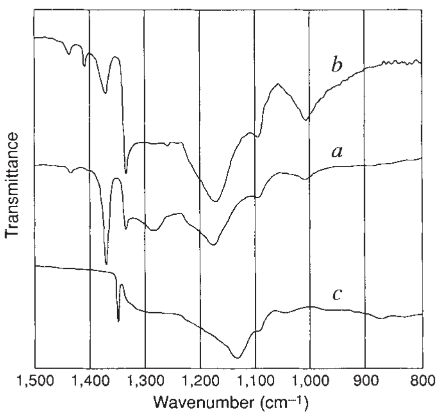
Errors in diamond synthesis

SIR — In 1955, some of us announced the first reproducible synthesis of diamond[1], details of which were subsequently published[2]. These results marked the beginning of the present synthetic-diamond industry. But from the outset there were doubts in our team as to whether the first diamond grown by our technique (which we will call the run 151 diamond) was truly synthetic at all, or whether it was instead just a fragment of a natural diamond seed that got into the experiment inadvertently. We have now reanalysed the run 151 diamond using modern spectroscopic techniques and have found that it is indeed a small piece of a natural type Ia diamond.



Infrared absorption spectra of: *a*, run 151 diamond; *b*, a type Ia natural diamond with 'B'-form nitrogen; *c*, a typical synthesized diamond (type Ib).

In the early 1950s four of us (H. P. B., F. P. B., H. M. S. and R. H. W.), together with H. T. Hall, developed an approach to diamond synthesis at high pressures and temperatures. The pressure scale used in our experiments was Bridgman's 'resistance-jump' scale, which was suspected to be in error in absolute terms above 30 kbar or so. The proximity of our experimental conditions to the calculated graphite–diamond phase boundary was therefore uncertain.

The run 151 diamond appeared in an experiment using apparatus made of hard steel. According to the Bridgman 'resistance' scale, the pressure in this run was about 53 kbar, within the diamond stability field[3]. But later developments revealed that the true pressure could not have been much above 42 kbar, which is insufficient to stabilize diamond.

To investigate the true nature of the run 151 diamond, we recently removed it from the GE archives, cleaned it with acids and rinsed it with water. An infrared absorption spectrum was measured using an IR PLAN microscope attached to a Nicolet 740 FTIR spectrometer. The portion of this spectrum shown in the figure resembles that of a natural nitrogen-containing type Ia diamond[4]. In particular, there are coincidences of the absorption bands at about 1,365 cm^{-1} (related to nitrogen platelets), 1,330 cm^{-1} (a Raman frequency, rendered infrared-active by defects and impurities), 1,280 cm^{-1} (from nitrogen in the 'A' aggregate form) and 1,175 cm^{-1} (from nitrogen in the 'B' aggregate form). We also show the spectrum of a typical nitrogen-containing synthetic type Ib diamond, which has characteristic bands at 1,130 and 1,343 cm^{-1} (ref. 5); neither of these bands is seen in the run 151 diamond. We conclude that the run 151 diamond is a small piece of a natural type Ia diamond.

How the natural diamond got into the run 151 experiment is not clear, although it came to light only a week later, when the iron pellet from the run was being polished for metallographic examination. After we found this diamond and took it to be synthetic, Hall used a similar synthetic system of iron/iron sulphide/graphite in his 'belt' apparatus, which used a carbide piston and cylinder to achieve high pressures[6]. This led to further successful runs and ultimately to the development of the process for synthesizing diamonds at high pressures and temperatures from graphite reacted with molten group VIII metals and alloys, which we described fully in 1959[2] (after a US Department of Defense secrecy order had been lifted). Our mistake was therefore clearly a most serendipitous one, as it provided the impetus to experiment with that system at higher pressures, leading quickly to the "right" and "reproducible" results.

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1. Bundy, F. P., Hall, H. T., Strong, H. M. & Wentorf, R. H. Jr *Nature* **176**, 51–54 (1955).
2. Bovenkerk, H. P., Bundy, F. P., Hall, H. T., Strong, H. M. & Wentorf, R. H. Jr *Nature* **184**, 1094–1098 (1959).
3. Strong, H. M. *Am. J. Phys.* **57**, 794–802 (1989).
4. Clark, C. D., Mitchell, E. W. J. & Parsons, B. J. in *The Properties of Diamond* (ed. Field, J. E.) 28 (Academic, London, 1979).
5. Chrenko, R. M., Tuft, R. E. & Strong, H. M. *Nature* **270**, 141–144 (1977).
6. Hall, H. T. *Rev. sci. Instr.* **31**, 125–131 (1960).

Galaxies and magnetic fields

SIR — The observed flat rotation curves of spiral galaxies constitute one of the most important facts suggesting the existence of large amounts of so-called dark matter in the Universe. However, if the galactic gas could be held in equilibrium by forces other than gravity alone, then an important argument for excess galactic mass would be weakened. Battaner *et al.*[1] suggest that stresses from an azimuthal magnetic field at the peripheries of a galactic disk can provide the confining stress needed. Here we reconsider the question of magnetic-field and gas equilibrium, and point out that the simple success of the one-dimensional Battaner *et al.* model depends on their incomplete treatment of the three-dimensional equilibrium. Application of the well-known virial theorem shows that the addition of magnetic field to their system would require more dark matter to maintain equilibrium, not less.

The pertinent steady-state virial theorem is[2,3]

$$2\,(T+T_t)+M+\int_V d^3\mathbf{r}\,x_i F_i = S \qquad (1)$$

where $T=\int_V d^3\mathbf{r}\rho v^2/2$ is the sum of directed kinetic energies; $T_t=\int_V d^3\mathbf{r}\rho\langle u^2\rangle/2$ is the sum of thermal or random kinetic energies; $M=\int_V d^3\mathbf{r}B^2/8\pi$ is the total magnetic field energy, and F_i is the force of gravity. $S=\int_S dS_k x_i\{-p\delta_{ik}+M_{ik}\}$ is the surface stress integral, with p the particle pressure and M_{ik} the Maxwell stress tensor.

Following Battaner *et al.*, consider an isolated system with $S=0$. The terms T, T_t and M in equation (1) are positive definite; only the last term on the left of the equation, the gravity integral, is negative. Regardless of the configuration or geometry, in the overall dynamical balance of a physical system, magnetic field is an expansive stress. Equation (1) shows explicitly that the only confining stress for large, isolated, astrophysical systems is gravity.

Applying equation (1) to the specific situation addressed by Battaner *et al.*, we first consider the case in which magnetic field stresses can be neglected ($M\approx 0$). Focusing only on the super-keplerian gas — treating it as an isolated system immersed in external gravity — it is clear that virial equilibrium requires a dynamical balance between the expansive tendency of the gas motions and the confining influence of gravity acting on that gas. The need for dark matter is already encapsulated in this analysis.

Now, with everything else unchanged, assume that the gas is magnetized. According to Battaner *et al.*, assuming a special field configuration, the magnetic stresses should take up some of the expansive tendency of the gas motion, so that the strength of gravity needed diminishes. But, from the more general virial rela-