Predicting the Performance of Nuclear Fusion Experiments

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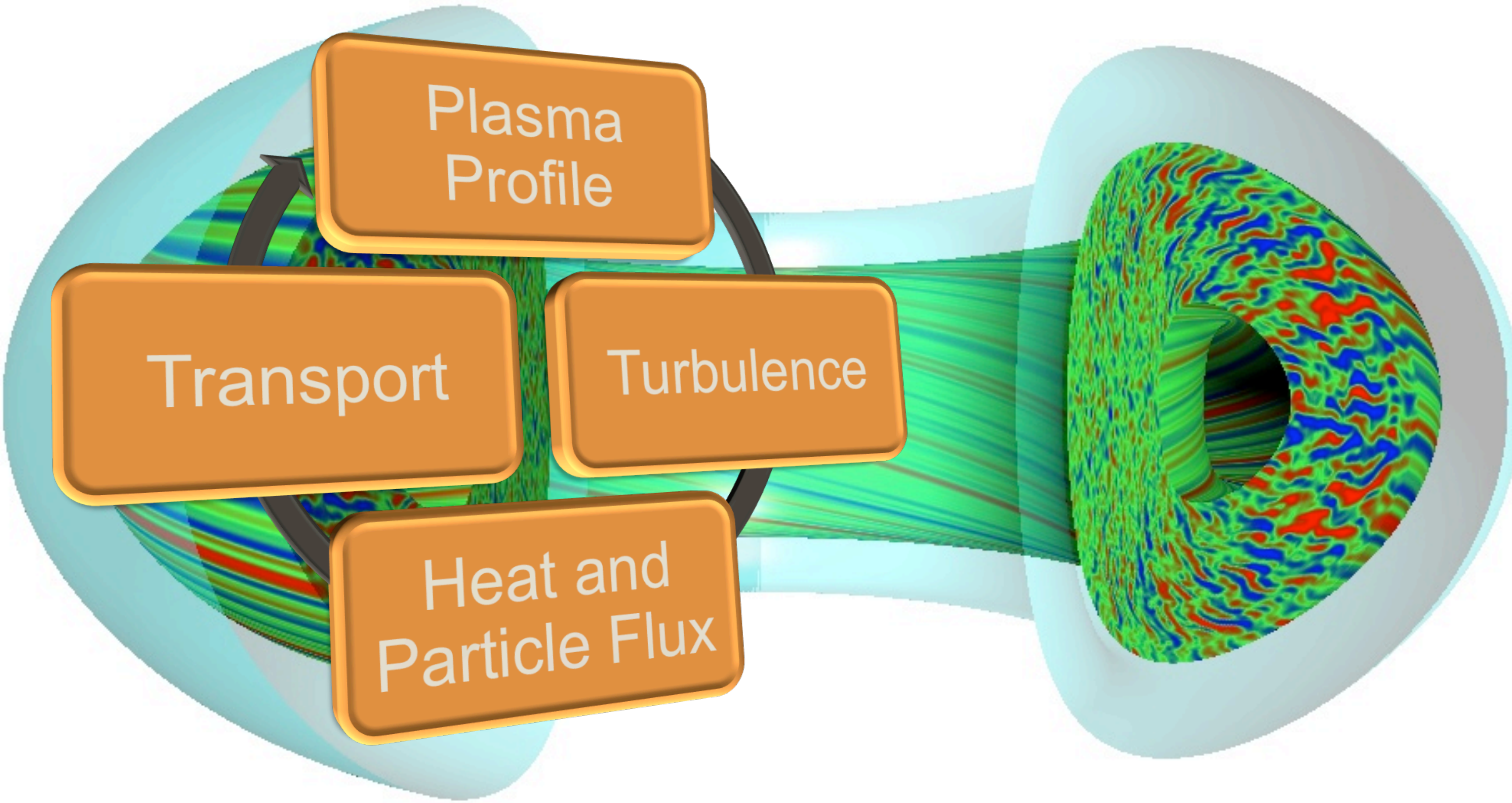
Turbulent Transport is a Grand Challenge in Fusion Modeling



CSPM Studies the Relationship Between Turbulence and Transport with 3 Major Code Suites

- GYRO/NEO/TGYRO
  - General Atomics
- GS2/Trinity
  - U. Maryland, Oxford
- GEM
  - U. Colorado

Turbulence, Transport "Continuum"

Turbulence "PIC"

Emphasis on Physics Fidelity

Turbulence Codes Solve the Gyrokinetic Equation

- Evolution of a 5-dimensional distribution function
  - Coupled PDEs
  - 3 space dimensions, 2 velocity dimensions
- Continuum Codes
  - Evolve function using finite difference/volume and spectral techniques
- PIC Codes
  - Sample distribution function with Monte Carlo particles

Wish-list upgrades for Continuum Turbulence Codes

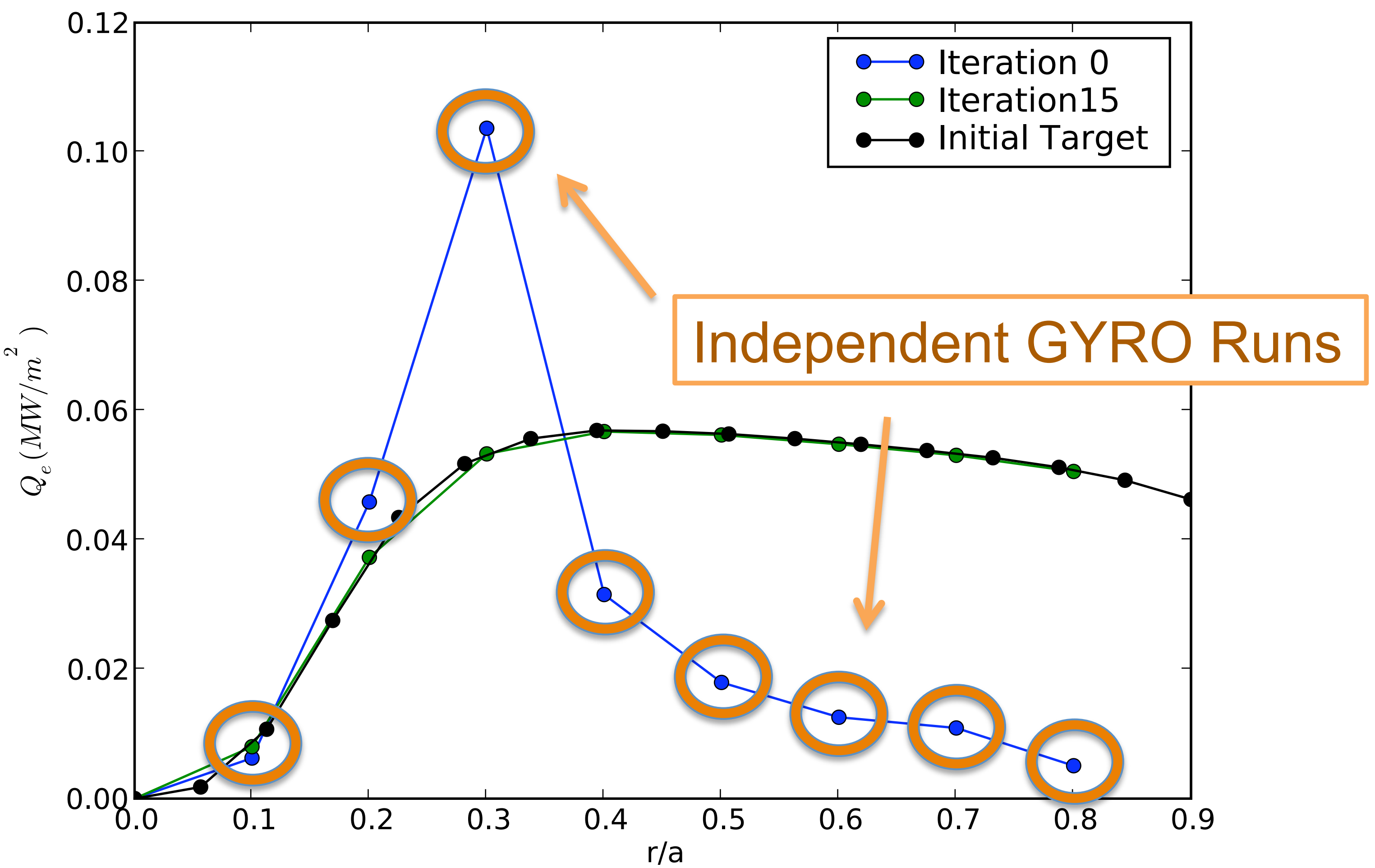
- Better multi-core performance
- Scalability above 5,000-10,000 processors
- Efficient dense matrix operators
  - Originally designed for problems with banded matrices
  - Next generation physics problems have dense structure
- E. Bass - GYRO

Transport Drivers Use Turbulence Codes

- Output of Turbulence is Input for Transport
  - Diffusion Coefficients, Fluxes
- Turbulence Driver evolves system to equilibrium
  - Time-dependent (Trinity)
  - Time-independent (TGYRO)

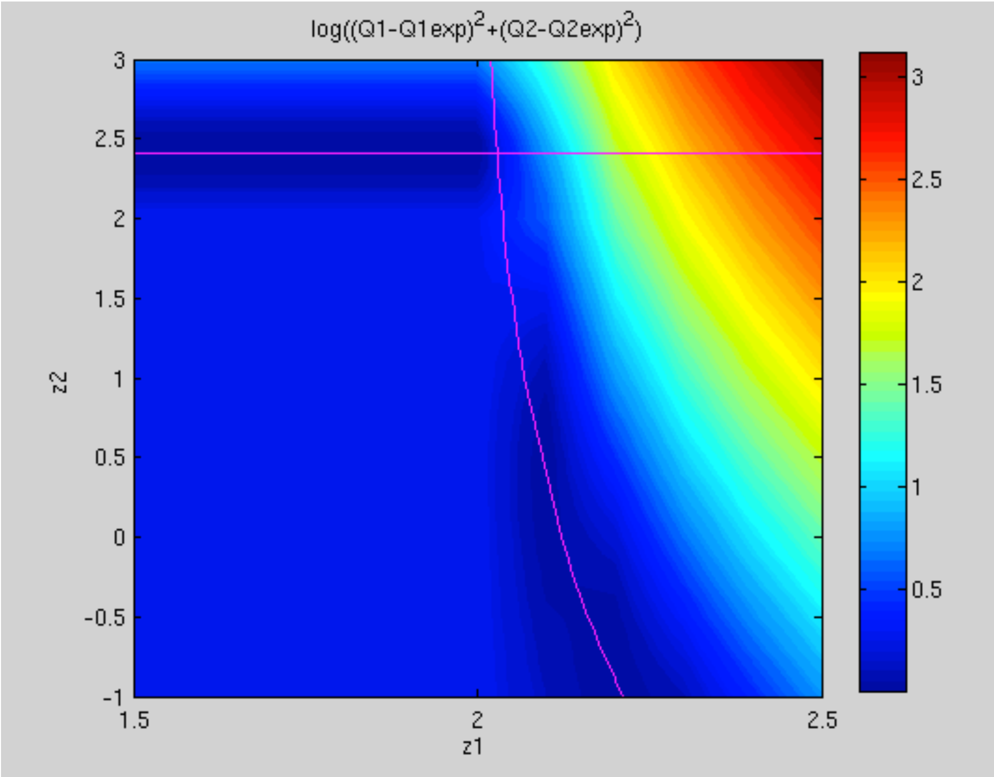
$$\vec{Q}_{code} = \vec{Q}_{exp}$$

TGYRO modifies inputs to GYRO/ NEO to find root



TGYRO is a Newton-Raphson Iterator

- Jacobian calculation is most expensive
  - GYRO ~ < 2000 processors each
  - ~ 500-100k cpu hours per GYRO call
- Phase space can be complicated



2-Point Toy Model
Shows Narrow Valleys
and Broad Plains

Computational Challenges for TGYRO

- Speed up Jacobian calculation
  - Extra layers of parallelization
  - Effective load balance
- Efficient Nonlinear Root Finding Method
  - Scales well
  - Robustly handles difficult terrain
- Wall-clock management
  - Time limits prevent many iterations