Comprehensive simulation of solar wind formation from the solar interior

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We present a simulation of the solar wind acceleration starting from the thermal convection in the solar interior. The turbulent plasma motion and small-scale magnetism in the solar convection zone are promising drivers of the supersonic solar wind. Because of the significant difference in the spatiotemporal scale, a wide variety of physical processes has been suggested as possible origins of the solar wind under empirical assumptions.

For the first time, we conducted a comprehensive simulation of the solar wind emanating from the edge of solar coronal holes. We included all the most important physical processes, such as the photospheric radiative transfer, the realistic opacity and the equation of states, optically thin radiative cooling, and the field-aligned thermal conduction in the low-dense atmosphere. The computational resource by RIKEN Fugaku allowed us to trace the energy and mass flow from the solar interior to the solar wind resolving energetically essential scales.

Turbulent thermal convection in the numerical domain spontaneously generates complex magnetic structures and excites various plasma waves. The simulated dense and slow solar wind exhibits time variations from minutes to days, including magnetic polarity reversals called magnetic switchbacks. The simulated photospheric field strength, coronal density, and mass-loss rate reasonably agree with observational constraints. The detailed analysis shows the energy input from closed coronal loops accounts for a large portion of solar wind energy, suggesting the importance of magnetic reconnection in solar wind formation.

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