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Atmospheric Gravity Waves

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Abstract. We compared a theoretical model for atmospheric gravity waves with observations of both intensity (I) and velocity (V) fluctuations of the solar photosphere. The preliminary results confirm the presence of g-waves in this part of solar atmosphere and rise new questions which deserve further investigation.

Key words. Sun: photosphere – Sun: waves

1. Introduction

We expect that g–waves can exist in the stably stratified photosphere and chromosphere, where convective overshoot is a natural mechanism to excite them. In fact, in last twenty years, observations of V–V and I–V phase differences have been used to support their presence (Deubner & Fleck 1989; Straus & Bonaccini 1997). Even so, for these *atmospheric* g–waves no model has been proposed yet that is supported by all the available observational constraints.

Ulrich (1999) studied the response of the solar atmosphere to the perturbations from convective overshoot, imposing a periodic velocity or pressure perturbation at the base of the atmosphere and calculating the driven response of the overlaying layers. He found that resonance–like response of the low solar atmosphere to steady driving due to convective overshoot occurs at fixed frequency ν and for a narrow range of the spherical degree ℓ, thus suggesting that a true resonance is present. The solution of a suitable eigenmode problem are g–waves trapped in an atmospheric cavity.

We started an observational test of this theoretical results, using the I and V power, the I–V and I–I phase differences computed by several authors from simultaneous I and V fluctuations at various atmospheric levels. The original data were obtained with the instruments MDI/SOHO, GONG and TRACE.

2. Results

Preliminary results of this work indicate that:

– The location of the theoretical g–mode ridge in the ℓ–ν diagram, as computed by Ulrich (1999), corresponds to a clear bulge in the observed gain, that is the

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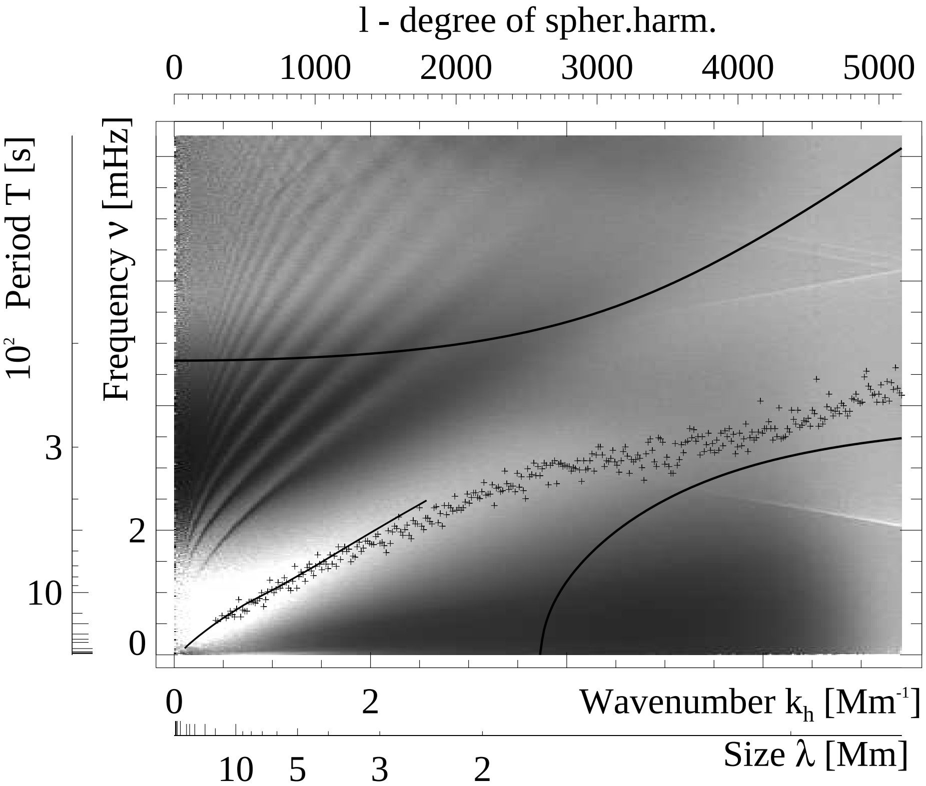

Fig. 1. The ℓ–ν diagram for the gain, i.e. the square root of the ratio between the I and V power, based on MDI/SOHO data, with superimposed the location of the theoretical g–wave ridge (short solid line). Crosses refer to local maxima of the observed gain. Long solid lines denote the theoretical boundaries of the evanescent region.

square root of the ratio between the I and V power, inferred from the analysis of MDI/SOHO data performed by Straus et al. (1999) (Figure 1).

– The observed I–V phases in this location are in agreement with the phases calculated for the trapped g–waves with the theoretical model (Figure 2). Note that the right panel of this figure shows that the observed coherence is high at the location of the gain maxima, which indicates that the corresponding I–V phase differences are statistically meaningful.
– The phase difference for the temperature signal computed with the model between the two atmospheric heights (above unity optical depth at 500 nm) $h_1 = 300$ km and $h_2 = 450$ km is $\phi(T(h_1) - \phi(T(h_2)) = -25°$. This value is close to the observed phase difference of about $-10°$ between two UV continua at 170nm and 160 nm, which are formed at h_1 and h_2 respectively, as reported by Krijger et al. (2001).

The last result indicates that both theoretical and observed I–I phase differences support downward phase propagation for g-waves in the high photosphere and, hence, upward energy flux.

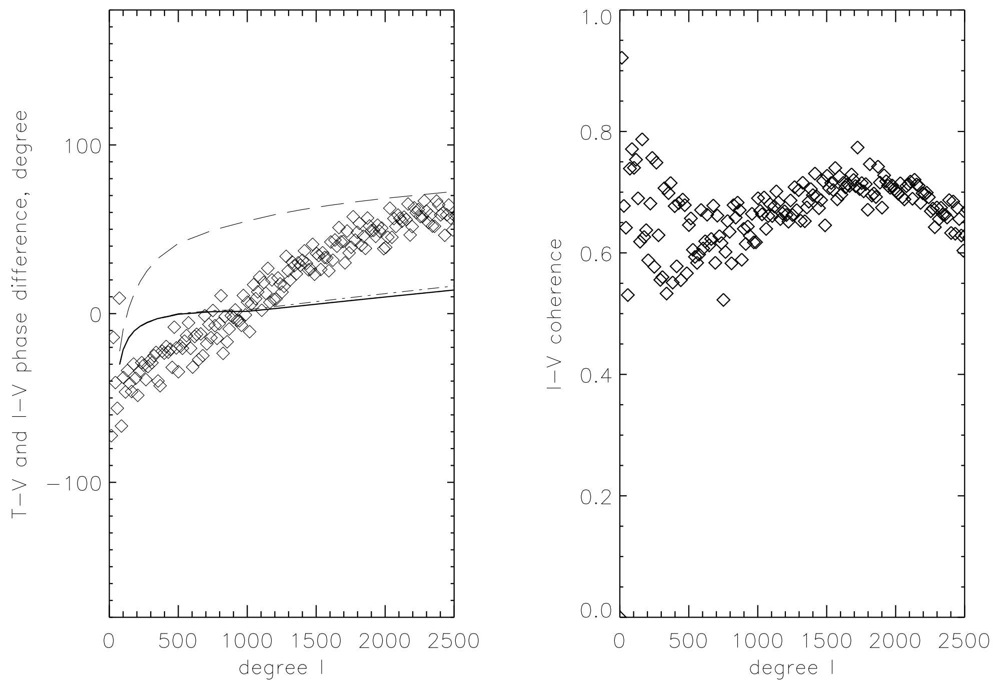

Fig. 2. Left panel compares the I–V phase differences at the location of gain maxima, based on MDI/SOHO data (*diamonds*), with the T–V phase difference computed with the trapped g–wave model at different heights (solid line refers to h=119 km, dash–dot line to h = 206 km, long dash line to h=500 km). Right panel shows the I–V coherence at the location of gain maxima, computed from the MDI data.

3. Conclusion

There is an aspect of the comparison theory–observation that is worthwhile to discuss in more detail. The model provides a dispersion relation for the atmospheric g–waves, and we found that this line corresponds rather well to the line where the observed gain (square root of the ratio of I to V power) is maximum in the diagnostic diagram. In fact, the observed gain has a broad ridge quasi-centred on the theoretical dispersion relation line. However, at the same location of the diagnostic diagram, no ridge is clearly visible in the V and I power, and, moreover, the I–V phase difference and coherence have a smooth behaviour without any feature. Observation seems to suggest that the dispersion relation for atmospheric gravity waves is not strictly defined. This may be a consequence of roughly–defined boundaries of the wave cavity, because of the inhomogeneous nature of the solar atmosphere, and, hence, to the co–existence of trapped waves with a consistent background of free waves. On the other hand, the very dispersive character of g–wave, which in presence of a broad spectrum of excitations would produce different frequency components propagating in different directions ((Leibacher & Stein

1999) may contribute to the smoothness of observations in the gravity wave part of the diagnostic diagram.

Certainly the problem of best fitting the theoretical model for g–waves to the observed V and I cross spectra deserves to be further investigated and, finally, solved, before we can afford the central question on atmospheric gravity waves, that is what is their role in the transport of energy from convective overshoot to the upper regions of solar atmosphere.

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