Report on the results of the STSM

i. Purpose of the STSM

The collaboration of Dr. Jiri Stepan (AIAS) with Prof. Javier Trujillo Bueno (IAC) and Dr. Luca Belluzzi (IAC) started during the post-doctoral stay of JS at IAC. One of the main results of this collaboration was development of a general numerical radiative transfer code capable of selfconsistent solution of three-dimensional non-LTE radiative transfer with multilevel atoms in the spectral lines including polarization state of the radiation and accounting for all the relevant processes involved in the line formation (optical pumping, atomic polarization, collisions, Hanle efect, ...). This code is capable of solving the non-LTE polarization transfer problem in state-of-the-art magnetohydrodynamical (MHD) simulation snapshots of the solar atmosphere, which are becoming realistic enough to justify comparisons between calculated and observed Stokes profiles. The purpose of the STSM was to extend the collaboration described above by implementing new capabilities into the radiative transfer code, namely the coherency effects in photon scattering in the spectral line wings, and by applying it to realistic MHD models of the solar atmosphere.

ii. Description of the work carried out during the STSM

We have implemented the multilevel atomic model of the Ca II ion, capable of treatment of atomic polarization, into our 3-dimensional radiative transfer code. The two particular cases have been considered:

1) The three-level atomic model including the UV lines H and K. In this atomic model, we have succeeded in incorporation of the effects of partial frequency redistribution in the spectral line wings, taking into account quantum coherence between the upper levels of the doublet according to the meta-levels theory of Landi Degl'Innocenti et al. (1997).

2) A five-level atomic model including the H and K resonant lines and the subordinary lines of the infrared triplet of Ca II has been implemented into our code according to the complete-redistribution theory of spectral line polarization.

The creation of the above models required collection of atomic and collisional data, development of a new software module optimized for three-dimensional solution of the non-LTE problem of calcium, and an analysis of the 3D MHD snapshots provided by the group of the Oslo University.

iii. Description of the main results obtained

The numerical tools developed within the STSM have been carefully tested. First, for the case of the semi-empirical one-dimensional model of the solar atmosphere by Fontenla et al., (1993). Secondly, for synthesis of spectra in a realistic three-dimensional MHD model of the quiet solar atmosphere. The results of the STSM are twofold:

1) The radiative transfer of the wings of the H and K lines of Ca II have been treated in the limit of coherent scattering in the laboratory rest frame, which is suitable for modeling the far wings of the line. Our results show that the spatially averaged spectrum of the lines is similar to the emergent spectrum of the one-dimensional semi-empirical model. However, significant departure from the 1D solution is found if the spatial resolution of the observation improves. As the spatial resolution becomes comparable to the typical size of the horizontal thermal inhomogeneities of the atmospheric plasmas, polarization signals due to the so-called 3D symmetry breaking effects do appear. We have found that the amplitude of such signals, which may provide us with valuable information on thermal structure of the solar atmosphere, increases with resolution of the

observation and it sensitively depends on the wavelength in the spectral line wing.

2) We have implemented the 5-level model of Ca II ion capable of treatment of the multilevel polarized radiative transfer problem in the limit of complete frequency redistribution. Such approximation is suitable for modeling intensity and polarization in the core of the spectral lines and provide us with useful information on the thermal structure of the solar chromosphere and its magnetization. An application of this model will be carried out in the frame of our near-future collaboration.

iv. Future collaboration with host institution

The collaboration carried out during the STSM has lead to new insights into the problem of formation of the polarized spectral lines and the role of symmetry breaking effects in the atmosphere. Apart from the new results, new questions emerged from this work. In particular, what is the role of symmetry breaking effects in formation of the infrared triplet of calcium in the 3D medium and how to implement the PRD effects in a more complicated redistribution schemes applicable in the formation of the transition-region lines such as Lyman-alpha lines of hydrogen and He II. These issues will be addressed in detail in our future collaboration.

v. Foreseen publications resulting from the STSM

The results of the STSM collaboration will be published in refereed journals and presented in international conferences.

vi. Confirmation by the host institution of the successful execution of the STSM

The host institution (Instituto de Astrofisica de Canarias), represented by the undersigned Prof. Javier Trujillo Bueno, confirms that the STSM has been successful and led to new scientific advances and improvements in collaboration between the involved subjects.

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