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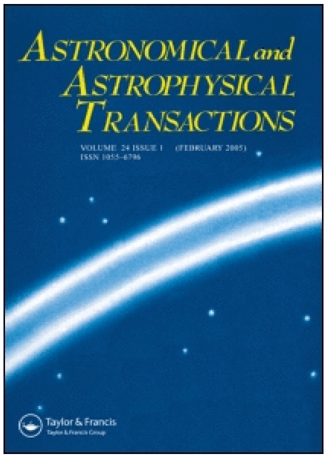

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GLOBAL INSTABILITIES IN DISKS OF SPIRAL GALAXIES: COMPARISON OF THEORY AND OBSERVATIONS FOR GALAXIES NGC 488, NGC 1566, AND NGC 6503

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We perform linear and 2D nonlinear simulations of spiral structure in the galaxies NGC 488, NGC 1566 and NGC 6503. The observed velocity dispersions and the rotation curves have been used to model background axisymmetric equilibria in these galaxies. The stability properties of the galactic disks are governed by the disk masses and by the ratio of the disk's radial and the vertical velocity dispersions. The massive disk of the galaxy NGC 488 has a few unstable modes with the two-armed spiral being the most unstable one. The nonlinear 2D numerical simulations show that spiral pattern in NGC 488 evolves into a patchy two-armed spiral structure. Disks of Sc galaxies NGC 1566 and NGC 6503 are unstable towards modes $m = 2$, and $m = 3$ when the ratio of the vertical to the radial velocity dispersion is about 0.8–1.0. The two-armed spiral is a dominant mode in galaxy NGC 1566, while the $m = 3$ mode prevails in the disk of NGC 6503. Theoretical spiral arms predicted for NGC 1566 and NGC 6503 are shorter compared to the observed ones showing the importance of mass redistribution by growing spirals within the galactic disks.

KEY WORDS Galaxies: kinematics and dynamics, spiral structure

1 INTRODUCTION

The spiral structure in galaxies is a manifestation of the global density waves developing in the galactic disks from gravitational instability of exponentially growing internal modes (Binney and Tremaine, 1987). An ultimate aim of the theory of spiral structure is the construction of models of particular galaxies based on the available observations. Previous comparisons of the theory and observations were based on some additional assumptions, namely on the empirical estimates of the positions of the corotation and Lindblad resonances, and on the assumption of the radial dependence of Toomre's stability parameter. In this paper we re-address the question of the comparison of the theory of global spiral modes with observations. Long-slit spectroscopic observations of the galactic disks provide a real basis for testing the global modal theory. These observations, together with the radial dependence of the velocity dispersions in the galactic disks, provide a quantitative estimate of the disks surface density distributions (Bottema, 1992). Using measured velocity dispersion and surface density together with a known rotation curve, we can build an axisymmetric background equilibrium for a particular galaxy without any additional assumptions. Such an equilibrium can be used in linear, and 2D nonlinear modeling of spiral structure. We use such an approach to model the spiral structures in galaxies NGC 488, NGC 1566 and NGC 6503.

2 DISKS MODEL

The radial dependence of the surface brightness and the velocity dispersion in the galactic disks are well fitted by the exponential profiles, with the velocity dispersion proportional to the square root of the surface brightness (Bottema, 1992). To model the behavior of the galactic disks, we use a hydrodynamical approximation considering them as a one-component 'gas' described by a polytropic equation of state with the polytropic index $\gamma = 2$. The ratio of the vertical to the radial velocity dispersion is adopted to be a constant throughout the galactic disk within the range 0.6–1.0. The behavior of the disks is then described by the standard set of the continuity equation, momentum equations, and Poisson's equation. We solve these equations numerically using the matrix method in linear approximation. The nonlinear set of equations is solved using a second order Van Leer advection scheme implemented by Stone and Norman (1992). A more detailed description of the model and the numerical methods can be found in Korchagin *et al.* (2000).

3 RESULTS

Table 1 summarizes the background equilibrium properties of the galactic disks for the particular galaxies built on the basis of the available observational data. Columns 4, 5 and 6 give the velocity dispersions in the centers of the disks, exponential scale lengths of the surface density distributions, and the total masses of the disks. The last column provides the source reference for observational data used in our simulations. Results of our linear analysis, and 2D nonlinear simulations are presented in Figure 1. The first two rows show the optical images of the galaxies and the dominant global modes found for each galaxy in linear stability analysis. The third row presents the time dependence of the global Fourier amplitudes calculated

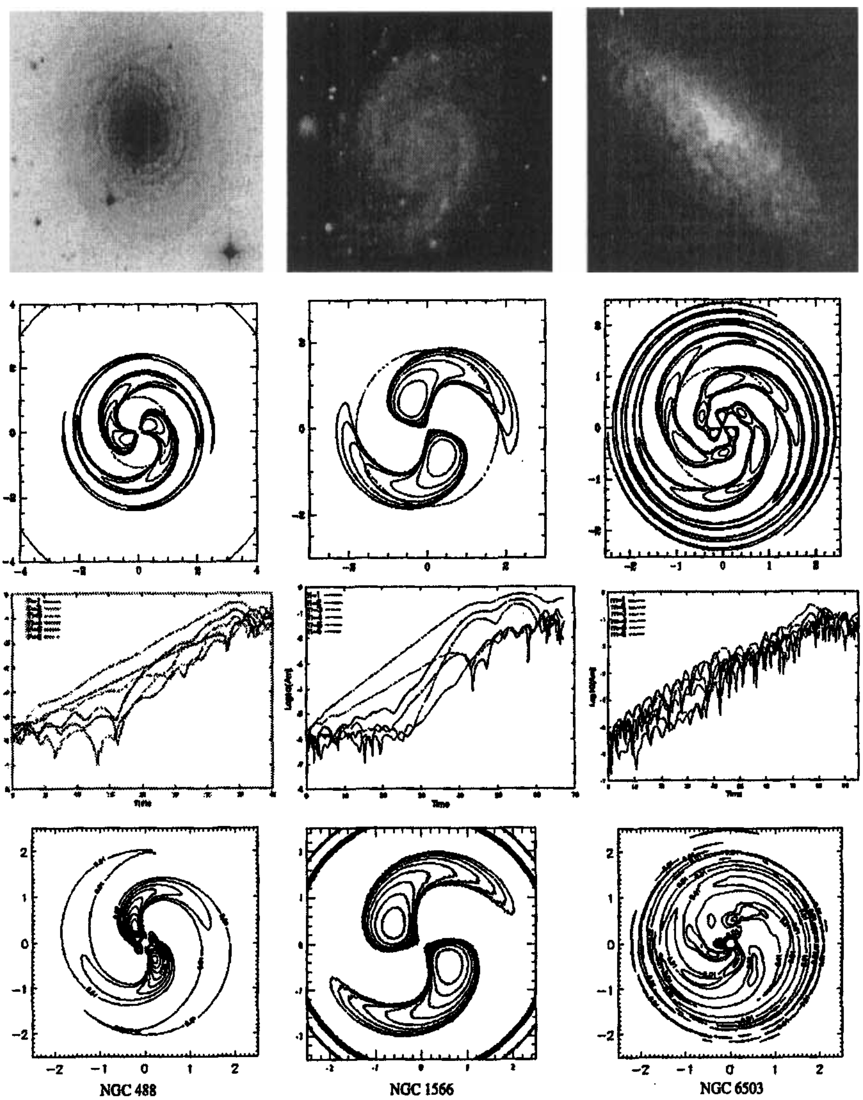

Figure 1 Optical images of galaxies NGC 488, NGC 1566, and NGC 6503 (upper frames), the surface density contour plots found in the linear global modal analysis, the time evolution of the global Fourier amplitudes for $m = 1$–6 spiral modes, and snapshots of the perturbed surface densities taken from the nonlinear 2D numerical simulations at the saturation phases (bottom frames). The contour levels are logarithmically spaced between the maximum and one-hundredth of the maximum density perturbations. Distance is measured in units of 2 kpc.

in the 2D nonlinear simulations with help of the expression:

$$A_m \equiv \frac{1}{M_d} \left| \int_0^{2\pi} \int_{R_{\rm in}}^{R_{\rm out}} \sigma(r,\phi) r dr\, e^{-im\phi} d\phi \right| . \tag{1}$$

Table 1. Parameters of galaxies.

Galaxy	*Type*	*Incl.*	c_{z0}, *km* s^{-1}	h_σ, *kpc*	M_{disk}, $10^{10} M_\odot$	*Reference*
NGC 488	Sa	40°	164	2.7	11.5	Gerssen (1997)
NGC 1566	Sc	28°	155	1.5	7.9	Bottema (1992)
NGC 6503	Sc	74°	55	1.2	0.7	Bottema (1989)

Here, M_d is the mass of the disk, R_{in} and R_{out} are the radii of the inner and the outer boundaries, and $\sigma(r, \phi)$ is the surface density of the disk. The time evolution of the Fourier amplitudes in all cases illustrates that the most unstable linear global mode indeed determines the evolution of the perturbations of the linear phase of instability.

NGC 488 This galaxy is an example of a perfectly outlined, tightly wound two-armed spiral structure. Linear stability analysis of the massive disk of NGC 488 shows that the $m = 2$ mode is indeed the most unstable global mode. The spiral pattern in NGC 488 is, however, more tightly wound compared to the linear global mode. At the nonlinear saturation phase, the amplitudes of the competing models become comparable to the amplitude of the $m = 2$ mode, which leads to a patchy appearance of the spiral pattern after saturation has been reached. It seems improbable that the spiral pattern in this galaxy is observed during the linear exponentially growing phase. The source of discrepancy between the theory and observations may arise from errors in observational data. Alternatively, the theoretical treatment might miss some important ingredients.

NGC 1566 The application of the global modal theory to this open-armed, grand-design spiral galaxy is more successful. The linear stability analysis of the disk of NGC 1566 shows that it is most unstable towards the two-armed spiral, which prevails over its competitors during the linear and the nonlinear saturation phases. The theoretical spiral pattern qualitatively explains the observed inner spiral structure in the disk of this galaxy. A more detailed description of the comparison for this galaxy can be found in Korchagin *et al.* (2000).

NGC 6503 A small galaxy with patchy spiral structure. The linear stability analysis shows that the disk of this galaxy is unstable to $m = 3$, and $m = 4$ spiral modes. The 2D nonlinear simulations show that the $m = 1$–6 global modes grow with approximately equal growth rates, and saturate at approximately the same amplitude. The simultaneous growth of a few spiral modes is a likely explanation of the patchy spiral structure in this galaxy.

References

Binney, J., and Tremaine, S. (1987) *Galactic Dynamics*, Princeton Univ. Press, Princeton.
Bottema, R. (1987) *Astron. Astrophys.* **221**, 236.
Bottema, R. (1992) *Astron. Astrophys.* **257**, 69.
Gerssen, J., Kuijken, K., and Merrifield, M. R. (1997) *Mon. Not. R. Astron. Soc.* **288**, 618.
Korchagin, V., Kikuchi, N., Miyama, S. M., Orlova, N., and Peterson, B. A. (2000) *Astrophys. J.* **541**, 565.
Stone, J. M., and Norman, M. L. (1992) *Astrophys. J. S.* 80, 753.