flux, assumed to be $10^4\ \Phi_4$ photons $\text{cm}^{-2}\ \text{s}^{-1}$, where $\Phi_4 \sim 1$ (refs 8, 9). This requires a cloud radius

$$r_{\text{UV}} \gtrsim 39\ \Phi_4 R_{50}^4 \dot{M}^{-2} v_7^{-2}\ \text{kpc} \tag{10}$$

and we obtain $r_{\text{UV}} < r_c$ if

$$\dot{M} \gtrsim 18 R_{50}^2 v_7^{-6.5} \Phi_4 M_\odot \quad \text{yr}^{-1} \tag{11}$$

(Fig. 1).

The details of the process of star formation are not well understood. However, there is a substantial range in $\dot{M}$ and v_7 (Fig. 1) for which Jeans unstable clouds can arise. We propose therefore that shells of $\gtrsim 10^8\ M_\odot$ of stars can sometimes form from galactic wind material at large distances from elliptical galaxies. The approximate spherical symmetry of the wind will be reflected in the distribution of the stars. To form a thin shell, the star formation must occur on a time scale which is short relative to the free-fall time. Patches of stars may form at several different radii following thermal instabilities in a thick region of shocked gas ($\Delta R \sim R$) or from velocity changes in the wind. These changes could be due to a cooling instability in the core of the galaxy[4], or to more dramatic events such as the accretion of a gas-rich companion or an outburst of the nucleus. Continuous star formation at a fixed radius gives the appearance of a thin shell, as the acceleration of the stars from rest under the influence of the galaxy gives a density profile $\rho_* \propto (R_s/R - 1)^{-1/2}$. Localized bursts of star formation in more peculiar galaxies might lead to small-scale wind shocks. The loop structures seen in Fornax A (NGC1316) could, in part, be due to this mechanism.

Star shells produced at large distances from a parent galaxy may remain roughly spherical for a reasonably long time scale $\sim t_{\text{ff}}$. This will be the approximate age of the component stars. We therefore expect the shells to appear bluer[11] than the parent galaxy (up to ~0.5 mag in $U-B$ and $B-V$) if the initial mass function is similar to that in the solar neighbourhood. Thereafter these high-velocity stars may contribute to the outer galactic envelope. Shocks in denser galactic winds at earlier epochs could have created substantial isothermal stellar envelopes to galaxies.

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Volcanic material from Mount St Helens in the stratosphere over Europe

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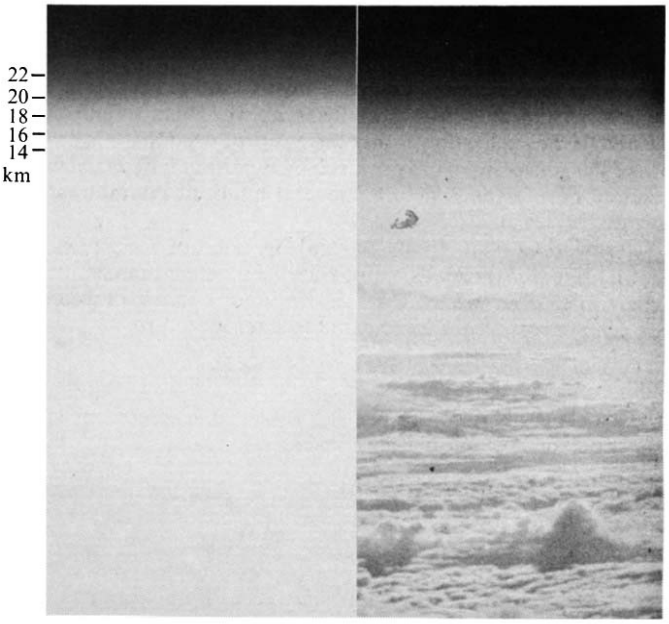
The two most recent balloon flights devoted to studying the stratospheric aerosol vertical structure by comparison with winds, temperature and ozone vertical structures took place on 7 May and on 5 June 1980. At 15.23 h GMT on 18 May Mount St Helens volcano (46 °N, 122 °W) erupted with a tremendous explosion, projecting ash into the stratosphere. An explosion of this size occurs only about once a decade[1]. This sudden introduction of material into the atmosphere offers the opportunity to study air motions both horizontally and vertically. The last such large-scale opportunity was offered by the Mount Fuego eruption which took place in 1974. In this latter case, the enhancement of stratospheric aerosols was observed by means of ground-based lidars and of balloon-borne particle counters. The time development of the aerosol event in 1974 and 1975 has been described elsewhere[2–4]. Mount St Helens material can now also be traced by various satellite-borne instruments. This new stratospheric aerosol event appears to be spectacular. As shown by the photographs discussed here, it leads in its early stage of development to an increase by a factor of three of the Earth limb reflectivity at 15-km altitude after a period of several years of low stratospheric aerosol content.

The new method[5] is based on the photographic observation from balloon altitude of the Earth limb in the azimuthal direction of the Sun at low solar elevation angles. Aerosols are known to scatter light mostly at small angles whereas, comparatively, Rayleigh scattering by air molecules occurs almost evenly at all angles. Our observational geometry favours aerosol detection.

At balloon altitude the camera lenses view the Earth limb below the horizontal line directly and the Sun above it through a neutral optical density ($D \cong 4$) screen which serves several purposes. It avoids penetration of straylight in the optics to obtain clean pictures of the Sun at various elevation angles providing an angular scale. It puts both the Sun and the Earth limb in the sensitive dynamic range of the film calibrated in relative units by means of a step wedge photographed before flight. The solar images provide the absolute scale. The gondola is Sun oriented so that the cameras have the Sun in the middle of the horizontal field of view. Colour (Kodak EPR 475) and black



5 June 1980 7 May 1980

Fig. 1 Photographs of the Earth limb taken with identical exposure settings in the azimuth of the Sun at low solar elevation angles from balloon gondolas on 7 May and on 5 June 1980. The gondolas were at 37- and 35-km altitude respectively. An altitude scale of the grazing line of sight is shown in kilometres. Below the dark blue sky horizontally stratified aerosol layers are revealed by scattered sunlight. In the 5 June case, material from the Mount St Helens volcano has spread in the low stratosphere over a large horizontal extent. It enhances the brightness of the limb so that the cloud cover in the foreground can hardly be seen through the whitish veil. In contrast, the cloud cover is well visible on 7 May. Note that the grazing point at 16-km altitude is some 500 km away from the camera. An altitude difference of 1 km at that altitude corresponds to 7 arc min.

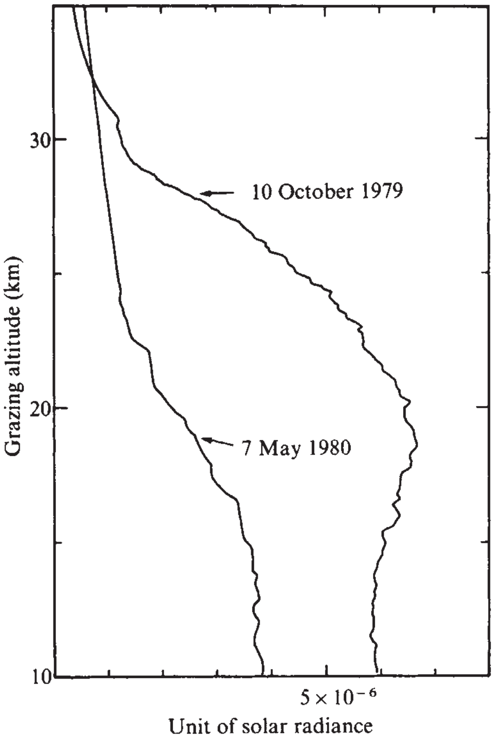


Fig. 2 Earth limb radiance in the azimuth of the Sun versus grazing altitude of the line of sight. The solar elevation angles were respectively 6.18° and 6.94° on 10 October 1979 and on 7 May 1980. The variation of the limb radiance versus altitude is relatively smooth in both cases. As most of the radiance observed is due to scattering by particles, their amount in the low stratosphere appears larger in October than in May where a low aerosol background had been reached. The situation at higher altitudes seems to be reversed. However, these aspects require confirmation from other flights and further interpretation of these raw data where ozone and air absorption should be taken into account. The uncertainties due to difficulties of the photographic photometry have also to be considered.

and white (Kodak Plus X Pan) 70-mm films are used. The results reported here were obtained in the red using Wratten filters nr. 25 set in front of the 80-mm focal length lenses of the Hasselblad EL500 cameras and without filter. The cameras are remotely operated from the ground. The telemetry return signal allows us to check their operation.

Three flights are considered here. The first two took place on the afternoons of 10 October 1979 and 7 May 1980 from Aire sur l'Adour in south-west France. To determine the geographical coordinates as accurately as possible, the tracking was performed by the CNES telemetry station and by radars located at the Centre d'Essais des Landes (Biscarosse). The altitude, longitude and latitude of the gondola at the time that the picture was taken were respectively 37 km, 1° E and 44° N. The third flight took place on 5 June 1980 from the other CNES range in the Alps. Radar tracking was performed in this case from Ile du Levant on the edge of the French Riviera. The coordinates were 35.2 km, 2° E and 44° N.

Inspection of limb pictures such as those shown in Fig. 1 reveals the presence of aerosol layers with a thickness ranging from 100 metres to several kilometres. The latter layers extend horizontally over the whole field of view whereas the thinner layers may have a smaller extension. The black and white photographs are analysed using a Jarrell-Ash densitometer. Grazing altitudes in the stratosphere are determined using the tables of Link and Neuzil[6], taking refraction into account.

The Earth limb radiance is deduced from the densitometric measurements. The radiance vertical profiles observed on 10 October 1979 and on 7 May 1980 in white light are compared in Fig. 2. These profiles are similar showing mostly smooth vertical structure. Figure 3 shows the vertical radiance profiles observed in red light on 7 May and on 5 June 1980. The abrupt radiance increase observed on 5 June between 15- and 16-km altitude is similar to the increase of particle amount observed shortly after the Fuego eruption[2-4]. The very sharp cutoff at the upper boundary of the layer is typical.

On the other hand, satellite-borne instruments have tracked at 16-km altitude material from the volcano crossing the east coast of the US on 23 May and moving towards Europe above the Atlantic Ocean on 27 May (M. P. McCormick, personal communication). The observation reported here is likely to have occurred shortly after the arrival over Europe.

Theory[7,8] predicts that a stratospheric aerosol increase reduces the amount of solar energy reaching the troposphere and the ground. Two main processes are involved: absorption in the aerosol layer and reflection to space of solar energy flux leading to small average temperature decreases in the troposphere[4,9]. The reflectivity data reported here will be augmented by further flights and together with other absorption data will hopefully improve the understanding of the problem and help to evaluate more precisely the possible impact of stratospheric aerosol events.

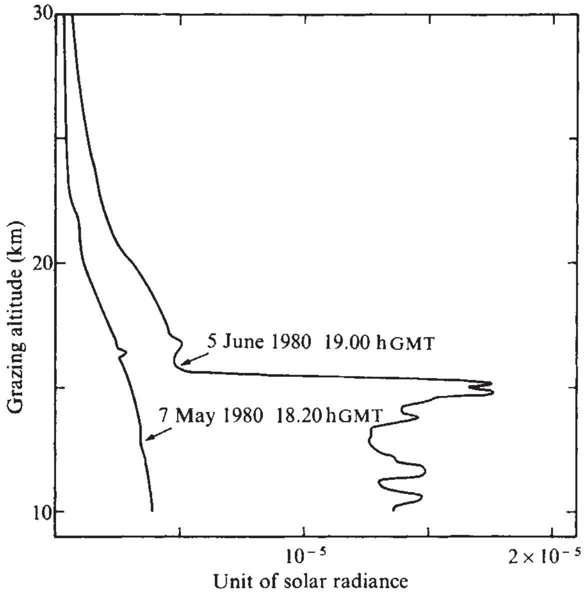


Fig. 3 Earth limb radiance in the azimuth of the Sun and in units of solar radiance versus altitude of the grazing line of sight. The solar elevation angles were respectively 6.94° and 6.26° on 7 May and on 5 June. The large and sharply cut radiance increase between 15.6 and 15.2 km is due to the stratospheric loading of volcanic material. The radiance increase at higher altitudes is thought to be partly due to the illumination increase of the upper levels by the lower levels. The thin layers (some 300-m thick) at some 16.5-km altitude seems to be a frequent feature of the mid-latitude stratosphere and is thought to be related with the height of the tropical tropopause.

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