Atomic and Molecular Processes in Stars

Collision processes affecting stellar models and the interpretation of stellar spectra are investigated by theoretical modelling. The calculations are applied to astrophysical models, where the effects of the new data are explored and the results used to more accurately interpret observations. Processes of particular interest include:

Inelastic collision processes

- electron-impact excitation
- hydrogen-impact excitation
- charge exchange involving H

These processes affect synthetic non-equilibrium spectra and thus measured stellar properties, such as chemical abundances and temperatures: e.g., Li and Na abundances measured in cool stars change by as much as 60% due to the inclusion of processes involving H shown in Fig. 1.

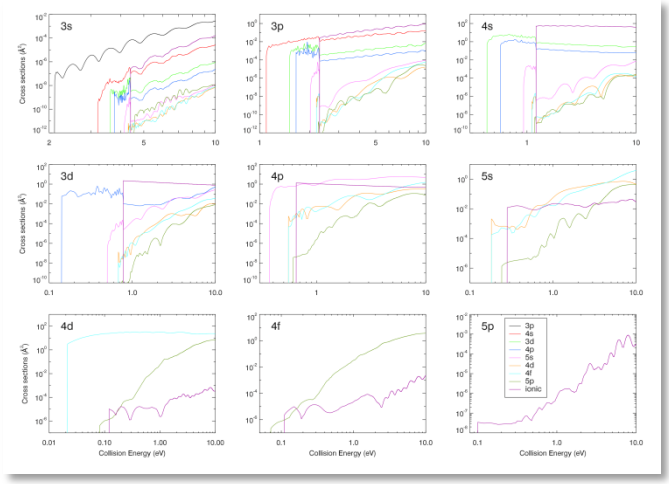

Fig. 1: The cross sections for excitation and charge exchange processes in Na+H collisions. The initial level is shown in each panel, and final states according to the key at the bottom.

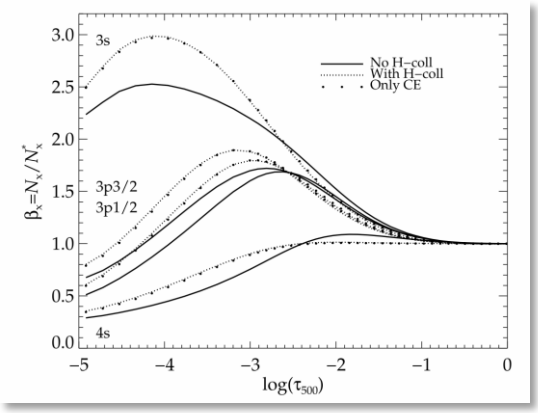

Fig. 2: Departure coefficients for Na in a solar model. Solid: neglecting H, Dotted: including H, Bullets: only charge exchange with H. Note the 4s level is driven towards equilibrium (β=1).

Fig. 2 shows the majority of this change in abundance is due to the charge exchange processes, e.g.

$$Na(4s) + H \rightarrow Na^{+} + H^{-}$$

These processes have the largest cross sections as shown in Fig. 1 (the final channel labelled "ionic"). The discovery of the importance of these processes has been one of our achievements.

Collisional broadening of spectral lines

- broadening of metal lines by H
- self broadening of H Balmer lines

These processes affect measured chemical abundances, temperatures, and gravities of cool stars. E.g., we calculated data for a large number of metal lines of many atomic species with <20% estimated accuracy. Fig. 3 shows the improvement in modelling the solar spectrum, supporting our error estimates and suggesting that strong lines can be used with confidence in other stars.

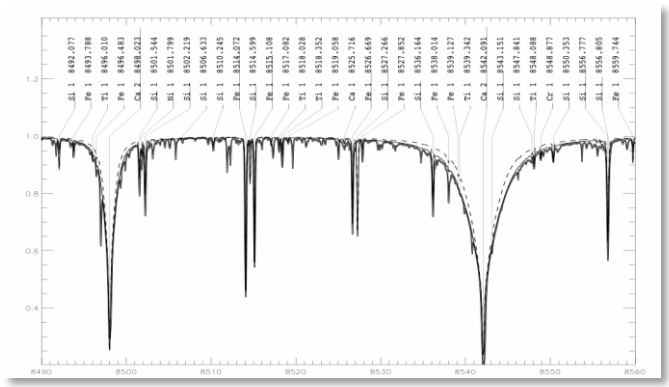

Fig. 3: Two lines of the Ca II infrared triplet in the solar spectrum. Synthetic spectra with our data (full) and old data in VALD (dashed), assuming the meteoritic abundance, compared to observed spectra (double line, NSO Data).