Participants:

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WG Report 1/2:

Prominence Diagnostics by Optically Thin Lines (Summary)

Daniele Spadaro

During the session of WG1 devoted to optically thin lines two papers recently accepted were presented and discussed:

1. 'Joint EUV and Radio Observations of a Filament'

F. Chiuderi Drago, T. Bastian, C.E. Alissandrakis,
K Bocchialini, R. Harrison (Solar Phys., in press)

Observational results:

1) The Filament (F)is not visible in all SUMER lines at $\lambda > 912 \AA$
2) The Filament is seen as a dark region in all CDS lines, in SUMER lines of NeVIII at 770 and 780 $\AA$ and at all Radio wavelengths

Point 1) indicates that NO T.R. EXISTS above the Filament (otherwise F should appear brighter). This result is also confirmed by Radio data. (A week TR emission is instead usually observed on limb prominences.)

Point 2) indicates that, for TR lines, the 'darkness' is due to the Ly-cont absorption of the underneath CCTR radiation when passing through the cold matter of the F.

This is confirmed by a good linear fit of $-\ln(I_{fil}/I_{QS})$ vs λ^3

The neutral H column density, C, is then derived.

>From C and assuming a filamentary structure with H_α cilinders of radius r ~ 200 Km and length l>> r, the H density in the thereads and the cold matter filling factor are derived:

$N(H) \sim 2\ 10^{10}$ $f_c \sim 2\ 10^{-2}$
(uncertainties of about 50% affect these data)

3) Coronal lines and Radio: the 'darkness' is due to the lack of coronal emission in the volume occupied by colder matter.

Radio (high optical depth) supplies only the total height of F.
Coronal lines suply the missing hot matter volume $V_m = V(T<10^6)$

Results: $V_m/V_F < 1$ => the interthread gas must be cold.

$V_m/V_F \gg f_c$ => presence of a TR around each thread: TR thickness $Dr \sim 700$ Km

In this framework the difference between top and side TR is due to the view angle of the threads: at the TOP we see them terpendicularly: Dh (l.o.s)=Dr
on the side Dh (l.o.s)=Dr/cos(theta)

theta is the angle between the l.o.s. and l, which is parallet to B.

Similar results were derived also by P. Heinzel from He line profiles.

2. 'EUV Transition Region Line Emission during the Dynamic Formation of Prominence Condensations'

Lanza A.F., Spadaro D., Lanzafame A.C., Antiochos S.K., MacNeice P.J., Spicer D.S., O'Mullane M.G.

(Ap. J., in press)

The authors calculated the emission expected in EUV transition region lines during the process of dynamic formation of prominence condensations in coronal loops, as predicted by the thermal non-equilibrium model of Antiochos et al. (1999, 2000). They selected some lines emitted by ions of carbon and oxygen, because they are among the most intense and representative in the temperature range corresponding to the solar transition region. The ionization balance was computed in detail and the deviations from the ionization equilibrium caused by plasma flows and variations of temperature and density are accounted for. The atomic physics was treated using the latest atomic coefficients and the collsional-radiative theory approach, as implemented in the ADAS package.

The carbon and oxygen lines synthesized from the hydrodynamic model at different times during the loop evolution exhibit a behavior significantly dependent on the variations of the plasma parameters inside the magnetic flux tube and therefore are suitable observational signatures of the processes giving rise to prominence condensations. In particular, a sizeable increase of line intensity as well as small blueshifts are expected from the loop footpoints during the first part of the evaporation phase that fills the loop with the material which subsequently condenses into the prominence. Once the condensation appears, line intensities decrease in the footpoints and simultaneously increase at the transition regions between the cool plasma of the condensation and the coronal portion of the loop. Line shifts are quite small for the adopted symmetric model, and during most of the condensation's lifetime, the nonthermal widths are relatively small. These results can be compared with detailed ultraviolet observations of filament/prominence regions obtained by recent space missions in order to test the model proposed for the formation of solar prominences.

Two works in progress were also presented:

1. Daniela Cirigliano discussed the modeling of the line profiles of metallic elements expected in quiescent prominences with macroscopic velocities. Considering several configurations of mass flux through the slab describing a prominence, she and co-workers deduced the optical depth, the source function and the profile of the lines of C II, C IV and O IV for inflows, outflows and passing flows. The populations of the different states of ionization were defined resolving the ionization equations for each atom adopting the relevant parameters describing the prominence plasma.
The shape of the profiles, as well as the Doppler shift, and the intensities of the lines calculated for different mass fluxes give a useful set of theoretical values characterizing the studied lines for a quantitative comparison between models and observations.

2. Vincenzo Andretta and co-workers proposed to use measurements of the EUV continuum absorption as a diagnostic tool to estimate the mass of the plasma confined in prominences, a key issue in several models describing the formation and the structure of solar prominences.
In fact, they pointed out that the wide wavelength coverage in the EUV range of

SOHO coronal instruments has made possible reliable diagnostics from continuum absorption measurement of coronal radiation by relatively cool prominence plasma.
Taking into account the wavelength dependence of the coefficient of absorption due to the ionization of neutral hydrogen and helium, the relative depletion of several coronal lines at different wavelenghts below 912 A can give therefore a good estimate of the column density of the cool absorbing material inside the prominence.

WG Report 2/2:

Working Group 1 (WG1) dealt with the spectroscopic diagnostics of prominences, both quiescent and eruptive.

Group leaders: Petr Heinzel (Ondrejov)
Daniele Spadaro (Catania)

Report by Petr Heinzel:

WG1 discussed the diagnostic of prominences in a wide range of wavelengths, from EUV to radio. Optically-thin emission was the subject of several contributions and this is summarized by D. Spadaro in his report. Other contributions mainly devoted to optically-thick diagnostic which requires non-LTE radiative transfer are reported here. SOHO contribution to this research is also mentioned.

Optically-thick diagnostic is important for central (cooler) parts of prominences or their fine structures and for the base of the prominence-corona transition region (PCTR). However, many thin transitions must also be considered due to coupling in multilevel atoms (but thin lines reported by D. Spadaro are formed in hotter or very hot parts of PCTR).

Three basic questions were addressed at the beginning of the workshop:

1. How SOHO (UV) and GBO (Ground-based observations, optical and IR) can help us to distinguish between various models of:
- fine structure
- PCTR
- flows (dynamics) ?

2. How spectral diagnostics and non-LTE modelling can help us to understand the energy balance in prominences ?

3. How can we determine the fine structure of the prominence magnetic field ?

All these items and questions were thoroughly discussed during the WG1 sessions and during some plenary sessions.

Summary of WG1 presentations mostly related to thick lines:

B. Schmieder (P. Heinzel, J.-C. Vial):
``SOHO/SUMER observations of the hydrogen Lyman spectrum in solar prominences''

The Lyman series plus the 907 A Lyman continuum were observed in several prominences by SUMER/SOHO in 1999. At least three classes of line profiles were recognized in different objects (not mentioning the Lyman-alpha which is affected by the SUMER attenuator): high-intensity emission profiles without self-reversal, strongly reversed profiles with similar intensity, and profiles showing a large asymmetry. Therefore, no 'canonical' Lyman spectrum can be considered for modelling purposes. Also within a given object, a large variability of intensities and profile shapes can be found. In contrast, filaments always show a rather strong reversal in all Lyman lines and this can be understood in terms of a relatively thin PCTR (seems to be consistent with results presented by F. Drago).

P. Heinzel (B. Schmieder, J.-C. Vial, U. Anzer):
``Non-LTE analysis of hydrogen Lyman lines''

Results of extensive non-LTE modelling of prominences in magnetohydrostatic equilibrium (fine-structure magnetic dips) and with PCTR were shown. Depending on the orientation of the field lines with respect to the l.o.s., one can construct models which give Lyman line synthetic intensities quite comparable to those observed by SUMER. The non-LTE code is based on MALI (Multilevel Accelerated Lambda Iteration) technique in 1D, 12-levels plus continuum hydrogen model atom with partial redistribution in L-alpha and L-beta. Extension to 2D is currently in progress (Heinzel and Anzer).

M.S. Madjarska (J.G. Doyle, K. Bocchialini, J.-C. Vial):
``Plasma diagnostics of quiescent solar prominences observed by SUMER and CDS on board SOHO''

Temporal series of prominence observations in optically-thin lines were analyzed in order to study Doppler velocities and electron densities in the PCTR. Densities of 7.6×10^9 cm^{-3} were derived, at temperatures of 1.7×10^5 K. Particular attention was devoted to the blending of the second-order O III with the lines belonging to the O IV multiplet. The problem of CDS/SUMER co-alignment was also discussed.

F. Paletou (A. Lopez Aristide, V. Bommier, M. Semel):
``Full Stokes spetropolarimetry of prominences with THEMIS''

F. Paletou presented the first results of prominence full Stokes spectropolarimetry with THEMIS. In June 2000, several prominences were observed in HeI D_3 and in H-alpha lines. The level of scattered light seems to be rather low, which was clearly seen in Stokes profiles. However, in order to get reasonable values of the magnetic-field intensity (using the polarization diagrams), one has to sacrifice either spatial or temporal resolution (or perhaps both), which were rather good (0.4'', 30 sec).
The preliminary B-intensity derived for one particular prominence was 30 Gauss, with uncertainty around 10 Gauss. The level of linear polarization was around 2 %. As a next step, full Stokes profiles will be used to determine B.

Impressive V variations were shown.

Although the spatial resolution of these first measurements is more than one order of magnitude higher than previously achieved by J.-L. Leroy, the derivation of the full B-vector (using two lines) at such resolution is not straightforward. Rather the spatial and temporal averaging is necessary at the moment and this certainly mixes structures and their evolutionary stages (A. Title).

D. Cirigliano (M. Rovira, P. Mauas):
``Different models of solar prominences''

1D multislab non-LTE prominence models were presented with the aim of synthetizing spectra of various species (HI, HeI, CaII and MgII). The models take into account the energy balance (including the ambipolar diffusion - AD) and flows. The transfer in hydrogen lines is computed with complete redistribution. AD models of threads lead to L-beta intensities (recomputed with PRD) much larger than currently observed by SUMER. The threads probably need some extra heating in central parts, otherwise they are very narrow.

P. Gouttebroze (P. Heinzel, J.-C. Vial):
``About pressure diagnostics based on calcium lines''

For gas pressures lower than 0.1 dyn/cm^2, Milkey and Heasley (1978) had shown the importance of the line ratio E(CaII 8542)/ E(H-beta) for pressure diagnostics. In order to extend the pressure range to larger values, new non-LTE computations were made with the IAS prominence code. Several preliminary results have been reported:

- new calculations for lower pressures are not fully consistent with those of HM78, the reason probably lies in rather different incident intensities (new values were tabulated by Gorshkov et al.);
- the line ratio seems to depend on the geometrical thickness;
- for higher pressures, a strong temperature dependence is evident.

The work is now in progress to establish the real usefulness of this line ratio for the gas-pressure diagnostics and to provide the basis for analysis of new high-resolution H-alpha, H-beta and CaII 8542 A data being available from THEMIS and VTT.

K. Tziotziou (P. Heinzel, P. Mein, N. Mein):
``Non-LTE inversion of chromospheric CaII cloud-like features (application to filaments)''

R. Molowny et al. have developed a non-LTE inversion technique for analysis of high-resolution MSDP H-alpha observations of filaments (and other cloud-like features). This is now extended to CaII 8542 A diagnostics. More than 10 thousand models were computed in order to construct a multidimensional grid which is then used to fit the observed profiles. However, since the formation depths of H-alpha and Ca 8542 A lines are somewhat different within the filament, the spatial distributions of individual parameters derived from the two lines also differ to a certain extent. A question was raised whether this kind of inversion can confirm the picture of filament counterflows (using MSDP time series in H-alpha or the 8542 line).

S. Regnier:
``Filament oscillations observed by SOHO''

The HeI line 584 A observed by SUMER was used to study filament oscillations. With a temporal resolution of 30 sec and using the solar-rotation tracking, oscillation periods were found in the range 3 min 36 sec - 89 min 36 sec. Using the model of Joarder and Roberts for MHD oscillations and with the observed oscillatory pattern, it is possible to derive several prominence parameters like temperature, geometrical extension and magnetic field.

N. Labrosse (P. Gouttebroze):
``Formation of helium lines in prominences''

A systematic modelling of helium line formation was started at IAS. First results concern the isobaric-isothermal 1D-slab models. The aim is to make a comparison with previous models of Heasley, Milkey and collaborators. Moreover, several lines which can be detected by SOHO were also computed. The next step is to extend this modelling to cases with PCTR and compare the synthetic profiles with SUMER/CDS prominence observations (already exisitng).

P. Heinzel (U. Anzer):
``Energy balance and flows in quiescent prominences''

Radiation losses in central cool parts of prominence structures are too high to be easily compensated by known types of the heating. These losses were computed for typical prominence temperatures 6500 - 8000 K, which are much higher than the radiation-equilibrium temperature (below 5000 K). It was suggested that for some prominences the inflows, if they exist, can cary enough enthalpy and ionization energy which can be dissipated in the central parts.

S. Koutchmy:
``Simultaneous H-alpha and HeII 304 A (EIT)
prominence observations''

Coronagraphic images in H-alpha and exactly co-aligned images in HeII 304 A from SOHO/EIT show significant differences in structural patterns of the limb emission features. The importance of instrumental effects was broadly discussed. Since HeII is formed at much higher temperatures, extension of its emission indicates a PCTR.

J.-C. Vial (C. Gontikakis, P. Gouttebroze):
``Lyman line diagnostics of eruptive prominences''

Eruptive prominences having large velocities in the plane of sky show-up important Doppler dimming in the hydrogen L-alpha line and a combination of Doppler brightening/dimming in L-beta (H-alpha is dominated by the brightening). Moreover, L-alpha exhibits a profile asymmetry which is due to the scattering of the Doppler-shifted incident radiation. However, this mechanism works only when the proper partial-redistribution treatment is used (with complete redistribution the L-alpha is symmetrical). The effect is much less important for L-beta. With proper calibration of L-alpha (problems with the attenuator), one could use the SUMER observations for velocity diagnostic of eruptive events.

Summary:
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Together with WG2, problems of the flows and fine-structure were extensively discussed. Future work should concentrate on two basic concepts: magnetic dips filled by plasma (inflows are expected to form condensations - WG3) and thin fluxtubes (seen as horizontal threads on the disk) with observed counterflows. Energy-balance studies, based on high-resolution spectral data and sophisticated non-LTE (2D, 3D) modelling can help to disentangle these pictures. Also high-resolution determinations of the B-vector would significantly contribute to this debate.

Indirectly, the presence of magnetic dips filled by cool plasma can be deduced from observational determination of the beta-parameter. This requires accurate diagnostics of the gas pressure in cool parts (e.g. from H-beta/CaII 8542 ratios) and determination of the horizontal B-component (THEMIS). Note that for beta=1 the dip field lines will be inclined by 45 deg ! Each type of models will also have a qualitatively different PCTR and this can be diagnosed using extensive data from SOHO and other instruments. However, one needs to develop various sophisticated inversion (optimization) techniques for spectral diagnostics; simple trial-and-error methods are hopeless when dealing with more than one line ! One has also to keep in mind that the spectral diagnostics is in most cases model-dependent and thus simple structural models can lead to quite misleading results. We need more MHD incorporated into detailed non-LTE modelling, including flows and temporal variations. Consistent determination of flow velocities (cloud models for filaments are needed) and mass contained in threads is a challenging diagnostic problem.