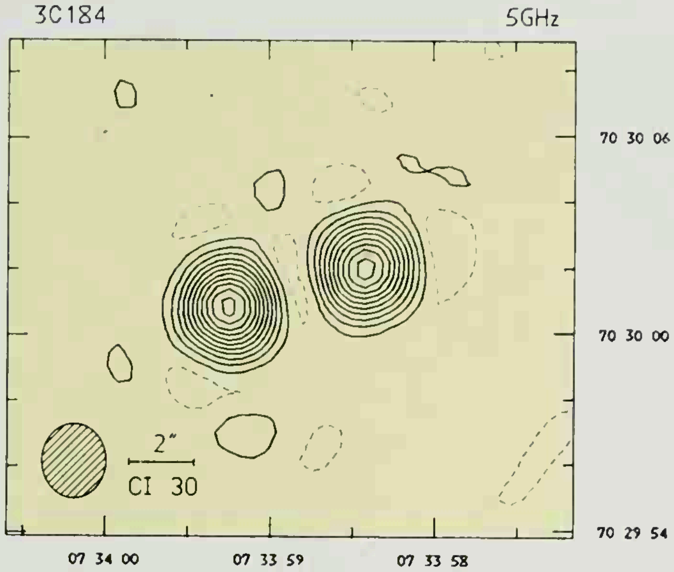
which can be made are not yet precise enough to lead to a definite decision.

It is now clear that radio observations can extend the detection of galaxies and the measurement of radiation received from them out further still and can, therefore, provide significant information about types of model. To this end **source counts** have been made, the number of sources with radiation at various intensities having been plotted: these show a significant departure from what should be expected for a steady-state universe (and so are yet another reason for discarding it), and make it clear that the universe does undergo evolutionary change (Fig. 8·13 and 8·14). But they do not lead to any unequivocal result over whether or not the universe will contract or continue expanding. Counts of quasars also tend to confirm this, but, of course, there is the problem of whether the redshifts of quasars are really due to recession or to shells of gas ejected from them, or even to the quasars themselves being objects which have been ejected from surrounding and not too distant galaxies. The American astronomer Halton Arp, for instance, is strongly of the opinion that there are too many photographs of quasars lying almost in the line of sight or close to galaxies, as well as having redshifts of related kinds, to allow of their being all – or mostly – very distant, but most astronomers remain unconvinced at the moment. Indeed, they feel not only that quasars are truly at cosmological distances but that they may well represent galaxies in an early stage of development when the nucleus could have been very active, for the more distant the objects are which we observe, the longer light has taken to reach us and so the further back in time we see.

We can not, then, be certain at the present time which model of the universe is correct. Evidence from the perihelion of Mercury, the deflection of starlight by the Sun, laboratory observations of the increase of the mass of atomic particles when travelling at velocities approaching light, the equivalence of gravitational and inertial mass, together with the evidence for neutron stars and black holes, all make it seem as if it must be a relativistic universe; if gravity waves are detected then this will be yet another confirmation. But astronomical observation does not allow us yet to choose a specific relativistic model; we can not at present say whether the universe will expand for ever, or whether it will one day contract, and if it does contract whether it will bounce back to a subsequent stage of expansion.

General comments

All through this section on cosmology we have assumed, for instance, that gravity is a constant unchanging with time, but there have been some suggestions that this may not be so. Originally proposed by Paul Dirac and Pascual Jordan, this theory has been investigated in recent years by many cosmologists, including Robert Dicke and Fred Hoyle, and it has interesting consequences. For instance, if, as is suggested, gravity decreases with time, then continental drift (page 93) could have been caused by the Earth's expansion as gravity decreased.



Using information gained from the radio observations shown opposite, the appropriate region of the sky was photographed by the 5-m (200-inch) telescope of the Hale Observatories, and then examined by Edward Kibblewhite's Automatic Plate Measuring machine (see page 238) back at Cambridge University. Ignoring all bright objects on the plate and concentrating on the dimmest images, a trace was produced. This is reproduced above in negative. The radio galaxy 3C 184 lies between the two crosses, which represent the positions of the galaxy's radio lobes shown in the small picture opposite. 3C 184 has a magnitude of 22.5 and is one of the faintest radio galaxies so far identified.

A star such as the Sun, while in the hydrogen-burning stage, would have had a greater luminosity in the past, and this could explain the long period of time between the first appearance of living cells on Earth and the arrival of more complex forms. Other consequences are that our Galaxy would have been more luminous in the past, and smaller too, while there would be some wider cosmological consequences. The relation between redshifts and apparent magnitude would be altered, and so would the predicted movement of Mercury's perihelion and the deflection of starlight by the Sun.

To explain why the gravitational constant should change, Dicke and his colleagues have evoked **Mach's principle** (named after the German physicist and philosopher Ernst Mach) that the inertial properties in any localized area depend on the rest of the matter in the universe; if this matter changes it will affect our local measurements. Dirac, Hoyle and his colleague Jayant Narlikar suggest the variation of gravitation could be due to the existence of two time scales in the universe, one an atomic scale, the other a cosmological one, which although once in step now no longer coincide.

There is also the question of the **isotropy of the universe**. The microwave background is isotropic – it appears the same in all directions – but it could be that the universe did not present this aspect in its early stages and was very anisotropic. The initial big-bang singularity might have been cigar shaped, or even like a disc. Charles Misner has suggested that the universe did start out in this uneven state, but that interaction between neutrinos caused a viscous treacly effect that allowed protogalaxies and collections of protogalaxies to form. On the other hand, Russian cosmologists like Ya.B. Zel'Dovich suggest that the production of nuclear particles caused by tidal pulls in the early stages of the universe caused the evenness we observe now. These are attractive hypotheses which overcome the difficulty in an isotropic big bang of explaining the presence of galaxies and clusters of galaxies which we now observe.

Even the very isotropy of the universe causes problems. This arises from the fact that particle physics, in particular the search for theories which unify the various forces controlling the behaviour of