NONGRAVITATIONAL EFFECTS AFFECTING SMALL METEOROIDS IN INTERPLANETARY SPACE

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Received 11 September 1983

ABSTRACT. The set of twenty best-known nongravitational effects affecting meteoroids in interplanetary space has been divided, using a suitably chosen criterion, into a group of four destructive, seven disruptive and ten disturbing effects. Each of the effects is briefly characterized, giving the appropriate literature. The suggested task demonstrates the possibility of using and the usefulness of the presented classification of nongravitational effects.

НЕГРАВИТАЦИОННЫЕ ЭФФЕКТЫ ВЛИЯЮЩИЕ НА МАЛЕНКИЕ МЕТЕОРОИДЫ В МЕЖПЛАНЕТНОМ ПРОСТРАНСТВЕ. Совокупность двадцати самих знакомых негравитационных эффектов влияющих на метеороиды в межпланетном пространстве распределена при помощи целосообразно избранного критериа в группы четырех деструктивных, семь диструптивных и десяти дистурбативных эффектов. Для каждого отдельного эффекта приведена его короткая характеристика вместе с соответствующей литературой. Предложена задача показывает возможность употребления и полезность представеной классификации негравитационных эффектов.

NEGRAVITAČNÉ EFEKTY POSÔBIACE NA MALÉ METEOROIDY V MEDZIPLANETÁRNOM PRIESTORE. Súbor dvadsiatich najznámejších negravitačných efektov pôsobiacich na meteoroidy v medziplanetárnom priestore, je podľa vhodne zvoleného kritéria roztriedený na skupiny štyroch deštrukčných, siedmych disrupčných a desiatich disturbačných efektov. Pre každý jednotlivý efekt je uvedená jeho stručná charakteristika s príslušnou literatúrou. Navrhnutá úloha demonštruje možnosť použitia a užitočnosť predloženej klasifikácie negravitačných efektov.

1. INTRODUCTION

There is no doubt that larger and smaller bodies of interplanetary matter are subject to numerous effects of nongravitational and mostly dissipative nature (massloss or decrease of sizes, respectively). If the bodies of interplanetary matter are larger, these effects need not necessarily cause significant changes in the physics and dynamics of the object being investigated (for example, impacts on bodies of asteroidal types). If the bodies are small and particularly if fine dust particles of interplanetary matter are involved, which is what we are mainly interested in in this paper, these effects may be responsible for changes of an essential nature.

In principle, all nongravitational, dissipative processes cause a loss of mass or decrease in the dimensions of the original bodies or particles, possibly even their complete disintegration into a number of fragments; however, they may simultaneously cause their own trajectories to become unstable and complicated. The dynamic consequences of dissipative processes are mainly caused by the repulsive pressure of solar radiation, the effect of which varies substantially and by no means simply with decreasing dimensions of the meteoroids. Under certain conditions, provided that the particles are sufficiently small, some of the dissipative processes involved may have a substantial influence not only on their physical state and dynamics, but also on their lifetime in the Solar System. From the point of view of the lifetime of the dust component of interplanetary matter, the Poynting-Robertson effect is generally considered to be most important. However, the question as to the extent to which the lifetime of small bodies may also be affected by other effects, remains open. To determine this, it is necessary to compare the efficiency of the individual nongravitational effects. The present paper will deal with this group of problems. According to the adopted criterion, the individual nongravitational effects have been divided into three basic groups. The characteristics of the individual effects together with the quantitative evaluation of their efficiency at least enables the problems of their influence on the evolution and lifetime of dust particles in interplanetary space to be discussed with regard to their principal features.

2. CLASSIFICATION OF NONGRAVITATIONAL EFFECTS

The expected nature of the resultant change of the original state of the meteoroid being investigated was adopted as the criterion of the schematic division of nongravitational effects which cause this original state to change. The whole set of nongravitational effects may thus be divided into three basic groups:

I. Destructive effects - effects which result in constant destruction of the original material of the meteoroid, but which do not cause its substantial physical change in the form of an explosion, disintegration, etc. Consequently, these effects mostly have no direct influence on the sudden change of the dynamic characteristics of meteoroids, but represent factors which create effective conditions for a change of this kind.

II. Disruptive effects - effects which cause the disintegration, fragmentation or possibly even complete extinction of the meteoroid involved. They are responsible not only for a substantial and sudden change of the physical parameters of the original meteoroid (mass, dimensions), but simultaneously for a serious dynamic change, i.e. a change in the character of its motion (velocity, direction) of the generated fragments as compared to the original motion of the parental body.

III. Disturbing effects - effects which are mainly responsible for the changes of dynamic parameters of the body involved. In the first instance, these are effects which exert a continuous influence on the particles and result in gradual changes of the elements of their trajectories (in special cases even more abrupt changes may be involved).

Since in the cases of the first and the second group of effects, a direct massloss (decrease of sizes) of original meteoroid is realized, one can call these effects "dissipative".

We shall now attempt to assign the individual nongravitational effects to the groups mentioned above, and give their brief characteristics. The references represent the most important literature in which the particular effects are related to problems of the dynamics and/or lifetime of small particles of the Solar System.

I. Destructive effects

a) Impact erosion: This involves the abrasion of the surface layers of the meteoroid due to collisions with the very small dust particles. In estimating the efficiency of impact erosion, it is assumed that mainly mutual collisions with classical particles of a zodiacal cloud with prevalent dimensions of tens of μm are involved, which means collisions with dust particles within Jupiter's orbit, moving along orbits with inclinations $i < 20^{\circ}$ (McCracken and Alexander, 1965; Giese et al., 1978). Assumptions of the collision velocity (~ 10 kms^{-1}), particle concentration in the zodiacal cloud and estimates of exposure times for the individual types of meteoroids enable the actual values of the rate of impact erosion to be determined. In this way it was found, for example, that the impact destruction of iron meteoroids (changes of dimensions and mass) in the neighbourhood of the Earth's orbit takes place at a rate of $\sim 5\text{x}10^{-8}$ cm/year which represents an original mass loss rate of $\sim 1.3\text{x}10^{-14}$ g cm^{-2} s^{-1}. The rates for stone meteoroids are $\sim 5\text{x}10^{-7}$ cm/year and $5.0\text{x}10^{-14}$ g cm^{-2} s^{-1}, respectively. As regards cometary meteoroids, with an assumed low density $\rho = 0.44$ g cm^{-3}, the erosion rate will increase to $\sim 10^{-4}$ cm/year and $7.0\text{x}10^{-13}$ g cm^{-2} s^{-1}, respectively (Whipple, 1967). According to other authors (e.g. Dohnanyi, 1978), however, this kind of collisions (erosive collisions) of small projectiles (eroding particles of zodiacal cloud) with much larger targets (eroded particles investigated in this paper) does not cause such an effective massloss as other dissipative processes of nondisruptive character (e.g. corpuscular sputtering Ib, or incomplete collisional destruction Id - see discussion also).

b) Corpuscular sputtering: This involves the sputtering of the surface layers of the meteoroid by solar wind particles. The erosion rate in this case has been estimated at $\sim 4\times10^{-9}$ cm/year. According to more recent results this kind of fluently affecting erosion has, however, the dominant importance at the distance ~ 1 AU from the Sun for particles with sizes less than ~ 100 μm (Kresák, 1960; Wehner et al., 1963; Whipple, 1967; McDonnell and Ashworth, 1972; Dohnanyi, 1978).

c) Melting - ablation - evaporation: The meteoroid is melted either by heating in interaction with the denser layers of the planet's atmosphere (ordinary ablation processes), or its surface layers begin to evaporate more abruptly as it passes close to the Sun. Calculations are concentrated on determining the minimum distance from the Sun at which the particle can still exist as a solid body in order to determine the extent of the "free zone" around the Sun (Singer and Bandermann, 1967; Schwehm, 1979; Mukai and Schwehm, 1981).

d) Incomplete collisional destruction (near-catastrophic collisions): As opposed to impact erosion, a meteoroid can also be destroyed by collisions with particles larger than the particles typical of a zodiacal cloud (the mass ratio of target and projectile is decreasing). This kind of destruction one can understand as transitional type between the impact erosion (where eroding particle is much smaller than the eroded one) and the extinction of eroded meteoroid by collision (catastrophic collision - where physical parameters of eroding particle are comparable to those of eroded one) and it should be distinguished from erosion of any kind. Unfortunately, more precise statistical evaluations of this way of massloss (sizes) are still absent (Piotrowski, 1953; Wetherill, 1967; Whipple, 1967; Dohnanyi, 1972; Belkovič et al., 1978; Trulsen and Wikan, 1979).

II. Disruptive effects

a) Windmill effect: The pressure of electromagnetic solar radiation may, if the geometry of the surface of the meteoroid is irregular, causes an increase of its axial rotation until finally the meteoroid disintegrates due to rotation. For idealized particles the time required for this type of rotational disintegration is only 60 years. For actual particles the time required may be as much as 60×10^{3} years. Calculations of the time required for this disintegration are problematic and display a large scatter of the resultant values not only because this type of mechanism depends strongly on the external geometry of the body, but also because the rotation may be magnetically decelerated if, for example, the meteoroid is purely metal or stone (Jacchia, 1963; Paddack, 1969; Sparrow, 1975; Paddack and Rhee, 1976).

b) Radzievsky effect: Another type of rotational disintegration occurs if the particle's rotational velocity is increased by radiation due to the non-uniform distribution of the albedo on its surface. For example, it was found that 1 cm^3 of granite at a distance of 0.4 AU from the Sun will disintegrate in this way after 10^3 years (Radzievskij, 1954; Paddack and Rhee, 1975; Sparrow, 1975).

c) Electrostatic explosion: As a result of the interaction of energy quanta of solar radiation with a dust particle, the particle may acquire an increasingly larger positive potential which finally ends in electrostatic explosion. Numerous difficulties and particularly the high value of positive potential that is required (several hundred Volts) do not make this disintegration mechanism particularly realistic. More profound theoretical analyses of this problem are, unfortunately, not available. However, it should be pointed out that analogous calculations of the electrostatic disintegration of interstellar and intergalactic dust particles indicate that the alternative of a similar disintegration of interplanetary dust particles cannot be ignored (Fechtig and Hemenway, 1976; Wyatt, 1977; Hughes, 1979; Švestka, 1981).

d) Catastrophic collisions: As opposed to impact erosion (Ia), or incomplete destruction by collisions (Id), complete fragmentation of one or two collision components may occur particularly when particles with the same or similar physical and dynamic parameters collide. Both the massloss and the change of dynamics of original meteoroid are in this case practically unlimited (the meteoroid is completely destroyed, giving rise to many individual fragments) and therefore this process is decisive in considering of the lifetimes of the particle. In spite of this fact, however, because of its character (random production, successive total changes both of original dynamical parameters and state of meteoroid) this effect is not suitable e.g. for studying successive, fluent changes appearing at physical and dynamical evolution of the meteoroid (Dohnanyi, 1972, 1978; Trulsen, 1976).

e) Corpuscular breakup: Under certain conditions (solar flares; particles composed of water ice; obsidian and magnetite) a much larger loss of mass may occur when solar wind particles interact with a meteoroid than in the case of corpuscular sputtering (Ib), and the particle may practically disintegrate in this way (Mukai, 1979).

f) Sublimational breakup: This is an analogy of ordinary evaporation and ablation of the surface layers of the meteoroid (Ic) which, however, take place with much larger intensity until complete destruction of the original particle occurs. This mechanism is in evidence particularly when abrupt penetration of the meteoroid into very dense layers of the atmosphere occurs (total ablation within a short period), or the particle is moving at distances of less than 0.1 AU from the Sun (roughly 20 solar diameters). Within this zone the loss of mass or the decrease in the radius of the original particle due to corpuscular sputtering (Ib) are negligible and the decrease in radius due to evaporation takes place at a rate of at least 10 μm per year. This mechanism of abrupt evaporation to sublimation is more effective in so-called "fluffy" particles, especially if the core is stone and its envelope of ice (Kaiser and Newkirk, 1967; Singer and Bandermann, 1967; Fechtig and Hemenway, 1976).

g) Chemical breakup: This mechanism again comes into consideration with "fluffy" particles in which the individual components can be structurally divided into core and envelope. Under particular conditions of chemical composition of the core and envelope, such particles may disintegrate complete when they penetrate into the Earth's ionosphere (Fechtig and Hemenway, 1976).

III. Disturbing effects

a) Effect of solar electromagnetic radiation (direct light pressure): This effect is closely related to the Poynting-Robertson effect (IIIc). Among the non-gravitational effects, these two are of the greatest importance for studying the dynamics of small particles in the Solar System. The outdirected solar pressure always acts on the particle against the gravitational force of the Sun. Its effect mainly depends on the dimensions of the particle in question. If the meteoroids are of larger dimensions, the outdirected pressure can be neglected in comparison to the Sun's gravitational force. As the size of the particle decreases, however, the efficiency of radiation pressure is changed in a more complicated way, substantially in dependence on physical and optical properties of particles (size, shape, chemical composition, dielectric properties, absorbtion, scattering, diffraction, refraction, etc.),with more serious consequences to their dynamics (Poynting, 1903; Debye, 1909; Robertson, 1937; Wyatt and Whipple, 1950; Whipple, 1967; Burns et al., 1979; Mignard, 1982).

b) Solar wind corpuscular pressure: The escape of solar wind particles into the surrounding interplanetary space causes, apart from erosion effects (Ib) with possible corpuscular breakup (IIe), also direct disturbances in the motion of the particular particle in two ways: by direct radial pressure of corpuscular radiation and by the so-called pseudo Poynting-Robertson effect (IIId). With a view to the spatial concentration and velocity of propagation of the individual components of the solar wind, it has been estimated that corpuscular pressure is 3 to 4 orders of magnitude weaker than the pressure due to solar electromagnetic radiation (IIIa). Even the comparison of the Sun's gravitational force with this pressure indicates that also under extreme conditions (solar flares) the gravitational effect is at least a hundred times as large (Vedder, 1966; Whipple, 1967; Dmitrievskij and Kostylev, 1975; Polyakhova, 1977; Burns et al., 1979; Mignard, 1982).

c) Poynting-Robertson effect: Apart from the outdirected solar pressure acting on the particles (IIIa), the absorption of solar energy by the particle and its isotropic emission causes a small force to be generated along the tangent to the trajectory which decelerates the particle in orbit. This tangential force decreases the kinetic energy and the orbital angular moment of the particle. Consequently, the particle is forced to move to an orbit closer to the Sun. Since this decelerating force acts continuously on the particle, the trajectory of the meteoroid cannot close and the meteoroid should constantly approach the Sun along an elliptical spiral. This effect does not change the orbital plane of the particle since the Sun is located in the orbital plane of the particle (the orbit inclination and node remain unchanged). Also the change in the position of the perihelion is negligible provided the original orbit is sufficiently eccentric. However, changes of the semi-major axis and orbital eccentricity cannot be neglected in this case. Using mathematical relations for the secular rates of change of the orbital elements mentioned, one is able to derive a relation which expresses the time required for the particle to spiral from the original elliptical orbit to the Sun's corona and become extinct (Poynting, 1903; Robertson, 1937; Wyatt and Whipple, 1950; Plavec, 1956; Whipple, 1967; Burns et al., 1979; Mignard, 1982).

d) Pseudo Poynting-Robertson effect: This is another way in which the motion of a particle is dynamically disturbed, connected with direct corpuscular pressure (IIIb). Analogously with the Poynting-Robertson effect (IIIc), caused by the pressure of electromagnetic radiation (IIIa), also in this case an effect is generated which in its final consequence contributes to the normal Poynting-Robertson decelerating force. With a view to the estimate of the proton flux at 1 AU from the Sun (about 2×10^{8} cm^{-2} s^{-1}) it is assumed that the pseudo Poynting-Robertson effect increases the classical Poynting-Robertson effect by about 22% (Whipple, 1955; Whipple, 1967; Biermann, 1967; Burns et al., 1979).

e) Yarkovsky effect: This effect is created by a small excess of the "evening" temperature on a spherical rotating body as compared with the "morning" temperature. It was found that this temperature excess in reverse rotation causes a deceleration of the body's motion very much like the Poynting-Robertson effect, and that both these effects add up. However, under direct rotation of the particle, both these effects compensate each other. More detailed studies have shown, apart from the complicatedness of the interrelations of these effects (dependence on the temperature difference, on the inclination of the particle equator to the orbital plane, on the orbiting velocity of the particle, etc.), also that the Yarkovsky effect will come to bear with larger meteoroids belonging to the bolid class (Öpik, 1951; Radzievskij, 1952; Lovell, 1958; Polyakhova, 1977; Dohnanyi, 1978; Burns et al., 1979).

f) Cosmic-ray effect: The consideration of this effect is of theoretical rather than practical significance. It was found that, in spite of the high individual energies of cosmic-ray particles and considerable cosmic-ray pressure in interplanetary space, their direct disturbing effect on the orbits of dust particles is very small and, compared to other disturbing non-gravitational effects, it may be neglected (Sitte, 1970).

g) Collisional drag: Apart from the effects due to collision drag between particles of the same or different type (Ia, Ib, Id, IId, IIe, IIId, IIIf), in studying the dynamics of dust particles also their deceleration due to mutual collisions of the particles of the zodiacal cloud is considered. The general opinion is that the decelerating force, generated in this way, is very small and that it can be neglected in nearly all dynamic considerations. However, for the sake of completeness, it should be mentioned that this question is much more complicated in special cases and that conclusions become ambiguous particularly if detailed investigation of the decelerating effect due to the Poynting-Robertson drag and to mutual collisions, is made (Belkovič et al., 1978).

h) Coulomb force effect: Since it is nearly certain that solid bodies in interplanetary space acquire a certain electrostatic potential, one may also consider the disturbance of their original orbits in electric and magnetic fields due to Coulomb and Lorentz forces (IIIi) regardless of the controversial discussions concerning polarity and level of potential. In comparison with other disturbing effects, the effect of Coulomb's force on a charge dust particle in electric fields is negligible (Shapiro et al., 1967; Peale, 1966; Singer and Bandermann, 1967).

i) Lorentz force effect: This effect appears when a charged particle is moving in a magnetic field. The opinions as to neglecting this effect are not as uniform as in the case of Coulomb's force (IIIh). Some of the more detailed analyses have even proved that in special cases the effect of this force on particles with a radius smaller than 1 μm and a positive charge of 10 V may exceed the Poynting-Robertson effect. However, in general this force is neglected in most theoretical studies, also apparently as a result of the more recent measurements of the characteristics of the interplanetary magnetic field which, apart from its interesting sectorial structure, have also proved that its total intensity is low (Parker, 1964; Belton, 1967; Singer and Bandermann, 1967; Polyakhova, 1977; Consolmagno, 1979).

j) Differential Doppler effect: Other very subtle effect operates, because the light emitted from retreating eastern hemisphere of the Sun will be red-shifted (decreasing its momentum), while photons from the approaching western hemisphere of the Sun will be blue-shifted (increasing their momenta). This asymmetric delivery of radiation momentum results in additional transverse force on particles. A more detailed analysis shows that differential Doppler effect is always less than the Poynting-Robertson effect. It becomes important only in the case when a particle is close to the solar surface or is orbiting in a contact binary system (McDonough, 1975; Burns et al., 1979).

Figure 1 shows a schematic representation of the division of non-gravit. processes acting on meteoroids in interplanetary space.

3. DISCUSSION AND CONCLUSIONS

As regards the classification presented above, it should also be said that there are other miscellaneous effects of a dissipative or disturbing nature which have not been included in this classification mainly because their physical essence is not quite clear and because of their low efficiency and disputable assumptions on which their action mechanism is based. We refer to many disturbing effects acting on electrically charged and extremely small particles (≤ 1 μm) moving in electromagnetic fields. Some effects were not included in the classification because they may be considered secondary, their effect being exerted on the meteoroid only indirectly via another medium. As an example we can mention the interaction of solar wind particles with the atoms or molecules in outer space which is connected with the generation of shock waves of a magnetohydrodynamic nature, whose direct disturbing influence on the motion of ions and dust particles in cometary tails is the subject of more detailed dynamic studies. As a matter of fact, the solar wind is also

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DISSIPATIVE EFFECTS		DISTURBING EFFECTS
DESTRUCTIVE EFFECTS	DISRUPTIVE EFFECTS	
Impact erosion	Windmill effect	Direct light pressure
Corpuscular sputtering	Radzievsky effect	Solar wind corpuscular pressure
Melting - ablation - evaporation	Electrostatic explosion	Poynting-Robertson effect
Incomplete collisional destruction	Catastrophic collisions	Pseudo Poynting-Robertson effect
	Corpuscular breakup	Yarkovsky effect
	Evaporation and sublimation breakup	Cosmic ray effect
	Chemical breakup	Collisional drag
		Coulomb force effect
		Lorentz force effect
		Differential Doppler effect

Fig. 1

responsible for one of the few mechanisms of a non-dissipative nature, i.e. the penetration of heavier atoms into the internal structures of solid bodies of the Solar System (Whipple, 1967), or the accretion (by gas particles of the solar photosphere) of a negatively charged particle escaping from the Sun's gravitational field (Mullan, 1977). For completeness, we should also mention so-called electrostatic accretion which creates larger conglomerates of neutral and charged dust particles as a result of their collisions. In actual fact, however, in this mechanism each individual component of a larger conglomerate continues to be subject to all the dissipative processes which prevail in the final balance and which play the decisive role (Wesson, 1981). Nor does the classification contain effects whose more detailed explanations authors have not published yet, e.g. Švarc (1982) who considers the interaction of a meteoroid with the neutrino background and the possibility of distinguishing this effect from other non-gravitational effects. Generally speaking, we know of no non-dissipative process which makes a substantial contribution to the total material balance of the small particles of the Solar System. We may thus draw the first conclusion, i.e. that dissipative processes (which we have attempted to classify and whose efficiency we have attempted to analyse) are absolutely predominant in acting on the fine dust component of interplanetary matter and that they are responsible for the constant decrease of the mass and dimensions of the particles investigated.

A qualitatively different problem is to determine which of these effects or mechanisms is the most important and most effective in solving a particular problem. The answer to this question depends primarily on the nature of problem being solved. As an example let us take the problem of the relation between the

Poynting-Robertson effect and the outdirected solar pressure, and their consequences for the resultant trend of particle motion. In selecting the effect which would have a significant influence on solving this problem, we shall clearly avoid effects which act over short intervals of time and also effects whose efficiency cannot be described mathematically more reliably (e.g. because they act discontinuously and randomly). Similarly, we shall avoid effects whose efficiency is low, as well as effects whose explicit application to the problem on hand creates difficulties of any kind. Therefore, in selecting the most suitable of all non-gravit. processes (which should cause an effective and continuous change mainly of the physical parameters of the original meteoroid, i.e. loss of mass and diminishing of dimensions), with a view to the character of the individual groups of effects, we must concentrate on group I of the destructive effects according to the classification given above.

Of the four effects in this group melting and evaporation (Ic) are unsuitable for our problem. Although this effect has a high efficiency, it occurs close to the Earth (when the meteoroid enters the Earth's atmosphere), or the Sun (close approach to the Sun at perihelion of its orbit; final phases of the Poynting-Robertson inspiralling to the Sun), which in itself is unfavourable for studying the general relations with the classical Poynting-Robertson effect. Also strong gravitational effects come into play, but especially the time scale is too short for studying these relations. For example, Singer and Bandermann (1967) claim that, at distances of less than 0.1 AU from the Sun, the rate of decrease of the radius of a meteoroid may exceed 10 μm per year. This would indicate not only that longer observation of the evolution of particles would be unsuitable in these cases, but also that there exists an extensive region round the Sun with no dust particles, extending out to some 20 solar radii. In the referenced paper,the authors also give the actual values for the rate of evaporation at distances closer than 0.1 AU separately for meteoroids of stone and metal composition, and show how any erosion is small and negligible with respect to this effect.

With respect to our chosen problem, incomplete collisional destruction (Id)cannot be considered as an suitable effect not only because of its confused and uncertain value mentioned above (certainly very high), but also because of its character which is random rather than continuously acting over longer intervals of time.

Corpuscular erosion (Ib) has been determined fairly reliably as regards its efficiency and in substance it is acting continuously over longer period also. However, for more thorough analysis of changes of its efficiency in dependence on other parameters (heliocentric distance, mutual energy of collisions, etc.) it seems to be more suitable to choose as eroding medium not solar wind particles, but zodiacal dust particles. This holds in spite of the opinion that the corpuscular erosion rate for particles smaller than 100 μm (at the distance 1 AU from the Sun) dominates over impact erosion rate (Dohnanyi, 1978).

We thus come to the second conclusion: from the point of view of the study of general, slow dynamic changes in the meteoroids motion, which take place mainly as a result of the diminishing of their original dimensions, it is more suitable to analyse the relations between the Poynting-Robertson effect, the effect of the outdirected solar pressure and the appropriate dissipative process, on the basis of impact erosion (Ia).

This conclusion was used in the previous papers dealing with dynamics and lifetimes of dust particles in the Solar System (Kapišinský, 1980; 1983). Since applications of the impact erosion (see quoted papers) led to serious dynamical consequences, the next step was to determine more precisely its efficiency (Kapišinský, 1984). At studying its influence on the lifetime of particles, this effect can be fairly appreciable, though of less extent than e.g. catastrophic collision effect or corpuscular sputtering.

From thorough analyses of the motion of larger interplanetary bodies (asteroids) a motion component was generated which with high probability represents effects of nongravitational origin (Sitarski, 1983; Ziolkowski, 1983). Application of the presented classification on larger bodies might serve in the physical explanation of these nongravitational anomalies.

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