Solar Orbiter observations of the Kelvin-Helmholtz waves in the solar wind

การสังเกตคลื่นเคลวิน-เฮล์มโฮลทซ์ในลมสุริยะด้วย Solar Orbiter

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The universe is mostly made up of plasmas, i.e., ionized gases. Plasma physics is related to fluid dynamics, with the additional physics of electrical currents and interactions with magnetic fields. Like any fluid, a plasma can be subject to the Kelvin-Helmholtz instability – the same instability that causes ripples on a pond when the wind blows overhead. More generally, between any two fluids flowing with a relative (shear) velocity, the interface can become unstable. The Kelvin-Helmholtz instability has been observed many times (including our previous work by Kieokaew et al. 2020) at the boundary between Earth's magnetosphere and the solar wind, a supersonic plasma flow from the Sun that permeates interplanetary space. Our previous work proposed that such an instability between solar wind streams with different velocities can explain an observed transition in solar wind fluctuations, can strongly energize turbulence in the solar wind, and can explain "switchbacks" or temporary reversals in the interplanetary magnetic field (Ruffolo et al. 2020; see https://physics.sc.mahidol.ac.th/research/highlights/Ruffolo-2021-a/).

The present work provides the first direct observational evidence of Kelvin-Helmholtz waves in the solar wind, using *in situ* observations by Solar Orbiter (SolO), a mission by the European Space Agency that travels inward toward the Sun. In an event on 23 July 2020, Solar Orbiter measurements of the solar wind velocity and magnetic field reveal a sequence of homologous structures that we identify as Kelvin-Helmholtz waves. The results are similar to those expected from our computer simulation (see Figure below) using the observed velocity difference on the two sides of the waves.

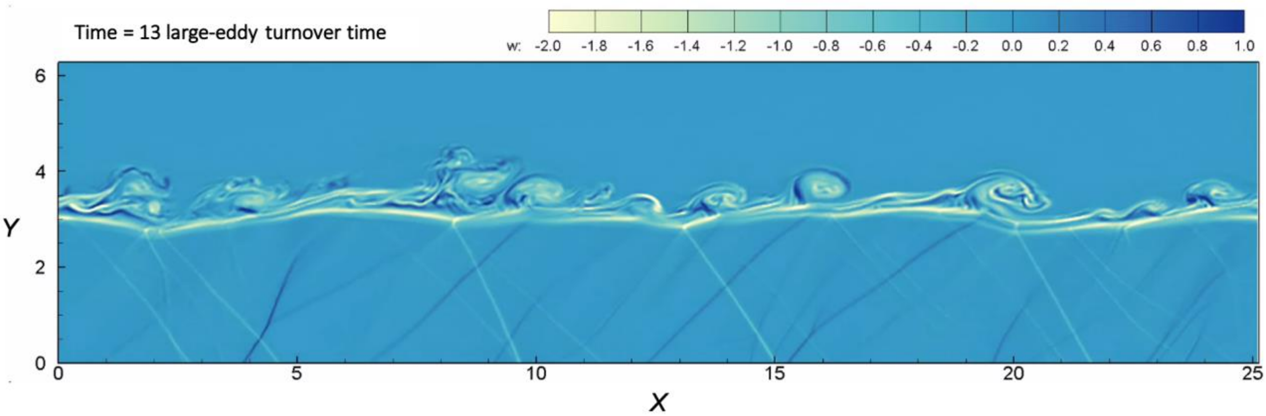

Figure: Snapshot of the numerical simulation of the Kelvin-Helmholtz (KH) instability using empirical values of the Solar Orbiter event from Side 1 and Side 2. The color-scale represents values of the out-of-plane flow vorticity (!). The KH instability quickly reaches the nonlinear stage where rolled-up KH vortices form and coalesce. The stripes in vorticity in the lower part of the simulation are shocks (known as vortex-induced shocks) produced by the supersonic flow as the Mach number on this side is ∼3.