Scaling up MPP NL ELM Simulations

M3D MPP code now able to run long time ELM simulations to saturation, several hundred Alfven times (fall 2007).

Limited scale computation – 128 to 256 cpus.
Assume toroidal periodicity to get high enough n (toroidal mode number), N=3 typical.

Scale up MPP ELMs - first increase the number of toroidal modes:
No toroidal periodicity (#cpus x 3)
Toroidal direction FFT – aliasing is bigger problem, so keep fewer modes (2/3 instead of 0.8) (#cpus x2)
Better finite element triangle resolution in 2D poloidal plane to match toroidal resolution (#cpus x 4) ?

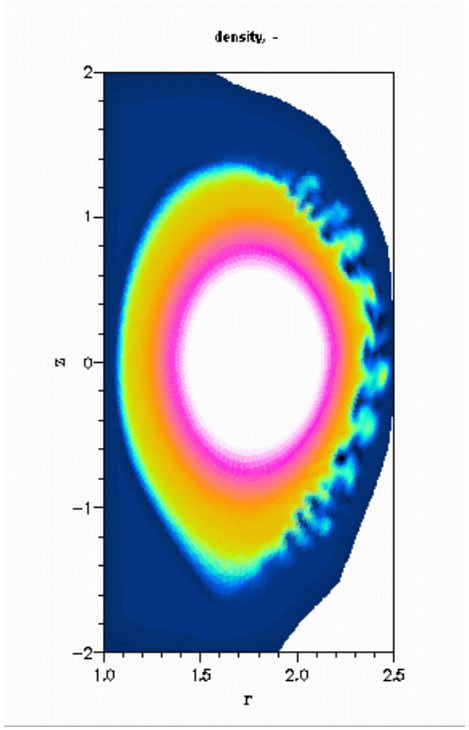
Part of NERSC Franklin scaling program, but still running 512 cpus (128 pol planes) to test physics.
Find that n=1 toroidal harmonic becomes important nonlinearly
Testing suggests real effect, not aliasing problem
(ELITE NL also suggested n=1 developed, but reduced MHD, other diffs)

RMP DIII-D simulations also see more n=1 in NL (for n=3 RMP)

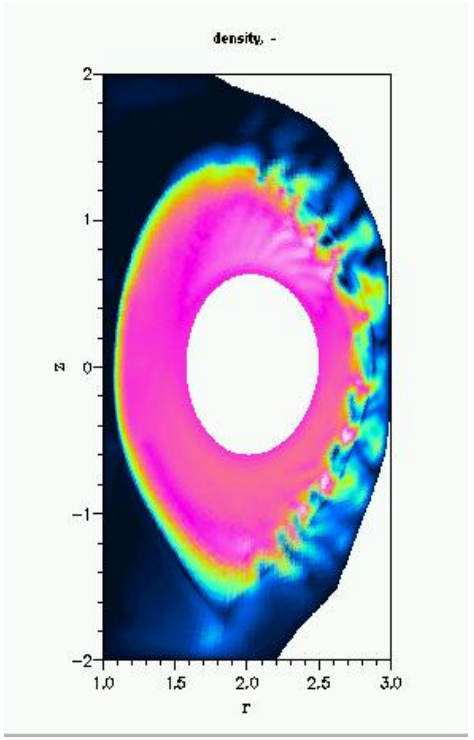
2007: M3D MPP ELM simulation improved to follow long time saturation after initial ELM crash

Numerical stabilization and models improved
- Nonlinear diffusion part of upwind advection
- Thicker plasma (plasma absorbs inward part of ELM perturbation)

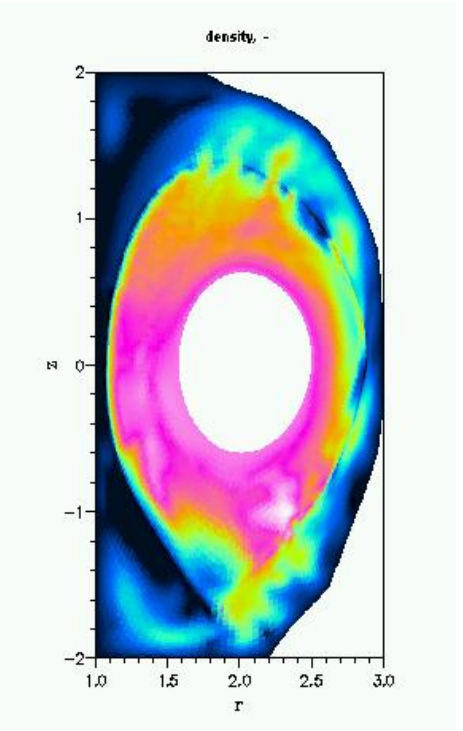
Example: MHD ELM stages of evolution (n=3 toroidal periodicity)
- Fast ballooning, Mixing/dispersal, Long-time healing



t=77 τA

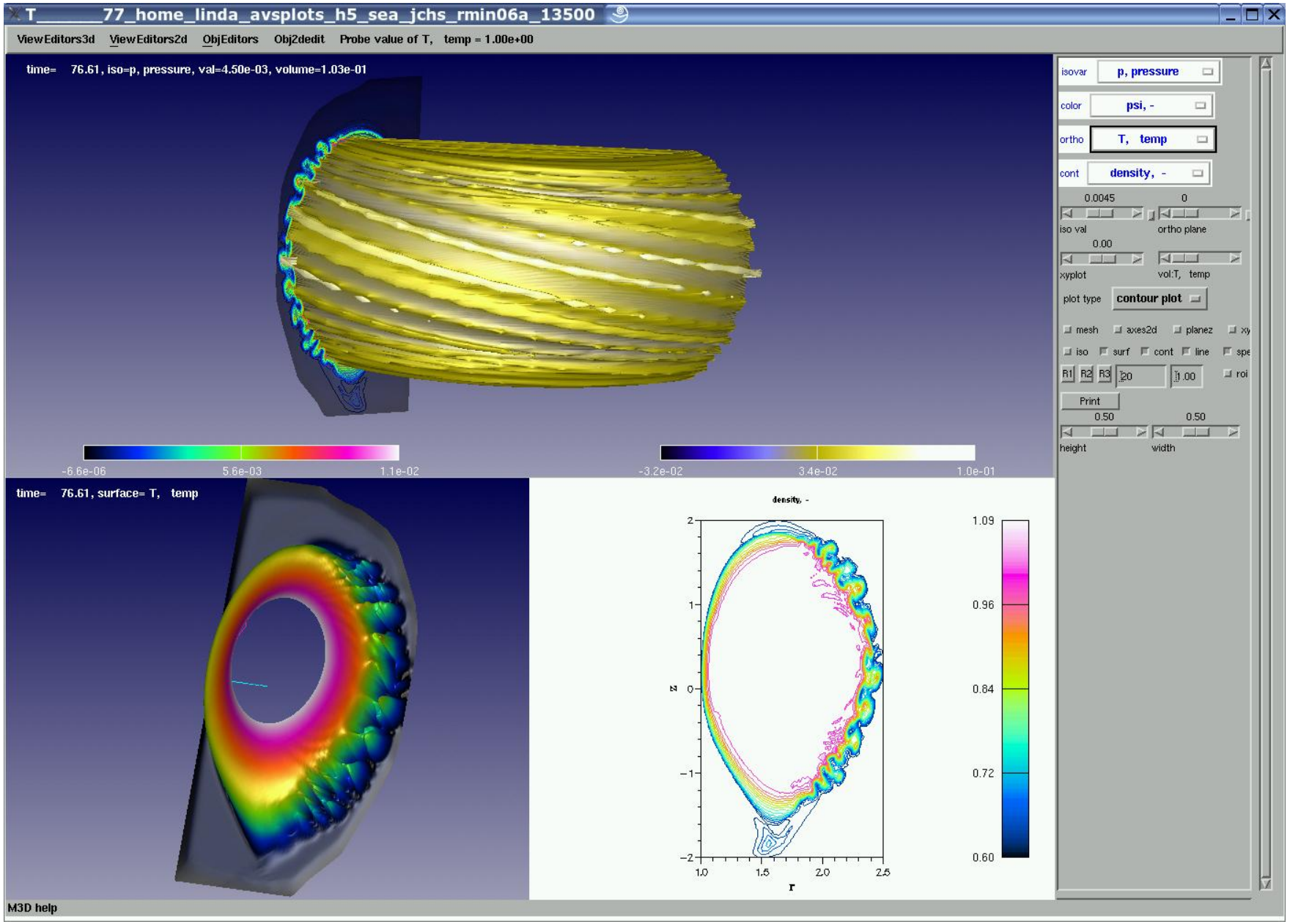


t=99 τA

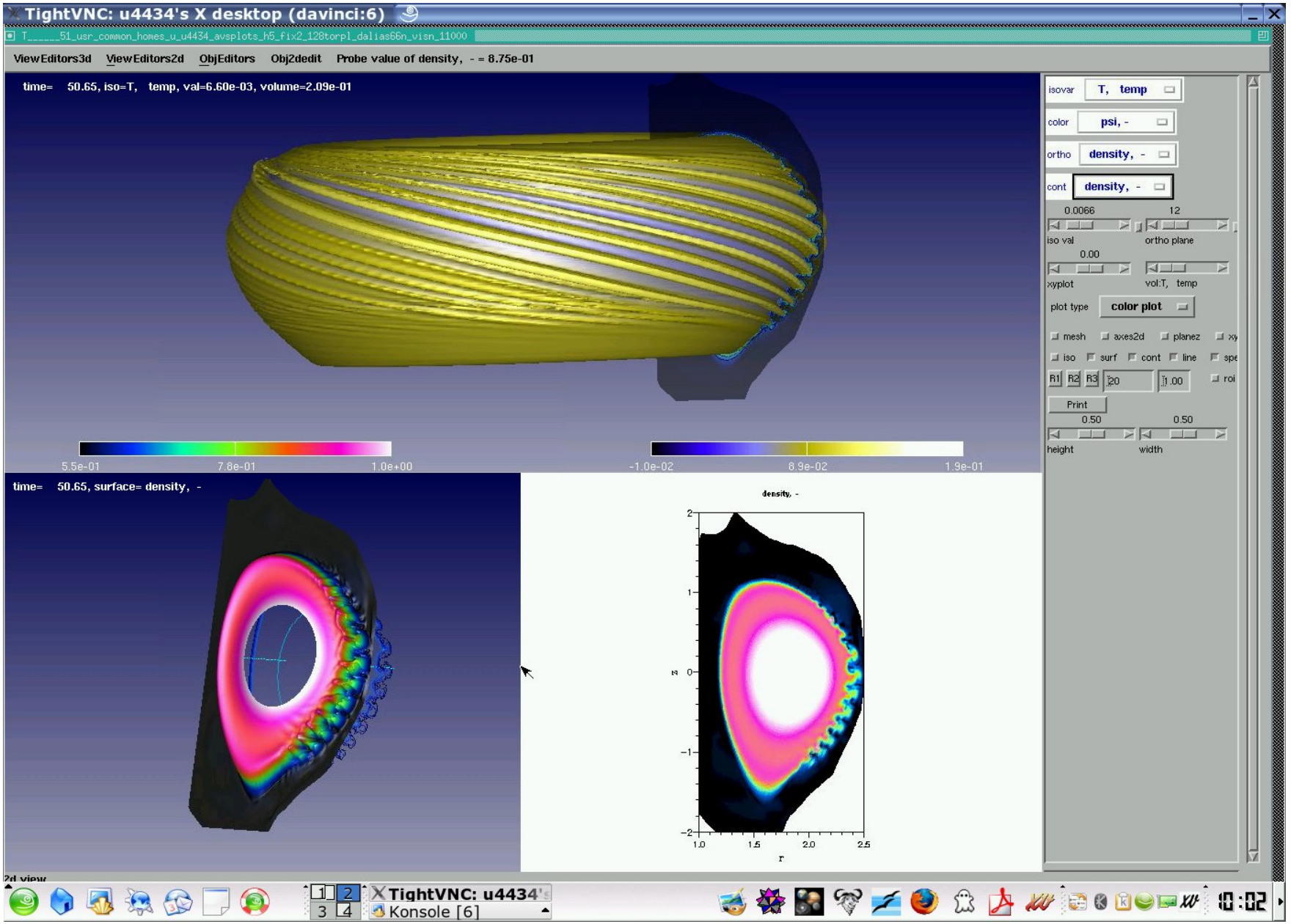


t=492 τA

N=3 toroidally periodic simulation
t=77. Ballooning perturbation follows magnetic field lines of plasma (p,T,n)



No toroidal periodicity. Perturbation initialized with range of mode numbers.
t=50. n=1 component contributes to NL ballooning perturbation (T,n,n)



Other M3D ELM-related work

RMPs and toroidal rotation in MPP M3D.
Input experimental RMP and rotation data via M3D-OMP generated input file

Alcator C-Mod plasma ELM regimes are different from DIII-D Type I ELMs.
Linear ELM growth rates in MHD, 2-fluid for APS-DPP 2007.
Need better 2D gridding in poloidal plane to handle strong outer wall shaping
TRIANGLE mesh generation (unstructured mesh) combined with packed grid (structured).
Done in OMP M3D, but need to distribute over MPP processors
Undergrad student (MIT)

Toroidal rotation of edge or plasma modes at edge may eject particles in preferred toroidal direction and spin-up remaining plasma.
Test of principle: ELM blobs eject particle density.
Can a plasma toroidal rotation or 2-fluid ELM mode with diamagnetic rotation eject particles and affect bulk plasma rotation?
(Graduate student, MIT)

Closer coupling of MPP code to XGC for CPES; 3D magnetic configurations, bootstrap current and radial electric field from GK code into M3D

Cray XT4's (JaguarCNL, Franklin)

Cray XT4's have problems with random compute failures for M3D.
Usually can restart, will run through problem spot.

From start, PETSc had problems with Compute Node Linux
Random MPI_AllReduce errors crash code, particularly on continuation runs
Could not run ELMs long time on jaguarCNL.

Worked with NCCS consultants to fix (M3D as test code). Conference call with
Cray Dec 5, 2007. Fixed Jan 10, 2008.
Switched M3D to NERSC Franklin shortly afterward, same problem.
Fixed Jan 22.

Still, random failures, either
aprun: Caught signal Terminated, sending to apid 1866605; aborting job
or
Apid xxxx killed. Received node failed or halted event for nid nnnn.

On Franklin, 1/3 to 1/4 of jobs fail after few 1000 timesteps, must restart from
checkpoint. Can run, but waste computer time, lose viz output.
Also saw on jaguarcnl, but ran too few jobs to see regularly.

Summary

Guiding center, small gyroradius plasma dynamics in 3D magnetic fields in terms of a gyroangle coordinate have

(1) velocity space nonuniformities for nonzero magnetic field torsion or parallel current.

(2) stringent existence conditions for second order equations, either 2D symmetry (eg, axisymmetry) or both $\mathbf{b}\cdot\nabla \times \mathbf{b} = 0$ and $\mathbf{b}\cdot\nabla\mathbf{e}_1\cdot\mathbf{e}_2=0$.

(3) Exact geometry requires $\partial\mathbf{A}/\partial t$ in electric field at level of $\nabla\Phi$

ELM simulations with M3D

Accurate simulation requires MPP scaling to larger number of processors
Remove assumption of toroidal periodicity, toroidal de-aliasing, larger 2D grid
n=1 toroidal harmonic seen in NL ELM

RMPs and toroidal rotation in MPP

Better 2D triangle mesh in poloidal plane (Alcator C-Mod NL ELMs)

Other ELM-related questions – blobs and main plasma toroidal spin-up
Two-fluid effects – to be continued