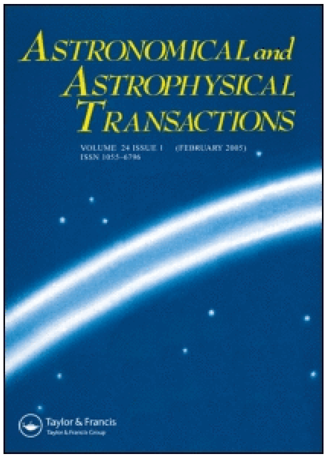

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What is the smallest number of giant molecular clouds to excite a coherent structure in a self-gravitating system?

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WHAT IS THE SMALLEST NUMBER OF GIANT MOLECULAR CLOUDS TO EXCITE A COHERENT STRUCTURE IN A SELF-GRAVITATING SYSTEM?†

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The evolution of a simple model of a two-component self-gravitating system is studied numerically. One component consists of a number of discrete particles which are assumed to model the "clouds" of molecular hydrogen (GMC). Another component representing a "star" subsystem is simulated by the collisionless system of Vlasov and Poisson equations. The components interact with each other via their mutual gravitational field. Our preliminary results show that the number of "clouds" greater than 100–200 with the total mass of about 1% of the total system mass is enough to excite a coherent structure in the "stellar" subsystem.

KEY WORDS Two-fluid instabilities, clouds, structure

1 INTRODUCTION

Under certain conditions, self-gravitating systems behave like a medium undergoing a second-order phase transition. In gravitating systems such transitions are associated with the breaking of a symmetry as some parameter, e.g. velocity dispersion of stars varies continuously and lower values of the velocity dispersion correspond to a lower-degree symmetry (Bertin and Radicati, 1976).

In the critical state, self-gravitating systems are more sensitive to external forcing. The sensitivity formally tends to infinity as the system approaches the marginally stable state, which is also indicated by a boundless growth of fluctuations (Saslaw, 1987). At the same time a long-range nature of the Newtonian potential leads to a selective growth of fluctuations: only perturbations with the critical wavelength are amplified (Morozov, 1983). In reality, however, the growth

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of fluctuations is restricted due to nonlinearity and, as simulations showed (Ivanov, 1992), they cannot reach the observed values.

To avoid this contradiction one can take into account fluctuation of the overall gravitational field produced by the giant molecular hydrogen clouds (GMC). As some preliminary investigations have shown, such fluctuations can generate an ordered structure. The influence of the gaseous component becomes stronger if the mutual influence of the stars and the gas is taken into account since a two-component system is unstable even if each component is stable itself (Jog and Solomon, 1984). In this case, a small number of GMSs can generate a significant structure in the stellar subsystem especially if it is on the verge of its stability.

2 THE MODEL AND METHOD

The dynamics of the two-component system was studied using a simple one-dimensional model system described in our earlier papers (e.g. Ivanov, 1992). The stellar subsystem was described by the collisionless system of Vlasov and Poisson equations. Cheng and Knorr's (1976) method was applied for solving the initial value problem for the distribution function. The particles presenting the GMSs were moved through the grid with the 'leapfrog' algorithm (Buneman, 1967).

3 RESULTS

Several runs were performed. In the first one, the ratio of the velocity dispersions of the stars and the gas clouds was chosen to be close to that in real galaxies. The number of clouds was assumed to be 1000 and their total mass comprised 5% of the system mass. The usual instability developed in both subsystems, but the cloud subsystem was less stable. About 80% of clouds were concentrated near the maximum of the stellar density.

In the second run, the number of clouds was reduced to 500. Fluctuations were enhanced so the structure in the cloud subsystem became more irregular.

In the third run, the number of the clouds and their total mass were 100 and 1%, respectively. So the structure in the cloud subsystem was very irregular, but not in the stellar one.

4 CONCLUSION

Extrapolating these very preliminary results to more realistic systems, one can estimate the lowest number of the clouds required to excite a spiral structure. For instance, to excite the structure of the amplitude of 5%, about 200 clouds are required with the mass of about (1–3)% total mass of the system.

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DISCUSSION

Efremov: You have shown that the number of density fluctuations in a galactic disk is essential, but are their masses also important?
Ivanov: Yes, because a larger mass produces a stronger response. However, the amplitude of the response depends on the driving force as $F^{1/1.7}$, so the effect is more significant for small F rather than for large ones.