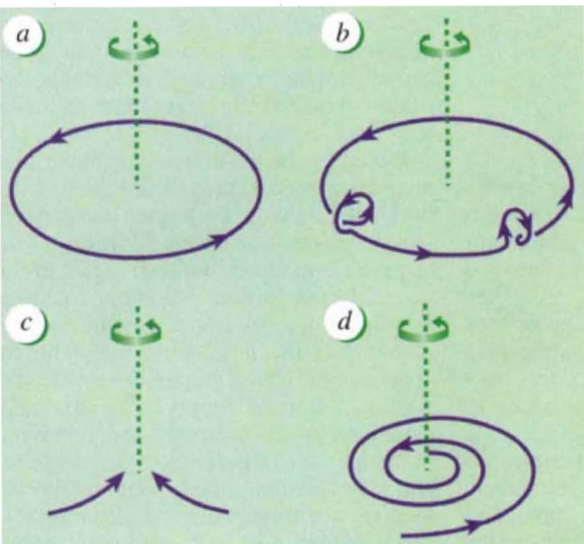
stage) contains a massive black hole as well as a thick plasma torus rotating about the black hole and at least partly supported by radiation pressure. Thermal battery processes in this torus create a weak azimuthal magnetic field, which, through the alpha-effect, gives rise to a weak meridional magnetic field (see figure). The meridional field is then sheared out in the azimuthal direction by the differential rotation, with the shear near the black hole being so strong that the resulting azimuthal field reaches local equipartition in less than a thousand years or so. Finally, the magnetic field produced near the galactic centre is rapidly distributed throughout the disk via a wind or some other kind of outflow.

How well does this square with observations? The new theory predicts that the large-scale azimuthal magnetic field falls off in inverse proportion to the galactocentric radius, R. Under these conditions and for realistic values of the central black hole mass, it is then possible to obtain the observed magnetic field strength near the Sun. Unfortunately, the predicted R^{-1} dependence of the galactic azimuthal field is not supported by observations[9]; in this respect, the magnetic field configurations obtained in the standard dynamo theory agree better.

On the other hand, the Faraday rotation detected in the absorption clouds of some quasars suggests that strong magnetic fields exist in very young galaxies[10,11]. If confirmed, this fact would be consistent with Chakrabarti and co-workers' model, which allows for rapid magnetic field growth after the formation of the central black hole, whereas the classical dynamo would not have had enough time to amplify a seed magnetic field up to the observed values.

Other implications of the model should also be confronted with observations. In particular, do black holes systematically form early in the cores of galaxies? And is the predicted relationship between the black hole mass and the magnetic field strength actually observed?



Galactic magnetic field generation according to Chakrabarti *et al.*[1]. *a*, A weak azimuthal magnetic field is produced by a thermal battery in the plasma torus around the massive black hole assumed to lie at the heart of the galaxy; *b*, this azimuthal magnetic field is stretched and twisted by cyclonic turbulent motions (alpha-effect) to produce a meridional magnetic field as shown in *c*; *d*, the meridional magnetic field is stretched in the azimuthal direction by differential rotation.

In brief, explaining the origin of galactic magnetic fields remains a challenge. The well-developed dynamo theory offers a physically compelling scenario, and appears to give good results in that it manages to reproduce the observed large-scale field structures. But it dodges the crucial question of exactly how small-scale turbulent motions interact with the large-scale magnetic field that they are supposed to amplify. If, for instance, magnetic suppression of the alpha-effect and of the turbulent diffusion is as severe as claimed by Vainshtein and Cattaneo[8], another mechanism clearly must come into play.

The idea that magnetic fields are first generated near the galactic core, where the local differential rotation stretches field lines very efficiently, and are then transported outwards by a wind, is certainly appealing. It solves a number of problems inherent in the standard dynamo theory, but it raises its own set of questions. Its fate will ultimately depend on how well these questions can be answered. □

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1. Chakrabarti, S. K., Rosner, R. & Vainshtein, S. I. *Nature* **368**, 434–436 (1994).
2. Rosner, R. & DeLuca, E. in *The Center of the Galaxy*, IAU Symp. 136 (ed. Morris, M.) 319–328 (Kluwer, Dordrecht, 1989).
3. Kulsrud, R. In *Galactic and Extragalactic Magnetic Fields*, IAU Symp. 140 (eds Beck, R., Kronberg, P. P. & Wielebinski, R.) 527–530 (Reidel, Dordrecht, 1990).
4. Parker, E. N. *Astrophys. J.* **163**, 255–278 (1971).
5. Rees, M. J. *Q. Jl R. astr. Soc.* **28**, 197–206 (1987).
6. Moffatt, H. K. in *Magnetic Field Generation in Electrically Conducting Fluids* (eds Batchelor, G. K. & Miles, J. W.) 145–178 (Cambridge Univ. Press, 1978).
7. Brandenburg, A. *et al. Astr. Astrophys.* **259**, 453–461 (1992).
8. Vainshtein, S. I. & Cattaneo, F. *Astrophys. J.* **393**, 165–171 (1992).
9. Heiles, C. in *Interstellar Processes* (eds Hollenbach, D. J. & Thronson, H. A.) 171–194 (Reidel, Dordrecht, 1987).
10. Kronberg, P. P. & Perry, J. J. *Astrophys. J.* **263**, 518–532 (1982).
11. Wolfe, A. M. in *QSO Absorption Lines : Probing the Universe* (eds Blades, J. C., Turnshek, D. & Norman, C. A.) 297–317 (Cambridge Univ. Press, 1988).

DAEDALUS

Expanded metal

LAST week Daedalus pointed out that a metal consists of an array of positive ions neutralized by immersion in a sea of delocalized free electrons. He proposed to explore a whole range of new 'hybrid alloys', with organic ions nestling among the metallic ones.

A metal-rich alloy, with only a small number of included alien ions, would simply be a modified metal. A roughly equal number of metallic and non-metallic ions might pack together badly. A metal-poor alloy would again pack well, this time with metal ions in the interstices of the lattice. If he can make an alloy of this composition, Daedalus wants to heat it. He recalls the trick of heating solvated silica gel above the critical point of the included solvent. The vapour escapes, leaving an amazingly light, open silica framework — an aerogel. Silica aerogel can be almost as light as air: it looks like (and is known as) 'frozen smoke'. Daedalus reckons that on heating a metal-poor hybrid alloy, the major organic component would similarly vaporize, leaving a sparse distribution of metal atoms as a metallic aerogel.

Metallic aerogel will be uncannily light and tenuous, yet utterly black. It should conduct electricity fairly well, but heat badly. Immersed in plastic monomer or molten glass, it could make novel metal-reinforced composites. Unlike other aerogels, it should be ductile. It could be formed into ghostly black wire, sheet and engineering parts of great toughness yet weighing almost nothing.

The ultimate metal-poor hybrid alloy would have no metal at all. It would consist entirely of non-metallic positive ions in a sea of free electrons. Ammonium (NH_4^+), or its tetramethyl derivative, seem the most promising candidates; free electrons dissolve in liquid ammonia, and neutral ammonium forms an amalgam with mercury. Atoms contract on forming positive ions, so metallic ammonium should be made by compressing ammonia with hydrogen.

Once made, metallic ammonium should be stabilized by electronic delocalization, and might persist even at atmospheric pressure. It would probably resemble lithium or sodium: very light but rather soft, too reactive to be much use structurally, but valuable in alloys and for batteries. It might, however, be rather explosive, reverting violently to ammonia and hydrogen gas: it could make a splendid rocket fuel. But nature may have got there first. Daedalus suspects that Jupiter, which contains abundant ammonia, hydrogen and methane under great pressure, is largely made of metallic ammonium or tetramethyl ammonium. David Jones