accurate absolute ages for globular clusters to test this assumption — which is also unfortunate for cosmology, as these objects provide the oldest identifiable structures in the Galaxy and would provide a good lower bound on the age of the Universe.

The best attempts can be made by comparing observations of the brightness and colours of their stars with theoretical models of stellar evolution, but the estimates are uncertain because of the influence of the chemical composition of the stars on their evolution. The chemical content affects lifetimes both by regulating the transfer of radiation through the star and in determining how much nuclear fuel is available. Nevertheless, by comparing globular clusters which have the same chemical composition[1], VandenBerg *et al.* have obtained *relative* ages of some clusters to an accuracy of half a billion years.

The interesting result is that for the chemically poorest (and, hence, probably the oldest) clusters, there is very little dispersion in age, whereas the more chemically rich clusters may have formed over an extended period in excess of two billion years. This implies a rapid, coherent start to the halo formation, but that the formation of the clusters then became more sporadic while the chemical abundances built up as a result of supernova explosions of the massive stars. The star clusters may have formed here and there in regions of different chemical composition, although locally the regions of cluster formation must have been chemically homogeneous because (with few exceptions) the stars in each cluster share a common chemical abundance.

Meanwhile the disk was forming. The most obvious difference between the disk and the halo (apart from chemical differences) is in their rotational properties. The disk rotates rapidly, whereas the average rotation of the halo is small, with some stars even on contra-rotating orbits. Presumably the disk's fast rotation is a result of conservation of angular momentum during the collapse associated with its formation. Stars with chemical abundances below about a sixth of that found in our local thin-disk star, the Sun, have generally been found to belong to the slowly-rotating halo. At least two surveys[2,3] now find stars which have considerably lower metal abundances (1/40 –1/10 of solar) but whose rapid rotation about the Galactic Centre implies that they are true disk stars, probably of the thick component. Thus it seems likely that star formation in the disk started not long after the start of halo formation, and both proceeded together for some considerable time.

Two other, rather preliminary results are rather curious. In the work by Morrison *et al.*[2], there is an indication that the fall off in density of stars with distance from the Galactic Centre may be steeper in the thick disk than in the thin component. This is the reverse of what might be expected if the thin disk had formed by contraction inside the thick disk. Second, although it has been known for some time that many red giant stars near the centre of the Galaxy have a high chemical abundance — a metal-rich component of the inner region of the halo — it has been assumed that the halo out near the Sun is chemically poor. Infrared photometry of M-type giant stars[4] now suggests that there are some M giants high in the halo above us which are just as chemically rich as stars in the nuclear region. These cool M giant stars have molecule-filled atmospheres which are rather tricky to analyse accurately, so it may be premature to accept the existence of an extended chemically rich halo component. But if it is real, this could be interpreted as further evidence indicating an extended period of star formation in the halo. It is hard to see how the old-disk stars could have low chemical abundance if a preceding halo had built up high abundances, unless there were very large chemical inhomogeneities.

Whether halo star formation continued until quite recent epochs is difficult to say, but it is an important question. If it did, there would be considerable implications for observational searches for evolutionary changes in other galaxies at relatively modest redshifts. A good test would be the discovery of stars showing halo-type kinematics but which are too massive, and hence too short-lived to have survived since the early epoch of halo formation. Metal-rich F or early G-type dwarfs would be suitable. Possible halo candidates with considerably higher masses are known, but they are generally accounted for in other, slightly *ad hoc* ways.

Faced with these latest archaeological artefacts, it may be prudent to abandon fixed ideas of a fast Galaxy formation. As realized by the authors of these new studies, the real formation may have been a much more drawn out and disorganized process[5], with isolated regions evolving on their own for some time before merging into the fairly well-defined structure we see. How long these dark ages actually lasted is a crucial question to answer, and fixing the absolute times at which the globular clusters and halo stars formed would be a significant advance. □

M. G. Edmunds is in the Department of Physics, University of Wales College of Cardiff, PO Box 913, Cardiff CF1 3TH, UK.

1. VandenBerg, D. A., Bolte, M. & Stetson, P. B. *Astr. J.* **100**, 445–467 (1990).
2. Morrison, H. L., Flynn, C. & Freeman, K. C. *Astr. J.* **100**, 1191–1222 (1990).
3. Norris, J., Bessell, M. S. & Pickles, A. J. *Astrophys. J. Suppl.* **58**, 463–492 (1990).
4. Feast, M. W., Whitelock, P. A. & Carter, B. S. *Mon. Not. R. astr. Soc.* **247**, 227–236 (1990).
5. Searle, L. & Zinn, R. *Astrophys. J.* **225**, 357–379 (1978).

DAEDALUS

Firefighting foam

THE greenhouse effect, that increased retention of the Sun's radiation by carbon dioxide accumulating in our atmosphere, is now worrying even politicians. One possible answer, which has been dignified by editorial discussion in these pages, is to reflect sunlight away from the Earth by terrestrial or space-borne mirrors. Even Daedalus rejects this notion as sheer technomania; but the idea behind it is sound. Extra cloud in the atmosphere would have the same effect. Does the vapour trail of an aircraft reflect away enough sunlight to cancel the effect of the extra carbon dioxide it puts into the air? Sadly, the answer is no; but a related idea looks much more hopeful.

A ship can leave a turbulent wake hundreds of metres wide, and thousands of kilometres long. If the white foam produced by its turbulence could be stabilized in some way, it could reflect many gigawatts of solar radiation away from the Earth for as long as it lasted. Daedalus recalls the early, non-biodegradable domestic detergents, and the terrible pollution they caused in rivers and sewage works with their tenacious, almost permanent foam. DREADCO's chemists are now resurrecting some of these long-banned detergents, and trying to make them more surface active, polluting and permanent still. A sufficiently surface-active detergent would not dissolve in bulk seawater at all, but would spread over the surface as a sort of slick. Spread from a ship, it would convert the transient wake into a wide swathe of stable white foam. Such a foam would reflect maybe 80 per cent of the sunlight hitting it, instead of the 5 per cent or so of normal seawater. A good detergent can foam in such low concentrations that a few tons of it, leaked steadily into the sea by a transatlantic vessel, might leave a stable foamy track the whole way across.

If sufficiently biologically inert and polluting, such a foam could last for weeks or months. Even when it finally collapsed, the underlying detergent slick would still remain, ready to be whipped into foam again by storms, or further passing ships. Daedalus estimates that the world's shipping could easily keep 5–10 per cent of the ocean surface covered with reflecting foam, quite enough to cancel out the greenhouse warming of our industrial and forest-burning carbon dioxide emissions.

Thus the greenhouse can be staved off without giving in to the Greens. All that is required is a simple modification to the world's shipping. Carbon taxes, limits to growth, conservation, harmony with nature, and pettifogging searches for efficiency and economy, can all be quietly forgotten. The glorious expansionist machismo of industrial growth and profligacy will be able to roll grandly on till Kingdom come. David Jones