Impact probability calculations — comparison of methods

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We compare three different methods of statistical impact-probability calculations: our Hill sphere method that uses a super-sizing of the planet's collisional cross-section, the numerical averaging of Wetherill's (1967) formula, and the novel MOID method developed by us. The first and third are Monte Carlo simulations methods. In the first we count the number of Hill sphere passages for a large, random sample of orbits. In the third we search for orbits with MOID less than the collisional radius in a similar sample, calculating the MOID by the method of Wiśniowski and Rickman (2013), after which we compute the encounter timing range leading to collision for each selected object and compare with the target's orbital period.

Our extensive comparisons use a constant semi-major axis of 3.5 au for the projectiles, and we focus on the parametric plane of perihelion distance and inclination. They show an excellent agreement among all the methods under practically all circumstances. However, in the vicinity of the singularities appearing in the Wetherill formulae (zero relative inclination, and equal perihelion distances) we find that only the MOID method yields accurate results. Due to the approximations inherent in the other methods, the super-sizing method underestimates the impact probability, and the Wetherill averaging overestimates it. This work was supported by the Polish National Science Center under Grant No. 2011/01/B/ST9/05442.

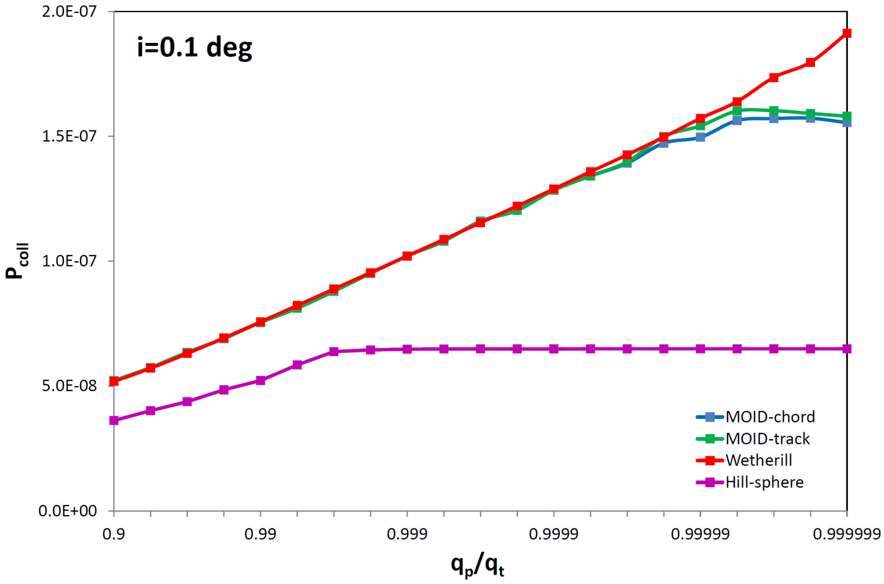

Figure: Collision probability with Mars (using its current orbital and physical properties) per orbital revolution as a function of the projectile perihelion distance (q_p) divided by Mars' perihelion distance (q_t) according to different methods. The variations are shown for the immediate vicinity of $q_p = q_t$, using an abscissa proportional to $\log(1 - q_p/q_t)$.

References: T. Wiśniowski, H. Rickman, 2013, Acta Astronomica, vol. 63, no. 2, pp. 293–307; G. W. Wetherill, 1967, JGR, vol. 72, no. 9, pp. 2429–2444.