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A study of the environmental influences on spiral galaxies in clusters

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1. Introduction

Gravitational fields in clusters as well as the hydrodynamic effects of the intracluster medium on the gas in galaxies are responsible for the observed differences between cluster and field galaxies. The thesis consists of two parts. The first part deals with the problem of atomic hydrogen deficiency in spiral galaxies in clusters. The second part describes a numerical study of the effects of the mean tidal field of a cluster on the dynamics of a disk galaxy travelling through it.

2. HI-deficiency in spirals

Global deficiency of the atomic hydrogen in cluster spirals is the strongest evidence of ongoing environmental changes (see Haynes 1990 for a review). An analysis of existing HI data on Virgo Cluster spirals (Warmels 1986) showed that a small faction of them were significantly deficient in their inner disks as well.

Head-on collisions between spiral galaxies can strip the interstellar gas from the colliding galaxies while leaving their stellar components undisturbed. It was shown that the filling factor of the gas component was crucial in determining whether or not it would be stripped. It was found that in a fast collision the HI would be preferentially stripped leaving the molecular components unaffected, thereby accounting for the observed inner deficiency (Valluri & Jog 1990).

For spiral galaxies in four clusters it was found that larger galaxies are more HI-deficient than smaller galaxies. None of the popular gas stripping mechanisms can account for the observed dependence of HI-deficiency on galaxy size. It was proposed, therefore, that tidal interactions between galaxies which occurred at early epoches could account for this dependence (Valluri & Jog 1991).

3. Effects of the mean cluster tidal field

A numerical study of the effects of the mean tidal field of a cluster on a disk galaxy travelling through it was carried out in the restricted 3-body framework (Valluri 1993).

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In the model adopted the tidal field is compressive in the core of the cluster. The tidal interaction with the mean cluster potential results in a substantial increase in the planar velocity dispersions of both the gas clouds and stars in the disk galaxy. The tidal fields also caused non-axisymmetric perturbations to the particle distributions in the disks which manifested either as a transient spiral or an oval compression. There is very little effect on the vertical motions of the stars although transient warps are likely if the disk is inclined to the orbital plane in the cluster.

It was shown that the selective increase in the planar velocity dispersion could make the disk unstable to the 'Fire-Hose' instability (Kulsrud *et al.* 1971). It was also shown that the tidal field, though apparently symmetric, could transport angular momentum (in a manner analogous to that described by Lynden-Bell and Kalnajs 1972) in the disk and would aid gas infall which could be followed by a burst of star formation.

The most easily observable effect of the interaction is on the rotation curves of the disk galaxies. The increase in the stellar velocity dispersions causes a systematic decrease in the mean tangential velocity owing to the increased radial "pressure" (referred to as the 'asymmetric drift' phenomenon—see Binney & Tremaine 1987). Thus the outer rotation curves begin to decline after the encounter despite the fact that the potentials of the galaxies are unaltered. This may account for the observed decline in the rotation curves of cluster galaxies (Whitmore, Forbes & Rubin 1988).

The main conclusion from this thesis is that tidal effects on spirals, either those which occurred at early epoches due to interactions between individual galaxies or the long lived effects of the interaction with the mean tidal field, can significantly affect the evolution of the gas and stars in these galaxies.

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