Energy Supply for Heating the Slow Solar Wind Observed by Parker Solar Probe between 0.17 and 0.7 au

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Solar wind heating has long been an intriguing problem in space plasma physics, in which solar wind turbulence is believed to play a critical role. An unsolved issue is whether there exist the energy-containing range and turbulence cascade process in the slow solar wind. The Parker Solar Probe mission (PSP) provides a good opportunity to study this issue. Recently, PSP observations found that the slow solar wind experiences stronger heating inside 0.24 au[1]. The magnetic moment of the slow wind from 0.17 to 0.24 au is observed to increase fast while it is almost constant outside 0.24 au. Why the slow solar wind experience strong heating inside 0.24 au remains a question.

In this study[2], we present for the first time the radial gradient of the low-frequency breaks on the magnetic-trace power spectra in the slow solar wind using PSP measurements from 0.17 au to 0.7 au. We identify the process of energy injection by low-frequency sweeping and propose a formula for calculating the energy supply rate. We find that the energy supply rate is consistent with the observed solar wind heating rate calculate based on the gradient of the magnetic moment. This finding explains why the slow solar wind is strongly heated inside 0.25 au but expands nearly adiabatically outside 0.25 au. This work discovers the low-frequency break sweeping process and demonstrates it is the energy injection mechanism in the slow solar wind turbulence.

Due to the different origins and properties, one may naturally ask if the same process works for the fast solar wind. We further analyze the data in the fast solar wind from Helios 2 and Ulysses and evaluate the energy rate by the low-frequency sweeping from 0.3 au to 4.8 au[3]. We found that the same process provides enough energy to heat the fast solar wind as well.

Our work supports the concept that the energy is added from the energy-containing range to the inertial range through the low-frequency sweeping mechanism, which is then transferred by an energy cascade process to the dissipation range to heat the solar wind. This energy injection process in the solar wind turbulence is different from that in the fluid turbulence.

References

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