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Kolmogorov-Sinai Entropy in Self-consistent Models of Barred Galaxies

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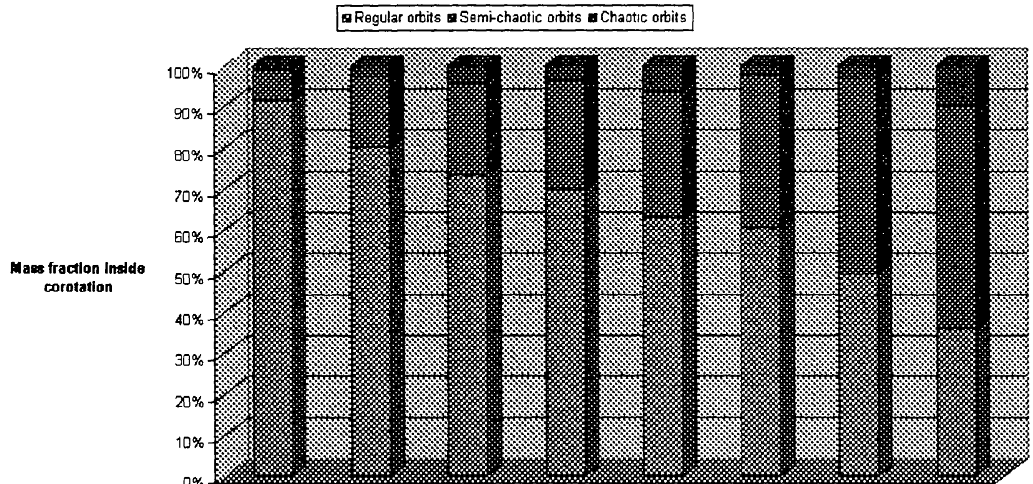
Abstract. The distribution of chaos in self-consistent models of barred galaxies is investigated using Kolmogorov-Sinai entropy. This quantity describes the rate of divergence of neighbouring trajectories. The models are constructed with Schwarzschild's (1979) method which combines orbits as elementary building blocks. We display and discuss the mass distribution inside a bar as a function of the nature of the orbits (regular, chaotic or semi-chaotic).

1. Introduction

Chaotic motion is expected to form a significant part of the orbits populating stellar bars. However, because realistic galactic distribution functions are difficult to construct, the proportion of chaotic orbits is barely determined. Pfenniger (1984) found between 10 and 30% of chaotic orbits in his models. In their N-body models, Sellwood & Sparke (1987) and Pfenniger & Friedli (1991) found a "hot" population which belong both to the bar and the stellar disc. This population may contribute up to 30% of the total mass. Kaufmann & Contopoulos (1996) confirmed that between 5 and 14% of chaotic orbits populate the bar and as much belong to the "hot" population. However, chaotic orbits play a major role in the secular evolution of galaxies because they introduce irreversibility. Thus, we decided to quantitatively determine the proportion of such orbits in Wozniak & Pfenniger (1997) models of barred galaxies.

2. The model

The self-consistent models are those made by Wozniak & Pfenniger (1997). The Kolmogorov-Sinai entropy ($\mathrm{h_{KS}}$) was used as a tool to quantify the amount of orbital chaos in a stellar system (cf. Wozniak & Pfenniger 1999). $\mathrm{h_{KS}}$ can be viewed as the rate at which an orbit looses information about its initial conditions. In Hamiltonian systems the h_{KS} vanishes only for regular orbits. Orbits with non-zero h_{KS} have a sensitive dependence on initial conditions which is a possible criterion of chaos. We have computed orbits during at least $T_{\mathrm{min}} = 18\,\mathrm{T_{bar}}$. We thus name 'regular' orbits with $h_{\mathrm{KS}} < \log(T_{\mathrm{min}})/T_{\mathrm{min}} \approx 0.0038$. Wozniak & Pfenniger (1999) have also defined two other classes: the chaotic orbits ($h_{\mathrm{KS}} \gtrsim 0.013$) and the semi-chaotic orbits ($0.0038 \lesssim h_{\mathrm{KS}} \lesssim 0.013$).



	Min (hKS)	Min (H)	Max (Lz)	Min (E)	Max(|Lz|)	Min (|Lz|)	Min(Lz)	Max (hKS)
Chaotic orbits	1,1	2,7	4,3	3,4	6,4	2,2	3,2	9,9
Semi-chaotic orbits	7,3	17,0	22,3	26,8	30,5	37,1	47,5	53,8
Regular orbits	91,5	80,3	73,4	69,8	63,1	60,6	49,3	36,3

Figure 1.

3. Discussion

The mass distribution as a function of $h_{\rm KS}$ (cf. Fig. 1) shows that a single population of 'regular' orbits cannot account for the mass distribution. Non-regular orbits are thus unavoidable. They are clearly present in all models.

Orbits with $h_{\rm KS} \gtrsim 0.013$ contribute less than 10% to the total mass of the models. Globally, when non-regular orbits contribute to the mass density, they are only moderately chaotic orbits ($h_{\rm KS} \lesssim 0.013$), even for the model that maximizes the Kolmogorov-Sinai entropy. These orbits remain confined inside the corotation. They are similar to the 'semi-chaotic' orbits of Wozniak (1994).

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