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Seismology of magnetic flux tubes in the photosphere with MHD waves detected by Hinode

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Abstract. We have detected magneto-hydrodynamic waves propagating along magnetic flux tubes in the photosphere with the spectro-polarimeter aboard Hinode. Observed phase differences between the l.o.s. magnetic flux (ϕ_B), the l.o.s. velocity (ϕ_v), and the intensity (ϕ_I) have striking concentrations at around -90° for $\phi_B - \phi_v$ and $\phi_v - \phi_I$, and at around 180° for $\phi_I - \phi_B$. Here, for example, $\phi_B - \phi_v \sim -90^\circ$ means that the velocity leads the magnetic field by a quarter of cycle. We suggest that the observed fluctuations are due to longitudinal (sausage mode) and/or transverse (kink mode) MHD waves.
The observed phase relations are not consistent with upward-propagating or downward-propagating waves, but are consistent with the standing kink wave or the standing slow standing sausage wave. These standing waves are interpreted to be due to the superposition of the ascending wave or the descending wave reflected at chromosphere/corona boundary. We point out that even with such reflected waves, the residual upward Poynting flux is estimated to be 2.7×10^6 erg cm^{-2} s^{-1} for one case that we examined.
We can obtain various physical parameters that characterize the flux tubes from the observed amplitudes of magnetic and the velocity waves and the wave period: the plasma density inside and outside the flux tubes, the plasma beta, the Alfvén velocity, the distance between the line formation layer and the reflecting boundary are estimated to be 6.3×10^{-8} g cm^{-3}, 2.4×10^{-7} g cm^{-3}, 0.22, 21 km s^{-1}, 4.9×10^3 km, respectively. The detection of the MHD waves allows us to estimate the plasma density inside the flux tube, that is otherwise difficult to obtain, and may pave the way to the photospheric seismology of the magnetic flux tubes.