# DIAGNOSTICS AND STRUCTURE

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The papers in this section discuss the structure of prominences and the diagnostic techniques used to evaluate their physical parameters. These include electron temperature, various densities ($n_p$, $n_e$, $n_h$), ionization degree, velocities, and magnetic field vector. UV and radio measurements have already evidenced the existence of different temperature regions, corresponding to different geometrical locations, e.g. the so called Prominence-Corona (P-C) interface. Velocity measurements are important for considering formation and mass balance of prominences but there are conflicting veolcity measurements which have led to the basic question: what structure is actually observed at a given wavelength; what averaging is performed within the projected slit area during the exposure time? In optically thick lines, the question of the formation region of the radiation along the line of sight is also not a trivial one. The same is true for low resolution measurements of the magnetic field. Although already reasonably well understood, we have made significant progress with the C.P.P. workshops. Coupling diagnostics with structure is now a general preoccupation as it reflects in the title of this section.

## I. TEMPERATURE DETERMINATION

New results are presented by Engvold and Brynildsen (1986) who used the Fourier Transform Spectrometer (Kitt Peak) to observe 3 prominences between 7740 and 14000Å. After a careful subtraction of the sky emission, Pachen lines are calibrated and provide directly the excitation temperature (8000 K). Line profiles of different ions or atoms help to separate the kinetic temperature T from the non-thermal veolcity V. T slightly increases from 6200 K (central region) to 7000 K (edge) and V remains around 6 km s$^{-1}$ with no edge variation.

Low temperatures are also obtained in radio wavelengths with some additional geometry information. Observations of Hiei et al. (1986) at 8.3 and 3.1 mm show that (radio) depression regions correspond to the position of magnetic field neutral lines but not always to Hα filaments (the reciprocal being always true). An Hα filament appears at a pre-existing depression channel, a phenomenon quite similar to the disparation brusque where the EUV flux remains after the total disappearance of the Hα filament. From the measured depression, the temperature is estimated at about 6600 K. The opacity at 8.3 mm (computed with an assumed electron density of $10^{10.5}$ cm$^{-3}$) is larger than 1, which makes possible radio observations at the limb.

## II. TRANSITION REGION (P-C)/ENERGY INPUT

At longer wavelengths, radio observations have been performed with the V.L.A., the resolution of which (2" at 15 GHz) is now rather competitive with optical instruments. Kundu (1986) reports brightness temperatures of $4.10^4$ K at 20 cm and $1.5 \; 10^4$ K at 6 cm, and depressions well correlated with Hα and He (10830 Å) filaments. The width of the radio depression is larger than the Hα filament but comparable to the He dark feature. Kundu concludes that the emission arises from the transition sheath surrounding the prominence. The modelling of the transition region indicates some pressure gradient. Similar features are shown by Gary (1986): depressions at 2, 6 and 20 cm, a good superposition with Hα filaments but structures appear larger at 6 and 20 cm than in Hα. Interestingly the 2 cm width is quite similar to the optical one and Gary notes bright "rims", about 2" (or less) wide, on each side of the filament. He concludes that it corresponds to the sheath between the cool and hot material, although footpoint emission is not discarded. Gary suggests a center to limb observational test.

In the UV, Skylab observations are revisited by Schmahl and Orrall (1986) who computed the differential emission measure from $10^4$ to $10^{6.4}$ K. They compare the observed low absorption in the Lyman continuum at high temperatures with the results of modelling sets of threads. They try 3 different geometries:

1) hot sheaths around cool cores
2) isothermal threads (a reference to Poland and Tandberg-Hanssen's SMM results, 1983)
3) threads with longitudinal temperature gradients along the magnetic field.

They find no solution with #2, and a rather improbable one with #1. Geometry #3 allows for a balance between radiative losses and conductive flux. The low absoprtion at high temperature is explained by the lower temperature gradient here, and the minimum of the Differential Emission Measure (DEM) around $10^5$ K is recovered for a coronal pressure of N.T $\sim 10^{14.2}$. However the strong absorption requires, either a gemoetrical explanation (such as a wrapping around cool cores of threads) or some non-LTE mechanism where emission is allowed from cooler regions.

The problem of the shape of the DEM between $10^{4.5}$ and $10^6$ K, in particular its commonality between the P-C and C-C interface, is attacked from a theoretical point of view by Rabin (1986). He recalls how classical models determined by thermal conduction along the magnetic field fail because the very thin transition region around T $\sim 10^{4.5}$ does not radiate enough to provide the (observed) increase of DEM toward lower temperatures. The cool "coronal" loops proposed by Antiochos and Noci (1986) are not compatible with the great vertical extension of prominences. Heating-cooling cycles, suggested by Athay (1984) for spicules, could work for prominences only if the heating function is carefully chosen and is remarkably similar in widely

different environments. The current-heating model of Rabin and Moore (1984) faces a similar question: why its proposed fine-scale electric currents should be present with comparable properties in prominences and in the chromosphere. In response to these difficulties, he advances the idea that the shape of the DEM can be produced by the combined action of longitudinal and transverse thermal conduction, even in the absence of internal heating, if the transition plasma is highly fragmented. The orthogonal conduction is also taken into account in the thermal equilibrium study of a 2 D structure by Demoulin et al. (1986). Here the energy input also includes some wave heating proportional to the density. Instability takes place for longitudinal length scales greater than about one arc minute. Orthogonal length scales smaller than 5 km enable the transverse conduction to stabilize the structure. Larger scales lead to an instability time of about $10^4$ s, comparable to the lifetime of prominences fine structure.

## III. DENSITIES AND IONIZATION DEGREE

These quantities were well established a few years ago (see Hirayama's review in the proceedings of the 1978 Oslo Colloquium): typical values of electron density (about $10^{10}$ to $10^{11}$ $cm^{-3}$) and ionization degree ($n_p/n_1 \sim 1$ to 3) were confirmed by Skylab, OSO 8 and eclipse results. Later on, they were questioned by Landman (1984): from the ratio of metallic lines (e.g. Mgb/SrII), he derived electron densities larger than $10^{11}$ $cm^{-3}$, ionization degree as low as 0.09 and (neutral) hydrogen densities as high as $4.5 \ 10^{12}$ $cm^{-3}$. Such values imply a very large amount of material (a prominence mass close to the corona's) and a $\beta$ ratio higher than 1. Hirayama (1986) compares Stark determinations of the electron density with measurements of MgI/SrII emissions. Contrary to Landman, he finds that electron densities range between $10^{10}$ and $10^{11.4}$ $cm^{-3}$ and the Mg/SrII ratio is independent of density. This point is crucial since massive prominences found by Landman (partly) resulted from high electron densities. Combining with the emission measure information, Hirayama derives an effective length of about 80 km and a filling factor of about 0.3. Thread diameters of, say, less than 300 km, spaced every 1000 km would have an ionization degree fixed by the full illumination of the Lyman continuum.

As shown above, emission measure and density determinations require a strong filamentation at low and high temperatures. However, any undisputable diagnostic must be established from the agreement of all possible observations. In this respect, the resonance UV lines, with their large range of formation "depths", seem appropriate although they need much care in their non-LTE treatment.

## IV. MODELLING

Heinzel et al. (1986) repeat the 1 D non-LTE computations of Heasley, Milkey and Mihalas (see Heasley and Mikley, 1983, and previous papers)

for the hydrogen atom, implementing new features such as the exact chromospheric incident line profiles and partial fequency redistribution (PRD). They find the usual wing lowering and also some frequency coherence in the near wings which explains why emergent prominence profiles mimic the incident ones (e.g. for Lα). A low pressure and density model fits the OSO 8 observed profiles quite well, except for the Lβ line (which requires more studies in redistribution and multidimentionality). In these computations, 5 atom levels are involved which demonstrates strong non-LTE interlocking. This is also well evidenced in the work of Heinzel and Romport (1986) who evaluate the influence of radial velocities on hydrogen lines in moving prominences. The Lα line shows a Doppler dimming (lower intensity) increasing with the velocity. On the contrary, Hα and Hβ have a Doppler brightening of about 3 peaking at velocities of 160 km s$^{-1}$. The Lβ line follows a complex behaviour. Such results, which apply for low density plasmas, may be used not only for transient phenomena but also for lower velocity structures such as loops. Permanent velocities are systematically studied in order to assess the mass, momentum and energy budgets and help to establish prominence models.


V. VELOCITIES AND MASS FLOW

Some contradiction has been found in the past between (apparent) downflows observed at the limb (Dunn's thesis, 1960) and upflows derived from Dopplershifts in Hα (Meudon Group, see for instance, Martres et al. 1981). Since then, more evidence has been accumulated for both flows in cool and hotter regions, as detected in C IV by the UVSP experiment on SMM. From HeI (10830Å) observations at Sac Peak, Engvold and Keil (1986) conclude that blue shifts dominate redshifts, the former reaching 3 km s$^{-1}$ in darkest areas, the latter being common in edges. They question the existence of such persistent flows on the basis of the insufficient spatial (and temporal) resolution which mixes different upward and downward structures. The already observed Hα and C IV blueshifts are confirmed by Simon et al. (1986) but they seem to be more systematic in an active region filament (between foot points) than in a quiescent one. Moreover, downflows (comparable in Hα and C IV) exist in the foot points of the active region filament. Simon et al. suggest a long magnetic rope rising while material drains at the foot points. 21 active region filaments have been studied also in C IV by Klimchuk (1986) with UVSP/SMM observations. A majority of them are associated primarily with relative blushifts, however local deviations exist and some filaments coincide with lines of apparent velocity reversal. Klimchuk discusses the problem of absolute velocity calibration in C IV Dopplergrams and proposes a procedure relying on velocities previously measured in quiet and active regions by Skylab, OSO 8, etc. His center to limb study leads to small velocity magnitudes (< 3 kms$^{-1}$) in filaments. Directions of flow are still uncertain.

Evidently, more studies are necessary and the UVSP/SMM database should be used extensively for center limb, quiescent/active/eruptive

filament comparisons. Thompson (1986) gives the key to this data base consisting of Dopplergrams, Rasters through the line and Profile Matrix observations. Certainly the addition of simultaneous ground based measurements will increase the interest of such studies.

In this respect, a sequence of simultaneous Hα and C IV observations of active region filaments has been analyzed by Schmieder et al. (1986). No significant power is found in Hα and C IV velocities around 200 s, except for regions identified as foot points where some oscillations in C IV exist, dominated by a systematic upward flow. The authors conclude that the enegy input is probably due to convective motions rather than pressure oscillations.

Velocities may also help to discriminate between possible models (KS, KR, Hiryama..) but magnetic fields are prime and necessary ingredient of these models.


## VI. MAGNETIC FIELD

Important recent progress has been achieved with the use of the Hanle effect ie. the depolarization by local magnetic field. Broad band polarimetry in D3 performed on 256 prominences at Pic du Midi by Leroy, Bommier and Sahal (see for instance, Leroy et al. 1984 and previous papers) has shown that the average field is horizontal, at an angle of about 20° with the filament axis and is lower than 30 G. From a statistical study, it appears that low altitude prominences have potential field (KS type) and high ones a non-potential field (KR). A review and a comparison with other Zeeman and Hanle (Sac Peak) measurements are given by Landi (1986). He shows how the polarization has been computed in an optically thick line such as Hα and how the use of thin and thick lines may help to solve the ambiguity in the direction of the magnetic vector. Simultaneous observations of circular and linear polarization in several spectral lines would be a significant step. Such an improvement is in progress with the computations of the hydrogen Hβ line (along with He D3) which are compared to previous observations (Bommier, 1986). When deoplarizing collisions with electrons are taken into account, not only the 3 coordinates of the magnetic field vector are unambiguously determined, but also the electron density can be derived. Out of 14 prominences, some 8 have a magnetic field significantly inclied to the horizontal plane. The electron density ranges from $10^9$ to $4.10^{10}$ cm$^{-3}$. Such a diagnostic, although difficult because of transfer problems, seems very promising.


## CONCLUSIONS

Since a complete review exists (Hiryama, 1985), we shall only discuss the results from these workshops. Although the observed range of temperatures probably reflects the range of situations in different prominences, mean values lower than 7000 K have been presented which may indicate the existence of thick structures. Such a tendency somewhat contradicts other

results concerning significant ionizaton degree and low densities.  All electron density determinations, for instance, are in the low range of values ($\leq 10^{11}$ cm$^{-3}$) as compared to Landman's higher values.  An agreement for low pressure around $10^{-1}$ dyn cm$^{-2}$ (and sometimes lower) was achieved through the different contributions.  With typical magnetic values of, say, 15G in prominences, we arrive at a picture where the noise gas pressure is lower in prominences than in the corona while the contrary stands for magnetic pressure.  Classical models that could take these features into account have been questioned in terms of geometrical structure.  Observed differential emission measures, velocitites and computed energy budgets certainly require some degree of material filamentation.  Much progress is occurring in transfer problems also (see e.g.  Fontenla and Rovira, 1985).  But such analysis should also rely on direct observations.  It is our feeling that such work should be supported by spectroscopic observations with a subarcsecond resolution (0.1"), necessary for velocity (and magnetic field ?) measurements, and a good temporal resoluton.  Perhaps very high resolution images coupled with lower resolution spectroscopy in many different lines would be a first realistic step.  Such an effort is certainly worthwhile in view of the important progress evidenced by these workshops.

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