PHYS:5905 Homework #11b

Please submit your solutions as a single PDF file with answers to the questions asked.
Please complete required problems before lecture on Tuesday, April 16, 2019.

The following exercises will give you experience compiling and running a CUDA GPU code on one of Argon's NVIDIA Titan V GPUs.

1. (Optional) **Compiling GPU Code `Gandalf` on Argon**

   (a) Here we will compile the Kinetic Reduced MHD code `Gandalf` for use on the NVIDIA Titan V GPUs on Argon. These cutting-edge GPUs use NVIDIA's latest Volta architecture with 5120 computing cores and 12 GB of memory.

   (b) Download the source code for the Kinetic Reduced MHD code `Gandalf` (G AND ALFven) at the PHYS:5905 course website at
   `https://homepage.physics.uiowa.edu/~ghowes/teach/phys5905/codes5905.html`

   (c) Copy the tar file to Argon (via `scp`, or simply use `curl` to download this tar archive directly to Argon.

   (d) Create a new directory `gandalf` and unpack the tar archive inside this new directory using
   `tar -jxvf gandalf-190410.tar.bz2`

   (e) Add the following lines to your `.bashrc` file in your Argon home directory
   ```
   module load cuda
   module load netcdf
   export CUDAARCH=compute_70
   ```

   (f) Exit the shell and log into Argon again (or simply issue the commands you added to your `.bashrc` file on the command line to ensure that the current shell is also updated).

   (g) In the directory `gandalf-190410` that was created when the `gandalf` tar archive was unpacked, compile the code using the command `make`. Check that it creates the executable file `gandalf`.

   (h) Note that, for the best performance, one should specify in the environmental variable CUDAARCH the appropriate architecture for the NVIDIA GPU model you intend to use. For the particular models on Argon, these are

NVIDIA Hardware	`CUDAARCH`	CUDA version
K20	compute_30	3.2
K80	compute_30	5.0
P40	compute_61	8.0
P100	compute_60	8.0
GeForce 1080ti	compute_61	8.0
Titan V	compute_70	9.0

   For the NVIDIA Titan V GPU, the appropriate choice is `CUDAARCH=compute_70`. Note that setting the appropriate architecture is only necessary at compile time.

2. (Optional) **Running GPU Code Gandalf on Argon**

   (a) Create a new directory named `gandalf` in your home directory on the NFS scratch directory system, located at `/nfsscratch/Users/`*hawkid*.

   (b) Create a symbolic link to the executable code `gandalf` that you compiled in the previous step. If you have followed the directions above exactly, you should be able to use the command
   `ln -s ~/gandalf/gandalf-190410/gandalf gandalf`

   (c) Copy the sample input file `tac2.in` for an Alfvén wave collision to the local directory, along with the batch submission script `tac2.sh`. Update the email address in the batch submission script
   `#$ -M username@uiowa.edu`
   to your own email address.

(d) Submit the batch script using
`qsub tac2.sh`

(e) After the run is complete (it should take less than two minutes to run once the job starts), on a semilogarithmic plot, show second (primary Alfvén wave), third (secondary nonlinear mode), and fourth (tertiary Alfvén wave) columns vs. the first column (time) of the output file `tac2.awcollp`. One should obtain results as in Figure 1.

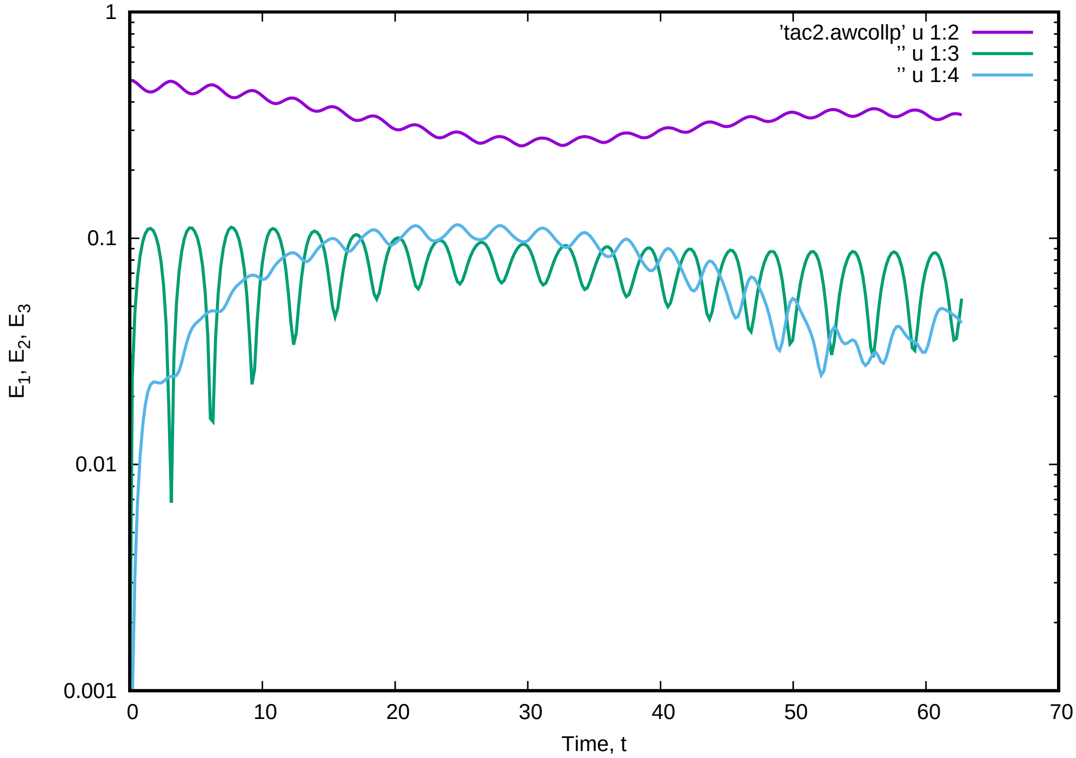

Figure 1: Plot of evolution of the energy in a nonlinear Alfvén wave collision at a function of time, showing the energy in the primary Alfvén wave E_1 (purple), in the nonlinear secondary mode E_2 (green), and in the tertiary Alfvén wave E_3 (cyan).

(f) Note that the `Gandalf` GPU code solves the Kinetic RMD equations described in Schekochihin *et. al*, *ApJSupp* **182**:310 (2009). The version here is a branch of `Gandalf` that only solves the reduced MHD equations.

(g) The Alfvén wave collision problem simulated here, solving for the nonlinear interaction between counterpropagating Alfvén waves, is described analytically in Howes & Nielson, *Phys. Plasmas* **20**:073302 (2013), is solved numerically using a gyrokinetic code in Nielson, Howes, & Dorland, *Phys. Plasmas* **20**:073303 (2013), and is verified experimentally in Howes *et. al*, *Phys. Rev. Lett.* **109**:255001 (2012). Alfvén wave collisions are thought to be the fundamental building block of turbulence in space and astrophysical plasmas.