Interpretation of the quasi-periodic intensity variations of the hard atmospheric γ radiation

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The observed quasi-periodic intensity variations of the hard, atmospheric γ radiation with an amplitude of $\sim 10\%$ can be explained by the air-density fluctuations caused by internal gravity waves in the stratosphere. It is shown that the vertical intensity is most sensitive to variations with a period of about 5 min.

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The discovery of short-period intensity variations of the hard γ radiation in the upper layers of the atmosphere has been reported earlier.[1] An analysis of a large volume of data obtained in a series of a balloon flights at altitudes of 30 to 40 km (4–10 g/cm^2 residual atmosphere) showed that the dominant variations in the spectrum are those with a period of about 5 min.[2] A similarity between the numerical values of a number of identified periods, especially the five-minute one, and the periods of solar-surface fluctuations served as the basis for a tempting assumption of the existence of an efficient but still unknown mechanism for the transport of solar fluctuations to the earth. However, as will be shown in this paper, the obtained experimental results can be accounted for in terms of the present-day concepts of the wave-like motion of air masses.

The internal gravity waves or buoyancy waves (we shall call them IGW) in the atmosphere, which manifest themselves as periodic fluctuations of the atmospheric parameters, in particular, density and strength and direction of wind and which are observable near the earth's surface and in the upper atmosphere, are known.[3] The relative oscillation amplitude is inversely proportional to the square root of the density and the IGW frequency ω at a given altitude is always lower than the so-called Väisälä-Brunt (VB) frequency ω_v. The VB period is equal to 4.8 min at altitudes of 30 to 40 km in the midlatitudes and it is equal to 4.5 min in the tropics. The IGW with wavelengths $\lambda \ll 100$ km are plane transverse waves,[4] which can be described by the approximate expression

$$\omega = \omega_v \cos \alpha \tag{1}$$

where α is the inclination angle of the phase plane with respect to the vertical plane.

At balloon altitudes the predominant number of recorded hard γ rays is produced in the decay of neutral pions that appear in the first event of the intraction of the nuclear component of the primary radiation with the air; therefore, the intensity I_γ of γ radiation in each given direction is proprotional to the corresponding thickness t of the residual atmosphere. The IGW induced periodic variation of the air density should lead to fluctuations of t and hence I_γ, which is maximum in the direction of the phase

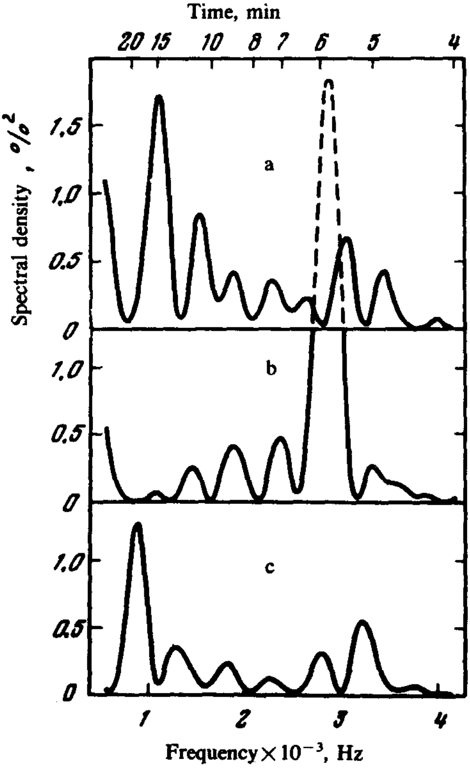

FIG. 1a–1c. Frequency spectra of pressure variations at 31-km altitude for three successive hours, obtained from the data of a barograph on board a high-altitude balloon. The spectral density, expressed in units of the square of the relative amplitude, is plotted along the Y axis.

plane. Since the altitude dependence $\epsilon_\rho(h)\approx\rho^{-1/2}(h)$ is valid for the relative density fluctuations,[3] we can show that if the measurements are performed at an altitude $h = h_0$, then

$$\frac{\Delta I_\gamma}{I_\gamma} = \frac{\Delta t}{t} \approx 2\epsilon_\rho(h_0).$$

If the vertical intensity of γ radiation is measured (the axis of the γ-telescope is pointed pointed at the zenith), according to Eq. (1), the IGW with periods of about 5 min will produce the largest effect, all other things being equal. According to the measurement data for the wavy structures in noctilucent clouds, the wavelengths $\lambda = 10$–20 km are the most typical for IGW, that propagate in the direction close to the horizontal.[5] For such IGW the region, which is isolated by the aperture cone of a γ-telescope with an angular opening $\lesssim 40°$ and which contains the effective thickness of the residual atmosphere, does not exceed a half wavelength.

At present, the limited observational data for IGW in the stratosphere do not shed much light on the nature of the frequency spectrum, characteristic amplitudes and conditions for the formation of IGW. In one balloon flight we measured the pressure for a period of 7 hours at an altitude of about 31 km by using a sensor with an error or $\pm 8\times10^{-3}$ mbar. The pattern of pressure variations was found to be extremely complicated and variable. A spherical analysis of the data was run after each hour of flight (the low-frequency trend was removed beforehand). Although each spectrum had its own individual set of pronounced peaks, their location and amplitude, on the whole, changed almost continuously with time. The selected power spectra for three successive hours are shown in Figs. 1a–1c.

We emphasize that the pressure fluctuations recorded by a barograph reflect a displacement of the balloon because of the effect on it of the vertical wind component of the due to the IGW, and their amplitude is small, whereas the intensity variations of γ radiation are caused by stronger density fluctuations.

The modulation effects due to IGW can also appear in the secondary charge component of the cosmic rays in the stratosphere, as noted in Ref. 6, but they are considerably weaker because of the equalizing effect of the earth's magnetic field; in this case the directivity of the detectors is also important. The results of Gehrels and L'Heureux,[7] who noticed that the fluctuation power spectrum of the counter telescope is three times higher than that of a single detector, can be interpreted in this context.

Thus, the quasi-periodic intensity variations of the hard, atmospheric γ radiation with an amplitude of $\sim 10\%$ are most likely due to internal gravity waves in the stratosphere. This is important for γ-astronomy observations in which the rapid anisotropic variations of the atmospheric background must be taken into account. In addition, this IGW effect may prove to be important in evaluating the results of measurements of the secondary cosmic-ray components at sea level[8] and astronomical observations in which allowance for the atmospheric transmittance is important.[9]

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