POSSIBLE DISTRIBUTIONS OF SOME ORBITAL ELEMENTS OF INTERSTELLAR PARTICLES IN THE SOLAR SYSTEM

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ABSTRACT:

Distribution of eccentricities, perihelion distances of interstellar particles and their concentrations in the Solar system have been computed in the assumption that their velocities are similar to ones of the nearby stars of late spectral classes. More than 75% of orbits have eccentricities not exceeding the value 1.1 and concentration of particles at the Earth's orbit 3.5 times greater than in the interstellar space.

All meteor catalogues contain some quantity of hyperbolic orbits. The question is: Are some of them real interstellar particles or are they just due to inaccuracy of observations (Matsenko and Tkachuk 1982, Radzievsky 1967, Stohl 1970). That is why estimation of characteristics of orbital elements of particles possibly of interstellar origin would be useful.

We consider as the most probable hypothesis that particles with masses that can be detected by Earth-based optical or radar observations were born during formation of systems similar to our Solar system. Losses of these particles are possible from the peripheries of the systems due to perturbations by nearby stars or due to mass loss by the central star. In this case the most probable velocity is the minimal velocity (minimal energy) of the particles relative the central star. Then the velocity distribution of the lost (interstellar) particles must be similar to one of the nearby stars. This distribution found as from the catalogue (Wooley et al., 1970) for F and G classes of stars is

$$p^{(n)}(v_S) = 3.68\ v_S^2\ \exp(-1.38\ v_S^2\ ), \qquad (1)$$

and the isotropic radiant distribution is

$$p^{(n)}(\varepsilon_S,\psi_S) = \frac{1}{4\pi}\ \sin\varepsilon_S, \qquad (2)$$

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where v_s is the particle velocity, ε_s is the elongation of a particle radiant from the apex of the Sun and ψ_s is the second angle in the frame system of the Sun's centroid. Here and then all velocities are given in the units of the Earth's velocity and distances in astronomical units. The index (n) will point out velocity and radiant direction distributions of particles in some volume of space and the index (q) does the same for flux.

The three-dimensional distribution of radiants and velocities of the particles can be written as the product of the two previous equations because of the independence of the variables v_s, ε_s and ψ_s:

$$P^{(n)}(v_s,\varepsilon_s,\psi_s) = 0.29\, v_s^2 \exp(-1.38\, v_s^2)\sin\varepsilon_s . \tag{3}$$

The distribution $P^{(n)}(\psi_s) = P^{(n)}(\psi_h) = \frac{1}{2\pi}$ i.e. the same in the frame of reference of the centroid and in heliocentric one. Then in the future we can use the two-dimension distribution $P^{(n)}(v_s,\varepsilon_s)$ which is the same as the eq.(3) except the factor 1.89 instead of 0.29.

The distribution of the impact parameter a of the particles is

$$P^{(n)}(a) = C_1 a, \tag{4}$$

where C_1 is the constant.

$$P^{(n)}(v_s,\varepsilon_s,a) = 1.84\, C_1\, a\, v_s^2 \exp(-1.38\, v_s^2)\sin\varepsilon_s \tag{5}$$

because of the independence of the variables v_s, ε_s and a.

Let ρ_s be the volume density of the particles outside the sphere of the Sun's gravitational influence and ρ_R the volume density at the distance R to the Sun. Than (Belkovich, 1983)

$$\rho_R P^{(n)}(v_R,\varepsilon_R) = \rho_s P^{(n)}(v_s,\varepsilon_s)\,\frac{v_R^2 \sin\varepsilon_R}{v_s^2 \sin\varepsilon_s}, \tag{6}$$

Here v_s and ε_R are the variables in the heliocentric frame of reference at the distance R to the Sun. They are functions of v_s and ε_s.

From eqs. (3) and (6) we have:

$$\frac{\rho_R}{\rho_s} = 1.84 \int_0^{\infty}\int_0^{\pi} v_R^2 \sin\varepsilon_R \exp(-1.38\, v_s^2)\, dv_R\, d\varepsilon_R . \tag{7}$$

The following approximation can be used for eq. (7):

$$\frac{\rho_R}{\rho_s} = 0.38 + 0.62 \exp\left(\frac{5}{R}\right)^{0.3} . \tag{8}$$

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The flux density Q of the sporadic meteors according tò Belkowich (1983) is

$$Q_s P^{(q)}(v_s,\varepsilon_s) = \rho_s v_s P^{(n)}(v_s,\varepsilon_s)\left[\int_0^{\infty}\int_0^{\pi} v_s P^{(n)}(v_s,\varepsilon_s)\,dv_s\,d\varepsilon_s\right]^{-1} =$$

$$= 1.21\ \rho_s v_s^3\ \exp(-1.38\ v_s^2)\ \sin\varepsilon_s, \qquad (9)$$

and in the heliocentric system at the distance R to the Sun the flux is

$$Q_R P^{(q)}(v_R,\varepsilon_R) = Q_s P^{(q)}(v_s,\varepsilon_s)\ \frac{v_R^3 \sin\varepsilon_R}{v_s^3 \sin\varepsilon_s} =$$

$$= 1.21\ \rho_s v_R^3\ \exp(-1.38\ v_s^2)\ \sin\varepsilon_R. \qquad (10)$$

From (5) and (10) we have

$$P^{(q)}(v_R,\varepsilon_R,a) = C_2\ a\ v_R^3\ \exp(-1.38\ v_s^2)\ \sin\varepsilon_R, \qquad (11)$$

where C_2 is a constant.

The distribution of eccentricities of particles orbits P(e) is

$$P(e) = \int_{v_{Re}}^{\infty}\int_0^{\pi} P^{(q)}(v_R,\varepsilon_R,e)\,dv_R\,d\varepsilon_R = \int_{v_{Re}}^{\infty}\int_0^{\pi} P^{(q)}(v_R,\varepsilon_R,a)\,\frac{da}{de}\,dv_R\,d\varepsilon_R. \qquad (12)$$

$\frac{da}{de} = \frac{e}{v_h^4\ a}$ can be found from $a^2 = v_h^{-4}\ (e^2-1)$. Here v_h is the heliocentric velocity of a particle at the distance $R \to \infty$. v_{Re} is the minimal value of v_R.

$$v_{Re} = \sqrt{\frac{1}{D_o} + \frac{2}{R}} \text{ for } e \le e_o \quad\text{and}\quad v_{Re} = \sqrt{\frac{e+1}{R}} \text{ for } e \ge e_o,$$

where D_o is the radius of the sphere of influence of the Sun taken to be equal to 10^5 a.u. and $e_o = \frac{R}{D_o} + 1$. The cumulative distribution of eccentricities was calculated from (12) for R = 1 and approximated as

$$P(e) = \begin{cases} \left(\dfrac{e-1}{e_o-1}\right)^{-0.145}, & (e_o \le e \le 1.14), \\ 0.1\ e^3(e-1)^{-0.6}, & (e \ge 1.14). \end{cases} \qquad (13)$$

This means that 75% of interstellar particle orbits have eccentricities within the limits 1.0 and 1.1 at the distance R=1 to the Sun and 8% only have eccentricities greater than 1.5.

The distribution of perihelions of the interstellar particles can be found in a similar way:

$$P(q) = \int_{\nu_{he}}^{\infty} \int_{0}^{\pi} p^{(q)}(v_h, \varepsilon_h, q)\, dv_h d\varepsilon_h =$$

$$= \int_{\nu_{he}}^{\infty} \int_{0}^{\pi} p^{(q)}(v_s, \varepsilon_s, a) \frac{v_h^3 \sin\varepsilon_h}{v_s^3 \sin\varepsilon_s} \frac{da}{dq}\, dv_h d\varepsilon_h = C_3 q, \qquad (14)$$

where C_3 is the constant, $\frac{da}{dq} = \frac{q}{a}(1 + \frac{2}{v_h^2})$, $v_{he} = D_o^{-0.5}$.

CONCLUSIONS

One must observe the strong concentration of the values of eccentricities of interstellar particle orbits to 1 that lead to the difficulties to select that particles from tose relating to the Solar system.

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