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# NLTE diagnostics of solar prominences using hydrogen and helium lines(*)

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**Summary.** — This contribution aims to present non-local thermodynamic equilibrium (NLTE) modeling of hydrogen and helium spectra in quiescent prominences. We investigate the formation of the whole helium spectrum—He I and He II—and hydrogen spectrum within the frame of one-dimensional, isothermal and isobaric static slab models. After some explanations on the kind of NLTE modeling used here, we shall focus our attention to the study of neutral helium triplet lines to see their behaviour with plasma parameters variations and how it compares with published observations.

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## 1. – Introduction

The interpretation of prominence observed spectra is often difficult, and the derivation of plasma parameters is not straightforward for optically thick lines. In this work we present new NLTE computations of hydrogen and helium lines in quiescent solar prominences. The numerical code presented here can be used as a diagnostic tool to help for the interpretation of prominence observations.

## 2. – Modeling procedure

The prominence is represented by a one-dimensional plane-parallel slab standing vertically above the solar surface, illuminated on both surfaces by the radiation field coming from the solar atmosphere. The models are defined by 5 physical parameters. The gas pressure, the temperature inside the slab, and the microturbulent velocity, are supposed

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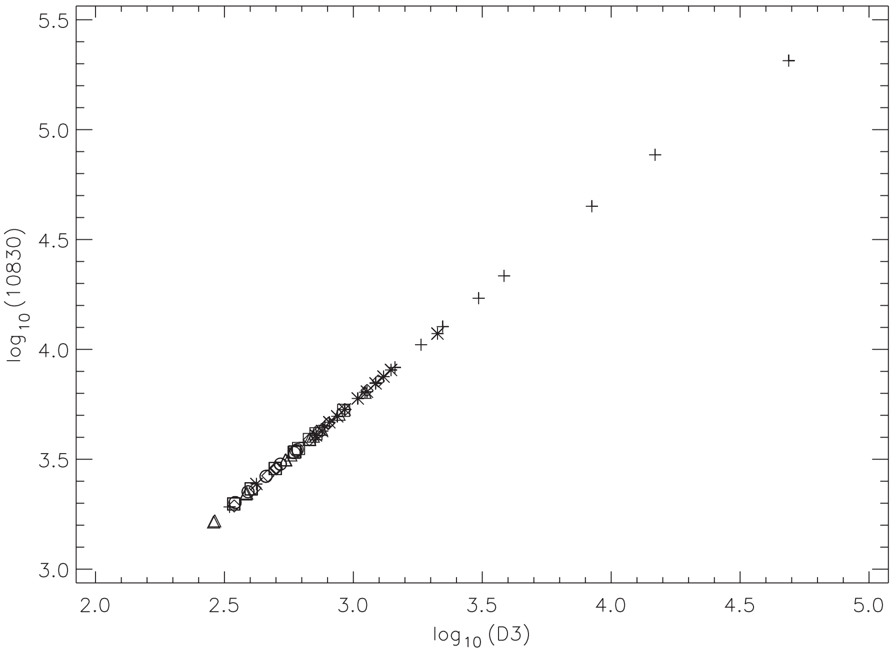


Fig. 1. – $I(\lambda\ 10830)$ *vs.* $I$(D3) (computed values) (erg cm$^{-2}$ s$^{-1}$ sr$^{-1}$). $T$ = 4300 (circle); $T$ = 6000 (square); $T$ = 8000 (triangle); $T$ = 10000 (diamond); $T$ = 12000 (asterisk); $T$ = 15000 (cross); $P$ = 0.020–1.000 dyn/cm$^2$; $W$ = 1000–5000 km; $V$ = 5 km/s; $H$ = 10000 km.

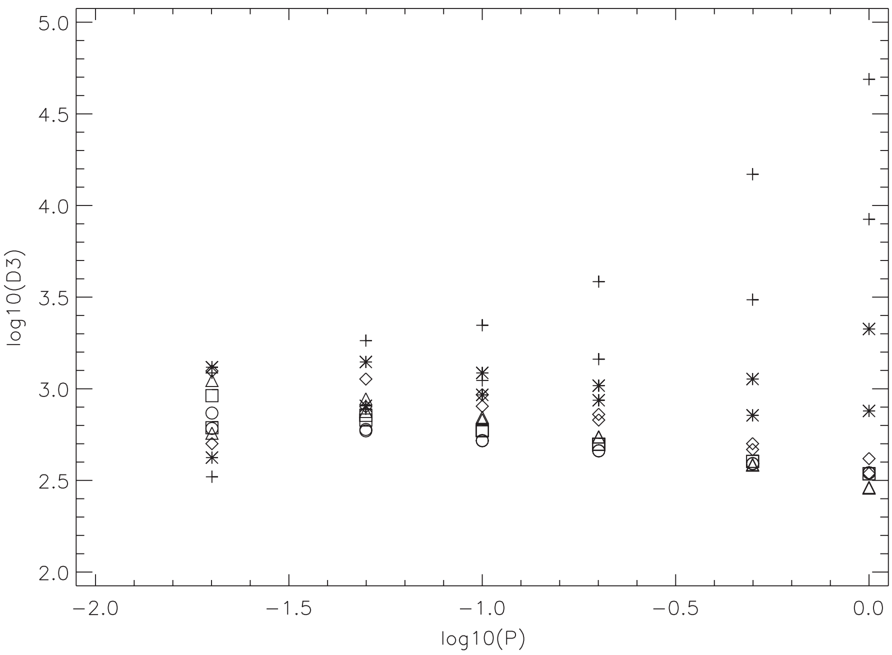


Fig. 2. – $I$(D3) *vs.* gas pressure (computed values). Symbols and parameters are the same as in fig. 1.

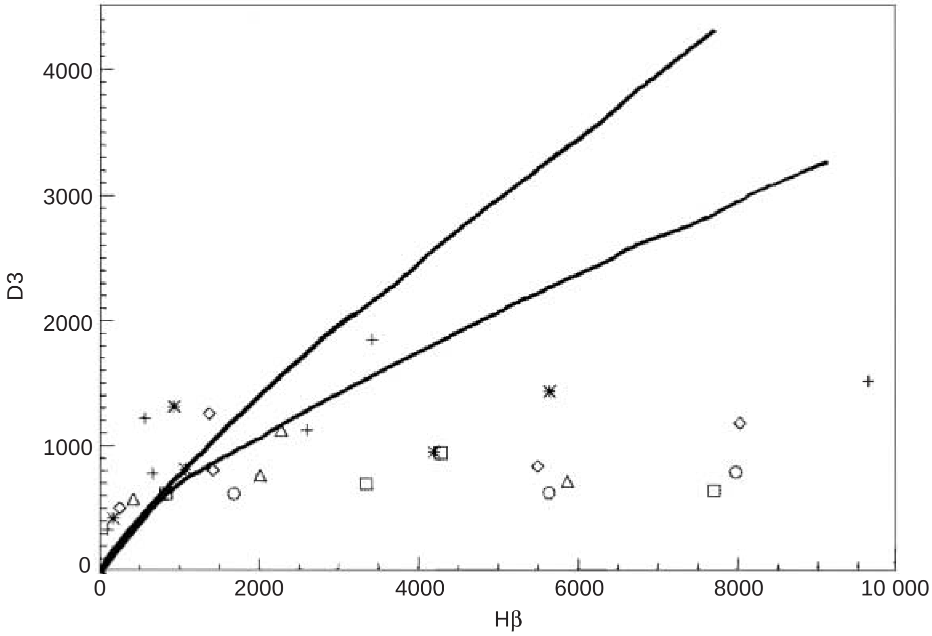


Fig. 3. – $I$(D3) *vs.* $I(H\beta)$ (erg $cm^{-2}$ $s^{-1}$ $sr^{-1}$). Points: computed values, as in the previous figures; solid line: mean relations from [1] and [2].

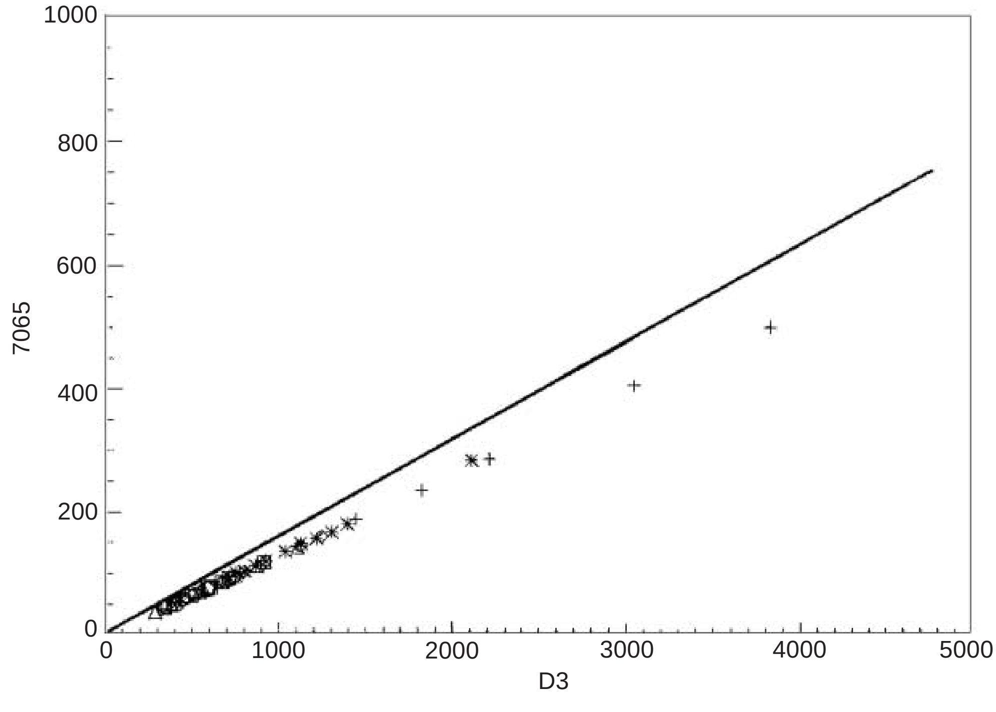


Fig. 4. – $I(\lambda$ 7065) *vs.* $I(\lambda$ 5876) computed (erg $cm^{-2}$ $s^{-1}$ $sr^{-1}$). Symbols and parameters are the same as in the previous figures. Solid line: mean relation of [1].

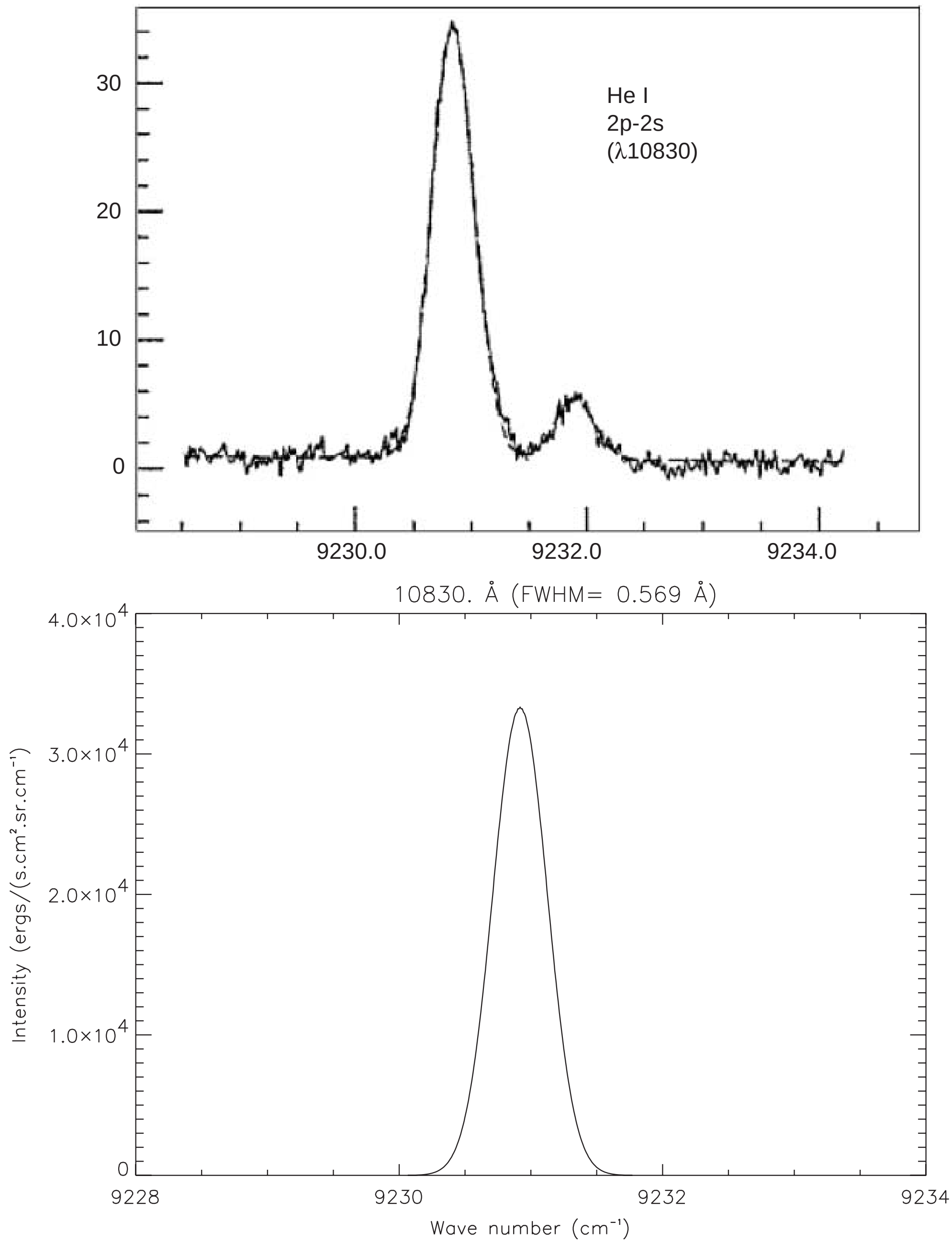


Fig. 5. – Top: observed emergent profile at 10830 Å (18 April, 1995) [3]; the specific intensity is in units of $10^3$ ergs/(s cm$^2$ sr cm$^{-1}$). Bottom: computed emergent profile at 10830 Å. $T = 15000$ K; $P = 0.5000$ dyn/cm$^2$; $W = 1000$ km; $H = 10000$ km.

to be constant throughout the slab; the height above the solar surface is the height of the line of sight, and the slab thickness is the only geometrical dimension.

The computations are first made for hydrogen to obtain the emergent spectrum, hydrogen level populations, electron densities and mean intensities at different wavelengths for different depths inside the slab. Observed intensities incident from the solar disk are used as boundary conditions for the radiative transfer equations. Statistical equilibrium and radiative transfer equations are then solved for helium, taking into account the radiation field in the slab due to hydrogen. Partial redistribution in frequency is considered for the formation of the first resonance lines of H I, He I and He II. We use a 29+4+1 helium model atom, allowing us to obtain 76 radiative transitions in the helium emerging spectrum, including optically thick EUV resonance lines. Further details on the modeling procedure can be found in Labrosse and Gouttebroze [4].

In this work we present computations corresponding to 72 prominence models, with 6 temperatures ranging from 4300 to 15000 K, 6 gas pressures ranging from 0.02 to 1 dyn/cm$^2$, 2 slab widths of 1000 and 5000 km, a microturbulent velocity of 5 km/s and a height of 10000 km.

## 3. – Results

We present in figs. 1 and 2 theoretical plots illustrating the behaviour of emergent line intensities with physical conditions variations. Figure 1 shows the integrated intensity of the He I 10830 line *vs.* the He I 5876 line. The linearity in this relation is due to the optical thinness of the prominence for these two lines. But a non-linear regime appears at high temperature and high pressure due to a saturation in the 10830 line. Figure 2 shows the predicted variation of the D3 line integrated intensity *vs.* the pressure inside the slab. This behaviour varies with the temperature. The D3 intensity increases with pressure at high temperature, but decreases with pressure below 10000 K.

We present also comparisons between our theoretical results and prominence observations made in visible lines. Figure 3 represents the variation of the D3 line intensity *vs.* the Balmer hydrogen H$\beta$ line. Solid lines are mean relations derived from observations made by Landman and Illing [1, 2] for 2 prominences in 1975. Points represent computed values. Figure 4 shows another relation between 2 neutral helium triplet lines, again compared with a mean relation derived by Landman and Illing [2]. The agreement in these two figures between our computations and observations by Landman and Illing is quite good, but we expect it to be improved if we consider in our model several thin slabs instead of a unique wide slab, in order to reproduce prominence fine structure.

Finally we present in fig. 5 an example of an emerging profile for the 10830 line, together with a profile observed by Chang and Deming [3] on a single prominence. The shape of the profile, the line center intensity and the FWHM are well reproduced.

## 4. – Conclusion

New NLTE computations of the helium emerging spectrum of a solar quiescent prominence are now becoming available in order to facilitate the interpretation of EUV (SoHO) and visible (THEMIS) observations of H and He lines. This allows us to predict observable lines, derive physical quantities from observed spectra and find to what physical parameters the helium level population densities and the emergent line profiles and intensities are sensitive [4].

REFERENCES

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