aflatoxins) is required. When sufficient cases of hepatocellular carcinoma have appeared in a cohort of HBA-positive carriers, previously collected and stored samples of blood and urine will be analysed for the presence of specific markers of exposure to carcinogens. If exposure to a defined chemical carcinogen (or group of carcinogens) is implicated, the same cohort could be used for intervention studies, whereby removal of the exposure should reduce the risk of hepatocellular carcinoma.

One case where human exposure to defined doses of alkylating carcinogens results in tumours is that of second cancers resulting from chemotherapy for childhood leukaemia. It has been calculated that in Europe and North America there

may be as many as 750 new cases annually of rapidly fatal, iatrogenic leukaemia per annual cohort of Hodgkin's disease patients, who have received treatments with alkylating agents. To eliminate this tragic side-effect of an otherwise efficacious therapy, it is necessary to elucidate the mechanisms of carcinogenic (as opposed to carcinostatic) action of drugs such as cyclophosphamide. The sort of rapidly advancing techniques of DNA-adduct identification and quantification that were described at the meeting, in combination with cancer epidemiology, are needed to address this problem (J. Kaldor, IARC). □

David E. G. Shuker is at the International Agency for Research on Cancer, 69372 Lyon, Cedex 08, France.

Solar System

Organic chemicals in comets

T.R. Geballe

THE generally accepted dirty-snowball theory of comets, formulated by Fred Whipple 37 years ago, predicts that comets are frozen mixtures of dust and various gases and that they formed out of material in the outer reaches of the primordial solar nebula. Observations of cometary material, therefore, can provide information on the original composition of the nebula and on the early evolution of the Solar System. Last year, space probes demonstrated that organic molecules are present in comet Halley^{1,2}, a frequent visitor to the inner Solar System. At least some of these molecules were also detected in Halley in several ground-based infrared spectroscopic measurements³. Now, Allen and Wickramasinghe report in a paper on page 615 of this issue⁴ the ground-based detection of similar organic molecules in the coma of comet Wilson (see figure), which is visiting the inner Solar System for the first time.

Their evidence lies at infrared wavelengths near 3 μm , a spectral region where vibrationally excited C-H bonds radiate strongly. The exact wavelengths of the vibrations depend on the other atoms to which the carbon atoms are attached. In comet Halley, and now in comet Wilson, the observed chemicals emit between about 3.3 and 3.5 μm ; the principal emission feature is approximately 0.1 μm wide and peaks near 3.36 μm . This is different from the profiles of features in this wavelength band, also attributed to organic molecules, seen in various interstellar environments (ultraviolet-excited nebulae, the diffuse interstellar medium and dark clouds).

Unfortunately, the number of hydrocarbons is so overwhelming and many of their spectra are so similar (as well as

complex) that unique identifications are very difficult, especially when observed spectra are limited by low spectral resolution and low signal-to-noise ratios, as they have been in comets. In the case of comet Wilson, detailed reports of higher-resolution spectra will soon be published (A.T. Tokunaga, personal communication), but they are unlikely to provide identifications. It is not even clear whether the molecules

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Comet Wilson, showing the short dust tail pointing towards the south-west and the ion tail (> 3° long) pointing to the south-east.

emitting the 3- μm feature are free or are embedded in solid matter.

Allen and Wickramasinghe suggest⁴ that the spectra of the organic materials in comets Wilson and Halley, and hence the materials themselves, are actually slightly different. They also hypothesize a sequence in the degree of chemical modification by starlight of a basic initial galactic mixture of organic materials, whose resultant spectra extend from that of comet Wilson to those seen in the diffuse interstellar medium, with comet Halley's spectrum somewhere in the middle. Both of these conjectures can be debated, and not only on arguments of signal-to-noise difficulties. It is dangerous to infer the

emission spectrum of a material on the basis of its absorption spectrum, and vice-versa, if the material itself is unknown. But, whether or not Allen and Wickramasinghe's suggestions are correct, perhaps the most interesting and basic result of their work is that the spectra of the two comets closely resemble each other.

When a comet approaches the Sun, the outer surface is vapourized and blown away, exposing fresh material. The diameter of comet Halley, for example, decreases by a few metres per orbital period. The similarity of the 3- μm spectra of comets Wilson and Halley therefore implies that the organic materials ejected from the surfaces of the youngest comets are similar to those that were deep within comet Halley when it formed. There are at least two possible explanations for this. The 3- μm emission feature in comet Wilson might have originated in molecules that were not altered significantly by exposure to cosmic rays or ultraviolet light during the 4.6×10^9 years that they spent on the surface of the comet while it was within the Oort cloud (where all comets formed). Alternatively, the emitting molecules in both comets could have formed only as the comets approached the Sun, after the destruction of similar parent molecules. It is well known that many molecular species observed in comets are the result of dissociation of other species by solar ultraviolet radiation.

A more basic question, still far from being answered completely, is how closely the chemical constituents buried in comets resemble the original molecular cloud material out of which the Solar System formed. It seems likely that the compositions should differ to some extent because, as the outer regions of the primordial solar nebula were heated by the forming Sun and as the comets were heated internally during their formation, the most volatile materials would have been lost from the dust grains out of which the comets were forming⁵. To answer these questions more quantitatively requires detailed laboratory and observational studies and modelling. Obviously, space missions that sample cometary materials on and below the surface, would be the most direct approach, but these are unlikely for the next decade. Nevertheless, with infrared astronomical spectroscopists willing and increasingly able to make ground-based measurements of comets, a steady stream of some of the necessary data should be forthcoming. □

1. Combes, M. *et al.* *Nature* **321**, 266-268 (1986).
2. Kissel, J. *et al.* *Nature* **321**, 336-337 (1986).
3. Baas, F., Geballe, T.R. & Walther, D.M. *Astrophys. J.* **311**, L97-L101 (1986).
4. Allen, D.A. & Wickramasinghe, D.T. *Nature* **329**, 615-616 (1987).
5. Yamamoto, T. in *Ices in the Solar System* (eds Klinger, J. *et al.*) 205-219 (Reidel, Dordrecht, 1985).

T.R. Geballe is at the United Kingdom Infrared Telescope, 665 Komohana Street, Hilo, Hawaii 96720, USA.

Royal Observatory, Edinburgh