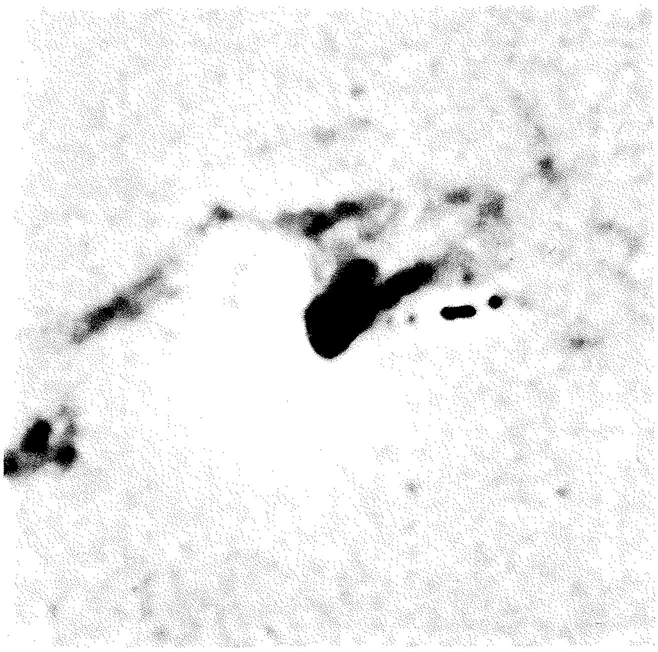

Figure 1.

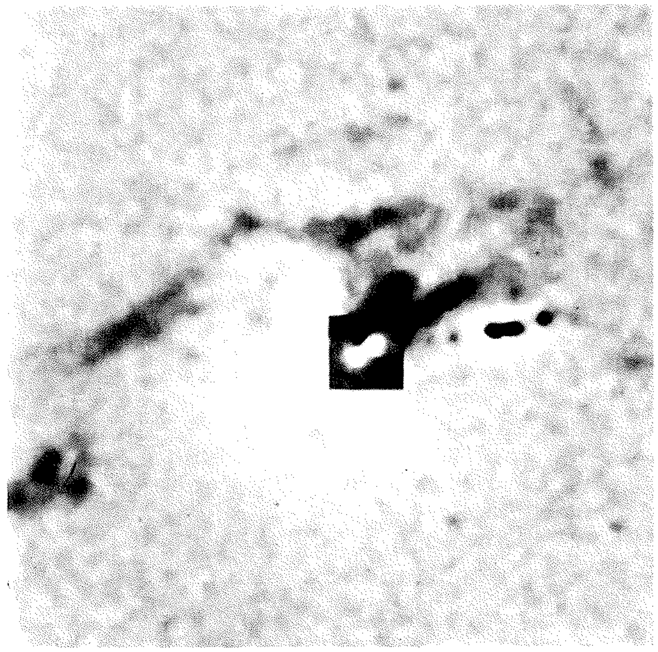

Figure 2.

substructure in the [O III] emission. This is also clearly seen in the case of M87 (see Fig. 2) except that the circumnuclear [O III] is aligned with the H_α + [N II] jet and not the well-known radio jet! How and if these features are related is currently unclear but may be associated with shock excitation and acceleration of the emission line region clouds by the radio jets, or, some mechanism for particle beaming of ionizing radiation along the radio ejection axis (see e.g. Wilson et al., 1988).

During the next observing season for M87 by which time the field rotator should be fully functional, it is planned to extend these observations, under much more favourable conditions as well as imaging in the other known emission lines, notably [O I] and H_β. These better signal-to-noise images from longer exposures will hopefully lead to a better understanding of what is really happening at the centre of M87.

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NTT Images of SN 1987A

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The fine optical quality of the NTT telescope, together with the good dome design and excellent La Silla site permit routine observing in conditions of subarcsec seeing. We have used the NTT and an RCA CCD on August 27, 1989 UT to obtain new direct images of SN 1987A. These images have a sampling of 0.26 arcsec per 30 μm CCD pixel and are described below.

Figure 1a–b reproduces two images taken through narrow band interference filters, one centred on [O III] and the other in the neighbouring continuum at λ 5118 Å. Gaussian fits to the star images in the CCD frames showed that the seeing disks are slightly less than 0.5 arsec full width at half maximum (FWHM).

With such good imaging it is possible to explore the circum-supernova environment in detail. It has been known for some time that the supernova is surrounded by a small nebula that was initially excited by a UV flash which accompanied the supernova explosion. Evidence for the nebula was first seen in IUE spectra taken several months after the explosion (Wamsteker et al., 1987; Fransson et al., 1989). Later, narrow optical lines from the nebula appeared in spectra obtained in Dec. 1987 (Wampler and Richichi, 1989). Crotts et al. (1989) have given results of images taken in late 1988 and early 1989 with seeing of 0.68–0.84 arcsec FWHM. On April 1 of this year, an ESO image of the nebula around SN 1987A was obtained in seeing conditions of 0.85 arcsec. That ESO data were published in an earlier *Messenger* article (D'Odorico and Baade, 1989).

Despite the fact that the airmass for our observations was nearly two, the seeing conditions for the narrow-band images shown here are better than any reported to date for SN 1987A. In addition to the better seeing, the continuing decline in the brightness of the supernova reduces the contamination of faint, nearby features by scattered supernova light. Thus, these data show the nebulosity near the supernova with unprecedented clarity. Ghost reflections in the equipment are not a problem since field star images are sharp, with no evidence of halos or extraneous images.

It is clear from Figure 1 that there is extended nebulosity in a "C" shaped arc running from 2 arcsec north of the supernova, through the east to about 2 arcsec south of the Supernova. The nebula is well marked in [O III] light and is also faintly seen in the λ 5118 Å continuum exposure. The knotty structure of this nebula was noticed in April 1989 by D'Odorico and Baade (1989) although they could not rule out its being an artefact of the extensive deconvolu-

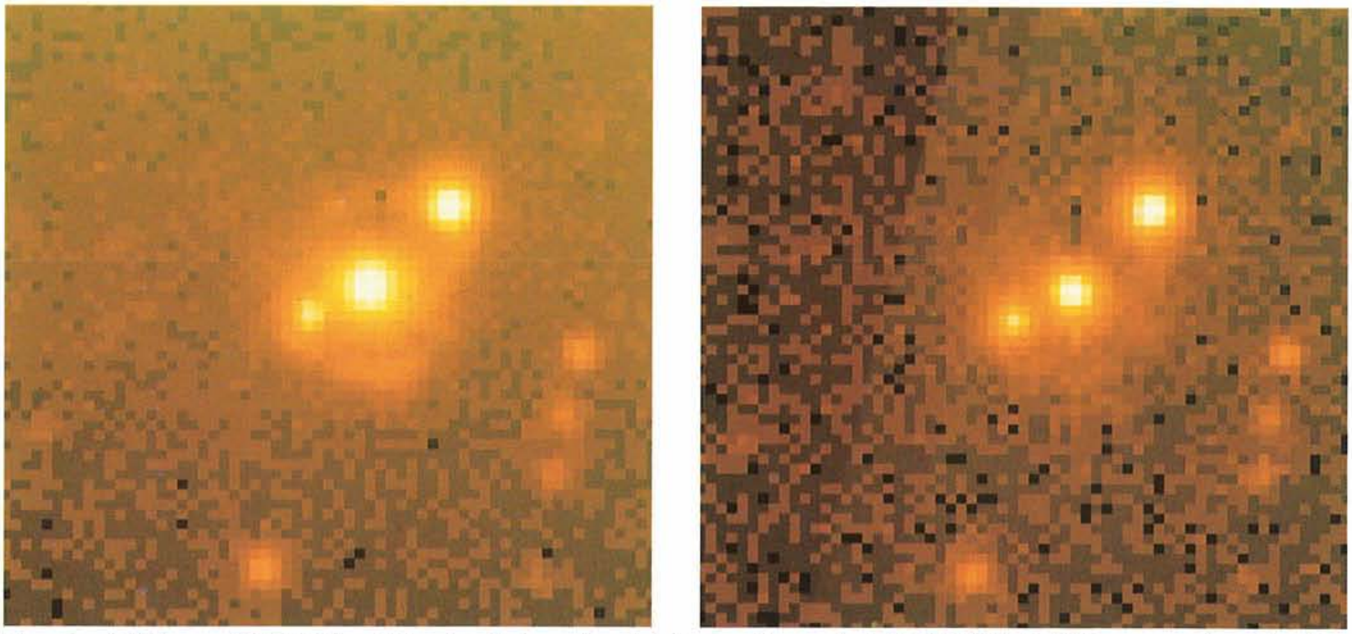

Figure 1 ***a:*** *(left) Image of SN 1987A neighbourhood taken with an interference filter centred at λ 5007 Å.* ***b:*** *(right) the same region with a filter centred at λ 5118 Å. For both pictures north is up and east is left. The supernova is the bright image located between two stars in the centre of the picture.*

tion applied to their (lower-resolution) data. The nebula was clearly detected by Crotts et al. (1989), and is attributed by them to a light echo from a dust sheet located behind the supernova.

This interpretation may not be correct, since our images show that the distribution of [O III] light is about the same as the distribution of continuum light. If the light echo explanation is correct, very rapid recombination of O^{++} would be required for the emission line light distribution to track the continuum light echo. Furthermore, the differences seen when comparing the Crotts et al. (1989) data with the NTT images do not confirm the general expansion that would be predicted by their light echo model; the morphology of the arcs near star 2 (the brighter, NW star) reveal little, if any, change between March and August 1989. By contrast, 2 arcsec to the south of the supernova a new patch has appeared (which is even brighter than any of its northern counterparts). The observations of D'Odorico and Baade (1989) further support these conclusions. A comparison between line and continuum images suggests that the outer nebula is a mixture of gas and dust. Clearly, light travel delays in the nebula must influence the appearance of the structures, but the observed changes indicate that the geometry is more complicated than the simple model given by Crotts et al. (1989).

Within the outer nebula, and approximately centred on the supernova, is a bright, smooth, oval nebula with radii of about 1.3 arcsec E-W and 0.9 arcsec N-S. The E-W elongation of the central part of the O[III] nebula was earlier noted by D'Odorico and Baade (1989). The elongation of the circumstellar nebula shows that the progenitor red supergiant wind was not symmetrical. Figure 2 gives two views of perspective plots of the raw images in continuum and [O III] light. It can be seen that, when compared to the continuum exposure,

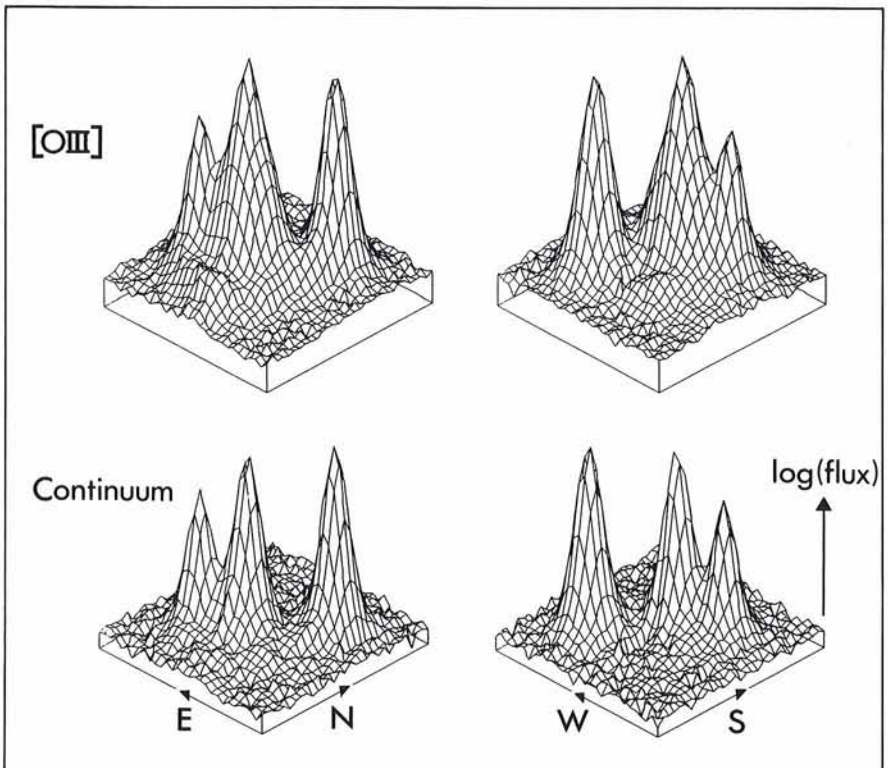

Figure 2: *Three-dimensional views of the images shown in Figure 1. For both the [O III] and continuum images two views, 180° apart, are shown. Note that the intensity is plotted on a logarithmic (magnitude) scale in order to show faint, outlying features. The upper plot is in [O III] light and shows excess emission around the (central) supernova image. The two outlying star images show little change between the upper [O III] plot and the lower continuum plot. Thus there was little change in the seeing during the 7 minutes that separated these two short exposures.*

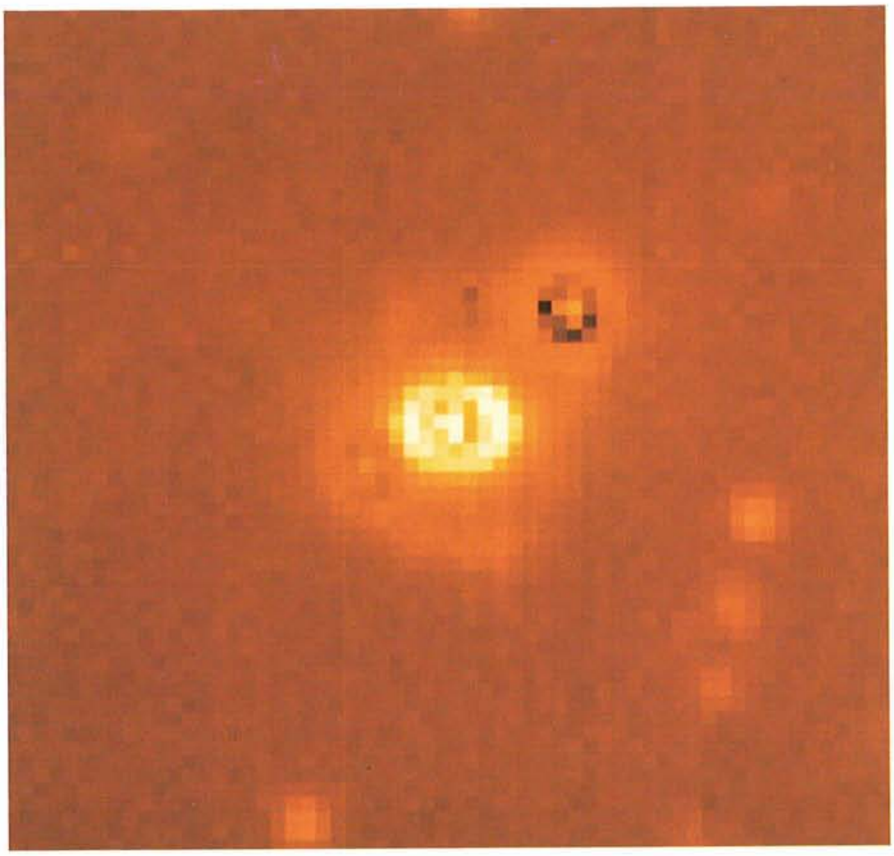

Figure 3: *The nebulosity around SN 1987A after model star images, centred on the real stars, were subtracted from the frame. Because the Gaussian profiles used to model the star images only approximately match the real stellar profiles, rather large residuals remain.*

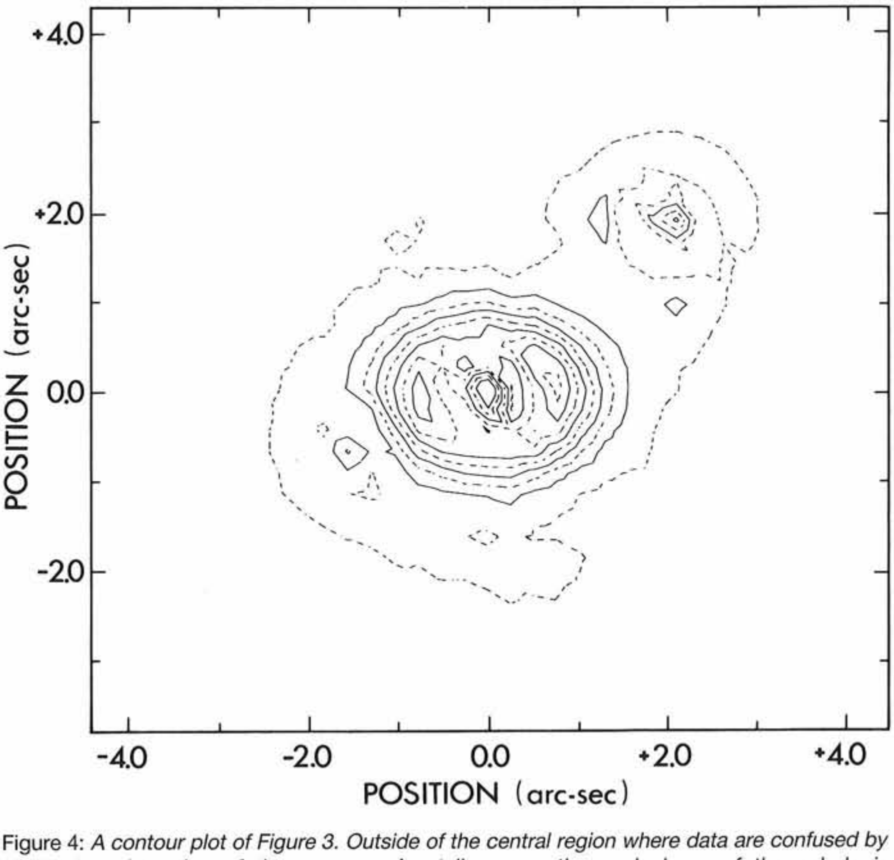

Figure 4: *A contour plot of Figure 3. Outside of the central region where data are confused by uncertain subtraction of the supernova's stellar core, the oval shape of the nebula is maintained over several contours.*

the [O III] exposure shows excess emission in the region around the supernova. Gaussian image profiles, adjusted to the field stars, were used to crudely remove the contribution of the supernova core and the two field stars from the image of the nebula. Figure 3 shows the results of this simple cleaning procedure. Figure 4 gives a contour plot of Figure 3. The amount of "supernova core" that was subtracted is arbitrary. In the future, more sophisticated models of the seeing images and a more careful scaling of the supernova core, using continuum information from slit spectra, will allow better separation of the nebula from the star images.

If the outer parts of the expanding supernova envelope are moving at 0.1 c, that gas would subtend 0.5 arcsec at the present time. When the expanding supernova envelope gas begins to interact with the circumstellar material one might expect that NTT images taken of the supernova in conditions of excellent seeing would show a bright, new nebula appearing in the core region. The pixel size of the CCD used for these observations is too large for good sampling of very small images, but a camera with a different scale should be capable of detecting the nebula.

The first indication of an interaction between the supernova envelope and the surrounding nebula could be a sudden increase in X-ray emission from the region since the collision of the rapidly expanding envelope with circumstellar gas will generate a strong X-ray flux. The NTT images will be important, since they will show if the expanding supernova envelope is also asymmetrical and how its asymmetry relates to that of the circumstellar cloud. Early polarization measurements in the I band (Schwarz 1987) indicate intrinsic polarization with a position angle near 0°.

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