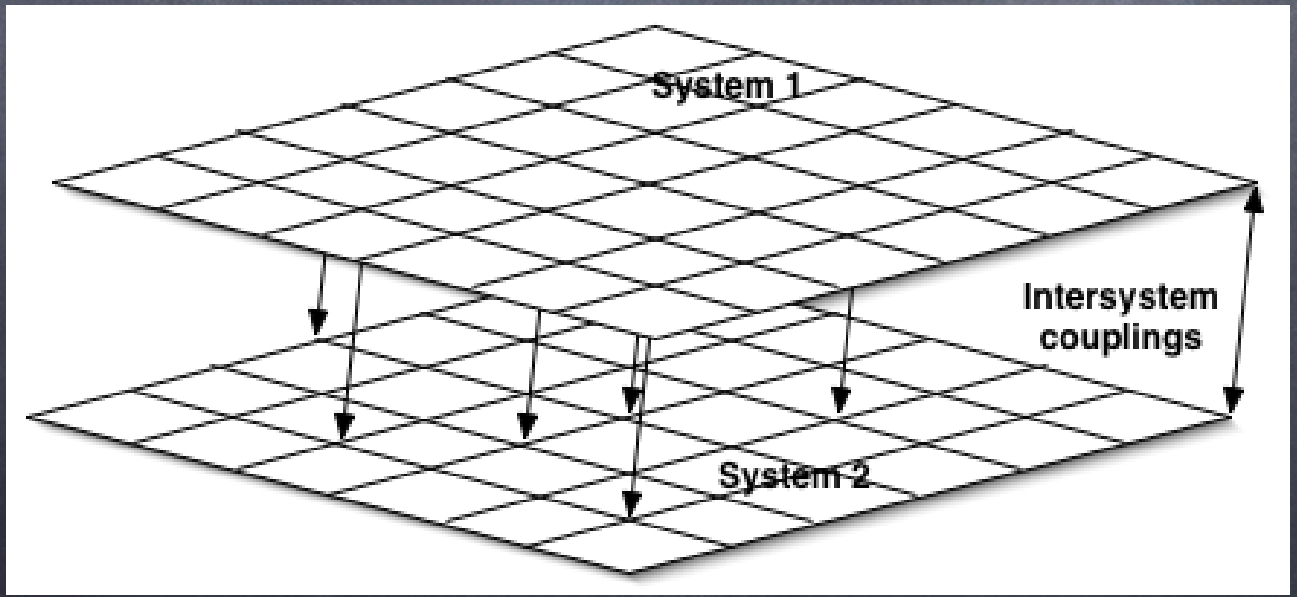
Coupled Complex Systems

- Systems can have variety of couplings
  - Mono directionally(Pipeline-communications systems, climate-animal??) or Bi-directionally (most other systems, ie power transmission-communications systems, people-climate)
    - » Fully symmetric or asymmetric coupling strengths
  - Homogeneously or heterogeneously
  - Negative reinforcement(Power transmission-communications) or positive (infrastructure systems - decision making "system"??, forests-weather??)



Universality

Measures that are the same or similar across different conditions or different systems

Historical evolution of our research

- Fusion plasmas - turbulent transport
- Power transmission systems
    - Forest dynamics
- Internet (and other communications systems)
- Human behavior

Turbulence

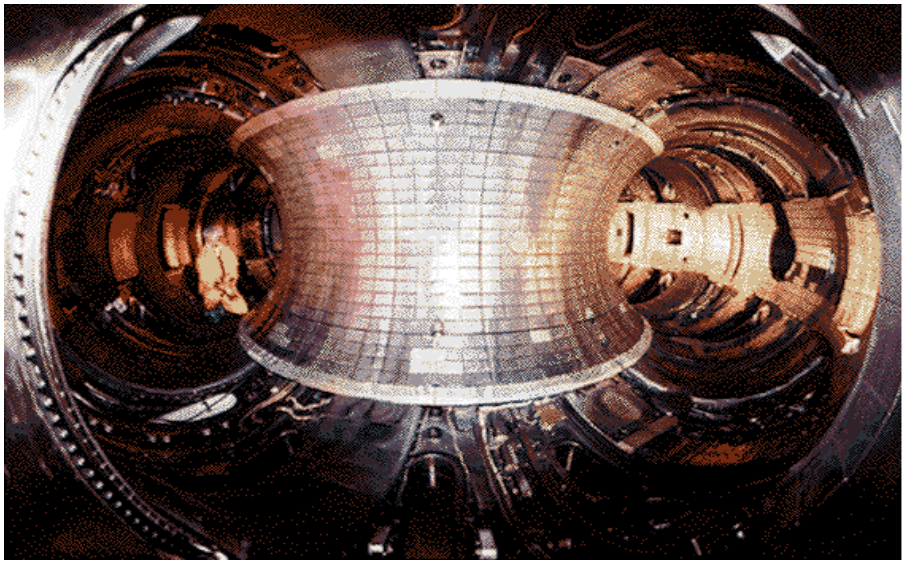
- **Typical picture ⇒ fluid (Navier-Stokes) turbulence**

http://info.pitt.edu/~maarten/work/soapflow/soapjpgs/dense.turb.JPG

ftp://mojave.wr.usgs.gov/pub/spurr/Spurr.html

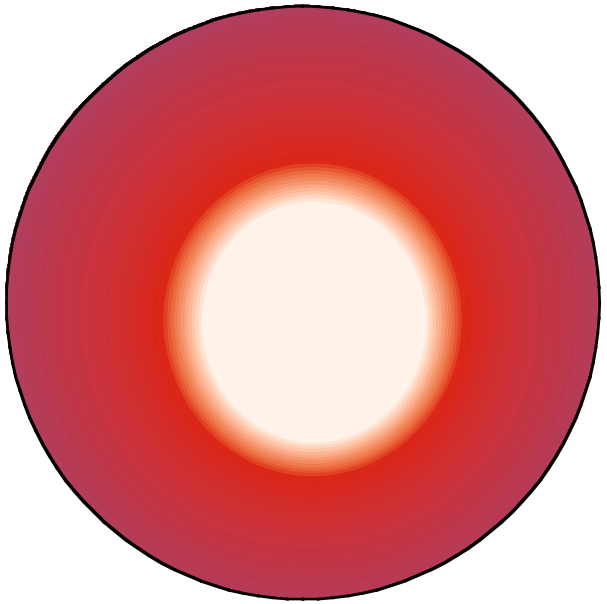
- **Our working definition: Any fluctuating system in which the nonlinear dynamics (couplings) dominate the linear dynamics over many spatial scales (not coherently)**

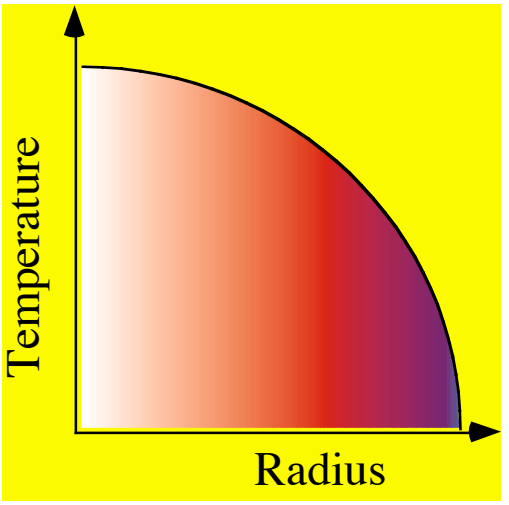
Turbulence relaxes gradient that drives turbulence - Universal transport dynamics?



http://www.pppl.gov/oview/pics/tftr_fish_lg.gif

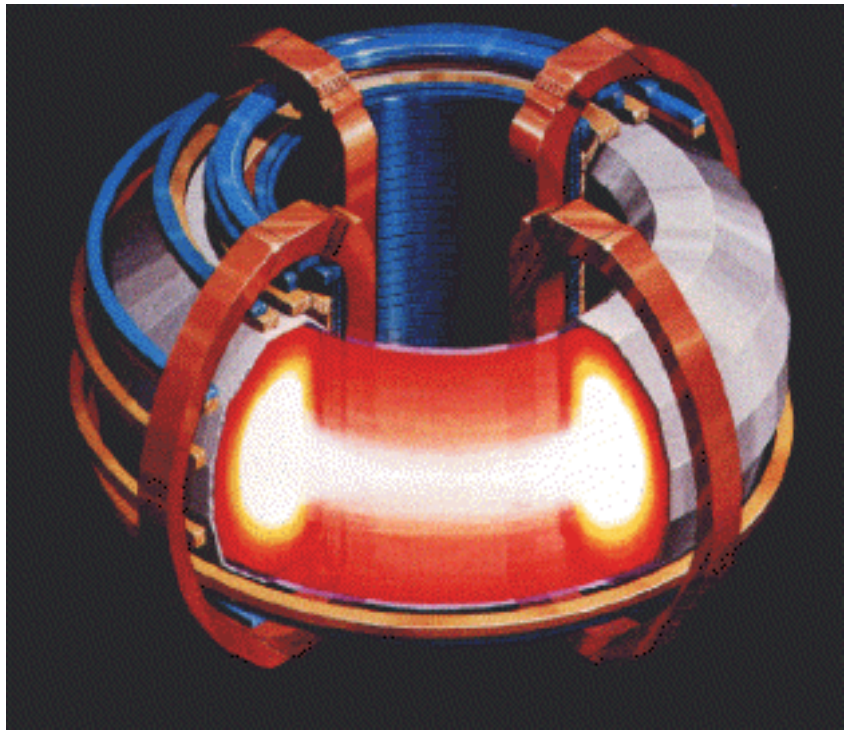
- Cross section in viewed in two different ways

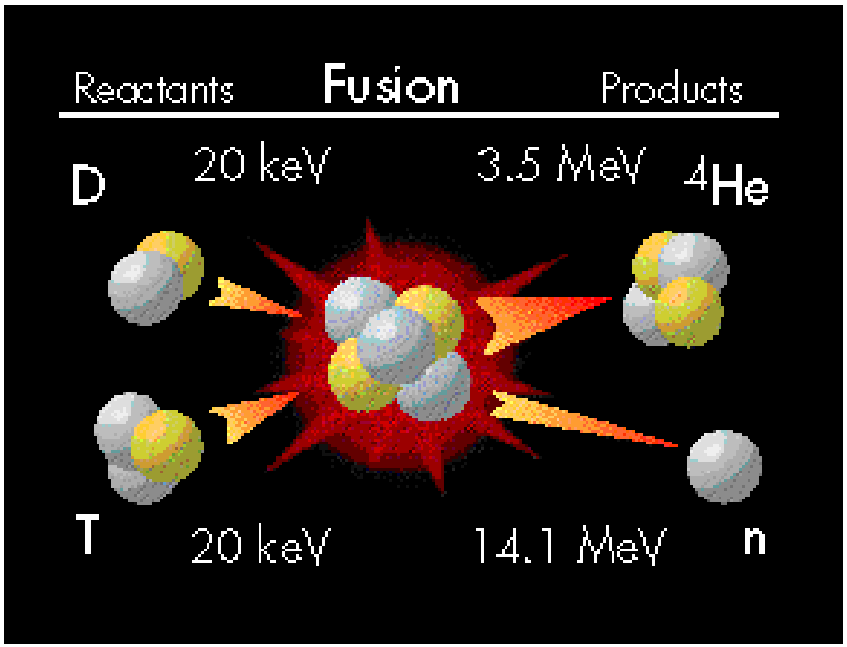




Tokamak based fusion

Need to heat and confine the plasma => wall interactions are bad

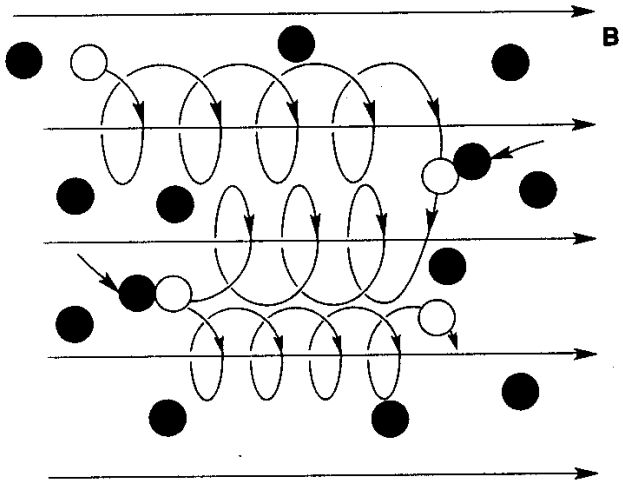


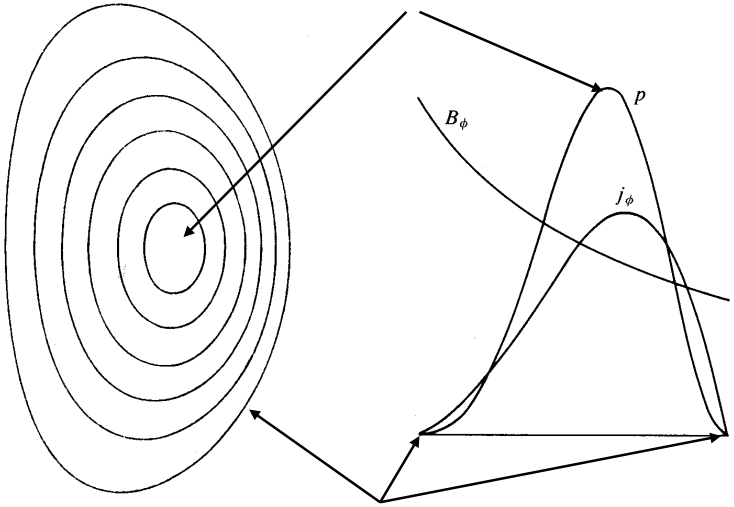


Toroidal magnetic confinement and huge energy gain

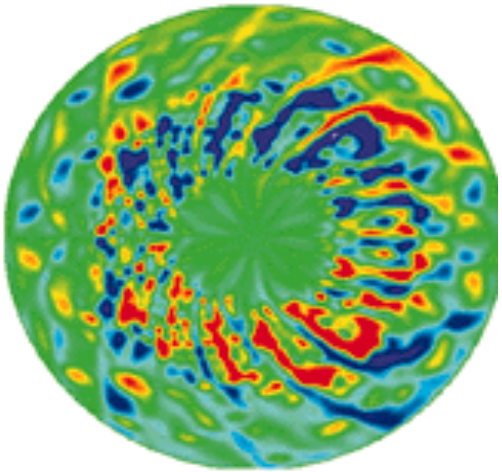
- **1 l water has deuterium equiv of ~ 500 l of gasoline (also note only ~0.015% deuterated water so water supply will not be used up)**
- **~ 1.5 kg of fuel/day for a 1.5GW plant**

Tokamak radial transport
Classical and turbulent



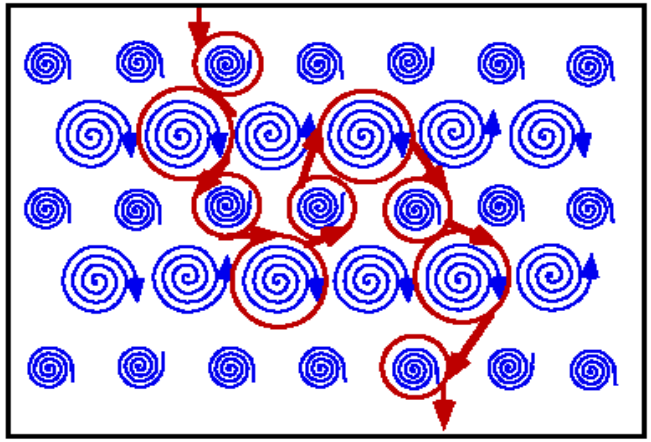


- Collisions move particles to another magnetic field line as a radial random walk.
- In the presence of a energy/density gradient, gives net energy/particle transport.



When describing turbulent transport with a standard transport model, a similar underlying picture is assumed with the steps being on the eddy scale.

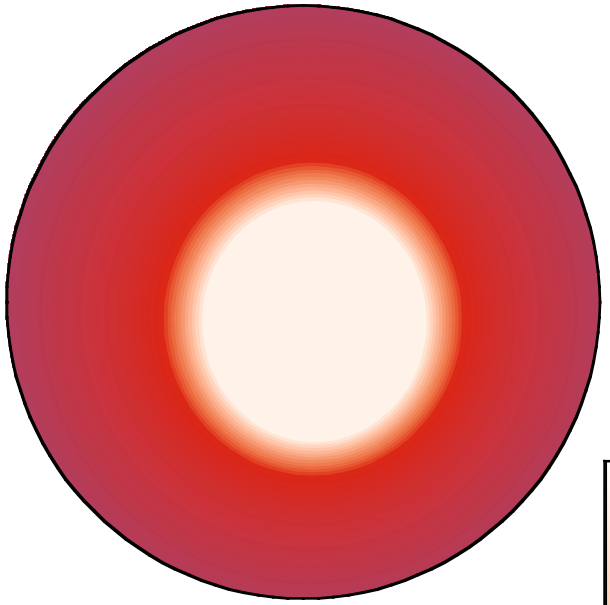
Turbulent transport dominates collisional transport.

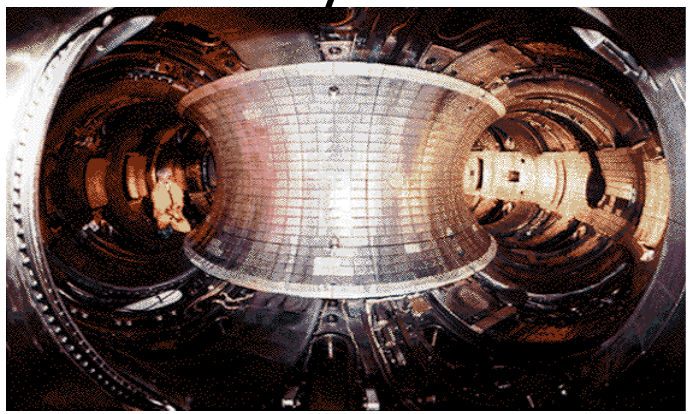


ornl

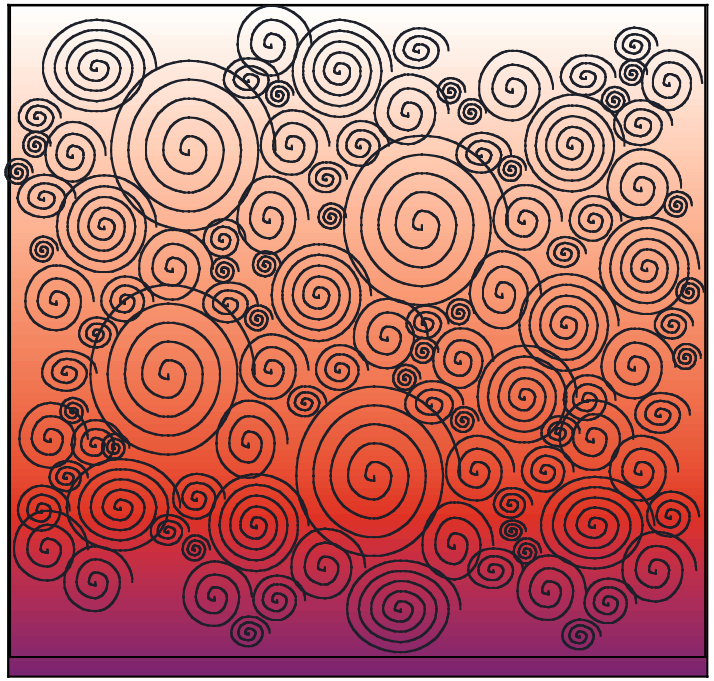
Turbulence relaxes gradient that drives turbulence

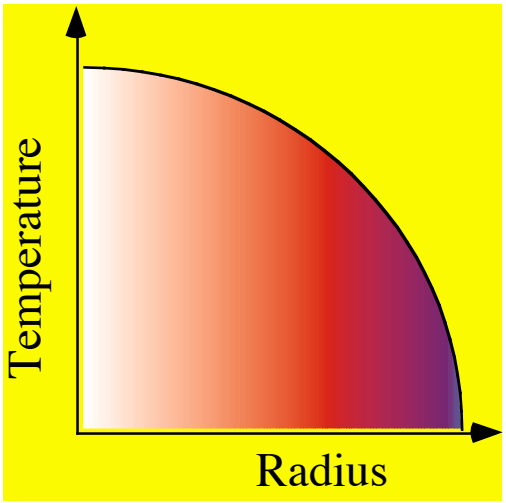
- Cross section with gradient viewed in two different ways





http://www.pppl.gov/oview/pics/tftr_fish_lg.gif



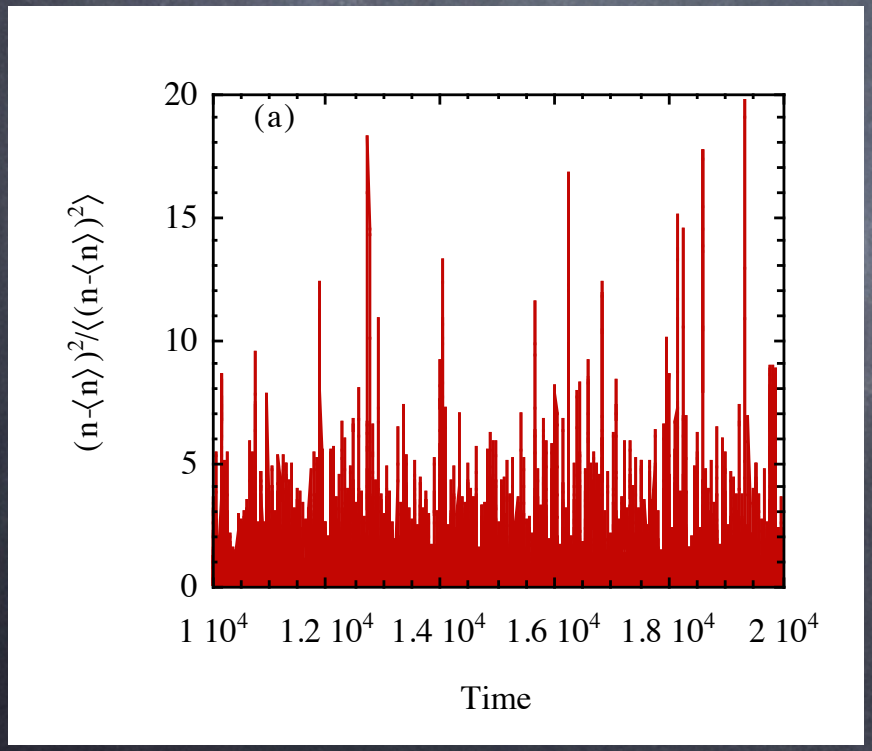


If transport is diffusive, bigger is better

Intermittency in Plasma Turbulence

- Data from W7-AS edge plasmas
- When we plot any of these measures, the intermittency of the signal is rather apparent.

Density fluctuation squared



Radial velocity squared