SYMMETRY BREAKING AND INVARIANT MASS APPROACH TO THE SPIRAL STRUCTURE OF GALAXIES

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The physical conditions in the centre of spiral galaxies as our own galaxy still are not very well known. They offer themselves to more or less exotic speculations, some of which involve the possible existence of black holes and mechanisms for the production of high energy cosmic rays. In view of such argumentations I feel it worthwhile to look in more detail into recent progress obtained in the understanding of the dynamics of the central region of spiral galaxies which turns out to be intimately related to the galaxy as a whole, especially its spiral structure.

The persistence of galactic spiral structure in the presence of differential rotation is explained in terms of a spiral shaped density wave rotating at a certain angular velocity inside the stellar disk (B. Lindblad, 1941). This notion still is the basis of the understanding of the dynamics of galactic spirals. Still the question of the physical mechanism underlying this density wave is not finally answered. According to "gravitational" density wave theory (Lin and Shu, 1964) adopted by many astronomes today, the density wave is produced primarily by the mutual gravitational attraction of stars inside the galactic disk.

One way of testing this hypothesis is by performing N-body simulations of differentially rotating stellar disks. Typical results (Hohl, 1971) show a short living 's'-shaped transient spiral and, finally, the formation of an oval shaped configuration rotating around its smallest axis without essentially changing its structure. This object is surrounded by a disk shaped low density distribution of stars, rotating differentially around the same axis. So far, these N-body simulations have not reproduced long-living spirals. Recently, the density distribution of stars inside the disk has been investigated carefully (Berman and Mark, 1979; Sellwood, 1980) and long-living spiral shaped trailing density waves have been found. These results obviously seem to confirm the basic assumption of "gravitational" density wave theory, namely that the spiral pattern is generated by the mutual gravitational interaction of stars inside stellar disks. As a further test of this

G. Setti, G. Spada, and A. W. Wolfendale (eds.), Origin of Cosmic Rays, 171 - 172.

assumption we have performed a different type of N-body simulations (Thielheim and Wolff, 1979). In these, no mutual gravitational interaction was provided for between stars inside the surrounding disk. Nevertheless, long-living spiral shaped trailing density waves were found again. These results therefore suggest, that the mutual gravitational attraction of stars inside the galactic disk might not be the mechanism which is primarily responsible for the existence of spiral density waves. Instead they suggest that the generation of a spiral pattern in a differentially rotating stellar disk primarily is a response to a central, rotating oval shaped mass distribution which may be understood as an equilibrium configuration growing "adiabatically" by accretion of stars from the surrounding disk. This interpretation implies that the ground state of a differentially rotating, self gravitating stellar system is (under certain conditions) not rotationally symmetric (but only mirror symmetric). This symmetry breaking may be understood as a consequence of the non-linearity of the dynamics governing the central object. The dynamics of the surrounding disk is essentially linear. But at this stage mirror symmetry is broken through the time dependence of the gravitational force exerted by the central object onto the stars in the disk, thus producing a spiral shaped, trailing density wave (Thielheim, 1980). The form of the spiral is determined by the distribution of mass in the central oval object , its (adiabatic) increase with time and by its rotational pattern velocity on the one hand and by the mean distribution of mass inside the surrounding disk on the other.

We are thus led to the conjecture that the oval shaped equilibrium configuration found in N-body simulations is what is otherwise observed as elliptical galaxies. During the formation of an elliptical galaxy essentially all the mass available is successfully incorporated into this stable distribution. In other cases part of the total mass was left outside as a disk. According to this line of thought each spiral galaxy in its centre houses an elliptical galaxy, the adiabatic increase of which produces a spiral density wave in the disk, the form of which would be influenced by gravitation among stars in the disk and interaction with the viscous interstellar gas.

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