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Correlation of a bar and spirals at formation of galaxies

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Numerical simulations of the evolution processes in disks of spiral galaxies are performed. The initial state is presented by physically substantiated equilibrium configuration for a stellar-gas disk. Possibilities of influence of a bar on the process of occurrence of spiral structure of galaxies are investigated.

Keywords: Galaxies; Galaxies pattern; numerical simulation

Observations and theory studies of galaxies suggest that bars and spirals are closely connected with each other and that strong bar correlation can be present at a strong spiral (see, e.g., [1]). This bar–spiral correlation confirms also that the two features have the same pattern speed. However the nature of this interaction still definitively is not clear.

In the present research we analyze the non-linear coupling between bar and spiral structure of galaxies. Possibilities of bar's influence on process of occurrence of spiral structure of galaxies are investigated in numerical simulations.



Figure 1

Our model consists of a self-gravitating exponential stellar disk, embedded in a spherical component which is described with an analytical force model. The influence of the gas component is neglected. The initial state is presented by physically substantiated equilibrium configuration for a stellar-gas disk. In the absence of external perturbation our standard simulation disk is stable against the formation of strong large-scale structures (Fig. 1). The central kpc is shown on Fig. 2.

A planar perturbation to the potential of stars disk with logarithmic two-armed spiral morphology is introduced analogically with the model Toomre potential [2]. Galaxies with bars as well as galaxies without evident bars have such spiral logarithmic

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Figure 2



Figure 3

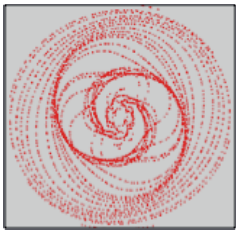


Figure 4

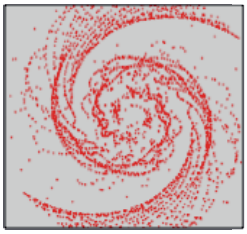


Figure 5

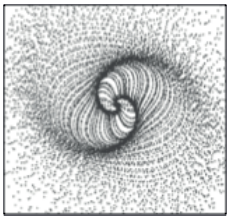


Figure 6

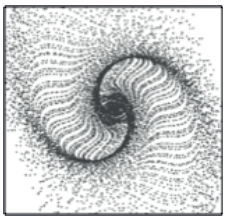


Figure 7

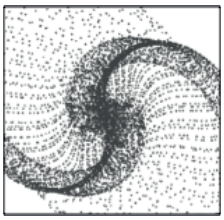


Figure 8

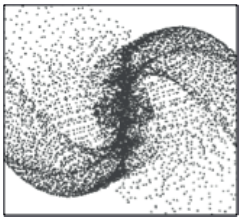


Figure 9

addition, what probably could show on non-participation of these non-axisymmetric formations to occurrence of spiral structure.

Deviations from the equilibrium distribution start in the central area of disk. External perturbation of stars gravitational potential contributes to non-circular motions of population of galactic disk. Non-circular motions of stars cause an oval elongation in nuclear region already in the early stages of development of concerned self-gravitating system (Fig. 3). Complicated open-ended motions path, with chaotic oriented orbits of different stars, quite rapidly (during the first half-turn of stellar disk) result in the formation of well-ordered spiral pattern. At later times in central region a minibar (Fig. 4) and then a bar are developed (Fig. 5). Details of forming of bar–spiral pattern could be traced also in full-scale format ambienting practically all range of self-gravitating stellar disk (Figs. 6–9). The region of the bar is well distinguished, and at the same time the bar as well as the spiral pattern are most developed, strong and distinct, with an evident tendency to transient formation in the spiral structure (see, e.g., [3]). The formation of exponential distribution of bulge is also distinctly visible (Fig. 10). It is interesting that the initial view of the galactic stellar disk "from edge" represented in Fig. 1 also qualitatively changes with time (compare Figs. 1 and 11).

The general structure of obtained solution for ideal gas flow in equatorial plane of concerned gas-stellar system is represented in Figs. 12–15. The pattern of gas flow is formed by influence of self-gravitating stellar disk, sunken in gravitational

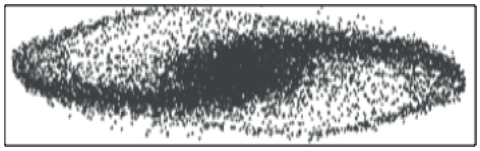


Figure 10

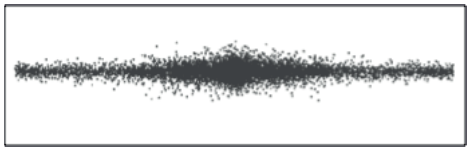


Figure 11

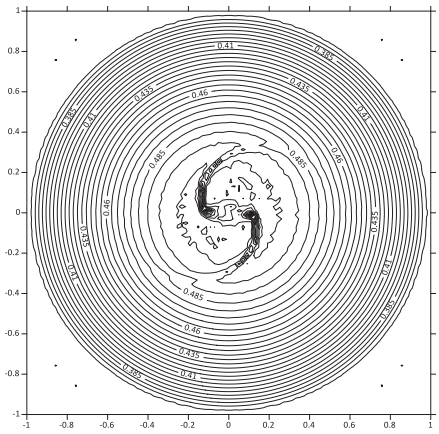


Figure 12

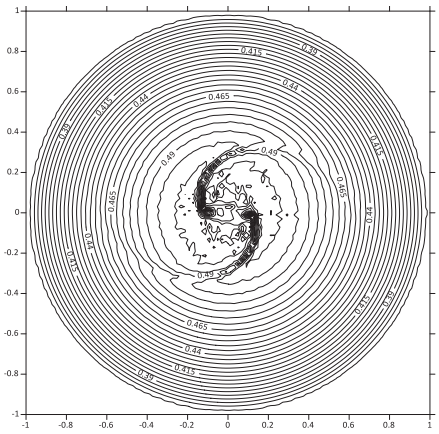


Figure 13

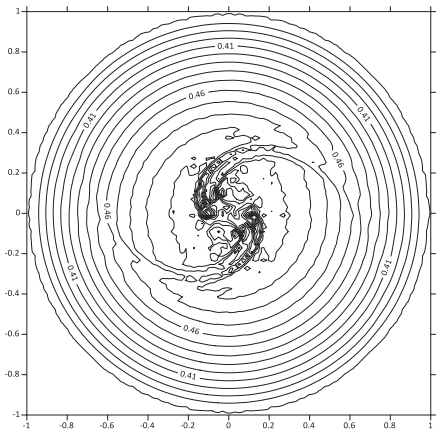


Figure 14

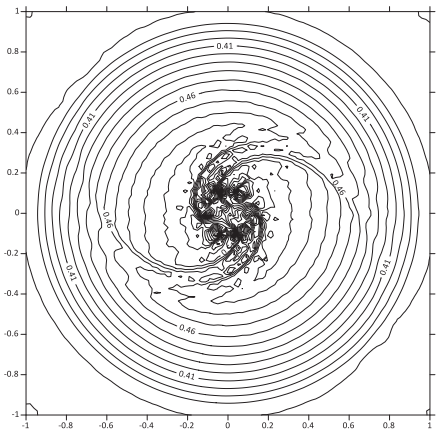


Figure 15

field of spherical component of system (halo), with taking into account additional stellar gravitational spiral potential. Apparently from these pictures, with time occurs the formation of two large spiral structures, appearing in elements of global spiral pattern, corresponding to the so-called Grand Design structure. Originated spiral structures represent strong shock waves, presenting during all time of calculation and well-ordered at the same time. The most considerable changes take place in central regions of gas disk. Here of elongated bar-like linear mode, enclosing spiral configuration on itself is formed. In Figs. 16–19 the picture of such formation is well detailed.

The presented results of numerical simulations show that the dynamics of development of gas disk are quite coordinated with evolutional dynamics of development of stellar disk. Both disks reproduce the same plotline: the formation of strong two-armed global spiral certainly leads to origin and development of strong connecting arms, bar. This addition supposes that bars and spirals are genetically closely connected with each other, and that strong bar correlation in strong spiral indeed could

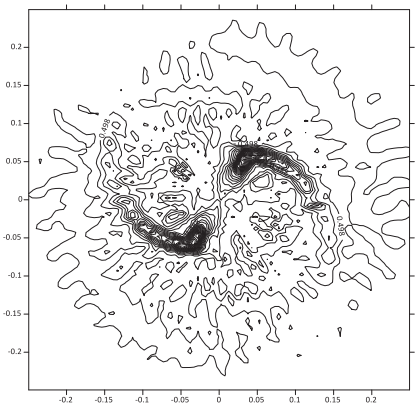


Figure 16

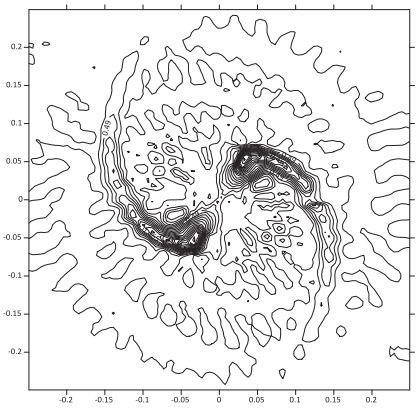


Figure 17

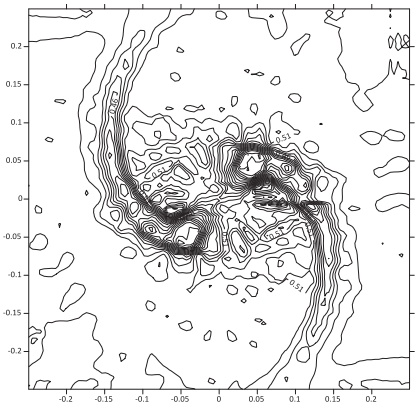


Figure 18

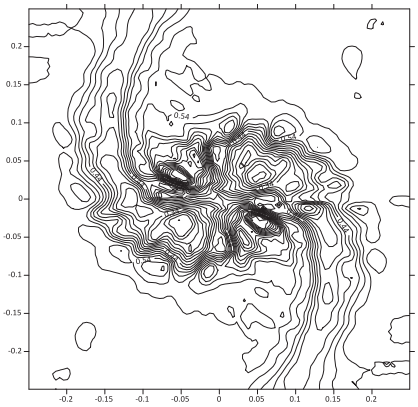


Figure 19

take place.

Our results are as follows:

1. In the numerical simulations of stellar-gas galactic disks, we find that formation of two-armed global spiral leads to origin and development of connecting arms, bar.
2. Spirals and bars grow together in global disk instability.
3. Strong spirals can form stronger bars.

Acknowledgement

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[3] A.D. Chernin, Astronomical and Astrophysical Transactions 18 393 (1999).