

Preface

The orbital dynamics in the near-regime gravitational fields of Solar System small bodies (SSSB) is an important aspect of modern celestial mechanics, which is of abundant physical phenomena and offers insights into the mathematical expressions of astronomical events. During last two decades, several deep space probes have been launched for in situ explorations to these small worlds, and the orbital dynamics around a small body comes as one of the biggest challenges in space engineering. As an application of basic research, the work advanced in this thesis is about the common issues in the orbital dynamics around SSSBs, using high-resolution models, which serves as a bridge to the understanding of the orbital motion in the vicinity of a real small body.

Four types of orbits are discussed in this thesis: equilibrium points, periodic orbits, resonant orbits near the equatorial plane, and natural motion close to the surface. Specific asteroids' models are employed in these studies, and new algorithms are developed based on the polyhedral models, i.e. the Hierarchical Grid Search Method (HGSM) designed for searching the large-scale periodic orbits around a small body, and the surface mitigation model in order to mimic the complicated motion of a particle close to the surface. FORTRAN packages are developed for numerical implementation of these algorithms.

In the studies of equilibrium points and periodic orbits, we focus on the qualitative properties of the system, especially for the general behaviours of vicinal orbits. Four equilibrium points of asteroid 216 Kleopatra are exposed by checking the 3D geometries of the zero-velocity surfaces, and then their stabilities and topologies are determined. The general motion around the equilibrium points are decomposed into three types of local invariant manifolds, sketching out the general behaviours of nearby orbits. Six continuous families of local periodic orbits are obtained in the centre manifolds. In the study of large-scale periodic orbits, 29 new families around Kleopatra are generated using HGSM. Poincaré mapping is introduced to investigate the stability of the 29 families, and these families are classified into different types based on their topologies. It is noticed that the transition within the same family follows specific strategies, which characterizes the

topological evolution of the periodic orbits. Motions around the orbits of the 29 families are attributed to five simple patterns, and the general motion near the periodic orbits is qualitatively determined.

In the studies of resonant orbits near the equatorial plane and free motion close to the surface, we highlight the role of numerical experiments. The variation of orbital energy is analyzed to understand the dynamical nature of the 1:1 resonance. Grid search on the parameter space reveals the condition of this type of resonance. Observing that 1:1 resonance is the major cause of ejecting motions, we present the distribution of ejecting orbits around Kleopatra on the parameter space and determine the critical conditions. A high-risk region for the probes is found near Kleopatra for the rich ejecting orbits in the equatorial plane. The surface mitigation method is applied to the study of surface motion on asteroid 1620 Geographos. The global surface environment is evaluated, showing the connections between the free motions and the surface local geometries. Monte Carlo simulations are performed to investigate the trajectories initialized close to the surface. The results show that the free motions close to the surface are highly influenced by the local terrain, and several mechanisms may govern the free motion of different processes.

Noticing that most of this work is based on a specific small body, we generalize the results as consultative for similar types of issues. Essentially, the topics investigated in this thesis are common and representative for a large group of small bodies, and the ideas and approaches proposed here are supposed to be generic and portable.

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Bodies

Yu, Y.

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