Workshop ASI

Tematiche e obiettivi per futuri programmi scientifici spaziali

ASI HQ, 20-22 April 2022

Heliophysics and Space Weather *session*

Chairs: Christina Plainaki, Marco Castronuovo

Agenzia Spaziale Italiana

Photo credit: ESA/NASA SOHO

Workshop ASI - Topics and science goals for future space science programs 20-22 April 2022

Heliophysics and Space Weather *session* – Preliminary Concluding Remarks

National context

At national level, **Space Weather** is considered among the **key topics** for research in the years to come. This is manifested through a series of initiatives and programmatic efforts, such as :

- The proposal of ASI for a Space Weather science roadmap elaborated by the *ASI Space Weather Working Group* (2020)
- Development of the **ASPIS scientific data center prototype** (ASI-INAF collaboration (starting in 2021); see also the CAESAR Project)
- ASI Piano Triennale di Attività (PTA) 2021-2023; ASI Documento di Visione Strategica per lo Spazio 2020-2029
- INAF Piano Triennale di Attività (PTA) 2021-2023
- "Piano Nazionale di Ripresa e Resilienza"(PNRR) guidelines (2021)
- …and others

International context

The concept of both **Space Weather science** and **services** is present in numerous **international initiatives** and **roadmaps**. All of the proposed ideas are either directly or indirectly coherent with such contexts, indicatively

- ESA Space Situation Awareness
- ESA Accelerators (*Accelerator 3:* Protection of Space Assets)
- 2021-2022 Horizon Work Programme of the European Commission
- ESA Voyage 2050 Science Themes for ESA Led Medium Missions (2021)
- ESA M and F missions Call (2021)
- ESA campaign for ideas for nanosatellite missions for monitoring Space Weather to propose at ESA's next Ministerial Council (2021)
- ESA Open Space Innovation Platform (OSIP) Campaign: Nanosats for Space Weather Monitoring (2021)
- …and others

Brief (and not exhaustive) summary of national expertise

- Solid experience in **theoretical plasma physics**, **numerical simulations** and **analysis of plasma and energetic particle data** from past missions
- Strong expertise in **theoretical** and **data-driven modeling** in **solar physics**, **magnetospheric physics**, **circumterrestrial** and **planetary space weather science**;
- Involvement in numerous past, current and upcoming **space missions** with science objectives related to Heliophysics and Space Weather science (e.g., ESA/SolarOrbiter; ESA-JAXA/BepiColombo; ESA/Proba-3; CNSA/CSES; JAXA/Solar-C; NASA-ESA/SOHO, etc.)
- Long-standing expertise in the **design** and **development of solar coronagraphs**, in stray-light control studies, in the development of narrow bandpass filters and the shadow positioning sensors for formation flight; Solid experience in theory and the interpretation of spectropolarimetric data
- Long heritage in **astronomical X-ray polarimetry**: concept design of GPDs, their ground calibration and scientific exploitation of the data; development of new Compton scattering polarimeters. Solid expertise in designing and building X-ray mirrors for space missions.
- Solid experience in the **development of ENA instruments** and related data exploitation and modeling.
- Solid experience in the **design** and **development** of **particle detectors** based on the use of a magnetic spectrometer (heritage: Pamela, AMS-01, AMS-02)

Heliophysics and Space Weather *session* – Preliminary Concluding Remarks

Proposed scientific mission concepts

Nano(or small)-Satellite Constellations at different locations of the terrestrial magnetosphere for monitoring the circum-terrestrial environment

- **Space Weather science** and **plasma physics** based on a multi-point observations approach (particles and fields)
- Possibility for **Space Weather alerts** (data-transfer capacity in near real-time)

CubeSat Constellations in LEO for measuring the solar Gamma and X-ray fluxes, imaging the UV solar emission and monitoring (through ENA detection) the ring-current and shock-front population dynamics

- **Solar physics** and **Space Weather science**: study of the evolution of the solar UV emission over one solar cycle and during flares
- Space Weather science: study the dynamics of the terrestrial magnetosphere and its interplay with the solar activity

Nano-Satellite Constellation around the Moon to perform solar corona observations

- **Solar physics, (planetary) Space Weather science**: detection and **propagation prediction** of Earth-directed Coronal Mass Ejections; monitoring of the heliospheric particle radiation (electron, ions) and magnetic field environment of the Earth-Moon system

Take-home message

New synergetic measurements for innovative sciencein Heliopysics, Space Weather science and Planetary Sciences

Important exercise for training towards future development of Space Weather services

Proposed experiments and R&D ideas

Solar observations

- Development of a new family of photoelectric and Compton X-ray polarimeters to study the **magnetic reconnection** and **particle acceleration** on the Sun.
- Development of a new **internally-occulted coronagraph** for **H I Lyman-α spectral line** (121.6 nm) to be deployed to the International Space Station.
- Development of a **Coronagraph Magnetograph** to map the vector magnetic field and line-of-sight and plane-of-the-sky velocities of the very dynamic inner corona at unprecedented spatial and temporal resolutions.
- Development of a **miniaturized Gamma** and **X-ray instrument** for solar flux monitoring
- Development of a **miniaturized UV-imager** to map the radiative emission of the Sun

Environment observations

- Development/upgrade of **charged particle detectors** for deep space and interplanetary missions based on the use of a **modular magnetic spectrometer**
- Development of a new type of detector for measuring the Solar Energetic Particle events based on **hydrogenated amorphous silicon substrate**.
- Development/upgrade of **ENA sensors** to globally view the ring current and shock-front population dynamics, especially during Space Weather events
- Development of **Ion Mass Spectrometer** for plasma measurements and **Particle Processing Unit**

Take-home message Most of the proposed payloads have a high TRL planned to be increased in a reasonable timeline varying between 1 and 3 years approximately (TBC)

Heliophysics and Space Weather *session* – Preliminary Concluding Remarks

Expected Science returns

- advance current knowledge in the field of **Heliophysics (Solar Physics and Plasma Physics)** and **Space Weather science** (e.g., energy transfer during SW events; ICME and SEP event evolution, particle energization in near-Earth plasmas, coupling of magnetospheric regions, etc.);
- upgrade current **Space Weather** and **plasma models** based on **new synergetic and simultaneous observations** of the Sun and the circumterrestrial environment;
- advance current knowledge on **space-weather conditions around the Moon** at different orbital phases → particularly relevant to the preparation for future human presence on the Moon → link with the Planetary Sciences and Life Sciences disciplines
- capacity building and training for the prediction of space weather technological and biological impacts
- provide new key measurements for obtaining a global picture of the **radiation environment** of a planet or a satellite → link with the Planetary Sciences discipline

Expected Technology returns

- Development of **advanced low-cost technology** of **nano-satellites constellations**
- **Upgrade** of current scientific instrumentation and **miniaturization of components** and **systems**
- **Technolgoy transfer** among different science disciplines (e.g.: use of a micro-patetern gas detector to develop an ENA sensor)
- **Capacity building** and training for the prediction of space weather technological impacts, also in view of future robotic and human space exploration missions → link with the Planetary Sciences discipline
- In the context of hard X-ray polarimetry, in the photoelectric regime, **overcome of the state of the art** of the present technology is expected
- Future cubesat missions will benefit from the results of the used satellite platform in terms of payload integration and onboard systems.

Take-home message

The proposed payloads and mission concepts, based on the long-standing scientific and technological experience in Italy, address **cutting-edge themes** in the field of **Heliophysics** and **Space Weather science**. At the same time, because of the experience matured within the Italian industry, **the use of small, nano and cubesats constellations for scientific missions is timely**. International cooperation may integrate the proposed efforts calibrating budget and programmatic needs.