thus emerges as not quite the bogey it is often assumed to be, but a bogey nonetheless.

The really important source of SO₂ is domestic and industrial heating—that is, small localized sources related to the distribution of population and industry. Evidence for this comes from the variation of SO₂ concentration throughout the year. In cities concentrations are usually higher in winter than in summer in spite of the fact that emission from power plants is the same throughout the year or even higher in summer. Golden and Mongan thus suggest that as a matter of policy, where low sulphur-bearing fuels are available they should be directed to small emission sources in highly polluted areas rather than to the bigger power plants. In many areas of Britain, however, the situation may be a little different. In regions where the Clean Air Act has been applied the proportion of SO₂ at ground level attributable to small localized sources is probably smaller than in Illinois.

RADIO GALAXIES

Dichotomy Confirmed

by our Cosmology Correspondent

OPTICAL spectra of nearby giant E and SO galaxies have been obtained by M. J. Disney and R. H. Cromwell at the Steward Observatory in Arizona. The spectrograms show a definite correlation between radio and optical activity in the galaxies (*Astrophys. J. Lett.*, **164**, L35; 1971). Earlier surveys of nearby galaxies have revealed that twenty-four of our near neighbours are radio sources. Most of these are fairly weak, but some are sufficiently strong that it has been suggested that they have quasars at their nuclei (Heeschen, *Astrophys. J. Lett.*, **6**, 49; 1970). These are known as active sources; the quieter, non-quasar-like radio galaxies are referred to as passive sources. This classification is far from being an arbitrary rule of thumb, because the active sources are all unresolved (radio diameters less than 1.5 arc sec) and the passive sources are extended over more than 1 arc minute, and show the "normal" inverse power law spectrum, indicating a thermal origin for the radiation.

The apparent similarity at radio wavelengths between some nearby galaxies and the general run of nearby quasars has been an attractive feature of these radio observations. However tenuous the link might be, many astronomers would be relieved to find a way to tie quasars into the normal evolutionary pattern of galaxies. Since Heeschen's work, these twenty-four nearby galaxies have been obvious candidates for optical study.

The latest survey, carried out on twelve of these radio galaxies, confirms this dichotomy. Disney and Cromwell found that the spectral properties of these

galaxies are related to their radio properties, but not in the way that might be expected on a naive quasar nucleus assumption.

Three of the galaxies studied by Disney and Cromwell have normal radio spectra, eight have the radio characteristics defined by Heeschen as active, and one seems to be an in-between case. All of the normal radio galaxies also show normal optical spectra. All but one of the active radio galaxies show emission lines of the type characteristic of planetary nebulae, and some of these lines are very strong. Although the sample of galaxies is rather small, the significance of this correlation is clearly unquestionable. Interestingly, the one active galaxy which does not show emission lines (NGC 4552) has already been shown to have an abnormally highly reddened centre, so that any emission lines originating in the nucleus might be obscured by matter

around the centre of the galaxy (see, for example, Tifft, *Astr. J.*, **66**, 390; 1969).

In one of the spectrograms studied, that of the galaxy NGC 3998, the hydrogen alpha line is seen clearly, and has broad extended wings of the kind seen in the emission from quasars at this wavelength.

But unfortunately for the quasar nucleus model, the activity revealed by these spectrograms is not the kind normally associated with quasars. In general, quasars have strong, broad hydrogen lines, which are not seen in any of these nearby galaxies, except NGC 3998, and the excitation (measured by the relative intensity of 5007 [OIII] to 3727 [OII]) is much lower in these galaxies than in quasar or Seyfert galaxies and is more typical of planetary nebulae. Although it is now clear that Heeschen's classification really does define two separate families of galaxies, the processes differentiating between them remain obscure.

Explaining Away the Anomalous Background

GOING by measurements at microwave wavelengths, the temperature of the universe is fairly certainly 2.7 K. This has been the consistent result since Penzias and Wilson in 1965 reported the detection of an isotropic background radiation at microwave wavelengths, apparently pervading the universe, which most likely is the fading glimmer of the flash that accompanied the start of the big-bang universe. But at wavelengths shorter than a few millimetres it is impossible to observe this radiation from the ground—the atmosphere is in the way. So do the surprisingly high fluxes that have recently been measured in the far infrared during rocket flights mean that something is wrong with the rocket experiments, or that the measurements at longer wavelengths cannot be extrapolated to the far infrared along the 2.7 K blackbody curve, or what?

The problem is important because the existence of the background radiation is the strongest card held by the proponents of the big-bang cosmology. It is extremely hard, for example, to account for the radiation as a result of the superposition of radiation from distant galaxies—it has to be that astronomers are recording something *primaeval*. But it would throw a spanner in the works if the radiation turned out not to follow the blackbody spectrum. Until there is an explanation of the anomalously high fluxes corresponding to 8 K which have been recorded in the far infrared on two occasions now, the big-bang cosmologists cannot be happy with their trump card.

The possible loophole is that the two rocket measurements covered a range of wavelengths, from 0.4 mm to 1.3 mm. Could it be that the radiation, in fact, follows the 2.7 K blackbody curve, but that superposed on the curve are spectral

lines which lead to an average temperature of 8 K? There have been several hints that this could be so. There has been observational work which places upper limits on the temperature at a number of specific wavelengths in the 0.4–1.3 mm interval which are less than 8 K. One possibility that would fit is that there is a line between 0.8 and 1 mm. A report in next Monday's *Nature Physical Science* describes the results of such a search for lines in this interval and on either side.

Beery and his colleagues have been able to carry out their measurements from the ground by taking advantage of the low atmospheric noise at the Mauna Kea observatory, Hawaii. What they have done is to look for lines using the 24-inch telescope, and attempt to ascertain whether or not the lines are atmospheric in origin (by seeing whether the line strengths depend on the air mass observed by the telescope). They particularly draw attention to a line on the long wavelength side of 0.8 mm which conceivably has a bearing on the far infrared measurements. Most likely the line is attributable to N₂O, however. It seems to be atmospheric therefore, making it an awkward explanation of the rocket measurements, although it might account for recent balloon observations by Muehlner and Weiss (MIT) of an anomalously large far infrared flux.

It is probable then that the team working at Mauna Kea have drawn a blank. All the same theirs is a useful negative result—it is the first high resolution search from the ground for isotropic emission features in this spectral region, and it fixes valuable limits for explanations of the anomalous flux. But it looks as if the astrophysicists will have to look elsewhere for a solution.