly identified.[1] Two others, Nova B Cassiopeiae (1572) and Nova Vulpeculae (1670), are probably not yet known; and a third, Nova Sagittarii (1898), is still doubtful. Charts of all objects observed are reproduced from direct photographs kindly obtained for the writer by Messrs. Baade and van Maanen with either the 60- or 100-inch

TABLE 1

NOVAE OBSERVED

Nova	α 1900	δ 1900	m_V Max.	m_V Min.	Sp.
B Cass (1572)	$0^h19^m.2$	+63°36′	−5?	?	?
Per (1901)	3 24.4	+43 34	0.0	11.8–14.0	O Em
T Aur (1891)	5 25.6	+30 22	4.5	14.8	O Em
Gem (1903)	6 37.8	+30 3	7.3	16.5	O Con
Gem (1912)	6 48.4	+32 16	3.7	14.7	O Em
T Pyx (1890–1902–1918)	9 0.5	−31 59	7	14.1	O Em
T Cor B (1866)	15 55.3	+26 12	2.0	10.6	? Em
Oph (1848)	16 53.9	−12 44	5.0	12.2–13.0	O Con
RS Oph (1898–1933)	17 44.8	− 6 40	4.3	11.8	O Em
Sgr (1919)	18 25.7	−29 28	7	14.0	O Con
Aql (1918)	18 43.8	+ 0 28	−1.4	10.8	O Em
Lyr (1919)	18 49.5	+29 6	6.5	15.2	O Con
Sgr (1898)	18 56.2	−13 8	4.7	16.5	O Con
Vul (1670)	19 43.5	+27 4	3	?	?
Cyg (1920)	19 55.9	+53 21	2.0	15.5	O Em
Sge (1913)	20 3.1	+17 24	7.2	15.2	O Con
Q Cyg (1876)	21 37.8	+42 23	3	14.4–15.2	O Em
Lac (1910)	22 31.8	+52 12	5.0	14.4	O Con

reflector (Pls. VII–X). All the photographs have been enlarged to approximately the same scale, about $7''.5$ per millimeter. Since the exposures varied from 10 to 60 minutes, the images of the different objects do not indicate their relative brightness.

Table 1 lists the novae observed, their positions and visual magnitudes,[2] and their spectral types, which are approximate because of the small dispersion used. All have been assigned to two groups designated as O Em, or type O with emission lines present; and O Con,

[1] The writer would greatly appreciate being informed of any known misidentifications.

[2] Most of the magnitudes in the fifth column are measures by W. H. Steavenson which appear in his yearly reports of "Observations of Novae" in *Monthly Notices.*

or type O without observable absorption or emission in what appears to be a simple continuous spectrum. The relative intensity of a continuous spectrum extending well into the blue region, and the absence of absorption lines, especially of calcium H and K, were the criteria for classification as type O.

NOVA B CASSIOPEIAE (1572)

Two stars have been observed in the field of this nova: one by Lundmark and the writer in 1922, and one by Baade and the writer in 1937. The 1922 observations were made with a slitless spectrograph attached to the Newtonian focus of the 60-inch reflector, and covered a field 40′ square. Spectra of fourteenth-magnitude stars were registered on the longest exposure, but none could definitely be identified as that of the nova. The spectrum of an M-type star appeared very close to the computed position of the nova, however, and was noted for the reason that at that time (1922) the spectrum of another nova, T Coronae, was believed to be of type Mb pec. There are now sound reasons for believing that T Coronae is not an M-type star, however; and[3] it is therefore extremely improbable that the M-type star mentioned is B Cassiopeiae.

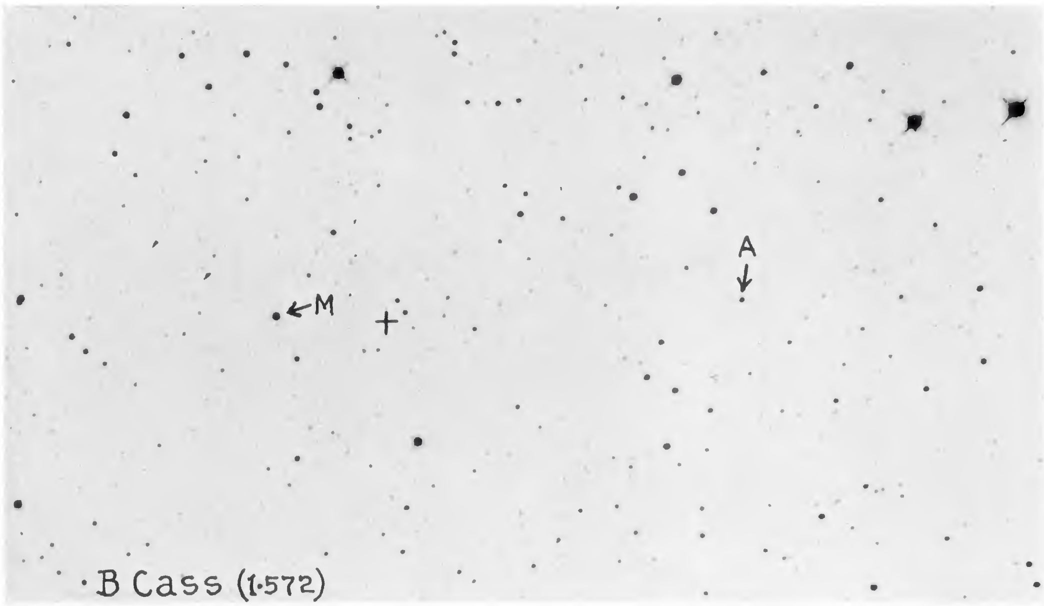
More recently Baade and the writer have again attempted to identify this nova. Assuming that B Cassiopeiae was a supernova with a large range in brightness, and that its present spectrum should be that of an O- or early B-type star, Baade is searching for faint blue stars[4] near the computed position of the nova. So far, one color plate has been obtained, on which the limiting photographic magnitude at the center of the field is about 18. In an area 21′ in diameter, only one blue star has been found. Baade estimates its photographic magnitude as 17.0 and its color index as 0.0. Its position for 1865 is: right ascension, $0^h16^m.4$; declination, $+63°23'$. A very good spectrogram of this star obtained by the writer in November, 1937, indicates that it is probably not B Cassiopeiae but is interesting, nevertheless, in its own right on account of its type and the resulting probable distance. The spectrum has been classified as Aon, as the hydrogen lines are strong and fairly wide and the calcium lines H

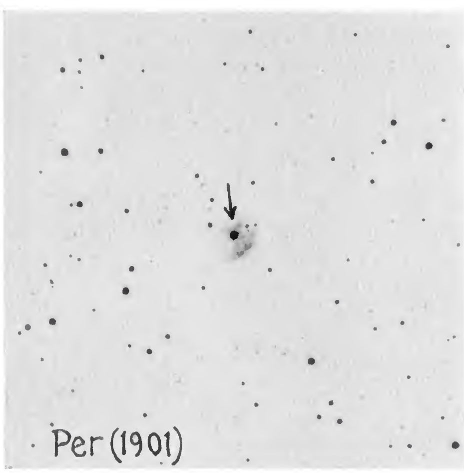
[3] See description of the spectrum of T Coronae on p. 233.

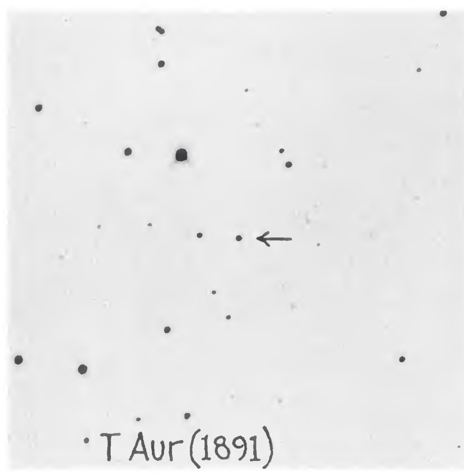
[4] *Mt. W. Contr.*, No. 600; *Ap. J.*, **88**, 285, 1938.

1938ApJ....88..228H

PLATE VII

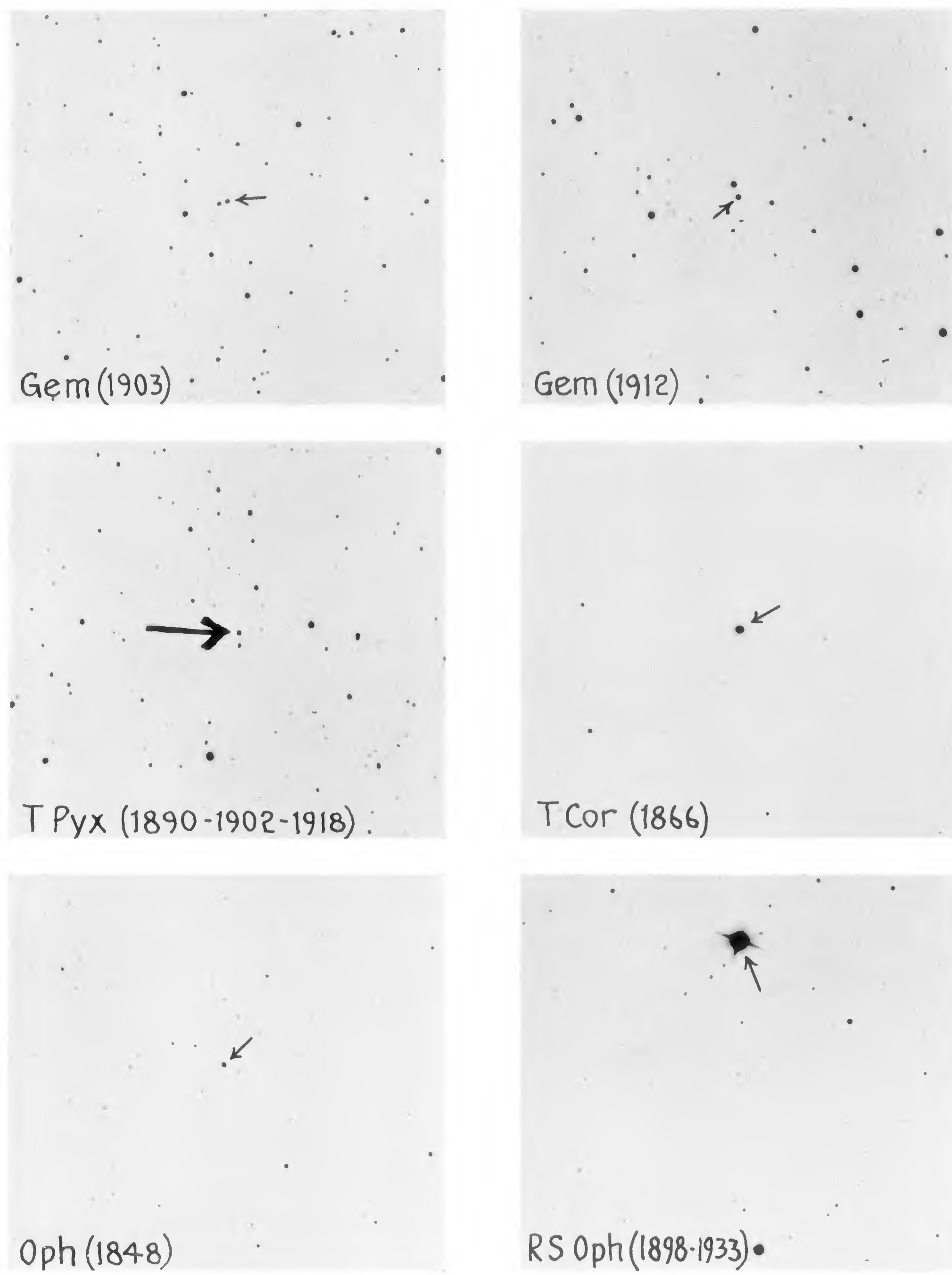






FIELDS OF NOVAE
Scale, 1 mm = 7″.5

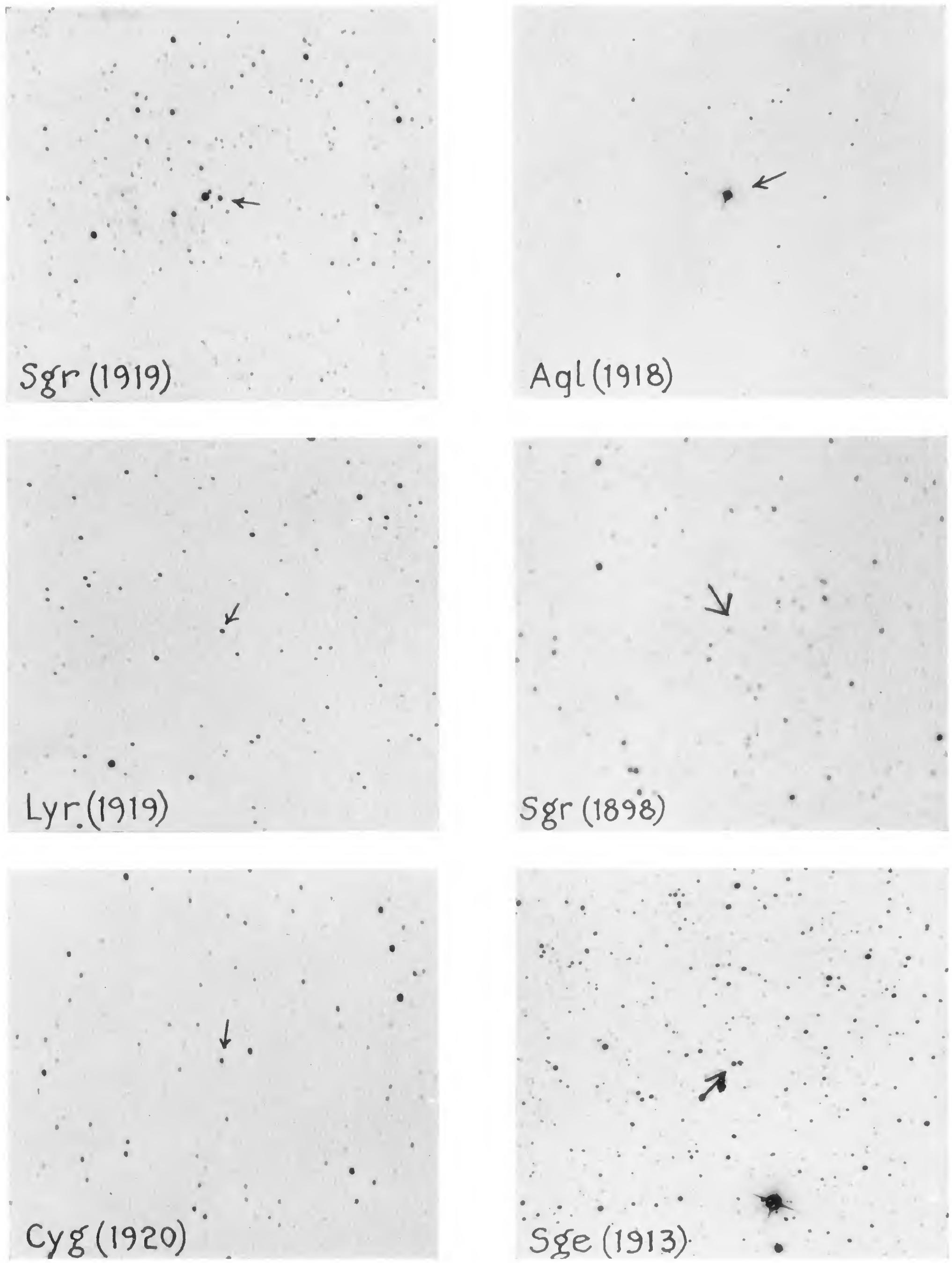
PLATE VIII



FIELDS OF NOVAE

Scale, 1 mm = 7″.5

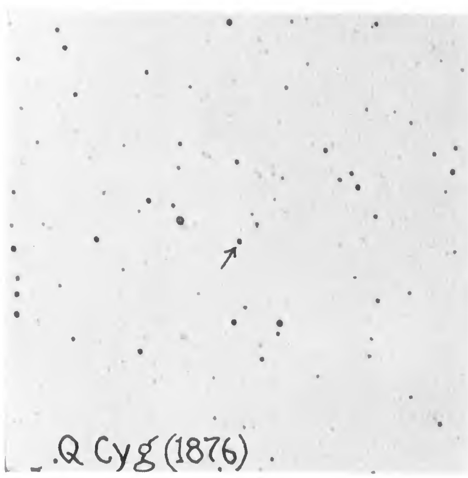
PLATE IX

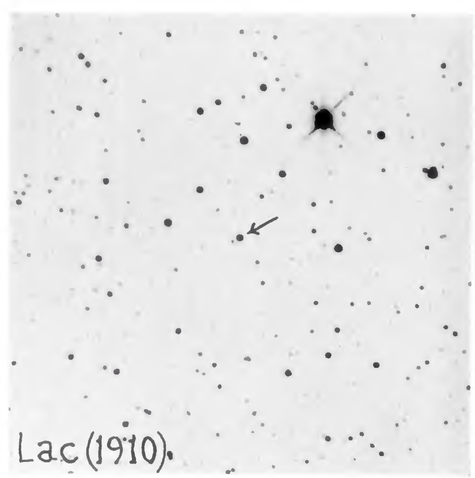


FIELDS OF NOVAE
Scale, 1 mm = 7″.5

1938ApJ....88..228H

PLATE X





FIELDS OF NOVAE
Scale, 1 mm = 7″.5

and K do not show. The strength of the hydrogen lines and the fact that they are not unduly wide indicate that the star is not a white dwarf but a normal A-type giant. The mean absolute magnitude of stars of this type is roughly +1.0, which gives for the distance modulus, uncorrected for space absorption, the value 16.0, thus indicating a distance of 16,000 parsecs in a direction 125° from that of the galactic center.

On the chart of the field of B Cassiopeiae (Pl. VII) the M-type star observed in 1922 is designated by "M," and the faint A star found by Baade by "A." The cross marks the computed position of the nova for 1922. The search for this nova will be continued over a somewhat larger area and to a fainter limiting magnitude in the near future.

NOVA PERSEI (1901)

This is one of the most interesting novae observed. Thirty-seven years after the outburst, its light is still variable over a range of 2 mag., and minor changes in the intensities of the emission lines also occur. It is also one of two novae having an expanding shell of gas which is bright enough to be photographed, the other being Nova Aquilae (1918). The shell now has a radius of 20″; and since 1917, when the nebulosity was first discovered, it has expanded at the uniform rate of 0″.4 per year.[5] The spectra of both the nova and the shell contain emission lines; but the only element common to both is hydrogen, which is strong in the nova and extremely weak in the spectrum of the gaseous envelope. Table 2 lists the lines observed in the nebula and in the nova, with their mean intensities as observed on eight Imperial Eclipse plates.

Emission lines in the spectrum of the nova are of the order of 16 A wide and should be classified as bands. Their intensities for the nova spectrum observed on the individual spectrograms are given in Table 3. Except on the 1933 spectrograms, λ 4686 appears to be the strongest emission feature in the spectrum. The lines of ordinary helium are weak and disappear altogether at times. $H\gamma$ is usually the strongest hydrogen line, although sometimes $H\delta$ becomes almost equal to, and on January 30, 1930, was stronger than, $H\gamma$. There seems to be no outstanding correlation between the variation in the

[5] *Pub. A.S.P.*, **46**, 229, 1934.

intensity of the emission lines and the variation in the light of the nova. The first six magnitudes in the table are Steavenson's values for the dates, or within a few days of the dates, on which the spectrograms were obtained. The last two are visual estimates made by the writer at the Cassegrain focus of the 100-inch reflector.

TABLE 2

EMISSION LINES OBSERVED IN THE SPECTRA OF THE NEBULA AND THE NOVA

NEBULA			NOVA PERSEI (1901)		
λ	Element	Int.	λ	Element	Int.
3727	*O* II	40	3835	*H*	2
3869	*Ne* III?	65	3889	*H*	3
3968	*Ne* III?	50	3970	*H*	3
4102	*H*	2	4026	*He* I	2
4340	*H*	5	4102	*H*	5
4363	[*O* III]	10	4340	*H*	6
4571	....	1	4471	*He* I	1
4722	*Ne* IV?	2	4686	*He* II	6
4861	*H*	3	4861	*H*	4
4959	[*O* III]	15			
5007	[*O* III]	25			

TABLE 3

EMISSION-LINE INTENSITIES IN THE SPECTRUM OF NOVA PERSEI (1901)

Date	m_v	3835	3889	3970	4026	4102	4340	4471	4686	4861
1930, Jan. 30	12.3	.....	.....	2	1	7	5	0	7	5
1933, Oct. 17	13.8	.....	.....	2	0	2	3	0	1	1
1933, Nov. 18	13.5	2	5	5	3	6	8	1	3	2
1934, Dec. 2	13.1	1	3	5	3	8	10	2	8	6
1935, Nov. 25	12.9	1	2	3	1	3	6	2	8	2
1937, Jan. 13	12.7	1	3	4	2	3	5	0	5	2
1937, Nov. 4	13.2	1	2	3	2	7	7	2	8	3
1937, Nov. 5	13.2	1	2	3	2	5	7	2	8	5

NOVA T AURIGAE (1891)

According to Steavenson, the light of this nova has remained constant at magnitude 14.8. Spectrograms were obtained on November 19, 1933; January 13, 1937; and March 6, 1937. On all three dates the spectrum appears the same. A strong continuous spectrum extends well into the violet, with λ 4686 and *H*δ showing as extremely weak emission lines, λ 4686 being slightly the stronger.

NOVA GEMINORUM (1903)

Nova Geminorum (1903) is one of the faintest novae observed. From its appearance on the slit of the spectrograph, the magnitude was estimated as 16.5. A single spectrogram obtained on October 21, 1933, shows an apparently continuous spectrum without observable absorption or emission lines. The extension into the violet is less pronounced for this nova than for the others.

NOVA GEMINORUM (1912)

The magnitude of this nova is now 14.7. A single plate taken on November 14, 1933, shows a fairly strong continuous spectrum, with $H\beta$, $H\gamma$, and $H\delta$ as weak emission lines, their intensities being only slightly greater than that of the continuous spectrum.

NOVA T PYXIDIS (1890–1902–1918)

This nova and RS Ophiuchi are the only novae known to have had more than one outburst. T Pyxidis on three occasions has brightened from magnitude 14± to a maximum magnitude of 7±. On each occasion the light-curve and the spectrum were typical of other novae; but until the causes of the outbursts are better understood, both T Pyxidis and RS Ophiuchi should probably not be classified as typical novae.

The only spectrogram of T Pyxidis on which the exposure was sufficient was obtained on March 12, 1934, sixteen years after the last outburst. On this plate the continuous spectrum is fairly strong, and the following lines are bright (intensities in parentheses): λ 5007 (1), $H\beta$ (3), λ 4686 (10), $H\gamma$ (2), and $H\delta$ (2). On account of the star's southern declination, it is impossible to judge as to the extension of the continuous spectrum into the violet. Two extremely weak plates with higher dispersion were obtained on February 20, 1927, and March 16, 1929. On the latter plate λ 4686 can barely be seen and is the only emission feature visible. Only a faint trace of the continuous spectrum is visible on this plate.

NOVA T CORONAE (1866)

The spectrum of this nova has previously been described by Adams and Joy in 1921[6] and by Lundmark in the same year.[7] A spectrogram obtained on March 6, 1930, shows strong titanium

[6] Adams and Joy, *ibid.*, **33**, 263, 1921. [7] Knut Lundmark, *ibid.*, p. 271.

oxide bands and $H\beta$, $H\gamma$, and λ 4686 as emission lines. On June 6 and 7, 1938, two spectrograms were obtained by Joy which show the emission lines stronger and considerably narrower than previously observed.

For many years the spectrum has been considered to be of type Mb. In 1921, Adams and Joy[6] describe it as having

> strong titanium oxide bands. The hydrogen lines $H\beta$ and $H\gamma$ are bright and very broad, the latter probably showing a dark reversal, but with the violet component much the stronger. $H\delta$ is an absorption line. The most interesting feature is the presence of the bright helium line at λ 4686 so characteristic of Wolf-Rayet stars. It resembles $H\beta$ in appearance.

In addition, they state that the radial velocity of the star, as derived from the absorption lines, is -5 km/sec, while the bright lines, $H\beta$, $H\gamma$, and λ 4686, are displaced toward the violet, relative to the absorption lines, by about 1.3 A.

At that time very little was known about the excitation potential necessary to excite the line λ 4686, or about the later history of novae in general. Now, however, there are strong arguments against accepting the hypothesis that the M-type absorption spectrum is that of the nova. These, in their order of importance, are:

1. The temperature of an M-type star is far too low to excite a line with an excitation potential as high as that of λ 4686.

2. The bright lines have not the same displacement as the absorption lines.

3. The light-curve during the rise to maximum, and for a relatively short interval after maximum, is like that of other novae; but on the steep down-branch of the curve, at magnitude 10.0, the light of the star suddenly became constant and except for infrequent brightening of about half a magnitude, has since remained so.

4. Without exception, other novae which have been observed are now blue stars.

Consideration of these facts leads to the conclusion that the nova T Coronae is probably a faint blue companion of the M-type star, similar to the known faint blue companions of *o* Ceti, R Aquarii, and Z Andromedae.[8]

[8] *Note added September 9, 1938:* Since the recently reported increase in brightness of T Coronae, additional spectrograms have been obtained by Joy and by Minkowski. They find a decided increase in the strength of the continuous spectrum when compared

Acceptance of this conclusion does away entirely with any forced interpretation of the observed spectrum or of the light-curve. The emission lines presumably belong to the nova itself, which thus accounts for the presence of λ 4686 and for the difference in displacement between the bright and the dark lines. The peculiarity in the light-curve is also explained, and the light-amplitude becomes greater and therefore more nearly normal than has heretofore been supposed.

If the foregoing explanation is true, then all the old novae formerly classified as red stars should now be eliminated from future records. Nova Aquilae No. 4 (1920) is now generally believed to be a long-period or an irregular variable star of type R, not a nova. Reasons for the rejection of the other two, B Cassiopeiae and T Coronae, seem sound and are presented in this paper.

NOVA OPHIUCHI (1848)

Recent observations by Steavenson of the brightness of this nova show it to be variable over a range of 0.8 mag. from 12.2 to 13.0. A single spectrogram obtained June 18, 1936, shows a strong continuous spectrum extending well into the violet, with neither absorption nor emission lines discernible.

NOVA RS OPHIUCHI (1898–1933)

Of the two outbursts of this nova, the first maximum, given as 7.7, was not well determined and may not be the true maximum. During the second outburst the star reached a magnitude of 4.3. At minimum the light remains fairly constant around magnitude 11.8. Four spectrograms have been obtained, one before, two at the time of, and one three years after, the 1933 outburst. Only the first and last are described here, since spectra of higher dispersion obtained during the 1933 maximum have already been described in detail by other observers. One interesting feature concerning the spectrum during the 1933 maximum should be mentioned, however; namely, the discovery by Adams and Joy of five coronal lines in the

with the 1921 spectrograms; and Minkowski's spectrograms, obtained with a Schmidt spectrograph, show that the spectrum to the violet of λ 3900± is essentially that of an early-type star. Both observers intend to publish detailed accounts of their observations in the near future.

spectrum of this star.[9] So far as known, this is the first instance in which these lines, previously observed only in the solar corona, have been observed in the spectrum of a nova.

The description of the first spectrogram, dispersion 175 A/mm at $H\gamma$, is that by Adams, Humason, and Joy,[10] repeated here for comparison with the spectrogram obtained after the 1933 outburst:

> A spectrogram of this star on July 20, 1923, shows a very strong bright $H\beta$ and a fainter emission line at $H\gamma$. Several of the prominent lines of ionized iron are present as faint emission lines. The absorption spectrum is difficult of classification, but seems to be of about type G5. The radial velocity, as determined from the bright lines, mainly of hydrogen, is approximately -35 km.

A re-examination of this spectrum confirms the probable presence of absorption lines, but the classification of the absorption spectrum as "of about type G5" is open to question. The difficulty in classifying this spectrum mentioned above rises mainly from the fact that the exposure is insufficient for the continuous spectrum, although the bright lines are well above the limit of the plate. In the region from $H\beta$ to λ 4400 the continuous spectrum is of moderate intensity, but from λ 4400 toward the violet the intensity drops rapidly and becomes exceedingly weak at λ 4150$\pm$. As the absorption lines are too weak and ill defined to measure accurately, it has been impossible to identify them with certainty; but it can be stated that if the G band or λ 4226, two of the strongest absorption features in the spectra of G5 stars, are present in this spectrum, they must be exceedingly weak. In fact, they appear to be absent. The basis for classifying the spectrum in 1923 as "of about type G5" must then have been primarily the relative intensity of the continuous spectrum rather than the absorption lines.

The spectrogram obtained on August 16, 1936, three years after the last outburst, is quite different in appearance. Seen as emission lines are λ 5007 and λ 4959, $H\beta$, $H\gamma$, and $H\delta$. The continuous spectrum is much stronger, relative to the emission lines, than on the 1923 plate and extends well into the violet. No absorption lines can be seen.

It is of interest to note that the spectrum of this star in 1923, twenty-five years after the first outburst, is the only one so far

[9] *Pub. A.S.P.*, **45**, 301, 1933.

[10] *Ibid.*, **39**, 366, 1927.

observed to have absorption lines which are strong enough to be observed in small-dispersion spectra and at such a long interval after the outburst.

NOVA SAGITTARII (1919)

This nova reached a maximum of 7.0 in 1919, and at the present time is about fourteenth magnitude. A single spectrogram taken on August 17, 1936, shows a strong continuous spectrum extending well into the violet without either absorption or emission lines.

NOVA AQUILAE (1918)

Unlike the unsymmetrical envelope about Nova Persei (1901), the nebulosity surrounding Nova Aquilae appears to be uniformly distributed in a sensibly circular shell concentric with the nova. The nebulosity is gradually becoming fainter, and Baade finds on plates taken in July, 1936, that it is stronger in yellow light than in blue. The angular increase in the radius of the expanding disk is still of the same order as that found by Hubble and Duncan in 1927, 1″ per year.[11]

An attempt to photograph the spectrum of the nebulosity surrounding the nova was made in 1934, but the relative faintness of the nebulosity and its proximity to the nova prevent the nebular spectrum from showing. Only the greatly overexposed spectrum of the nova appears on the plate.

On May 30, 1938, the spectrum of the nova contained the following emission lines (intensities in parentheses): $H\beta$ (1), 4686 (1), $H\gamma$ (5), $H\delta$ (3). The continuous spectrum is strong and extends into the violet region.

NOVA LYRAE (1919)

Nova Lyrae is now one of the bluest of the old novae. Its magnitude has been estimated as 15.3, but on account of its blueness the star is very active photographically. Two spectrograms obtained on June 19 and June 20, 1936, show an extremely strong continuous spectrum with neither emission nor absorption lines observable. The intensity of the continuous spectrum in the violet is much the same as that of O-type stars.

[11] *Mt. W. Contr.*, No. 335; *Ap. J.*, **66**, 59, 1927.

NOVA SAGITTARII (1898)

The identification of this nova is uncertain, as only its position is indicated on the chart supplied by the Harvard College Observatory. The object observed as the nova agrees in position with that marked on the Harvard chart, and is the brightest star within 24″ of this position. Its magnitude has been roughly estimated as 16.5. The single spectrogram, taken on July 22, 1936, is weak on account of the southern declination of the nova, as a result of which the violet region has been much reduced by atmospheric absorption. The spectrum appears, however, to be similar to that of many of the other old novae in the fact that no lines are seen. The blue end is so weak, however, that it is not possible to state that H and K are not present.

The G band is absent, however, and one certainly has the impression that the star is blue.

NOVA VULPECULAE (1670)

Several stars have been observed in this field in an attempt to locate the nova. According to the spectra, however, there is not much doubt that so far the nova has not been observed.

The first star observed was the object suspected by Steavenson of being variable in light.[12] He estimates the visual magnitude as 15.5 at present and finds no variation in the light during the past few years. Measures made at Mount Wilson give a value of 17.1 for the photographic magnitude. On fifteen direct photographs of the field, taken by van Maanen for measures of parallax and proper motion, no indications of variability can be detected. The plates cover a two-year interval between September, 1935, and September, 1937. Four spectrograms have been obtained: April 26, 1935; July 20, 1936; and two plates on August 16, 1936. The estimated spectral type is F8, and no change can be detected in the spectrum. While, on account of its spectral class, it is not likely that this star is the old nova, it seems, according to Steavenson's observations, very probable that an increase in brightness has occurred within a comparatively recent time, as the object was not noted by Barnard in 1913, although near-by fainter stars are included on his chart of the field. In addition to Steavenson's star, three others have been observed in

[12] W. H. Steavenson, *M.N.*, **95**, 78, 1934–35.

or near the field of Nova Vulpeculae. The first of these is Hind's star, or Barnard No. 26 on Steavenson's chart, given as of about the eleventh magnitude; its spectrum is G5. The second is Barnard No. 20, for which Steavenson's rough estimate of the magnitude is 13.7. Its spectral type is A0. The third star is considerably farther away from the computed position of the nova and was observed because of its remarkably red color, as seen at the Cassegrain focus of the 100-inch. This star is 1!6 south, 10!6 preceding Hind's star or Barnard No. 26. Its spectrum has been classified as M2, and the visual magnitude is roughly about 11.5.

It is improbable that any of the foregoing stars is the old nova, and consequently the search will be continued by observing spectroscopically several of the fainter stars in the near vicinity of the computed position.

On the chart (Pl. X) of this field Steavenson's star is indicated by an "S"; Hind's star, by the Barnard number 26; Barnard No. 20 is designated as 20; and the M-type star, by "M."

NOVA CYGNI (1920)

According to Steavenson, this nova was about 15.5 in 1936. Since 1923 five spectrograms have been obtained,[13] the two earliest

TABLE 4

EMISSION-LINE INTENSITIES IN THE SPECTRUM OF NOVA CYGNI (1920)

Date	3970	4102	4340	4363	4686	4961	4959	5007	Continuous
1923, May 7	.....	.....	2	0	2	5	60	100	Moderate
1927, June 18	.....	.....	2	0	5	5	25	60	Moderate
1934, Sept. 6	5	8	10	2	15	15	2	5	Strong
1936, June 17	2	12	15	2	12	8	0	2	Strong
1938, May 26	.....	2	2	.....	2	2	.....	.....	Strong

of which have previously been described. For comparison they are included in Table 4, which gives the intensities of the emission lines observed and the strength of the continuous spectrum for each plate. The plate of May 26, 1938, is very weak, since the exposure was stopped by clouds. It is consequently impossible to say that the

[13] Adams, Humason, and Joy, *op. cit.*, p. 365.

[O III] lines at λ 4959 and λ 5007 have actually disappeared completely on this date. The continuous spectrum is strong and extends well into the violet on the later plates. The two earliest plates were taken with a dispersion of 125 A/mm at $H\gamma$.

NOVA SAGITTAE (1913)

This nova is interesting on account of its parallax and proper motion. Van Maanen's value for the parallax is $+0\overset{''}{.}013$, which gives +2.8 for the absolute magnitude at maximum, while for the proper motion he finds $0\overset{''}{.}080$,[14] which is exceptionally large for stars of this class.

The nova is now of about the fifteenth magnitude, and its light remains fairly constant. Two spectrograms have been obtained, on July 11 and August 4, 1934. Both plates show a fairly strong continuous spectrum which extends well into the blue region with neither absorption nor emission lines visible. Although this nova, according to van Maanen's parallax, is a dwarf, its spectrum is in all respects similar to that of the intrinsically brighter novae.

NOVA CYGNI (1876)

According to Steavenson, this nova is still variable, with a range of 0.8 mag. around a mean of about 14.8 for the past few years. Spectrograms were obtained on August 4, 1934, and August 16, 1936. On both plates the continuous spectrum is strong and extends well into the violet. No absorption lines are seen; but on the later plate, $H\beta$, $H\gamma$, and $H\delta$, although extremely weak, are suspected of being bright.

NOVA LACERTAE (1910)

The light of this star seems to remain about constant at 14.4. Two plates obtained on July 22, 1936, show a strong continuous spectrum extending well into the violet region of the spectrum. Neither emission nor absorption lines can be seen. The star is decidedly blue and, with the exception of Nova Lyrae, is one of the bluest observed.

DISCUSSION

Besides B Cassiopeiae and Nova Vulpeculae, sixteen objects have been observed. Of these it is probable that fifteen have been cor-

[14] *Mt. W. Contr.*, No. 321, p. 5, 1926.

rectly identified and that the sixteenth, Nova Sagittarii 1898, is still doubtful. The most noticeable feature is the fact that, with the exception of T Coronae, all the objects are now decidedly blue. The extension of the continuous spectrum into the violet region corresponds to that of the early B- and O-type stars. In many of the older novae the emission lines have disappeared, or are now so nearly of the same intensity as the continuous spectrum as to be unobservable with small dispersion. A critical classification of the spectra is impossible on account of the small dispersion.

As for B Cassiopeiae and Nova Vulpeculae, it seems certain that in neither case are any of the objects observed to be identified with the old nova. The fact that the old novae that can be reliably identified are, without exception, blue stars having a strong continuous spectrum, with no absorption lines observable with small dispersion, leads one to expect that the spectra of B Cassiopeiae and Nova Vulpeculae should now be closely similar. Both novae differ greatly from the other objects in the list as regards the interval of time since the outburst—366 years for B Cassiopeiae and 268 years for Nova Vulpeculae. It should also be remembered that, since B Cassiopeiae was most probably a supernova, its spectrum at minimum may differ from that of the common galactic novae at minimum.

The enigma concerning the spectrum of T Coronae, which for years has been classified as Mb, is reasonably explained if it be conceded that the nova is a faint blue companion of the red star. Such a concession would explain the presence of the high excitation line at λ 4686 in an M-type spectrum, the difference in displacement between the bright and dark lines, and the peculiarity in the light-curve.

Densities.—Densities of novae in the final state can be obtained by using the spectral types given in Table 1 (O type), in case the distances are known. For two objects, Nova Persei (1901) and Nova Aquilae (1918), reliable values of the distance can be obtained from the observed expansions of their nebulous envelopes, by comparing the measured transverse motions (in seconds of arc per year) with the radial motions, obtained spectroscopically in kilometers per second. In the case of Nova Persei (1901), $m - M = 8.9$; and since the mean m_v is now 13.0, the present $M_v = +4.1$.

If we assume that the temperature, and hence the surface brightness, of an old nova is the same as that of a normal O-type star, we have

$$\log r - \log r_0 = 0.20\,(M_0 - M)$$

and

$$\log d - \log d_0 = 0.60(M - M_0) + \log \mathbf{M} - \log \mathbf{M}_0\,,$$

where r is the radius, M the absolute magnitude, d the density, and $\mathbf{M}$ the mass of the nova, and r_0, M_0, d_0, and $\mathbf{M}_0$ the corresponding values for a normal O-type star.

For a normal O-type star we may take

$$M_{0v} = -3.5\,, \qquad \mathbf{M}_0 = 16\,\odot\,, \qquad d_0 = 0.1\,\odot\,.$$

For Nova Persei we have $M_v = 4.1$; and if it was a normal star before its outburst, its mass would be about unity. Using these values, we find $d = 220\,\odot$.

For Nova Aquilae (1918), $m - M = 7.8$; m_v is now 10.8, $M_v = +3.0$. Hence, if $\mathbf{M}$ is 1.5 $\odot$, the mass corresponding to $M_v = +3.0$, then $d = 70\,\odot$.

For the remaining stars in the list, reliable distances are not known, but the mean density for the group, T Coronae, T Pyxidis, and RS Ophiuchi being omitted, can be determined by using -7.0, the mean absolute magnitude of galactic novae at maximum, together with $\overline{M}_{max} - \overline{M}_{min} = +9.8$, whence

$$\overline{M}_{min} = +2.8\,, \quad d = 60\,\odot\,.$$

It appears, therefore, that the densities of old novae are intermediate between those of ordinary stars and of the white dwarfs, which are of the order of 10^4 times that of the sun. Milne's suggestion that the nova process is a transition from a star of ordinary density to a white dwarf[15] is, therefore, not entirely substantiated by these observations.

It is our intention at Mount Wilson to reobserve many of the novae included in the present list with larger dispersion in order

[15] *M.N.*, **91**, 4, 1930; *Obs.*, **54**, 140, 1931.

that a more critical classification of their spectra may be made. In addition, we hope in the near future to obtain a better value of their present apparent brightness, and finally a more reliable determination of the densities.

I wish to thank Dr. Shapley, director of Harvard College Observatory, for his kindness in forwarding charts of six fields from which identifications have been made.

CARNEGIE INSTITUTION OF WASHINGTON
MOUNT WILSON OBSERVATORY
June 1938