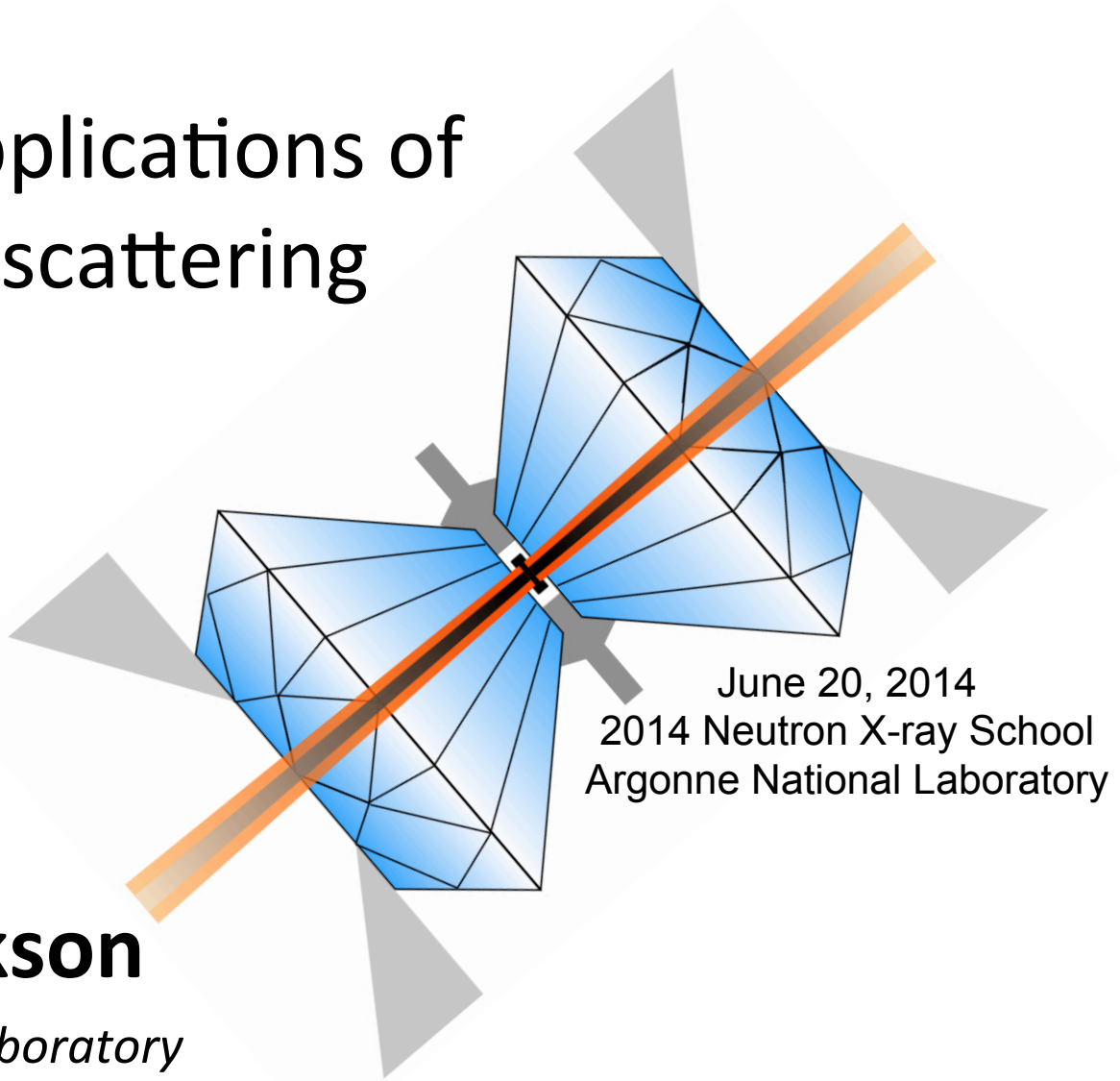
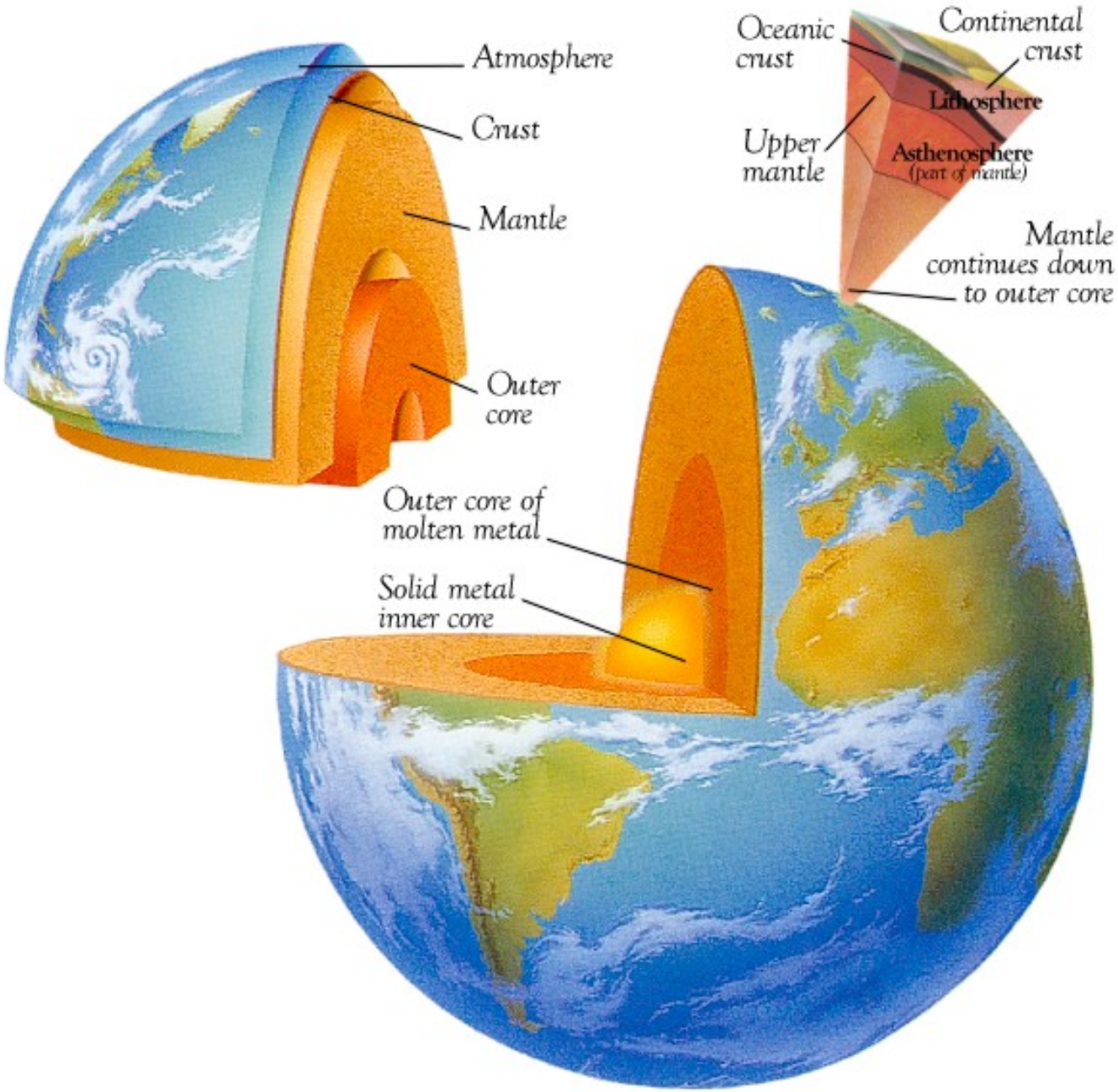
High-pressure applications of inelastic x-ray scattering



June 20, 2014
2014 Neutron X-ray School
Argonne National Laboratory

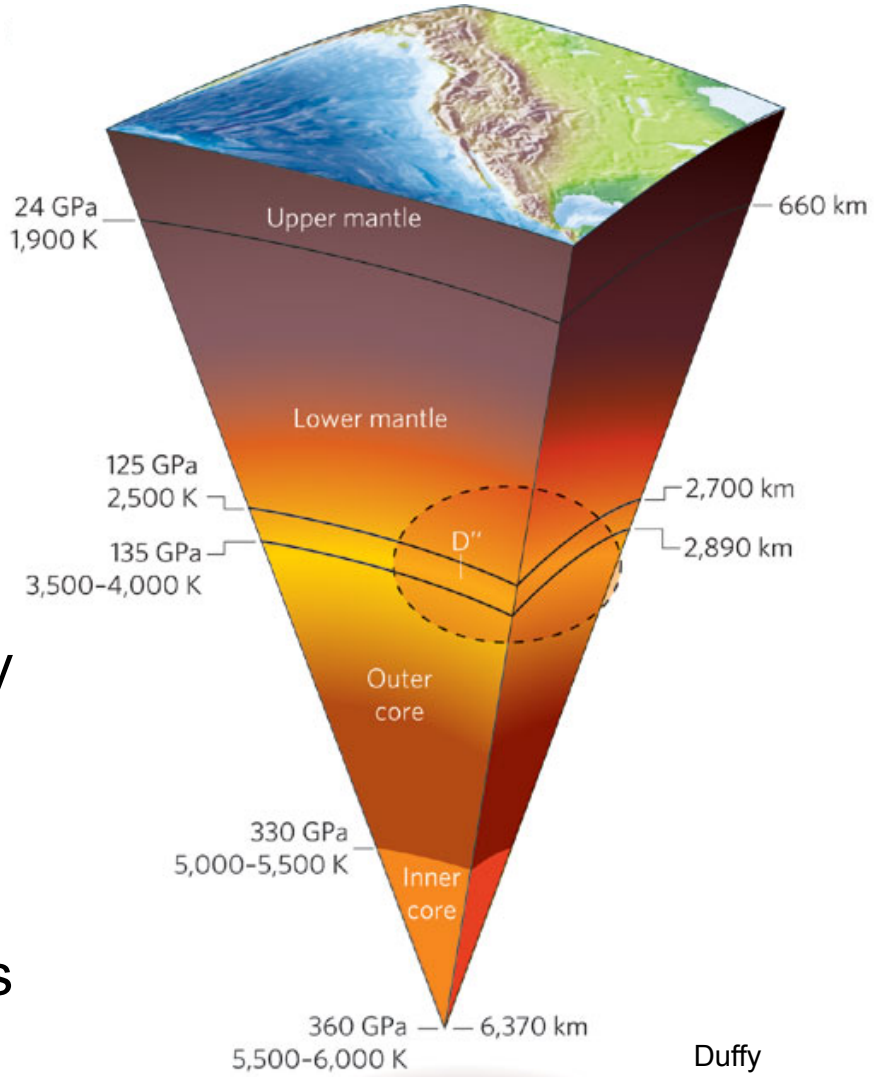
Jennifer M. Jackson

Seismological Laboratory
Geological and Planetary Sciences
California Institute of Technology


Atmosphere
Crust
Mantle
Outer core
Outer core of molten metal
Solid metal inner core
Oceanic crust
Continental crust
Lithosphere
Upper mantle
Asthenosphere
(part of mantle)
Mantle continues down to outer core

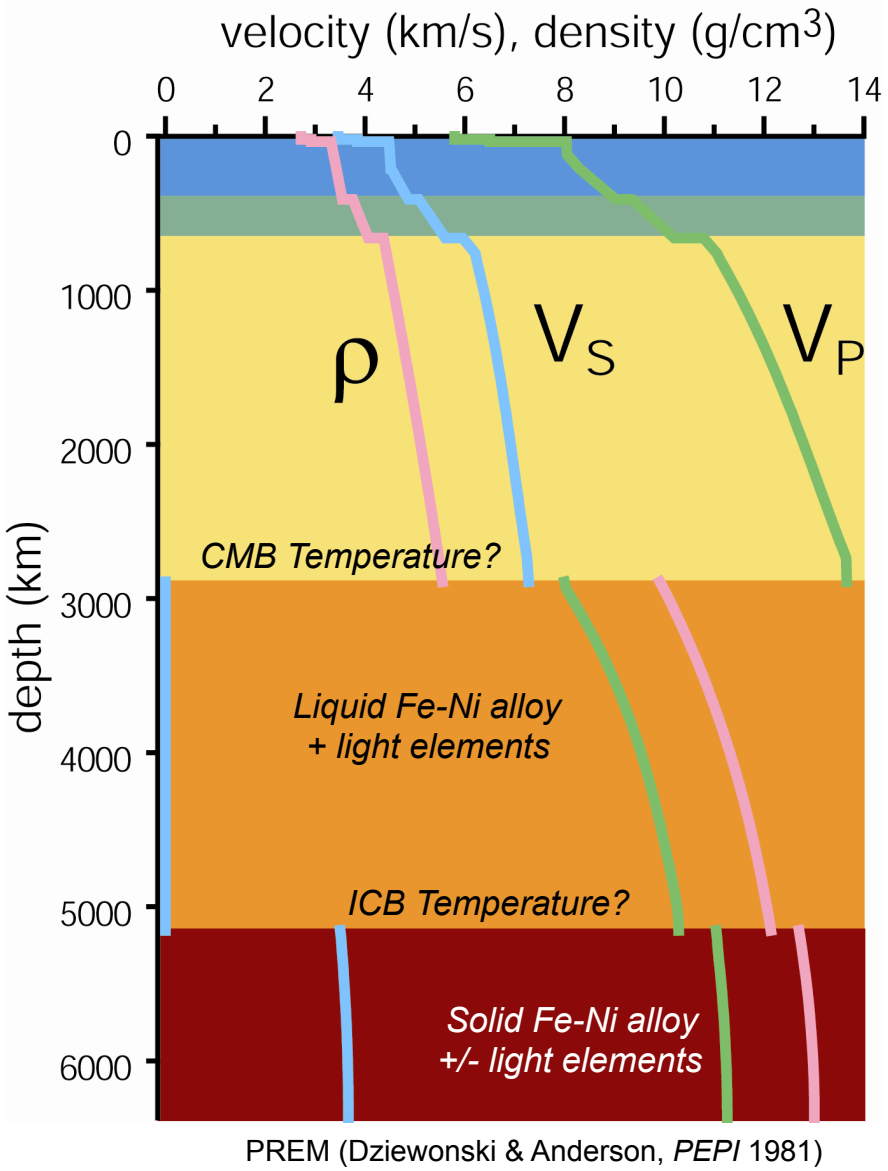
Outline

- Interior of the Earth
  - Seismic imagining
  - Petrologic observations
  - A dynamic planet
- Experiments
  - Diamond-anvil cells
  - Nuclear resonant inelastic x-ray scattering (NRIXS)
  - Thermoelastic properties
- Applications
  - Upper mantle seismic reflectors
  - Core-mantle boundary heterogeneity
  - Composition of Earth's core
- Conclusions

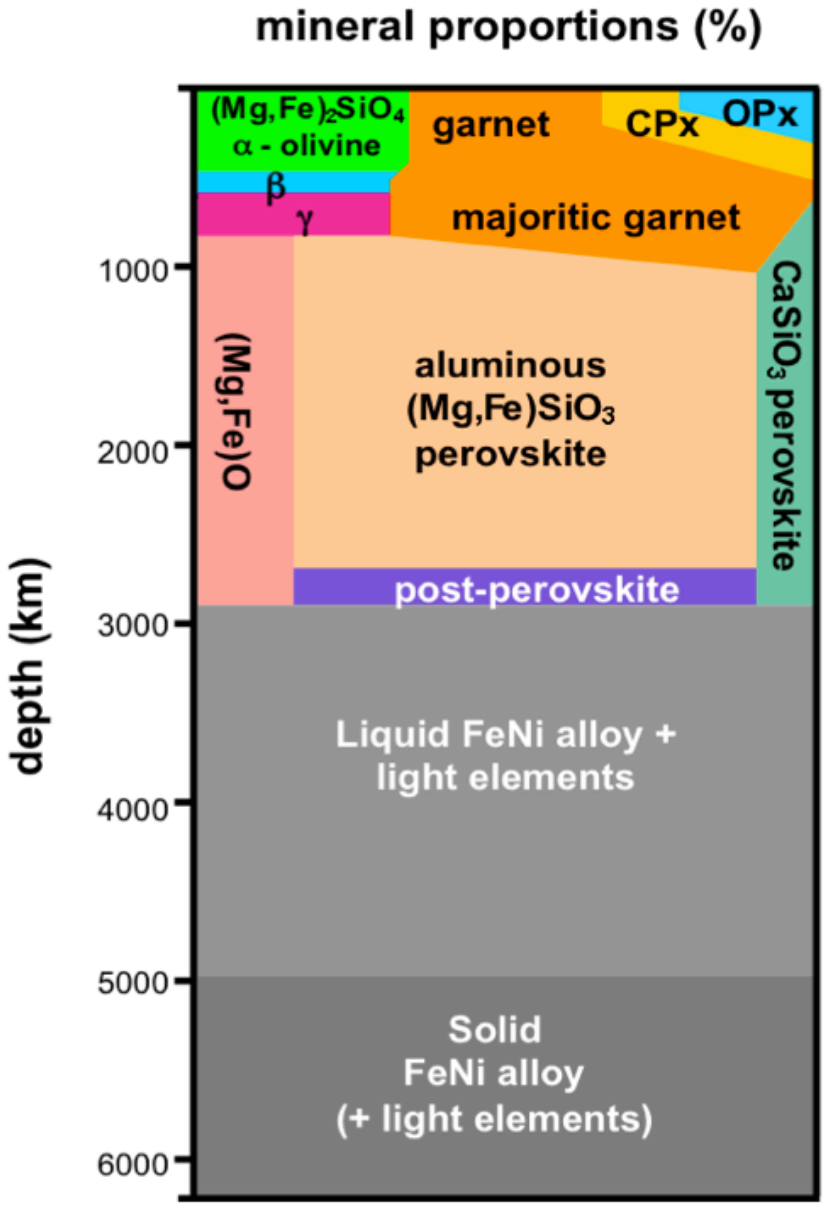


Duffy
(Nature 2008)

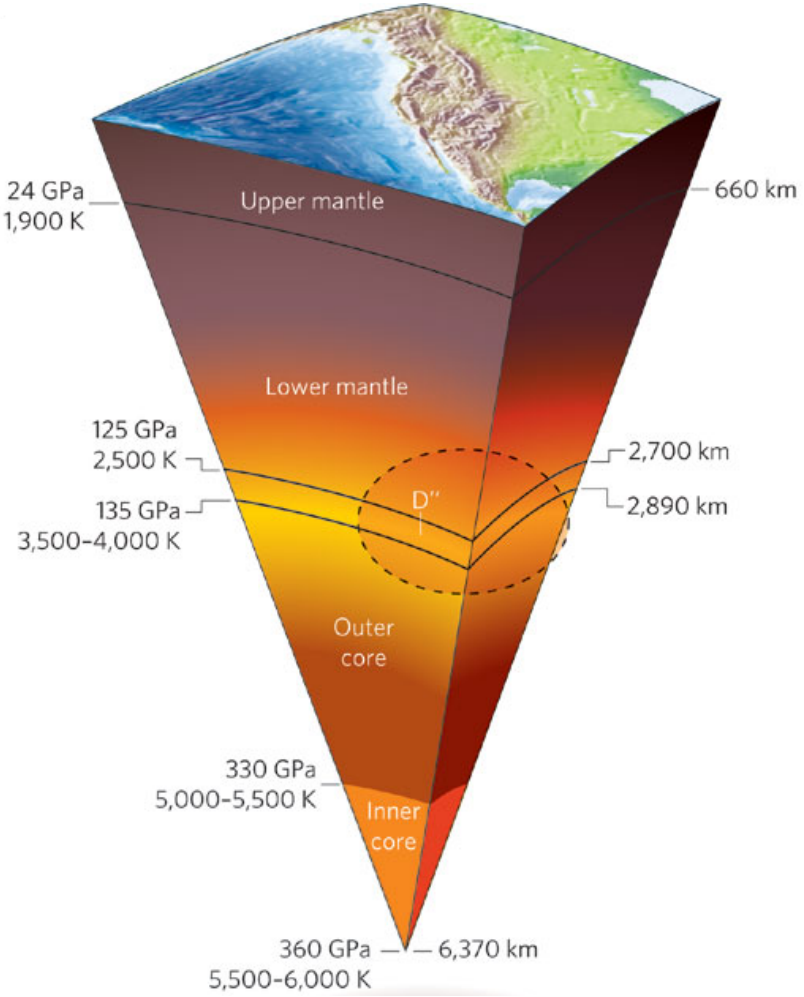
Earth's interior



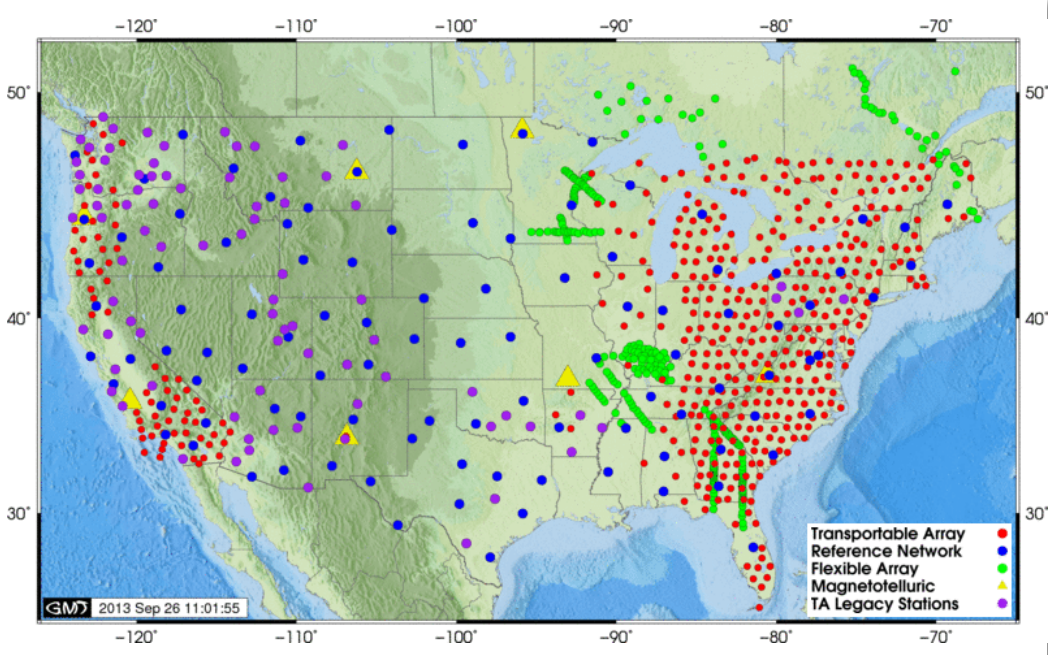
PREM (Dziewonski & Anderson, *PEPI* 1981)

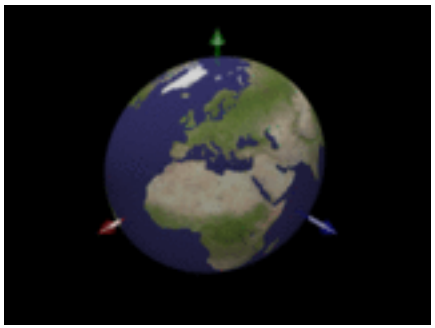


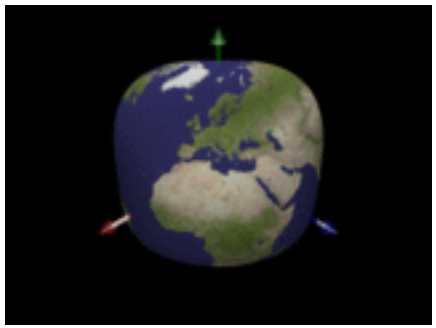
Dense seismic networks (USArray) provide ultra-high spatial resolution of seismic wave sampling of Earth's interior



Duffy
(Nature 2008)



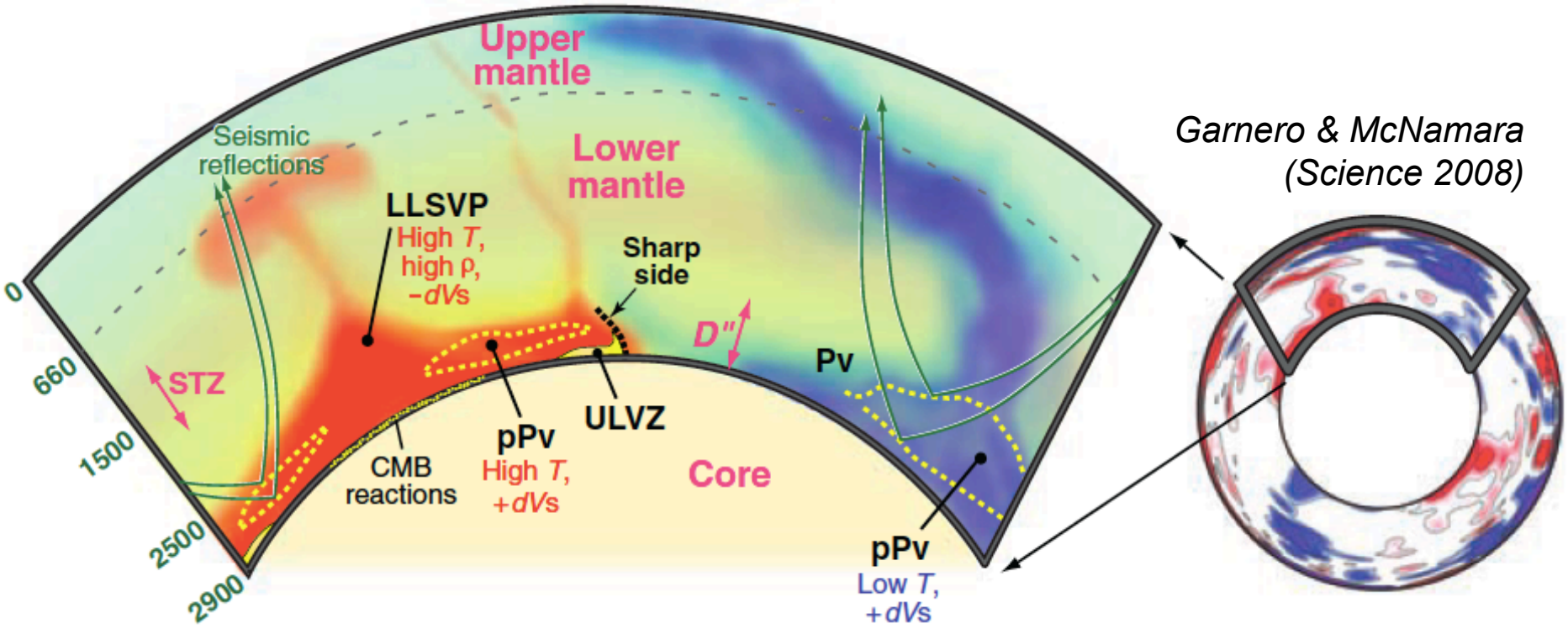




Free oscillations
(normal modes)
of the Earth

Credit: http://icb.u-bourgogne.fr/nano/manapi/saviot/terre/index.en.html#

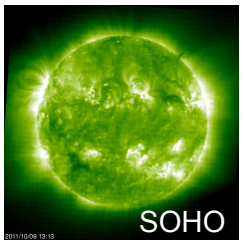
Imaging deep Earth structures



e.g., Tan & Gurnis *GRL* 2005, Sun *et al. PNAS* 2007, Tan *et al.* G^3 2011, Tackley *ESR* 2011, Davies *et al. EPSL* 2012, Li & McNamara *JGR* 2013, Sun *et al.* 2013, Bower *et al.* G^3 2013, and references therein

Sources of information about Earth's interior

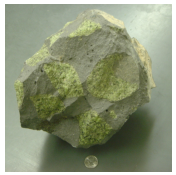
Solar atmosphere analyses

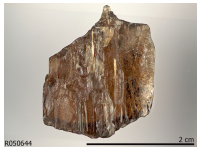


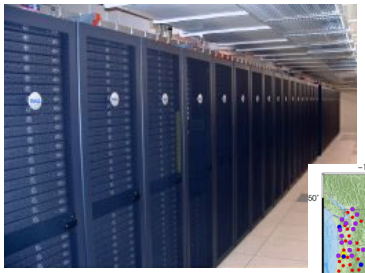
12.262 km (Kola 1989)
12.345 km (Sakhalin 2011)

Mineralogy and (isotope) geochemistry

Meteorites, mantle xenoliths, inclusions in diamond



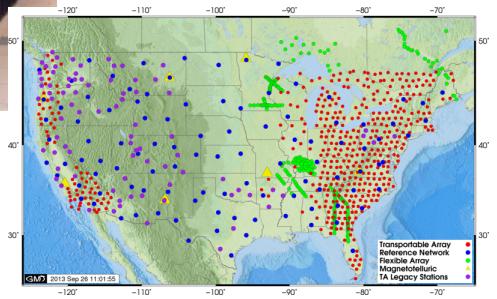




Going deeper:

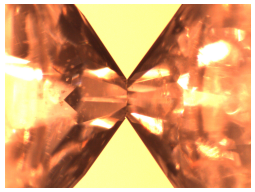
Geophysical observations and modeling

Dense seismic networks, gravity, magnetic field, viscosity, heat flow, dynamic modeling

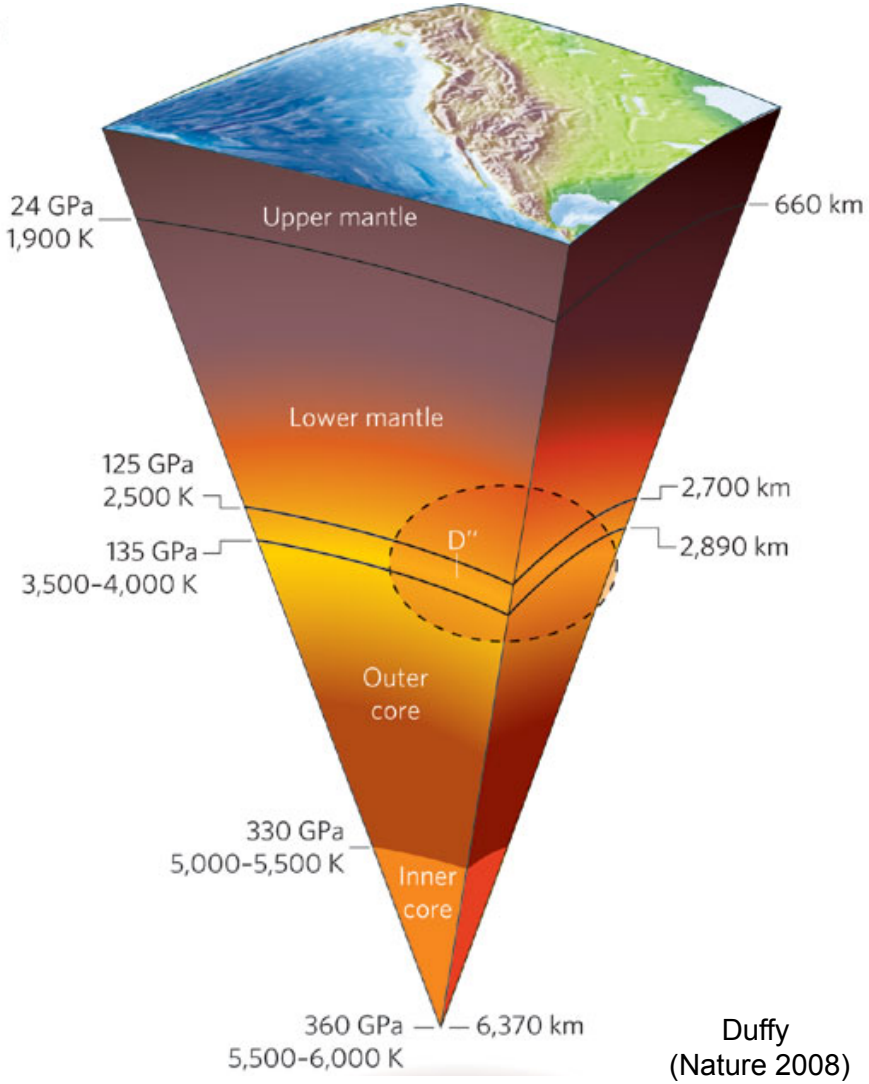


Experiments/Theory:

Vibrational/elastic, density, phase equilibrium, crystal structure, transport, chemistry



Behavior of minerals at depth plays an important role in controlling the activity we observe at the surface



Duffy
(Nature 2008)

Seismic wave speeds (V_P, V_S)

and density (ρ)

Anisotropy (elastic modulus tensor)

Dynamic morphology (P-ρ equations of state, transport properties)

Phase relations and stability (equilibria)

Temperature of the CMB region (melting of core materials at the ICB)