Italian Contribution to Space Weather

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Thanks to:
Mauro Messerotti (INAF), Daniele Biron (ITAF-COMET), Paola De Michelis (INGV), Francesca Zuccarello (Uni CT), Alessandro Bemporad (INAF), Ester Antonucci (INAF), Domenico Di Mauro (INGV). Lili Cafarella (INGV), Marco Pietrella (INGV), Anna Milillo (INAF), Francesco Berilli (UniTOV), Marco Stangalini (INAF), Mirko Piersanti (Uni AQ), Federica Marcucci (INAF), Lucilla Alfonsi (INGV), Enrico Zuccheretti (INGV), Massimo Materassi (ISC-CNR), Loredana Perrone (INGV), Stefania Lepidi (INGV), Yenca Migoya-Orue (ICTP), Fabio Reale (UNIPA), Roberto Piazzesi (INAF)

Pamela

Ionosonde and autoscaling

Solar Orbiter

SuperDarn

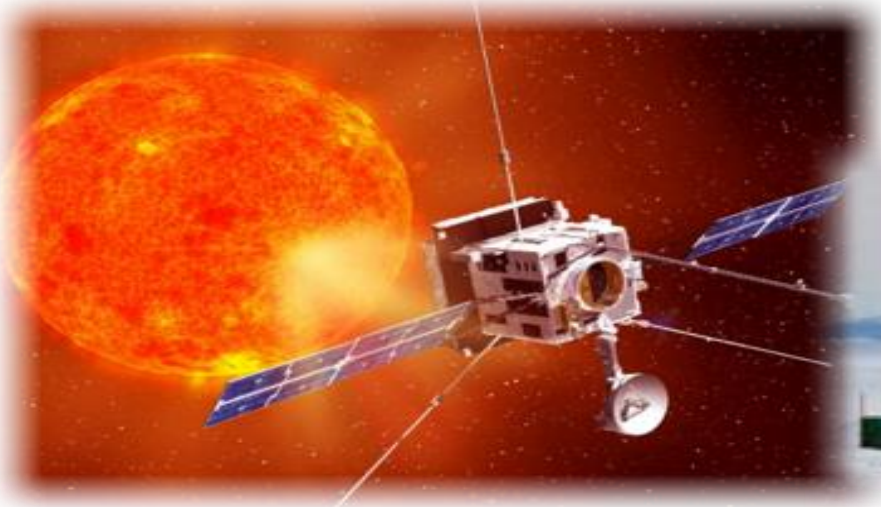
Themis

Outline

- Italian strategic Initiatives
- Solar physics
- Interplanetary space physics
- Solar-Terrestrial physics
- Upper atmosphere physics

Pamela

Ionosonde and autoscaling

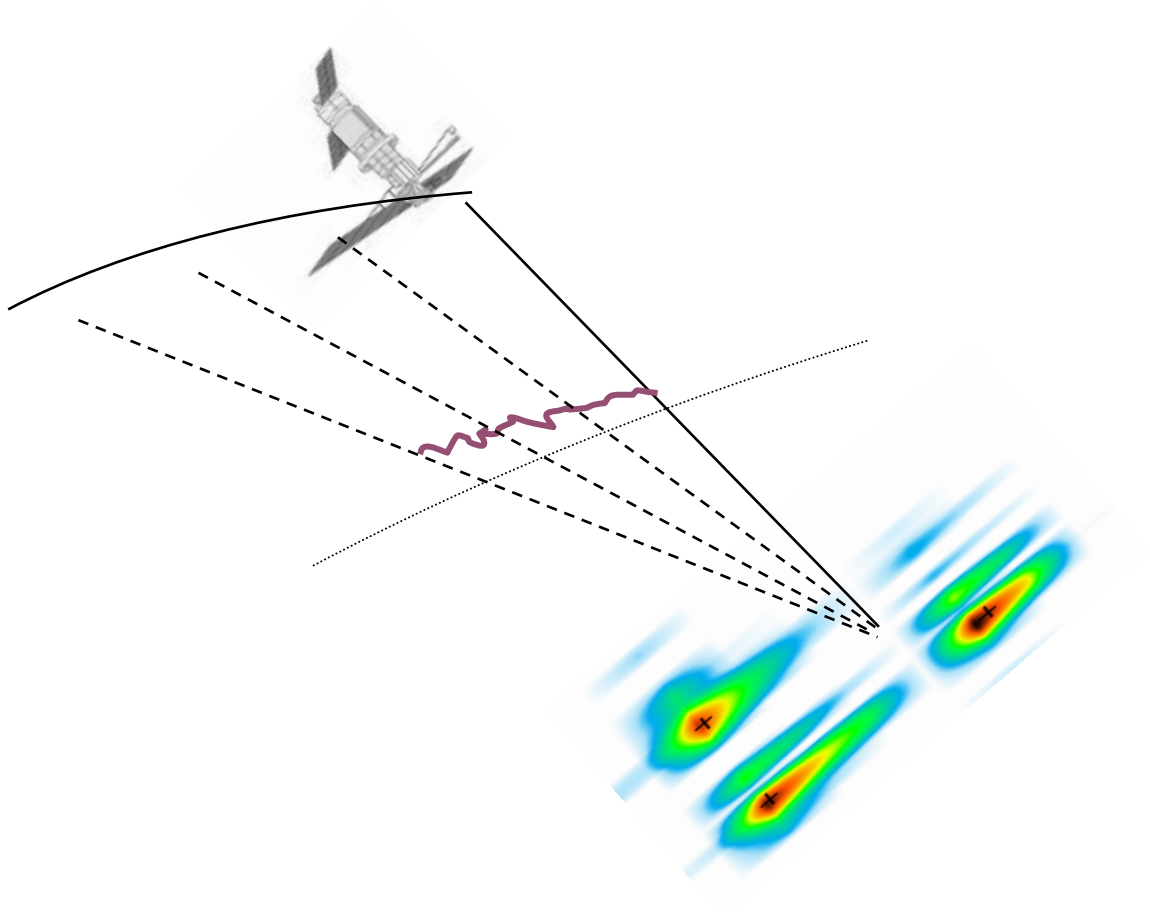


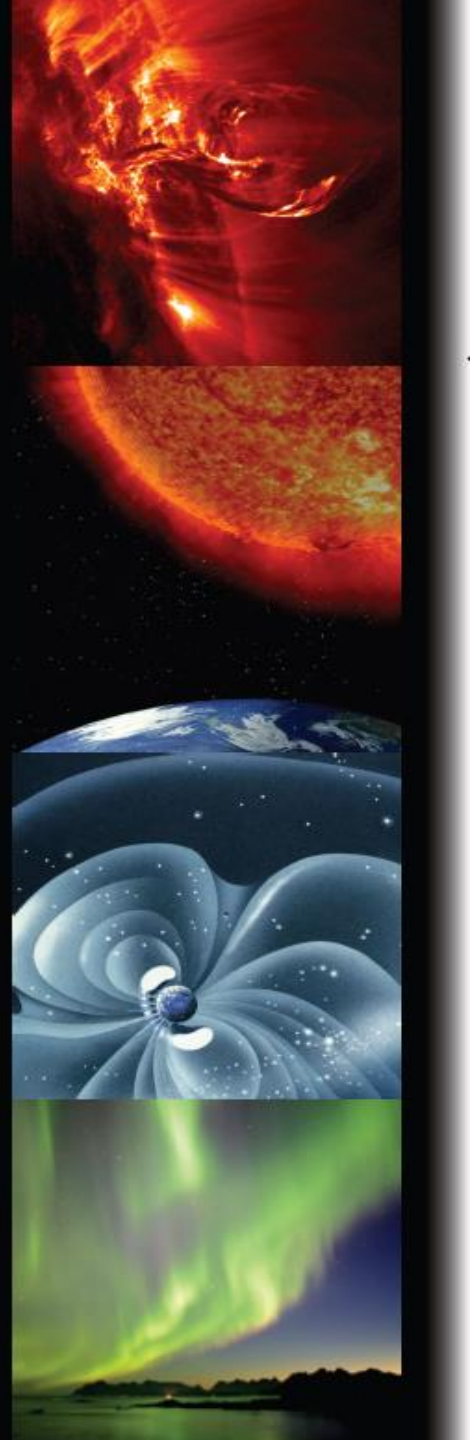
Solar Orbiter

SuperDarn

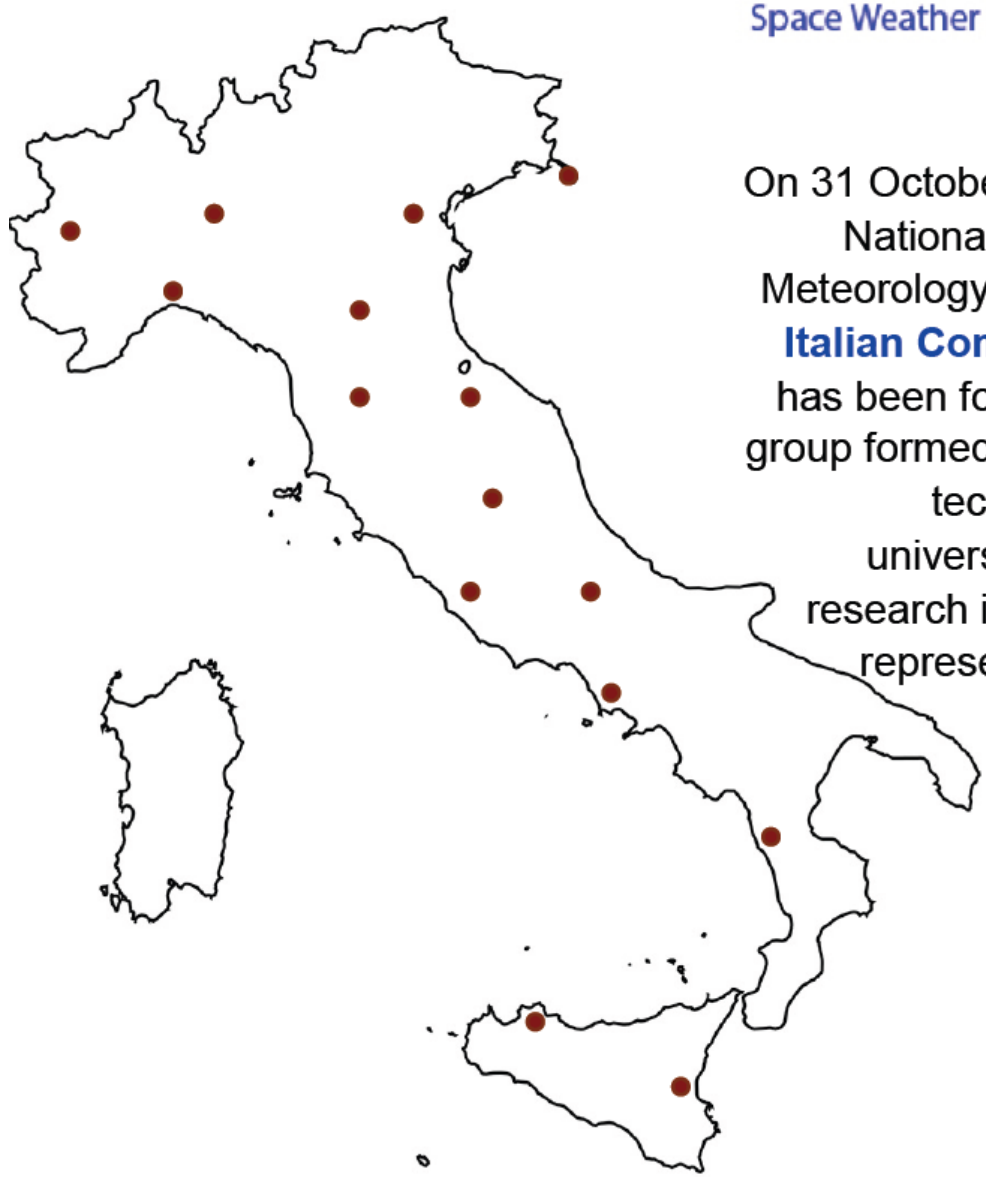
Themis

Italian Space Weather strategic initiatives





SWICo
Space Weather Italian Community



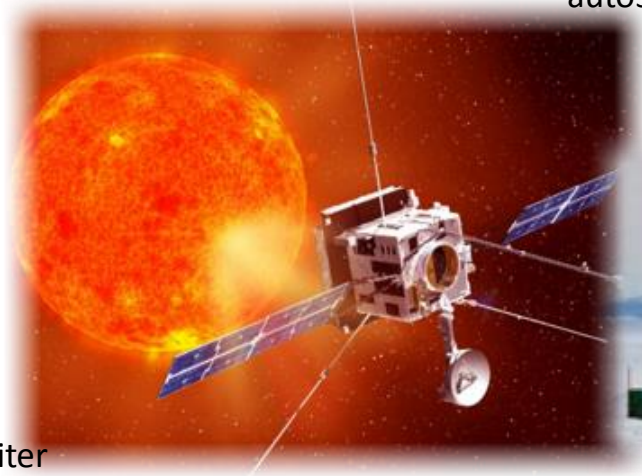
On 31 October 2014 the Italian National Group for Space Meteorology (**Space Weather Italian Community, SWICo**) has been founded as interest group formed by scientists and technologists of both universities and national research institutions and by representatives of Italian industries.

Observational, theorethical studies and modeling

- Solar physics from photosphere to corona and sola irradiance
- Interplanetary medium physics: structures, turbulence and propagation of CMEs and SEPs
- Solar wind-magnetosphere coupling and interactior
- Magnetospheric-Ionospheric dynamics
- Ground based magnetic field variations
- Forecasting and nowcasting modelling
- Planetary Space Weather

Pamela

Ionosonde and autoscaling



Solar Orbiter

SuperDarn

Themis

World Meteorological Organization Congress

Resolution 38 (Cg-17) — “Four-year Plan for WMO Coordination of Space Weather Activities”.

Since 2012 Italy joined the WMO Space Weather initiative

<u>Inter-programme Coordination Team on SW</u>, ITAF – INAF - INGV

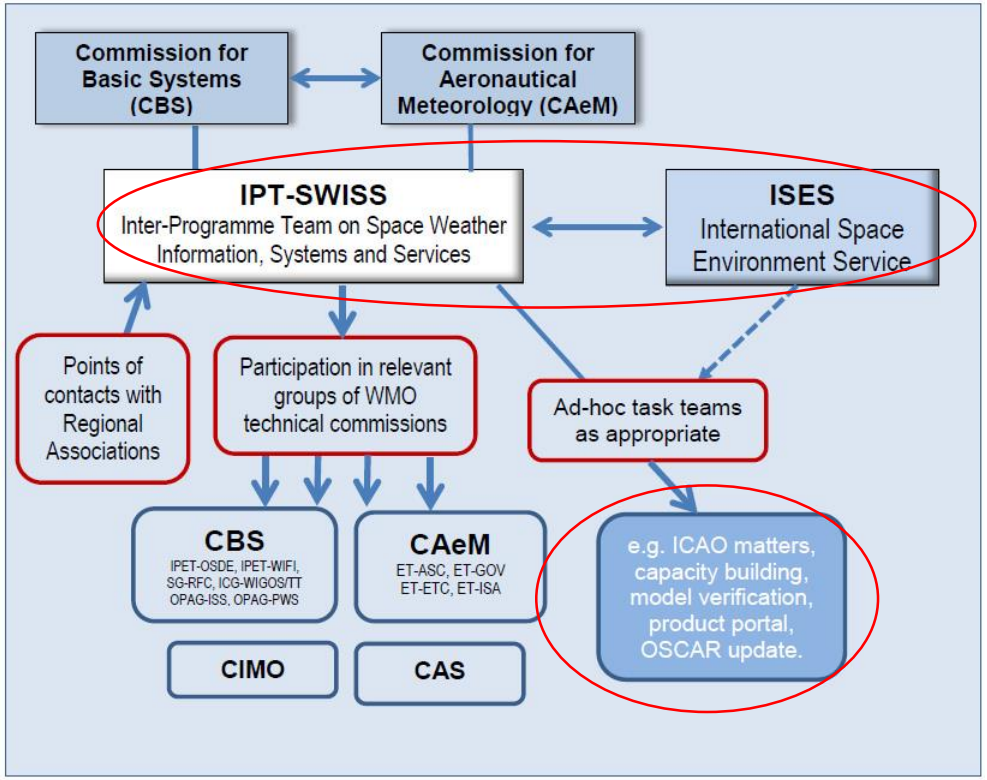


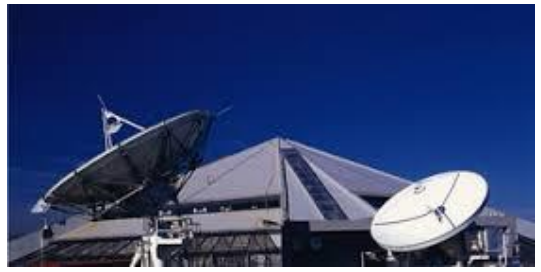
Figure 2: Proposed organization of space weather activities.

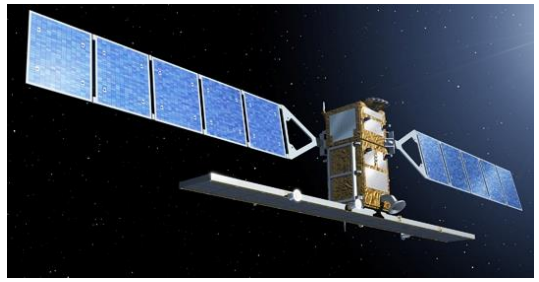
World Meteorological Organization

Weather • Climate • Water

Space Weather italian initiative for operations

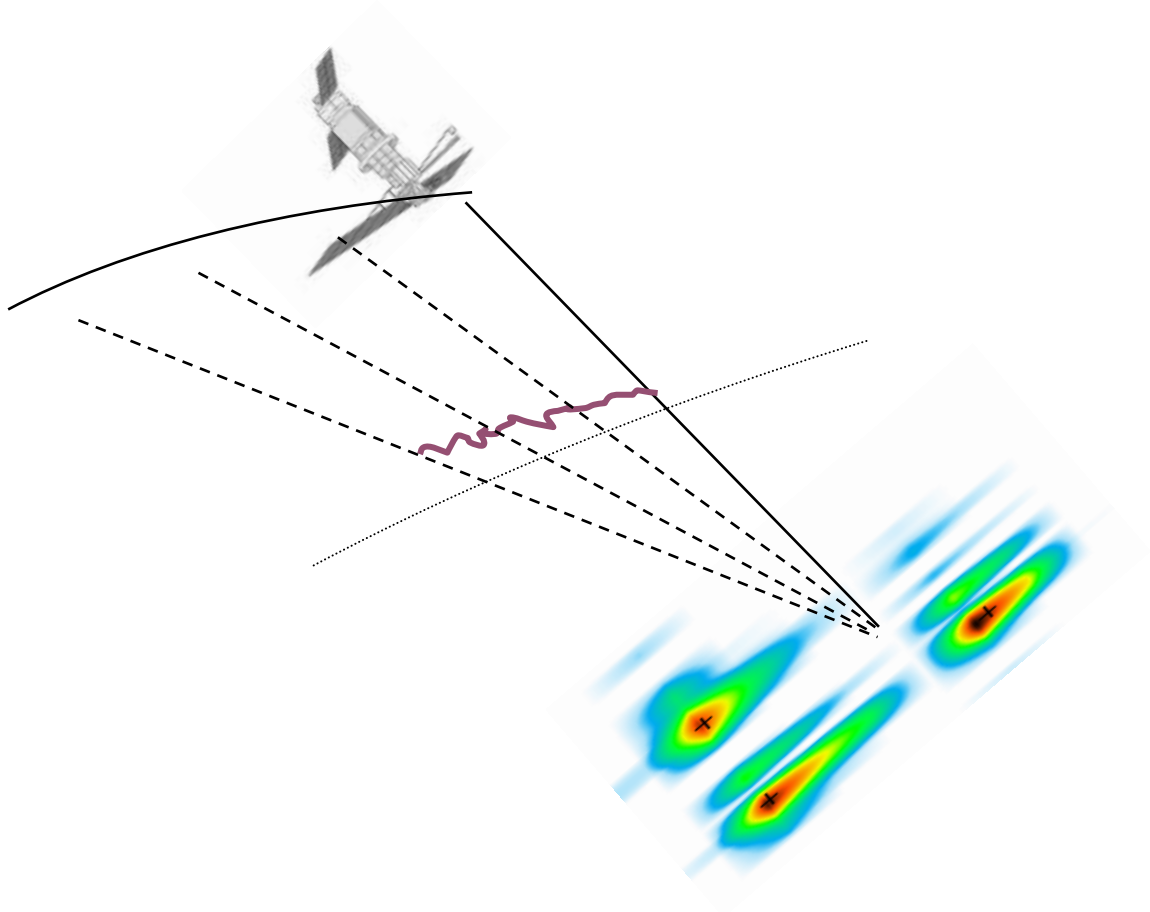
SW nowcasting and safety support





Space Weather knowledge is not only for safety but also for capacity augmentation, as weather.

Solar physics to Space Weather



Osservatorio Astronomico di Trieste
Astronomical Observatory of Trieste

Solar Physics activities in Trieste

ESA Space Weather Working Team, Steering Board Member

European Space Weather Week Programme Committee, Chair

NATO Science for Peace (SfP) Project 984894 on “Ionospheric Monitoring”, Co-Director

Solar Orbiter/METIS Co-Investigator, Responsible for the Italian segment data handling

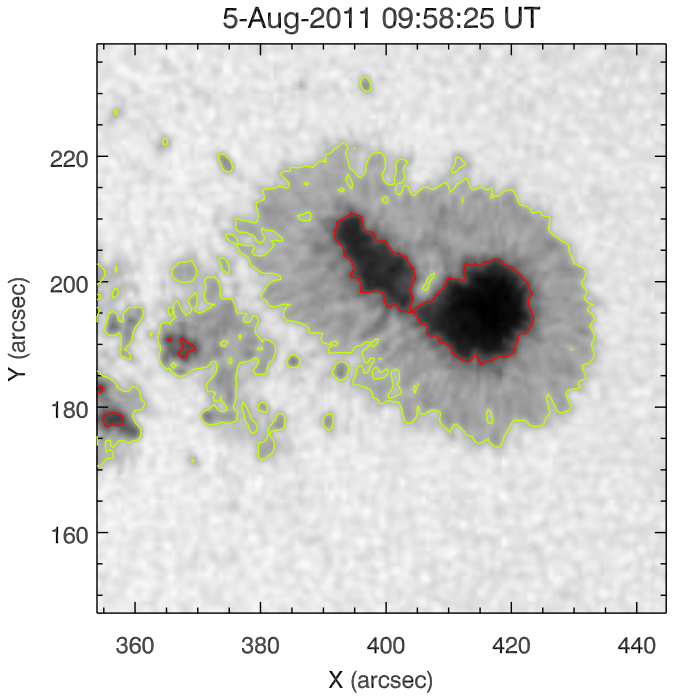
Solar Physics Group in Catania

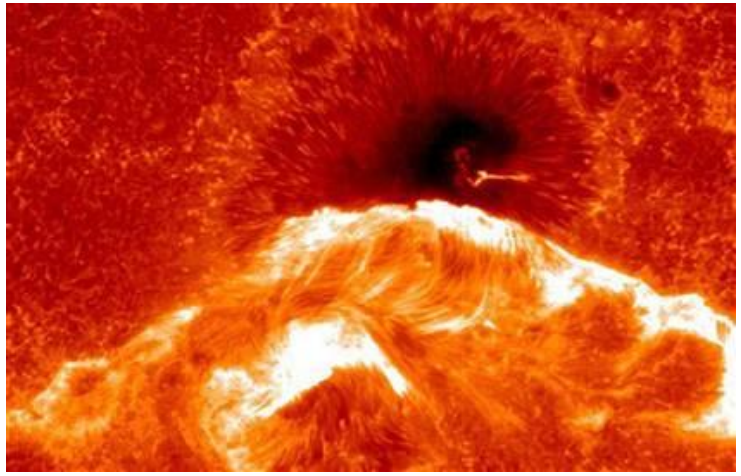
Personnel

V. Capparelli (UniCT), A. Compagnino (UniCT), M. Falco (INAF), S.L. Guglielmino (UniCT), M. Murabito (UniCT), P. Romano (INAF), F. Zuccarello (UniCT).

Main Research Fields

Participation in the European Solar Telescope Design Phase; Emergence of magnetic flux tubes in the solar atmosphere; Formation and evolution of solar active regions; Flares and Coronal Mass Ejections: drivers and effects on the space environment; Space Weather.





Methods

- Coordinated observing Campaigns between ground-based and space-based satellites
- Analysis of spectroscopic and spectro-polarimetric data acquired from space and ground.
- Design and development of new instrumentation for future ground based observations.

Solar Physics Group in Catania

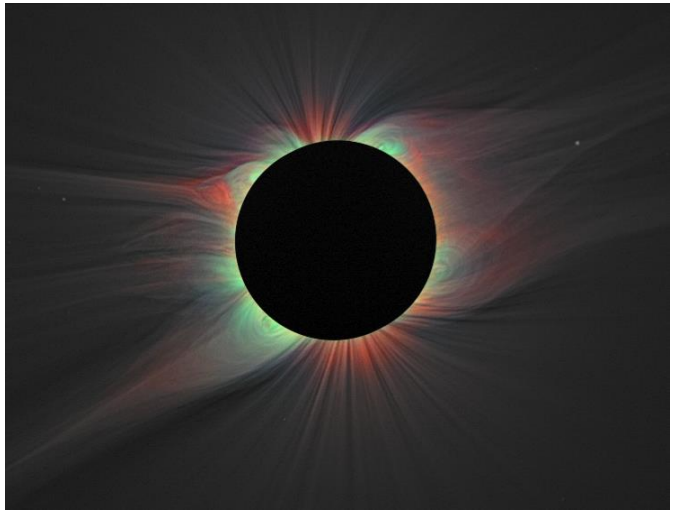
Project Name	Short description	Role	Timeline
SOLARNET	The project brings together and integrates the major European research infrastructures in the field of high-resolution solar physics, in order to promote their coordinated use and development (FP7)	Responsible for WP30: Networking Activities (Leader: F. Zuccarello)	2013 April 1 – 2017 March 31
F-CHROMA	To acquire, analyse and interpret ground- and space-based observational data of solar flares, test these against model predictions, and create an archive of solar flare observations and models (FP7)	Responsible for WP5: Joint analysis of space-based and ground-based observations (Lead: F. Zuccarello)	2014 January 1 – 2016 December 31
PRE-EST	To provide both the EST international consortium and the funding agencies with a detailed plan regarding the implementation of the European Solar Telescope.	Participation of UniCT and INAF teams	2017 April 1 – 2021 March 31
Metis	WL and UV Coronagraph for ESA-Solar Orbiter spacecraft → first close-up (0.3 AU) observations of coronal plasmas	Participation to Science Team	Launch: October 2018, nominal mission 7.5 years

Falco, M., Borrero, J. M., Guglielmino, S. L., Romano, P., Zuccarello, F., Criscuoli, S., Cristaldi, A., Ermolli, I., Jafarzadeh, S., Rouppe van der Voort, L.., 2016, Kinematics and Magnetic Properties of a Light Bridge in a Decaying Sunspot, Sol. Phys. 291, 1939

Solar Physics Group in Turin

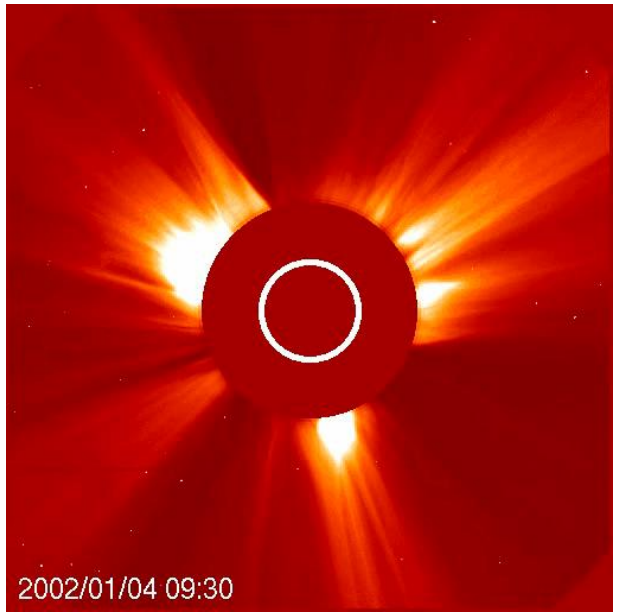
Personnel

E. Antonucci, S. Fineschi, A. Bemporad, C. Benna, G. Capobianco, M. Casti, F. Frassati, S. Giordano, S. Mancuso, G. Massone, R. Susino, D. Telloni, L. Zangrilli.



Main Research Fields

- Physics of the solar corona, understanding the origin and evolution of the main drivers of Geomagnetic Storms on Earth: Solar Wind and Coronal Mass Ejections (CMEs).



Methods

- Coordination of observational campaigns from space and ground (total solar eclipses)
- Development of diagnostic techniques for the analysis of coronagraphic and spectroscopic data acquired from space and ground.
- Development of new instrumentation for future space missions and ground based observations.

Solar Physics Group in Turin

Project	Short description	Role	Timeline
Metis 	WL and UV Coronagraph for ESA-Solar Orbiter spacecraft → first close-up (0.3 AU) observations of coronal plasmas	Leader of the international science consortium (PI: E. Antonucci)	Launch: October 2018, nominal mission 7.5 years
ASPIICS 	WL coronagraph for ESA-PROBA3 satellite → first eclipse-like, long-term observations of the inner corona	Italian leader for Formation Flying metrology (Lead Co-I: S. Fineschi)	Launch: 2019, nominal mission 2 years
SCORE 	Helium Sounding rocket coronagraph → first determination of coronal Helium abundance	Leader of the italian instrument consortium (PI: S. Fineschi)	First launch: September 2009, Second launch: 2017
ESCAPE 	Coronagraph in Antarctica (Concordia base) → first long-term coronal magnetic fields monitoring	Leader of the italian instrument consortium (Co-PI: S. Fineschi)	Deployment: Antarctic summer 2017/2018, nominal duration 3 years
SOLAR 	SOHO long-term Archive at Turin Obs. → archiving of space solar data (http://solar.to.astro.it/)	Hosted at, and maintained by INAF Turin Observatory	Established in 1996, still active

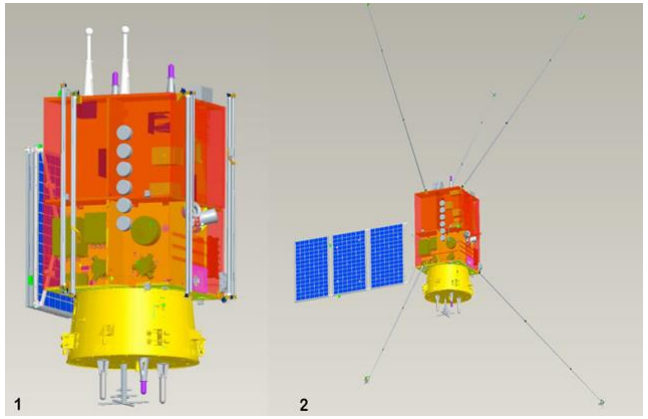
University of Rome Tor Vergata

https://www.fisica.uniroma2.it/solare

F. Berrilli, M. Casolino, D. Del Moro, L. Giovannelli, R. Forte, M. Lovric, M. Martucci, M. Mergè, L. Narici, V. Penza, G. Pucacco, F. Pucci, A. Rizzo, S. Scardigli, R. Sparvoli

Main Projects: FP7-EST, FP7-SOLARNET, H2020-GREST, EU-REACT-SPARC, EU-Ionosphere Prediction Service, PAMELA, ALTEA, CSES

Activity: Solar Dynamics and Activity, Sun-Earth interaction, Space Weather, Improve tools for solar synoptic observations and particle detection.



Italian Collaboration to CSES China Seismo-Electromagnetic Satellite

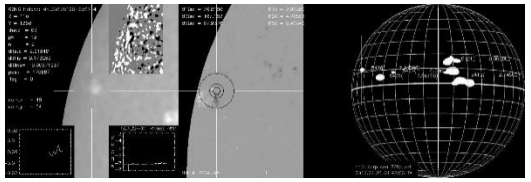
PAMELA satellite in orbit since 2006

The South Pole Solar Observatory

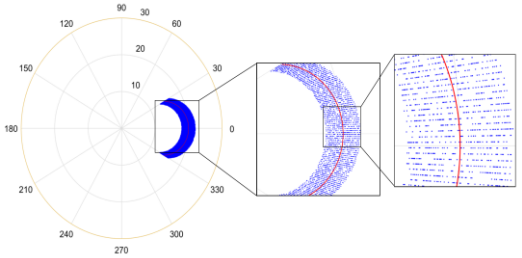
Amundsen-Scott South Pole Station
December 2016 - February 2017

Stuart Jefferies (GSU, IfA), Neil Murphy (NASA-JPL)
Bernhard Fleck (ESA), Bill Giebink (IfA),
Francesco Berrilli (UNITOV), Stefano Scardigli (UNITOV)

South Polar Solar Observatory: two telescopes based on Magneto Optical filters (MOF) for simultaneous LOS velocity maps and magnetograms at two heights.



Automated Solar Flare Forecasting with multiline MOTH synoptic magnetograms



24-h prediction for existing CMEs and long term probability for possible CMEs

PAMELA collaborations

Cosmic Rays Laboratory, Moscow Engineering and Physics Institute, Moscow, Russia
Laboratory of Solar and Cosmic Ray Physics, P.N. Lebedev Physical Institute Academy of Sciences, Moscow, Russia
Ioffe Physical Technical Institute, St. Petersburg, Russia
Physics Department of Siegen University, Germany
Royal Institute of Technology, Stockholm, Sweden

INAF-OAR
National Institute for Astrophysics
Rome Observatory

SAMM Solar Activity MOF Monitor

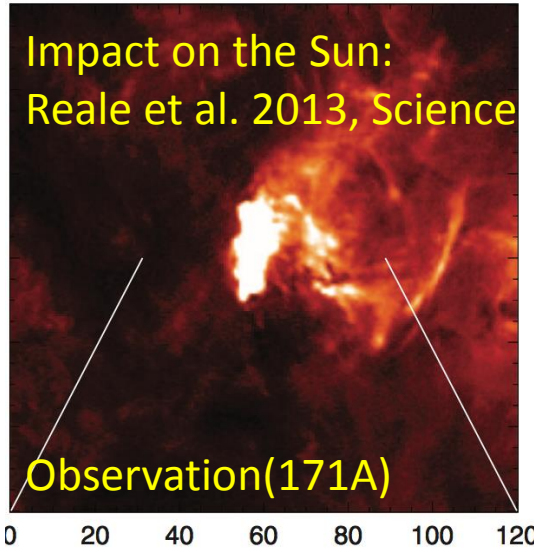
INAF personnel: R. Piazzesi, R. Speziali, M. Stangalini
Industrial Partner: Dal Sasso srl / **Avalon Instruments**

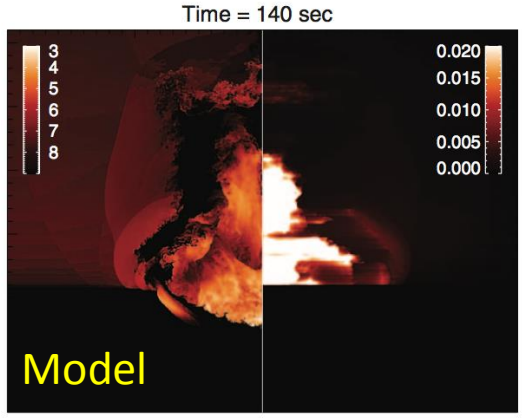
In cooperation with:
BDP Engineering and Manufacturing

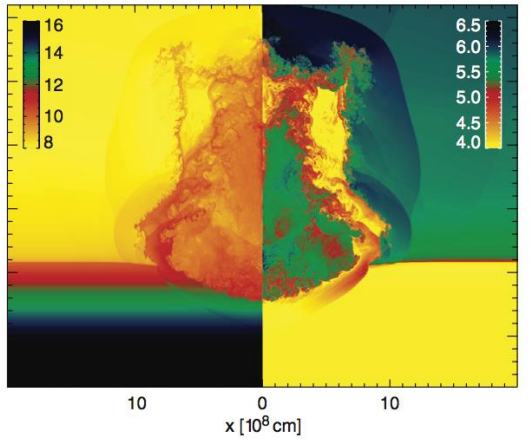
- Robotic tomographic telescope for the 3D reconstruction of magnetic fields and solar activity monitoring:
  - high cadence (5s)
  - multi-height (3 spectral lines coverage, from photosphere to chromosphere)
  - high sensibility (10 G)
- MOF (Magneto-Optical Filter) technology
- Funded by MiSE (Italian Ministry for Economic Development: 1 M€)
- Designed as prototype of a network
- First light: 2017 Q1

Solar Physics Group in Palermo

- **Personnel**
  - A. Ciaravella (INAF/OAPa), S. Orlando (INAF/OAPa), G. Peres (UniPa), F. Reale (UniPa)
- **Main Research Fields**
  - Heating and dynamics of magnetically confined and not confined coronal plasma;
  - Solar and stellar flares;
  - Coronal Mass Ejections;
  - Plasma diagnostics.
- **Methods**
  - MHD modeling and high performance computing (EU/PRACE)
  - Analysis of EUV and X-ray data from space missions (e.g., SoHO/UVCS, Hinode/XRT, Solar Dynamics Observatory/AIA)
  - Mission involvements: SoHO/UVCS, Hinode/XRT, Coronas-Photon/SphinX, Solar Orbiter/METIS



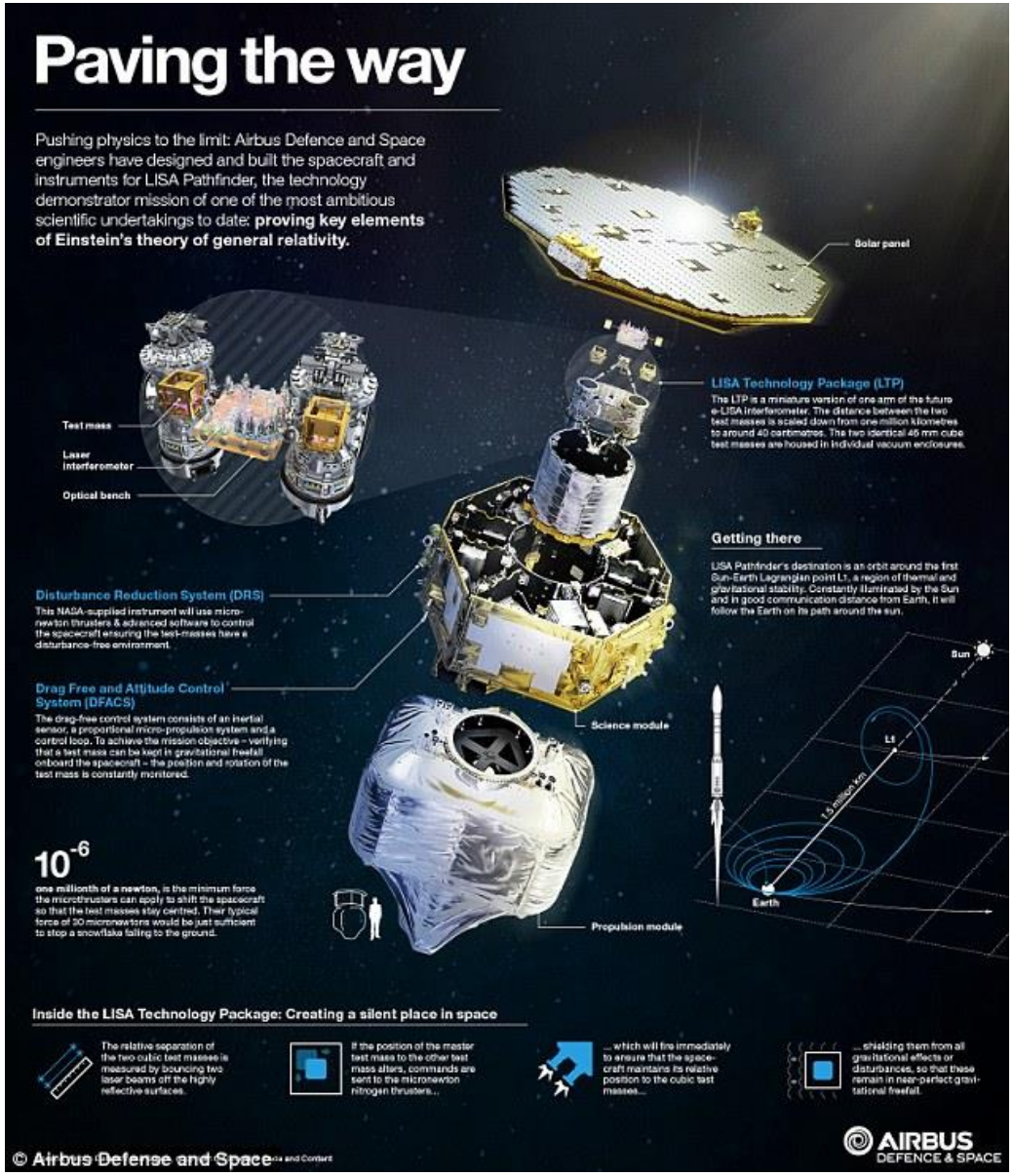




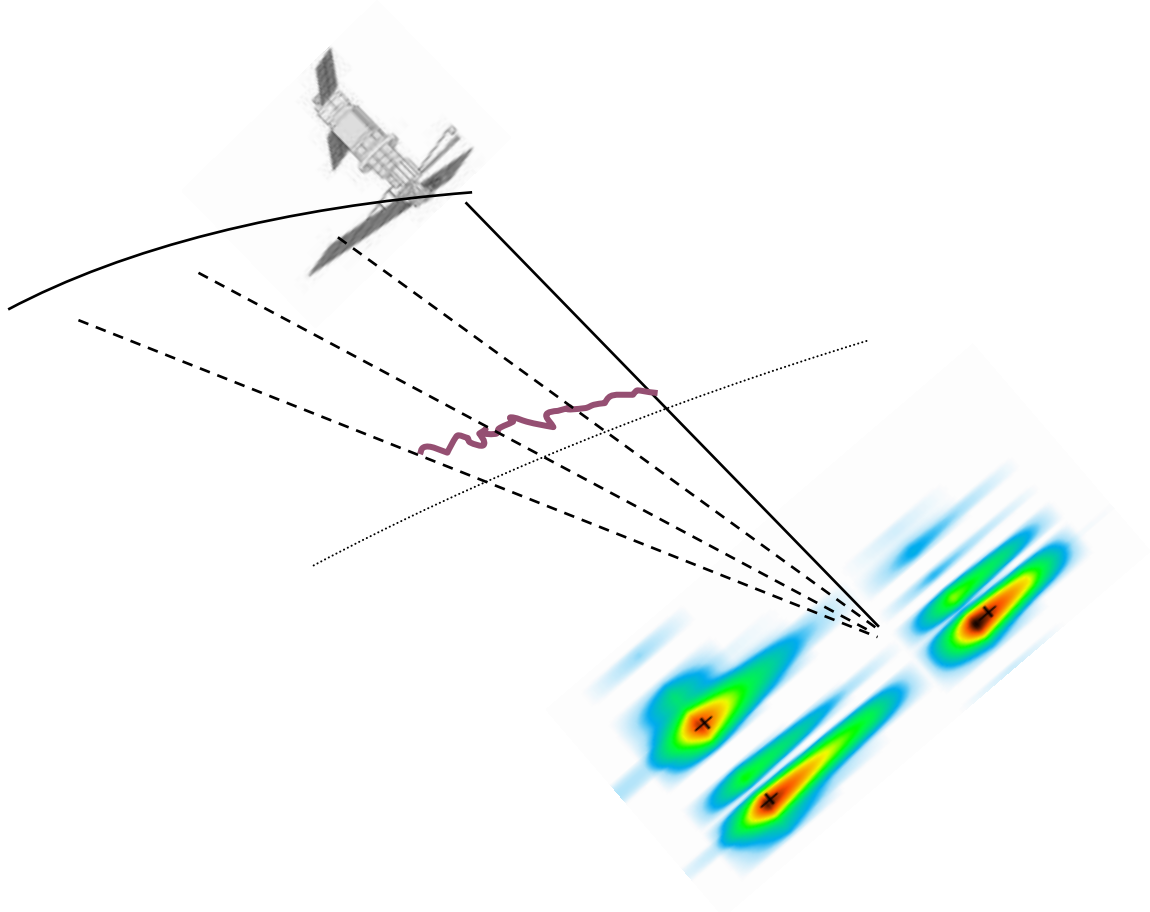
LISA PATHFINDER

- Mission dedicated environmental studies were carried out to estimate the impact of galactic cosmic rays and solar energetic particles on efficiencies of instruments in space

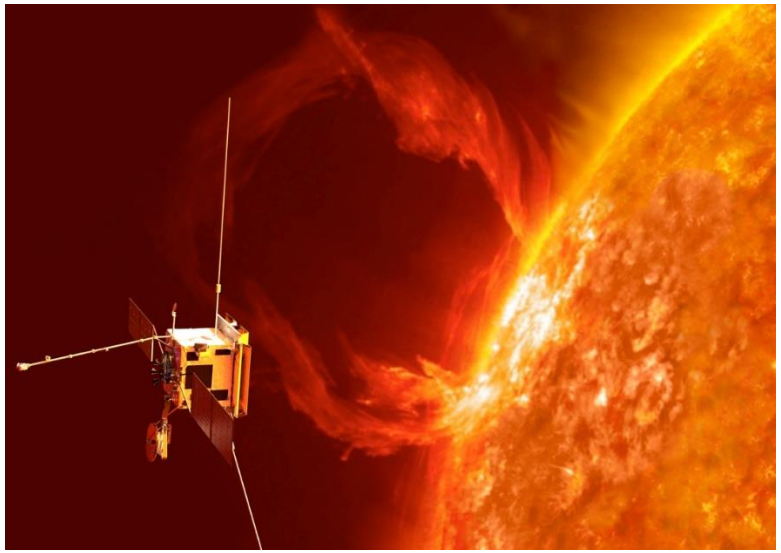
- Particle detector and magnetometers aboard LISA Pathfinder show capability of provinding alerts for geomagnetic activity



Interplanetary space physics to Space Weather

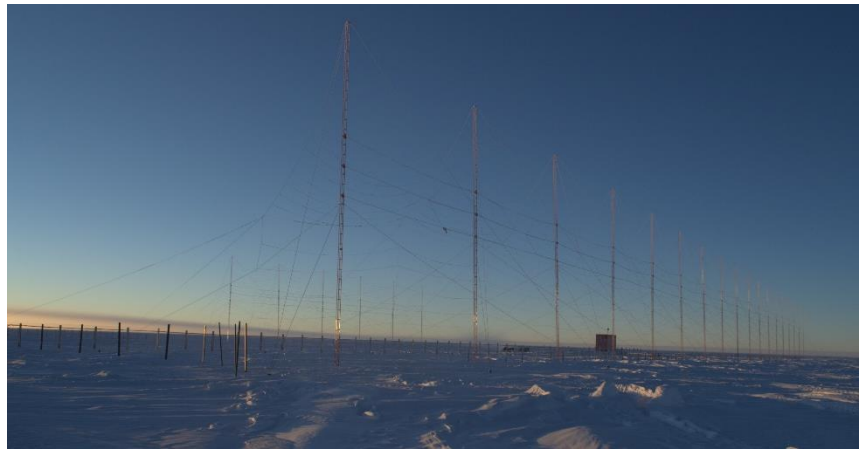


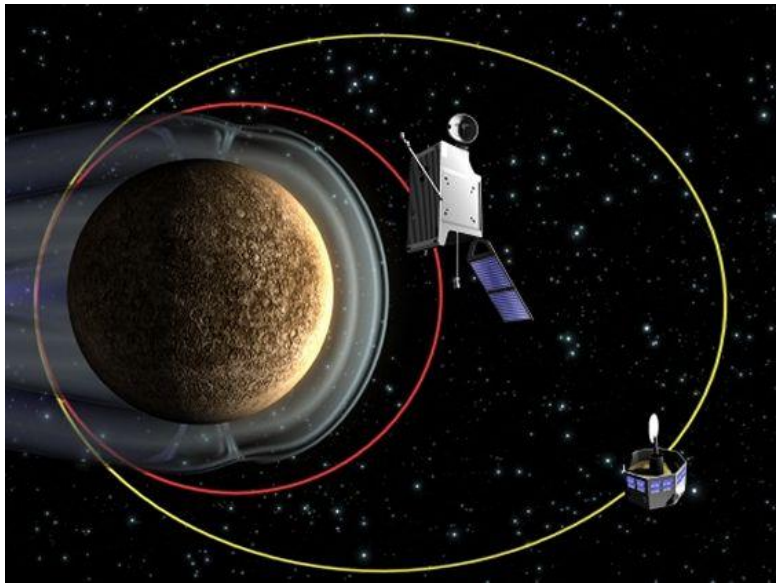
Interplanetary Space Physics Group @ INAF/PSSW



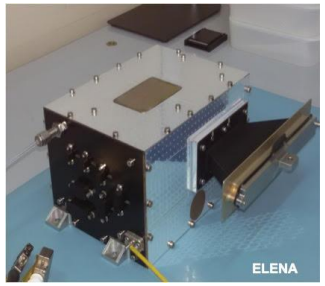
Solar Orbiter - A high-resolution mission to the Sun and inner heliosphere. The ISP group participates to the SWA, a plasma feature instrument suite, with the responsibility of the development of the on board DPU.

Super Dual Auroral Radar Network international network of HF ionospheric radars dedicated to the study of the magnetosphere-ionosphere system - The ISP group is responsible for the Dome C East radar located at the research station Dome Concordia in Antarctica.



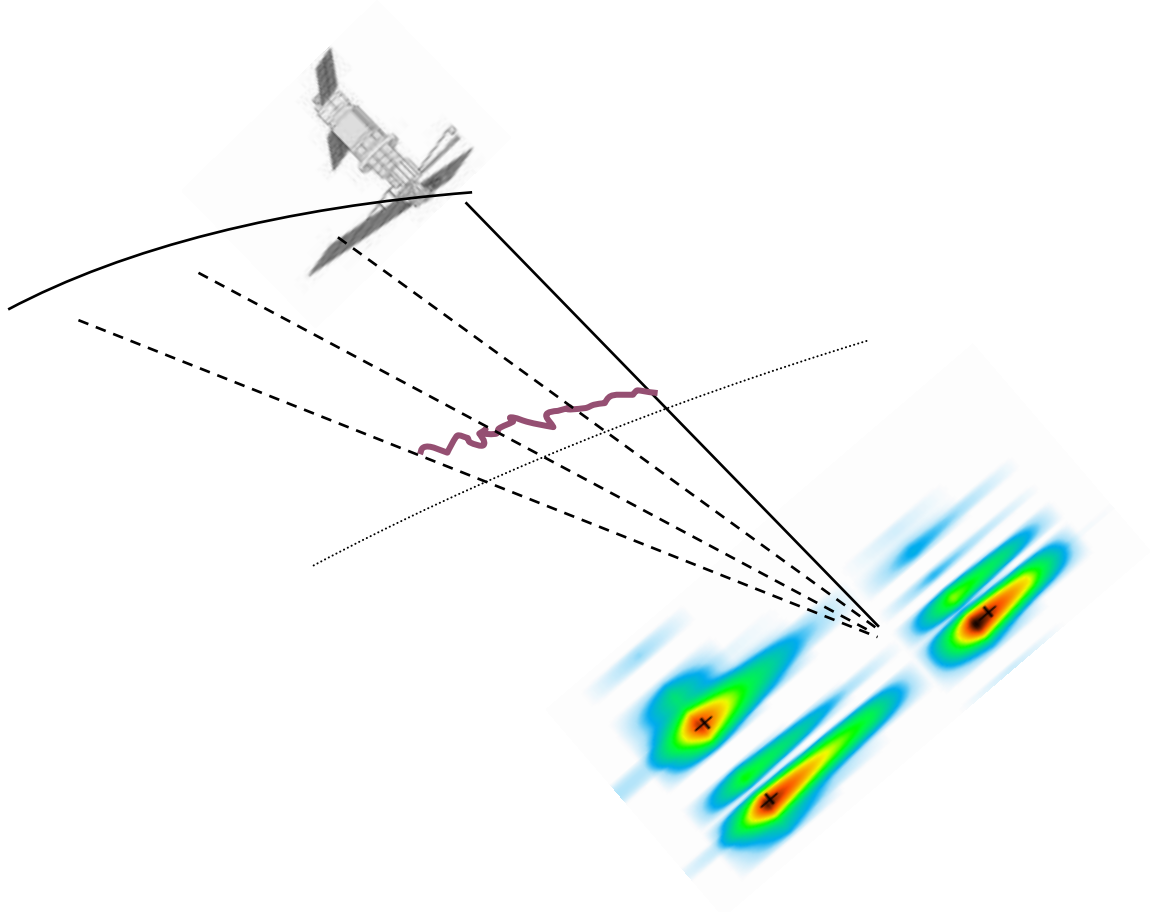


BepiColombo an ESA mission to Mercury – The PSSW group has the Pi-ship of the SERENA (Search for Exospheric Refilling and Emitted Natural Abundances) particle package on Mercury Planetary Orbiter and is involved in the MEA (Mercury Electron Analyzer) and SIXS (Solar Intensity X-ray and particle Spectrometer) experiments onboard Mercury Magnetospheric Orbiter and Mercury Planetary Orbiter, respectively.



The **ELENA** sensor, part of **SERENA** package, has been almost fully developed at INAF/ with the participation of CNR and IRAP. It will detect the energetic neutral atoms results of the solar wind interaction with Mercury’s surface"

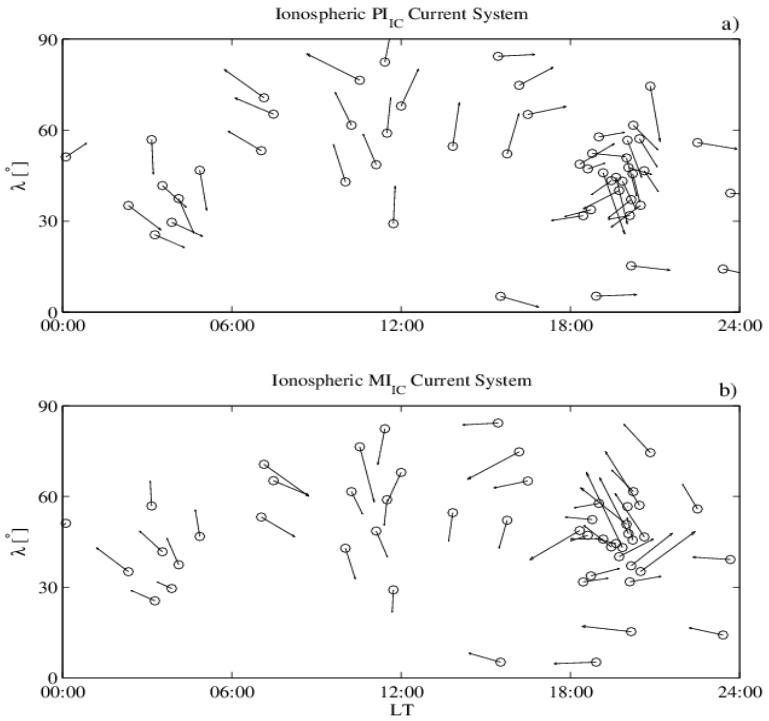
Solar-Terrestrial physics to Space Weather



SolarTerrestrial and Space Physics GROUP
Dipartimento di Scienze Fisiche e Chimiche
Università degli Studi dell'Aquila

University of L'Aquila

Analysis and modeling of magnetospheric, ionospheric and ground-based response to active Solar Wind (SW) conditions

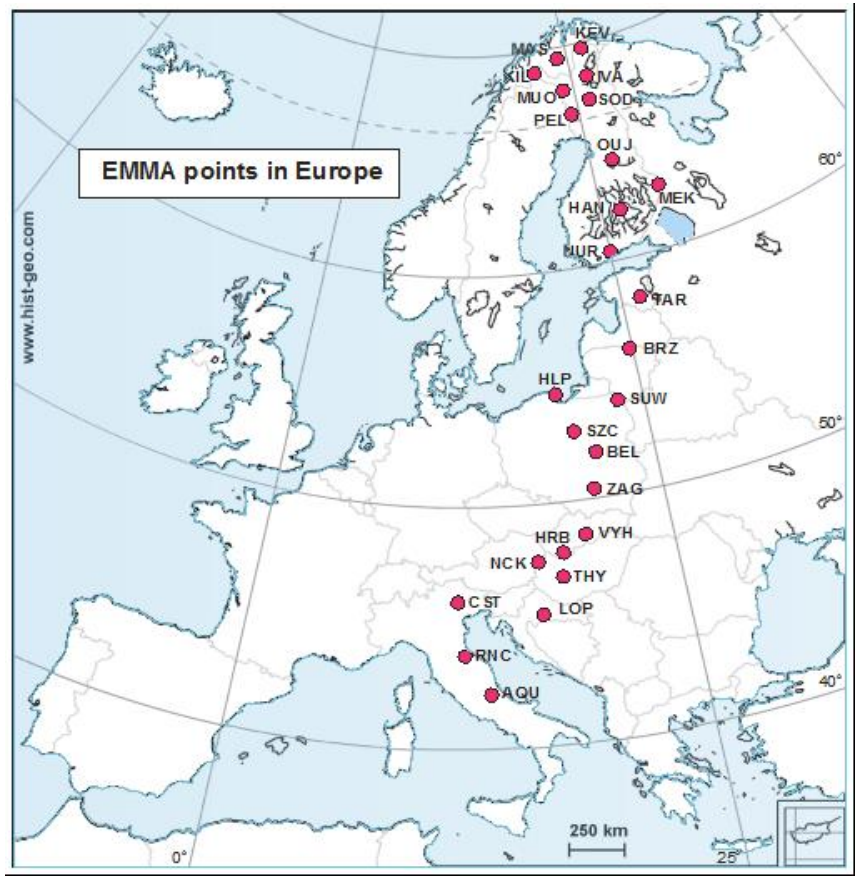


Example of the reconstruction of the Global ionospheric current flow pattern during theJune 22, 2015 SI event.

Scientific collaborations

- *Geological and Geophysical Institute of Hungary, Hungary*
- *Electrical Engineering Department, New Mexico Tech, USA*
- *Institute of Geophysics-PAS, Poland*
- *Finnish Meteorological Institute, Finland*
- *Space Research Institute (IWF), Graz, Austria*
- *School of Mathematical and Physical Sciences, University of Newcastle, Callaghan, New South Wales, Australia.*
- *Physics Department, University of Calabria, Rende (CS), Italy.*
- *National Institute for Geophysics and Volcanology INGV, Rome, Italy.*
- *National Research Council, Institute for Complex Systems ISC-CNR, Florence, Italy.*
- *Space Research Centre of RMIT University, Australia.*
- *NASA's Goddard Space Flight Center, U.S.A*

EMMA magnetometer Array: 25 stations, 1.6 < L < 6.1



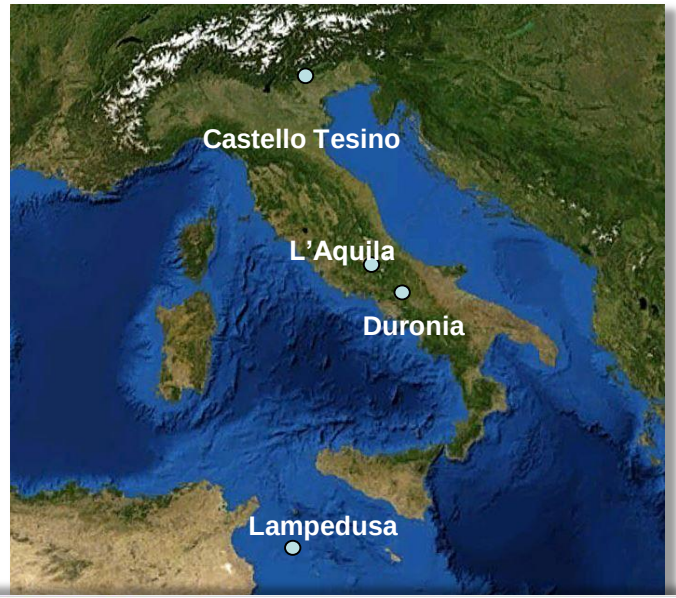
Mirko Piersanti, U. Villante: **On the discrimination between magnetospheric and ionospheric contributions on the ground manifestation of Sudden Impulses.** *Journal of Geophysical Research: Space Physics* 07/2016; DOI:10.1002/2015JA021666.

B. A. Carter, E. Yizengaw, R. Pradipta, J. M. Weygand, Mirko Piersanti, A. Pulkkinen, M. B. Moldwin, R. Norman, K. Zhang: **Geomagnetically induced currents around the world during the 2015 St. Patrick's Day storm**. *Journal of Geophysical Research: Space Physics* 10/2016; DOI:10.1029/2016JA023344.

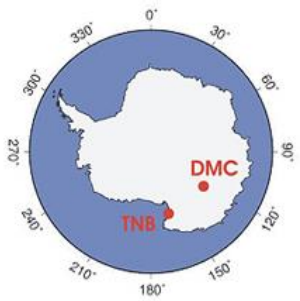
Mirko Piersanti, Claudio Cesaroni, Luca Spogli and Tommaso Alberti, **Does TEC react to a sudden impulse as a whole? The 2015 Saint Patrick's day Storm event.** Accepted *in Advances in Space Research*, 2017.

De Lauretis, M., M. Regi, P. Francia, M.F. Marcucci, E. Amata, and G. Pallocchia (2016), **Solar wind driven Pc5 waves observed at a polar cap station and in the near cusp ionosphere**, *J. Geophys. Res.: Space Physics*, doi:10.1002/2016JA023477.

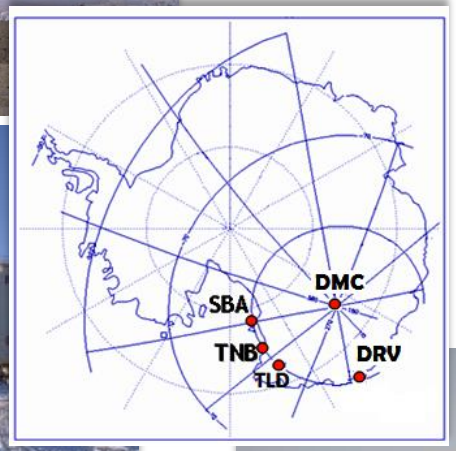
Geomagnetic Observatories

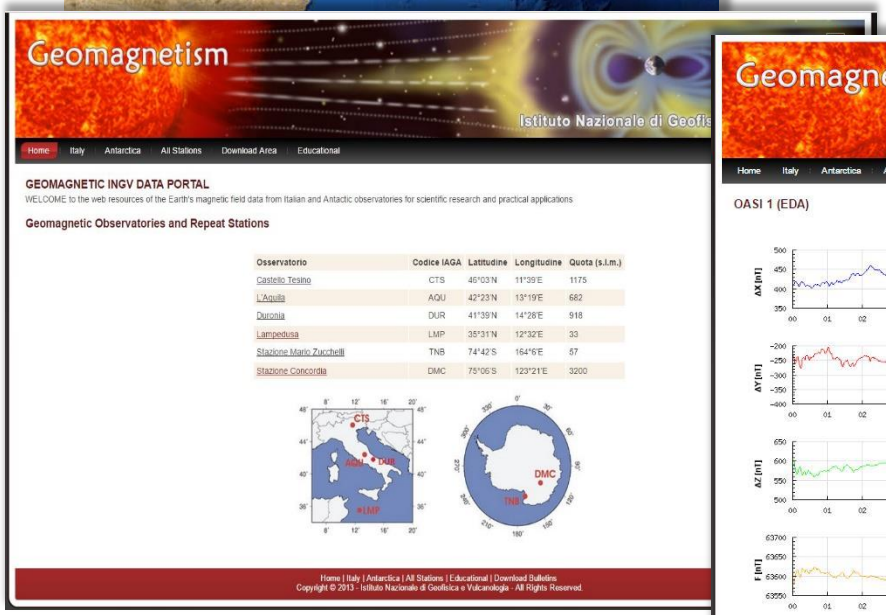


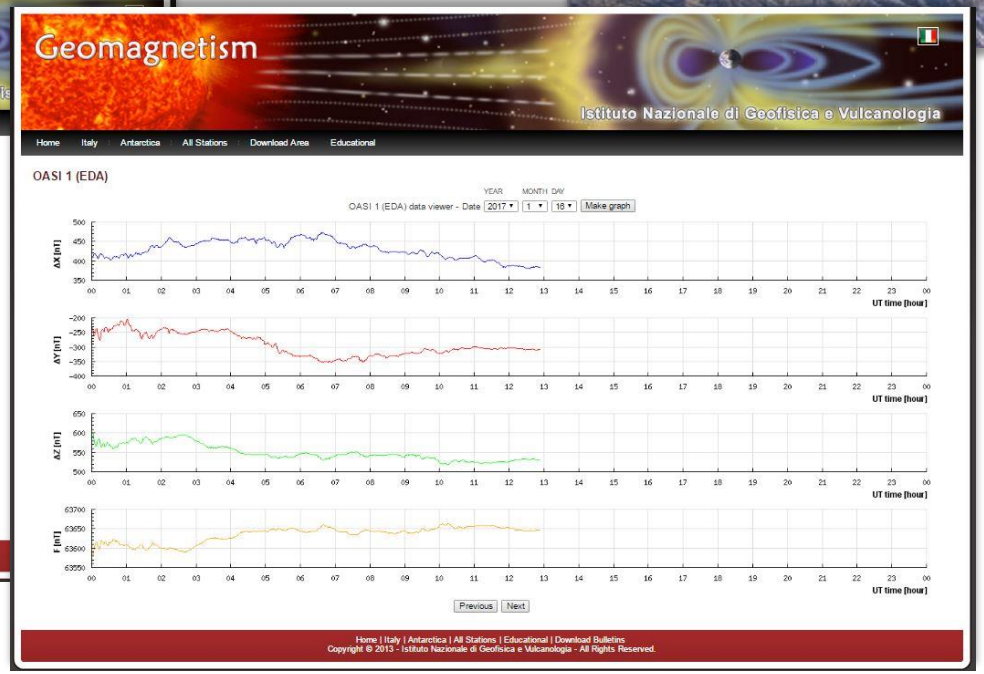
Italy



Antarctica

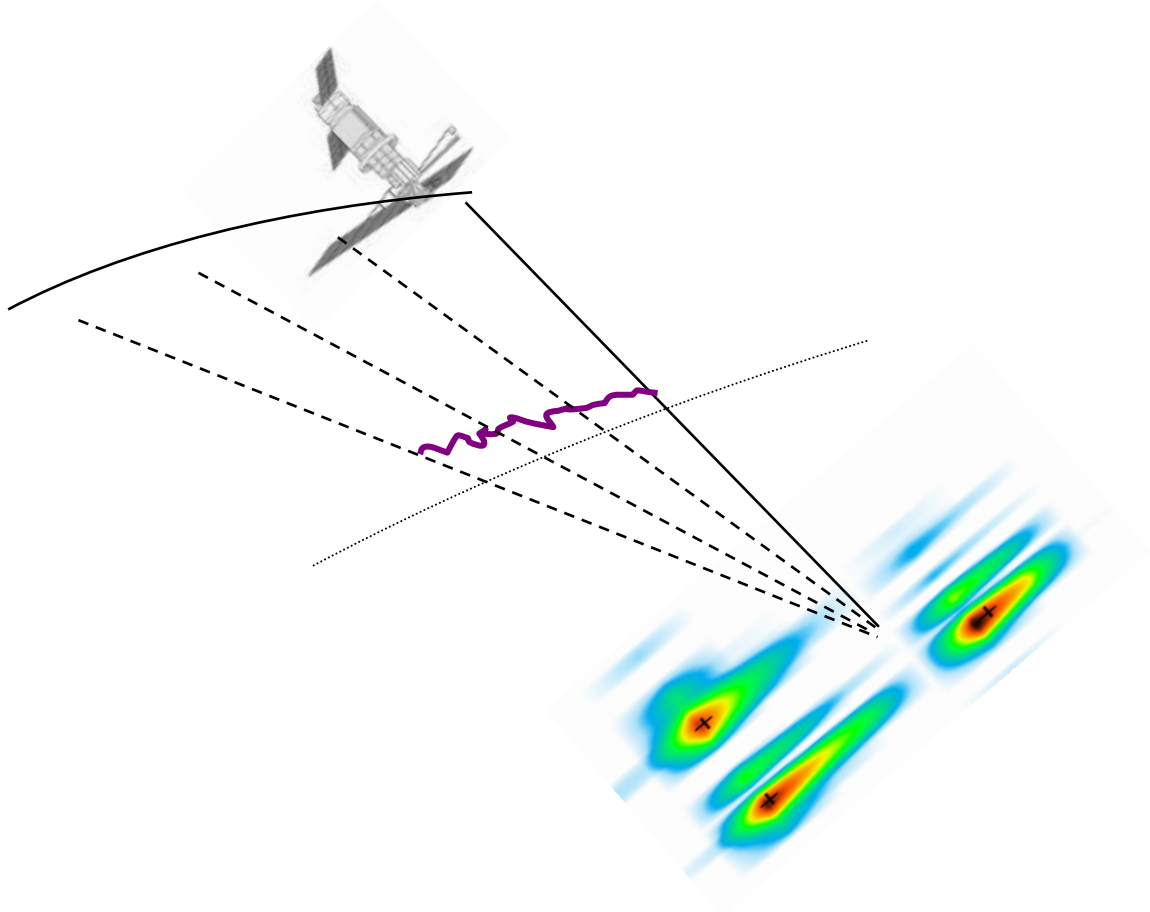




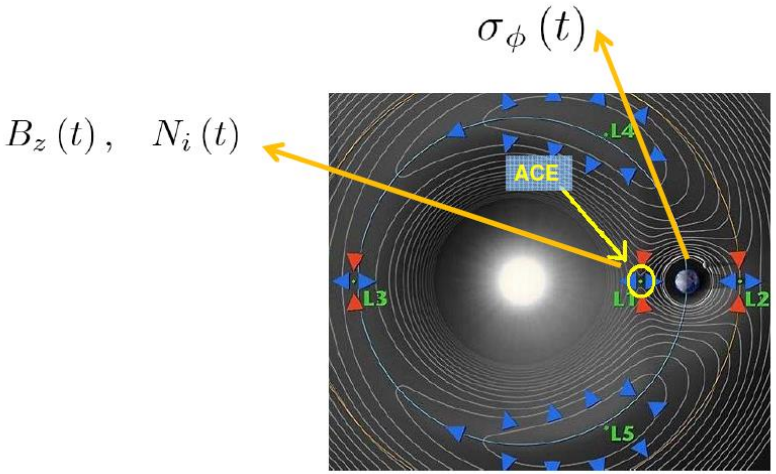


Observatory data are available **in real time** at the following URL address: http://geomag.rm.ingv.it

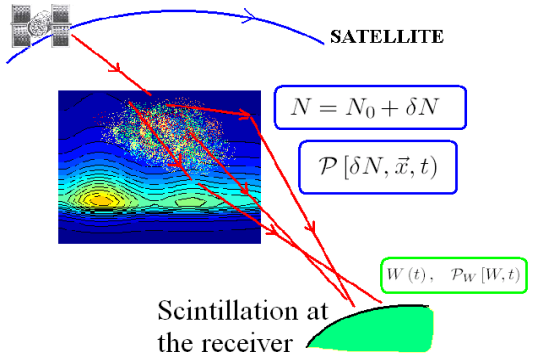
Upper atmosphere physics to Space Weather



National Research Council (Institute for Complex Systems) Recent Activities:



Predictive Space Weather via information theory tools for data analysis



Ionospheric irregularity sensing through multi-scale analysis of radio scintillation on GNSS signals

- Space Research Centre of the Polish Academy of Science, Warsaw, Poland (ionospheric irregularities and radio scintillation)
- Centre for Theoretical Physics of the University of Marseille, France (dissipative Magneto-Hydro-Dynamics)
- University of Bath, UK (information theory analysis tools applied to Space Weather)

Wernik, A. W., L. Alfonsi, and M. Materassi (2007), Scintillation modeling using in situ data, Radio Sci., 42, RS1002, doi:10.1029/2006RS003512.

Ionospheric Observatories

Gibilmanna (Italy)

Rhombic Antennas (TX and RX)

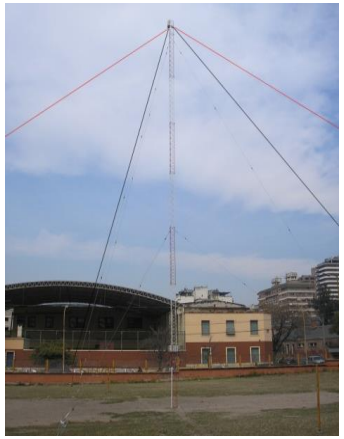
AIS - INGV

Rome (Italy)

AIS - INGV

Antennas (TX and RX)

S. Miguel de Tucumán and Bahia Blanca (Argentina)



Delta Antennas (TX and RX)

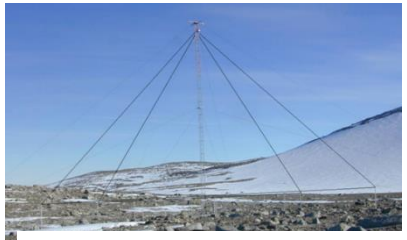
AIS – INGV

with

AUTOSCALING

Mario Zucchelli Station (Antarctica)

AIS - INGV



Antennas (TX and RX)

Space Weather forecast

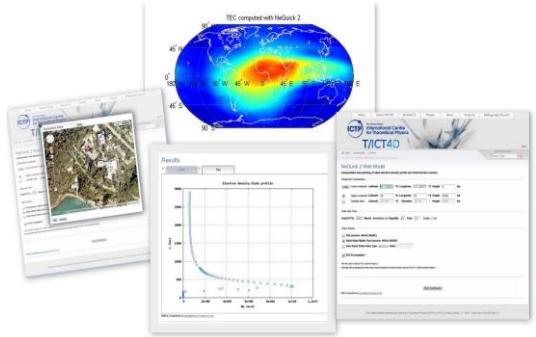
Achievement of forecasting and nowcasting three dimensional (3-D) electron density mapping of the ionosphere.

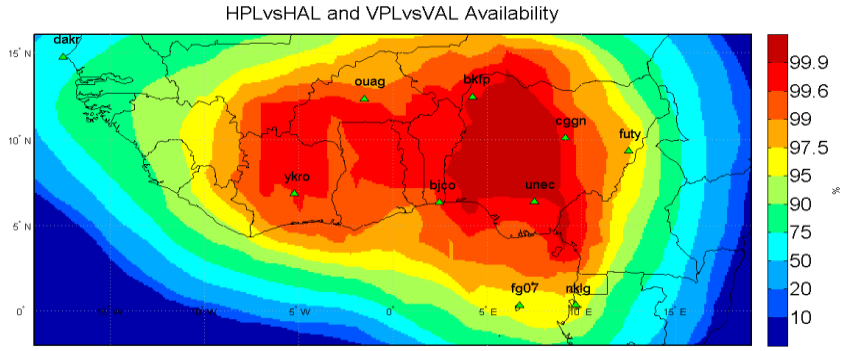
EUROMAP forecasting model 24 hours in advance - FORECASTING OF CRITICAL FREQUENCY OF F2 LAYER

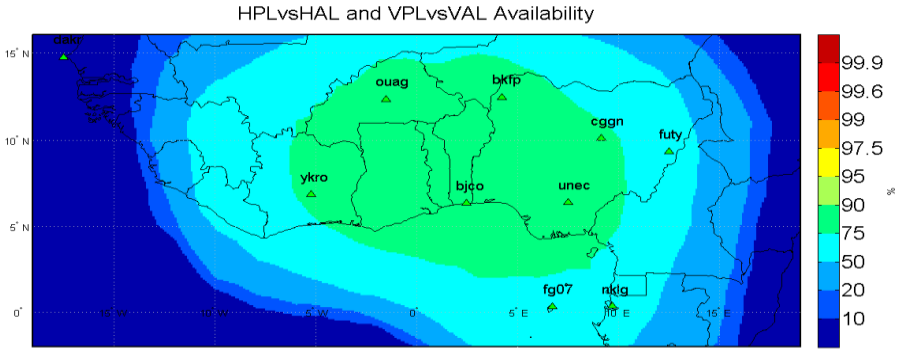
Space Weather studies in the ICTP, Trieste

Ionospheric Modeling: **NeQuick model**

- **NeQuick 2** recommended by ITU-R for trans-ionospheric RP applications (Rec.P531).
- **NeQuick v.1** has been used to produce 'ionospheric scenarios' for EGNOS.
- Basis of the model for the GALILEO single frequency ionospheric correction algorithm.







Examples of SW effects on an SBAS availability performance in West Africa

Projects related to SW studies:
ESA ALCANTARA Initiative (AFRICA)
ESA Monitor
EC – ICTP TREGA (TRaining on EGNOS GNSS in Africa)

INGV GNSS receivers network for ionospheric scintillation and TEC (including Galileo)

- First receiver installed at Ny-Alesund (Svalbard) on 2003
- Polar ionosphere
  - Svalbard islands (3)
  - Antarctica (4)
- Mid latitude ionosphere
  - Chania (Crete)
  - Huelva (Spain) – stopped
  - Huelva station moved to Lampedusa
- Equatorial Ionosphere
  - Tucuman (Argentina)

Data are accessible at the *electronic Space Weather upper atmosphere* website

eSWua

www.eSWua.ingv.it

INGV terremoti vulcani ambiente

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

GINESTRA – MIMOSA - MEDSTEC

COMPETENCE SURVEYS WITHIN THE ESA ALCANTARA INITIATIVES

MImOSA2

Monitoring **I**onosphere **O**ver **S**outh **A**merica to support high precision applications

ERICA

Equato**R**ial **I**onosphere **C**haracterization in **A**sia

WHO WITH

INGV terremoti vulcani ambiente – Istituto Nazionale di Geofisica e Vulcanologia

ISMB – Istituto Superiore Mario Boella

The University of Nottingham – United Kingdom · China · Malaysia

Politecnico di Torino

Đại học Bách Khoa – navis

unesp

INPE

LAPAN

V.A.S.T

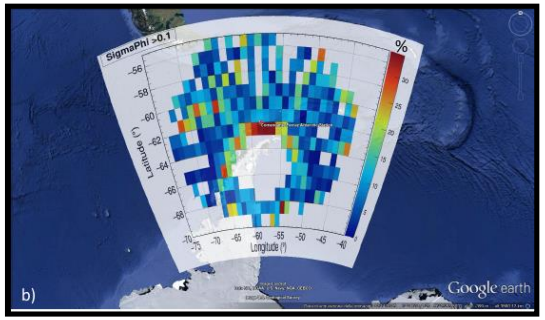
Đại học Bách Khoa

Demonstrator for GNSS Research and Application for Polar Environment

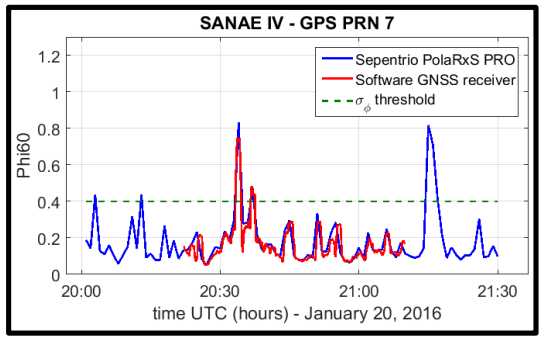
A pilot project for Space Weather e-science in Antarctica

This project has received funding from the PNRA, under contract 2013/C3.01.

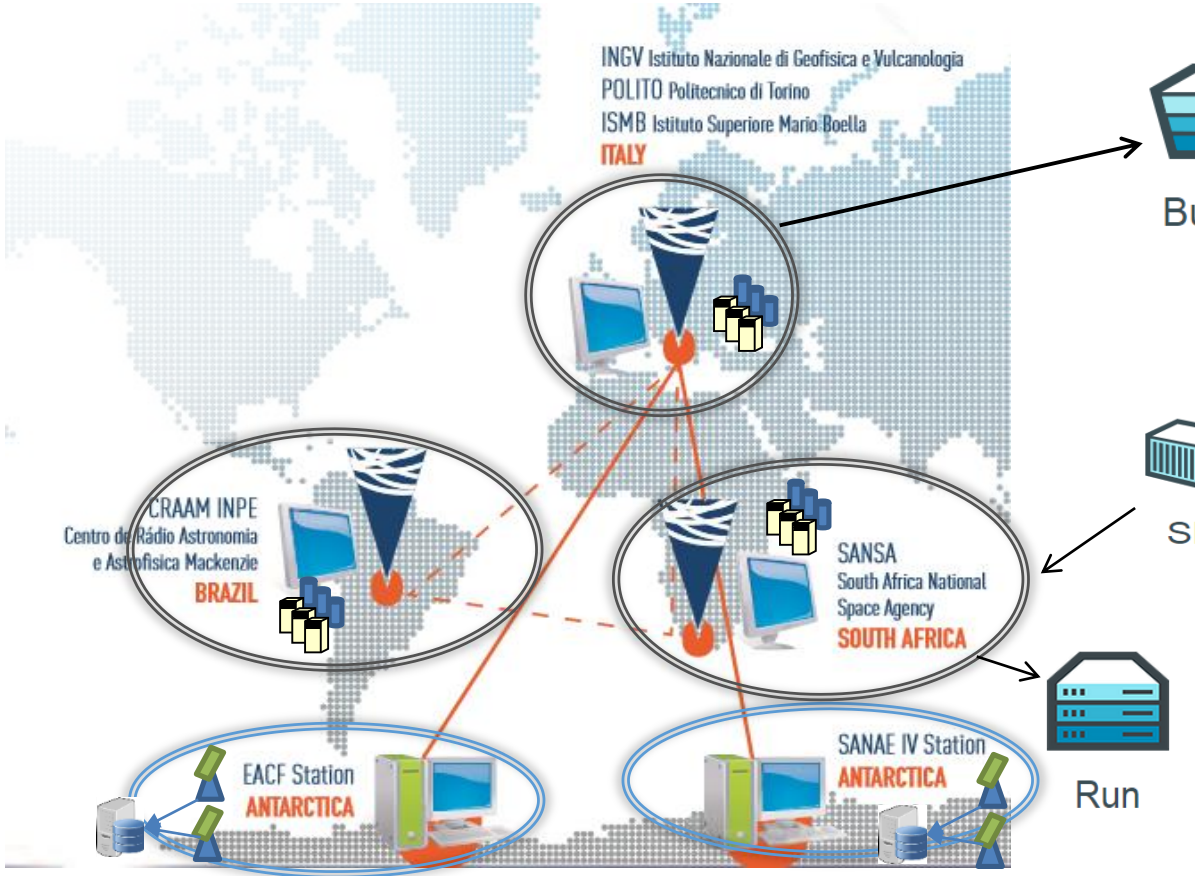
The DemoGRAPE software handled by the Federated Cloud



Comandante Ferraz occurrence of $\sigma_\Phi > 0.1$ - 10-13 November 2015



σ_Φ monitoring from SDR and Professional receiver SANAE IV 20 January 2016



DemoGRAPE Data Management
From Polar Regions to Scientist Community

Sensors, equipments for scientifics measurements

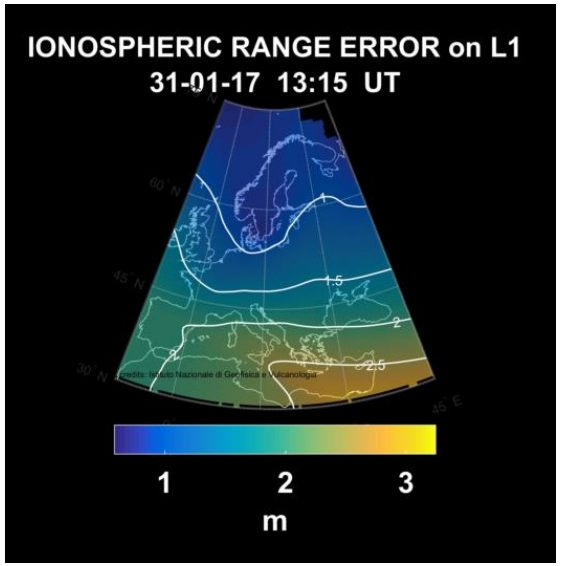
- Building applications
- Moving applications to data
- Data upload
- Sensors
- Dataset
- Resources

Ionospheric Prediction Service

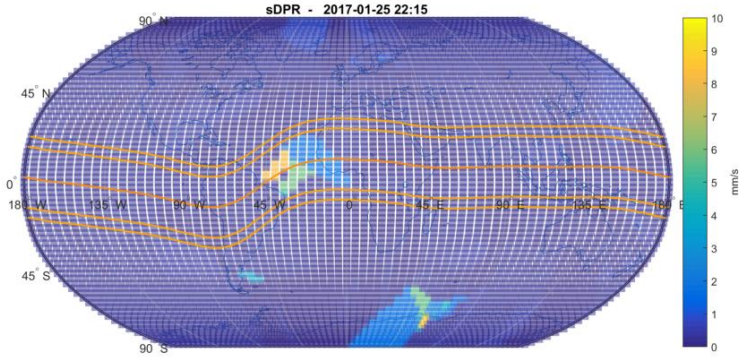
Parameter(s)	Type of casting	Refresh rate (min's)	Coverage	Spatial Resolution (lat x long)
TEC, IRE, TEC_gradNS, TEC_gradEW	Nowcasting	10	Italy	0.1° x 0.1°
TEC, IRE, TEC_gradNS, TEC_gradEW	Nowcasting	15	Europe	0.5° x 0.5°
TEC, IRE, TEC_gradNS, TEC_gradEW	Nowcasting	15	Global	2.5° x 5°
TEC, IRE	Short term (30 minutes)	10	Italy	0.1° x 0.1°
TEC, IRE	Short term (30 minutes)	15	Europe	0.5° x 0.5°
TEC, IRE	Short term (30 minutes)	15	Global	2.5° x 5°
TEC, IRE	Long term (24 hours)	120	Global	2.5° x 5°
Scintillation indices (S4, σ_Φ)	Nowcasting	15	Europe	Values at the IPP
Proxy scintillation indices (PSI)	Nowcasting	15	Global	2.5° x 5°
Proxy scintillation indices (PSI)	Long term (24 hours)	180	Global	2.5° x 5°

Example of the products

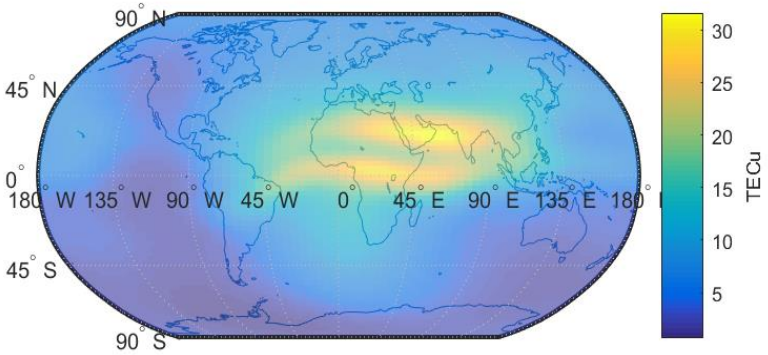
Nowcasting IRE over Europe



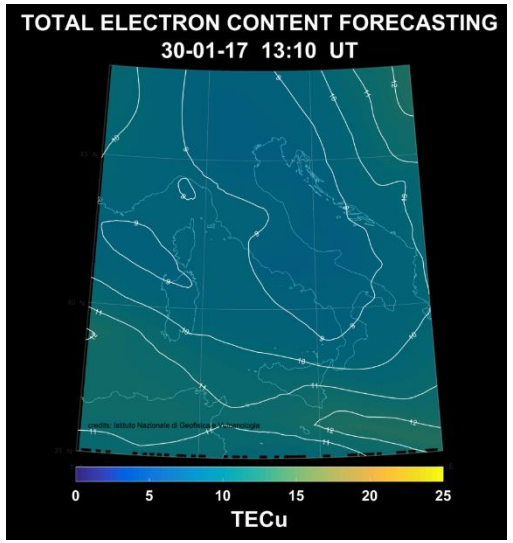
Nowcasting PSI at global level



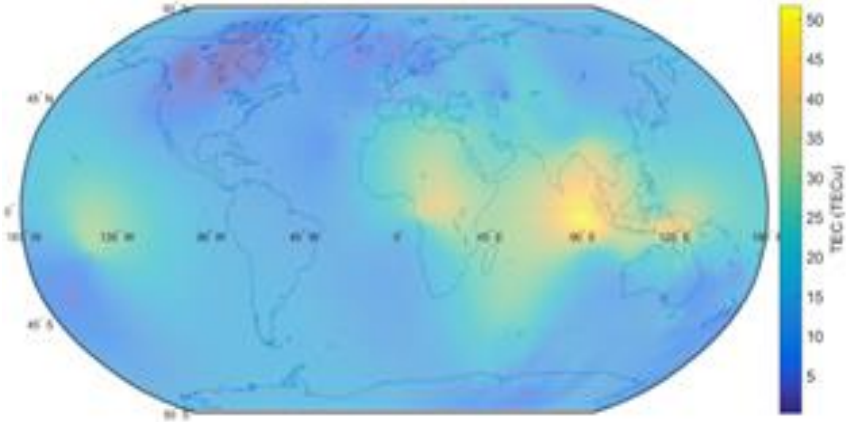
Long term forecasting TEC at global level



Short term forecasting TEC over Italy

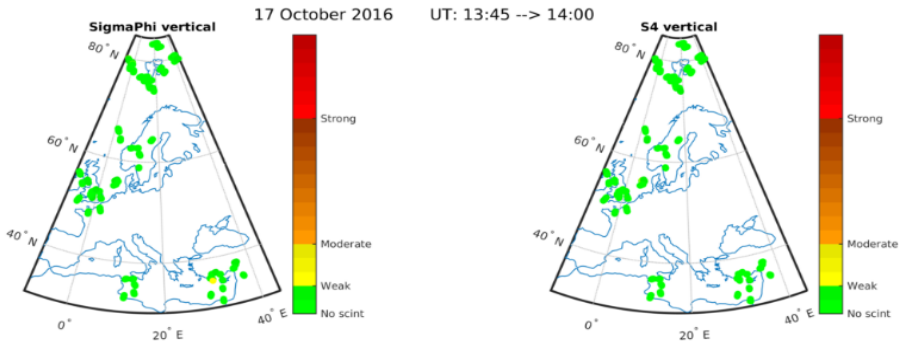


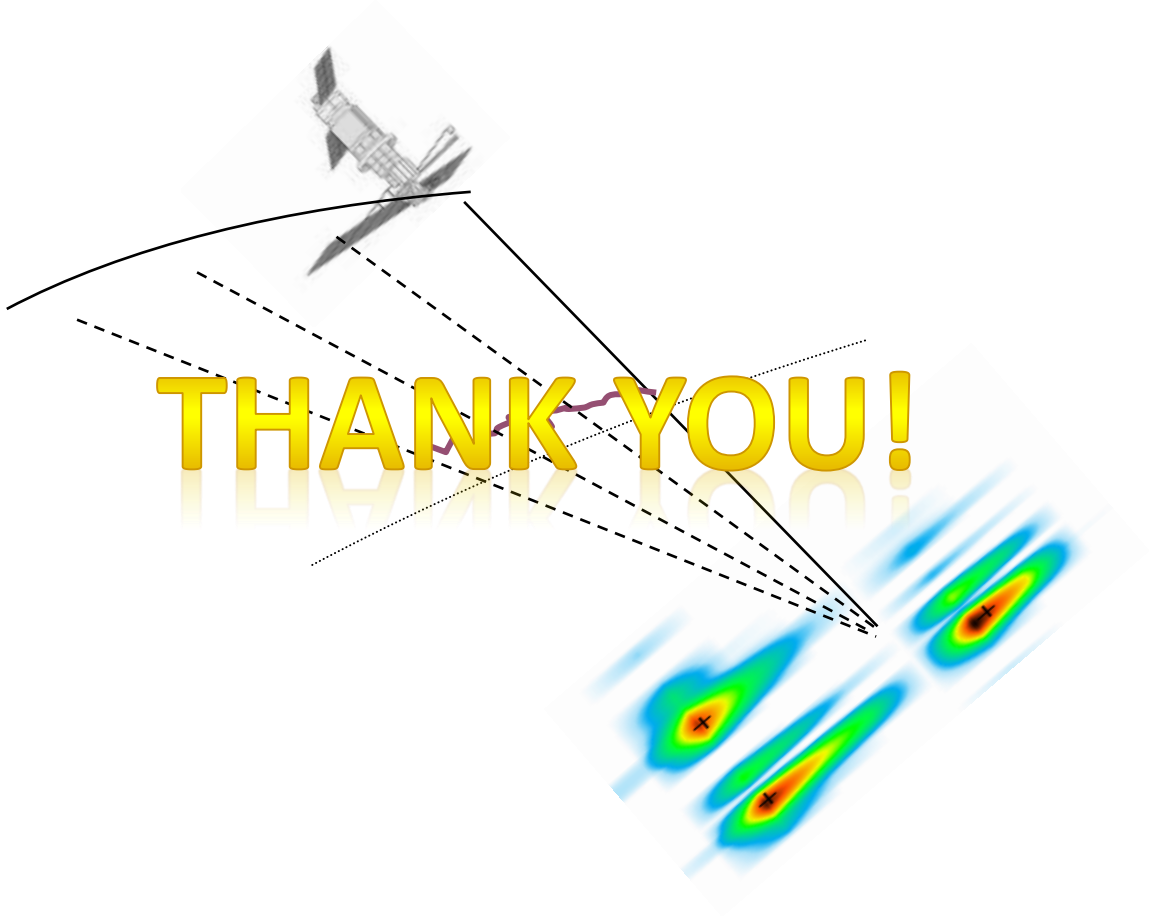
Nowcasting TEC at global level



10 October 2016 at 09:00 UT

Nowcasting scintillation indices over Europe





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