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Modelling of Solar Coronal Oscillations

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Abstract

The study of coronal oscillations is important since these oscillations could be responsible for the heating of the solar corona. Coronal structures are expected to undergo three types of oscillations - non-compressional Alfven waves and the compressional slow and fast magnetosonic waves. Since the data from the eclipse of October 24, 1995 shows intensity oscillations, these are interpreted as the slow and or fast magnetosonic modes. The corresponding values of the plasma parameters as well as an estimate of the flux in these modes is also given.

Key Words : Coronal oscillations, Slow and fast magnetosonic waves, Coronal heating

Introduction

The study of coronal oscillations is important since these oscillations could be responsible for the heating of the solar corona. These can be observed either as the intensity oscillations of a spectral line or of the continuum, or as the velocity oscillations in the Doppler profiles. The velocity oscillations without the accompaniment of intensity oscillations are interpreted as non-compressional Alfven waves, whereas the intensity oscillations accompanied by velocity oscillations are interpreted as compressional magentoacoustic waves.

Coronal structures are expected to undergo three types of oscillations - non-compressional Alfvén waves, and the compressional slow and fast magnetosonic waves. The restoring force in Alfvén oscillation is the magnetic tension whereas in the magnetosonic waves, the magnetic and kinetic pressures provide the restoring forces. It has been argued that all buoyancy effects related to gravitational forces can be neglected in the corona. The compressional modes may reveal themselves in the form of intensity oscillations through the variation of the emission measure. The Alfvénic oscillations are essentially the velocity oscillations and do not cause any density oscillations and since our data show intensity oscillations, these could only be interpreted either as the slow mode or the fast mode. From theoretical studies of the coronal oscillations (Zirker, 1995; Porter, Klimchuk, and Sturrock, 1994, and refeiences therein), one expects a wide range of periods of these oscillations.

It has been recently concluded by Porter, Klimchuk, and Sturrock (1994) that the fast magnetosonic waves have the right fluxes and dissipation rates to overcome the radiative losses.

Results and discussion

We have observed intensity oscillations with periods 56.5, 19.5, 13.5, 8.0, 6.1 and 5.3 sec. with amplitudes of 1.3, 0.3, 0.5, 0.3, 0.3 and 0.2 x 10^{-2} respectively (Singh *et al.*, 1996). In order to identify these waves, we choose canonical parameters for the quiet and active region of the Sun from Porter, Klimchuk, and Sturrock (1994). The most unknown parameter in the model is the wavelength of the oscillations. For a system to support oscillations, the size of the system must be equal or larger than the wavelength of the oscillations. In the absence of spatial resolution required to discern these oscillations, one can surmise that there are regions with sizes of the order of a wavelength and all these regions are oscillating with some degree of coherence among them giving a net oscillatory contribution to the intensity. Thus, we parametrize the wavelength λ of the oscillations as $\lambda = L/n$, where L is the size of the observed region and n can be interpreted as the number of separate smaller regions in it. For the quiet Sun, we take the electron density $n_e = 5 \times 10^8$ cm^{-3} at 1.25 solar radii, the magnetic field B = 3 G, the electron temperature $Te = 1.5 \times 10^6$ K. This gives the sound speed C_s = 143 km s^{-1} and the Alfven speed V_A = 378 km s^{-1}. Assuming that the observed oscillations are slow modes with dispersion relation $\lambda = C_sP$, where P is the period of the wave, we estimate the wavelength and the fluxes for all the observed periods and these are given in Table I. Similarly choosing the parameters of active region as $n_e = 3.0 \times 10^9$ cm^{-3}, $T_e = 2.5 \times 10^6$ K, B = 100 G, we list the results for wavelengths and fluxes for the active region in Table II. The flux is given by $F = \frac{1}{2} \zeta_0 (V_1^2 / C_s^2) C_s^3$, where ζ_0 is the mean density, and $V_1^2 / C_s^2 = \delta_1^2 / \delta_0^2$ = amplitude of intensity modulation. In this case the sound speed C_s = 185 km s^{-1} and the Alfven speed V_A = 5150 km s^{-1}.

Table 1. Slow mode in quiet Sun, C_s = 143 km s^{-1}

P(s)	$\lambda = C_sP$(cm)	δ_1^2 / δ_0^2	F(ergs cm^{-2} s^{-1})
56.5	0.8 x 10^9	1.3 x 10^{-3}	9.6 x 10^3
19.5	2.8 x 10^8	2.7 x 10^{-3}	2.0 x 10^3
13.5	1.9 x 10^8	4.8 x 10^{-3}	3.5 x 10^3
8.0	1.1 x 10^8	2.6 x 10^{-3}	1.9 x 10^3
6.1	0.9 x 10^8	3.1 x 10^{-3}	2.2 x 10^3
5.3	0.8 x 10^8	2.0 x 10^{-3}	1.5 x 10^3

Table 2. Slow mode in active regions, C_s = 185 km s^{-1}

P(s)	$\lambda = C_s P$(cm)	δ_1^2 / δ_0^2	F(ergs cm^{-2} s^{-1})
56.5	1.1×10^9	1.3×10^{-2}	5.2×10^5
19.5	3.6×10^8	2.7×10^{-3}	2.5×10^4
13.5	2.5×10^8	4.8×10^{-3}	4.5×10^4
8.0	1.5×10^8	2.6×10^{-3}	2.4×10^4
6.1	1.1×10^8	3.1×10^{-3}	1.2×10^4
5.3	1.0×10^8	2.0×10^{-3}	1.8×10^4

The identification of the observed oscillation with the fast magnetosonic waves is a little more tricky. Here we attempt to estimate the magnetic field from the observed periods. The dispersion relation for the fast modes is given as $\lambda = PV_A = L/n$. Assuming the magnetic field B to be the same for all the periods, we estimate the fluxes and the value of n and present them in Table III for the quiet Sun and Table IV for active region. The flux F in this case is given by $F = \frac{1}{2} \zeta_0 V_A^3 (V_1^2 / V_A^2)$, and $V_1^2 / V_A^2 = (\delta_1 / \delta_0)^2$ = fractional amplitude of intensity modulation.

Table 3. Fast mode in quiet Sun, for B ~ 2.4 G, V_A ~303 kms^{-1}

P(s)	$\lambda \times 10^{-9}$	n	F(ergs cm^{-2} s^{-1})
56.5	1.7	4.0	1.0×10^5
19.5	0.6	11.6	2.0×10^4
13.5	0.4	16.8	3.3×10^4
8.0	0.3	28.0	1.8×10^4
6.1	0.2	37.6	2.2×10^4
5.3	0.2	43.0	1.4×10^4

Table IV. Fast mode in active regions, for B ~ 34 G, V_A ~1754 km s^{-1}

P(s)	$\lambda \times 10^{-9}$	n	F(ergs cm^{-2} s^{-1})
56.5	10.3	0.7	
19.5	3.4	2.0	2.2×10^7
13.5	2.4	3.0	3.8×10^7
8.0	1.4	5.0	2.0×10^7
6.1	1.0	6.6	2.5×10^7
5.3	0.9	7.4	1.6×10^7

The flux for the wave with period P = 56.5s is not determined since the region under observations, i.e., a region of 1.5 arc min width cannot support even one complete oscillation. From the above estimates, it follows that fast mode in active region can provide enough flux for the heating of the corona as also concluded by Porter, Klimchuk, and Sturrock (1994).

References

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