THE STRUCTURE OF THE LOWER SOLAR CHROMOSPHERE IN UNDISTURBED AND ACTIVE REGIONS

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As observational material in this work we used spectroheliograms taken with the Crimean solar tower telescope in K_{232} and Hα filtergrams taken with the chromospheric telescope in Simeis. The Hα birefringent filter was so adjusted, that by tuning the last polaroid we could take filtergrams in the centre of Hα or combined filtergrams in the two wings at H$\alpha \pm 0{\cdot}5$ Å. So the effect of Doppler shifts on image-brightness distribution was diminished. We compared the brightness distribution with that of spectroheliograms.

We also used the idea proposed by Thomas and Athay about the temperature jumps in the chromosphere. From our previous calculation it follows that such a thin boundary region in which temperature increases very rapidly would be connected

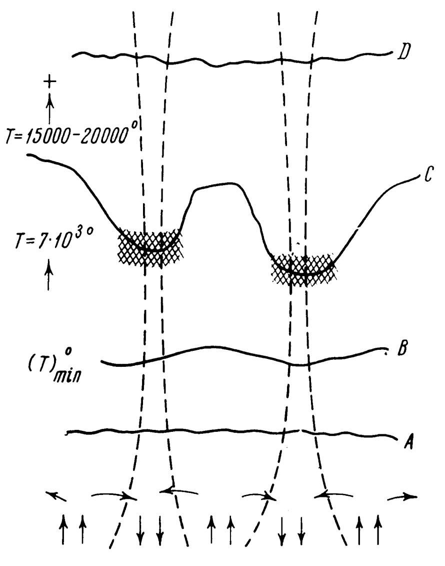

FIG. 1. *The structure of the undisturbed chromosphere. A – upper part of the convective zone, B – boundary between photosphere and chromosphere (level of temperature minimum), C – boundary between upper and lower chromosphere, D – transition to corona. The arrows indicate the matter movement. Dotted lines – magnetic lines of force. The regions bright in K* Ca II *line are dashed.*

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with hydrogen ionization in the chromosphere. We regard this boundary as dividing the chromosphere into two parts – the lower chromosphere, where the temperature rises to some 7000° (its height is about 1500–2000 km) and the higher one, where the temperature rises to about 15000°.

The picture seen on spectroheliograms and filtergrams in Hα (the chromospheric network) might be accounted for as a result of different height of this boundary upon the middle or upon the border of supergranules. So at some heights hot and cold chromospheric elements coexist. The change of height is caused by different amounts of mechanical energy supply, depending on differences in the strength of magnetic fields. This is seen in Figure 1.

In active regions on filtergrams taken in both Hα wings (Hα ± 0·5 Å) we may note three types of areas (Figure 2):

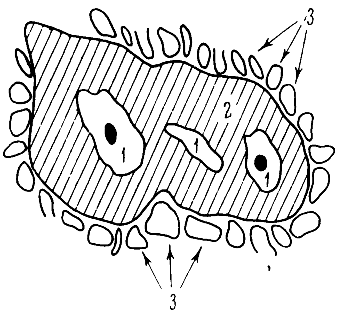

FIG. 2. *Schematic picture of an active region, observed in the Hα wings (Hα ± 0·5 Å). 1 – bright areas, 2 – dark areas, darker than dark elements of the undisturbed chromospheric network, 3 – areas more bright than bright elements of the undisturbed chromospheric network.*

(1) Bright areas near the spots. These flocculi are less extended than Hα flocculi seen in the line centre and therefore much less than K Ca II flocculi.

(2) The dark regions, darker than the dark elements of the chromospheric net. Their areas are somewhat larger than the flocculi areas in K Ca II and therefore much larger than flocculi in Hα centre.

(3) Finally, on these filtergrams, there are sometimes chains of rather bright elements surrounding the whole active region. I think they are similar to those dark features in K Ca II about which we had spoken during the first session.

So the active region seems to be larger in area when we take the solar image in Hα ± 0·5 Å.

The observed picture may be interpreted if we accept that, in an active region, the amount of non-thermal energy supply increases as fast as the magnetic field increases toward the spot, and, that by this reason, at the same time, the boundary between the upper and lower chromosphere is lowered.

We may see from Figure 3 what happens when we approach the spot from outside. Curve 3 on the plot is the magnetic-field strength H. The lower boundary of the lower chromosphere (physically this boundary is the minimum-temperature level where the energy supply by mechanical waves exceeds the energy absorption from the radiation field) is depressed towards the spot (curve 1). The behaviour of the upper boundary of the lower chromosphere is quite similar (curve 2). The Hα brightness (curve 4) (we see corresponding depth levels only in the Hα wings) enhances when the boundary is

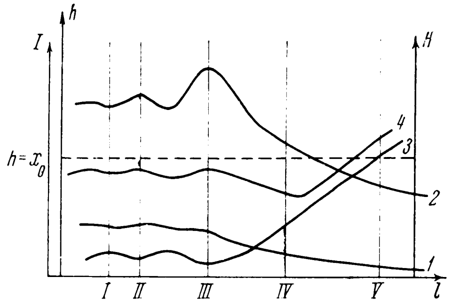

FIG. 3. *Position of lower and upper boundary of the lower chromosphere in different regions of the solar disk. 1 – lower boundary of the lower chromosphere, 2 – its upper boundary, 3 – magnetic-field strength, 4 – brightness of the chromosphere in Hα wings.*

Sections: I – dark element of the undisturbed chromospheric network, II – bright element of the undisturbed chromospheric network, III – border of the active region, IV and V – different places of the active region (still outside spots).

higher – because the Hα-emitting slice is then thicker. The upper chromosphere emits less in Hα, in spite of its high temperature. This is connected with strong deviations from LTE conditions. But as the boundary is lowered the higher chromosphere begins to emit an increasing fraction of the total enhanced Hα emission arising in the chromospheric flocculi. The sections are denoted on the plot as follows: I – the dark part of the chromospheric net (the border of supergranules, dark in Hα), II – the bright elements of the chromospheric net, III, IV, and V – sections through several parts of the active region, corresponding to the areas 3, 2, and 1 on Figure 2.

An investigation of the brightness distribution on magnificent spectroheliograms taken in Meudon by Professor D'Azambuja and kindly made available to me by courtesy of Dr. Michard, does not contradict to such a picture of the structure of the lower chromosphere. These spectroheliograms were taken in several parts of 4202 and 4388 Fe I, 4227 Ca II, 4078 Sr II and 5890 Na I spectral line profiles. Most of the brightness fluctuations on these spectroheliograms are caused by Doppler shifts. In most cases the material is ascending near the supergranule border (except for line 5890 Na I, which behaves conversely); it is sometimes ascending, sometimes descending in other parts of the supergranules.

Furthermore, the network best seen in the wings of metallic line spectroheliograms does not correspond to chromospheric but rather to photospheric levels. The same might be said about the bright areas in active regions – that is, they are photospheric faculae but not chromospheric events. This conclusion is confirmed by the observational fact noted by D'Azambuja, that the wavelengths of best visibility of these faculae are on different distances from spectral line centres – the stronger the line the more distant is the wavelength of best visibility from the line centre. The corresponding levels have an optical depth of about $\tau_{5000} = 0{\cdot}3$ where the faculae have their maximum-temperature excess over the surrounding photosphere. So we may observe the photospheric faculae in the disk centre if we use metallic-line spectroheliograms. It is the result of additional (selective) absorption in spectral lines that we cannot see the deeper and – as compared with their surroundings – colder photospheric regions of the faculae.

DISCUSSION

Acton: The preceding speakers have shown that many emissions appear to originate at physically higher levels over active regions. As I understand your last slide, your model predicts the opposite. Does this indicate a conflict between your model and observation or have I misunderstood your slide?

Dubov: I think that there is no contradiction. In active regions the upper boundary of the low chromosphere is at a lower level, and that only means that the temperature jump is at a lower level. Because in this case the upper chromosphere provides the major part of the total Hα emission of the chromosphere, and as the density gradient is small in active regions, we will observe that the whole Hα-chromosphere is optically thicker in active regions than in undisturbed ones.