GROUP DYNAMICS AND COMPACT GROUPS

G.A. MAMON
DAEC, Observatoire de Meudon
F-92195 Meudon Cedex, FRANCE

Groups of galaxies may constitute an excellent laboratory for the study of galaxy interactions. These should naturally be more spectacular in the apparently densest groups, known as "compact groups", presumably the densest isolated regions in the Universe. The theoretical question that arises is *what is the dynamical evolution of a dense group?*, while a more down-to-earth question is *are compact groups as dense as they appear?* I will attempt here to answer both of these questions in turn, basically summarizing two contributions to an earlier conference (Mamon 1990a,b).

Besides their mutual attraction, galaxies in groups are subject to tides, mergers, and attraction to as well as dynamical friction against a perhaps dominant intergalactic background of dark matter. The competition between these processes is best understood through numerical simulations. In "explicit-physics" simulations, galaxies and the intergalactic background are treated as single particles, and the physics described above must be explicitly included, while in "self-consistent" simulations, galaxies and the intergalactic background are modelled by as many particles as possible. The self-consistent method provides an accurate description of encounters. The explicit-physics method is orders of magnitude faster to run, thus allowing the construction of statistical samples of simulated groups in evolution. However explicit-physics algorithms are more difficult to code and the physics has usually not been all properly included in such simulations of clusters and groups of galaxies (see Mamon 1990a).

All of five self-consistent studies (Carnevali *et al.* 1981; Cavaliere *et al.* 1983; Barnes 1985, 1989; and Ishizawa 1986) and two explicit-physics studies (Roos and Norman 1979; and Mamon 1987) point to the importance of mergers. The mean time between successive mergers as averaged over the first four and normalized to the group's earlier cosmological collapse time at half-mass radius, ranges between 0.2 and 4 (Mamon 1990a). These differences are understood to be caused by physical, numerical, and statistical effects. When the evolution timescales are converted to physical units one finds that groups as dense as appear Hickson's (1982) compact groups (hereafter, HCGs) coalesce by mergers into a single galaxy, such that their compact group identity is lost within a small fraction of a Hubble time (Mamon 1987). If dense groups formed at large redshift from very strong initial density pertubations, then they must have collapsed and virialized in a small time compared to H_0^{-1}, and hence coalesced in a short time compared to the Hubble time. Alternatively dense groups may have formed recently by two-body processes within larger loose groups. However, an analysis of 100 simulations of loose groups has shown that virtually no dense

F. Combes and F. Casoli (eds.), Dynamics of Galaxies and Their Molecular Cloud Distributions, 394–396.

groups form in this way (Mamon 1987).

These arguments weaken the possibility that HCGs are bound dense systems. One alternative is that HCGs are dense, but unbound transient 3D chance configurations within larger loose groups (Rose 1979). Another possibility is that HCGs are caused by 1D chance alignments along the line of sight within larger loose groups (Mamon 1986; Walke and Mamon 1989). Simulations of loose groups have shown that 1D chance alignments occur more frequently than 3D unbound dense subsystems, especially when the dark matter is in individual galactic halos (Mamon 1987). I will now summarize the ongoing debate between the respective advocates of bound dense groups and chance alignments.

The arguments raised forth in Mamon (1986) against HCGs as bound dense systems and for chance alignments were the following:
1) *Demographics:* As mentioned above, dense groups formed too infrequently within the simulated loose groups and lived too short a time in isolation to explain HCGs as such dense bound systems.
2) *Chance alignments:* Simulated loose groups viewed in projection contained enough subgroups that met the HCG criteria to explain all HCGs as 1D chance alignments (in fact I had found too many such systems).
3) *Dynamical evolution:* By analyzing sets of 50 simulated groups at various stages of their evolution, statistical signatures of luminosity segregation (when the dark matter is in an intergalactic background) and mergers become rapidly evident. However, these statistical tests applied to the observed sample of HCGs showed no evolution.
4) *Galaxy morphological types:* HCGs do not obey the general morphology-density relation found for groups and clusters by Postman and Geller (1984), but follow instead a parallel relation, which could be reconciled with the general relation if HCGs were 200 times less dense than they appear.

The responses of the bound dense group partisans and my rebuttals are listed below:
1) *Demographics:* It has been suggested that the ratio of HCG to loose group number densities in the Universe is simply the ratio of their lifetimes, which in turn is the ratio of their crossing times, or $\simeq$ 1% (Barnes 1989). But if dense groups form within loose groups by two-body relaxation, then the ratio of number densities must be multiplied by the probability that a loose group will witness a bound dense subgroup form within it sometime during its lifetime (Mamon 1990b). From hundreds of simulations of loose groups, this probability turns out to be lower than 10% (see Mamon 1987).
2) *Chance alignments:* Non-dynamical simulations performed by Hickson and Rood (1988) have led these authors to conclude that the typical loose group has a probability of the order of 10^{-5} of showing a compact group within it. An analytical followup by Walke and Mamon (1989) confirms the Monte-Carlo results of Hickson and Rood and the 2-25% of chance alignments observed in Mamon's (1987) simulated loose groups (the discrepancy is caused by different parameters and selection criteria). The strong sensitivity to parent group size causes the *mean* frequency of chance alignments to be much larger than the *median* frequency considered by Hickson and Rood, and large enough to explain roughly half or more of the HCGs as chance alignments.
3) *Morphological types:* Hickson and Rood also argue that the morphological mix of galaxies in groups is more dependent on the group velocity dispersion than on its density, hence that HCGs disobey Postman and Geller's (1984) morphology-density relation is not a cardinal sin. This is an important point which must be investigated in more detail for loose groups and clusters. If HCGs are chance alignments, than one would expect that the correlation between chance alignment and parent group surface number densities be less than for the corresponding velocity dispersions, hence the trend seen by Hickson and Rood.

4) *HCG environments:* Various authors (Williams and Rood 1987; Sulentic 1987; Rood and Williams 1989) have studied the environment of HCGs and find a substantial fraction to appear too isolated to be embedded in a loose group. The three studies use three different isolation statistics that yield little agreement on a group by group basis. Considering the HCGs that are bright and close enough for at least two of their members to be included in galaxy catalogs used to build loose group catalogs, I find 5 such HCGs plus an additional compact group not included in the HCG catalog but meeting the HCG criteria (Mamon 1989), of which *all* are embedded in loose groups (Mamon 1990b).
5) *Galaxy interactions:* Numerous studies have detailed many HCGs with evidence of galaxy-galaxy interaction, based upon continuum radio (Menon and Hickson 1985, 1990), HI (Williams and Rood 1987), IR (Hickson *et al.* 1989), blue ellipticals (Zepf and Whitmore 1990), and rotation curves (Rubin *et al.* 1990). These interactions involve altogether more than half of all HCGs. However, if HCGs are chance alignments within larger loose groups, one is preferentially selecting binaries and triplets, and should thus see interactions among two or three galaxies. The details work out well to first order (Mamon 1990b). But interactions do not last forever, and one has yet to do a detailed study where the duration of interactions is considered when estimating the number of galaxies with signs of interaction.

In summary, the nature of compact groups is still a matter of much debate. Dynamical simulations will continue to be a useful tool, mainly for estimating the statistics of the duration of interaction (where self-consistent simulations must be used) and the statistics of pairs and triplets in chance alignments within loose groups (for which explicit-physics simulations are best suited). Another promising avenue of research consists of automatic sky-survey scans that should yield with better precision the ratio of HCG to loose group number densities, as well as systematically probe the regions surrounding HCGs.

Barnes, J. 1985, *M.N.R.A.S.*, **215**, 517.
Barnes, J. 1989, *Nature*, **338**, 123.
Carnevali, P., Cavaliere, A., and Santangelo, P. 1981, *Ap. J.*, **249**, 449.
Cavaliere, A., Santangelo, P., Tarquini, G., and Vittorio, N. 1982, in *Clustering in the Universe*, ed. D. Gerbal and A. Mazure (Gif-sur-Yvette: Editions Frontières), p. 25.
Hickson, P. 1982, *Ap. J.*, **255**, 382.
Hickson, P., Menon, T.K., Palumbo, G.G.C., and Persic, M. 1989, *Ap. J.*, **341**, 679.
Hickson, P. and Rood, H.J. 1988, *Ap. J. (Letters)*, **331**, L69.
Ishizawa, T. 1986, *Ap. Sp. Sci.*, **119**, 221.
Mamon, G.A. 1986, *Ap. J.*, **307**, 426.
Mamon, G.A. 1987, *Ap. J.*, **321**, 622.
Mamon, G.A. 1989, *Astr. Ap.*, **219**, 98.
Mamon, G.A. 1990a,b, *in Paired and Interacting Galaxies, IAU Colloq. 124*, ed. J.W. Sulentic and W.C. Keel, in press.
Menon, T.K., and Hickson, P. 1985, *Ap. J.*, **296**, 60; 1990, in preparation.
Postman, M., and Geller, M.J. 1984, *Ap. J.*, **281**, 95.
Rood, H.J., and Williams, B.A. 1989, *Ap. J.*, **339**, 772.
Roos, N., and Norman, C.A. 1979, *Astr. Ap.*, **76**, 75.
Rose, J.A. 1979, *Ap. J.*, **231**, 10.
Rubin, V.C., Hunter, D., and Ford, W.K. 1990, in preparation.
Sulentic, J.W. 1987, *Ap. J.*, **322**, 605.
Walke, D.G., and Mamon, G.A. 1989, *Astr. Ap.*, **295**, 291.
Zepf, S.E., and Whitmore, B.C., 1990, in preparation.