Possible lines for the diagnostics of the deep photosphere with IBIS

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In this paper we explore the behavior and the diagnostic power of some lines that are possible candidates for studying the solar photosphere with IBIS, that has a different wavelength range with respect to IPM.

1 Introduction

The different wavelength range of IBIS (Cavallini et al., 2001) with respect to IPM does not allow the observation of some spectral lines traditionally used for studies of the deep photosphere (e.g. the C I 538.032 nm). Moreover, because of the narrow bands of its prefilters, it will be necessary to select well in advance a suitable set of alternative lines to be at disposal from the beginning.
We present preliminary results about the intercomparison of 4 lines (2 in the IBIS and 2 in the IPM range), in view of future applications to the study of the granulation and of other photospheric structures. On that purpose, observations of a short list of lines spanning the whole photosphere and low chromosphere have been made with the Horizontal Spectrograph at the Dunn Solar Tower of the NSO Sacramento Peak Observatory, during an observing campaign in May-June 2001. Among the observed lines we point out the following: Ca II - K, Ca II 854.2 nm, C I 538.032 nm (537.96 FeI [928], 538.10 TiII [69]), C I 833.515 nm, Fe I 557.601 nm (g=0) (556.963 nm of the same [686] multiplet of 557.601), Fe I 709.039 nm (g=0), Fe II 7224.45 nm.
In this paper we restrict ourselves to studying the possibility of replacing the C I 538.032 nm and Fe I 557.601 nm lines with Fe I 709.039 nm and Fe II 722.45 nm (available in the IBIS range) and analyse their diagnostic power for spectroscopic tomography of the deep atmosphere.

2 Line synthesis

We have calculated all lines profiles in LTE, using the latest Kurucz's model (Kurucz, 1994) and compared our results with the experimental profiles, taken from the flux atlas by Kurucz et al. (1985). We report

Element	$\lambda(\AA)$	$\chi_{ex}\,(eV)$	$\log(gf)$	ζ	I/I_c	$W(m\AA)$
C I	5380.32	7.68	-1.61	9	0.87	774
Fe I	5376.09	3.43	-1.45	11	0.28	1071
Fe I	7090.38	7.87	-1.3	15	0.56	928
Fe II	7224.53	3.89	-3.28	50	0.86	380

Table 1: Line parameters: ζ is a fudge factor multiplying the Unsöld value of γ in the Lorentz part of the absorption profile. The values of $\lg(gf)$ and ζ are those that optimize the comparison with the experimental data of solar flux.

in Tab. 1 the fundamental line data we adopted and show, in Fig. 1, the comparison of the theoretical and experimental profiles.

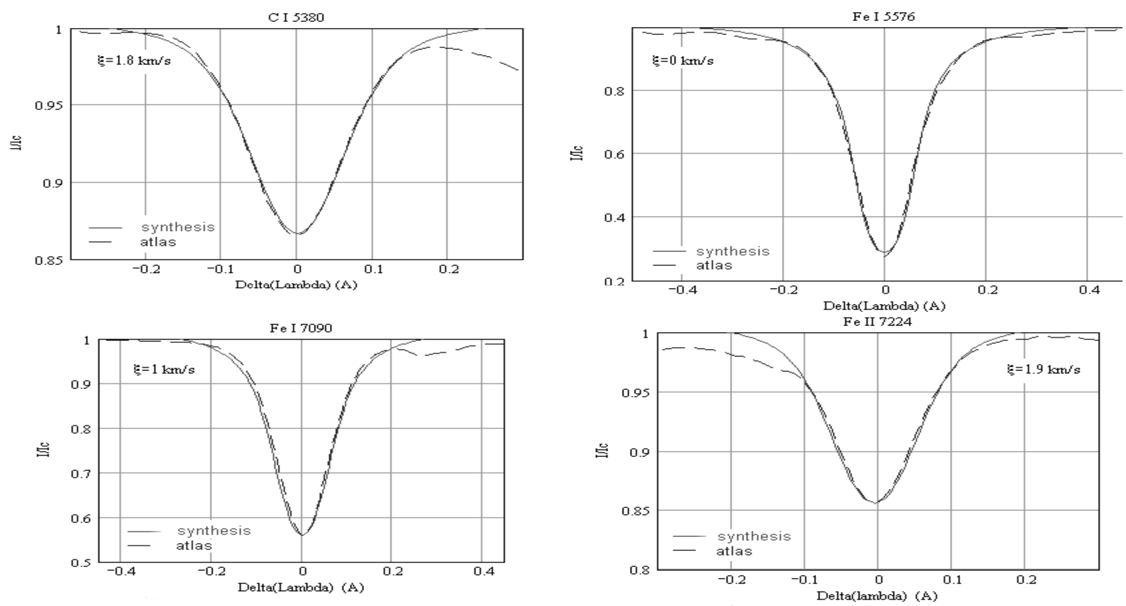

Figure 1: The theoretical synthesis of the considered lines, comparised with these from the Kurucz et al. atlas (1985). ξ is the value of the microturbulence.

3 The response functions

To compare the formation depths of the "old" and "new" lines, we have calculated their velocity and temperature response functions (RF). The RF is defined as the kernel that, in presence of a perturbation ε_A of any quantity A (velocity, temperature, etc.), provides the corresponding intensity perturbation in a linearized approach (Caccin et al., 1977):

$$\delta I = \int_{-\infty}^{\infty} RF(z)\,\varepsilon_A(z)\,z \tag{1}$$

and is given, with usual notations, by the following expression:

$$RF(z) = (\frac{\partial S(z)}{\partial A}\,\chi(z) + \frac{\partial \chi(z)}{\partial A}(S(z) - I(z)))\,e^{-\tau(z)} \tag{2}$$

In Fig. 2 we report the response functions of velocity and temperature (at constant pressure) for the lines under study, in the line core ($\Delta\lambda = 0$) and in the line wing (where the derivative of the unperturbed profile, $dI/d\lambda$, is maximum).

4 The 5^m oscillations

From the experimental data, we obtained the values of the oscillatory velocities in the core of three lines (Fe I 557.601, Fe I 709.039 and Fe II 722.45), for which simultaneous observations were available, by integration of the power spectra in the 5 min range and, as a quick check, we compare the experimental results with rough theoretical estimates. In Fig. 3 we plot the experimental and theoretical oscillation amplitudes of the line cores vs the corresponding positions of the maximum of the velocity RFs (convolved with a gaussian instrumental profile). The calculations have been made with an *ad hoc* velocity field (Bertello & Caccin, 1990):

$$V(z) = V_0 exp^{-z/H} \tag{3}$$

with $V_0 \approx 0.3$ km/s and $H \approx 850$ km.

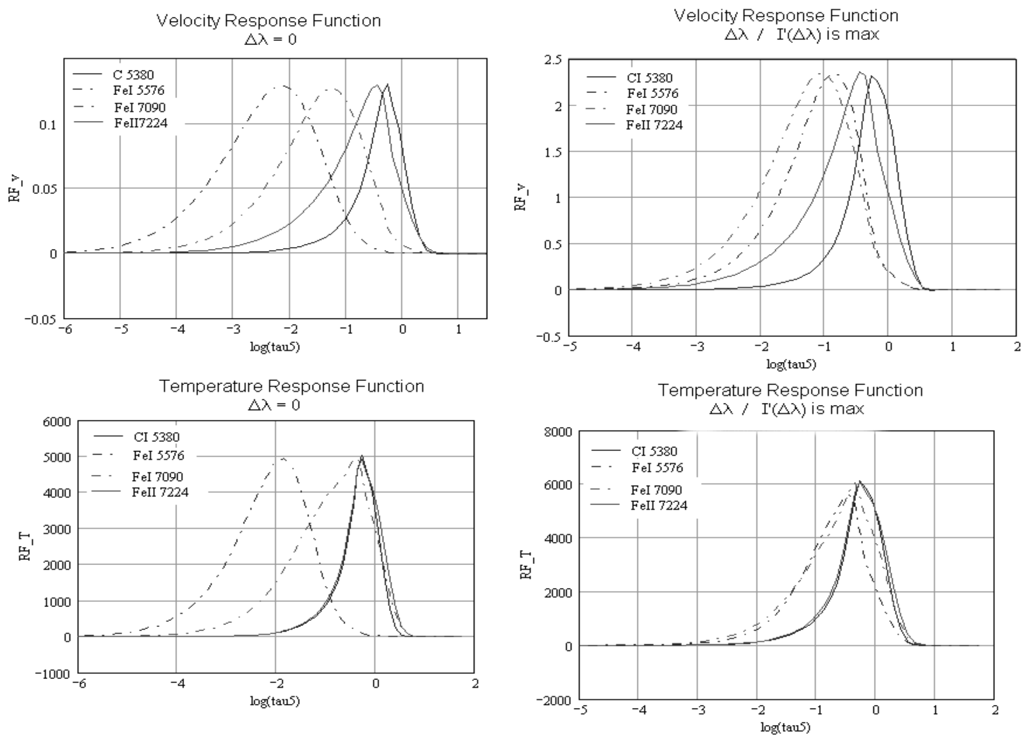

Figure 2: The response functions for the considered lines, in the line core and in the line wing.

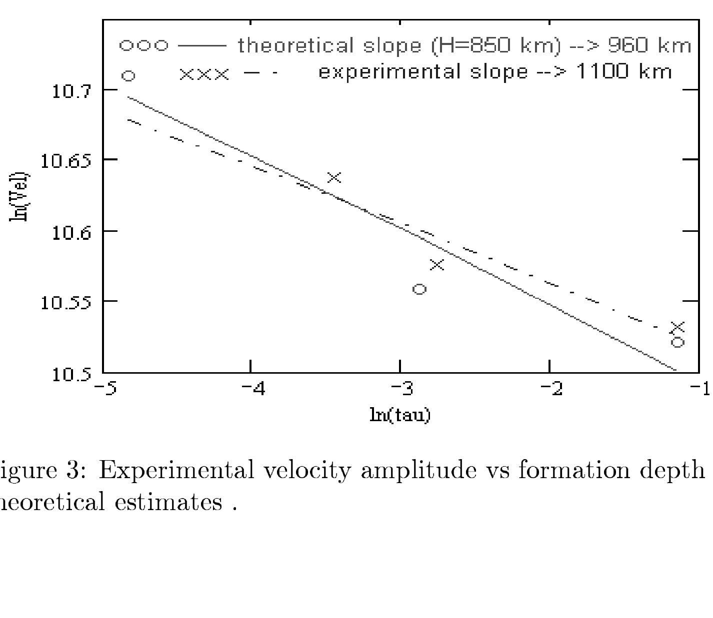

Figure 3: Experimental velocity amplitude vs formation depth at different points in lines compared with theoretical estimates .

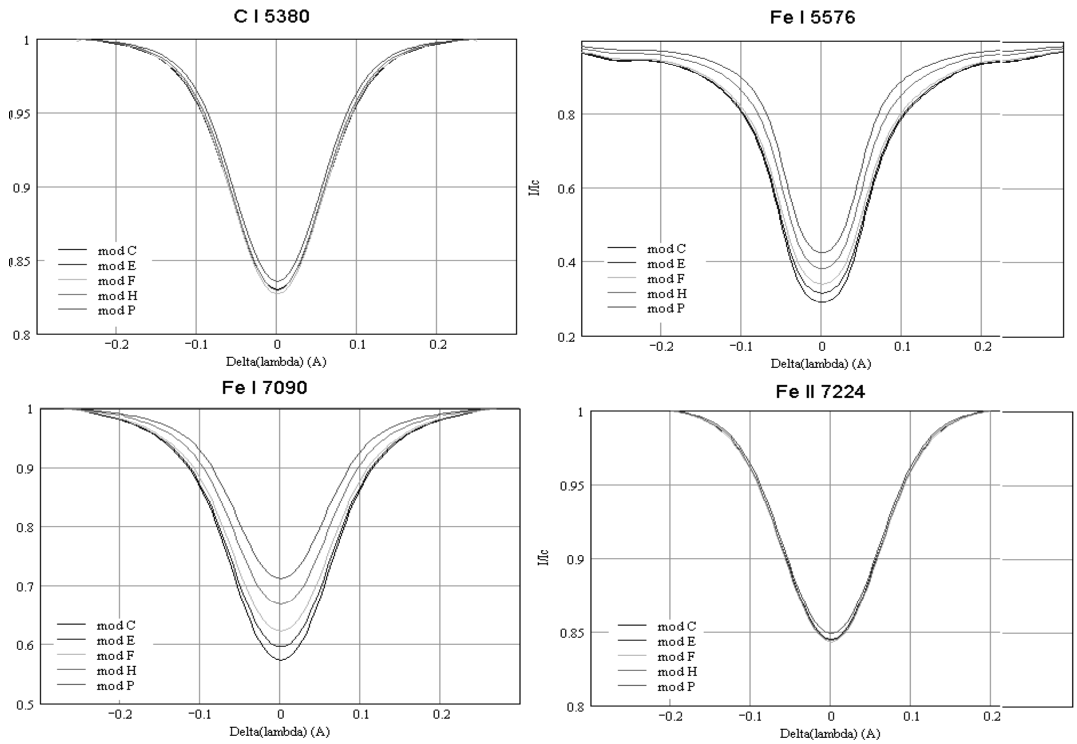

Figure 4: The computed profiles of "our" lines for different active regions: modA (faint supergranule cell), modC (average supergranule cell), modE (average network), modF (bright network or faint plage), modH (average plage) and modP (bright plage).

5 Line profiles in bright magnetic regions

We observed also the lines in bright magnetic regions (network and plages) and we recalculated them using the RISE models (FAL, Fontenla et al., 1999), that are semiempirical atmospheric models representative of "typical" active regions. The effect of these different models on the line synthesis is shown in Fig. 4.

6 Conclusions

Our preliminary results seem to confirm the possibility of using with IBIS the Fe I 709.039 nm and Fe II 722.45 nm lines as reasonable substitutes of C I 538.032 nm and Fe I 557.601 nm, used with IPM, in the study of the deep photosphere.

References

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