ANALYSIS OF HeI 10830 A LINE IN A QUIESCENT PROMINENCE

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Abstract - In order to explain an enhanced emission in the wings of the prominence HeI 10830 A line, Landman et al. (1977) have introduced a concept of several prominence layers having different temperatures and/or turbulent velocities. As previously reported, our photographically measured profiles of this line also exhibit substantial surplus radiation which can hardly be explained in terms of isothermal models. Assuming that the line-core radiation comes mainly from the cool prominence parts, we have tried to fit the line-core intensities of both HeI 10830 A peaks using only one-temperature models with line-center optical thickness $\tau_0$.

Since the amount of a surplus radiation in the line wings was found to increase almost linearly with $\tau_0$, we deduce that cool prominence threads are surrounded by a hot plasma sheets rather than that the prominence periphery as a whole is hot. The amount of a surplus radiation also increases with the geometrical height in the prominence which may be connected with the coronal temperature rise.

One of the open questions to be solved in prominence research is that of the proper nature of a prominence-corona transition region (PCTR). There is a generally accepted concept that quiescent prominences consist of cool threads or knots surrounded by a hot coronal plasma. A pair of prominence fine-structure models based on cool thin cylinders or slabs, surrounded by thin sheets, was tested by Orrall and Schmahl (1980). The idea of a two-component prominence model with a temperature rise towards the corona was proposed by Landman et al. (1977) to explain the profiles of Hα, Hβ, HeI D$_3$ and 10830 A, CaII and other emission lines. The wings of these prominence lines were found to be more intense than those


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Fig. 1  A comparison of an observed HeI 10830 A line profile (dashed) with the evaluated one (full). The dashed area α represents the hot plasma radiation excess in the 0.1 A gap range between the two main components of the triplet.

predicted from isothermal models. Heinzel et al. (1986) have made similar conclusions when interpreting profiles of the HeI 10830 A line triplet, obtained with the spectral and angular resolution higher than that of Landman (1976). Particularly an about 10% surplus radiation in 10830 A line wings couldn’t be explained in frame of a simple isothermal prominence model, and thus certain temperature rise in the PCTR has been supposed to explain this phenomenon. An investigation of such a surplus radiation in the wings of selected lines seems to provide some independent information about the character of PCTR (see Fig. 1).

On September 15, 1983 at 11.26 UT we obtained a series of photographic spectrograms of the HeI 10830 A triplet in a hedgerow-type quiescent prominence located on E-S limb. Data were taken with the Ondrejov HSFA-2 spectrograph using the Soviet infrared emulsion I-1060-V. The angular resolution was
restricted to 4" by a quality of the seeing, the exposure time was 2 minutes. We used 1" wide spectrograph slit. Subsequently, 10 equidistant scans of the spectrum have been recorded on the microphotometer, the distance of each two neighbouring scans being 4400 km. The microphotometer slit used was 32 x 210 μm, which is about 1/5 of the spectrograph slit width and 1.25" in height. Our spectral data were reduced for all components of the instrumental profile, scattered light and noise.

Center line optical thickness of the investigated prominence as derived from the ratio of peak intensities was found to be less than 1.0, in most cases even less than 0.5. Therefore, we can consider this prominence as optically thin even in the line center. Further we suppose that the radiation in the line core is emitted from the cool prominence plasma, while optically thinner line wings are formed inside the hot PCTR. Analysing the amount of the hot-component plasma radiation with respect to optical thickness of the cool central component, we expect to get some qualitatively new information about the character of the PCTR. Particularly we want to decide whether

I - the prominence consists of cool threads surrounded by thin hot plasma sheets, or if

II - the hot plasma component dominates on the prominence periphery only, not encompassing each thread.

Note that the first picture corresponds to models discussed at this conference by Vial et al. and Heinzel, while the second picture is related to the concept of a global transition between the prominence body and surrounding corona (see e.g. Vial, 1990).

In the first case we expect the hot plasma radiation to be proportional to the line-center optical thickness \( t^c \) derived from the cool plasma component. On the other hand in the case II we can't expect any such proportionality because an extra emission of the hot component should depend rather on the prominence shape than on the total thickness of its cool parts.
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Fig. 2 Dependence of $\alpha$ – the measure of a surplus radiation on the Doppler widths $\Delta \lambda_\alpha^C$ as derived from the central parts of HeI 10830 A profiles. The symbols + and $\times$ correspond to two different fitting procedures (see the text).

In our fitting procedure, we have supposed that the HeI 10830 A line core radiation was predominantly coming from cool parts of the prominence. Only the central parts of each line profile were used for an evaluation of one-component models based on an isothermal constant source function approximation according to Landman (1976) (see Fig. 1). Each model was characterized by its optical thickness $\tau_0^C$ and Doppler width $\Delta \lambda_D^C$ as derived from the cool component by an optimization procedure for the best fitting. Having matched the line cores, we have compared the calculated line profiles with the observed ones, particularly in line wings which have not been used for the fitting. The measure of intensity differences $\alpha$ (see Fig. 1) was considered as a representative indicator of the hot-component plasma radiation for every prominence scan. We defined $\alpha$ as the sum of differences of the measured and calculated profiles in the gap between the two peaks, within the range of 0.1 A.
Fig. 3 Optical thicknesses $\tau^c_0$ of the cool plasma component as derived from the central parts of each line profile. The numbers on the abscissa scale denote individual spectral scans. The distance of two neighbouring scans is 4400 km. The greater number corresponds to a higher location in the corona. Symbols + and $\times$ have the same meaning as in Fig. 2.

Variations of the parameter $\alpha$ versus calculated Doppler widths $\Delta^c_D$ are demonstrated in Fig. 2. Two different ranges of line core intensities were used to fit the line profiles. The first one corresponds to a mean value of FWHM (results are denoted by $+$), while the second one coincides with a mean $\Delta^c_D$ (results denoted by $\times$). A slight rise of $\tau^c_0$ with the relative height $h_r$ in the corona is obvious from Fig. 3. The higher scan in our prominence, the greater value of the optical thickness $\tau^c_0$ as derived from central parts of the HeI 10830 Å line.

In Fig. 4 we can see the dependence of the gap surplus radiation versus the optical thickness as derived from the cool component. An almost linear relation between $\alpha$ and $\tau^c_0$ appears for most of the measured profiles. Our data seem to favour the hypothesis in question that each cool prominence thread is surrounded by a hot plasma sheet, emission of which causes a surplus radiation in the line wings.
Fig. 4 Variation of $\alpha$ - the measure of a surplus radiation with optical thickness $\tau^c$ of a cool prominence component as derived from the HeI 10830 Å line core. For the meaning of + and × see Fig. 2.

The parameter $\alpha$ also increases with the relative height $h^c$ in the solar corona as displayed in Fig. 5. This may be understood in terms of the coronal temperature rise (see also the results of Engvold, 1990). Note that both $\Delta\lambda^c_D$ and FWHM fittings lead to similar results.

Generally speaking, our data seem to favour the first hypothesis mentioned above, which was also used in several other studies presented at this conference. The second model may correspond to that of Poland and Tandberg-Hanssen (1983), where temperature of threads increases towards the prominence periphery. However, there is also a third picture representing a combination of I and II: the temperature of threads increases towards the prominence boundary and moreover each thread exhibits its own hot sheet as considered in the first model. This kind of model may be consistent with our results if a global temperature rise towards the prominence periphery.
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Fig. 5 The measure of a surplus radiation in the wings varies for individual prominence scans. The higher scan in the prominence, the greater difference between the wings of the observed and evaluated HeI 10830 Å profiles. Symbols + and × have the same meaning as in Fig. 2.

is less important than the effect of hot sheets surrounding the individual threads.

References
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ANALIZA SPEKTRALNE LINIJE HeI 10830 A U JEDNOJ MIRNOJ
PROMINENCIJI

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izlaganje

Sažetak: Da bi objasnili pojačanu emisiju u krilima spektralne
linije HeI 10830 Å u prominencijama, Landman et al. (1977)
uevo su pojam postojanja nekoliko slojeva prominencija sa
dluzitim temperaturama i/ili turbulentnim brzinama. Naša
fotografska mjerenja profila te linije također pokazuju suvišak
zračenja koji se teško može objasnit izotermičkim modelom.
Pretpostavivši da zračenje iz središta linije potiče uglavnom
iz hladnijih dijelova prominencije, pokušali smo uskladiti
središnje intenzitete oba maksimuma linije HeI 10830 Å koris-
teci samo jednotemperaturne modele s optičkom debljinom \( T_0 \)
in središtu linije. kako se je količina suviška zračenja u kri-
lima linije povećava skoro linearno s \( T_0 \), zaključujemo da
nije sam rub prominencije vruć kao cjelina, već da su hladna
vlakna prominencije okružena vrućim opnama različite temepra-
ture. Količina suviška zračenja povećava se i s geometrijskom
visinom prominencije, što bi moglo biti povezano s porastom
temperature u koroni.

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