MANCHA-RAY: 3D PARALLEL CODE FOR SPECTRAL SYNTHESIS FROM RMHD SIMULATIONS OF THE STELLAR ATMOSPHERES

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The radiative transfer equation (RTE) is of critical importance in modern studies of the solar near-surface convection and atmosphere. In the realistic 3D radiative-magnetohydrodynamical simulations RTE is primarily used to compute the time-dependent net radiative energy exchange that appears as a term in the energy equation. To reduce the computational expenses RTE is usually solved for a small number of rays and small number of statistically representative opacity bins. On the other hand, comparison between the simulation results and the high-resolution solar observations requires fast and accurate detailed synthesis of polarized spectral lines. Numerical codes used for modelling the atmosphere and for the spectral synthesis are usually written by different groups causing not only various inconsistencies in the physical method and its numerical implementation, but also a waste in computing time, storage and memory space due to different input-output formats and computational strategies.

MANCHA is a state-of-art numerical code for comprehensive simulations of the solar atmosphere developed by our group. The code solves the system of the MHD equations including the non-ideal effects present in partially ionized plasma (ambipolar and Ohmic diffusion, Hall effect, Biermann battery term), a realistic equation of state and radiative transfer solver based on the short-characteristics method for ray tracing.

Here we present MANCHA-RAY, a fork project of the main MANCHA code, designed for detailed spectral synthesis. The two codes share the parallelization strategy using distributed memory and domain decomposition in 3D. They also share modules for parallel and efficient input/output in the HDF5 file format. MANCHA-RAY solves 3D polarized RTE for a given set of atomic or molecular lines. Solvers based both on long- and short-characteristics are supported. The long-characteriscs are implemented using several different interpolation schemes (cubic splines, monotonic splines, FFT shifting theorem). The results of the short- and long-characteriscs are compared and the numerical diffusion of the two schemes is evaluated. The code is subjected to a number of validation tests that it completes with good results (coherent scattering, LTE synthesis of polarized with and without the hyperfine structure, and of unpolarized molecular band). MANCHA-RAY shows near linear efficiency scaling to thousands of computing cores.

Its computational efficiency makes MANCHA-RAY already suitable for massive computations of the spectral lines that will be needed in the coming era of the solar 4-m telescopes DKIST and EST.

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