Investigating a self-consistent galactic potential with central mass concentration

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Abstract. The evolution of a barred galactic potential containing a central mass concentration is examined by means of a self-consistent 2-D N-body simulation. It is found that the bar weakens as the central mass grows and eventually dissolves, in agreement with earlier orbital studies of this problem.

Key words: barred galaxies, central mass concentration, orbits

1. Introduction

We pursue an earlier idea (Hasan and Norman, 1990; Hasan, Pfenniger and Norman, 1992) that the growth of a central mass in a rapidly rotating barred galaxy causes the bar to dissolve. This happens because some stellar orbits which support the bar become stochastic, while others are converted to orbits which are anti-aligned to the bar by the appearance and outward motion of an Inner Lindblad Resonance. Stable z orbits, which take stars outside the plane and could perhaps help in heating the disk stars into the bulge, were also found to exist. As a first step towards constructing fully self-consistent 3-D models of this phenomenon, we have used Sellwood's (1981) N-body code for simulations in two dimensions.

2. 2-D Simulations

All our simulations begin with 75% of the total mass represented by 50K particles in an axisymmetric Kuz'min/Toomre disk. The remaining mass is in the form of two concentric, unresponsive, Plummer spheres representing the bulge and core; initially both have a scale radius equal to one half that of the disk. The system is allowed to evolve self-consistently for 100 dynamical times, during which a bar forms and settles into steady rotation. Then during the next 4 bar tumbling periods (from $t = 100$ to $t = 150$), the scale radius of the core is gradually reduced to a value of 0.01 disk scale lengths after which it is held steady at its new value. The behaviour of the bar and disk are followed to at least $t = 200$. Simulations are performed for five different cases in which the mass of the core component is varied so that it contains a fraction x of the total mass, leaving a fraction $0.25 - x$ in the unchanging bulge.

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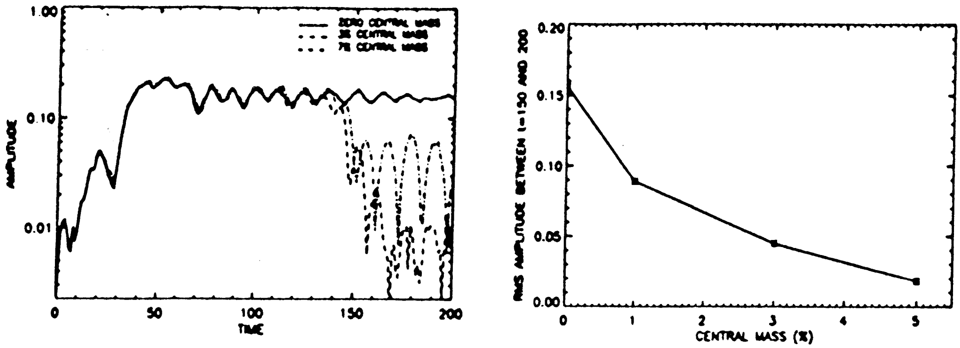

Fig. 1. Variation with central mass of (a) amplitude (b) rms amplitude of the $m = 2, \gamma = 0$ Fourier component. The weakening and destruction of the bar with increasing central mass is evidenced by a reduction in the amplitude.

3. Results

We find that when there is no central mass a steady bar remains till the end of the simulation. The bar weakens as the central mass is introduced, but thereafter it survives at a lower amplitude. The larger the fraction of mass in the core, the weaker the bar at late times. Figure 1(a) shows the time variation of the amplitude of the $m = 2, \gamma = 0$ Fourier component of the potential (which represents the bar) and Figure 1(b) the rms amplitude (between $t = 150$ and $t = 200$) for all the cases we have run. (The amplitude variations are caused by beats between the bar and weak spiral patterns in the outer disk which rotate at different rates.)

Surfaces of section were computed for various Hamiltonian values in a static potential approximated by the average of the potential computed for the period $t = 150$ to $t = 200$, for (a) no central mass and (b) 3% central mass. In the first case, invariant curves (IC) corresponding to B (or x_1) orbits which support a bar were found for all Hamiltonian values considered, while in the second case it was found that the ICs have dissolved for Hamiltonian values corresponding to tightly bound orbits, indicating a weakening of the bar in the presence of a central mass. We also see that some B orbits have been replaced by A orbits.

The present study supports our earlier results that a concentrated central mass ($\sim$ 7% or greater than the total mass) would cause a bar to dissolve because some orbits become irregular and others switch from B orbits to A orbits which can no longer support the bar. It would be challenging to find observational evidence of this phenomenon as well as to study implications for the structure and stability of barred and elliptical galaxies as such central mass concentrations form.

References

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