# How to explore the Earth's deep interior under extreme conditions

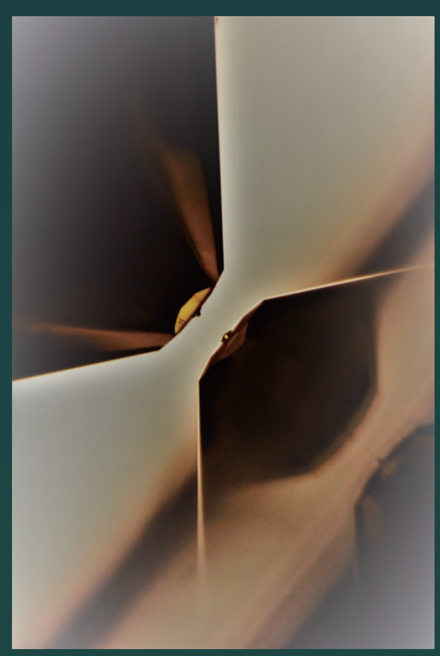
## High-pressure and temperature experiments

### Multi-anvil apparatus

ORANGE-2000 and 3000. Precise experiments up to 80 GPa are possible.

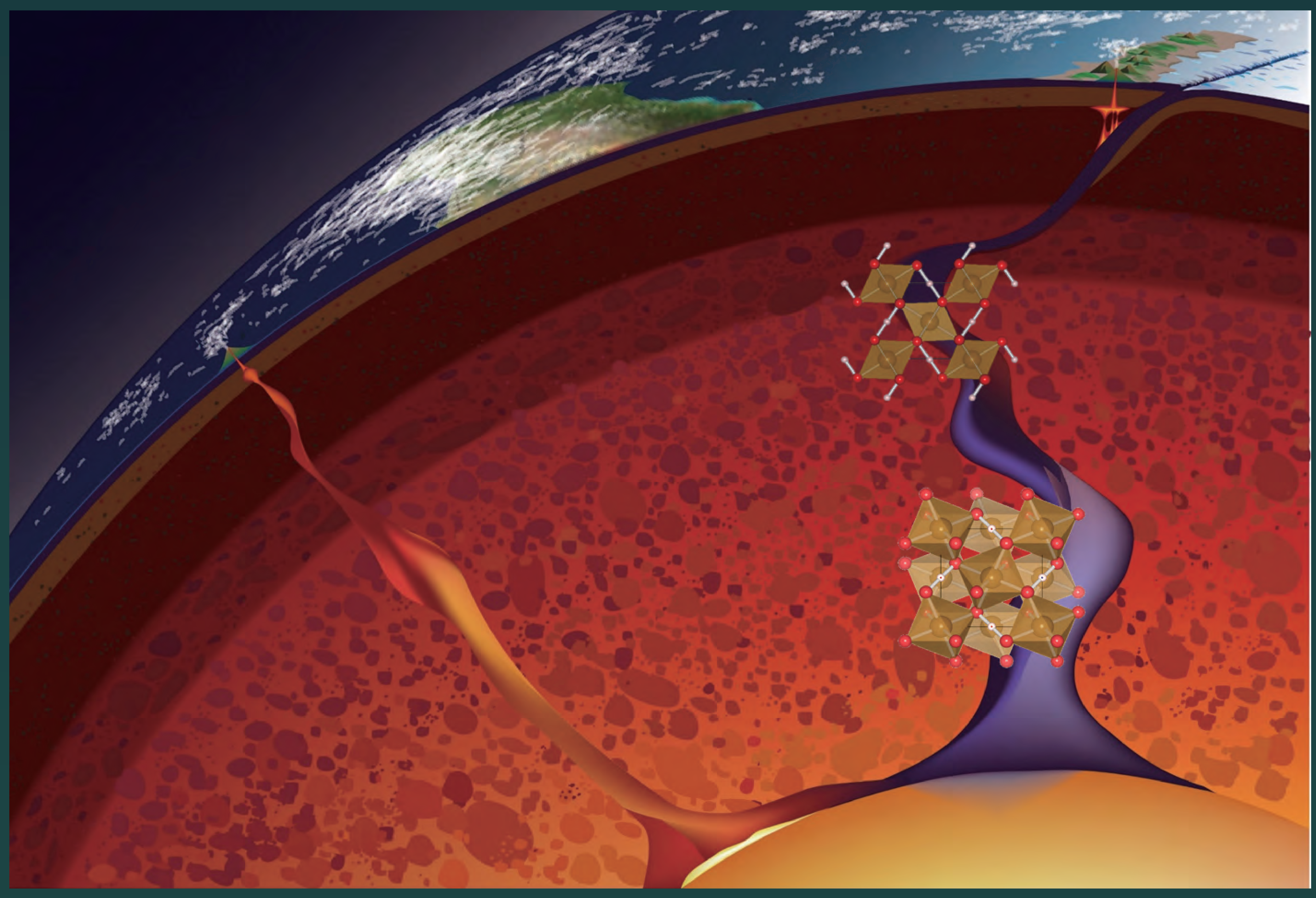

### Diamond-anvil apparatus

Pressures over 300 GPa at the Earth's center can be generated by pressing samples by a pair of diamonds.



### Phase transitions of minerals

A “phase transition” is characterized by the change of configuration of atoms in mineral by the effect of pressure. Diamond is a high pressure form of graphite, whose phase transition occurs at 5 GPa (150 km depth). Measurements of the conditions where the phase transitions occur and changes of the physical properties of minerals (density, sound velocity, chemical properties etc) accompanying the phase transition bring fruitful information for understandings of the Earth's deep structure and materials.



Phase transition of a hydrous mineral FeOOH and water transportation into the deep Earth’s mantle with subducting slabs.

## Numerical simulations

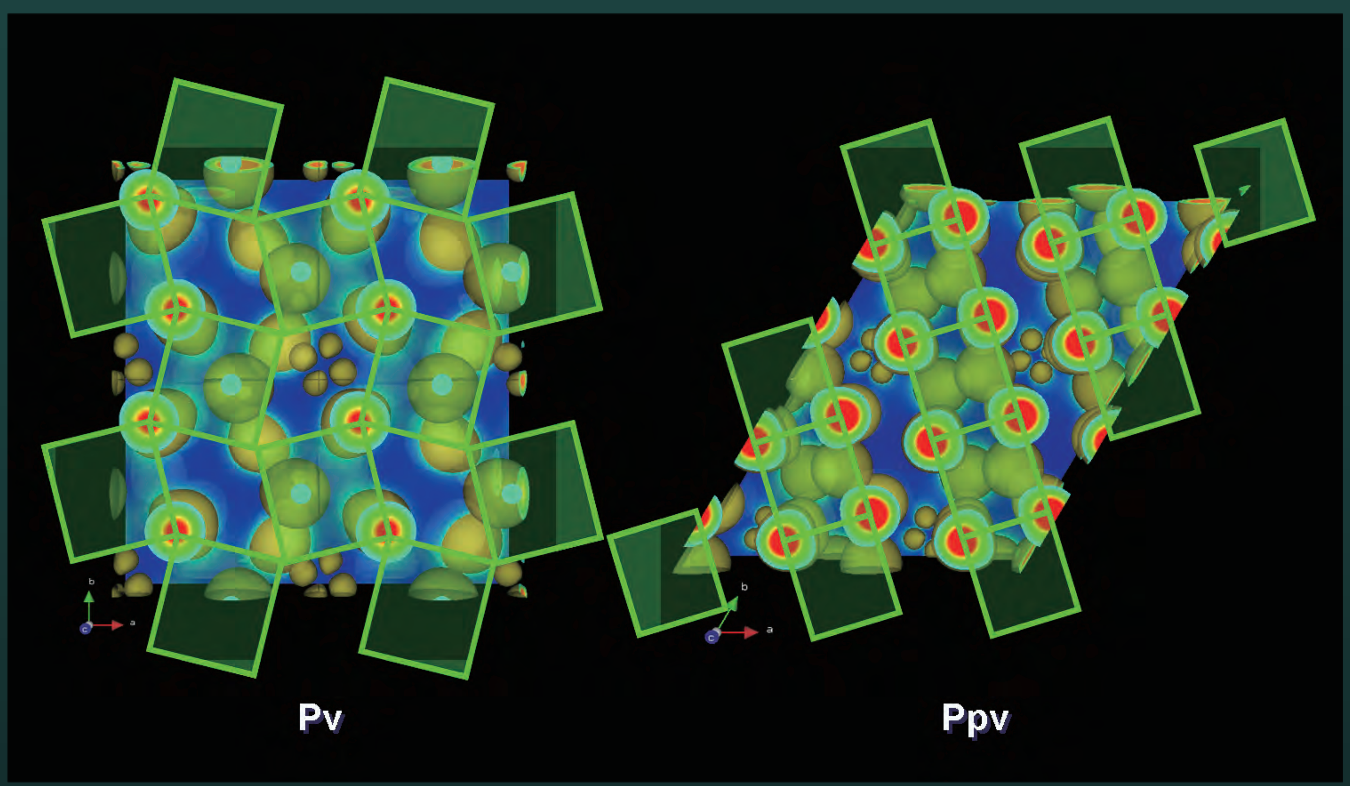
### *Ab initio* computation

Theoretical and computational investigation on the ultrahigh-pressure behaviors of materials in the Earth and planets are conducted by using computer simulations based on quantum mechanics.

$$\left[-\frac{h^2}{2m}\Delta + V_n[n(r)] + V_H[n(r)] + V_{XC}[n(r)]\right]\psi_i(r) = \varepsilon_i \psi_i(r),$$

$$n(r) = \sum_i |\psi_i(r)|^2$$

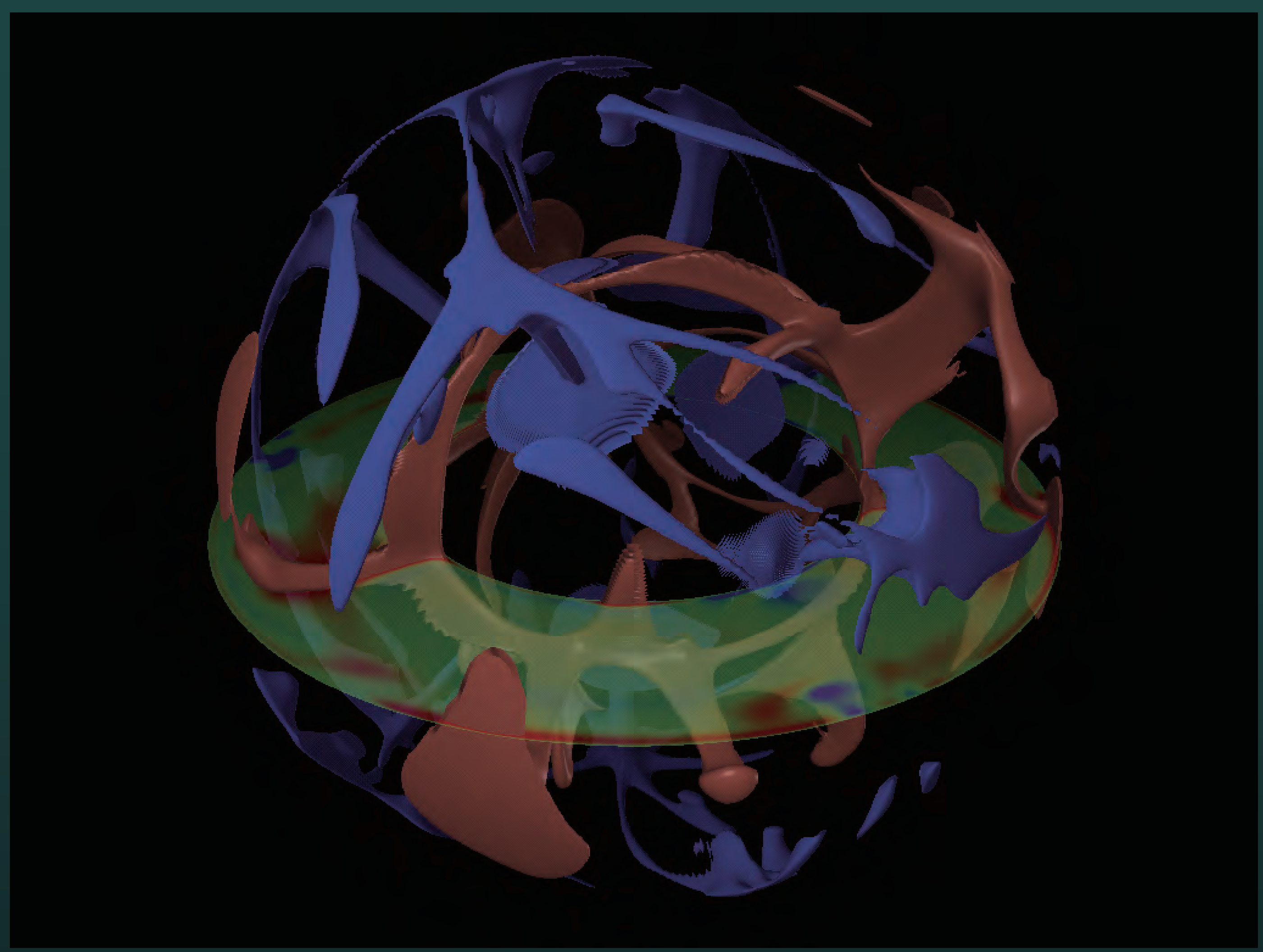
Ab initio computations use exact solutions of the Shrödinger equations that state the behavior of electron, in order to study distributions and properties of electrons in minerals.




Ab initio computation reveals the changes in crystal structure and distribution of electrons in $MgSiO_3$ bridgmanite, the major mineral of the earth's lower mantle. The phase transition from perovskite (left) to post-perovskite structure occurs at 125 GPa (2700 km depth).

### Fluid mechanics computation

Numerical simulations based on the fluid and continuum mechanics are conducted to reveal the convective motions in the mantle and core of the Earth and terrestrial planets for the understandings of the dynamics and evolution processes of the planets. Large scale computations using realistic parameters of the Earth, phase transitions, viscosity and compression behaviors under high pressure, are performed for 3-D spherical-geometry simulations.



Three dimensional simulation of the mantle convection. Red area is hot and ascending (upward) flows, and blue is cold and descending (downward) flows.