From The Research Front

MERGING GALAXIES

The relative motion of two galaxies differs from that of two mass points in an important respect. The stars in the two galaxies are generally accelerated due to tidal effects with the result that the energy of the orbital motion of the two galaxies is continually decreased. As a result of this phenomenon, binary galaxies revolve around each other with mean separation that goes on decreasing until the two systems finally merge and form a single system. Recent studies have indicated that this merging process is very rapid for close pairs. White (White and Sharp: *Nature*, **269**, 395, 1977) has carried out N-body simulations of the interaction between pairs of 250-particle "galaxies". His results show that for the nearly iso-thermal ($p \backsim r^{-2}$) galaxies studied, the condition $r_{peri} \lesssim 3\, r_{\frac{1}{2}}$ was sufficient for the binary to merge completely within one initial orbital time of its first close approach where r_{peri} is the peri-centric distance of the initial orbit and $r_{\frac{1}{2}}$ is the half mass radius of the initial galaxies. Estimates made by Alladin and Parthasarathy (to be published in Monthly Notices) from impulsive approximation assumption for spherical galaxies of density distribution that of a polytrope of index n = 4, movng in relative circular orbit, are consistent with this result.

The work of Toomre (*IAU Symp.*, **58**, 347, 1974) and of van Albeda and van Gorkom (*Astr. Astrophys.*, **54**, 121 1977) emphasize the vehement nature of the dynamical friction in galaxies approaching each other slowly from a great distance in a head-on collision. They find that the two galaxies soon tumble into a single heap. It should be noted, however, that the braking action depends strongly on the relative velocity of the two galaxies. The two galaxies pass through each other without coalescing if the relative velocity is not sufficiently small.

Toomre (in '*Evolution of Galaxies and Stellar Populations*' ed. Tinsley and Larson, Yale Univ. Press, p. 401, 1977) finds that two disk galaxies approaching each other slowly, face-to-face, soon merge and form an elliptical galaxy with a density profile resembling that of the elliptical galaxy E3 or E4. Marchant and Shapiro (*Astrophs. J.*, **215**, 1, 1977) have also proposed that elliptical galaxies are formed by tidal interactions between initially flat galaxies and have suggested that in clusters of galaxies, flat S0 galaxies are converted into ellipticals.

Toomre (1977) regards 500 to be a reasonable estimate for the number of galaxies in the NGC catalogue that have undergone mergers.

In clusters of galaxies, the giant galaxies would accrete their dwarf neighbours. Ostriker and Hausman (*Astrophys. J. Litt.*, **217**, L125, 1977) have shown that this process of cannibalism will alter the bright end of the luminosity function in certain clusters, tending to produce a too-bright and too-fixed brightest galaxy and a too-large gap between the first and second member of a cluster. The supergiant CD galaxies in rich clusters have extensive envelopes and often exhibit multiplicrty

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REPORT ON IAU SYMPOSIUM ON STRUCTURE AND PROPERTIES OF NEARBY GALAXIES

IAU Symposium on "Structure and Properties of Nearby Galaxies" was held at Bad Munsterefel (near Bonn) between August 22-26, 1977. The symposium covered a wide range of topics under the following sections: (a) the smooth background, (b) spiral structure and star formation, (c) nearby galaxies of large angular size, (d) active galaxies and their nuclei and (e) the outskirts of galaxies. The emphasis of the symposium was on the recent high resolution radio observations of continuum and 21 cm line, and optical observations particularly in the outerparts of the galaxies.

The radio continuum properties of the nuclei of nearby galaxies were discussed by de Bruyn, Ekers, Kerr and Carlson and many others. About 2% of spirals may have relatively strong nuclear components of size less than 200 pc emitting about 25% or more of the total radio emission from the Galaxy. There is no strict correlation between the optical and radio activity of nucleus. Seyferts usually show stronger nuclear radio component than spirals, but are similar to spirals in other respects. The nuclear components have broad spectral index distribution centred around -0.7. Components of size 10^{-3} pc showing synchrotron self absorption spectra are also seen in a few cases, e.g. NGC 3031 and 4594. None of spirals or Seyferts show double radio sources characteristic of energetic radio galaxies. In a few cases, intense radio components are seen fairly symmetrically located with respect to the nucleus (NGC 4631 and 4736), but their origin as part of the spiral features cannot be ruled out. The nuclear radio components do not seem to influence the radio emission from the outer parts of the galaxy However, in NGC 4258, 3079, anomalous emission is seen over a large area possibly related to nuclear activity. The observational evidence, particularly the morphology and environment of the galaxies with active nuclei suggest that gas (probably infalling) lights up the nuclear radio sources.

Van der Kruit reviwed the large scale radio continuum emission from nearby spirals. The disk component extending over the entire optical image is largely nonthermal and shows a radial exponential fall off like the optical light. He argued that the observed steepening of the radio spectrum with increasing radial distance in M51 and NGC 6946 is due to the mixture of thermal and nonthermal emission. The nonthermal emission correlates with the total stellar population rather than Population I and has a nearly constant spectral index over the entire disk of the galaxies. The extension of the disk emission in the z-direction, perpendicular to the plane has been observed up to 2 to 6 kpc in some edge on galaxies (eg. NGC 891, 4631). The radio spectrum steepens rapidly with increasing distance above the plane. The thick disk or flattened halo is clearly a consequence of diffusion of relativistic electrons from the disk into the halo. Ekers summarised large scale distribution of radio continuum in E and S0 galaxies and pointed out that none of the elliptican have radio emission distributed like optical light as is the case of spirals. In general, radio emission from S0s is similar to that from ellipticals and flat S0 galaxies do not show radio emission.

Levy reviewed the dynamics of interstellar gas, magnetic field and cosmic rays. The observed distribution of nonthermal radio brightness over the disk of spiral galaxies and the constancy of the radio spectrum suggest that the sources of cosmic rays and relativistic electrons are distributed like total stellar disk and the electrons diffuse out of the disk within characteristic life time 10^7 years. Thus the relativistic electrons escape predominantly along the z-direction, through the faces of the galactic disks rather than by streaming along the spiral arms to the outer edges of the disk. The mechanism for particle escape perpendicular to the disk is provided by the dynamical instability of composite system of magnetic field, gas and cosmic rays and also by inflation of the field by cosmic ray pressure. In a stationary halo, the particle does not mix freely throughout the halo or thick disk. The dynamical halo (Owens and Jokipii, *Astrophys. J.*, **215**, 677 and 685, 1977), which considers both adiabatic expansion losses and synchrotron losses accounts for the observed steepening of the radio spectrum with increasing z-distance.

The enhancement of continuum radio emission seen along the spiral arms (eg. in M51) are interpreted as density wave compression regions. Visser discussed the 21 cm line observation of spiral galaxy M 81 and presented model density and velocity fields computed with nonlinear density wave theory for the gas. Shane discussed problems relating to spiral arms such as stability, propagation, maintenance, regeneration of spiral waves and presence of several spiral modes. He also commented on the difficulties in interpreting some of the observational quantities such as arm to inter-arm ratio of intensity. Shu examined how extensive is the hot phase ($\backsim 10^{6\circ}$K) of the intercloud medium and pointed out difficulties with the hot gas filling the entire interstellar space, considering the observed compression of interstellar medium by spiral density waves in galaxies as well as H I, UV and X-ray observations. He suggested that hot gas observed in soft X-rays may not be extensive as part of the general intercloud medium but likely to be local surrounding the solar neighbourhood.

Freeman reviewed the large scale distribution of light and mass in S and E galaxies and pointed out evidences for the presence of large massive haloes. Van der Bergh in his review showed deep photographs of nearby ellipticals (NGC 5128 and 1316) showing that the galaxies are embedded in very extensive haloes of rather chaotic structure. He pointed out that the missing mass in Coma cluster could have been stripped off from the dominant elliptical glaxies and is distributed throughout the cluster. In rich clusters about 90% of the total mass of galaxies might be stripped off by tidal shocks during one Hubble time.

In a review on star formation in galaxies, Tinsley pointed out that about 5% H I in the galaxy can be converted into stars in about 10^7 years. In general, rate of star formation decreases monotonically with age, but interacting galaxies may have bursts of star formation.

Observations of H I in the outer parts of galaxies were discussed by van de Hulst and Burke. Schweizer presented new radio and optical observaations of interacting galaxies. The optical colours show evidence for active star formation near tip of the tails in NGC 4038/39. Toomre reviewed the theories mainly tidal, for the observed distortions near outer parts of galaxies.

There were many discussions on the optical and radio properties of S0 galaxies. In his review on evolution of disk galaxies, Strom pointed out evidences to favour the interpretation that S0 galaxies are spirals without gas rather than a transition between spirals and ellipticals. Observations of S0s in clusters suggest that they may have suffered removal of gas by stripping.

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of nuclei. Merging of galaxies due to tidal force effects appears to be a likely mechanism for the formation of these galaxies as suggested by several authors. (Ostriker and Tremaine, *Astrophys. J. Lett.*, **202**, L113, 1975; Ostriker and Hausman, *Astrophys. J. Lett.*, **217**, L125, 1975; White, *Mon. Not. R. astr. Soc.*, **174**, 19, 1976; Richstone, *Astrophys. J.*, **204**, 642, 1976; Marchant and Shapiro, *Astrophys. J.*, **215**, 1, 1977).

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