Clusters of galaxies

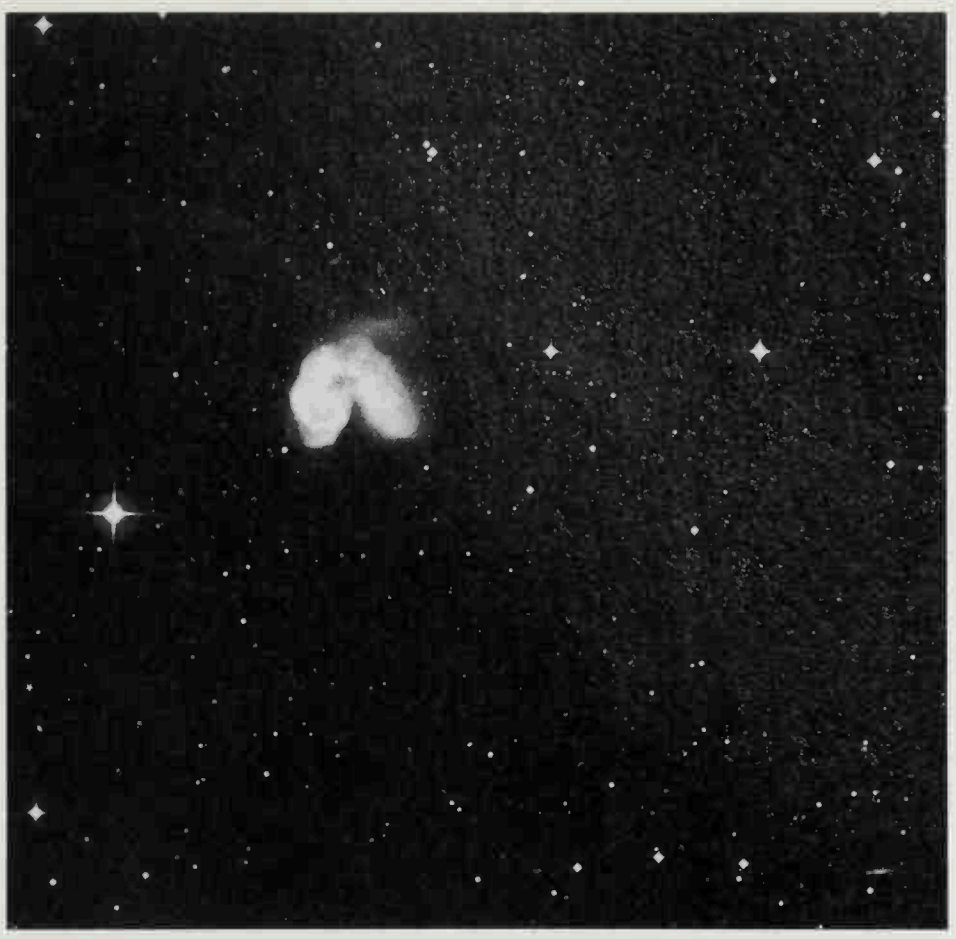
The distribution of galaxies in the sky is not random. Over large areas of sky the numbers are affected by interstellar obscuration within our Galaxy; within small areas, there is a strong tendency towards clustering. A cluster is a real physical clumping of galaxies, with a higher number density of galaxies inside than outside; the diameter may be as large as 10 Mpc. Clusters range from groups with ten or twenty known members, similar to the Local Group, up to rich clusters containing several thousand. Tens of thousands of discrete groups and clusters can be identified in survey photographs; the most conspicuous ones are named after the constellations in which they lie.

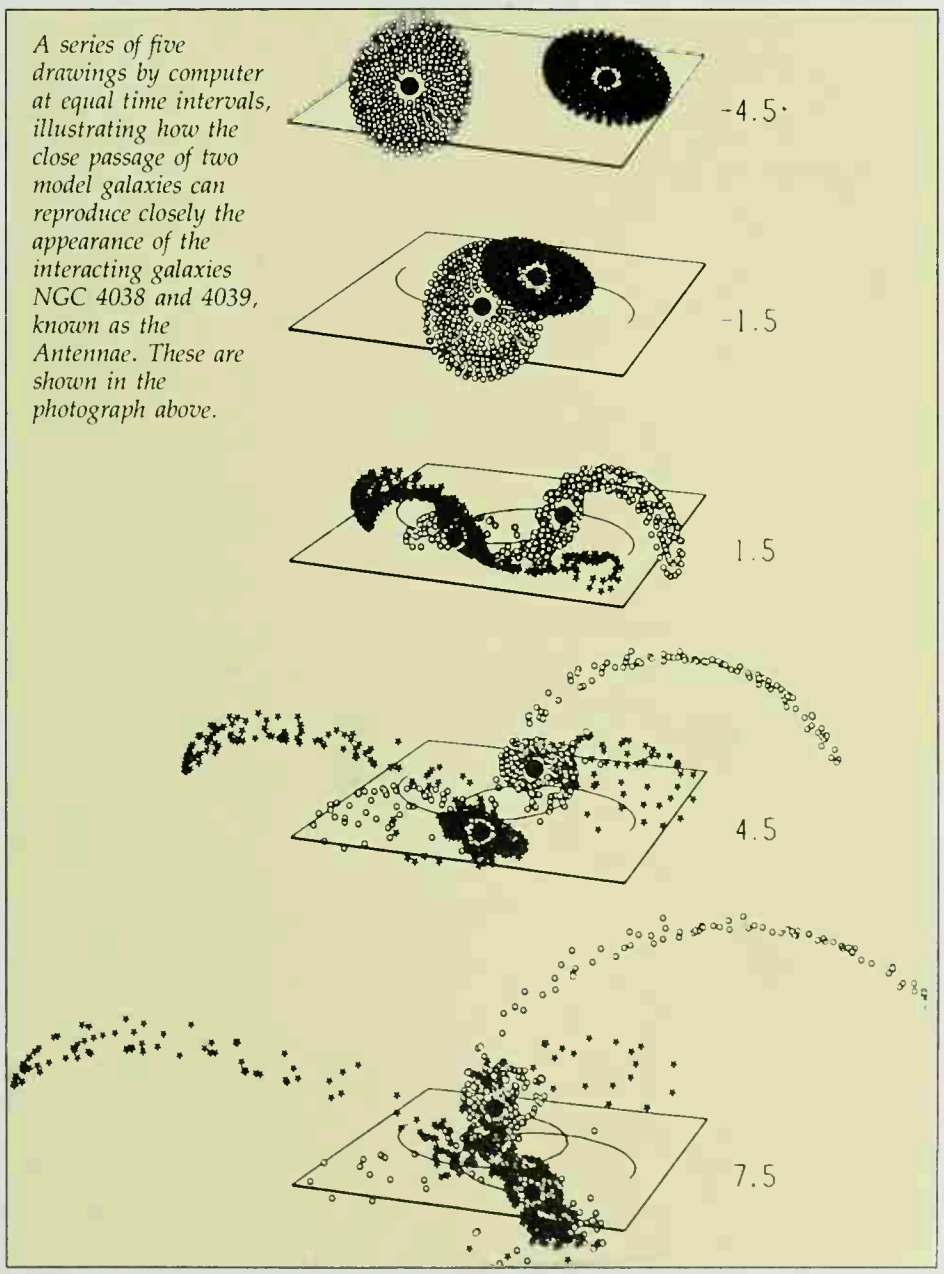
Following George Abell, clusters are classified as **regular** or **irregular**. All regular clusters are large, with thousands of members, and have a spherical shape with a high concentration of galaxies towards the centre, where there is often a cD galaxy; a well-studied example is the Coma cluster. Irregular clusters extend in a continuous range from small groups to large, rich clusters. They have little symmetry and little concentration towards a centre; examples are the Local Group and the Virgo cluster, the nearest large one, which has about 2 500 known members. The centre of the Virgo cluster is about 20 Mpc from the Sun (if Hubble's constant H_0 = 55 km per s per Mpc).

Compared with the statistics for galaxies in general, irregular clusters contain slightly fewer spiral galaxies, and regular clusters very few, particularly in the central regions. Some years ago, it seemed that the probable explanation was that in the denser clusters direct-hit collisions between galaxies would be more frequent, with the result that gas and dust would be swept from the colliding galaxies, causing spirals to become ellipticals. However, using the increased distance scale of recent years, such collisions would be too infrequent. It now seems probable that the gas and dust are pushed out of a galaxy as it passes through relatively dense intergalactic material in the central region of a cluster. There is, however, another possibility – that, for some unknown reason, fewer spirals formed in these higher-density regions in the first place.

About half of the nearby regular clusters and a quarter of the irregular clusters contain radio galaxies; indeed, about a fifth of all radio galaxies lie inside rich clusters, and it may be that many of the more distant radio galaxies which appear separate belong to clusters in which the other galaxies are too dim to be seen. In any case, the figures we have are consistent with giant elliptical galaxies having about the same chance of being strong radio sources whether they are in rich clusters or not.

About a third of the nearby regular clusters, but many fewer irregular ones, have been identified as sources of X-ray emission. They include most of the optically identified, extragalactic X-ray sources. Generally, the X-rays are emitted from an extended region in the cluster centre, larger than a galaxy, and in some cases there is also emission from a central active galaxy. The most probable source of X-ray





A series of five drawings by computer at equal time intervals, illustrating how the close passage of two model galaxies can reproduce closely the appearance of the interacting galaxies NGC 4038 and 4039, known as the Antennae. These are shown in the photograph above.