MANCHA: a non-ideal MHD code for realistic simulations of the solar atmosphere.

First public release

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The MANCHA code was originally developed in 2004-2006 by Elena Khomenko and Manolo Collados to study wave dynamics in sunspots.

“Mancha solar” stands for “Sunspot” in Spanish Multi (purpose/physics/fluids/dimensional) Advanced Non-ideal Code for High-resolution simulation of the solar Atmosphere

- Solves non-linear non-ideal MHD equations for perturbations in 3D;
- Magneto-static equilibrium is explicitly removed from the equations;
- Radiative energy losses assuming LTE;
- Realistic equation of state for solar chemical mixture;
- 4th order in space and time;
- Parallel input/output with HDF5 files format;
- MPI parallelized using domain decomposition in all directions
Equations, physics

\[ \begin{align*}
\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) &= \left( \frac{\partial \rho}{\partial t} \right)_{\text{diff}} \\
\frac{\partial \rho \mathbf{u}}{\partial t} + \nabla \cdot \left[ \rho \mathbf{u} \mathbf{u} + \left( p + \frac{B^2}{2\mu_0} \right) I - \frac{BB}{\mu_0} \mathbf{u} \mathbf{u} \right] &= \rho \mathbf{g} + S(t) + \left( \frac{\partial \rho \mathbf{u}}{\partial t} \right)_{\text{diff}} \\
\frac{\partial \mathbf{e}}{\partial t} + \nabla \cdot \left[ \mathbf{u} \left( e + p + \frac{B^2}{2\mu_0} \right) - \frac{B \mathbf{u} \cdot \mathbf{B}}{\mu_0} + \left( \frac{\eta_A + \eta_H}{e_n e \mu_0} \right) J \times \mathbf{B} + \nabla \left( \frac{p_e B}{e_n e \mu_0} \right) \mathbf{B} \right] &= \left( \frac{\rho \mathbf{g} + S(t)}{\mu_0} \right) \cdot \mathbf{u} + Q_R + \left( \frac{\partial \mathbf{e}}{\partial t} \right)_{\text{diff}} \\
\frac{\partial \mathbf{B}}{\partial t} &= \nabla \times \left[ \mathbf{u} \times \mathbf{B} - \eta J - \eta_A J_\perp \right] + \frac{\nabla p_e B}{\mu_0 e_n e} - \frac{\eta_H}{e \mu_0} \mathbf{J} \times \mathbf{B} - \frac{\nabla \mathbf{p} \times \mathbf{B}}{|B|^2} = \left( \frac{\partial \mathbf{B}}{\partial t} \right)_{\text{diff}} \\
e &= \frac{1}{2} \rho u^2 + e_{\text{internal}} + \frac{B^2}{2\mu_0} \\
\mathbf{J} &= \frac{1}{\mu_0} \nabla \times \mathbf{B} \\
\mathbf{J}_\perp &= \frac{(\mathbf{J} \times \mathbf{B}) \times \mathbf{B}}{|B|^2} \\
\text{Equation of state (ideal gas law or precomputed lookup tables)} \\
\text{Biermann battery and Hall effects} \\
\text{Ambipolar diffusion due to neutrals} \\
The radiative loss term is computed either by solving the radiative transfer equation (with precomputed opacity tables) assuming LTE with the short characteristics method or by the Newton cooling law.
MANCHA features

Split variables for both linear and non-linear equations:
\[ \rho = \rho_0 + \rho_1 \]
\[ e = e_0 + e_1 \]
\[ B = B_0 + B_1 \]

PML boundary conditions – simplifies bc for wave simulations

Hyperdiffusion and filtering – stabilization

STS (super-time-stepping) method – speed up simulations with ambipolar diffusion and thermal conduction. HDS (Hall diffusion scheme) is used for Hall effect

"Grey" box – a user modifies only his/her setup (initial, boundary conditions, configuration files) without looking into the main code

Same code for idealized and realistic simulations
Horizontal velocity profiles of Alfvén waves in an isothermal, stratified atmosphere with a vertical constant magnetic field.
Solid line: exact solution; diamonds: numerical solution. The dashed line is the difference between both solutions. The vertical dashed line indicates the position of the PML interface.

3D view of the vertical velocity in the simulation with 50s harmonic force located at the bottom off the sunspot axis.

Rayleigh-Taylor instability in prominence

Density evolution together with velocity field in 2D simulation of RTI including partial ionization effects and inclined external magnetic field.

Resolution 1km, 1000x1800 grid points.

E Khomenko, A Díaz, A De Vicente, M Collados, M Luna. A&A 565, A45
Evolution of the temperature, vertical velocity and magnetic field in the 3D MHD simulation of the solar near-surface convection. Magnetic field is generated by Biermann battery effect and amplified by local dynamo action.

Simulation domain is $5.8 \times 5.8 \times 1.6 \text{ Mm}^3$ domain with resolution $288 \times 288 \times 114$ grid points.

*E Khomenko, N Vitas, M Collados, A De Vicente, 2017, A&A 604, A66*
What do we share

Source files
- Manual
- IDL scripts
- Python scripts
- Submission scripts

You need:
- Fortran compiler (GNU, Intel)
- MPI library (openmpi, impi, mpich, ...)
- HDF5 library
- Cmake package

aux

samples

- Acoustic wave
- Alfven wave
- Ambipolar
- Hall_HDS
- Orszag
- Pulse
- Riemann test
- RTI
- KHI

- Initial condition (.F90)
- Boundary conditions (.F90)
- Control (.trol)
- Submission script (.sub)
- Equilibrium.h5
- Perturbation.h5
- EquilibriumHDF.pro
Registration form

At the first stage the public MANCHA will be distributed via private Gitlab repository

New users will need to fill a simple form to get access to the code

References


More info on our group webpage:
http://research.iac.es/proyecto/PI2FA
http://research.iac.es/proyecto/PI2FA/pages/codes.php