

Supplementary Information

Measured energy exchange in coronal hole solar wind from its coronal origins to the heliosphere
Rivera et al

Supplementary Table 1: Summary of remote observations utilized in the study. The table includes the diagnostics, associated mission or instrument, observation dates, altitude of observations, and methodology for deriving corresponding diagnoses.

Diagnostic	Observation Date (UT)	Altitude	Methodology
Density			
SDO/AIA	2024-04-01 to 2024-04-15	1-1.25 R _☉	DEMT (Frazin et al. [70], Lloveras et al. [77])
DKIST Cryo-NIRSP	2024-04-09 18:00	1.05 R _☉	Fe XIII line ratio
MLSO/UCoMP	2024-04-09 18:00	1.05-1.95 R _☉	Fe XIII line ratio
MLSO/K-Cor	2024-04-09 18:00	1.05-1.95 R _☉	WL pB (van de Hulst [38])
Solar Orbiter/Metis	2024-03-29 05:15	2-4 R _☉	WL pB (van de Hulst [38])
SOHO/LASCO-C2	2024-04-01 to 2024-04-15	2.5-6 R _☉	WL pB SRT (Frazin & Janzen [72], Vasquez et al. [74])
Electron Temperature			
SDO/AIA	2024-04-04 18:30-19:30	On disk	DEM (Cheung et al. [44])
Solar Orbiter/SPICE	2024-04-04 06:20	On disk	DEM (Plowman et al. [50])
Velocity			
Hinode/EIS	2024-04-01 to 2024-04-03 (daily)	On disk	Doppler velocities
Solar Orbiter/Metis	2024-03-29 05:15	2-4 R _☉	Ly α Doppler dimming
SOHO/LASCO-C2	2024-04-01 to 2024-04-15	2.5-6 R _☉	Mass conservation and expansion factor*
Magnetic Field			
MLSO/UCoMP	2024-04-09 18:00	1.05-1.95 R _☉	Coronal seismology (Yang et al. [22])
Non-thermal widths			

DKIST Cryo-NIRSP	2024-04-08 18:00	1.05 R _☉	Spectral line fitting**
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*see details in Methods Section 4.7

**see details in Methods Section 4.5

Supplementary Table 2: Summary of all the mean values used to compute the energy budget at the Sun, Parker Solar Probe, and Solar Orbiter. At the Sun, we take the mean values between 1.040-1.06 R_{sun}. At Parker Solar Probe and Solar Orbiter, we use the average value across the carrington longitude 90-122

Properties of the solar wind	Sun (1.05 R _☉)	Parker Solar Probe (11.75 R _☉)	Solar Orbiter (70 R _☉)
$n_{p,e}$ (cm ⁻³)	$1.6 \pm 0.6 \times 10^8$	$3.6 \pm 0.48 \times 10^3$	53.05 ± 11.46
v_p (km s ⁻¹)	11.48 ± 6.1 (EIS), 9.98 ± 10.60 (SPICE)	285.03 ± 42.87	456.04 ± 78.79
T_p (MK)	1.23 ± 0.04	0.826 ± 0.201	0.322 ± 0.123
V_A (km s ⁻¹)	424.89 ± 67.01	352.26 ± 40.18	103.45 ± 20.8
B_R (gauss, nT)	–	-901.12 ± 94.25 ,	-16.86 ± 7.44
$ B $ (gauss, nT)	2.65 ± 1.07 , $2.65 \pm 1.07 \times 10^5$	$9.64 \pm 0.5 \times 10^{-3}$, 964.01 ± 49.89	$2.4 \pm 0.09 \times 10^{-4}$, 23.95 ± 0.90
n_α/n_p	0.04	0.04 ± 0.01	0.04
v_α (km s ⁻¹)	11.48 ± 6.1	396.32 ± 49.83	–
T_α (MK)	1.23 ± 0.04	6.65 ± 1.22	–
T_e (MK)	1.23 ± 0.04	0.668 ± 0.032	–
dB (km s ⁻¹)	22.4 ± 1.6	255.15 ± 175.90	17.76 ± 10.96
dV (km s ⁻¹)	22.4 ± 1.6	92.08 ± 58.78	38.40 ± 33.94

Supplementary Table 3: List of all the energy flux budget terms at the Sun, Parker, and Solar Orbiter. Each term at the Sun and Solar Orbiter has been scaled to Parker Solar Probe by $f_{Sun} = 0.27$ and $f_{solo} = 0.95$, respectively, to account for non-spherical expansion.

Energy Flux (W m ⁻²)	Sun (1.05 R _☉) $\times f_{Sun}$	Parker Solar Probe (11.75 R _☉)	Solar Orbiter (70 R _☉) $\times f_{solo}$
Kinetic Flux	0.067 ± 0.033	10.96 ± 3.98	24.76 ± 6.56
Enthalpy Flux	44.86 ± 17.27	3.62 ± 0.66	1.35 ± 0.55

Alfvén Wave Flux	18.3 ± 2.17	1.75 ± 1.32	0.44 ± 0.53
Gravitational Energy Flux	5.67 ± 2.83	47.82 ± 7.19	39.05 ± 4.50
Total Energy Flux	68.91 ± 18.18	64.15 ± 6.32	65.60 ± 12.14