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ON THE NATURE OF THE SOLAR SYSTEM: THE WAVE STRUCTURE AND GLOBAL OSCILLATION OF THE SUN AND PLANETS

Introduction

The first investigations of exoplanet systems showed that the principles of the ordering of semi-major axes of planets differ substantially [1,2]. One important conclusion is that there are no rules for ordering of planets by a scientifically proved physical mechanism. But it is well known that the program of magnetic field registration of the Sun as a star led to discovery of "enigmatic" pulsations of the Sun with a period $P_0 = 160$ min [3] and a common "L_0- resonance" with unusual principles the ordering of planets in the Solar system [4,5]. The physical nature such ordering of planets was not explained and in connection with the detection of extrasolar systems was become necessary to analyze these principles. This led to a detection of the wave algorithm as a possible explanation of the ordering of planets in the Solar system.

Standing waves and the spatial organization of the Solar planetary system

Thus, in the Solar system 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 [5]. The positions of planets in the Solar system were determined by two simple principles: $2\pi a = L_0 / n$ for the orbits length of inner planets and $2a = nL_0$ for the orbit intersections of outer planets (where a is the semi-major axis of an orbit and n is a natural number). 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 were transformed into a wave form [6].

The ordering for outer planets can be represented as $a = n\lambda/2$ or $a = (2n+1)\lambda/4$ (where a is a semi-major axis and n is a whole number). Then the distances of the outer planets from the Sun are multiple of a quarter or half wave: Jupiter - $\lambda/4$, 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 - $7\lambda/2$. These results resemble the determination of standing waves which arise in the interference of direct and reflected waves in the same body. The standing wave have a length $\lambda_{sw} = \lambda/2$, 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 - the schematic ordering of outer planets is snowed in Fig. 1.

Introduced algorithm also satisfies the conditions of the location of most of the largest transneptunian objects (TNO) with determined kinematic parameters of their orbits including comet families. Interestingly, the distribution of periodic comet aphelions with very eccentric orbits and direct motion near the plane of the ecliptic was obtained in the range of 15 - 200 AU [7]. Three families of comet at average distances 56, 86 and 106 AU, which corresponds to standing waves 6, 9 and 11 $\lambda_{sw} = \lambda/2$ were detected. The distance of trans-Neptunian comet families from the Sun are multiple of the standing wave lengths as a parameter of their positions. In keeping with the resonant relation $a = n\lambda/2$ the "quantization" of these objects can be traced to a distance the order of 100 AU, i.e. approximately to limits of the heliosphere.

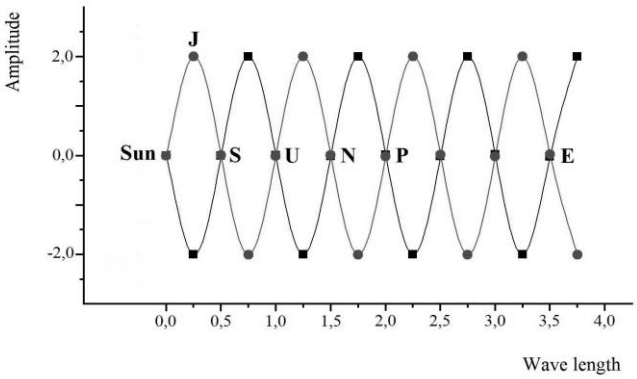

Fig. 1. The schematic ordering of outer planets in the phenomenon of standing waves

Thus, the distances from the Sun to outer planets, dwarf planets, TNO and trans-Neptunian comet families are represented by simple wave equation. The outer planets, dwarf planets are located from the Sun at distances that are multiple to the standing wave length or to the half its length. This is well illustrated from the fourth column of Table where the distance to the planets a are expressed in $\lambda/2$. The Table also includes the following characteristics of the Solar system: the planet masses that are in given units of the Earth mass - the second column; the semi-major axes of the planet orbits a that are given in AU - the third column; the orbits length of planets $2\pi a$ that are expressed in $\lambda/4$ in the the fifth column. The next columns of this Table describe global periods of the planets oscillations that are given in minutes and in fractions of period $P_0 = 160$ min - more details in the second part of the article.

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.,3	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

From the wave equation $a = (2n+1)\lambda/4$ follows that Jupiter ($n = 0$) is located on the shortest distance $a = \lambda/4$ from the Sun. The inner planets can not obey the wave algorithm for the outer planets because their distances from the Sun are smaller than $\lambda/4$ (see the fourth column of Table). It was founded that the principle of the orbit ordering for inner planets can be expressed as $2\pi a = m\lambda^1_{sw}$ with the $\lambda^1_{sw} = \lambda_{sw}/12 = \lambda/24$ and $m =$ 3, 6, 8, 12 for orbit lengths from Mercury to Mars that are the commensurable quantities with the length of standing wave $\lambda/2$ and its harmonics. 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 $\lambda^1_{sw} = \lambda_{sw}/12 = \lambda/24$ 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 as $\lambda/8 : \lambda/4 : \lambda/3 : \lambda/2$ or in standing waves as $(1/4)(\lambda/2) : (1/2)(\lambda/2) : (2/3)(\lambda/2) : (\lambda/2)$ - 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

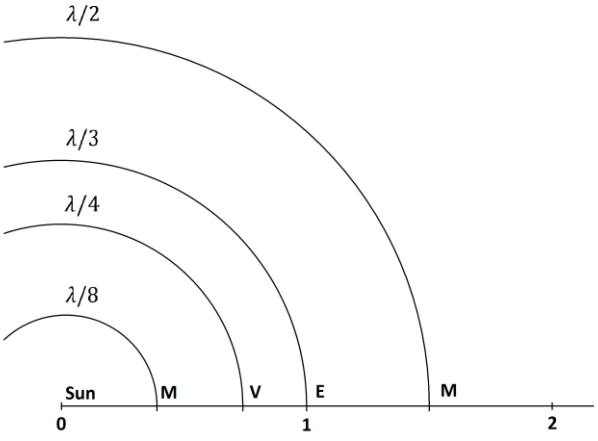

Fig. 2. Fragment of orbits of the inner planets shown in wavelengths. Distances to the planets are normalized to $a = 1$ as to the semi-major axis of Earth's orbit

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 in which the length of the orbits of the inner planets $2\pi a$ expressed in fractions of $\lambda/4$). Analysis of the equation $2\pi a = m\lambda_{sw}^{1}$ showed that the extended set of resonant relations of the orbit lengths for the inner planets could be presented in the following form: $\lambda/24:\lambda/12:\lambda/8:\lambda/4:\lambda/3:\lambda/2:\lambda$. The lack of planets with the orbital lengths $\lambda/24$, $\lambda/12$ and λ can be attributed to evolution of the Solar system that led to its uniqueness compared with the exoplanet systems [1,2]. In particular, 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 that can arise because of the equality of the wave with the length λ and the orbit length of this hypothetical planet.

Therefore, the spatial organization of the Solar planetary system could be formed in one physical process namely in two interrelated kinematic algorithms of the mechanism of the standing waves with one length $\lambda_{sw} = \lambda/2$. Their equations are identical to those of standing waves in many physical processes. 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.

Standing waves and the resonance of the global oscillations of the Sun and planets

It was known about the amazing proximity of "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. In view of the phenomenon of standing waves this fact intrigued. That is why we decided also estimate the global oscillations of the planets and discovered the general resonance of proper oscillations of the Sun and planets.

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).

For the inner planets from Mercury to Mars calculated global T-periods are 85, 90, 84 and 100 minutes and respectively for the outer planets from Jupiter to Neptune - 172, 236, 177 and 158 minutes (see the sixth and the seventh columns of Table where T periods are expressed in minutes and in fractions of period $P_0 = 160$ min and also the eighth column where cT are expressed in numbers of $\lambda_{sw} = \lambda/2$). T-periods for the inner planets from Mercury to Mars are in a relation 0.5 : 1 to the P_0-period of the Sun. For the outer planets from Jupiter to Neptune they 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 corresponded to low averaged density of Saturn in comparison with other giant planets). In general such behavior of these objects can be described by simple equation $T \approx kP_0/2$ which corresponds to such equation $cT \approx k\lambda/2$. 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%). Therefore, there is a general resonance of global oscillations of planets and Sun. Since $\lambda = cP_0$ this result shows the obvious signs of a quantization of the gravitational interaction of the Sun as a star and planets and simultaneously it confirms the length of the standing wave $\lambda_{sw} = \lambda/2 = cT$ as a factor in the structuring of planets in the Solar system. These simple calculations gave unexpected results about the unusual aspects of gravitational interactions between the Sun and the planets. Wave and gravitational resonances put questions about their origin in the Solar system.

Conclusions

In the first place, analysis of the Solar planetary system certifies a fact that a basic physical mechanism for structuring of the Solar system could be a phenomenon related to the standing waves. Discrete structure of the Solar system looks in the mechanism of standing waves as a quite natural and nonrandom phenomenon. The spatial organization of the Solar planetary system is described by two interrelated kinematic algorithms of the single wave mechanism. In this case, the lengths of "stationary" orbits of the inner planets from Mercury to Mars correlate as numbers 3, 6, 8, 12 in proportion to the first, second and third harmonics of the fundamental tone of the standing wave. The outer planets, TNO and trans-Neptunian comet families are located from the Sun at distances that are multiple of the length or half of the standing wave. The ordering of all planets obeys the laws of prime numbers according to clear resonance relations. These results are quite accurate and can be considered as empirical. Deviations of the planetary system objects from the calculated position are within 2-5% that could be explained by long-term evolution of the Solar system. The factor of standing waves in the structuring of planets is becoming a new aspect of the wave planetary physics. In the mechanism of standing waves can be explained basic issues of modern planetary cosmogony: why the planets' orbits are nearly circular and coplanar, why the distances of the planets from the Sun are arranged in a certain way, why the space of the Solar system is divided into two parts, and there are two groups of planets, the inner group of which consists of four planets.

Secondly, there is a common resonance of global oscillations of Sun and planets and these oscillations are directly associated with the standing wave of the same length. The simple calculations gave unexpected results about the unusual aspects of gravitational interactions between the Sun and planets. Indeed, if we take into account that global periods of the planets and the Sun as a star were calculated without regard to their internal structure (the formula $T = 2\pi(R^3/GM)^{1/2}$ for the global period reflects the averaged densities for all objects) it is not clear why these periods have a certain quantized interaction. 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 $T \approx P_0/2$ but for the massive outer planets it grew twice $T \approx P_0$ while 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 they are interconnected on the basis of the simple physical equations.

Such interconnected findings should be also considered as essential on the background of the current knowledge about the Solar and exoplanet systems.

References: 1. *Lovis C., Segransan D., Mayor M.* et al. The HARPS search for southern exstra-solar planets. XXYII. Up to seven planets orbiting HD 10180: probing the architecture of low-mass planetary systems // August 13, 2010, Astron. Astrophys. Man., N HD10180, P. 1-15. 2. *Flores-Gutierrez J.D. and Garsia-Guerra C.* A variant of the Titius-Bode law // 2011, Rev. Mex. Astron. Astrophys., 47, P. 173-184. 3. *Kotov V. A., Severny A. B., Tsap T. T.* Observations of oscillations of the Sun // 1978, Mon. Not. R. Astr. Soc., V. 183, N 1, P. 61-78. 4. *Kotov V.A. and Koutchmy C.* On the possible relationship of the law of planetary distances to the phenomenon of a 160-minute pulsation of the Sun // 1985, Izv. Crimean Astrophys. Obs., V. 72, P. 199-208. 5. *Kotov V.A. and Khaneychuk V. I.* The pulsations of the Sun and the beat period 399 days // 2011, Izv. Crimean Astrophys. Obs., V. 107, N1, P. 99-104. 6. *Skulsky M. Yu.* Magnetic Sun, pulsations and standing waves in the structure of the Solar system // 2013, Izv. Crimean Astrophys. Obs., V. 109, N4, P. 1-10. 7. *Kozlov V. A.* The trans-Neptunian comet families // 2009, Asron. School's Report, V. 6, P. 163-166.

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