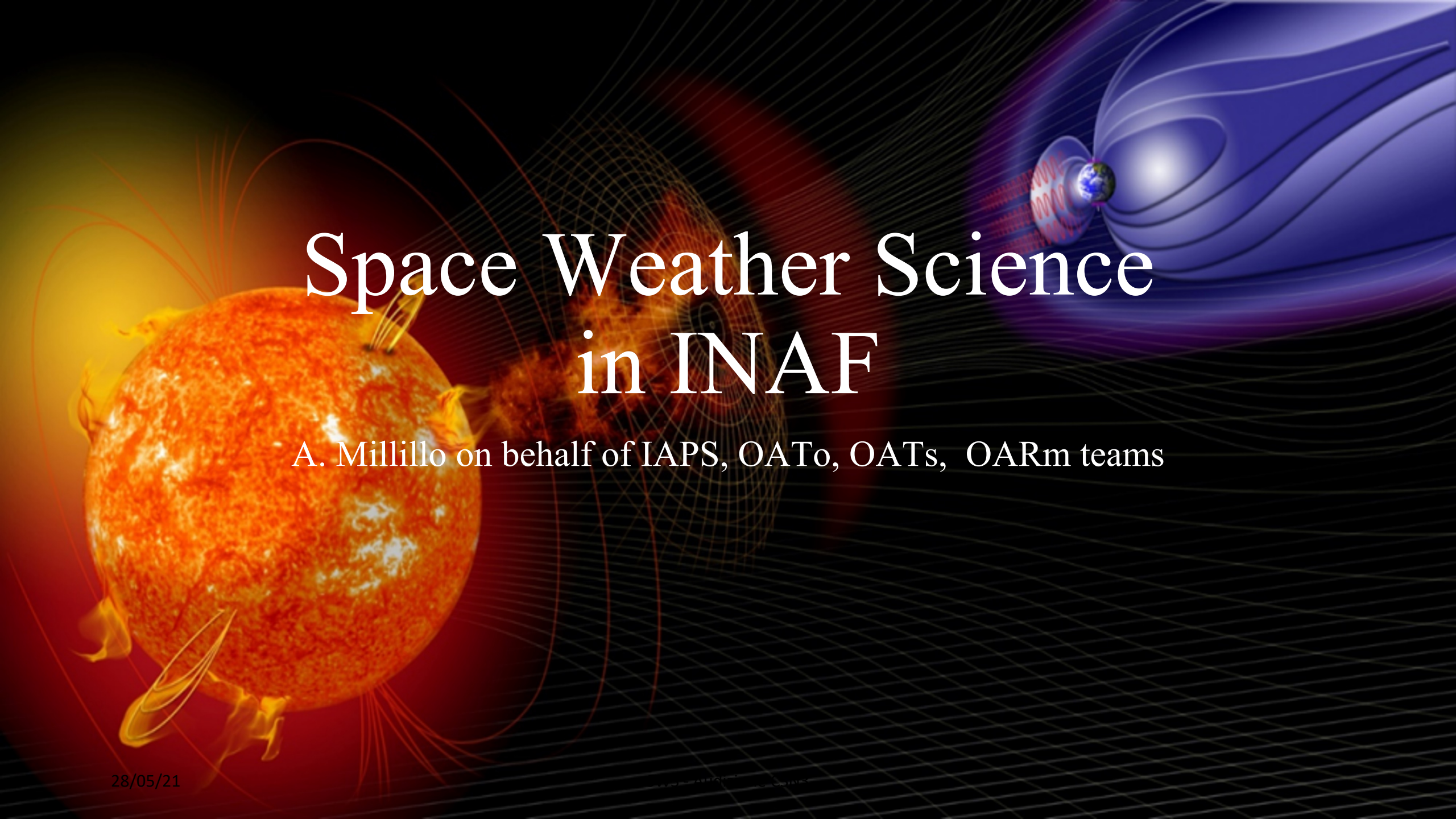

Space Weather Science in INAF

A. Millillo on behalf of IAPS, OATo, OATs, OARm teams

Space Weather Science

The Space Weather Science (SWS) represents a fundamental subject in the modern space research. It includes synergic investigations in different fields such as the Sun, the solar wind, the interplanetary medium, the atmosphere, the ionosphere and the magnetosphere in the terrestrial and planetary environments, the geomagnetism, the energetic particles, including galactic cosmic rays, and their effects on the biological and technological systems. Such investigations could be performed with data analysis tools and/or models, but also developing innovative instrumentations for space and ground-based observations.

INAF is the Italian institution most involved in this synergic sector.

Space Weather Science @ INAF

- Analysis of real time observations of the Sun and the interplanetary space.
- Modelling the turbulence in the magneto-convection of the sunspots.
- Analysis of the perturbations of the photosphere, cromosphere and the solar corona with multi-band data and study of the processes at the base of the solar flares and CME.
- Monitoring and analysis of the real-time measurements of the Cosmic rays and of the Ground level enhancements generated by the SEP.
- Study of the ionosphere- magnetosphere system with radar observations.
- Magneto-hydro-dynamical models (MHD) development and data analysis for the study of the magnetospheric phenomena.
- Study of the turbulence in the coupling of the solar wind with the magnetosphere and in the polar ionosphere.
- Study of the interaction of the solar wind with the planetary magnetospheres, exospheres and surfaces.
- New sensor designs for the identification of phenomena related to geomagnetic storms and solar processes:
  - Ionospheric and geo-magnetospheric disturbances, transient luminescence in the atmosphere,
  - monitoring of ring current Energetic Neutral Atoms,
  - Advanced instrumentation deveopement for new observations of the solar atmosphere.

Space Weather Science @ INAF

Note that these activities are strictly connected to and at the base of the Space Weather technological activities related to SW forecast service

- Analysis of the perturbations of the photosphere, cromosphere and the solar corona with multi-band data and study of the processes at the base of the solar flares and CME.
- Monitoring and analysis of the real-time measurements of the Cosmic rays and of the Ground level enhancements generated by the SEP.
- Study of the ionosphere- magnetosphere system with radar observations.
- Magneto-hydro-dynamical models (MHD) development and data analysis for the study of the magnetospheric phenomena.
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  - Ionospheric and geo-magnetospheric disturbances, transient luminescence in the atmosphere,
  - monitoring of ring current Energetic Neutral Atoms,
  - Advanced instrumentation deveopement for new observations of the solar atmosphere.

INAF team involved in Space Weather Science

1. ASPIS – IAPS (A. Milillo & team)
2. SWELTO – OATo (A. Bemporad & team)
3. SVIRCO - IAPS (M. Laurenza & team)
4. SWSoats – OATs (S. Ivanovski & team)
5. SP4GATEWAY – IAPS (A. Milillo & E. De Angelis)
6. SWEATER – IAPS (E. De Angelis & team). In collaborazione con INFN & CERN.
7. CEI6 – IAPS (G. Consolini). Il progetto è coordinato a livello nazionale dal Prof. Vincenzo Carbone (UniCal) e vede coinvolti ricercatori di: UniCal, UniCt, UniTov, UniAq, INAF e INGV. Il responsabile INAF è G. Consolini.
8. SPIRiT– IAPS (G. Consolini) Il progetto è coordinato a livello nazionale dalla Dott.ssa Paola De Michelis (INGV) e vede coinvolti ricercatori di INGV e INAF. Il responsabile INAF è G. Consolini.
9. CoSD -IAPS (S. Massetti & M.F. Marcucci)

i. Fluttuazione Alfveniche – IAPS (R. D'Amicis)

ii. Interazione Vento Solare – Pianeti - IAPS (A. Mura & team)

iii. Irradianza solare, brillamenti ed eventi estremi - OARoma (Ilaria Ermolli, Mariarita Murabito, Fabrizio Giorgi)

iv. Solar flare forecasting e eventi estremi di Space Weather – Università di Roma Tor Vergata (F. Berrilli, D. Del Moro) in collaborazione con INAF/IAPS e OAC

ASPIS (ASI Space Weather InfraStructure)

The scope of ASPIS project is the realization of a **prototype of scientific data center for collection, analysis and distribution of SW data and simulations** already available to the Italian scientific community. It will be done at the ASI Space Science Data Center (SSDC).

ASI and INAF signed an agreement of **800 kEuro** for the development and population of ASPIS prototype with the aim of:

- Promote and facilitate the **national research activities** in the frame of SW;
- Optimize the past results to consolidate and strengthen the position of **scientific and technological international leadership** in the SW field;
- Support and promote **interactions within the Italian scientific community** in order to optimize national strategies by harmonizing them in the European and international context;
- Promote and enhance the **collaboration between Universities and Research institutions** to optimize investments and results.

INAF/IAPS is managing the **call** that has just been launched on **18 May 2021**.

Proposal selections will be done within 2021.

Activities will close in 2023.

Total FTE depends on the selected proposals. The estimated INAF FTE is 20 and total FTE is 27.

SWELTO – Space WEather Lab. in Turin Observatory

OBJECTIVES

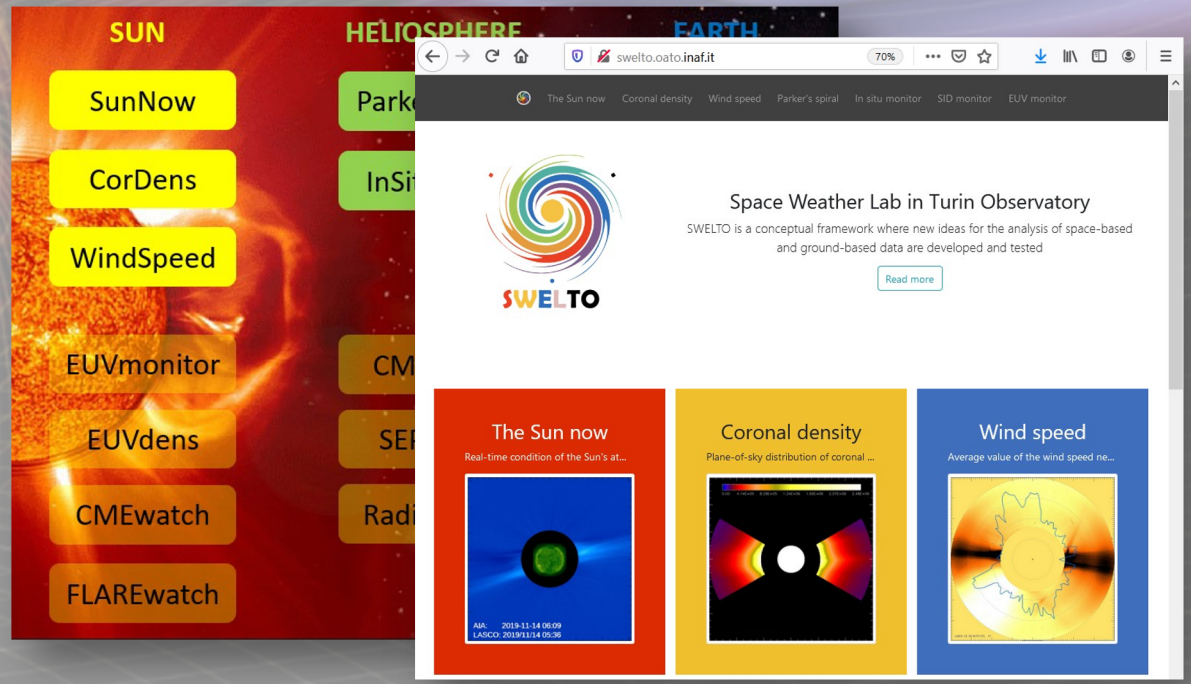
- **SW tools:** development & test of new tools for automated analysis of real-time space observations of the Sun and i.p. medium;
- **SW sensors:** installation of new sensors (e.g. SID monitor, FG magnetometer) and use of existing sensors (e.g. PRISMA full-sky cameras) to monitor from ground the Ionospheric and Geomagnetic disturbances;
- **SW dissemination:** involvement of students in SW data analysis and outreach activities

MAIN MILESTONES

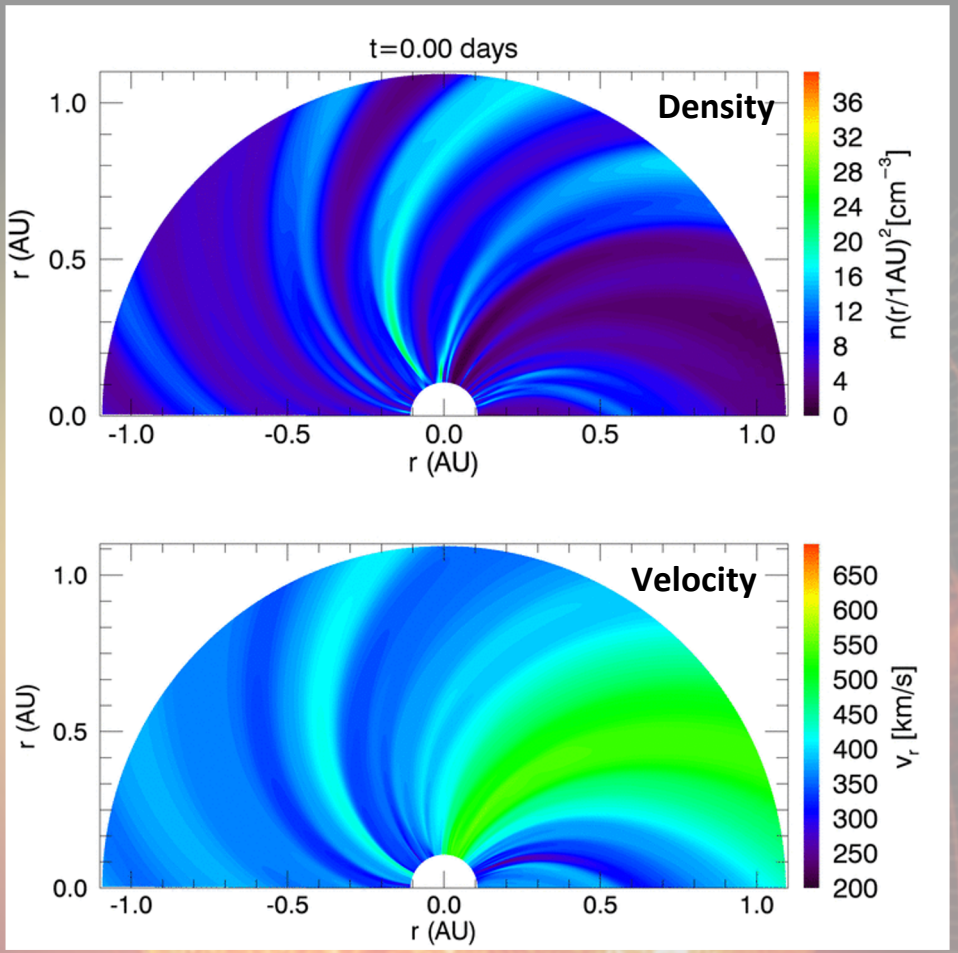
- **2018:** project start (still on-going)
- **2018-2019:** procurement and setup of the SWELTO Workstation, development of first tools, procurement of FluxGate magnetometer
- **2019-2020:** real-time implementation of the tools on the data archive, procurement of SID monitor, setup of SWELTO portal, meeting presentations
- **October 2020:** SWELTO portal on-line
- **February 2021:** multimedia stand activated

RESOURCES

- **Data** from on-line data catalogs;
- **Local expertise** on solar and heliospheric physics data and on instrument development and characterization;
- **Local funding** from INAF – Turin Observatory



Existing (full boxes) and future (transparent boxes) tools. The existing tool are running in real-time and providing access via the ***SWELTO on-line portal:*** **http://swelto.oato.inaf.it/**



SCIENCE (example)

MHD simulation of an interplanetary CME propagation from 0.1 to 1.1 AU into the interplanetary medium as reconstructed with RIMAP. The reconstruction is **based on in situ data** acquired in March 2009, hence representative of real conditions met by the propagating disturbance. The animation is running in a reference system at rest with the rotating Sun.

(*Biondo et al., JSWSC, 2021*)

PERSONNEL

- **INAF staff:** 11 people at INAF-OATo
- **INAF no staff:** 4 people (Ph.D., post-docs, etx.)
- **Non INAF staff:** 3 people at Turin University and Palermo University
- Project totally **conceived and led by INAF**

TOTAL FTE ('21-'23)

- SW science (A. Milillo): **2.90**
- SW operations (M. Messerotti): **0.95**
- SW (P. Romano)

FUNDING

- Only internal funding from INAF-OATo so far for a total of ~ 8 k€

PUBBLICATIONS

- 2 refereed papers (1 published, 1 in prep.), 2 INAF tech. rep., 2 outreach papers

More info on OA@INAF: https://openaccess.inaf.it/handle/20.500.12386/27715

CRITICALITIES

SWELTO reached almost the maximum possible development capacity based on the available resources. A real **jump-start** of these activities will now require funding for **~ 90 k€** for the next 2 years to hire 1 post-doc fully dedicated to the project + costs for meetings, publications and hardware. The person will work on hardening and validation of existing tools, development and implementation of new tools.

SVIRCO Observatory at INAF/IAPS

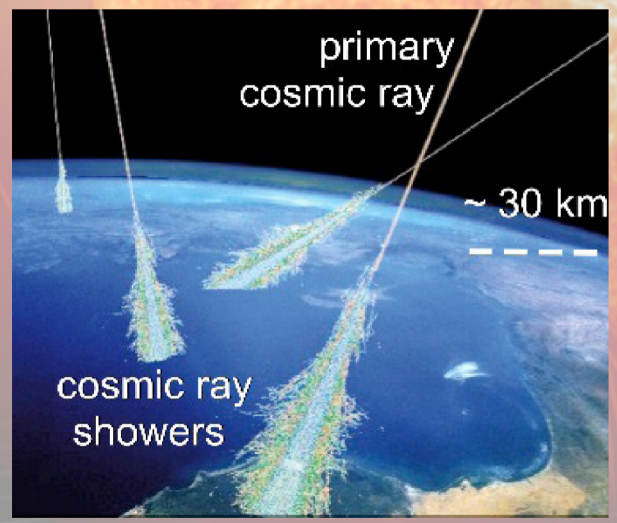
DESCRIPTION

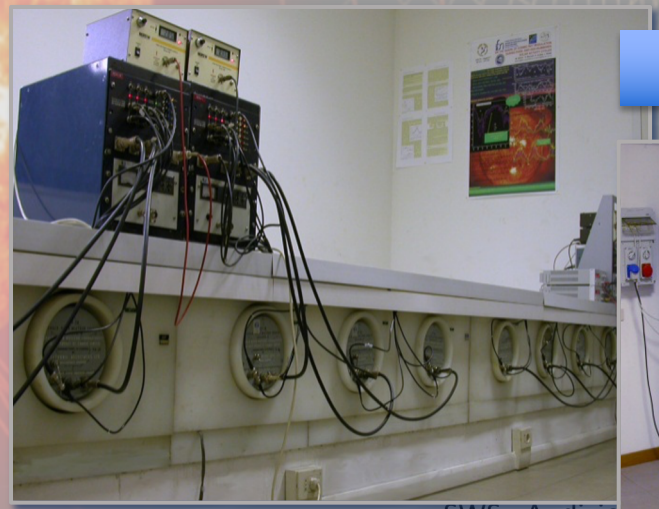
- Since **July 1957** the SVIRCO (Studio Variazioni Intensità dei Raggi COsmici) Observatory has been recording the secondary nucleonic component of the galactic and solar cosmic ray (CR) intensity through a **neutron monitor** (NM-64 type).
- It is part of the **worldwide network** of neutron monitors, the only facility of its kind existing in Italy, it represents a national asset for Space Weather, characterized by efficiency and reliability.
- It is located at the Department of Mathematics and Physics of the University Roma Tre.

MEASUREMENTS

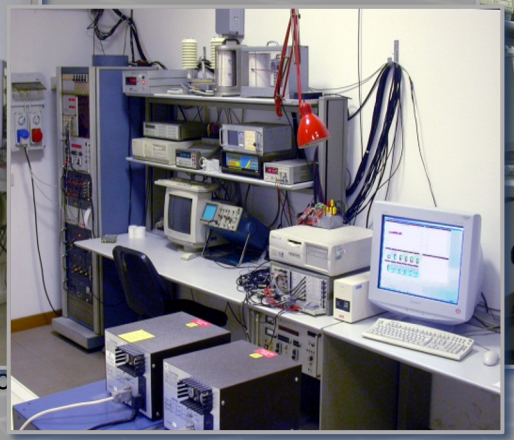
- **Galactic CR** intensity;
- **Ground level enhancements**, produced by relativistic particles during the events of solar energetic particles (SEPs), also called solar cosmic rays, which are **the most extreme Space Weather events;**
- **Forbush Decreases** due to the CME arrival**.**

Real time data to the "Real-time database for high-resolution neutron monitor measurements" (NMDB) and to the ESA – SSA.





SVIRCO 1957 - 2021



SCIENCE

These measurements are essential for the study of several important topics for the Space Weather Science:

- the **acceleration of high-energy particles** at the Sun, with important consequences for a wide variety of astrophysical phenomena;

- CR modulation, **solar variability** and the conditions in the Heliosphere (e.g., transient perturbations) for particle acceleration and propagation;

- Effects of solar and galactic **CRs in planetary environments**;

- **SEP and CME forecasting**;

- Estimation of radiation environment in the interplanetary and near-Earth space, the evaluation of which is essential for **dosimetry** and planning the profile of any space mission (e.g., the group is involved in BepiColombo, Solar Orbiter, LISA, ATHENA).

PUBLICATIONS (in the last 5years)

36 refereed papers.

Technical reports: prompt data reports on monthly basis; definitive data reports on six months and yearly basis; diurnal wave reports on 2-year basis.

PERSONNEL

INAF/IAPS leadership and management

- **INAF staff:** 6 people at INAF/IAPS
- **INAF associate:** 1 technician

TOTAL FTE (‘21-’23)

- SW science (A. Milillo): **1.35**
- SW operations (M. Messerotti): **1.25**

FUNDING

The SVIRCO Observatory has been supported by INAF/IAPS (100kEuro) and the PNRA (50kEuro) over the period 2000-2020.

CRITICALITIES

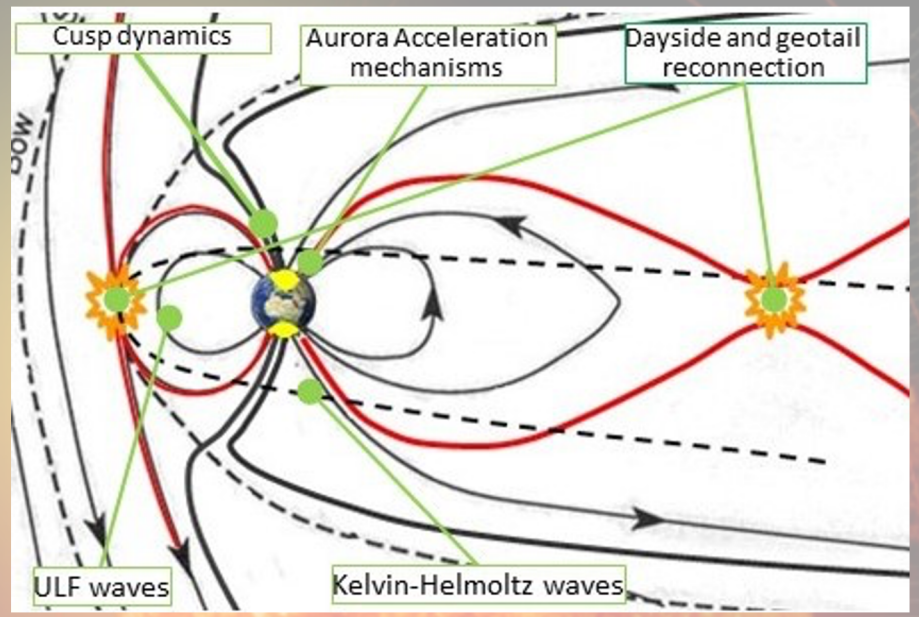
- It is mandatory to move the location to INAF/IAPS within the next year.
- Lack of dedicated technical and scientific personnel and continuous and adequate ordinary funding compromise the proper functioning of the Observatory, the continuity of measurements, the real-time data transmission, instrumentation renewal, development of new technology and scientific return.

Request: 10 k€/year; ~100 k€ for moving and instrum.; 1 technician; 1 tecnologist and 1 researcher.

Concordia SuperDARN radars (CoSD)

Italian participation in the international Super Dual Auroral Radar Network

Context



Polar regions ionosphere reaches outer space and connects to key-regions in the magnetosphere via magnetic field lines

Scientific Objectives

- Remote sensing of reconnection and K-H waves
- MHD, ULF, Magnetic Field Line Resonances
- Geomagnetic storm and substorms
- Joule heating
- Ionospheric absorption
- Ionospheric plasma structures

SuperDARN

A **network of HF radars** pairs providing the full **horizontal velocity of the ionospheric plasma** and monitoring the Earth's space processes effects at high and middle latitudes.

Participants: 10 nations, 17 institutions/universities.

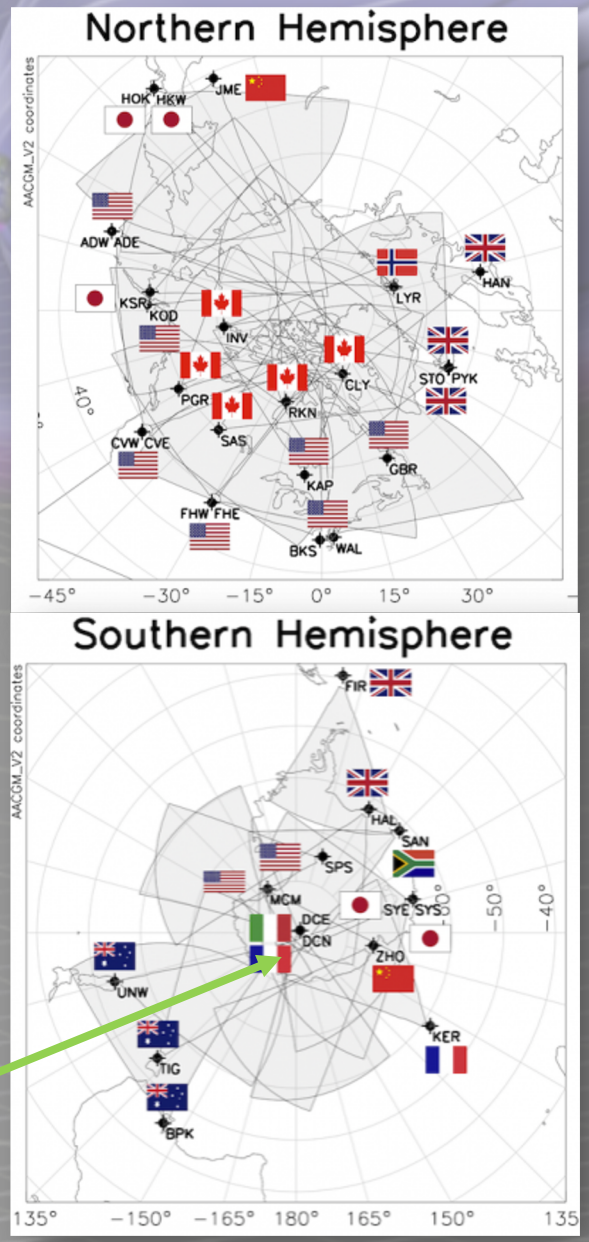
A several decades project bringing to a **strategic infrastructure in the Space Weather** context (Opgenoorth +, 2019)

Important **synergy with spacecraft in situ measurements**.

Several "firsts", e.g.: Polar Cap Patches tracking (Zhang+, Science, 2013); observation of magnetic flux transport in the Dungey cycle (Milan+, GRL, 2007); convection imaging (Chisham+, Surv. Geophys, 2007).

More than 800 publications listed in WoS with the keyword SuperDARN (200 in the last five years and a peak of 1211 citations in 2019).

Italy participates in SuperDARN with the **two Dome C East (DCE) and Dome C North (DCN) radars** at the Italian-French research station Concordia (Antarctica) and the scientific exploitation of data.



Credits Virginia Tech

Concordia SuperDARN radars (CoSD)

Italian participation in the international Super Dual Auroral Radar Network

The Italian radars @ Concordia (Antarctica)

Italy installed DCE in 2013, in collaboration with France, and DCN in 2019. **DCE and DCN operation is under INAF responsibility.**

Principle: DCE and DCN emit HF pulses that are backscattered by electron density irregularities between 100 and 400 km. Echos are then elaborated to obtain scientific information.

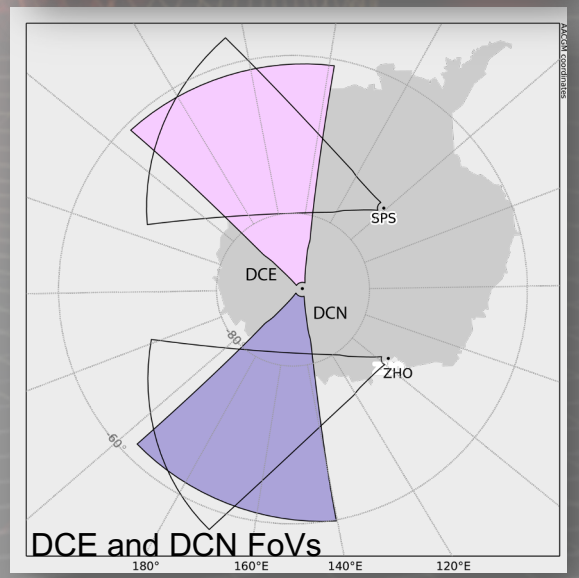
Each radar has 20 Rx/Tx antennas (4 interferometric) installed on 24 towers. A shelter contains the radar electronics and the data acquisition system.

DCE and DCN **fields of view** extend from the geomagnetic pole towards the auroral latitudes (extension of 10^6 km^2) and overlap with the South Pole (USA) and the Zhongshan (Cina) radars FoVs, respectively.

Daily data provision: data are transfered daily to IAPS and to the British Antarctic Survey and made available to the scientific community.

DCE and DCN are «Osservatori permanenti di climatologia spaziale» within the Italian National Program for Antarctic Research (PNRA)

DCE: Shelter of the electronics and TX/RX antennas



Personnel

IAPS: S. Massetti (Project Manager), M.F. Marcucci (PI, member of the SuperDARN Executive Council), D. Biondi (Electronics Responsible); **CNR**: E. Simeoli (IT Responsible) and S. Longo (CoI) ; **INGV** I. Coco (CoI).

CNR and Milano Bicocca personnel has supported the yearly maintenance activity for the last 7 years together with ENEA and Concordia personnel.

FTE

INAF 1, collaborators 0.4

Publications (last 5 years)

9 by team members + 9 on DCE/DCN data

Topics: convection during dual lobe reconnection and By dominated IMF, ionospheric absorption during X-Ray solar flares, pulsations, effects of solar wind dynamic pressure variations

Funding

Support of PNRA, INAF and CNR from the Italian side, and of IPEV and INSU from the French side.

The radars maintenance is supported by PNRA.

Needs

+ 1 FTE researcher + 0.5 FTE electronic engineer

SWSoats – Space Weather Science @ OATs

Modelling magnetic reconnection, Solar Radio Physics and Modelling Sunspot Turbulence

MHD modelling at planetary magnetosphere and in interplanetary shock

Objectives:

- Kelvin-Helmholtz and tearing mode **instabilities in magnetopauses**
- Magnetic **reconnection** at planetary magnetospheres (e.g. Mercury and Earth
- Local plasma processes within **interplanetary shocks** when sharp changes of the shock-ambient environment configuration is present.

Resources

-Local MHD model (Ivanovski et al. 2011)

-1D CWENO shock capturing code

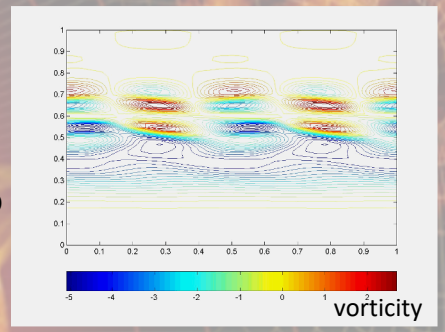
Publications and presentations 2 refereed papers

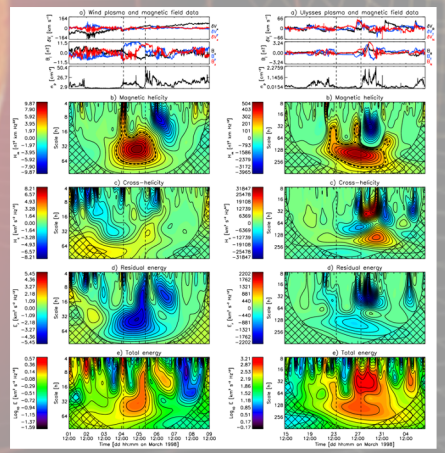
Personnel INAF staff: 3 at INAF-OATs and 1 at OATo

Working Groups:

WG1: MHD modelling of instabilities and propagating CME shocks (S. Ivanovski, F. Fiore)
WG2: Turbulent evolution of the MHD properties of the embedded magnetic cloud based on observations of Interplanetary coronal mass ejections (D. Telloni, S. Ivanovski)

Local MHD modelling WP in Proposed Project PRIN 2020:
Tittle: SHOCKS AND SOLAR ENERGETIC PARTICLES IN THE INNER HELIOSPHERE: FROM SPACE OBSERVATIONS AND NUMERICAL SIMULATIONS TO SPACE WEATHER
(Coord. G. Zimbardo Resp. INAF: A. Bemporad)





Solar radio data and analysis

Objectives: Scientific cases(e.g. analysis of radio events of type III and spikes produced by the **acceleration in chromosphere and in the solar corona**) with the data of the new solar radiospectropolarimeter (Trieste Solar Radio System 2.0, 3.7 m diameter parabolic antenna, operating band 1-18 GHz), which will perform diachronic solar radio observations and will become a **node of the national network** of 'INAF as well as the **international one** of ESA.

Personnel INAF staff: 6 at INAF-OATs

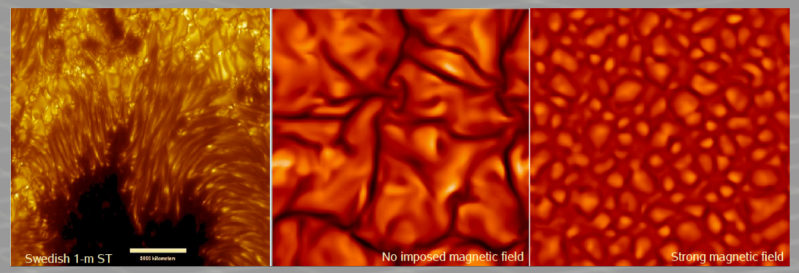
Working Groups: *WG3*: Solar radio data and analysis (M. Messerotti, V. Baldini, M. Molinaro; G. Jerse; V. Alberti; R. Cirami)

Modeling of turbulence in the magnetoconvection of sunspots

Objectives: to investigate is the anisotropy and magnetic quenching in slightly stratified magnetoconvection in sunspots. In order to model the magnetoconvection in sunspots the transition from 3D to 2D turbulence under the influence of strong magnetic fields can be simulated.

Personnel INAF staff: 1 at INAF-OATs (S. Ivanovski)

Resources



Current Total FTE: 1.0

SWEATERS
Space WEAThER Ena Radiation Sensor

Project to realize innovative sensor for Energetic Neutral Atom detection devoted to investigation of Space Weather phenomena at low altitude orbit.

- **Team**

Project leaded by INAF:

-PI: E. De Angelis (INAF reseracher), 7 staff, 1 associated, 2 no staff (1 TD, 1y PhD student)

-partner INFN-Pisa: F. Pilo coordinator, 8 staff

-collaboration with CERN (RD-51), SWRI (USA), ENEA.

- **Technological and Scientific aspects**

First ENA gas detector based on MPGD: it will allow to detect ENA in a large energy range (1-100keV), with high spatial resolution (few degrees) and direction identification in a **unique, compact, low budget system.** This challenge goal has never been reached before for technological limits in ENA instruments.

The new instrument characteritics will open an important step on ENA investigation, a technique well established in last decades to study interaction phenomena with global imaging and particle remote sensing.

The gas detector development for ENA application opens a new techonological and scientific field for MPGD (MicroPattern Gas Detector) used mostly in HEP field (mostly at CERN).

- **Results and Prospectives**

MPGD detectors for ENA are now in the **devolpment and testing phase**. They are providing promising results at low energy, both with ions and X-signal (Fe-55 emission). This technology used for ENA will be the first space application of this detector and will open several new applications both on ground and in space. The compact system open easy access to cubesat payloads.

From a scientific point of view, the **ENA monitoring at low altitude** with this kind of instrument can add detailed information on the source region and energy of generated particles, useful for phenomena discrimantion and Space Weather study.

- **Plan (mid and long term)**

The project foresees **2 years** of activity for instrument prototype realization (supported by ASI contract)

A possible roadmap of further **3 years** for space instrument development and mission payload has been planned.

- **Funds (2y)**

As for 'ACCORDO ATTUATIVO ASI/INAF n. 2020-14-HH.0' :

importo finanziato **350kE** (225kE INAF capofila, 125INFN partner)

importo cofinanziato : **200kE** (130kE INAF capofila, 70kE INFN partner)

- **Critical points**

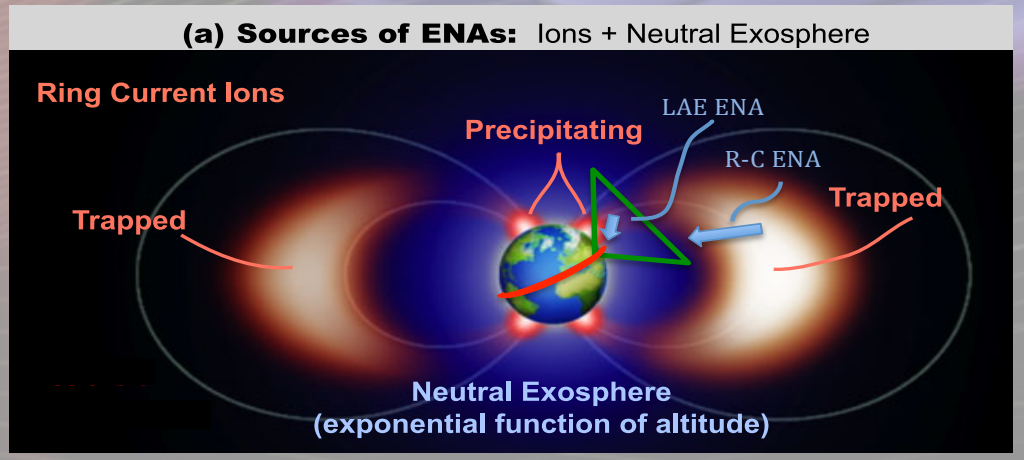
Impact of COVID emergency on planned activity (lab access, procurements, Cern and INFN collaboration)

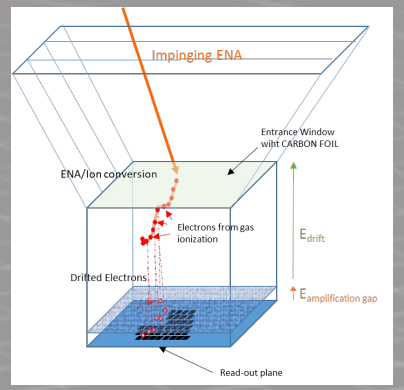
Training of new skills (personel devoted to this R&D activity)

28/05/2

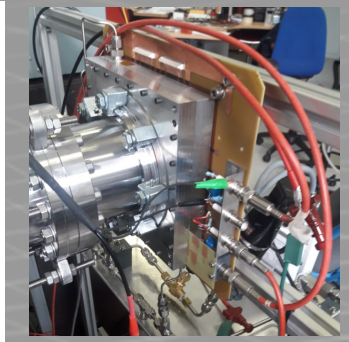
SW

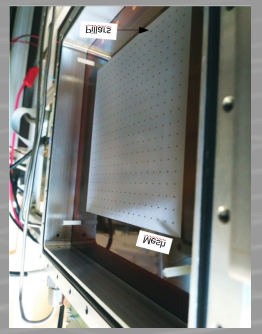
S - Audizione CSN3





SWEATERS concepts





Ion/ENA beam on MPGD type detector

SP4GATEWAY (Space Plasma Physics Payload Package Conceptual Design for the Deep Space Gateway)

Participation to the ESA topical team for plasma payload science requirements definition and in the study for the conceptual design definition. In particular, IAPS team has been involved in the definition of **cMENA** that is intended to **monitor the geomagnetic activity** providing wide-field Energetic Neutral Atom (ENA) images of magnetospheric regions in two populations: ENA generated in the **ring current region** and ENA generated by **high latitudes precipitating ions.**

The **final report** has been delivered **to ESA**, but a follow-up is expected in 2022 (instrument development in 4 years).

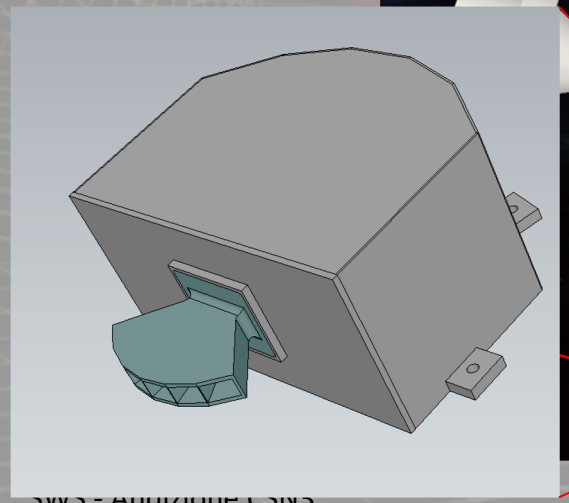
Personnel:

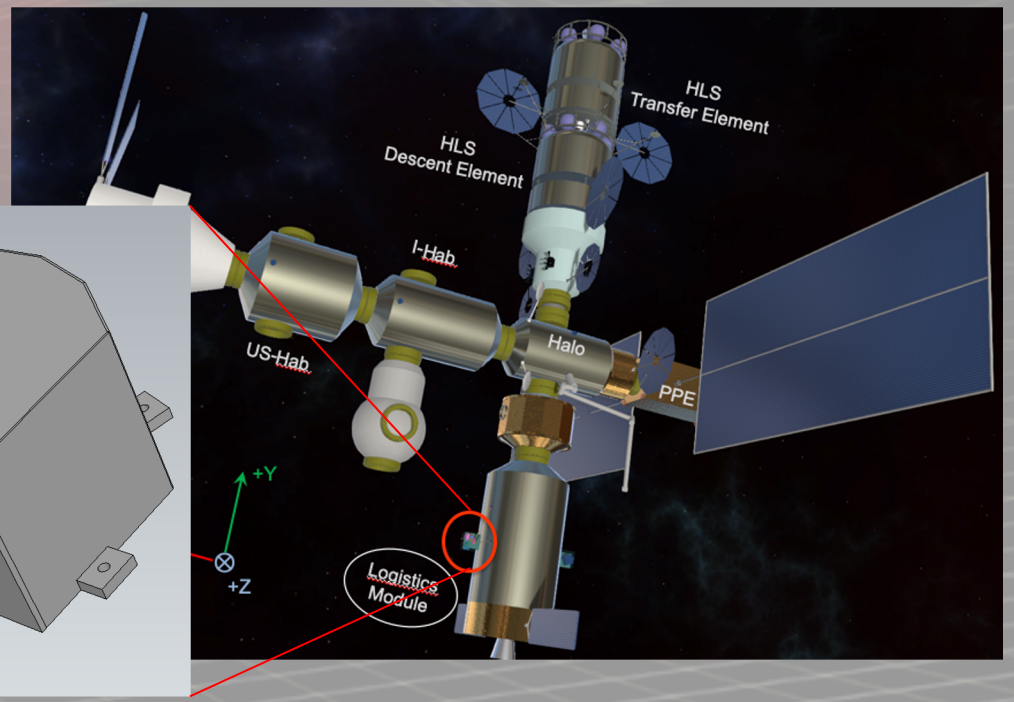
- A. Milillo (IAPS) science definition;
- E. De Angelis (IAPS) instrument concept and design;
- new personel will be involved for the next advanced studies.

The team has a long heritage in the field: with **18 refereed publications** (since 1996).

Criticalities:

The realization of the project can be done with ESA and/or ASI support. The required funds for phase A and B studies (expected to begin within the reference period) are about 2000 kEuro.

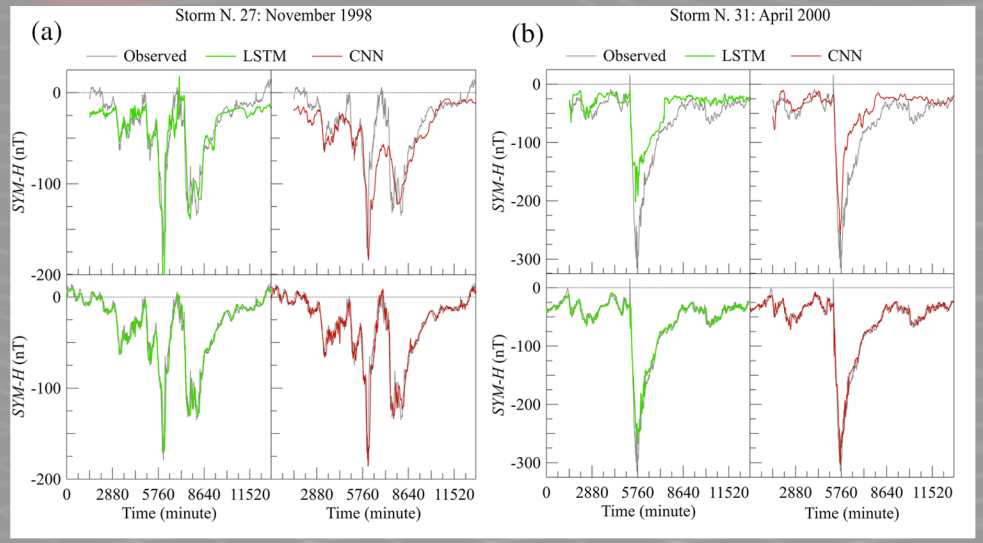




CEI6: Circumterrestrial Environment: Impact of Sun-Earth Interaction (PRIN MIUR 2017)

- CEI6 project collects expertise from **6 research groups** from Universities and research institutes (INAF and INGV) and it is coordinated by Prof. V. Carbone (UniCal).
- The project started in November, 2019 and it is a 3 years project plus an extension of 6 months due to Covid 19.
- The main WPs of CEI6 projects are:
  - Observation and study of the **Sun-Earth interaction**
  - Observation and study of the **dynamic processes** in the Geospace and at ground
- INAF group: 8 staff researcher from 5 institutes (IAPS, OAR, OAC, OACt, OATo) plus a two-years AdR (IAPS)- Total FTE 2.85.
- The INAF groups is involved in all the work packages in the tasks:
  - Precursors of Space Weather events in the solar atmosphere.
  - Energy transfer from Sun to Earth
  - Realization and Upgrade of instruments for solar observations.
  - Space Weather events in the Geospace. The magnetosphere.
  - Space Weather events in the Geospace. The ionosphere.
  - Space Weather events in the Earth atmosphere and on the ground.
- The funded MIUR budget of the INAF UdR is of approx. 115 k €

- The INAF UdR, coordinated by Dr. G. Consolini at IAPS, since now has actively been involved in a large number of studies that appeared in series of publications (22) on international journals.
- One of the target of the CEI6 project is to provide some possible extension of previously developed forecasting models of Space Weather events.
- In this framework, INAF group in collaboration with INGV UdR has worked on an **ANN modelling of geomagnetic storms** and it is now working on ML approaches to ESP forecasting.

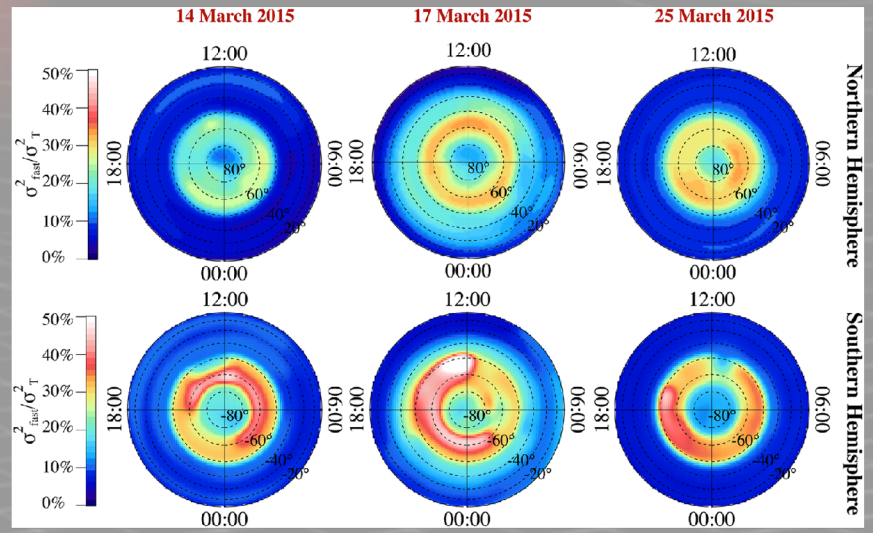


From Siciliano et al, Space Weather, 2021

SPIRiT: Space weather in the Polar Ionosphere: the Role of Turbulence (PNRA 2018)

- SPIRiT project collects expertise from **2 research groups INAF and INGV** and it is coordinated by Dr. P. De Michelis (INGV).
- The project started in April 15, 2020 and it is originally a 2 years project extended of 1 year more due to Covid 19.
- The project is organized in two OUs consisting of researchers of both the two groups.
- SPIRiT aims to investigate the **plasma dynamics and the physical state of the ionosphere at polar latitudes** in the two hemisphere using novel methods based on dynamical systems approaches.
- The main tasks are:
  - Analysis of the **daily variations** of scaling/spectral features of magnetic field and plasma parameters using data from ground and space.
  - Investigation of the **magnetic field and plasma parameters' turbulent fluctuations** via the reconstruction of daily average maps under different conditions of geomagnetic disturbance.
  - Characterization of the **ionospheric turbulence** level for different high-latitude regions (auroral oval, polar cap, and cusps) and magnetic local times during intense /moderate magnetic storms.
  - **Outreach and dissemination** of Space Weather relevant aspects.
- The INAF group is composed by 2 staff researcher from IAPS plus a one-year AdR (IAPS) - Total FTE 1.7. – and is involved in the following task:
  - Development of analysis techniques and interpretation of results.
- The INAF group, coordinated by Dr. G. Consolini at IAPS, since now has actively been involved in some initial studies that appeared as publications (2) in international journals.
- One of the target of the SPIRiT project is to provide some possible extension of previous studies on ionospheric turbulence by the ESA-INTENS project by integrating space data analysis with ground based magnetic field and plasma features' measurements (SuperDARN, EISCAT, ….).
- The INAF budget is very limited for this work being 28.8 k€.

Contribution of the fast magnetic field fluctuations during the 2015 St. Patrick' storm



From Santarelli, De Michelis & Consolini et al, JGR, 2021

Modelling of solar irradiance

OBJECTIVES

- **RECONSTRUCTION OF SOLAR IRRADIANCE VARIATIONS** on time scales of minutes to centuries.
- **STUDY OF THE SOLAR ACTIVITY** over the past century.

Origin of flares and Extreme Events

OBJECTIVES

- **IDENTIFICATION OF THE CONDITIONS LEADING TO MAGNETIC RECONNECTION:** analysis of flaring regions.
- **RECONSTRUCTION OF EXTREME SW EVENTS OCCURRED IN THE PAST**: analysis of solar source regions, resultant magnetic disturbances and SW impact.

IN NUMBERS

- **REFEREED PAPERS (2016-2021) : 13**
  irradiance → 10
  flares and extreme events → 3
- **FUNDS (2011-2021) : 300 kEuro**
  FP7 SOLID, FP7 EHEROES, PRIN-INAF, PRIN-MIUR
- **PERSONNEL : 4 INAF+ external collaborators**
  INAF TI: 2 @INAF-OAR
  INAF TD: 2 @INAF-OAR (post-docs)
  ASS INAF & NON ASS INAF: 4+
- **FTE (2021-2023) : 1.6 + external**
  1 FTE/TI, 0.6 FTE/TD, +external

RESOURCES

- **SOLAR DATA (FULL-DISK & HIGH RESOLUTION)**
  PSPT@OAR and other telescopes (ground- and space-based)
  IBIS-Archive@OAR and other archives (SST, SDO, IRIS, ..)
- **MODELS AND TOOLS**
  Irradiance models, Inversion and RT codes, processing tools

CRITICALITIES

- **UNDER-STAFFING**

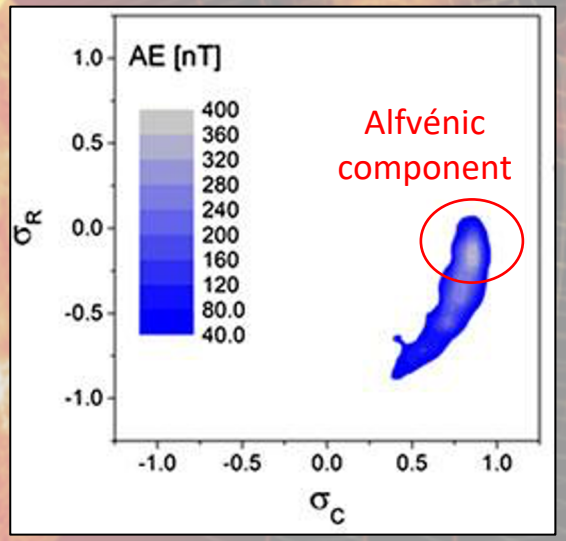
Role of Alfvénic turbulence in the solar wind – magnetosphere coupling

OBJECTIVES

- **Advanced analysis** to investigate the link between Alfvénic turbulence and geomagnetic response at high and low latitudes.
- **Single case and statistical studies**.
- **Exploit interplanetary data** from next generation missions such as Solar Orbiter and Parker Solar Probe and Bepi Colombo.

RESOURCES

- **Interplanetary data** from existing missions and next generation missions;
- **Geomagnetic indices** from on-line data catalogs.



PUBBLICATIONS

- 2 refereed papers (1 published, 1 in preparation)

PERSONNEL

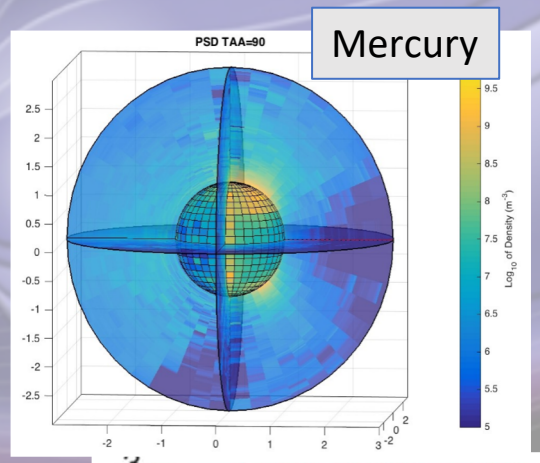
- **INAF staff:** 1 at INAF-IAPS and 1 at INAF-OATo

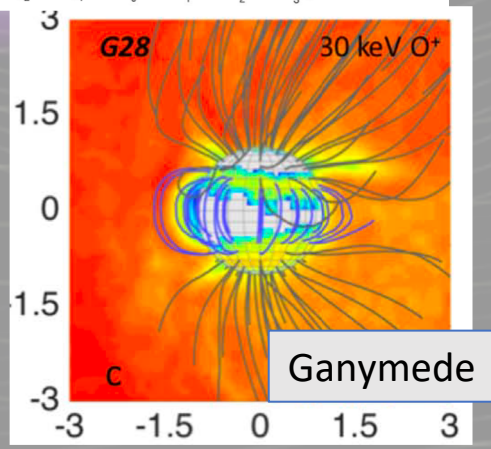
TOTAL FTE ('21-'23)

- SW science (R. D'Amicis): **0.1 extra + 0.2 'presunti'**

Planetary Space Weather

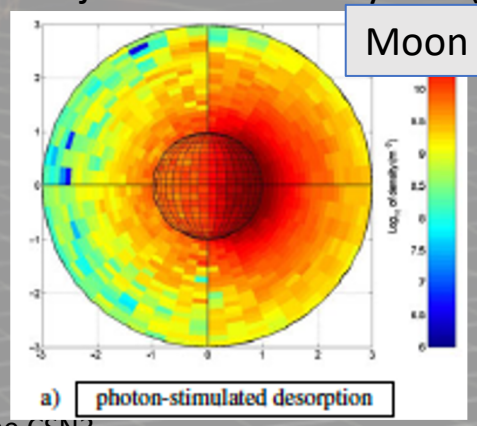
- Study if the **interaction of solar wind / planetary environment with the planets**.
- Study and modelling **plasma circulation** in the planetary environents
- Study and modelling of **exosphere generation and circulation** in different environments: Mercury, Moon, Jupiter's icy moons, asteroids…
- **Comparative planetology**





PUBBLICATIONS

About 11 refereed papers on the subject in the last 5 years (2016-2020)



PERSONNEL

Reference: A. Mura, M.Moroni (IAPS)

This topic is partially shared with the SERENA team and in synergy with EPN SPIDER activities.

FUNDING

No specific funds in the last 5 years

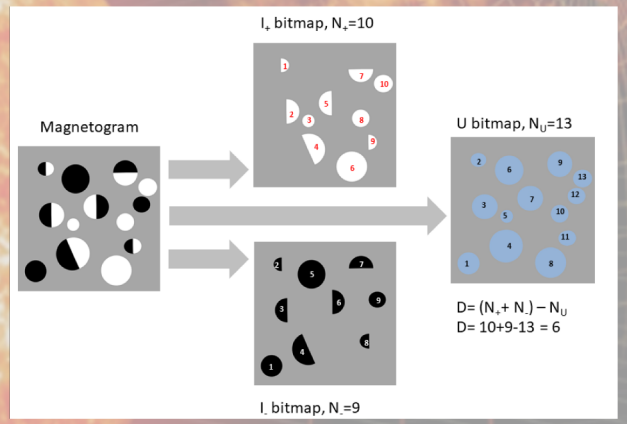
Solar Flare Forecasting Algorithms in SWERTO (SpaceWEatheR@TOr Vergata)

OBJECTIVES

- **Development** and test of algorithms for SW forecast and nowcast.
- **Development** and calibration (Solar Cycle 24) of the new topological parameter **D** to predict the occurrence of X- or M- class flares in a given solar active region during the following 24 hours period.
- Build the **SWERTO data center (http://spaceweather.roma2.infn.it/)** FILAS Grant 2016, for instruments in space or on ground, with data on the conditions of the near Earth environment and on the solar regions responsible of the Space Weather.

RESOURCES

- **Data from TSST and MOTH telescopes**
- **Data** from on-line data catalogs (**SDO/HMI**);



PUBBLICATIONS

- 5 refereed papers (4 published, 1 in press)

PERSONNEL

- **INAF staff:** 2 at INAF-OAC
- **Non INAF staff:** 2 at Rome Tor Vergata University

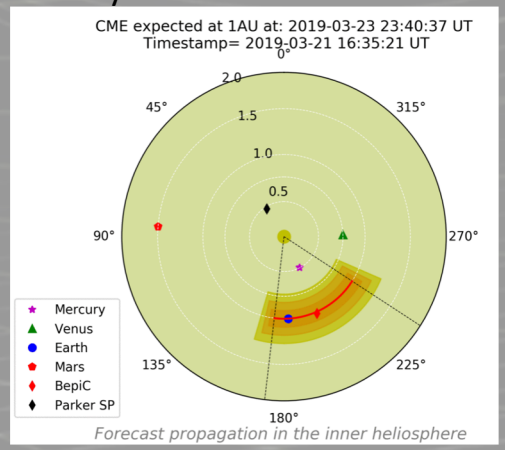
CME and Extreme SW events

OBJECTIVES

- **exploit data** from the recently launched missions such as **Parker Solar Probe, Solar Orbiter and BepiColombo**
- applying state-of-the-art data assimilation techniques to the new, extensive datasets,
- **Advanced analysis** of the complexity, turbulence and dynamics of the solar wind and interplanetary perturbations and their role in the acceleration of energetic particles;
- analyze and model the solar-driven disturbances for a deeper understanding of the **underlying physical mechanisms** and **prediction of the arrival** in the interplanetary and planetary environments.

RESOURCES

- **Data** from on-line data catalogs;
- Real-time implementation of the **Probabilistic Drag Based Model (P-DBM)** for CME propagation



Forecast propagation in the inner heliosphere

PUBBLICATIONS

- 4 refereed papers (3 published, 1 in prep.)

PERSONNEL

- **INAF staff:** 1 at INAF-IAPS
- **Non INAF staff:** 2 at Rome Tor Vergata University

FTE e Funds

The SWS activities have a long history in INAF, starting in the 80s', even if the allocated funds have not always been adequate.

Recently, the importance of this sector has been recognized by the Italian institutions. In fact, ASI has published a roadmap of scientific activities to be performed for promoting the SW science development.

Total FTE INAF since 2000: 40.0
FTE INAF as staff (TI): 26.0
Total FTE (including close collaborators): 65.

46 INAF personnel
and **10 associated**

Total funds (k€): 5000
INAF funds up to 2023 (k€): 3800
INAF funds up to 2020 (k€): 541

INAF/OATo supports SWELTO.
INAF/IAPS supports SVIRCO.
Other fund sources are ASI (ASPIS, SWEATER), EU (OARoma) e PRIN-MIUR (OARoma, CEI6), PNRA (SVIRCO, SPIRIT, CosD).

Future prospective for the INAF SWS community

- Despite the under-funding in the past years, the INAF team involved in SWS acquired a great heritage and international recognition.
- Participation in various networks and involvement in international projects.
- 152 refereed publications in the last 5 years (30 papers/year)
- In the next years, with the increase of the resources a great opportunity for further results and for new synergic collaborative studies is expected.
- The criticality remains the under-staffing of almost all the involved groups/projects and the necessity to transmit the heritage to the next generation of scientists.