news and views

Holes in the microwave background?

from M. Birkinshaw and S. F. Gull

RADIO sources lying outside prominent clusters of galaxies typically appear as two bright lobes of emission on either side of an 'active' galaxy. Those sources within the great clusters, on the other hand, often have highly irregular shapes. One hypothesis advanced to explain this phenomenon is that each cluster of galaxies holds an atmosphere of very hot (10^7 – 10^8 K) gas which affects the evolution of any radio source within it. The discovery of cluster X-ray sources seemed to confirm the existence of these atmospheres—X-radiation being the predominant thermal bremsstrahlung of gases at such temperatures. A strong test of this model is provided by observations of the temperature of the microwave background (the thermal radiation surviving from the 'big-bang' and now at about 2.9 K) towards an X-ray cluster; the thermal model predicting that it should be depressed by about 10^{-3} K due to the presence of hot gas. No such depression is expected from the main rival model—indeed an excess of radio sources, giving a temperature enhancement, would be anticipated.

Some of the problems associated with the very difficult observations needed to find a temperature decrement of 10^{-3} K have been highlighted recently by J. Tarter (*Astrophys. J.* **220**, 749; 1978). The experiment is performed by continuously measuring the temperature difference between directions towards the centre of a test cluster and reference points outside it. This method removes most of the effect of our atmosphere and saves having to measure temperatures of 2.899 and 2.900 K independently to high accuracy. However, since the expected

cooling is very small, it would be swamped by even the most modest radio source lying along the line to the cluster, or would be falsely produced by that source lying near the reference points—so both regions have to be checked carefully for interfering sources. The effect of radio sources is diminished by working at high frequencies, but here the atmosphere becomes unstable, and temperature fluctuations of some hundreds of 10^{-3} K may occur. This forces the use of a non-ideal frequency (10.6 and 33 GHz have been used), and the main and reference beams of the telescope have to be set close together. Unfortunately both beams then lie within the gas distribution of the test cluster—so less temperature decrement is expected and the experiment is made harder.

Even then there are problems. If any cooler gas (at 10^4 – 10^6 K) lies within the cluster, it will emit radio radiation in the same way as the hotter gas emits X-radiation. Only a little cool gas is needed to swamp the expected temperature decrement. Last, but not least, is the problem of observing time. Long-term atmospheric instabilities are such that about 60 h of observing at any one point is necessary to establish the presence or absence of a temperature decrement at a useful level, and telescope time is more commonly allocated by the night than by the week or month.

Despite these difficulties a number of papers reporting detections or limits to the magnitude of the background cooling have now appeared (for example, Parijskij *IAU Symp.* 79; Gull & Northover *Nature* **263**, 572; 1976; Lake & Partridge *Nature* **270**, 502; 1977). The disagreements among these observations can, in general, be explained by differences in the precise experimental details. Four out of a total of 11 clusters observed have been

found to show the background cooling—though one of these (Abell 2125) is a subject of some debate. Two of the clusters have now been scanned to show the extent of their atmospheres. Furthermore, on the basis of work on the background radiation, the cluster Abell 2218 was predicted to be an X-ray source. This was later confirmed by observations made on the Ariel V satellite. These results indicate strongly that the diffuse cluster X-ray emission has a thermal origin—and allow measurements of the density of the emitting gas. The detection of the decrement also constitutes proof that the microwave background really is of cosmological origin and exists on scales of at least 3,500 million light-years.

Microwave background astronomy has tended, in the past, to concentrate on the measurement of the radiation's spectrum—to confirm its thermal nature. Early attempts to search for slight anisotropies in the background due to the peculiar velocity of the Earth or the presence of condensing clusters of galaxies (protoclusters) were severely limited by the available technology; but recent improvements in telescopes and receivers have made high-precision measurements possible—as shown by the detection of the motion of the Earth relative to the background radiation by Smoot *et al.* (*Phys. Rev. Lett.* **39**, 898; 1977). Although protoclusters have not yet been detected, further work should reveal them and provide important information on the evolution of structure in the present-day Universe. The new generation of X-ray telescopes and microwave receivers will undoubtedly provoke more work on the structure of gas distributions within clusters—and with this superior information on the environment of radio sources some of their cryptography may, at last, be decoded. □

M. Birkinshaw and S. F. Gull are at the Mullard Radio Astronomy Observatory, Cavendish Laboratory, Cambridge.