Simulating high-speed solar wind streams from coronal holes using an L5-L1 configuration of Lagrangian points

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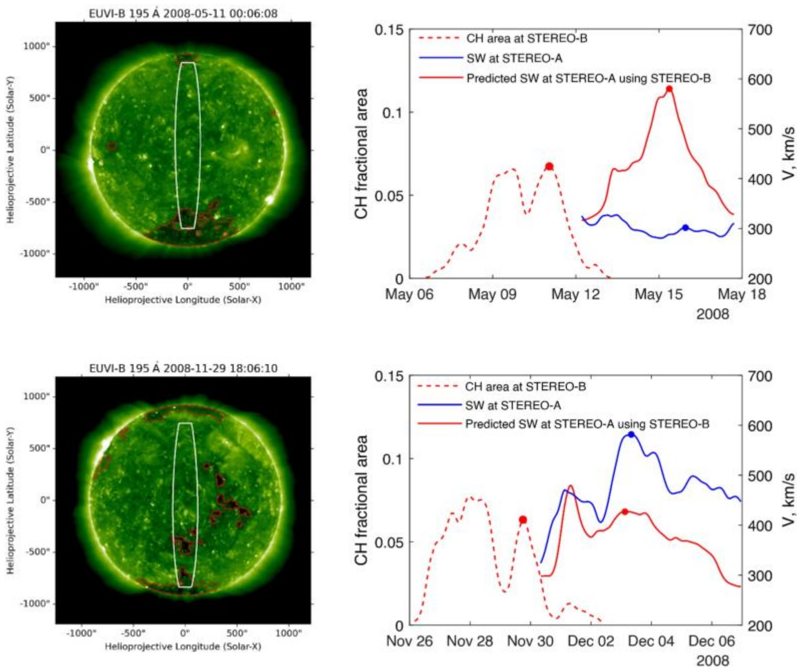
Why It Matters

Coronal holes (CHs) on the Sun launch high-speed solar wind streams (HSSs) that shape the heliosphere and drive recurrent geomagnetic storms, yet the physical mechanisms linking CHs to the generation of HSSs remain unclear, complicating accurate predictions. In preparation for the upcoming ESA *Vigil* mission at L5, our study shows how this vantage point can extend HSSs prediction lead times from hours to days, improve their accuracy, and explain why velocities differ between L5 and L1.

What We Did

We simulated L5–L1 observational conditions using multi-spacecraft data from STEREO-A, STEREO-B, and Earth (2008–2010). By linking CH areas seen in EUV images to measured solar wind speeds, our study revealed that differences between solar wind at L5 and L1 arise from the combined effect of smaller coronal holes, their exact locations on the Sun, and the latitudinal positions of the observing spacecraft.



Coronal hole and spacecraft latitude effects on solar wind velocity at simulated L1/L5.

Left: STEREO-B 195 Å images with segmented coronal holes and meridional slices (15°) for two events in May & November 2008. **Right:** L1 (blue) and L5 (red) velocities with coronal area (red dotted).

Top panel: The coronal hole (-51°) and STEREO-B (-5.7°) share a southern latitude, while STEREO-A (+0.8°) does not. This >6° difference with the coronal hole properties causes the fast solar wind to weaken at L1 compared to L5.

Bottom panel: combination of the small coronal hole at -35° latitude, STEREO-B's latitude (+5.9°) and that of STEREO-A's (-4,8°), creating a >10° latitudinal difference — that reverses the expected velocity trend, enhancing the solar wind speed at L1 compared to L5.

Key Finding – The Garden Hose Effect

We introduce the **'garden hose effect'**: like water from a hose, solar wind streams deliver their full impact when a spacecraft is aligned with the flow, but appear weaker when observed off-axis. This explains why solar wind at L5 can appear stronger or weaker than at L1, depending on relative geometry. This effect is most pronounced for smaller coronal holes at higher solar latitudes, and depends strongly on the latitudinal separation between spacecraft. In contrast, larger coronal holes deliver solar wind more uniformly across the heliosphere.

The Sun's garden hose: how solar winds spray across the Solar System.

Toward Better Forecasts

We developed a predictive indicator that integrated CH area, location on the Sun, and spacecraft latitude, allowing us to correct HSSs forecasts between L5 and L1. Our results demonstrate that including EUV imaging of coronal holes on *Vigil* will meaningfully improve space weather forecasting.

Broader Impact

This study highlights the scientific and operational value of diverse vantage points in space, such as L5 and L4, setting benchmarks for future mission design and enhancing preparedness against space weather effects.

Reference

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