STSM Report

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Abstract

Within this project we have been developing a tool to study and quantify the contributions to polarization in the solar continuum radiation. Starting from "state-of-the-art" 3D hydrodynamic models of the solar atmosphere computed at the Swiss National Supercomputing Centre, I plan to carry on radiation transfer calculations through these models taking into account different contributions to polarized light and hence evaluate quantitatively but from an empirical point of view which are the dominant contributions to polarization in the solar continuum radiation at each wavelength range.

The radiation transfer equations are solved using the PORTA code, which now allows continuum polarization calculations, and provides a powerful development framework to extend such calculations.

1 Details of the project

The main developer of the PORTA code [1] is Jiří Štěpán, who is working at the Astronomical Institute of the Academy of Sciences of the Czech Republic, in Ondřejov (near Prague). The aim of this application was to request travel support for a collaboration within the framework of this project. This visit lead to the development of a new module for the PORTA code, allowing for full 3D polarized radiation transfer in the continuum, as was planned.

This module is now being used in combination with the magnetohydrodynamic models of the solar atmosphere we have computed to generate highly realistic spectra of the continuum polarized radiation.

2 Development of a continuum module for the PORTA code

The emerging polarized solar spectrum is modulated by a few physical processes involving a large amount of chemical elements. It can be thought as the superposition of lines on a flatter continuum. The major physical processes contributing to the *polarized* continuum in the visible are Rayleigh scattering at neutral Hydrogen in the ground state (Lyman scattering) and Thomson scattering at free electrons [2], but one might expect other potential contributions, such as Rayleigh scattering at Hydrogen on excited levels, Rayleigh scattering on Helium and other atoms, photoionization processes on atoms or molecules, inverse bremsstrahlung, etc.

Moreover, it is now known that 3D modeling is in far better agreement with semi-empirical determinations of the polarized spectrum than 1D-modeling [3]. The 3D geometry of the model can therefore also be thought as a "contribution" to the emergent spectrum, and it provides extra free parameters in the generation of polarized spectra.

During my stay at Ondřejov observatory we developed a module for the PORTA code, which now allows us to perform polarized RT in the continuum. In its present form, the module allows to reproduce the results published in paper [3], and it also permits to incorporate in an easy manner other physical processes, in order to estimate their contribution to the emerging spectra. The module has also been fully tested with a FALC model (a plane-parallel model reproducing the stratified solar atmosphere).

Moreover during this stay I was able to exchange new ideas with Jiří Štěpán and learned the main functionality of the PORTA library, so that I can now use and extend the program with relative ease.

The computation of full 3D non-LTE radiation transfer (RT) from a model atmosphere is a considerable task, even for the biggest supercomputers available. For this reason, having now access to a flexible 3D code like PORTA and been able to use it in the framework of my PhD thesis is an important step forward.

3 Further developments

Most well-known physical effects contributing to the formation of the polarized solar continuum have already been included in the new PORTA module during this visit. Other effects, specially in the near-UV, like photoionizations from a polarized ground level, require further theoretical developments that are held in other parallel projects and that could, in a later step, be also included in this PORTA module.

I also have high-resolution radiative (M)HD simulations from which I can now compute radiative transfer using the PORTA code. We plan to carry on center-to-limb RT calculations to produce polarization maps, that will be further used to compare emerging spectra of different simulations (magnetic versus non-magnetic, high resolution versus low resolution), and also simply for visualization purposes.

References

[1] J. Štěpán and J. Trujillo Bueno. PORTA: A three-dimensional multilevel radiative transfer code for modeling the intensity and polarization of spectral lines with massively parallel computers. *A&A*, 557:A143, September 2013.

[2] J. O. Stenflo. Polarization of the Sun's continuous spectrum. *A&A*, 429:713–730, January 2005.

[3] J. Trujillo Bueno and N. Shchukina. Three-dimensional Radiative Transfer Modeling of the Polarization of the Sun's Continuous Spectrum. *Astrophys.J.*, 694:1364–1378, 2009.