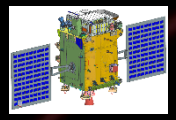
Aditya-L1 mission of India
and
Aditya solar wind Particle EXperiment (ASPEX)

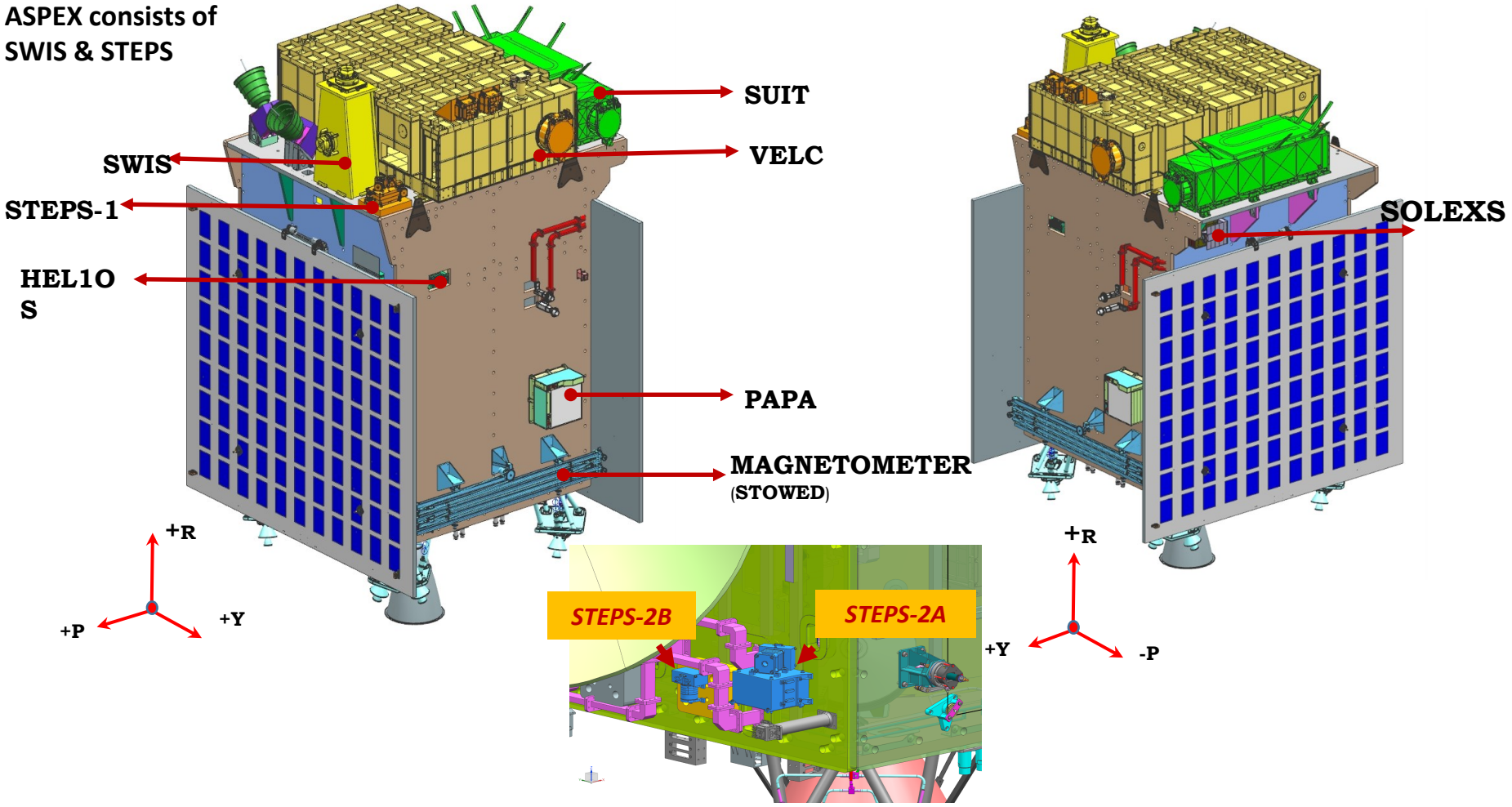


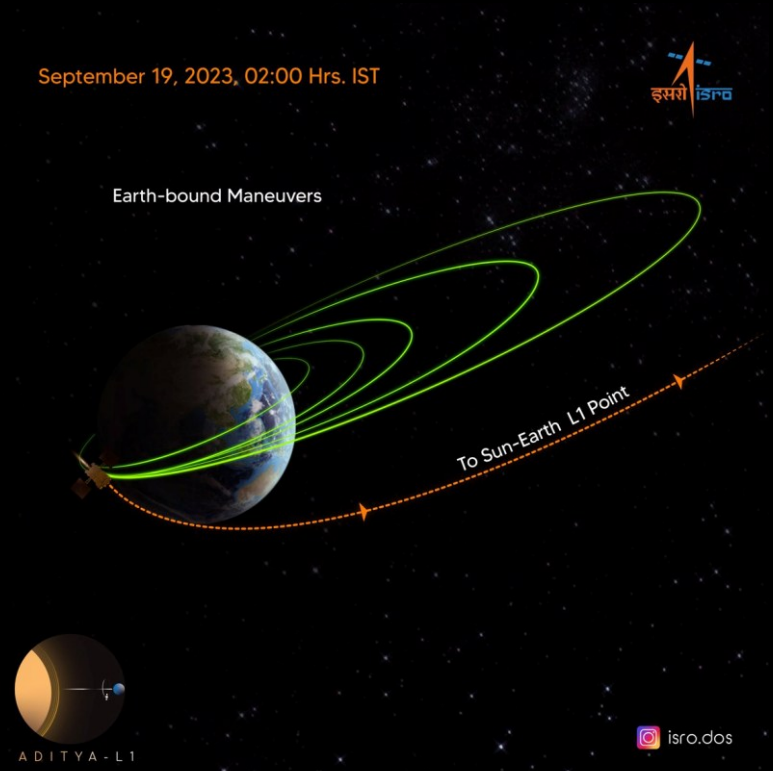
Dibyendu Chakrabarty
PRL, India
dipu@prl.res.in

Global Space-based Inter-Calibration System (GSICS)
GRWG SWx Sub-group meeting
18 December, 2024

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

Mission life – 5-years



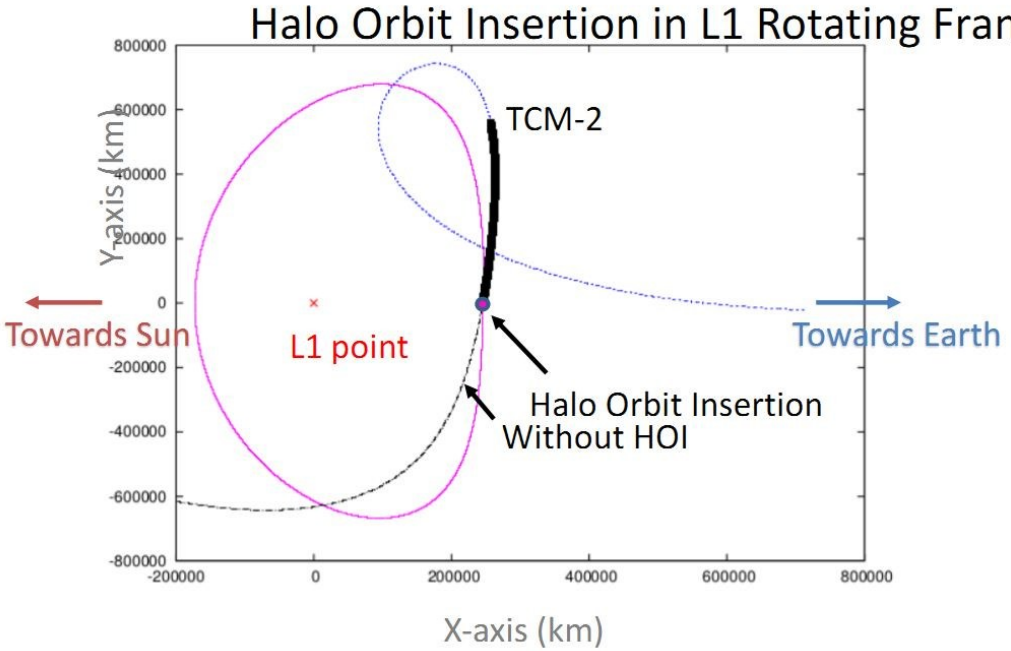


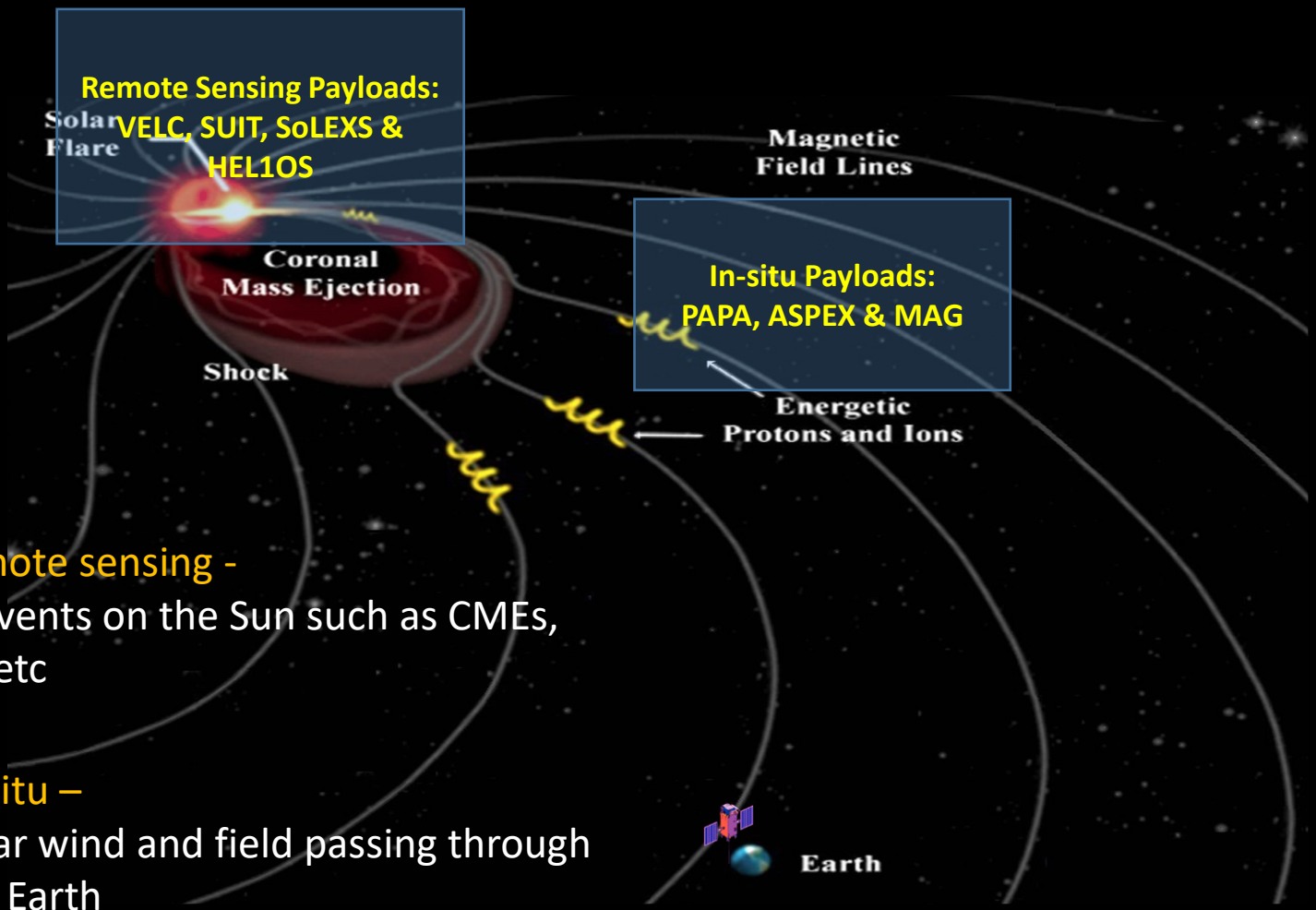
PSLV C57 was launched at 11:50 IST on 02 September 2023.

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.



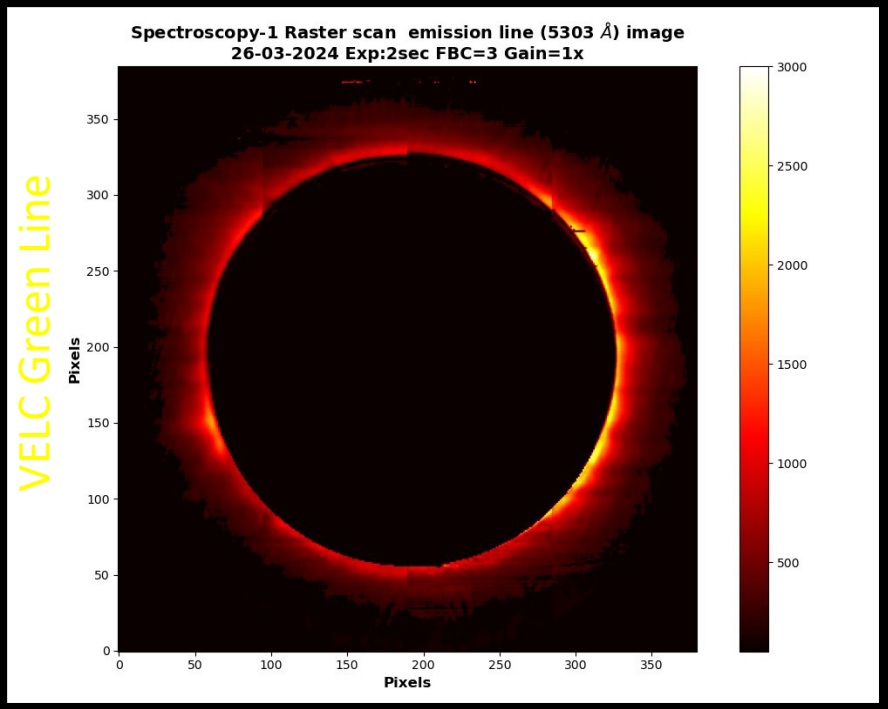


Through remote sensing -
Dynamical events on the Sun such as CMEs, Solar Flares etc

Through in-situ –
Ambient solar wind and field passing through L1, ahead of Earth

Courtesy: Nunez et al., 2016

Visible Emission Line Coronagraph (VELC)

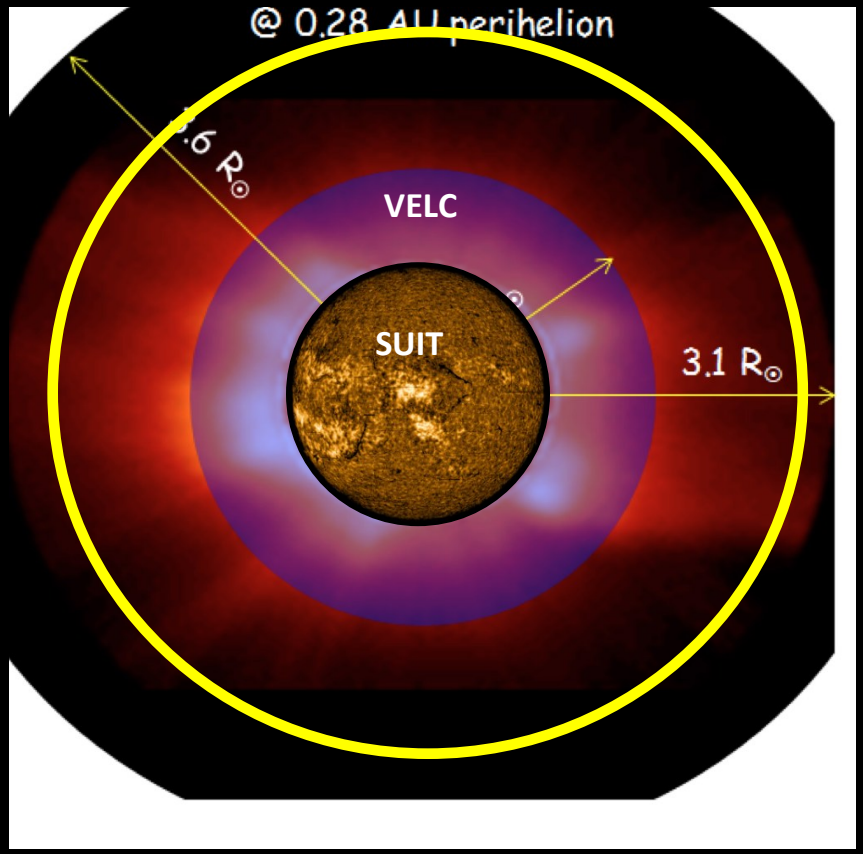


- To investigate CME initiation, dynamics, and large-scale transient events below 1.5R_{sun} (where R_{sun} is Solar Radius) using Green emission line spectra.
- To study Long term variation of the solar coronal structures.
- To study Coronal plasma dynamics and its relevance to coronal heating.

- **Spectroscopic channel 5303** shows coronal signatures → requires processing to bring it out from the background. Regular 5303 scans are being carried out and do observe coronal loop structures in the corona
- **Spectroscopic channel 7892 and 10747** and continuum channel are also being operated and performance evaluation is yet to be completed.

VELC instrument was developed at the Indian Institute of Astrophysics (IIA), Bengaluru with major support from ISRO centres - Laboratory for Electro-optics Systems (LEOS), Space Application Centre (SAC), ISRO Inertial Systems Unit (IISU), and UR Rao Satellite Centre (URSC).

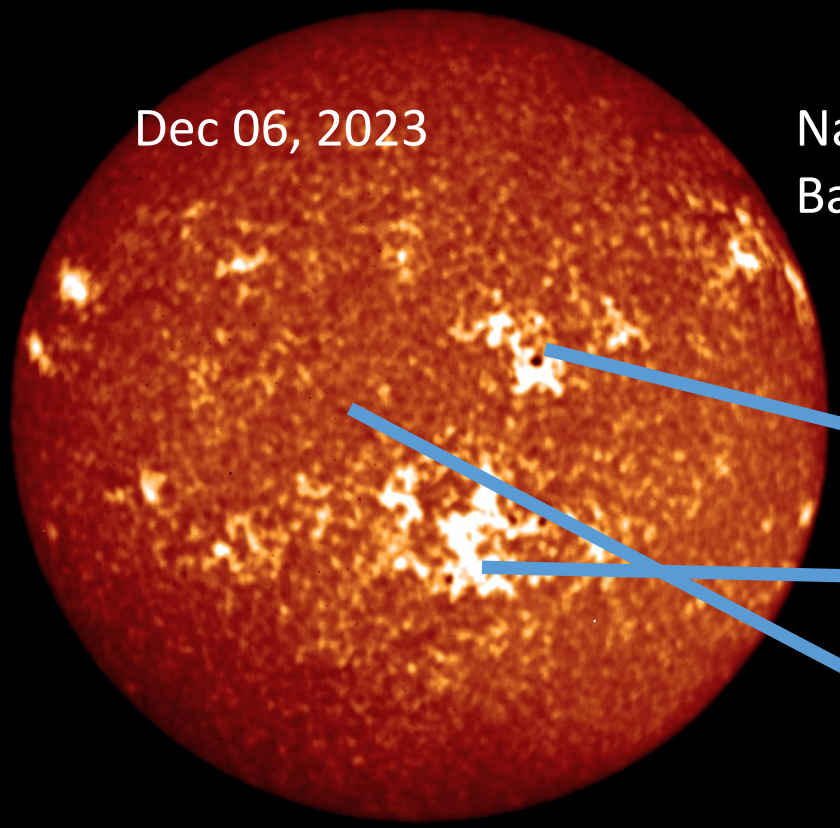
METIS/SO and VELC/AL1



- Joint observations while in the Sun-Earth line
- Joint observations at certain vantage point for 3D studies (of CME)
- Line-of-sight coronal magnetic field information

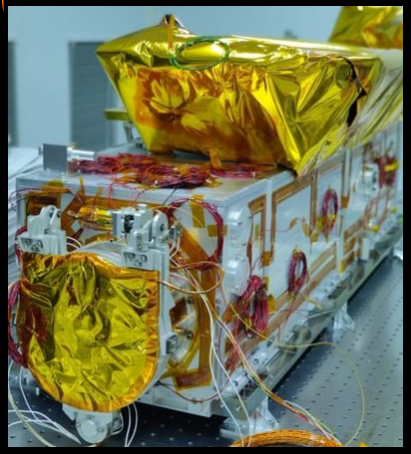
Antonucci et al, 2020

Solar Ultra-violet Imaging Telescope (SUIT)



SUIT is developed by Inter University Centre for Astronomy and Astrophysics (IUCAA), Pune with major support from ISRO. Optics, electronics, and mechanisms for SUIT are developed in-house at different ISRO centres. The developed components are also tested, and qualified at these centres before delivering to IUCAA. The integration and integrated payload calibrations were carried out by IUCAA at the CLASS 100 facility of U R Rao Satellite Centre/ ISRO, Bangalore.

Solar Ultra-violet Imaging Telescope (SUIT)



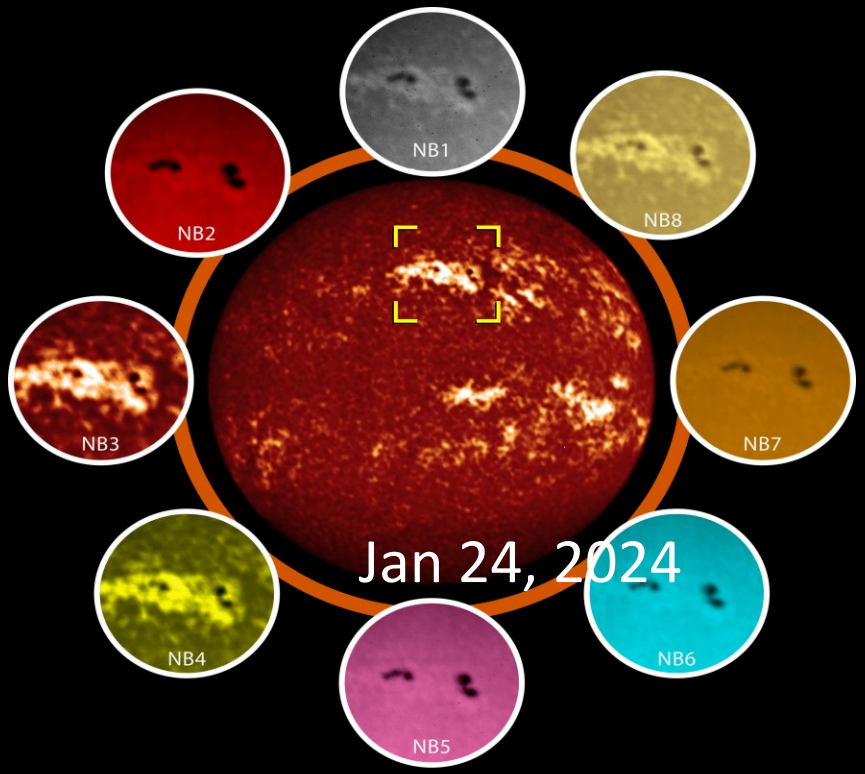
SUIT is a multi-wavelength (200-400nm) Imaging Instrument
11-filters – 8 Narrow band and 3 Broad band

- To investigate the coupling of the energetics from the photosphere to the lower corona using multiple narrow-band images obtained at specific wavelengths with each waveband forming at different heights of the solar atmosphere.
- To decipher the mechanisms responsible for stability, dynamics and eruption of solar prominences and filaments
- To provide the contextual images for VELC and hence support to investigate the initial phase (pre-eruptive and eruptive) of CMEs
- To understand Solar flare dynamics including pre-flare phase in chromosphere in combination with X-ray instruments on-board Aditya-L1
- To obtain the variation of solar irradiance in UV and its correlation to the activities on the Sun using the spatially resolved UV images.

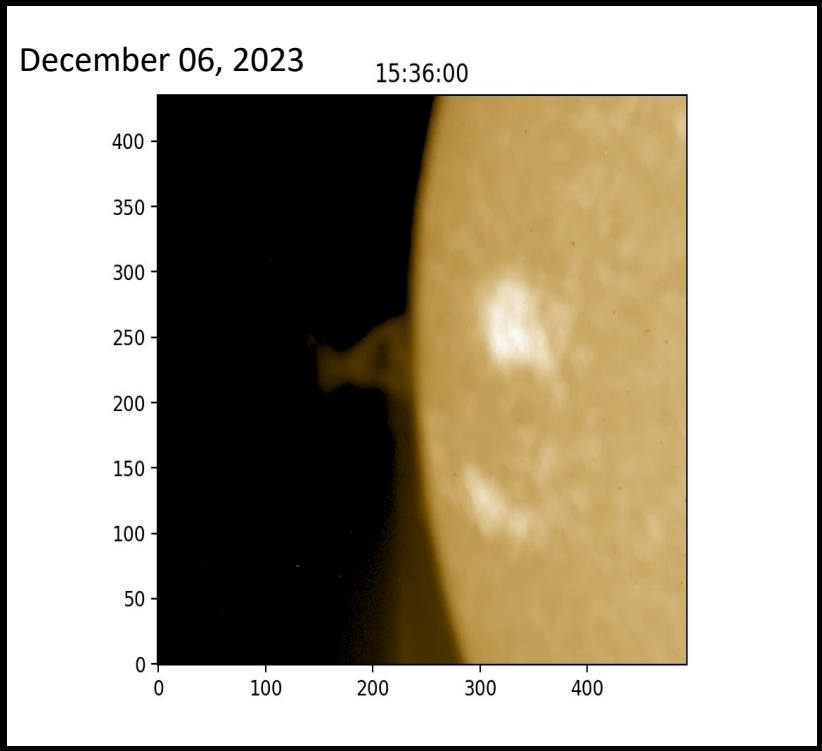
Solar Ultra-violet Imaging Telescope (SUIT)

S. No.	Name	Centre (nm)	Band pass (nm)	Description
1	NB1	214	5	Photosphere
2	NB2	276.7	0.4	Wing of Mg II k
3	NB3	279.6	0.4	Mg II k
4	NB4	280.3	0.4	Mg II h
5	NB5	283.2	0.4	Wing of Mg II h
6	NB6	300	1	Sunspots
7	NB7	388	1	Lower Photosphere
8	NB8	396.85	0.1	Ca II
9	BB1	200-242	42	Continuum
10	BB2	242-300	58	Continuum
11	BB3	320-360	40	Continuum

SUIT

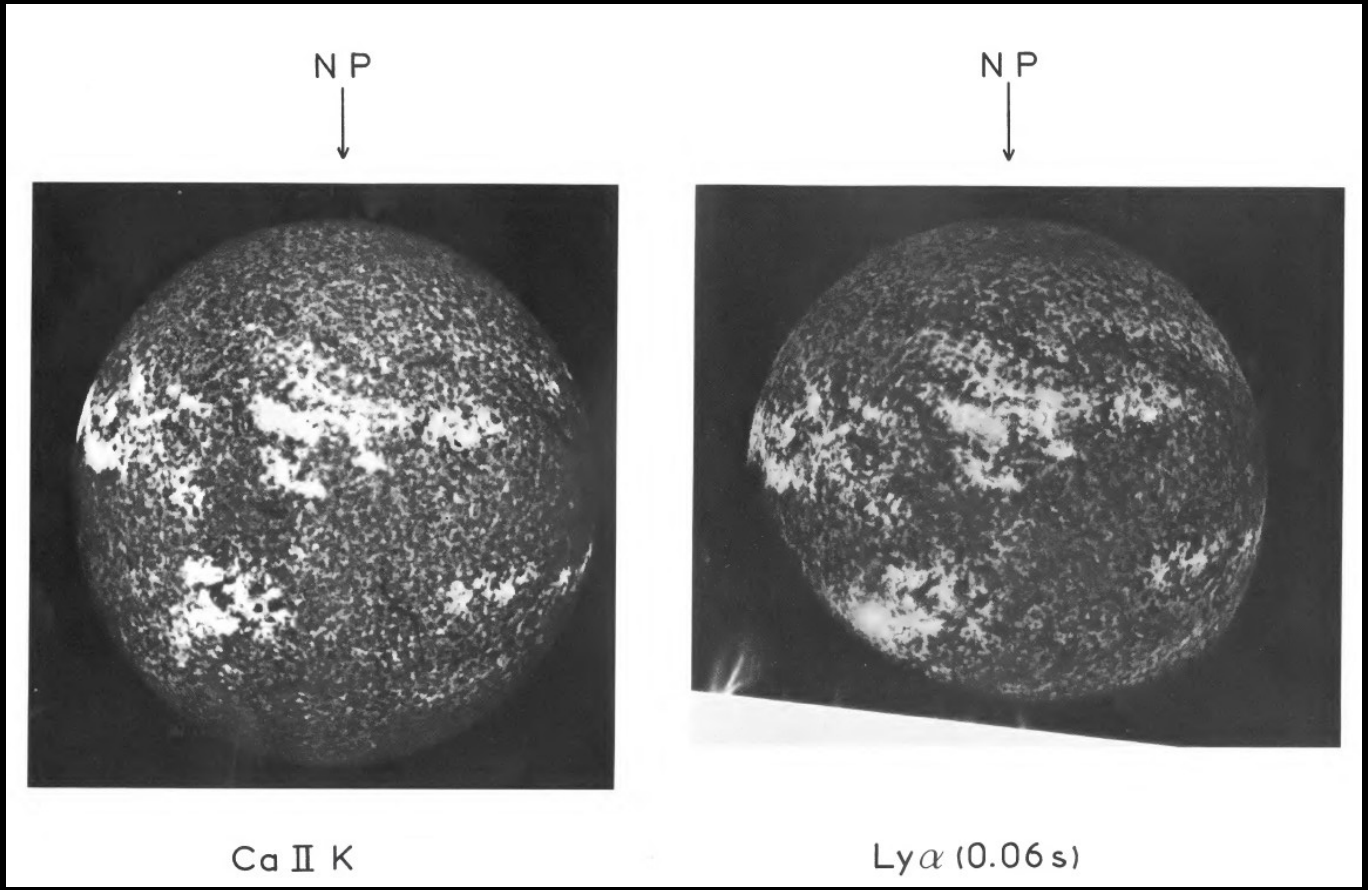


SUIT Mg II k full sun image and Region of Interest as seen through all narrow band filters.



SUIT
solar ultraviolet imaging telescope

METIS/SO and SUIT/AL1



Ly-Alpha & Ca K images

SUIT – Ca K
0.1nm Ca II K disk images

Bonnet, 1980

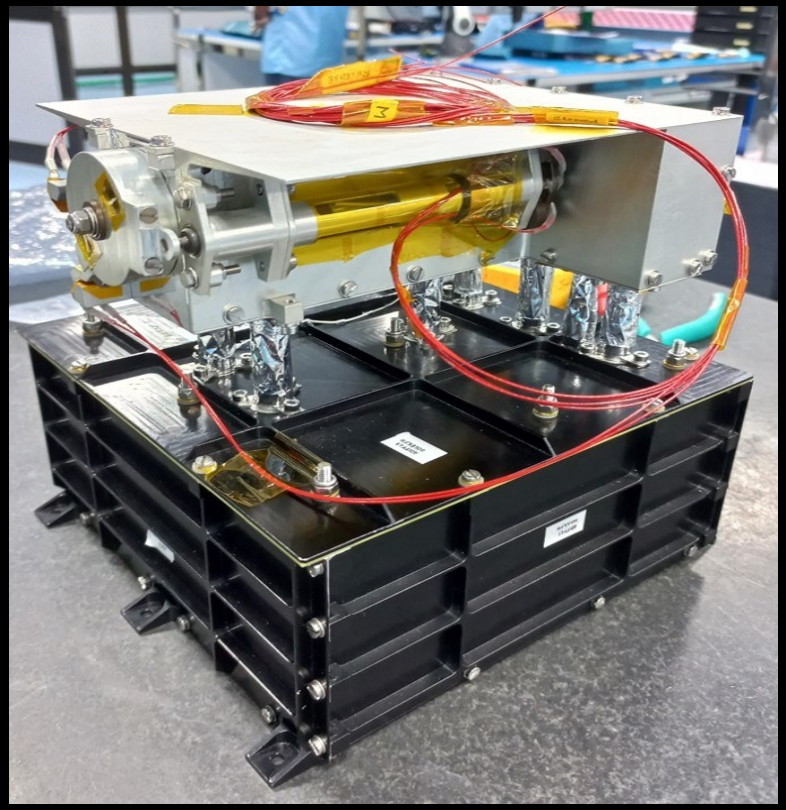
Solar Low-energy X-ray Spectrometer (SoLEXS)

High Energy L1 Orbiting Spectrometer (HEL1OS)

- Estimate the thermal and non thermal (during large events) energy during solar flares by observing soft X-ray spectra. The thermal energy content of the flares which heat the solar coronal plasma can be calculated using the soft X-ray spectra along with the flaring volume using SUIT and/or soft X-ray images observed by other missions.
- To study the physical characteristics of coronal plasma, for example coronal temperature, differential emission measure (DEM) and the elemental abundances using the moderate resolution (< 250eV at 6 keV) X-ray spectra during solar flares ranging from the X-class to A-class.
- Long term variation of the quiet coronal plasma parameters by using the X-ray spectra from quiet period
- In combination with VELC and SUIT, SoLEXS can comprehensively address the CME-flare relation, Flare related filament eruption
- Study the evolution of the cut-off energy between thermal and non-thermal emission as a function of flare evolution and its relation with the spectral parameters of the accelerated electron distribution.
- Study Quasi-periodic pulsations (QPP) in HXR during the flare impulsive phase to understand its connection with particle acceleration mechanisms.
- Study Hard X-ray (HXR) flare and CME association in the context of relation between temporal behavior of HXR intensity and magnitude of

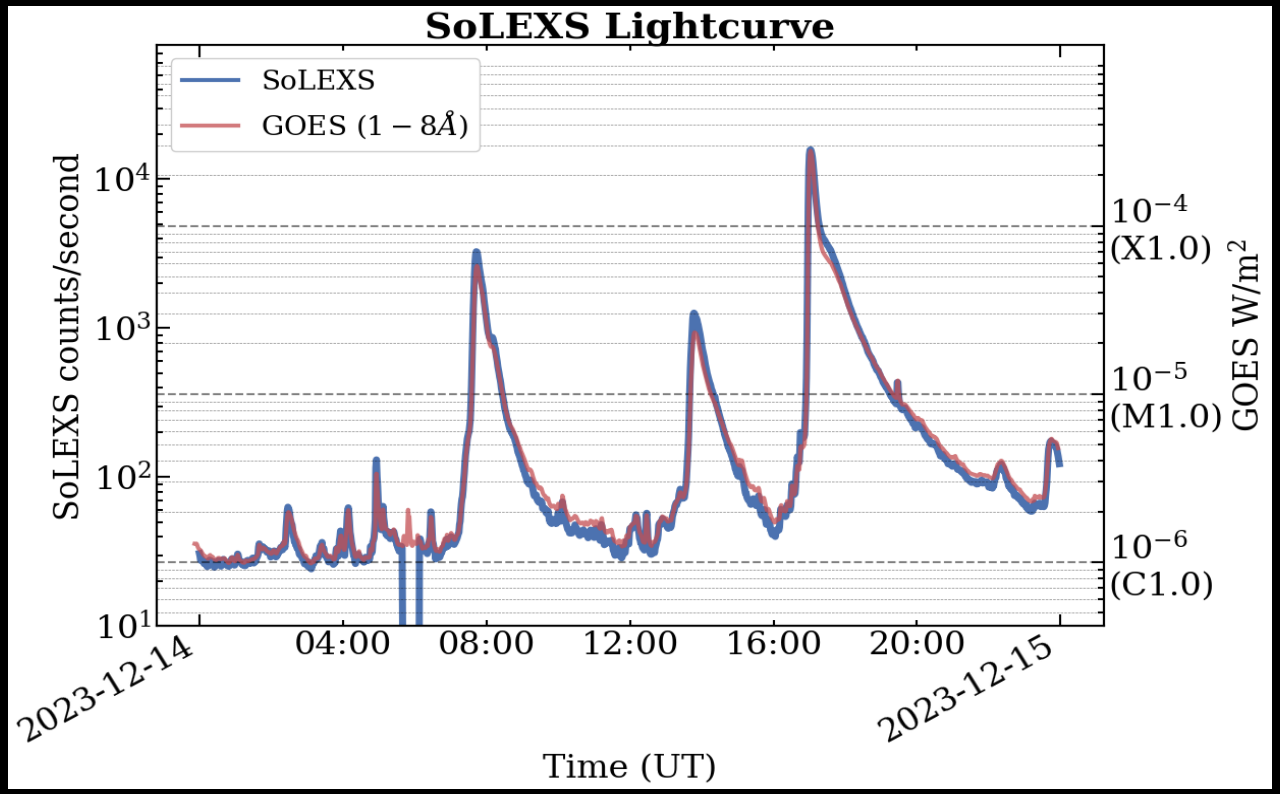
SoLEXS and HEL1OS were developed at the UR Rao Satellite Centre (URSC), Bengaluru.

Solar Low-energy X-ray Spectrometer (SoLEXS)



Low energy X-ray (1 – 22keV) Sun-as-a-star Spectrometer

Solar Low-energy X-ray Spectrometer (SoLEXS)



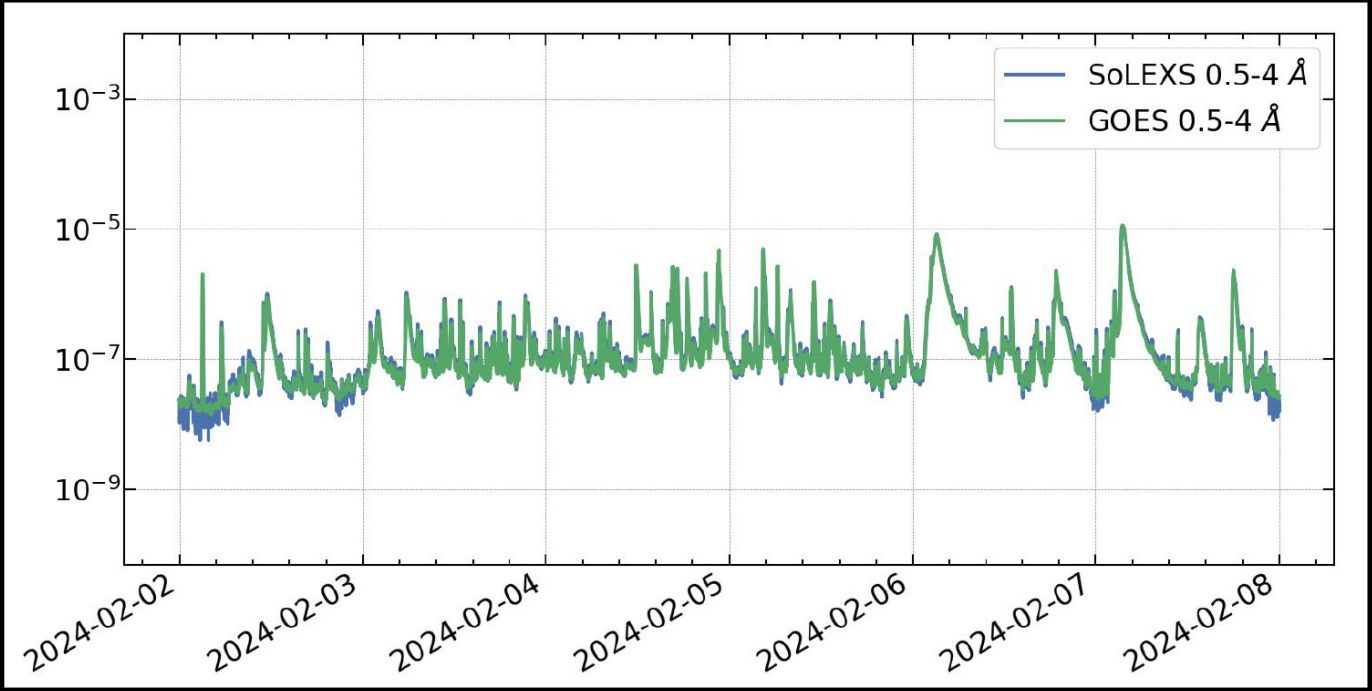
SoLEXS Light Curve

X-ray Photon count change with time

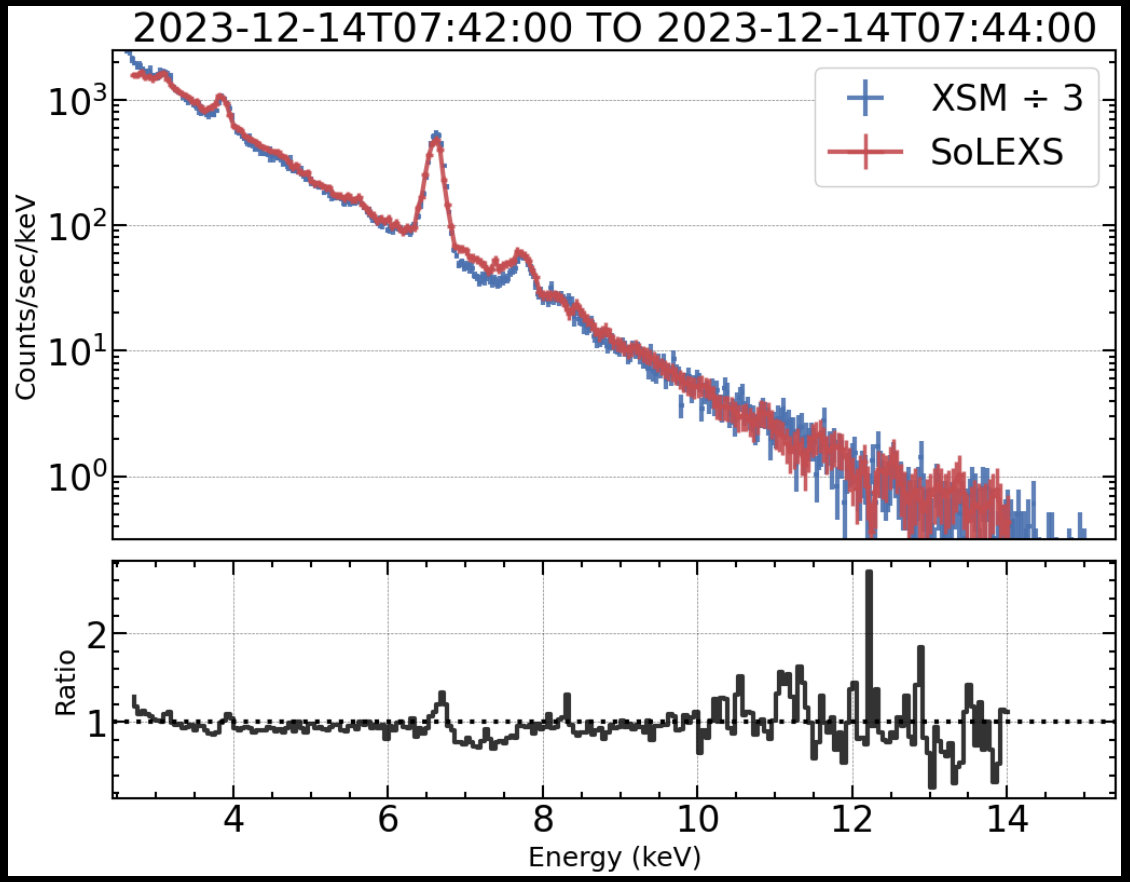
Sudden increase in the count – Flares

Multiple flares are seen on 14th Dec 2023

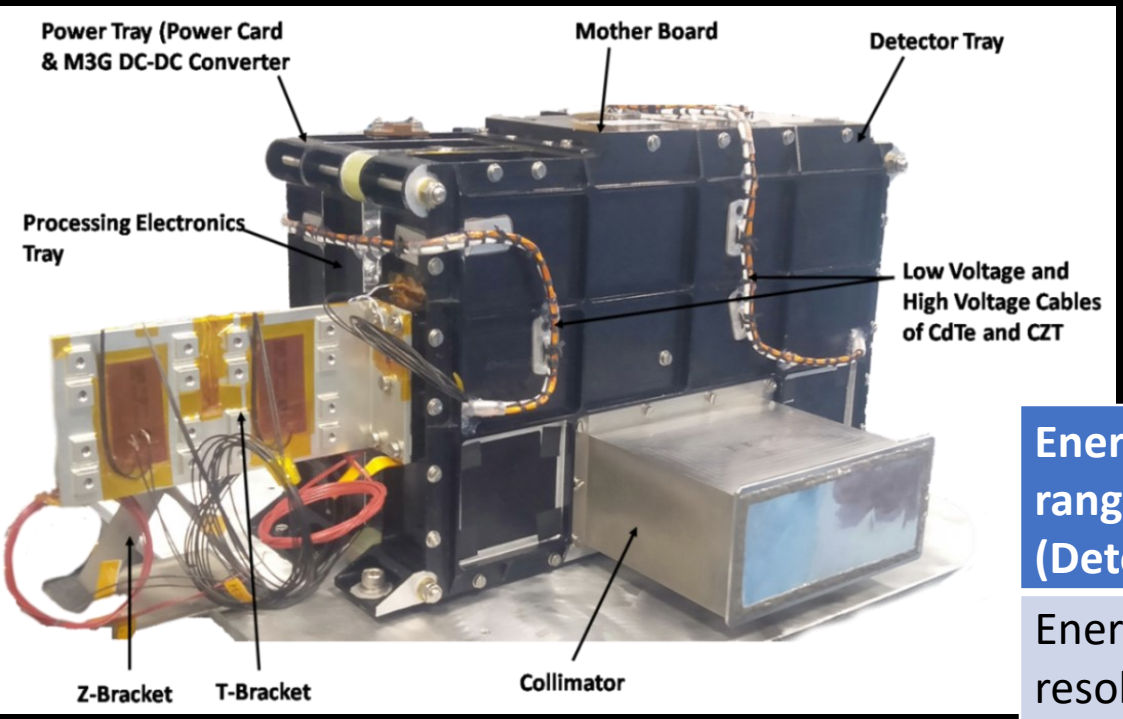
SoLEXS Vs. GOES



SoLEXs Vs. XSM

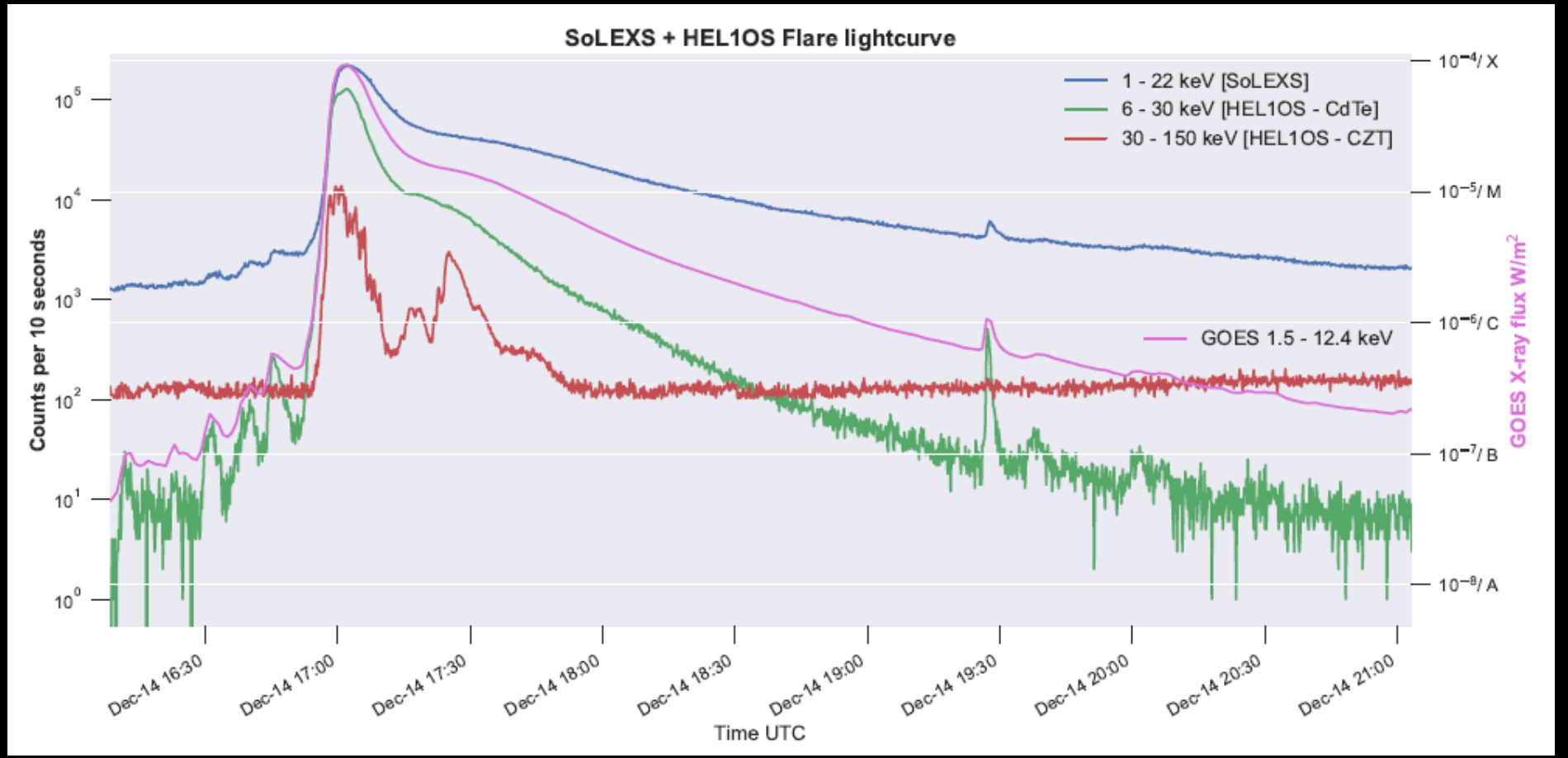


High Energy L1 Orbiting Spectrometer (HEL1OS)

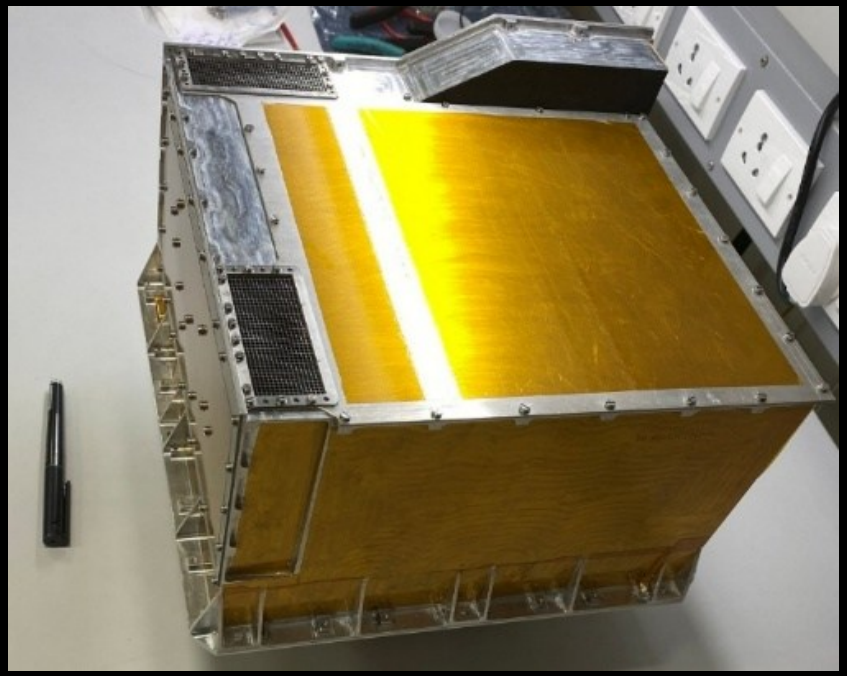


To study the high-energy (8 – 200 keV) processes during solar X-ray flares

Energy range (Detectors)	8 – 200 keV (CdTe: 8 – 65 keV, CZT: 20 – 200 keV)
Energy resolution	CdTe: 0.8 keV @ 13.9 keV CZT: 6.3 keV @ 60 keV
FOV	5.6^0 x 5.6^0


SoLEXS + HEL1OS Flare lightcurve
1 - 22 keV [SoLEXS]
6 - 30 keV [HEL1OS - CdTe]
30 - 150 keV [HEL1OS - CZT]
GOES 1.5 - 12.4 keV
Counts per 10 seconds
GOES X-ray flux W/m²
10⁻⁴/ X
10⁻⁵/ M
10⁻⁶/ C
10⁻⁷/ B
10⁻⁸/ A
Dec-14 16:30
Dec-14 17:00
Dec-14 17:30
Dec-14 18:00
Dec-14 18:30
Dec-14 19:00
Dec-14 19:30
Dec-14 20:00
Dec-14 20:30
Dec-14 21:00
Time UTC

Plasma Analyser Package for Aditya (PAPA)

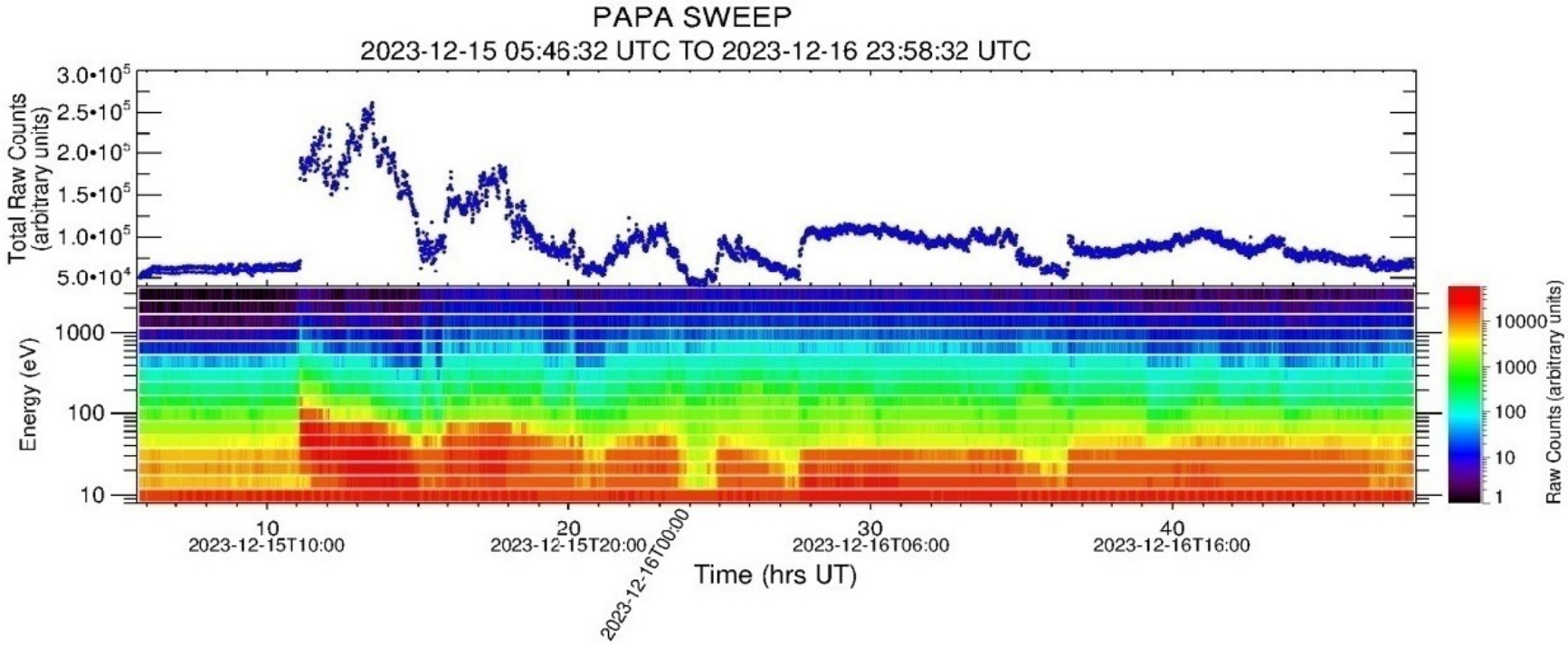


In-situ electron and ion measurements

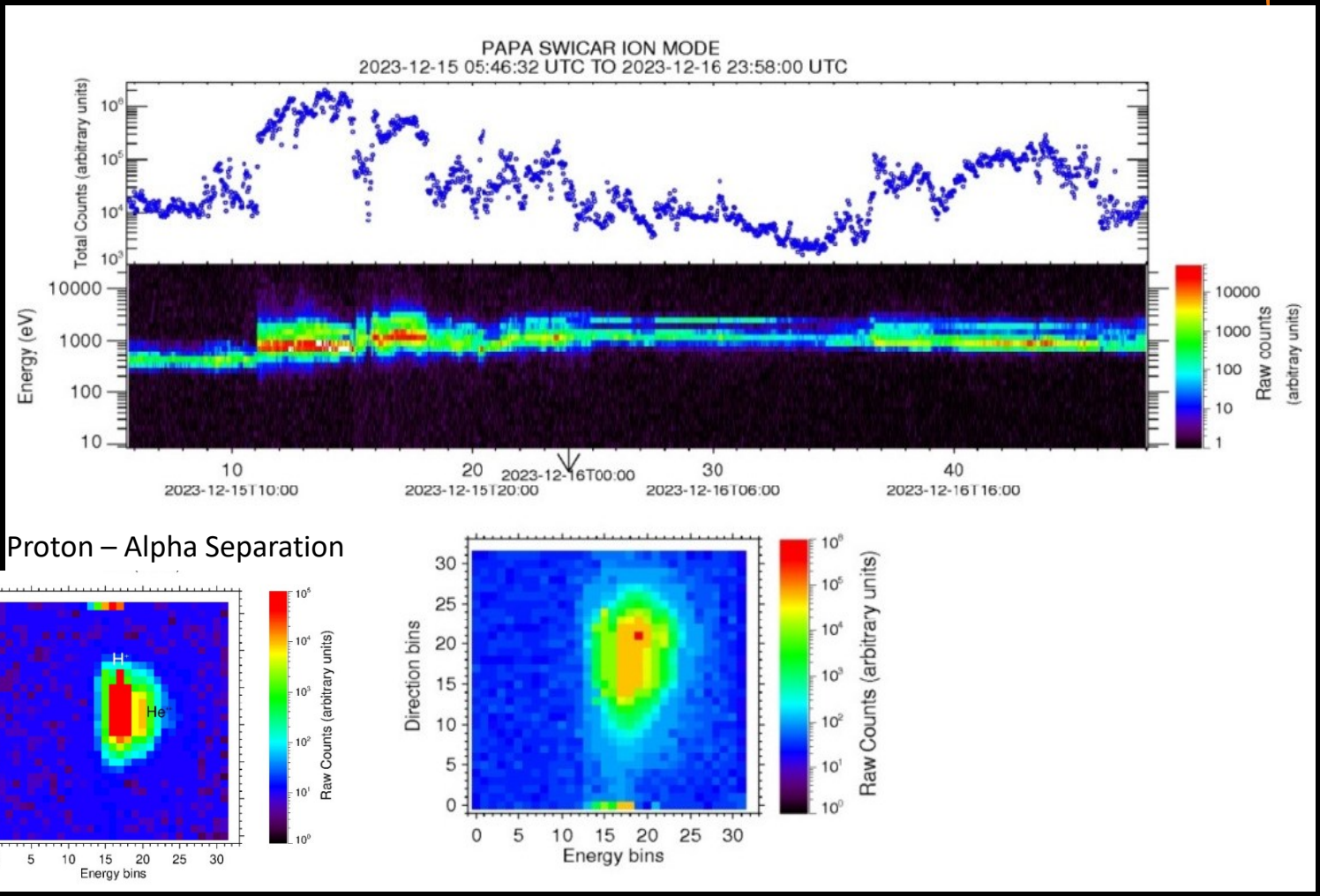
- Continuous measurement of the solar wind and interplanetary electron distribution functions in the energy range of 0.01-3 keV
- Study of the composition of solar wind and thereby understanding about the origin of solar wind like high speed solar wind in Coronal Mass Ejections (CMEs), Co-rotating Interactive Regions (CIRs), and/or interplanetary shock
- To study pick-up ions

PAPA is developed by Space Physics Laboratory (SPL) of Vikram Sarabhai Space Centre (VSSC) of ISRO at Thiruvananthapuram.

SWEEP Electron Mode

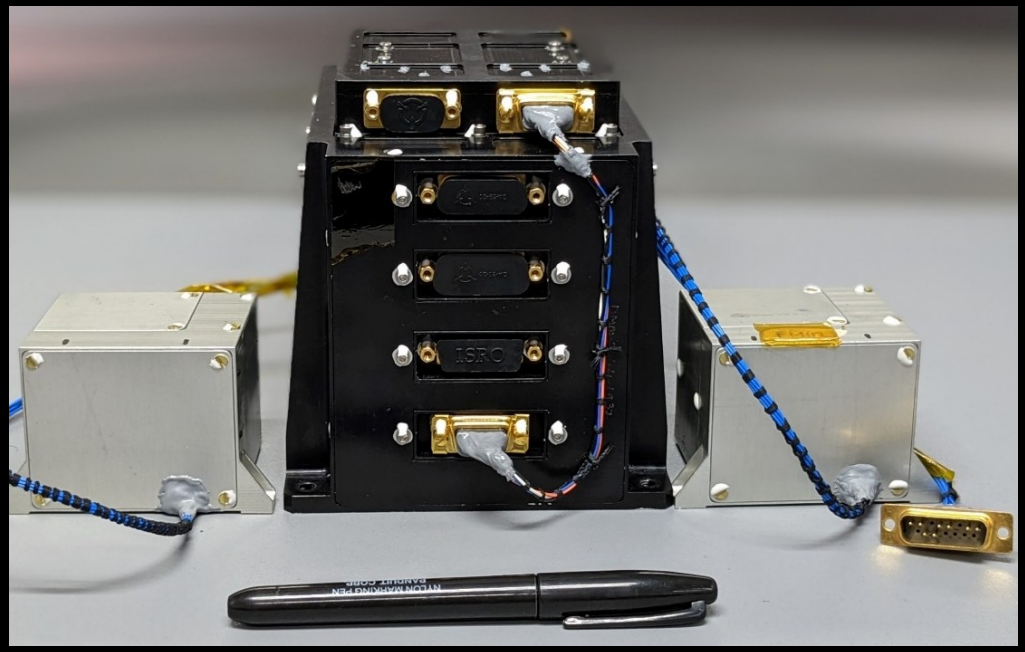


SWICAR Ion Mode



MAGnetometer (MAG)

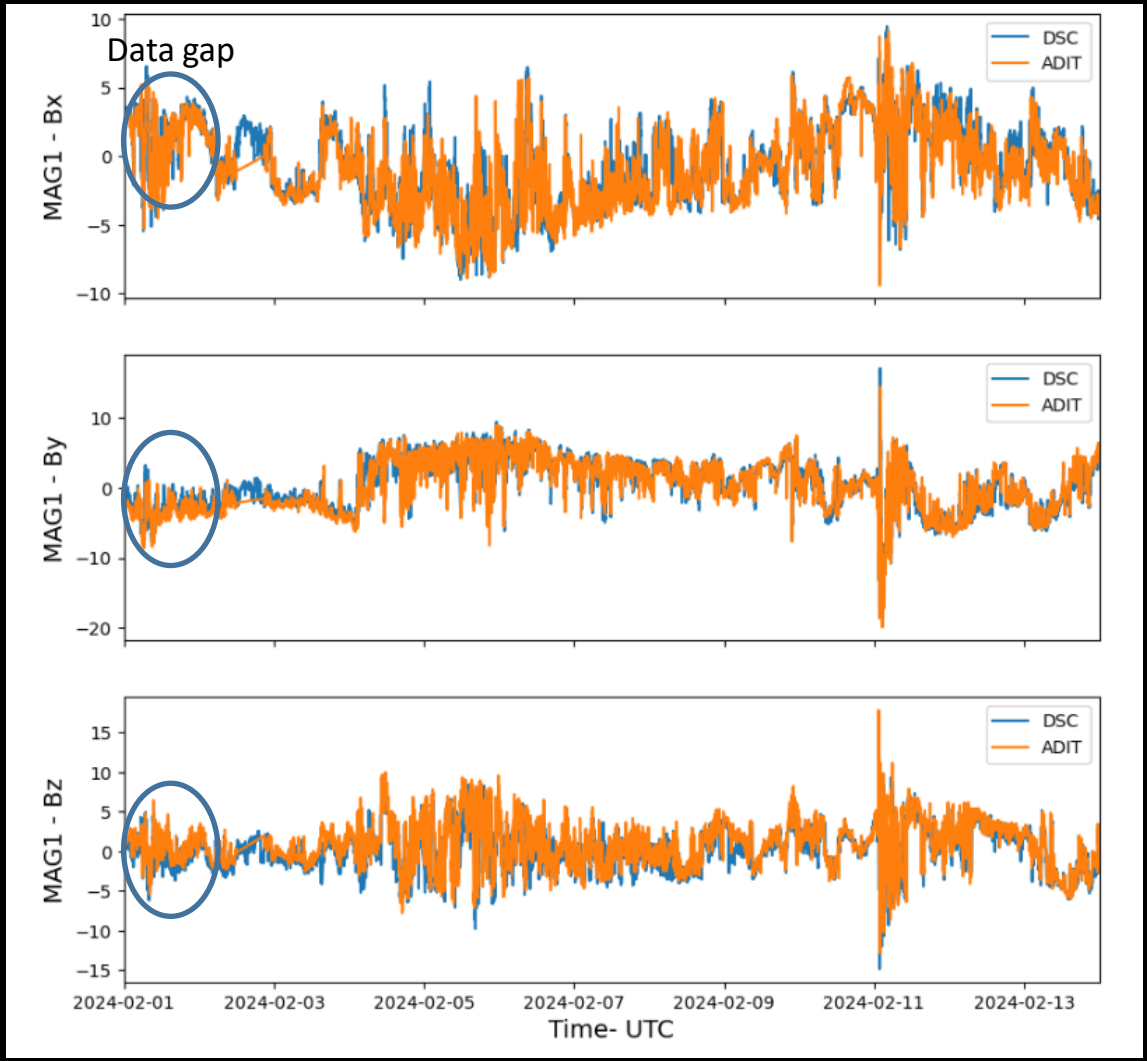
In-situ Magnetic Field components



- To study the variation of the in-situ magnetic field due to transient phenomena from the Sun for example CME passing through L1.
- Geomagnetic storm

MAG is developed by Laboratory for Electro-optics Systems (LEOS)/URSC, Bengaluru in close collaboration with Space Physics Laboraary, VSSC, Thiruvanathapuram and Space Astronomy Group, URSC, Bengaluru.

MAG and DSCVR Comparison



After Bias correction

Aditya Solar wind Paticle 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

-- 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 -- Radial, Parker, Anti-sun,

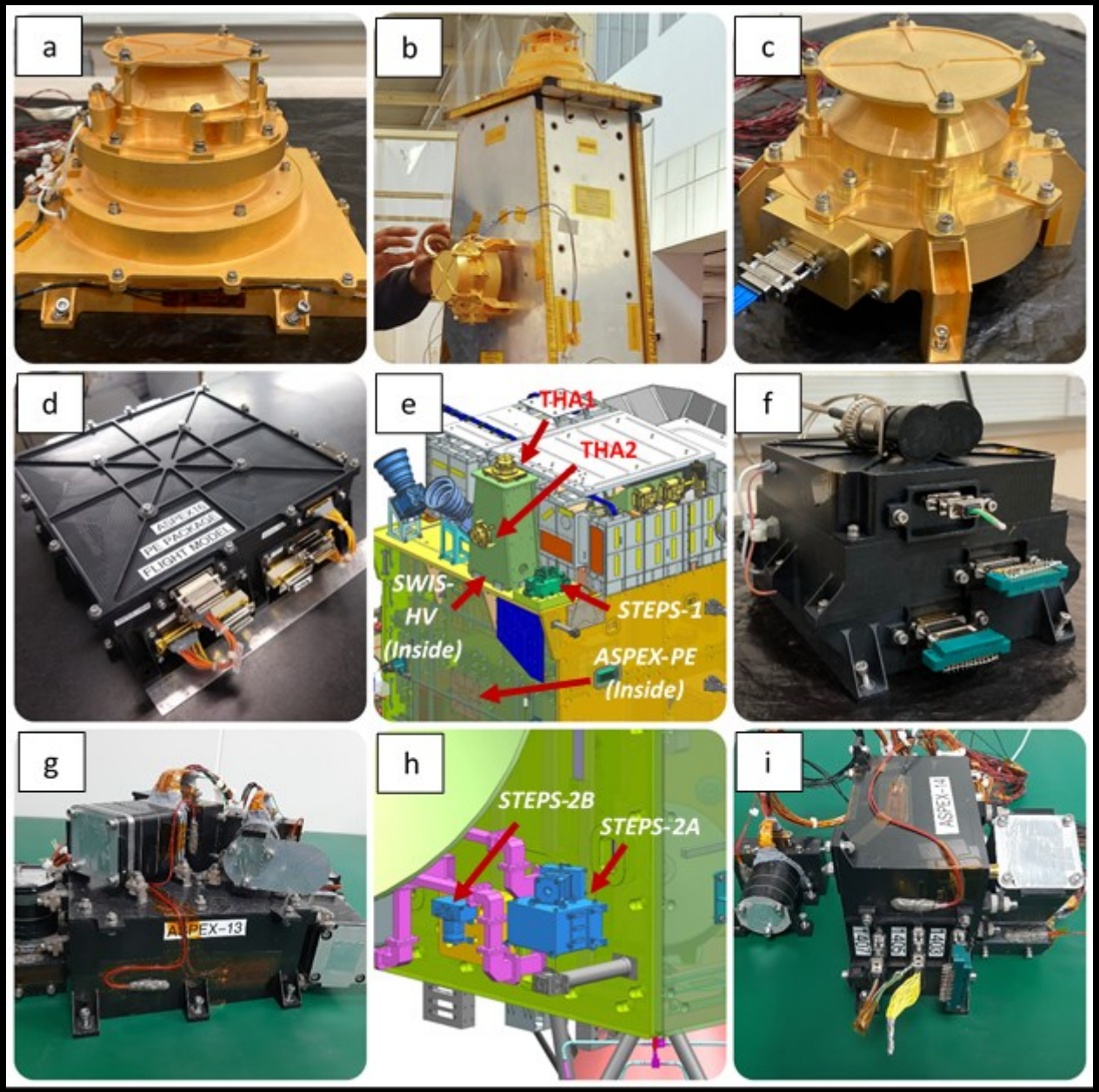
-- H^+ and He^{++} integrated -- Intermediate, North and South

ASPEX is developed by Physical Research Laboratory (PRL), Ahmedabad. The hardware is developed in close collaboration with Space Application Centre (SAC), Ahmedabad of ISRO.

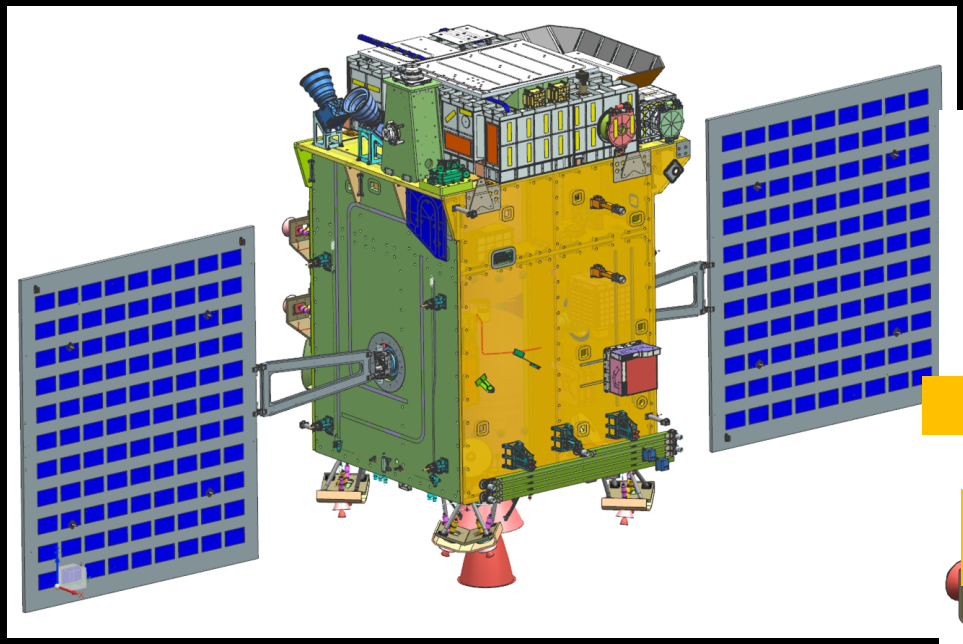
Aditya Solar wind Paticle EXperiment (ASPEX)

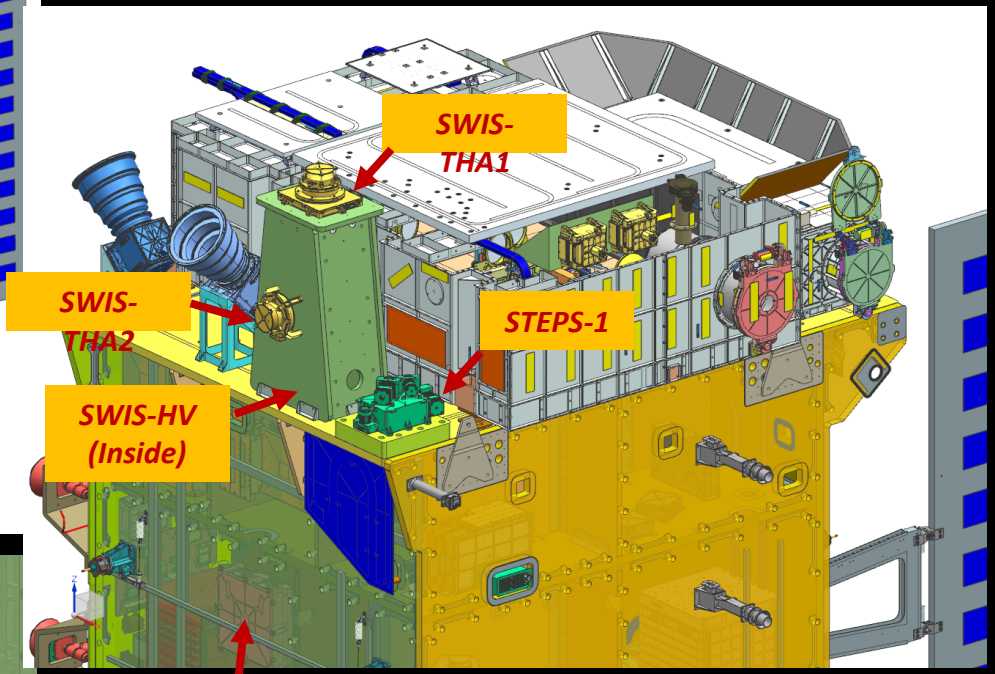
- What are the processes that give rise to the solar wind particles with different energies?
- In what way the supra-thermal population in the solar wind responsible for the generation of solar energetic particles in the solar wind?
- How does A_{He} change corresponding to various solar events (Flares, CME's, CIR's)? A spin-off of these investigations will be an insight into efficacy or otherwise of A_{He} as a space weather forecasting tool.
- What plasma processes cause the thermal anisotropies in the solar wind?
- What processes make the solar wind turbulent?

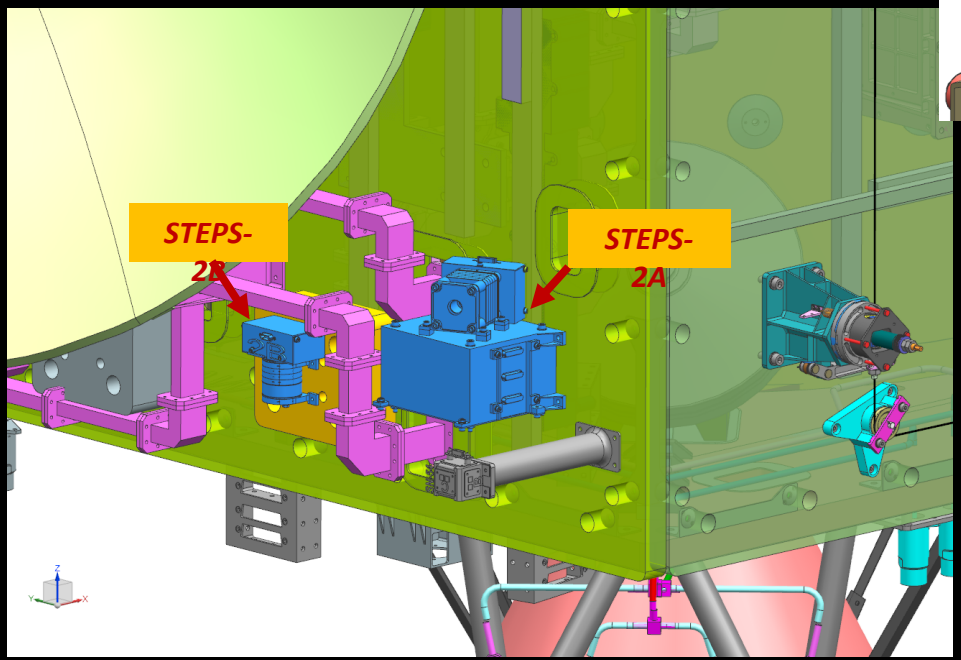
ASPEX (Aditya Solar wind Particle Experiment)

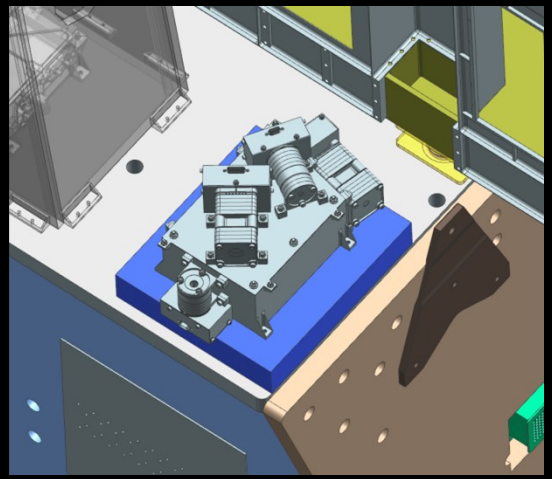


ASPEX package mounting locations on Aditya-L1

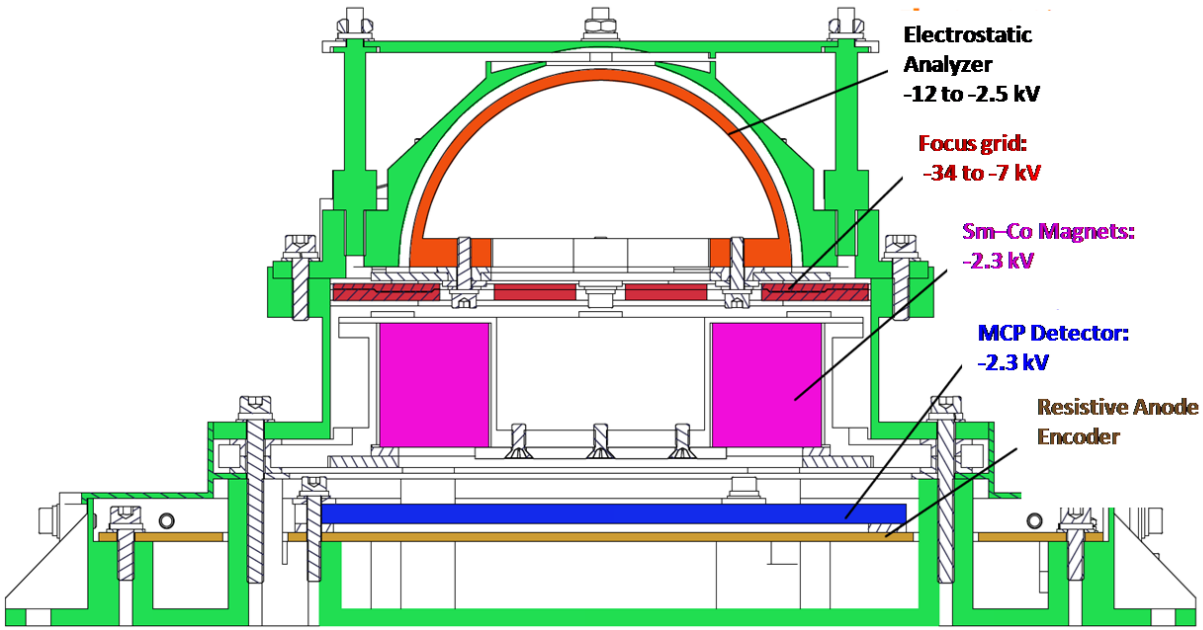


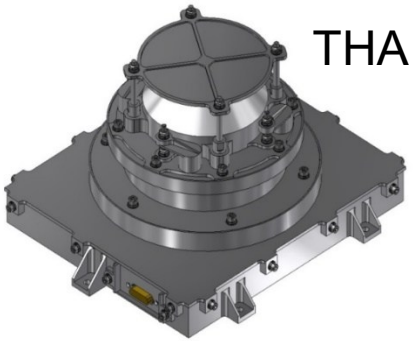


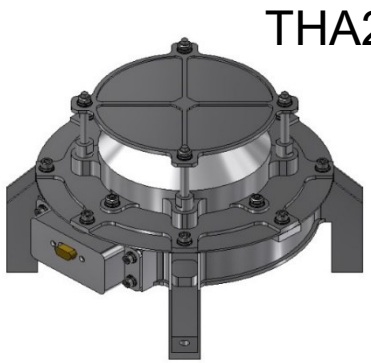


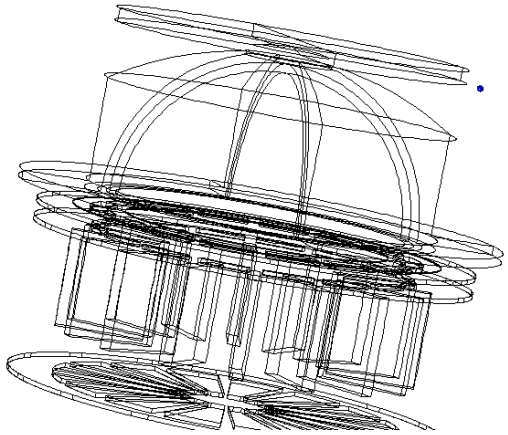


SWIS Top Hat Analyser (THA) Configuration

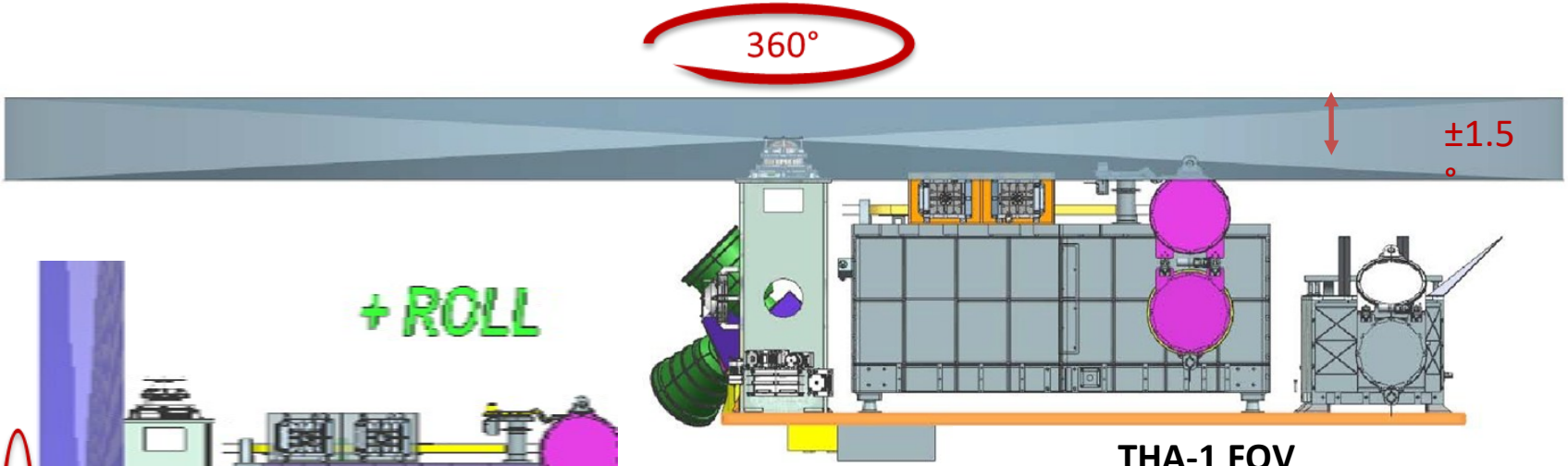




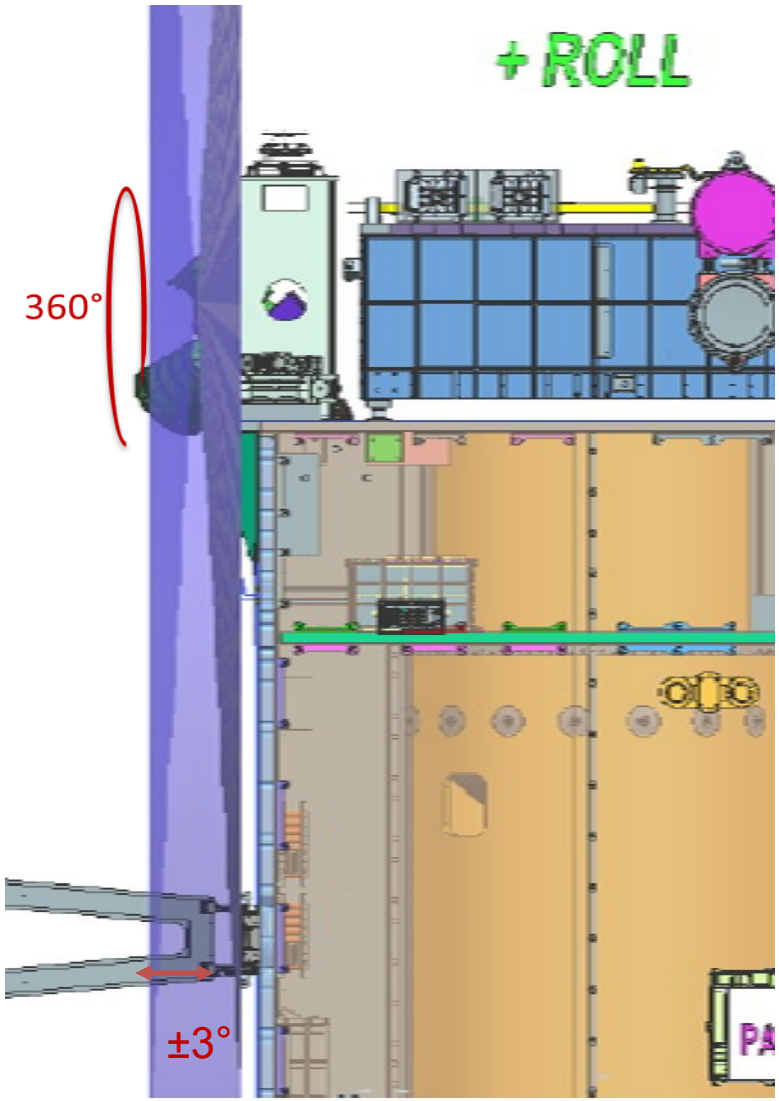




- Electrostatic Analyser (ESA), Magnetic Mass Analyser (MMA), Micro-Channel Plate (MCP) detectors, Resistive Anode Encoder (RAE).
- High Voltage (HV) bias.

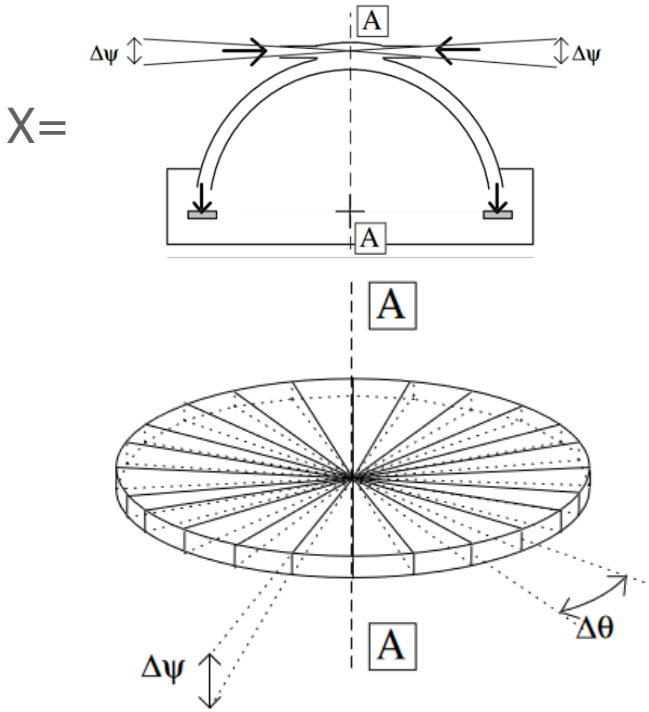


THA-1 FOV
VIEW FROM + YAW



THA-2 FOV
VIEW FROM + YAW

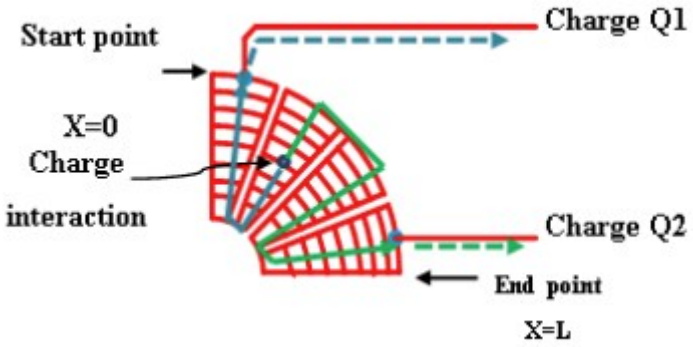
Top Hat Analyzer (THA)



THA-1 will observe in the ecliptic plane

THA-2 will observe in the perpendicular to the THA-1 plane

Resistive Anode Encoder

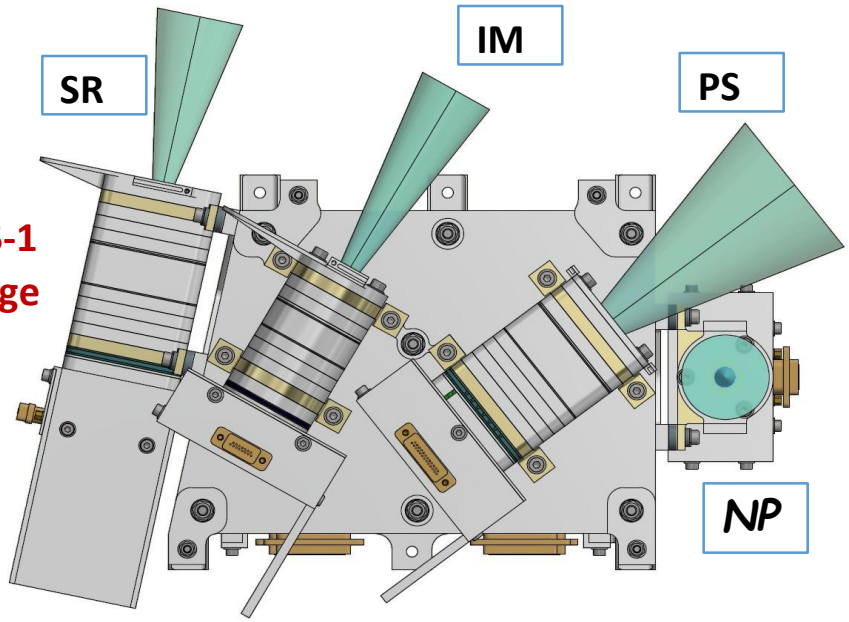


Both THA-1 and THA-2 have 4 such quadrants

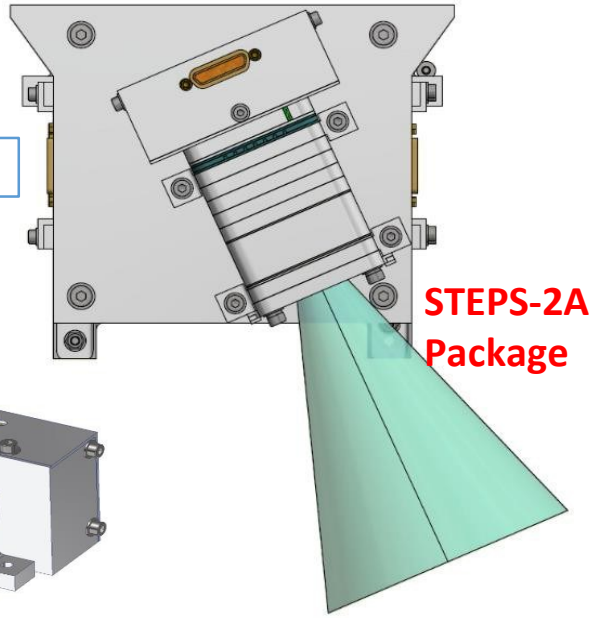
THA-1 has 16 sectors
THA-2 has 32 sectors

Each sector in THA-1 is separated by 22.5°
Each sector in THA-2 is separated by 11.25°

Supra Thermal and Energetic Particle Spectrometer

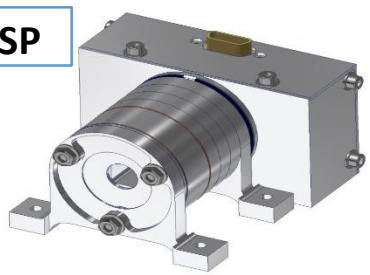


STEPS-1 package

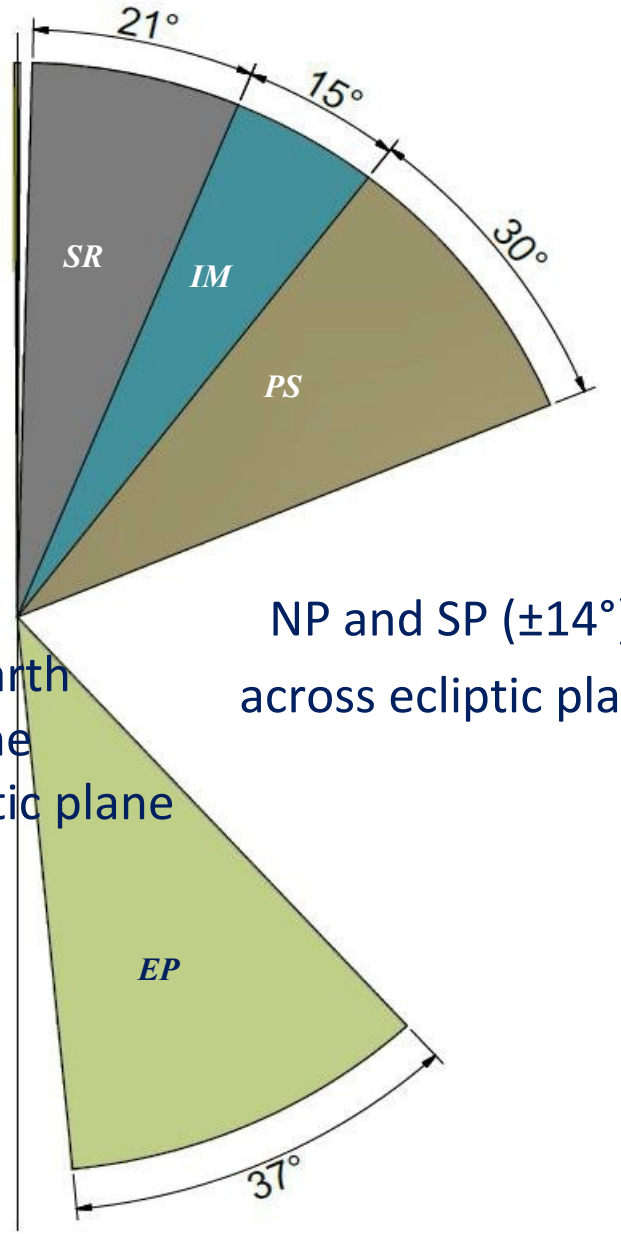


STEPS-2B Package

SP



STEPS-2A Package

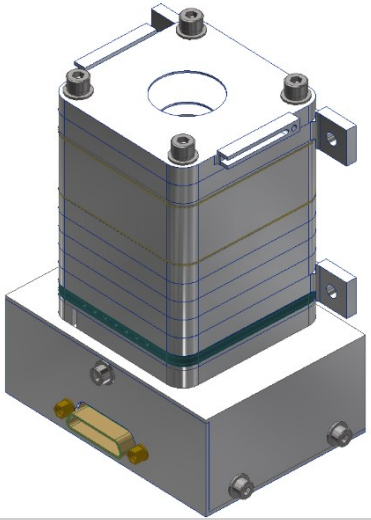


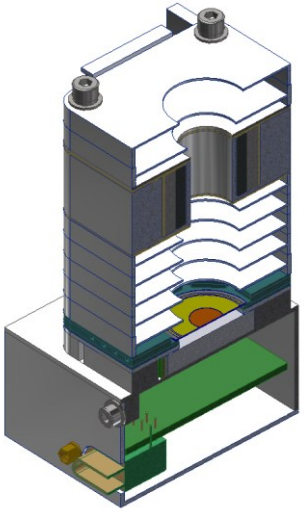
Sun-Earth Line (in the ecliptic plane

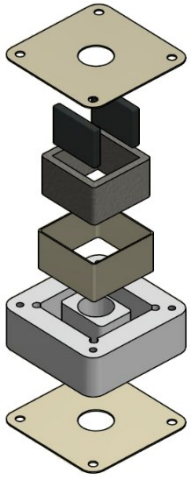
NP and SP (±14°), across ecliptic plane

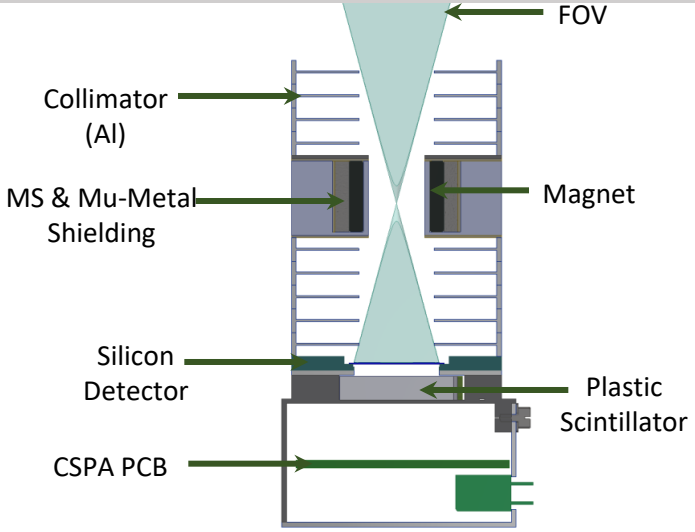
STEPS Detector Units

Alpha and Proton Separated

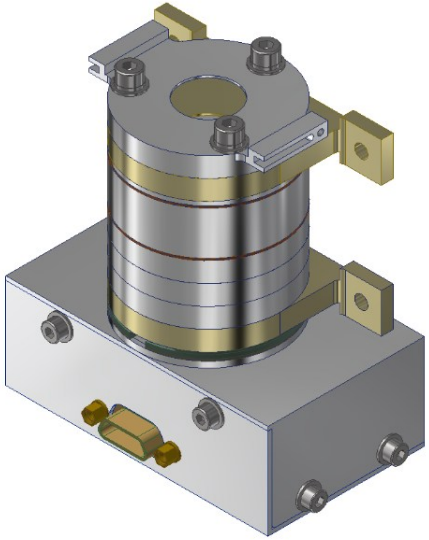


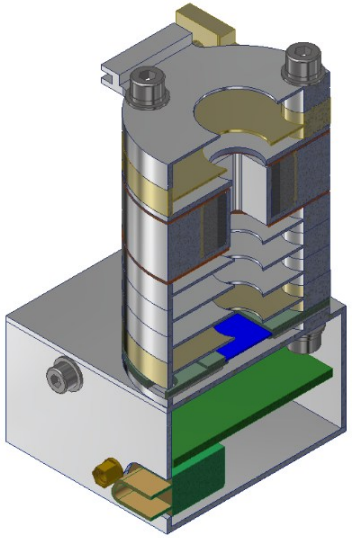


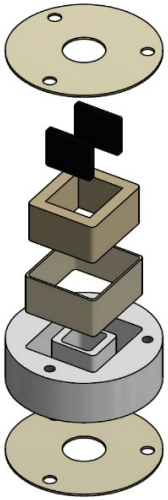


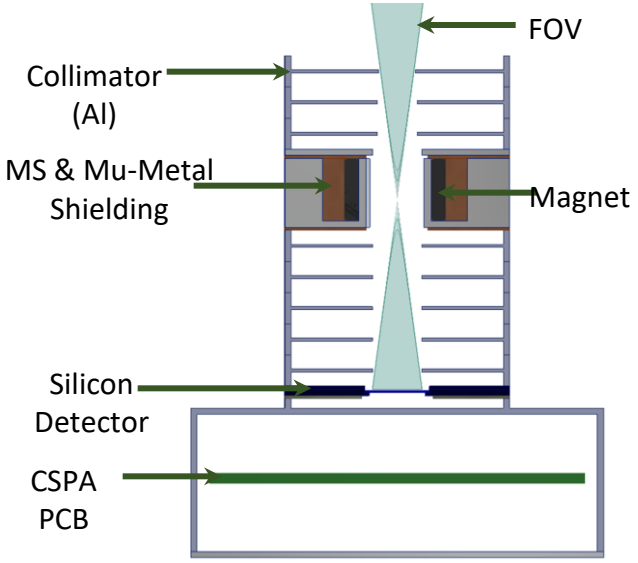


Alpha and Proton Integrated









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

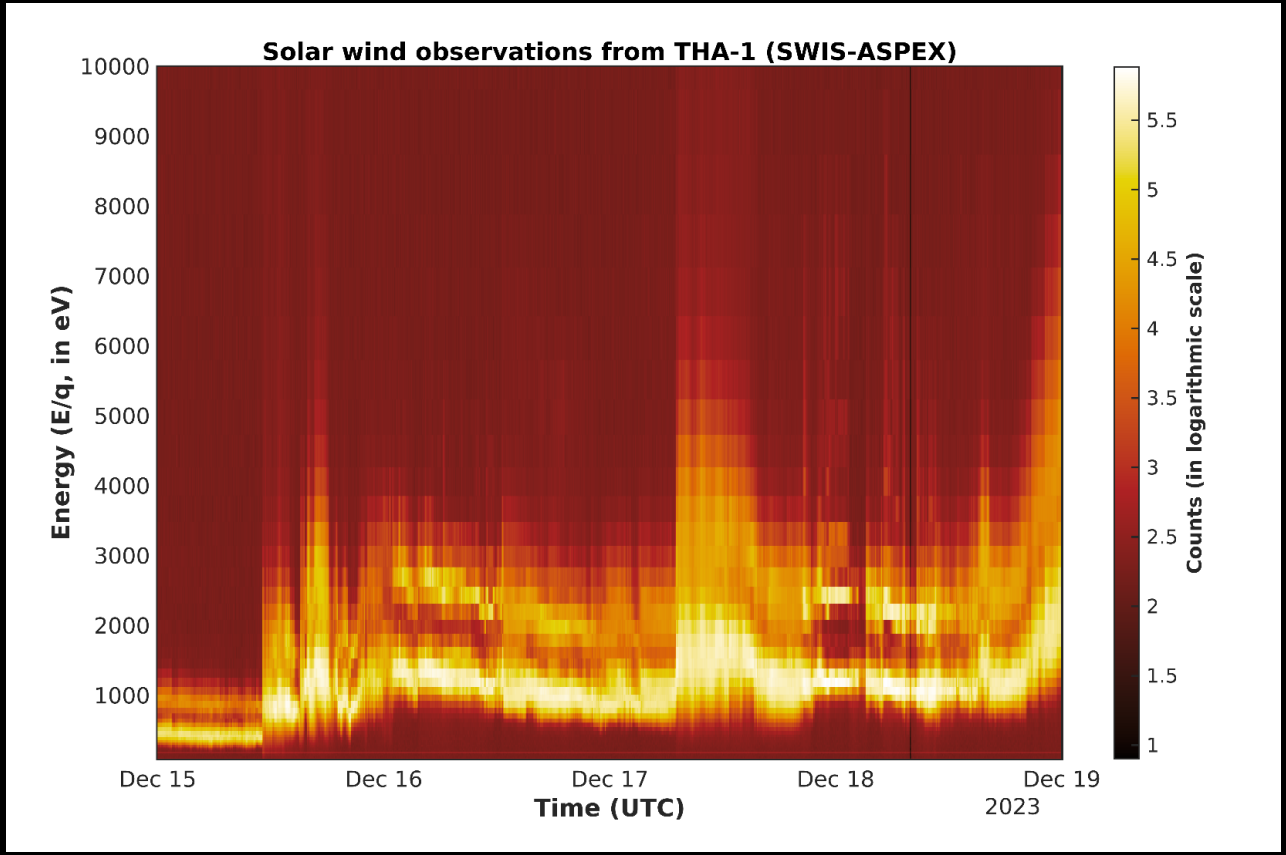
Number of files: 3
Content : Payload frames containing spectrum and HK data
Format : CDF
Processing : Valid frame detection, processing SPICE kernels, segregating sensor data, UT time and angle derivation
Science ready: No

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

SWIS-THA1: Energy histogram of solar wind

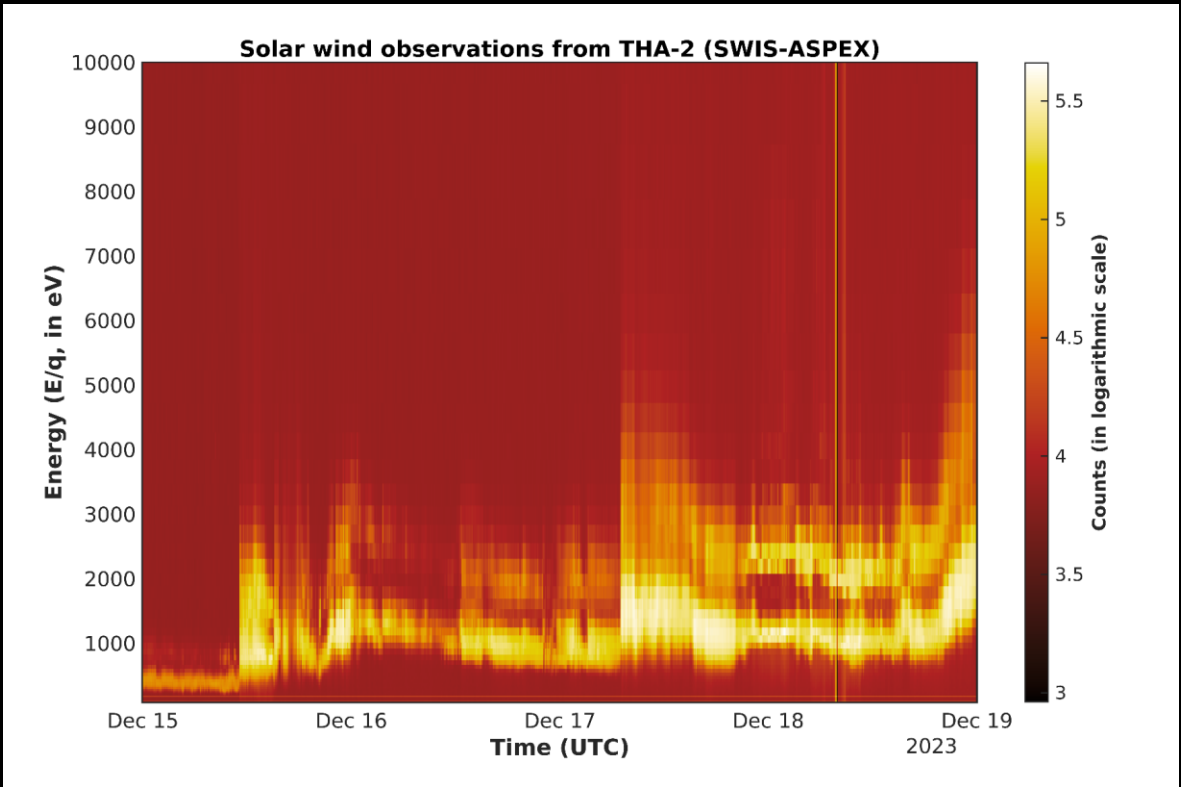
15-19 December, 2023



- E/q separation of protons and alphas in the solar wind as measured by THA-1
- Sharp enhancements indicate arrival of transient structures like CME at the S/C location

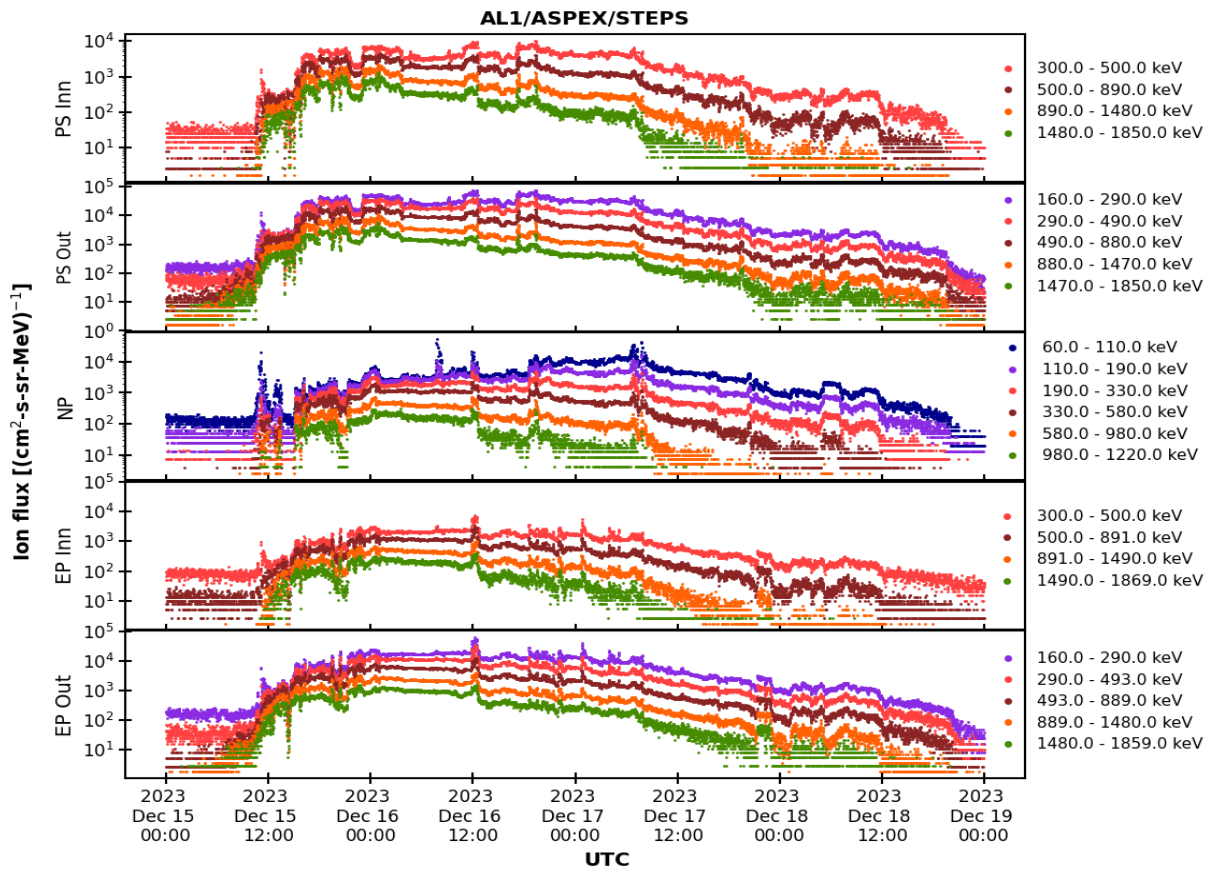
SWIS-THA2: Energy histogram of solar wind

15-19 December, 2023



- THA-2 measurements at a plane perpendicular to THA-1
- E/q separation of protons and alphas in the solar wind.
- Sharp enhancements indicate arrival of transient structures like CME at the S/C location

ASPEX-STEPS: Supra-thermal and energetic ions



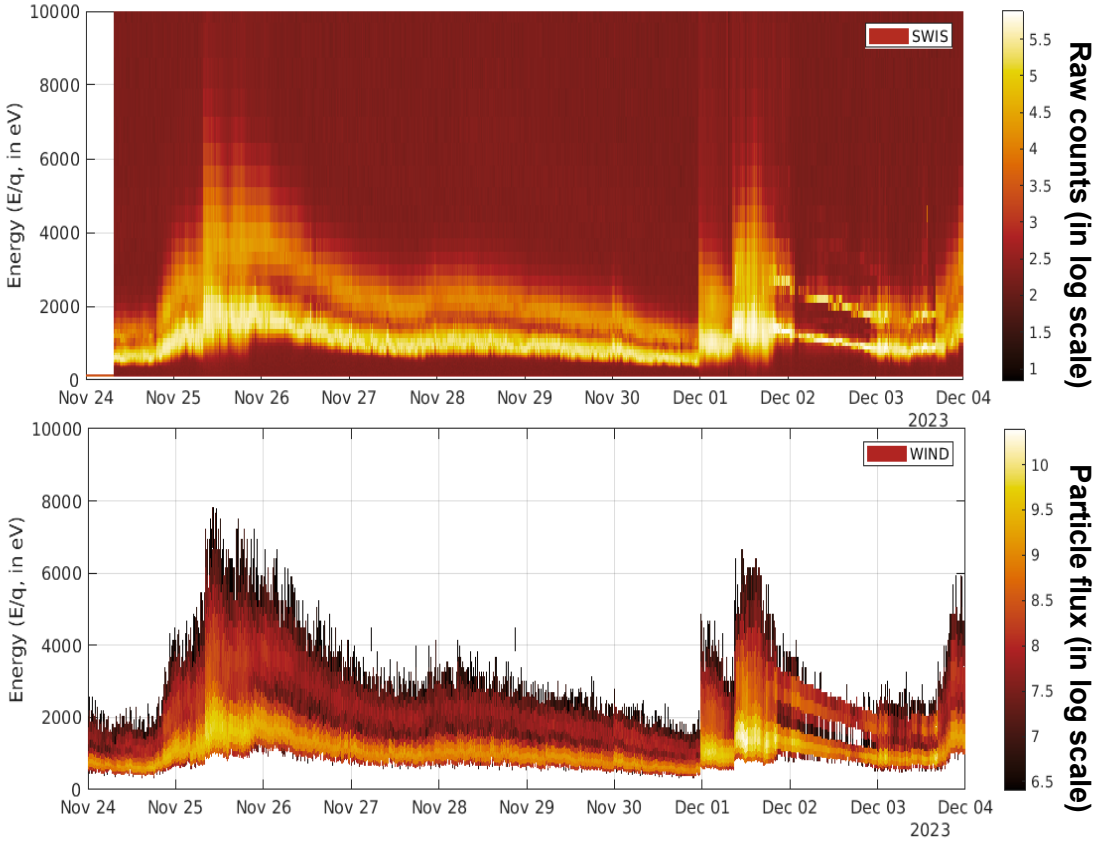
15-19 December, 2023

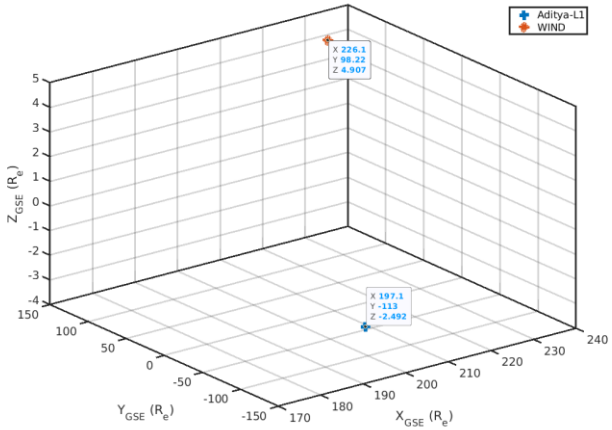
Measurements by three units of STEPS (**PS**: Parker Spiral; **NP**: North Pointing; **EP**: Earth Pointing)

Enhancements in counts indicate arrival of energetic particles associated probably with the CME shock (PS, NP) and bow shock (NP) of the earth.

CMEs (~25 Nov and ~01 Dec, 2023) detected by ASPEX-SWIS-THA1

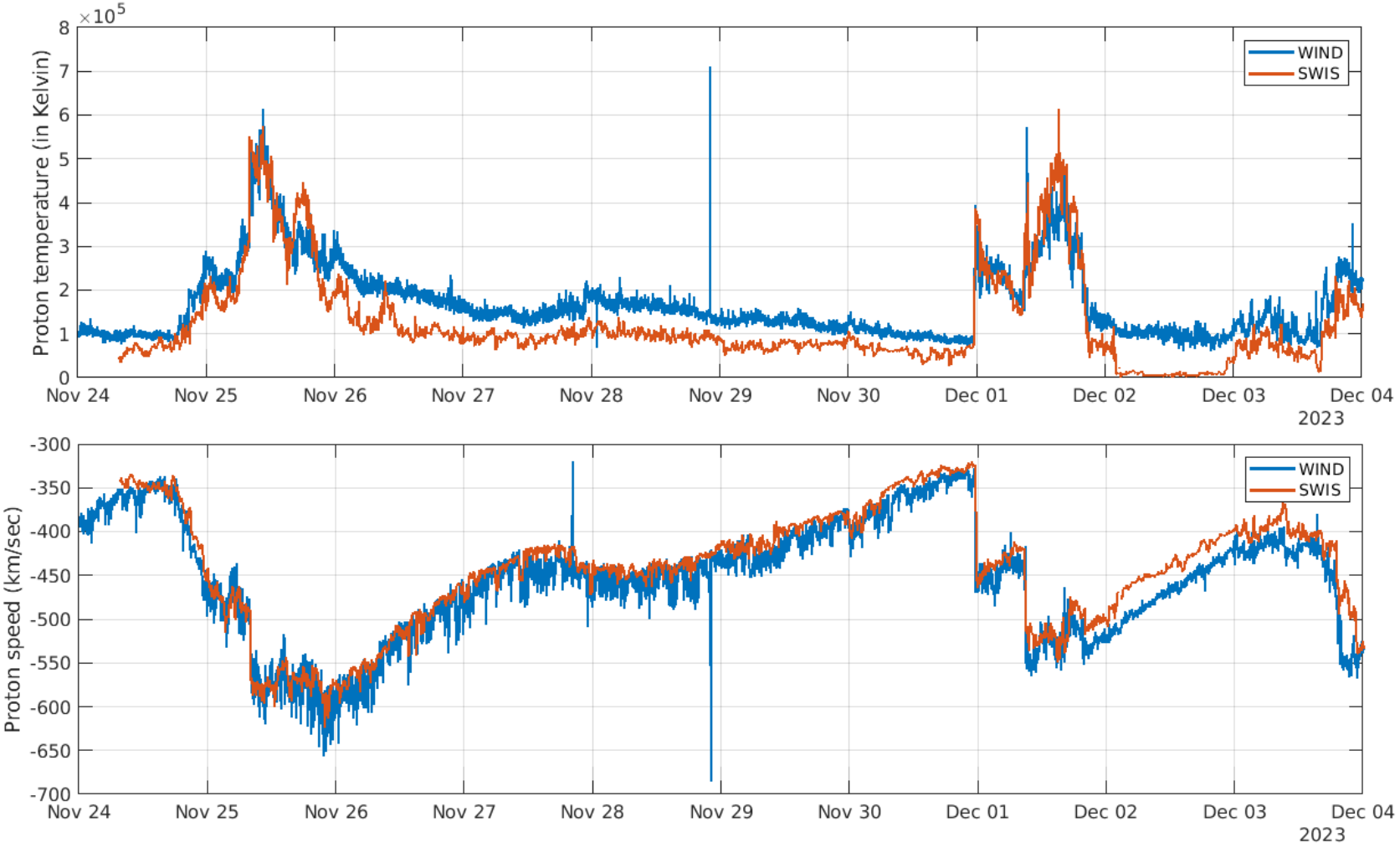
Comparison with WIND measurements





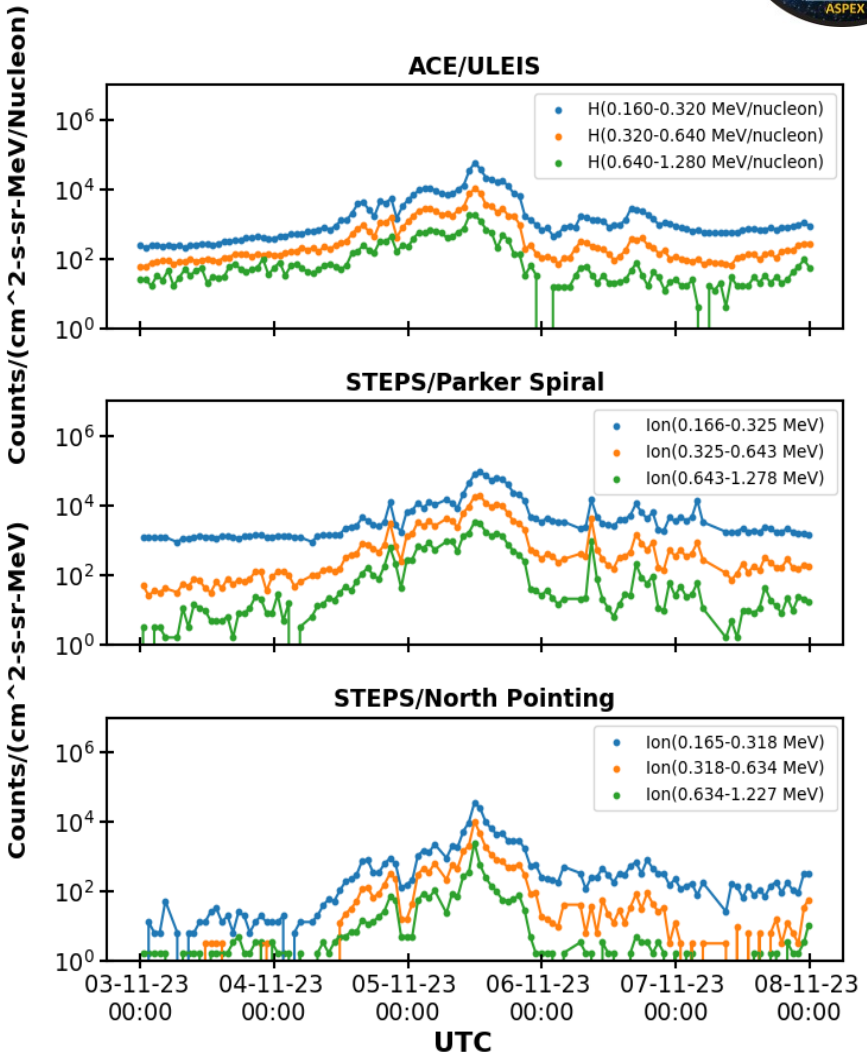
Position coordinates of Aditya-L1 and WIND

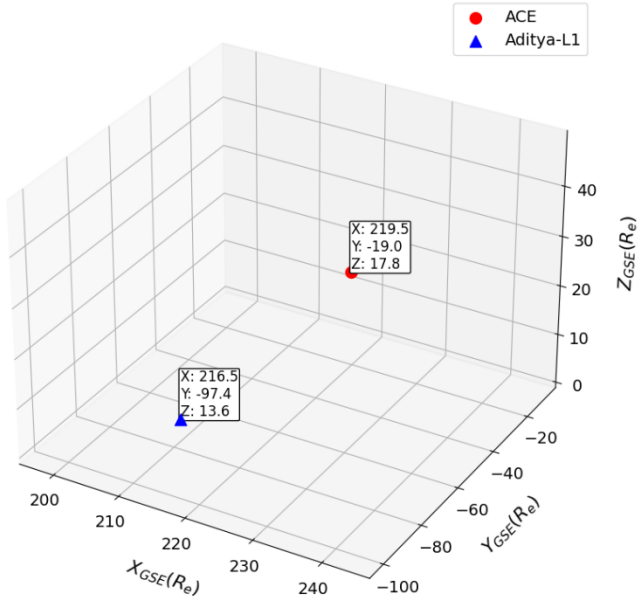
The two lines in the above curves correspond to Proton and Alpha particles


×10^5
Proton temperature (in Kelvin)
WIND
SWIS
Nov 24
Nov 25
Nov 26
Nov 27
Nov 28
Nov 29
Nov 30
Dec 01
Dec 02
Dec 03
Dec 04
2023
Proton speed (km/sec)
WIND
SWIS
Nov 24
Nov 25
Nov 26
Nov 27
Nov 28
Nov 29
Nov 30
Dec 01
Dec 02
Dec 03
Dec 04
2023

SEP events (~6 Nov, 2023) detected by ASPEX-STEPS-PS and NP units

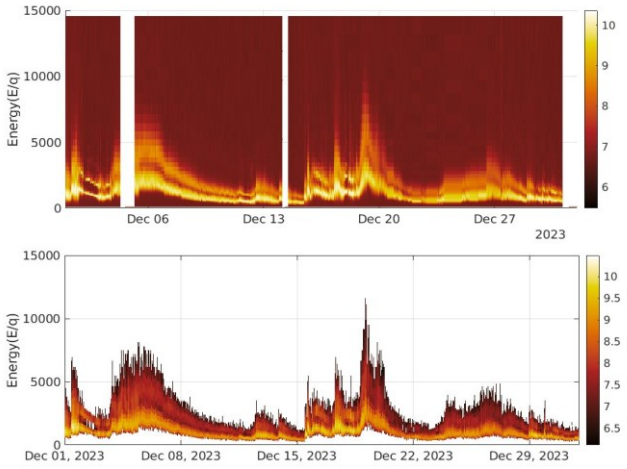
Comparison with ACE measurements



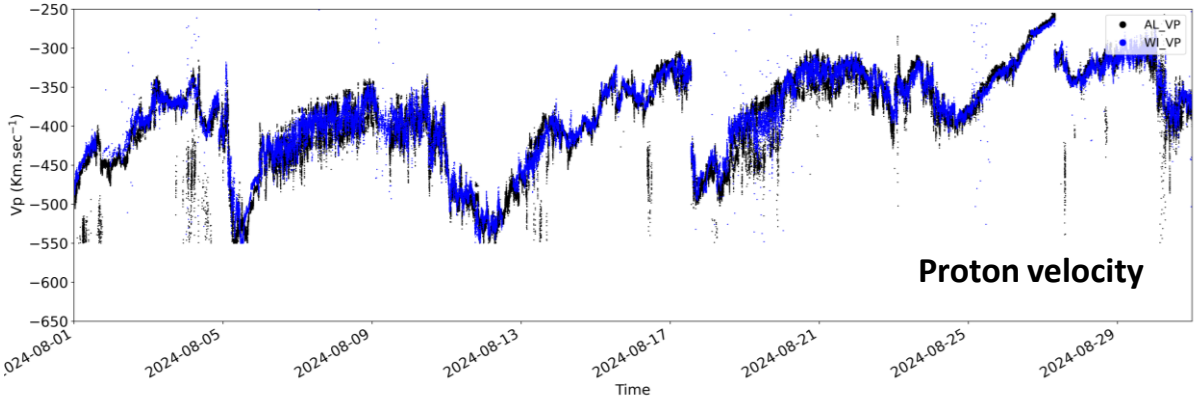


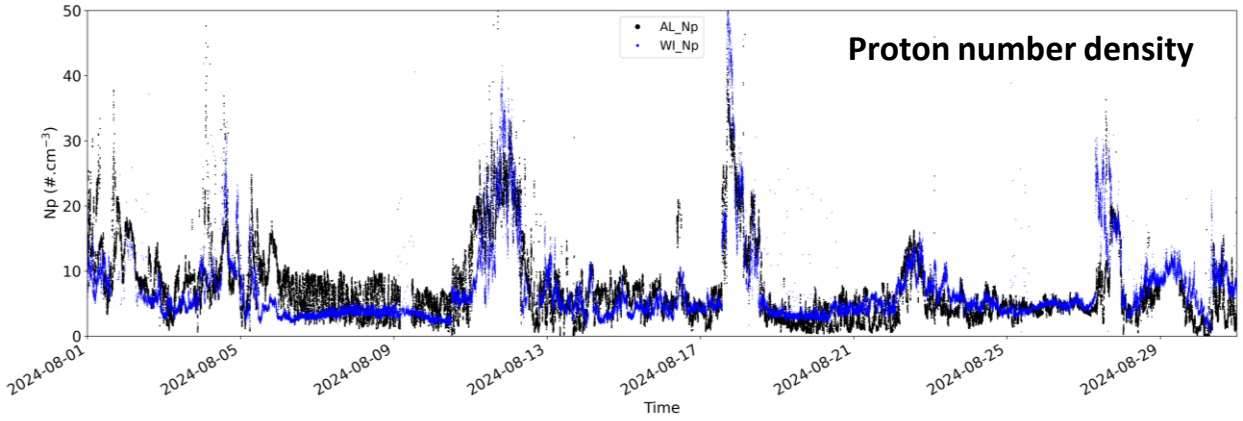
Position coordinates of Aditya-L1 and ACE

Overview of SWIS level 2 data set



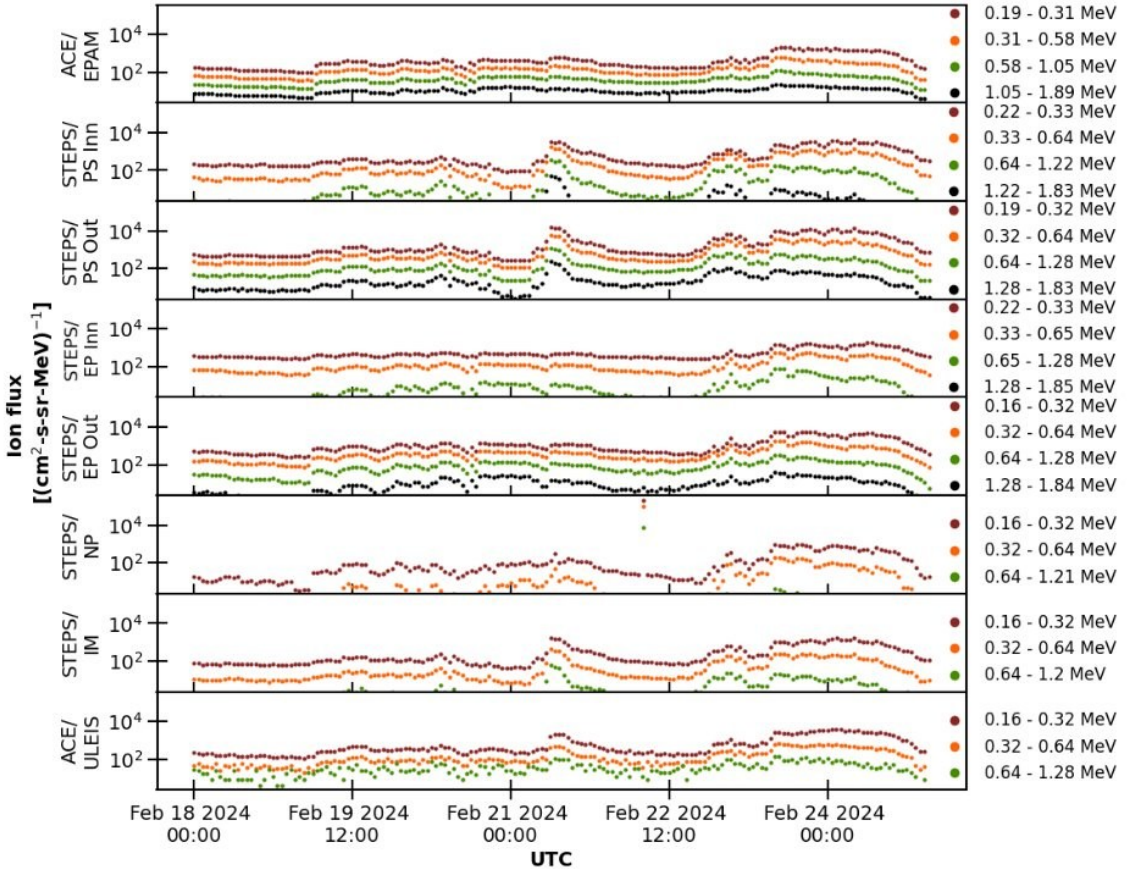
Flux





Overview of STEPS level 2 data set

Flux from different units



Thank you