ON THE FORMATION AND DYNAMICS OF SHELLS AROUND ELLIPTICAL GALAXIES

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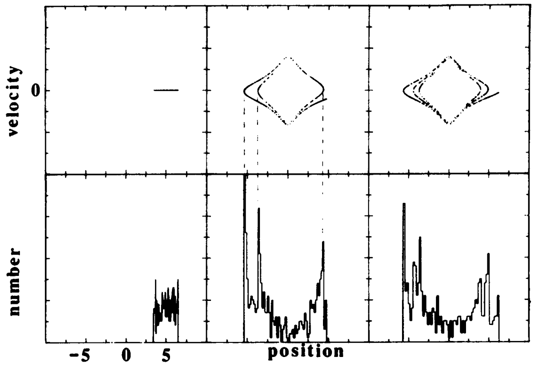
Sharp shell-like structures around elliptical galaxies can be modelled by the phase wrapping of a cold disk of stars in the fixed potential of a massive elliptical galaxy. Such structures can then be used as probes of the potential field of ellipticals and a diagnostic of the merger event.

Schweizer (1980) has suggested that the sharp, ripple-like structures around Fornax A may be the result of a merger involving a disk galaxy. Sharp ripple or shell-like structures can also be seen around several ellipticals in the Arp Atlas (1966) and many examples have been recently found by Malin and Carter (1980, 1981) around otherwise normal ellipticals. Photometry of the shell structures (Carter, Allen, Malin, 1982), indicates their extremely low surface brightness and colours which appear to be bluer than the central galaxy. Contrast enhanced prints of prime focus plates of shell galaxies taken on the Anglo-Australia Telescope have been used to characterise the shell structures. It has been found that the shells are incomplete, that is they do not completely encircle the central galaxy. They occur over a large range in radius (outer shell radius = 30 x inner shell radius, NGC3923) and the shells are interleaved in radius, that is the next outermost shell occurs on the opposite side of the nucleus. The "shells" can be considered as caps of stars with no two caps being at the same radius.

As an attempt to model such structures, experiments involving the radial encounter of self-gravitating, N-body disks and fixed spherical potentials have been conducted. Two dimensional encounters have produced sharp, incomplete "shell-like" structures which appear on either side of the post-collision system and spread slowly in radius. N-body models failed to produce large numbers of shell-like structures due to a lack of particles to populate an increasing number of shells, particularly in three dimensions.

The formation of shells can be viewed as a simple phase wrapping of a cold system in a fixed potential, (pig-trough dynamics), Lynden-Bell (1967). Figure 1 shows the evolution of a one dimensional system of test particles falling into a fixed Plummer potential with a scale length of one unit.

E. Athanassoula (ed.), Internal Kinematics and Dynamics of Galaxies, 347–348.



The difference in periods of the leading and trailing edge of the infalling system causes the system to phase wrap. The maximum spatial excersion of each phase wrap corresponds to a spatial density clump. These clumps correspond to the shells. As the system evolves, the number of shells increases at a rate determined by the range of periods available in the initial system. Shells therefore occur between two well defined radii set by the spread in energy of the initial system; the shells are interleaved in radius and occur at different radii.

The distribution of shells around several shell galaxies is not a smooth distribution as would be expected from a simple wrapping of a single system in a fixed smooth potential. It is not possible to rule out the suggestion that the observed shell structures are the result of several mergers with disk systems. However, the fact that the shells appear to be predominantly interleaved over a large range in radius, argues against the suggestion that they arise from the random infall of several disks. If the shells are the product of the merger of a massive elliptical and a single disk, the distribution of shells can be used to probe the potential of the elliptical over many effective radii of the central luminous galaxy. The shell distribution of two bright ellipticals with a large number of shells ($\sim$20) suggests that the shells are moving in a potential that is not as centrally condensed as the central luminous galaxy. A "halo-like" component would be a natural component of an elliptical if it were to be formed by or made move massive by a merger with a disk and its halo component.

Shells represent the tell-tale evidence that the history of some ellipticals is linked to mergers involving disk galaxies. It is clearly very important to investigate the statistics of shell ellipticals and identify the importance of mergers to the current epoch distribution of ellipticals and to use the shells as a probe of the mass distribution of ellipticals.

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