A TWO-PARAMETER SCHEME FOR THE EVOLUTION OF SYMMETRICAL GALAXIES

R. CAIMMI
Istituto di Astronomia, Università di Padova, Italy

and

N. DALLAPORTA
International School for Advanced Studies, Trieste, Italy

(Received 1 July, 1981)

Abstract. In the present paper, a general evolutionary scheme for axisymmetrical rotationally supported equilibrium models for galaxies is considered. Its main phases are: an expansion phase of the initial protogalaxy, assumed to consist into an homogeneous gas sphere structured into clouds, from recombination to maximum expansion, during which it is surmized that angular momentum is acquired by tidal interactions by the expanding configuration; then a violent relaxation collapse phase, following maximum expansion and ending into a virialized deformed polytropic configuration; the reaching of virialization is considered as an adequate initial state for the new phase of virialized contraction of the gaseous component, due to the collisions of the constituent gas clouds, while the stellar component, due to the stars already formed according to a generalized Schmidt-type law during the early expansion and violent relaxation phases, is assumed to have reached a stabilized situation.

The initial mean density and radius for both galaxy and component clouds expressed as functions of the density fluctuation spectrum at recombination, act as physical parameters determining the characteristics of the system at maximum expansion, together with the total amount of angular momentum acquired during the expansion phase. The main physical parameters at virialization are then completely specified when the initial distribution of the clouds inside the galaxy is assigned and the constants appearing in it are derived by normalization with the observed data.

We find for systems of given mass that the larger the angular momentum per unit mass is: (1) the larger are the equatorial semiaxis at maximum expansion and at virialization and the lower the mean density; (2) the larger is the time elapsed up the maximum expansion and to virialization; while for systems of different mass, we obtain that to the larger mass correspond the larger time elapsed up to maximum expansion and to virialization, and the lower mean density.

For the contraction phase following virialization, two limiting cases are considered: (A) either the star component already present at virialization is entirely neglected; (B) or it is thought to contract as the gas component. In such cases, it is found for systems of equal mass that lower angular momenta lead to final configurations characterized by no or small flat gaseous components (which may correspond to lenticulars and early type spirals) while the contrary is true for large angular momenta (corresponding to late type spirals and irregulars). As mass and angular momentum per unit mass decrease, according to an assumed law $j \propto M$, the allowed configurations on the late type side of the morphological sequence tend towards earlier and earlier types, until for masses low enough ($\lesssim 10^{10} M_\odot$), only halo type configurations seem to exist. According to this view, the observed lack of spirals with masses below $10^{10} M_\odot$ and the wide mass range exhibited by the stellar halo type galaxies might be interpreted. In general, it appears that in the limit of the approximations made, a morphological sequence of galaxies can be described by two parameters, mass and angular momentum.

1. Introduction

Up to a few years ago, most of the theoretical work concerning the origin and the evolution of galaxies was almost entirely based on symmetrical models, assuming
either spherical or axial symmetry for both the initial and the following configurations, as it was generally surmized that all galactic objects observed in the sky were axisymmetric spheroids in a state of rotationally supported equilibrium. However since 1975, when the first results concerning the rotation of elliptical galaxies were obtained (Bertola and Capaccioli, 1975; cf. Schechter and Gunn, 1979, for other references), it became apparent that at least in some cases the rotation was too slow to be compatible with a rotationally supported equilibrium state, and further studies on the twisting of the axes of the isophotes opened the way to the formulation of triaxial models for ellipticals and to theories of formation based on largely non-symmetrical models for the protogalactic configurations (Binney, 1976–1980; Rees and Ostriker, 1977).

Although there appears to be no doubt concerning the necessity of largely widening the frame of the possible theoretical approaches able to explain the whole phenomenology related to the non-symmetrical observed objects, still there are no clear cut signs that the largest part of the Hubble sequence running from lenticulars up to late type spirals should not be represented adequately by the traditional axisymmetric equilibrium rotationally supported models. Thus it seems to be still justified that, next to studies concerning the new non-symmetrical situations, one should still pursue the work along the more conventional line of the symmetrical configurations, in the hope of succeeding to focus with increasing evidence some correlations between a number of physical parameters and the observed types of the sequence. The present paper is an attempt to reach a more complete outlook on the whole process of formation and evolution in the frame of this symmetrical line of thought. A common feature to all approaches along this path assumes that, when the matter of a protogalaxy has been separated from the background at recombination time, due to some primordial density fluctuations of the cosmic matter, and has further expanded, following the general cosmic trend, up to a maximal extension for which gravitational forces counterbalance expansion, it then begins to recontract in a kind of free fall collapse, whose main characteristics and phases are somewhat differently outlined by different authors.

Gott (1973, 1975) and Gott and Thuan (1976) consider a non-virial dissipationless contraction phase of the assumed initially spherical protogalactic structure, leading after some oscillations of decreasing amplitude to a collapsed virialized state more or less concentrated on the equatorial plane, virial equilibrium being reached in an about three times longer time than that necessary to reach maximum expansion from the original separation time at recombination. The protostellar component of stars formed during expansion and early collapse settles through a violent dissipationless relaxation phase into a final spheroidal structure, while the remaining gas component after some radial dissipative oscillations flattens into a thin disk.

In Larson's (1976) approach, collapse from the maximum extension state is followed through integration of the fluido-dynamical equations of the gas; the predicted disk-bulge ratio turning out to be mostly dependent on different rates of star formation, more rapid in the bulge and slower in the disk, the different rates being assumed to be dependent on the previous state of the gas.