CLUSTER TIDAL FIELDS: EFFECTS ON DISK GALAXIES

Monica Valluri
Department of Physics
Indian Institute of Science, Bangalore 560012, India.

Introduction

A variety of observations of galaxies in clusters indicate that the gas in these galaxies is strongly affected by the cluster environment. Here we present results of a study of the dynamical effects of the mean cluster tidal field on a disk galaxy as it falls into a cluster for the first time on a bound orbit with constant angular momentum (Valluri 1992). The problem is studied in the restricted 3-body framework. The cluster is modelled by a modified Hubble potential and the disk galaxy is modelled as a flattened, spheroid.

In the model adopted the galaxy experiences a mean tidal field which is strongest within 2 core radii of the cluster centre and is compressive within the core. The effect of the cluster tidal field on the disk galaxy resembles the phenomenon of compressive shocking of globular clusters by the Galactic disk (Ostriker, Spitzer & Chevalier 1972). Also since the time taken for the galaxy to cross the core (a few times 10^8 yrs) is comparable to the rotation time in the disk, the tidal perturbation may be considered to have a "pattern frequency" Ω_p, which is comparable to the rotation frequency in the disk $\Omega(R)$ and the epicyclic frequency κ. Thus resonances can enhance the tidal effects.

Thickening the Disks of Spiral Galaxies

The tidal effects on the disk are seen in the changes in the velocities of test particles. Gas clouds are represented by particles with low random velocities (5-10 $\mathrm{km\,s^{-1}}$) and stars are represented by particles with random velocities of 20-35 $\mathrm{km\,s^{-1}}$). The low velocity dispersion gas clouds experience a relatively larger increase in random velocity than the hotter stellar component. A strong tidal field increases the planar random velocities of all particles to between 50–60 $\mathrm{km\,s^{-1}}$. In most cases the vertical dispersion of particles is almost unaffected because the frequency of vertical oscillation is nearly an order of magnitude higher than the "pattern frequency" making the encounter adiabatic in the vertical direction.

The increase in planar random velocities results in a strong anisotropy between the planar and vertical velocity dispersions. Previous analytic (Kulsrud, Mark and Caruso 1971) and numerical (Raha *et. al.* 1991) work has shown that in such a situation the disk will become unstable to the "fire-hose instability" which leads to bending modes normal to the disk. This helps to transfer planar kinetic energy to energy of vertical motion and results in an increase in disk thickness. Using energy conservation considerations we estimate that the disk thickness will increase typically be a factor of 1.5-2.0.

Gas Infall and Starburst

The spatial distribution of particles is also strongly perturbed by the tidal field. A disk parallel to its orbital plane in the cluster develops a spiral pattern primarily due to the bisymmetry in the tidal field. Circular orbits have resonaces at Ω and $\Omega \pm \kappa/2$, and these enhance the tidal perturbation producing a kinematic spiral pattern (Kalnajs 1973).

A disk which is perpendicular or inclined to the orbital plane, is transiently compressed as it passes through the cluster core. The originally circular disk is deformed into an oval or ellispe. The disk re-expands to 1.5 times its original size after it leaves the core region indicating a heating of the disk. Disks inclined to the orbital plane form transient warps which are fairly pronounced especially in the gas component.

These transient non-axisymmetric perturbations will transport angular momentum (Palmer & Papaloizou 1982). Simultaneously increasing the cloud velocity dispersion increases the frequency of cloud collisions leading to kinetic energy dissipation. These two processes can together lead to gas infall to the galaxy center and subsequently an enhanced rate of star formation. We also suggest that the mean tidal fields of rich clusters could have been stronger in the past particularly at the epoch of cluster formation and could have trigger activity in spiral galaxies in high red-shift clusters (the Butcher–Oemler clusters).

Acknowledgement: I am grateful to the Council of Scientific and Industrial Research, India, and Organisers of the 3rd Teton meeting for financial assistance. A special note of thanks to Harley Thronson for hospitality and for having made it all possible.

References

Kalnajs, A.J. 1973, Proc. Astr. Soc. Austr. 2, 174.
Kulsrud, R.M., Mark, W.-K. & Caruso, A. 1971, Astr. Sp. Sci, 14, 52.
Ostriker, J.P., Spitzer, L. & Chevalier, R.A. 1971, ApJ, 176, L51.
Palmer, P.L. & papaloizou, J. 1982, MNRAS, 199, 869.
Raha, N., Sellwood, J.A., James, J.A. & Kahn,F.D. 1991, Nature, 352, 411.
Valluri, M. 1992 ApJ, Preprint (Submitted)