# MHD Simulation of Magnetospheric Processes

October 20, 2004

## Educational Aims:

- Simulation of basic magnetospheric processes.
- Plasma and energy entry from the solar wind into the magnetosphere.
- Energy release in the magnetotail

## Schedule:

- Basic properties of magnetic reconnection.
- Properties of magnetic reconnection through two-dimensional simulation of magnetic reconnection.
- Magnetic reconnection and flow shear
- Kelvin-Helmholtz mode at the magnetopause.
- Tail reconnection: Plasmoids

# Organization:

Programs and this summary are available as tar or gezipped tar files at http://what.gi.alaska.edu/ao/2dprog/. The program package contains 5 directories:

- 4 of them with two-dimensional magnetohydrodynamic simulation codes. + all IDL visualization programs needed for the specific simulation
- The 5th directory named "idl" contains all of the visualization programs and subroutines.

## Organization of each of the program directories:

**mhd2d.f:** fortran program (source code) for two-dimensional mhd simulations

**hinclude.f:** include file needed for the program header (variable declaration, grid size, etc)

**magin:** parameter file for the simulation parameters

**makefile:** simple makefile for compilation; type make to compile the program. New compilation is not needed for changes in magin. The executable is named mhd2d

**compile:** duplicates make and can be used from a file manager

**cleanstuff:** cleans up all the files generated by the execution of the program

**colortab.priv:** colotable needed by IDL for these programs - if it works at all

## Technical execution of a simulation:

- Set the parameter you want to change in magin.
- If this is the first time you run the program: compile it with make, compile, or type g77 -O1 mhd2d.f -o mhd2d; if you had it compiled before (in this directory) this is not need unless you changed program code or hinclude.f.
- To run the program: Type './mhd2d' in a terminal window or (double)click on the name 'mhd2d' in the file manager.

## Visualization:

- If it is not possible to put all IDL programs in a single directory and set a path to this directory you will need to
  - either copy the files magt* and magdtraj into the subdirectory named idl,
  - or copy the IDL programs into your working directory.
- change into the directory idl if this is where the outpufiles are now.
- Enter 'idl' on the command line in a terminal
- After the IDL prompt appears type: .r *command,* where command is different depending on the directory (MHD code) you are using:
  - directory: rek => *command*=plotrek
  - directory: kh => *command*=plotkh
  - directory: rekshear => *command*=plotrs
  - directory: tail => *command*=plotail
- After starting the program it will ask for a file number. This number corresponds to the last (or last two) digits of one of the data files magtap*. For the first time enter 1 and hit return and the program reads the data from magtap01.
- In the next step the program gives you a menu. For the first time don't worry about the menu and just hit return and you generate your first IDL plot of the simulation.
- After that you can try options from the menu (note some of these may not work - this is on purpose because there is always something in free software that doesn't work) or hit q for quit and try a different filenumber.

**Physics:**

- In the simulation code all quantities are normalized to typical values, i.e., magnetic field is measured in units of a typical $B_0$, length scales are measured in a typical length $L_0$, particle number densities in $n_0$, velocities in $v_0 = v_{A0} = B_0/\sqrt{\mu_0 m n_0}$, and time in $t_0 = L_0/v_0$.
- For the magnetopause: $B_0 = 40nT$, $L_0 = 400km$, $n_0 = 4cm^{-3}$, $v_0 = v_{A0} = 400km/s$, and $t_0 = 1s$.
- For the magnetotail: $B_0 = 25nT$, $L_0 = 6400km$, $n_0 = 0.5cm^{-3}$, $v_0 = v_{A0} = 700km/s$, and $t_0 = 9s$.
- The file magin contains many parameters with which one can alter the simulation configuration or setup. For the present purpose only some of these may need to be altered.

**Important general parameters in magin:**

**isafe, dt;** output generated every $isafe \cdot dt$ time.

**iend:** last integration step

**xmin, xmax, ymin, ymax:** system dimensions

**etsw:** switches between spatially fixed or current dependent resistivity

**eta:** magnitude of resistivity

**Simulations:**

- rek: Setup to simulate magnetic reconnection for configurations relevant to the magnetopause.
  - Parameters to change the initial configuration in magin:
  - psi: rotates the the magnetic field configuration in the $y, z$ plane
  - phi: angle between the field vectors on the two sides of the current sheet
  - bmsh: magnetic field magnitude on the magnetosheath (solar wind) side of the current sheet.
  - bmsp: same for the magnetospheric field
- rekshear: Setup to simulate magnetic reconnection for configurations with different plasma flow on the two sides of the current layer.
  - Parameters to change the initial configuration are similar to 'rek'
  - v0: magnitude of the shear flow
- kh: Setup to simulate Kelvin Helmholtz mode at the magnetopause
  - bx0: introduces a normal magnetic field of magnitude bx0
  - psi: rotates the the magnetic field configuration in the $y, z$ plane
  - phi: angle between the field vectors on the two sides of the current sheet
  - v0: velocity shear magnitude
  - v1: initial perturbation
- tail: program to simulate magnetic reconnection in the magnetotail
  - by0: magnetic field in the cross tail direction.