an exponential atmosphere reveal a smaller tendency to fragmentate. As said above, however, it is not yet possible to make an appropriate choice of the galactic atmosphere. Moreover, the structure of the disk in the z direction appears to be dependent on blow-out events and the following dynamical evolution of the expelled gas. Corbelli and Salpeter (1988) have for instance shown that relatively weak current blow-out activity can be effective in compressing an outer H I disk and, possibly, in giving it a sharp edge.

The evolution of the expelled gas may be described in terms of a "galactic fountain" model, as proposed by Shapiro and Field (1976). Due to thermal instability, the rising hot gas converts into H I clouds falling onto the disk. These clouds resemble some of the so-called "high velocity" clouds (HVC) discovered by Dutch astronomers in the middle of the 60's; see the recent survey paper of Hulbosh and Wakker (1988). Such models of the galactic HVC – the first one was elaborated by Bregman (1980) – seem to be attractive. The main problem of the models is poor knowledge of n and T in the galactic corona and consequently a badly known cooling time scale. For typical $T = 2 \times 10^6$ K and $n = 2 \times 10^{-3}$ cm^{-3}, say, the (radiative) cooling time exceeds 10^8 years, which appears to be longer than the time scale of heating by supernovae.

Without discussing in detail the results obtained in our model calculations (see Igumentshchev et al. 1988, 1989; very recent results are in preparation for publication), we note that cool fragments may be interpreted as seed clouds for HVC. The masses of observed HVC, when estimated under the assumption that they are situated at mean galactic distances, are 10^4–10^7 solar masses. The fragments seem to be smaller, but it is possible for them to grow. They are massive and large enough ($R \sim 20$–50 pc) to persist against evaporation. Moreover, if rising with the given velocities up to 0.7–2 kpc over the plane, they could act as a sink of thermal energy of hot coronal gas. A simple estimate, according to the theory of McKee and Cowie (1977), shows that the largest fragments are resistant to evaporation (radii exceeding the critical value) and should condense.

Note also that the proposed mechanism of sequential supernova explosions cannot explain the extremely large ($R \simeq 1$ kpc) supershells unless one assumes very low densities $n \simeq 0.01$ cm^{-3}. Even in that case one must suppose enormously rich OB associations in order to explain the large kinetic energies. On the other hand, the most common supershells with radii ~ 0.2–0.5 pc are explained quite well by this model.

I am grateful to the staff of ESO for help and friendly assistance during my stay in Garching.

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Searching for Light Echoes from Circumstellar Dust Shells Around SN 1987A

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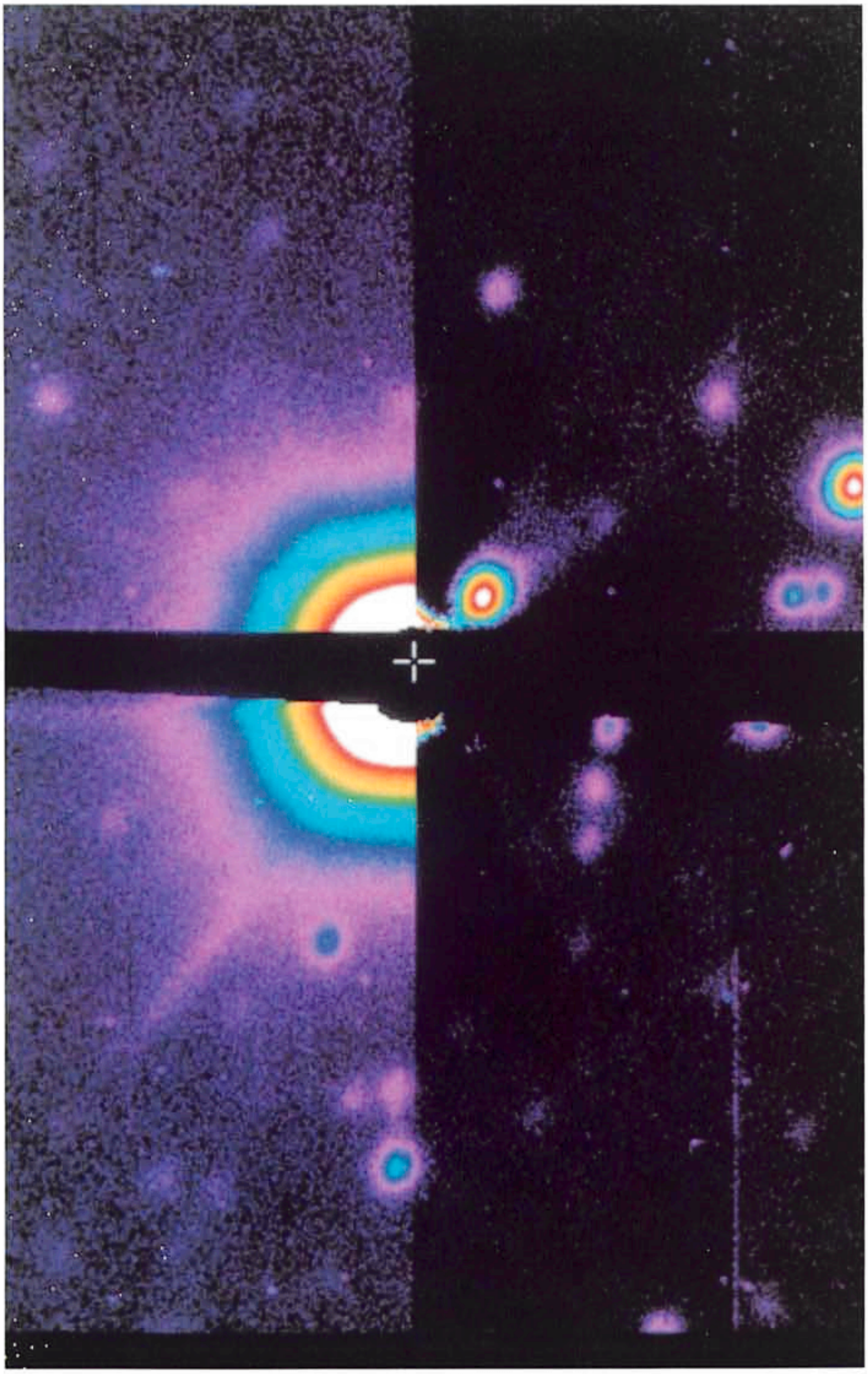
The Space Telescope Science Institute coronograph (described in the *Messenger,* **47,** p. 43) mounted on the 2.2-m telescope at La Silla was used by myself and my colleague Chris Burrows to look for light echos in the immediate vicinity of the SN 1987A in the LMC. This technique allows us to probe circumstellar regions from about 2 to 20 arcseconds in the vicinity of very bright objects such as the SN 1987A for faint features otherwise completely lost in their glare. At the time of the observation reported here, carried out on December 21, 1987, the SN brightness was V = 6.2. Echoes at these angular distances and time of observation correspond to linear distances from the SN roughly in the range of 1–15 parsecs in front of the star near the observer's line of sight. At these distances, any echo would most probably be emitted from matter expelled from the SN itself at some earlier epoch when it was a hot main-sequence giant and/or a red giant star in its way towards eventually becoming a SN. Theory predicts and many observations confirm that shells of swept-up stellar material including dust formed in the outer layers of an expanding photosphere or wind would be expected to linger in the general vicinity of the SN and be observable by the delayed scattering of the SN light pulse. The echo would manifest itself in the form of a luminous ring of several arcseconds radius centred roughly on the SN itself. The ring might, in practice, be incomplete if the shell structure were not homogeneous. Rings of this type located much further away have been observed around SN 1987A (see the *Messenger,* No. 52, p. 13) but are thought to be due to scattering from sheets of interstellar dust lying between us and the SN and not related to the SN itself.

The accompanying composite image corresponding to a 10-minute exposure taken with the ST ScI coronograph through a standard B filter illustrates graphically the result we obtained. The full field of view shown in this image is 22 by 36 arcseconds with North up and East to the left. The occulted centre of the SN is located at the position of the cross at the centre of the image where the occulting wedge running EW is 1.9 arcseconds thick. Each pixel in the 512 × 320 pixel frame corresponds to an area of $5 \cdot 10^{-3}$ arcseconds^2 while 1″ corresponds to a linear scale of ~ 0.83 light-years at the source. The left or



eastern half of the image corresponds to the eastern half of the cleaned, bias-subtracted, flat fielded image of the SN and its surroundings. In this portion, the seeing broadened image of the bright central source extending to approximately 5 arcsec from the centre is very prominent. The seeing during this exposure was 0″.8 approximately, as evidenced by the size of the stars in the field and the narrow diffraction spike in the SE.

The right or western half of the composite image represents instead the western half of the image obtained from the first by careful subtraction of the purely stellar profile. We found that a comparison of the observed profile with the theoretically expected one from atmospheric turbulence theory provides an effective means of assessing the residual circumstellar emission down to ≃ 2 arcseconds from the star. As can be seen from even a superficial inspection of the right half of this image, no conspicuous features appear anywhere in the field beyond the dozen or so stars and a few artifacts associated with the detector. All the stars observed were known to be there before the eruption including star 2 of the Sk-69 202° complex located at 2″.8 and 320° p.a. in the image shown here. This is the first sighting of this star after the SN 1987A eruption and its magnitude (B = 15.1) confirms the pre-eruption measurements. The rather surprising result we obtain is that excluding the thin occulted strip running EW through the image, the presence of significant amounts of circumstellar material in the region probed by the light pulse at the time of observation can be excluded to a reasonable degree of confidence. Specifically, the absence of detectable rings around the SN to brightness levels greater than approximately 22.5 blue magnitudes arcsec^{-2} implies upper limits to shell column densities of hydrogen ranging from about 10^{16} atoms cm^{-2} in the innermost observable regions to about 10^{18} atoms cm^{-2} in the outer ones. If the shell is broken up into smaller and isolated components, these limits would have to be revised upwards, of course, since irregular diffuse features are harder to detect.

Since the echo emission pattern around the SN is very time dependent owing to the rapid expansion of the echo ellipsoid as it sweeps out into the surrounding circumstellar medium, it will be interesting to see whether this result will continue to hold true. If it does, it implies that this particular SN is located in a cavity of suprisingly low gas density. How this can come about is now a subject of some speculation. Continued monitoring of the SN as it fades and the delay ellipsoid sweeps into areas unobservable in the December 21, 1987 time period should provide exciting new information on the past evolution of this amazing object.

Note added in proof

On February 6, H.E. Bond, N. Panagia, R. Gilmozzi, and M. Meakes, Space Telescope Science Institute, report (IAU Circular 4733) that direct CCD images of SN 1987A, obtained in B, V, and R at Cerro Tololo on January 24, 1989, appear to show a new light-echo feature. In addition to the two previously known echo rings, which now lie at radii of approximately 46″ and 78″ from the supernova, a new, nearly circular feature is seen at a radius of only 9″.5 (projected radius 2.4 pc). Its surface brightness is comparable to that of the two outer rings, but is highest in a rim on the eastern side of SN 1987A. This feature would imply the existence of dust lying at a distance of 5.9 pc from the supernova (assuming that it is illuminated by light emitted at the optical maximum in May 1987).