ASTROPHYSICS

M.Yu. Skulsky

On the wave structure in the spatial organization of the Solar planetary system

M. Yu. Skulsky
Lviv Polytechnic National University, Lviv, Ukraine
E-mail: mysky@polynet.lviv.ua

Abstract. Taking into consideration the current knowledge about planetary structure of the Solar system it was noticed that both planets groups could be formed by one physical process similar to the phenomenon of standing waves with length $\lambda_{sw} = \lambda/2$ (here: $\lambda = cP_0$, c is the speed of light and $P_0 = 160$ min is a certain period). The principle of the ordering for outer planets and dwarf planets is represented in the wave form as $a = n\lambda/2$ or $a = (2n+1)\lambda/4$ (where a is a semi-major axis and n is a whole number) arranged these planets at distances from the Sun proportional to a quarter and a half of the wavelength (Jupiter – λ/4, Saturn – λ/2, Uranium – 2λ/2, Neptune – 3λ/2, Pluto – 4λ/2, Eris – 7λ/2). This algorithm also satisfies the conditions of the location of the most major transneptunian objects including comet families. The principle of the orbit ordering for inner planets is expressed as $2\pi a = m\lambda'_{sw}$ with the step $\lambda'_{sw} = (1/12)\lambda_{sw}$ and m = 3, 6, 8, 12 for orbit lengths from Mercury to Mars that is commensurable with the length of standing wave $\lambda_{sw} = \lambda/2$ and its harmonics. The spatial organization of the Solar planetary system is described by two related kinematic algorithms of the single wave mechanism.These results are quite accurate and can be considered as empirical. It is important that the wave principles of structuring of the planets do not support the idea of the formation of the Solar planetary system in the form of power law including the law of Titius-Bode. Also it was revealed an explicit resonance of proper oscillations of the Sun and planets. Their global periods are virtually multiples of $kP_0/2$, where k = 1, 2, 3. This result is showing signs of a quantization of the gravitational interaction of these objects and is associated with the length of the standing wave $\lambda_{sw} = \lambda/2$ as with the ordering factor in the Solar planetary system.

In whole, these interconnected findings should be considered as essential on the background of the current knowledge about the laws of structuring the planets in the Solar and exoplanet systems.

Keywords: *Solar system, exoplanets, principles of the ordering for planets, standing waves*

Introduction

The list of discovered exoplanets reached one thousand. Several hundred well-studied exoplanets and tens their systems promoted a research of scenarios of their dynamical evolution. The first investigations of exoplanet systems (Lovis et al. 2010; Flores-Guttierrez and Garsia-Guerra 2011) showed that the principles of the ordering of semi-major axes of planets differ substantially. In some cases these orderings are similar to power laws or the Titius-Bode law. One important conclusion is that there are no rules for ordering of planets by a scientifically proved physical mechanism.

At the same time, for the Solar system were revealed other principles the ordering of planets on the basis the program of magnetic field registration of the Sun as a star. This program led to discovery of “enigmatic” pulsations of the Sun with a period $P_0 = 160$ min (Severny et al. 1976) and the ordering of planets in the Solar system (Kotov and Kuchmi 1985, Kotov and Khanejchuk 2011). It was shown that in the Solar system there exists a common “L_0-resonance” of the planets with the “scale” $L_0 = cP_0 = 19.24$ AU, where c is the velocity of light. The positions of planets in the Solar system were determined by two simple principles: $2\pi a = L_0/n$ for orbits of inner planets and $2a = nL_0$ for orbits of outer planets (where a is semi-major axis of an orbit and n is a natural number). For the inner planets (Mercury, Venus, Earth and Mars) the numbers are $n = 8, 4, 3, 2$ and for asteroids $n = 1$. For the outer planets (Saturn, Uranus, Neptune) and dwarf planets (Pluto and Eris) these numbers are respectively $n = 1, 2, 3$ and $n = 4, 7$. But for Jupiter such number is fractional $n = 1/2$.

The physical nature such ordering of planets are not explained. However, in connection with the detection of extrasolar systems it becomes necessary to study these principles more carefully. Considering the planets position in accordance with the principles of the L_0 – resonance was offered a wave algorithm for explaining of the ordering of planets in the Solar system.

Standing waves and principles of the ordering of main objects in the Solar system

Since L_0 – scale has the dimension of a wave with the length $\lambda = cP_0 = 19.24$ AU both principles of L_0 – resonance can be transformed into a wave form.

For orbits of outer planets the principle of the L_0 – resonance $2a = nL_0$ can be represented as $a = n\lambda/2$. Then the distances of the outer planets from the Sun are multiple of a quarter or half wave: Jupiter – $\lambda/2$, Saturn – $\lambda/2$, Uranus – $2\lambda/2$, Neptune – $3\lambda/2$. The distances of well-known dwarf planets are: Pluto – $4\lambda/2$ and more distant Eris – $7\lambda/2$. This corresponds to the determination of standing waves which arise by interference between direct and reflected waves in the same body.

Their standing wave is $\lambda_{sw} = \lambda/2$, the linear dimension of this body is multiple to $\lambda/4$, the wave nodes and antinodes with the zero amplitude and double amplitude respectively are distributed along the body with this multiplicity – see Fig. 1.

Numbers of $\lambda/2$ and $\lambda/4$ one can find from the Table 1 which contains certain characteristics of the Solar system: planet masses, semi-major axes of the planet orbits and periods of the planet oscillations (for more details see the text).

This algorithm satisfies also the conditions of the location of the well-known major transneptunian objects (TNO) with determined kinematic parameters of their orbits including comet families. Semi-major axes of the majority of these TNO are multiple of $\lambda_{sw} = \lambda/2$ or of even numbers of $\lambda/4$. For example, for Pluto, Orcus and Ixion they are equal to $4.1\lambda/2$ i.e. these objects are arranged in the 4-th node from the Sun; for 2002 AW semi-major axis is equal to $4.9\lambda/2$ i.e. this object is in the 5-th node; for GK147, SM331, VK305, XR190, YW134 semi-major axes are equal to $6\lambda/2$ or they are in the 6-th node. Semi-major axes of Eris and 2007 OR_{10} are close to $7.0\lambda/2$ i.e. these objects are in the 7-th node from the Sun. Semi-major axes of the minority of these TNO are multiple of odd numbers of $\lambda/4$.

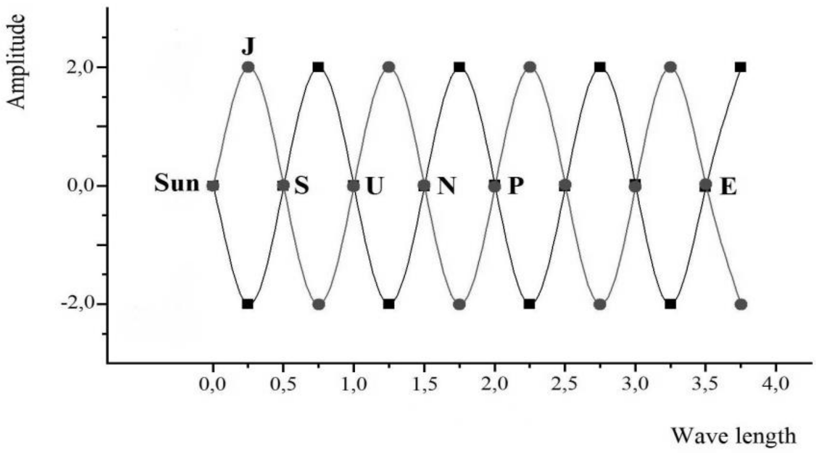

Fig. 1. The schematic ordering of outer planets in the phenomenon of standing waves

Table 1. The Solar system characteristics

Planet	M	a	$a, \lambda/2$	$2\pi a, \lambda/4$	T, min	T, P_0	$cT, \lambda/2$
Mercury	0.055	0.387	0.040	0.50 - 1/2	85	0.5	1
Venus	0.815	0.723	0.076	0.95 - 1	90	0.5	1
Earth	1.000	1.000	0.104	1.31 - 4/3	84	0.5	1
Mars	0.107	1.524	0.158	1.99 - 2	100	0.5	1
Jupiter	317.9	5.203	0.54 - 1/2	6.80	172	1	2
Saturn	95.16	9.509	0.99 - 1	12.42	236	1.5	3
Uranus	14.54	19.25	2.00 - 2	25.14	177	1	2
Neptune	17.14	30.19	3.13 - 3	39.43	158	1	2
Pluto	0.022	39.50	4.10 - 4	51.59			
Eris	0.029	67.67	7.03 - 7	88.39			
Sun					167	1	2

Distances from the Sun are equal to $4.5\lambda/2$ for Haumea, Quaoar and Varuna and respectively equal to 7.5 and 8.5 $\lambda/2$ for 2007 UK126 and CP105.

Distances from the Sun of transneptunian comet families with very eccentric orbits and direct motion near the plane of the ecliptic are also commensurable to the standing wave length $\lambda_{sw} = \lambda/2$ as a parameter of their position. In the range of 15–200 AU from the Sun three families of such comets were revealed (Kozlov 2011). They are located at the average distances 56, 86 and 106 AU, which correspond to 2.91, 4.47 and 5.51λ or in standing waves their distances are 6, 9 and $11\lambda/2$, i. e. these comet families are concentrated at the nodes of the standing waves.

Thus, the distance from the Sun to outer planets (excepting Jupiter) and to the majority of transneptunian objects including a families of comets are represented by simple equation in the wave form $a = 2n\lambda/4$, where $n = 1, 2, 3, \dots 11$. The distances from the Sun to the minority of transneptunian objects and Jupiter are represented as $a = (2n+1)\lambda/4$ (for Jupiter $n = 0$ and $a = \lambda/4$). From the foregoing it follows that Jupiter is located at the shortest distance from the Sun.

The inner planets cannot obey the wave algorithm for the outer planets because their distances from the Sun are smaller than $\lambda/4$. However, they are represented by their own principle of the L_0-resonance $2\pi a = L_0/n$. This principle transforming to the form $2\pi a = m\lambda_{sw}^1$ is the equation of standing waves for orbits of inner planets. Here, $\lambda_{sw}^1 = (1/12)\lambda_{sw}$ is a “daughter" standing wave and the numbers $m = 3, 6, 8, 12$ “quantize” the orbit lengthes of the inner planets from Mercury to Mars respectively. The equation of standing waves for inner planet orbits follows from simple resonant relations of orbit lengths for the planets Mercury–Venus, Venus–Earth, Earth–Mars. They are close to 1 : 2, 3 : 4, 2 : 3. The number 12 as the least common multiple of these resonances points to a discrete set of daughter standing waves $\lambda_{sw}^1 = \lambda_{sw}/12 = \lambda/24$ that is contained in the fundamental standing wave $\lambda_{sw} = \lambda/2$.

The structural architecture of inner planets on the basis of the relation of lengths of planet orbits from Mercury to Mars can be represented in standing waves as $(1/4)(\lambda/2):(1/2)(\lambda/2):(2/3)(\lambda/2):(\lambda/2)$ or as $\lambda/8:\lambda/4:\lambda/3:\lambda/2$ – see Fig. 2. The length of the Mars orbit is directly equal to the length of the standing wave $\lambda_{sw} = \lambda/2$ as to the fundamental harmonic. Its first and third harmonics are strictly contained in the length of the orbits of Venus and Mercury and its two second harmonics are contained in the orbit length of Earth (see the fifth column of Table 1).

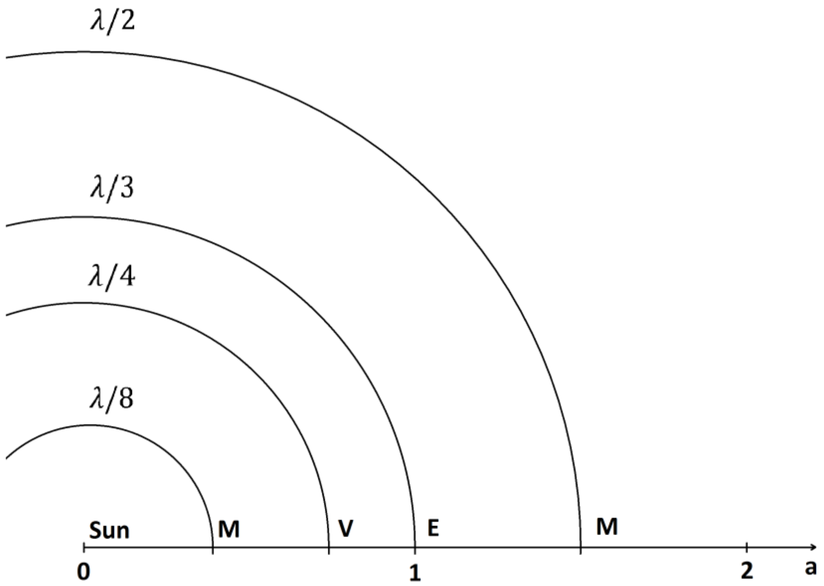

Fig. 2. Fragments of schematic orbits of the inner planets are shown in the wavelengths. Distances to the planets are normalized to the semi-major axis of Earth's orbit.

Analyzing equation $2\pi a = m\lambda_{sw}^{1}$one can ascertain that there is a limited number of integers m which determine the number of standing waves with the length $\lambda_{sw}^{1} = \lambda_{sw}/12$ contained in possible "stationary" orbits. In their quantity the resonance of orbit lengths for inner planets plays a key role. The extended set of resonant relations of the orbit lengths for the inner planets could be presented in the following form: $\lambda/24{:}\,\lambda/12{:}\,\lambda/8{:}\,\lambda/4{:}\,\lambda/3{:}\,\lambda/2{:}\,\lambda$.

It is logically to expect the existence of planet with the orbit length equal to λ. The absence of such a planet behind Mars (in place of the asteroid belt) can be explained not only by the "pumping out" of planetesimals by Jupiter but also by negative role of a powerful resonance 1 : 1 which can arise because of the equality of the wave with the length λ and the orbit length of this hypothetical planet. The absence of the planets with the minimum length of their orbits ($m = 1, 2$) between the Sun and Mercury can be explained similarly. In particular, for $m = 1$ the distance of such hypothetical planet from the Sun would be equal to 0.127AU. Meanwhile, in the exoplanet systems as a rule there are several planets at such distances from a central star (Lovis et al. 2010). In this sense the Solar system is unique.

Thus, all main objects in the Solar system are arranged on the basis of two algorithms of the standing waves of one length $\lambda_{sw} = \lambda/2$. Their equations are identical to those of standing waves in many physical processes.

Phenomenon of standing waves and the resonance of the global oscillations of the Sun and planets

The phenomenon of standing waves initiates the calculation periods of "global" oscillations of planets because it is known about amazing proximity the "enigmatic" P_0-pulsations of the Sun that is equal to 160 min and the global oscillation of the Sun as a star with the period 167.3 min.

The formula which is used to estimate periods of such oscillations of the Sun and the planets of mass M and radius R is known as $T = 2\pi(R^3/GM)^{1/2}$, where G is the gravitational constant. It is valid for spherical objects with the symmetric distribution of mass and the homogeneous gravitational field. Such eigenmodes can be considered as global oscillations of these objects (without considering their internal structure). The calculated global T-periods (see Table 1) for the inner planets from Mercury to Mars are equal to 85, 90, 84 and 100 min respectively, i.e. they are in a close relation 0.5 : 1 to the P_0-period of the Sun. For the outer planets from Jupiter to Neptune they are equal to 172, 236, 177 and 158 min, i.e. the T-periods of the Sun and outer giant planets are in relation 1 : 1 to the P_0-period of the Sun (only for Saturn it is 1.5 : 1, but this result is perfectly correspond to low averaged density of Saturn in comparison with other giant planets). This can be described by simple equation $T \approx kP_0/2$. It obeys the rules of integers $k = 1, 2, 3$ and here $P_0/2$ as the first harmonic of P_0-pulsations of the Sun is the least common multiple for these T-periods (with an average relative error in 5%). It is recognized that there is a common resonance of global oscillations of planets and Sun. It is the first unusual result: the whole "planetary orchestra" is tuned to the frequency of global pulsations of the Sun. Table 1 shows also for all of these objects that there is the second simple equation, $cT \approx k\lambda/2$ where $k = 1, 2, 3$. Consequently, global oscillations of planets are determined of the standing wave with the length $\lambda_{sw} = \lambda/2 = cT$. There is the second unusual result: periods of global oscillations of planets and the Sun are directly associated with the standing wave $\lambda_{sw} = \lambda/2$ as with the structural factor in the Solar system.

In general, these simple calculations gave unexpected results about the unusual aspects of gravitational interactions between the Sun and the planets. These findings can be also considered as to a certain extent the confirmation of the existence of global "enigmatic" P_0-pulsations of the Sun.

Conclusions: phenomenon of standing waves and the Solar system structure

The results of the wave investigation of the Solar system structure could be explained by existence of a physical mechanism similar to the phenomenon of standing waves presented in two variants but with the same length of the standing wave. In the first of them, the lengths of "stationary" orbits of the inner planets agree with the first, second, third and fundamental harmonics of the standing wave. In case of outer planets and main transneptunian objects including the families of comets, their distances from the Sun are multiple of the length or half length of the standing wave. The ordering of all planets obeys the rules of integers according to distinct resonance relations. These results can be considered as empirical and are quite accurate. Their average deviations from the calculated positions are within 3-5% which could be explained as a result of long-term evolution of the Solar system. It is reasonable to suppose that the formation of both groups of planets in the Solar system could be realized by means of a specific wave process. And their movements in a circle on the orbits corresponded to these wave processes. These wave principles of the orbit ordering for planets do not support the idea of the formation of the Solar system structure in the form of power law including the Titius-Bode law and its modifications. Also it was revealed an explicit resonance of proper oscillations of the Sun and planets.

The analysis of the standing waves phenomenon evinced the common resonance of global oscillations of the Sun and planets. This resonance irrespective of the inner structure of these objects showed the definite connection between gravitational and waves processes.

The phenomenon of standing waves proved itself as a factor of structuring the planets in the Solar system and as a new aspect in the scientific investigations.

Brief remarks on the nature of the phenomenon of the standing waves

In the mechanism of standing waves the discrete structure of the Solar system looks as a quite nonrandom phenomenon. One can draw a conclusion that the wave algorithm of the structure of the Solar planetary system is the accomplished fact. This puts a question about the origin and nature of this phenomenon.

Empiric data offer a suggestion that global P_0-pulsations of the Sun, regardless of reason and time of their origin, were able to synchronize and save the wave structure of the Solar system in the process of its evolution up to the present tense, although now these pulsations can be observed in relict form. Indeed, according to estimates made by Molchanov (1969) the probability of casual formation of the planetary system with properties of the Solar system is about 10^{-10}–10^{-11}. Then, in the terms of the current knowledge, it is not difficult to represent the scenario of forming of the Solar system by the mechanism of interference of coherent waves within a protoplanetary disk but without considering the physical nature of these waves (Skulsky 2013). These waves have the velocity of light, but it is difficult to study them with the help of hypotheses of the electromagnetic or gravitational nature. The energy of electromagnetic waves with $\lambda = 19.24$ AU is very small. Nevertheless, it would be interesting to model the formation of planets in the protoplanetary disk taking into account the influence of the Schumann-like resonances (Schuman 1952) in the cavity between the surface of the young Sun and ionized gravitational shafts. A possibility of origin and interference of coherent waves from spherical objects interacting gravitationally is problematic because this is forbidden in the general theory of relativity. However, there are other possible interpretations of gravitation. For example, the gravitational field can have not only the tensor component (as in the general relativity) but also the scalar one. The scalar component may be emitted in spherically symmetric oscillations of any source of gravitation, including the Sun (Sokolov 1992). The phenomenon of wave structurization of the Solar system can be represented as a relativistic delay of scalar part of the gravitational field or a disturbance on the Newtonian potential. In any case, the hypothesis of the possible existence of gravitational waves (including those with length $\lambda = cP_0 = 19.24$ AU) and their interaction can have the right to existence although it is not easy to interpret in terms of the accepted modern concepts.

The next aspect of the problem consists in that the wave algorithm in the structure of the Solar system confirms existence of P_0-pulsations of the Sun, while theoretical studies of internal structure of the Sun do not confirm the existence of these pulsations (Appourchaux and Palle 2013). They note the fast damping of low-frequency g-modes at their transfer to surface of the Sun. Howerer, it should be noted that one of possible variants in searches of an answer can consist in consideration of the interaction of gravitational and magnetodynamic processes. Indeed, the surface P_0-pulsations of the Sun (Severny et al. 1976, Kotov and Khanejchuk 2011) were revealed by the method of registration the magnetic field of the Sun as a star. It is known that tachocline region which is responsible for the enhancement of the magnetic field of the Sun and plays a key role in nature solar cycle lies on the bottom of the convection zone. The global g-modes should reach this zone without significant damping. It allows to suppose the modulation of general magnetic field by g-modes and their transfer together with this field to surface of the Sun. Then the impact on the structure of planets will be carried out the magnetic field of the Sun which is modulated by the low-frequency oscillations of global g-modes. In this aspect, such observation method is a promising in the study of the internal structure of the Sun and solar-planetary interactions. In particular, one can expect to detect the variability of the P_0-pulsations of the Sun within the 22-year cycle.

Henceforth, we should take into account that the gravitational interactions between the planets and the Sun as a star can be characterized without considering their detailed internal structure (the formula $T = 2\pi(R^3/GM)^{1/2}$ for the global period reflects the averaged densities for all objects). Their interactions are described by certain quantized parameters. But there are the saltatory variations in the interaction between the Sun and the terrestrial planets and between the Sun and the giant planets. For the inner planets there is relation $T \approx P_0/2$ while for the massive outer planets it grew twice $T \approx P_0$ but for the Saturn it grew three times $T \approx 3P_0/2$. It is not surprisingly because these estimations concern to very low density of Saturn in comparison to other outer planets but there is an amazing coincidence the calculated and observed radius of Saturn. It should be considered as an accomplished fact the good coincidence of effective radii of all objects according to the equation $T = kP_0/2$ and their observed radii. It is obvious that the Sun as a star and the planets are showing signs a quantization of their gravitational interaction and this is associated with the length of the standing wave $\lambda_{sw} = \lambda/2$ as the structural factor in the Solar planetary system. These results are unusual but are interconnected on the basis of the simple physical equations.

In general, the discovered findings of this research are related to the basic foundations of our worldview and represent problem in their interpretation. The nature of Solar P_0-pulsations and the mechanism of generation of waves of the length $\lambda = cP_0$ including the phenomenon of standing waves in the structure of the Solar planetary system remains still inexplicable. Such studies should be continued because they raise questions about the formation of Solar and exoplanet systems. For example, the phenomenon of standing waves could explain the basic questions of the planetary cosmogony: why the planet orbits in the Solar system are nearly circular and coplanar and why there are two groups of planets which are located from the Sun according to two algorithms of one wave mechanism.

Thus, it is worth paying attention to the need for a more complete analysis of this physical problem.

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Скульский Ю.М.

О волновой структуре в пространственной организации Солнечной планетарной системы

Аннотация. Анализируя современные представления о пространственной структуре Солнечной планетной системы, было замечено, что обе группы планет могли бы быть сформированы в едином физическом процессе, уподобленному явлению стоячих волн с длиной $\lambda_{sw} = \lambda/2$ (здесь $\lambda = cP_0$, c – скорость света и период $P_0 = 160$ min). Принцип упорядочения для внешних и карликовых планет, представленный в волновой форме, имеет вид уравнений $a = n\lambda/2$ или $a = (2n+1)\lambda/4$ (где a – большая полуось и n – целые числа), согласно которым эти планеты располагаются относительно Солнца на расстояниях, кратных четверти или половине длины волны (Юпитер – $\lambda/4$, Сатурн $\lambda/2$, Уран – $2\lambda/2$, Нептун – $3\lambda/4$, Плутон – $4\lambda/4$, Эрида – $7\lambda/4$). Этот алгоритм удовлетворяет такого рода расположениям наиболее крупных транснептуновых объектов, включая семейства комет. Принцип упорядочения орбит внутренних планет выражен в форме $2\pi a = m\lambda'_{sw}$ с шагом $\lambda'_{sw} = (1/12)\lambda_{sw}$ и m = 3, 6, 8, 12 для длин орбит планет от Меркурия до Марса, что соизмеримо с длиной стоячей волны $\lambda_{sw} = \lambda/2$ и ее гармоник. Пространственная организация Солнечной планетной системы четко описывается двумя родственными кинематическими алгоритмами единого волнового механизма. Эти результаты являются достаточно точными и могут рассматриваться как эмпирические. Важно, что волновые принципы структурирования планет не поддерживают идею образования Солнечной планетной системы в виде степенного закона, включая закон Тициуса-Боде. Обнаружен также явный резонанс собственных колебаний Солнца и планет. Их глобальные периоды практически кратны $kP_0/2$, где k = 1, 2, 3. Этот указывает на признаки квантования гравитационного взаимодействия этих объектов в их связи с длиной стоячей волны $\lambda_{sw} = \lambda/2$ как с фактором упорядочения планет в Солнечной системе.

Результаты этого исследования взаимоувязаны и могут рассматриваться как существенные на фоне современных представлений о законах структурирования планет в Солнечной и экзопланетных системах.

***Ключевые слова**: Солнечная система, экзопланеты, принципы упорядочения планет, стоячие волны*