ARE GRAVOTHERMAL OSCILLATIONS GRAVOTHERMAL?

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Abstract. We examine critically the properties of the large-amplitude oscillations seen in Fokker–Planck simulations of globular clusters, with both continuous and stochastic binary heating, and compare them to the defining characteristics of gravothermal oscillations.

1. Introduction

Gravothermal oscillations were first reported in gas-sphere models of star clusters by Sugimoto & Bettwieser (1983). They have since been observed in both analytical (Goodman 1987) and Fokker–Planck (e.g. Murphy et al. 1990) studies of post-collapse cluster evolution. Very recently, Makino (1996) has described similar core oscillations in N-body simulations. The essential features of these oscillations are: (1) they are driven by a temperature inversion in the inner halo that drives energy into the core, causing it to expand, (2) their long-term behavior is largely unrelated to the heat source triggering them, and (3) once established, they require no central heat source to sustain them. We examine these features in Fokker–Planck cluster models incorporating a variety of binary heating mechanisms.

2. Continuous and Stochastic Binary Heating

With continuous binary heating (as described by Murphy et al.), we find that the early stages of every expansion phase occur *without* any temperature inversion, suggesting that binary heating is the initial driving mechanism. Further, when the heating is terminated early enough in this phase, the expansion does *not* continue—the system recollapses, even if a small

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temperature inversion has already appeared. Only if there is a substantial inversion when the heating stops does further expansion occur.

Figure 1 shows the time variation of the central density for a model in which binaries form stochastically, then heat the cluster at a constant rate until they are ejected from the system after depositing 100 kT of energy. The periods during which binaries are heating the system are marked in grey. In almost every expansion cycle, recollapse begins as soon as binary heating stops, and binary heating is more than sufficient to account for the gross energetics of the core expansion. Only when binaries drive a particularly large expansion does a true gravothermal "coasting" phase ensue.

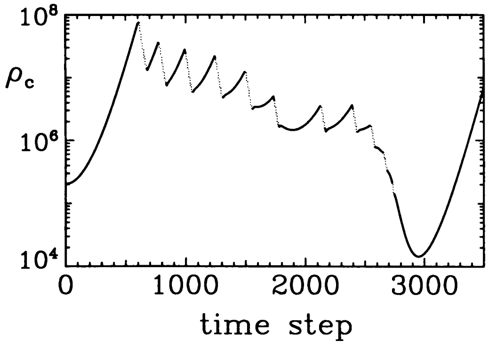

Fig. 1: Time variation of the central density ρ_c for stochastic binary heating. The abscissa shows time step, rather than time, to bring out the structure of the peaks. In reality, the expansion episode at right occupies almost the entire interval shown.

3. Conclusions

We find that the large-scale core oscillations observed in Fokker–Planck models are not entirely gravothermal in nature. Parts of the expansion are not associated with any temperature inversion at all, and the expansion is closely tied to the continuation of heating in the core. Indeed, the core expansion is initially driven entirely by binary heat input. There appears to be a truly gravothermal phase in some, but not all, cycles, but the temperature inversion driving it develops quite slowly, and may not have time to take effect before heating stops. The most important indicator of gravothermal expansion is not the existence of a temperature inversion, but rather continued core expansion once the heat source is removed.

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