RYDBERG EMISSION LINES IN THE SOLAR SPECTRUM

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Abstract. This is a latex and bibtex example for astronomy students, accompanying the manual at `https://robrutten.nl/Report_recipe.html`. Sloppy authors use "....." instead of ".....", do not add space-making backslashes after et al., \AA, etc., do not use tildes for non-breakable spaces before units and after initials, do not end italics with \/, do not set units in roman font, do not set the e of electron in m_e or the eff in T_{eff} in roman, do not use bibtex, do not use a spell checker, do not use \url for weblinks, do not link citations to NASA's ADS. Probably they do nothing well – unlike us.

1. Introduction

The existence of two emission features in the solar spectrum near 12 μm was announced by Murcray et al. (1981)[1], but only when they were informed by L. Testerman and J. Brault that they had noticed them too. Before that, Goldman et al. (1980) had white-pasted them out of their spectrum atlas in the mistaken belief that all solar and telluric lines should be in absorption. We explained these emission features many years ago (Carlsson et al. 1992, henceforth Pub I; see also Rutten & Carlsson 1994).

2. Model computations

2.1. Background

In the solar photosphere NLTE departure diffusion occurs in the upper reaches of the Mg I term structure (see Figs. 3 and 4[2] of Pub I). It is akin to optically-thin collisional-radiative recombination along Rydberg levels in tenuous plasmas as sketched in Fig. 1[3]. The righthand cartoon in Fig. 2 here[4] shows the H I Rydberg ladder more formally.

2.2. Method

We solved the statistical equilibrium and radiative transfer equations for all relevant levels and frequencies in Mg I and Mg II for various models of the solar atmosphere, including the standard one formulated in the monumental articles by Vernazza et al. (1973, 1976, 1981).

3. Conclusion

Our computation explained the formation of the enigmatic Mg I 12 μm emission features. They arise through population depletion by line photon losses and population replenishment
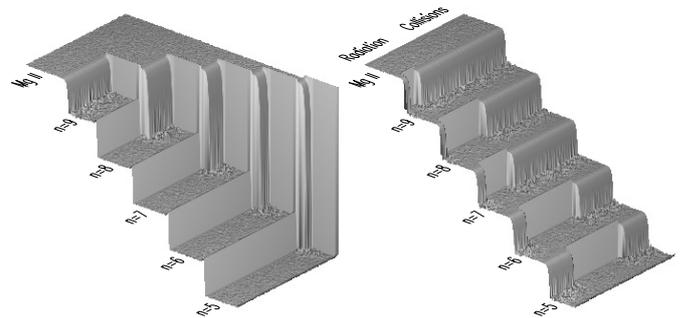

Fig. 1. Collisional-radiative recombination along Mg I Rydberg states visualized by Mats Carlsson for drop-pool kayakers. *Left:* the largest recombination flow from the magnesium population reservoir in the Mg II ground state is into the highest Mg I level ($n = 9$ in the present model). *Right:* along the $\Delta n = 1$ downward ladder the flow is initially dominated by collisional transitions but radiative transitions take over lower down. The recombination flow is driven by photon losses in strong Mg I lines and is balanced by radiative ionization in ultraviolet Mg I edges. Similar Rydberg flows occur in other elements, but the Mg I Rydberg levels contain the largest photospheric populations, exceeding even the H I ones. From Rutten & Carlsson (1994).

from the ionic reservoir through highly excited levels. A Rydberg-channel replenishment flow is realized by collisionally-dominated population diffusion via ladder-wise departure divergence (see Fig. 1 in Sect. 2).

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[1] Depending on your pdf-viewer settings, clicking a name-year citation may open the corresponding ADS abstract page in your browser.

[2] Links to cited figures or equations may open the pertinent page via ADS (but macOS Preview may shunt to the start page).

[3] Multi-panel figure production: prepare separate figures, each with full axis annotation, and paste them together using the latex commands in my `cutmultipanel.tex`. These remove superfluous axis annotation between adjacent panels and rescale them to the same size; they also maintain image resolution for zoom-in per pdf viewer. This way you can define the multi-panel assembly layout (e.g., column-wide vertical stacking or page-wide horizontal) while writing, including re-ordering figures from coauthors.

[4] Link to a figure page in the arXiv pdf for a Springer publication not directly accessible at ADS.

References

Carlsson, M., Rutten, R. J., & Shchukina, N. G. 1992, A&A, 253, 567 ADS (Pub I)
Goldman, A., Blatherwick, R. D., Murcray, F. H., et al. 1980, New atlas of IR solar spectra, Tech. rep. ADS
Murcray, F. J., Goldman, A., Murcray, F. H., et al. 1981, ApJ, 247, L97 ADS
Rutten, R. J. & Carlsson, M. 1994, in IAU Symposium, Vol. 154, Infrared Solar Physics, ed. D. M. Rabin, J. T. Jefferies, & C. Lindsey, 309 ADS
Vernazza, J. E., Avrett, E. H., & Loeser, R. 1973, ApJ, 184, 605 ADS
Vernazza, J. E., Avrett, E. H., & Loeser, R. 1976, ApJS, 30, 1 ADS
Vernazza, J. E., Avrett, E. H., & Loeser, R. 1981, ApJS, 45, 635 ADS