# EXCITATION OF THE SOLAR OSCILLATIONS BY OBJECTS CONSISTING OF $y$-MATTER*

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**Abstract.** Modern development of particle physics makes it probable that new, still undiscovered, particles exist interacting with the ordinary matter by means of gravitation only. Okun suggested to call such particles the $y$-particles and to call the matter consisting of them the $y$-matter. We show that planet-like object orbiting inside the Sun and consisting of $y$-matter may explain 160 min nonradial solar oscillations.

The difficulties of explanation within the frame of standard solar model of 160-min oscillations observed in Crimean Observatory (Severny *et al.*, 1976, 1979) are well known (Vorontsov and Zharkov, 1981). In fact these oscillations perhaps are not free, but forced. In the paper by Severny *et al.* (1979) a possibility of excitation of the oscillations by a small black hole orbiting the Sun at the depth $2 \times 10^4$ km below the photosphere was mentioned (D. O. Gough in his remark at Toulouse conference 1978 on solar physics was apparently the first to suggest such a possibility). Modern particle physics may offer another possibility, to the same extent exotic, but perhaps free of some difficulties of the black hole model.

Recently Okun (1980) suggested that there may exist so called $y$-particles having the only mutual interaction with the ordinary matter – the gravitational one (the history of this idea may be traced back the papers by Lee and Yang (1956) and Kobzarev *et al.* (1966)). These $y$-particles may have their own interactions, similar to the weak, strong and electromagnetic interactions of ordinary particles. The existence of such $y$-interactions, not acting on the ordinary matter, may lead as a result of the cosmological evolution to the formation by the $y$-matter of compact astronomical objects ($y$-stars and $y$-planets) which may be discovered only by their gravitational effect on the ordinary matter.

Oscillations of celestial bodies might be an example of $y$-matter manifestations. Unlike the Okun's (1980) suggestion to search for terrestrial oscillations, we draw attention to the solar pulsations with the period 160 min. According to Severny *et al.* (1979) the parameters of these pulsations are: the period $P = 160^{\mathrm{m}}.010 \pm 0^{\mathrm{m}}.004$, the velocity amplitude 0.5–1 m s$^{-1}$.

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In the approximation of hydrostatic adiabatic tide (Zahn, 1966) the body of the mass $m$ at the depth $h$ under the surface of the star of mass $M$ and radius $R$ displaces the surface for the distance of order

$$\Delta R \simeq \frac{R}{h} \frac{m}{M} R . \tag{1}$$

The estimate (1) is valid if $h/R \ll 1$, but $h^2/R^2 \gg m/M$. The velocity amplitude 1 m $s^{-1}$ corresponds to the total displacement of the surface $\Delta R$ (the double amplitude) of about 3 km. Substituting $h = 2 \times 10^4$ km, $R = R_\odot$, $M = M_\odot$ into (1) we obtain $m = 10^{-7} M_\odot$. This estimate is not very reliable. If we take into account that the observed $\Delta R$ may be underestimated because of the averaging over the large area of the solar disk $\sim \pi R^2/2$ (and in Equation (1) $\Delta R$ corresponds to the area of order $\pi h^2$), then $m$ may increase substantially. On the other hand, the estimate of $m$ may strongly decrease due to the resonance with a solar $g$-mode, so we prefer to use the value $m = 10^{-7} M_\odot = 2 \times 10^{26}$ g (the exact value is necessary for the model with a black hole, in the case of the $y$-planet the crude estimate is sufficient).

According to the standard solar model (Allen, 1977) at the depth $h = 2 \times 10^4$ km the density $\rho = 2 \times 10^{-4}$ g $cm^{-3}$, the temperature $\simeq 10^5$ K, so the sound speed is $v_s = 3 \times 10^6$ cm $s^{-1}$. The velocity of the body is $v = 4.4 \times 10^7$ cm $s^{-1}$, i.e. the accretion is supersonic. For $m = 10^{-7} M_\odot$ we find the accretion radius

$$R_A = 2Gm/v^2 \simeq 10^4 \text{ cm} . \tag{2}$$

By the standard formula for the accretion rate we obtain

$$\dot{m} = \pi R_A^2 \rho v = 10^{12} \text{ g s}^{-1} . \tag{3}$$

Such an accretion rate onto the black hole with account for the magnetic field results in the energy release (Shvartsman, 1971; Bisnovatyi-Kogan and Ruzmaikin, 1974) of order $0.1\dot{m}c^2 \simeq 10^{32}$ erg $s^{-1}$. This is comparable to the solar luminosity and so absolutely unacceptable. The account for the radiation pressure decreases the luminosity of the hole down to the Eddington limit $\simeq 10^{31}$ erg $s^{-1}$ – being unacceptable either, so black hole must excite the oscillations by its thermal effect and not by gravity.

Accretion onto $y$-planet differs substantially from the accretion onto a black hole. If radius of $y$-planet, $r > R_A$, then the solar matter is not captured by the $y$-planet. If $r \sim 10^8$ cm, as it is in the case of ordinary planets, i.e. $r/R_A \gg v/v_s$, the velocity perturbations of the infalling gas $\Delta v$ turn to be everywhere less than $v_s$: $\Delta v \lesssim vR_A/r$. It means that if the accretion shock wave is formed, then the shock is weak and maximum heating of the matter is low, being of order $\dot{m}(\Delta v)^3/v_s$, where in contrast to Equation (3) $\dot{m} \sim \pi r^2 \rho v$ is the mass perturbed (but not captured!) by the $y$-planet in unit time. So the heating is less than $10^{24}$ erg $s^{-1}$. Thus the $y$-planet induces inside the Sun only gravitational and weak acoustic effects. The same is true even if our evaluation of $m$ is underestimated by orders of magnitude (it is surely true if $m$ is overestimated). The mass $m$ must not be too large. 'Spreading' $m$ along the ring of radius $R_\odot - h \simeq R_\odot$ (which is reasonable since $P = 160^{\text{m}} = \frac{1}{9}$ day $\ll$ 88 days $= P_{♀}$ – the period of Mercurian revolution) we obtain the perturbation of the perihelion precession of the Mercury (Landau and Lifshitz, 1965) per one revolution

$$\delta\varphi = \frac{6\pi m R_{\odot}^2}{4\,M_{\odot} d_{♀}^2}, \tag{4}$$

where $d_{♀}$ is the mean distance of the Mercury from the Sun. For $m = 10^{-7} M_{\odot}$ Equation (4) gives the precession of the perihelion of Mercury $\sim 0\overset{''}{.}02$ per century. However, if $m$ is higher by 2–3 orders of magnitude then the value of $\delta\varphi$ will contradict the predictions of general relativity. Besides that the oscillations of the whole figure of the Sun will be large, since the centre of mass of the system is to be at rest.

Leaving aside the question of origin of the $y$-planet inside the Sun, we note that the value $m = 10^{26}$ g corresponds to 1–10% of the amount of $y$-matter which might be accreted by the Sun during its lifetime if the parameters of the interstellar $y$-matter in the Galaxy are the same as for ordinary matter.

The presence of a body inside the Sun may be in principle discovered by its gravitational effect on the solar probe approaching the Sun for a distance of few $R_{\odot}$. For the test of this opportunity the delaited analysis is needed of possible noncircular (and non-elleptic!) orbits inside the Sun.

Summarizing we conclude that the presence of the $y$-matter inside the Sun seems now not excluded. More serious consideration of the $y$-planet inside the Sun (e.g. the problems of its formation and evolution due to the tidal friction) would be necessary if the existence of 160 min oscillations becomes generally accepted, if phase of the oscillations and their period are stable, and if alternative theoretical models fail to explain this phenomenon.

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