Preface

The theory of chaos invades a large part of modern physics (celestial mechanics, fluid mechanics, particle accelerators, solid mechanics, etc.), together with other branches of knowledge (biology, ecology, economics, etc.). In particular, important results have been obtained in astronomy, especially in the study of gravitational systems.

In this domain, one kind of chaos is due to interactions between several resonances, which are at the origin of the weak chaos detected in our Solar System, particularly for the inner planets and, for example, in the attitude variations of Mars; let us recall that our Earth, thanks to the influence of the Moon, does not suffer attitude variations (which would be catastrophic for the stability of the climate) as strong as the latter planet. Theoretically speaking, the KAM theorem establishes the persistence of invariant tori in weakly perturbed Hamiltonian systems; besides, the Nekhorochev theorem allows the confinement over very long times, under some constraints, of weakly chaotic orbits.

But another kind of chaos, completely independent from interactions between resonances, is due to close encounters between celestial bodies, and is responsible for, for example, rapid transfer of "killing" asteroids which cross the orbits of telluric planets and can hurt them (let us recall, for example, the Cretaceous-Tertiary event); this can be the cause of ejection of comets and some asteroids away from the Solar System, too. Moreover, we should remind ourselves of the use of these close encounters by space missions, during which energy is given to spacecrafts through "rebounds" on planets (e.g. for the Cassini mission). In the equations of motion, denominators equal to the square of mutual distances between the bodies become, during such close encounters, very small and induce *singularities*; one of the solutions found for "rubbing out" these singularities during the integration is called *regularization*, which uses transformations on space and time. More recently, Öpik's works have allowed modeling of this close-encounter-induced chaos, and have been applied to the study of meteor streams and to chaotic diffusion of particles in planetary rings. These were the topics lectured on during the Arc 2000 School in 2000 (organized together with our colleague Patrick Michel, also from Nice), and which consequently constitute the main focus of this book.

The early chapters introduce the mathematical methods used in the theory of singularities in gravitational systems (e.g. regularization).

The second part of the book develops the modelization techniques, in particular the elaboration of "mappings" in which the basic ingredient consists of introducing delta functions to represent close encounters as shocks.
Finally, the concluding chapters present the state of the art about the study of the diffusion of comets, wandering asteroids, meteors and planetary ring particles. Note that such studies are particularly relevant today, as the advances in modern observational instrumentation (LINEAR, Spacewatch, etc.) have lead to an enormous increase in the frequency of discovery of minor bodies in the Solar System.

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