Solar, Interplanetary and Magnetospheric Physics

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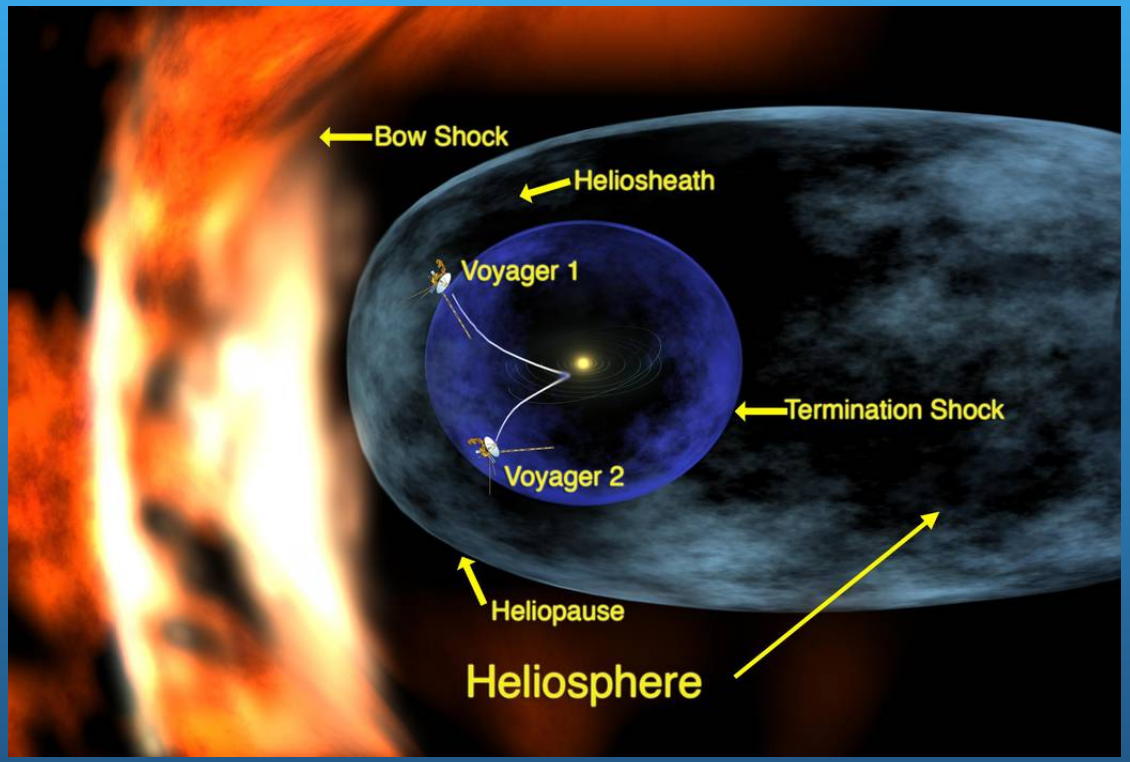
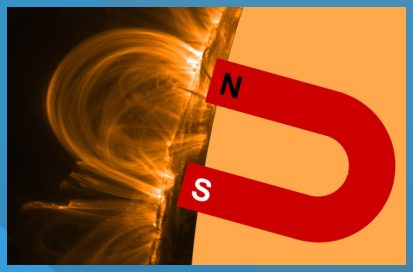
Key question:

How does the Sun and its magnetic field give origin to the heliosphere and control its evolution?

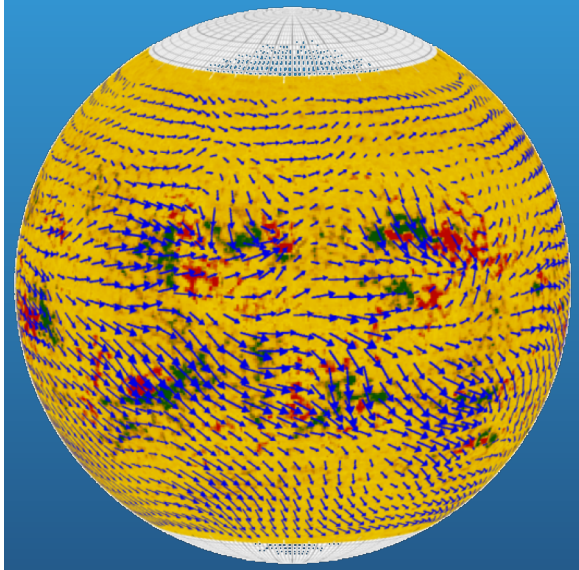


The Earth and the whole Solar System are immersed in the atmosphere of a star:
Sun–Heliosphere connection
Interactions Heliosphere–Planets

Generation of magnetic fields and their role in the solar atmosphere: the backbone

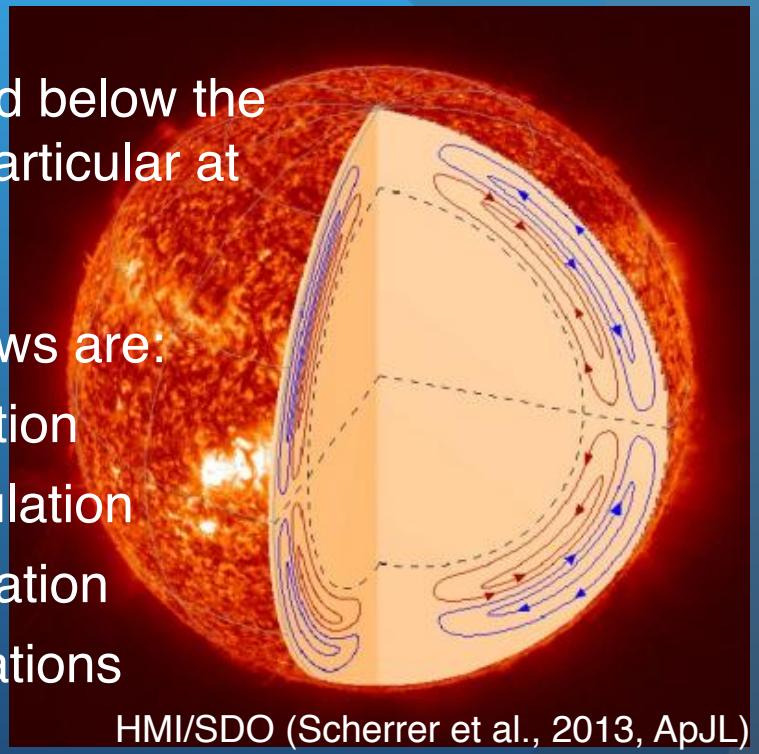


How is magnetic flux transported to and reprocessed at high solar latitude?



- Detect flows at and below the solar surface, in particular at high latitudes
- Most important flows are:
  - Differential rotation
  - Meridional circulation

    Two-level circulation
  - Torsional oscillations



HMI/SDO (Scherrer et al., 2013, ApJL)

Structure and dynamics of the polar convection zone not yet probed via helio-seismology – requires going out of the ecliptic to observe polar flows and fields

Heating of the outer solar atmosphere: still one of the major enigmas of solar and (stellar) physics

Proposed scenarios based on turbulent dissipation of twisted magnetic fields rooted in the lower atmosphere, continuously stressed or braided by photospheric motions.

Support of MHD modeling with high performance computing is a crucial ingredient.

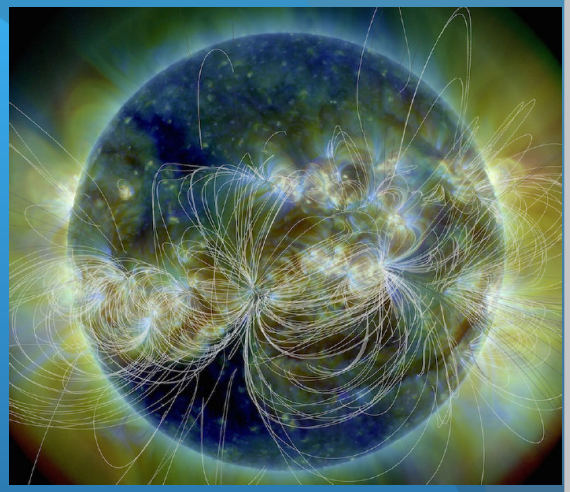
Most energetic and explosive events: flares and CMEs.

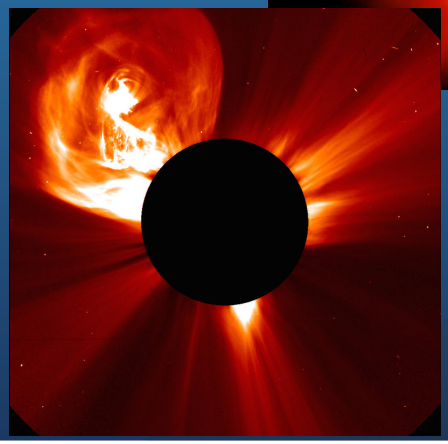
Ejection of high-speed particles.

Magnetic reconnection…

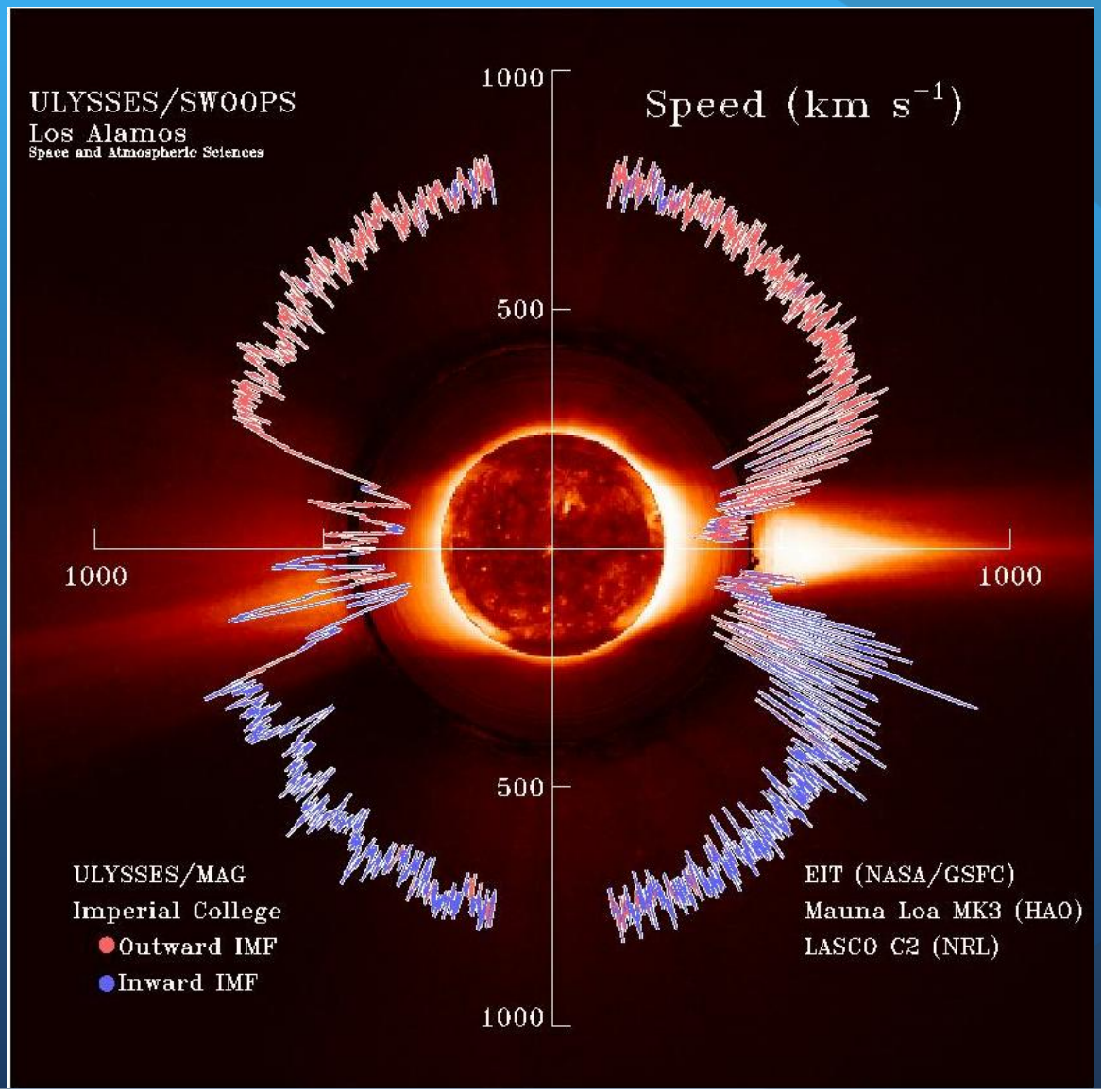
Direct measurements of the intensity of coronal magnetic fields…

Importance for basic plasma physics.





The heliosphere is originated by the expanding hot coronal plasma



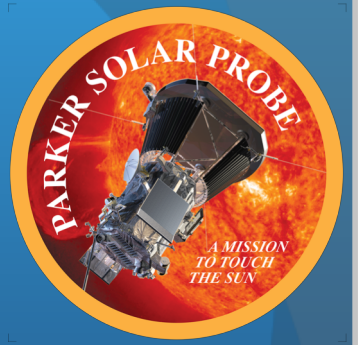
To understand the solar winds, their acceleration and their relationship to the originating solar regions and magnetic structure (other astrophysical plasma flows)

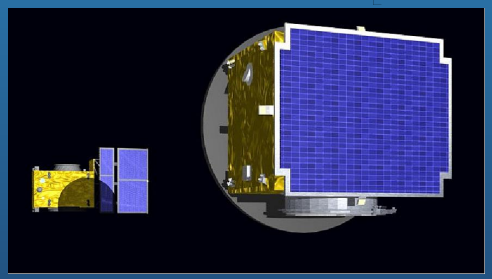
- explore the interface region where the solar wind originates and heliospheric structures are formed
- sufficient observational capabilities to link solar wind structures back to their source regions at the Sun
- perform in-situ measurements close enough to the Sun, with simultaneous high-resolution imaging and spectroscopic observations and inner corona, in and out of the ecliptic plane, for a longer temporal interval
- investigation of the plasma flow in turbulent state
- affecting the interplanetary medium, the planetary bodies and their environments

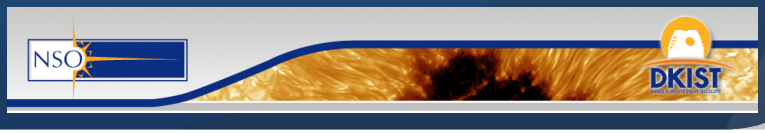
- Great opportunities in the near future, in addition to a series of instruments still operating and covering the temperature range from the photosphere to the “base” of the heliosphere: IBIS/DST, SST, GREGOR, Hinode, SDO, STEREO, IRIS

- **Parker Solar Probe**
- **Solar Orbiter**
- **Proba-3/ASPIICS**
- **EST**
- **DKIST**

solar orbiter

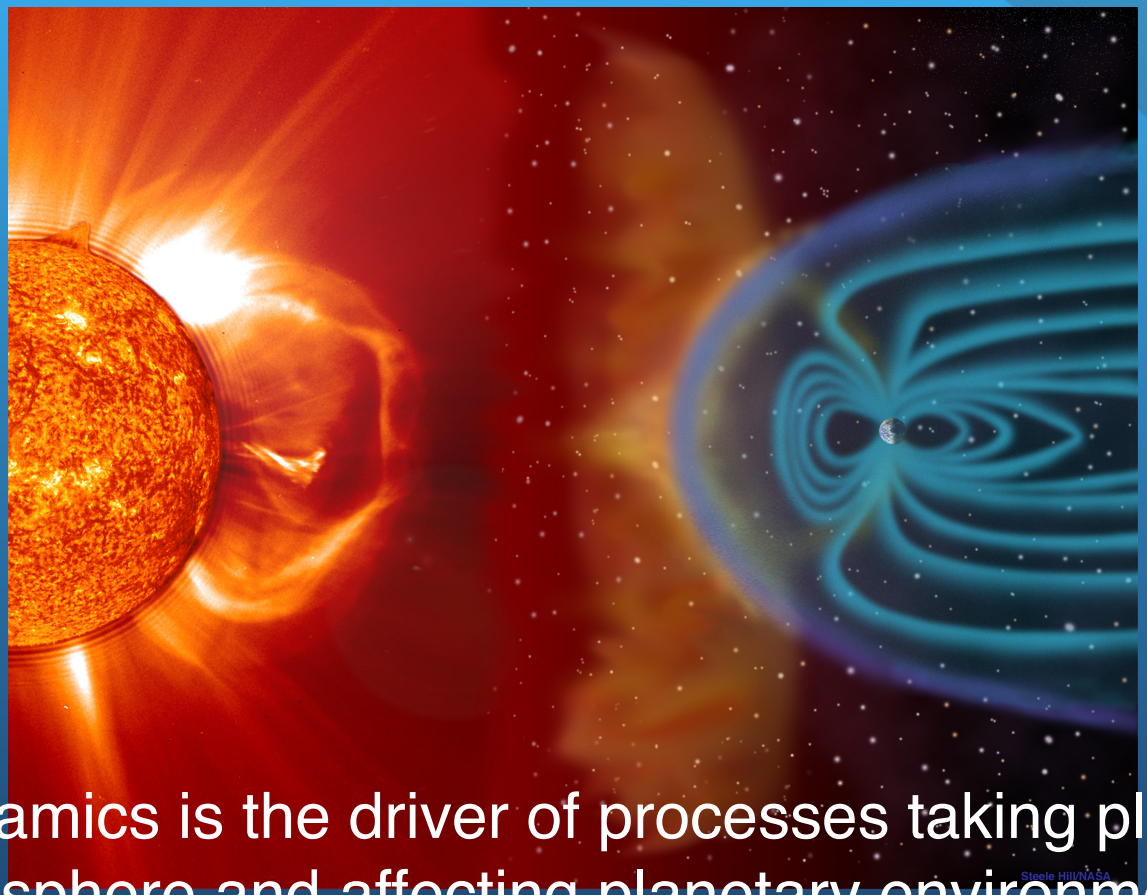






Key question:

Which is the influence of the Sun and the radiation environments on the human activities and on life ?



Solar dynamics is the driver of processes taking place in the heliosphere and affecting planetary environments.

Space Weather

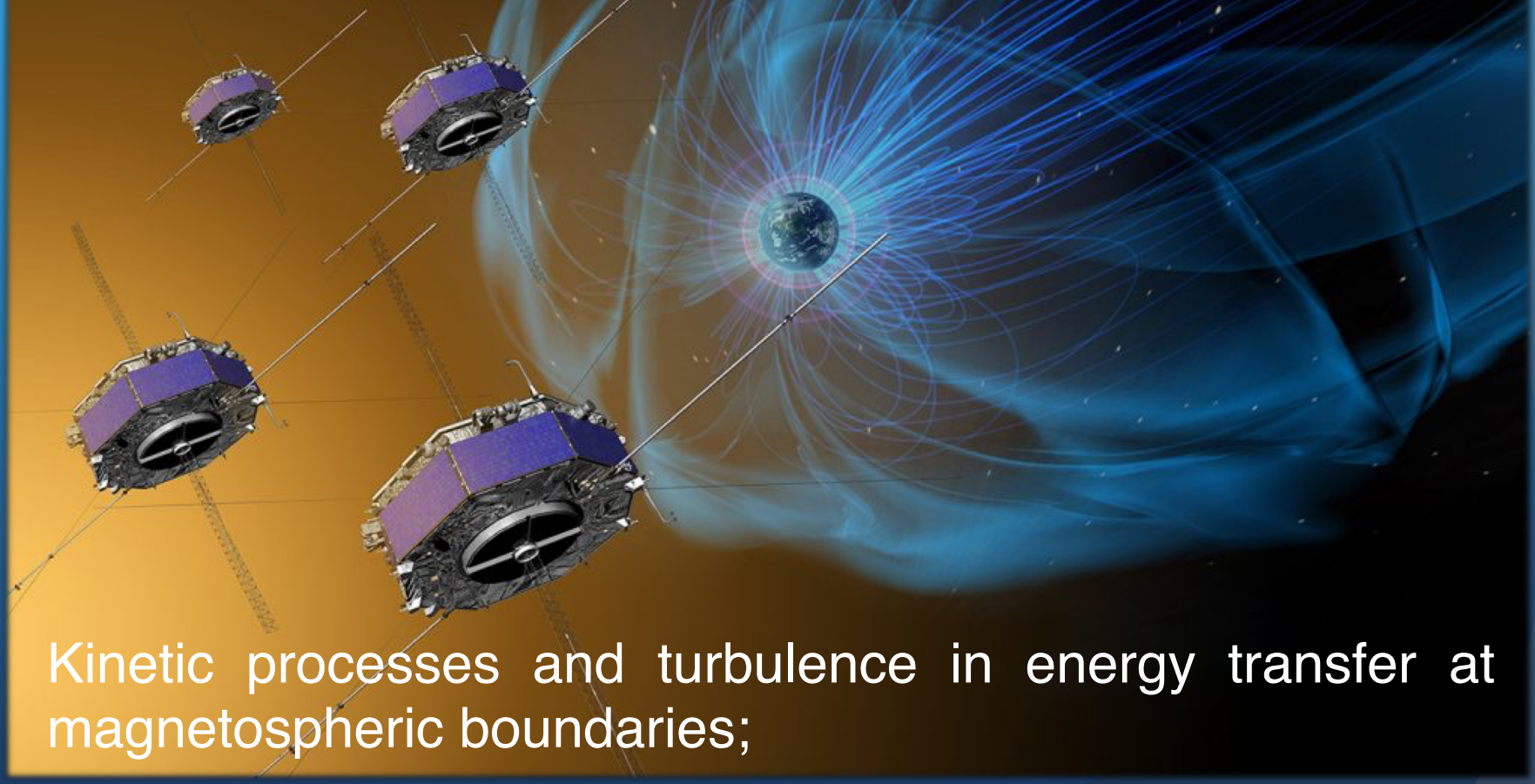
Space Weather:

a branch of space physics related to the time varying conditions within the Solar System, including the solar wind, emphasizing the circumterrestrial and planetary environments.

- Monitoring, analyzing and modelling solar wind-near planetary space interactions;
- Predicting the state of the Sun, the interplanetary and planetary (Earth's) physical conditions;
- Forecast/now-cast of the impact on biological, technological and anthropic systems

Key physical processes:

Magnetic reconnection and flux transfer events: energy, mass and momentum transfer from the solar wind to terrestrial and planetary magnetospheres;



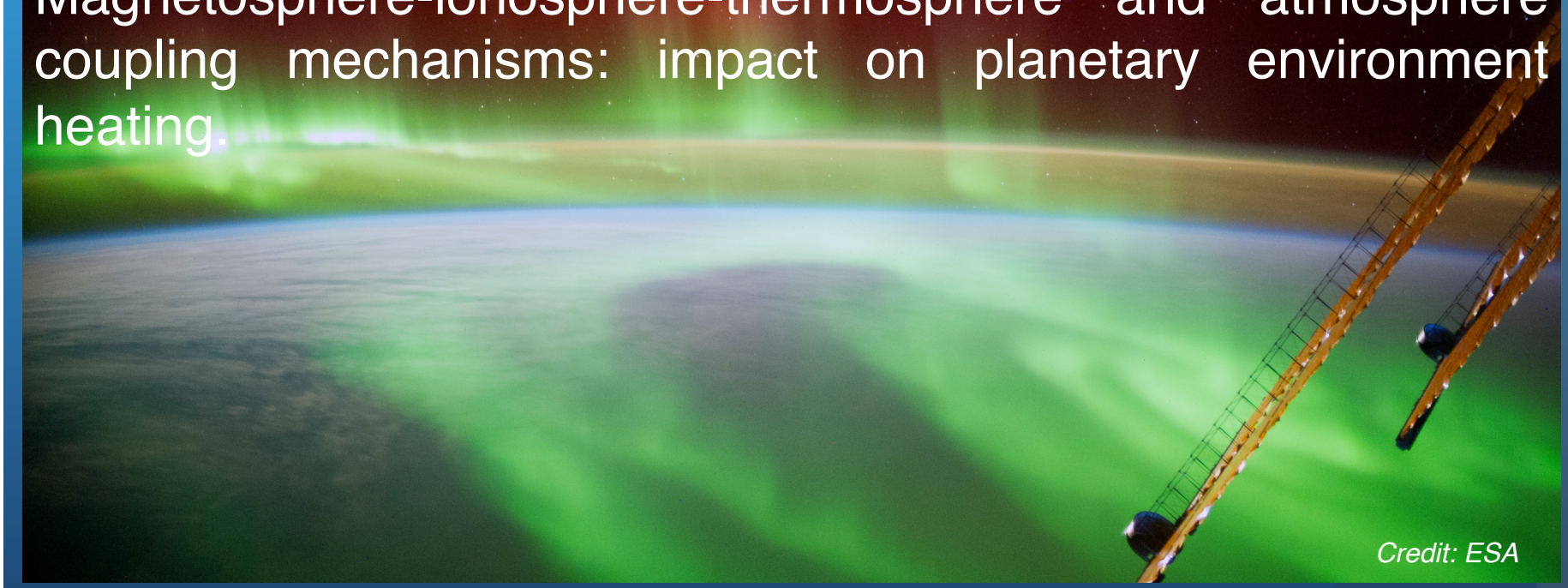
Kinetic processes and turbulence in energy transfer at magnetospheric boundaries;

Credit: NASA/GSFC

Key physical processes:

Magnetosphere dynamics: understanding the internal magnetospheric dynamics responsible for the occurrence of geomagnetic storms and substorms;

Magnetosphere-ionosphere-thermosphere and atmosphere coupling mechanisms: impact on planetary environment heating.



Credit: ESA

Key physical processes:

Role and impact on planetary and terrestrial environments of solar energetic particles (SEP) and galactic cosmic rays.

Effects of extreme conditions of solar wind, UV fluxes and surface temperature on exosphere state and dynamics, occurrence of surface currents and induction effects (Mercury)

Planetary Space Weather: understanding impact of solar activity on external planet (Jupiter, Saturn, Uranus, Neptunus) magnetospheres and interaction processes with icy moons and minor bodies.

Credit: NASA and the Hubble Heritage Team

Methods and Strategies:

- *In-situ measurements of fields and particles;*
- *Remote sensing and ground based observations;*
- *Theoretical modeling and numerical simulations;*
- *Laboratory experiments on ionospheric planetary conditions and plasma interactions.*

In addition to a series of active space mission (e.g., ESA-Cluster, JUNO, MEX, Swarm…) and ground based instruments (e.g., SuperDARN, ITACA^2, SVIRCO, THEMIS…) new opportunities will be provided by the new space missions and initiatives:

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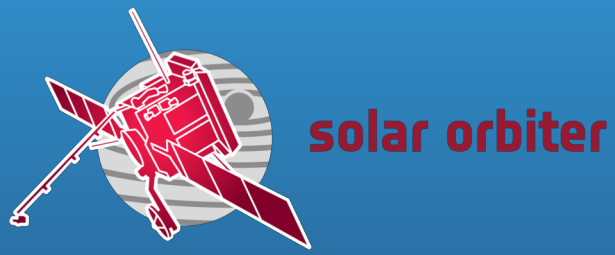
- *Solar Orbiter*



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- *EST*

solar orbiter

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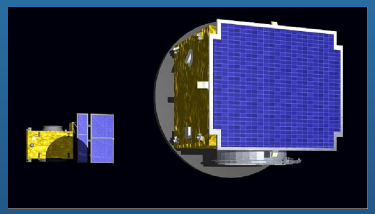

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- *ESA-BepiColombo*
- *JUICE*
- *Solar Orbiter*
- *EST*
- *Proba-3*
- *SWEATERS*
- *CSES 02*
- *INAF-NSWSN (National Space Weather Service Network)*
- *LOFAR*

solar orbiter