The Spectrum of Supernova 1987A

In the early phase of a supernova, the dense atmosphere of the progenitor star is blasted off with a high velocity. This surface radiates like a "black-body" and, as such emits a continuous spectrum which is essentially independent of the chemical composition and whose energy distribution is determined solely by its temperature: the light is radiated by charged particles as they scatter off one another.

As the "atmosphere" grows in size, the range of depths from which the photons can escape increases and the chemical composition becomes important in determining the opacity of the gas at different wavelengths. This is when spectral lines start to become apparent. But still, and indeed for a long time after maximum light, most of the energy is radiated as an approximately black-body continuum with a temperature – at least in type II supernovae, which are supposed to be hydrogen rich – corresponding to the layer where the hydrogen becomes fully ionized. The lines just impose a modulation on this underlying continuum. The outer part of the atmosphere, well above the continuum emitting surface, will radiate emission lines while that part between the surface and us will absorb the same lines. Since the atmosphere is expanding, the absorbing part will have the greatest component of velocity towards us and so will produce "blue-shifted" lines. Such an emission/absorption structure is known as a "P-Cygni" profile after the prototype Be star with an expanding atmosphere. Measurements of the positions (in wavelength), strengths and shapes of such profiles provide astronomers with the means to study the composition and the velocity evolution of the expanding shell.

The first optical spectra of SN 1987A obtained at ESO on the night of 24–25 February show very weak spectral features and an overall energy distribution which corresponds to that of a hot star. Over the next two days, strong, broad spectral features began to appear and by 27 February (Fig. 1a), strong P-Cygni lines are seen which correspond primarily to the Balmer series of hydrogen. The shift of the H-alpha absorption trough with respect to the rest wavelength corresponds to a velocity of over 17,000 km/s when the first measurements were made. The spectrum now appears to be evolving in the sense that the overall energy distribution is becoming redder (a cooling of the continuum emitting "photosphere") and the velocity shifts of the P-Cygni absorption components are slowly decreasing. The lines are also becoming stronger as the volume of the emitting gas increases and the temperature of the absorbing column decreases (Fig. 1b). There are other, more subtle, changes as broad spectral features appear and fade as the ionization conditions in the atmosphere change. Because they are so broad,

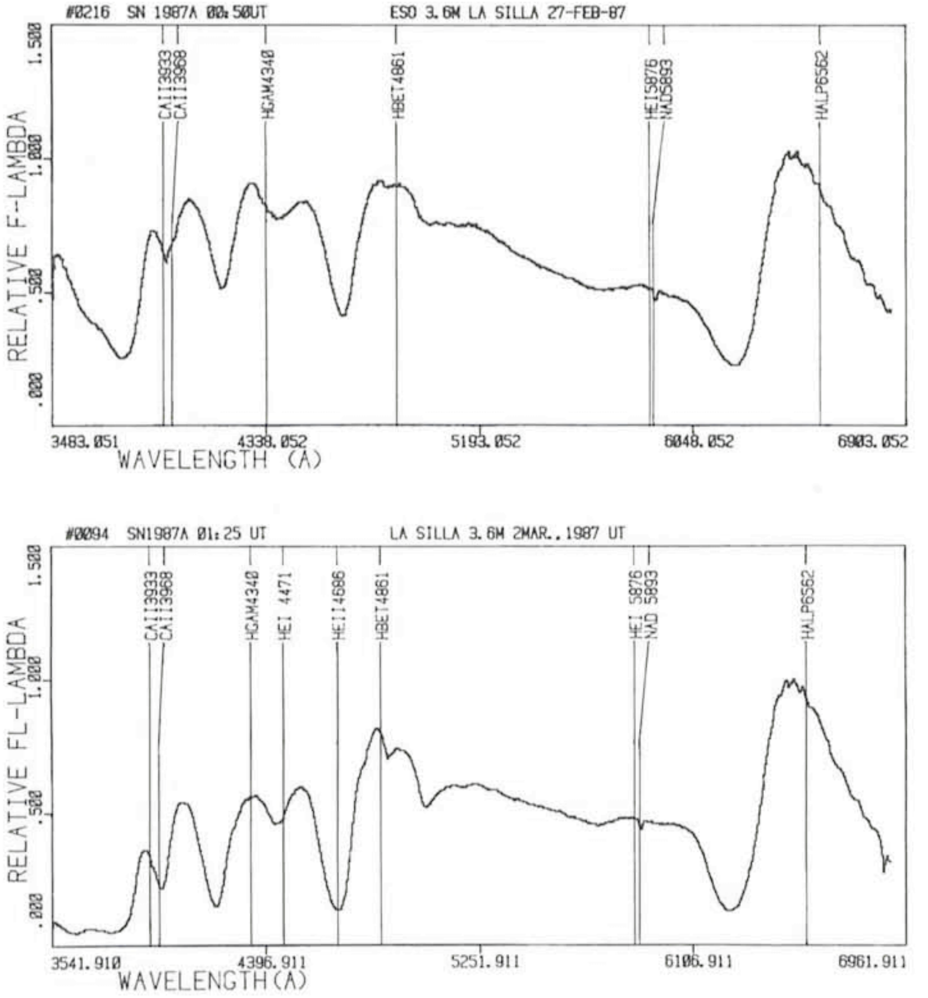


Figure 1: *Spectra of 1987A, obtained by J. Danziger and R. Fosbury at the ESO 3.6-m telescope with the Boller and Chivens spectrograph. The upper spectrum (a) was obtained on February 27.05, four days after the explosion and already shows the strong P Cyg profiles mentioned in the text. The lower spectrum (b), although qualitatively similar, displays important changes in the amplitude and also in the velocities of the main features.*

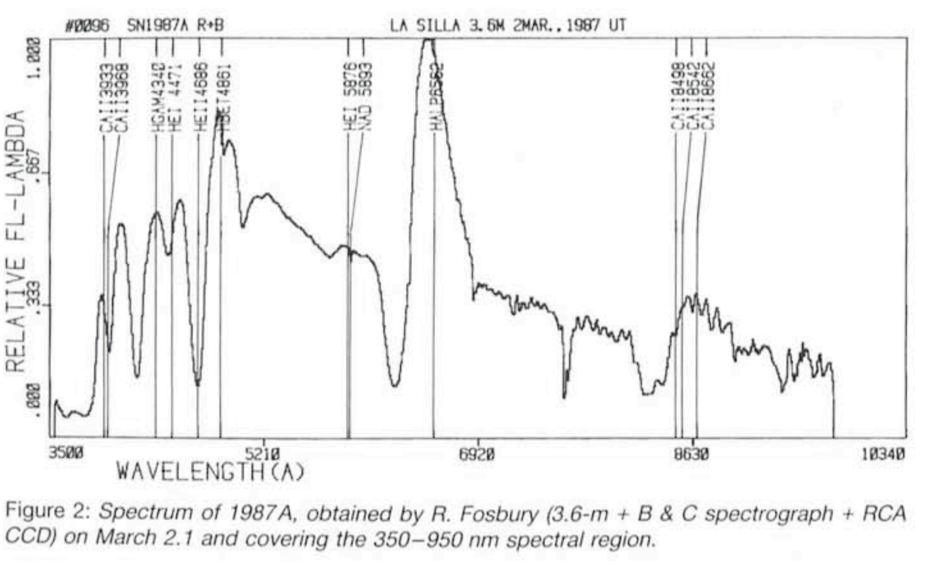


Figure 2: *Spectrum of 1987A, obtained by R. Fosbury (3.6-m + B & C spectrograph + RCA CCD) on March 2.1 and covering the 350–950 nm spectral region.*

these features are notoriously difficult to attribute to different chemical elements but it appears likely that the strongest of them can be identified with singly ionized calcium and iron. When the optical and infrared data are combined, the temperature of the "black-body" continuum is readily measured; it was 5900 K on the night of 1–2 March (see the plot of the infrared – optical photometry). The fact that this temperature was higher in the initial phase was good news for the IUE for which the supernova now provides a greatly weakened source.

Another aspect of the spectroscopy which is causing great excitement is the possibility such a bright object in the LMC provides for the study of the interstellar/intergalactic medium between us and the supernova. Sight lines outside our own Galaxy have been studied before, using as background sources bright stars in the Magellanic Clouds and much more distant Quasars and Seyfert galaxies. These, however, are very faint objects and the opportunity presented by a naked eye supernova has already resulted in a Bonanza of results from the very high resolution spectrograph (CAT/CES) at ESO (see contribution by Andreani, Ferlet and Vidal-Madjar). *R. Fosbury (ST-ECF)*

High-resolution Spectroscopy of 1987A

Observations at the 1.5-m CAT telescope with the Coudé Echelle Spectrograph and the Reticon Detector at resolution 100,000 (3 km/sec) have led to the identification of the following eleven intervening main structures in the direction of the supernova: 7–22 km/s (heliocentric), strong Na I, Ca II, K I; 38 km/s, weak Ca II; 55–63 km/s, strong Ca II, weak Na I; 70–74 km/s, same; 121–127 km/s, strong Ca II; 160–169 km/s, same; 206–218 km/s, strong Ca II and Na I; 248–253 km/s, weak Ca II and Na I; 264–269 km/s, same; 278–283 km/s, strong Ca II, Na I, K I; 293 km/s, weak Ca II. Many of these main structures are resolved into two or three nearby components. In particular, the 7–22 km/s structure clearly shows three distinct components.

In addition to the identification of a large number of intervening clouds, these observations establish with certainty that supernova 1987A is situated in the Large Magellanic Cloud, since no absorption lines are seen with velocities higher than that of the LMC.

P. Andreani, R. Ferlet and R. Vidal-Madjar (IAP, Paris)

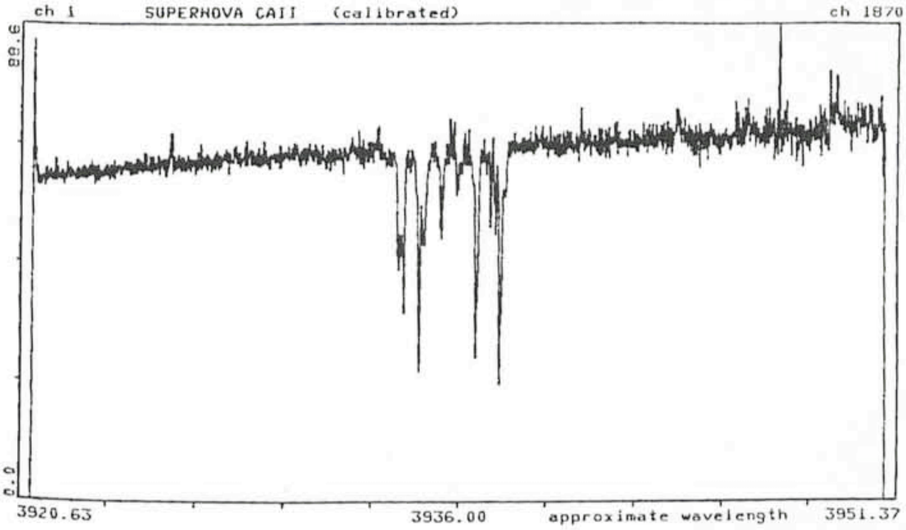


Figure 1: *The spectrum of 1987A, around the Ca II (K) line at 393.3 nm, as obtained on February 25.05, with the CAT + CES + Reticon detector at resolution 100,000. The exposure time was 1,200 sec. This figure shows the main absorption structures only; up to 22 absorption lines from interstellar and intergalactic clouds were detected.*

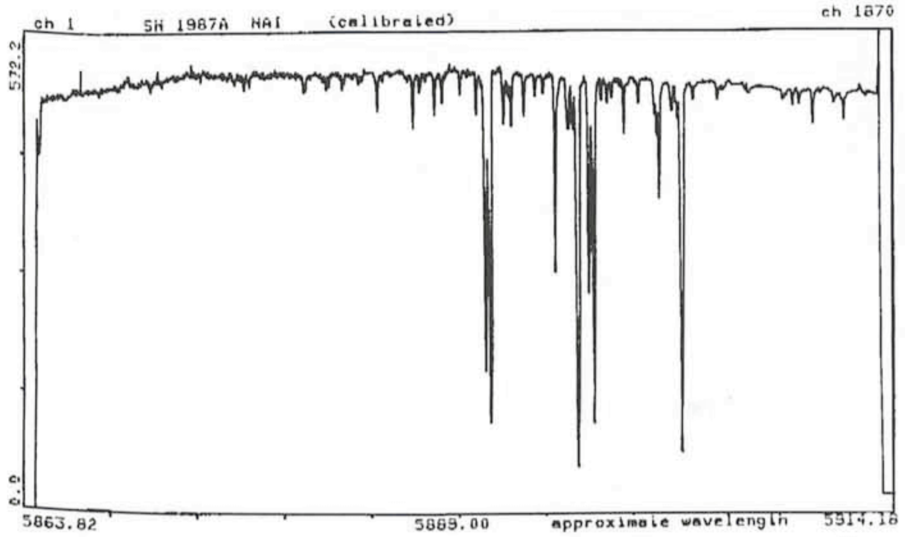
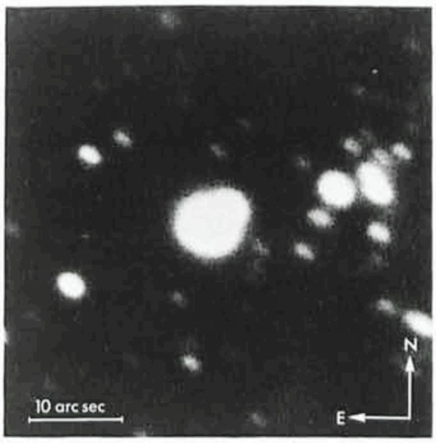


Figure 2: *A spectrum taken by G. Vladilo on February 28 with the CAT + CES + Reticon detector, around the Na I doublet at 589 nm. The strongest lines correspond to absorption in the Galaxy and in the LMC.*



This red photo (098-04 + RG 630, 60 min) of Sanduleak –69202, *the suspected progenitor of supernova 1987A, was obtained with the ESO 3.6-m telescope on December 6, 1979. The star has at least two companions; one of them is clearly seen here (as a prominent bulge) to the northwest at a distance of only 2.6 arcseconds. It is not the progenitor, since its position does not coincide with that of the supernova. A third star lies about 1 arcsecond southeast of Sanduleak –69202, but it cannot be seen on this photo. The stellar images are very close to the edge of the plate and are somewhat elongated, due to less than optimal optical adjustment.*