A. B. Severnyi, V. A. Kotov, and T. T. Tsap. *Investigation of the sun's pulsations and the problem of its internal structure.* Attempts to detect neutrinos from the sun and its global oscillations represent two new trends in the experimental study of the sun's internal structure and energy sources. The studies of H. Hill *et al.*[1] (USA) marked the beginning of research in the field of helioseismology; observing the trembling of the edge of the sun's disk, they observed a whole spectrum of oscillations with periods from 7^m to 70^m. At the same time, in 1974, the sun's pulsations came under study in the Crimea, where the work was based on the Doppler shift of the absorption lines in its spectrum. The work was done with a solar magnetograph and a differential technique: the position of a spectral line from a central zone ($\sim R_\odot$ across) of the disk is measured with respect to the average position from the limb zone of the disc. The sensitivity of such measurements is ~1 m/sec.

The average period of the oscillations according to data from the first 76 hours of observations in 1974 was[2] $2^h40^m \pm 0^m.5$, and the amplitude was about 2 m/sec. It is remarkable that Birmingham physicists[3] observed a similar effect with the same period ($2^h39^m \pm 3^m$) and an amplitude of ≈3 m/sec almost simultaneously by another method; the phases of maximum velocity practically coincided in both measurements.

The 160^m period is close to the period of the pulsations of an almost homogeneous sphere with the sun's M and R (167^m). However, the conclusion of homogeneity would imply a radical departure of the sun model from existing versions, although it would result in a negligible neutrino yield; the luminosity would have been smaller than the observed value by a factor of 10^5. Further, strong Rayleigh-Taylor convective instability should appear in this model.

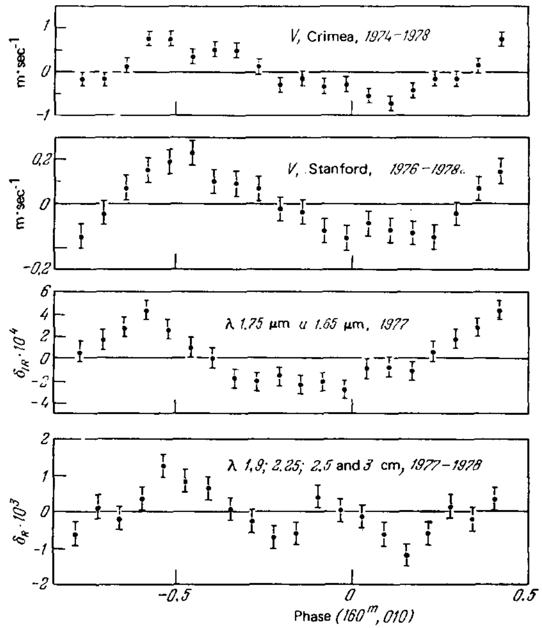

FIG. 1. Average curves of differential ("center-to-limb") velocity (V) of the sun from observations in the Crimea and at Stanford (top), and average brightness curves in the infrared (λ 1.75 and 1.65 μm) and centimeter radio bands (λ 1.9, 2.25, and 3.5) for the pulsation period $160^m.010$. Zero phase corresponds to 00 UT on July 15.

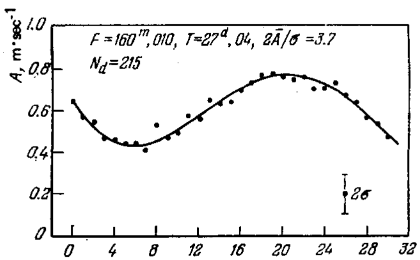

FIG. 2. Amplitude (A) of pulsations with period $160^m.010$ vs. phase of sun's rotation with period $T=27^d.04$. Measurements on $N_d=215$ observing days in 1974–1978 were used. The significance of the wave $2\bar{A}/\sigma=3.7$; the horizontal coordinate is the rotation phase (in days), and the curve was drawn through the points "by hand." The "resolution" in the rotation phase is $\approx 0.5\ T$.

At the same time Christensen-Dalsgaard and Gough[4] pointed the way out of the difficulty; the model adopted with an abundance of heavy elements $Z=0.04$ can be reconciled with observations if the oscillations are of the gravitational quadrupole type.

Analysis of measurements made over five years, from 1974 through 1978 (for a total of more than a thousand observing hours on 215 days) showed that the best value of the period is $P=160^m.010\pm 0^m.004$. Similar measurements that have been underway at Stanford, California[5] since 1976 yielded the same value of P, and the maximum-velocity phases agreed to within 15^m (Fig. 1). Further, the recent measurements of Snider *et al.*[6], who used resonance spectroscopy, also confirmed the existence of pulsations with a 160^m period. Synchronously with the velocity oscillations, there are changes in the brightness and total magnetic field of the sun[7] and in its radio emission (see paper by V. A. Kotov and S. Kuchmi below).

The final argument in support of the idea that we are observing an effect of definite solar origin is found in the dependence of the pulsation amplitude on the phase in the 27-day rotation of the sun[8] (Fig. 2). This dependence may suggest a quadrupole oscillation in which an antinode (node) appears to "run" across the surface with a period close to the period of rotation (the effect discussed by Zharkov and Vorontsov[9]).

It was observed later that the oscillations practically vanish at certain times but then resume with nearly the same phase. It is therefore possible[10] that the sun is a system with a low "figure of merit" Q in which oscillations are damped out rapidly due to turbulence in the photosphere. Another possibility is splitting of the oscillation modes due to the rotation, which would result in beats and modulation of the oscillation amplitude if several modes are present.

The presence of global (g-mode-type) long-period oscillations, which should involve interior layers of the sun, indicates the possibility of an additional agency for thermal dissipation of energy from the sun via wave motions, which may make it easier to solve the problem of the low neutrino flux. It is also important to note the significant asymmetry of the velocity curve (see Fig. 1), which probably suggests a nonlinearity in the 160^m oscillation arising in the uppermost atmosphere of the sun. However, the answer is not definite, and no natural explanation for the observed oscillations has as yet been found within the framework of the contemporary solar-structure model.

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