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Research Note

Five-colour Photometry of the Supernova in NGC 5253 (1972e)

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Summary. Five-colour observations (Walraven system) of the bright supernova in NGC 5253 (1972e) are presented. The period covered is nearly 300 days and the number of nights is 49. The light-curves show to be very smooth with a slight non-linearity in the U (3620 Å) curve after the end of the steep decline. A steep decline of about 30% in brightness in the L band (3850 Å) which lasts roughly 35 days starts 100 days after maximum. This can probably be attributed to the appearance of a strong absorption feature (Ca II?) visible in the spectral energy distributions measured by Kirshner *et al.* (1973). The $B-L$ curve shows before this decline a wavy pattern. The photometry presented here is compared with the *UBV* observations of Ardeberg and de Groot (1973, 1974) and with five-colour observations (also Walraven system) of the SN 1968 d in M 83 by Wamsteker (1972).

Key words: supernova – photometry

1. Introduction

On May 18, 1972 the Radcliffe Observatory in Pretoria (now S.A.A.O. in Sutherland) reported to our station that a bright supernova of the 8.5 mag had been discovered by Kowal (1972) in NGC 5253. Soon it was shown to be a type I supernova (Ardeberg and de Groot, 1972; Herbig, 1972). Since then a large number of paper appeared on this object. Many papers are listed by Ardeberg and de Groot (1973), who themselves presented the photometric (*UBV*) results from the first observing season obtained at the E.S.O. in Chile.

Other later papers are: by Jarrett and Eksteen (1973) and Jarrett (1973) presenting a light-curve in m_{pg}, by Lee *et al.* (1972) with *UBVRIJK* photometry, by Wamsteker *et al.* (1973a, b) describing photometry to 2.2 μ, by Osmer *et al.* (1972) giving *UBV* and spectroscopic observations, by Ciatti (1973) and McCarthy and Araya (1973) with a study of the infrared spectrum, by Kirshner *et al.* (1973) presenting spectrophotometry from 0.33 – 2.2 μ, by Holm *et al.* (1974) discussing the ultra-violet photometry made by the OAO-2, by Bolton *et al.* (1974) who obtained blue spectra and last Ardeberg and de Groot (1974) with *UBV* photometry from the second observing season.

2. Observations and Reductions

The observations were made with the Walraven five-colour simultaneous photometer, attached to the 90-cm lightcollector of the Leiden Southern Station in South-Africa during 46 nights from May 18 till September 9, 1972 and in 3 nights in early 1973. The effective wavelength of the five medium broad bands are roughly: 5500 Å(V), 4300 Å(B), 3850 Å(L), 3620 Å(U) and 3250 Å(W). A description of the photometer and the photometric system is given by Walraven (1960) and Rijf *et al.* (1969). The observations started on May 18 and further observing was done until the object disappeared in the bright evening sky. Then three observations were obtained in early 1973, when the supernova was very faint but still just visible through our telescope. At March 11, 1973 the visual brightness was 15.1 mag. At April, 24 there was no trace of the supernova so that because of lack of an offset star we could not do any measurement. As the primary comparison star we used CD-30° 10790, the same as Ardeberg and de Groot. To check its constancy a second star of the 12 mag was often measured together with the first one. The 1950 coordinates for the secondary are (see the finding chart given by Ardeberg and de Groot) $13^h 36^m 52^s$ and $-31° 22' 48''$. No trace of variability of the primary star was recorded.

Adaption into the Walraven system was made through comparison of the primary star with the Walraven standard stars during four occasions. The brightness and colours of these standards were redetermined by Pel in 1970 and 1971 (private communication). Table 1 shows the results with the uncertainty in the last decimal. As is the normal practice in the Walraven system the

Table 1. Photometric parameters of the primary comparison star CD-30° 10790

V	$V-B$	$B-L$	$B-U$	$U-W$	V_J	$(B-V)_J$	Ref.
−1.731	+0.209	+0.206	+0.294	+0.17	11.17	+0.50	This paper
					11.19	+0.54	Ardeberg and de Groot

Table 2. Brightness- and colour differences supernova minus primary comparison star (in log intensity)

J.D.-2440000	ΔV	$\Delta(V-B)$	$\Delta(B-L)$	$\Delta(B-U)$	$\Delta(U-W)$
1456.448	+0.981	−0.133	−0.061	−0.067	+0.35
1457.310	+0.965	−0.119	−0.061	−0.068	+0.34
1458.270	+0.944	−0.105	−0.072	−0.046	+0.39
1459.350	+0.919	−0.090	−0.057	−0.039	+0.37
1460.350	+0.901	−0.068	−0.064	−0.023	+0.34
1461.372	+0.867	−0.055	−0.061	−0.010	+0.36
1462.240	+0.838	−0.032	−0.062	+0.010	+0.40
1463.310	+0.822	0.000	−0.065	+0.009	+0.36
1470.284	+0.688	+0.177	−0.050	+0.017	+0.35
1471.313	+0.671	+0.191	−0.035	+0.028	+0.34
1472.339	+0.647	+0.205	−0.037	+0.021	+0.33
1473.295	+0.622	+0.211	−0.039	+0.034	+0.33
1474.233	+0.605	+0.233	−0.033	+0.018	+0.33
1476.242	+0.562	+0.251	−0.039	+0.017	+0.33
1477.242	+0.544	+0.252	−0.048	+0.049	+0.31
1478.226	+0.523	+0.260	−0.042	+0.026	+0.42
1479.241	+0.498	+0.257	−0.037	+0.030	+0.39
1480.223	+0.478	+0.269	−0.062	+0.009	+0.36
1481.279	+0.448	+0.248	−0.020	+0.030	+0.30
1482.243	+0.424	+0.252	−0.064	+0.006	+0.30
1485.354	+0.361	+0.244	−0.046	+0.020	+0.36
1486.242	+0.350	+0.239	−0.050	−0.002	+0.42
1487.249	+0.334	+0.227	−0.050	−0.018	+0.37
1488.279	+0.316	+0.222	−0.044	+0.004	+0.38
1489.235	+0.300	+0.230	−0.053	+0.014	+0.33
1490.242	+0.268	+0.208	−0.065	+0.018	+0.31
1492.303	+0.254	+0.214	−0.048	+0.032	+0.50
1498.240	+0.177	+0.179	−0.041	0.000	+0.38
1499.295	+0.174	+0.174	−0.042	+0.010	+0.62
1500.240	+0.164	+0.177	−0.028	+0.021	+0.36
1501.228	+0.148	+0.159	−0.038	+0.030	+0.35
1503.243	+0.122	+0.158	−0.077	+0.005	+0.36
1507.226	+0.087	+0.145	−0.005	+0.011	+0.45
1508.232	+0.067	+0.140	−0.022	+0.016	+0.30
1509.312	+0.070	+0.143	−0.042	−0.006	+0.27
1511.283	+0.051	+0.139	−0.025	−0.001	+0.27
1512.326	+0.031	+0.130	−0.028	+0.020	+0.28
1515.247	+0.012	+0.106	−0.009	+0.018	+0.48
1516.246	−0.007	+0.123	−0.008	+0.031	+0.30
1518.251	−0.034	+0.111	−0.006	+0.007	+0.35
1533.233	−0.186	+0.064	−0.033	+0.042	+0.34
1538.226	−0.222	+0.063	−0.054	+0.021	+0.36
1541.241	−0.269	+0.042	−0.023	+0.049	+0.64
1550.252	−0.335	+0.037	+0.003	+0.061	
1564.228	−0.442	+0.006	+0.163	+0.025	+0.65
1567.226	−0.467	−0.002	+0.197	+0.084	+0.02
1698.538	−1.302	−0.011	+0.280	−0.006	+0.30
1724.500	−1.486	−0.022	+0.78		
1753.417	−1.575	+0.007	+0.50	−0.05	−0.31

brightness and colours are expressed in terms of logarithm of the intensity rather than magnitudes. However to make a comparison with the UBV system possible, we also show the V magnitude and $B-V$ colour in this system (V_J and $(B-V)_J$ respectively). The transformation of the Walraven V into V_J has been made with the aid of the formula:

$$V_J = 6.88 - 2.5[V + 0.08(V-B)]$$

(Walraven, private communication). $V-B$ has been transformed into $(B-V)_J$ with the aid of Table 7 in Walraven *et al.* (1964). The results of Ardeberg and

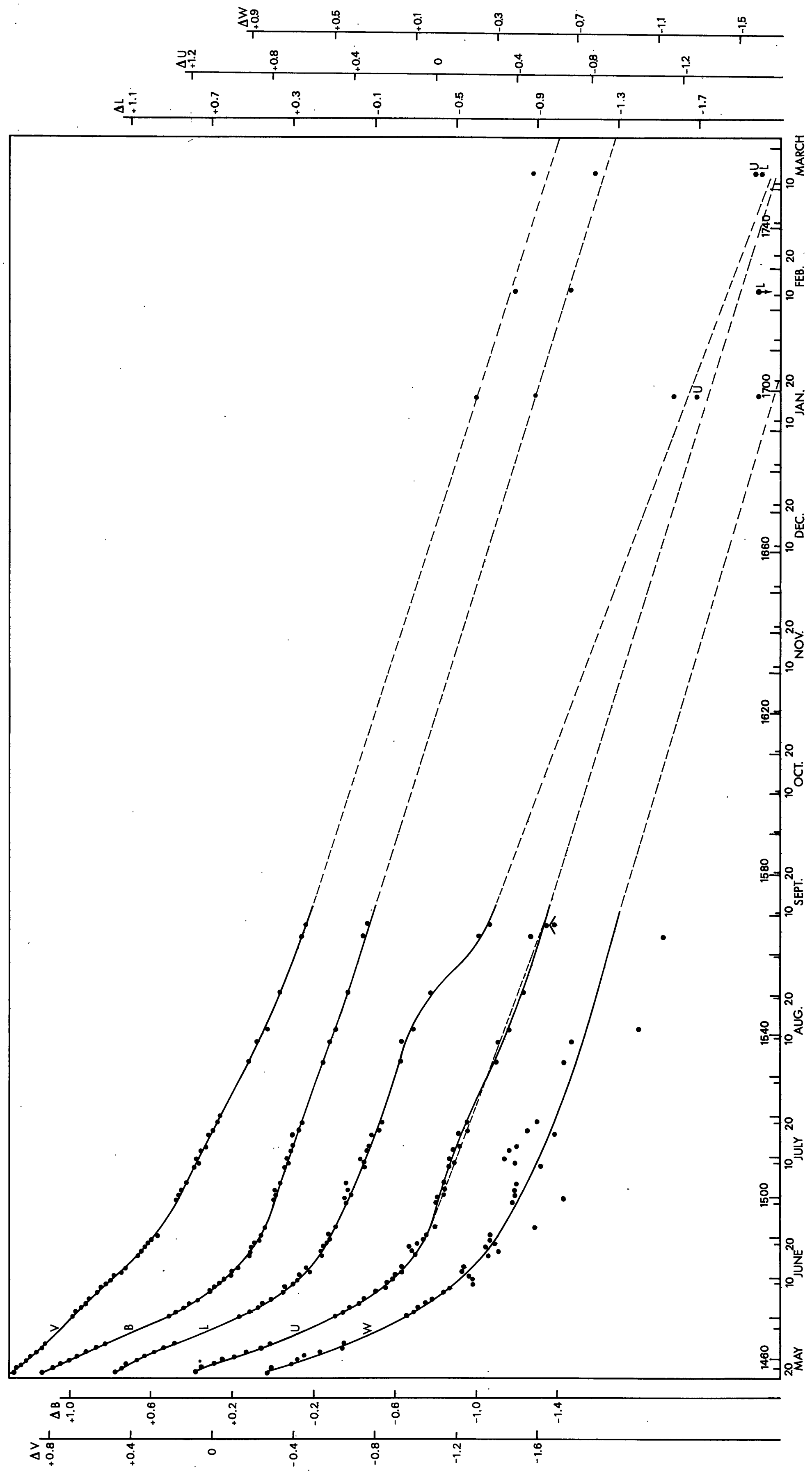

Fig. 1. Brightness differences SN-comparison star in the five passbands (in log intensity) plotted versus JD-2440000 and the calendar date in 1972 and 1973

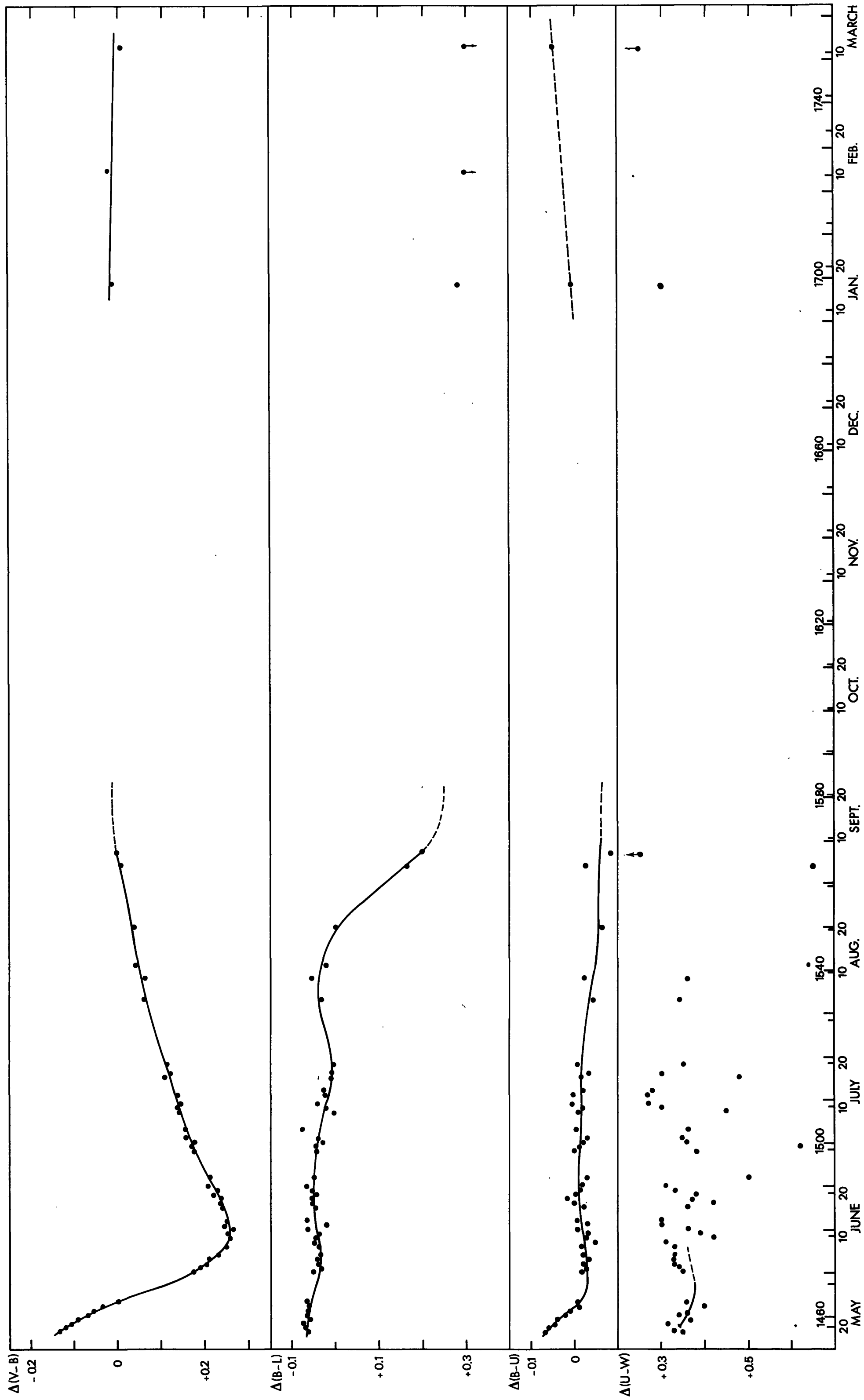

Fig. 2. The colour indices plotted versus JD-2440000 and the calendar date in 1972 and 1973

de Groot are also listed. Because of the very special energy distribution it is difficult to estimate the inaccuracy of the transformed V_J and $(B-V)_J$ values. Probably it amounts to a few hundredths of a mag.

Usually the supernova was measured two or three times alternated by the primary comparison star, only in the first nights long runs were made to detect possible short time scale variations. Because of unfavourable sky conditions this failed and we only give in Table 2 the average brightness- and colour differences supernova minus comparison star. The sky brightness was always measured 45″ E of the supernova. The diaphragm used is 20″ in diameter. When the supernova was bright the integration time per measurement was $\frac{1}{2}$ min, which gradually became 3 min when it was very faint. Correction for differential extinction has been applied. The standard deviations of the averages in Table 2, range for V roughly from 0.005 in the beginning till 0.03 at the end (or in magnitudes from 0.012 to 0.075), in the colours $V-B$, $B-L$ and $B-U$ from 0.007 to 0.05 and in $U-W$ from 0.04 to 0.1.

3. Discussion of the Light- and Colour-curves

Figures 1 and 2 show the brightness and colour difference supernova minus comparison star in log intensity scale. In Fig. 2 blue is at top (this is contrary to the custom in supernova literature). The general behaviour of our curves are in many respects equal to those of Ardeberg and de Groot, so that we shall limit us to details, which are more obvious here because of a better coverage by observations and by narrower passbands. Remarkable is the very smooth and after the first steep drop the linear decline of the V, B and U curves, which seems to be continued till early 1973. The non linear trend in the B_J curve as claimed by Ardeberg and de Groot is not very clear in the B curve of Fig. 1, rather it is obvious in the U curve (compare with the dotted straight line), and probably also in the W curve, but there the scatter is large. The reddest transformed value of the $V-B$ curve viz. $(B-V)_J=+1.07$ (equal to that of Ardeberg and de Groot) falls at JD … 1479. This is 41 days after the estimated epoch of maximum brightness by both authors viz. JD…1438. It does not agree well with Pskovskii's (1970) analytical curves and Barbon's *et al.* (1974) composite $(B-V)_J$ curves, which rather indicate an interval of 30–35 days.

The sudden drop in the L intensity by about 30% after JD…1540 can be also traced in the U_J band (which also includes the Walraven L band) of Ardeberg and de Groot, but is absent at the other wavelengths.

Apparently it is due to a very important spectral feature, only present near 3850 Å. The duration of the decline is about 35 days. An inspection of the spectral energy distribution by Kirshner *et al.* (1973, Fig. 7) showed that between JD … 1507 and … 1684 a very strong absorption feature appeared near 3850 Å, which coincides just with the L band. Probably it is this absorption line, perhaps of the blue shifted Ca II (Pskovskii, 1969; Mustel′, 1971, see also Branch and Patchett, 1973), which causes the quick decline at JD … 1540, 100 days after the maximum. It could well be that this phenomenon can be used as a clear mark for the start of Oke and Searle's (1974) Phase D of the spectral evolution of type I supernovae. It would be very interesting to see whether the appearance of this Ca II (?) line in future supernovae comes always at the same epoch. This can be a contribution to our knowledge of the processes which are active in the expanding shell. Also remarkable is the smooth wavy pattern in the $B-L$ curve before the step drop.

4. The Colour-Colour Diagrams

Figures 3 and 4 show the $V-B/B-L$ and $V-B/B-U$ diagrams in which we plotted the paths of the supernova corrected for interstellar reddening. We adopted $E_{(B-V)_J}=0.25$ (Ardeberg and de Groot) or $E_{V-B}=0.1$. The other indices are then corrected with $E_{B-L}=0.42\,E_{V-B}$, $E_{B-U}=0.63\,E_{V-B}$ (Walraven, quoted by Oosterhoff and Walraven, 1966). The numbers in the diagrams give the sequential order of the points read off from the colour curves at five days intervals, except

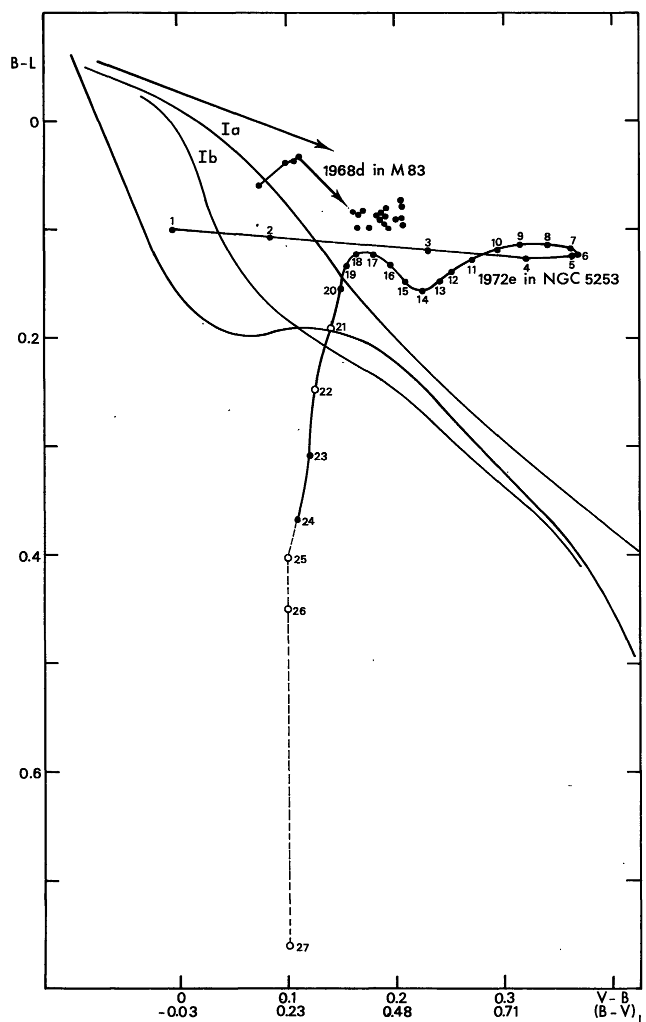

Fig. 3. The path (corrected for reddening in the $V-B/B-L$ diagram showing the readings from the colour curves at regular time intervals numbered sequentially. Also shown are the unreddened observations of the SN 1968d in M 83 by Wamsteker (1972). The horizontal axis also indicates the $(B-V)_J$ of the UBV system

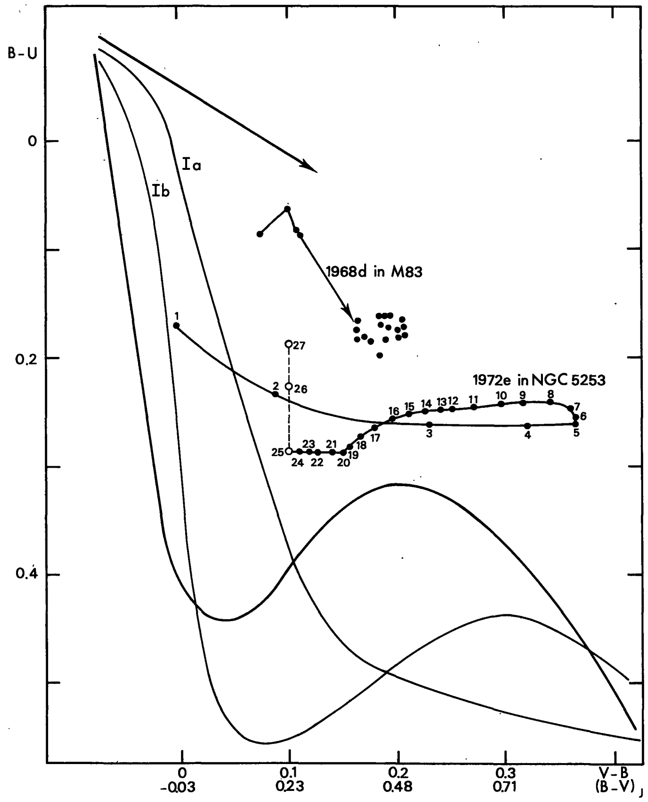

Fig. 4. The same as Fig. 3 but now in the $V-B/B-U$ diagram

at the minimum of the $V-B$ curve, where the intervals are shorter (Nos. 5–7) and at those parts of the curves representing the 1973 observations (Nos. 26 and 27). Uncertain points have been represented by circles and uncertain paths are dashed. Further the main sequence (thick curve) and the relations for Ia and Ib supergiants (thin lines) and the reddening line (long arrow). Also plotted are the unreddened observations of the supernova 1968d in M 83 made in the same photometric system by Wamsteker (1972) covering a period of 62 days. Wood and Andrews (1974) consider this one as of Type II. Wamsteker considered the existence of synchroton radiation causing the observed emission. Also Lee *et al.* (1972) made this suggestion which was based on their *UBVRIJK* photometry indicating that a continued infrared flux existed after the decay of the optical flux.

In the $V-B/B-U$ diagram, both supernovae paths stay in the neighbourhood of the black body relation and starts and ends not far from the supergiant relations. The rapid drop in the $V-B/B-L$ diagram at about 100 days is presumably due to the effect of the strong absorption line mentioned above. It is a pity that no comparison can be made with the further evolution of Wamsteker's supernova.

In the $V-B/U-W$ diagram, which is not shown because of the large scatter, the path runs somewhere at $U-W=+0.47$ for our supernova. This position is just below the relation for the Ia supergiants of type *F* and *G* (Walraven, 1966, Fig. 9) and for Wamsteker's supernova the mean $U-W=+0.31$, which is in between the Ia and Ib relations. Holm's *et al.* (1974) initial ultraviolet colours of the supernova in NGC 5253 also resembled that of an *F* supergiant.

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