SPECTROSCOPIC AND PHOTOMETRIC OBSERVATIONS OF SN1987a OBTAINED AT SAAO

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Introduction

The dedication of at least 24 local and visiting observers has enabled the SAAO to accumulate a large body of spectroscopic and photometric observations of SN1987a. Broad band photometry has been obtained on every possible photometric night while spectra at 7A(FWHM), including the first spectrum in the world, were obtained every night for the first 14 nights and thereafter on a weekly basis. These data, which have been more fully presented elsewhere (Menzies et al. 1987, Catchpole et al. 1987) are briefly discussed here for the time interval 24 February until 31 August 1987. Throughout this paper we adopt a distance modulus of 18.5 and a reddening of Av=0.6 for SN1987a.

Spectroscopy

All spectra were obtained with the Grating Spectrograph attached to the Cassegrain focus of the 1.9-m telescope at Sutherland. These spectra, covering the wavelength range 3400 to 7600 A, have been first converted to relative fluxes using spectrophotometric standards and then to absolute fluxes by comparison with simultaneous broad band V photometry. Representative spectra are shown in Fig. 1 where the time in days since the Kamiokande-II neutrino event is shown at the top right of each spectrum. The first spectrum, obtained on day 1.6 shows a very blue continuum with broad blue-shifted hydrogen absorption lines and He I 5876A. Over the next 5 days the velocity of Hα decreased from 18500 km s^{-1} at the rate of 789 km s^{-1} day^{-1}. By day 8 SN1987a had completed its initial rapid fading, the photospheric temperature had declined from an initial 14000K to 6000K, Hα had developed a P Cygni profile and many other absorption lines had appeared. This is well illustrated in the remaining spectra which also show the sudden rapid decline in brightness shortward of 4200A undoubtedly due to line blanketing. The strength of Hα emission steadily increases with time as does [Ca II] at 7300A which first appeared on about day 70.

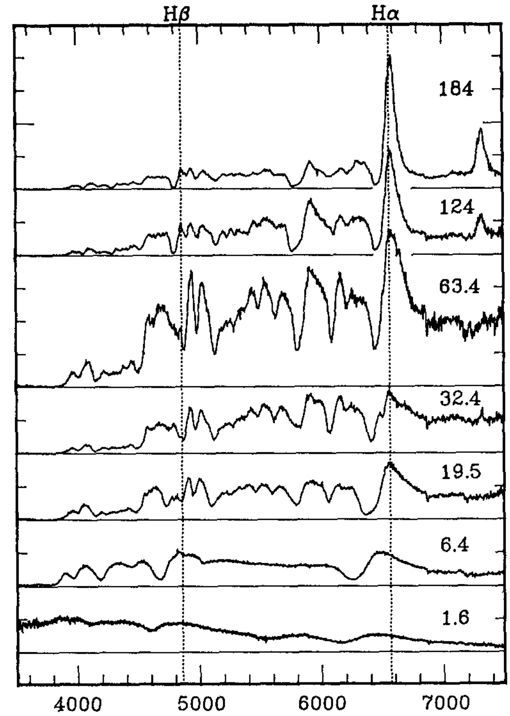

Figure 1. Spectra of SN1987a on a relative flux scale. The numbers indicate days since the Kamiokande-II neutrino event.

Photometry

$UBV(RI)_C JHKL$ photometry has been obtained on 109 of the 184 days discussed in this paper. Details of the observations and the reduction are given in Menzies et al. 1987 and Catchpole et al. 1987. However it is important to draw attention to one aspect of the reduction method. The observations obtained on the telescope natural system are transformed to the Johnson UBV and Cousins RI photometric systems using colour equations defined for normal stars. It is important to realise that although this method will produce a self-consistant body of data it will be systematically different from that produced at another observatory, unless the two natural systems are identical. This happens because the supernova spectrum differs considerably from those of the stars which define the colour transformations. Care should therefore be taken when combining data from different observatories, especially when looking for subtle changes of slope and claims that one observatory is closer to the Johnson and Cousins systems than another should be treated with great caution. This problem is not so serious when working with narrow band photometric systems where data should be published on the natural system along with the wavelength sensitivity curves.

One of the most useful data that can be obtained from the photometry for comparison with theory is the variation of the bolometric flux with time. SN1987a provides an ideal opportunity to make this comparison because we know the distance to the LMC with an uncertainty of about 10% based on independent distance indicators, the reddening is well constrained by observations of the progenitor and we have broad band photometry covering the region in which after day 3 more than 95% of the flux is emitted. We have used two methods to determine the bolometric flux. The first method fits a blackbody, which has the advantage of providing the parameters, temperature and radius while the second method is to integrate under a spline curve which by definition passes through all the points. The end points of the spline curve are taken at $F_\nu=0$ at $\nu=0$ and $F_\nu=0$ at the frequency at which a line through F_U and F_B intersects the frequency axis. Examples of blackbody and spline fits to the data are shown in Fig. 2 for three representative days. Day 8 is the time of the first bolometric minimum, day 86 is at bolometric maximum while day 163 occurs during the radioactive decline and is a day on which the M magnitude was also measured. The variation of the bolometric flux with time given by the two methods is shown in Fig. 3 for two values of the reddening. In Fig. 3 the data points have been suppressed for the sake of clarity and the curves are made up of chords joining individual data points.

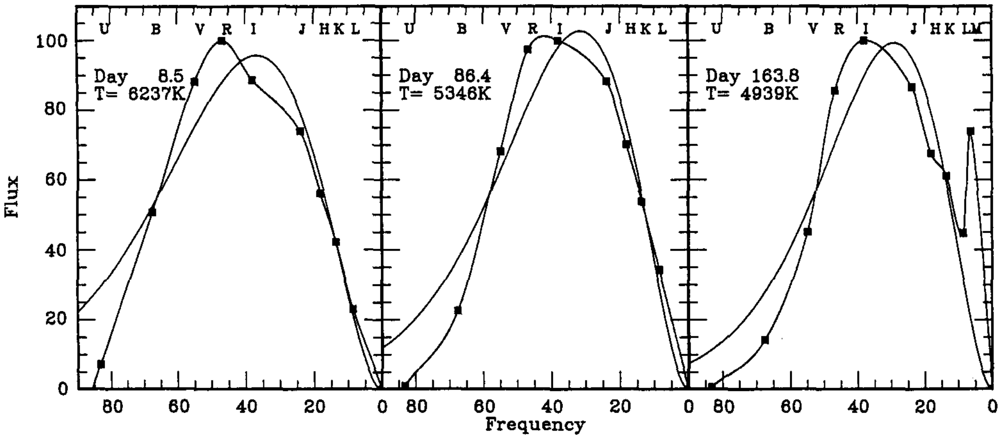

Figure 2. Normalized broad-band fluxes, corrected for $A_V=0.6$ and joined by spline curves, are shown for three representative days. The best fitting blackbody is also shown. An M measurement made on day 163 is illustrated but was not included in the determination of the bolometric flux curves shown in Fig. 3.

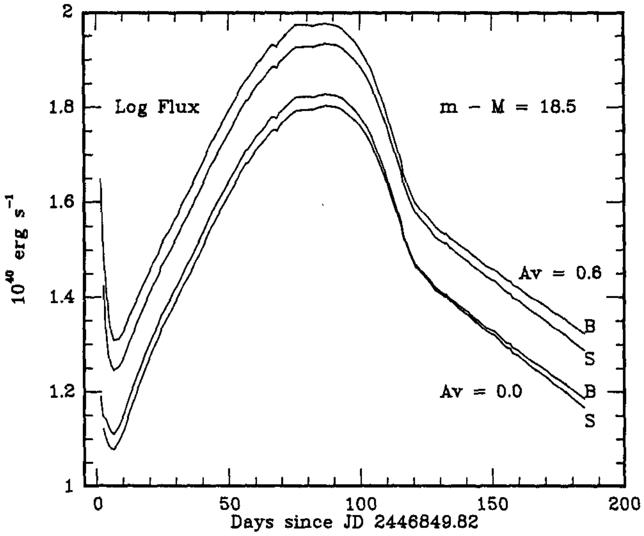

Figure 3. The logarithm of the bolometric flux given by blackbody (B) and spline (S) fitting is shown as a function of time for 2 values of A_V.

The maximum difference between the blackbody and the spline method is always less than 12%. However it is important to note that the slope on the radioactive decline part of the flux curve depends on the method of integration. Direct comparison between the bolometric flux curves and models is given elsewhere in these proceedings.

The variation of the temperature and radius deduced from the blackbody fitting is shown as a function of time in Fig. 4. Both the radius and the temperature curves show a marked change of slope at day 5. The slope of the angular radius curve has been interpreted as an indicator of the density gradient in the atmosphere by Branch (1987). On day 5 the density gradient changes from $R^{-11.7}$ to R^{-5} on his model. None of the models so far presented for the explosion predicts this change, which may correspond to the passage of the photosphere through the hydrogen shell. A second change of slope is seen in the temperature curve at about day 32.

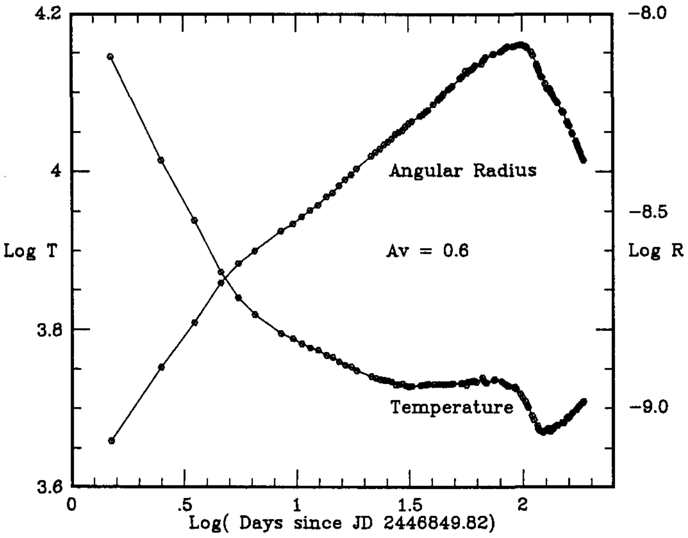

Figure 4. Logarithm of radius and temperature given by blackbody fitting are shown as a function of log time.

Infrared M band (4.8 micron) Photometry

We have obtained a number of 4.8 micron observations which are combined with those kindly obtained by J Albinson and R Maddison and are illustrated in Fig. 5. Until day 60 (L-M) remained constant while M increased in lock step with the increase in brightness of SN1987a. As the bolometric flux of the supernova has declined the M flux has remained constant while (L-M) has increased so that SN1987a now shows a significant excess at M. The effect of the M excess on the bolometric flux is at present small. On day 163, which is illustrated in Fig. 2, the effect of including M in the spline integration is to increase the flux by 4% while the effect on the blackbody integration is to increase the flux by only 0.4%. There is however a correspondingly greater change in the derived temperature and radius.

At present we are making observations in an attempt to distinguish between the possibilities of a light echo, a dust excess or possible CO emission.

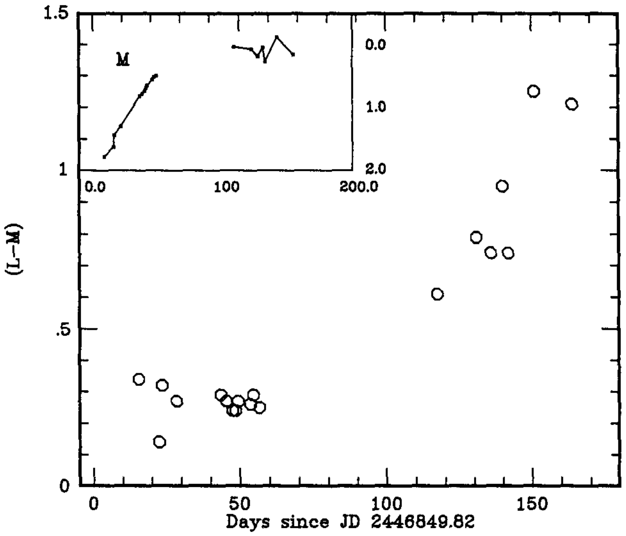

Figure 5. Variation of (L-M) and (inset) M as a function of time.

References

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Menzies, J.W., et al., 1987. Mon. Not. Roy. astr. Soc. **227**, 39p.