REFEREE REPORT OF PROF. JAVIER TRUJILLO BUENO ON THE THESIS

POLARIZED RADIATIVE TRANSFER IN SOLAR ATMOSPHERE
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Polarized light provides the most reliable source of information at our disposal for the remote sensing of the physical properties of astrophysical plasmas, including the magnetic fields of the extended solar atmosphere (photosphere, chromosphere and corona). In particular, in the atmospheres of the Sun and of other stars the physical mechanisms that control the polarization of the emergent spectral line radiation are the Zeeman effect, atomic level polarization and the Hanle effect.

The solar and stellar physics communities are indeed very familiarized with the polarization of the Zeeman effect as a diagnostic tool. Afterall, the mere detection of polarization induced by the Zeeman effect implies the presence of a magnetic field. However, the polarization of the Zeeman effect is of limited practical interest for the determination of magnetic fields in chromospheric and coronal plasmas because the Zeeman polarization scales with the ratio between the Zeeman splitting and the Doppler-broadened line width. Another serious disadvantage is that the Zeeman effect polarization is blind to magnetic fields that are tangled on scales too small to be resolved.

The Hanle effect modifies the atomic level polarization (population imbalances and quantum coherences) that anisotropic pumping processes induce in the atomic levels, and this modification gives rise to observable signatures in the polarization of the emergent spectral line radiation. Interestingly, the Hanle effect is especially sensitive to magnetic fields for which the Zeeman splitting is comparable to the natural width of the upper (or lower) level of the spectral line used, regardless of how large the line width due to Doppler broadening is. It is therefore sensitive to weaker magnetic fields than the Zeeman effect: from at least 1 mG to hundreds of gauss. Moreover, the Hanle effect is sensitive to the presence of hidden, mixed-polarity magnetic fields at sub-resolution scales. Unfortunately, in spite of these very good news, only a relatively small number of astrophysicists have experience with the physics and with the radiative transfer modeling of the spectral line polarization that results from the atomic level polarization and its modification through the Hanle effect.

On the one hand, some of such scientists developed in the eighties the quantum theory of spectral line polarization, which provides the (complicated) equations that govern the generation of the spectral line polarization produced by the joint action of the Hanle and Zeeman effects in optically thick plasmas. Such equations are the statistical equilibrium equations for the multipolar components of the atomic density matrix and the transfer equations for the Stokes parameters of the radiation beam under consideration. On the other hand, about ten years ago some other scientists developed powerful iterative methods and formal solvers of the Stokes-vector transfer equation for the numerical solution of the above-mentioned equations (i.e., the so-called non-LTE problem of the 2nd kind). Several successful applications with the computer programs that they developed, aimed at interpreting some of the enigmatic signals of the linearly-polarized solar limb spectrum (i.e., of the so-called second solar spectrum), have reinforced the conviction that the observation and modeling of the spectral line polarization produced by the joint action of atomic level polarization and the Hanle and Zeeman effects might lead to a new revolution in our empirical understanding of solar magnetism. To this end, two things are crucial: (1) that the design of any future solar telescope incorporates the scientific case of the spectral line polarization that results from the joint action of the Hanle and Zeeman effects and (2) that rigorous but increasingly efficient radiative transfer diagnostic tools are developed for the physical interpretation of such polarization signatures.

In this respect, the PhD thesis work of Mr. Stepán is very much welcomed because it makes a very significant contribution to the second research area mentioned above. From a careful reading of his thesis one realizes immediately that Mr. Stepán has been able to reach a very good understanding of the quantum theory of the spectral line polarization and of the numerical methods that were developed for the solution of the non-LTE problem of the 2nd kind. With such a know-how he has then developed a sophisticated radiative transfer computer program, which allows him to model the spectral line polarization that results from the joint action of the Hanle and Zeeman effects in one-dimensional models of the solar atmosphere. Moreover, he has successfully applied his computer program to a rather complicated radiative transfer problem: the calculation of the linear polarization of the H-alpha line taking into account the atomic level polarization that is induced by the joint action of anisotropic radiative pumping and by directional beams of protons. From his model calculations he finds that impact polarization does not seem to play any significant role on the linear polarization of the H-alpha line in solar flares, and that the emergent linear polarization turns out to be dominated by anisotropic radiative pumping processes. He also finds that the calculated fractional linear polarization amplitudes are far below the 5% value that some observers found when observing solar flares using standard polarimeters, but in agreement with the recent observational results of another group who used instead a novel polarimeter based on the concept of extremely fast modulation. This is an important result.

For all these reasons I consider his PhD thesis as exceptional, and that it deserves to be defended to obtain the doctoral degree.

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