GALAXY FORMATION

Link with Expansion of Universe

from our Cosmology Correspondent

THE plausibility of the Eddington–Lemaître equations as representing the true mathematical description of our universe has been considerably enhanced by calculations which show that not only can galaxies form and grow in such a universe in a reasonable time, but that this process is itself inextricably linked with the expansion of the universe. Since Lifshitz's work more than twenty years ago, galaxy formation has posed a considerable problem to cosmologists, because it seemed clear that the universe just is not old enough for galaxies to have evolved from local condensations in an approximately homogeneous cloud of gas. This has caused models to be suggested in which either more complex cosmologies are required or special conditions are imposed to enable galaxies to grow. Recently R. Simon has developed the proposal of W. C. Saslaw that long range forces of gravitational attraction may be important in the growth of irregularities, producing density waves with wavelength close to the Jeans length.

Simon's calculations confirm this possibility, but of even greater significance is his discovery that another peak in the spectrum of possible density waves becomes significant for late epochs in the history of the universe. Unlike the peak corresponding to the Jeans length, which remains constant and can produce condensations of around galactic mass, the second peak moves in the direction of larger wavelength as the universe evolves and becomes increasingly significant (*Astron. Astrophys.*, **6**, 151; 1970). It is tempting to interpret this behaviour as implying that the galaxies formed by the condensations due to the first wave will become clustered about the maxima in the second wave, and that these clusters of galaxies will move away from each other (with relative velocities proportional to their separations) due to the increase in wavelength of the second wave. Clearly this picture is most agreeably consistent with observations, while providing the long sought after clue as to why the Eddington–Lemaître model affords a good description of the universe.

Detailed questions of why galaxies have the variety of structure which is observed, and how stars form from the protogalaxies, remain to puzzle theorists interested in the formation of galaxies.

COMETS

Silicate Grains in Comet Bennett

by our Astronomy Correspondent

THE infrared astronomy group at the University of Minnesota, last year one of the teams that presented evidence for the presence of silicate grains in the interstellar dust (*Nature*, **222**, 326; 1969), has reported what seems to be the silicate emission feature in the spectrum of Comet Bennett (R. W. Maas, E. P. Ney and N. J. Woolf, *Astrophys. J. Lett.*, **160**, L101; 1970). The comet was observed on April 4 with a thirty inch telescope at wavelengths between 2 and 20 microns, and an emission feature was detected at 10 microns. This seems to be the feature already detected in emission from cool stars and from the Orion nebula, and in absorption in the spectrum of the cool supergiant 119 Tauri. In a series of papers in *Astrophys. J. Lett.* last year the feature at 10 microns was attributed to the presence of silicate grains (**155**, 181–199; 1969).

The experiment on Comet Bennett is interpreted by the Minnesota group as confirmation that the 10 micron feature is indeed probably due to a silicate or a combination of silicates. The association between comets and meteor streams—which has long been well established—indicates the probable presence of silicate grains within comets. Although the finely divided particles which make up meteor streams are almost certainly in a different class from the more substantial objects which survive the flight through the atmosphere and which have a known composition, evidence for silicate elements in shower meteors comes from the optical spectra seen as meteors burn up in the atmosphere. Thus the detection of the 10 micron feature in a location where silicates are expected is accepted by the Minnesota group as adding some weight to the silicate hypothesis. But in line with the current view that interstellar dust is as likely as not a mixture, chiefly of silicates and graphite, the group say their infrared data point to a second refractory material in the nucleus of Comet Bennett which could easily be carbon.

HUBBLE SEQUENCE

New Light on Galaxy Evolution

from our Cosmology Correspondent

THE evolution of galaxies and the reasons for the existence of the different categories of galaxies have yet to be explained with anything like the confidence which can be placed in the accepted models of stellar evolution. But the progress being made in the investigation of these problems is emphasized by P. Brosche, who has incorporated several recent developments in a model where the Hubble sequence is interpreted as an angular momentum sequence of galaxies of roughly equal mass (*Astron. Astrophys.*, **6**, 240; 1970).

It is assumed that star formation simply occurs when the gas making up a protogalaxy becomes sufficiently dense for local regions to collapse under their self gravitation, and on this interpretation protogalaxies with small angular momenta shrink relatively rapidly, becoming relatively dense and converting most of their mass into stars before they can become highly flattened, so that they form the elliptical nebulae. The galaxies with more angular momentum convert only a small percentage of their mass into stars before they become highly flattened, resulting in a distribution of stars within a disk as seen in the spiral nebulae. Models of this type require a mechanism for the release of energy during the collapse of a protogalaxy, and in this particular case the efficiency of the mechanism must be linked to the angular momentum of the protogalaxy. Brosche favours a process involving collisions of interstellar gas clouds, the number densities of which have been estimated as 10^6 per kiloparsec for our galaxy. The energy loss considered is the macroscopic kinetic energy of these gas clouds, not the thermal energy of the molecules, so that quasi-static evolution rather than a violent collapse is certainly plausible. Although many aspects of Brosche's work are so far rather unsophisticated, it seems to be pointing in a highly profitable direction. Measurements of the rotational veloci-