Solar 5-min Oscillation Amplitude Anisotropy and Doppler Velocity Systematics

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Several measurements of 5-min velocity amplitudes have yielded confusing and conflicting information on the l and m dependence of the modal excitation (Kuhn and O'hanlon, 1983 – henceforth KO; Deubner, 1985; and Hill et al. 1985). We have obtained considerably more data than was described in KO using similar observing techniques. Additional analysis has illuminated a systematic effect related to the finite spatial resolution, and line asymmetry of the data that can lead to errors in inferred velocity amplitudes. Even though Doppler shifts are calculated from the Fraunhofer line center positions the effect can lead to 5-min oscillation amplitude errors at the 10 percent or greater level. Line wing observations should be more susceptible, and comparable resolution 2-dimensional data may be less sensitive to this systematic.

The apparatus described in KO was used to obtain approximately 20 hours of data from 30 May, and 20, 21 June 1984. Solar spectra along a north-south and east-west oriented slit are obtained once per minute with about 75 pixels across the solar diameter and, in wavelength, 1 pixel corresponds to 600 m/s. The data were analysed as in KO and similar results were obtained – the E-W oriented slit showed larger velocity power than the corresponding N-S slit orientation. A convenient measure of the fluctuating power is the standard deviation of the velocity in each pixel measured with respect to a 30 minute running mean of the velocity, also evaluated at each spatial pixel. Figure 1 shows the implied velocity

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standard deviation in m/s at each pixel along a N-S and E-W solar diameter. Several features are apparent from the figure: 1) The velocity fluctuation drops toward the solar limb, and 2) The E-W signal is larger than the N-S orientation. The first point is due to the projection of the radial velocity structure of the 5-min oscillation on the line-of-sight to the telescope. The 2nd effect we have found to be due to the asymmetric Fraunhofer line profile in combination with the different and large underlying spatial velocity gradient (due to solar rotation) between the two slit orientations. The finite spatial resolution of the observations results in an effectively broader line profile for the E-W slit data. If wavelength, λ, is measured from line center and the line profile has the form $I(\lambda) = I_0 + b\lambda^2 + d\lambda^3$ then the line minimum is not necessarily shifted by the usual 1st order Doppler shift, $\Delta\lambda_0 = \lambda_0 v/c$, where v is the source velocity. Depending on the particular form of the "Point Spread Function" (PSF) the line shift is $\Delta\lambda = \Delta\lambda_0(\alpha + \beta\Delta\lambda_0 d/b)$, where α and β are constants of order unity that depend on the PSF. Thus the broader the line, the smaller b is, and the larger the systematic. This is the case for the E-W versus N-S slit orientation and describes the difference in standard deviation seen in Figure 1. Measurements of d and b for the system described by KO indicate that the correction term can be of order 10 percent.

Two dimensional observations will be less sensitive to these effects because the velocity gradient and resolution will be more nearly the same over the entire dataset. Higher spatial resolution will also reduce the systematic but it is clear that any complete description of photospheric Doppler observations should address the problem of the lineshift-to-inferred velocity calibration, and its possible spatial variation across the solar image.

Deubner, F.-L. *Seismology of the Sun and Distant Stars* (ed. Gough, D.O.) 83 (Reidel, Dordrecht, 1986).

Hill, F., Habor, D.A., Toomre, J. and L.H. November *Seismology of the Sun and Distant Stars* (ed. Gough, D.O.) 85 (Reidel, Dordrecht, 1986).

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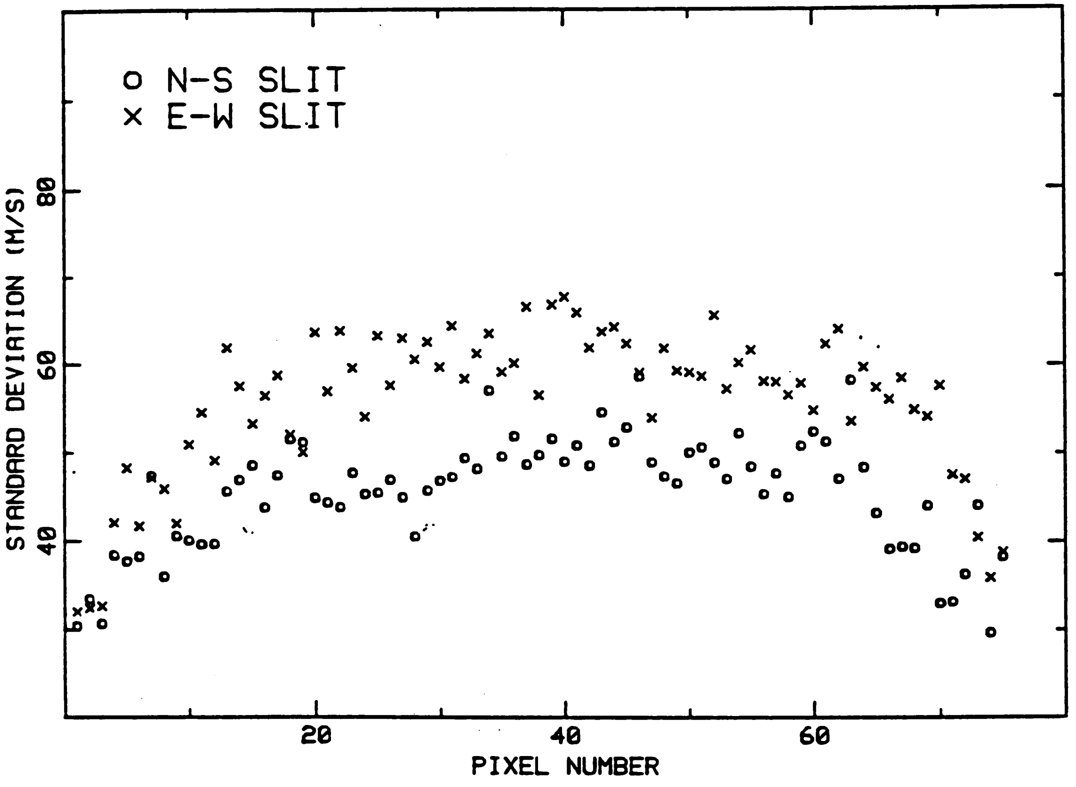

Figure 1: Limb to limb variation of velocity standard deviation by pixel number along N-S and E-W oriented spectrograph slits.