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LIGHT CURVE OF NOVA V1500 CYGNI 1975

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ABSTRACT

A photoelectric sequence and visual light curve are presented for Nova Cygni 1975 for the period 1975 August 29 to November 29. The time and apparent visual magnitude at maximum, t_0 = 1975 August 30.88 = JD 2,442,655.38; $m_0 = 1.85$, are derived from 33 observations. The characteristic time scales for the pre- and postmaximum branches of the light curves, $\log t_2{}^* = 0.178$, $\log t_2 = 0.386$, $\log t_3 = 0.605$, suggest that Nova Cygni 1975 was the fastest (and presumably the most luminous) galactic nova on record.

The absolute magnitude at maximum derived from the apparent magnitude 15 days past maximum, $m_{15} = 6.80$, is $M_0 = -10.25$. The interstellar extinction $A_v = 1.4$ mag is derived from the color-excess–distance relation for the comparison stars $E(B-V) = 0.33$ mag kpc^{-1} and $R = A_v/E = 3.1$. At the estimated distance of the nova $\Delta = 1.4$ kpc, the expansion velocity $V_e = 1300$ km s^{-1}, derived from the premaximum Hα absorption and postmaximum emission half-widths, should produce a visible expanding nebula 0''.4 in diameter by mid-1976.

Subject heading: stars: novae

I. INTRODUCTION

Nova V1500 Cygni 1975 was discovered by Osada (1975) on August 29.48 at $m_v = 3.0$, and independently on August 30.10 by a group of students from the University of Texas, including two of the authors (P. J. Y. and J. B.). The report was promptly communicated to and verified by G. de V., who alerted McDonald Observatory, where spectrophotometric observations began within a few hours (Tomkin, Woodman, and Lambert 1976). In Austin, three of the authors (J. B., G. de V., and P. J. Y.) began coordinated visual observations initially with respect to bright stars of known V-magnitude and later (when the nova had declined below naked-eye visibility) with respect to additional comparison stars which were measured photoelectrically (by H. C.) in the U, B, V system at McDonald Observatory.

We report here on a visual light curve derived from these combined visual and photoelectric observations (with some additional data as published in the IAU Circulars) for the period from 1975 August 29 to November 29, when the nova became fainter than $m_v = 9$. Observations have been continued by one of us (P. J. Y.) after that date and will be reported on after the comparison star sequence has been photoelectrically extended to $V \geq 9$. The present report supersedes the preliminary results reported in IAU Circulars 2832 and 2839.

According to de Vegt (1975), the prenova is not visible on either the blue (mag ≥ 21) or red (mag ≥ 20) Sky Survey prints, indicating an amplitude in excess of 19 mag. The average of five positions reported in IAU Circular 2827 is $\alpha = 21^h09^m52^s.863$, $\delta = +47°56'41''.25$ (equinox 1950.0, epoch 1975.66), or $l = 89°49'$, $b = -00°04'$. This places the nova almost exactly in the galactic plane and 90° from the galactic center. Examination of Figure 1a (Plate 10) shows the nova to be in a semitransparent region of the Milky Way with several absorbing clouds only 15' to the S and E. Figure 1b shows the immediate vicinity of the nova on a larger scale.

The large body of historical data on the brighter galactic novae recorded prior to 1953 (e.g., Payne-Gaposchkin 1957) is in the visual rather than the photoelectric V-system. Thus it is advantageous to have a visual light curve of Nova Cygni 1975 to compare with those of previous novae.

Because of the rapid spectral evolution of a nova past maximum from an early-type supergiant continuum to a nebular spectrum dominated by Hα (and later [O III]) emission, visual observations are not directly comparable with V-system magnitudes measured with a 1P21 photomultiplier, especially one selected for its low sensitivity in the red in order to minimize red-leak corrections. This effect probably accounts for the 0.7 mag difference between nearly simultaneous photoelectric and visual observations in early October, when the nova was visually very red but had only a moderate $(B-V)$ color; no such difference was present near maximum light.

In §§ II and III we list the observed magnitudes of the comparison stars and of the nova; in § IV we analyze the light curve and use it to infer the absolute magnitude at maximum; in § V we derive the galactic reddening and corrected distance modulus; in § VI we use preliminary values of the expansion velocities to predict the apparent diameter of the nebular disk in 1976.

TABLE 1

PHOTOELECTRIC SEQUENCE FOR NOVA V1500 CYGNI 1975

Designation	HD No.	Name	V	$B-V$	$U-B$	Source	Spectral Type*
A.................	197345	α Cyg	1.25	+0.09	−0.24	USNO 17953	A2 I
B.................	194093	γ Cyg	2.21	+0.67	+0.53	USNO 17671	F8 I
C.................	203280	α Cep	2.44	+0.22	+0.11	USNO 18421	A7 V
D.................	197989	ε Cyg	2.46	+1.04	+0.86	USNO 17995	K0 III
E.................	186882AB	δ Cyg	2.87	−0.03	−0.09	USNO 16830	A0 III
F.................	202109	5 Cyg	3.20	+1.00	...	BS 8115	K0
G.................	198149	η Cep	3.42	+0.92	+0.62	USNO 18008	K0 IV
H.................	200905	ξ Cyg	3.72	+1.69	...	BS 8079	K5
J.................	202444AB	τ Cyg	3.74	+0.38	+0.04	USNO 18373	F0 IV
K.................	199629	ν Cyg	3.93	+0.02	0.00	USNO 18146	A0 V
L.................	205435	ρ Cyg	4.02	+0.90	+0.56	USNO 18560	G8 III
M.................	207330	π^2 Cyg	4.23	−0.12	−0.71	USNO 18704	B3 III
N.................	206672	π^1 Cyg	4.67	−0.11	−0.69	USNO 18647	B3 IV
P.................	203064	68 Cyg	4.98	−0.01	...	USNO 18413	O7 V
Q.................	204771	71 Cyg	5.23	+0.97	+0.80	USNO 18522	K0 III
R.................	204411	...	5.29	+0.07	+0.16	USNO 18504	A3
S.................	200310AB	60 Cyg	5.37	−0.23	−0.92	USNO 18206	B1 V
T.................	204153	...	5.60	+0.30	...	USNO 18495	F0
U.................	199478	...	5.68	+0.46	−0.33	USNO 18127	B8 I
W.................	203245	...	5.77	−0.16	...	USNO 18420	B5 V
X.................	199612	...	5.91	+1.04	+0.92	USNO 18142	G8 III
Y.................	200753	...	6.32	+0.25	...	USNO 18249	A5
Z.................	201836AB	...	6.51	0.00	−0.37	McD	B5 V
a.................	202654	...	6.52	−0.14	−0.71	McD	B5
b.................	204131	...	6.59	−0.04	...	USNO 18491	A0
c.................	203535	...	6.91	...	...	HD corrected	A2
d.................	201599	...	7.02	+0.39	+0.02	McD	F2
e.................	201359	...	7.28	−0.05	...	USNO 18303	A0
f.................	201836C	...	7.37:	+1.55	+1.36:	McD	M5 III†
g.................	201320	...	7.39	+0.04	+0.04	McD	A0 V
h.................	201076	...	7.45	−0.05	...	USNO 18282	A0 IV
k.................	202766	...	7.56	+0.14	+0.15	McD	A2
m.................	201269	...	7.66	+0.03	−0.02	McD	A0 V
n.................	201416	...	7.78	+1.00	+0.75	McD	G5 III
p.................	201522	...	7.88	−0.05	...	USNO 18314	B7 IV
q.................	202216	...	8.16	+1.09	+0.96	McD	K0
r.................	202383	...	8.47	0.00	−0.12	McD	A0
s.................	201612	...	8.59	−0.08	−0.30	McD	A0
t.................	201250	...	8.88	−0.02	...	USNO 18294	B7 IV
u.................	SAO 050526	...	9.05	+0.21	−0.17	McD	
w.................	SAO 050523	...	9.10	+0.35	+0.25	McD	
x.................	...	...	10.53	+0.66	−0.20	McD	B2 V
y.................	...	...	11.01	+1.76	+2.05:	McD	

* Spectral types were taken from the USNO and HD catalogs.

† Variable?

II. COMPARISON STARS

The V-magnitude and $(B-V)$, $(U-B)$ colors of 43 comparison stars from $V=1.25$ to $V=11.01$ are presented in Table 1, and the field within 1° of the nova is displayed in Figure 2 with the positions of 19 comparison stars, with $V \geq 6.51$.

The sources of the magnitudes are as follows:

(1) USNO catalog (Blanco *et al.* 1968); mean of measurements therein (25 stars). (2) Yale catalog of Bright Stars (Hoffleit 1964) (2 stars). (3) HD catalog (Cannon and Pickering 1924) (1 star). The transformation from the HR magnitude in the HD catalog to the V-system was found from comparison stars a, b, g, and m, all of similar spectral type (B5–A0) to the comparison c (A 2); and $V = \text{HR} + 0.20$ was derived. (4) McDonald Observations referred to standard stars in Johnson *et al.* (1966) on four nights during 1975 October with the 91 cm reflector. Standard U, B, V filters and 1P21 photomultiplier were employed, in conjunction with a d.c. amplifier. The nova was observed on all four nights (Table 8) and the comparison stars on two nights, each with 17″.1 and 15″.8 apertures. Three 10 s integrations of the nova and two of the sky (N and S) were made for a single observation of the nova, and two 10 s integrations of a comparison star and one of the sky for the comparison star observations. Sky fields were free from stars with $V < 16$; fainter stars were not seen visually but had an effect less than 0.01 mag on an object with $V < 11$.

The observations of the comparison stars have internal mean errors, derived from residuals, $\sigma_V = 0.028$, $\sigma_{B-V} = 0.011$, $\sigma_{U-B} = 0.015$ mag (except for two stars of extreme color, where the values marked approximate have $\sigma_{U-B} = 0.039$). External mean errors were $\sigma_V = 0.040$, $\sigma_{B-V} = 0.015$, $\sigma_{U-B} = 0.021$

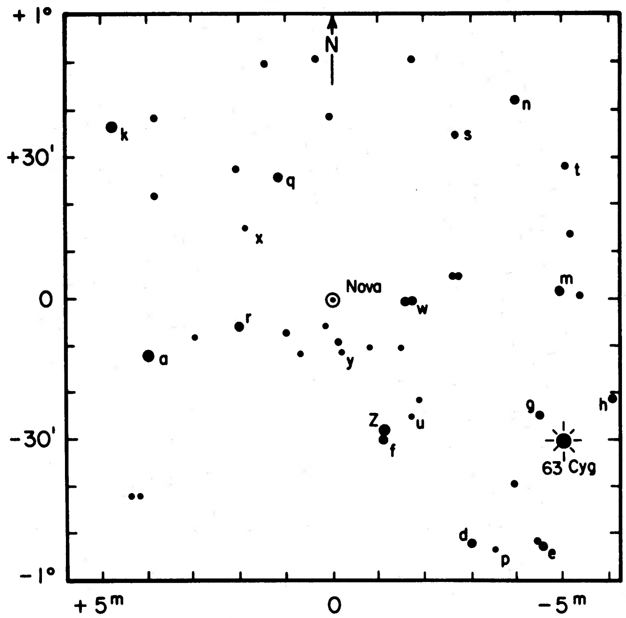

FIG. 2.—Field of 19 comparison stars within 1° of Nova Cygni 1975, with $6.51 \leq V \leq 11.01$

(or 0.055 for the two red stars) from comparisons with stars in common with the USNO values.

Star f may be variable: USNO lists $V = 7.29$. Two McDonald observations gave October 4, $V = 7.41$; October 7, $V = 7.33$. It was seldom used as a visual comparison because of its redness and proximity to c.

III. OBSERVATIONS

A total of 94 independent visual observations (by J. B., G. de V., P. J. Y.), each comprising from 2 to 12 separate estimates, were obtained; the observations were appropriately grouped and are collected into mean points in Table 2. The instruments used by each observer are presented in Table 3. No discontinuity in the derived magnitudes was detected when instruments were changed. G. de V. used the Pogson step method with a step of 0.10 mag; J. B. and P. J. Y. used the fractional method with variable step (usually about 0.1 mag). In each individual observation, from two to six comparison stars were used and a mean of these individual estimates was taken. Then the tabulated values are unweighted means of these observations grouped by time. Only five observations were rejected; they were all designated doubtful because of patchy cloudiness and other problems.

The mean errors listed are the unbiased standard deviations of the residuals of the individual observations from their mean.

Residuals of the individual observers from the mean are also given, along with the number of estimates in each observation. These residuals are analyzed at the foot of the table to determine individual accidental and systematic errors.

The visual magnitudes m_v in Table 2 are on the V-system zero point but not necessarily on the same color system.

To supplement our observations, we will make use of the following additional information: (1) 16 prediscovery photovisual observations m_{pv} (the very first is photographic m_{pg}) (Table 4); and (2) 17 photoelectric observations in the V-system (Table 5). Six other published observations—reportedly in the V-system—leave residuals of 0.3 to 0.8 mag and were omitted.

These observations were necessary to define the time and magnitude accurately at maximum light, and a comparison of the visual m_v and photoelectric V-magnitudes is made in § IV.

IV. ANALYSIS OF THE LIGHT CURVE

a) The Rise

The 16 prediscovery observations are plotted in Figure 3. The rising branch may be approximated by two overlapping linear segments.

1. From August 28.732 to August 29.252, the very steep rise is at a rate of 16.5 ± 0.6 mag day^{-1}, indicating that most of the initial rise of at least 19 mag took place in only 1 day.

2. From August 29.217 to August 29.495, the rise rate slowed to 9.7 ± 1.2 mag day^{-1}. This change of rate on the rising branch at ~ 1.8 mag below maximum has been reported for other fast novae (Payne-Gaposchkin 1957).

TABLE 2

VISUAL OBSERVATIONS, MEAN POINTS

No.	UT 1975	JD (2,442,000+)	$t - t_0$	m_v	n	Residuals Obs.-Mean (No. of Estimates) J. B.	G. de V.	P. J. Y.
1.....	Aug. 30.13	654.63	−0.75	2.01	3	−9(4)	−2(3)	+10(6)
2.....	Aug. 30.26	654.76	−0.62	1.95	3	+4(5) − 8(4)		+3(2)
3.....	Aug. 31.07	655.67	+0.19	1.92	3	+1(3)	+2(4)	−2(4)
4.....	Aug. 31.20	655.70	+0.32	1.93	1	...(6)	...	...
5.....	Sept. 1.08	656.58	+1.20	2.34	1	Rej.	...	...(4)
6.....	Sept. 1.44	656.94	+1.56	2.88	1	...	...(8)	
7.....	Sept. 2.08	657.58	+2.20	3.64	2	−4(2) + 4(2)		
8.....	Sept. 2.15	657.65	+2.27	3.62	3	+8(2)	−7(4)	0(4)
9.....	Sept. 2.40	657.90	+2.52	4.18	1		...(7)	
10.....	Sept. 3.15	658.65	+3.27	4.49	4	+14(6)	−6(7) − 16(5)	+8(6)
11.....	Sept. 3.36	658.86	+3.48	4.60	3	+3(4)	−11(7)	+8(3)
12.....	Sept. 4.09	659.59	+4.21	4.88	3	+21(4)	−21(4)	+1(3)
13.....	Sept. 5.07	660.57	+5.19	5.20	2	+2(2)		−3(3)
14.....	Sept. 6.09	661.59	+6.21	5.52	2	+7(2)		−7(4)
15.....	Sept. 7.17	662.67	+7.29	5.71	3	−2(2) + 8(2)		−5(3)
16.....	Sept. 8.11	663.61	+8.23	6.08	2	...	+10(12)	−10(4)
17.....	Sept. 9.11	664.61	+9.23	6.19	3	−3(2)	+3(2)	0(5)
18.....	Sept. 10.12	665.62	+10.24	6.28	2		+1(4)	−1(2)
19.....	Sept. 12.09	667.59	+12.21	6.56	3	+5(4)	−9(5)	+4(3)
20.....	Sept. 13.14	668.64	+13.26	6.75	1	...	...(7)	
21.....	Sept. 15.18	670.68	+15.30	6.88	2	...	+8(4)	−9(4)
22.....	Sept. 16.10	671.60	+16.22	7.03	3	+4(2)	+5(5)	−10(4)
23.....	Sept. 17.11	672.61	+17.23	7.04	3	−6(2)	+13(5)	−7(4)
24.....	Sept. 18.08	673.58	+18.20	7.12	3	−13(2)	+10(7)	+2(4)
25.....	Sept. 19.15	674.65	+19.27	7.14	3	−14(2)	+12(8)	+3(6)
26.....	Sept. 21.14	676.64	+21.26	7.28	3	−11(2)	+13(6)	−3(6)
27.....	Sept. 23.12	678.62	+23.24	7.33	3	−19(2)	+18(5)	+1(4)
28.....	Sept. 24.11	679.61	+24.23	7.27	2	−6(2)		+6(4)
29.....	Sept. 25.10	680.60	+25.22	7.54	2	...	+10(3)	−10(4)
30.....	Sept. 26.11	681.61	+26.23	7.38	2	−8(2)		+7(3)
31.....	Sept. 27.15	682.65	+27.27	7.45	2	−4(2)		+4(6)
32.....	Sept. 28.10	683.60	+28.22	7.44	2	−2(2)		+1(5)
33.....	Sept. 29.21	684.71	+29.33	7.76	2	−4(2)		+3(3)
34.....	Sept. 30.13	685.63	+30.25	7.69	2	+5(2)		−5(3)
35.....	Oct. 1.08	686.58	+31.20	7.61	1	...		...(3)
36.....	Oct. 2.10	687.60	+32.22	7.73	1	...		...(4)
37.....	Oct. 3.28	688.78	+33.40	7.67	1	...		...(4)
38.....	Oct. 4.15	689.65	+34.27	7.74	1	...		...(2)
39.....	Oct. 5.11	690.61	+35.23	7.71	2	+4(2)		−5(4)
40.....	Oct. 7.13	692.63	+37.25	7.75	1	...(2)		
41.....	Oct. 8.06	693.56	+38.18	7.80	1	...		...(3)
42.....	Oct. 10.31	695.81	+40.43	7.96	1	...		...(4)
43.....	Oct. 11.10	696.60	+41.22	8.01	1	...(2)		
44.....	Oct. 15.14	700.64	+45.26	8.27	1	...		...(2)
45.....	Oct. 19.18	704.68	+49.30	8.50	1	...		...(2)
46.....	Nov. 2.06	718.56	+63.18	8.82	1	...		...(4)
47.....	Nov. 9.06	725.56	+70.18	8.89	1	...		...(4)
Mean..........						−1.1	+1.7	−0.5
Standard deviation..........						8.6	10.8	5.7

TABLE 3

INSTRUMENTS USED FOR VISUAL OBSERVATIONS

P. J. Young	
$m_v < 4.0$	Naked-eye
$4.0 \leq m_v < 7.6$	9 × 6 cm Bino.
$7.6 \leq m_v < 8.5$	30 × 6 cm Refr.
$8.5 \leq m_v$	80 × 22 cm Refr.
G. de Vaucouleurs	
$m_v < 3.0$	Naked-eye
$3.0 \leq m_v < 6.0$	8 × 3 cm Bino.
$6.0 \leq m_v < 7.6$	25 × 4 cm Refr.
J. Bryan	
$m_v < 4.0$	Naked-eye
$4.0 \leq m_v < 8.5$	7 × 5 cm Bino.
$8.5 \leq m_v$	80 × 25 cm Refl.

TABLE 4

PREDISCOVERY PHOTOVISUAL OBSERVATIONS*

UT 1975	JD (2,442,000+)	m_{pv}
Aug. 28.732......	653.232	13.5†
Aug. 29.052......	653.552	8.41:
Aug. 29.055......	653.555	8.21:
Aug. 29.168......	653.668	6.19
Aug. 29.193......	653.693	5.85
Aug. 29.217......	653.717	5.14
Aug. 29.252......	653.752	5.33
Aug. 29.276......	653.776	4.64
Aug. 29.300......	653.800	5.12
Aug. 29.325......	653.825	4.37
Aug. 29.373......	653.873	3.28
Aug. 29.398......	653.898	3.39
Aug. 29.422......	653.922	3.18
Aug. 29.446......	653.946	3.06
Aug. 29.471......	653.971	2.89
Aug. 29.495......	653.995	3.11

* Garnavich, Mayer, and Suyarkova, 1975*a*, *b*. m.e. given as 0.2 or (:) 0.3.

† m_{pg}.

It is on this second portion of the light curve that we determine t_2*, the time taken to rise the last 2 mag to maximum as defined by Schmidt (1957). With $V_2^* = 3.85 \pm 0.03$ (from V_0 determined in the next section),

$$\log t_2^* = 0.178 \pm 0.005\,; \qquad t_2^* = 1^{d}51 \pm 0^{d}02\,.$$

This speed of rise is considerably faster than any in Schmidt's sample, where the smallest well-determined value is $t_2^* = 2^{d}5$. [A value $t_2^* = 1^{d}3$ is listed for Nova Q Cygni 1876, but we believe there is no basis for it, because the rising branch of that nova was not observed (Müller and Hartwig 1920).]

b) *The Maximum*

The light curve at maximum is defined by (1) the 17 photoelectric observations in Table 5; (2) the mean of the six photovisual observations with $m_{pv} \leq 3.39$ in Table 4; and (3) the 15 visual observations between August 30.14 and September 2.40 listed in Table 6. Here we have given details of the individual observations (two discordant points were rejected).

A cubic polynomial was fitted by least squares; the 33 points and best-fitting curve are shown in Figure 4. The time of maximum derived from the polynomial

TABLE 5

PHOTOELECTRIC OBSERVATIONS NEAR MAXIMUM*

UT (1975)	JD (2,442,000+)	V	$B-V$	$U-B$
Aug. 29.8167.......	654.3167	2.55	+0.35	...
Aug. 30.0470.......	654.5470	2.26	+0.45	...
Aug. 30.23.........	654.73	2.04	+0.50	−0.44
Aug. 30.30.........	654.80	2.04	+0.52	−0.34
Aug. 30.3..........	654.8	1.98	+0.51	...
Aug. 30.9..........	655.4	1.88	+0.62	−0.19
Aug. 30.96.........	655.46	1.79	+0.58	...
Aug. 31.25.........	655.75	1.92	+0.64	−0.11
Aug. 31.3..........	655.8	1.87	+0.62	...
Aug. 31.33.........	655.83	1.90	+0.64	+0.02†
Aug. 31.51.........	656.01	2.02	+0.65	−0.15
Sept. 1.161.........	656.661	2.45	+0.62	−0.29
Sept. 1.31..........	656.81	2.61	+0.49	−0.21
Sept. 1.47..........	656.97	2.80	+0.49	−0.40
Sept. 2.131.........	657.631	3.61	+0.4†	−0.3†
Sept. 2.18..........	657.68	3.73	+0.34	−0.52
Sept. 2.254.........	657.754	3.75	+0.35	−0.50

* From IAU Circulars 2826, 2828, 2830, 2832, 2834.

† Rejected.

TABLE 6

INDIVIDUAL VISUAL OBSERVATIONS NEAR MAXIMUM

UT (1975)	JD (2,442,000+)	Obs.	m_v	n	Residual*
Aug. 30.11	654.61	J. B.	1.92	4	(−21)†
Aug. 30.14	654.64	P. J. Y.	2.11	6	−2
Aug. 30.15	654.65	G. de V.	1.99	3	−13
Aug. 30.23	654.73	J. B.	1.99	5	−7
Aug. 30.24	654.74	P. J. Y.	1.98	2	−7
Aug. 31.05	655.55	J. B.	1.93	3	+9
Aug. 31.06	655.56	P. J. Y.	1.90	4	+6
Aug. 31.10	655.60	G. de V.	1.94	4	+9
Aug. 31.20	655.70	J. B.	1.93	6	+7
Sept. 1.06	656.56	J. B.	2.08	4	(−38)†
Sept. 1.08	656.58	P. J. Y.	2.34	4	−10
Sept. 1.44	656.94	G. de V.	2.88	8	+7
Sept. 2.06	657.56	J. B.	3.60	2	+5
Sept. 2.10	657.60	J. B.	3.68	2	+8
Sept. 2.14	657.64	J. B.	3.70	2	+5
Sept. 2.15	657.65	G. de V.	3.55	4	−11
Sept. 2.16	657.66	P. J. Y.	3.62	4	+0

* Residual from polynomial fit in 0.01 mag.

† 2 σ reject data.

and checked by Pogson's method of bisected chords is

$$t_0 = 1975 \text{ August } 30.88 \pm 0.02$$
$$= \text{JD } 2{,}442{,}655.38 \pm 0.02\,.$$

The polynomial fit gives, for the magnitude at maximum, $m_0 = 1.82$, while the mean of the five observations nearest to t_0 is $m_0 = 1.89 \pm 0.03$; we will adopt

$$m_0 = 1.85 \pm 0.03\,.$$

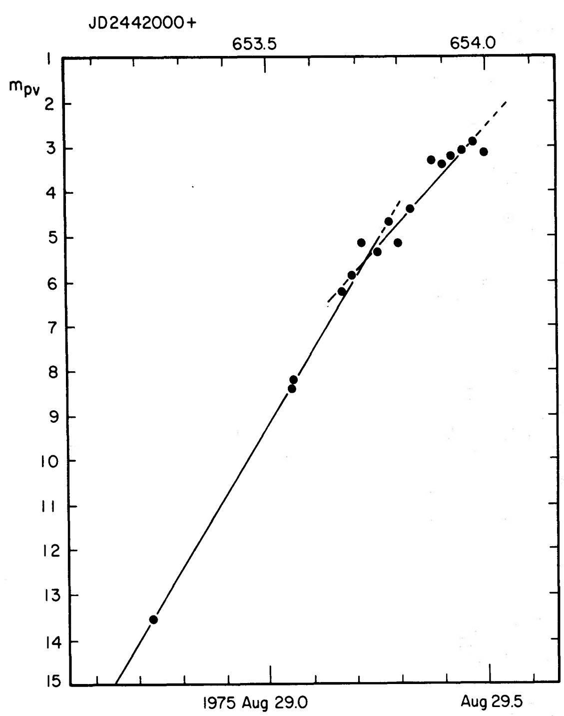

FIG. 3.—Rising branch of light curve from prediscovery photographic observations. Linear fits to the two stages of the rise are shown.

When we inspect the scatter of points around maximum, it seems possible that the nova was undergoing small-amplitude (≤ 0.1 mag) oscillations; in this case, m_0 represents the mean maximum rather than the peak maximum of the fluctuations. Behavior of this type was reported on September 9–10 by Tempesti (1975) as the nova was declining.

Table 7 summarizes the residuals of the polynomial fit; it may be noted that a single careful visual observation has only twice the mean error of a photoelectric observation.

c) The Initial Decline

1. The parameter t_2, the time taken to fall 2 mag from maximum determined from the polynomial fit above, with $m_2 = 3.85 \pm 0.03$, is

$$\log t_2 = 0.386 \pm 0.007\,; \qquad t_2 = 2^d.43 \pm 0^d.04\,.$$

2. The parameter t_3 (McLaughlin 1945) was found by a linear least-squares fit to a plot of m_v versus

TABLE 7

RESIDUALS FROM POLYNOMIAL FIT*

Observations	Mean Residual	Standard Deviation	No. of Obs.
Visual	+0.4	7.9	15
Photovisual . .	+4.1	. . .	1†
Photoelectric .	−0.6	4.1	17

* Unit: 0.01 mag.

† Mean of 5.

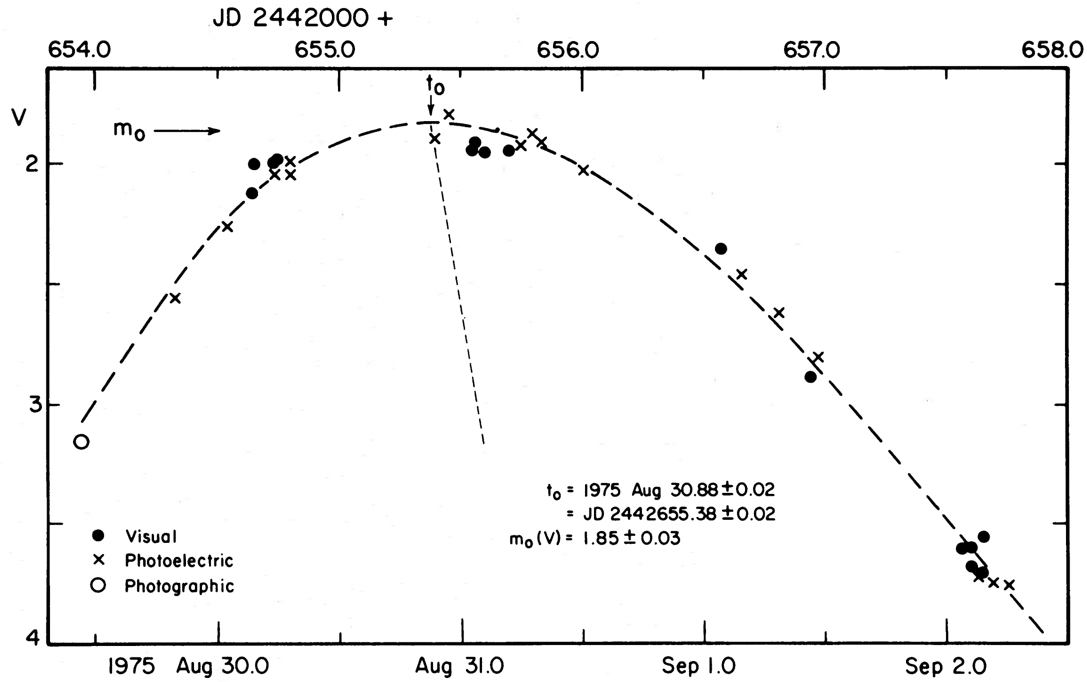

FIG. 4.—Light curve near maximum, with best-fitting cubic polynomial and the time of maximum from Pogson's method of bisected chords.

$\log (t - t_0)$ (Fig. 5) for $2.5 \leq (t - t_0) \leq 20$:

$$m_v = \underset{\pm 0.056}{2.722} + \underset{\pm 0.054}{3.519} \log (t - t_0) .$$

Then, with $m_3 = 4.85 \pm 0.03$,

$$\log t_3 = 0.605 \pm 0.008; \qquad t_3 = 4^{d}.03 \pm 0^{d}.08 .$$

Schmidt (1957) derived from several novae the mean relations

$$\log t_2^* \approx -0.3 + 0.7 \log t_2$$
$$= -0.5 + 0.7 \log t_3 .$$

The above values were plotted on Figure 2 of Schmidt's paper. Although $\log t_2^*$ was some 0.2

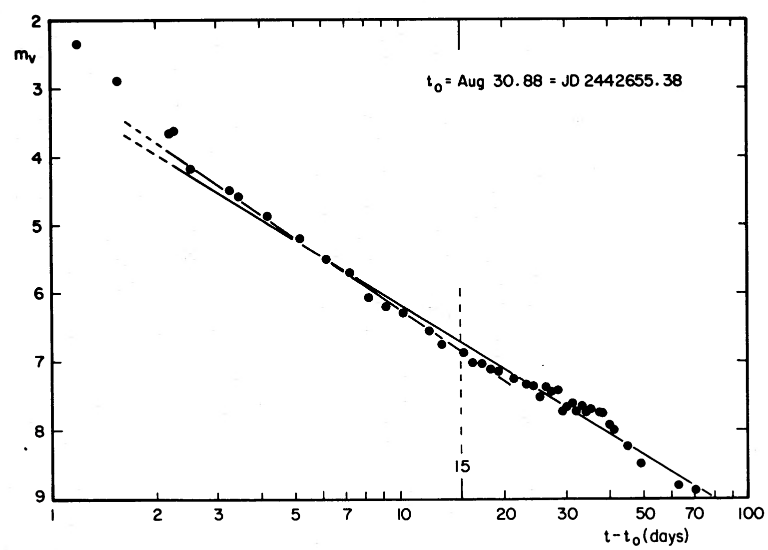

FIG. 5.—Postmaximum light curve in logarithmic coordinates. Abscissae are times $(t - t_0)$ in days past maximum. The interpolated magnitude at $(t - t_0) = 15$ days is a distance indicator. Two linear fits to the decline are shown.

above the mean relations, the departures are within the range of the scatter.

It may be noted that t_2 and t_3 are considerably smaller than any listed by Schmidt, confirming our early reports (Young, Bryan, and de Vaucouleurs 1975*a*, *b*) that Nova Cygni 1975 is the fastest galactic nova on record. Reference to Figure 6 of Schmidt's paper shows that these values of $\log t_2$ and $\log t_3$ are on the ill-defined upper portion of the rate-luminosity relations and suggest an absolute magnitude at maximum $M_0 \lesssim -9$.

A linear approximation to the (M_0, $\log t_3$)-relation (Schmidt 1957) is

$$M_0 = -11.5 + 2.5 \log t_3$$

and yields $M_0 \approx -10.0$ and an apparent distance modulus $(m - M) \approx 11.85$. However, application of this relation to Nova Cygni 1975 involves a significant extrapolation beyond the range of $\log t_3$ within which it was established.

d) *Distance Modulus from the m_{15} Method*

A more reliable estimate of the distance modulus may be derived by the m_{15} method (Buscombe and de Vaucouleurs 1955), which rests on the empirical findings that: (1) the mean light curves of novae of all types are approximately linear in the [m, $\log (t - t_0)$]-diagram (Fig. 5); and (2) all novae have approximately the same absolute magnitude ~15 days past maximum, $M_{15} = -5.2 \pm 0.15$ (m.e.), within the rather large errors of available parallaxes (cf. Fig. 2 in Buscombe and de Vaucouleurs).

A linear least-squares fit of the logarithmic light curve of Nova Cygni 1975 (Fig. 5) for $2.5 \leq (t - t_0) \leq 71$ days gives $m_{15} = 6.72$, while a linear fit for $2.5 \leq (t - t_0) \leq 20$ days gives $m_{15} = 6.86$. The former averages out the small-amplitude, long-term oscillations; the latter is a better fit to the actual light curve one to three weeks past maximum. We may adopt $\langle m_{15} \rangle = 6.80 \pm 0.05$, from which $(m - M)_v = 12.0 \pm 0.2$ (m.e.).

It may be argued that Nova Cygni 1975 is more nearly comparable to the three fastest novae (CP Puppis 1942, $t_3 = 7^d$; V603 Aql 1918, $t_3 = 8^d$; CP Lac 1936, $t_3 = 9^d$) used by Buscombe and de Vaucouleurs; revising their estimated distance moduli (Schmidt 1957; Payne-Gaposchkin 1957) raises the mean absolute magnitude of this group by 0.3 mag to $M_0 = 9.9 \pm 0.2$, and brings their $\langle M_{15} \rangle$ into closer agreement with the other groups of slower novae, for a revised $\langle M_{15} \rangle = -5.3 \pm 0.15$ (m.e.). Then $(m - M)_v = 12.1 \pm 0.2$ and the absolute magnitude at maximum $M_0 = -10.25 \pm 0.2$, brighter than all previous well-observed novae.

e) *Visual Light Curve*

The visual light curve is presented in Figure 6 and contains all the visual observations (mean points) (Table 2), photovisual observations (Table 4), the first two photoelectric observations (Table 5), and the McDonald photoelectric observations (Table 8). The probable cause of the difference between the McDonald photoelectric observations and the visual observations was discussed in § I. The last three visual observations (by P. J. Y.) with the dashed light curve are reductions with a provisional comparison star sequence and do not appear in Table 2.

Color curves $(B - V)$ and $(U - B)$ are also plotted from observations in IAU Circulars 2826–2858. Direct comparison with other bright galactic novae is not possible, since previous observations have not been on the U, B, V system. However, Schmidt (1957) quotes, after Arp (1956), $(B - V)_0 = +0.35 \pm 0.05$ for the average corrected color index at maximum of novae in M31.

V. INTERSTELLAR REDDENING AND DISTANCE MODULUS

The uncorrected distance modulus $(m - M) = 12.1 \pm 0.2$ derived in § IV must now be corrected for the effects of interstellar extinction. We will use a variant of the Q-method previously applied to Nova V723 Sco 1952 (de Vaucouleurs 1960).

a) *Reddening of Comparison Stars*

The comparison stars listed in Table 9 were plotted on a [$(U - B)$, $(B - V)$]-diagram (Fig. 7) and projected onto the main-sequence standard curve along reddening lines of slope 0.76 or $(0.76 + 0.03A_v)$ in the case of the B stars, after Blanco (1956). All the stars were of known spectral type, allowing an unambiguous solution, except u, which was taken to be of type B6 V to be consistent with its intersection with the intrinsic color curve. The absolute magnitude of each spectral type was taken from Allen (1973),

TABLE 8

McDonald Photoelectric Observations

UT 1975	JD (2,442,000+)	$t - t_0$	V*	$B - V$†	$U - B$†
Oct. 3.107......	688.607	+33.227	8.38	−0.30	−0.58
Oct. 4.086......	689.586	+34.206	8.42	−0.32	−0.52
Oct. 7.062......	692.562	+37.182	8.55	−0.34	−0.51
Oct. 10.069.....	695.569	+40.189	8.70	−0.39	−0.51

* Mean error 0.04.
† Mean error 0.02.

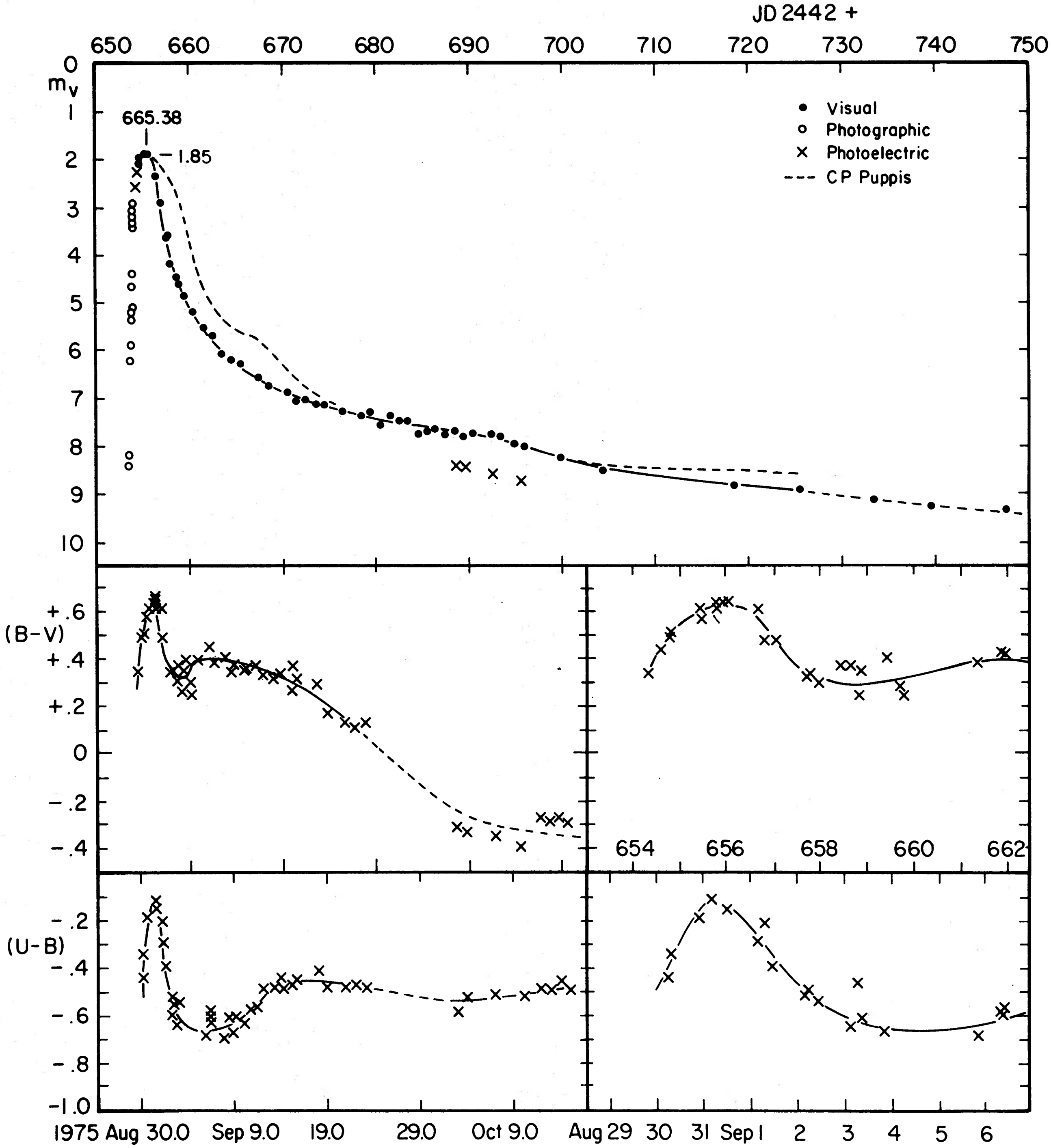

FIG. 6.—Visual light curve of Nova Cygni 1975, with (*above*) Nova CP Puppis 1942 for comparison. (*Below*) Color curves shown on (*left*) the same scale as the visual light curve and (*right*) on an expanded scale near maximum. Note "photographic" refers to m_{pv}.

1976ApJ...209..882Y

TABLE 9

Reddening of Comparison Stars

Star	Spectral Type: Spectra	Spectral Type: Colors	M_v	V	A_v*	$V - A_v$	$(m - M)_0$	r (kpc)	A_v/r
X.........	G8 III	G9	+0.33	5.91	0.10	5.81	5.48	0.12	0.83
Z..........	B5 V	B6	−2.42	6.51	0.45	6.06	8.48	0.50	0.90
k..........	A2	A2	+0.58	7.56	0.25	7.31	6.73	0.22	1.14
m.........	A0 V	A0	+0.08	7.66	0.16	7.50	7.42	0.30	0.53
n..........	G5 III	G7	+0.58	7.78	0.25	7.53	6.95	0.25	1.00
u..........	...	B6	−1.92	9.05	1.09	7.96	9.88	0.95	1.15
x..........	B2 V	B1	−4.52	10.53	2.90	7.63	12.15	2.69	1.08

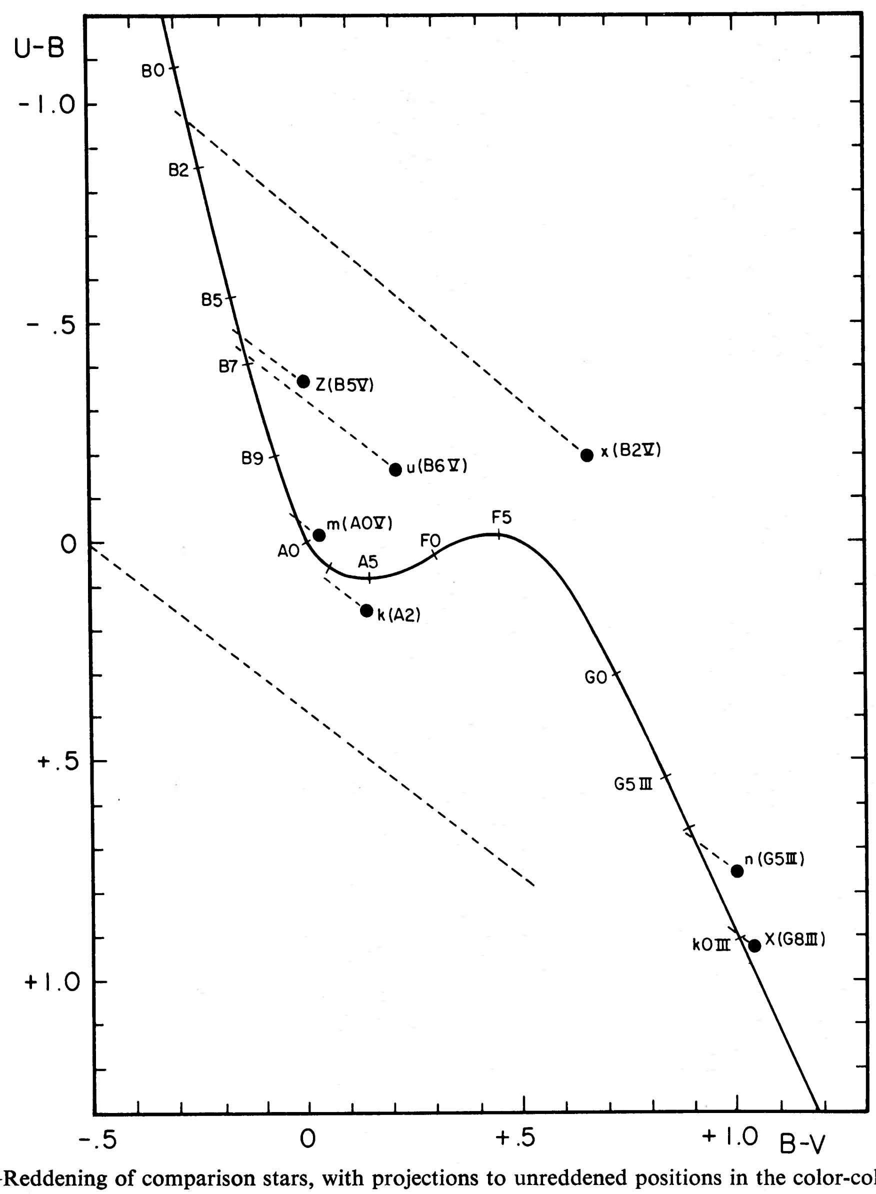

Fig. 7.—Reddening of comparison stars, with projections to unreddened positions in the color-color diagram

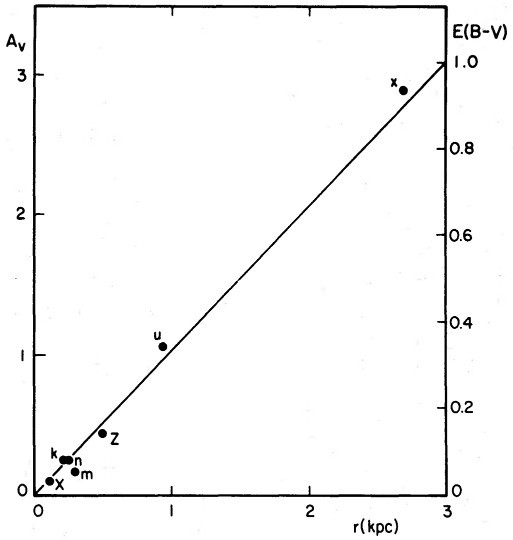

FIG. 8.—Reddening $E(B - V)$ and visual extinction A_v versus distance r in kpc derived from comparison stars.

whence the distance can be determined as shown in Table 9.

The seven stars were carefully selected to lie in areas where the background star density was comparable to that around the nova. A plot of the calculated values of $E(B - V)$ and $A_v = 3.1E(B - V)$ is shown in Figure 8, where the linear least-squares fit gives

$$E(B - V) = 0.33 \pm 0.033 \text{ mag kpc}^{-1} ,$$

$$A_v = 1.03 + 0.10 \text{ mag kpc}^{-1} ,$$

from which we derive the corrected distance modulus,

$$(m - M - A) = 10.7 \pm 0.2 ,$$

and distance,

$$\Delta = 1.4 \pm 0.1 \text{ kpc} .$$

The visual extinction of the nova corresponding to Δ is

$$A_v = 1.4 \pm 0.12 ,$$

with

$$E(B - V) = 0.45 \pm 0.04 ,$$

and

$$E(U - B) = 0.35 \pm 0.03 ,$$

where $E(U - B)$ is derived from Blanco's relations (1956). A confirmation, though of lower weight, is available from spectroscopy.

b) *Reddening of Nova from Spectral Data*

Tomkin, Woodman, and Lambert (1976) have estimated the reddening from the equivalent width of the interstellar line 7699 Å; they calculate a column density $N(\text{K I}) = 1.5 \times 10^{12} \text{ cm}^{-2}$ and, from the calibration of the $[N(\text{K I}), E(B - V)]$-relation by Hobbs (1974), derive $E(B - V) = 0.45 \pm 0.07$ (the m.e. is our estimate from the scatter in the calibration diagram). This is in excellent agreement with the value derived from the star colors.

c) *Color at Maximum*

From the photoelectric observations of Table 5 displayed at the bottom of Figure 6, the color index of the nova at maximum light was

$$B - V = +0.62 \pm 0.01 ;$$

$$U - B = -0.15 \pm 0.04 .$$

With the reddening determined above, we obtain

$$(B - V)_0 = +0.17 \pm 0.04 ;$$

$$(U - B)_0 = -0.50 \pm 0.05 .$$

The mean color curves plotted in Figure 6 were inserted into a two-color diagram in order to display the locus of the nova (Fig. 9).

d) *Comparison with Other Fast Novae*

In Table 10 we compare Nova Cygni 1975 with four previous, well-observed fast galactic novae and with the fastest or brightest novae observed in M31 by Hubble (1929), Arp (1956), and Rosino (1973).

Compared with the galactic novae, Nova Cygni 1975 is clearly exceptional in all respects: it is the fastest and the most luminous and has the greatest amplitude on record; only Nova CP Puppis 1942 is a distant rival. The light curve of Nova Puppis 1942, normalized to make the maxima coincident, is included in Figure 6 for comparison.

Nova Arp 1 was even faster than Nova Cygni 1975 but was not observed at maximum light; the value $m_{pg} = 15.7$ quoted by Arp was extrapolated and very uncertain. Nova Rosino 57 was comparable in speed to the first three galactic novae in Table 10, slower than Nova Cygni 1975, but at its observed maximum $m_{pg} = 15.0$ was the brightest seen in M31. Hubble 54 also was not so fast as Nova Cygni 1975 but was seen at $m_{pg} = 15.3$; and the maximum, extrapolated by us, was $m_{pg} = 15.0$.

From van den Bergh (1976), we may take the distance modulus of M31 to be $(m - M)_v = 24.66 \pm 0.13$ with galactic reddening $E(B - V) = 0.11$; assuming an equal amount in M31, the total color excess of a nova in M31 may be $E(B - V) \approx 0.2$.

Arp (1956) gives the conversion $m_{pg} = B - 0.27 + 0.18(B - V)$ used for novae Arp and Rosino 57, and we have used $B = 15.2 + 1.18[(IP_g + 0.1) - 15.2]$ for conversion of the Hubble magnitudes (Brown 1974).

We derive the visual absolute magnitudes at maximum of the three novae in M31 listed in Table 10, column (8), where we assumed an intrinsic color

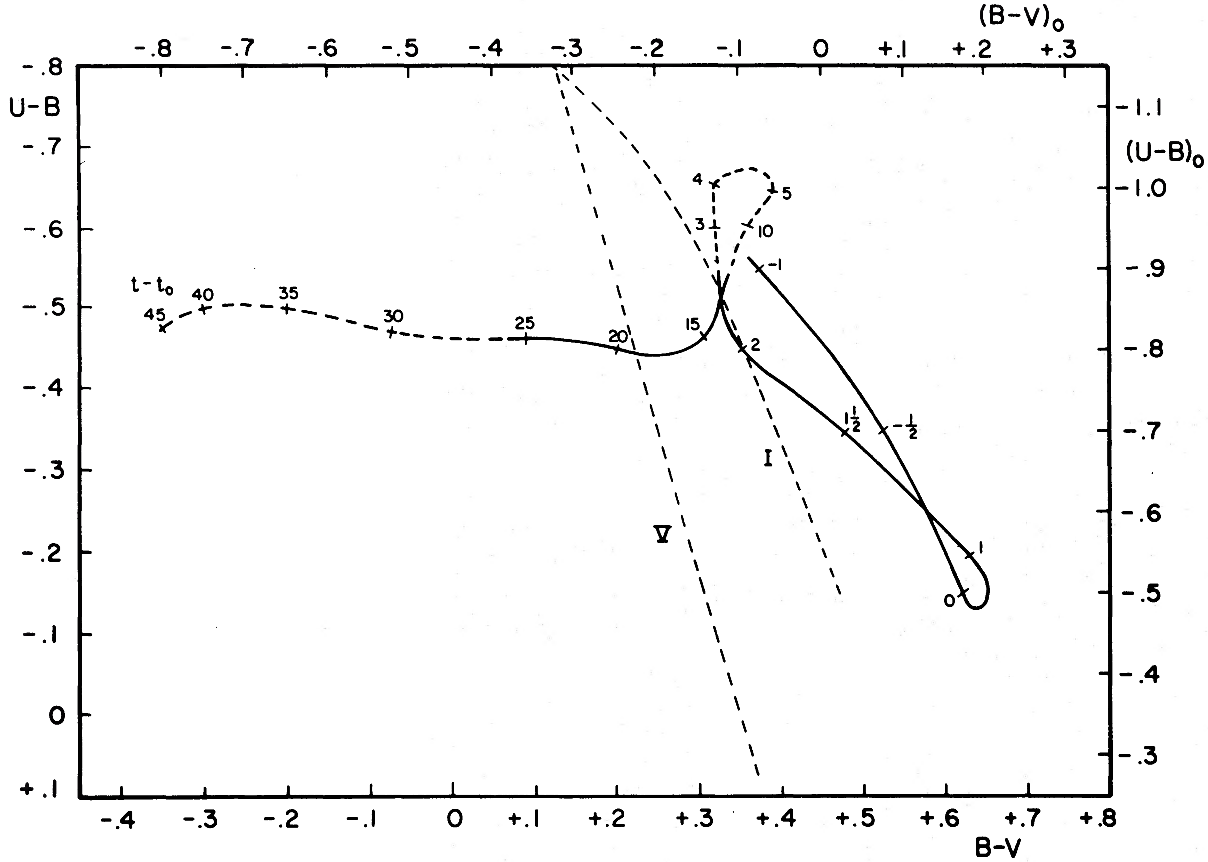

FIG. 9.—Locus of Nova Cygni 1975 in the color-color diagram as a function of time past maximum ($t - t_0$) in days. Dashed portions of curve are uncertain. Loci of luminosity classes I and V are given.

index $(B - V)_0 = +0.15$ at maximum as observed for Nova Cygni 1975.

VI. PREDICTED EXPANDING NEBULOSITY

a) The Doppler shift of the Hα line in absorption on August 30–31 was very roughly -1300 km s^{-1} with only slight contamination by Hα emission (Tomkin, Woodman, and Lambert 1976). The apparent velocity was -2100 km s^{-1} on August 31.25 and -2400 km s^{-1} on September 1.13, as the absorption line was progressively contaminated by rising Hα emission.

TABLE 10

COMPARISONS OF NOVA CYGNI 1975 WITH OTHER FAST NOVAE

Nova	Maximum $m_0(V)$	Prenova m	Ampl. $m - m_0$	log t_2*	log t_2	log t_3	$M_0(V)$	Rise Rate (mag d^{-1})	Notes
Galactic:									
V1500 Cyg 1975...	+1.85	>21	>19	0.178	0.386	0.605	−10.25	16.5	
CP Pup 1942.....	+0.75	>17	>16.3	...	0.45:	0.75	−9.4	...	
CP Lac 1936......	+2.6	15.3	12.7	0.3:	0.85	1.18	−8.6	9	
V476 Cyg 1920....	+2.5	...	...	0.6:	1.04	1.34	−8.8	...	
V603 Aql 1918....	−0.75	10.5v	11.3	0.3:	0.60	1.08	−8.8	9.5	
M31:									
Rosino 57, 1964...	15.0*	...	...	0.4:	1.0:	...	−9.8	...	
Arp 1, 1953.......	15.7:*	...	...	...	0.27:	0.50:	−9.1:	(24)	1, 2
Hubble 54, 1925..	15.0:*	...	...	0.5:	1.2:	...	−9.9:	...	2

NOTES: (1) rise rate from 2 plates only 45 minutes apart, uncertain; (2) extrapolated maximum, uncertain.

SOURCES: for galactic novae, Schmidt (1957), Payne-Gaposchkin (1957); for M31 novae, Rosino (1973), Arp (1956), and Hubble (1929).

* m_0 (pg).

b) As the Hα emission line strengthened, on September 4 and after, the emission exhibited a quadruple peak with Doppler shifts of roughly -1100, -550, $+150$, and $+750$ km s^{-1} (Tomkin, Woodman, and Lambert 1976).

c) The Hα emission line progressively narrowed from September 4 to September 18, when its half-intensity points had Doppler shifts of ± 1550 km s^{-1} on September 7 and ± 1300 km s^{-1} on September 18 (Tomkin, Woodman, and Lambert 1976); the rate of narrowing between these dates was small.

From these various indications, we provisionally estimate the expanding shell to have a velocity of 1300 ± 100 km s^{-1}; and with $\Delta = 1.4 \pm 0.1$ kpc, the diameter of the nebula may be expected to grow at the rate of 0".4 per year. It could become visible in the summer or fall of 1976, when the nova will have faded to $m_v \approx 11$ to 12, if the logarithmic decline continues.

Addendum (1976 April 13).—Through the courtesy of Professor W. H. Sandmann, Harvey Mudd College, Claremont, CA, we were able to examine his photoelectric observations in the *UBV* system near the time of maximum (Aug. 30 to Sept. 2). The color curves are in good agreement with Figure 6, showing maximum at $U - B = -0.03$ on August 31.2 and $B - V = +0.70$ on August 31.5, followed by a rapid drop to $U - B = -0.51$ and $B - V = +0.37$ on September 2.3. The V light curve tends to be systematically brighter by $\sim$0.1 mag than indicated by our data, with a maximum near $V_0 = 1.75$ on or about August 30.9.

We thank Mr. T. Montemayer and Dr. J. D. Mulholland for permission to reproduce their photographs of the nova.

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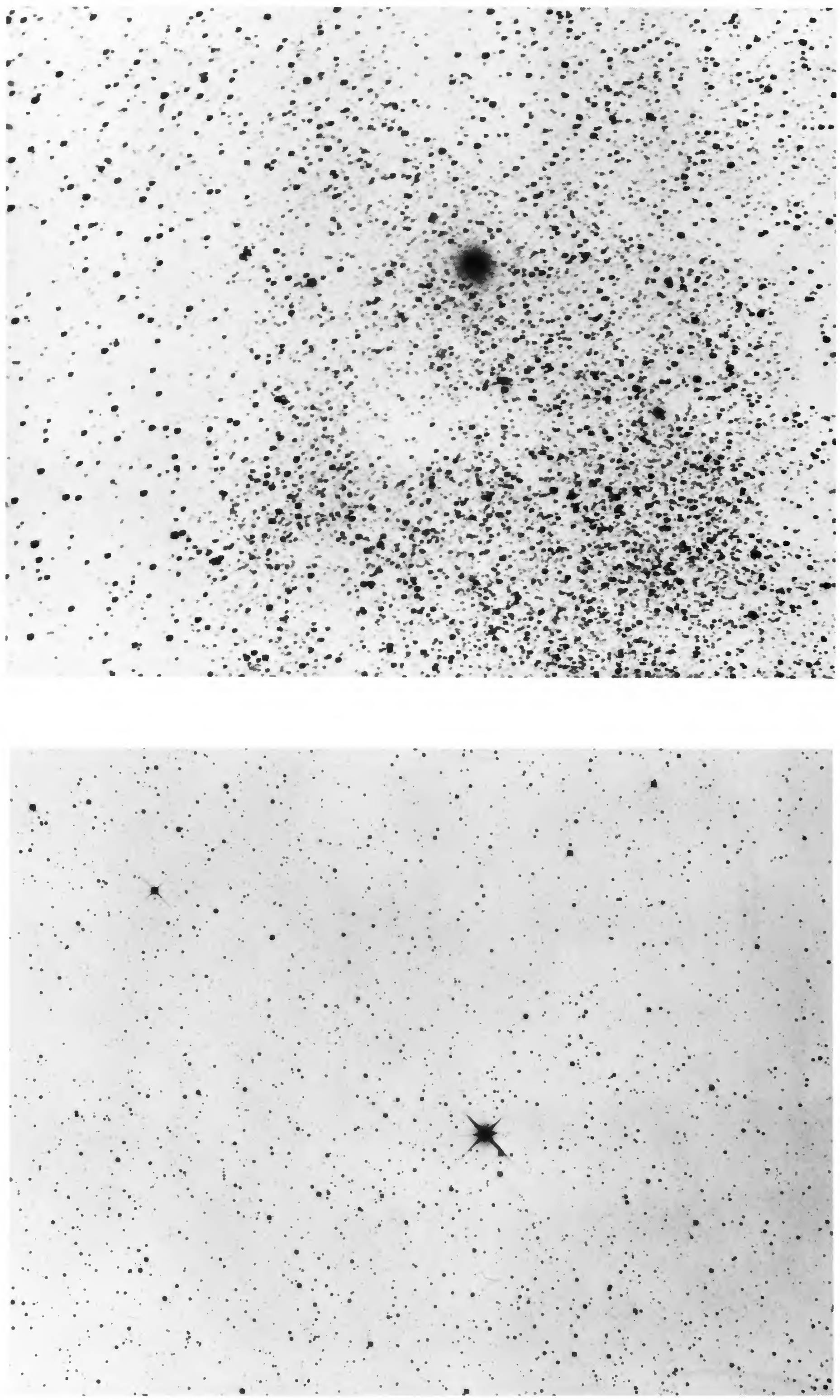

FIG. 1.—Field of Nova Cygni 1975. N at top, E to left. (*a*) *Above:* McDonald Observatory, 8 cm, f/8 patrol camera, 1975 Sept. 1, exp. 45 min, emulsion IIa-D, photograph by T. Montemayer. Field 3°.4 by 2°.8. (*b*) *Below:* McDonald Observatory, 204 cm Struve reflector, 1975 Oct. 8, Cassegrain focus, exp. 45 min, emulsion IIa-O, photograph by J. D. Mulholland. Field 17′.2 by 13′.6.

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