Summary of the Conference

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This meeting has been the third in a series on SN 1987A. The first workshop on the object was held at ESO and the second at George Mason University. In this review I shall concentrate on those subjects that were not already discussed at these two meetings.

Perhaps the most exciting development has been the discovery of light echoes around SN 1987A by Arlin Crotts. At this meeting we saw beautiful ESO and CTIO images of these ring-shaped light echoes. Furthermore Gilmozzi showed IUE observations which strongly suggest that the echo's UV precursor has now been detected at the expected radial distance from the supernova. It is particularly interesting that the light from the supernova appears to be expanding at 16c, which is the highest super-luminal velocity so far observed. It is particularly important to keep taking pictures of the light echoes around SN 1987A (at least once a month) since this is the only known way of establishing the three-dimensional structure of the interstellar medium. Such "interstellar tomography" should tell us whether the ISM consists predominantly of clouds or of sheets.

Two quite independent lines of evidence now support the 'standard model' in which SN II are powered by the decay of ^{56}Ni into ^{56}Co.

1. The exponential tail of the photometric light curve of the supernova has an e-folding time between 105 and 114 days; values which bracket the 113-day decay timescale of ^{56}Co. From the bolometric luminosity of the exponential tail it is estimated that the supernova will eventually form 0.085 ± 0.029 $M_\odot$ of Fe.

2. Infrared observations, which allow us to see deeply into the supernova envelope, have detected freshly-minted cobalt. Danziger described his observations of [CoII] at 1.547μ and 10.52μ. Danziger *et al.* estimate that 0.002 $M_\odot$ of Co was present at 400 days after core collapse.

The SAAO observations reported by Menzies show that, due to the leakage of γ-rays from the supernova, the bolometric light curve of SN 1987A has now fallen below the expected exponential decline by ~0.2mag. Extrapolation of the SAAO light curve predicts that the supernova will have m = 14 at 1000 days after core collapse. This suggests that Sk −69°202 B and C will start to interfere with observations of the supernova about three years after the time of core collapse. All bets on the luminosity evolution of the supernova are off if, as Dwek has suggested, dust starts to form in the supernova ejecta.

One of the great mysteries surrounding SN 1987A remains why its progenitor was of spectral type B3I. Quite special initial conditions are required to produce a supernova precursor that will explode as a blue supergiant. Stellar evolutionary calculations by both Nomoto and Woosley appear to require $Z(SN) \sim Z_\odot/4$. This seems to conflict with stellar observations that indicate the $Fe(LMC) \simeq 0.6Fe\ (\odot)$. Since the LMC is a barred spiral, in which the interstellar medium will be constantly stirred up, it is implausible that this discrepancy is due to localized abundance variations. (Photometry of LMC Cepheids on the Washington System also militates against localized variations of Fe in the Large Cloud). Perhaps the most plausible resolution of this problem is that the solar oxygen abundance, which is observed to be ~0.3dex higher than that in the Orion nebula, is wrong. Alternatively the solar surface abundance of oxygen might have been affected by infall of comets (which are oxygen-rich) or by mass-loss via the solar wind (which is oxygen-poor). [I am indebted to Mike Dopita, Reg Dufour, Michael Feast, Hugh Harris and Manuel Peimbert for helpful discussions and correspondence on the Z(LMC) problem].

The observations of SN 1987A show that the structure of supernova progenitors is more complex than had previously been thought. It now appears that the Nickel bubble at the centre of the progenitor becomes R-T unstable resulting in some mixing of radioactive material to the surface. This explains why hard X-rays emerged earlier than predicted from homogeneous models and it also accounts for the observed ratio of γ-ray lines to X-rays. That mixing is important in supernova progenitors is also demonstrated by observations of the optical remnant of Cassiopeia A. In this object some pure S filaments are observed at greater distances from the centre of expansion than some pure O knots. Since sulphur is formed in deeper layers than is oxygen this suggests that the progenitor of Cas A mixed immediately after core collapse. Mixing during the explosion of the progenitor of SN 1987A might also explain the presence of Ba without C.

Shull pointed out that there may be an 'ultraviolet Renaissance' in the fall of 1988 due to the fact that the Balmer continuum in the SN shell will then become optically thin. It is presently expected that the 'dark ages' resulting from dust formation will not occur before the beginning of the ultraviolet Renaissance. The reason for this is that the radio activity of the supernova shell will inhibit the formation of the nuclei of dust grains.

Other interesting new results reported at the meeting were:

1. The neutrino mass is <16eV at the 95% confidence level.

2. Burrows reported that the statistics of neutrino arrival times show that (a) SN 1987A collapsed to a neutron star and not to a black hole and (b) this neutron star must have a mass in the range of 1.2-1.7 $M_\odot$.

3. Observations at the AAT, CTIO and ESO have set new limits on the fraction of the luminosity of SN 1987A that can be due to the pulsar. The limits obtained by observers at these three observatories are:

- ESO $< 2 \times 10^{-4}$
- AAT $< 1 \times 10^{-5}$
- CTIO $< 7 \times 10^{-6}$.

Finally, the presentation by the Rev. Robert Evans reminded us of the great debt which professional astronomers owe to the amateurs who provided us with the crucial first data points on the light curve of SN 1987A and who have also found many of the supernovae that we studied.

On behalf of all of the visitors from overseas, I should like to take this opportunity to thank our Australian hosts for their splendid hospitality.