QUASISTELLAR OBJECTS

Are All QSOs in the Nuclei of Galaxies?

by our Cosmology Correspondent

"ALL quasars occur in the nuclei of giant galaxies"—or, at least, "the observations are consistent with the hypothesis", according to Jerome Kristian, of the Hale Observatories. Coming close on the heels of the recent report that the QSO redshift-magnitude relation agrees well with the idea that these objects are at the cosmological distances implied by a Doppler interpretation of the redshifts (see *Nature*, **241**, 506; 1973), this discovery seems to have brought QSOs back into the limelight of astronomy, after a period in which the centre of the stage has been held by objects closer to home, within our own Galaxy.

Kristian's study (*Astrophys. J. Lett.*, **179**, L61; 1973) starts from the often discussed similarity between N galaxies, Seyfert galaxies and QSOs. These objects not only have the same qualitative properties, in terms of spectra, colours and variability, but also show a quantitative gradation in activity. This has led to speculation, for example, that the objects might be members of an evolutionary chain in which QSOs are the forerunners of Seyfert galaxies which in turn evolve into N galaxies. That idea does not stand up too well if there is no evidence for luminosity evolution of QSOs as a class, which now seems to be the case (Bahcall and Hills, *Astrophys. J.*, **179**, 699; 1973). Instead, the idea that QSOs are events occurring in the nuclei of galaxies, like those observed in the nuclei of N and Seyfert galaxies, becomes attractive. In that case, QSOs could easily be so much brighter than the equivalent events in N and Seyfert galaxies that their light output masks the light from the galaxies in which they lie, so that the characteristic starlike image of a QSO is produced on photographic plates. This is the idea that Kristian set out to test, using direct photographs of QSOs in an attempt to detect galaxies surrounding them. The results he obtains are impressive.

In order for such a photographic search to be successful, the image produced by a QSO at the centre of a galaxy must be smaller than the image produced by the galaxy itself. The QSO image size depends only on brightness, because QSOs are essentially point sources, but the galaxy image size depends on the actual size of the galaxy and its distance from the observer. This provides enough flexibility to make a photographic search for QSOs at galactic nuclei—or rather, galaxies centred on QSOs—feasible.

Kristian has taken the QSO redshifts as straightforward distance indicators, and has used calibrations of image size against magnitude for the QSOs and of apparent size against redshift for the galaxies. The latter calibration was already available from Sandage's work on brightest members of galaxy clusters (*Astrophys. J.*, **173**, 485; 1972); the former calibration was made by Kristian using *V* plates obtained with the 200-inch telescope. QSOs are usually identified from the *Palomar Sky Survey*, which is based on plates obtained with the 48-inch Schmidt camera. Underlying galaxies are not usually found associated with QSOs on the Schmidt plates, and it now seems that this is simply because, at the distances implied by QSO redshifts, galaxies are, in most cases, too small to produce an image larger than the QSO image on 48-inch plates.

Kristian has restricted his survey to objects which "have at one time or another been called quasars, and for which 200-inch plates or other indications of an underlying galaxy are available"; this gives twenty-six objects for analysis. In regions of the Hubble diagram where galaxies should be easiest to detect there are few QSOs (four were studied by Kristian) "but all of those for which good plate material is available show an underlying galaxy". These galaxies all satisfy the requirements of N galaxies, although because of the historical accident of discovery some are known by other names.

At the other extreme, where galaxies which are centred on QSOs should be difficult to detect none is found, although there are fourteen QSOs which satisfy Kristian's criteria, and in intermediate regions of the Hubble diagram there is evidence that five out of eight QSOs are at the nuclei of galaxies. The apparent diameters of the galaxies are as would be expected for N galaxies and bright cluster galaxies, and there are, says Kristian, also several cases in which the QSO is a little displaced from the centre of the galaxy rather than coincident with the nucleus. The evidence is impressive, but, of course, some QSOs may still not be at galactic centres.

Spin, Torsion and Gravitational Singularities

THE big-bang model of the Universe contains a singularity which is interpreted as the beginning. This is unsatisfactory in one way because the details of physical processes near to singularities are not well understood. It is, however, clear that quantum effects become important at high densities, although how to incorporate these effects into gravitational theory is an open question.

Oscillating models of the Universe also collapse periodically into singularities. The most obvious explanation is their very high symmetry and it would seem that the periodic collapse would be avoided if the model were slightly perturbed, allowing the incoming particles of matter to miss each other. Calculations by Penrose, Geroch and Hawking have, however, shown that this is not the case and that singularity is an intrinsic feature of general relativity which occurs under quite wide conditions subject only to very general and reasonable energy conditions.

General relativity therefore needs to be modified if singularities are to be avoided. Such a modification was suggested by Cartan and by Sciama in 1958 and incorporates an asymmetrical connexion to provide a model of spin. The cosmological consequences of this idea are worked out in next Monday's *Nature Physical Science* (March 5) by Trautman. In his communication the field equations of general relativity are modified by the presence of terms describing the torsion of the geometry arising from the spin of particles. Recently Kopczynski constructed non-singular models, based on the resulting modification of the Friedmann equations describing the expansion of the Universe according to the big-bang model. It turns out that there is a minimum radius for the 10^{80} particles of which the Universe is thought to consist. This radius is about 1 cm—quite large enough to avoid the difficulty of singularity, but small enough to have a negligible effect on the subsequent development.

Trautman considers the possibility that the spins were correlated in the hottest stage of the development of the Universe; the cosmic magnetic field might have played a significant part in this context. Trautman's is not a complete model, however, in that it neglects the magnetic field energy. Pressure is also ignored in the preliminary calculation.

Trautman also mentions the possibility of avoiding a singularity in a closed cosmological model. It is interesting to note the similarity of his modified Friedmann equations to those proposed some years ago in a continuous creation model of an oscillating universe by Hoyle and Narlikar.