Headon-Collisions Between Plummer Models

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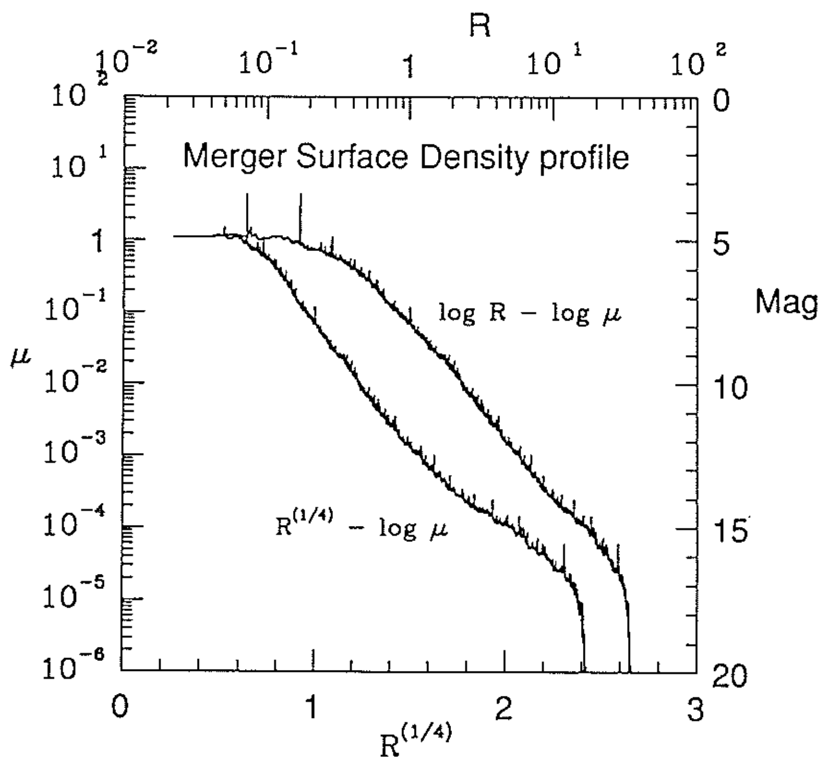
We present a framework for a detailed analysis of encounters between stellar systems, on two levels: an interaction analysis and a scattering analysis. The interaction analysis covers a closeup investigation of the details of the time-dependent deformations of the systems during an encounter. The scattering analysis describes the encounter as a transformation between the asymptotic states of the systems in the early past and the far future. Such gravitational scattering experiments can be described in a way similar to laboratory experiments in other branches of physics, such as nuclear, atomic and molecular physics.

Our interaction analysis compares different ways of measuring physical variables such as density (spatial, projected as well as phase space density), and of classifying and describing the different parts of the system, including the clouds of escaping stars produced during an encounter. We also discuss different ways of following the trajectories of individual star systems and star clumps. From a practical point of view, we discuss strategies for automatizing the setup, execution and analysis of simulations of encounters between galaxies. We present real-life examples of command sequences, in the form of shell scripts, which orchestrate such experiments.

Our scattering analysis is focused on the relation between observable physical variables before and after the encounter on the one hand, and their dependence on the choice of non-physical parameters and numerical methods characterizing the experiments on the other hand.



We start with a detailed investigation of isolated spherical galaxy models, realized as a finite set of mass points. Already on this level there are interesting relations between the deviations from the ideal mathematical models from which they are constructed, both for individual observable variables and their correlations. Knowledge of these deviations and their time dependence then allows us to discriminate between these one-galaxy errors, and the additional two-galaxy errors introduced during the simulations of an encounter. We illustrate our discussion with the results of a large variety of test runs. The detailed understanding of the process of gravitational scattering simulations, should anable us to put error bars on the physical measurements presented in subsequent analysis.

In the current work we present a detailed analysis of the simplest type of encounters between galaxies, in which two spherically symmetric, isotropic galaxies undergo a head-on encounter. Among our results are the dependence of energy loss and mass loss as a function of encounter velocity, as well as an accurate determination of the criterion for merging. A qualitatively new result is the determination of the shape of the cloud of escaping particles, both in the merging and non-merging cases. In addition, we present a detailed analysis of the luminosity profiles and three-dimensional shape of the galaxies after an encounter, and of their orbit structure.

In the accompanying figure the projected surface density of a merger product is shown. The obvious bump at a radius of about 20 units is due to the relatively early time of this snapshot, and will smoothen out in time.

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Cover picture: The interacting galaxies M51 (NGC 5194) and NGC 5195.
The photographic plate was obtained at the 2.2 m telescope of the Calar Alto Observatory in Spain of the Max-Planck-Institut für Astronomie in Heidelberg by K. Birkle and J. A. Quesada.

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