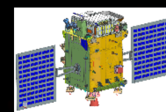
Aditya-L1 mission of India
and
Cross-calibration of ASPEX



ASPEX: Aditya **S**olar wind **P**article **EX**periment

Prof. Dibyendu Chakrabarty

PRL, India

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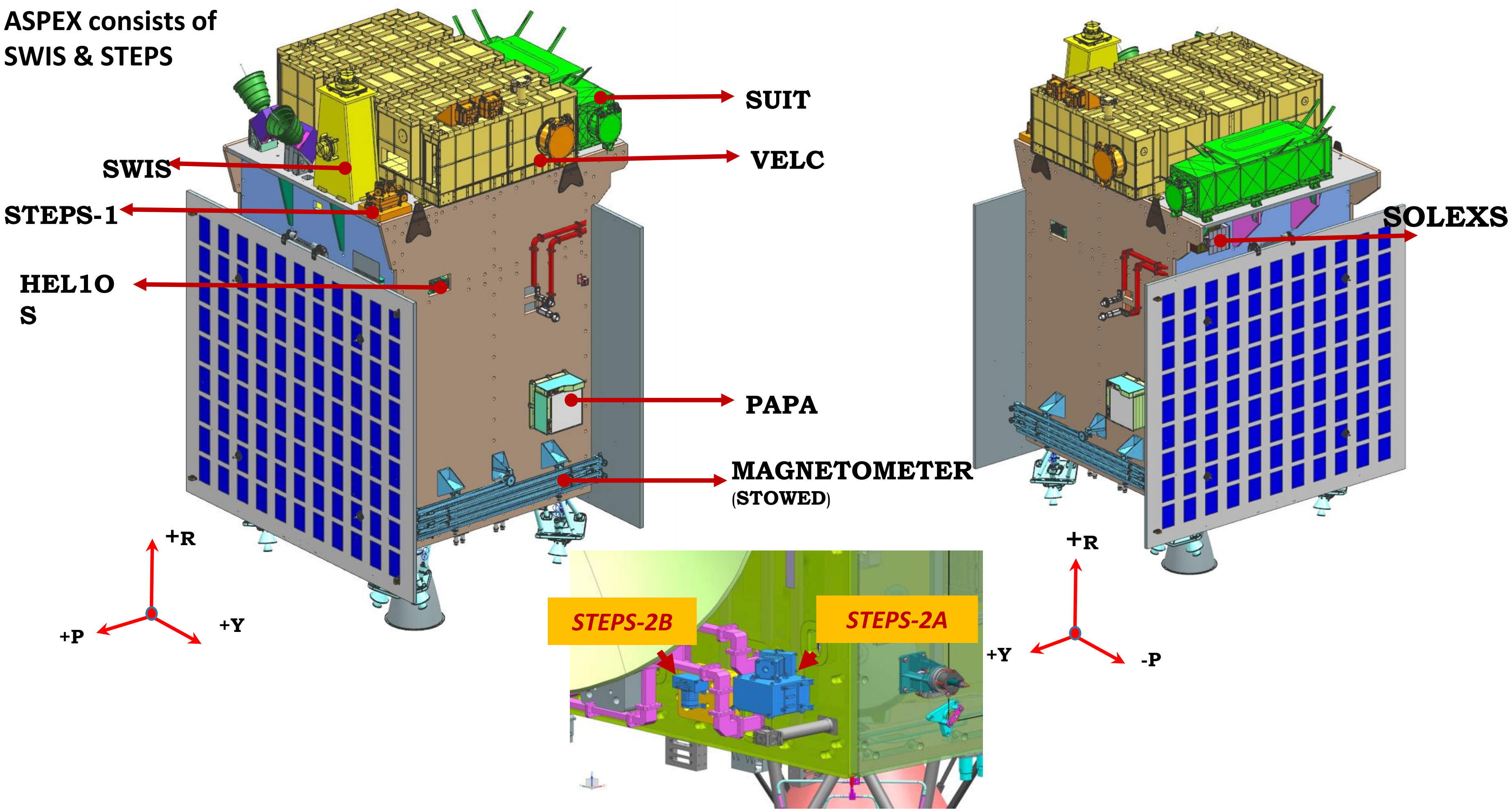
Global Space-based Inter-Calibration System (GSICS)

Annual meeting

17 March, 2025

ADITYA-L1 – The first Observatory class dedicated mission from India for Solar & Heliospheric studies

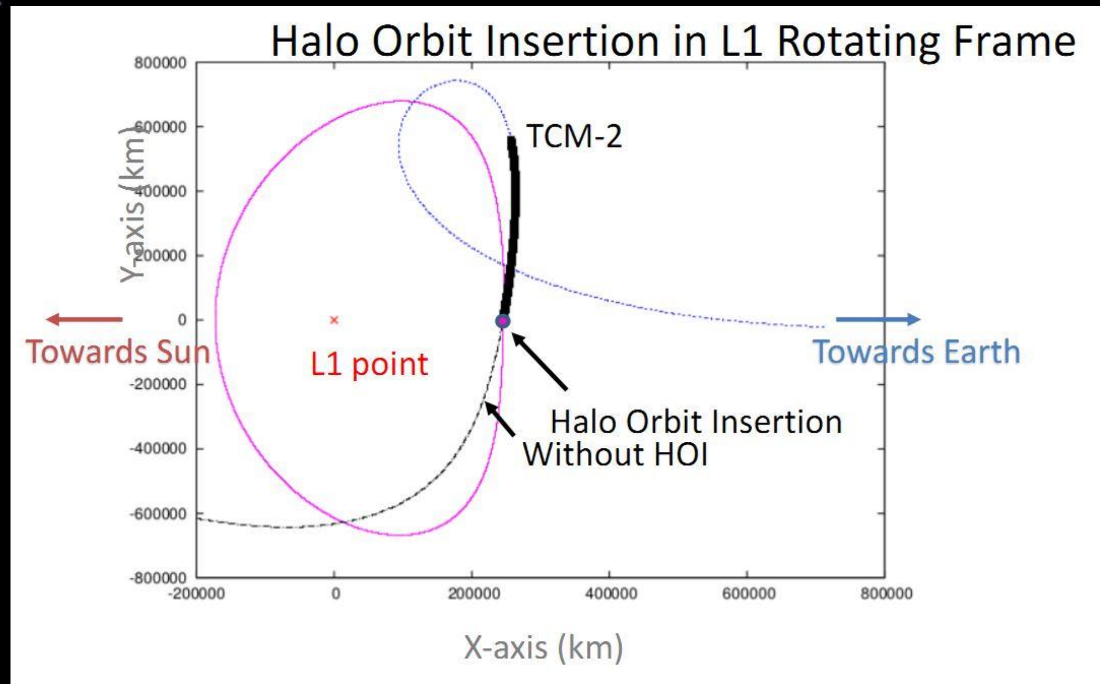


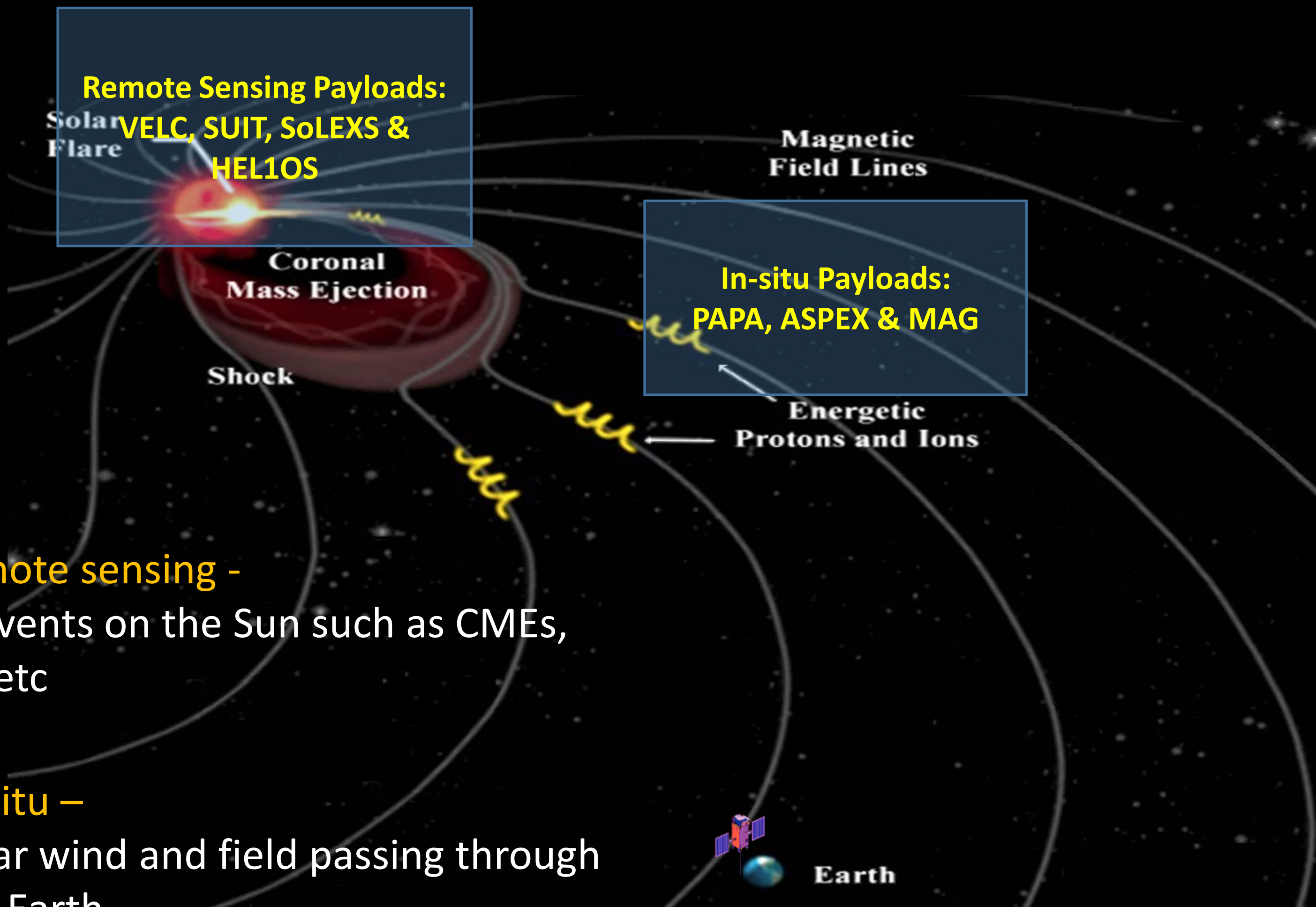
PSLV C57 was launched at 11:50 IST on 02 September 2023.

It successfully achieved its intended orbit nearly an hour later, and separated from its fourth stage at 12:57 IST.

Cruise phase starts at 02:00 hrs IST on 19 September, 2023

Halo Orbit insertion at the L1 point on 6 January 2024, at 4:17 pm IST.





Through remote sensing -

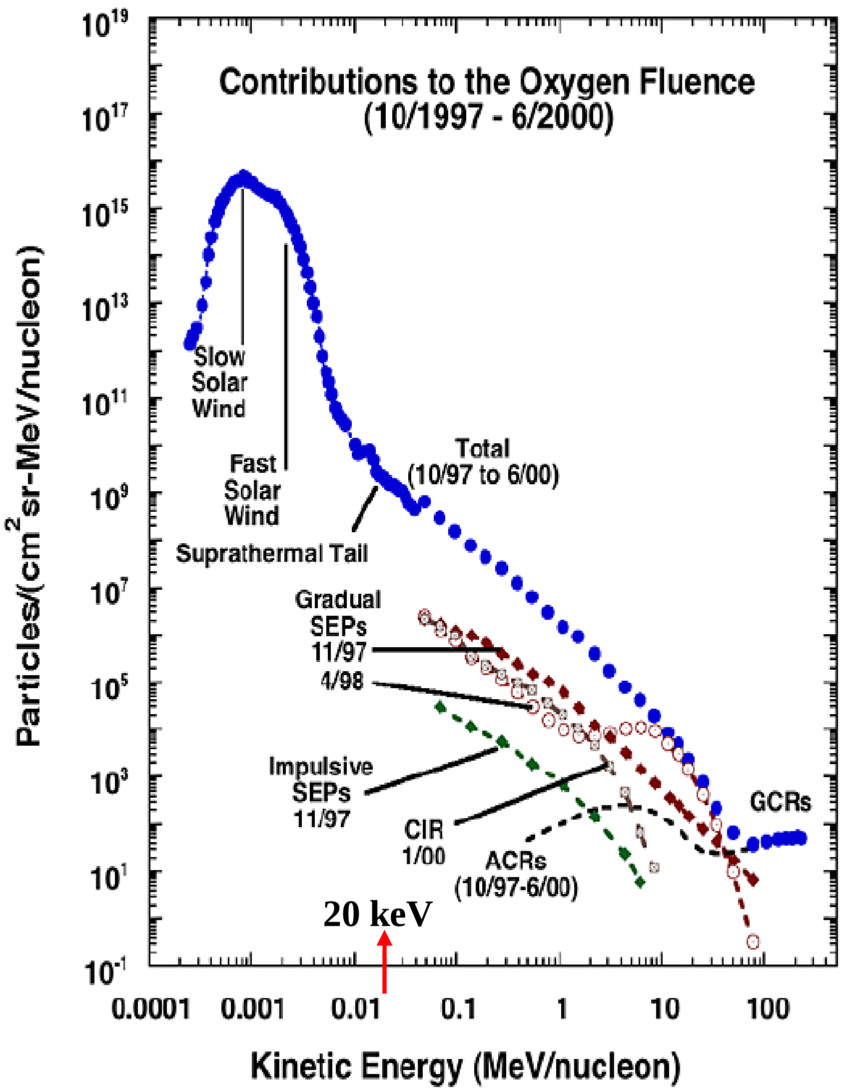
Dynamical events on the Sun such as CMEs, Solar Flares etc

Through in-situ –

Ambient solar wind and field passing through L1, ahead of Earth

Courtesy: Nunez et al., 2016

Solar wind Ions in the interplanetary medium



Mewaldt et al., 2007

Three distinctly different regimes

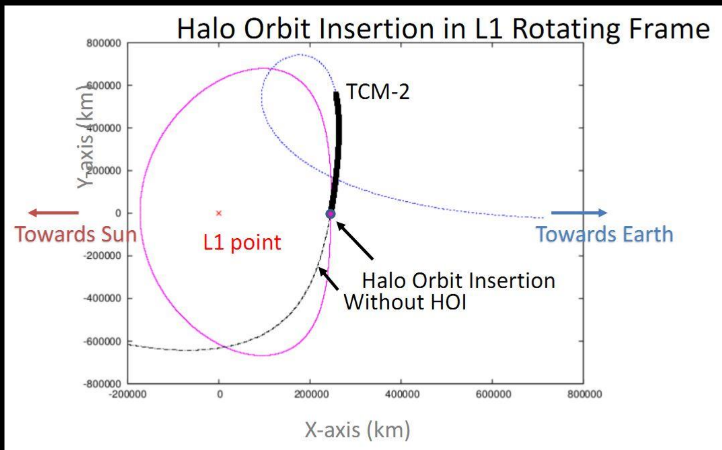
- **Slow and Fast solar wind particles** (upto ~3 keV)
- **Suprathermal particles** (3 keV to a few hundreds of keVs)
- **Solar Energetic Particles, SEP** (~ a few to tens or hundreds of MeVs)

✓ **Generation**
✓ **Inter-connection**
✓ **Energization**
✓ **Anisotropy**
✓ **Impact**

Differences in L1 parameters: Connundrum

How much of it is due to measurements ? How much of it is due to spatial inhomogeneity?

With 6 satellites in near future at L1, time has come to address this problem in greater detail



Solar wind spatial scales in and comparisons of hourly Wind and ACE plasma and magnetic field data

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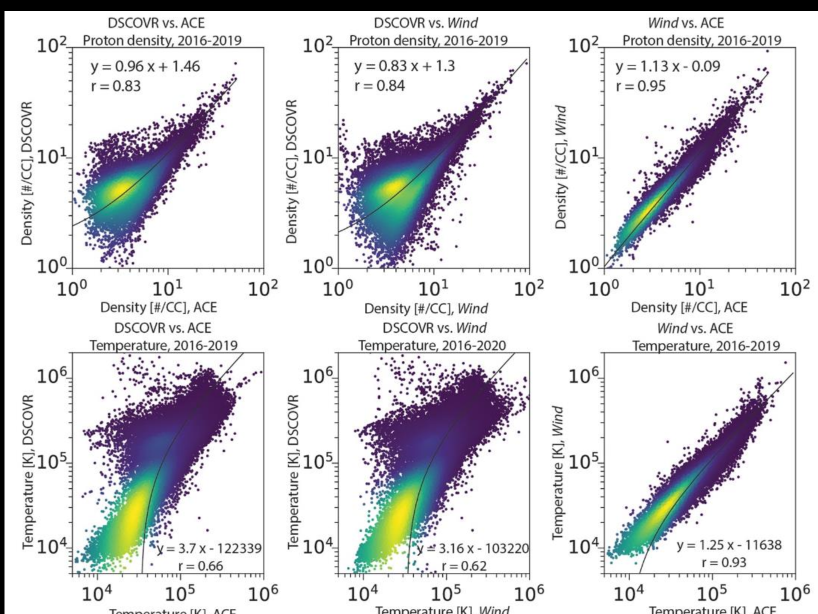
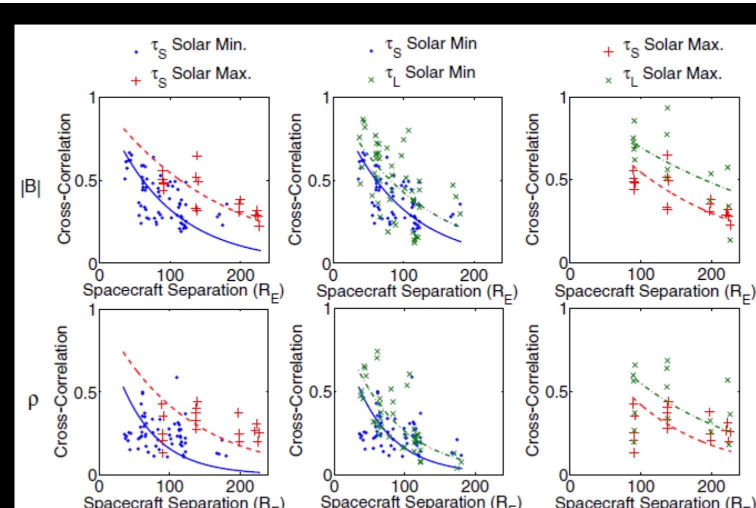
Received 24 June 2004; revised 17 November 2004; accepted 16 December 2004; published 16 February 2005.

[1] Hourly averaged interplanetary magnetic field (IMF) and plasma data from the Advanced Composition Explorer (ACE) and Wind spacecraft, generated from 1 to 4 min resolution data time-shifted to Earth have been analyzed for systematic and random differences. ACE moments-based proton densities are larger than Wind/Solar Wind Experiment (SWE) fits-based densities by up to 18%, depending on solar wind speed. ACE temperatures are less than Wind/SWE temperatures by up to ~25%. ACE densities and temperatures were normalized to equivalent Wind values in National Space Science Data Center's creation of the OMNI 2 data set that contains 1963–2004 solar wind field and plasma data and other data. For times of ACE-Wind transverse separations <60 R_E, random differences between Wind values and normalized ACE values are ~0.2 nT for $|B|$, ~0.45 nT for IMF Cartesian components, ~5 km/s for flow speed, and ~15 and ~30% for proton densities and temperatures. These differences grow as a function of transverse separation more rapidly for IMF parameters than for plasma parameters. Autocorrelation analyses show that spatial scales become progressively shorter for the parameter sequence: flow speed, IMF magnitude, plasma density and temperature, IMF X and Y components, and IMF Z component. IMF variations have shorter scales at solar quiet times than at solar active times, while plasma variations show no equivalent solar cycle dependence.

Citation: King, J. H., and N. E. Papitashvili (2005), Solar wind spatial scales in and comparisons of hourly Wind and ACE plasma and magnetic field data, *J. Geophys. Res.*, *110*, A02104, doi:10.1029/2004JA010649.



Loto'aniu et al., Space weather, 2022



Wicks et al., ApJ, 2008

Aditya Solar wind Particle EXperiment (ASPEX)

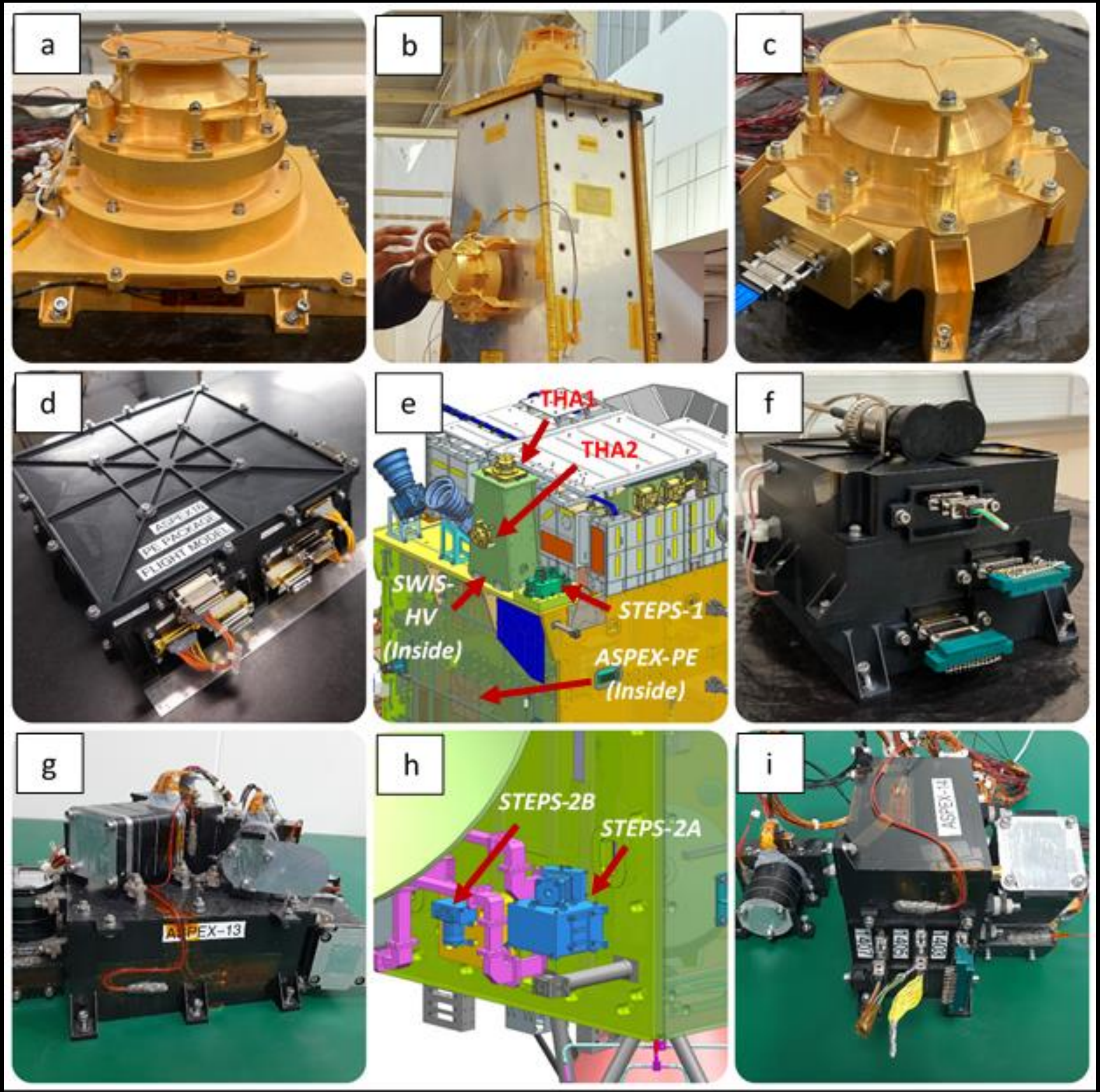
- ✓ Multi-directional measurements
- ✓ Alpha-Proton separation
- ✓ Both low and high energies

SWIS: Solar wind Ion Spectrometer
-- 100 eV- 20 keV
-- Two planes: 2π in and across ecliptic (Top Hat Analyzer -1 or THA1 and Top Hat Analyzer-2 or THA2)
-- Species (H^+ and He^{++}) separated in the ecliptic and integrated across ecliptic

STEPS: Supra Thermal and Energetic Particle Spectrometer
-- 20 keV/n – 6 MeV/n
-- Six directions
-- H^+ and He^{++} separated (beyond 6 MeV) – Sun Radial (SR), Parker Spiral (PS), Earth Pointing (EP)
-- H^+ and He^{++} integrated – Inter-Mediate (IM), North Pointing (NP) and South Pointing (SP)

ASPEX is conceived and developed by Physical Research Laboratory (PRL), Ahmedabad. The hardware is developed in close collaboration with Space Application Centre (SAC), Ahmedabad of ISRO. Support from URSC and LEOS are also acknowledged.

Flight models of ASPEX



ASPEX data sets

Solar Wind Ion Spectrometer (SWIS)

Level 1

Number of files: 3
Content : Payload frames containing spectrum and HK data
Format : CDF
Processing : Valid frame detection, processing SPICE kernels, segregating sensor data, UT time and angle derivation
Science ready: No

Level 2

Number of files: 3
Content : Direction differentiated flux data from THAs, bulk parameters (*Proton density, velocity, temperature*)
Format : CDF
Processing : Count corrections, energy derivation, flux conversions, bulk parameter estimation
Science ready: Yes
Validation: Compared with other L1 point measurements

ASPEX data sets

Supra-Thermal and Energetic Particle Spectrometer (STEPS)

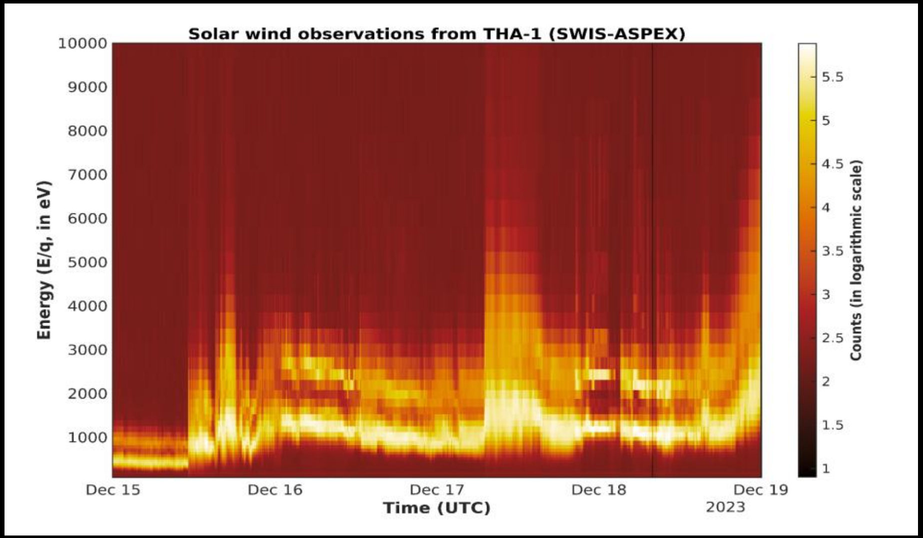
Level 1

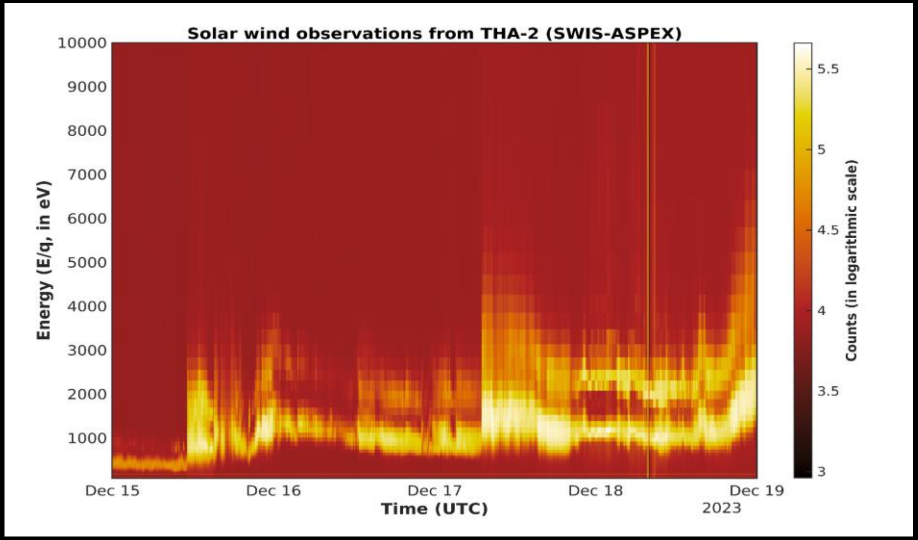
Number of files: 3
Content : Payload frames containing spectrum and HK data
Format : CDF
Processing : Valid frame detection, processing SPICE kernels, segregating sensor data, UT time and angle derivation
Science ready: No

Level 2

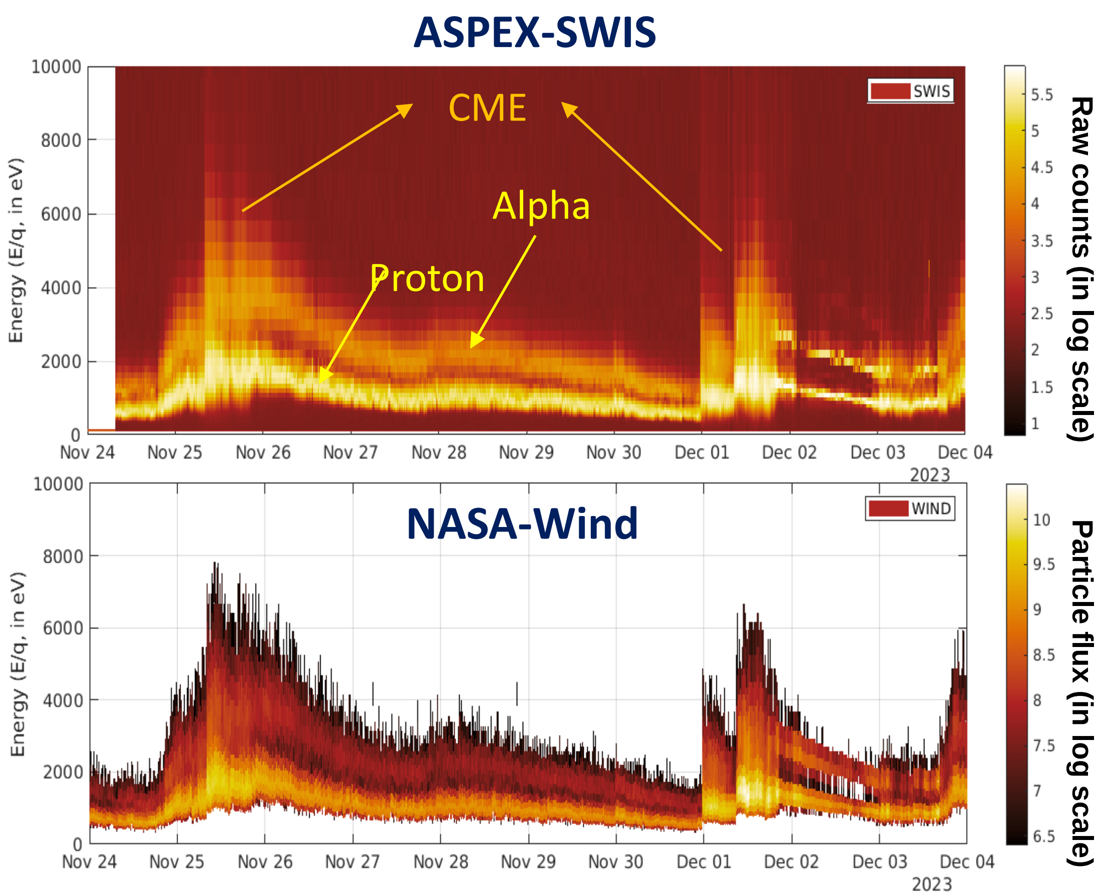
Number of files: 6
Content : Direction differentiated flux data from different STEPS units
Format : CDF
Processing : Count corrections, energy derivation, flux conversions
Science ready: Yes
Validation: Compared with other L1 point measurements

Energy (E/q) histogram
AL1-ASPEX-SWIS
THA-1 Vs. THA-2





Energy (E/q) histogram
AL1-ASPEX-SWIS Vs. Wind-SWE



24 November – 04 December 2023
GSE coordinates

AL1 (X, Y, Z in R_E)
197, -113, -2.5
Wind (X, Y, Z in R_E)
226, 98, 5

Velocity Distribution Function (VDF), moments and Bulk parameters like density, velocity etc.

- ❑ Construct VDF (Differential flux Vs. Energy or PSD Vs. Velocity)
- ❑ Fit with Maxwellian distributions for different species, bi-Maxwellian for H^+ and He^{2+}
- ❑ Estimate zeroth and higher order moments

For example,

$$\int_{\forall \mathbf{u}} d^3u \, f_j(\mathbf{u}) = n_j$$

where n is the number density of species

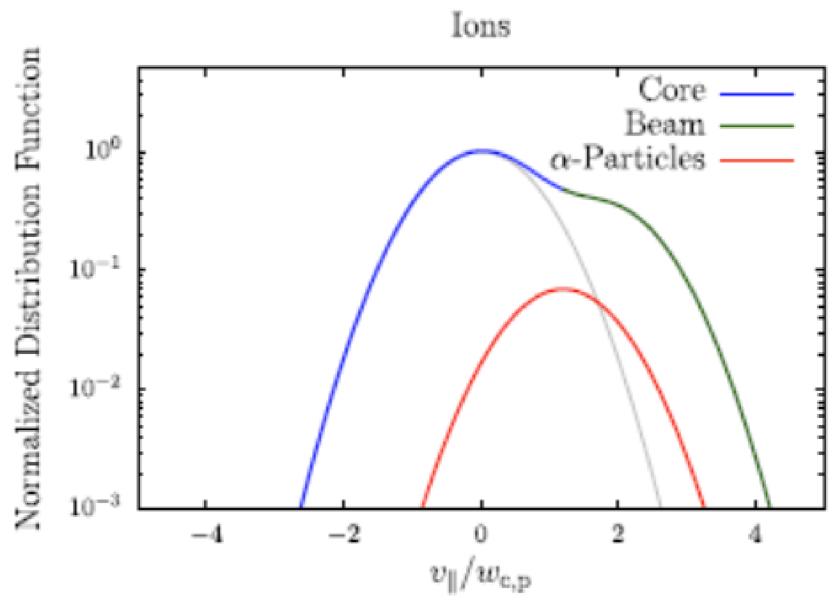
$$\int_{\forall \mathbf{u}} d^3u \, \mathbf{u} \, f_j(\mathbf{u}) = n_j \, \mathbf{v}_j$$

V is its bulk velocity

$$\int_{\forall \mathbf{u}} d^3u \, u^2 \, f_j(\mathbf{u}) = n_j \left(v_j^2 + w_j^2\right)$$

Where wj is the thermal speed and

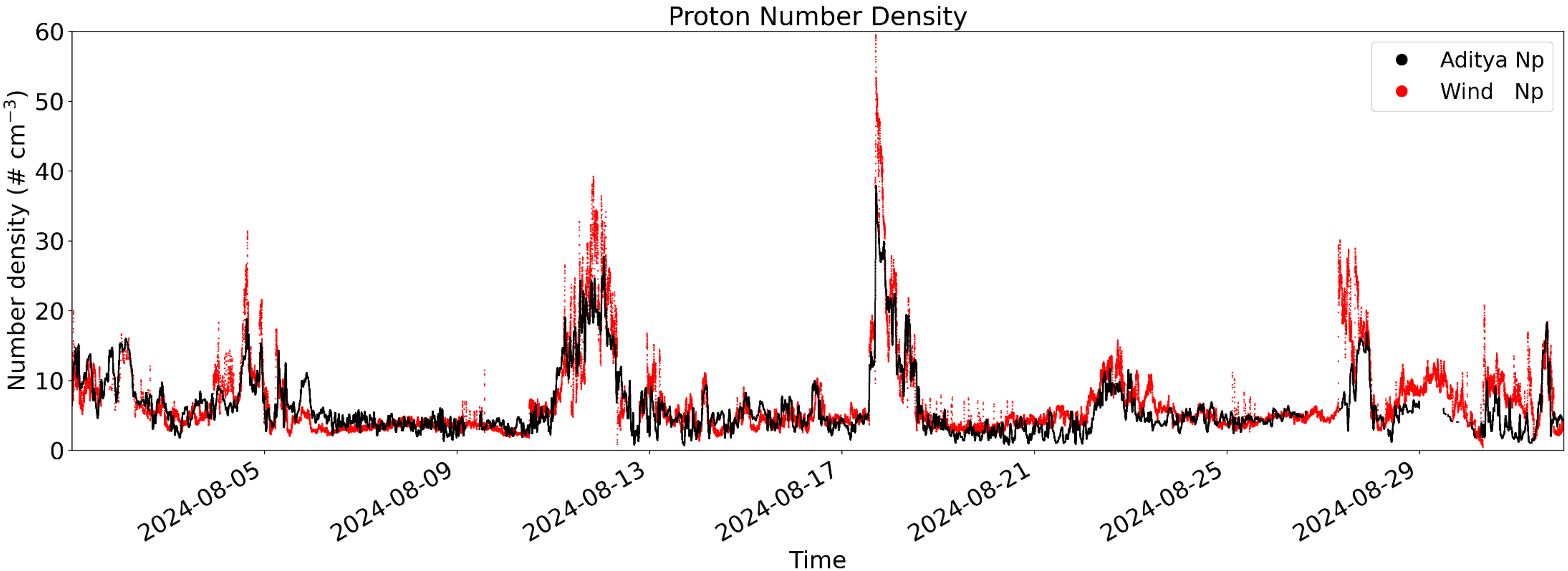
$$T_j = \frac{m_j \, w_j^2}{k_B}$$



Here, the distribution function is normalized to the maxima of the proton distribution functions, respectively and the parallel velocity is normalized to the thermal speed of the proton core components. The distributions are shown in the reference frames in which the core distribution is at rest

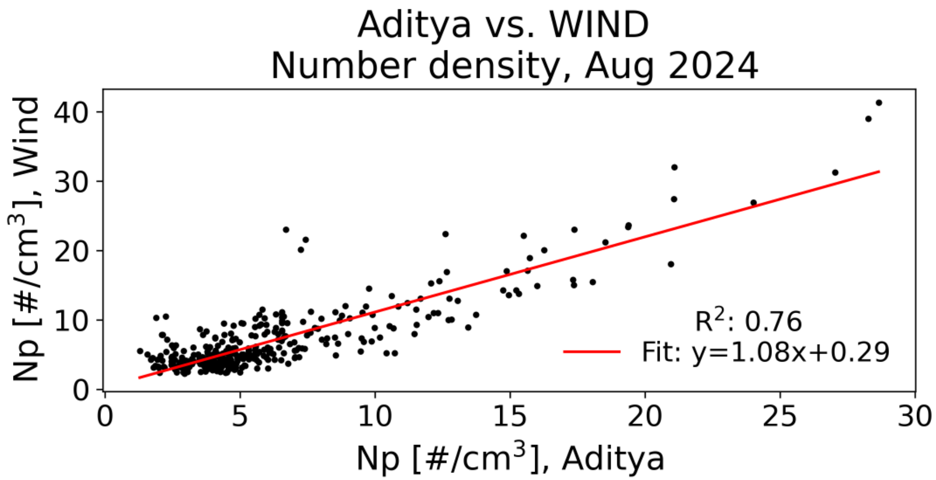
Verscharen et al., 2019

Solar wind parameters
AL1-ASPEX-SWIS Vs. Wind-PESA-L

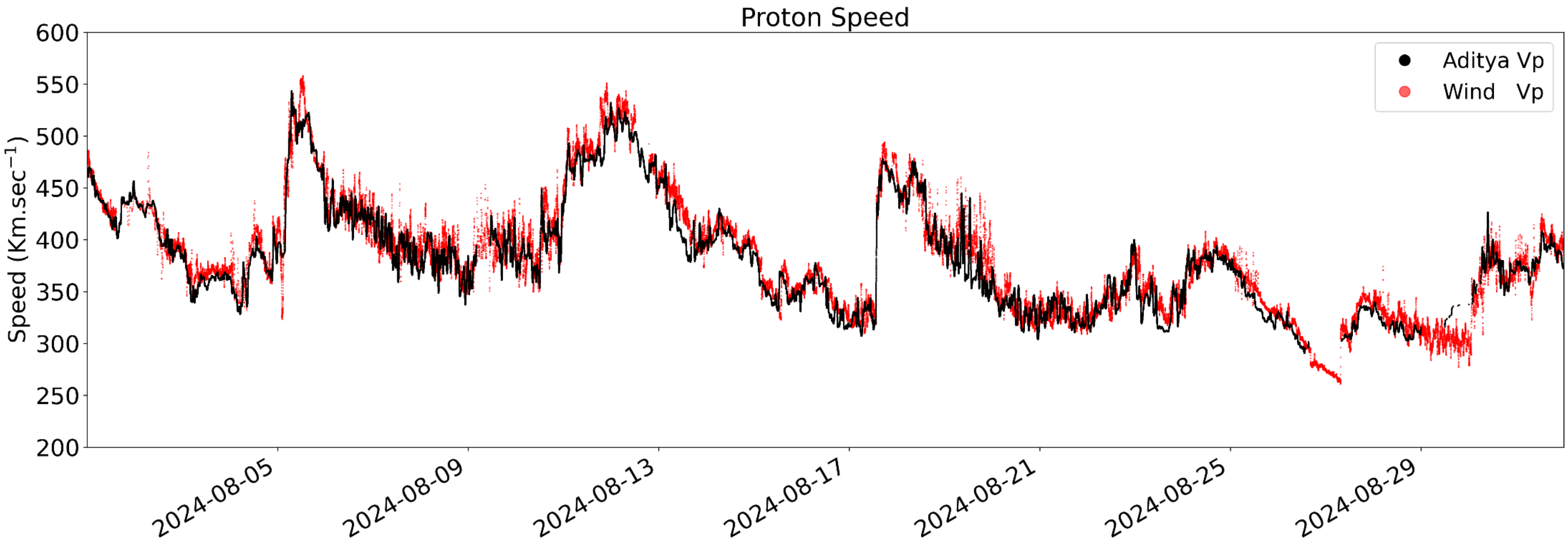


01 – 30 August 2024
GSE coordinates

AL1 (X, Y, Z in R_E)
207 => 239; 91 => 94, -6 =>11
WIND (X, Y, Z in R_E)
246 => 211, -85 => -96, 8 =>-2



Solar wind parameters
AL1-ASPEX-SWIS Vs. WIND-PESA-L



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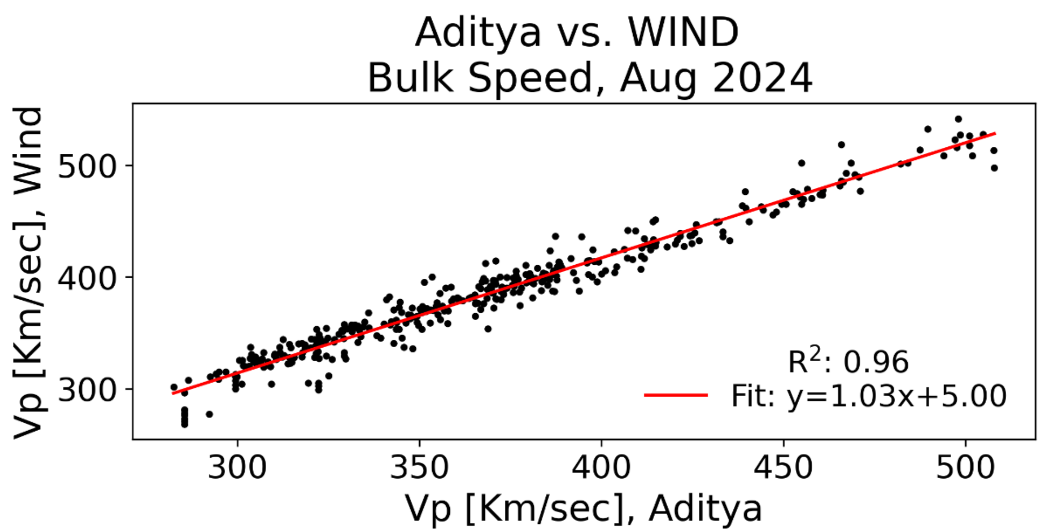
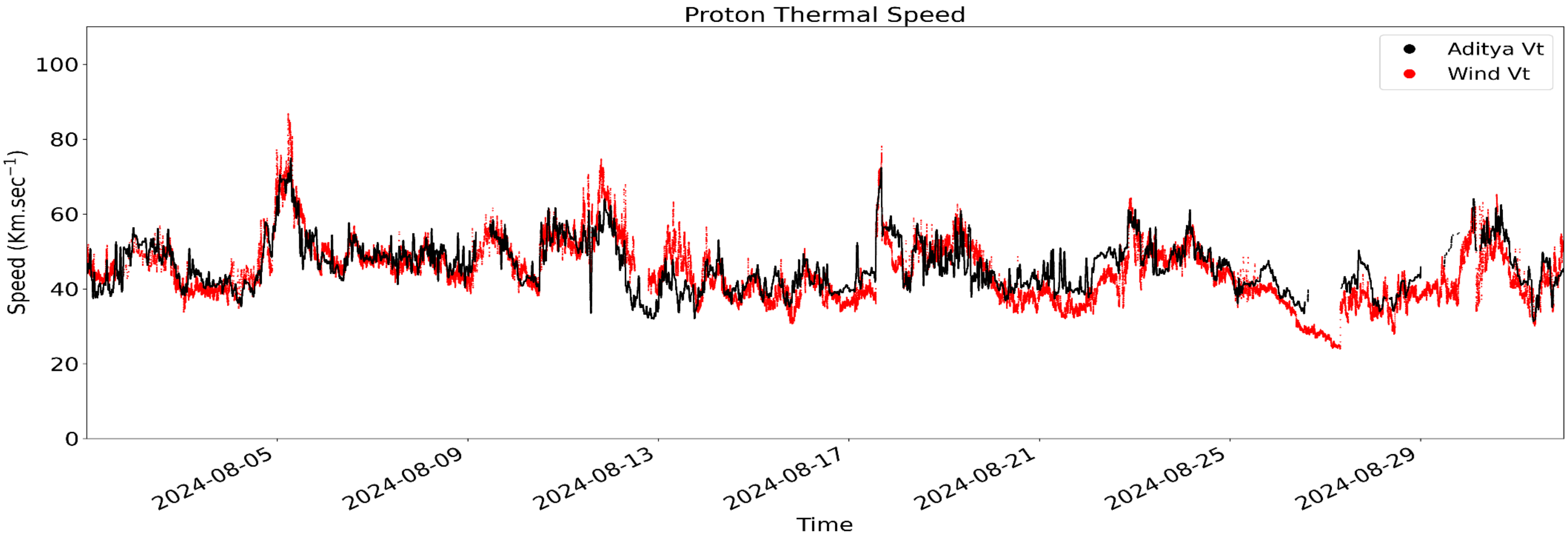


Solar wind parameters
AL1-ASPEX-SWIS Vs. WIND-3DP-PESA-L



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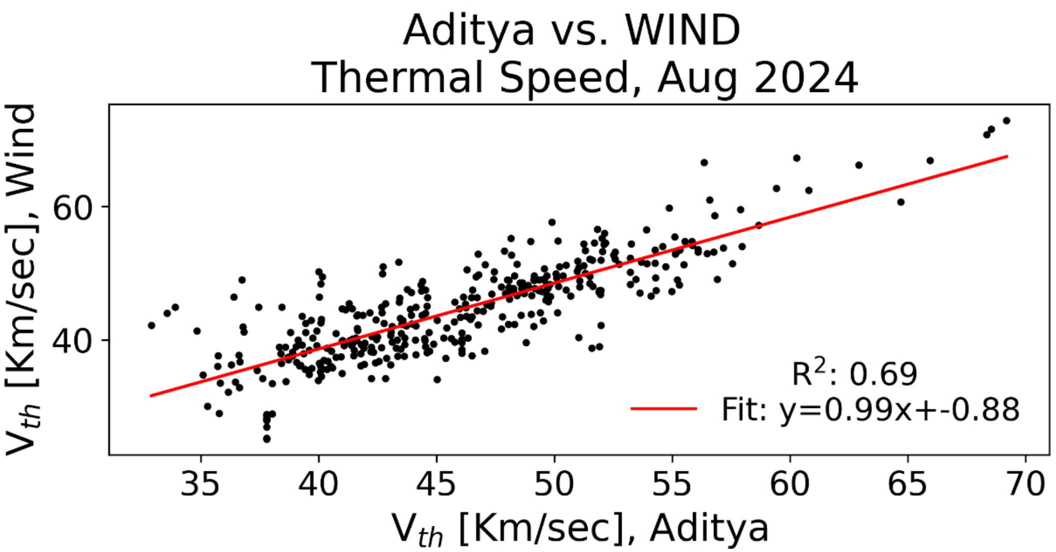
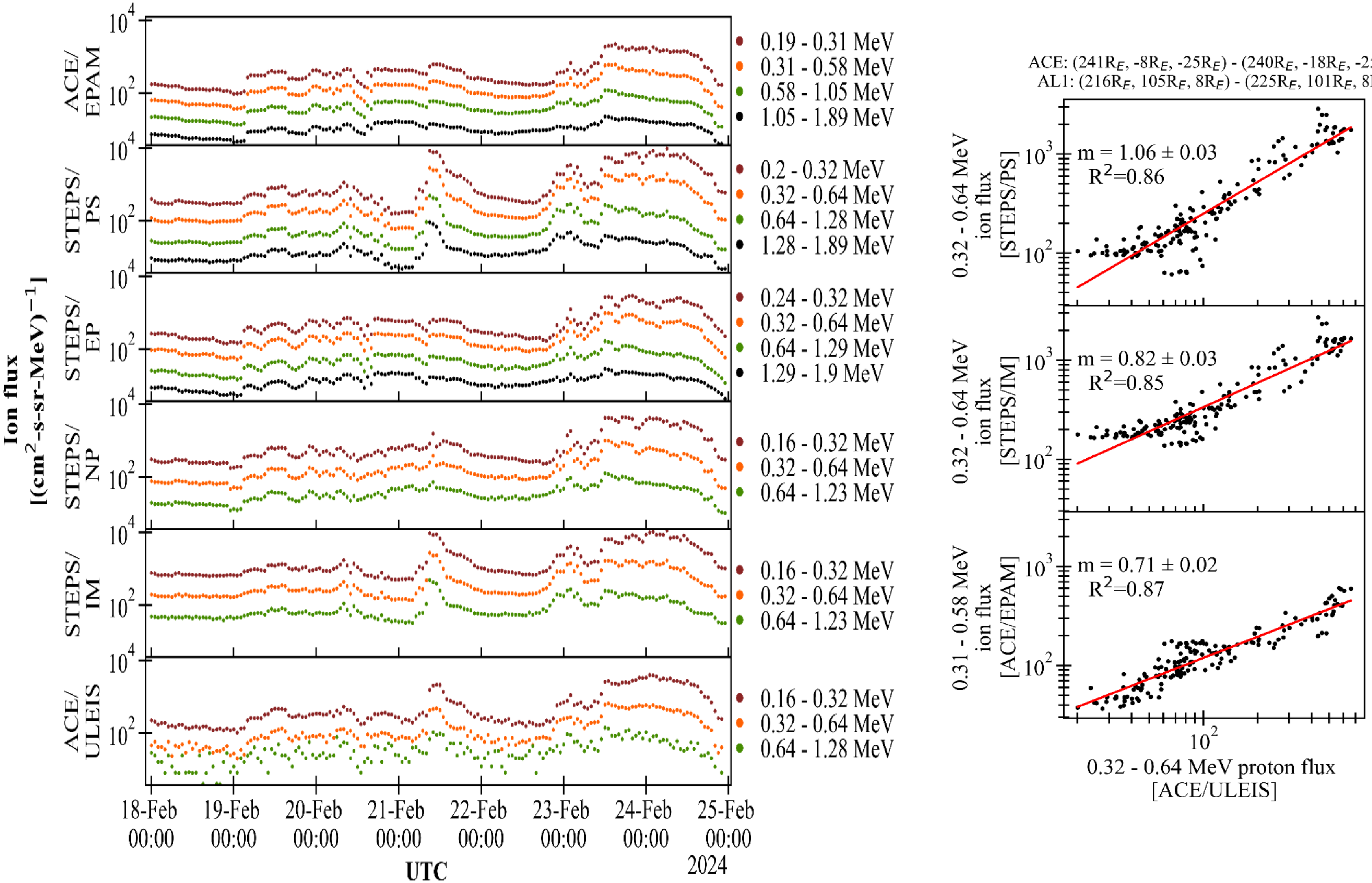


AL1-ASPEX-STEPS Vs. ACE-ULEIS and ACE-EPAM



- There will be six satellites at L1 at the end of this year.
- It will give us unprecedented opportunities to cross-calibrate and understand solar wind spatial inhomogeneity at L1.

Thank you