SOLAR PULSATIONS

A.B. Severny, V.A. Kotov, T.T. Tsap
Crimean Astrophysical Observatory,
P.O. Nauchny, Crimea 334413, USSR

Oscillations of the Sun with the period of $160^m$ first observed in Crimea in 1974 and described in a set of papers by Kotov, Severny and Tsap (Severny et al. 1976, 1978; Kotov et al. 1978) were observed also by Brookes et al. (1976) and have been afterwards observed during the last three years in Stanford (Scherrer et al. 1979) and Kitt Peak (Snider et al. 1978). This fact excludes possible instrumental origin of the effect. Moreover, the phase coherence (after elimination of integer number of $160^m$-periods) between these four observatories makes the assumption of Earth atmospheric origin of the oscillations (Fossat and Grec 1978) very unlikely. Besides that, (1) the dependence of amplitude of oscillations on the phase of solar rotation and (2) slow, synchronous (at Crimea and Stanford) drift of the phase of maximum from year to year, pointing to a true period slightly higher $160^m$ ($160^m0.1$), make the "telluric hypothesis" of the effect completely inconsistent.

Figure 1 illustrates the mean for 5 years (Crimea) and for three years (Stanford) line-of-sight velocity curves (with amplitude of about 0.5 m/s) in the sense: central zone (with the size $\sim R_\odot$) minus the rest of the outer rim of the solar disk.

In Figure 2 we see the dependence of amplitude of the oscillations versus the phase of solar rotation. Figure 3 shows the yearly drift of phase of the velocity maximum according to our (C) and Stanford (S) observations. The regression line on this graph leads to the period $P = 160^m.010$.

This period is too long for purely radial pulsations of a standard model adopted at the present time. It would be in good agreement with the period of such pulsations for an almost homogeneous sphere (polytrope $n \approx 0.5$), but such a model would not produce the observed luminosity and would possess Rayleigh-Taylor instability. It is well known, as was pointed out by Cowling, that quadrupole oscillation described by spherical harmonics $\ell = 2$ in the case of a fluid sphere has a period $186^m$. Christensen-Dalsgaard, Dilke and Gough showed that



*Patrick A. Wayman (ed.), Highlights of Astronomy, Vol. 5, 453–456.*

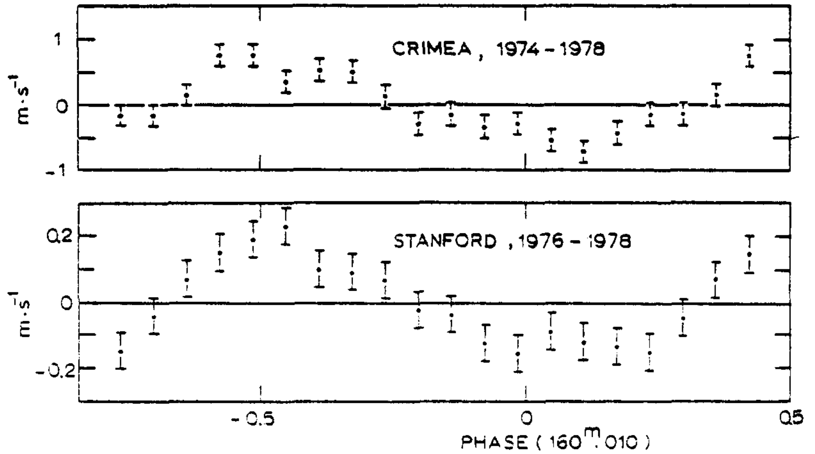


Figure 1. The velocity oscillations curves according to Crimean and Stanford observations. The optimal period P = $160^m.010$, zero phase is taken at $00^h$ UT, July 15, 1978.

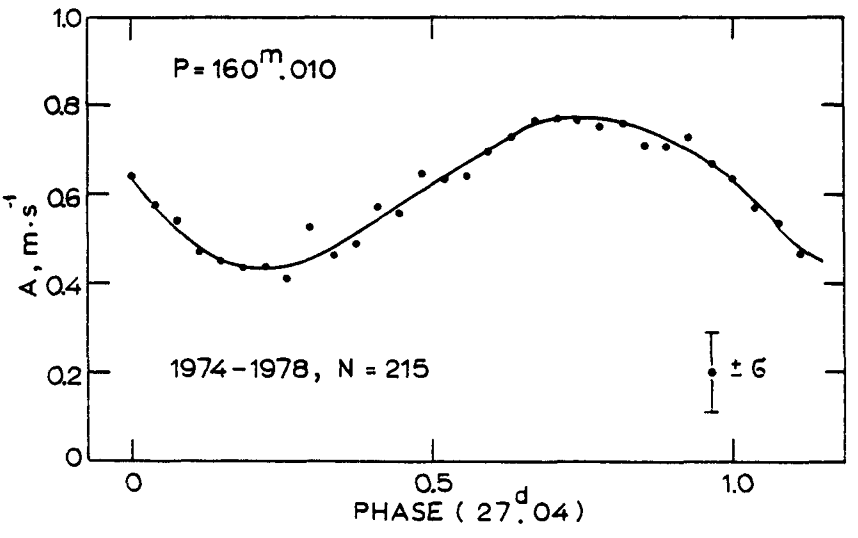


Figure 2. The amplitude (A) of $160^m.010$ oscillations vs the phase of solar rotation (27.04 days period). N = 215 is the number of days with the observations in 1974-1978 years. Zero phase is taken at $00^h$ UT, August 11, 1974; resolution is ≈ 14 days.

the period of about $2^h$ can appear for $\ell = 1$ harmonic of the first gravity g -mode of the Sun at some stage of its evolution (after $2.10^8$ years from zero age); this mode becomes unstable (due to inhomogenity of He in energy generating core). Later it was found (Christensen-Dalsgaard and Gough 1976) that the higher g -modes (e.g. g = 9) having the period $159^m$ can also arise for a standard solar model if one assumes Z = 0.04. Higher Z is in accordance with observed data for metal rich open cluster stars of the disk population. However, a standard model with high Z seems to be not compatible with low neutrino flux.

Moreover the interpretation is not unique while $\ell$ is not known from observations (different $\ell$ may have the same period). But the observed dependence of an amplitude on the phase of solar rotation (Figure 2) shows that we can interpret this effect as due to rotational splitting of $S_1^m$ mode at $\ell = 2$. The Coriolis force effect leads to one wave running in the direction of rotation and the other - in the opposite direction; superposition of these two waves produce the stationary knot slowly running with the period of revolution close to to the solar rotation period, if one makes some definite assumption about the solar model. (This effect however disappears when the axis of rotation coincides with that of the symmetry of oscillation. The problem of an inclination of these two axes is now being considered, and we hope this will help to avoid an ambiguity in the choice of the solar model).

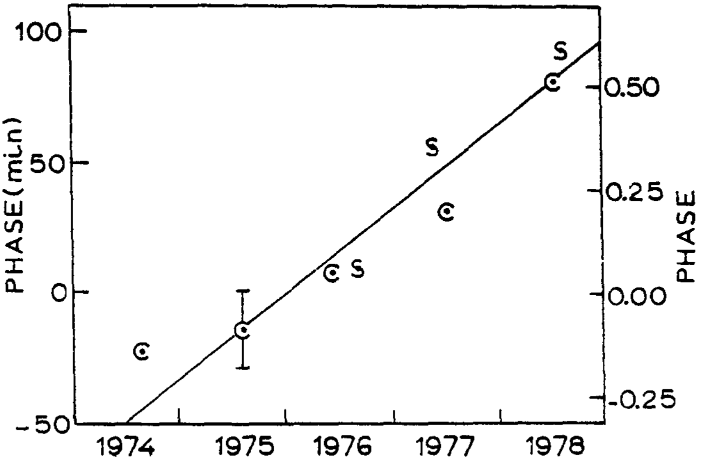


Figure 3. Time of maximum expansion in minutes from $00^h$ UT for Stanford (S) and Crimean (C) observations. The error bar shows typical uncertainty in phase.

https://doi.org/10.1017/S1539299600004226 Published online by Cambridge University Press

In conclusion, we wish to point out the following interesting features of the oscillations:

1. Sometimes the $160^{m}$ oscillations disappear or almost disappear (in May - June 1976, etc.) and reappear again with nearly the same phase. It means that the oscillations look like high-Q oscillations (as was pointed out by the Birmingham group).

2. The oscillations can offer the possibility of energy transport different from a radiative one, especially if we take into account that at higher modes and high amplitudes near the center of a star the Reynolds stresses at such wave motions might be very large.

REFERENCES

Brookes, J.R., Isaak, G.R. and van der Raay, H.B., 1976. Nature, 259, 92.
Christensen-Dalsgaard, J. and Gough, D.O., 1976. Nature, 259, 89.
Fossat, E. and Grec, G., 1978. in Proc. 2nd European Meeting on Solar Physics, "Pleins Feux sur la Physique Solaire", Toulouse; 151.
Kotov, V.A., Severny, A.B. and Tsap, T.T., 1978. Mon. Not. Roy. Astron. Soc., 183, 61.
Scherrer, P.H., Wilcox, J.M., Kotov V.A., Severny, A.B. and Tsap, T.T., 1979. Nature, 277, 635.
Severny, A.B., Kotov, V.A. and Tsap, T.T., 1976. Nature, 259, 87.
Severny, A.B., Kotov, V.A. and Tsap, T.T., 1978. in Proc. 2nd European Meeting on Solar Physics, "Pleins Feux sur la Physique Solaire", Toulouse; 123.
Snider, J.L., Kearns, M.D. and Tinker, P.A., 1978. Nature, 275, 730.