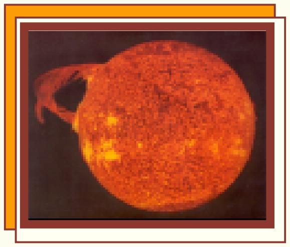
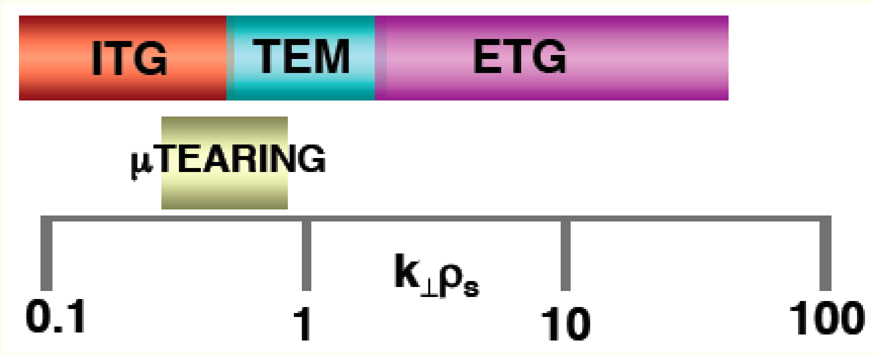
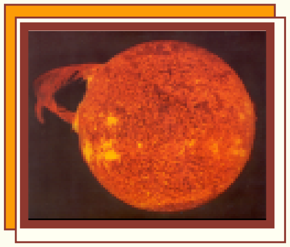


Multi-scale Transport Physics

- **The U.S. leads the international research effort to determine the instabilities responsible for turbulent transport.**
- **The combination of the three machines improves ability to separate out the variables that control energy confinement through cross-machine studies.**
  - Combination of facilities also makes it possible to perform cross-machine *identity* and *similarity* experiments.



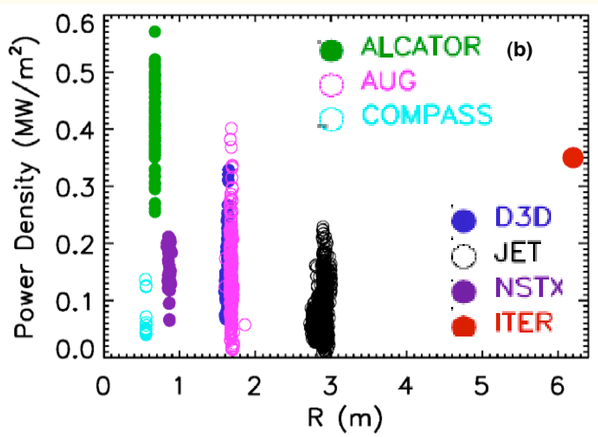
- **The U.S. facilities have diagnostics covering a wide range of inverse wavelengths *k*, from ion to electron scales.**
  - Although ion transport is reasonably well understood, electron transport is not.



Capabilities to Study Transport

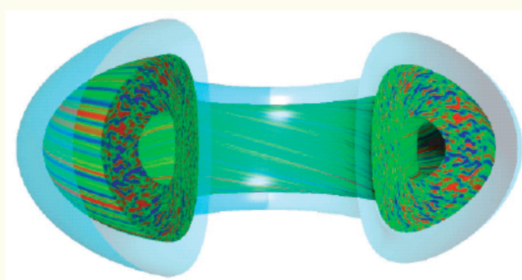
C-Mod

- Studies at high field and power density (for same β_N and ρ_*), with $T_i = T_e$
- Particle/momentum-free heating
- Novel diagnostics



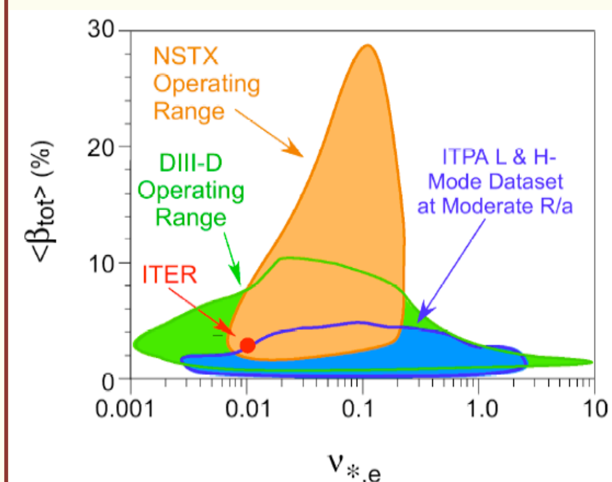
DIII-D

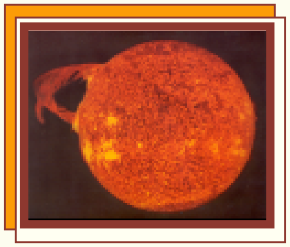
- Integrated control of shape, profiles, and rotation
- Comprehensive diagnostics
- Advanced gyrokinetic simulation code



NSTX

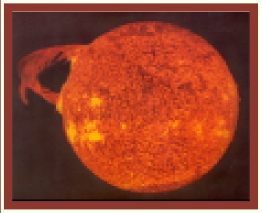
- Studies at high beta (EM effects) and low *R/a*, with rotation
- Novel diagnostics





Thermal Transport (Ions)

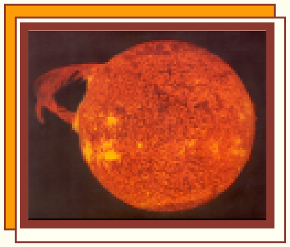
- **C-Mod:**
  - Extends collisionality range for assessing zonal flows (which are being investigated in all three facilities)
  - Various fluctuation diagnostics
- **DIII-D:**
  - Pioneered research on role of ExB shear in the reduction of ion transport to neoclassical level
  - Upgraded BES fluctuation diagnostic for local comparison of the ExB shearing rate and the turbulence de-correlation rate
- **NSTX:**
  - High edge magnetic shear should lead to lower ion thermal transport
  - New fluctuation diagnostics: tangential scattering, microwave imaging



Thermal Transport (Electrons)

- **Frontier issue for transport studies:**
  - Emphasized by U.S. Transport Task Force and 2005 FESAC Priorities Report
  - Enabled by new diagnostic capabilities—e.g., phase contrast imaging (C-Mod, DIII-D), backscattering & tangential scattering (DIII-D, NSTX)

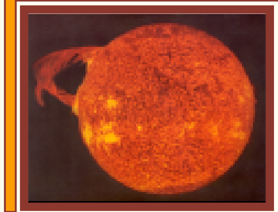
- **Capabilities for complementary studies on three facilities:**
  - Ion transport can dominate heat loss in high-performance C-Mod and DIII-D; electron transport dominates in high-performance NSTX
  - Ion-to-electron temperature ratio:
    - High T_i/T_e is stabilizing for ITG, destabilizing for ETG
    - C-Mod has equal temperatures across the plasma radius; NSTX and DIII-D vary the ratio by altering the mix between auxiliary heating methods



Momentum Transport

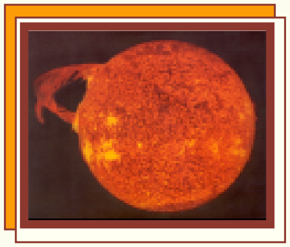
- **Another frontier issue for transport studies:**
  - Emphasized by U.S. Transport Task Force and 2005 FESAC Priorities Report
  - Research needed to bridge the gap between most present experiments (with fairly high rotation) and ITER (slow rotation)

- **Capabilities for complementary studies on three facilities:**
  - **C-Mod**: Discovered self-generated rotation with no momentum input during ICRF wave heating, and confirmed during Ohmic operation
  - **DIII-D**: Extreme flexibility to vary the torque direction and the ratio of heating power to torque magnitude, in order to separate heat input and angular momentum input
  - **NSTX**: Ability to run at high rotation (Alfvén Mach # = 0.45) or low; and to compare forward and reversed plasma current to study origin of momentum transport, with rates approaching neoclassical level



Particle Transport

- **Research objectives**:
  - Predict residence time of fuel and impurities
  - Predict ash build-up in a burning plasma
- **Substantial progress during 1990's on transport/exhaust of helium and impurities, impurity screening, and density limits**
  - Hence less emphasis on particle transport cf. to other transport issues, although basic transport processes are not yet completely understood
- **New developments:**
  - BES data for turbulent radial particle flux (DIII-D)
  - Impurity transport studies (NSTX)



Conclusion

- **Deep understanding of the complex turbulence processes that govern magnetized plasma transport is a *Grand Challenge* problem**
  - Development of a predictive model for turbulent transport is a major goal of the international fusion program
  - Experimental capabilities, new diagnostics, and modeling advances are now putting this within reach
- **Each of the three U.S. facilities contributes important elements to a vibrant domestic program on multi-scale transport physics**
  - The three machines in combination provide high leverage for cross-machine utilization of complementary and unique capabilities
- **The U.S. has a world-leading research effort in this area**