Matrix assembling on GPU

- The new assembling code is in ludef_t_gpu.f90 and metricterms_new.f90.
  - They will only replace the old version in compiling when ARCH ends with "_gpu".
  - The new code can run both on CPU and GPU. To compile a GPU version, set ACC=1 during compiling.
- Currently only part of the code is migrated and tested. According to the regression test, only RMP passes.
  - We are working on RMP_nolin test now.

Motivation of thermal ion kinetic simulation

- In the traditional kinetic-MHD approach like M3D-K, kinetic effects of EPs are treated as perturbative effects, based on the assumption that EPs only takes a small portion of ion density.
  - This assumption is not true for many of the current DIII-D experiments.
  - For ITER the high-energy alpha particles can bring kinetic effects to the MHD evolution, and cannot be treated perturbatively.

A new hybrid method for kinetic-MHD simulation

- Thermal ions are simulated as kinetic particles like EPs.
- The MHD equations (momentum equation, pressure equation, Ohm’s law, Faraday’s law) are kept. Here the pressure equation only solves the electron pressure.
- The thermal ions are coupled to MHD equation through pressure coupling or current coupling.

Synchronization of parallel velocity

- When using kinetic equation to solve thermal ions dynamics, one can obtain the thermal ion parallel and perpendicular flow velocity.
- The parallel velocity can differ from the parallel velocity obtained from MHD equation, which is critical to the electron pressure equation.
  - The electron should “follow” the ion motion to satisfy the quasi-neutrality condition.
- In terms of that, we force the MHD parallel velocity to be equal to the thermal ion velocity after every timestep.

Steps

- Calculate the parallel velocity from thermal ion particles, store it in a scalar field.
- Remove the component parallel to B field from the 3 velocity fields (phi, vz, chi).
- Add the particle parallel velocity to the M3D-C1 velocity field.

First result: low-frequency mode in DIII-D experiment

- The low-frequency Alfven eigenmode (LFAM) has been studied last year theoretically (Ma PPCF2021) and using gyrokinetic simulation (Choi, NF2021)
  - It is found that this mode is not driven by EPs but by thermal ions, with transverse wave polarization and frequency close to zero.
  - Using the thermal ion kinetic in M3D-C1, we can calculate the unstable mode in linear simulation, which cannot be obtained with MHD-only simulation.

M3D-C1 simulation result for n=6

Spectrogram for DIII-D #178631