*2.2 The [N II] doublet*

On our IDS spectra, we could measure the [N II] doublet for 267 nebulae. We found: I (658.3)/I (654.8) = 2.92 ± 0.32, comparable to the theoretical value of 2.95. On figure 3a, we show the observed intensities corrected of the interstellar reddening and of the "Rosa effect". The average behaviour of the I (658)/I (655) line ratio versus the I (655) value is comparable to the correlation found for the [O III] lines shown on Figure 1a, but it appears that the "Rosa-correction" has perhaps not to be applied here.

The measure of the [N II] doublet is affected by the proximity of the Hα line, implying for all [N II] doublets the use of the "Multiple-Gaussian-Fit" procedure of the IHAP programme. The deconvolution of the (Hα, [N II]) blend becomes measurable if I (Hα)/I(655) > 0.2, as shown by the Figure 3b. On this figure, the value of the [N II] lines ratio decreases with an increasing ratio R = I (Hα/I (655): if R < 1, the intensity of the 655 line seems underestimated. If 1 < R < 4, the I (658)/I (655) ratio is near to the theoretical value of 2.95. For higher values of the [N II] lines, saturation would decrease the observed line ratio. This effect is clearly visible for the strongest lines (Figure 3c).

The number of CCD spectra measured up to now is not sufficient to allow any conclusion concerning the [N II] lines ratio.

## 3. Conclusions

From the analysis of our IDS and CCD spectra of planetary nebulae, we have shown that a nonlinearity proposed for the IDS receptors cannot be made responsible for the apparent discrepancy between the observed [O III] line ratio and the predicted one expected to lie around 2.9. It seems possible that the true intensity ratio of these forbidden lines is likely to be around 3.0 – as proposed by Rosa (1985). Further observational and theoretical work is needed.

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# EFOSC Observations of the Inner Echo Around SN 1987 A


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Time varying light echoes around bright supernovae have been known since their first detailed observation in 1901–1902 by Ritchey, Kapteyn and Perrine around Nova Persei 1901 (GK Per) and the first comprehensive theoretical model put forth by Couderc in 1939.

In this framework, they are understood as due to the delayed reflection (echo) of the supernova light pulse from nearby interstellar or circumstellar dust clouds. The temporal variability, of course, is a consequence of the sweeping action of the pulse through an anisotropic and inhomogeneous reflecting medium.

The recent SN 1987A has not disappointed observers of this phenomenon due to its relative vicinity and complexity of the surrounding material. The overriding scientific importance of the detailed study of the SN light echoes resides in their ability to shed light on its past evolutionary history (the SN in search of its past as it has been aptly put recently) by progressively illuminating the circumstellar region into which objects as massive as the SN 1987A progenitor are expected to deposit a very significant fraction (up to 1/2) of its mass. The two key observational as-

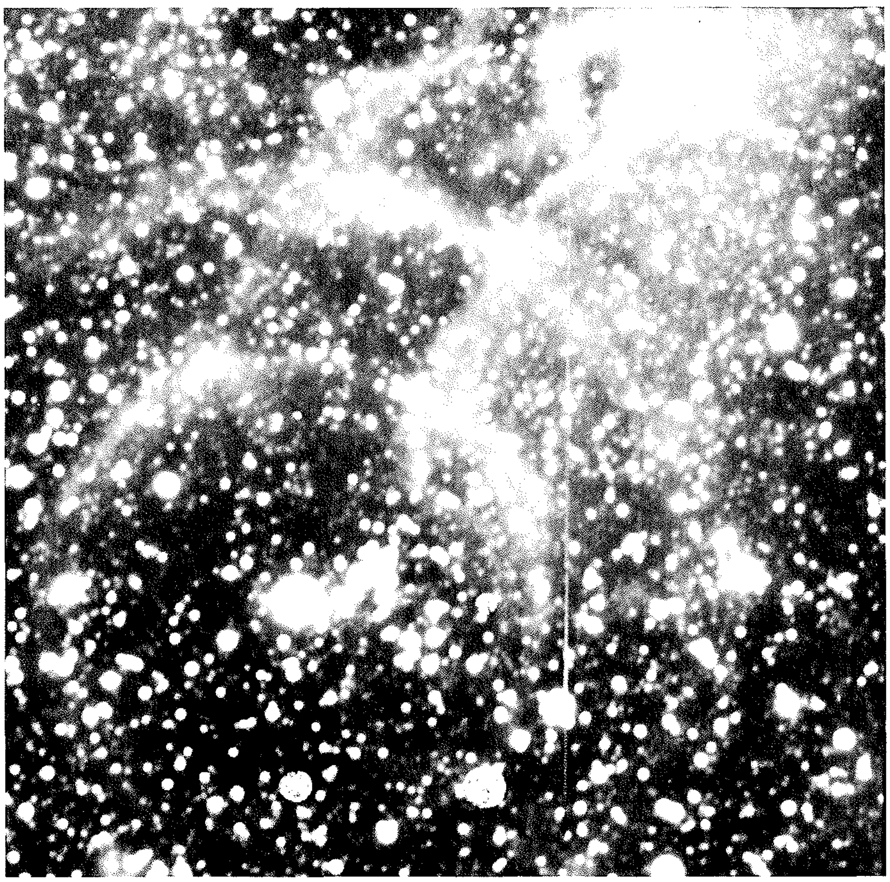

Figure 1.

pects of this endeavour are the ability to image very faint features next to relatively bright objects and continuous monitoring to capture the complex temporal variations of the phenomenon.

The most dramatic echoes around SN 1987A are those first announced by Crotts in 1988 and now located at approximately 500 and 1250 light-years from the SN (see *The Messenger,* **52,** p. 13, and **54,** p. 28) these are understood to be due to sheets of intervening interstellar gas and dust completely unrelated to the SN itself and, thus, of limited significance to the issue of SN evolution. As the SN fades, however, it becomes easier to discern faint features located in the immediate vicinity of the SN, but until September 1988 nothing within 10″–20″ of the star could be measured even under intense and very sensitive scrutiny (see *The Messenger,* **55,** p. 49).

This situation changed suddenly when Crotts and Kunkel and Bond, Panagia, Gilmozzi and Meakes both reported evidence of the appearance of an inner echo at 8″–10″ from SN 1987A in October 1988 and January 1989. Because of the inherent faintness of the ring against the glare of the SN and the clutter of the crowded star field nearby, its reality had to be tempered with some caution.

To better establish not merely its existence but, more importantly, its physical association with the SN, we used a slightly different approach to the problem. On February 10, 1989 we used the EFOSC operating in the coronographic mode on the 3.6-m telescope with a broad-band V filter and four linear polarizers oriented at position angles 0°, 45°, 90° and 135° to measure not only the total but also the polarized flux of radiation scattered from circumstellar material around SN 1987A. We clearly detected a faint arc of V-band emission with a sharp inner and outer boundary centred on the supernova and of radius 8.″3 and width ≈2.″5 most prominent in the Eastern quadrant between 45° and 135° position angle. Its azimuthally averaged surface brightness in this position angle range is 21.8 ± 0.2 V mag arcsec$^{-2}$. In this particular region, the detected radiation is found to be partially linearly polarized with a degree of polarization 0.15 ± 0.04 and an electric vector orientation of ≃0° position angle.

The accompanying image (Fig. 1) taken with our set-up at La Silla shows the direct 1-minute V band exposure taken during our February run. The field of view is 2.′9 × 2.′9; North up and East to the left with a linear intensity scale from 250 adu (black) to 450 adu (white). The SN is the bright source at the centre of the well-known outer two interstellar ring echoes. The SN lies behind the 3″ diameter coronographic spot (the other spots in the field are barely visible as noisy circular regions forming a square pattern with the SN). The inner echo can be seen as the faint circular feature surrounding the SN with a sharp outer rim in the East at ≃10″ radius. For a distance of 52.5 kpc, 1 arcsec in this image corresponds to ≃0.8 light-year.

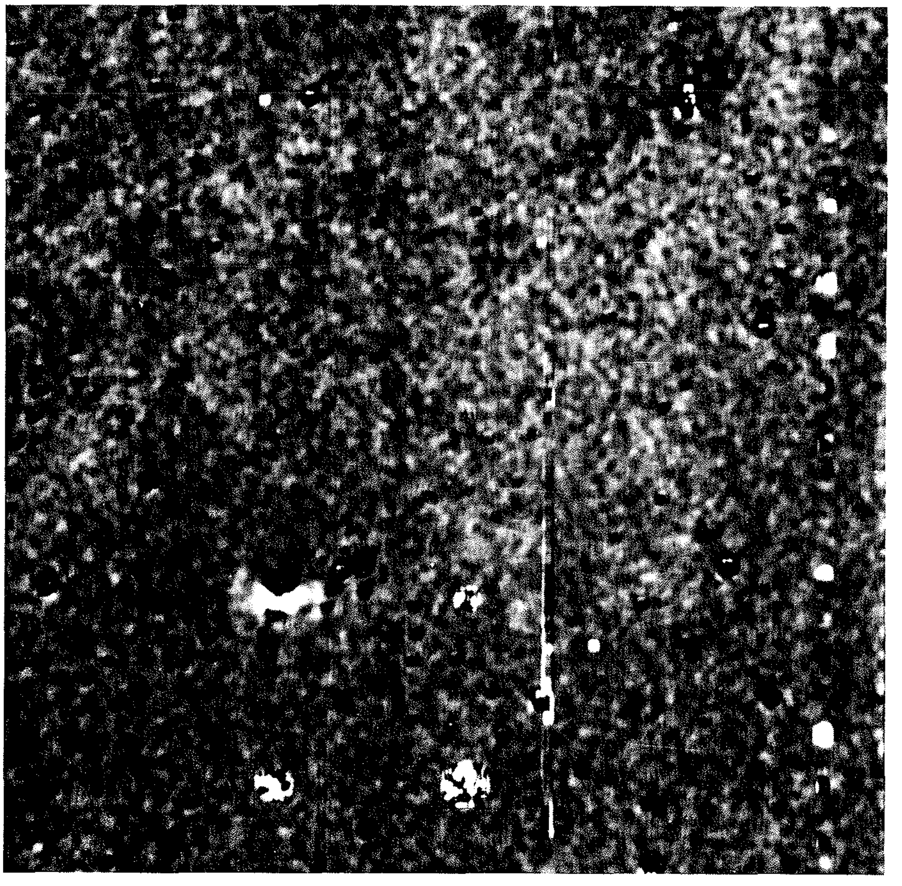

Figure 2.

A peculiarity of this inner echo in contrast to the outer ones is its marked spatial asymmetry. This characteristic is quite obvious in the polarized flux and especially in the Q Stokes parameter image shown in the accompanying Figure 2 obtained with EFOSC. In this latter figure, we show an image of the difference between the 0° polarizer intensity and the 90° polarizer intensity of the same field as shown in Figure 1. Notice how effectively all the stars seen in Figure 1 have dropped out from Figure 2 leaving only the SN and its echo. This last image reveals the ring to actually consist of two bright ≃90° long arcs centred on the East and West directions. It is not too clear yet whether there is any emission at all in the N and S quadrants. The light immediately inside the areas in the butterfly pattern is also polarized but we cannot determine yet whether this is instrumental in origin. Incidentally, the disappearance of the two outer echoes from Figure 2 shows that they are not linearly polarized, as expected.

The linear polarization figure of 15% unambiguously establishes the feature to be due to scattered light from dust grains located at ≃15 light-years in front of the SN such that the scattering angle is ≃30°. These grains most plausibly reside in a fragment of a circumstellar shell formed by the deceleration of a red giant wind by the bubble of gas formed by the fast wind of the main sequence supergiant progenitor. Thus, these measurements can be taken as clear indications of the reality of the postulated red giant phase of the SN. Continued investigations of this type should prove very beneficial in unraveling the nature of the SN through the detailed study of the structure and composition of its immediate surroundings. No other technique we know of at this point will allow such an investigation.

We hope ESO will continue to carefully monitor the immediate surroundings of this fascinating object especially now that the SN is rapidly fading and the reflected radiation begins to probe the inner regions behind the SN.