Chaotic dynamics of Halley's comet: Lyapunov exponents and survival-time prospects

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We have explored the dynamical evolution of the comet 1P/Halley over 1 Myr with detailed numerical simulations, under the gravitational influence of all the planets in the present-day Solar System (except Mercury). To this purpose, we have employed the Mercury 6.2 code, including, in addition to the planets, the 9 largest minor bodies (among them those known as dwarf planets except for Sedna) to conduct the N-body simulation. The comet's fiduciary orbit, and a set of orbits surrounding it in the phase space $(a-e)$, are solved as test particles in this problem. The ensemble of orbits explored is constructed as a mesh of 10,000 particles with different initial conditions covering the observational error of the orbit in the semimajor axis and eccentricity ($\pm 10^{-6}$ au and $\pm 10^{-6}$, respectively).

We find that the comet's fate is highly sensitive to initial conditions. Survival time maps from the simulations and Laskar frequency analysis maps for the vicinity of Halley's comet are shown. Also, the maximum Lyapunov exponent for neighboring orbits is calculated. This shows that chaos is dominant for these highly eccentric orbits as found by Chirikov & Vecheslavov (1989) and produces large non-stable regions for the comet's surrounding phase space. We provide estimations of the probability of survival of Halley's comet and a general perspective about the dynamical evolution of comets on a wider region of phase-space which covers several currently known Halley-type comets.

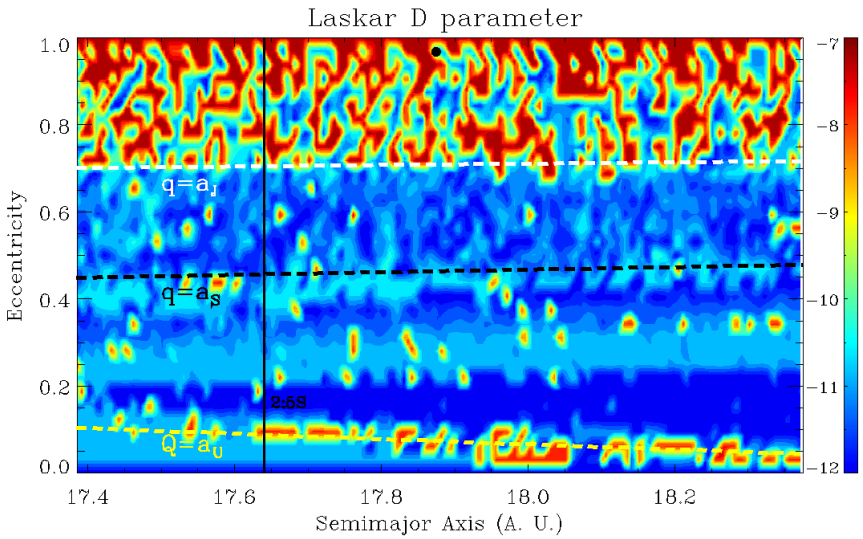

Figure: Laskar frecuency analysis map. Color indicates the stability of the orbits after 500 kyr. Blue zones correspond to stable regions while the red ones indicate the more unstable ones. The black dot shows the current position of Halley's comet in the phase space. The black vertical line marks the position of the 2:5 MMR with Saturn. Lines of constant perihelion at the Jupiter and Saturn semimajor axes, as well as a line with aphelion distance equal to the Uranus semimajor axis, are shown.

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