ASTR 5120: Numerical Project (due Monday 16th March)

Calculating the transfer probability for Martian meteorites

A small number of meteorites recovered from Antarctica have been securely identified (via analysis of the composition of trapped gases) as being of Martian origin. Presumably these rocks were lofted from the surface of Mars in impact events before finding their way into Earth-crossing orbits and eventually impacting Earth. It is of some interest to know (a) the probability for such events to occur and (b) how long the transfer typically takes (and thus, whether life could conceivably survive the journey).

Useful data: Mars has a radius of 3400 km and a mass of $M = 6.4 \times 10^{26}$ g. The semi-major axis is 1.524 AU and the eccentricity is $e = 0.0934$. Earth has a radius of 6400 km and a mass of $M = 6.0 \times 10^{27}$ g, The semi-major axis is 1.000 AU and the eccentricity is $e = 0.0167$.

Consider meteorites ejected from Mars with velocities *at infinity* (i.e. after escaping the Martian potential) of 1 km/s or 2 km/s. Determine (a) the cumulative probability of collisions with the Earth in the first 10 Myr, and (b) the distribution of collision times. It's probably OK to assume that the distribution of impacts on Mars (and hence the directions of ejected bodies) is isotropic, but you might want to check whether the orbital phase and the presence or absence of other planets (especially Jupiter and Venus) makes any significant difference.

Methods: It's probably going to be easiest to track the trajectories using a Solar System integration code (the simplest to use is MERCURY), treating the meteorites as test particles. But you could also write your own integration routine for test particle orbits in the gravitational field of Earth and Mars (in which case I'd assume that *their* orbits are fixed Keplerian orbits with no mutual interactions).