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THE BRIGHTEST VARIABLE STARS IN EXTRAGALACTIC NEBULAE. I. M31 AND M33

EDWIN HUBBLE AND ALLAN SANDAGE

MOUNT WILSON AND PALOMAR OBSERVATORIES
CARNEGIE INSTITUTION OF WASHINGTON
CALIFORNIA INSTITUTE OF TECHNOLOGY

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ABSTRACT

Light-curves are obtained for five irregular variables: one in M31 and four in M33. Observations extend continuously from 1916 to the present. Spectra are available for four of the five variables. The light-curves, color indices, and spectra show that a new class of variable star has been isolated. This class is characterized by (1) high luminosity, (2) blue color indices, and (3) intermediate F-type spectra.

The absolute magnitude at maximum for these stars is a quantity of small dispersion. If $m - M = 22.4$ for M31 and $m - M = 22.3$ for M33, the observations give $\bar{M}_{pg}$ (max.) $= -6.9 \pm 0.2$ (A.D.). If the provisional revision to the cosmic distance scale of $\delta M = -1.5$, suggested by Baade, is adopted, these five variables have an absolute magnitude $\bar{M}_{pg}$ (max.) $= -8.4 \pm 0.2$ (A.D.). The small dispersion in this value shows the usefulness of this group of blue irregular variables as distance indicators. Additional stars of this type are known in other nebulae and provide a larger sample for future study.

I. INTRODUCTION

A study of the brightest individual objects in extragalactic nebulae is important for two reasons: (1) Statistical studies of the objects themselves are unhampered by the large selection effects present in similar studies in the galactic system, and (2) the recognizable individual objects in extragalactic nebulae provide the only means of obtaining a calibration of the cosmic-distance scale. The group of recognizable individual objects consists of (*a*) globular clusters, (*b*) normal novae, (*c*) the brightest variable stars (usually irregular), (*d*) the brightest nonvariable stars, and (*e*) cepheid variables.[1] These are listed in the order of their absolute luminosities and hence in the inverse order in which these objects fade and can no longer be recognized as the nebular distances increase. It is important that the group characteristics of any of these objects be known before that group can be used as a distance criterion.

Only a few nebulae are so close that all or most of the six groups can be studied simultaneously. Such a study is essential for a calibration of the relative luminosity function of each group. It is this small sample of nebulae which must be used to calibrate the distance scale. Previous work[2] with the 100-inch telescope at Mount Wilson had given the best absolute-magnitude calibration available for most of these groups. With the

[1] Also visible as individual objects in nebulae are supernovae and emission patches. Supernovae are so rare in a given nebula that they are of little use as distance indicators. Emission patches vary widely in size and magnitude and hence are difficult objects to use.

[2] E. P. Hubble, *Ap. J.*, **69**, 103, 1929; **76**, 44, 1932; **84**, 158, 1936.

200-inch Hale telescope now in operation and with the revisions to the magnitude scale at the faint end now under way, a complete re-examination of the individual distance criteria in all close resolvable nebulae must be undertaken in an effort to improve the accuracy of the first reconnaissance of nearly 20 years ago.

Among the individual objects which might be used as distance indicators are the brightest variable stars occurring in nebulae. Owing to their variability, they are the easiest objects to recognize. Furthermore, they are among the brightest objects in spiral systems and hence can be seen as individuals to large distances. To be of use, however, these variables must have group attributes with dispersions small enough to provide characteristics capable of calibration. This paper is a report of the study of the brightest variable stars in M31 and M33, with particular attention directed to those group characteristics which may prove useful as distance indicators.

II. IDENTIFICATION AND MAGNITUDE STANDARDS

The first variable stars recorded in extragalactic nebulae are the three found in M33 by J. C. Duncan[3] in 1922. The brightest of the three was later found independently by Max Wolf[4] working at Heidelberg. These historic variables are Nos. 1, 2, and 3 identified on prints published in this *Journal* in 1926.[5] Numbers 1 and 2 are irregular variables, while No. 3 (the faintest of the three) is a cepheid of period 41.7 days. During the course of routine examination of many plates of M33 in the years following the initial work on this system in 1926, three additional bright irregular variables have been found. These are assigned letters—A, B, and C—and are identified in Figure 1. Each of these five irregular variables has rivaled or exceeded the brightness of the most luminous nonvariable stars in M33. One additional bright variable, discovered by Baade while at the Hamburg Observatory, is near the edge of most of the plates of M33 in the Mount Wilson collection, so extensive data are not available. This star is not shown in Figure 1.

No additional bright variables have been found in M31 since the list of 1929 was published.[6] Variable No. 19, identified in Figure 2, is the brightest of the variables known in M31.

The five stars whose characteristics are reported in this paper are: in M33, var. No. 2, A, B, and C; and in M31, var. No. 19.[7]

New magnitude standards in the vicinity of each of the variables were determined by intercomparisons between the nebular fields and Selected Area 68. All magnitudes are based upon Stebbins, Whitford, and Johnson's photoelectric standards[8] in SA 68. One sequence near the center of M33 was determined in the photographic spectral region, while a sequence near variable A in M33 and a sequence near variable 19 in M31 were determined in both the photographic and the photovisual spectral regions. The stars for each of these sequences are identified in Figures 2, 3, and 4. Eastman 103*a*-O plates behind a Schott GG1 filter were used to obtain the photographic magnitudes, while Eastman 103*a*-D plates behind a Schott GG11 filter were used for the photovisual magnitudes. The color equations converting magnitudes obtained with these plate and filter combinations (m_{pg} and m_{pv}), to **P** and **V** of the SWJ system, are[9]

$$\mathbf{P} = m_{pg} - 0.09\,(\mathbf{P} - \mathbf{V}) + 0.05\,, \tag{1}$$

$$\mathbf{V} = m_{pv}\,, \tag{2}$$

$$\mathbf{P} - \mathbf{V} = 0.92\,(m_{pg} - m_{pv}) + 0.05\,. \tag{3}$$

[3] *Pub. A.S.P.*, **34**, 290, 1922.

[4] *A.N.*, **217**, 475, 1923.

[5] E. P. Hubble, *Ap. J.*, **63**, 83, 1926.

[6] *Ibid.*, **69**, 103, 1929.

[7] Variable 1 in M 33, which attained its maximum magnitude of 17.3 in 1911, has been fainter than $m_{pg} = 18.5$ since 1925. Data for this star are not discussed in this paper.

[8] *Ap. J.*, **112**, 469, 1950.

[9] A. R. Sandage, *A.J.*, **58**, 61, 1953.

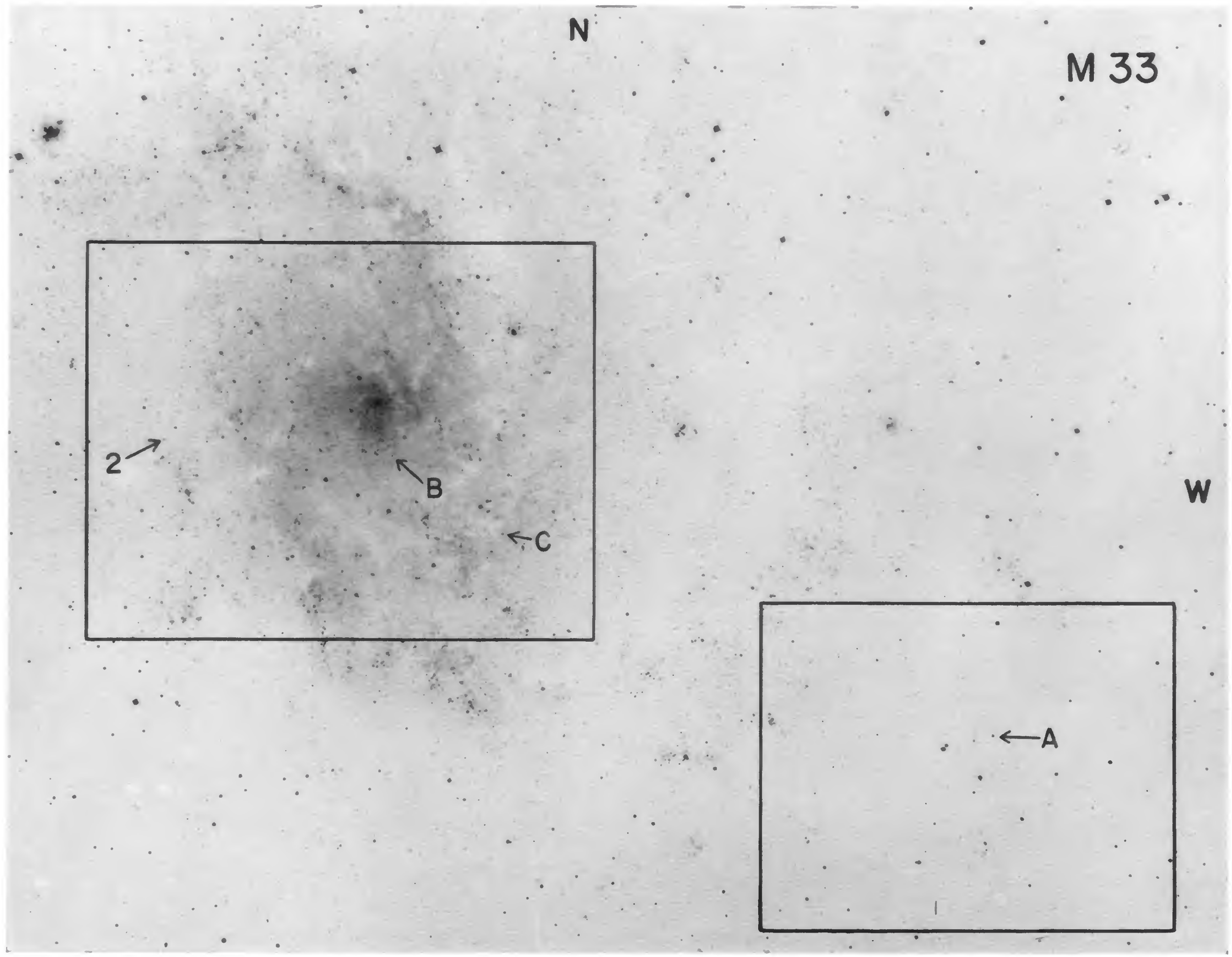

FIG. 1.—Identification chart for variables A, B, C, and 2 in M33. The two areas outlined are shown in Figures 3 and 4 with the sequence stars identified.

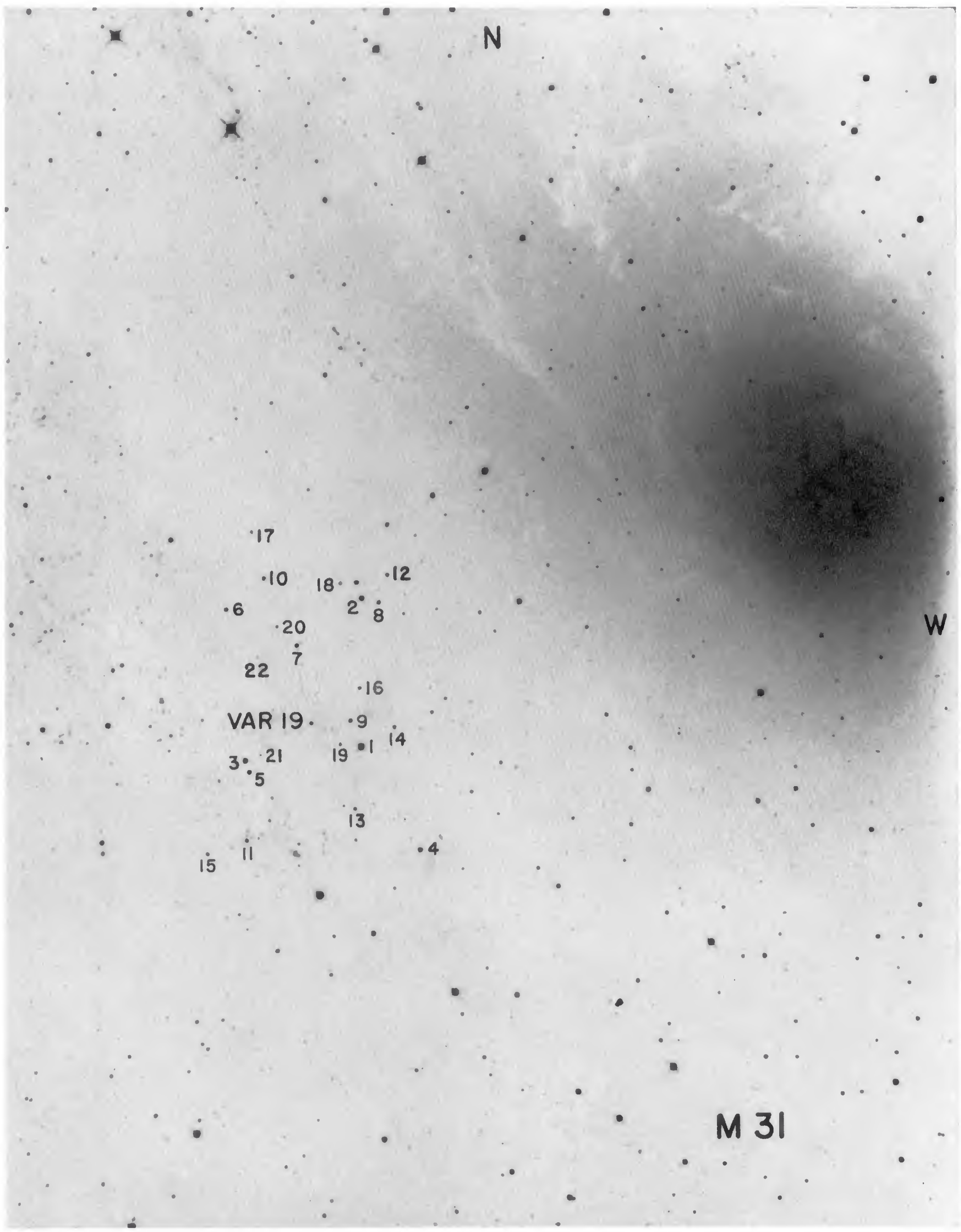

FIG. 2.—Identification chart for the sequence stars for variable 19 in M31. Magnitudes for these stars are given in Table 1.

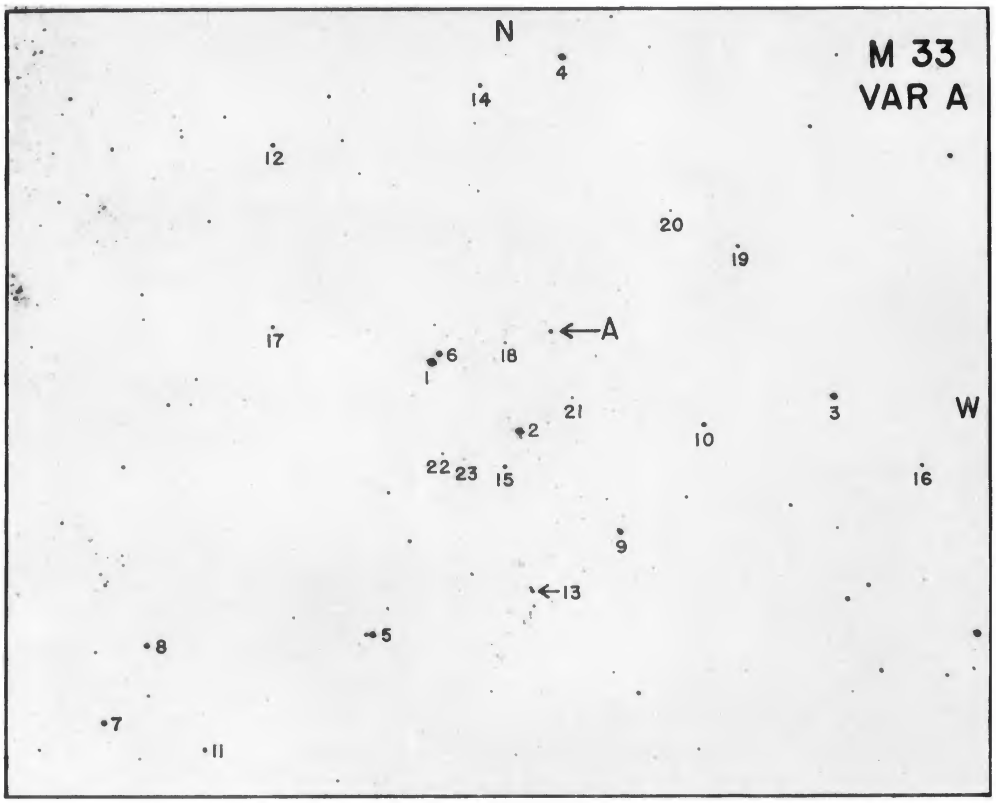

FIG. 3.—Identification chart for the sequence stars for variable A in M33. Magnitudes for these stars are given in Table 1.

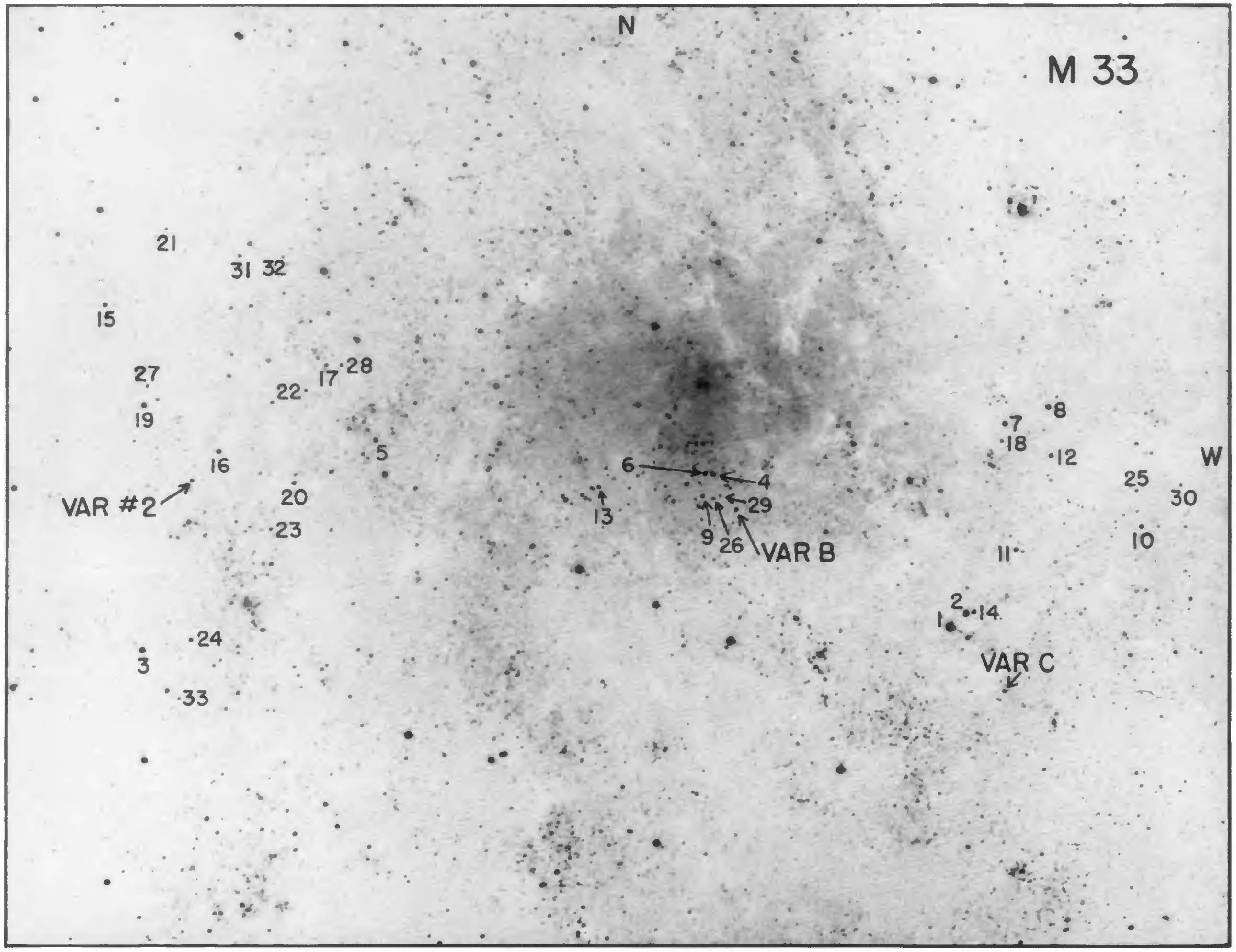

FIG. 4.—Identification chart for the sequence stars for variables B, C, and 2 in M33. Magnitudes for these stars are given in Table 1.

All data reported in this paper are on the m_{pg} and m_{pv} system. Equations 1 and 2 may be used to transform to the **P**, **V** system, although the accuracy of the data presented ($\delta m \cong 0.1$) hardly warrants such transformation. The intercomparisons between SA 68 and the three sequence fields were reduced by H. F. Weaver's Q_0 method[10] and by the more common direct-comparison method. No significant difference was found between these methods of reduction. The adopted magnitudes of the sequence stars are given in Table 1. The sequence in M33 (center) is the most uncertain, owing to the background of the unresolved nuclear region. Although the systematic effect of this background is probably small,[11] the random error is larger than for the clear regions encountered in the other two sequences. The number of intercomparisons for each sequence is as follows: M33, center, three for m_{pg}; M33, A, five for m_{pg} and three for m_{pv}; M31, 19, five for m_{pg} and three for m_{pv}. The internal agreement indicates that the final magnitudes are reliable to $\delta m \cong \pm 0.1$.

TABLE 1

MAGNITUDES OF THE STANDARD STARS

M31; Var. 19			M33 Center		M33; Var. A		
No.	m_{pg}	m_{pv}	No.	m_{pg}	No.	m_{pg}	m_{pv}
1	13.13	11.56	1	13.79	1	13.67	13.23
2	14.65	13.83	2	15.46	2	14.39	13.72
3	14.68	13.94	3	15.72	3	15.00	13.92
4	15.04	14.28	4	15.93	4	15.05	14.20
5	15.40	14.25	5	16.04	5	15.15	14.22
6	15.55	14.63	6	16.07	6	15.27	14.89
7	15.71	14.99	7	16.35	7	15.53	14.91
8	15.89	15.30	8	16.41	8	15.68	15.02
9	16.20	15.08	9	16.49	9	15.99	15.15
10	16.23	15.31	10	16.52	10	15.99	15.64
11	16.30	16.18	11	16.77	11	16.16	15.94
12	16.33	15.63	12	16.88	12	16.37	16.13
13	16.65	16.06	13	16.90	13	16.62	16.46
14	16.83	16.00	14	16.93	14	17.02	16.57
15	16.96	16.79	15	16.96	15	17.17	16.71
16	17.03	16.39	16	17.01	16	17.23	17.03
17	17.05	15.99	17	17.24	17	17.35	16.98
18	17.07	16.69	18	17.49	18	17.42	....
19	17.47	17.56	19	17.50	19	17.69	16.92
20	17.61	17.62	20	17.58	20	18.02	....
21	17.98	17.18	21	17.66	21	18.06	....
22	18.62	18.28	22	17.69	22	18.35	....
			23	17.71	23	18.37	....
			24	17.71			
			25	17.71			
			26	17.75			
			27	17.91			
			28	17.97			
			29	18.01			
			30	18.04			
			31	18.11			
			32	18.21			
			33	18.38			

10 *Ap. J.*, **106**, 366, 1947.

11 See Seyfert and Nassau, *Ap. J.*, **101**, 179, 1945, for an evaluation of the background effect.

III. THE LIGHT-CURVES, ABSOLUTE MAGNITUDES, AND COLORS

The extensive observational material on M33 and M31 available in the Mount Wilson plate collection from 1920 to the present (1953) permitted a rather complete coverage of the photographic light-curves of these variables.

Fast photovisual plates have come into general use only in the last five years. Color indices for these stars are therefore available from 1950. The photographic light-curves

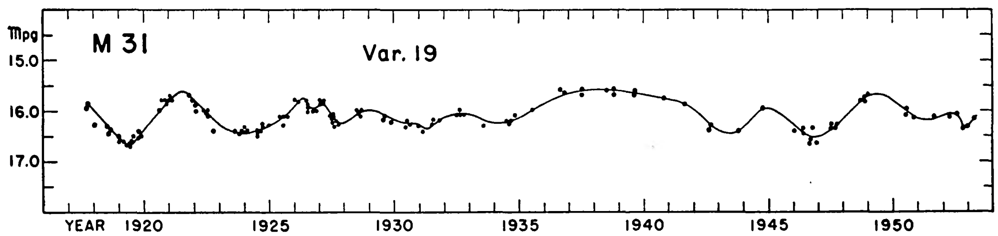

FIG. 5.—The light-curve for variable 19 in M31 from 1917 to 1953. The apparent photographic magnitude is plotted as ordinate.

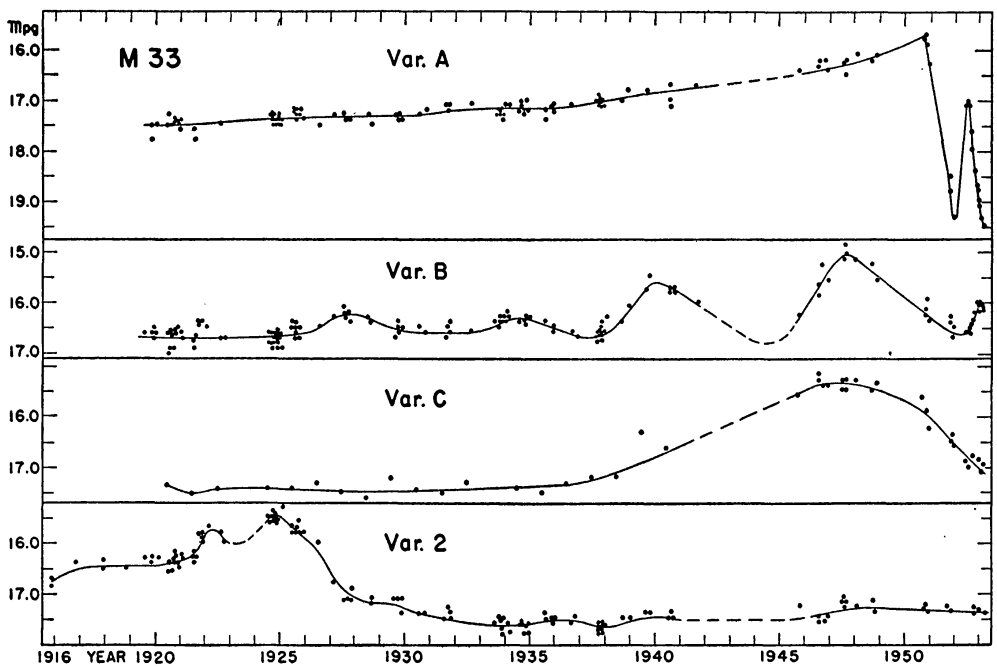

FIG. 6.—Photographic light-curves for the four variables in M33

for all five stars are shown in Figures 5 and 6.[12] The individual points were obtained by eye-estimates of the variables compared with the appropriate sequence stars. The accuracy of this method is somewhat less than one-tenth of a magnitude but is entirely sufficient to show the characteristics of the light-curves.[13]

Magnitude estimates are available for the variables in M33 prior to 1920 from two

[12] It is of interest to inspect the distribution of points in Figs. 5 and 6. The lack of points in the interval 1941–1945 shows the imprint of the last war on observational activity at Mount Wilson.

[13] Variable C in M33 is crowded by a close optical companion which makes magnitude estimates difficult when the variable is fainter than $m_{pg} = 16.5$. Yearly means are given in Fig. 6 for this star while it was fainter than 16.5 mag. Only plates of the best seeing were used to establish the mean values shown.

sources: (1) Table III in Hubble's[5] paper gives Duncan's[3] and Wolf's[4] published magnitudes reduced to the photographic International System plus a few additional data obtained from existing early plates, and (2) early plates taken with the 36-inch Crossley reflector at Lick (mostly by Keeler) were made available through the kindness of Director Shane and Dr. N. U. Mayall, and a few additional plates taken at Mount Wilson by

TABLE 2

ADDITIONAL PHOTOGRAPHIC MAGNITUDES FOR VARIABLES IN M33

Date	Variables in M33				Observer
	2	A	B	C	
1899 Sept. 12	17.6	18.1	16.4	17.1	Lick
1903 Jan. 16	17.4	17.6	....	(16.7)	Isaac Roberts
1908 Nov. 17	17.7	17.6	16.3	....	Lick
1909 Sept. 10	17.5	17.7	16.3	....	Ritchey
1910 Oct. 24	17.4	....	16.2	17.3	Lick
1914 Dec. 14	17.4	17.6	16.0	....	Lick
1915 Aug. 5, 6, 7	17.4	17.4	16.3	17.7	Ritchey
1915 Nov. 5	17.2	17.5	16.1	....	Lick

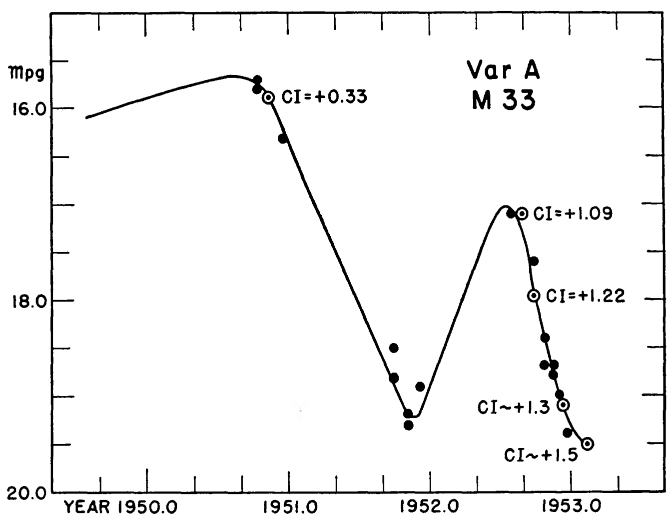

FIG. 7.—Details of the light-curve of variable A in M33 from 1950 to 1953. Color indices were determined on five dates and are indicated in the figure.

Ritchey were examined. The additional magnitudes obtained from these old plates are given in Table 2. These points are not plotted in Figure 6.

Figures 5 and 6 show the irregular character of the variations of these stars. The light-curves for M33, A, and M33, B, have unique characteristics. The light-curve for M33, A, together with the additional observations in Table 2, shows that the magnitude of this star increased since the early observation in 1899 from $m_{pg} = 18.1$ mag. to the peak value of 15.7 mag. in 1950.9. At its maximum light, the star's color index was 0.33 mag. The very sudden drop in brightness with the corresponding change in the color index is shown in detail in Figure 7. The large light-variation is partially a result of the finite spectral response of the detector. The change in the bolometric luminosity is much smaller. Since data for the color-index variation are available (shown in Fig. 7), the bolometric corrections may be inferred.[14] The amplitude of δM_{bol} is 1.4 mag., compared with a range of 3.5 mag. in the photographic region. This bolometric range is correct only if the color index is a measure of the effective temperature, an assumption which is near the truth if (1) the Planck function approximates the true energy-distribution-curve and (2) if the light-changes are internal to the star, i.e., not caused by changing amounts of obscuration in the light-path due, for example, to drifting interstellar clouds in M33. This hypothesis of drifting obscuring clouds can be checked from the absorption-to-reddening coefficient obtained from the data of Figure 7. The average value derived from these data is $\Delta m/\Delta(CI) = 2.5$, which is somewhat less than the value of 4.0 currently adopted.[15] For this reason the obscuration hypothesis is probably invalid. The light-variations are most likely internal to the stars themselves.

Perhaps the most interesting of the five stars is M33, B. The undamped, oscillatory character of the light-curve is unique among variables. Careful watch of this star is desirable. The next maximum should occur in 1954 if the present trend of light-variation continues.

TABLE 3

SUMMARIZED DATA

	M31, 19	M33, 2	M33, A	M33, B	M33, C
1. m_{pg} (max.)	15.6	15.4	15.7	15.1	15.3
2. Date at max.	1921.5, 1938.2	1925.0	1950.9	1947.7	1947.5
3. m_{pg} (min.)	16.7	17.6	19.6	16.7	17.5
4. Date at min.	1919.4, 1946.9	1934	1953	Many	1921–1935
5. *CI*	0.07	−0.4	0.33	−0.3	−0.2
5. Date	1950.9	1952.6	1950.9	1952.6	1952.6
6. M_{pg} (max.) old distance scale	−6.8	−6.9	−6.6	−7.2	−7.0
7. M_{pg} (max.) new provisional scale	−8.3	−8.4	−8.1	−8.7	−8.5

Although these five stars show little similarity in their light-variations, they do show a strong similarity in their maximum magnitudes. The summarized data are given in Table 3. Rows 1–5 of this table are self-explanatory, while rows 6 and 7 are discussed later.

Two conclusions are evident from Table 3: (1) The similarity of the maximum apparent magnitudes indicates that the peak luminosities of this group of bright variables have a rather small dispersion; this is precisely the characteristic which makes this class of stars important as distance indicators. (2) The color indices in row 5 show that these are blue variables—a surprising result for which there is no known galactic analogue.

It therefore seems that a new class of variables has been isolated. The members of this class are exceedingly luminous and have quite blue color indices. This type of luminous, blue, irregular variable is rather rare in extraglactic nebulae, since only one is known in M31 and five in M33 (including Baade's star, which is also blue and very bright). Hence it is not strange that analogous stars are not known in our galaxy. The chance of discovery of such rare objects is small.

Additional stars of this type are known in the extragalactic nebulae which have been surveyed in some detail. The Sb spiral M81 has six blue variables which have become at least as bright at maximum as the brightest stars associated with the nebula. NGC 2403, M101, NGC 4486, and others in the Virgo cluster have similar bright variables.

[14] G. P. Kuiper, *Ap. J.*, **88**, 492, 1938.

[15] See *Statistical Astronomy* by Trumpler and Weaver (Berkeley: University of California Press, 1953), p. 450, for a summary of the determination of this value.

Although these systems have not yet been studied in sufficient detail, the similarities with the stars in M31 and M33 are evident.[16]

The absolute magnitudes to be assigned to the stars in Table 3 depend upon the apparent distance moduli of M31 and M33. The values which have been adopted in recent years are $m-M = 22.4$ for M31 and $m-M = 22.3$ for M33. The M_{pg} (max.) corresponding to these moduli are given in row 6 of Table 3. The corresponding mean for the five stars is

$$\bar{M}_{pg}\,(\text{max.}) = -6^{M}.9 \pm 0^{M}.2\ (\text{A.D.})\ .$$

Recent work on the Andromeda nebula with the 200-inch Hale telescope by W. Baade,[17] together with the new[9] color-magnitude diagram of M3, has provided evidence that the modulus of M31 of $m - M = 22.4$ is incorrect by about $\delta M = -1^{M}.5$. If this value is eventually substantiated, the apparent modulus of M31 is $m-M=23.9$, and that of M33 is $m - M = 23.8$. The absolute magnitudes of the blue variables discussed would then be those in row 7 of Table 3, with a mean of

$$\bar{M}_{pg}\,(\text{max.}) = -8.4 \pm 0.2\ (\text{A.D.})\ .$$

The present study provides no information for a decision on a new distance scale. The only conclusion which may be drawn from the present study is that this new class of variable stars will provide rough distances to other nebulae containing such stars in terms of the distance to M31 and M33. The calibration of this unit of distance is proceeding along lines described elsewhere;[17] the preliminary value of the correction to the scale being $\delta M = -1^{M}.5$, as already quoted.

IV. SPECTRA

Spectra for four of the five variables are available from plates taken with the 100-inch telescope, largely by R. Minkowski, who has generously placed these at our disposal for discussion. Dr. George Herbig, of the Lick Observatory, has obtained spectra of variables B and C with the nebular spectrograph at the Crossley reflector which gives 430 A/mm at $H\gamma$ and has sent his results for inclusion in the present discussion.

A summary of the available plates is shown in Table 4. The phase of light-variation corresponding to the dates given may be found from Figures 5 and 6. Most of the 100-inch prism plates were obtained with a dispersion of 220 A/mm at $H\gamma$. Nearly the same normal dispersion applies to the grating material. Discussion of these plates follows.

The one available plate of variable A in M33 was taken near the star's peak luminosity in 1950.9. This particular plate is the best of the group. Many faint metal lines are just at the limit of visibility. The most prominent feature is strong H and K of *Ca* II in absorption. The lines $H\gamma$ and $H\delta$ are very weak in absorption, while $H\beta$ is weakly in emission. There is, however, a suggestion of P Cygni characteristics in the hydrogen lines, i.e., very weak emission to the red of the absorption components of $H\gamma$ and $H\delta$ may be present. The high-luminosity criteria lines of *Fe* II at λ 4171 and λ 4177 are clearly present. The *Mg* I triplet at $\lambda\lambda$ 3890, 3892, and 3896 is just visible. The spectrum matches that of ϵ Aurigae fairly well (class F0 I*a* by the MKK atlas), except for the weakness of the hydrogen lines. This may be due to weak emission partially filling the absorption

[16] The star S Doradus in the Large Magellanic Cloud may also be of the type discussed here. Its P Cygni characteristics and color show this. The maximum absolute magnitude to be assigned to this star, with the new provisional modulus to the Magellanic Clouds of $m - M \approx 19.0$, is $M_{pg} = -10.8$, which is considerably brighter than the M31 and M33 stars. S. Gaposchkin has, however, found that most of the light-variation of S Doradus may be explained by an eclipse. If this is true, classification with the intrinsic variables in M31 and M33 is doubtful.

[17] Annual Report of the Director, Mount Wilson and Palomar Observatories, *Carnegie Institution of Washington Yearbook, 1950–51*, and *1952–53*.

cores. Judging by the weakness of the hydrogen lines, the class may be as late as F8, with extreme supergiant characteristics. The dispersion is too small and the spectrum insufficiently wide (the magnitude of this star was $m_{pg} = 15.8$ when the spectrogram was taken) to give a more detailed match. The best compromise classification is probably intermediate F, I*a*. The color index of variable A in M33 at this time was $CI = +0.3$, which is normal for this spectral class.

Six spectrograms of variable B in M33 are available: four from Mount Wilson and two by Herbig. The Mount Wilson plate of August 10, 1940, is near the peak luminosity of variable B in 1940.0. This plate shows $H\beta$ and possibly $H\gamma$ in emission, with H and K of equal strength weakly in absorption. No other features are clearly visible. The class

TABLE 4

SPECTROGRAMS AVAILABLE

Variable Star	Date	Optics	Observer
Var A, M33...	Nov. 7, 1950	100″ prism	Minkowski
Var B, M33...	Aug. 10, 1940	100″ prism	Hubble
	Aug. 22, 1950	36″ Crossley	Herbig
	Oct. 31, 1951	36″ Crossley	Herbig
	Nov. 28, 1951	100″ grating	Minkowski
	Sept. 28, 1952	100″ grating	Sandage
	Nov. 21, 1952	100″ grating	Minkowski
Var C, M33...	Nov. 30, 1946	100″ prism	Minkowski
	Aug. 23, 1947	100″ prism	Humason
	July 24, 1949	36″ Crossley	Herbig
	July 25, 1949	36″ Crossley	Herbig
	Sept. 22, 1949	36″ Crossley	Herbig
	Aug. 3, 1951	36″ Crossley	Herbig
	Oct. 28, 1951	36″ Crossley	Herbig
	Oct. 31, 1951	36″ Crossley	Herbig
	Nov. 29, 1951	100″ grating	Minkowski
Var 19, M31...	Nov. 5, 1951	100″ prism	Minkowski

cannot be earlier than F0 judged by the H and K lines. The next spectra of this star, obtained by Herbig, were taken on the descending part of the light-curve. Herbig writes:

> The spectrum of B is quite featureless except for a rather weak emission at $H\beta$, and faint absorption H and K. From comparison with galactic supergiants I believe the strength of H and K, their ratio and the weakness of the hydrogen lines indicate that the spectral type cannot be earlier than F0, and may be considerably later. . . . I estimated the color index on these two plates as +0.3 and 0.0 respectively, so [the star] can hardly be a very late type.

(The somewhat uncertain color index from the Mount Wilson photometric data is −0.3 at this time.) Herbig's first plate, on August 22, 1950, was taken about midway between maximum light in 1947 and minimum light in 1952. His second plate was near minimum phase. Apparently, no great change occurred in the spectrum in this interval.

A plate by Minkowski of variable B on November 28, 1951, shows that a change had occurred since Herbig's last plate of October 31, 1951. The hydrogen lines $H\beta$, $H\gamma$, $H\delta$, and $H\zeta$ were visible in emission together, with the two strongest *He* lines at λ 3889 and λ 4471 also weakly in emission. No other lines were visible. H and K were not seen, but they may have been lost in the grain, since the spectrum could not be widened at the telescope, owing to the faintness of the source. This plate was obtained near minimum light, which occurred in February, 1952. The two remaining plates were taken on the ascending branch of the light-curve in 1952. The plate of November 21, 1952, shows very weak $H\beta$ and $H\gamma$ in emission. Furthermore, P Cygni characteristics are rather pronounced, especially for $H\beta$. The H and K lines are possibly visible but of much weaker intensity than on September 28, 1952. The pronounced P Cygni characteristics on November 21 and their absence on September 28 clearly indicate that a change in the spectrum had occurred in this interval.

With the exception of the plate of November 28, 1951, which showed only hydrogen and helium in emission, the spectra of variable B in M33 are, in general, characterized by weak $H\beta$ and $H\gamma$ in emission (with P Cygni characteristics some of the time) and with H and K in absorption. No other features are prominent. The H and K lines, together with the blue color index, point to an F spectral type.

Three Mount Wilson spectrograms of star C are available. Two of these occur at the phase of maximum light. Both show H and K in absorption of nearly equal strength,

TABLE 5

SUMMARY OF SPECTRAL FEATURES

Star	Date	Light-Phase	Hydrogen Lines	H and K *Ca* II
Var A, M33	Nov. 7, 1950	Max. light	β in em.; γ, δ with P Cyg	Strong
Var B, M33	Aug. 10, 1940	Near max.	β and γ in em.	Present
	Aug. 22, 1950	Decreasing light	β in em.	Present
	Oct. 31, 1951	Near min.	β in em.	Present
	Nov. 28, 1951	Near min.	$\beta, \gamma, \delta, \zeta$, and *He* 3889 *He* 4471 in em.	Not seen
	Sept. 28, 1952	Increasing light	β and γ in em.	Strong
	Nov. 21, 1952	Increasing light	β and γ in em; P Cyg	Just visible
Var C, M33	Nov. 30, 1946	At max.	γ and δ in abs.	Strong
	Aug. 23, 1947	At max.	None seen	Present
	July–Sept. 1949	Decreasing light	β in em.	Not seen
	Aug.–Oct. 1951	Decreasing light	β and γ in em.	Present
	Nov. 29, 1951	Decreasing light	β and γ in em.	Not seen
Var 19, M31	Nov. 5, 1951	....	β and γ in em.	Present

indicating that the spectral class is at least later than F0. Lines of $H\gamma$ and $H\delta$ are weakly in absorption. Herbig's 1949 spectra occur just after maximum light on the slow decline to minimum. He writes: "The 1949 plates of Variable C show a faint emission at $H\beta$ and little else. The 1951 spectra show that the $H\beta$ emission is considerably stronger and emission is present at $H\gamma$; H and K appear in absorption." Minkowski's spectrogram of November 29, 1951, deep on the descending light-curve toward minimum, shows $H\beta$ and $H\gamma$ in emission, with little else clearly seen. H and K are not visible.

Only one plate of variable 19 in M31 is available. This plate of November 5, 1951, shows bright $H\beta$. The line $H\gamma$ is also weakly in emission. H and K may be faintly visible. The continuous spectrum of this star extends far into the ultraviolet—again showing that this class of object is quite blue.

The characteristics of the spectra of these stars are summarized in Table 5. In general, the spectra now available for these variable stars show sufficient similarities to indicate that we are dealing with a group of objects which may be classed together as a unit. The spectra usually show the hydrogen lines weakly in emission, with H and K in absorption. The strength of the H and K lines, together with the blueness of the continuum, indicate that the spectral class may be intermediate F. Furthermore, the spectrum of variable A in M33 showed sufficient detail to indicate the supergiant nature of these objects.