



Planetary Exploration

2061

# Planetary Space Weather For Planetary Systems

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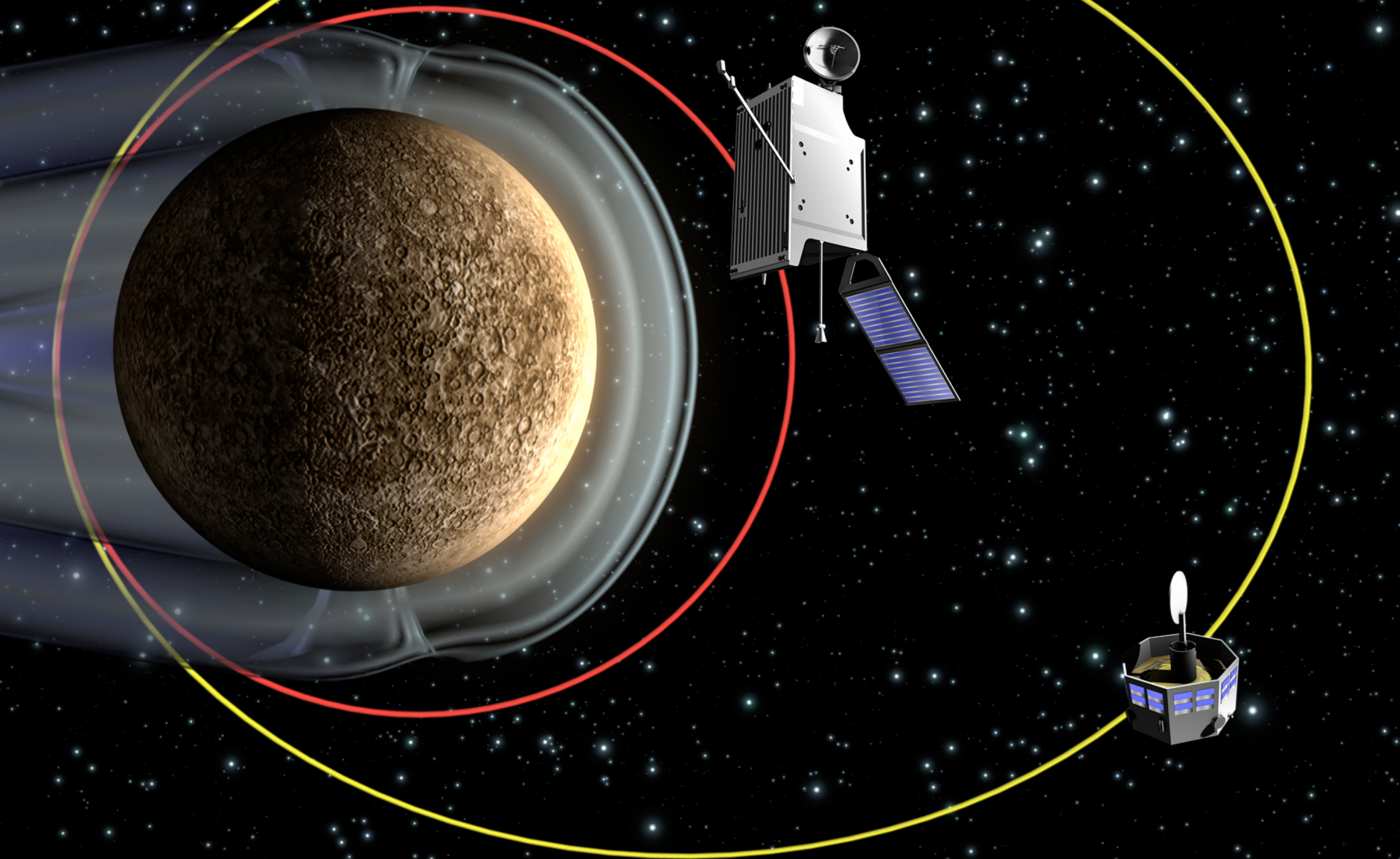
# Planetary Space Weather

In a 2008 definition agreed among 24 countries (Lilensten & Belehaki 2009), it was stated that “Space Weather is the physical and phenomenological state of natural space environments; the associated discipline aims, through observation, monitoring, analysis and modelling, at understanding and predicting the state of the Sun, the interplanetary and planetary environments, and the solar and non-solar driven perturbations that affect them; and also at forecasting and now-casting the possible impacts on biological and technological systems”.

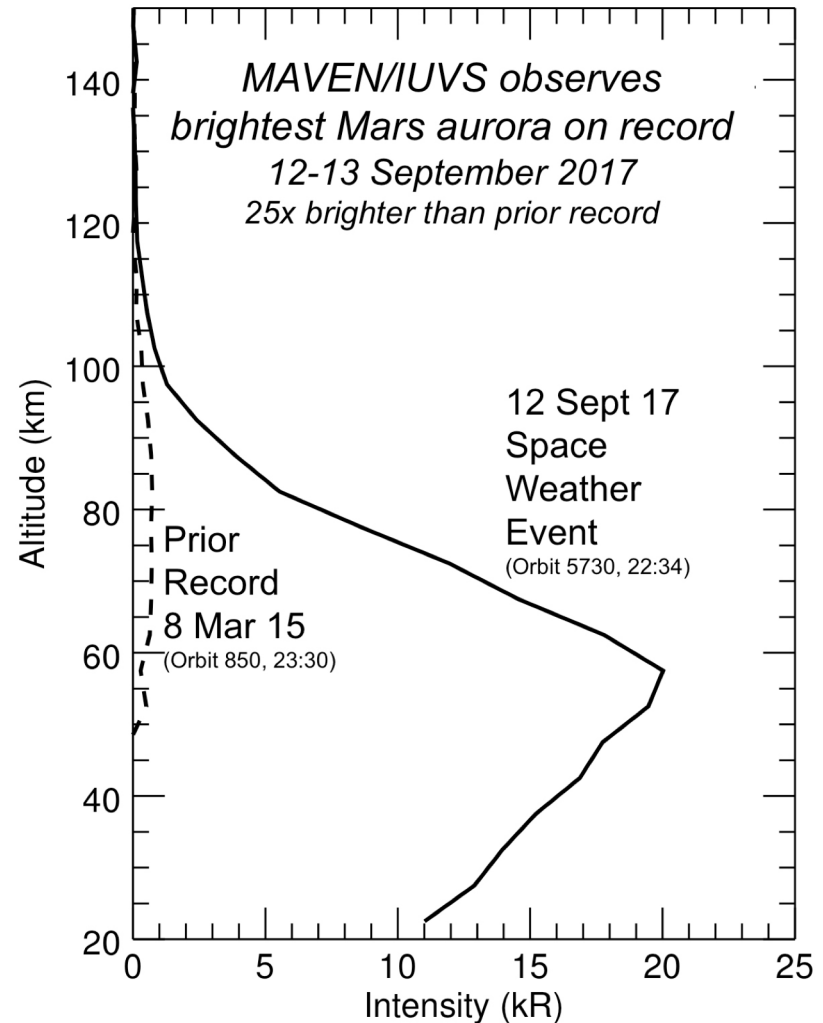
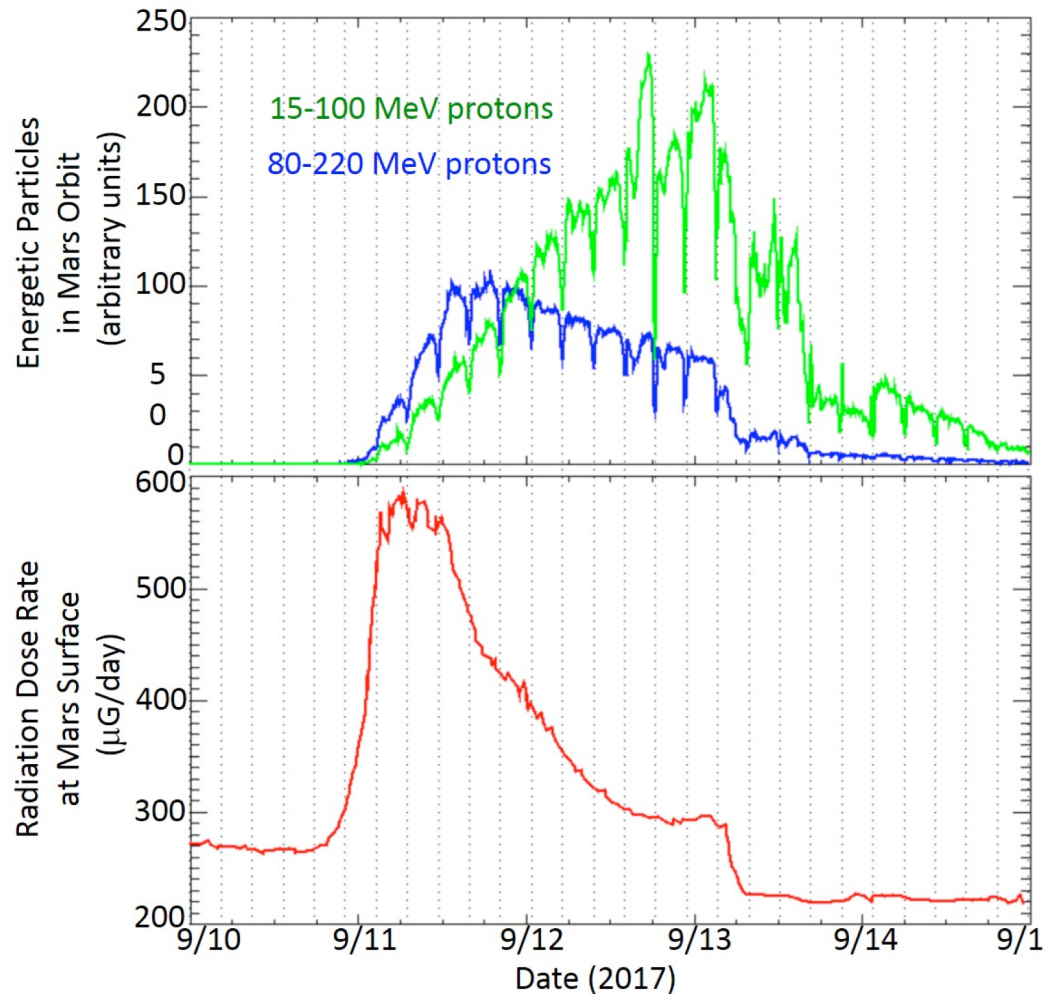
# Earth vs. (?) Planets

- Earth System
  - Surface, Atmosphere, Thermosphere, Ionosphere, Magnetosphere, Solar Wind
  - Implications for human activities: critical
- Planetary Systems
  - Need for multi-point measurements (rare)
    - E.g., MAVEN/TGO/Curiosity
    - Cassini/Galileo flyby of Jupiter
    - BepiColombo MPO + MOI
    - Cassini-Huygens + HST
  - Implications for human exploration: strong (a driver)
    - Mars, Moon

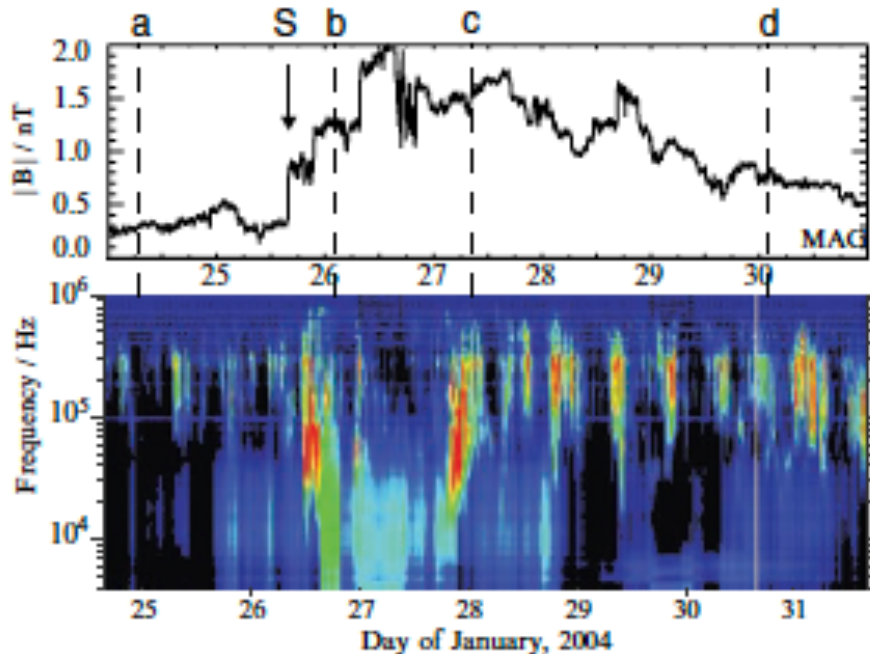
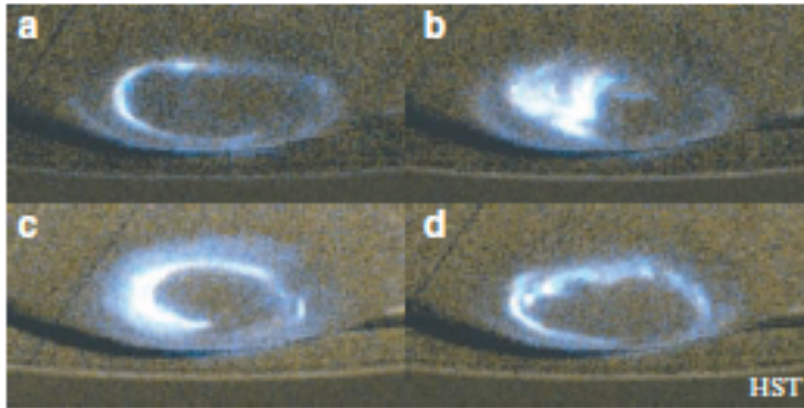
# BepiColombo MPO + Mio



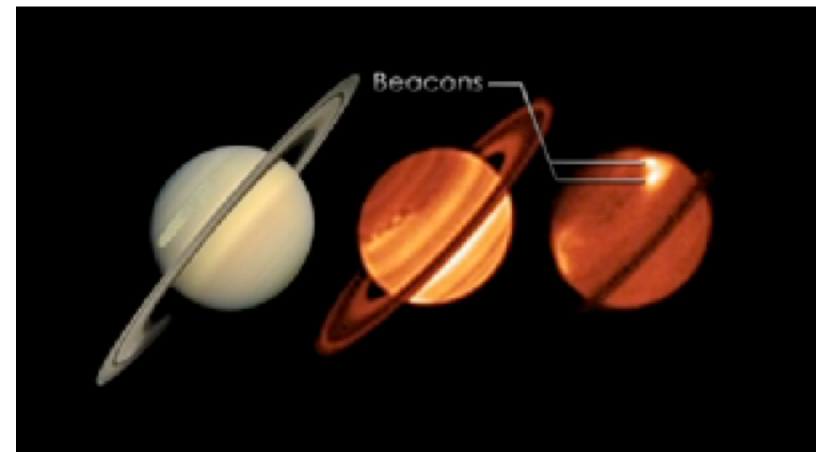
# September 2017: a strong solar storm impacts Mars



# Cassini-Huygens / HST campaigns

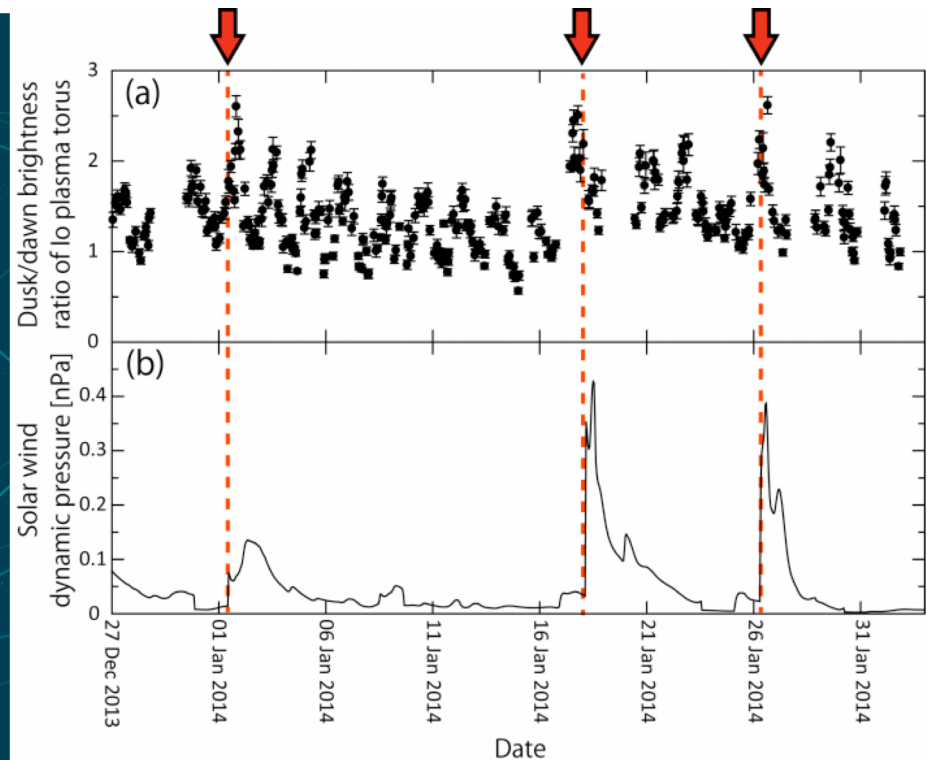
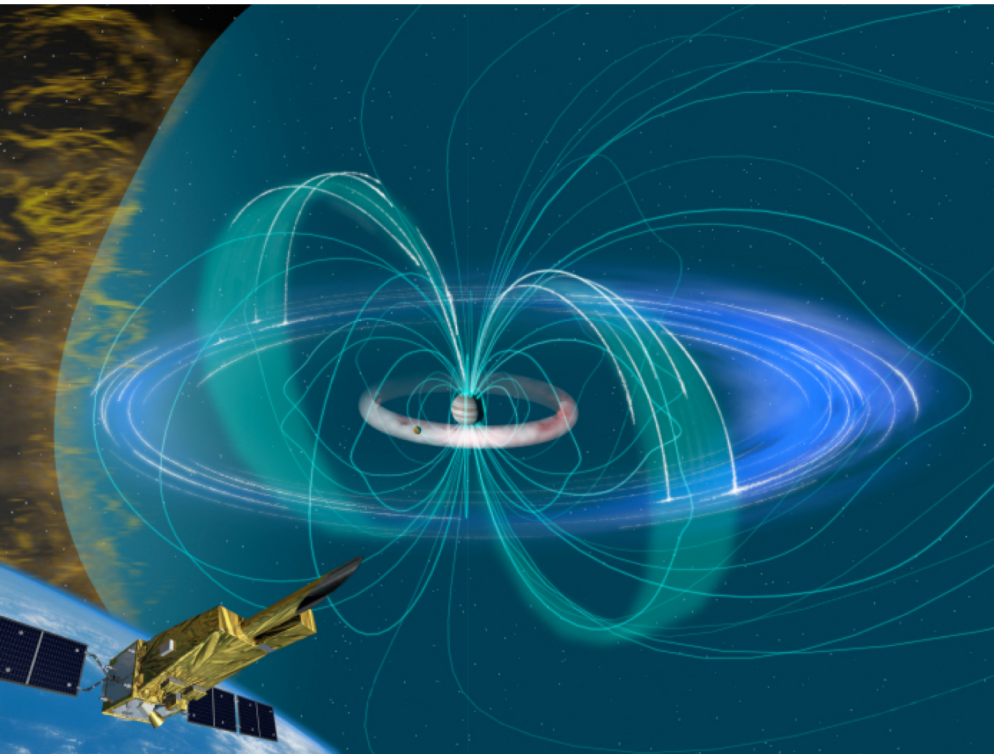


- Synergy worked very well
- JWST, LUVOIR will help
- Gd-based observatories



# Jupiter/ Hisaki / HST / Juno

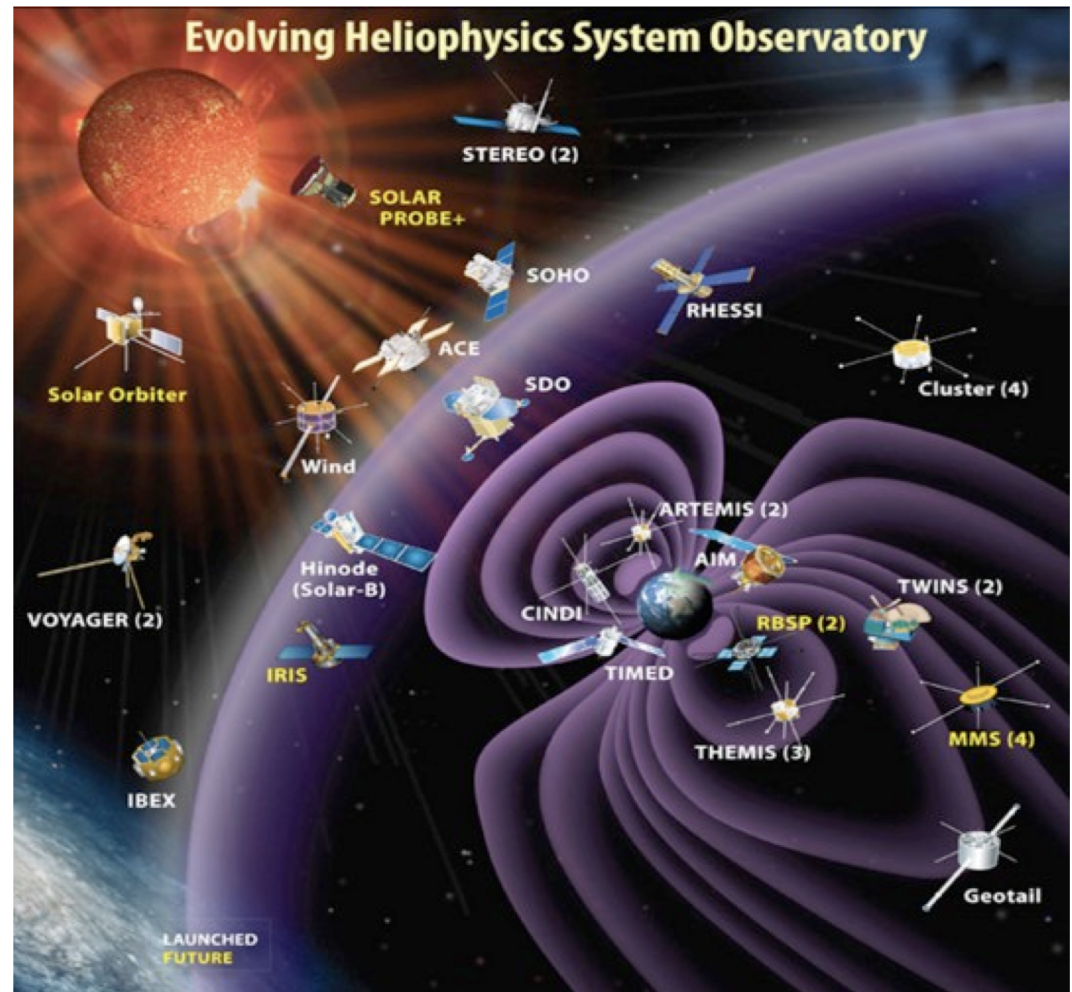
- Hisaki / HST: remote + Juno: remote & in situ
- Lack of solar wind monitor at Jupiter -> rely on virtual solar wind monitor (simulations)



# Current Earth Space Weather Missions

New window opened  
In the coming years:

- Parker probe
  - Close view
- Solar Orbiter
  - Out of ecliptic view



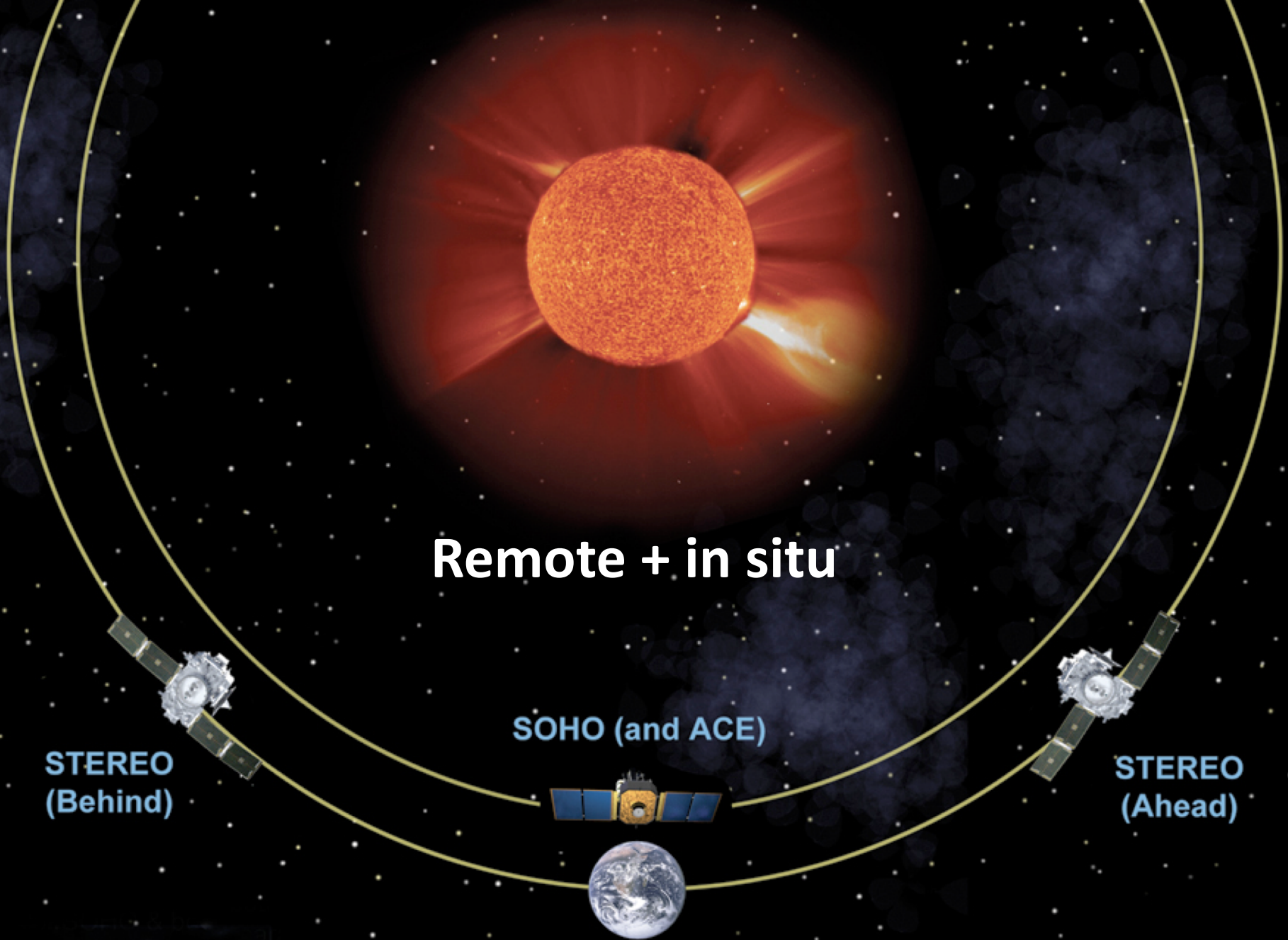


# Remote + in situ

STEREO  
(Behind)

SOHO (and ACE)

STEREO  
(Ahead)

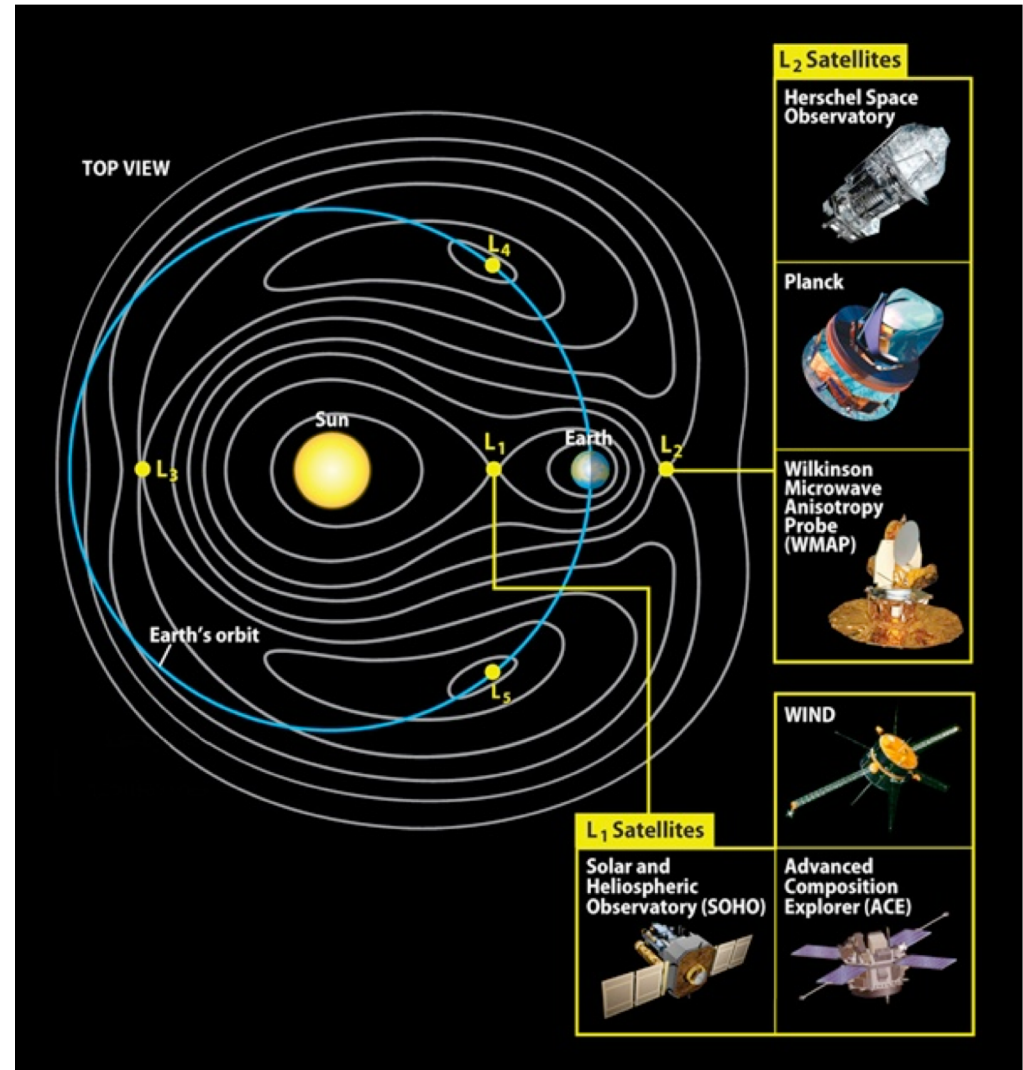


# Sun-Earth Lagrangian Points

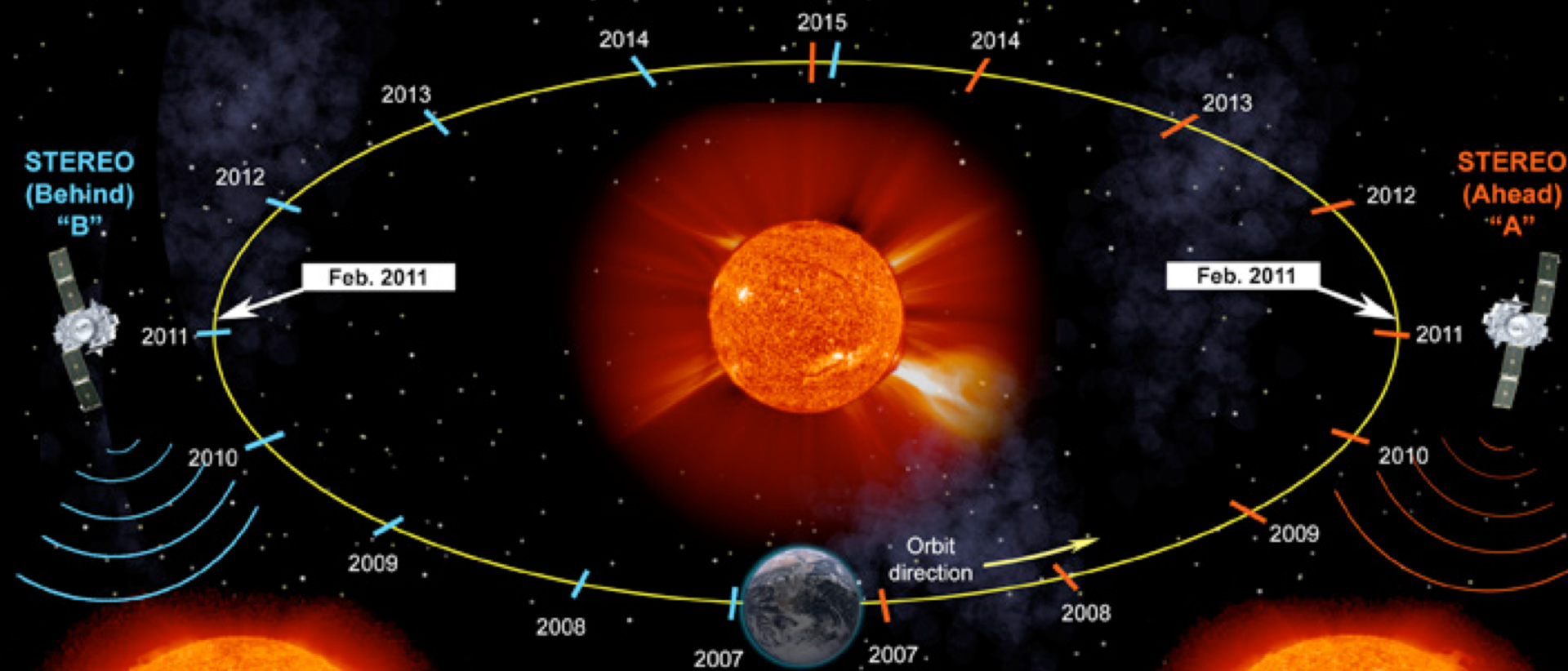
- L1 SW monitor
  - In-situ
- L5 (L4)
  - Remote

Future missions (NASA) will focus on specific regions of the Earth System

Upstream monitors need to be replaced !



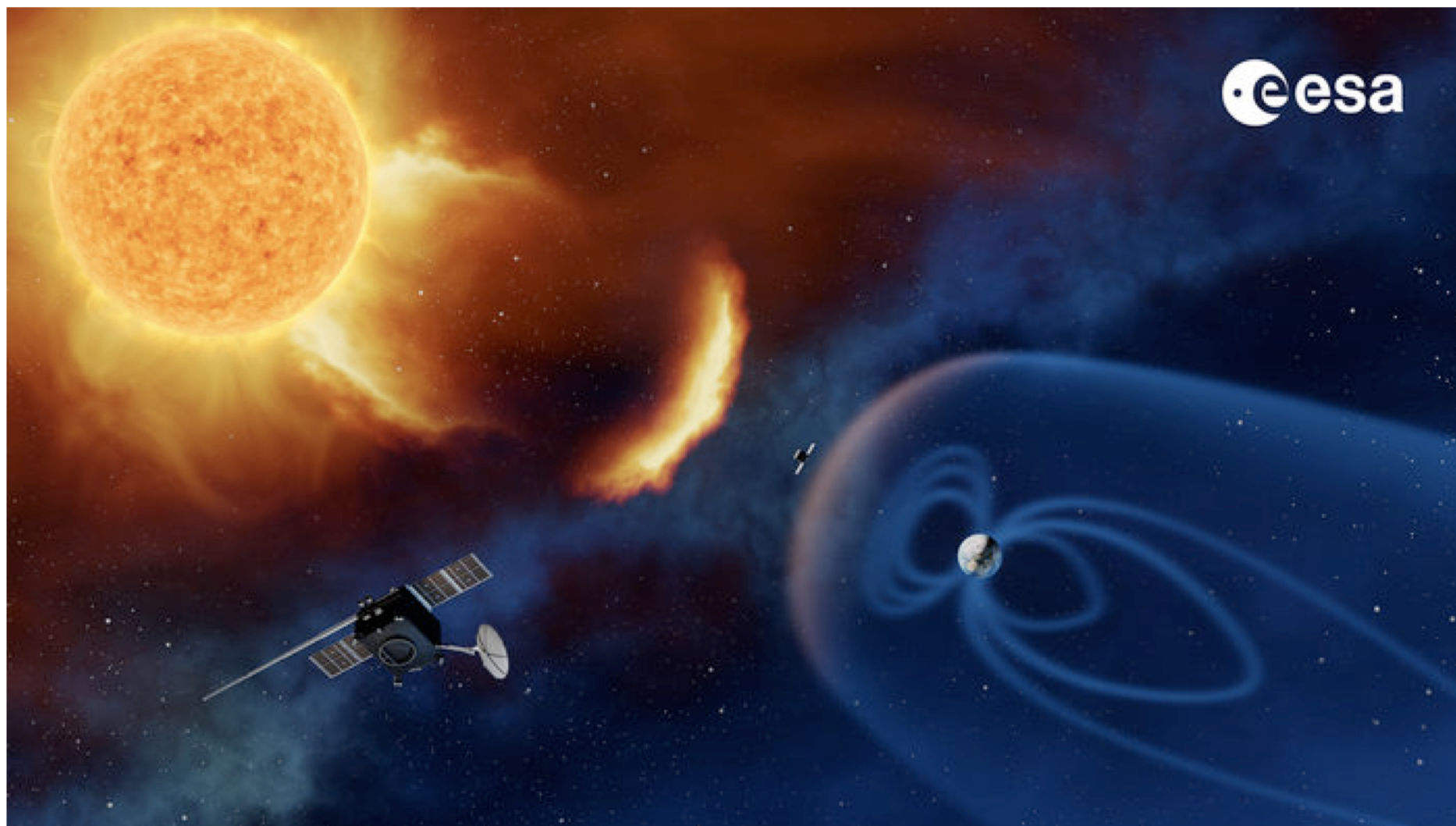
# NASA's STEREO Sees the Entire Sun

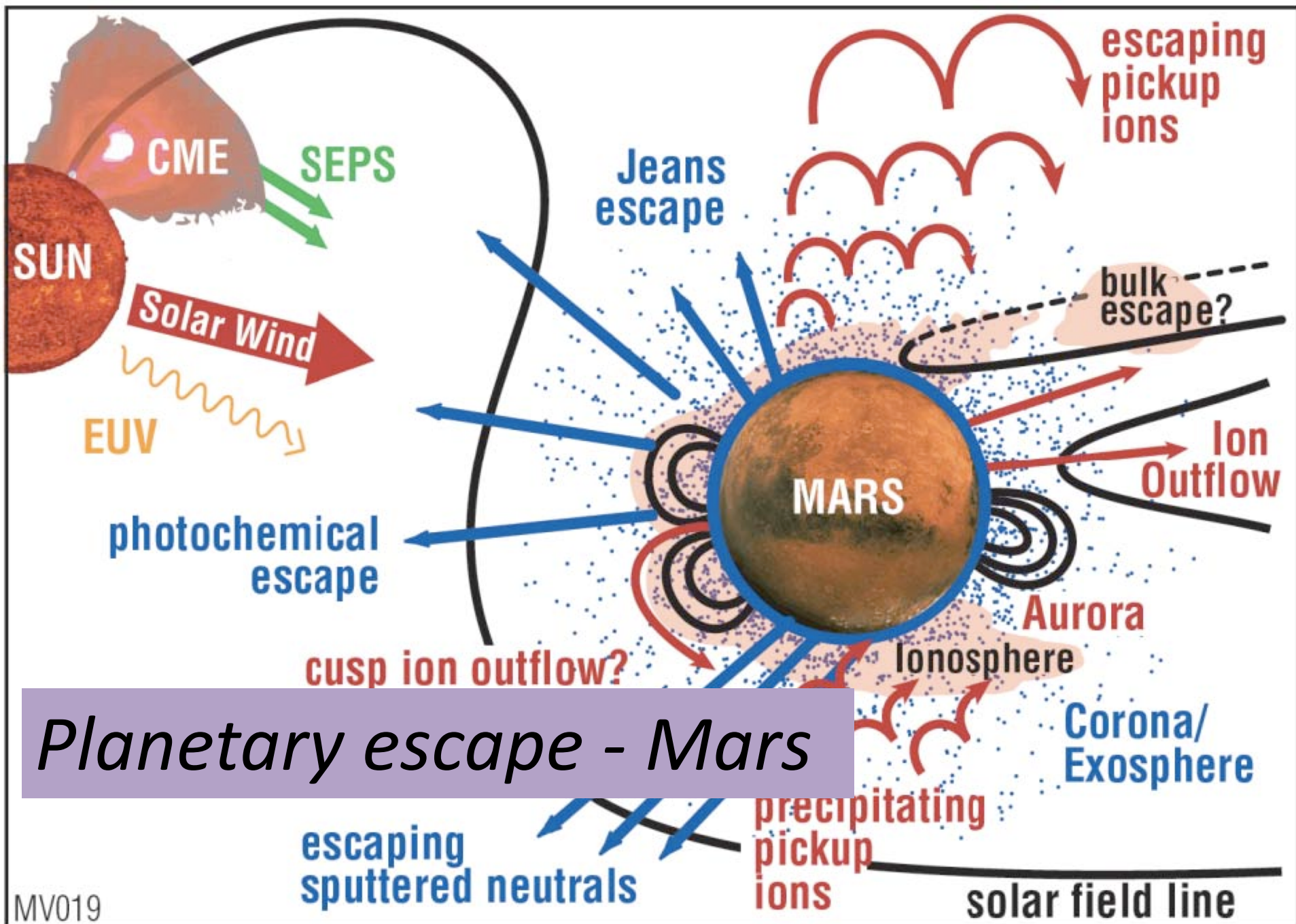


The two **STEREO** spacecraft reach 180 degrees separation and observe the *entire* Sun for the first time ever.

Drawing gives the relative orbital positions of both STEREO spacecraft for each year from June 2007 to June 2015.  
(Not to scale)

# Sun-Earth L5 mission





# Planetary escape - Mars

# Planetary Space Weather Services

- Europlanet H2020 & H2024 activities
  - Space Situation Awareness
    - Prediction of meteor showers at planets
    - Transplanet (Mars, Earth, Venus, Jupiter) Runs on request (cf. CCMC in the USA)
    - Prediction of Solar wind properties at planets
    - Propagation tool
    - Detection of giant planet fireballs
    - Detection of lunar flashes
    - Solar Wind properties from cometary images
    - Cometary tail crossings
    - Mars radiation environment runs on request
    - Giant planet magnetodisc runs on request
    - Alerts

# Perspectives

- Multipoint measurements is the key
  - At planets
  - In the heliosphere
    - but hard to achieve (science focused planetary missions)
    - Cubesats may help (but propulsion ...)
- Support from ground-based and space-based observatories (UV, IR, X-rays, radio, ...) essential
- Mercury and Venus as upstream monitors for Earth

# Instrumentation

- Ideally:
  - Magnetometer
  - Solar wind plasma analyzer
  - Energetic Particles
  - Radiation monitor
  
  - Radio instrument
  - UV Imager
  - ENA imager
  - ...

Good to have a minimum payload dedicated to space weather (radiation monitor)

Compact package ?