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Dynamics of the parabolic restricted three-body problem

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ABSTRACT

The main purpose of the paper is the study of the motion of a massless body attracted, under the Newton's law of gravitation, by two equal masses moving in parabolic orbits all over in the same plane, the planar parabolic restricted three-body problem. We consider the system relative to a rotating and pulsating frame where the equal masses (primaries) remain at rest. The system is gradient-like and has exactly ten hyperbolic equilibrium points lying on the boundary invariant manifolds corresponding to escape of the primaries in past and future time. The global flow of the system is described in terms of the final evolution (forwards and backwards in time) of the solutions. The invariant manifolds of the equilibrium points play a key role in the dynamics. We study the connections, restricted to the invariant boundaries, between the invariant manifolds associated to the equilibrium points. Finally we study numerically the connections in the whole phase space, paying special attention to capture and escape orbits.

1. Introduction

Astronomy textbooks typically present galaxies as calm, solitary and majestic island worlds of glittering stars. However, the Hubble images support the well-known idea that galaxies are dynamic and energetic. In particular, the bridges and tails seen in some multiple galaxies are just relics of close encounters. The consequences of the brief but violent tidal forces have been studied by Toomre and Toomre [16] and by Namboodiri et al. [10] considering a simple-minded fashion: each encounter is considered to involve only two galaxies describing a roughly parabolic path.

This approach of the dynamics of the close encounters for two galaxies has been used, for example, by Condon et al. [2], in the case of the galaxies UGC 12914 and 12915, or by Günthardt et al. [7], for the system AM1003-435. The parabolic model has been also used in the study of the formation of planetary systems. Fragner and Nelson [6], examine the effect of parabolic stellar encounters on the evolution of a Jovian-mass giant planet forming within a protoplanetary disc. Pfarzner et al. [12] study the close encounter of two stars, one of them surrounded by a disc. More recently, in [14], Steinhausen et al. present a numerical investigation to study the effect of gravitational star-disc interactions on the disc-mass distribution, considering coplanar, prograde encounters on parabolic orbits.

A close approach of two galaxies (or stars surrounded by a disc) cause significant modification of the mass distribution or disc structure. Focussing just on one particle that initially stays in one galaxy (or around one star), after the close encounter, it can jump to the other galaxy or escape. One aim is to study the regions in the phase space where the particle remains or not around each galaxy. To perform this study, we consider a very simple model, the so called planar parabolic restricted

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