ing spent the night in La Serena, they flew back to Santiago on March 27 [18].

The Dedication Symposium on the Magellanic Clouds

The dedications also induced ESO to organize its first broad scientific symposium at the Headquarters in Santiago on March 28 and 29. Subject were the Magellanic Clouds, one of those objects of research at which ESO had aimed from its very beginnings. Participants came from Argentina, Australia, Chile, Mexico, South Africa, the United States and, naturally, from the ESO member states. The Proceedings of the symposium, edited by André Muller, were published in 1971 [19]. The symposium underlined ESO's taking up its tasks in astronomical research – although at that time modest observing programmes had been underway with the first telescopes, as we shall see in the next article. An early report on the subjects discussed at the symposium was given by Bengt Westerlund in *Sky and Telescope* of July 1969 (Vol. 38 No. 1).

References and Notes

Abbreviations used:
EC = ESO Committee, the committee that preceded the ESO Council.
EHA = ESO Historical Archives. See the description in the *Messenger* No. 54 of December 1988.
EHPA = ESO Historical Photographs Archive.
FHA = *Files belonging to the Office of the* Head of Administration of ESO.

[1] EHA-I.A.2.14.
[2] Frank Middelburg became an ESO employee in 1967. By the time of his untimely death in the year 1985 he had become a specialist in the fields of image processing and software systems. See the obituary by A. Ardeberg in the *Messenger* No. 42 of December 1985.
[3] See the ESO Annual Report for 1968.
[4] A copy of this report occurs in the Oort Archives of the Leiden University Library; a duplicate from this has been put in EHA-I.A.1.18.
[5] EHA-I.A.1.22.
[6] Cou. Doc. Chi-7 in EHA-I.A.2.14. and minutes of the 2nd Cou Meeting.
[7] Cou. Doc. Chi-12 and 14 in EHA-I.A.2.14. and letters of Heckmann to Oort of 4 and 13 Oct. 1964 in EHA-I.A.2.10.
[8] ESO Basic Texts, Section B4.
[9] See the sketches included in the Annual Report 1965.
[10] See, for instance, Ann. Rep. 1968, p. 10. The realization of this telescope became part of the task of the ESO TP-Division.
[11] See FHA File 2.9.2. The last one of the signatures was on Sept. 11, 1969, by the Chancellor of the Un. of Bochum.
[12] See FHA File 2.9.3.
[13] See Doc. Cou-205 of Nov. 7, 1975 in FHA File 2.9.3.
[14] See Council Minutes December 1968.
[15] "Problèmes posés à l'ESO par l'implantation sur ses terrains d'Instruments étrangers".
[16] See Minutes 13th Cou Meeting, p. 12.
[17] Cou-doc No. 55 of May 30, 1969 in FHA 1.1.1/1.2.1.
[18] Details of the programme of the Council visit are in EHA-I.A.2.16. See also B.E. Westerlund's report in *Sky and Telescope*, Vol. 37, No. 6 of June 1969.
[19] A.B. Muller, ed., *The Magellanic Clouds*, Astrophysics and Space Library, Vol. 23, Reidel Dordrecht 1971.

REPORT ON THE FOURTH JOINT ESO/CTIO COLLOQUIUM

"The 1001 Nights of SN 1987 A"

Compiled by P. BOUCHET, ESO

1. Introduction

The fourth joint ESO/CTIO colloquium was held at La Silla on November 20, 1989, in order to celebrate properly the results of the 1001 nights spent after the outburst of SN 1987A. This colloquium consisted of informal talks followed by debates and a round-table discussion dealing with the acquired experience in a supernova follow-up, the current observations of SN 1987A, the future joint ESO/CTIO monitoring of SNs, and the preparation for the next bright supernova(e?) (observations in Chile).

Most of the staff astronomers and visitors from the three observatories of the IVth region of Chile (La Silla, CTIO, Las Campanas) were able to attend the meeting, which largely contributed to its success.

The colloquium ended in the gymnasium of La Silla where the ESO Astronomy volleyball team brilliantly defeated the CTIO one, in an intense game. To conclude in the very best way this pleasant and fruitful day, a cocktail was then offered to everybody.

We present in the following a summary of the talks given during the meeting.

2. VISIBLE SPECTROPHOTOMETRY: Mark M. Phillips/CTIO

SN 1987 A in the Large Magellanic Cloud has provided a unique opportunity to study the spectral evolution of a Type II supernova. Taking advantage of the superb observing conditions that characterize the "Norte Chico" of Chile, astronomers at ESO and CTIO have led the way in obtaining precise spectrophotometry of this important object at visual wavelengths. These observations have yielded a number of important findings, a few of which are listed below:

2.1 Abundance Anomalies in the Hydrogen Envelope

The first spectra obtained of SN 1987 A were characterized by strong H and He P-Cygni emission lines. Attempts to model these early spectra have suggested that the helium abundance in the outer envelope of the supernova may have been as much as a factor of 2-3 times the solar value. As the supernova expanded and cooled over the following weeks, strong ab-

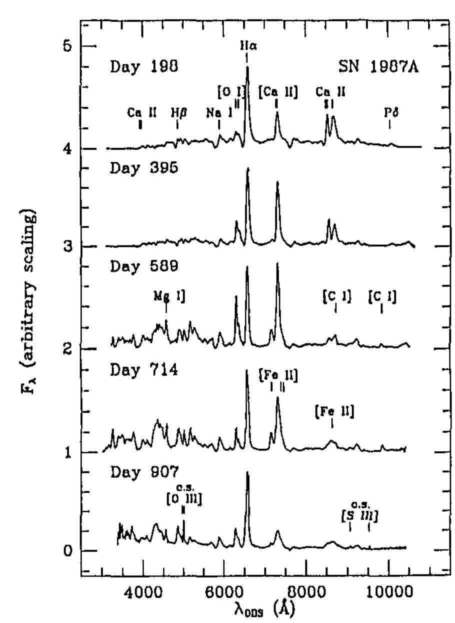

Figure 1: *Selected optical spectra of SN 1987 A obtained at CTIO which illustrate the evolution from days 198–907. Identifications of the most prominent emission and absorption features are indicated. The narrow [O III] and [S III] lines visible in the spectrum for day 907 are due to the circumstellar material that surrounded the progenitor Sk -69202.*

sorption lines of Ba, Sr, and Sc were observed, indicating similar enhancements of the s-process elements. These findings suggest that the progenitor of SN 1987 A, Sk -69202, may have undergone a phase where the products of a He-burning shell were mixed in significant quantities to the surface.

2.2 The "Bochum Event"

Approximately three weeks after the outburst of SN 1987A, two emission "bumps" appeared in the blue and red wings of H-α and several other emission lines. It seems likely that these bumps were the first observable consequence of the arrival, at the photosphere, of energy associated with the radioactive decay of ^{56}Ni and ^{56}Co. For this to have occurred less than a month after outburst implies significant mixing of radioactive material outwards into the hydrogen envelope.

2.3 [Fe II] Emission During the "Nebular" Phase

Emission lines of [Fe II] became clearly visible in optical spectra of SN 1987 A around 200 days after outburst, growing in strength until approximately day 650 (Fig. 1). Forbidden emission lines of Fe, Ni, and Co were observed in the infrared at approximately the same time. These observations represent the first unambiguous detection of the products of explosive nucleosynthesis in a type II supernova.

2.4 Emission Line Profile Variations

At the beginning of the nebular phase (day 200 or so), the peaks of the H I, Na I, Ca II, and [Fe II] lines all displayed a prominent redshift, apparently due to scattering by electrons in the hydrogen

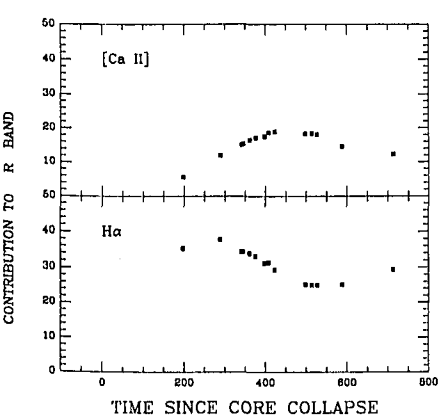

Figure 2: *The contribution of the Hα (lower panel) and [Ca II] 7291, 7323 (top panel) emission lines in SN 1987 A to the flux in the CTIO R band, plotted as a function of time.*

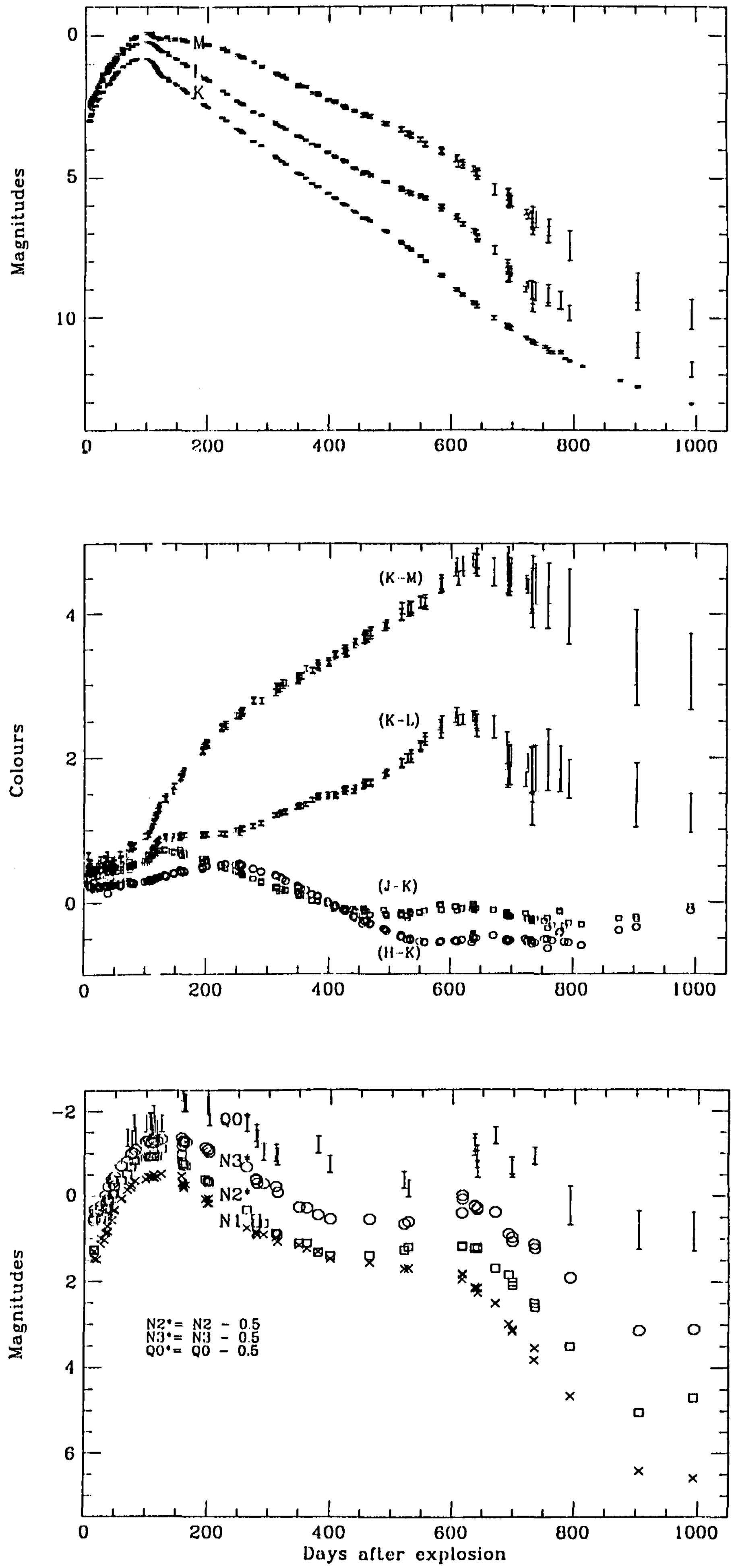

Figure 3: *The lightcurves in the broad band filters, as indicated.*

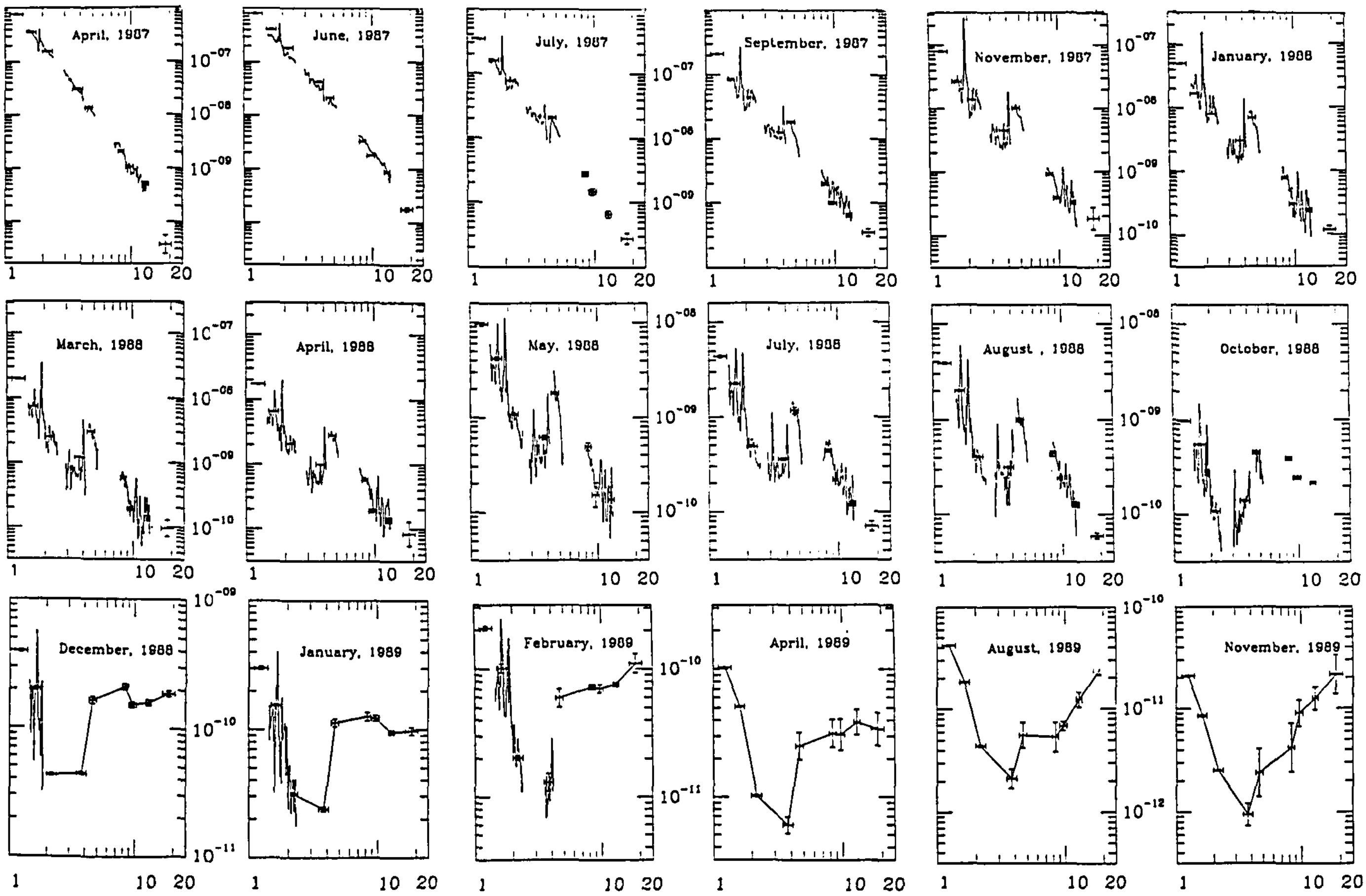

Figure 4: *The evolution of the spectral energy distribution from 1 to 20 μm deduced from ESO broad band photometry, and the evolution of the spectrum obtained through CVF filters, for the indicated dates (X-axis: wavelength in μm; Y-axis: flux density in erg s^{-1} cm^{-2} μm^{-1}).*

envelope. The peaks of the [O I] 6300, 6364, [Ca II] 7291, 7323, and [C I] 9824, 9850 lines lacked such a redshift during the same period, proving conclusively that these emission lines originated in a physically distinct zone. Between days 525-590, however, the peaks of all of the observed emission lines underwent a sudden blueshift, coinciding nearly exactly in time with the development of a far-infrared excess in the flux distribution of the supernova. These two phenomena have been successfully interpreted (by ESO astronomers at first) as observable consequences of the formation of dust in the ejecta. Although the blueshifted peaks have persisted to the present, further changes have continued to occur in the profiles of at least some emission lines. Most prominent of these has been a broadening of the [O I] 6300, 6364 lines which occurred between days 700-800, the cause of which is not yet fully understood.

3. UBVRI PHOTOMETRY: Mario Hamuy/CTIO

Since the announcement of the outburst of SN 1987 A, the CTIO staff has undertaken a regular photometric monitoring of the Supernova. The data obtained have been used together with the ESO infrared observations to construct the ESO/CTIO bolometric light-curve.

Large discrepancies have been found between the observations of UBVRI photoelectric photometry of SN 1987 A carried out a CTIO and at SAAO. In order to clear up the origin of these differences we calculated synthetic magnitudes using different bandpasses from our spectrophotometric database. For this purpose we made laboratory measurements of the bandpasses used at CTIO, with which we were able to successfully reproduce the CTIO photoelectric photometry. On the other hand, the SAAO photometry could be synthetically reproduced using the standard Kron-Cousins band functions. We conclude that the discrepancies between both data sets are due only to the differences between the photometric systems used at both observatories. In addition, we found that the contribution of the emission lines in the spectrum of SN 1987 A to the R and I magnitudes is non-negligible for the purpose of transforming the broad-band magnitudes to monochromatic fluxes (see Fig. 2). The effect of the emission lines in the UBVRI photometry must be carefully taken into account when deriving the bolometric light curve of SN 1987 A.

4. INFRARED OBSERVATIONS: Patrice Bouchet/ESO

An infrared monitoring programme of SN 1987 A was started at La Silla on February 27, 1987, and is still going on. The observations carried out (at the 1-m, 2.2-m and 3.6-m telescopes) concern broad band photometry from J (1.24 μm) to Q0 (20 μm), as well as spectrophotometry in the four atmospheric windows (1.4–2.4 μm; 2.9–4.2 μm; 4.7–5.4 μm; 8–13 μm) with CVFs ($\lambda/\Delta\lambda$ ~80). The ESO team working on this programme include I.J. Danziger and L.B. Lucy from ESO-Garching and, familiar to all ESO infrared users, our observer R. Vega, whose active and enthusiastic participation has been crucial for the programme. T. Le Bertre and A. Moneti also collaborated for some of the observations.

Since we started this work, a large amount of observing time has been dedicated to it, resulting in the most complete set of such data ever collected on a supernova (including SN 1987A!). Figures 3 and 4 illustrate our results.

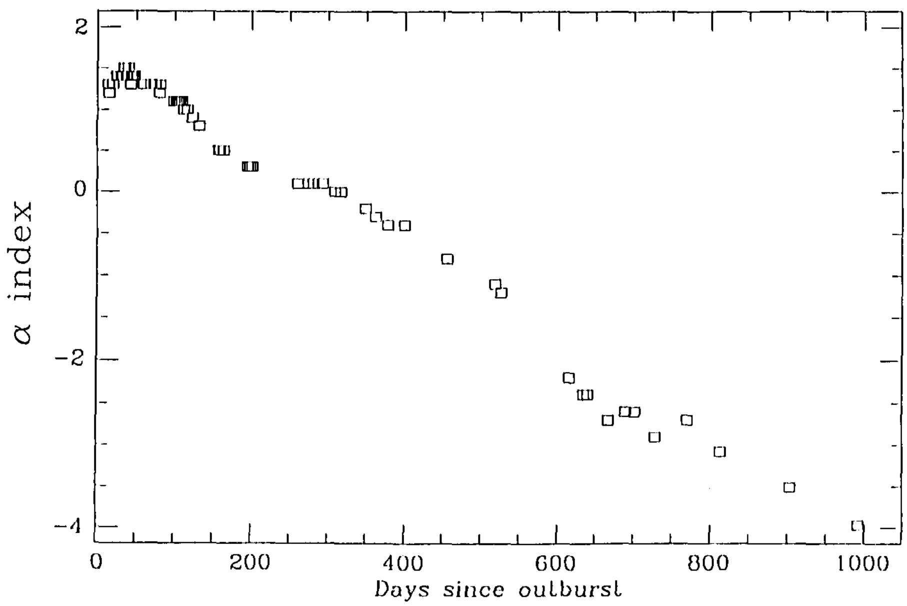

Figure 5: *The spectral index α as function of time.*

4.1 The IR Excess and Excess Emission at M

Even in the earliest photometry, there was a clear excess in the far IR. By day 100, an emission started to develop in the M band (4.8 μm), which was attributed to CO. By day 260, an excess appeared at N1 (8.4 μm), probably due to SiO. We define the infrared spectral index α by fitting from L (3.8 μm) to Q0, excluding M and N1, the function:

$$F_\nu = F_0 \nu^\alpha$$

Figure 5 shows the evolution of the α index: it started near the Rayleigh-Jeans law (α = 2) and decreased rather uniformly. Such a continuous temporal variation argues for a single physical cause, the most obvious explanation being the *early* and continuous formation of dust (starting at about day 100). However, with these data alone it is not possible to rule out that several effects may have conspired to produce the uniform variation. The IR excess till day 300 could be due just to the gradual transformation from a dense and optically thick plasma radiating like a black body to a low density optically thin plasma radiating by free-free emission (α = 0). Indeed, α leveled out a 0 between days 200 and 300. After that time, α resumed its decrease as a cool component appeared.

4.2 The Thermal Component

Around day 550, our broad band photometry reveals the emergence of a cool component (Fig. 4). When the thermal emission rapidly dominated the total observed flux, the optical magnitudes began to accelerate their decline in brightness. (U-V) decreased roughly uniformly while (V-K) suddenly changed evolution from blue to red, even though there has been no corresponding change in the bolometric lightcurve (see next section). The simultaneity of these events can be most easily explained by the formation of dust (or the accelerated formation of dust, if the early IR excess is due to dust) local to the Supernova. The ESO team (Danziger et al. 1989, and Lucy et al. 1989, 1990) were first to announce and discuss the formation of dust in the ejecta of SN 1987 A. These authors have estimated the dust extinction in various optical emission lines, and using these line optical depths, have shown that the inflection in the V lightcurve at around day 500 can be modelled by a simple extrapolation of this lightcurve from the linear decline phase, reddened according to the estimated extinction from the emission lines. They have also shown that the line optical depths appear to provide evidence for selective extinction.

4.3 The Bolometric Lightcurve

The CTIO UBVRI photometry together with the ESO infrared photometry have been used to derive the bolometric lightcurve (Suntzeff and Bouchet, 1990). In order to estimate the luminosity of the thermal component (discussed in the previous section) a black body fitted between L and Q0 (with an interpolation at M to avoid the contamination by CO) has been integrated up to zero frequency. Since the actual flux in the far IR is probably a combination of line emissions *and* thermal re-radiation from dust, the estimated total flux from the fits is an *upper* limit to the thermal radiation. The resulting bolometric lightcurve (the only one available which takes into account the measured infrared flux up to 20 μm), is by now well known and understood (see the curve on page 41 of this issue of the *Messenger*) as follows:

- During the first 10 days the high temperature plasma produced by the passage of the shock, cooled to a temperature typical of hydrogen recombination (T ~5500 K), which produces a rapid decline of the lightcurve.
- Between days 10 to 125, there was a slow brightening to maximum followed by a rapid decline as the hydrogen recombination front propagated inward into material that was being heated by radioactive decay of ^{56}Ni and ^{56}Co. At that time, the radioactive decay energy was trapped behind the hydrogen recombination front and produced both mechanical work in accelerating the plasma and later a diffusion wave of energy that was seen as the broad maximum (mixing of the radioactive material outward, and of hydrogen inward into the core). Note that the light curve slowed its rise around day 30 at the time when SN 1987 A began to be powered by energy released from the diffusion wave of thermalized radioactive energy, rather than the recombination of the hydrogen ionized purely by the shock, as discussed by M. Phillips in his talk (see also Lucy, 1988).
- Between days 125 and 800, the recombination front had passed through the diffusion wave of trapped energy, and the observed bolometric flux became due to the fraction of the radioactive energy from the decay of ^{56}Co that was thermalized by inverse Compton scattering.
- After day 800, measurements made in August and November 1989, showed a levelling off of the lightcurve. Subsequent observations made in December and January confirmed the reality of the levelling off. This result, and its interpretation as probably due to the presence of a pulsar, has been communicated recently in I.A.U. Circular 4933 (January, 1990) and the ESO Press Release PR 01/90. It is presented in this issue of the Messenger (page 41).

In conclusion, the main results concerning the ESO/CTIO bolometric light curve are:

At least up to day 800:

The sum of the observed flux (between 3200 Å and 20 μm) with the observed high-energy flux as fit by the models, is consistent with SN 1987 A being powered purely by the decay of ~0.07 $M_\odot$ of ^{56}Co.

No more than 30 % of the thermal flux can be due to an infrared echo without violating the energy budget. Any pulsar, IR echo or radioactive source other than

^{56}Co must have a luminosity inferior to 1.5×10^{38} erg s^{-1}.

At least from day 900 on, the bolometric lightcurve lies above a linear extrapolation from earlier epochs, which implies that a hitherto undetected energy source started to contribute significantly to the total energy output.

4.4 The Spectrophotometry

The infrared range is perfectly suited for spectroscopic studies of supernovae: in fact, whereas optical emission lines are strongly temperature and density dependent, the infrared forbidden line fluxes depend only weakly on temperature (for $T \gtrsim 1000$ K). In addition, for several years after the explosion, the densities in the ejecta exceed the critical densities of most of the fine-structure levels, so the line fluxes are independent of the density in the emitting region. Once the transitions become optically thin, the masses of heavy elements in the ejecta can be directly determined from the IR line fluxes. Moreover, the major IR continuum opacity in the H/He gas envelope is free-free absorption, which becomes small after several months. In the mantle, where the heavy elements are ionized, the total free-free optical depth is small at infrared wavelengths after ~6 months, and the formation of optically thick dust in the envelope produces a continuum (and alters the gas phase abundances in the ejecta). Our CVF spectra have been used to determine the masses of the heavy metals in the mantle, and particularly for ^{56}Co, through the observation of the [CoII] line at 10.52 μm.

The modelling of the spectrum leads to the conclusion that, at $t \gtrsim 1000$ days, an "Infrared catastrophe" should occur as the radioactive heating rate drops below the saturated, high temperature cooling produced by fine structure lines. At the time of this writing (January 1990) this "catastrophe" has not yet occurred.

5. SEARCHING FOR THE PULSAR: Christian Gouiffes/ESO

The duration of the neutrino burst detected by the Kamiokande and the IMB groups as well as its energy suggest that a neutron star was born after the explosion of the supernova SN 1987 A in the LMC. If the conditions are not too unfavourable (optical thickness too high or a pulsar beam not pointing in the direction of the earth for example) one might expect to detect optical pulses from the Pulsar.

We have started at ESO a continuous search in order to look for the possible emergence of this pulsar. The observations were carried out at different telescopes where the installation of a photometer was possible:

- The 3.6-m telescope and the Danish 1.54 were the most used.
- The acquisition programme allowed us a time resolution of 1 msec.
- The famous Crab Pulsar (which has a period of rotation of 33 msec and is bright enough to be detectable with certainty in a few seconds integration at the 3.6-m telescope) was observed when possible to check our acquisition programme.

After the announcement in January 1989 by Middleditch et al. (IAU Circular 4735) of the discovery of a nearly 2-KHz periodic signal from SN 1987 A, we modified our equipment in order to get a sample rate of 10 KHz. In February 1989, SN 1987 A was observed at the 3.6-m telescope. The data, which were immediately sent to Garching (Max-Planck-Institut für Physik und Astrophysik) to be analysed, did not show any significant signal, giving an upper limit of magnitude 20 for the pulsar (Ögelman et al., IAU Circular 4743).

We continue our monitoring at a rate of approximatively 1-2 nights per month. A Fast Fourier Algorithm developed by P. Grosbøl from ESO is used at La Silla at the Sun computers to have a quick look at the data a few hours after their acquisition and react immediately if something is wrong in the acquisition programme or in case we detect something . . .

At the moment of writing, no significant signal has been detected from SN 1987 A in the many hours of observations that we got. Even for this 1001 nights meeting no significant signal came out.

The recent infrared observations (P. Bouchet, this article) that show a levelling off of the bolometric lightcurve encourages us to continue our effort.

6. THE NEBULOSITY NEAR SN 1987 A: E. Joseph Wampler/ESO

Because the progenitors of type II supernovae were expected to be red supergiant stars, there have been a number of studies of the expected interaction of a supernova explosion on the remnant red supergiant wind (see Chevalier, 1987 for an early discussion of the SN 1987A situation and other references). Beginning on about day 80, narrow nebular lines were seen in IUE spectra of SN 1987 A (Wamsteker et al., 1987, Fransson et al., 1989). These lines grew in strength for about 400 days and then faded. This suggested that the supernova is surrounded by a thin nebular shell with a radius of about 400 light-days (~1.3 arcsec at the distance of the Large Magellanic Cloud). On about day 300 the optical continuum had faded sufficiently that nebular lines could be seen in the optical spectral region, and the extension of the nebular lines beyond the width of the supernova continuum spectrum indicated the presence of a small bright nebula, about 2 arcsec in diameter (Wampler and Richichi, 1989). It was already expected that the blue supergiant phase of SN 1987 A that occurred just before SN 1987 A exploded would produce a high density shell of shocked gas around the progenitor star. The UV flash that accompanied shock break-out in the first minutes of the explosion would then ionize the shell; the observed nebular lines are a signature of the recombining gas.

On August 29, 1989, UT, the NTT was used to obtain images of the supernova in conditions of 0.4 arcsec seeing; some of these were published in the December issue of the *Messenger*. A composite of more recent images taken on December 18 by Sandro D'Odorico and Massimo Tarenghi is shown here in Figure 6. We are indebted to them for permission to publish their data here. With the stellar images subtracted, it is seen that the nebula consists of three main structural components: an inner oval nebula, an outer filamentary loop north and south of the inner nebula and a "light echo" that is shaped like "Napoleon's hat" and extends to about 6 light-years to the north of the supernova. The inner structure of the nebula appears to be morphologically very similar to galactic planetary nebula.

It has been supposed that planetary nebulae begin during the red giant phase of a star's evolution, but that their complex structure results from an interaction between the red giant wind and the wind and radiation from the subdwarf nucleus (Balick, 1987; Balick and Preston, 1987). Because SN 1987 A never became a subdwarf and after its red giant phase it was only a blue giant for a short period of time these observations may prove useful for constraining models of planetary nebula formation. Even if the nebulosity around SN 1987 A is classified as a planetary nebula, it is not likely that SN 1987 A is the first observed supernova to explode inside a planetary nebula. Dickel and Jones (1985) have suggested, on the bases of modelling Tycho's supernova remnant, that Tycho's supernova (a type-I supernova) exploded inside a planetary nebula.

We are very fortunate to have had a nearby supernova explode in our lifetimes. At the present time the studies of the expanding envelope and the surrounding nebulosity can proceed independently, but soon the two will begin to interact and we can expect even more fireworks!

7. WHAT THE STORY TEACHES US: Patrice Bouchet/ESO

The following is certainly not intended to be a complete review of the subject (for this purpose, the reader may refer to Arnett et al., 1989 and Hillebrandt and Höflich, 1989), but rather a brief summary, from an observer's point of view, of the highlights of SN 1987 A. (Note that additional references can be found in these two reviews.)

7.1 The "Peculiarities"

The fact that the progenitor was a blue supergiant has certainly been the first surprise of SN 1987 A. However, it was already known before SN 1987 A exploded, that a low metallicity and/or an extensive mass loss could lead massive stars to such a blue phase. Only the effects of an appropriate mixing seem to have been studied after the explosion of the supernova. The blue appearance of the progenitor is probably due to these three interconnected effects, and it is therefore not considered anymore as an extraordinary characteristic of SN 1987 A, but rather as one possible road in the stellar evolution. However, it is worth noting that it is thanks to SN 1987 A that we are now aware of it!

The second surprise was the relatively low luminosity of SN 1987 A relative to other "normal" SN IIs: this has been explained as a consequence of the more compact structure of the progenitor. Moreover, as we have seen above, the bolometric lightcurve is perfectly interpreted in the same frame and with the same mechanism as those used for other SN IIs. In particular the role of the radioactive decay of ^{56}Co to power the lightcurve is a confirmation of the first suggestions made by Weaver and Woosley (1980).

It turns out, then, that the main "peculiarity" of SN 1987 A is that it could be seen! Selection effects (like extinction and distance) favour, indeed, the detection of bright explosions (in visible light). And, for instance, if the same supernova would explode near Cass A (which is closer but in a region of high extinction), it could only be detected as a neutrino emitter and (perhaps) as an infrared source. This leads one to question the present supernova rates.

The (relative) proximity and low extinction of this supernova allowed intensive and complete studies, which proved the absolute necessity of such observations in order to get a trustworthy picture of what was going on. For

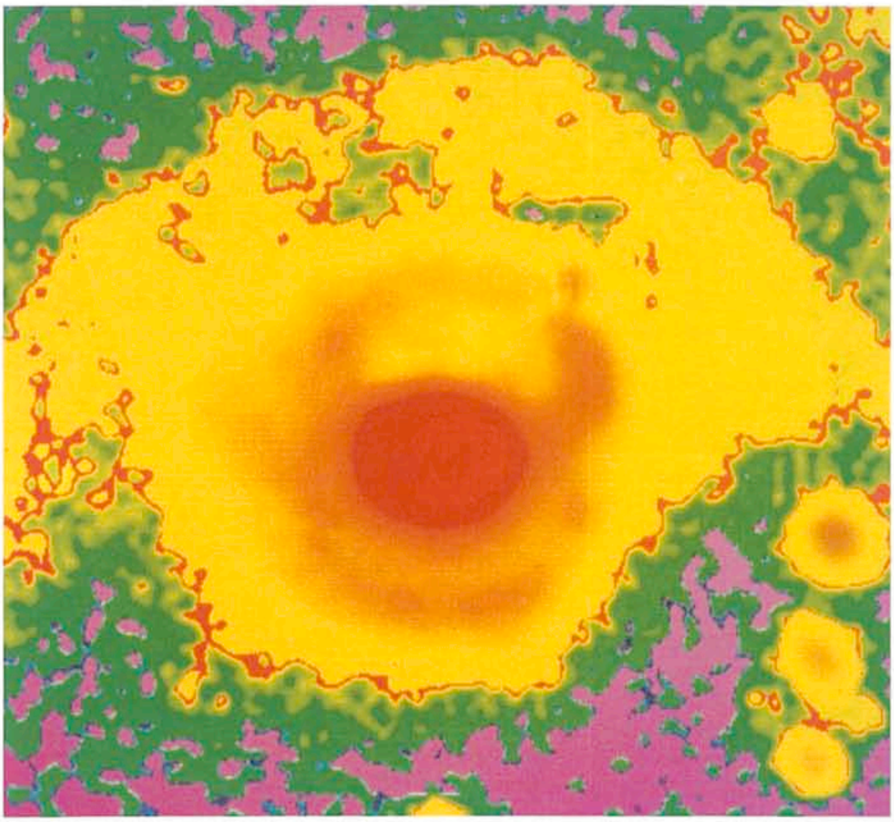

Figure 6: *A composite image in [OIII] and [NII] light of the nebulosity near SN 1987 A. The images were taken with the NTT by S. D'Odorico and M. Tarenghi on December 18, 1989. The images of SN 1987 A and its two field stars have been removed in order to show the nebular structure more clearly. North is up and East is to the left. The size of the figure is 14 × 13 arcsec.*

instance, the use of SN 1987 A to check the reliability of the absolute fluxes deduced from theory, showed that the models have to be quite sophisticated, and that a large amount of observational data has to be available. It now seems dangerous to use SN IIs as a kind of standard candles.

7.2 The New Concepts

The detection of the neutrinos a few hours before the explosion indicates the formation of a neutron star: this is the first direct evidence that this can really occur! These direct observations have been used to place new constraints on the fundamental properties of such particles (rest masses, lifetimes, magnetic moments, mixing angles, etc.), on important physical quantities such as the nuclear equation of state, and on the existence of exotic particles (axions and majorons). This is especially interesting as axions can be of importance in cosmology as candidates for the dark matter. However, although numerical simulations have reproduced the luminosity and the spectrum of those neutrinos, none could account for the energy balance of the explosion. Clearly, something is still missing in the current models.

Another important new concept introduced by the observations of SN 1987 A refers to the presence of an inhomogeneous mixing of shells of different chemical composition. In fact, mixing occurred:

- Before the explosion (induced by large-scale motions due to the rotation of the progenitor). This makes the academic dogma of an onion-shell-like structure (before the explosion) quite obsolete.
- During and after the explosion (due to Rayleigh-Taylor instabilities or to the expansion of hot bubbles of radioactive Nickel). This was realized because of the early detection of X and γ rays, the need to match the theoretical models to the observed bolometric lightcurve ("plateau"), and the interpretation of the visible and infrared spectra.

Finally, a major discovery was the detection by the ESO team of dust condensation in the metal rich ejecta with a clumpy distribution (Danziger et al., 1989, Lucy et al., 1989, 1990). One of the first implications of this discovery may be that the isotopic anomalies observed in meteorites can be explained in terms of dust of elementary and isotopic composition characteristics of the ejecta of a supernova which has condensed before being diluted into the primitive nebula of normal isotopic composition (Clayton, 1982). It seems then plausible that at least one supernova exploded in the vicinity of the proto-sun, some 10^6 years before its formation (Lee, Pappanasstassiou and Wasserburg, 1976).

7.3 The Open Questions

Although the appearance of SN 1987 A has led to new concepts as well as an extraordinary improvement in our understanding of type-II supernovae, some points remain obscure:

- The amount of dust condensed and its possible contribution to the total amount of dust in the galaxies. As pointed out by J. Wampler during this colloquium, the dust formed in the ejecta is expelled at great velocity and sooner or later will have to slow down, with a high probability of being destroyed.
- The enrichment of the circumstellar and interstellar matter in heavy elements (Danziger et al., 1990 were first to determine abundances and they show that there are large uncertainties in the quantitative estimates which are strongly model dependent).
- The stimulating role in star formation in dense interstellar clouds (Öpik, 1953; Herbst, 1977). Klein (1990) showed that the clouds could be destroyed in Rayleigh-Taylor time scales, and give rise to fragmented small clouds which could prevent star formation.
- The determination of H_o through a thermal interpretation at maximum visible light (Branch, 1977, found $H_o = 49 \pm 8$ kms^{-1} Mpc^{-1}). With the VLBI, Bartel (1990) estimated the distance to the LMC and deduced $H_o = 60 \pm 20$ kms^{-1} Mpc^{-1}, which in itself is not so new. However, Bartel stressed the point that he could get a far higher accuracy (~20%) by radio interferometry with Arecibo and VLBI.

On the other hand, some points traditionally related to the supernova phenomenon, or still speculative theories, have not received any input yet from SN 1987 A. Among them are the following ones:

- The relation between supernovae and phenomena observed in quasars;
- The acceleration of galactic cosmic rays in the shock wave fronts created by the explosion;
- The role of supernova induced star formation in producing and sustaining spiral structures in galaxies (Mueller and Arnett, 1976; Gerola and Seiden, 1978);
- The possibility that supernova explosions that took place during the first billion years or so after the big-bang (at a time when the galaxies we see today had not yet formed) impressed on the universe its large-scale structure (Ostriker and Cowie, 1981; Ikeuchi, 1981).

As one can see, future topics of interest are not missing! Much has still to be done to exhaust all the information collected during these first 1001 nights of observing SN 1987 A. These observations will be continued at La Silla, especially in the infrared and sub-millimetre ranges, where more than 80% of the energy is now concentrated. We will also witness the birth of the remnant, watching for any kind of surprise. New telescopes and new detectors will soon be in operation, and new exciting results will certainly be obtained.

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The Bolometric Light Curve of SN 1987 A

Continuing IR photometry in the J, H, K, L, M, N1, N2, N3, Q bands at ESO – La Silla combined with UBVRI photometry reported from CTIO (IAUC 4881, 4910) shows that the bolometric light curve on 10 November 1989 (day 991) lies 1×10^{38} ergs s^{-1} above a linear extrapolation from earlier epochs (Suntzeff and Bouchet, *A.J.* 1989, in press). This levelling off was already apparent for the previously observed day 14 August 1989 (day 903) though at a lower level of significance and is confirmed by observations in less than ideal conditions on 20 December 1989 (day 1030) when black body fitting gives T = 160 K and log L = 38.30 ± 0.05. Because more than 80 per cent of the flux is now emitted redward of the M band, the levelling off is almost completely due to the near constancy of the flux integrated over the M, N, Q bands for days 903, 991 and 1030. This implies that a hitherto undetected energy source is now contributing significantly to the total energy output. If it were due to ^{57}Co, the original amount would have to be 20–25 times the anticipated 0.0017 solar masses (Woosley and Pinto, Workshop on Gamma-ray Spectroscopy, 1988), but this is contradicted by the observed [Co II] 10.52 μ line strength on day 526 (Danziger et al., Proceedings of Santa Cruz Workshop, July 1989). A thermal echo from external dust seems unlikely since it would coincidentally need to have a colour temperature (150–180 K) similar to that of the SN's emission. Moreover, the corresponding scattering echo (cf. IAUC 4746) is not evident in the smooth UBVR light curves (IAUC 4881, 4910). Nevertheless, CCD frames should be inspected for new echoes within 5 arcsec of the SN.

Uncertainties in luminosities derived by fitting black body curves to the far-IR data have been checked using emission curves for isothermal dust clouds of as-