NOVA OPHIUCHI OF 1604 AS A SUPERNOVA*

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Received January 11, 1943

ABSTRACT

Nova Ophiuchi of 1604 is one of the earliest well-observed novae. Its position has recently been redetermined by Schlier and Boehme from the original measures of Fabricius and Kepler. The light-curve, derived in the present paper, shows that the star was a supernova of type I, which at maximum reached the apparent magnitude -2.2. A check of the Chinese version of the apparition against the light-curve shows that the Chinese reports about new stars were based on careful observations.

A search for the remnant of the supernova led to the discovery of a small patch of emission nebulosity, which is undoubtedly a part of the masses ejected during the outburst. The investigation of this remnant meets with unusual difficulties because the supernova is behind heavy obscuration. The determination of the distance and the luminosity of the supernova must therefore be left to future observations.

The recent investigations of the Crab nebula have supplied data concerning the final state of one particular supernova; but additional examples of former galactic supernovae are highly desirable, since only a comparison of several will enable us to distinguish between those features which are typical and those which are more or less incidental. Thus one would like to know whether the surprisingly low velocity of expansion of the Crab nebula is a general characteristic of the shells of all supernovae. One would like to know, too, whether in every supernova the mass ejected during the outburst is of the order of several solar masses and whether the stellar remnant is always a white dwarf.

To obtain such additional information we have recently investigated the remnant of another galactic supernova, Nova Ophiuchi of 1604. That this star was a supernova of type I is shown beyond doubt by the light-curve derived in the first part of the present paper. The second part deals with the remnant of the supernova found by the writer a year ago. The investigation of this remnant meets with unusual difficulties because the supernova is in a heavily obscured region. It is to be expected, however, that future observations—in particular, measures of the motions of the ejected masses—will provide the answer to questions which have to remain open at present.

I. THE NOVA OF 1604

The nova appeared at the beginning of October, 1604,[1] far down in the southwestern sky, close to Jupiter and Mars. Notwithstanding its unfavorable position, it was discovered promptly, since numerous observers were watching the approaching conjunction of the two planets which took place on October 9. The nova reached its maximum brightness—somewhat brighter than Jupiter—near the middle of October and was still about as bright as Jupiter when it disappeared in the rays of the sun in November. Reappearing in the eastern sky at the beginning of January, 1605, it had become much fainter, equaling Antares in brightness. The decrease in brightness continued throughout the summer, and, when last seen by Kepler in October, 1605, the nova had reached the fifth magnitude. By the spring of the following year it had become invisible to the naked eye.

Since the main interest of the contemporary observers centered on the question of whether the nova, like Tycho's of 1572, was to be classed with the fixed stars, most of

* *Contributions from the Mount Wilson Observatory, Carnegie Institution of Washington,* No. 675.

[1] All dates given in the present paper are Gregorian style. The original observations were partly dated in the old Julian style.

their efforts were directed toward measuring its position relative to neighboring stars. As a result of these measures the position is well determined. Estimates of the brightness played a secondary role but are sufficient to establish the main characteristics of the light-curve. In this respect it was a fortunate circumstance that Jupiter and Mars, both within a few degrees of the nova, provided convenient photometric standards when the nova reached its maximum low in the western sky.

THE POSITION OF THE NOVA

For the determination of the position of the nova two sets of observations are available, one by Kepler and his associates at Prague, the other by David Fabricius. Fabricius measured the distances between the nova and a number of the brighter stars. The Prague series includes distances both from stars and from the near-by planets, Mars, Jupiter, and Saturn. From these observations Kepler[2] derived the position of the nova,

$$\alpha = 17^{\mathrm{h}}7^{\mathrm{m}}8^{\mathrm{s}}\,, \qquad \delta = -21^{\circ}1\overset{\prime}{.}5 \quad (1605.0)\,.$$

Kepler's value is of only historical interest. That it is poorly determined is obvious from the large discordances, which far exceed the errors of the measures. The reasons for the

TABLE 1

COMPUTED POSITIONS OF NOVA OPHIUCHI OF 1604

α 1605.0		δ 1605.0		Authority
$17^{\mathrm{h}}7^{\mathrm{m}}3^{\mathrm{s}}$	$\pm 3\overset{\mathrm{s}}{.}0$ m.e.	$-21^{\circ}4'42''$	$\pm 57''$ m.e.	Schoenfeld (1865)
17 7 3	± 3.1	-21 5 18	± 42	Schlier (1934)
17 7 3	± 2.0	-21 5 17	± 26	Boehme (1937)

poor agreement seem to be insufficient allowance for the refraction—most of the measures were made in zenith distances greater than 80°—and considerable uncertainties in the reference system, enhanced by the inclusion of the planets as reference objects.

In recent years the observations have been rediscussed by E. Schoenfeld,[3] O. Schlier,[4] and S. Boehme.[5] For obvious reasons only distances between stars and nova were used. Since practically all the reference stars used by Kepler and Fabricius are included in the modern *Fundamental Catalogues*, the star places for the epoch 1605.0 present no further problem. The resulting positions of the nova, together with the computed mean error of each co-ordinate, are given in Table 1. Schoenfeld and Schlier used only the measures of Fabricius,[6] which, judged by their internal agreement, are far superior to the Prague observations. Boehme's solution includes both sets "after some obvious misprints in the Prague observations had been corrected." All three determinations agree within the limits of their respective errors. The mean of the more recent determinations of Schlier and Boehme is adopted in this paper, mainly because their results are based on the accurate proper motions of the modern *Fundamental Catalogues*. That further improvements of the proper motions will not affect these latest solutions is indicated by the insignificant difference between the values of Schoenfeld and those of Schlier, the one

[2] *Gesammelte Werke* (ed. Caspar), **1**, "De nova stella in pede serpentarii," p. 216.

[3] *A.N.*, **65**, 7, 1865.

[4] *A.N.*, **254**, 181, 1934, with a chart of the field of the nova.

[5] *A.N.*, **262**, 479, 1937.

[6] They consist of eleven distances of the nova from five reference stars.

obtained in 1865, the other in 1934. The latest values can therefore be considered as definitive. Reduced to the equinox 1935.0 they give as the position of the nova:

$$\alpha = 17^{\mathrm{h}}26^{\mathrm{m}}44\overset{\mathrm{s}}{.}9\,, \qquad \delta = -21^\circ 25' 55'' \ (1935.0)\,,$$

with a computed mean error of $\pm 1'$. The corresponding galactic co-ordinates are:

$$l = 332\overset{\circ}{.}3\,, \qquad b = +5\overset{\circ}{.}4\,.$$

Considering the very unfavorable circumstances under which the observations had to be made and the crude instruments of that time, the accuracy attained by these early observers appears highly satisfactory.

THE LIGHT-CURVE OF THE NOVA

From the reports collected by Kepler in "De stella nova" and the statements of the Italian astronomers we know that on account of the approaching conjunction of Mars and Jupiter the region of the nova had been kept under close observation since the end of September, 1604. The fact that up to October 9 nothing unusual was noticed is of importance, because a conspicuous new object within less than 2° of Jupiter could hardly have failed to attract the attention of some observer. In particular, we have the emphatic statements of Fabricius and several other reliable observers that nothing extraordinary was noticed when they observed Mars and Jupiter on the evening of October 8. During the following days a period of rainy weather interfered with observation, especially for observers north of the Alps, which explains why the independent discoveries of the nova extend over nearly a week.

The nova was first seen on the evening of October 9 by two Italian observers, a physician in Cosenza (Calabria), whose name is unknown and who reported his discovery and observations to the astronomer Chr. Clavius in Rome, and I. Altobelli in Verona. On October 10 it was seen by B. Capra and S. Marius in Padua and by J. Brunowsky in Prague, who caught a glimpse of the nova between clouds and notified Kepler of his discovery. Later discoveries are those of Heck in Rome (October 11), Magini in Bologna, Roeslin in Hagenau (October 12), and David Fabricius in Osteel (October 13). Although a close watch of the sky was kept at Prague after Brunowsky's discovery of the nova on October 10, it was not until October 17 that the sky cleared and Kepler saw the nova for the first time.

These data leave no doubt that the nova was still inconspicuous—probably fainter than magnitude 3—on October 8 but had become a striking object—about as bright as Mars—by the following evening.[7]

The estimates of the brightness of the nova, beginning with October 9, are collected in Table 2. In order to avoid any bias they are reproduced as closely as possible in the original terms of the observers. The list probably contains all important observations except those of David Fabricius, whose reports about the nova were not accessible to the writer. The few estimates occurring under his name in Table 2 are known from his correspondence with Kepler. For three of the estimates in the compilation the approximate date of the observation had to be inferred from the date of the letter in which they were communicated and from some earlier date mentioned therein. They are uncertain by ± 14 days and are therefore marked approximate.

[7] Kepler in "De stella nova" puts the appearance of the nova on October 10 because his former teacher, Maestlin, claimed to have observed Jupiter and Mars on October 9 without noticing anything unusual. It seems, however, that Maestlin's date must be in error. For one thing, there is no reason to doubt the veracity of Altobelli and the anonymous physician. Indeed, the report of the latter contains the best description of the final rise of the nova to its maximum. Moreover, it is hard to believe that the period of bad weather which set in between October 8 and 9 and which eliminated all other observers north of the Alps on October 9 should not have affected Maestlin. It is therefore probable that his observation refers not to October 9 but to October 8. The same conjecture has been made by E. Zinner in his report in *Geschichte und Literatur der veränderlichen Sterne*, **2**, 438.

TABLE 2

ESTIMATES OF BRIGHTNESS AND COLOR OF NOVA OPHIUCHI OF 1604

Date (Gregorian)	Brightness of Nova	Color	Observer
1604 Oct. 8....	Not seen	....	Several
Oct. 9....	As bright as Mars	Like Mars	Anonymous physician (Cosenza)*
	As bright as Jupiter	Like half of ripe orange	Altobelli (Verona)†
Oct. 10....	Somewhat brighter than on Oct. 9	....	Anonymous physician*
	Very similar in brightness to Mars	Like Mars	Capra-Marius (Padua)‡
Oct. 11....	Still brighter than on Oct. 10	....	Anonymous physician*
	Twice as bright as Jupiter	....	Heck (Rome)§
Oct. 12....	Almost as bright as Jupiter	....	Roeslin (Hagenau)‖
Oct. 15....	As bright as Jupiter or somewhat more	Like Jupiter	Anonymous physician*
	Much brighter than Jupiter; no further increase after this day	....	Altobelli†
	As bright as Jupiter or a little more; no further increase afterward	....	Capra-Marius‡
	A little brighter than Jupiter	Like Jupiter; white, not red	Fabricius (Osteel)¶
	As bright as or brighter than Jupiter	....	Brenzoni (Verona)**
	Brighter than Jupiter and equal to Venus	....	Maestlin (Tübingen)††
Oct. 17....	Much brighter than Jupiter (almost twice as bright)	....	Kepler (Prague)‡‡
1605 Jan. 3....	Brighter than α Sco, much fainter than α Boo	....	Kepler‡‡
Jan. 13....	Brighter than α Boo and Saturn	....	Kepler‡‡
Jan. 14....	About as bright as Mars (in Oct., 1604)	....	Fabricius¶
~Jan. 21....	About as bright as α Sco, a little brighter than Saturn	....	Maestlin††
End of Jan....	As bright as α Vir	....	Heydon (London)§§
March 20....	Not much brighter than ζ and η Oph	....	Kepler‡‡
March 27....	Not much brighter than ζ and η Oph	....	Brengger (Kaufbeuren)‖‖
~March 28....	Not much brighter than η Oph	....	Cristini¶¶
April 12....	As bright as η Oph	....	Fabricius¶
April 21....	As bright as η Oph	....	Kepler‡‡
Aug. 12–14.	As bright as ξ Oph	....	Kepler‡‡
Aug. 29....	About as bright as ξ Oph	....	Kepler‡‡
Sept. 13....	Fainter than ξ Oph	....	Kepler‡‡
Oct. 8....	Difficult to see; fainter or equal ξ Oph	....	Kepler‡‡

* The excerpt from the letter of the anonymous physician in Cosenza to Clavius, concerning the nova, is published in A. Favaro, *Carteggio inedito di Ticone Brahe, Giovanni Keplero, etc.*, pp. 283–84, Bologna, 1886.

† Galileo, *Opere* (ed. naz.), **10**, 132–33, 136, 1900.

‡ *Ibid.*, **2**, 293 ff., 1891.

§ *Geschichte und Literatur der veränderlichen Sterne*, **2**, 439.

‖ Kepler, *Gesammelte Werke* (ed. Caspar), **1**, "De stella nova," 483, 1938.

¶ Kepler, *Opera omnia* (ed. Frisch), **2**, 597–98, 1859.

** Galileo, *op. cit.*, **10**, 138.

†† Kepler, *Opera omnia*, **2**, 582–83.

‡‡ Kepler, *Gesammelte Werke*, **1**, 161–64. That the nova at maximum was nearly twice as bright as Jupiter is mentioned on p. 384.

§§ Kepler, *Opera omnia*, **2**, 604.

‖‖ *Ibid.*, p. 588.

¶¶ A. Favaro, *op. cit.*, p. 304.

Since, during the maximum, Mars and Jupiter and, later on, Saturn served as comparison stars, their magnitudes had to be computed. This was done for the dates in Table 3. Positions and distances of the three planets were obtained with the help of the very convenient tables of P. V. Neugebauer.[8] For the computation of the magnitudes Müller's light-elements[9] were used, with the exception of the constant terms, for which the values recently derived by W. Becker[10] were adopted. Allowance for the phase was made only in the case of Mars. In computing the brightness of Saturn the contribution of the ring system was taken into account.

Through the use of Becker's constants in Müller's formulae the magnitudes of Table 3 are on the Harvard system. We adopt, therefore, for the remaining comparison stars the Harvard magnitudes α Boo (0.24), α Sco (1.22), α Vir (1.21), η Oph (2.63), ζ Oph (2.70), and ξ Oph (4.46) to bring the whole light-curve into the Harvard system.

TABLE 3

POSITIONS AND MAGNITUDES OF MARS, JUPITER, AND SATURN, 1604–5

Planet	Date	α 1604.0	δ 1604.0	log r	log Δ	m_v
Mars.	1604 Oct. 9	$17^h13^m7^s$	$-24°39'.0$	0.1446	0.1870	+0.90
Jupiter.	1604 Oct. 8	17 12 0	−22 51.6	.7180	.7475	−1.87
	Oct. 15	17 17 26	−22 58.2	.7178	.7546	−1.84
	Nov. 12	17 40 40	−23 19.2	0.7171	0.7775	−1.73
		α 1605.0	δ 1605.0			
Saturn.	1605 Jan. 13	17 22 9	−21 57.6	1.0044	1.0387	+0.78

We are now able to convert the estimates of Table 2 into magnitudes. It is hardly necessary to remark that in doing so we have to adopt a much larger photometric step than the customary 0.1 mag., which applies to the estimates of the modern variable-star observers. The proper value is probably best indicated by the smallest photometric unit—one-third of a magnitude—used in the star catalogues of that time. Since the nova was mostly intercompared with near-by stars, the accuracy of the estimates may be a little better in the present case. I have therefore adopted the accompanying conversion table:

Much brighter.	−0.75 mag.
Brighter.	−0.50
Not much brighter.	−0.25

For the estimates near the maximum when the nova was brighter than magnitude −1, conversion factors 1.5 times as large have been used to allow roughly for the fact that the width of the photometric step increases rapidly in the range of high intensities.

The magnitudes derived in this manner are given in the second column of Table 4, following one another in the same order as the estimates in Table 2. The adopted magnitudes in the last column are the straight means of the second column, except in the following cases:

1. I have rejected the estimates of Altobelli (October 9, 1604) and of Heck (October 11, 1604), which differ from those of the other observers by more than 2 mag. The dif-

[8] *Tafeln zur astronomischen Chronologie*, **2**, Leipzig, 1914.

[9] G. Müller, *Pub. Ap. Obs. Potsdam*, **8**, 1893.

[10] *Sitzungsberichte Preuss. Akad. d. Wissenschaften*, 1933, p. 839.

ference is much too large to be explained by observational errors. Moreover, the alleged magnitudes imply a final rise of the nova which appears impossible. Probably both writers became victims of a tendency which is all too apparent in certain reports about the new star—the tendency to make the nova of 1604 a worthy rival of Tycho's, at least in print.

2. For similar reasons I have rejected the estimates of Altobelli and Maestlin for October 15. These excessive estimates of the maximum brightness have already been criticized by Fabricius, who insisted in a letter to Kepler that at best the nova became only a little brighter than Jupiter. Kepler himself, who was inclined to stress the similarity

TABLE 4

MAGNITUDES OF NOVA OPHIUCHI OF 1604

Date (Gregorian)	Observed Magnitudes	Adopted Magnitude
1604 Oct. 8......	Fainter than mag. +3	$>+3^{m}$
Oct. 9......	+0.9; (−1.9)	+0.9
Oct. 10......	+0.1; +0.9	+0.5
Oct. 11......	−0.7; (−2.9)	−0.7
Oct. 12......	−1.5	−1.5
Oct. 15......	−2.1; (−3.0); −2.1; −2.3; −2.2 (brighter than −3.0)	−2.2 }
Oct. 17......	−2.6	−2.6 } −2.25
1605 Jan. 3......	+0.7; +1.0	+0.9
Jan. 13......	−0.3; +0.3	0.0
Jan. 14......	+0.9	+0.9
∼Jan. 21......	+1.2; (+0.5)	+1.2
End of Jan.....	+1.2	+1.2
March 20......	+2.4; +2.4	+2.4
March 27......	+2.4; +2.4	+2.4
∼March 28......	+2.4	+2.4
April 12......	+2.6	+2.6
April 21......	+2.6	+2.6
Aug. 12–14...	+4.5	+4.5
Aug. 29......	+4.5	+4.5
Sept. 13......	+5.0	+5.0
Oct. 8......	+4.8	+4.8

to the nova of 1572, admits in "De stella nova" that the star never approached Venus in brightness.

3. Of Maestlin's two estimates of January 21, 1605, I have retained only the comparison with α Boo, since Saturn at that time was still close to the horizon.

The resulting light-curve of the nova is presented in Figure 1. It shows that the nova was discovered about a week before the maximum, which was reached October 17, 1604. This date of the maximum is firmly established, since all observers agree that the nova showed no further increase in brightness after October 15. For the maximum brightness of the nova we obtain the value −2.25 mag., which, in spite of the rejections mentioned above, may still be somewhat too high. But it cannot be far from the truth and is probably correct within 0.25 mag. The gap in the observations after maximum is due to the conjunction of the nova with the sun, and the star was well on its way toward the final decline when it reappeared in January, 1605.

Considering the rather rough estimates on which it had to be based, the light-curve appears most satisfactory. It is a typical light-curve of a supernova of type I. If any proof is needed, it is provided by the curve in Figure 1 representing the decline of the nova from maximum to the end of the observations. This curve is actually the visual light-curve of the recent supernova in IC 4182, properly adjusted. The remarkable agreement in the light-changes of the two stars is characteristic of supernovae of this type, which all follow closely the same pattern. Minor variations in the widths and heights of the maxima occur; but, when supernovae of this type have reached the final decline, which sets in 80–100 days after the maximum, the further decrease in brightness is the same for all, with a linear gradient of $+0.0137 \pm 0.0012$ mag. per day.[11] Since the nova of 1604 conforms to this pattern, we conclude that it was a supernova of type I.

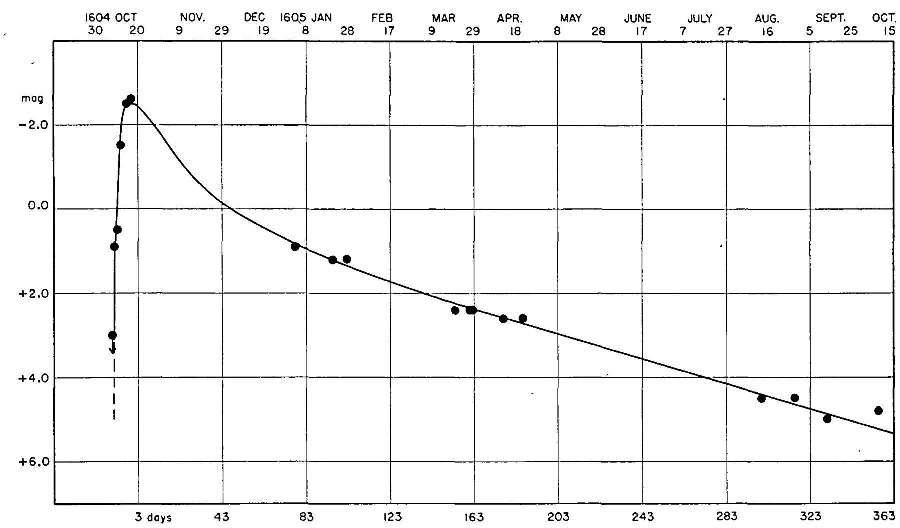

FIG. 1.—Light-curve of Supernova Ophiuchi of 1604. The smooth curve representing the descending branch is the visual light-curve of the recent supernova in IC 4182, properly adjusted.

THE CHINESE OBSERVATIONS OF THE NOVA

In view of the important role which the Chinese records of "guest stars" have recently played in reconstructing the early history of the supernova of 1054,[12] it is most fortunate that for the supernova of 1604 we have a good light-curve with which to check the Chinese version of the apparition. The nova occurs in the She-ke, being one of the last entries in a list of "guest stars" observed in the times of the Ming dynasty. Both Biot[13] and Williams[14] have given translations. We reproduce the text according to Williams, since Biot's version is somewhat abridged. For convenience the Gregorian dates have been added in brackets. The Chinese report concerning the nova of 1604 is as follows:

In the 32nd year of the same epoch, the 9th moon, day Yih Chow [October 10, 1604] a star was seen in the degrees of the stellar division Wei.[15] It resembled a round ball. Its colour was reddish yellow. It was seen in the southwest until the 10th moon [October 27–November 26,

[11] A more detailed discussion of the light-curves of supernovae will be presented in a forthcoming paper by the writer.

[12] J. J. L. Duyvendak, *Pub. A.S.P.*, **54**, 91, 1942, and N. U. Mayall and J. H. Oort, *Pub. A.S.P.*, **54**,95.

[13] *Connaissance des Temps*, 1846.

[14] *Observations of Comets from B.C. 611 to A.D. 1640*, p. 93, London, 1871.

[15] The stellar division Wei (see chart given by Williams, *op. cit.*, n. 14) extends in R.A. from about 16^h40^m to 18^h, in Dec. from $-20°$ south into the constellation Ara. The nova appeared close to the northern boundary of Wei.

1604] when it was no longer visible. In the 12th moon, day Sin Yew [February 3[16], 1605] it again appeared in the southeast, in the stellar division Wei. The next year, in the 2nd moon [March 24–April 23, 1605], it gradually faded away. In the 8th moon, day Ting Maou [October 7, 1605] it disappeared.

This description is in such excellent agreement with the data gathered by the European observers that comment is unnecessary. The test shows that we can place full confidence in the Chinese records and that, whenever specific dates are given, they are obviously based on careful observations.[17]

II. THE REMNANT OF SUPERNOVA OPHIUCHI OF 1604

After Nova Ophiuchi had been established as a supernova, a search was made for the remnant in the expectation that the ejected masses would still be visible, as are those of the supernova of 1054. Since the supernova is in a heavily obscured part of the Milky Way, the search was carried out in red light (λλ 6300–6700). The very first plate of the field, taken at the 100-inch reflector, June 18, 1941, with an exposure time of two hours on an Eastman 103E plate behind a Schott RG2 filter, revealed a small patch of nebulosity close to the expected place (see Pl. XV). Its center has the co-ordinates

$$\alpha = 17^h 26^m 42^s.8,\ \delta = -21^\circ 25' 54'' \ (1935.0),$$

which differ from those of the nova (p. 121) by only $-2^s.1$ and $+1''$.

The nebulosity appears as a broken mass of bright knots and filaments covering a fan-shaped area, about 40 seconds of arc long. There are indications, however, that this fan-shaped mass, which is quite strong on the red plates, represents only the brightest part of a more extended nebula since faint wisps of nebulosity are scattered over a much larger field, perhaps 80–100 seconds of arc in diameter. This estimate of the extent of the nebula needs further confirmation, since on the plates thus far obtained (which are of only average quality) it is difficult to distinguish small patches of nebulosity from stars.

In the photographic region (λλ 5000–3600) the nebulosity is extremely faint; hence it is easily missed, even in a careful search. Comparisons with extrafocal exposures of S.A. 131 show that the photographic surface brightness of the fan-shaped mass amounts to only 25.2 mag. per square second of arc, which is 4 mag. fainter than the corresponding value for the Crab nebula. The integrated photographic magnitude of the fan-shaped mass is 19.0. This faintness of the nebulosity in the photographic region is without doubt due to selective absorption,[18] and a comparison of the red and the blue images suggests—on the assumption that we are dealing with an emission spectrum—that the color excess may amount to nearly 1 mag. Aside from this weakening by selective absorption, the structure of the nebulosity in the photographic region is quite different from that in the red. It is much more nearly uniform, and the strong knots and filaments which are so prominent on the red exposures barely rise above the level of the faint nebulous background.

The different characteristics of the nebulosity in the blue and in the $H\alpha$ region might lead to the inference that, as in the Crab nebula,[19,20] the main part of the emission be-

[16] Both Biot and Williams give the Gregorian date, January 24, 1605, but according to several independent checks by the writer February 3 seems to be the correct date.

[17] Other records of the nova of 1604, mostly from Korean sources, have been collected by Y. Iba, *Pop. Astr.*, **46**, 142, 1938. One of these reports (from Ressei Jitsuroku) is of special interest because it contains intercomparisons of the nova with Jupiter for October 13 and 15, 1604. According to these estimates the nova at maximum was fainter than Jupiter.

[18] See also the following paper by R. Minkowski, *Mt. W. Contr.*, No. 676; *Ap. J.*, **97**, 128, 1943.

[19] W. Baade, *Mt. W. Contr.*, No. 665; *Ap J.*, **96**, 109, 1942.

[20] R. Minkowski, *Mt. W Contr.*, No. 666; *Ap. J.*, **96**, 121, 1942

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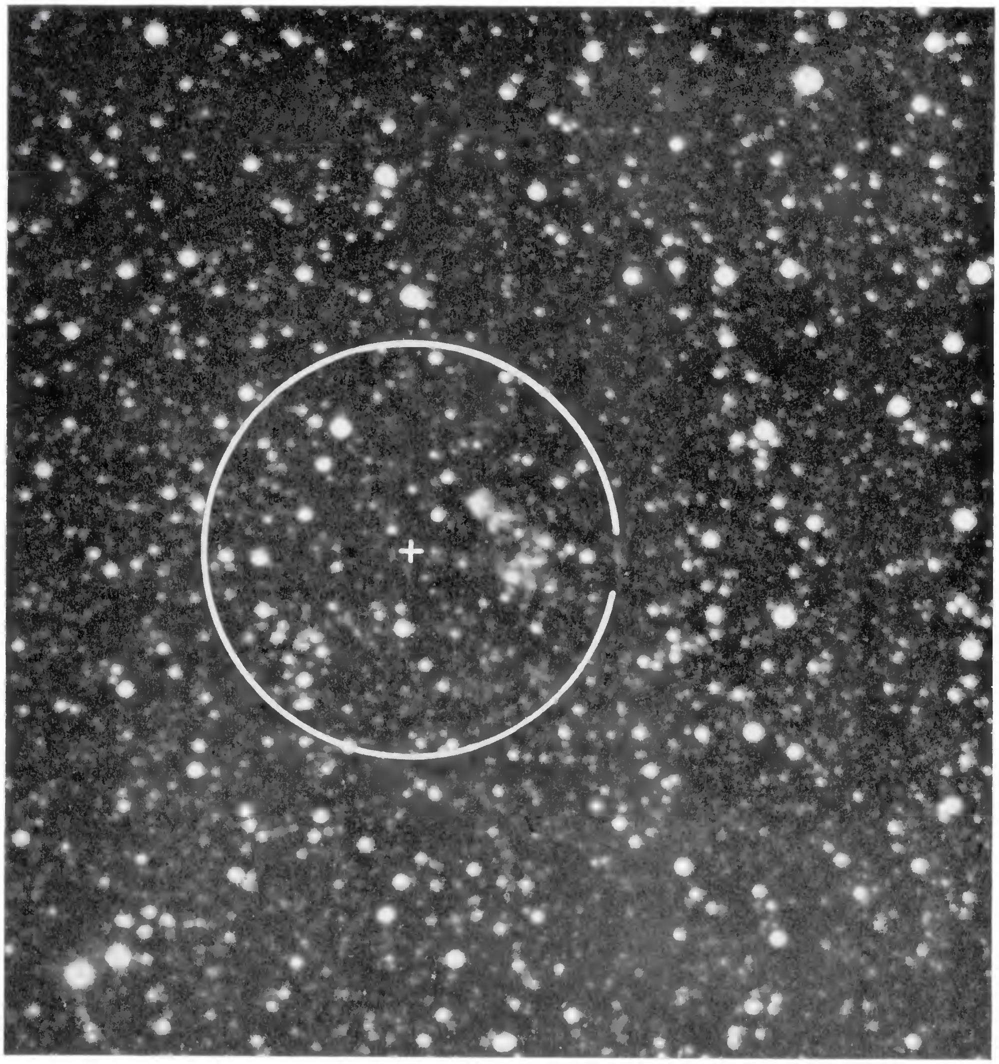
PLATE XV



EMISSION NEBULOSITY NEAR NOVA OPHIUCHI OF 1604

Photographed in red light ($\lambda\lambda$ 6300–6700) with 100-inch reflector, on June 9, 1942, exposure time $3\frac{1}{2}$ hours. Scale of reproduction 1 mm = 2".51. The computed position of the nova is marked by a cross; the circle indicates the mean error of the computed position.

tween λ 5000 and λ 3500 is due to a continuous spectrum. However, a plate taken in the near infrared between λ 8400 and λ 7200 does not support this conclusion. As pointed out in an earlier paper,[19] this spectral region is free from strong nebular emission lines and is therefore well suited to reveal a continuum. The test should be especially convincing for Nova Ophiuchi, since, on account of the smaller absorption at longer wave lengths, the nebulosity should be an easy object on infrared exposures if a continuum contributes materially to the intensity of the image in blue and violet light. The infrared plate, however, shows only a vague and possibly spurious trace of the nebulosity. There seems to be little doubt, therefore, that the strong continuum characteristic of the Crab nebula is absent in the nebulosity of Nova Ophiuchi and that the high intensity of the knots and filaments in the $H\alpha$ region must be due to unusually strong localized emissions of the pair of [*N* II] lines λ 6548 and λ 6584.

The stellar remnant—the exciting star of the nebulosity—cannot be identified at present. The only object whose association with the nebulosity might suggest a physical connection is a faint star of photographic magnitude 18.6, which is imbedded in the bright patch forming the tip of the fan-shaped mass. It may well be a chance coincidence, but the star deserves further attention because its color index appears to be as small as that of any other star in a field of 50″ radius. Of the other stars within the field the few with magnitudes brighter than 18 can be ruled out because their color indices—allowing for a color excess of 1 mag.—are so large that they must be of advanced spectral types. Altogether it seems quite certain that the stellar remnant of the supernova is fainter than magnitude 18.

The preceding description shows that our present knowledge of the nebulosity is still very meager, but the fact that it is a remnant of the former Supernova Ophiuchi seems to be established beyond doubt. The strongest argument is, of course, the agreement in the positions of nebulosity and supernova, which is perfect, considering the accuracy with which the position of the star is known. But there is another observational fact which supports this view. According to the measures of Humason and Minkowski, the radial velocity of the nebulosity amounts to -200 km/sec.[18] This large velocity is readily explained as due to the motion of the ejected matter if the nebulosity is a part of the expanding shell around the supernova. On the other hand, it presents a very serious difficulty if one tries to dismiss the agreement in the positions of nebulosity and star as a mere chance coincidence. In that case the nebulosity would be a small galactic nebula which happens to be close to the position of the former supernova. The radial velocity has, then, to be explained in terms of galactic rotation alone, since according to all evidence the peculiar motions of interstellar dust and gas are negligible. This would place the galactic nebula at a distance of more than 4000 parsecs, which seems quite impossible in view of the very heavy obscuration extending over the field. We have, therefore, every reason to believe that the patch of nebulosity near the place of the nova is a part of the shell which was ejected during the outburst.

About the structure and the extent of this shell we know at present practically nothing. As mentioned previously, there is good evidence that the recently discovered fan-shaped nebula is only the brightest part of a more extended nebulosity. Perhaps it will be possible to define the extent of the shell with some accuracy in the near future by means of long exposures of excellent definition. Another possible line of attack is the determination of the radial velocities of some of the brighter wisps of nebulosity outside the fan-shaped area, which undoubtedly would help in locating the center of the expansion and the stellar remnant. Finally, some twenty to thirty years hence, we should be able to measure the tangential motions in the fan-shaped mass which, properly combined with the radial velocities, will lead to a reliable determination of the distance of the supernova. Until these data, together with measures of the intervening space absorption, are forthcoming, any conclusions regarding the luminosity and the distance of the supernova will be mere guesses.