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PHOTOELECTRIC INTERMEDIATE BAND PHOTOMETRY OF SN 1993J

SN 1993J has been the brightest supernova in the northern hemisphere for the last decades. It has been monitored photometrically mainly by broad band photometry using CCD-images. As a result, mostly $BVRI$ measurements were obtained, omitting information on the U-colour.

Deviating from this general line we have decided to carry out a 6 filter photoelectric photometry, both to include information on the near ultraviolet and on other filters in the visual domain to be compared to the broad band colours.

The filter set comprises the Stroemgren filters u (352.6 nm, HW 16.0 nm), v (410.1 nm, HW 21.4 nm), b (467.0 nm, HW 19.5 nm), y (547.3 nm, HW 18.8 nm) and two additional filters with central wavelengths between b and y, i.e. $g1$ (501.7 nm, HW 12 nm) and $g2$ (521 nm, HW 12 nm). The latter two filters have been described by Maitzen and Floquet (1981).

The measurements have been carried out at the 1m telescope of the Purgathofer Observatory (Klosterneuburg nr. Vienna) by one of us (RP). A novel type of photoelectric photometer has been used: it contains a rapidly rotating filter wheel, but with fast stop (=filter measurement, in our case 60 milliseconds) and go (20ms) motion. The photomultiplier (EMI 6256B) was operated at 1170 V and Peltier-cooled. A more detailed description of this photometer can be found in Pressberger and Stoll (1993).

Due to the proximity of urban light (mostly from Vienna which, however, fortunately is minimized in our case since it is situated to the SE, while SN 1993J was in the NW direction) the sky contribution had to be reduced as far as possible employing a *very small diaphragm* (6.6 arc seconds). Although such a small size is prohibitive for bright star and millimag precision work, it is useful in our case also for reducing the galaxy background of M81. The very good tracking and frequent monitoring of centering enabled us to reach an acceptable precision close to the Poisson limit.

As *comparison star* the nearby star 'B' = GSC 4383.0928 was used. Its proximity renders all differential extinction corrections negligible. Stroemgren indices were derived tying this star to the bright stars HD 87141, HD 87243 and HD 90508 observed on Jan. 18, 1994 at nearly the same airmasses. This way we obtain:

$V = 11.91$, $b-y = 0.335$, $m1 = 0.157$ and $c1 = 0.300$. The corresponding mean errors are 0.030, 0.014, 0.015 and 0.019 mags, respectively. Following the study of Oblak et al. (1976) these colours indicate an F7V type star with zero reddening. From Relyea and Kurucz (1978) we quote log $g = 4.2$ for these indices in perfect accord with the foregoing luminosity class.

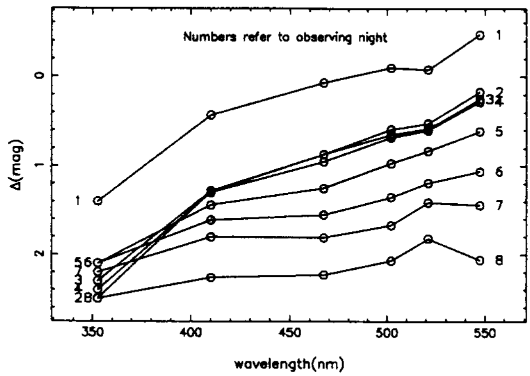

Figure 1. SN 1993J - GSC 4383.0928

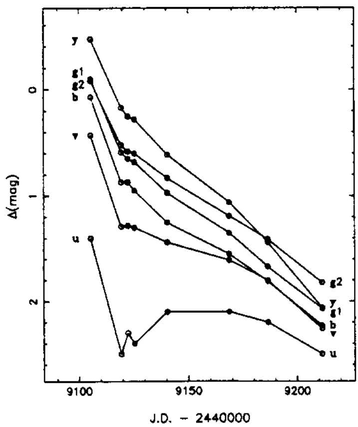

Figure 2. Light curves SN 1993J - GSC 4383.0928

Table 1. Differential 6-colour photometry of SN 1993J

No.	JD-2440000	Date (1993)	Δu	Δv	Δb	$\Delta g1$	$\Delta g2$	Δy	V
1	9105.39	Apr 27.89	1.4	0.43	0.07	-0.10	-0.08	-0.47	11.44
2	9119.41	May 11.91	2.5	1.29	0.87	0.59	0.52	0.17	12.08
3	9122.41	May 14.91	2.3	1.28	0.87	0.65	0.58	0.25	12.16
4	9125.39	May 17.89	2.4	1.30	0.95	0.68	0.60	0.28	12.19
5	9140.39	Jun 01.89	2.1	1.44	1.25	0.97	0.83	0.61	12.52
6	9168.43	Jun 29.93	2.1	1.61	1.55	1.35	1.19	1.06	12.97
7	9186.43	Jul 17.93	2.2	1.80	1.81	1.67	1.41	1.44	13.35
8	9211.40	Aug 11.90	2.5	2.26	2.23	2.07	1.82	2.06	13.97

The *differential observations* were carried out on 8 nights spanning the interval Apr. 27 to Aug. 11, 1993. SN, star 'B' and sky alternated 2 - 3 times on each night, one measurement set per object consisting of 5 integrations after each of which recentering in the diaphragm was done. One such integration typically comprised 200 filter wheel rotations yielding 12 seconds total measuring time for each filter.

The *average precision* for the nightly magnitude differences is 0.02 mag, except for u which should be accurate to 0.1 mag. In Table 1 we list the results of the 8 observing nights. Partially, they have been previously published by us in the IAU circulars (Pressberger and Maitzen, 1993).

In Fig. 1 we display the *differential flux distributions* with wavelength. Inspection of this picture immediately reveals the blueing of the optical flux during the interval covered, most of which is dominated by the exponential brightness decrease due to radioactive decay of Co^{56}.

Although with the rather small bandwidth of the filters of our system local spectral features are expected to considerably influence the picture, we notice only one band where this effectively takes place, i.e. $g2$ which changes from a flux deficient band to a flux excess domain. Since the changes in this band are large compared to the adjacent filters y and $g1$ (about 40%), comparison with spectrophotometry would be useful. A certain similarity may be recognized in the case of the ultraslow nova PU Vul which also showed a strong flux excess in the $g2$ band after entering the general emission line phase (Maitzen, Pavlovski, 1994).

Fig. 2 contains the *lightcurves* in 6 colours. The steepest decrease in all filters occurs between nights 1 and 2 ranging from 0.078 in u to 0.046 mags per day in y. Then until night 6 the slope characterizing the exponential decrease is distinctly smaller, strongest in y (0.018 mags per day), weakest in v (0.008 mags per day), whereas in u the brightness even increases to reach a maximum during June. In broad band U Wheeler (1993) also noticed an increase of brightness from May 23-26 until June 8-11 by 0.07 mags. A similar maximum in satellite UV is visible in the IUE observations (Kirshner, 1990) of SN 1987A. The nature of the agent producing the third maximum has not been cleared up. While Kirshner (1990) proposes decreasing UV opacity in the SN atmosphere, Wheeler et al. (1993) assume a "buried source of constant luminosity in addition to the radioactive decay".

From June 29th on there is a general trend to level off from the straight line, probably caused by the beginning of transparency for γ rays. It just occurs at the time predicted by Prugniel and Rau (1993) based on their assessment that the rate of evolution in SN 1993J is generally a factor of 4 faster than in SN 1987A.

Although they did not measure SN 1993J in U their prediction of factor 4 also applies to the duration of the "third" maximum if we compare our u-curve with Kirshner's (1990) IUE curve for the region 300-320 nm. The deviating behaviour of $g2$ has been introduced already in the discussion of Fig. 1. Our decline rates during the exponential phase match very well with B and V results: e.g. Prugniel and Rau (1993) derive 0.009 and 0.018 mags per day, respectively.

In *conclusion* we may state that our photometry :

a) establishes similarity of 1993J and 1987A ultraviolet (roughly 300-350 nm) light curve behaviour concerning the existence of a third maximum,
b) confirms the factor 4 in evolution speed also with respect to the duration of this maximum,
c) verifies the factor 4 concerning the onset of γ ray transparency,
d) exhibits decline rates for the violet to yellow filters which are in very good accord with published B and V results, except
e) the behaviour in the $g2$-filter showing a 40% increase in flux relative to the mean value of the adjacent filters $g1$ and y during the observing period, and
f) demonstrates a general blueing of the flux distribution.

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References:

Kirshner, R. P.: 1990, in: *Supernovae,* ed. A. G. Petschek, Springer-Verlag, New York et al., p. 59.
Maitzen, H. M., Floquet, M.: 1981, *AA*, **100**, 3.
Maitzen, H. M., Pavlovski, K.: 1994, in preparation.
Oblak, E., Considére, S., Chareton, M.: 1976, *AAS* 24, 69.
Pressberger, R., Maitzen, H. M.: 1993, *IAUC,* Nos. 5816, 5822, 5832.
Pressberger, R., Stoll, M.: 1993, *Proc. IAU Coll.*, No. 136 (Poster Papers on Stellar Photometry), eds. I. Elliot and C. J. Butler, Dublin Instit. Adv. Stud., p. 86.
Prugniel, P., Rau, G.: 1993, *Lettre OHP*, No.11, 6.
Relyea, L. J., Kurucz, R. L.: 1978, *ApJS*, **37**, 45.
Wheeler, J. C.: 1993, *IAUC,* No. 5817.
Wheeler, J. C., Barker, E., Benjamin, R., Boisseau, J., Clocchiatti, A., de Vaucouleurs, G., Gaffney, N., Harkness, R. P., Khokhlov, A. M., Lester, D. F., Smith, B. J., Smith, V. V., Tomkin, J.: 1993, *ApJ*, **417**, L71.