GRANULATION AND THE NLTE FORMATION OF K I 769.9

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Abstract. The diagnostic use of solar spectral lines often requires NLTE analysis of their formation. Such NLTE modeling is usually done for static model atmospheres. When dynamical structures such as the granulation or the 5-minute oscillation are studied, it is convenient to assume that the velocities and the temperature and density perturbations do not affect the size of the departures from LTE, so that the atomic level populations may be obtained directly by applying the static departure coefficients to the dynamic LTE populations. This approach has been used by Keil and Canfield (1978) for selected Fe I lines, and by Severino *et al.* (1986) for the K I 769.9 nm resonance line. We discuss this assumption here for the latter line. It is of interest because the K I resonance line attracts much attention as a helioseismological diagnostic.

We have used an atomic model for K I similar to the one specified by Severino *et al.* (1986) together with the Carlsson (1986) radiative transfer code to study the effects of granular perturbations on the K I departure coefficients.

Previous discussions of the granular influence on NLTE departures have typically addressed metal lines such as Fe I lines. For Fe I it is clear that overionization due to strong ultraviolet radiation fields is the main NLTE mechanism to be taken into account (Lites 1972, see also Rutten 1988). Nordlund (1984) has shown that the horizontal fluctuations related to granulation alter the NLTE iron ionization equilibrium drastically, and that the non-local nature of the ionization equilibrium has to be taken into account for realistic modeling of photospheric iron lines.

We find that ultraviolet overionization is also important in the case of potassium but less than for iron. The ionization cross sections from the K I *s*-states are unusually small due to spin-orbit interaction (see Aymar et al. 1976, Sandner et al. 1981), and there is an effective compensation of the ultraviolet overionization due to radiative recombination to the 3D level. Recombination exceeds ionization for such low-energy bound-free transitions because they occur in the red part of the spectrum, for which the Planck function exceeds the mean intensity in the upper photosphere. In the case of K I, the ultraviolet overionization is canceled by this recombination, so that the ground state population is very close to LTE throughout the photosphere, and actually overpopulated in the deep photosphere. The populations of the higher levels are lower than the LTE values, however, due to photon losses in the lines. This is just the reverse of the behaviour of the optical Fe I lines, of which the source functions obey LTE while their opacities are below the LTE values.

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An additional NLTE phenomenon in the K I spectrum is the overpopulation of the 5P level, due to optical pumping from the ground state by violet radiation. A cascade down from this level to the ground state compensates the photon losses partially.

The K I population sensitivity to temperature fluctuations turns out to be also just the reverse of the Fe I population sensitivity. A granule, being much hotter than the mean photosphere in deep layers, produces a hotter-than-average radiation field in the upper photosphere where the K I and typical Fe I line cores are formed, even if at that height the granular temperature variation itself is negligible. This enhanced radiation produces increased photoionization and correspondingly larger departures from LTE in the case of Fe I. For K I there is also a similar increase in ultraviolet ionisation, but in addition the amount of overrecombination is reduced so that the overall K I populations are lowered. The ground state becomes underpopulated above a hot granule. In addition, the 4S–5P pumping loop is enhanced, and the source function of the 769.9 nm line is closer to LTE.

Our computations show that indeed the granular temperature perturbations in the deep photosphere affect the departure coefficients higher up. We find that the change in the departure coefficients by the hot radiation field from a granule, compared to the static atmosphere, is typically 30 % at the height where the 769.9 nm line is formed.

The changes in the K I departure coefficients that are due to granular density variations are smaller, typically less than 20 %. The density variations counteract the temperature variations, so that the combined changes of the departure coefficients are about 10%.

We conclude that full dynamical NLTE modeling is required only for detailed interpretation of observations employing the K I resonance line. However, one should be specifically aware of the effects of the bound-free transitions that 'feel' local differences in the radiation from the deep photosphere.

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