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Analysis of Sunspot oscillations observed with the DST in Hida Obs.



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Abstract

Since 3-minute oscillations in the chromospheric umbra are waves of upward propagataion to the solar atmosphere, it is important to confirm variation of the physical quantity due to understand sunspot structures.

So, we obtained the full stokes parameters observed with the DST-VS in Hida Observatory and have carried out inversions using the HAZEL (described below). This data (see *Observation*) contained a large sunspot and the upper chromospheric He I 10830 triplet--present strong Zeeman--.

By the inversions (*Fig.3*), the chromospheric velocity shows a period of 3 minutes with a clear sawtooth shape of propagating shock wave fronts and the magnetic field strength shows variation (mean value is 1856 G). Comparison of phase shows that the magnetic field strength and the doppler velocity are nearly opposite, while the optical depth and the doppler velocity are nearly corresponding (*Fig.4*).

The fact implicates that the chromosphere in He line broaden by the shock wave, the column density become thin, and the optical depth decreases, therefore the magnetic field strength increases it. That means due to differentce of oberved He line layer with optical depth variation.

HAZEL (HAnle and ZEeman Lights) that a inversion code in order to diagnostic of magnetic fields in the chromosphere and the prominence (Asensio Ramos, Trujillo Bueno & Landi Degl'innocenti, 2008).

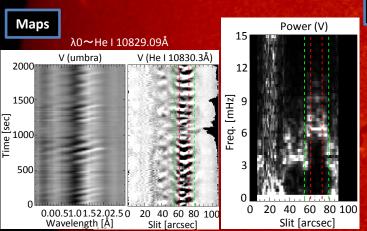


Fig.2. - Left: Wavelength - Time diagram of Stokes V in the umbral center (from the start time to 2000 sec). He I 10830 profile shows periodic variation with a clear sawtooth shape. Center : Space -Time diagram of Stokes V in He I 10830.3 Å (contrast adjustment). Red & green dashed line are umbra & penumbra boundary, respectively. The umbral oscillation has spread outward. Right : Power map of Stokes V shows 3 minute oscillations (around 6mHz) in the umbra and 5 minute period (around 3.3mHz) with running penumbral waves.

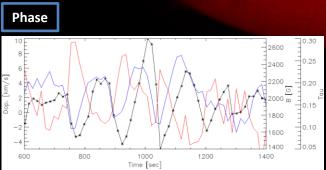


Fig.4. - Comparison of the magnetic field strength (Red line), the optical depth (blue line) and the doppler velocity (black line and points). Note that the redshift of the doppler velosity is positive, and this figure represents range of blue dashed line in *Fig.3*.

Observation

Date : 13 May 2012 Target : NOAA AR 11476 (near N10, W30) Total time : 01:02:27 (UT) - 03:46:42 (UT), 9855 sec Time cadence : 14 sec Instrument : The polarimeter (Anan et al. 2011) of the Vertical Spectrograph

Background image : H α center solar disk (SMART)

Fig.1. - Hα center image shows NOAA AR 11476 observed the DST-HIS (Hα Imaging System) on the same day. The slit (0.2 mm wide and 20 mm long) was placed over the target (and filament) and was kept fixed during the entire observing run with a spectral sampling of 0.03 Å / pix and a spatial sampling of 0".6 / pix. Horizontal lines show hair line.



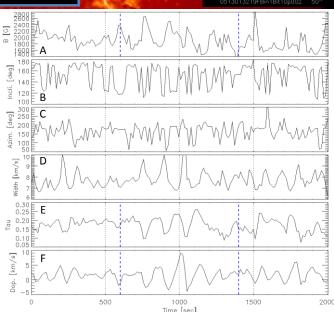


Fig.3. - Inversion results in the upper chromospheric He I 10830Å in the umbral center (from the start time to 2000 sec); A : magnetic field strength (B), B : inclination angle of magnetic field line, C : azimuth of magnetic field line, D : doppler width, E : optical depth (Tau), F : doppler velocity. The angle of the inclination is a normal line direction toward the surface. The angle of the azimuth is the line-of-sight direction from disk center toward target, and the clockwise is positive. Note that the redshift of the doppler velocity is positive. The power spectra of each parameter variation shows a clear peak around 6.5 mHz (near equal to 3 minutes).

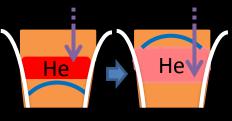


Fig.5. - The shock wave model. Blue curve is shock wave, white line is the magnetic field line, and purple line is like optical depth.Orange background is the chromosphere.