To the development of the mechanism of interaction of galactic comets with the terrestrial planets

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Abstract. We formulate an approach to the study of the physics of interaction of galactic comets with the terrestrial planets and the Moon, based on idealized hydrodynamic models of “elastic” and “inelastic” impact proposed by M A Lavrentiev. According to these models, a large crater arises on the solid surface of planet in case of “elastic” collision, whereas the narrowly focused shock wave is formed in result of “inelastic” impact. This shock wave penetrates deep into the lithosphere rocks causing their heating. Using the factual data for Earth, Mars and Moon, we came to the conclusion that the interaction of galactic comets with planets goes on with the participation of both the physical processes at once. At that, with a decrease of power of gaseous envelope of planet, the action of “inelastic” collision mechanism is reduced, “elastic”—amplified.

1. Introduction

It is known that in resulted of fall cosmic bodies on the surface of planets, the pressure can appear so large that we can neglect strength and plastic properties of medium and also friction forces in comparison with the inertial forces. In this case, collision of body with the surface can be seen as the interaction of two ideal incompressible fluids [1]. In accordance with the idealized hydrodynamic models by Lavrentiev [2, 3], the collision process can occur along two physically different schemes, which we shall call “elastic” and “inelastic” impacts.

In the case of “elastic” impact, most of the kinetic energy of the cosmic body is spent on the crater formation, and the momentum of the body goes to the emission from the crater of rock fragments [4]. If impact is “inelastic” collision energy and the momentum of the body are passed narrowly focused shock wave, which can penetrate deep into the lithosphere of the planet, expending energy at evaporation, melting and heating the rocks [5–7]. This thermal energy accumulating in the asthenosphere [8] then is expended into the tectonic, magmatic and geodynamic processes [9–11].

Facts suggest if planet has gas shell, high-speed galactic comets interact with such planets in model of “inelastic” impact. While on the planet with no atmosphere, this interaction can be described by the model of “elastic” impact.

Perhaps it is connected with the destruction of galactic comets in the planet atmospheres. Why is the destruction of the comet its main energy goes onto heating the deep-lying rocks of the lithosphere, and without destruction—onto the formation of a large crater? Any explanation for this phenomenon is not currently available. Besides the result of the interaction of galactic...
comets with planets depends on a combination of four main factors: (i) the presence and density of the gaseous envelope of the planet, (ii) layer thickness of the lithosphere rocks, (iii) material composition and rock temperature, and (iv) the frequency of falls of galactic comets [7, 9, 10]. At the current level of knowledge to theoretically establish the degree influence of each factor on the final result is not possible.

The purpose of the article is to formulate the task of designing the interaction mechanism of galactic comets and planets, using Galaxycentric paradigm submission [12, 13]. Another important aspect is the involvement of the comparative planetology data, which must be taken into account in the formulation of this problem. We also want to pay the attention of specialists in the field of impact process to the approach based on Lavrentev’s theoretical models which, in our opinion, adequately describe the interaction mechanism of galactic comets with planets.

In this paper we discuss the effect of both mechanisms on Earth, Mars and the Moon, which have a gaseous envelope of different density. The discussion we conduct using the submissions of Galaxycentric paradigm [12, 13].

2. Galaxycentric paradigm
Galaxycentric paradigm asserts that the Sun due to its orbital motion in Galaxy crosses the spiral arms of our stellar system through 19–37 million years. And every time in such epoch duration 2–5 million years the Earth and other planets are subjected to intense bombardments by galactic comets. During one bombardment $10^4$–$10^7$ such comets may fall on the Earth and other planets.

Without exception, epochs of galactic comets falls to Earth coincide with the periods of global natural accidents (geological, climatic, biotic), which in geology are chosen as boundaries of stratons of modern Phanerozoic geochronological scale [14]. At that the tectonomagmatic and orogenic processes, because of the inertia of heat and mass transfer in the lithosphere, usually are delayed relative eras of cometary bombardments onto the first few million years [11].

Last bombardment of the Solar system by galactic comets took place in the period from 5 to 0.7 million years ago, at the boundary of Neogene and Quaternary. According to our data at this time about $10^5$ galactic comets fell on the Earth. The density of their falls was $\sim 5$ comets on area $100 \times 100$ km$^2$ [15]. Cometary material was mainly composed of water ice and other frozen gases with a density of $\approx 1$ g/cm$^3$. Comets move relative to the Sun at a speed of 450 km/s; they had a diameter of 0.1–3.5 km, mass of $10^{12}$–$10^{17}$ g and the kinetic energy of $10^{20}$–$10^{25}$ J.

The total energy of galactic comets that have fallen to Earth is estimated $\approx 2.5 \times 10^{27}$ J. Calculations have shown [12, 13] that this amount of energy is enough to crack lithospheric plates, create underwater mountains and hot spots, as well as to form in asthenosphere large magma chambers, which are needed to explain observed volumes of trappean outpourings. The cause of all tectonomagmatic phenomena is the heating of lithosphere rocks by high-speed galactic comets [5–7]. Therefore in the periods of galactic comets falling in the bottom of lithosphere occurs formation layer of unevenly heated and partially molten rocks of asthenosphere. Emergence of asthenosphere beneath the Earth’s continents leads to significant lifting their surface, whereas under the oceans leads to an intense outpouring of lava, especially in areas of mid-oceanic ridges [9, 15–18].

2.1. The mechanism of “inelastic” interaction
The study of the interaction mechanism of galactic comets with our planet revealed that this is three-stage process [5, 6].

At the first stage in the Earth’s atmosphere, the comet nucleus is transformed into a particular flow from cometary material undergoing ablation and shock-heated air [19]. In the second phase, after falling to Earth’s surface, the jet forms a supersonic narrowly focused shock wave that penetrates deep into lithosphere, heating the cylindrical column of the rock. The heating is so
Figure 1. Density distribution of craters by diameter: (a)—differential $N(\Delta D)$ with a step $\Delta D$ from $D$ to $\sqrt{2}D$ in a double logarithmic scale [21]; and (b)—integral distribution $N(\geq D)$ in a logarithmic scale. Distribution for Mars, Moon and Mercury constructed according to data [22] and for Earth on data Feldman [13]. The dotted line in the figure corresponds inversely square dependence on $D$.

Great that rocks in the top of the column evaporate, forming a crater. Rocks under the crater are melted, creating an extensive magma chamber. Finally, in the third stage, in the system occurs a conductive and convective redistribution of heat as in a heated column and in its surrounding environment. The time of redistribution heat, depending on the size of comet nucleus and thermobaric state of the lithosphere rocks occupies of $\sim 10^4$–$10^6$ years.

Calculations show [5, 6] that if small galactic comets are able to heat the lithosphere rocks under the continents to a depth of $\sim 10$–$20$ km, and melt them in depth interval $\sim 1$–$3$ km. Then for large comets a zone of heating rocks reaches depths of $\sim 250$–$300$ km, and besides the melting of rocks takes place at depths of $\sim 6$–$40$ km. At this there is a channel through which the magma from the asthenosphere is capable to flow to the surface for a long time.

It is important to note that according this mechanism most of the kinetic energy of the comets is converted into heat, which is involved in melting and heating of deep lithosphere rocks. The heating causes strong convective processes in the asthenosphere, initiating tectonic and magmatic processes observed on the surface of the planet.

2.2. The mechanism of “elastic” interaction (a few observations)

Unlike the Earth, where almost all kinetic energy of galactic comets after their destruction in the atmosphere goes in heating of rocks lithosphere, on Mercury and the Moon, galactic comets reach the surface and part of their energy goes on formation of large craters with a diameter $D \geq 10$ km (figure 1). The same thing happens on Mars where the loss mass of nuclei comets in very thin Martian atmosphere is comparatively small [12, 20].

Analyzing the data on different planets it may seem at first glance that the physical process of crater formation by galactic comets is not much different from the well-studied mechanism of formation of craters as a result of falling asteroids and comets of the Solar system [4, 23]. However, this conclusion is not true.

The first thing that must be said is that the number of craters from galactic comets is almost 100 times greater than formed by usual asteroids and comets of Solar system. These craters
are morphologically more complex (they are more flat, may have central peaks and a several concentric topographic rings), they are characterized by exponential distribution by diameter and their vast majority has arisen as a result of the latest bombing of the Solar system by galactic comets [13, 24, 25].

Another important feature is that the craters from galactic comets are located on upland (continental) sites of surface of the Moon, Mercury and Mars, where they reach limit of integral density \( N(\geq 10 \text{ km}) \approx 100 \) craters on an area of 1 million km\(^2\) [12]. While the craters created by ordinary asteroids and comets of the Solar system are much less, they tend to be located on topographically low (maritime) areas surface planets (figure 1a), and their distribution by diameters obeys inversely square dependence.

And finally, the third important feature is that distributions of “continental” and “marine” craters on Moon, Mars and Mercury are similar in configuration and are close in numerical parameters (figure 1a). Since the craters created by galactic comets on planets without atmosphere are more numerous, their exponential distribution is intrinsic for these planets in general (figure 1b).

On figure 1b we showed the integral distribution of craters of the same size for Earth. On our planet craters created by galactic comets do not exist in area of diameters \( D \geq 80 \) km which weakly exposed to observational selection large craters of Earth are followed by back to the quadratic dependence that indicates on their formation by asteroids and comets of Solar system. It is noteworthy that the density of these craters is the same as in marine areas of Moon and Mars.

These facts indicate that regardless of presence or absence of atmosphere on the planets, the galactic comets interact with the planets, using both mechanisms immediately. The difference is that on planets with atmosphere is dominated by “inelastic” mechanism, while at the absence of atmosphere or its low density, like on Mars, the mechanism of “elastic” impact begins to play an essential role.

This issue is discussed below on example of Earth, Mars and the Moon. For its consideration we have attracted some other well-known facts, established for our and other planets, as well as have used Galactic model of geological cyclicity [12, 13].

3. The Earth

On figure 2 we have led the distribution density of falls galactic comets through the breadth of the Globe, calculated for the last 700 million years on the basis of Galactic model of the geological cyclicity [12, 26]. The calculation takes into account the Sun movement on galactic orbit, the angle of the ecliptic to galactic plane 62\(^\circ\), as well as possible precession of the ecliptic with a period of 2.7 \( \pm \) 0.5 billion years. The angle of tilt and precession of Earth’s axis of rotation with a period of 26 thousand years are not taken into account. In addition to simplifying the analysis of the results of calculation it is assumed that comets move strictly in the galactic plane and their flow does not change over time.

According to our model, frequency of fallings of comets reaches maximum at equator and on poles of Earth at certain times. At the end of Riphean and in Early Vendian, in Permain-Carboniferous time, as well as in Cenozoic, galactic comets bombed mainly Southern hemisphere of Earth, while most part of Northern hemisphere was not exposed to their bombing. In Ordovician and Jurassic the pattern was reversed. During these periods, the Sun is in point pericenter of orbit and move with at higher speed. Therefore region of the North Pole is subjected to a smaller number of cometary bombardments than of the Southern Pole.

It should be noted that flux of comets bombarding our planet is greatly mutable. It depends on the Sun position in an orbit and dramatically increases when the Sun is found in the zones-starburst of galactic sleeves [13]. Calculations figure 2a did not take into account these circumstances.
3.1. Super-continental cyclicity

It is known that most important geological processes on Earth (tectonomagmatic, climatic and biotic) demonstrate long-period cyclicity with characteristic times of 150–300 million years. Figure 2b illustrates the existence of such cycles on example formation and collapse supercontinents Pangaea and Pannotia [27], as well as Wilson’s tectonic cycles, boundaries of which are associated with the eras of the formation and closing ocean basins in the Phanerzoic [28].
Established, that supercontinents are formed in one hemisphere of our planet [31]. After the collapse of the single supercontinent on the opposite side of the globe another formation begins. In this process, the continental masses alternately pulled together [32] one time at southern hemisphere and next at northern. Over lifetime of the supercontinent occur two large tectonomagmatic events: one time in the assembly period, and the second at the end of the existence of the supercontinent. The latter event leads to the disintegration of the supercontinent.

Disintegration of supercontinents is explained [33] by the influence of Large igneous provinces (LIPs) [34]. Provinces LIPs cover an area $\geq 10^5 \text{ km}^2$, exist $\sim 50$ million years, and their own activity is manifested in form pulses of duration 1–5 million years, during which the volume of magma erupts $\sim 10^5$–$10^6 \text{ km}^3$.

According to the model [26], formation of supercontinents in southern hemisphere in Riphean–Vendian and Carboniferous is due to lower speed of Sun movement in aphelion its orbit in Galaxy. As a result, galactic comets are more often and for a longer time bombarded the southern hemisphere, than the north. At the same time the boundaries of cycles Bertrand’s coincide with the times of most intense falls of comets in belt latitudes ($-30^\circ$, $+30^\circ$), where their density reaches a maximum for two–three bombardments. Such picture corresponds quite well to modern views on existence of short-lived LIPs, which show their activity by pulses.

### 3.2. Periods of glaciation

Figure 2c shows the data on the paleolatitudes spread of glaciers for 5 known glacial periods: on the border of Vendian and Cambrian, Late Ordovician–Early Silurian, Late Devonian–Early Carboniferous, Middle Carboniferous–Permain, and in the late Cenozoic. Last glaciation began in Antarctica in Paleocene and continued in Arctic in Neogene. Within limits of individual glacial periods alternation of glacial and interglacial phases [30] is observed. Almost all ice phases occur in eras fallings of galactic comets [13].

The dashed line in figure 2c shows the boundary in latitudes above which in the glacial periods the Earth has not been subjected to cometary bombardments. It is assumed [8, 11, 26] that during of cometary bombardments on Earth’s poles, as well as in elevated areas there appeared deposits of ice, which do not have time to melt between eras of cometary falls.

Coincidence paleolatitudes spread of ice sheets with an area of cometary fallings leads to the conclusion [8] that the formation of glaciers is connected with rise surface of continents. This phenomenon is similarly to phenomenon of recent uplifts of the crust [35,36], which to data [15] has been caused by last cometary bombardment.

### 3.3. The phenomenon of newest uplifts

It is known that in Pliocene–Quaternary time on all continents almost simultaneously took place the uplifting of surface with amplitudes from 100–200 meters to several kilometers. As a result, the majority of modern mountain structures, plateaus and other positive forms of relief were formed. Particularly large uplift occurred in Central and South Asia, western North and South America, Eastern and Southern Africa and in East Antarctica. An increase thickness of asthenosphere that is accompanied by modern intensive outpouring of magma occurred under many mountains [35, 36].

The uplifts of continental surface can be explained [36] by increasing the thickness of the asthenosphere beneath the continents due to entering the fluid into $\sim 100$ km layer of mantle part of the lithosphere rocks. The composition and source of fluid as well as question why it enters almost simultaneously beneath all continents remain unanswered.

It is believed that in the Phanerozoic the tectonic phenomenon analogical the newest uplifts on our planet occurred infrequently. In [37] found that in the previous $\geq 100$ million years
Figure 3. The structure surface of Mars [38]. Curve line is tectonic border in form of global ledge, which separates “marine” and “continental” Martian hemispheres [39].

topographic altitude of continents surface does not exceed a few hundred meters, reaching \( \sim 0.5 \text{ km} \) in their inner parts.

The Galactic model geological cyclicity allows understanding this question, if we attract it to the analysis of features structure relief of Martian surface.

4. The Mars

Rotation axis of Mars and Earth are oriented to the ecliptic plane is almost the equally, so the calculations (figure 2a) are applicable to Mars. It follows that the last time galactic comets bombarded the southern hemisphere not only Earth, but Mars. This circumstance is clearly expressed in topography of Martian surface (figure 3).

It is known that the main forms of marine and continental topography of Mars are located on opposite sides of a kind of tectonic boundary, obtained as a trace of section of spherical surface of Mars by plane inclined to its equator at an angle of \( \sim 35^\circ \). The border is confined to the sharp bend relief with a height difference of 2–6 km and divides the planet, as it were into two hemispheres. The difference between the hemispheres is so large that it allows to say [39] about existence on Mars two hemispheres of different ages: continental—“geologically passive” and the marine—“geologically active.”

Passive continental hemisphere of Mars is characterized by a large number of craters with a diameter \( \geq 10 \text{ km} \) and is identical to the continental areas of the Moon. The density of craters in this hemisphere reaches the theoretical limit, which for Mars, as well as the Moon, is equal \( \approx 100 \) craters on area of \( 10^6 \text{ km}^2 \). Craters are distributed exponentially (figure 1b), which indicates their formation by galactic comets. The leading type of relief “active” marine hemisphere is smooth plains with smooth immersions and uplift of large amplitude [39]. The plains are covered with rare and relatively small craters. Their diameter distribution obeys the inverse square dependence (figure 1a). In the area of the equator of Mars, the plains are intersected by canyon system. Four extinct volcanoes in height from 15 to 25 km largest in Solar System are located here.
4.1. *Reason of formation the continental hemisphere*

The presence of the continental hemisphere of Mars, as well as forming supercontinents in Earth’s southern hemisphere is explained [40, 41] by galactic comets. Their bombardments and especially the last, on the one hand, cover the surface of southern hemisphere by a large number of craters, and on the other, may form in lithosphere a thick layer of asthenosphere, which causes lifting of surface southern hemisphere in whole. To explain the excess of height “continental” hemisphere over “marine”, the layer asthenosphere on Mars depending on the degree of melting of rocks should be $\sim 100–250$ km [40]. It should be noted that this estimate coincides well with the thickness of asthenosphere layer at phenomenon of newest uplifts on Earth [36].

Another conclusion is that, the northern polar area of Mars has not been bombed by galactic comets in last $\sim 60$ million years. All craters with a diameter $\geq 10$ km in the belt latitudes $60^\circ–90^\circ$ were created by falling asteroids and comets of the Solar system. The distribution of diameters these craters indicate the Cenozoic age of Martian marine surface [42].

4.2. *Reason of formation the marine hemisphere*

We believe that, unlike continental hemisphere, which has recently experienced uplift of the surface, marine hemisphere of Mars is in the process of isostatic leveling, which annihilates the previously emerged craters. We assume that the layer of asthenosphere beneath the sea hemisphere of Mars today became cold enough. As a result, its thickness has decreased, causing a lowering of marine surface. If the speed of this process is the same as on Earth, the time of $\sim 20–37$ million years between the bombings is enough to transform the surface of marine hemisphere of Mars in low-lying smooth plains.

Since in result of the Sun motion in Galaxy, galactic comets alternately bombard the south and the northern hemisphere of Mars, a layer of asthenosphere naturally migrates beneath the Martian surface. Therefore, through half the Sun orbital period the “marine” and “continental” hemispheres change places. Judging by super-continental cyclicity (figure 2b) something similar is happening on the Earth.

4.3. *The similarity of tectonic magmatic processes on Mars and on Earth*

Data on Earth and Mars suggests that in eras of falling galactic comets, due to heating rocks of the asthenosphere layer, there is a rise of the continental surface of planets. But after tens or hundreds of millions years these rocks undergo cooling, that leads to a lowering of the surface and isostatic compensation of arisen earlier mountain structures. Therefore, it is difficult to agree with the opinion [37] that the phenomenon of recent uplifts is a rare phenomenon of nature, which was absent on Earth during the past 100 million years.

Our conclusion about the previous existence of high mountain structures on the Earth, that later rather quickly ceased to exist, is supported by data on the glaciations (figure 2c). It is known [43], that glaciers on our planet are formed at all latitudes, although at different heights. In the mountainous equatorial regions they are today at a height of more than 4 km, and as we approach to the poles are reduced to sea level.

This conclusion of glaciologists is general in nature, and obviously it is applicable to the former ice ages. A good agreement of the actual data with the calculations (figure 2c) gives reason to believe [8] that a necessary condition for the development of ice sheets is the uplifting surface of continents, similar to the newest uplifts. If the amplitude of uplift of continental surface at the Pole, as at the last comet bombardment, reaches $\sim 1$ km or more, this may be enough for the emergence in the polar zone of ice sheet, which later can spread to other areas of the planet.
5. The Moon
In recent years the Moon has attracted increased attention in connection with the discovery on lunar surface the water (ice) as well as studies the gravity anomalies of mascons. These studies have put a number of new problematic issues, which are actively are debated in planetology [44, 45].

5.1. The origin of mascons
Mascons are called clusters of dense material beneath the surface that cause positive gravity anomalies. Mascons usually have a rounded shape and are often located under the lunar mares, craters or complex multi-ring structures [45]. Currently mascons also are found on Mars and Mercury.

Ancient origin of mascons is not possible to explain by the fall of bodies of asteroid belt [46]. We believe that mascons are created by the falls of fairly large galactic comets. Therefore the lunar seas and craters containing mascons are located on elevated areas of the surface and occupy...
Figure 5. (a) The region of crater bottom to the north-east of the central peak. Arrows indicate the border of plume elevation; (b) volcano in the center of area is highlighted by square in figure 5a.

Figure 6. (a) Glacier tongue sliding down to the bottom of crater on the south-western steep slope of central peak of crater (see figure 5a); (b) the rocks sliding down from the slopes of the crater.

In figure 1a region $D \geq 150$ km. It is possible that mascons, like most large craters and seas on the Moon were formed in result of the last bombardment of the Solar system by galactic comets.

The mechanism of formation of mascons is probably not much different from the mechanism of formation on Earth by galactic comets the oceanic crust [18] and diatremes on continents [7, 10]. Important factors in this mechanism are the lithosphere thickness and heating temperature of its rocks. In the case of small thickness lithosphere, the magma produces a lot of and its large amount pours on the surface. And there where the lithosphere is thicker and its temperature is
lower the amount of magma is less. This circumstance in our opinion explains the fact [45] that on the visible side of the Moon many pools $c \, D \geq 350 \text{ km}$, while the back side is dominated by smaller pools.

5.2. Water on the Moon

Our estimates show [47, 48] that in the period of only one last bombing (from 5.0 to 0.6 million years ago) the galactic comets could bring to the Moon $\sim 10^{11} \text{ tons of water}$. This quantity of water is more than sufficient to explain mass of water ice on the Moon [44].

To understand the mechanism of “elastic” interaction of galactic comets with planets without atmosphere, the question about the future of water is of great importance. Water evaporates on impact of galactic comets on the surface. The factual data suggest that, in eras of cometary bombardments part of evaporated comets, water remains on the Moon. Some part of this water, presumably, some time may be in a liquid state on the lunar surface, another part till now is present in magma chambers under the bottom of the craters, and the third part is frozen in rocks of walls craters.

Let us illustrate this by the example of crater Tsiolkovsky on far-side of Moon (figure 4). This is a typical crater, which did not test strong changes after formation by galactic comet. The diameter of the crater is 184 km, its depth of about 2.2 km. The crater has a central peak, and its bottom is covered with young basaltic lava. According to our data, the age of the crater is $\sim 1$ million years. Supposed direction of fall galactic comet is shown by the arrow.

In pictures (figure 5) with high-resolution of crater’s bottom in the site of supposed comet impact we found a small, perhaps, an active volcano which is located on an oval elevation plume.

Figure 7. Gullies and rivers on the bottom of the crater to the north of the central peak.
nature [48, 49]. The height of the volcanic cone is of 102 meters, the diameter of its base of 1700 m. The volcano apparently pours out “liquid lava” with plenty of water, which freezes and rapidly sublimates. Diameter of the uplift is 24–26 km. We believe that beneath the elevation exists the magma chamber with volume of at least about 100 km$^3$ [48].

The snapshot (figure 6a) shows from above the tongue of glacier, which descends on bottom of the crater by the south-western steep slope of central peak of the crater. Figure 6b illustrates another phenomenon widespread in crater Tsiolkovsky associated with stones, sliding down on the slopes of the crater. Note that the resolution of the image allows you to see the stones of about 1 meter.

Data (figures 6) show that in the crater Tsiolkovsky is currently an intensive “defrosting” wall of crater, which is accompanied by outcrop of rock fragments located therein. Expiring in this process fragments of rocks either slide down on the slopes, filling depressions and indentations in relief of wall crater, or remain on the high parts of the surface with a zero slope. An example is figure 6b, where large rocks in large numbers are concentrated at the top edge of a mountain.

Finally, figure 7 shows a portion of bottom of the crater to the north of the central peak, where there are gullies and “frozen rivers.” It is assumed that these structures could arise earlier with the participation of liquid water. We assume that the necessary conditions for this could well be on the Moon’s surface during the last comet bombardment.

6. Conclusion
In paper we discussed the approach to the study of the physics of interaction of galactic comets with the terrestrial planets based on idealized hydrodynamic models of “elastic” and “inelastic” collision proposed by M A Lavrentiev. In the first model, the kinetic energy and of a comet in mostly spent on the mechanical formation of a crater. In the second model, the energy and impulse are transferred to the shock wave, which in addition to formation of a crater causes melting and heating of deep lithosphere rocks.

The main conclusions of the article are as follows:

- Earth and Venus, characterized by a thick atmosphere, interact with comets by “inelastic” model impact. While the model of the “elastic” impact plays an important role on planets with no atmosphere (Mercury, Moon), or with a very tenuous atmosphere (Mars).
- Mass falling comets lead to heating the layer of asthenosphere rocks, which causes a lifting of surface portions subjected to cometary bombing. These elevated portions of surface are interpreted as “continents”.
- During the time between cometary bombardments (20–30 million years) the rocks of asthenosphere are cooled; the level of planet’s surface in these areas declines, and the relaxation processes eliminate all irregularities. These low-lying places on the surface Mars, Moon and Mercury are considered to be the “marine.”
- Owing to the orbital Sun’s motion in the Galaxy, comets are alternately bombing southern as well as northern hemispheres of planets, resulting in a change to their “continental” and “marine” landforms. Last time the comets fallen on the surface of southern hemisphere of all planets. This circumstance we explain the fact [50] that on the Moon, Mars, Mercury and Venus the average levels of the heights of the southern hemisphere is systematically higher than the average levels of the northern hemisphere, where the “marine” landforms occupy large area.
- In the crater Tsiolkovsky, we see evidence of the past presence of liquid and vaporous water. This fact indicates that in period of the last bombing, the Moon had an atmosphere, which may delay water of evaporated galactic comets.

The lunar images in the paper are borrow from Arizona State University website where several millions images (!) are put in the open access. They are images of high and super-high
resolution delivered and transmitted to the Earth by spacecrafts Apollo-17 (figure 4, 5 and 7—metric camera), Apollo-15 (figure 6a—panoramic camera) and Lunar Reconnaissance Orbiter (figure 6b—Narrow Angle Camera). We are grateful to the scientists and specialists providing high quality of orbital survey.

In connection with the conclusions of this article, we emphasize that the known interaction models of large cosmic bodies (comets and asteroids of the Solar system) with planets are not applicable to describe the approach proposed in our article for explaining the facts of comparative planetology.

In this article, we reviewed some of the issues of interaction of galactic comets with terrestrial planets, which are still far from being solved. Therefore, our findings regarding the mechanism of such interactions, of course, require additional confirmation and theoretical study.

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