RECEPTION OF GRAVITATIONAL RADIATION OF EXTRATERRESTRIAL ORIGIN

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Recently Weber [1, 2], using a system of quadrupole gravitational antennas, recorded signals that might, in his opinion, be due to gravitational radiation of cosmic origin. The level of the signals, which followed each other at a frequency of about 5 a month [2], was several times higher than the noise-power level. The approximate equivalent parameters of the receiving mass quadrupole were: mass 4×10^5 g, length $\ell \approx 10^2$ cm, frequency $\omega_0 = 10^4$ rad/sec,

$Q = 10^5$.

In connection with this experiment, we wish to make the following remarks:

1. Knowledge of the "signal/noise" ratio of the receiver of [1, 2] (if the noise is thermal) makes it possible to estimate the energy of the gravitational wave under various assumptions concerning the structure of the radiation.

If the antenna is excited by a gravitational wave in the form of a resonant train of approximate duration 1 - 2 sec, the response of the receiver at the noise level requires a gravitational energy $F \sim 10^6$ erg/sec-cm^2.[1)] In the case of a single nonperiodic pulse (frontal collision of two bodies) of duration $\tau \sim 1/\omega \sim 10^{-4}$ sec the required flux is $t \sim 3 \times 10^{13}$ erg/sec-cm^2, the energy transported by the entire radiation being $\sim 3 \times 10^9$ erg/cm^2. Finally, a quasiperiodic pulse with variable frequency is possible, corresponding to the radiation of binary systems as they revolve in their orbit. When $d\omega/dt \sim 10^6$ rad/sec the estimated required flux (at the instant when $\omega = 10^4$ rad/sec) turns out to be $F \sim 3 \times 10^{11}$ erg/sec-cm^2 (this quantity is proportional to $(d\omega/dt)^{-1/2}$).

Assuming further that the radiation comes from the center of the galaxy ($R \approx 8200$ psec $= 2.5 \times 10^{22}$ cm), let us estimate the absolute power of the sources.

For a pulsed source, the energy yield after $\tau \sim 10^{-4}$ sec amounts to $\sim 4\pi R^2 F \approx 3 \times 10^{55}$ erg; collision of two bodies with reasonable dimensions $M = 10M_{\odot}$ and a gravitational radius $R_g \approx 3 \times 10^6$ cm can ensure only [3] an energy equal to $0.02M_{\odot} c^2 \approx 3 \times 10^{53}$ erg ($\tau \sim r_g/c \approx 10^{-4}$ sec), i.e., short by two orders of magnitude.

A quasiperiodic source should have a power $\sim 2 \times 10^{57}$ erg/sec. Passage through the required frequency $\omega = 10^4$ rad/sec can be ensured by two bodies with $M \approx M_{\odot}$ on a circular orbit with dimension $a \approx 2 \times 10^6$ cm, but the radiation power in this case, $\sim 10^{55}$ erg/sec, again is too low by two orders of magnitude. Finally, a sinusoidal train calls for $\sim 10^{52}$ erg/sec. According to Thorne [4], this is precisely the order of magnitude of the power radiated in the case of non-radial oscillations of a neutron star with frequency 10^3 Hz in $\sim 1 - 2$ sec.

The level of the signals in [1, 2], and the frequency of the events, about 60 per year [2], are ensured by a galaxy-core lifetime ($M \approx 5 \times 10^9\ M_{\odot}$) of $\sim (10^7 - 10^6)$ years relative to loss by gravitational radiation (see also [10]).

2. The hypothesis that the radiation comes from the center of the galaxy can be verified by measuring the dependence of the signal intensity on the receiver orientation, characterized by the angle ϕ between the meridian and the direction to the galactic center: $\phi = \pi(t - t_c)/12$, where t is the sidereal time and $t_c = 17^h40'$. The reception efficiency will be determined by a certain number ψ varying with sidereal time:

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1) A short-duration radiation source is more conveniently characterized by the spectral density of the time-integrated flux H_ω (erg/Hz·cm^2). For a pulsar at the center of the galaxy $H_\omega \approx 500$ (erg/Hz·cm^2) (calculated at the suggestion of N. S. Kardashev, see also [9]), and for a double star $H_\omega \approx 1500(M/M_{\odot})^{5/3}$ (erg/Hz·cm^2). If, purely theoretically, we represent the bursts observed by Weber as the result of an in-phase addition of a noise $\sim\beta kT$ and a signal $(\alpha - \beta)kT$, where $(\alpha - \beta) << \beta$, then the estimate of the required H_ω is decreased by a factor $(\alpha - \beta)^2/\beta$. For example, $H_\omega \approx 2 \times 10^4$ erg/Hz·cm^2 when $\alpha = 2.5$ and $\beta = 2$, but the probability of registering a signal by this method is low.

$$\psi \cong \frac{25}{64}\left(1 + \frac{3}{5}\cos 2\phi\right)^2 = \frac{5}{128}\left(1 + \frac{60}{59}\cos 2\phi + \frac{9}{59}\cos 4\phi\right)$$

for unpolarized radiation; for two independent polarizations of a plane gravitational wave:

$$\psi_1 = \frac{43}{128}\left(1 + \frac{60}{43}\cos 2\phi + \frac{25}{43}\cos 4\phi\right),$$

$$\psi_2 = \frac{1}{8}(1 - \cos 4\phi)$$

in accordance with Weber's formulas [8] (in the calculation, account was taken of the known angle of inclination of the galactic center, $\sim 30°$). A formal Fourier analysis of Weber's data [8] yields small (~ 0.04) Fourier amplitudes at $\cos 2\phi$ and $\cos 4\phi$, not exceeding the Fourier amplitudes at the odd harmonics; the amplitudes should be of the order of unity for a source at the center of the galaxy. In spite of the incorrectness of such an analysis, owing to the incompleteness of the statistics [8], in our opinion, the hypothetical radiation from the galactic center is not confirmed.

3. The choice between the hypothesis that the radiation is produced by the revolution along the orbit and the hypothesis that it is due to oscillations can be based on the dependence of the frequency on the time.

During revolution along the orbit, the frequency increases (and the power increases at the same time). Two receivers with frequencies differing by a factor of two, $\omega_1 = 6 \times 10^3$ and $\omega_2 = 1.2 \times 10^4$ rad/sec, produce pulses shifted by $(\omega_2 - \omega_1)/(d\omega/dt) \sim (0.6 - 0.006)$ sec (if $d\omega/dt \sim 10^4 - 10^6$). In the case of oscillations, the frequency is constant in the first approximation. The nonlinear effects and the influence of the cooling of the star do not exceed 10 - 20%. Finally, for pulsars (the observation of modern pulsars will be discussed later), the frequency decreases with time.

4. It should apparently be admitted that the feasibility of Weber's receivers, in the sense of the attainable sensitivity, have been fully utilized (under conditions when the relaxation time does not exceed the measurement time). We wish to emphasize, however, that the considered receiver is a converting pickup, the capabilities of which are lower, in principle, than those of a modulating pickup [5].

Let us point out a variant of a gravitation-radiation receiver of the modulator type.

Let two mass quadrupoles (two dumbbells) crossed at an angle of 90° and having a common center rotate in one direction at a frequency half as large as the frequency of the gravitational wave incident normally to the quadrupole plane. At suitable phase relationships, the wave will accelerate one of the quadrupoles and decelerate the other, so that the quadrupole masses will come closer together (move farther apart). The deviation of the rotation frequency from the wave frequency will produce beats. According to Shklovskii's estimates [6] a pulsar in the Crab nebula should produce on earth a gravitation-radiation flux $\sim 10^{-6}$ erg/sec-cm^2. Under the influence of this flux, two dumbbells with dimensions 0.5 m, whose rotation frequency deviates by $\Delta f \sim 10^{-3}$ Hz from the pulsar radiation frequency, will experience beats with amplitude $\sim 10^{-12}$ cm - a perfectly recordable quantity. Thus, the recorded flux can be lower by 10 orders of magnitude than the sensitivity of Weber's receivers (but at another frequency, 30 Hz).

5. We note in conclusion that a possible source of the signals in the experiments of [1, 2] is the action of dynamic gravitational fields in the induction zone. If it is assumed that the simultaneous local change of g for the two detectors is due to a resonant acoustic wave, then the level of the signals received in [2] will correspond already to $\Delta g/g \sim 10^{-12}$ (at a gradient $\partial g/\partial \ell \sim 10^{-11}$ sec^{-2}). Usual gravimeters (including the control gravimeter [7] used in the experiments of [12]) are not very effective at frequencies higher than ~1 Hz.

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