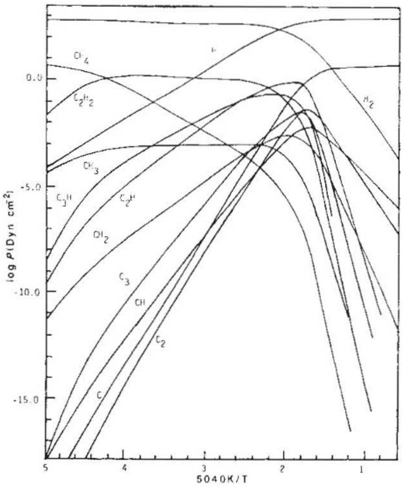
Diamond formation in carbon-star atmospheres

SIR—Lewis *et al.*[1], from electron-microscopic examination of HF/HCl-insoluble residues of the Murchison (type C2), Murray (C2), Allende (C3V) and Indarch (EH4) meteorites, have discovered diamond grains typically 50 Å in size and in concentrations up to 400 p.p.m. Mass spectrometry revealed Kr and Xe to be enriched twofold in the lightest and heaviest isotopes, ^{15}N depleted relative to terrestrial standards, and to have ^{13}C within the terrestrial range. They argued that the diamonds are of extra-solar origin, with hydrogen, nitrogen and the noble gases having been ion-implanted during a supernova event after ejection of the grains from a red giant or planetary nebula, and that laboratory experiments that produce diamond films from the gas phase[2] support a stellar-atmosphere origin.

I have examined this hypothesis to determine whether it is consistent with stellar atmosphere models. Calculations of the equilibrium abundance of molecular species in carbon-star atmospheric conditions[3] (see figure) show a decrease in atomic hydrogen abundance at temperatures below 3,150 K. Also in this temperature range, many carbon molecules (CH, CH_2, CH_3, CH_4, C_2, C_2H, C_2H_2, C_3, C_3H) are formed. This is interesting because the stellar atmospheric pressure, $P_g = 10^3$ dyn cm^{-2} = 0.75 torr, and composition ratio, H/C = 200, are comparable with those of diamond-film-forming experiments by vapour deposition, in which atomic hydrogen appears to be necessary[2]. A gradient in hydrogen-atom concentration is to be expected in both the laboratory experiments and stellar atmospheres. In the laboratory this gradient exists because of the association of hydrogen atoms into molecules at the substrate surface, resulting in hydrogen-atom depletion in a layer near the surface and diamond film formation on the substrate. In the stellar environment the gradient in hydrogen-atom concentration would be a consequence of a thermal gradient and the relation given by the equilibrium calculation[3] shown in the figure.

The envelope of an evolved star is convective, causing thermal (and atomic hydrogen) gradients across the surface as well as radially. As pressure scale-heights are comparable to the stellar radius, the number of convection cells is ~ 10–100. Large temperature differences of the order of 1,000 K can exist over the stellar-atmosphere surface area, resulting in patches of grain formation[4]. The distribution, across the stellar surface, of the convective cells would be expected to change on timescales of 200 days, resulting in temperature variation other than that due to radial motion. The constantly



Atomic and selected molecular abundances in the atmosphere of a giant carbon star (ref. 3). The H/C abundance ratio is 200.

changing temperature of a parcel of gas will result in variable hydrogen-atom partial pressures, with the formation of diamond grains when conditions are optimum.

What remains to be established is the mechanism by which diamond grains are nucleated by a decrease in hydrogen-atom partial pressure. Experiments directed at the formation of grains (as opposed to films) are desirable. The task might be accomplished by passing a gas mixture with H_2/CH_4 = 200 through a tungsten tube at 2,000 °C, and taking the stream out through a temperature gradient established along an attached sapphire tube that is radiatively cooled along its length. Evidence for particle formation as diamond smoke would be sought by observing through the sapphire.

Wright and Grady[5] have suggested that, because the $^{13}C/^{12}C$ ratio of the meteoritic diamonds is not very different from terrestrial values, one should examine a Solar System origin. This is reasonable, because diamond formation on mineral grains in the Solar System is more like what has been demonstrated in the laboratory. For a pre-solar origin, conditions in the solar nebula, or at least the local conditions in which the diamond material of the four meteorites consolidated, would have had to be similar to a carbon-star atmosphere in pressure, temperature and composition. Perhaps comets falling into the solar nebula could have provided these conditions on a local scale. This work was supported by NASA.

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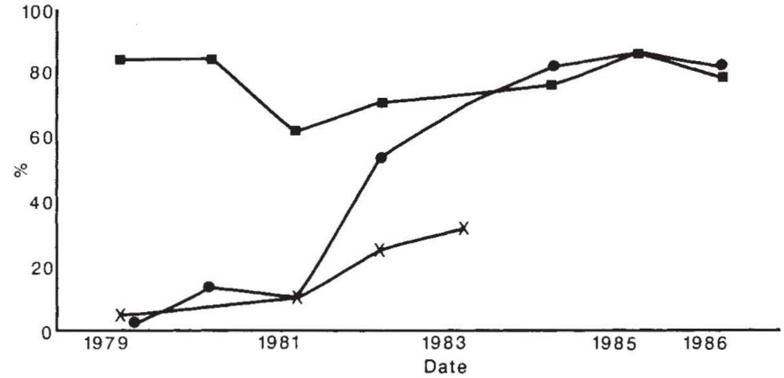
Italian HIV infection updated

SIR—In order to understand the epidemiology of AIDS (acquired immune deficiency syndrome), simple mathematical schemes are needed to clarify the meaning of many parameters which may influence the dynamics for transmitting HIV (human immunodeficiency virus). In their recent article, however, May and Anderson report some unclear findings[1]. The data indicate the rise in HIV seropositivity in two Italian cities as representative of Italy and compared them to those in London, San Francisco and New York. In addition, data on Italian drug addicts are compared with those from homosexual cohorts, even though the article seems to stress the necessity of collecting clear information in selected groups sharing a certain homogeneity in their behaviour. It is incorrect to compare a homosexual HIV transmission plot with an HIV intravenous route, which probably occurs in the majority of drug addicts.

This, however, is not the main uncertainty emerging from the article. In Italy and Spain drug addicts account for 51% and 46% respectively of the total number



Evaluation of 451 sera collected in Rome during 1979–1986, showing % seropositive. ■, Drug addicts still continuing abuse in 1987; dates indicate when abuse was started. ●, Drug addicts stopping abuse; dates indicate when abuse stopped. ×, Frozen sera stored at different times from drug addicts.