Infrared Emission from the Sub-Arcsecond Vicinity of SN 1987 A

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Introduction

The fireball in the LMC called SN 1987 A offered an exceptional opportunity to study spatial structure of a supernova phenomenon. Obviously, special high angular resolution techniques at large telescopes had to be employed. The results of speckle interferometry in the visible spectral range, carried out at CTIO and AAT were reviewed by Meikle (1988). Here, we would like to present the results of speckle interferometry in the near infrared (λλ 2–5 μm), carried out at the ESO 3.6-m telescope during May–August 1987. In contrast with the work in the visible range, mainly concerned with the ejecta (≈ 10 marcsec), the near IR speckle interferometry deals with the structure of the close environment of the supernova (≈ 100 marcsec). In particular, it addresses the interesting question whether this environment contained dust and thus provides a useful test of current models of the progenitor evolution. Indeed, some models suggest that the exploded blue supergiant (BSg) Sk-69°202 has once been a red supergiant (RSg). Part of the dust, condensed around the progenitor during its RSg phase, could survive destruction by the fast and hot wind of the BSg (Chevalier, 1987; Renzini, 1987). The burst of supernova radiation at shock breakout with $L_b \sim 10^{43}–10^{44}$ erg · s^{-1} should heat this dust up to 1,000–2,000°K. The corresponding thermal emission should then appear as an infrared echo (Bode and Evans, 1979). The size of the dusty region was expected to be of the order of $10^{17}–10^{18}$ cm. At Earth, the corresponding angular size of 0.1–1.0 arcsec is well within the possibilities of speckle equipment. Shortly after the announcement of the supernova, we began to study the feasibility of observations. Computer modelling showed that the IR echo, if it existed, could be resolved already during the first months following the arrival of the explosion light. Independently, Prof. L. Woltjer, ESO Director General at that time, reserved 5 nights in May 1987 at the ESO 3.6-m telescope for IR speckle observations. After an exchange of telexes, we were in a plane to Santiago.

We used the ESO general user's IR specklegraph designed for the 1–5 μm spectral range. It provides a one-dimensional spatial spectrum of an image up to the maximum frequency of 3 to 6 arcsec^{-1}, depending on the spectral band and seeing (for more details, see Perrier, 1986). The observing procedure consists in scanning a stellar image at the telescope focal plane across a narrow slit. The width of the slit is chosen according to the spectral band and/or the seeing conditions: for example, for the L'band in good seeing conditions we use a 0.2 arcsec wide slit. The scanning must be fast enough to "freeze" the

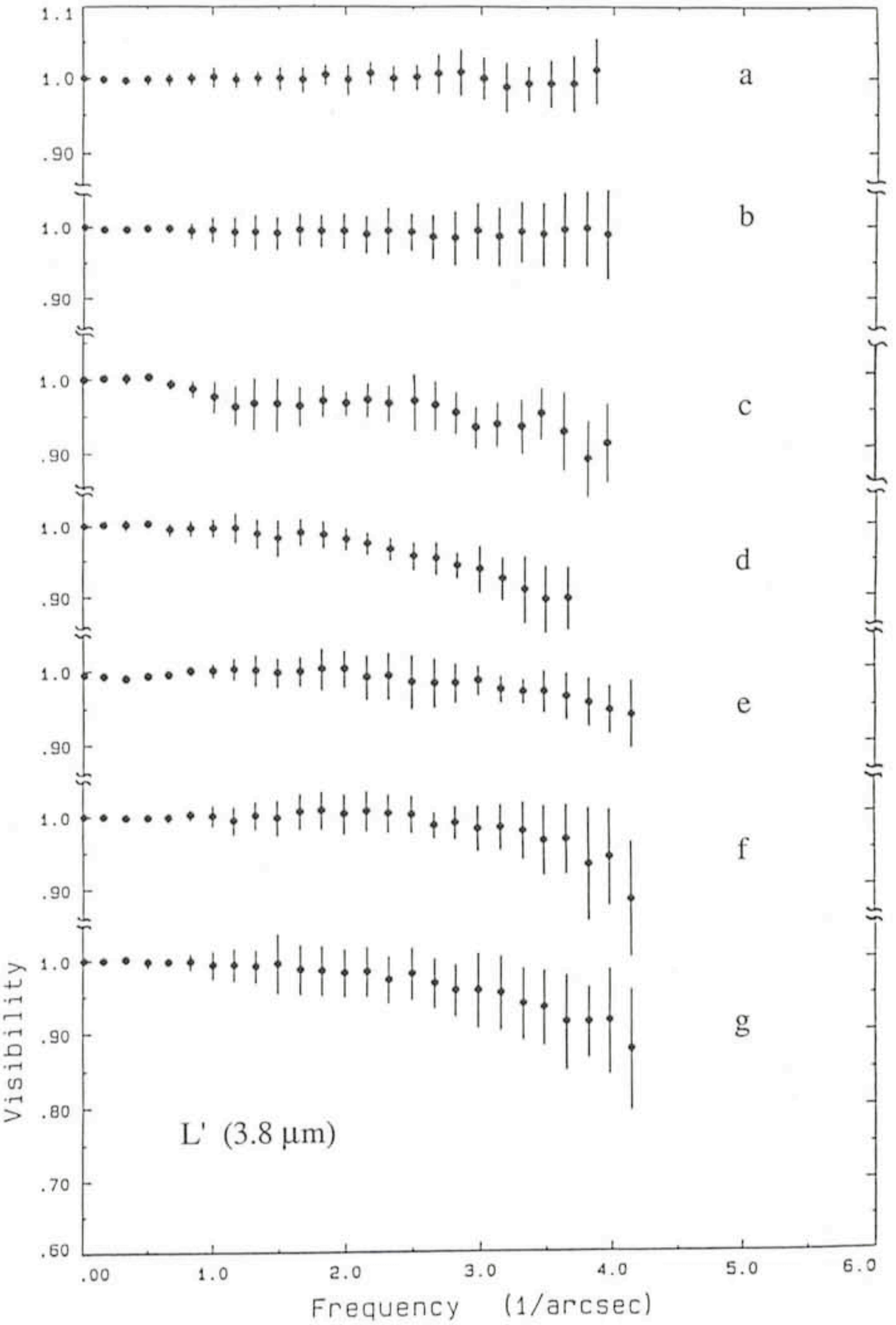

Figure 1: *Evolution of visibility curves of SN 1987 A in the L' band in May–June 1987: a: May 9, NS direction; b: June 8, EW direction; c: June 16, NS direction; d: June 17, NS direction; e: June 18, EW direction; f: June 22, EW direction; g: June 22, NS direction.*

speckles; typically, the image is crossed in 50 ms time. Each scan is Fourier transformed; the average power spectrum of the object is divided by that of a reference star thus giving the visibility curve. More details on the observing procedure, data and their discussion can be found in accounts given by Perrier et al. (1987) and Chalabaev et al. (1988a, b). Note, however, that, as a rule, the presentation of speckle results makes extensive use of technical terms. Let us recall that, as it is always the case of interferometric methods, we deal with measurements of Fourier transform of light pattern. Often, a speckle observer has no possibility to "come back" into the image space, i.e. to present a nice, easily understandable reconstructed image. Then, he is bound to "live" in Fourier space which is not an every-day experience of everybody. The necessity to use terms like Fried parameter, MTF of speckles, phase of Fourier transform and so on, makes articles on speckle interferometry difficult to digest. We would like to take advantage of writing for the *Messenger* to try a more friendly way of reporting on speckle data. Let us use where it might help terms of fishing, at least in parentheses. This may be especially important for our June observations.

TABLE 1. *Journal of observations.*

Date 1987	Day[1]	Band	Direction	Quality[2]	$\Delta\varphi$ marcsec[3]
May 9	75	L'	NS	3	non resolved
May 9	75	M	NS	1	non resolved
June 7	104	L'	EW	2	non resolved
June 8	105	K	EW	3	non resolved
June 8	105	L'	EW	4	non resolved
June 8	105	M	EW	1	non resolved
June 16	113	K	NS	2	non resolved
June 16	113	L'	NS	2	marginally resolved
June 17	114	L'	NS	4	144 ± 44
June 18	115	L'	EW	4	92 ± 18
June 22	119	L'	EW	4	126 ± 19
June 22	119	L'	NS	4	73 ± 49
August 5	163	K	EW	4	330 ± 80
August 6	164	K	NS	4	330 ± 80
August 6	164	L'	NS	4	350 ± 50
August 6	164	M	NS	2	390 ± 100

Notes:
[1] Day is counted from the arrival of the neutrino pulse, 1987 Feb 23.4
[2] "Eye-estimated" quality of a visibility ranging from 1 (acceptable) to 5 (excellent)
[3] For days 114–119, $\Delta\varphi$ is the FWHM of a Gaussian disk contributing 15% to the total flux; for days 163–164, $\Delta\varphi$ is the separation of a secondary spot from the supernova.

Bendings of the Rod

The Journal of observations is given in Table 1. The evolution of visibility curves in the L'band is illustrated in Figure 1. [In terms of fishing, we were observing the L-rod . . .]. Visibility curves, measured on May 8–9 and on June 8, could be described merely as a horizontal line, corresponding to the unresolved supernova. [The rod was straight, no fish . . .). On June 16, the visibility curve showed a first, though marginally perceptible, sign of emerging spatially distinct structure: namely, the high frequency part of the visibility curve began clearly to deviate from a straight line. [The rod got bent: a fish began to bite . . .]. This was confirmed by further observations on June 17, 18 and 22. [See Fig. 1; it bit even stronger . . .]. No significant difference was found between the visibility curves measured in the North-South and East-West directions of scans. The curves in the K and M bands remained those of the unresolved supernova (see Fig. 2 and 3).

The type of visibility curves like those observed in the L'band from June 16 to 22 is usually referred to as "partially resolved": that is only a fraction of the spatial spectrum of a resolved object could be measured. One can also say that the size of the object was less than the Rayleigh resolution. Attempting to restore the image is subject to extrapolation of the recorded tendency beyond the maximum frequency of the equipment. Due to extrapolation, the image reconstruction is not unique. Theoretical visibility curves produced by the most plausible images are given in Figure 5 together with typical observed visibilities. [There was a fish in mid-June. It was not possible to get it out of the water. But we kept record of the rod reaction. Now we go to a fish shop, take different fishes and see the reaction of the rod. It turns out that only fishes of a certain kind and of a certain size can reproduce the observed reactions . . .] They come in two kinds: a "point-like" spot(s) and a disk halo emission. Three images can equally account for the visibility curves in L', measured on June 17–22, namely: (1) two "point-like" spots, one in the NS direction (180° ambiguity) and another one in the EW direction; (2) one "point-like" spot, resulting from the combination of two spots, and laying in one of the intermediate directions: NE, NW, SW or SE; and (3) an axially symmetric disk halo around the supernova. To estimate the angular scale, we need to know the relative contribution, ε, of the source(s) to the total flux from SN (cf. Perrier et al., 1987). [Stronger the fish, smaller its size . . .]. The lowest value of ε which is

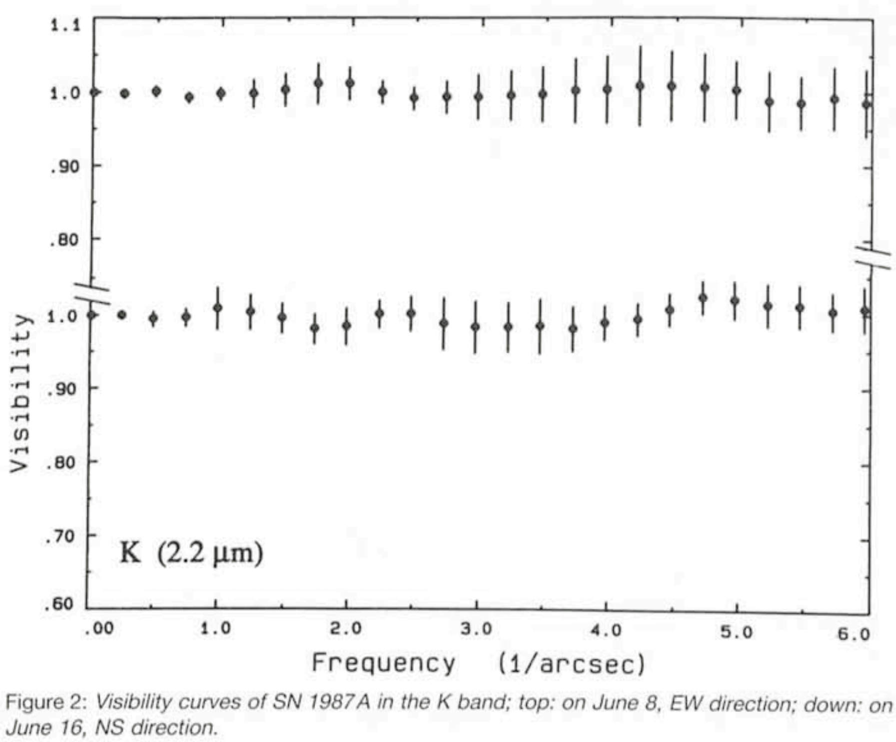

Figure 2: *Visibility curves of SN 1987A in the K band; top: on June 8, EW direction; down: on June 16, NS direction.*

still compatible with the observed shape of the visibility curves is about 10% or 17 Jy. On the other hand, the relative smoothness of the light curve in L' between June 8 and 18 seems to discard any "flare", exceeding 20% of the total flux. We adopt $\varepsilon \approx 15\%$. Then, in the case of two spots, their angular separation from the supernova is $\Phi \approx 55$ marcsec and the projected distance $p \approx 17$ light-days (l.d.). If the spots are combined in one, then $\Phi \approx 78$ marcsec and $p \approx 24$ l.d. Finally, if the real image was an axially symmetric disk halo, which we favour as the most simple case, its weighted average FWHM was about 109 ± 24 marcsec (Gaussian distribution of brightness was assumed). The corresponding projected distance from the supernova to the edge of the halo at half maximum was $p \approx 17$ l.d.

On August 5 and 6, the visibility curves (Fig. 4) displayed a different pattern: an oscillation with the amplitude of about 4% and the first minimum at about 1.25 arcsec^{-1}, superimposed on the visibility of the unresolved supernova. [It bit once again, but that was a different fish . . .]. This is a very faint signal, comparable to the level of systematic errors. However, none of the numerous test observations of unresolved stars showed this pattern, and we must conclude that the oscillation was related to the supernova. It appeared in all three bands: K, L' and M, scanned in North-South. One visibility curve, in the K band, was measured in EW; it showed a similar oscillation. Since the August visibility curves display secondary maxima and minima, there is no necessity in extrapolation, and interpretation is less ambiguous than for the mid-June data. A disk halo is easily ruled out. We have suggested a ring of light of 420 marcsec diameter (Chalabaev et al., 1988a). However, it produces too strong a damping of secondary oscillations (cf. Fig. 5) and is also ruled out. Only secondary "point-like" spots match the observed oscillations. Yet, as far as the phase of the Fourier transform is not restored (although we hope to resolve this problem), there is an ambiguity concerning the number of spots (one or two) and their positional angle. [We got some fish parts out of the water. However, the puzzle is not assembled . . .]. One needs a secondary spot, contributing $2.6 \pm 1.0\%$ (3.0 ± 1.2 Jy) in K, $2.7 \pm 1.0\%$ (2.5 ± 0.9 Jy) in L' and $1.8 \pm 1.0\%$ (2.8 ± 1.6 Jy) in M, situated in the North-South direction (180° ambiguity) and separated from the supernova by 350 ± 40 marcsec. This corresponds to the projected distance $p = 106$ l.d. A similar secondary spot in the East-West direction explains the visibility curve measured in the K band. As in the previous case, the spots can be combined in one, lying at 495 ± 60 marcsec ($p = 150$ l.d.) in one of the intermediate directions.

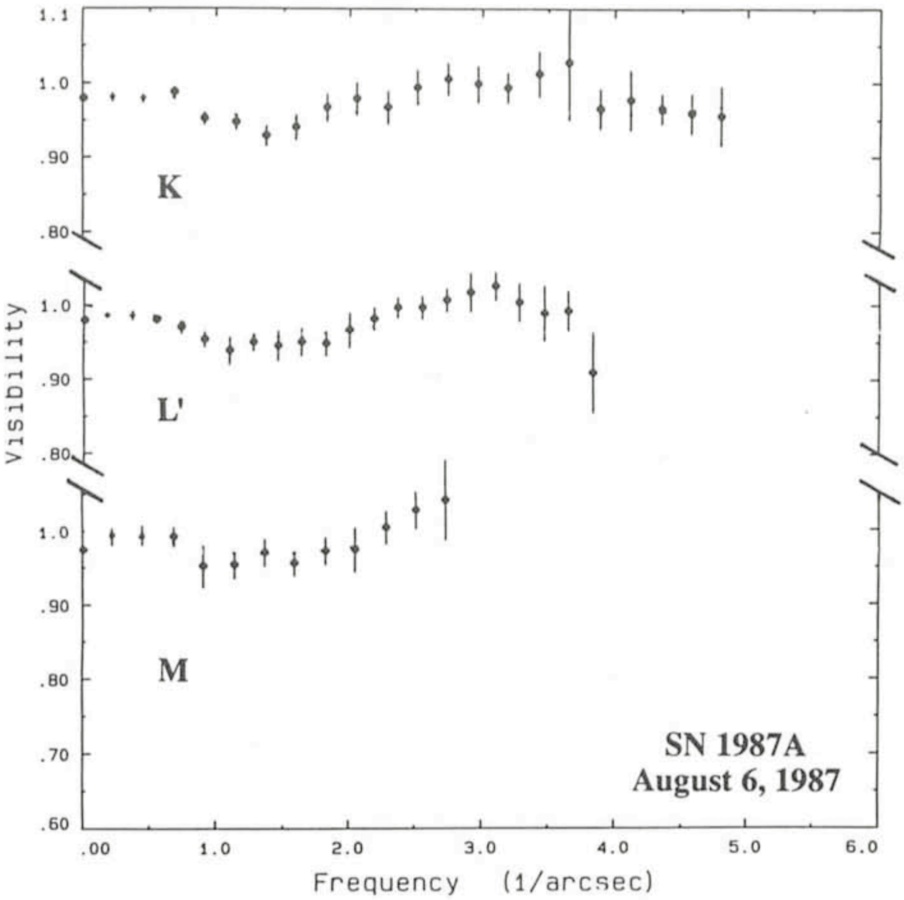

Figure 4: *Visibility curves of SN 1987A on August 5–6, NS direction.*

What Was It?

The first fact we wish to point out is the projected distance from speckle source(s) to the SN: in June 17–22 it was about 20 l.d. which implies the apparent velocity of the source(s) to have been 18% of the speed of light c. In August, the distance was at least 106 l.d., and the velocity was at least 0.65 c. Clearly, the speckle sources must be located outside the ejecta. We see two possibilities to explain the observed velocities. Following Rees (1987), one can consider a relativistic jet. However, the apparent June-August acceleration makes this explanation unlikely. Instead, we suggest a light echo to be the origin of the speckle sources. In this case, the apparent velocities close to the speed of light find a natural explanation. The second fact we wish to

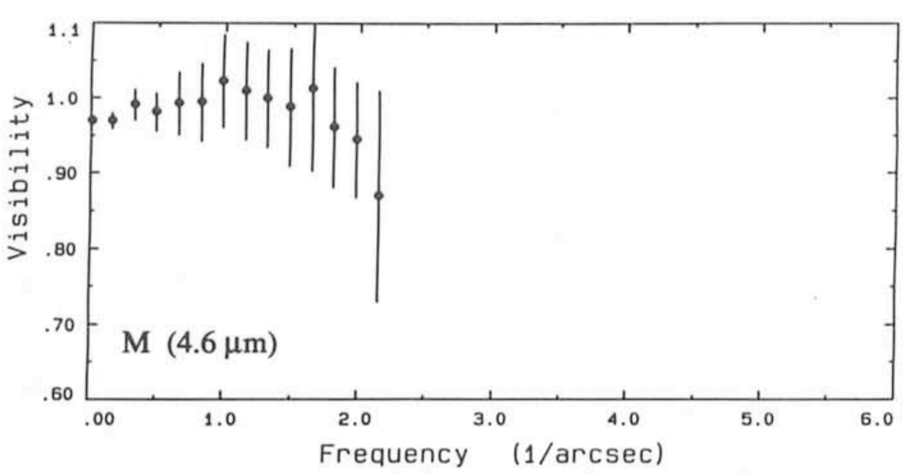

Figure 3: *The visibility curve of SN 1987A in the M band on June 8, 1987, EW direction.*

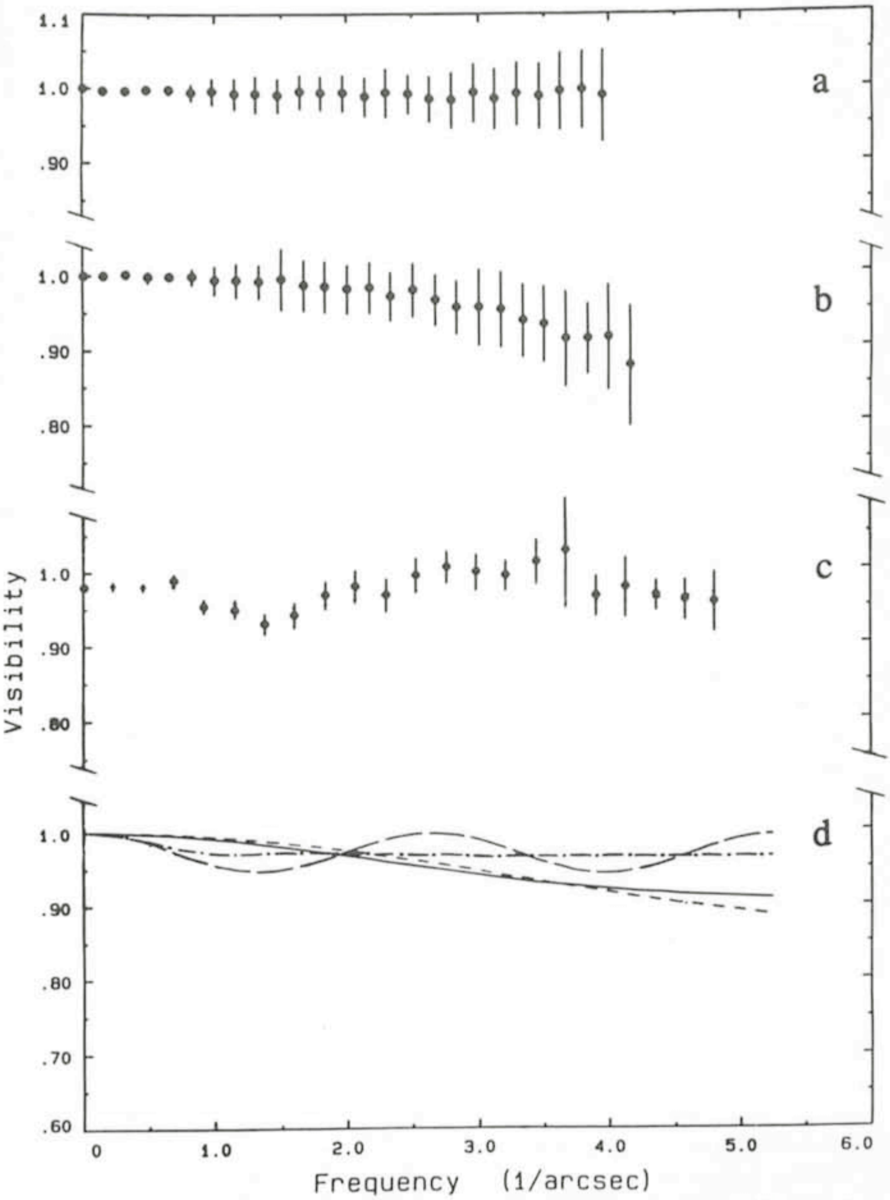

Figure 5: *Comparison of observed and theoretical visibility curves of SN 1987A in the L' (3.8 μm) spectral band:*
a: June 8, 1987, East-West direction; b: June 22, 1987, East-West direction; c: August 6, 1987, North-South direction; d: solid line, the unresolved supernova plus a disk halo with $\varepsilon \approx 10\%$ and the FWHM = 120 marcsec; short-dashed line, the supernova plus a secondary spot with $\varepsilon \approx 6\%$ and the separation of 62 marcsec; long-dashed line, the supernova plus a secondary spot with $\varepsilon \approx 2.6\%$ and the separation of 350 marcsec; dot-dashed line, the supernova plus a ring of $\varepsilon \approx 3\%$ and the radius of 210 marcsec.

point out is the rather low colour temperature of the speckle emission. On June 16, when we have measured both K and L' visibilities, $T_{col} \leq 2200$ °K. In August, $T_{col} = 2000 \pm 900$ °K. This is close to what one would expect for a hot dust emission. Thus, as we have suggested (Perrier et al., 1987), an IR light echo from dust, heated by the light burst at shock breakout, appears as the most plausible explanation.

Applying the theory of light echoes (Couderc, 1939), we can deduce the location of the IR speckle sources. As seen by a distant observer, the echoing dust grains lie on a paraboloid of revolution with the vertex point at the distance $c\tau/2$ from the supernova, where τ is the time interval counted from the arrival of the explosion light to the Earth. The distance from the supernova to the sources is: $R = (p^2/c\tau + c\tau)/2$, where p is the projected distance. Therefore, the distance to the edge of the disk halo or to the spots, detected in mid-June, is $R \simeq 1.5 \cdot 10^{17}$ cm; for the August spots, $R \simeq 3 \cdot 10^{17}$ cm. Chevalier and Fransson (1987) and Chevalier (1987) also considered the possibility of the IR echo from SN 1987A. According to their work, the shock wave of the BSg wind expansion should sweep the relict RSg dust into a shell. They expected only a weak IR echo, appearing as a ring of light, coming from the inner edge of the shell at $R \approx 10^{18}$ cm or 400 l.d. At this distance, the temperature of dust, heated by the light burst with the luminosity $L_b \approx 10^{43}$ $erg \cdot s^{-1}$, should be about 500–600 °K. The detection of speckle emission at $T_{col} \sim 2000$ °K in the form of spots or halo, and not of a ring, and at a distance to the supernova closer than expected then looks surprising. However, even at this distance, dust could partially survive the destruction by the BSg wind if it is concentrated in clumps, formed when the RSg wind material fragmented due to the Rayleigh-Taylor instability (Renzini, 1987). The observed IR speckle sources can well be the emission from the clumps of the relict dust. Thus, the following three spherical regions can be distinguished in the environment of SN 1987A:

(1) the inner cavity, free of any dust because the dust supply by the RSg wind had been turned off; its radius $R_1 = t_1 v_d$, where t_1 is the time elapsed since the RSg wind ceased to blow, and v_d is the velocity at which dust flowed away from the star; (2) an intermediate region where the fast BSg wind is passing through the RSg wind material; it is delimited by a shell of swept RSg wind material at $R_2 = t_2 v_{sh}$, where t_2 is the time elapsed since the BSg wind began to blow and V_{sh} is the velocity of expansion of the BSg wind into RSg wind material (Chevalier, 1987) and, possibly, (3) the region of the unperturbed RSg wind at $R > R_2$. This is illustrated in Figure 6.

Time Scale of the Progenitor Evolution

In the favoured case of the Gaussian halo for the mid-June L' visibilities, the heated dust closest to the supernova grains are at the vertex point of the paraboloid, at $c\tau/2$. Then, the first detection of the dust echo on day 113 suggests an upper limit on the radius of the dust free cavity, $R_1 < 56.5$ l.d. or $1.46 \cdot 10^{17}$ cm. The corresponding limit on the time interval, elapsed since the wind of the RSg ceased to blow, is $t_1 < 4600 \cdot (10\ km\ s^{-1}/v_d)$ yr. The typical RSg wind velocity about $10\ km \cdot s^{-1}$ is used as a first guess for v_d, but the actual value of v_d might be greater if dust is accelerated by the fast BSg wind. For the halo, R_1 cannot exceed the distance to its edge which is at the distance of about $1.5 \cdot 10^{17}$ cm from the supernova. Consequently, a stronger upper limit on t_1 is $5000 \cdot (10\ km\ s^{-1}/v_d)$ yr. Finally, allowing for the uncertainty of image reconstruction, we must consider the most distant unique "point-like" spot case. Then $p \approx 24$ l.d. and $R \approx 1.6 \cdot 10^{17}$ cm. The corresponding con-

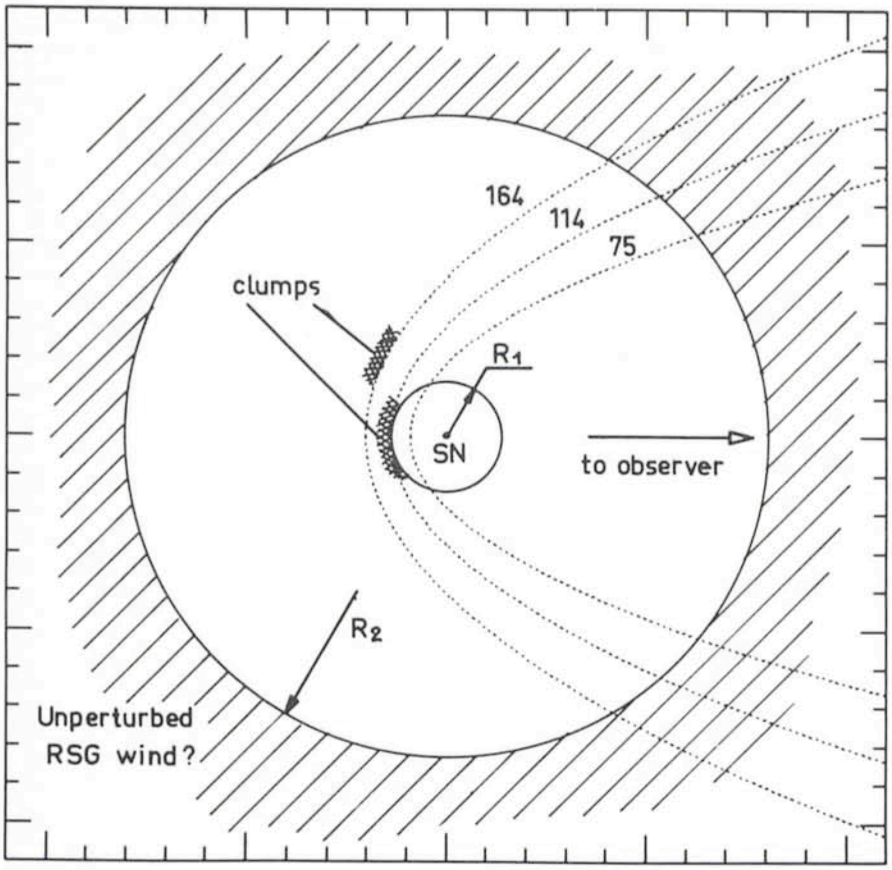

Figure 6: *The close environment of SN 1987A as suggested by IR speckle interferometry. Parabolae of light echo are labeled by number of days after the arrival of the explosion light. Double hatched areas show the location of dusty clumps heated by the light burst. For further explanations, see the text.*

servative upper limit on time scale is: $t_1 < 5100 \cdot (10\ \mathrm{km\ s^{-1}}/v_d)$ yr. The upper limits on t_1 are rather small. They imply that the evolution from red to blue was unexpectedly short, just of the order of the thermal timescale of the hydrogen envelope about 10^3 yr. Another hint on the time scale of the RSg – > BSg evolution can be obtained from the absence of the ring-induced pattern on August 5–6 visibilities. A ring emission would be the signature of the shell sweeped by the BSg wind. From the August visibilities, the lower limit on the diameter of such a ring is 0.5 arcsec. Then the shell should be at $R_2 > 2.6 \cdot 10^{17}$ cm, and the BSg wind should have begun to blow at least $1{,}600 \cdot (50\ \mathrm{km \cdot s^{-1}}/v_{sh})$ yr ago. However, the upper limit on the flux from the ring in the L' band is rather high, 14 Jy. This limit is not that significant: a faint ring would escape detection. A stronger constraint on the ring emission will be hopefully set by later IR speckle observations.

The UV Burst

The colour temperature of the IR speckle emission allows to constrain the magnitude of the very first point of the supernova light curve, i.e. the luminosity of the burst of radiation at shock breakout, L_b. The upper limit $T_{col} \leq 2200$ °K on June 16 implies the dust temperature $T_d \leq 1500$ °K (we assume that the dust absorption depends on wavelength as λ^{-1}). Solving the equation of the radiative balance for dust grains, we obtain $L_b < 3 \cdot 10^{43}\ \mathrm{erg \cdot s^{-1}}$. With similar assumptions, we obtain for the August 5–6 spots $T_d = 1{,}350 \pm 500$ °K and $7 \cdot 10^{42}\ \mathrm{erg \cdot s^{-1}} \leq L_b \leq 5 \cdot 10^{44}\ \mathrm{erg \cdot s^{-1}}$ (the case of two spots at $R = 3.2 \cdot 10^{17}$ cm) and $1 \cdot 10^{43}\ \mathrm{erg \cdot s^{-1}} \leq L_b \leq 8 \cdot 10^{44}\ \mathrm{erg \cdot s^{-1}}$ (the case of a unique spot at $R = 3.9 \cdot 10^{17}$ cm). Finally, combining the June and August estimates, we obtain $7 \cdot 10^{42}\ \mathrm{erg \cdot s^{-1}} \leq L_b \leq 3 \cdot 10^{43}\ \mathrm{erg \cdot s^{-1}}$. The IR speckle emission comes from a mixture of dust grains at different temperatures. However, theoretical models give an extremely short burst with the e-folding time not exceeding a few minutes (e.g. Woosley, 1988). Therefore, the echo emission is strongly dominated by the hottest grains and our estimate of L_b should be close to the value at maximum within a few percent. It compares well with the calculations of Woosley who gives $L_b = 3 \cdot 10^{43}\ \mathrm{erg \cdot s^{-1}}$ for the model 10 H (which is also his best model to account for the whole body of observations of SN 1987A).

Relation to Other Data

Given that the IR speckle data gathered at ESO are unique, we can verify them only indirectly. The first set of data which provides comparison are observations of the fluorescence echo in UV lines of HeII, OIII, CIII, NIII, NIV and NV, detected by the IUE satellite (Fransson et al., 1988) and in the visible lines of OIII and H, detected at ESO (Wampler and Richichi, 1988). They gave strong evidence in favour of reality of the RSg phase in the past evolution of the progenitor. This is in agreement with the interpretation of the IR speckle emission as due to dust grains, formed in the "antique" RSg wind. Furthermore, Wampler and Richichi (who coined the term "antique" wind) succeeded in measuring the spatial extent of the line emitting region and thus obtained an estimate of the time interval elapsed since the BSg wind began to blow, $t_2 \approx 7{,}000 \cdot (50\ \mathrm{km\ s^{-1}}/v_{sh})$ yr. Taking into account uncertainties in measurements and in scaling factors, we consider the agreement with our estimate of the end of the RSg wind epoch, $t_1 \leq 4{,}600–5{,}100$ yr at $v_d = 10\ \mathrm{km\ s^{-1}}$, as encouraging. Another point of comparison may be provided by observations of the far UV scattered echo (the external "invisible" part of the famous rings at 30 and 50 arcsec). As proposed by Chevalier and Emmering (1988), such observations could yield an independent estimate of L_b. The third kind of observations to keep eye on are the X-ray data and IR photometry. Indeed, Itoh et al. (1987) and Itoh (1988) predicted intense X-ray and IR emission at the time when the supernova ejecta will collide with the dense RSg wind material. Assuming the velocity of the blast shock wave from the supernova to be $2 \cdot 10^4\ \mathrm{km\ s^{-1}}$, it should reach the mid-June IR speckle source(s) at $R = 1.5 \cdot 10^{17}$ cm in the middle of 1989, giving rise to a flare of X-ray and IR radiation.

The Companion Object

A speckle companion (alias the "Mystery Spot") was announced to have been detected in the vicinity of SN 1987A from the speckle observations in the visible range in March-April 1987 (Nisenson et al., 1987; Meikle et al., 1987). It was situated approximately South of the supernova. Measured values of the angular separation vary from 52 to 74 marcsec. Our closest-in-time observations, carried out on May 9, i.e. 24 days after the last detection in the visible, did not reveal the companion, yielding an upper limit of 21 Jy on its flux in the L' band. Further, as the reader recalls, the partially resolved L' visibilities in mid-June can be fitted by "point-like" sources, situated about 50 marcsec from the supernova. However, ascribing the NS source to the Companion would lead to a quite inconsistent picture. One needs a second companion to explain the EW source. Also, one would have to explain why none of the companions were seen during the June 7–13 observing period. Therefore, we conclude that the mid-June L' visibilities, although they show a resolved structure, are not related to the companion. Further, speckle observations in the visible, carried out between May 30 and June 2, did not detect the companion (Karovska et al., 1987).

A number of mechanisms (synchrotron radiation, bremsstrahlung, line emission from ionized gas) have been proposed to explain the companion. However, according to a summary by Phinney (1988), the only model without severe difficulties with observations was a thermal emission at T = 3,000 K from a compact object. The corresponding black-body curve together with the visible and IR data is plotted in Figure 7. Our upper limit in L' lies below by a factor of 2.8 and provides a useful constraint. It implies that the temperature of the compact object should have remained constant at 3,000 °K from March 25 to April 14 (dates of observations in the visible) and then dropped down to below 1,800 °K by May 8, 1988. Phinney also mentioned the possibility of an echo from melting dust. Given the projected distance of about 17 l.d. on April 14, the corresponding distance from the dust to the supernova was about 28 l.d. From the equation of thermal equilibrium, we estimate the luminosity of radiation, necessary to heat this dust up to 3,000 °K, as $L_b = 2 \cdot 10^{44}$ erg $\cdot$ s^{-1}. This appears to be in conflict with the non-resolved K visibility on June 16.

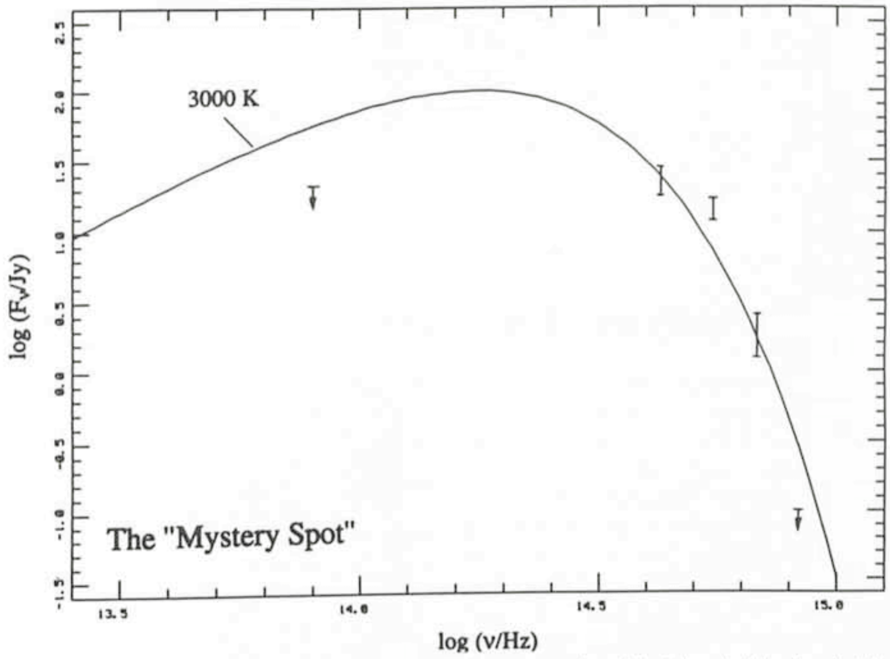

Figure 7: *The spectral distribution of energy for the companion object, implied by the visible and infrared data. The solid line corresponds to a black body of 3,000 K.*

Some Conclusions and Future Horizons

The reported work is the first study of a supernova at high spatial resolution in the infrared. Discussion of data from this sort of measurements provides valuable information on the past progenitor evolution as well as on the important parameter L_b, the luminosity of light burst at shock breakout, which is difficult to measure. More IR speckle data on SN 1987 A were obtained in December 1987 and June 1988 and await their analysis. Further development of this new field can be easily foreseen. We think first of all about galactic supernovae and bright novae. A higher signal-to-noise ratio than what we had on SN 1987 A would allow much more refined studies. Also, spatially resolved observations of an echo at a high signal-to-noise ratio may give the distance to the exploded object (Chalabaev, 1987). Overwhelming possibilities are promised by the coming new generation of telescopes of 8–10 m diameter. Estimates show that with such a telescope one could undertake similar studies of supernovae up to the distance of the M31 galaxy. Furthermore, the ESO VLT project includes the IR interferometry option and will certainly play a highly privileged role.

Acknowledgements

Behind the visibilities of SN 1987 A presented here there is an effort of a number of persons at La Silla. Jacques Roucher spent long sleepless hours in improving the electric set-ups of the specklegraph. The electronics were refined by Michel Maugis and the control software by Flavio Gutierrez. The first 4 nights out of 5, allocated in May, were lost due to a snowfall. Due to the courtesy of Paul Le Saux, we could get the May 9 visibilities. The detection of the L' source(s) in June became possible due to the kindness of scheduled observers, A. Chelli, I. Cruz-Gonzalez, B. Reipurth and H. Zinnecker, who shared the telescope with us. The August oscillations could be detected thanks to difficult technical interventions at the telescope of Daniel Hofstadt, Loïc Baudet and Jacques Roucher. Patrice Bouchet took part in the May observations and supplied IR photometry data all along our observing runs. A trip of A.C. to Chile was financed by INSU-CNRS (France). The analysis of data greatly benefitted from discussions with W.S.P. Meikle, R. Chevalier and E.J. Wampler. Last but not least, Prof. L. Woltjer, the former Director General of ESO, allocated telescope time for this off-schedule programme and constantly encouraged our work. We are indebted to all these persons.

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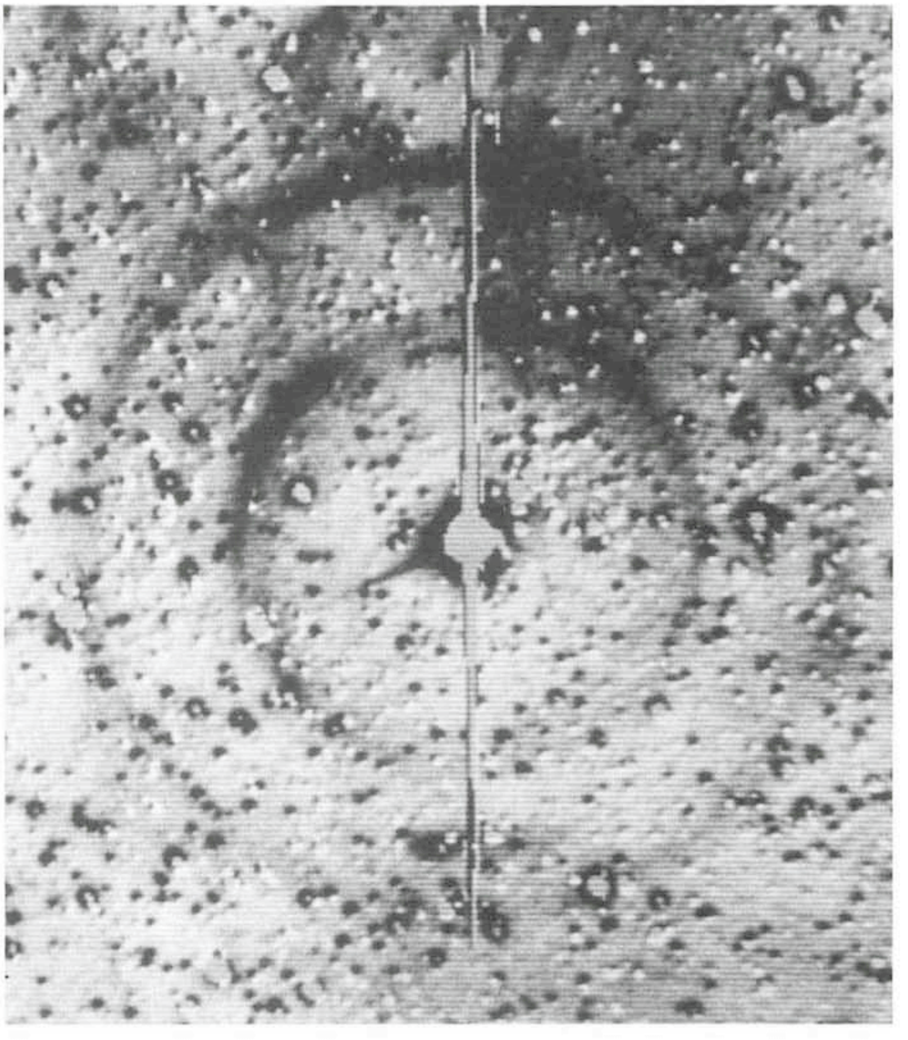
An Update on the Light Echoes of SN 1987 A



The ring shaped light echoes found earlier this year around the supernova SN 1987A in the LMC (*The Messenger* **52,** 13) have been under close monitoring ever since. The picture shows an artificially enhanced image of the rings as observed by H. Pedersen and J. Melnick on the nights 29th through 31st of October 1988, using a CCD camera in the Gascoigne adapter at the prime focus of the 3.6-m telescope. The resolution is 0.58 arcsec per pixel and the seeing was about 1.2 arcsec. In order to enhance the contrast, the photo shows the ratio of averages of five 3-minute exposures in B and V each.

The outer ring has reached a radial distance of about 77 arcsec and the inner ring of about 45 arcsec, very close to the predictions for plane parallel sheets of reflecting material perpendicular to the line of sight. In February the radii measured 52 and 32 arcsec respectively. The most interesting aspect is that the echoes retain their near circular shape. This implies that, at least over the area swept by the echoes since February, the interstellar dust must be highly concentrated into two thin layers located roughly 120 und 320 pc in front of the supernova. The very small deviation from circularity of the rings imposes tight constraints on any inclination and curvature of these sheets of matter, which are likely to belong to the halo of the LMC. *M. ROSA*

The ESO Schmidt Telescope

The ESO(R) half of the joint ESO/SERC Survey of the Southern Sky will soon be finished. For more than 90% of the 606 fields, Atlas-quality plates have now been obtained. Reasonably good, but not quite optimal plates are available of another 5% of the fields and only for ~20 fields (3%) has no acceptable plate yet been obtained. The Atlas production in Garching in also nearing the end; 22 shipments out of a total of 24 have been sent to about 200 customers. It is hoped that the last two shipments will become available in the course of 1989.

Most of the missing Atlas plates are in the right ascension interval between 20 hours and 4 hours and high priority will be given to the atlas work during the corresponding season (August to December). For the rest of the year, virtually all time is now available for other purposes.

One of the current programmes is the extension of the Quick Blue Survey from declination $-20°$ to the equator. This involves taking about 300 Atlas-quality IIa-O + GG 385 plates, each with 60-minute exposure time. This project procedes rapidly and more than one quarter of the fields have been covered with excellent plates.

Other Projects now under consideration include retaking the entire QBS, about 15 years after the first survey of this type. This would provide a very good basis for determination of proper motions in the southern sky, even of rather faint stars. The supernova search programme in brighter galaxies might also be re-activated. Other possibilities include deep infrared plates along the galactic plane or very long exposures