PERTURBATIONS OF METEORS' PARTICLES MOTION UNDER ACTION OF PHOTONS AND PROTONS.
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Introduction: Action of forces of an electromagnetic nature on bodies of the small sizes is researched more than 100 years [1]. Interest to a problem of evolution of the dust making interplanetary environment now has increased in view of light pressure and the effects of: Yarkovskii, Yarkovskii - Radzievskii, Poynting - Robertson and corpuscular analogue of Poynting - Robertson effect, in connection with intensive research of problems of an origin of Solar system and asteroid-comet-meteoroid hazard [2-4]. Below, analytically tractable, evolution of' meteor particles' elliptic orbits in a gravitational field of the Sun is considered in view of light pressure and the effect of Poynting - Robertson, thus a) the compact formulae connecting parameters of initial and final elliptic orbits of meteor particles are deduced; b) the quadrature describing dependence eccentricities of these particles' orbits from time is received; c) the method of an identification parent comets and meteoric showers is submitted; d) the method of an estimation of a meteoric shower's life time is developed; e) dependence between variations of eccentricities, semimajor axes of meteoroid's orbits and shift of meteoric radiants at the interval of time appropriate to one orbital revolution of meteoroid particles is found in a clear form; f) the way of modernization of the given ratio is specified in view of corpuscular analogue of Poynting - Robertson effect.

Fundamental Equation: Solution and Applications: The differential equation of motion submitted in the vector form, absolutely black spherical body, isotropic reradiating a solar energy and moving with velocity v, making an angle u with a direction of a heliocentric radius - vector **r** looks like [1]

$$\ddot{\mathbf{r}}=-GM'\mathbf{r}/r^3-2\pi R^2 q r^2_{S-E}/(Mc^2)v\cos u\,\mathbf{r}/r^3-\pi R^2 q r^2_{S-E}/(Mc^2 r^2)v\sin u\,\mathbf{e}_t \quad (1)$$

Here G - a gravitational constant, r - distance between the Sun and a particle, R - radius of a particle, c - speed of light, q_{S-E} - a solar constant for average distance r_{S-E} from the Sun up to the Earth, $\mathbf{e}_r$ и $\mathbf{e}_t$ – unit vectors of radial and transversal accelerations, M' – the reduced mass of the Sun connected to mass of the Sun M_S and mass of (spherical) particle M, by the ratio:

$$M'=M_S-\pi R^2 q r^2_{S-E}/(GMc). \quad (2)$$

The effect of Poynting - Robertson is characteristic for particles with radii from 1 μm up to 1 cm, and effect of Yarkovskii becomes essential to bodies with radii from 10 cm up to 10 km. [3]. For a case of small perturbations from the equation (1), after averaging for one orbital evolution of a meteoric particle and the subsequent integration, we shall find

$$a/a_0-e^{4/5}(1-e_0^2)/(e_0^{4/5}(1-e^2))=0, \quad (3)$$

and also a quadrature (4)

$$I(e,e_0)=\int_{e_0}^{e}\frac{e^{3/5}}{(1-e^2)^{3/2}}de=-\frac{5\pi^2 R^2 q_{S-E} r^2{}_{S-E} e_0{}^{8/5}}{\sqrt{GM'}Mc^2 T_0 a_0{}^{1/2}(1-e_0{}^2)^2}(t-t_0) \quad (4)$$

From the equations (3) and (4) follows, that in the given model *a* and *e* decrease eventually.

For identification of meteoric showers and their parent comets in view of Poynting-Robertson effect we shall put criterion (3) and we shall believe, that inclinations of comets' and meteoric streams' orbits differ from each other a little (<10º) and close collisions of comets and meteoroids with major planets are also absent (at least, on a considered interval of time). For identification of Quadrantids and the comets 12P and 35P by criterion (3), with using of the data [4], k=0.0529 и k=0.0346, accordingly.

With the help of the integral (4) the estimation of life time (τ_{LT}) of meteoric stream is cleared out. For example, after the artificial explosion made July, 4, 2005 during space mission "Deep Impact" (comet 9P (1867 G1) / Tempel 1), at density of meteoroids' substance ρ =1 gm/cm^3 , we shall come to the following estimations of a required interval of time τ_{LT}, at various values of meteoroids' radii R: R=100 μm, τ_{LT} ≈337400 years; R=10 μm τ_{LT} ≈32800 years; R=1 μm, τ_{LT} ≈2200 years.

Let's determine a difference of true anomalies Δv of one and the same meteoroid, radius and density of which are R and ρ correspondingly, after a full revolution, "migrated" from one elliptic heliocentric orbit on another, at the little changed parameters. We admit, that the values of true anomalies of the meteoroid in these two orbits correspond to average distance from the Sun up to the Earth (r_{S-E}=1AU). Let's take into account light pressure and the effect of Poynting-Robertson (see the equation (1)) and we shall assume, that the argument of perihelion of meteoroid's osculating orbit does not change, and angular shift of meteors' radiants coincides with value Δv. Then,

$$\Delta v=\mp\frac{3\pi a^{-1/2}q_{S-E}r^2_{S-E}\left[a\left(1-e^2\right)-5r_{S-E}\right]}{4R\rho c^2\sqrt{G\left(M_S-\frac{3}{4}\frac{q_{S-E}r^2_{S-E}}{GcR\rho}\right)}(1-e^2)\sqrt{\left[r_{S-E}-a(1-e)\right]\left[a(1+e)-r_{S-E}\right]}}. \quad (5)$$

In table 1 the variations of meteoroids' true anomalies, connected with the known meteoric showers are given. [4]. At calculations numerical values of the parameters which are included in the formula (5), were accepted equal: $r_{S\text{-}E}$=1AU=1.49597·10^{11} m, M_S=2·10^{30} kg, $q_{S\text{-}E}$= 1360Wt/m^2, G=6.672·10^{-11}N·m^2/kg^2, c=3·10^8 m/s, ρ=1000 kg/m^3, and the radius of particles, R=1·10^{-6} m.

Table 1. Heliocentric angular shifts (Δv) of meteors' showers radiants at one period (with taking into account light pressure and Poynting–Robertson effect)

Shower	a, AU	e	Δv, degrees
Quadrantids	3.122	0.686	-0.192
Leonids-Ursids	2.309	0.634	-0.095
Virginids	4.246	0.914	-0.082
π Virginids	2.257	0.728	-0.082
σ Leonids (S)	1.968	0.620	-0.092
Lyrids	66.509	0.986	-0.072
α Scorpiids	2.546	0.872	-0.112
θ Ophiuch (N)	2.367	0.761	-0.082
θ Ophiuch (S)	1.949	0.660	-0.089
ι Aquarids	3.599	0.929	-0.129
α Capricor (N)	2.427	0.758	-0.080
α Capricor (S)	2.149	0.762	-0.089
δ Aquarids (N)	3.002	0.971	-0.359
δ Aquarids (S)	3.206	0.969	-0.313
Perseids	27.396	0.965	-0.091
Perseids-2	1.995	0.542	-0.133
κ Cygnids	3.535	0.721	-0.216
Sept. Perseids	-44.510	1.016	-0.050
Piscids (S)	3.314	0.844	-0.077
Andromedids	2.550	0.760	-0.078
Andromedids-2	2.409	0.679	-0.083
Oct. Draconids	2.338	0.575	-0.401
Taurids (N)	2.071	0.839	-0.117
Taurids (S)	2.232	0.836	-0.107
Orionids	27.478	0.978	-0.057
Leonids	7.641	0.894	-0.061
σ Hydrids	76.920	0.994	-0.067
χ Orionids (N)	2.143	0.798	-0.097
χ Orionids (S)	2.215	0.761	-0.087
Geminids	1.375	0.899	-0.279

In the considered examples with the increase of semi-major axes of meteoroids' orbits influence of Poynting-Robertson effect on evolution of orbits decreases.

Analytical Description of the Poynting-Robertson Drag Caused by Solar Wind: In G.O.Rjabova's work [1] in semi analytical form influence of a solar wind on motion of meteoroids is taken into account. We solve this problem analytically in view of simultaneous action of photons, protons and α-particles (plasma of a solar wind consists of protons, electrons, α-particles and heavy ions) results in a quadrature:

$$\frac{a}{a_0} - \frac{\left(1-e_0^2\right)e^{\frac{4+k}{5+2k}}}{\left(1-e^2\right)e_0^{\frac{4+k}{5+2k}}} = 0\ , \qquad (6)$$

where $k=k_w/k_p$,

$k_w = 3.65 \cdot 10^3 \Psi \overline{U}$ (In systemCGS),

$$k_p = \frac{\pi q_{S-E} r_{S-E}^2 a_0^{3/2}}{\sqrt{GM'} c^2 T_0}\ ,$$

a_0 and e_0 are origin values of semimajor axes and eccentricity of meteoroid's orbit. Let's pay attention, that for possible maximal value of k_w ($\overline{U}$ =400·10^5 cm/s, ψ =1.6) and possible minimal value of k_p ($M'=M_S$, $a_0^{3/2}/T_0 = \sqrt{GM_S}/(2\pi)$) Their ratio is not greater than 1.5, therefore it is possible to put $0 < k_w / k_p < 1.5$. The criterion k allows estimating reliability of an identification of comets and meteoric showers. For example, for meteoric shower Quadrantids and a comet 12 P, we have: at e_Q=0.683 and 2.115<a_Q<2.14 AU, the parameter k is in an interval 0<k<1.5; at a_Q=3.08 AU and 0.7665<e_Q<0.77 the parameter k appears in the same interval - 0<k<1.5.

Conclusion: Variations of semimajor axes and eccentricities of particles of meteoric showers in cosmogonical intervals of time due to the effect of Poynting – Robertson are presented analytically tractable. The new integrals of motion that have been found in the frame of the averaged perturbed two-body problem are used for identification of meteoric showers and their parent comets. The Poynting - Robertson drag caused by solar wind is taking into account. A new formula for determination of shifts of meteoric radiants by Pointing-Robertson effect at one orbital revolution of meteoroid particles is deduced.

References: [1] Ryabova G.O. (2005), *Dynamics of populations of planetary systems* / Eds., Knežević Z. and Milani A. Proc. of the 197th Coll. of the International Astronomical **Union**. Belgrade, Serbia and Montenegro. Aug. 31 – Sept. 4, 2004. Cambridge University Press, 2005., P. 411 - 414. [2] Ipatov S.I. and Mather J.C. (2005), (See 197th Coll. of IAU), P. 399 - 404. [3] Vokrouhlický D., Brož M., Bottke W.F., Nesvorný D., Morbidelly A. (2005), (See 197th Coll. of IAU), P. 145 - 156**.** [4] Gajdoš Š. , Porubčan V. (See 197th Coll. of IAU), P. 393 - 398.