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NGC 1058 AND ITS SUPERNOVA 1961

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ABSTRACT

A few preliminary data on the supernova of 1961 in NGC 1058 are given which are significant for a future comprehensive analysis of this star. The light-curve appears to be analogous to that of η-Carinae showing a rise of a few magnitudes over a period of several decades. The symbolic velocity of recession of the galaxy as a whole is found to be 440 km/sec in contradistinction to the value of 80 km/sec given in the catalogue by Humason, Mayall, and Sandage. The symbolic velocity of recession of the supernova is estimated to be about 750 km/sec and the velocity of expansion of the gas clouds ejected from it of the order of 3000 km/sec. The spectrum of the supernova during the first 15 months after maximum shows only low-excitation emission lines of H, He I and Fe II. No forbidden lines are observed. The absolute photographic magnitude of the supernova, which like η-Carinae is classified as being of Type V, is estimated to be about $M_{pg} = -15.3$.

I. DISCOVERY OF A NEW TYPE OF SUPERNOVA

In July, 1961, P. Wild in Bern, Switzerland, discovered a new variable star or nova on the outskirts of the spiral galaxy NGC 1058. He also reported that, as far as could be ascertained from the small scale of his films, a faint star of the photographic magnitude $m_{pg} \sim 17.5$ had occupied the position of the new or variable star long before its flareup. F. Bertola, who came to the I.A.U. meeting in Berkeley in August, 1961, brought with him the first spectrograms which he had obtained with the reflector in Asiago, Italy. On this occasion he pointed out that the spectrum of the new star differed markedly from those of the supernovae of the then-known Types I and II. It therefore was not certain that the new star belongs to the galaxy NGC 1058 and is a new type of supernova. There remained the possibility of its being a new type of variable or a common nova which is a member of our own Galaxy.

Subsequently, after a more detailed study of the light-curve and of a series of spectra of the new star it became probable that it is a new type of supernova whose characteristics in some way resemble those of η-Carinae of 1843.

An extensive light-curve and a detailed analysis of the spectra of the new star in NGC 1058 are to be published by Bertola (1963). In the present note some additional data and considerations are presented which are of importance for a future comprehensive analysis of the physical nature of the new star.

II. NGC 1058

NGC 1058 is a normal Sc spiral galaxy seen almost exactly face on (Fig. 1). Its diameter is about 3 minutes of arc and its apparent photographic magnitude about 12.7. The brightest stars appear just resolved on average plates obtained with the 48-inch Schmidt telescope. The apparent photographic magnitude of these stars which appear blue is about $m_{pg} = 19.5$. There do not seem to be any H II regions brighter than the brightest blue stars, which indicates that NGC 1058 is a galaxy of only moderate size. We therefore assume that the brightest blue stars are not brighter than the absolute photographic magnitude $M_{pg} = -8$. With this magnitude and dimming by Δm magnitudes because of interstellar obscuration the distance modulus of NGC 1058 becomes

$$\mu = 27.5 - \Delta m \quad (1)$$

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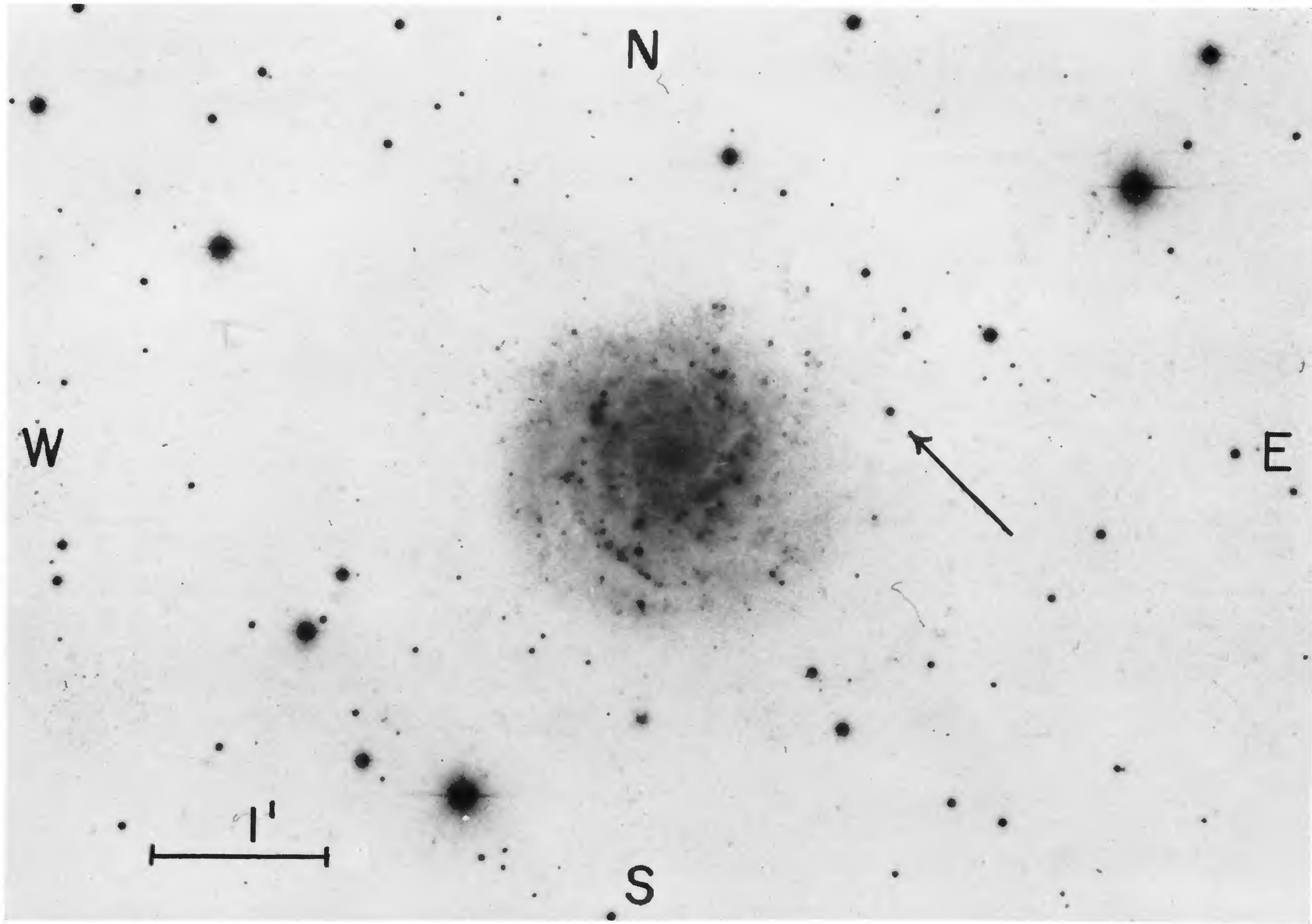

FIG. 1.—Photograph of the spiral galaxy NGC 1058 at R.A. $2^h40^m29^s$ and decl. $+37°08'$ (Epoch 1950.0), obtained on October 22, 1962, with the 200-inch Palomar telescope on emulsion 103*a*-O, exposure time 20 minutes, seeing 1–2. The scale is as indicated. The supernova is marked by the arrow. The galactic longitudes and latitudes of NGC 1058 are, respectively, 115° and $-20°$.

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and its absolute photographic magnitude $M_{pg} = -14.8$. Disregarding any dimming the absolute distance of NGC 1058 would be

$$D = 3.2 \times 10^6 \text{ pc.} \tag{2}$$

Since the apparent diameter of NGC 1058 is 3 minutes of arc, its absolute diameter, under the stated assumption, is $d = 2800$ pc, and the distance of the supernova from the center, normal to the line of sight, is $\delta = 1200$ pc.

III. THE SPECTRUM AND THE SYMBOLIC VELOCITY OF RECESSION OF NGC 1058

In the compilation of symbolic velocities of recession by Humason, Mayall, and Sandage (1956) the symbolic velocity of recession, uncorrected for solar motion, is +80 km/sec; the corrected value is +221 km/sec. In view of the fact that the identifiable lines in the spectrum of the supernova in NGC 1058 seemed to be shifted toward the red by

TABLE 1

SYMBOLIC VELOCITIES OF RECESSION, V_s, AS MEASURED FROM ELEVEN LINES IN THE BLUE PART OF THE SPECTRUM OF NGC 1058

Line	Unshifted Wavelength	V_s (in km/sec)
Hβ	4861 33	435
Hγ	4304 47	454
G-band	4309 47	415
Ca I	4226 84	484
Hδ	4101 74	420
H } Ca II	3968 50	402
K } Ca II	3933 70	323
Hζ	3888 22	432
Hη	3835 57	424
Hθ	3798 60	448
O II	3727 30	474

almost 1000 km/sec, it seemed worthwhile to redetermine the symbolic velocity of recession of NGC 1058. I therefore re-observed its spectrum with the prime-focus spectrograph of the 200-inch telescope on emulsion II*a*-O with a dispersion of 400 Å/mm. The redshifts of ten absorption lines and one emission line which could be measured are listed in Table 1. The slit used was 30 seconds of arc in length and was oriented north-south, passing over the nucleus of NGC 1058. Except for λ 3727 which is a weak emission line all lines are in absorption. The position of the K line is obviously affected because of a blend with interfering night-sky lines. Omitting this line we obtain for the average velocity of recession

$$\langle V_s \rangle = 439 \text{ km/sec} \tag{3}$$

and for the standard deviation

$$\Delta V_s = 24.8 \text{ km/sec} . \tag{4}$$

The symbolic velocity of recession given by Humason *et al.* (1956) seems to be in error by a factor of 5.

It should be noted in this connection that the separation of what appear to be the H and K lines in the night-sky light is by 3–4 Å greater than the normal separation of

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34.80 Å of these lines. This discrepancy, which may affect the determination of small redshifts, is due to blends with emission bands of the sky glow, a phenomenon which remains to be investigated in greater detail.

IV. THE SUPERNOVA IN NGC 1058

a) Remarks on the Light-Curve

On checking back a few decades it becomes apparent that the object in NGC 1058 under discussion has shown activity over a long period of time preceding the outburst in the fall of 1962. With the aid of plates kindly made available to me from the Lick and

TABLE 2

APPARENT PHOTOGRAPHIC MAGNITUDES, m_{pg}, OF THE SUPERNOVA 1961 IN NGC 1058

Date	m_{pg}	Telescope	Observatory
October 10, 1937	18 2	100-inch	Mount Wilson
November 4, 1937	18 2	Crossley 36-inch	Lick
November 27, 1946	18 0	100-inch	Mount Wilson
November 29, 1946	18 0	100-inch	Mount Wilson
October 22, 1949	18 1	20-inch astrograph	Lick
November 17, 1949	17 9	20-inch astrograph	Lick
October 23, 1951	17 7	100-inch	Mount Wilson
November 28, 1951	17 7	48-inch Schmidt	Palomar
August 23, 1952	17 7	100-inch	Mount Wilson
December 21, 1954	18 0	48-inch Schmidt	Palomar
November 21, 1960	15 8	16-inch Schmidt	Bern
July 11, 1961	13 5	16-inch Schmidt	Bern
September 1, 1961	14 0	200-inch	Palomar
September 7, 1961	13 6	18-inch Schmidt	Palomar
October 11, 1961	13 8	18-inch Schmidt	Palomar
November 8, 1961	14 2	48-inch Schmidt	Palomar
December 4, 1961	12 8	48-inch Schmidt	Palomar
December 5, 1961	12 2	48-inch Schmidt	Palomar
January 8, 1962	15 3	18-inch Schmidt	Palomar
February 4, 1962	16 3	48-inch Schmidt	Palomar
March 3, 1962	16 5	48-inch Schmidt	Palomar
September 4, 1962	16 8	48-inch Schmidt	Palomar
September 30, 1962	17 3	48-inch Schmidt	Palomar
October 22, 1962	17 6	200-inch	Palomar
October 26, 1962	17 4	48-inch Schmidt	Palomar
October 27, 1962	17 7	48-inch Schmidt	Palomar
December 1, 1962	17 8	48-inch Schmidt	Palomar
January 24, 1963	18 1	48-inch Schmidt	Palomar
March 24, 1963	19 0	48-inch Schmidt	Palomar

Harvard Observatories as well as some older plates in our files at the Mount Wilson and Palomar Observatories, the fragmentary data shown in Table 2 were assembled.

The supernova seems thus to have shown small variations for 23 years before its luminosity rose sharply by 6 magnitudes within a year or so, in this sense acting similarly to η-Carinae. Using the value (1) for the distance modulus its absolute photographic magnitude at maximum was about $M_{pg} = -15.3$, that is, perhaps 2 magnitudes brighter than η-Carinae in 1843, and about three magnitudes fainter than supernovae of Type I. Also the decline of its brightness during the first 15 months after maximum is faster than that of η-Carinae.

About the frequency of occurrence of supernovae of the type in NGC 1058, and of η-Carinae, which we propose to call Type V, little can be said at the present time. Al-

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though no spectra are available for them, the supernova of 1909 in Messier 101 (NGC 5457) and those of 1923 and 1957 in NGC 5236 may have been of the same type.

We add that the nucleus or rather the central unresolvable spherical disk of NGC 1058 has an apparent photographic magnitude $m_{pg} = 17.5$ and therefore a probable $M_{pg} = -10.0$, that is, somewhat fainter than the nuclei of Messier 31 and Messier 32.

The plates used were all 103*a*-O or their equivalents (for the three Lick data), without any filters, and all mirrors Al-coated. Data on standard stars around NGC 1058 have been published by Bertola (1963), and their magnitudes were checked by photographic transfers of Selected Area 68. The photographic magnitudes given by Stebbins and Whitford for the stars in SA 68 were used with extensions to the faintest stars kindly supplied by Dr. W. A. Baum from his photoelectric determinations. The m_{pg}'s given by Bertola check within 0.1 magnitudes with mine, which is as close as may be expected, considering the quality of the 103*a*-O plates available and the observing conditions encountered.

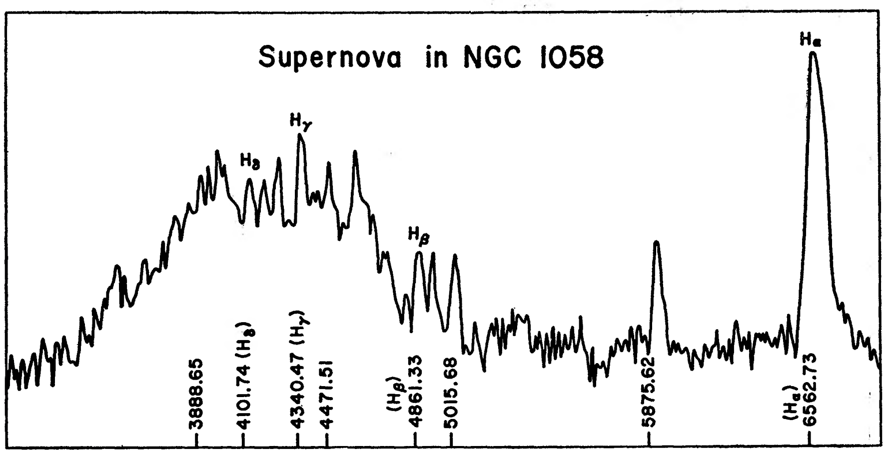

FIG. 2.—Direct tracing of a spectrogram of the supernova in NGC 1058 obtained with the 200-inch prime focus spectrograph on February 1, 1962. Emulsion 103*a*-F, dispersion 400 Å/mm, exposure time 65 min at seeing 3. In addition to the Balmer lines, which are indicated, many emission lines due to He I and Fe II are clearly discernible.

b) Spectra of the Supernova in NGC 1058

Between September 1, 1961, and March, 1963, numerous spectra of the supernova were obtained with the 200-inch telescope, by the author and by J. L. Greenstein. These spectra resemble those of bright common novae shortly after maximum and show in particular Hα, Hβ, Hγ, Hδ in emission, the He I lines at λ 5875.62, λ 5015.7, λ 4482.7, etc., as well as the Fe II lines at λ 4923.9, λ 4583, etc. While in a common nova forbidden lines like [N1] and [N2] appear shortly after maximum brightness, none of these lines had made their appearance on October 23, 1962, that is, 15 months after maximum brightness. Only the above-mentioned low-excitation lines persisted, which indicates that the mass of gas and the density in the emitting layers around the star in NGC 1058 were much greater than the corresponding quantities in a common nova.

Several additional features in the spectrum are of interest. These features are clearly visible in the two tracings reproduced in the Figures 2 and 3.

It is seen that the emission lines are broad but asymmetrical, steep toward shorter wavelengths, and staggered on the long wavelength side. These features may be due to various causes such as non-spherical ejection of the gas clouds, local turbulence, and local excitation, and, finally, partial self-absorption of the light.

The Hα emission line shows the greatest width which, taken at face value, would in-

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dicate an expansion velocity of the ejected gas clouds of about 3700 km/sec. Since some of the lines are narrower, however, the real expansion velocity is probably smaller and the extra width of the Hα lines is presumably due to turbulence.

All lines are redshifted by various amounts, the intense lines Hα and λ 5875.62 of He I showing the greatest apparent shift because of their great asymmetrical width. The best value for the redshift is presumably obtained from the location of the peaks of the narrow weak lines, such as λ 4482.7 of He I, which give a shift of +750 km/sec. This value is about 300 km/sec greater than the value of the average symbolic velocity of recession of 439 km/sec which we have derived for the galaxy as a whole.

V. GENERAL REMARKS

At the time Wild discovered the flareup of a star near NGC 1058 he left open whether this star might be a variable or a common nova in our own Galaxy, lying in the line of sight of NGC 1058. Although a single spectrum of the star is very similar to the spectrum of a common nova a few days after maximum brightness, it is obvious that the

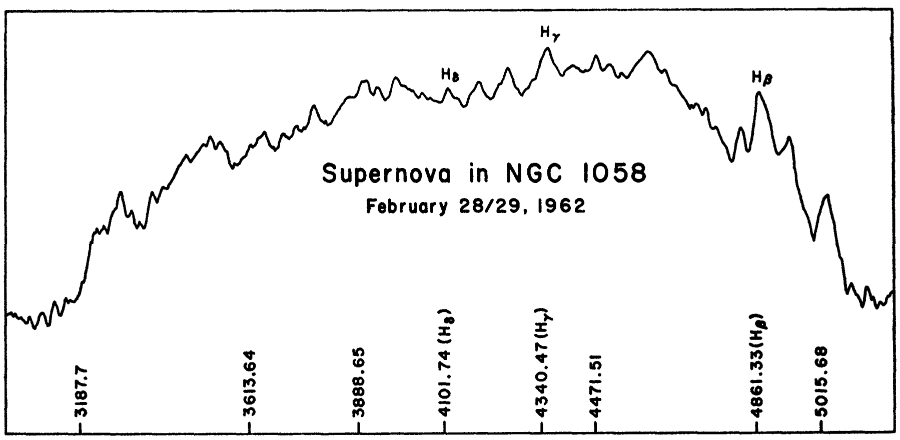

FIG. 3.—Direct tracing of spectrogram of the supernova in NGC 1058 obtained with the prime-focus spectrograph of the 200-inch telescope on February 28, 1962. Emulsion IIa-O, dispersion 400 Å/mm, exposure time 90 min at seeing 3. The same features are discernible as in the blue region of the tracing reproduced in Figure 2

star is some new type of supernova, because (*a*) its spectral lines are shifted to the red by an amount corresponding to a symbolic velocity of recession of the order of 1000 km/sec and (*b*) no forbidden lines have been found in the spectrum which means that the mass of the ejected gas clouds is much larger than the mass of the gas clouds ejected by common novae.

Although the star in NGC 1058 at maximum had a luminosity which lies between that of a bright common nova and that of a supernova of Type I, its total emission of light may be of the same order as that of a supernova of Type I since its outburst appears to be of considerably longer duration than that of a supernova of Type I. A total emission of energy of the order of 10^{50} ergs may therefore be involved. As a matter of classification we propose in a preliminary way to designate η-Carinae and the star in NGC 1058 as supernovae of Type V, adding this type to those of the supernova in IC 4182 (Type I), NGC 4725 (Type II), NGC 4303 (Type III), and NGC 3003 (Type IV).

The difference of about 300 km/sec between the symbolic velocities of recession of the galaxy as a whole and of the supernova remains unexplained, but may be due either to a real velocity of the supernova or to the fact that the ejected gas clouds are ejected preferentially and more or less jetlike in directions opposite to the observer.

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REFERENCES

Bertola, F. 1963, *Asiago Contribution*, No. 142.
Humason, M. L., Mayall, N. U., and Sandage, A. R. 1956, *A.J.*, **61**, 97 (also *Mount Wilson and Palomar Observatories Reprint*, No. 181).
Wild, P. 1961, Bureau Central des Télégrammes Astronomiques (I.A.U. Circulaire No. 1764).

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