NLTE MASKING AND THE KIEV Fe I OSCILLATOR STRENGTHS

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This contribution serves to advertise the empirical solar-spectrum determinations of the oscillator strengths of 860 Fe I lines by Gurtovenko and Kostik (1981), by showing that these Kiev data contain just the lines needed in cool-star abundance analyses, and by explaining why they are so good. For details, see Rutten and Kostik (1982) and Rutten and Zwaan (1983).

Figures 1 and 2 show why the Kiev gf-values are so useful. While the precise Oxford measurements (see Simmons and Blackwell, 1982, for references) cover the low-excitation lines (Fig. 1a) which are mostly too violet and too strong for abundance studies, the Kiev workers have added the best lines in the solar visual, thus precisely the weaker lines of higher excitation one needs (Fig. 1b). Figure 2 demonstrates this for the solar Fe I curve of growth: the Doppler part, which is the only really useful part, is made up of Kiev lines (dots).

The Kiev gf-values are empirical determinations based on LTE fitting of the

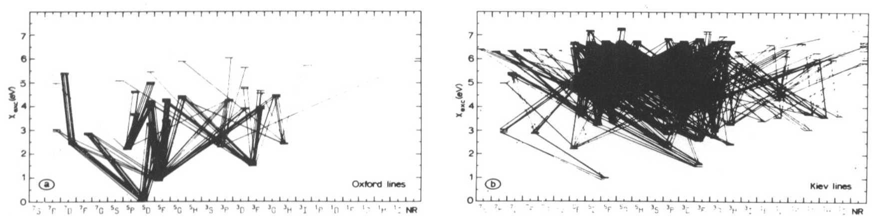

Fig. 1: Gotrian diagrams of Fe I lines measured at Oxford and fitted at Kiev, respectively.

observed central intensities of the lines in the solar spectrum. Thus, they are susceptible to all errors in the line formation modeling adopted by Gurtovenko and Kostik; most notably, to the neglect of departures from LTE. The latter are summarized in Figure 3, respectively for low-excitation levels (β^L), middle-excitation levels (β^M), high-excitation levels (β^H) and the visual lines between them (T^{LM}_{exc} and T^{MH}_{exc}), following Lites (1972). The departure coefficient β is the ratio (actual population/LTE population). The line opacity scales with the lower-level coefficient β_ℓ, while the deviation of the line source function (or the

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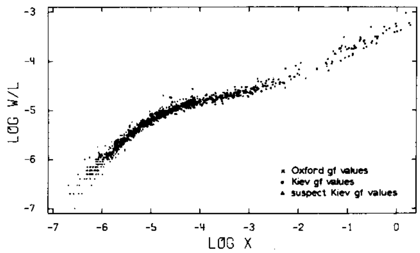

Fig. 2: Solar curve of growth for 991 Fe I lines.

excitation temperature) from the Planck function (or the electron temperature) is set by the upper-to-lower ratio β_u/β_ℓ. The excitation temperatures in the upper panel, correspond to the departure ratios of the lower panel, assuming the HSRA (Gingerich et al. 1971) electron temperature.

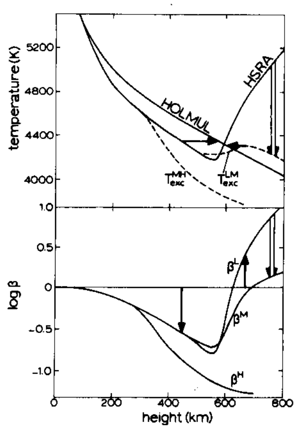

Fig. 3a(top): Electron temperatures of solar model atmospheres and typical NLTE Fe I excitation temperatures. Fig. 3b(bottom): Fe I NLTE departure coefficients, after Lites (1972).

The small values of β^L and β^M in the upper photospheres (h=500 km) imply that LTE fitting of the central intensities of weak to medium-strong LM lines leads to underestimates of their line opacities (thus their gf-values) by as much as 0.7 dex, even though the line source functions are still in LTE at the height of line-core formation ($\beta^L=\beta^M$). These large errors are, however, fortuitously cancelled when one adopts the Holweger-Müller (1974, HOLMUL) photospheric model, as was done by the Kiev workers. This model masks the Fe I NLTE departures in the fashion schematically illustrated by the arrows in Fig. 3. The neglected opacity departures (single arrows) are balanced at all heights by appropriate horizontal shifts of the HOLUML temperature. In addition, the neglected line source function departures (double arrows) of the strongest lines are suitably balanced by ignoring the existence of the solar chromospheres. This masking happens to work quite well for most Kiev lines, so that the assumptions of LTE and the HOLMUL model together, both wrong, have led to quite good gf-values.

The single category of Kiev lines for which the NLTE departures are not well fudged in this manner are the strongest high-excitation lines which are also, due to a selection effect, the only lines in the Kiev data with large oscillator strengths. Their excitation temperature T_{exc}^{MH} drops below the electron temperature at the height of line-core formation, so that it falls short of the HOLMUL temperature even after application of the opacity shift. Their Kiev gf-values are therefore too large. However, these lines tend to lie in the flat part of the curve of growth (triangles in Fig. 2), which is not very sensitive to such errors in gf-values.

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