Dr. Brachet’s visit yielded progress in several distinct, but related, areas. First, new generalized equations of motion for the Weber-Clebsch potentials that describe both Navier-Stokes and MHD were derived; they depend on a new parameter which is used to detect reconnection in several paradigmatic flows. Periods of intense activity in the magnetic dissipation are correlated with increasingly frequent resettings of the Clebsch variables which thus offer a new diagnostic for reconnection, both for fluids and for MHD (1).

We completed the implementation of a robust, low storage, third and fourth–order accurate Runge–Kutta algorithm in both scalable TNT/GTP codes, GHOST and GASpAR, which are, respectively, a 2D/3D pseudo–spectral code, and a 2D/3D adaptive spectral element code. This algorithm, developed during Dr. Brachet’s visit, replaces an algorithm cited often in the literature that we show to be valid only to second order for nonlinear problems (2), and which respects energy conservation for very long time integrations.

Finally, using a newly developed parallel version of a symmetric FFT algorithm for use in pseudo-spectral studies of problems that have the same symmetries as the so-called Taylor–Green vortices, we have studied the ideal and dissipative magnetohydrodynamic (MHD) flows at equivalent resolutions of up to $2048^3$ grid points. These simulations were carried out with a new code based on the new FFT algorithm in the ideal, which preserves the symmetries numerically during the dynamical evolution. In the ideal case we find that the temporal evolution of the logarithmic decrements $\delta$ of the energy spectrum remains exponential at the highest spatial resolution considered, for which an acceleration is observed briefly before the grid resolution is reached. Up to the end of the exponential decay of $\delta$, the behavior is consistent with a regular flow with no appearance of a singularity (3). We also observe in the ideal case evolving structures similar to those observed in the solar wind as in Fig. 1. For the dissipative case, we find that global temporal evolution is accelerated, compared to the corresponding neutral fluid case (4).
Figure 1: Left: Current density intensity in a $200 \times 200 \times 120$ subvolume of the $2048^3$ ideal run at $t = 2.5$. Note the two current sheets approaching each other. Middle: Magnetic field lines in the same structure (viewed from the back). The current intensity in a slice is given as a reference. To the right and left of the slice, the magnetic field is strong (purple color), whereas in the transition region it decreases to $\approx 1/6$ of the maximum (yellow), corresponding to a strong local drop in intensity. Note also the rapid spatial rotation of the field lines (in approximately 6 grid spacing) between the two current sheets. Visualization using VAPOR. Right: Energy spectra, averaged in the plateau of total dissipation, compensated by $k^2$ (red), $k^{5/3}$ (green) and $k^{3/2}$ (orange) corresponding respectively to weak turbulence, Kolmogorov and IK spectra; dissipative $2048^3$ run. Note that wave turbulence seems to dominate in this flow possibly at all scales.

References


