The SMILE MISSION

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ESA/ESTEC

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Outline

- Brief history of the mission development
- Discovery of solar wind charge exchange
- SMILE science goals
- SMILE payload and spacecraft
- SMILE complementarity with MMS, THEMIS
- Summary and conclusions

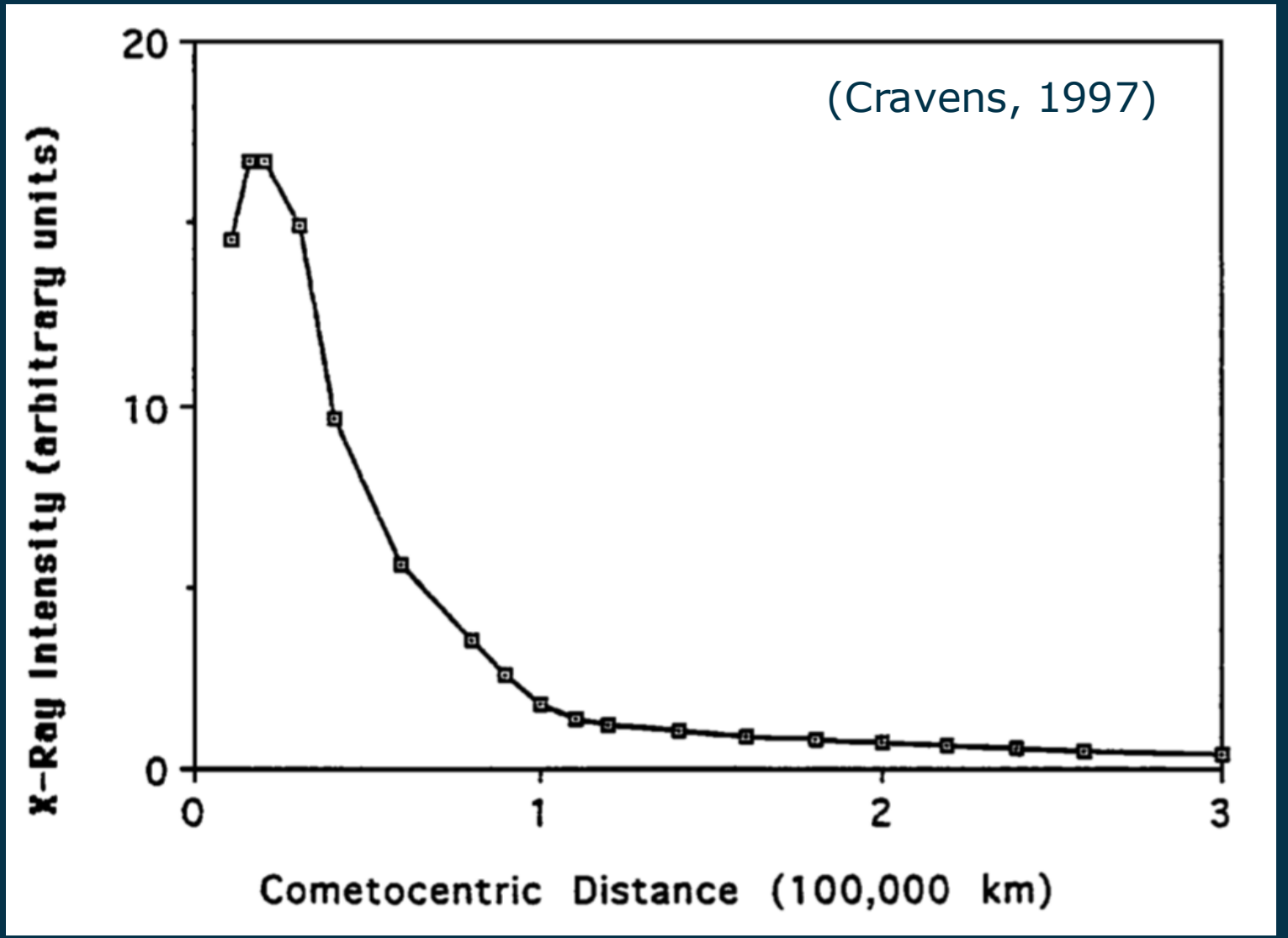
History of the SMILE mission development

- Collaboration started on Cluster (Chinese students coming to European institutes) in early 90s
- Double Star, Chinese mission with two spacecraft, 8 European and 8 Chinese instruments in early 2000s
- Two workshops in 2014 to get small science missions proposals from combined European and Chinese teams
- Common call ESA/CAS for new mission in 2015
- Graziella Branduari-Raymont (MSSL, UK) and Chi Wang (CAS, China) proposed SMILE in 2015
- SMILE selected in November 2015 by ESA Science Programme Committee
- SMILE funding approved by ESA Science Programme Committee in 2019

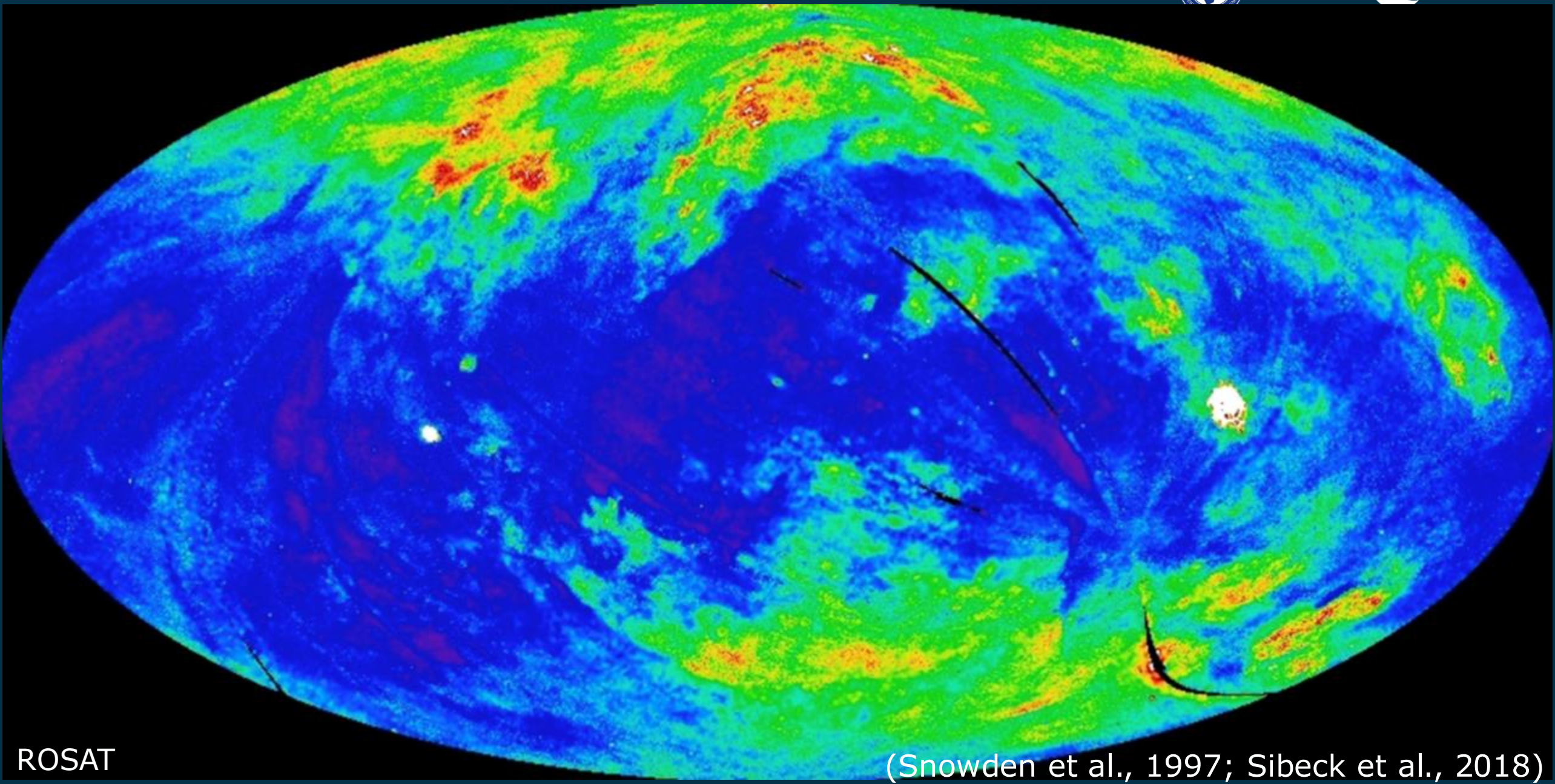

Comet Hyakutake on 1996 March 25
- One of the brightest objects in the sky
- Longuest comet tail: > 3.8 AU (Ulysses)
- Ethane and Methane detected
- X-ray emissions
(E. Kolmhofer, H. Raab; Johannes-Kepler-Observatory, Linz, Austria)

Solar wind charge exchange

- Solar wind minor/heavy ions O^{6+}, C^{5+}, N^{5+}, Si^{10+} exchange charge with cometary neutrals
- $O^{6+} + M \rightarrow O^{5+*} + M^{+}$
- O^{5+*} emits X-ray photons



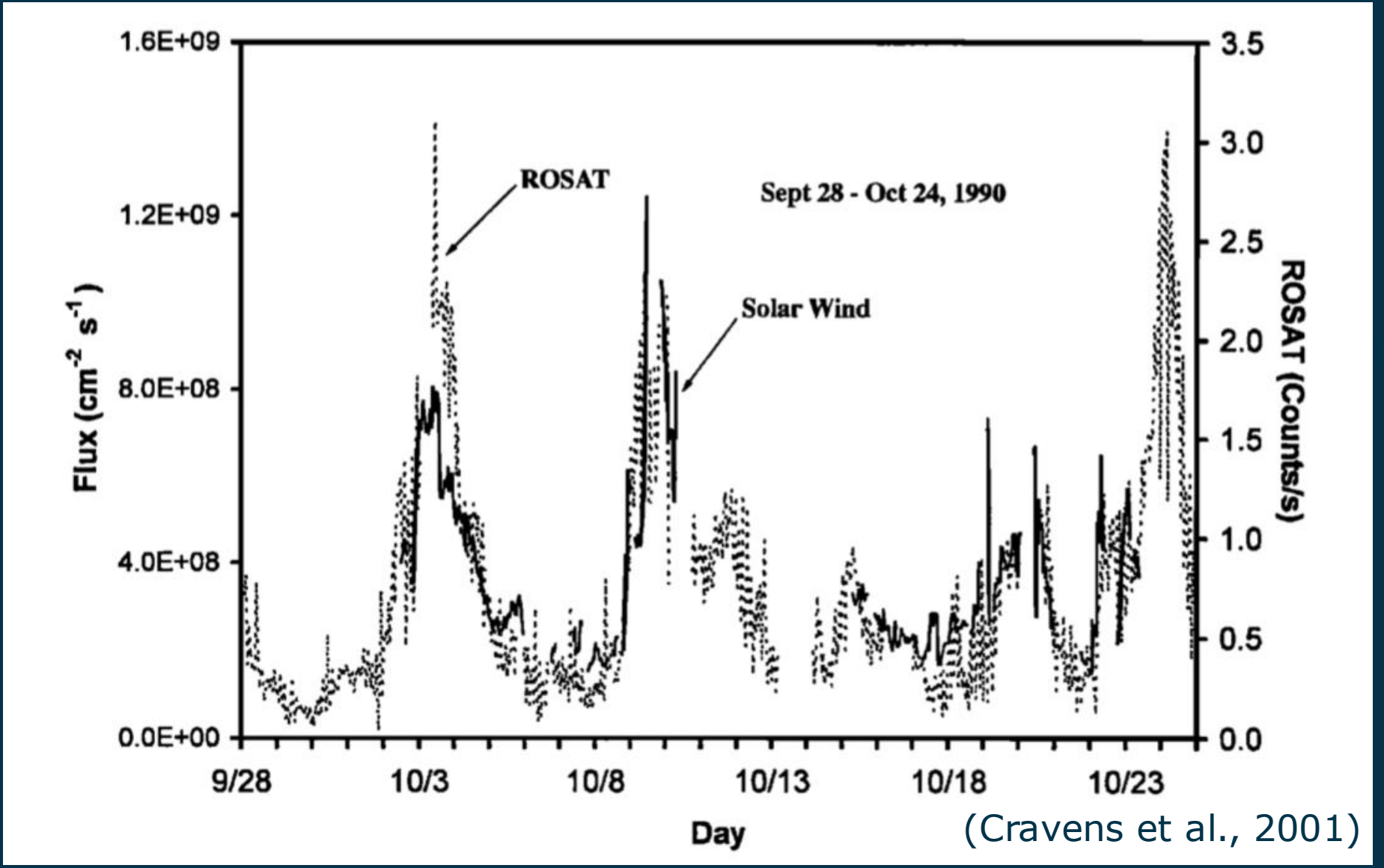
X-ray Long Term Enhancements



ROSAT

(Snowden et al., 1997; Sibeck et al., 2018)

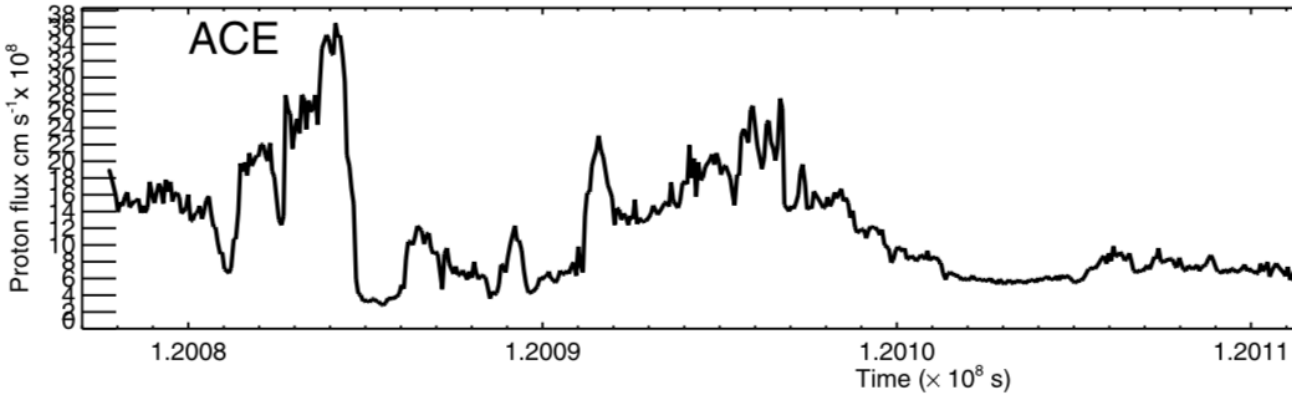
Solar wind charge exchange at Earth



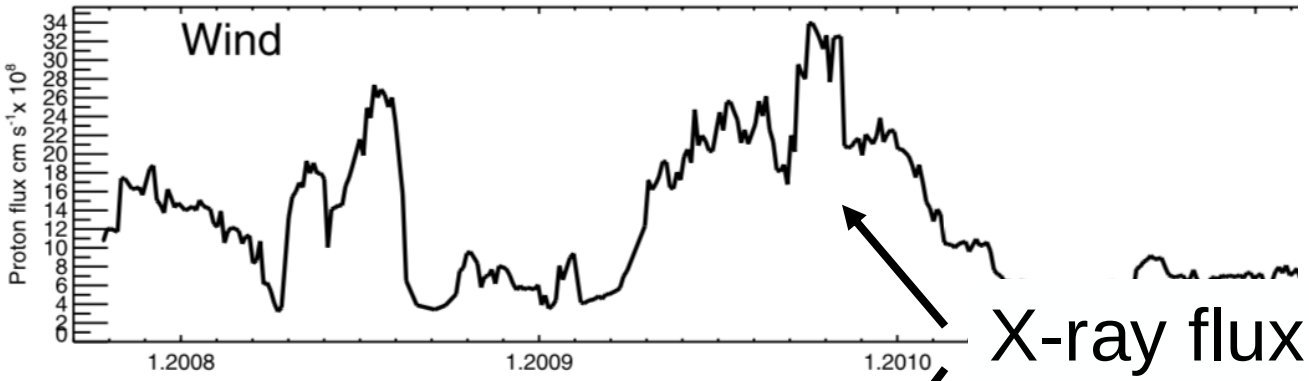
(Cravens et al., 2001)

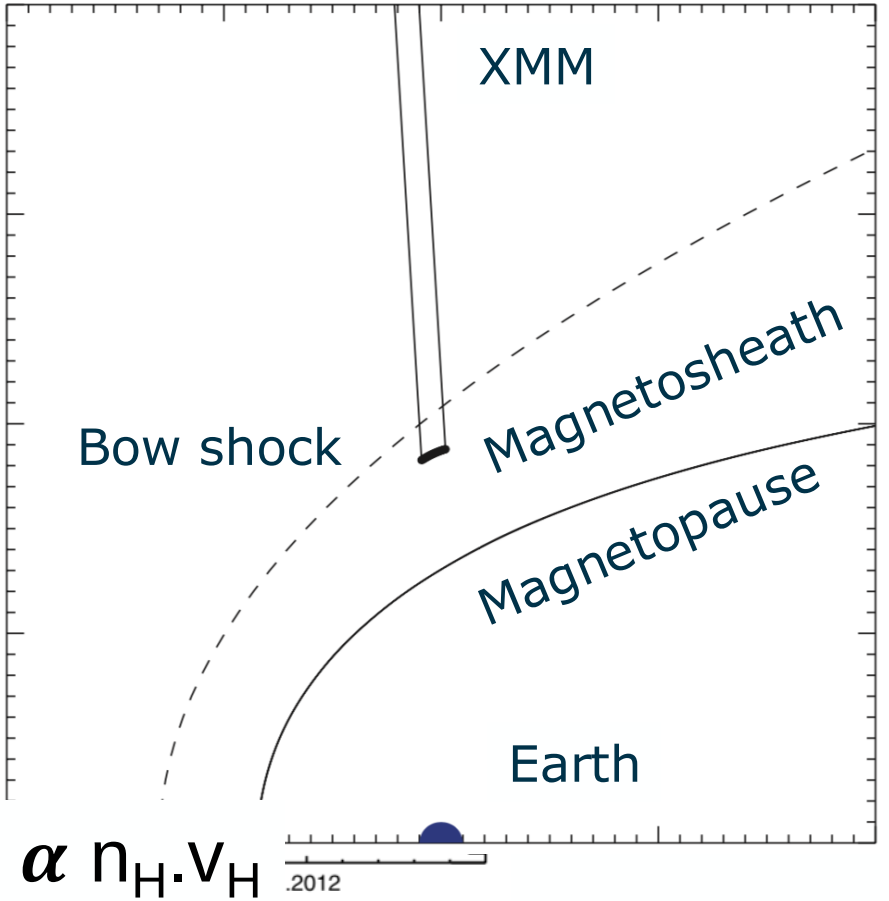
Solar wind charge exchange at Earth

Solar wind flux



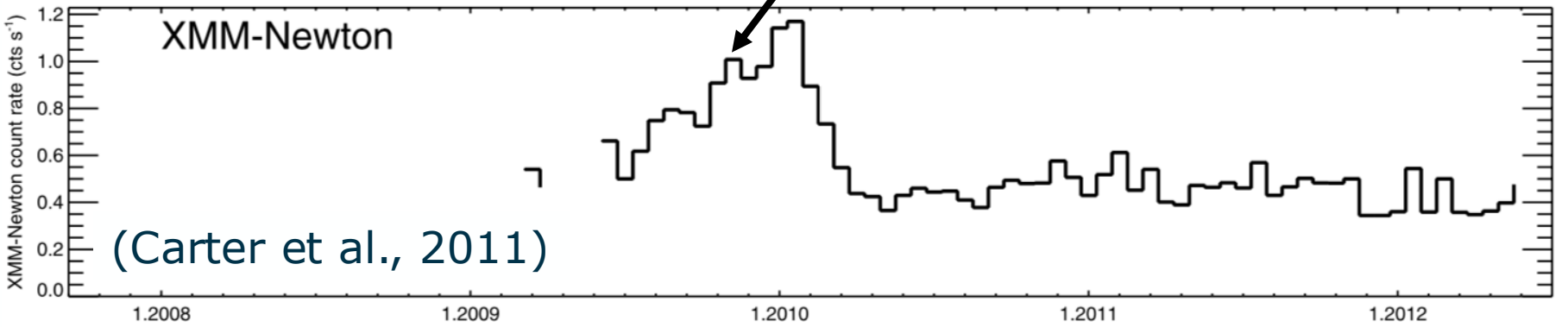
Solar wind flux





X-ray flux α $n_H.v_H$

Soft X-ray

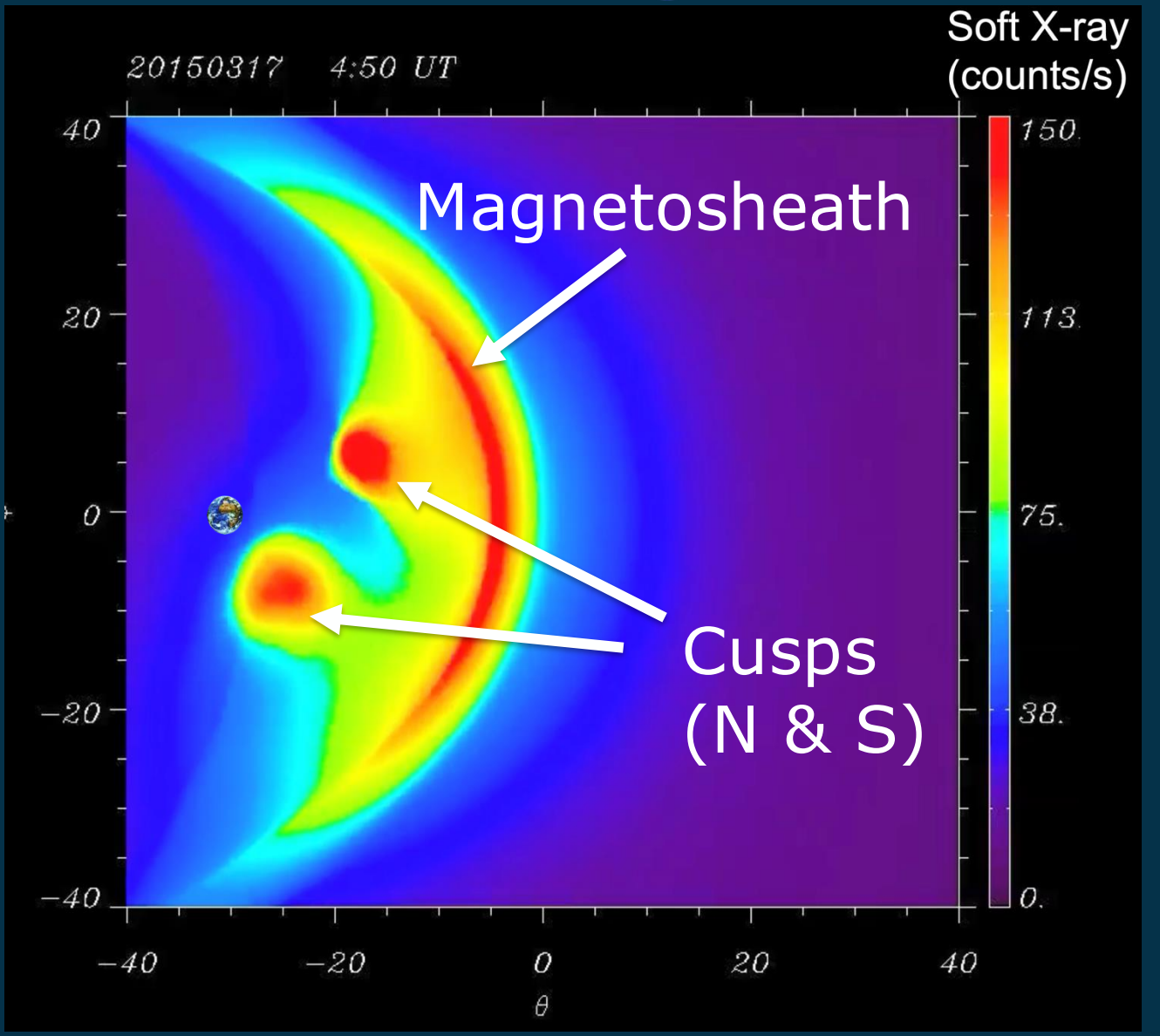


(Carter et al., 2011)

Soft X-ray intensity

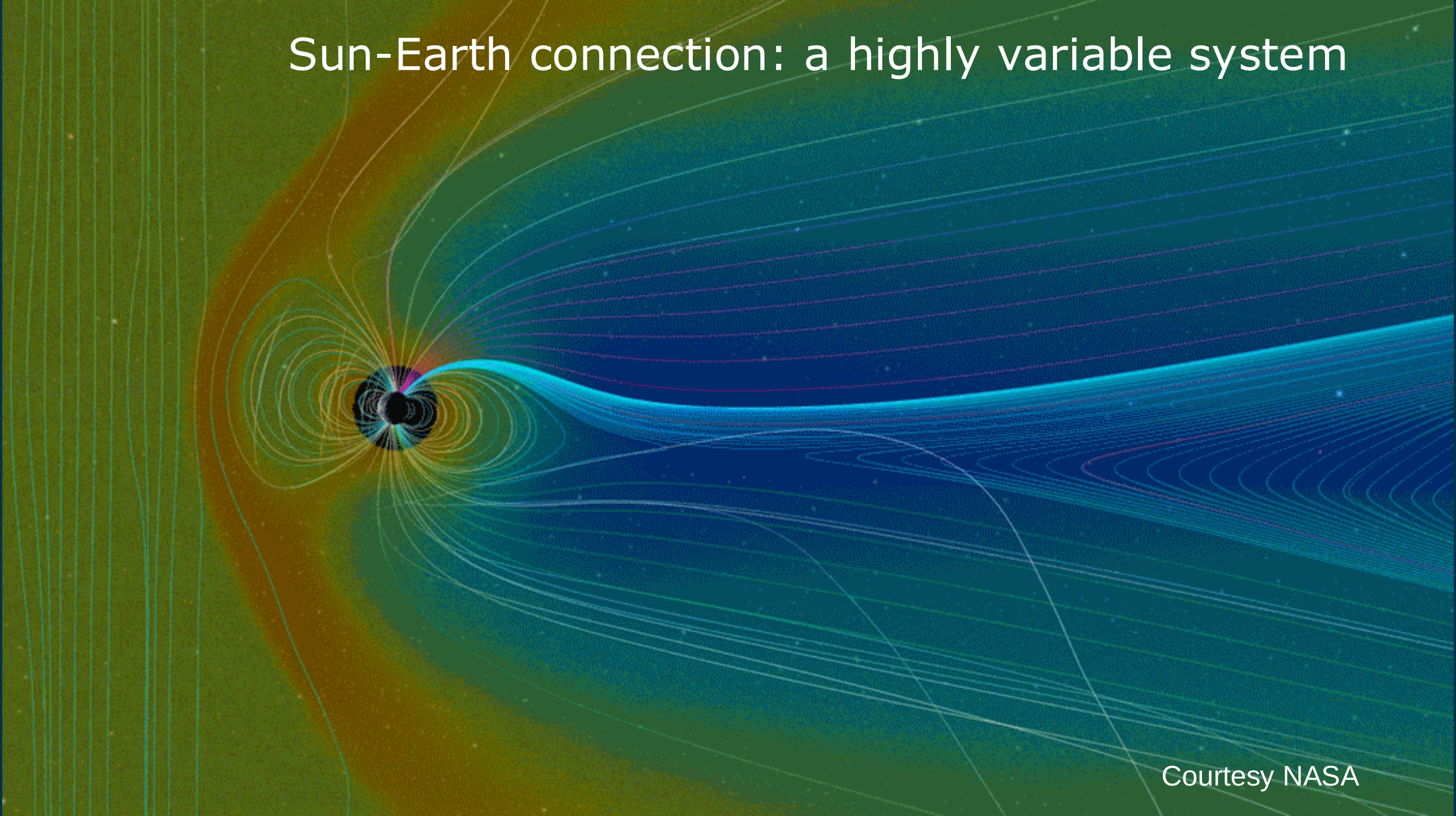
$$I_X = \frac{1}{4\pi}\int P_X dr = \frac{1}{4\pi}\int a_X n_H n_{SW}\sqrt{u_{SW}^2 + u_{th}^2}\,dr,$$

a_X *is the interaction efficiency factor*
n_H *is the number density of exospheric hydrogen*
n_{SW} *is the plasma number density in the solar wind*
u_{SW} *is the plasma bulk velocity*
u_{th} *is the plasma thermal speed*



[Sun et al., 2015]

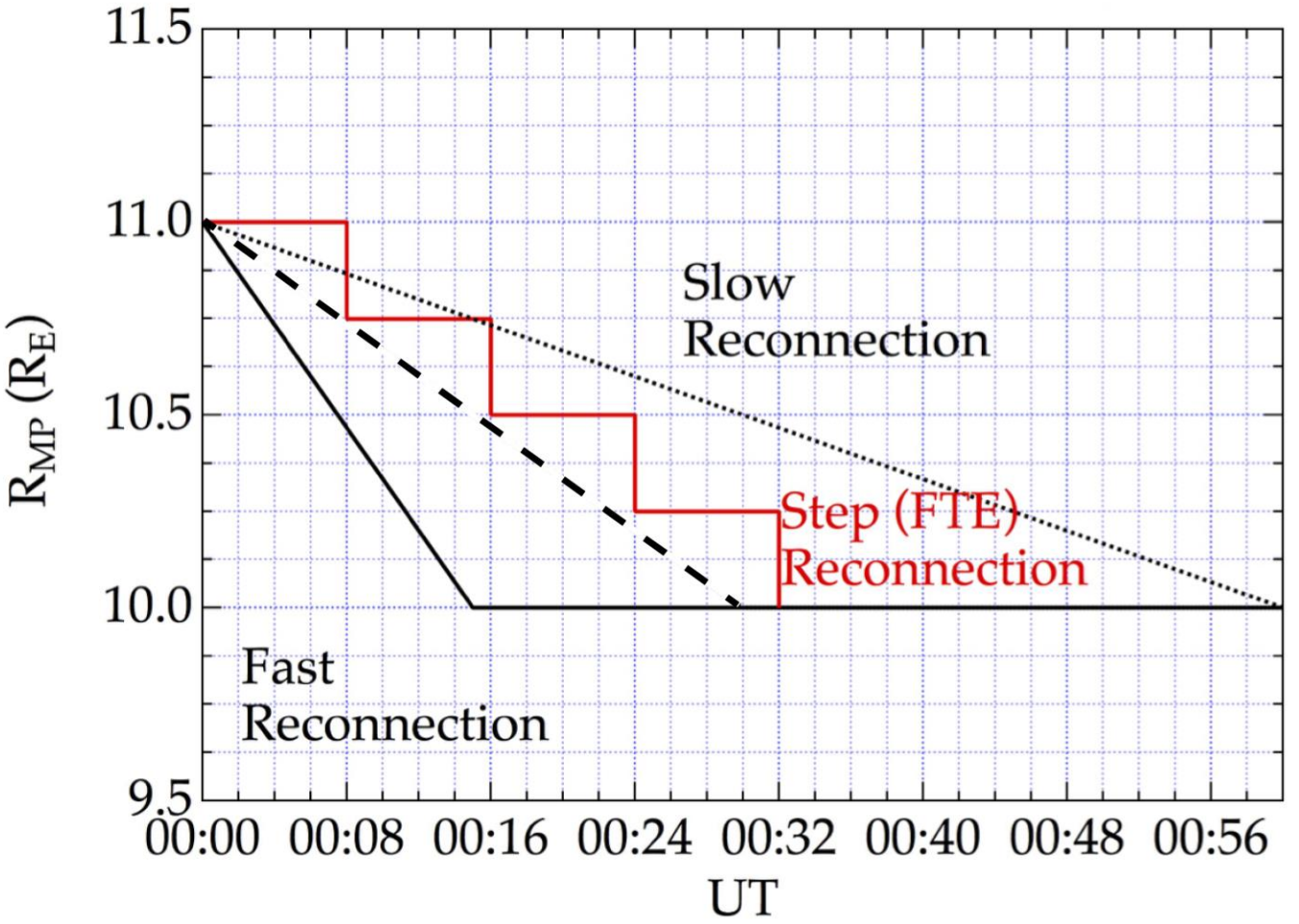
Sun-Earth connection: a highly variable system



Courtesy NASA

1. What are the fundamental modes of the solar wind/magnetosphere interaction?

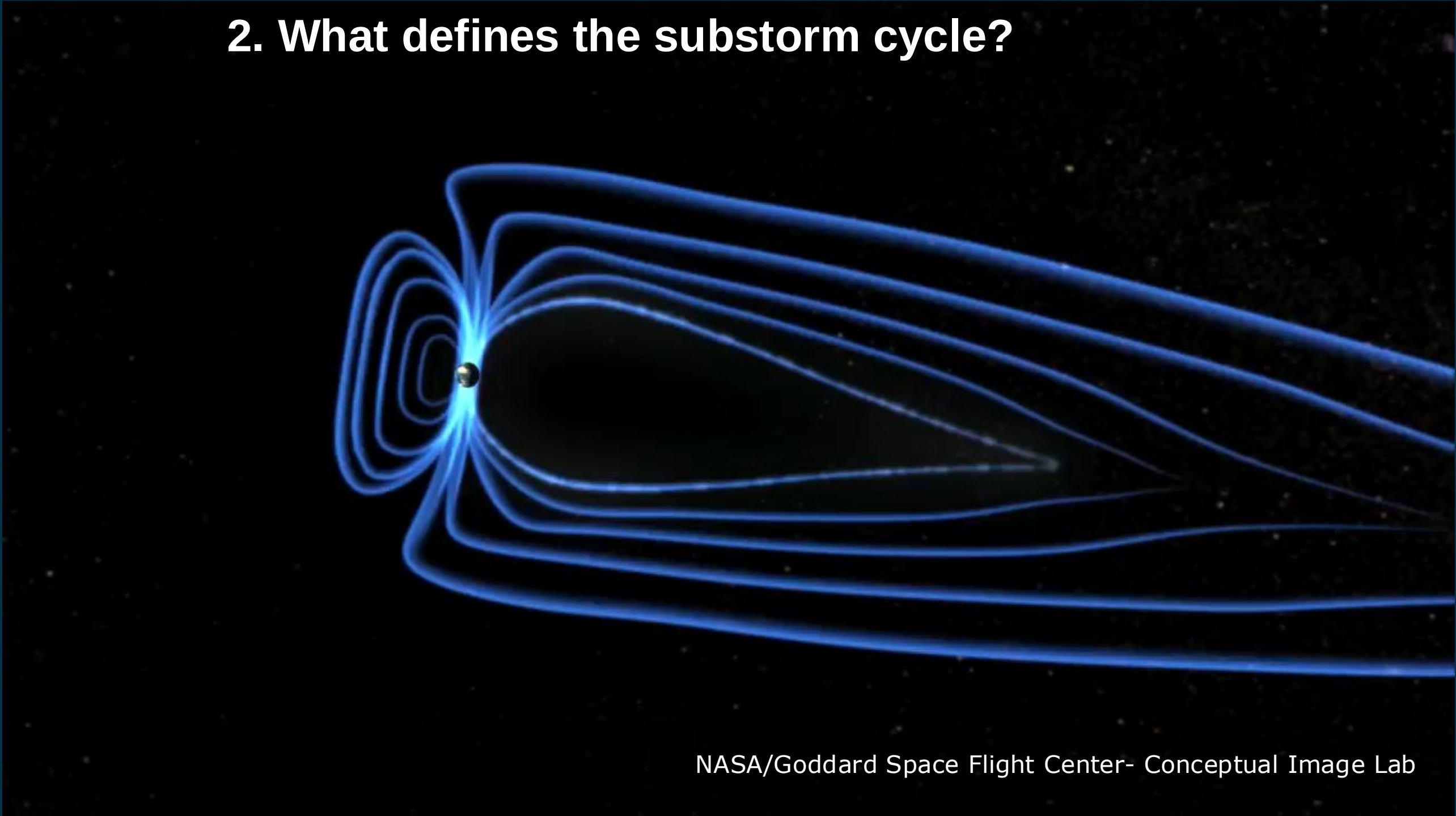
- When/where is **reconnection** steady/transient/bursty, patchy or global?
- Dependent on solar wind parameters or intrinsic instabilities?
- Role of the magnetospheric cusps in solar wind/magnetosphere coupling



SMILE will measure the position of magnetopause versus time

(Sibeck et al., 2023)

2. What defines the substorm cycle?

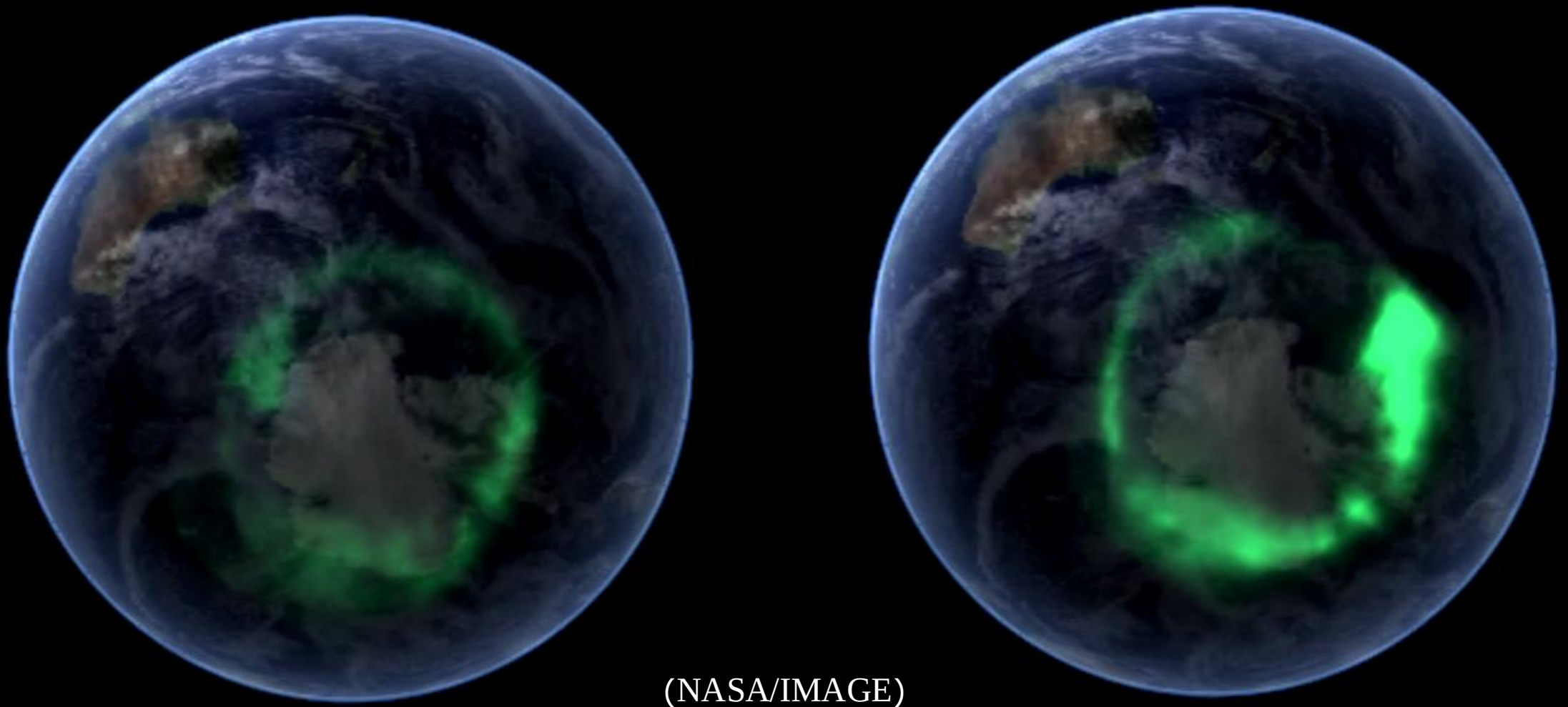


NASA/Goddard Space Flight Center- Conceptual Image Lab

2. What defines the substorm cycle?

Quiet time

Substorm time

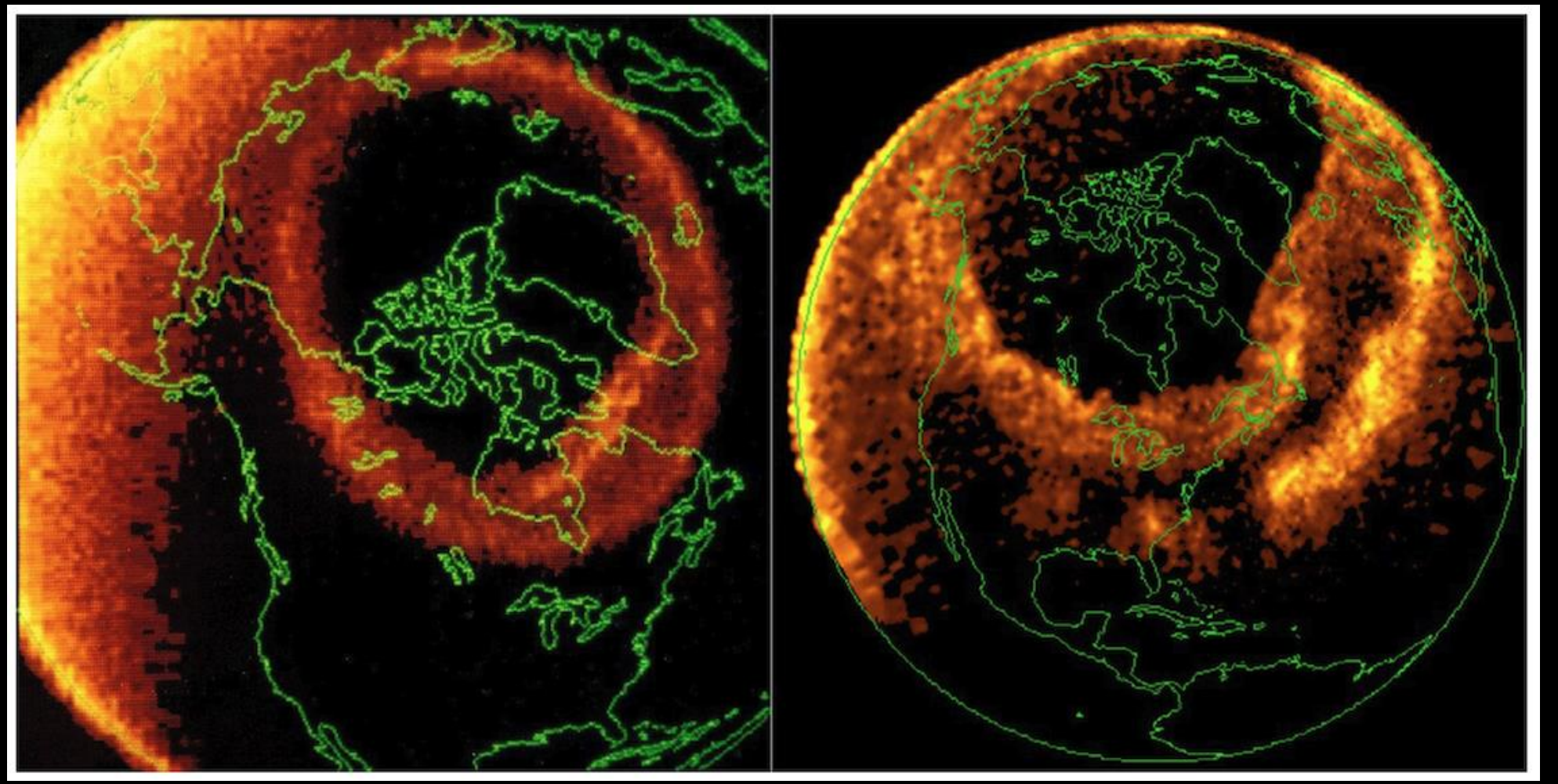


(NASA/IMAGE)

3. How do CME-driven storms arise and what is their relationship to substorms?

Quiet time

Great geomagnetic Storm March 1989



(NASA/DE-1)

(Johnsen, 2013)

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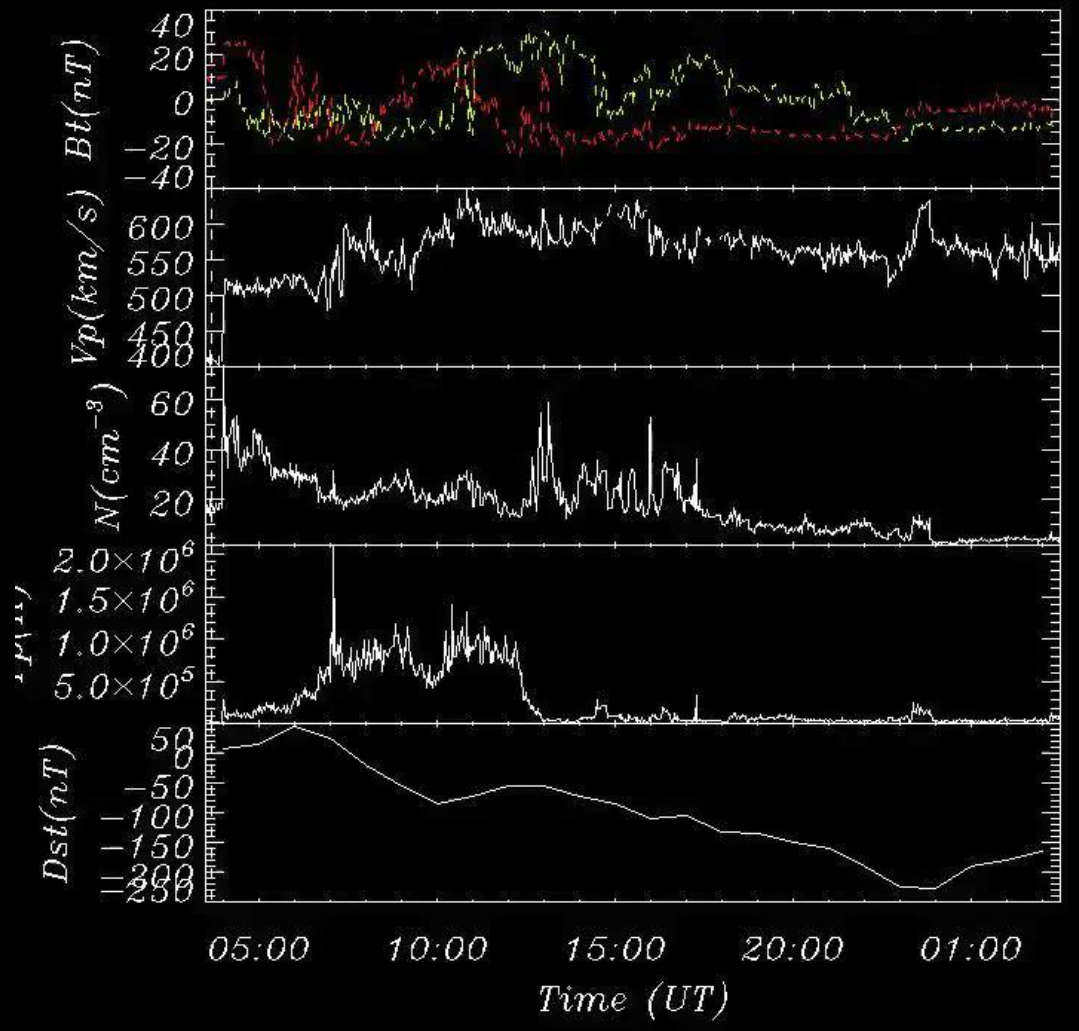
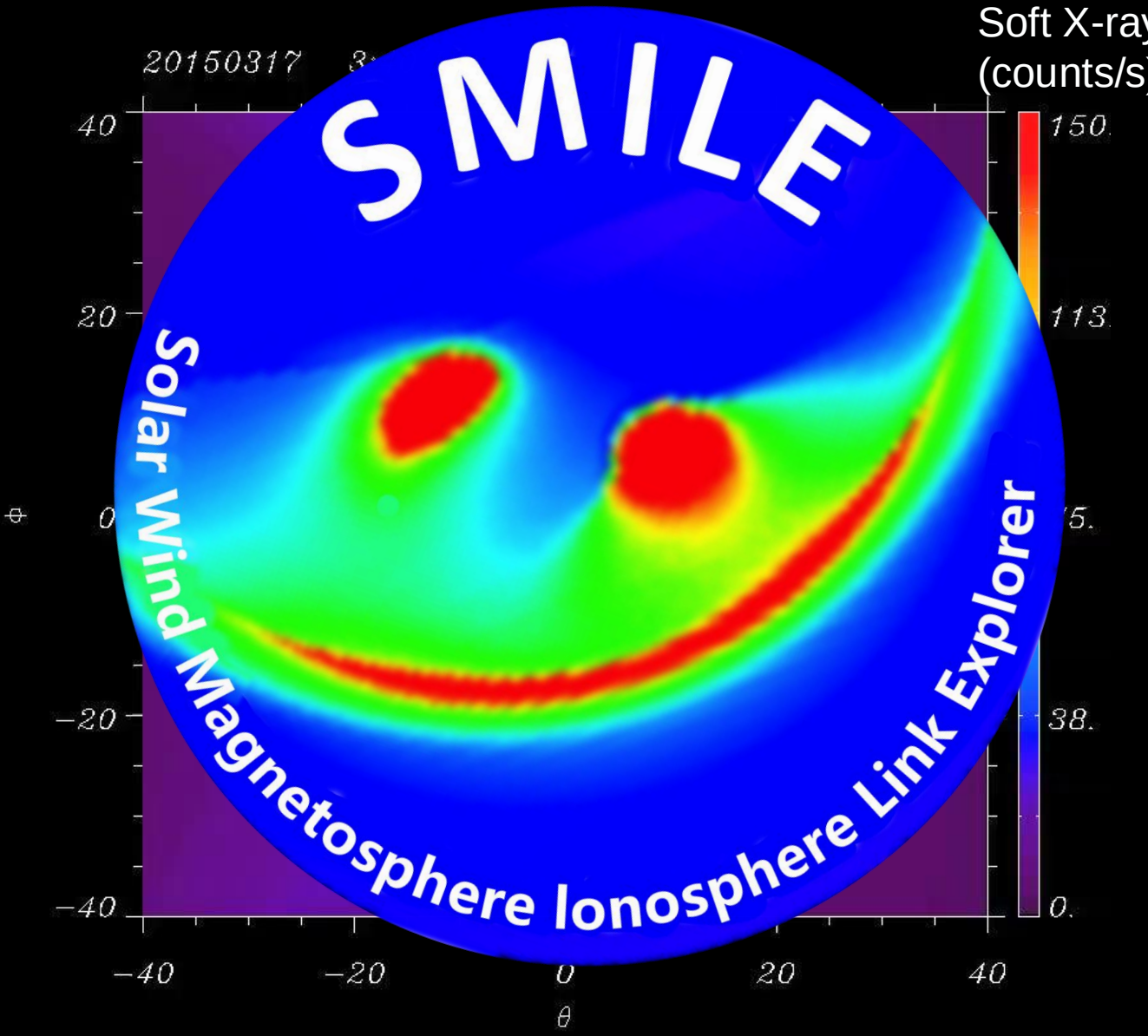
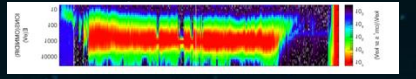
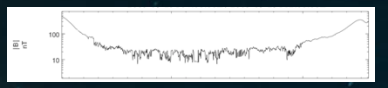






ions



magnetic field

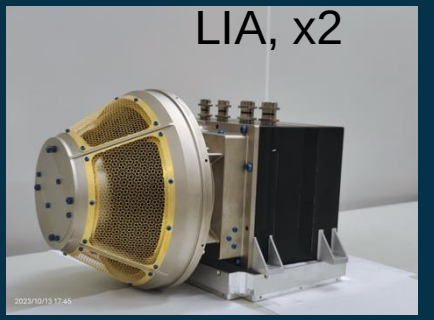
Magnetosheath/
Magnetopause

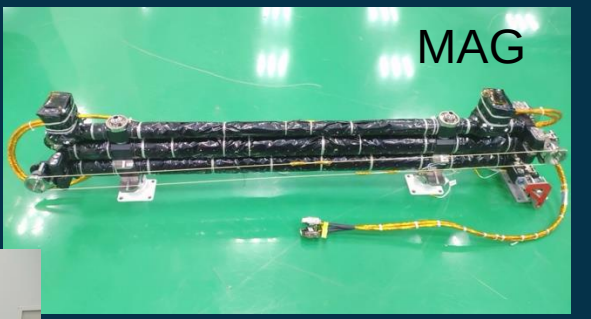
Cusp

Aurora

SMILE INSTRUMENTS

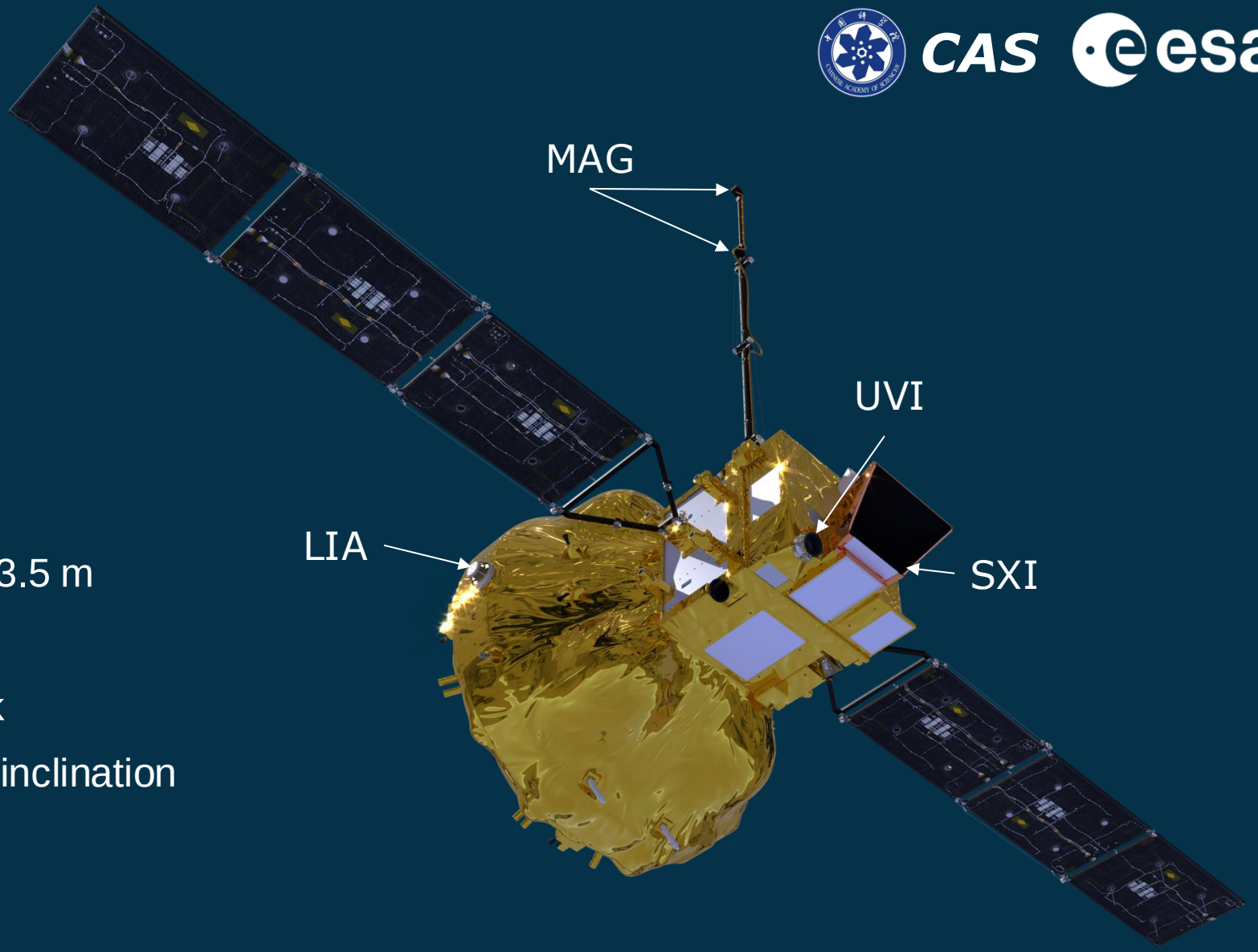
1. LIA (Light Ion Analyser) is a top-hat analyser for detection of ions. Energy range 5 eV-20 keV, 4 π FOV at up to 0.25s resolution. **PI: Lei DAI, NSSC, CAS, China**
2. MAG (Magnetometer) is a flux-gate magnetometer with two sensors on a 3m boom. **B** measured up to 40 Hz. **PI: Lei LI, NSSC, CAS, China**
3. SXI is a wide field lobster-eye 0.2-5 keV X-ray imager. CCD detectors. 16 x 27 degree FOV. Resolution: 1-5 min., 0.25-1^{o}. **PI: Steve Sembay, Leicester, UK**
4. UVI (UV imager) is a four mirror imager in the range 155-175 nm, 10^{o} FOV. Resolution 60 s, 150 km. **PI: Xiaoxin ZHANG, NCSW, CMA, China**



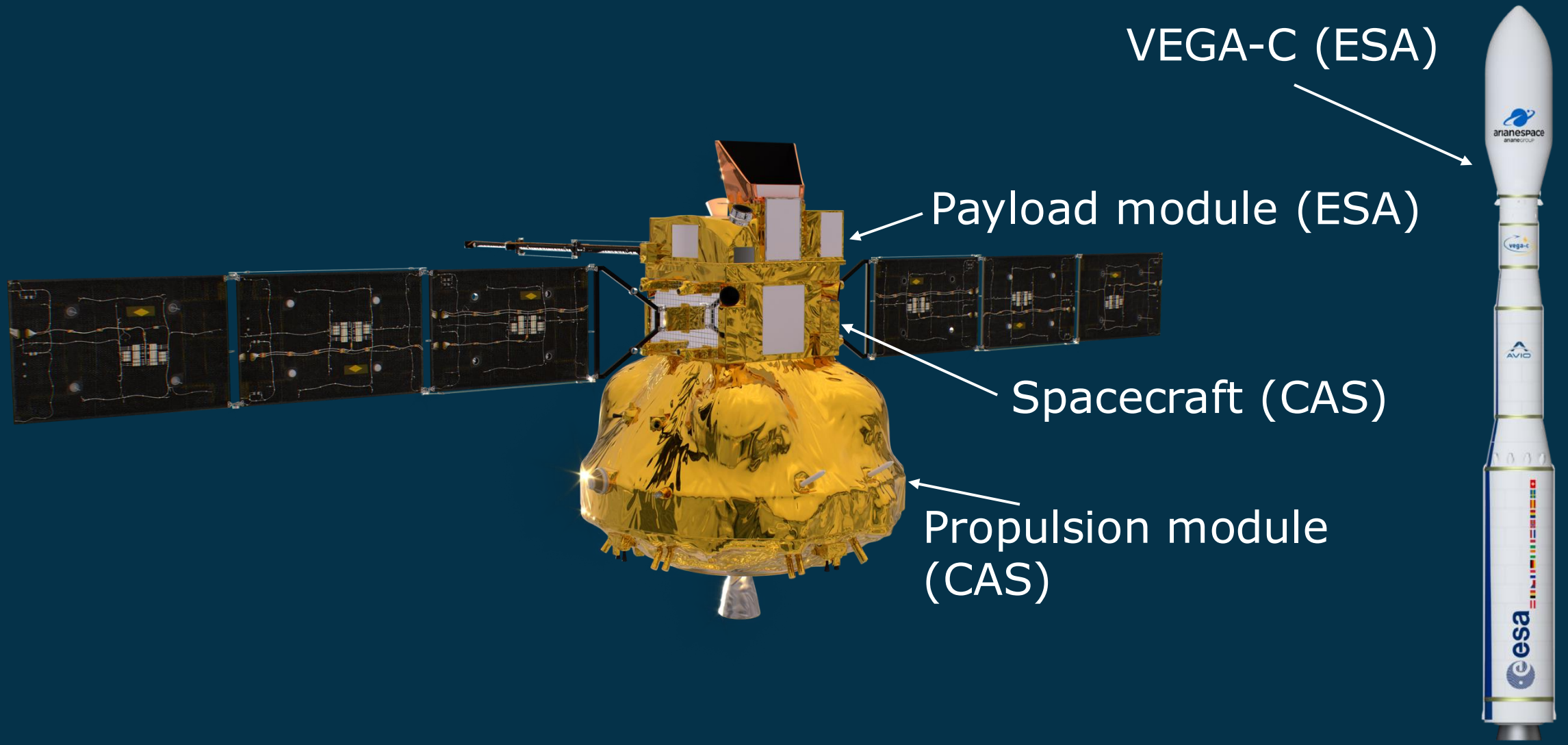


SMILE spacecraft

- 3-axis stabilised
- Dry mass: 690 kg
- Propellant: 1560 kg
- Total mass: 2250 kg
- Dimensions in orbit: 4.7 m × 9.8 m × 3.5 m
- S-band and X-band
- Telemetry rate: 36 Gbit/orbit downlink
- Baseline orbit: 1 x 20 Earth radii, 70º inclination
- Launch: 2025 with Vega C



Chinese Academy of Sciences (CAS)-ESA collaboration

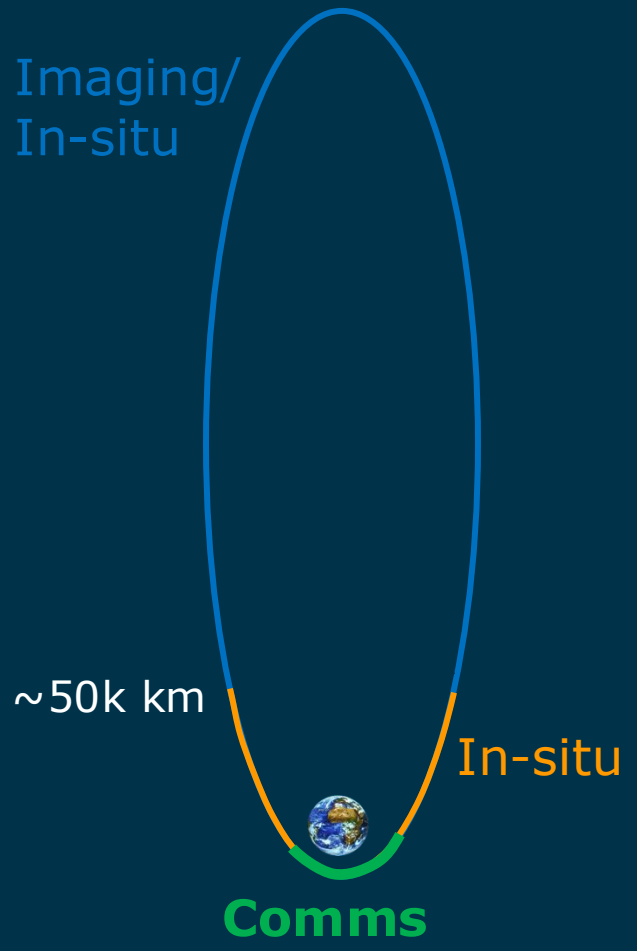


Operations and Data Volume

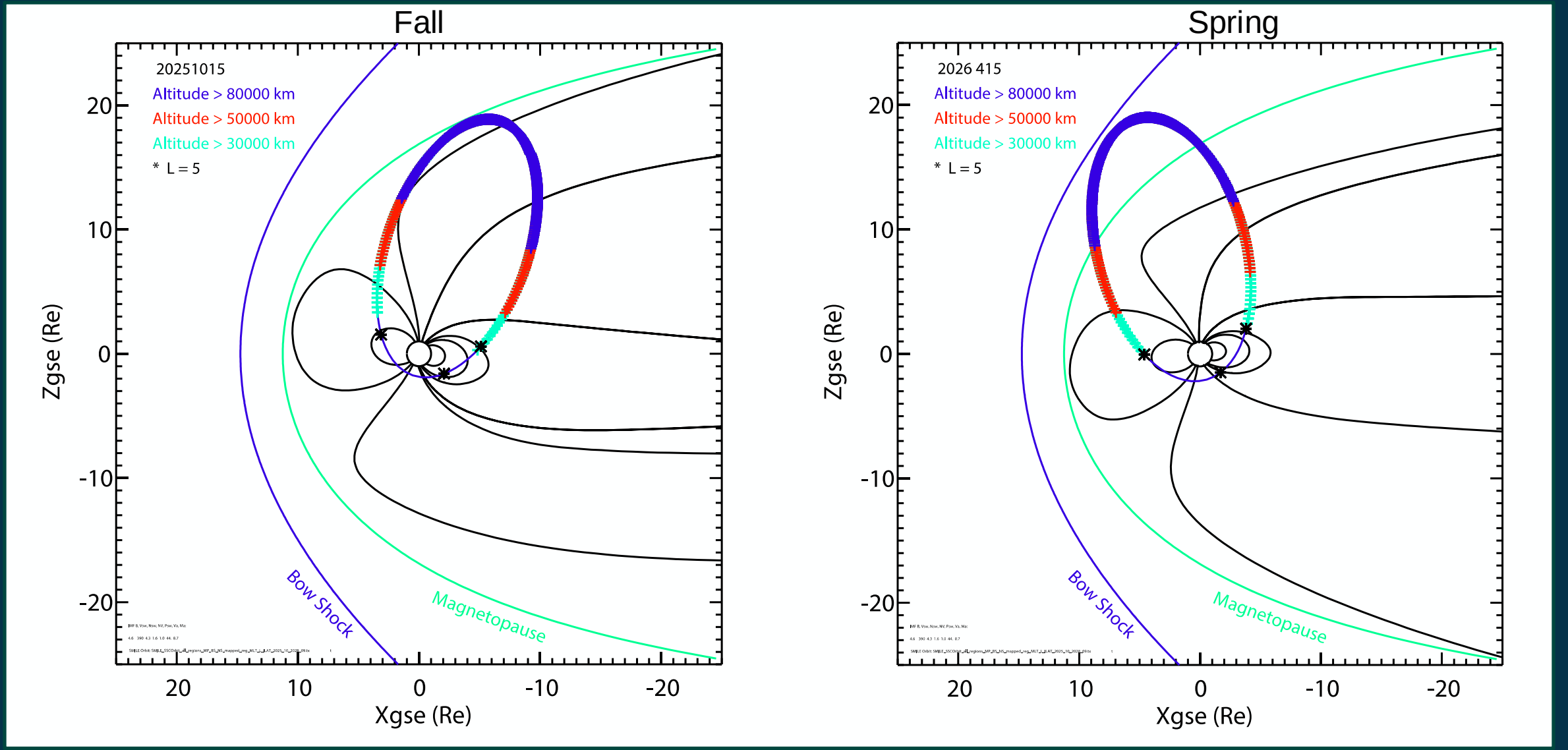
1. Baseline: 5000 x 120000 km HEO; orbit duration: ~50 h
    a. 41h and 45 h imaging with SXI and UVI
    b. In–situ MAG and LIA (except radiation belts) observing entire orbit
2. Science data volume dominated by imagers

	SXI	UVI	LIA	MAG
Data rate (kbps)	120	17.6 – 840	12 – 48	3
Data volume (GBytes per orbit)	2.5	1.15	0.654	0.07

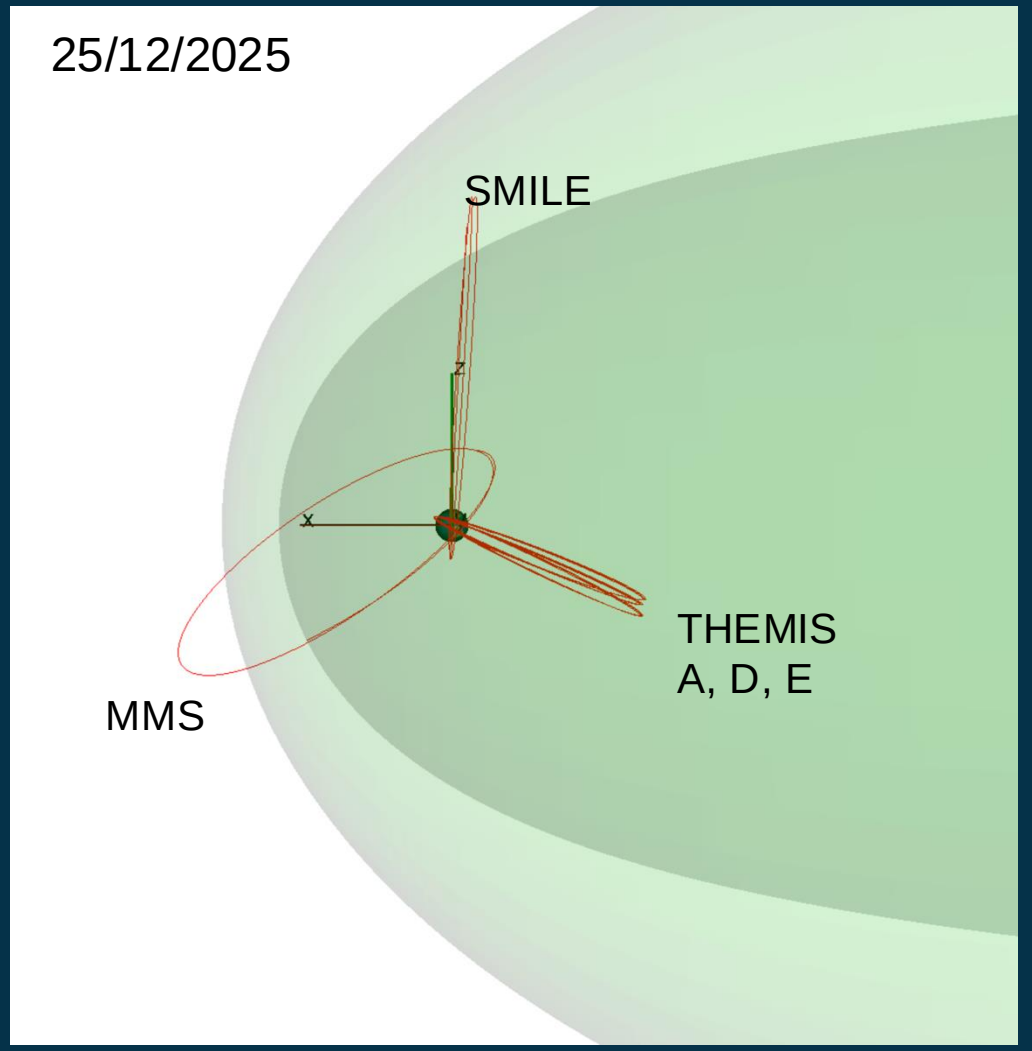
3. Estimated downlink time: ~10 min
    a. X-band, 36 Gbits of data/orbit
    b. Ground station network (X-Band): O'Higgins 10m (Antartica) Sanya 12m (China) as baseline, Kourou 15m as back-up
    c. S-band used for commanding and health checks (China)

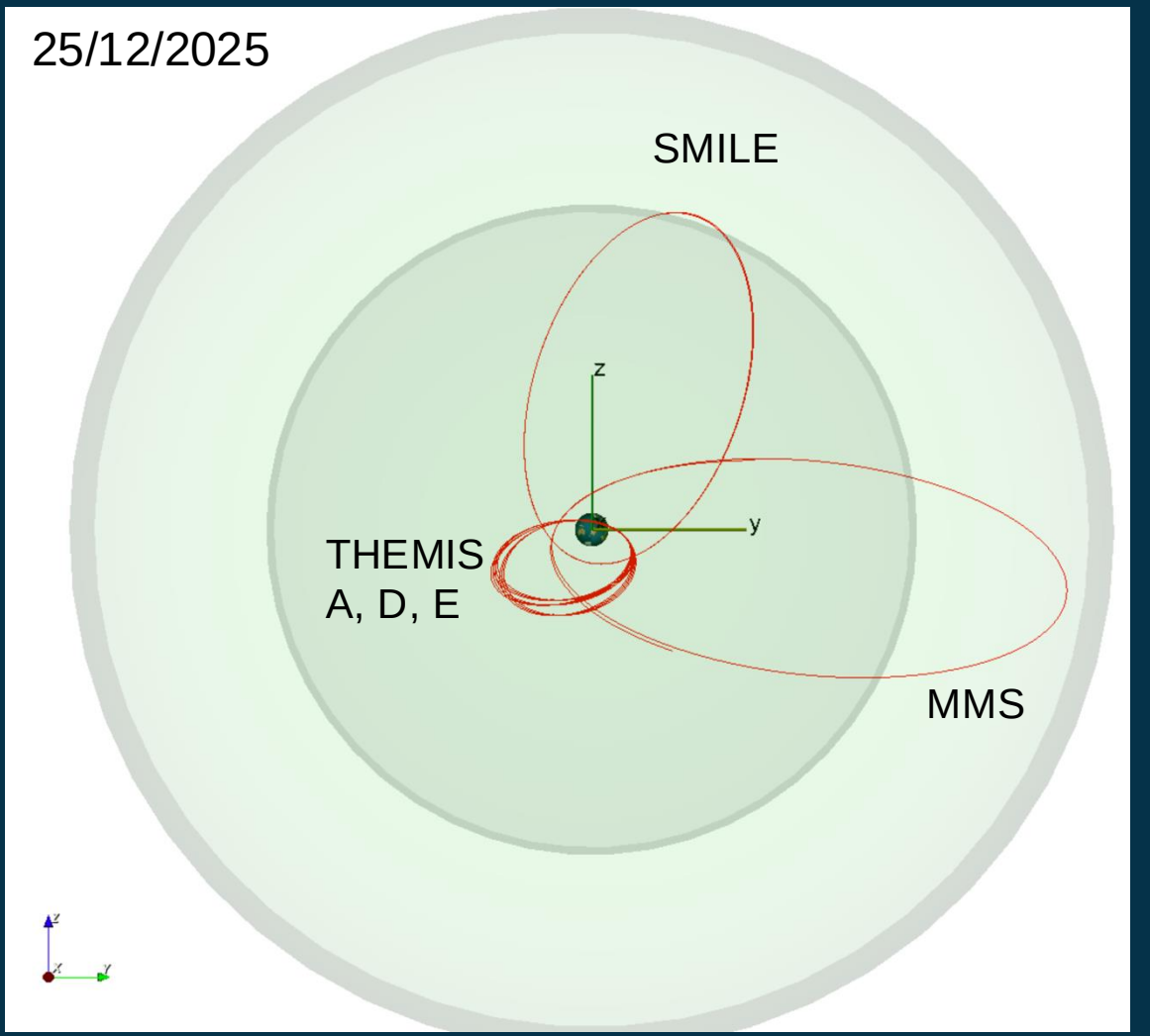


Science orbit around the Earth

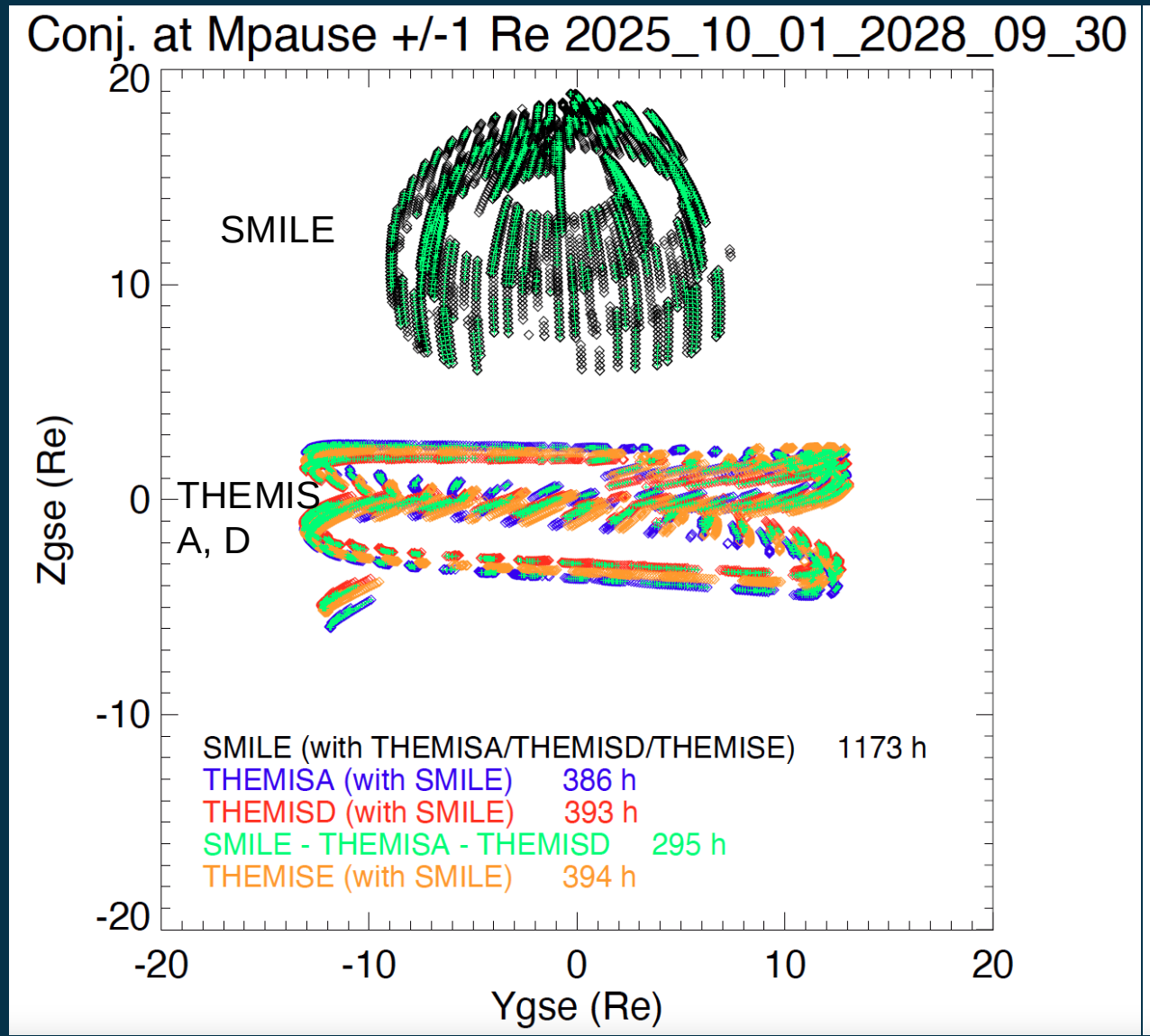


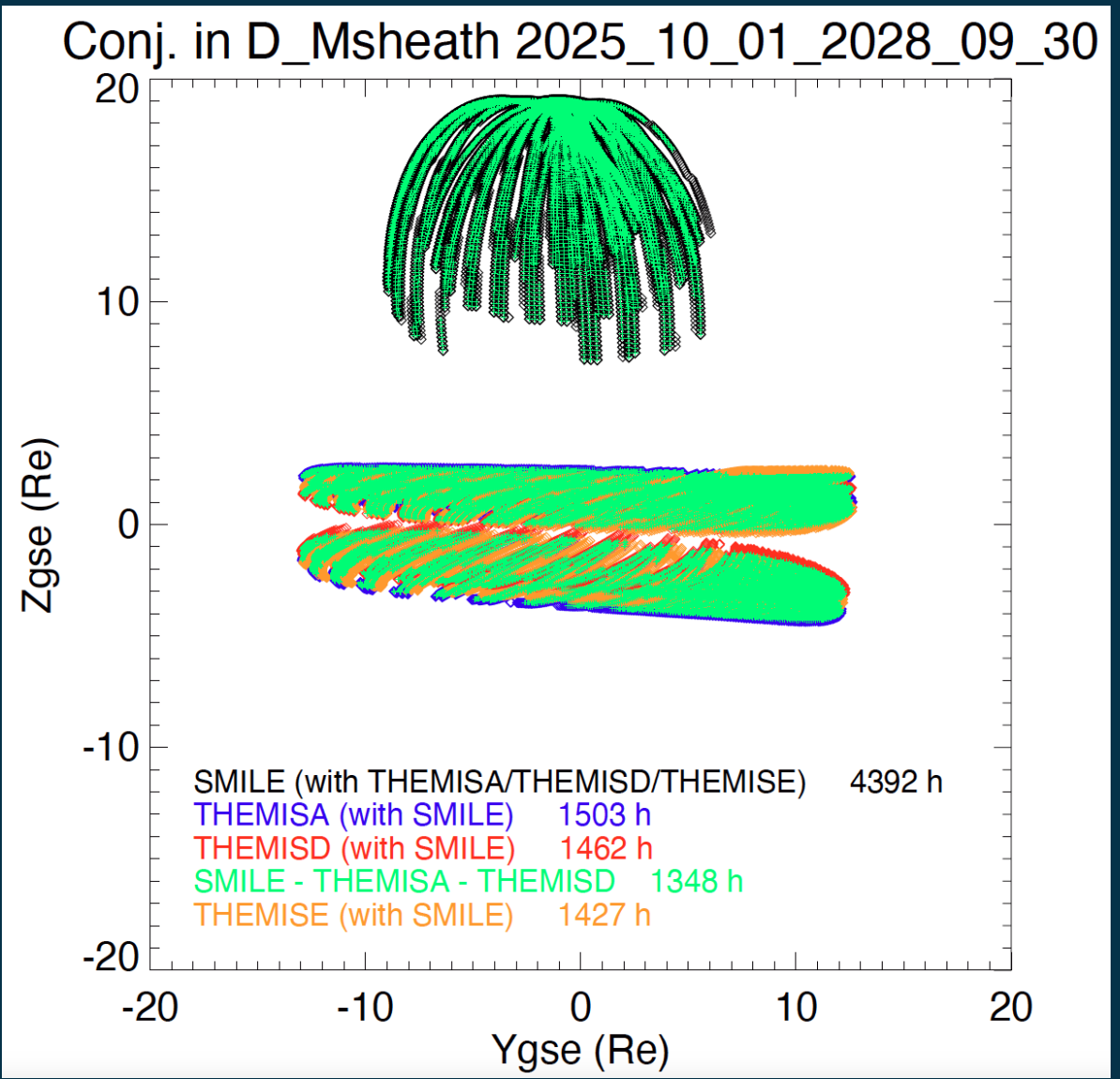
Complementarity of SMILE, MMS and THEMIS



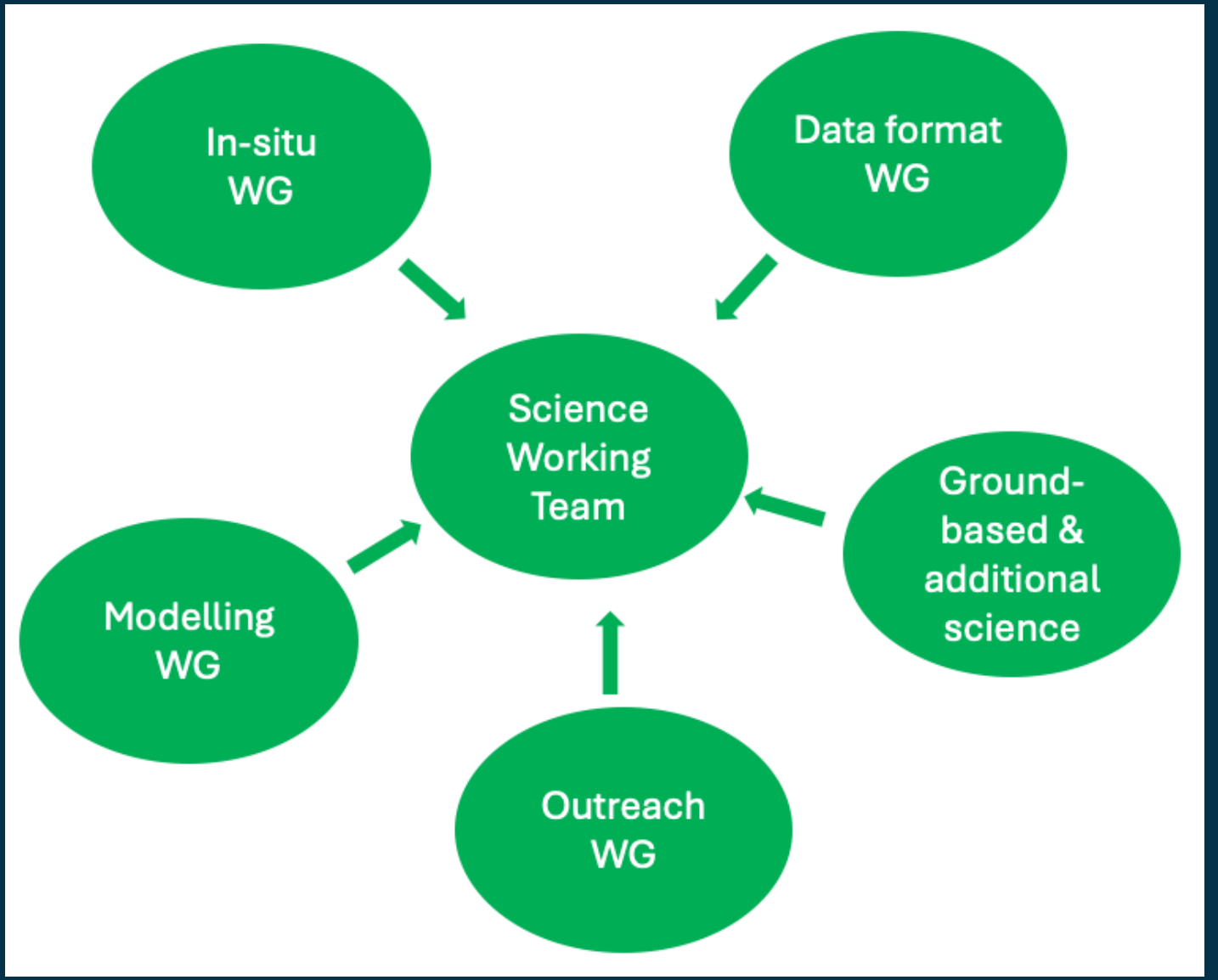


Conjunctions SMILE-THEMIS (2025-2028)





SMILE working groups



Summary and conclusions

- SMILE will observe the cusp, magnetopause and magnetosheath for the first time in soft X-rays
- SMILE will fill in the gap of auroral imaging since IMAGE and Polar spacecraft stopped operating 15 years ago
- It will measure the solar wind and magnetosheath plasma simultaneously to imaging.
- It will be highly complementary to all other magnetospheric missions (Arase, Geo-X, MMS , Swarm and THEMIS)
- Cooperation between ESA and CAS with equal share, building on Double Star experience
- SMILE mission will be launched in 2025