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FTS Polarimetric Survey of the Infrared Solar Spectrum between 1.0 and 2.5 μm

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Abstract. Polarized FTS spectra between 1.0 and 2.5 μm of solar plage and of an umbra have been surveyed to compile a list of useful lines for determining the properties of solar magnetic features. We searched systematically for lines with strong Stokes V or Q profiles and paid particular attention to lines showing special properties such as especially low or high formation level, large Landé factors or strong temperature sensitivity.

1. Introduction

Due to the wavelength dependence of the Zeeman effect, the infrared is the best spectral range for solar magnetic field measurements. We survey polarized FTS infrared spectra between 1.0 and 2.5 μm of solar plage as well as of a sunspot umbra in order to uncover new interesting diagnostic lines and compare them with lines that are already commonly used, such as the Fe I line at 15648.5 Å ($g = 3$).

We systematically searched for lines showing large amplitude Stokes V (circularly polarized light) or Stokes Q (linearly polarized light) profiles or having large Landé factors. We also looked for lines distinguished by extreme heights of formation, peculiar Stokes V profile shapes, or strong temperature sensitivity (e.g. molecular lines). Besides providing diagnostics of solar magnetism, such polarized spectra serve to test line identifications, the validity of LS-coupling through their Zeeman splitting, the importance of telluric blends, etc.

Here we only discuss a few lines picked from the complete sample due to their particular diagnostic capabilities. The complete sample is discussed by Rüedi et al. (1995).

2. He 10830 Å

The He I 10830 Å triplet is probably the best currently available diagnostic of upper chromospheric magnetic fields. It is formed over a narrow height range in the upper chromosphere, without any contribution from the photosphere (Fontenla et al. 1993). It is optically thin in most solar features outside filaments (Giovanelli & Hall 1977) and is still in the weak field regime even over umbrae (i.e. $\Delta\lambda_H < \Delta\lambda_D$ where $\Delta\lambda_H$ is the Zeeman splitting and $\Delta\lambda_D$ the Doppler width of the line). Magnetograms in this line were first observed by Harvey & Hall (1971). We have measured the first polarized spectra of this line.

The chromospheric longitudinal field strength obtained from an umbral profile of this line is 1400 G. The proximity of the photospheric Si I line at 10827.14 Å ($g_{\text{eff}} = 1.5$) enables a simultaneous and cospatial determination of the photospheric magnetic field ($B = 2600$ G). The expected difference in height of formation of 1500–2000 km between these two lines gives a longitudinal magnetic field gradient of approximately 0.6 G km^{-1} above both plage and umbra.

3. The Ti I multiplet at 2.2 μm

The Ti I multiplet at 2.2 μm (Saar & Linsky 1985) contains five lines differing in their Landé factors (1.167 to 2.5) and Zeeman splitting patterns. They are very temperature sensitive, being relatively strong in sunspot umbrae, just discernible in the quiet sun and completely absent from solar plage spectra.

The line having the largest Landé factor (Ti I 22310.6 Å, g=2.5) is a Zeeman triplet and, due to its larger wavelength, is even more sensitive to magnetic fields than the generally employed Fe I g=3 line at 15648.5 Å. These lines are strongly blended by telluric lines, which, due to the strong temperature sensitivity of the Ti I lines, can easily and efficiently be removed, also from the polarized profiles.

The combined analysis of these relatively unsaturated lines enables the measurement of umbral field strength with unprecedented accuracy and should reveal the cause of excess line broadening in sunspot umbrae.

4. Peculiar Stokes V and Q asymmetries

In the plage spectra, strong asymmetries were observed between the σ-components of the Stokes V and Q profiles. In each recorded spectrum, corresponding to a different wavelength-range, the asymmetry was of a well-defined kind and affected all lines in the spectrum in the same way. These asymmetries are much stronger than those observed in the visible at corresponding μ value and do not show the same dependence on line strength. We can rule out instrumental polarization as the cause of these asymmetries. It is not yet clear if these asymmetries are typical of the wavelength range observed, i.e. due to the larger Zeeman splitting of the lines, or if a possibly peculiar velocity structure of the observed region is responsible for them (Grossmann-Doerth et al. 1989).

References

Fontenla, J. M., Avrett, E. H., & Loeser, R. 1993, ApJ, 406, 319

Giovanelli, R. G., & Hall, D. N. B. 1977, Solar Phys., 52, 211

Grossmann-Doerth, U., Schüssler, M., & Solanki, S. K. 1989, A&A, 221, 338

Harvey, J. W., & Hall, D. N. B. 1971, in Solar Magnetic Fields, R. F. Howard, Dordrecht: Reidel, IAU Symp. 43, 279

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Saar, S. H., & Linsky, J. L. 1985, ApJ, 299, L47