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# Fast motion of exoplanets

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**ABSTRACT**

Do exoplanets revolve randomly around their stars? A substantial part of superfast exoplanets is shown to move with periods near-commensurate with timescales $P_{\rm E}$ and/or $2P_{\rm E}/\pi$, where the value $P_{\rm E}$ = 9590(90) s coincides with both 1/9th of the mean solar day and the period of solar pulsations, 9600.606(12) s (confidence level of the composite resonance is nearly 99.97% for exoplanetary periods less than two days). There is a noticeable lack of orbits with periods of/about $3\pi P_{\rm E} \approx 1.05$ days as well. The true cause of these strange $P_{\rm E}$-coherent phenomena is unknown.

**Key words:** Sun, planets, exoplanets, close binary stars, resonances, gravitation

## 1 Introduction

Among universal constants, the Newtonian gravitational constant is determined with the worst precision: $G = 6.67430(15) \times 10^{-11}$ m$^3$ kg$^{-1}$ s$^{-2}$ (Zyla et al., 2020; uncertainty in brackets presents the standard error, and notations are usual). As to the properties of gravity, no phenomenon leading to new knowledge has been proposed so far, after zero results of the Eötvös–Dicke–Braginsky experiments to check the principle of equivalence. (Leaving apart Dirac's hypothesis about a decrease of $G$ with time, as well as abstract gravitation emission and refined, rather questionable theories of gravity, we can cite here Simpson (1964): *"It is inherent in any acceptable definition of science that statements that cannot be checked by observation are not really about anything – or at the very least they are not science".*) As Dicke (1970) noted, to analyze the theoretical problems of gravity, one must address to astrophysical objects instead of laboratory devices: astronomy has good possibilities confirming the principle, though with comparatively low precision. The recent discovery of a number of exoplanets (EPs) revolving super-rapidly around "parent" stars offers a new challenge.

We note, in particular, a theoretical peculiarity of motion of a particle around large spinning mass (Mitzkevich, 1976; Bowler, 1976): the rate of motion depends on the direction of revolution, so that the difference of the direct and retrograde periods,

$$\Delta P = 2\pi \frac{L}{Mc^2}, \qquad (1)$$

is free of $G$, orbit radius, and mass $M$ of the central body (since $L$ is its angular momentum, and $M$ is canceled); theorists therefore conclude that the problem of rotation in the general relativity theory is not yet well settled.

It has recently been shown that *(a)* the largest and fastest objects of the Solar system rotate with periods near-commensurable with a timescale of 9594(65) s, which coincides amazingly well with a period of global pulsations of the Sun, $P_0$ = 9600.606(12) s (of unknown nature; see Fig. 1, Kotov, Haneychuk, 2020, and references therein); and *(b)* motion of a significant amount of superfast EPs occurs to be in the near-resonance with timescales $P_{\rm E}$ and/or $2P_{\rm E}/\pi$, where $P_{\rm E} = P_0$ within the error limits (Kotov, 2019a).

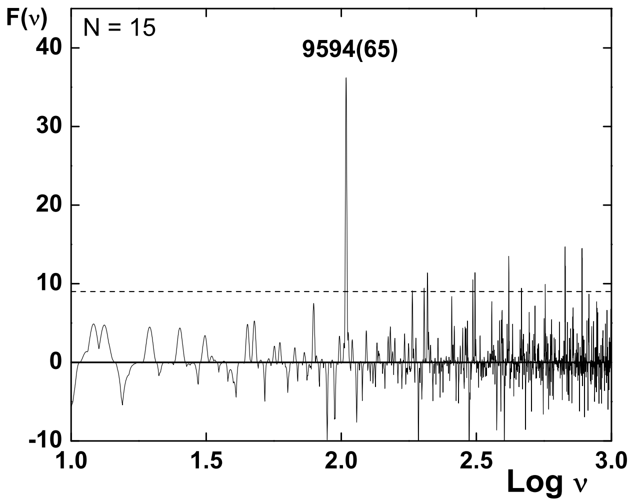


**Fig. 1.** Resonance spectrum $F(\nu)$ computed for 15 motions of the largest and fastest rotators of the Solar system. The horizontal axis gives the logarithm of frequency $\nu$ (in $\mu$Hz); the dashed line corresponds to a $3\sigma$ confidence level; and the primary peak corresponds to a timescale of 9594(65) s (Kotov, 2019a).

It is remarkable that the global pulsation of the Sun – with a period of 1/9th of a day – was predicted by Sevin (1946) long time before the actual discovery by a few groups of observers: Brookes et al. (1976), Severny et al. (1976), Grec et al. (1980), Scherrer, Wilcox (1983), but its true nature is yet unknown.

It has recently been found that the “ubiquitous” $P_0$-commensurability also characterizes the period distribution of close binary stars (Kotov, 2008).

Indeed, an object with the orbital period $P$ presents an example of unrecurrence – in time and space – of the binary system on a timescale of $P/2$, and perhaps this fact can explain an appearance of the $\pi$ number in the analysis of both EPs and cataclysmic variables (CVs, with related objects), whose periods reveal a gap on the timescale $P_{CV} \approx P_0 \approx 0.11$ days (see, e.g., Spruit, Ritter, 1983) and the best commensurability with $2P_0/\pi$ (Kotov, 2019a).

The EP orbit stability with periods commensurate with $2\pi P_0$ (in addition to the above commensurability with $2P_0/\pi$) would be treated then as a time analogue of the expression $l = 2\pi r$ for the length $l$ of the $r$-radius circumference in space. (According to Platon, circular motion is ideal, characterized by “the highest beauty and completeness”; here we ignore orbital ellipticities, the more so as for a number of the EP orbits the eccentricities are not yet determined.)

We also note the following theoretical expressions for the centers of the EP and CV gaps, in days (Kotov, 2019a):

$$P_{CV} = \frac{3}{\pi} P_0 \approx \frac{P_D}{3\pi} \approx 0.106, \tag{2}$$

$$P_{EP} = 3\pi P_0 \approx \frac{\pi}{3} P_D \approx 1.047, \tag{3}$$

with $P_D \approx 9P_0$, the mean solar day, so that, within the error limits of observations (i.e., of the $P_{CV}$ and $P_{EP}$ errors), the ratio $P_{EP}/P_{CV} = \pi^2$.

Equation 3 means the Earth’s spin period $P_D$ = 1.000 days (with respect to the Sun) could not be a chance timescale observed at the contemporary epoch of the Solar system evolution. The same conclusion concerns the Earth’s orbital period $P_Y$ = 365.256 days as well:

$$P_Y = \frac{P_\odot^2}{2P_D} = 365.23(16) \ \text{days}, \tag{4}$$

with the synodic period $P_\odot$ = 27.027(6) days of the Sun’s spinning (of the solar gravitating mass; Kotov, 2019b). This signifies that $P_\odot$, $P_{CV}$, $P_{EP}$, and both Earth’s timescales, $P_Y$ and $P_D$, as observed today, might be not an accidental product of the Solar system evolution only.

The remarkable correlation $P_0$–$P_D$–$P_\odot$–$P_Y$ presented above proved to be statistically significant and physically motivated (being hypothetically a result of coherent time-variable gravity perturbations?), even not yet fully understood. Here we can check the above $b$ effect by a special analysis of the most complete sample of EPs available to the present time and with extended interpretation.

## 2 Motion of exoplanets

While the total sum of 5113 EPs was discovered by 14 July 2022, only 672 of them are superfast, revolving with *orbital* periods $P < 3$ days. To analyze their orbital and spinning rates, following the previous algorithm (Kotov, 2019a), we calculated the resonance spectrum $F_2(\nu)$, whose maximum corresponds to frequency, with the best commensurability being with $1/P_i$ and/or $\pi/2P_i$, where $P_i$ is the EP period with the ordinal number $i = 1, 2, \ldots N$; $\nu$, the test frequency; and $N$, the complete number of objects in a given EP sample (the function $F_2(\nu)$, in fact, presents metric of periodic motion).

Namely, to take into account both above potential effects we are looking for (i.e., the plausible EP excesses at the orbital periods $\approx Z_1 P_0$ and $\approx 2Z_2P_0/\pi$, with the small positive integers $Z_1$ and $Z_2$), we introduce the spectrum $F_2(\nu)$, based on the calculation of deviations $\delta_{i1}$ and $\delta_{i2}$ of respective frequency ratios (see below) from the nearest integers:

$$F_2(\nu) = F_{02}(\nu) \ |F_{02}(\nu)|, \tag{5}$$

where

$$F_{02}(\nu) = A[B - R_2(\nu)] \tag{6}$$

with

$$R_2(\nu) = \left[ \frac{\sum_{i=1}^{N} (\delta_{i1}^2 + \delta_{i2}^2)}{2N} \right]^{1/2}. \tag{7}$$

The summation in Eq. (7) is performed for orbital periods $P_i$, while the values $\delta_{i1} = r_{i1} - Z_{i1}$ and $\delta_{i2} = r_{i2} - Z_{i2}$ are deviations of the frequency ratios $r_{i1}$ and $r_{i2}$ from the integers $Z_{i1}$ and $Z_{i2}$, their best approximations, and those ratios themselves are

$$r_{i1} = (\nu_i/\nu)^p \geq 1, \quad r_{i2} = (2\nu_i/\pi\nu)^q \geq 1, \tag{8}$$

where the powers $p$ and $q$ are equal to 1 or −1. The quantity $B = 12^{-1/2}$ in Eq. (6) presents the average value of $R_2(\nu)$ for random ratios $r_{i1}$ and $r_{i2}$, and the value $A = (120N)^{1/2}$ is the normalizing coefficient reducing the standard deviation of differences $B - R_2(\nu)$ to unity for a random set of $P_i$ (for other details see also Kotov, 2008).

The $F_2(\nu)$ spectrum of 366 EPs with $P < 2$ days, computed within the frequency range around the *a priori* frequency $\nu_0 = {P_0}^{-1} \approx 104.16$ μHz, is plotted in Fig. 2, where the main peak corresponds to a timescale of $P_E$ = 9590(90) s, which agrees well with the “solar” period $P_0$ = 9600.606(12) s (at the 3.5σ confidence level, C.L., corresponding to the probability $3 \times 10^{-4}$ that the two timescales coincide with each other by chance). An increase in the number of observed EPs allowed us to extend the test frequency range by a few times in comparison with the previous study, and we note that the $P_E$ effect cannot be caused by the choice of the cut-off limit $P_L$, set to be two days in Fig. 2, – see Kotov (2019a) and Table 1 (with $P_m$, a timescale of the $\nu_0$ commensurability peak for a given $P_L$ value).

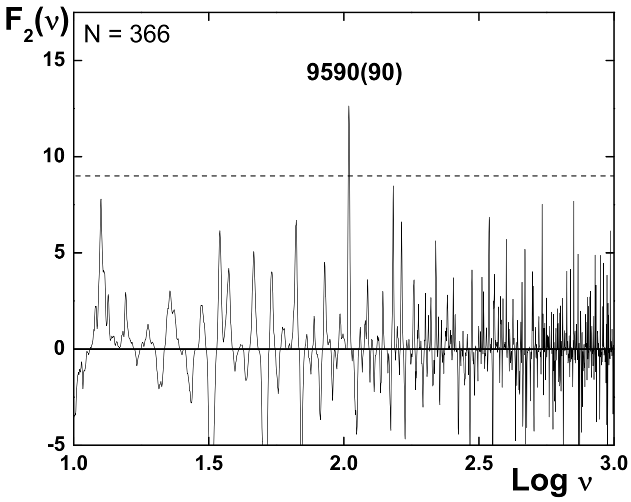


**Fig. 2.** Same as in Fig. 1 for the resonance spectrum $F_2(\nu)$ of 366 exoplanets with periods $P < 2$ days; the highest peak corresponds to a timescale of 9590(90) s.

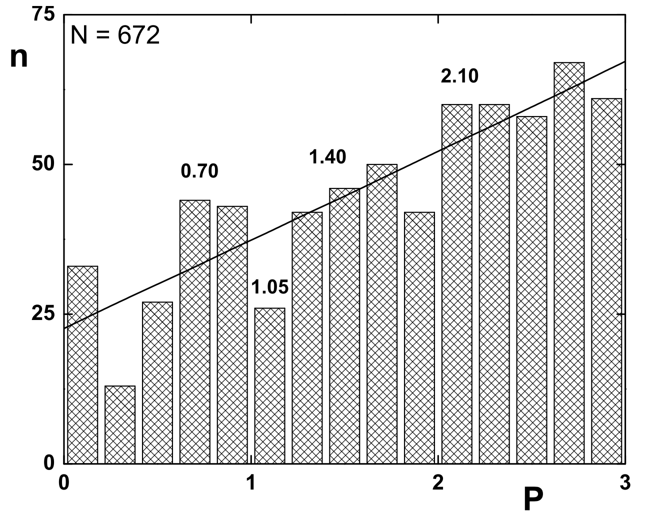


**Fig. 3.** Histogram of 672 periods of the superfast EPs ($P < 3$ days). The horizontal axis gives the period $P$ in days; the vertical one, the number $n$ of EPs within each 0.2-day block of data; and the solid line shows the best-fit parabolic approximation of the distribution. The numbers indicate periods of three excesses ($P \approx 0.70$ days, $\approx 1.40$ days, and $\approx 2.10$ days) and the gap, $P \approx 1.05$ days.

**Table 1.** The $P_E$ effect for various cut-off boundaries $P_L$.

| $P_L$ (d) | $N$ | $P_m$ (s) | C.L. |
|---|---|---|---|
| 1.25 | 199 | 9692(145) | 3.6$\sigma$ |
| 1.50 | 251 | 9643(120) | 3.6$\sigma$ |
| 1.75 | 313 | 9557(100) | 3.0$\sigma$ |
| 2.00 | 366 | 9590(90) | 3.5$\sigma$ |
| 2.25 | 445 | 9612(80) | 2.7$\sigma$ |
| 2.50 | 514 | 9623(70) | 2.9$\sigma$ |
| 2.75 | 591 | 9643(65) | 2.0$\sigma$ |
| 3.00 | 672 | 9627(60) | 2.3$\sigma$ |

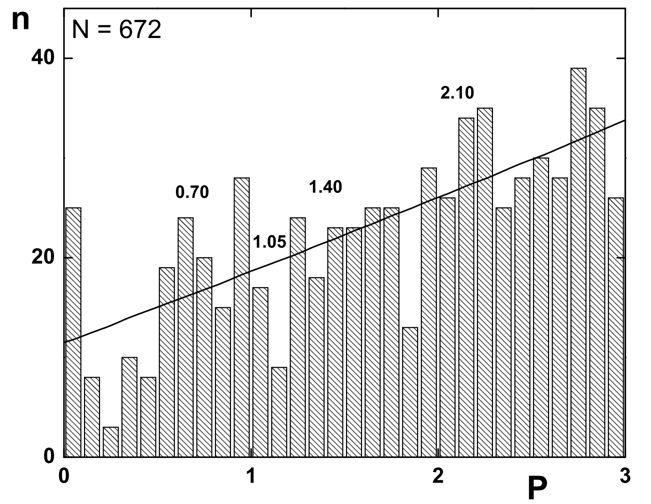


**Fig. 4.** Same as in Fig. 3, but for the EP-period bin size 0.10 days.

## 3 Period gap

The distribution of 672 EPs with the orbital periods $P < 3$ days is shown in Fig. 3, where the prominent gap on a timescale of $P_{EP} \approx 1.05$ days is well noticeable. We already argued that the center of this gap corresponds to $3\pi P_0$, where the $\pi$ number appears as a factor of the best incommensurability of EP periods with respect to the $P_0$ perturbation (of unknown physical origin); the deficit of objects itself is thought to be caused by a stability of orbits with periods close to $2\pi P_0 \approx 0.70$ days and $4\pi P_0 \approx 1.40$ days.

Some opponents noted, however, that the EP-period histogram might be highly variable in its shape as a function of the bin size. To make the 1.05-day gap more evident, another histogram in the same range of [0, 3] days, but for a bin size of 0.10 days, is plotted in Fig. 4. Here a few gaps appear at periods of about 0.30, 1.10, 1.85, 2.35 and 2.95 days, with a 0.66(7)-day spacing on average. The primary excess at $P \approx 0.95$ days might be *(i)* a chance fluctuation, *(ii)* real, of unknown origin, or *(iii)* the result of the observation selection effect owing to a probable 1-day periodicity of a substantial amount of EP observations (in the latter case, the selection effect can explain both an appearance of the 0.95-day excess and a shift of the center of the nearby gap from the expected 1.05 days to $P \approx 1.15$ days).

To make the above period-gap feature more evident, the power spectrum (or periodogram) was computed by the direct Fourier transform for deviations $\delta(P) = n(P) - f(P)$, where $n(P)$ and $f(P)$ are the observed period distribution and its parabolic approximation, respectively (see Fig. 4). The resultant periodogram is plotted in Fig. 5, where the primary peak corresponds to a periodicity of 0.71(3) days, which agrees well with the modulating timescale $2\pi P_0 \approx 0.70$ days claimed above.

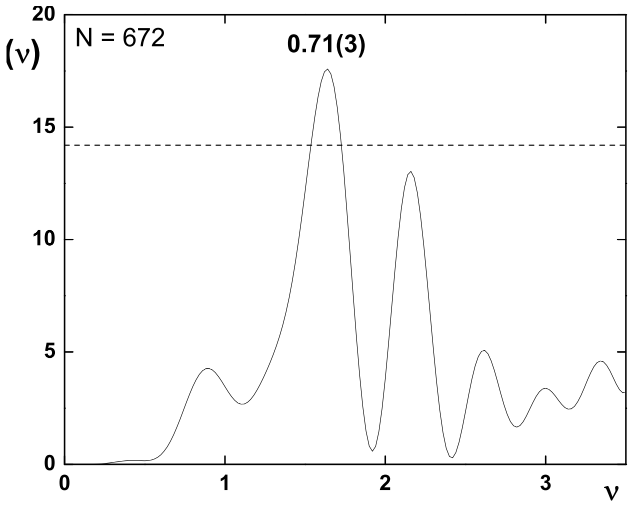


**Fig. 5.** Periodogram of deviations $\delta(P)$ (see the text; the number of exoplanets $N = 672$); $\nu$ is frequency in units $10^{-5}$ Hz; $I(\nu)$ is power in arbitrary units; and the dashed horizontal line corresponds to the $2\sigma$ C.L. The primary peak corresponds to a timescale of 0.71(3) days.

## 4 Conclusions

The above results strongly confirm the earlier finding (Kotov, 2019a) that the motion of ultrafast exoplanets (with periods less than two or three days) urges to be statistically commensurable with timescales $P_E$ or/and $2P_E/\pi$, where the time modulus $P_E = P_0 \approx 1/9$ days, a "mysterious" period of solar oscillations.

We advance a hypotheses that *(a)* "solar" $P_0$ pulsation has cosmic origin; *(b)* the $P_0$ timescale characterizes the striving (of unknown physical nature) of ratios of cosmic periods and cycles to be integers, rational numbers, or factors containing $\pi$; and *(c)* the $P_0$ timescale, rotation period of the Sun, as well as the two periods of the Earth's motion, axial and orbital ones, might be the fundamental time constants of the World (at the present epoch of evolution). It seems worthy therefore to cite L. Kronecker: *"God made the integers; all else is the work of man"*. And we remind that the model of an atom and quantum mechanics, the Mendeleev table, and all theories of resonances are based on the harmony of integers and rational numbers.

The true origin of the $P_0$ ($P_E$) phenomenon strangely emerging in the Solar system and EPs is, however, far from clear.

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