THE ASTROPHYSICAL JOURNAL, 458:L83–L85, 1996 February 20
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OBSERVATIONAL SEARCHES FOR SOLAR *g*-MODES: SOME THEORETICAL CONSIDERATIONS

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Received 1995 September 25; accepted 1995 December 12

ABSTRACT

We argue that the solar *g*-modes are unlikely to have caused the discrete peaks in the power spectrum of the solar wind flux observed by Thomson et al (1995). The lower limit to the energy of individual *g*-modes, using the amplitudes given by Thomson et al., is estimated to be at least 10^{36} ergs for low-order *g*-modes; the resulting surface velocity amplitude is at least 50 cm s^{-1}, larger than the observational upper limit (5 cm s^{-1}).

We suggest that the most likely source for the excitation of solar *g*-modes is turbulent stresses in the convection zone. The surface velocity amplitude of low-degree and low-order *g*-modes resulting from this process is estimated to be of order 10^{-2} cm s^{-1}. This amplitude is interestingly close to the detection threshold of the *SOHO* satellite. The long lifetime of *g*-modes ($\sim 10^6$ yr for low-order modes) should be helpful in detecting these small-amplitude pulsations.

Subject headings: Sun: interior — Sun: oscillations

1. INTRODUCTION

Gravity mode oscillations of the Sun are primarily confined to its radiative interior, and their observation would thus provide a wealth of information about the energy-generating region, which is poorly probed by the *p*-modes. In the past 20 years a number of different groups have claimed to detect *g*-modes in the Sun (e.g., Brookes, Isaak, & van der Raay 1976; Brown, Stebbins, & Hill 1978; Delache & Scherrer 1983; Scherrer et al. 1979; Severny, Kotou, & Tsap 1976; for a detailed review of the observations, please see the article by Pallé 1991 and references therein), but thus far there is no consensus that *g*-modes have in fact been observed. Recently, Thomson, MacLennan, & Lanzerotti (1995, hereafter TML) have reported detection of *g*-modes in the flux of high-energy particles in the solar wind. In the absence of a detailed model of how pulsation affects the solar wind flux, it is difficult to determine the velocity amplitude of the pulsation in the photosphere from the amplitude of the solar wind flux variation. We, however, use general physical arguments to make an estimate of the photospheric velocity amplitude of *g*-modes from the wind data (§ 2) that can be compared with the results of optical searches. In § 3 we provide estimates of the surface velocity amplitude, arising from excitation by turbulent convection, of *g*-modes of several different degree (l) and order (n) for comparison with this and future observations. The main results are summarized in § 4.

2. OBSERVATION OF *g*-MODES IN THE SOLAR WIND?

The dispersion relation for solar *g*-modes in the limit of $n \gg l$ is (e.g., Christensen-Dalsgaard & Berthomieu 1991)

$$P_{nl} = \frac{P_0}{2\sqrt{l(l+1)}}\,(2n + l - \delta),$$

where

$$P_0 = \frac{2\pi^2}{\displaystyle\int_0^{r_1} dr\, N_B/r} \approx 2160 \text{ s},$$

N_B is the Brunt-Väisälä frequency, r_1 is the upper turning point of the mode, and $\delta \approx 5/6$. Thus the order n of a *g*-mode of frequency 5 μHz (the low-frequency end of the observed peaks attributed to *g*-modes by TML) and degree $l = 1$, 2, and 3 is $\sim$130, $\sim$230, and $\sim$320, respectively. Thomson et al. (1995) find several groups of very closely spaced frequencies in their data, for instance, 106.768, 111.938, and 114.042 μHz (see Table 2 of TML). These can not be modes of the same l, if indeed they are *g*-modes, since the observed frequency spacing is considerably smaller than the frequency spacing expected for modes of fixed l but larger than that due to rotational splitting (high-degree *g*-modes have smaller frequency spacings, but they are unlikely to be observed because their surface velocity amplitudes are very small because of large attenuation in the convection zone). Thus, if *g*-mode amplitudes in the solar wind have a frequency dependence similar to that of Table 2 of TML, then one expects there to be $\sim$2000, $l = 1$ and 2, *g*-modes with frequencies in the observed range, which should have amplitudes of order those detected by TML. (This is a conservative estimate since TML attribute some of their peaks to modes of $l > 2$.) TML, however, detect only $\sim$40 such modes, which is a surprisingly small fraction of the total number of observable modes. Although there may be unstated reasons that other frequencies were not observed, it seems unlikely from an a priori point of view that such a small subset of frequencies should be detected.

The mean mass flux in the solar wind is $\sim 1.3 \times 10^{12}$ g s^{-1} (or $2 \times 10^{-14}\ M_\odot$ yr^{-1}), and the mean wind speed is 400 km s^{-1}. Thus, the total kinetic energy flux in the wind is $\sim 10^{27}$ ergs s^{-1}; most of this energy is carried by the thermal particles, while

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