THE GRANULATION SENSITIVITY OF NEUTRAL METAL LINES

J.H.M.J. Bruls, H. Uitenbroek, R.J. Rutten

Sterrekundig Instituut Utrecht, The Netherlands

Abstract. We discuss the sensitivity of neutral metal lines to the temperature variations imposed by the granulation on the solar atmosphere. We concentrate on the Ni I 676.78 nm line, which the Global Oscillation Network Group (GONG) has chosen as Doppler sensor for helioseismological study of the sun. We have studied the NLTE formation of this line, in particular its sensitivity to granular temperature fluctuations, because these may represent a major noise source in the oscillation signal. A more detailed account will be published elsewhere.

The GONG line turns out to be a typical metal line from a minority ionization stage. As in the case of Fe I (Lites 1972, see Rutten 1988), the most important NLTE aspect of its formation is its sensitivity to the hot ultraviolet radiation field. This causes two effects which affect the observed line core.

The first effect is the large overionization due to the ultraviolet imbalance $J_\nu > B_\nu$. This overionization empties all Ni I levels in the upper photosphere considerably. It results in an appreciable rescaling of the optical depth scale for all Ni I lines, giving a lower height of formation (for a given transition probability) than LTE modeling of the ionization equilibrium would indicate. This ultraviolet overionization effect is not compensated by overrecombination to high levels in the red (where $J_\nu < B_\nu$) as it is in the case of alkalids as K I (Gomez *et al.*, these proceedings), because the levels that are high enough in the Ni I term diagram to feel the red imbalance are too high to affect the overall populations.

The second effect is overexcitation in the upper photosphere, again due to the ultraviolet imbalance $J_\nu > B_\nu$. This effect has been studied for Fe II (Cram *et al.* 1980; Watanabe and Steenbock 1986), but it appears in Ni I and probably Fe I as well: the numerous ultraviolet lines overexcite their upper levels, and these overpopulations produce enhanced source functions in the upper photosphere for subordinate lines at longer wavelengths such as the GONG line (see Rutten 1988).

How do these NLTE formation effects interact with the granular temperature modulation for the GONG line? We have studied this in detail, using the Carlsson radiative transfer code (Carlsson 1986, Scharmer and Carlsson 1985) for granulation models that were kindly supplied by M. Steffen from his simulation (Steffen and Muchmore 1988).

The computations show that although Steffen's granules have only a very small (and reversed) temperature contrast at the height where the core of the GONG line is formed, it is nevertheless sensitive to what happens in the granulation. This is so because the ultraviolet radiation carries the large temperature contrasts present in the granulation

R. J. Rutten and G. Severino (eds.), Solar and Stellar Granulation, 311–312.

in deep layers all the way up to the height of formation of the line core, and there affects both the line opacity and the line source function through the two NLTE mechanisms described above. As a result, the line core brightens appreciably above a hot granule, although in Steffen's results the temperature at that height is actually slightly lower than above an intergranular lane.

In conclusion: the core of the GONG line shows granular intensity variations due to NLTE coupling with the ultraviolet radiation from deeper layers, even if the granulation temperature contrast has vanished at its formation height.

This behaviour is not typical for this specific Ni I line, and we may expect that other comparable minority-species metal lines such as Fe I lines behave similarly.

References

Carlsson, M., 1986, Uppsala Astronomical Observatory Report **33**

Cram, L.E, Rutten, R.J. and Lites, B.W., 1980, Astrophys. J. **241**, 374

Lites, B.W., 1972, *NCAR Cooperative Thesis* **28**, University of Colorado, Boulder

Rutten, R.J., 1988, in: R. Viotti, A. Vittone, M. Friedjung (Eds.), *Physics of Formation of FeII lines Outside LTE*, Proceedings IAU Colloquium 94, Reidel, Dordrecht, p. 185

Scharmer, G.B. and Carlsson, M., 1985, J. Comput. Phys. **59**, 56

Steffen, M, and Muchmore, D., 1988, Astron. Astrophys. **193**, 281

Watanabe, T. and Steenbock, W., 1986, Astron. Astrophys. **165**, 163