THE AVERAGE RELATIVE VELOCITY AND AVERAGE RMS RELATIVE VELOCITY OF THE METEOROID POPULATION.

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INTRODUCTION: The purpose of this paper is to estimate the average relative velocity and the average squared velocity of the impacting meteoroid population on an object, labeled S distant R from the Sun and at an angle of β above the ecliptic with velocity, $\vec{v}_S$. In what follows we shall derive the specific expressions required to perform the average of the velocity and the square of the velocity over the meteoroid population. We shall then look at specific cases to show how these quantities change as the location speed and direction of the object are varied.

APPROACH: The probability of a collision between an object distant R from the Sun and with an ecliptic latitude, β, and a meteoroid with orbital elements a, e, i, q, and q$'$ as well as equally probable longitude of the node and longitude of perihelion, is

$$dN/dt = \sigma V*(2\pi^3 Ra)^{-1}*\{(\sin^2 i-\sin^2\beta)*(R-q)*(q'-R)\}^{-0.5} \qquad [1]$$

(1) where V is the intersection velocity and σ is the cross section of the object. If n_j is the fraction of the meteoroid population with orbital elements not sensibly different from a, e, i, q, and q$'$, then

$$\langle V^n\rangle = \Sigma V_j^n*(dN/dt)_j*n_j/\Sigma(dN/dt)_j*n_j \qquad [2]$$

respectively where the summations are over all j. In practice, we do not possess the suite of values $\{n_j\}$. We do have catalogs of the orbits derived from meteors which may be viewed as a sample of the meteroid population, the chief of these being the catalog of more than 2000 meteoroid orbits compiled by McCrosky and Posen (2), which with correction for observational effects(3) and for the gravitational focussing gives

$$(dN/dt)_j^0*n_j = (K*m_j/V_{j\infty}^{3.5})*n_j*(V_j/V_j^\infty)^2 \qquad [3]$$

This rate still includes the effect of the motion of the Earth through space. An object, S, moving through space at some heliocentric velocity different from that of the Earth would possess different intersection velocities with the meteoroid population. However, the relative rates still follow from equation [1], and one can show that

$$(dN/dt)_j^S*n_j \quad K*(m_j/V_{j\infty}^{5.5})*(\sigma_S/\sigma_0)*V_j^S*V_j. \qquad [4]$$

For 1AU the two moments of the velocity can be put in simple form

$$\langle V\rangle_S = \Sigma V_j^S*(m_j/V_{j\infty}^{5.5})*V_j^S*V_j/S$$

$$\langle V^2\rangle_S = \Sigma V_j{}^2*(m_j/V_{j\infty}^{5.5})*V_j^S*V_j/S \qquad [5]$$

$$S = \Sigma(m_j/V_{j\infty}^{5.5})*V_j^S*V_j\,(m_j/V_{j\infty}^{5.5})*V_j^S*V_j.$$

To extend the calculation of the momments of the velocity to a general position in space charcterized by (R,β) it is neccessary to assume that the distribution of a/R, e, and i for the population of meteroids is independent of R, the distance from the Sun. In a system of units in which R is measured in AU it will be shown that

$$(dN(r)/dt)^S_j = \{K*(m_j/V_{j\infty}^{5.5})*V_j^A*V_j\}* \{((V_j^S(R)/V_j^S(1))/R^3)*(\sin i/(\sin^2 i-\sin^2\beta))\} \qquad [6]$$

CALCULATIONS NEAR 1 AU: Many useful problems requiring the estimation of the effect of meteroid impact occur near 1 AU. These calculations also illustrate the approach. We shall first look at an object near 1 AU whose velocity is in the plane of the ecliptic and moving with velocity $\vec{v}_S$ and with components:

$$v_a^S = S*V_E*\cos(\lambda);\ v_r^S = S*V_E*\cos(\lambda);\ v_z^S = 0.0. \qquad [7]$$

where λ is the angle made by the velocity vector with the a-axis(defined by the apparent apex direction). Results are summarized in Table I. Calculations done for three values of S are listed at 10° intervals. Similar calculations, also in Table I, were done for an object near 1 AU whose velocity is in the plane containing the z-axis and the apparent apex direction and moving with velocity $\vec{v}_S$ with components:

$$v_a^S = S*V_E*\cos(\phi);\ v_r^S = 0.0;\ v_z^S = S*V_E*\cos(\phi). \qquad [8]$$

What both sets of results show is that any departure from keplerian motion in the vicinity of 1 AU leads to an increase in the mass average and RMS intersection velocities.

FURTHER NOTES: These results will be used to estimate the erosion rates and impact vaporization rates on near-Earth asteroids, and the calculations will be extended to the orbit of Mars.

(1) Kessler, D. J., (1981) Icarus, 48, 39-48. (2) McCrosky, R. E. and Posen, A.,(1961) Smith. Contri. Astrophys., 4, 15-84. (3) Kessler, D. J.,(1969) AIAA Jour., 7, 2237-2238.

TABLE I. AVERAGE VELOCITY AND RMS VELOCITY NEAR 1 AU FOR AN OBJECT MOVING WITH TOTAL VELOCITY S*29.8 KM/S DIRECTED AT AN ANGLE TO THE APEX DIRECTION

	IN THE A-R PLANE						IN THE A-Z PLANE					
ANGLE	S=0.5		S=1.0		S=1.5		S=0.5		S=1.0		S=1.5	
0	22.4	22.9	15.8	18.1	20.2	22.1	22.3	22.9	15.8	18.1	20.2	22.2
10	22.7	23.3	16.9	19.1	21.5	23.4	22.7	23.2	16.7	18.7	21.3	23.1
20	23.7	24.2	19.5	21.5	24.7	26.6	23.6	24.1	19.1	20.7	24.2	25.7
30	25.1	25.7	23.0	24.7	29.0	30.7	25.0	25.5	22.4	23.6	28.2	29.4
40	27.0	27.6	26.9	28.3	33.7	35.2	26.9	27.3	26.2	27.1	32.9	33.8
50	29.1	29.7	30.9	32.1	38.5	39.8	29.0	29.4	30.3	31.0	37.8	38.5
60	31.4	31.9	35.0	36.0	43.4	44.6	31.2	31.6	34.4	35.0	42.8	43.4
70	33.7	34.1	38.9	39.8	48.3	49.2	33.5	33.8	38.5	39.9	47.7	48.2
80	35.9	36.4	42.7	43.5	52.9	53.7	35.8	36.1	42.4	42.8	52.4	52.8
90	38.1	38.5	46.4	46.9	57.3	57.9	38.0	38.3	46.1	46.4	56.9	57.2