Visualizing Velocity Fields from Fusion Simulations using Advected Particle Trajectories

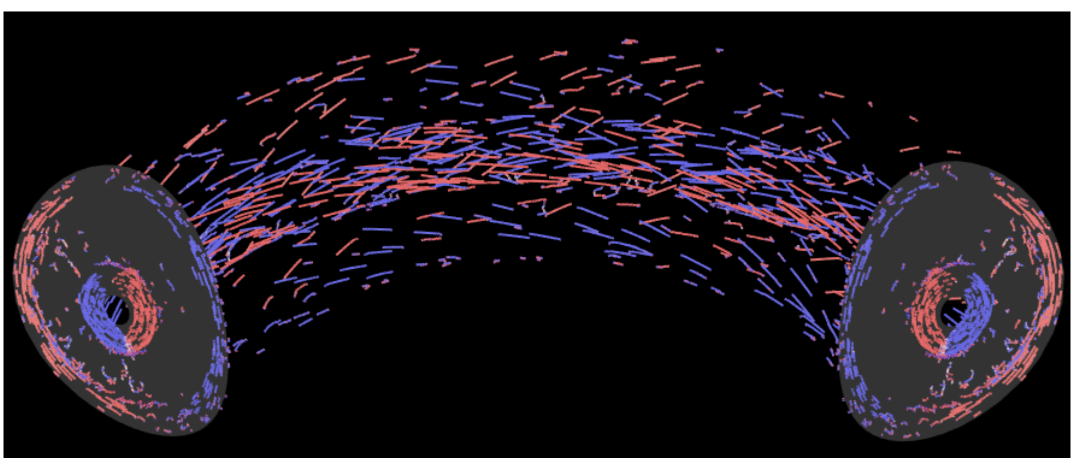
Franz Sauer[1], Yubo Zhang[1], Weixing Wang[2], Stephane Ethier[2], Kwan-Liu Ma[1]

Computer scientists at UC Davis and fusion scientists at the Princeton Plasma Physics Lab have been working together to develop a visual means for studying patterns in flow fields from magnetic confinement fusion simulations. In our presentation, we will show how the resulting visualizations can potentially help us validate and understand flow field output from a non-linear gyrokinetic simulation of collisionless trapped electron mode turbulence. The simulation uses the GTS code to investigate momentum transport and toroidal rotation generation relevant to the ITER burning plasma experiment.

We visualize the field by advecting 30,400 particles throughout the time varying flow field and drawing particle trajectories in a 3D domain representing the torus shape used in the fusion simulations. In addition to the 3D view, we also project trajectories onto a slice of the torus to allow us to better visualize patterns as if one is looking along the toroidal direction. Particles can be colored using a variety of velocity projections along either the toroidal or poloidal directions, or onto the flux surface normals. This allows us to easily visualize the magnitude and direction of the flow field throughout the torus and makes it clear when parts of the field make sudden directional changes.

We have also developed a set of filters which enable us to select particles/trajectories of interest based on their inherent properties. Such properties include the velocity of the particle, the length of the trajectory, the total displacement, the number of "turns" a particle makes (the angular sum of all directional changes), etc. This capability allows us to interactively isolate specific parts of interest to see where they dominate the flow field. The image below shows an example of an angled view of half of the torus along with a projection of the particles onto two slices. Particles with a very high number of "turns" have been filtered out and the remaining particles are colored according to their toroidal velocity. It is easy to identify which regions are dominated by particles with a low number of "turns" and whether they are moving in the positive toroidal direction (blue) or the negative toroidal direction (red).

Our work will lead to very effective tools for interpreting fusion simulation results. For this particular simulation we can readily see the interesting and complex structures of the sheared flows generated in the plasma. Our interactive filtering techniques allows us quickly explore properties of the simulation in real time, and we plan to apply our results towards the development of a versatile visualization system that can be applied to a variety of fusion experiments.



An angled view of half of the torus and two slices showing only particles with a low number of "turns". Particles in blue have a positive toroidal velocity while particles in red have a negative toroidal velocity.

[1] University of California at Davis
[2] Princeton Plasma Physics Laboratory