

To Estimate the Effect of Leaking P Modes on Solar UV Intensity – A Physical Explanation for UV Variability

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Thematic topic: environmental sciences

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INTRODUCTION

Acoustic eigenmodes (p modes) are trapped within the solar interior by the sharp decrease of the pressure scale height near the visible surface of the Sun (photosphere). This decrease in the scale height gives rise to the so-called acoustic cut-off frequency below which p modes cannot propagate into the higher solar atmosphere, i.e. the chromosphere and corona (Ulrich, 1970). In recent years several groups of researchers found that the acoustic cut-off frequency is being modified in the presence of magnetic fields, thus giving rise to p-mode power escaping the solar acoustic cavity in magnetized areas (e.g. Jefferies et al. 2006, DePontieu et al. 2004). Numerical simulations based on a one-dimensional model by Goode, Gough, and Kosovichev (Goode et al. 1992) show that the escaping p modes form shocks around 1 Mm above the photosphere as they propagate into the thinner plasma. The shock fronts dissipate heat and hence contribute to the heating of the chromosphere above magnetized areas (plage and probably sunspots, Fig. 1). In quiet sun areas only the high-frequency waves (above the normal acoustic cut-off frequency) escape and form shocks. However, these waves have a much lower amplitude and hence carry less energy than the powerful p modes. The simulations show striking coincidence of the shock-induced heating with the observed chromospheric temperature above plage regions (Fig. 2). It is therefore reasonable to assume that

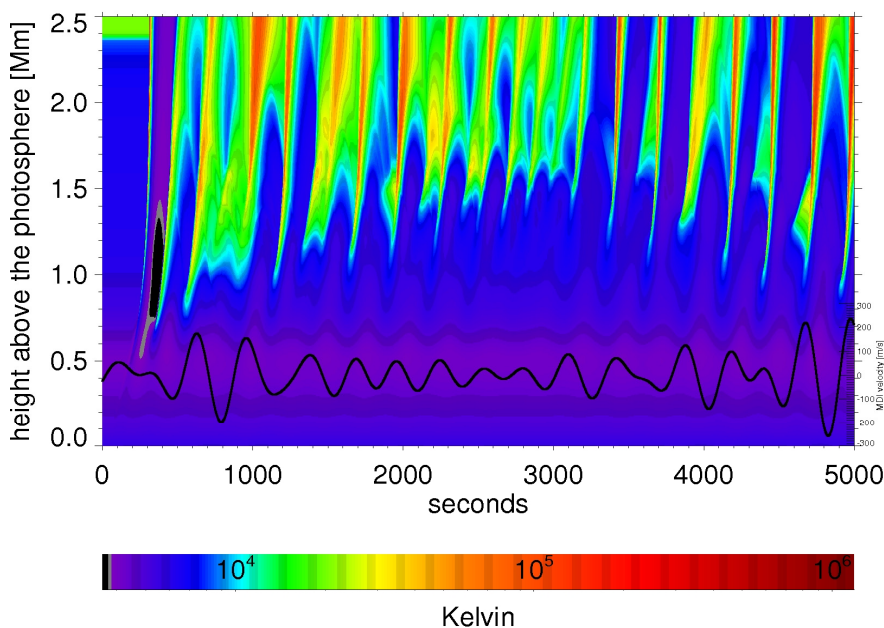


Fig. 1: Numerical simulation of the temperature in the solar atmosphere in the presence of leaking p modes. The black line is the velocity of the piston that drives the simulations at the base of the photosphere, taken from MDI measurements.

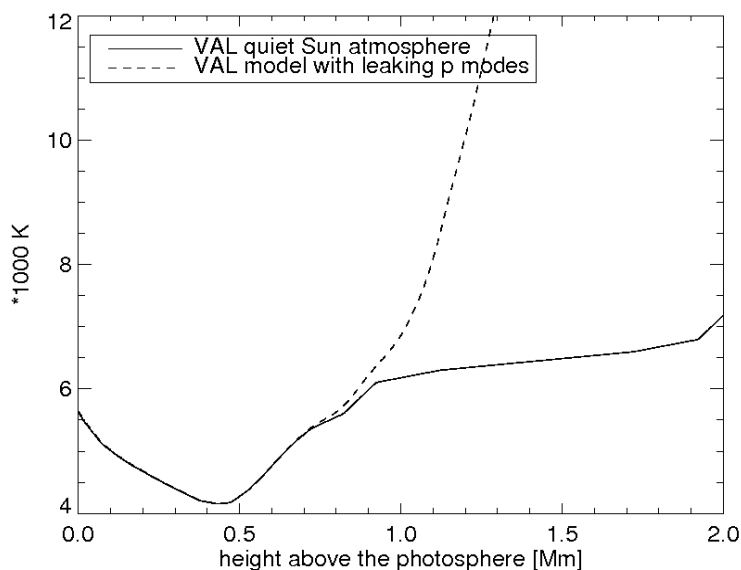


Fig. 2: Temperature profile in an undisturbed VAL model atmosphere for quiet Sun (solid line, Vernazza et al. 1981) and when leaking p modes form shocks (dashed line). The dashed line is compatible with observed chromospheric temperatures in plage regions.

the chromospheric temperature excess in plage is caused by the p-mode induced shocks. We will present first results from a project aiming at the consolidation of this theory by observational evidence.

DETECTION TECHNIQUES FOR SHOCKS

We used multi-layer simultaneous imaging from space borne and ground-based observatories such as HINODE-SOT (Ichimoto et al., 2004), SOHO-MDI (Scherrer et al., 1995) and MOTH/MOTH-II (Finsterle et al., 2004) to detect propagating waves in magnetic regions. In these observations propagating p modes can be detected by cross-correlating the oscillatory signal at different heights in the solar atmosphere. The oscillatory spectrum of these modes then can be compared to Lyman- α intensity oscillations by TRACE (Handy et al., 1999). The Lyman- α intensity is supposed to be modulated by the shock induced temperature variation in the line forming layer (Fig. 3).

COMPARISON WITH OBSERVED LYMAN-ALPHA VARIABILITY

The oscillatory spectrum of Lyman- α observations in a plage region by TRACE is shown in Fig. 3 (solid line). The TRACE spectrum was derived from a 71-minute run with one minute sampling interval. The dotted line is the oscillatory spectrum of the simulated temperature between 1.5 and 2.0 Mm above the photosphere. Both curves show a prominent peak in the 3-4 mHz area, indicating that the shock-induced temperature fluctuations could indeed be responsible for the observed Lyman- α variability. On larger time scales, the same mechanism could even cause the solar cycle related intensity changes in Lyman- α emission due to the changing surface fraction of magnetized areas on the solar disk.

RESULTS AND DISCUSSION

P-mode induced shocks modify the temperature stratification of a standard quiet Sun atmosphere to closely resemble that for a plage atmosphere (Fig. 2). Since p-modes leakage predominantly occurs in magnetic areas the described mechanism could explain why the chromosphere in plage appears hotter than in quiet Sun. We found that Lyman- α intensity oscillations in the p-mode frequency

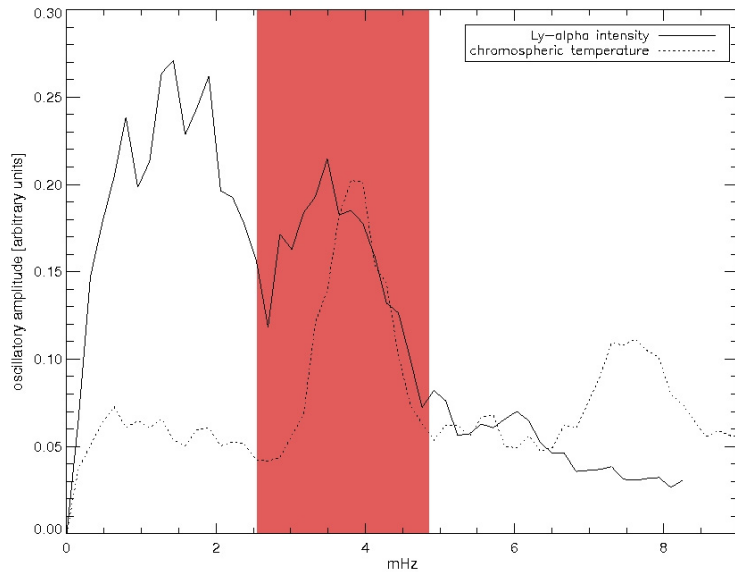


Fig. 3: The observed variability of Lyman- α intensity (TRACE, solid line) and the simulated variability of the temperature in the line-forming layer (1.5–2 Mm, dotted line). The temperature in the line-forming layer is directly affecting the intensity of the emission line. The increased power around 3–4 mHz is due to leaking p modes.

range are comparable to the simulated temperature oscillations of the chromosphere when realistic assumptions for the driving piston are extracted from observations (Fig. 3).

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