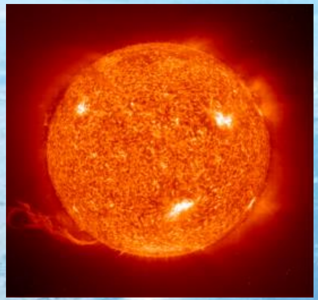
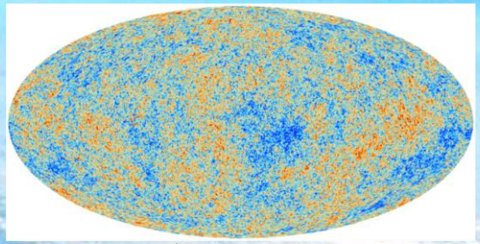
# Astronomy/Astrophysics/Atmosphere

## PNRA activities: state of art






**Massimo Gervasi**

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Comitato per la Ricerca Polare – CNR

Physical Science Group - SCAR

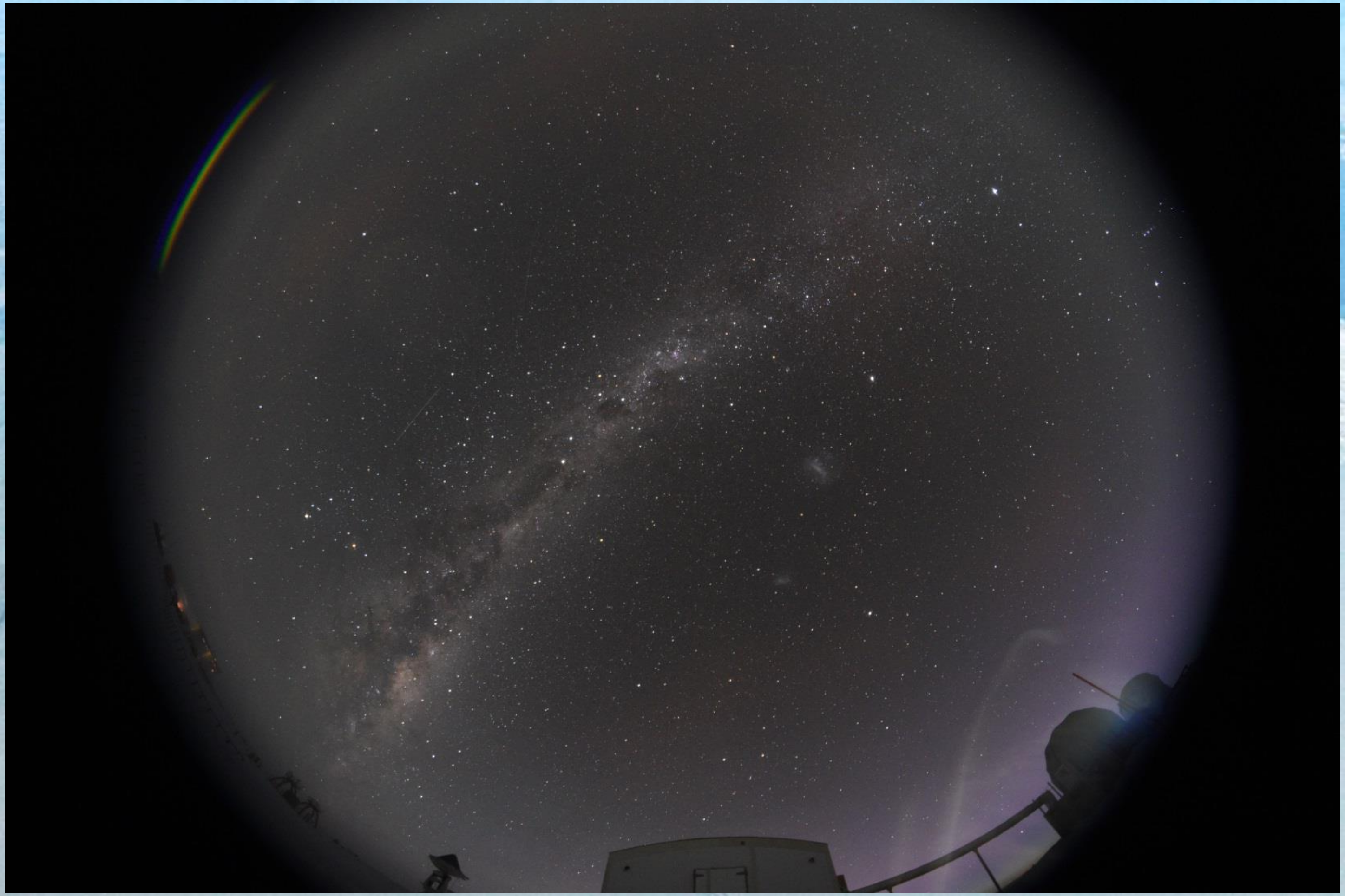
# Astronomy/Astrophysics/Atmosphere

## Outline

- ❑ Science Motivations: peculiarities of the place
- ❑ Recommendations from AAA-SCAR and Antarctic community
- ❑ PNRA activities:
  - Deep Universe observations;
  - Solar observations;
  - Ionosphere and Space Weather.

# Astronomy/Astrophysics/Atmosphere

## Antarctica: a special place for sky observations



# Astronomy/Astrophysics/Atmosphere

## Antarctica: a special place for sky observations

- **Atmospheric transparency** in Infrared and at Microwaves. Dome C is a high altitude, dry site with stable atmosphere and high transparency. Here we can observe in windows prohibited in other sites;
- **Stability of environmental conditions** and a **minimal electromagnetic pollution** in optical and microwave bands allows to enhance the sensitivity;
- Polar sites are allowed to **observe continuously** the same region of the sky or the same
- The **magnetic south pole**, located in Antarctica, allows the low energy **Cosmic Ray** components to penetrate down in the magnetosphere. In Antarctica it is therefore possible to study the **interaction** of these energetic particles with the **magnetosphere** itself, with the **ionosphere** and with the **atmosphere**.
- Polar sites are the best sites to study and monitor the **Space Weather** conditions.


# SCAR Astronomy & Astrophysics from Antarctica

The objectives of ***Astronomy & Astrophysics from Antarctica*** are to coordinate astronomical activities in Antarctica in a way that ensures the best possible outcomes from international investment in Antarctic Astronomy and maximizes the opportunities for productive interaction with other disciplines.

AAA aims to deliver:

- Quantitative assessments of the **potential of each Antarctic plateau** station to contribute to astronomy,
- Advances in the understanding of **Antarctic meteorology**, as it applies to astronomical observations,
- Improved **coordination with atmospheric and ionospheric researchers**,
- Properly **archived** data sets of **site-testing data**.

# SCAR Astronomy & Astrophysics from Antarctica


# Recommendations from AAA - SCAR

## Science goals

• **Optical and Infrared Astronomy** • First Light in the Universe • Stellar Populations • The Galaxy and Galactic Ecology • **Exo-planets**

• **Terahertz and Sub-millimetre Astronomy** • Formation of Molecular Clouds • Origins of Stellar Mass • Galactic Star Formation Rate • Interstellar Medium of the Magellanic Clouds • Templates for high-redshift galactic emission

• **Cosmic Microwave Background Radiation** • Small-scale temperature anisotropies • **B-mode Polarization**

• Neutrinos • Astrophysical Sources of Neutrinos • **Cosmic Rays** • Extension to lower energy Neutrinos • Cosmogenic Neutrinos • Dark Matter

• **Solar Astronomy** • **Corona-Chromosphere interface**

• **Magnetic fields, MHD or Alfvén waves**

# Recommendations from 2021 Concordia Science Plan

- *Scientific background*

**The Concordia station is a strategic location for Astronomy** for several reasons. **The near-continuous winter night, excellent meteorology, extremely dry conditions and cold temperatures makes it a unique site** for the confirmation and characterization of **long-period exoplanets**, in particular habitable ones, and for extremely sensitive measurements in **the mm and submillimeter range**, and in particular of the **Cosmic Microwave Background**. Dome C has also proven to be an excellent site for ground-based observations of **the solar corona** and its dynamics. Observations from Concordia thus ideally complement those from major space missions such as JWST, ARIEL, LiteBIRD and Proba-3. These assets are also important for the search for counterparts of gravitational wave signals and generally **for galactic and extragalactic Astronomy**. Concordia is unique for its collection of tiny witnesses of the formation of our solar system: **rare ultra-carbonaceous micrometeorites** which were discovered there and are thought to originate beyond Neptune’s orbit.

Concordia is located near the **South geomagnetic pole** and is therefore a special location for observations of the large variety of phenomena that are produced by the **interaction between the solar wind and the magnetosphere-ionosphere system** and in the wider field of the **Solar –Terrestrial relationship and Space Weather**. Beyond Astronomy, Concordia is also a strategic location for the development of optical communications with satellites on Low-Earth polar orbits and the follow-up of spatial debris.

# Recommendations from 2021 Concordia Science Plan

- ***Scientific perspectives***

**The Concordia station is unique for its near-continuous night during the Southern winter** (especially May to July), **its exceptionally good weather**, **its low scintillation**, **its low water vapor content yielding atmospheric frequency windows not available elsewhere**, **its stable atmospheric emission**, its cold temperatures and resulting **low sky-background for observations in the infrared, its exceptional seeing** (at an elevation), **its low average wind**. Its very southern declination **provides access to a part of the sky that is difficult to access from other mid-latitudes telescopes**. It is a remote observing site, **far from electromagnetic disturbances**, and is the site with **the lowest geomagnetic cutoff**. This also presents challenges that must be recognized: **The station's remoteness implies additional delays** compared to traditional sites and **uncertainties in the logistics**, more difficulties to get spare parts, a **limited bandwidth for data transfer**, a **limited power supply**. Among other things, the low temperatures, large fluctuations of this temperature, low relative humidity and high rate of cosmic rays imply that glitches in electronics and detectors are frequent, requiring spare parts and regular maintenance.

The Concordia station, built in 2005, at an elevation of 3233m, offers conditions that are much better than at the South pole and almost as good as those at Dome A in terms of weather, water vapor content and sky background. At the same time, it has the considerable advantage of being manned all year long, with the possibility to deliver heavy loads by traverse from Dumont D'Urville.

# Recommendations from 2021 Concordia Science Plan

- ***Scientific perspectives***

**Scientifically, the prospects for cutting-edge Astronomy at Concordia are high**. The overlap with the continuous viewing zones of JWST, Ariel almost guarantees a high scientific return of an astronomical observatory there. The low-temperature and low water content make the site ideal for infrared astronomy, and recent progress on these detectors imply that relatively affordable and sensitive cameras can be used.

**In the field of Cosmology**, due to the excellent properties of the atmosphere, Concordia can be successfully used looking for aspects which are non-yet investigated or pushing observations to higher frequency. Actual **limitations of logistics advise against the installation of a large telescope facility**. Therefore, **observations aimed at a moderate angular resolution are preferable**.

**In the field of solar physics**, the **Antarctic Coronagraph** (AntarctiCor) has already been deployed at Concordia during the last Summer Expeditions and will operate during the next summer campaigns (Fineschi et al., 2019). The daytime sky brightness at Dome C makes of Concordia a unique site for ground observations of the solar corona. A **solar monitor at microwaves**, using facilities already on-site, has been also proposed. These observations need long-term continuous monitoring for mapping the brightness temperature of the free-free radio emission in the centimeter and millimeter range to characterize the vertical structure and physical parameters of the solar atmosphere.

# Recommendations from 2021 Concordia Science Plan

- ***Scientific perspectives***

**Concordia is a unique site to implement a cosmic ray observatory**. A **Neutron Monitor counter** and a Neutron Spectrometer will serve as a monitor for solar activity, by detecting neutrons generated by cosmic rays propagating in the atmosphere (Usoskin et al., 2015). **Other detectors can be added for direct monitoring of the atmospheric shower induced by Cosmic Rays and for measuring cosmic ray induced radiation doses and their correlations with the Solar Cycle and the geomagnetic dipole field variations**. Several long-term activities are already in operation. One of the major activities in this field, which will still operate in the next years, is represented by **Dome C East (DCE) and Dome C North (DCN) radars** located nearby the base and in operation since 2013 and 2019, respectively (Piersanti et al., 2017). DCE and DCN are HF coherent radars and are part of the international program **Super Dual Auroral Radar Network**, for the continuous observation of the ionospheric plasma convection at mid-latitudes, in the auroral zones and in the polar caps. DCE and DCN, with their paired radars at McMurdo and Zhongshan, contribute significantly to complete the coverage of SuperDARN in the Southern Hemisphere. Besides having a crucial importance for the investigation of fundamental science questions in their respective environments, **the observations of the solar corona, the continuous monitoring of cosmic rays modulation and the constant measurement of high latitude ionospheric conditions, are all extremely relevant in the study of Space Weather** (see also paragraph 4.2) and in the understanding of the complex chain of events, from the Sun to the Earth, that can severely impact our technologically advanced society and even endanger human health.

# Recommendations from 2021 Concordia Science Plan

- **Logistic requirements**

Operating astronomical instruments at Concordia requires **a reliable internet connection**, both to operate instruments and download data. Before 2016, telescopes at Concordia had to be operated on site by dedicated winterover astronomers, with most of the data archived to be analyzed one year later. Since then, the near-permanent internet connection allows to fully control and operate the instruments remotely from Europe and to transmit processed data for analysis and publication. This opens the **possibility to develop robotic instruments, limiting interventions by winter-over personnel to routine and maintenance operations**. However, the need for reliability requires separating the internet bandwidth between that available to the instruments and that for the life on the base. Ensuring the reliability of the connection should be the utmost priority. A foreseen increase of remote operations will also require an increase of the bandwidth above the present 512kb/s, all year-long.

Even without seeking exceptional seeings, most ambitious astronomical observatories will seek **to escape at least a fraction of the boundary layer**. This **implies putting telescopes on stable towers, to elevations between 10 and 30 meters**. Solutions exist but must be implemented.

Finally, the main logistic need **for the CMB experiments** like COSMO is the **electric power to run the cryo generators**. Instruments generally **require at least 10 kW** of power continuously during the measurements, which will cover at least 4 months every year and allow for heating of the container and cryogenic operations.

# Recent, On-going, Future Activities

- Observing the far Universe: COSMO
- Galactic/extragalactic observations: ITM

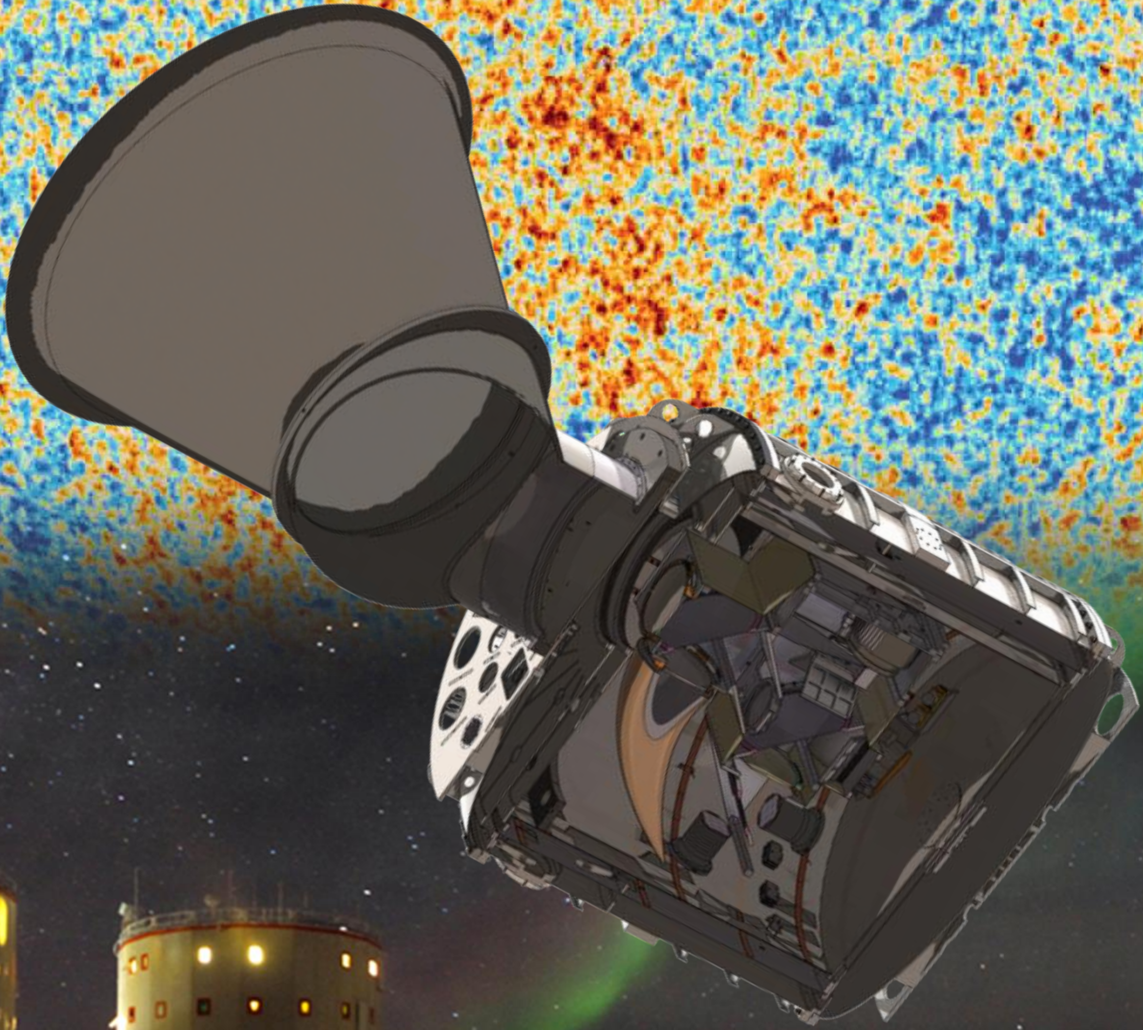
- Solar coronagraphic observations: ESCAPE
- Solar microwave observations: Solaris

- Ionosphere, Sun-Earth relations, Space Weather:
  - SuperDARN + Auroral cameras
  - ISACCO ionospheric observatories
  - International coordination efforts: AGATA, GRAPE
  - Geomagnetic Observatory

# PNRA activities: deep universe observations

- **COSMO** – COSmic Monolope Observer
- **ITM** – International Telescope Maffei

# COSMO (COSmic Monopole Observer)



E. Battistelli, P. de Bernardis, F. Cacciotti, J. Chluba, S. Cibella, F. Columbro, A. Coppolecchia, M. Bersanelli, G. D’Alessandro, M. De Petris, C. Franceschet, M. Gervasi, A. Limonta, L. Lamagna, E. Manzan, E. Marchitelli, S. Masi, L. Mele, A. Mennella, A. Paiella, G. Pettinari, F. Piacentini, L. Piccirillo, G. Pisano, S. Realini, C. Tucker, M. Zannoni

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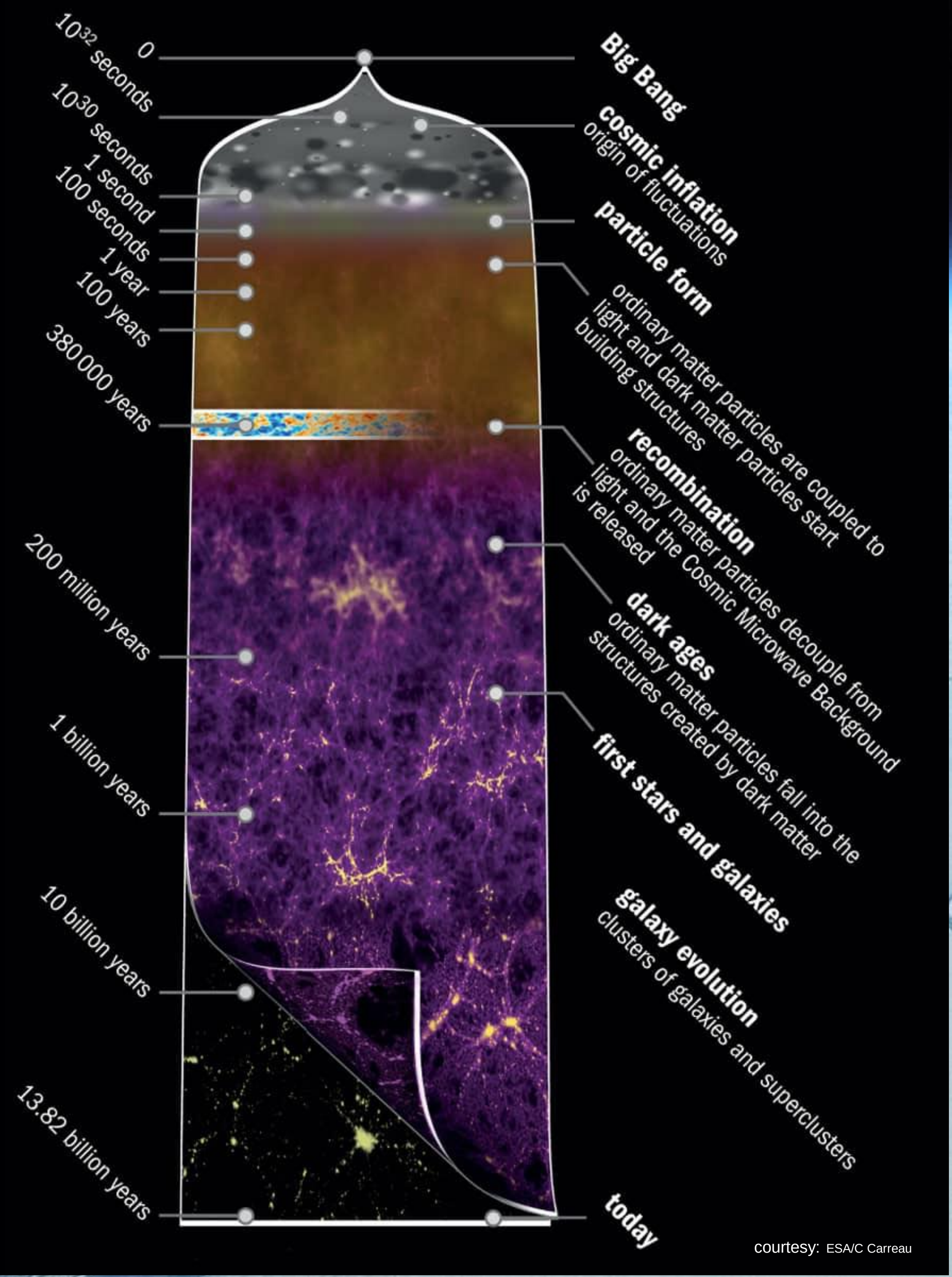
MANCHESTER 1824 The University of Manchester
CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

PRIN Programmi di Ricerca Scientifica di Rilevante Interesse Nazionale
PROGRAMMA NAZIONALE DI RICERCHE IN ANTARTIDE ItaliAntartide

https://cosmo.roma1.infn.it

# Spectral distortions of the CMB




Small departures from a perfect blackbody shape are expected, due to well known as well as exotic physical processes;

and can provide information about processes that occurred before and after recombination. See e.g. :

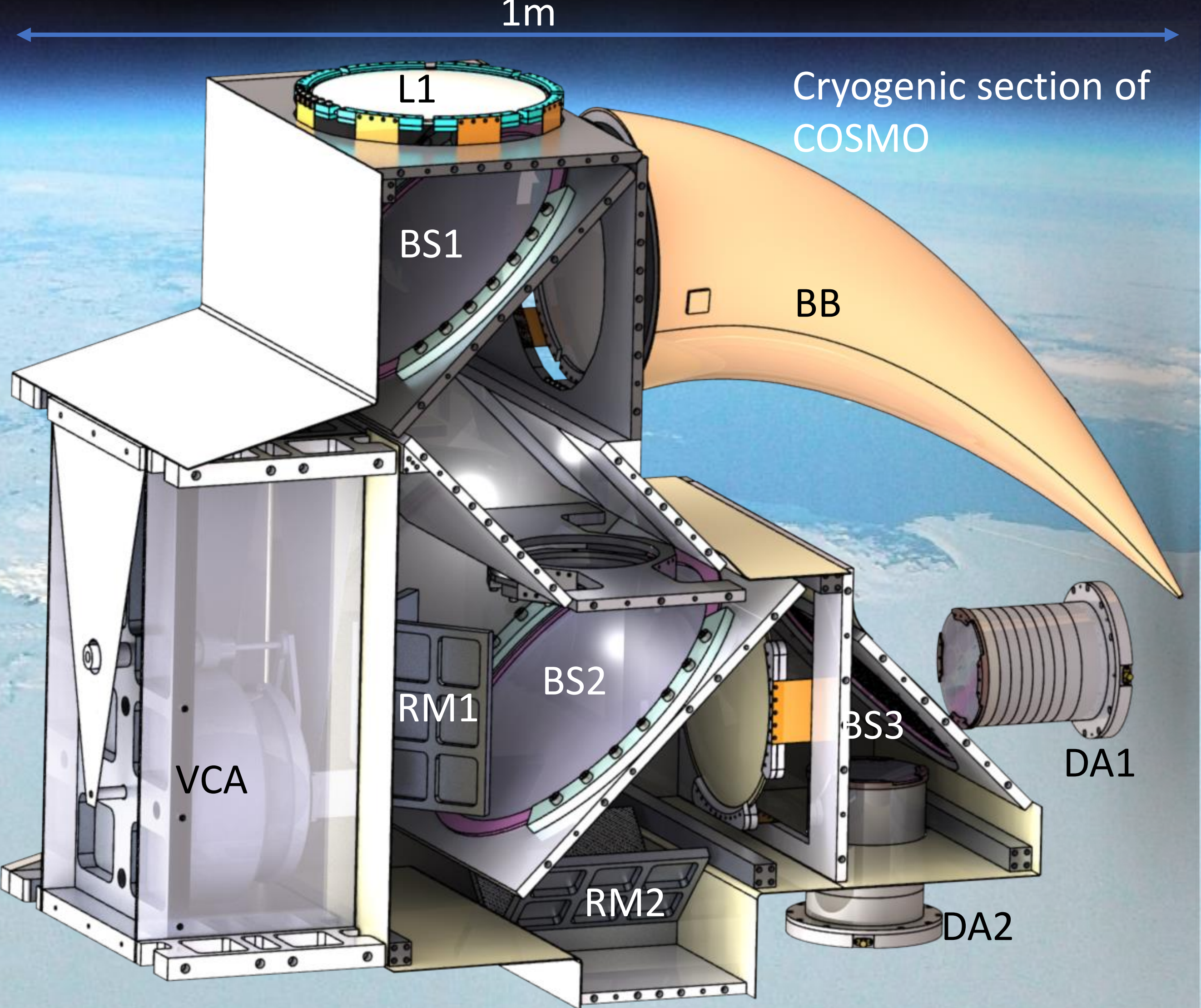
- Reionization and structure formation (De Zotti et al., 2016)
- Adiabatic cooling of baryons and electrons (Chluba and Sunyaev, 2012)
- Damping of small scale acoustic modes -> inflationary power spectra (Chluba et al., 2011)
- Cosmological recombination radiation (Dubrovich, 1975, Sunyaev and Chluba 2008)
- Decaying and annihilating particles (Acharya and Kharti 2019)
- …… and many more

Current upper limits for the comptonization parameter *y* and for the chemical potential $\mu$ are still close to the ones from COBE/FIRAS :

$$y, \mu < 10^{-5}$$

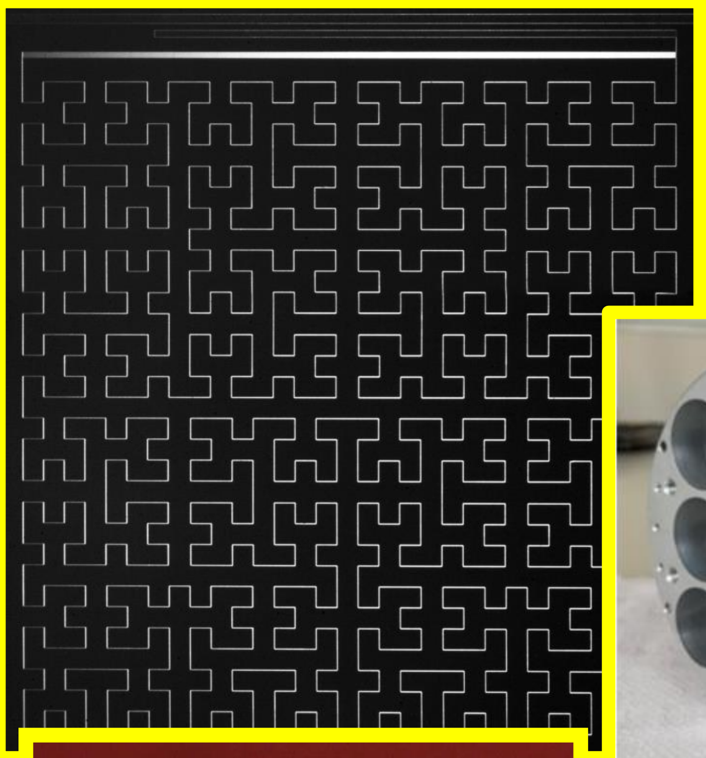
# COSMO in a nutshell

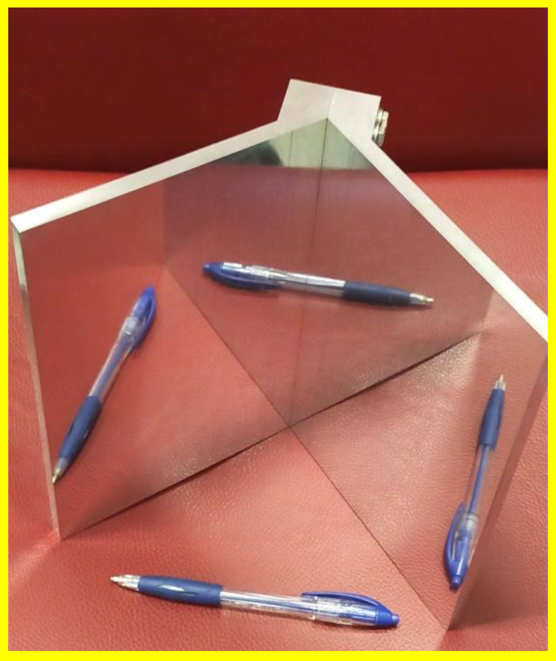
- **COSMO** is a pathfinder experiment, ground-based in the first implementation, balloon-borne in its second step.
- A cryogenic **Differential Fourier Transform Spectrometer**, comparing the sky brightness to an internal blackbody (configuration similar to COBE-FIRAS)
- Operation from the Concordia French-Italian base in **Dome-C, Antarctica**. Average PVW of 210µm, T < -60C, stable weather in the winter season (*Tremblin et al. A&A, 2011*). Atmospheric emission strongly reduced wrt mid latitude sites.
- High transmission bands: **125-175 GHz** (ySD<0) and **200-285 GHz** (ySD>0) ~**5 GHz** resolution.
- Uses fast detectors (multi-mode KIDs, $\tau$=60 $\mu$s) so that **fast sky-dips** are continuously performed to measure and reject atmospheric emission and its slow fluctuations.
- The FTS is cryogenically cooled @3K;
- The reference blackbody can be tuned to 2.5-4 K;
- A continuous and **fast** (few seconds) **interferogram scan** is achieved via a voice-coil actuator.
- Several **10ºx10º** sky patches are observed with **1º resolution**, in the southern sky and with varying levels of galactic signals.
- In **100 days of integration** in the Antarctic winter, the *y SD* can be detected at **5$\sigma$**.

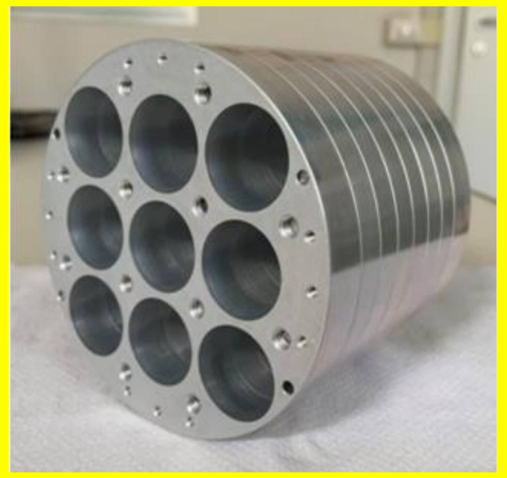


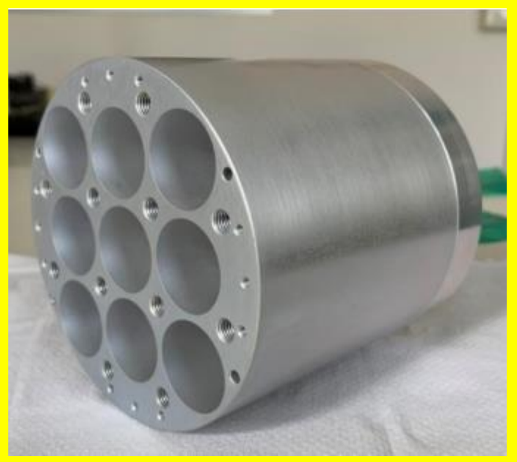
Credit : G. D'Alessandro

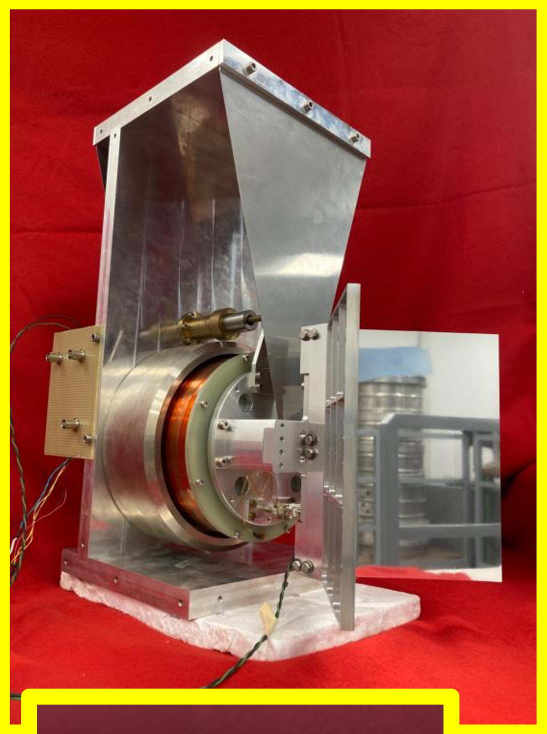
# COSMO HW

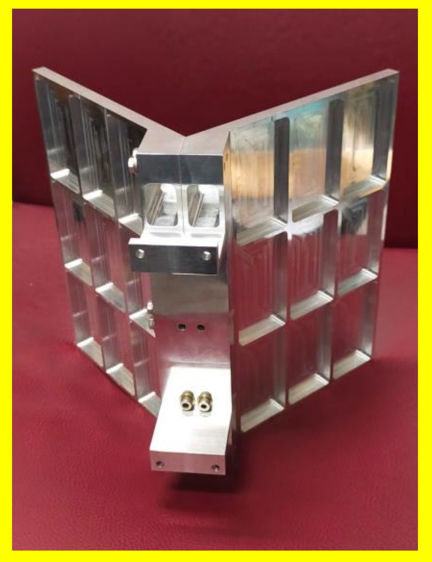






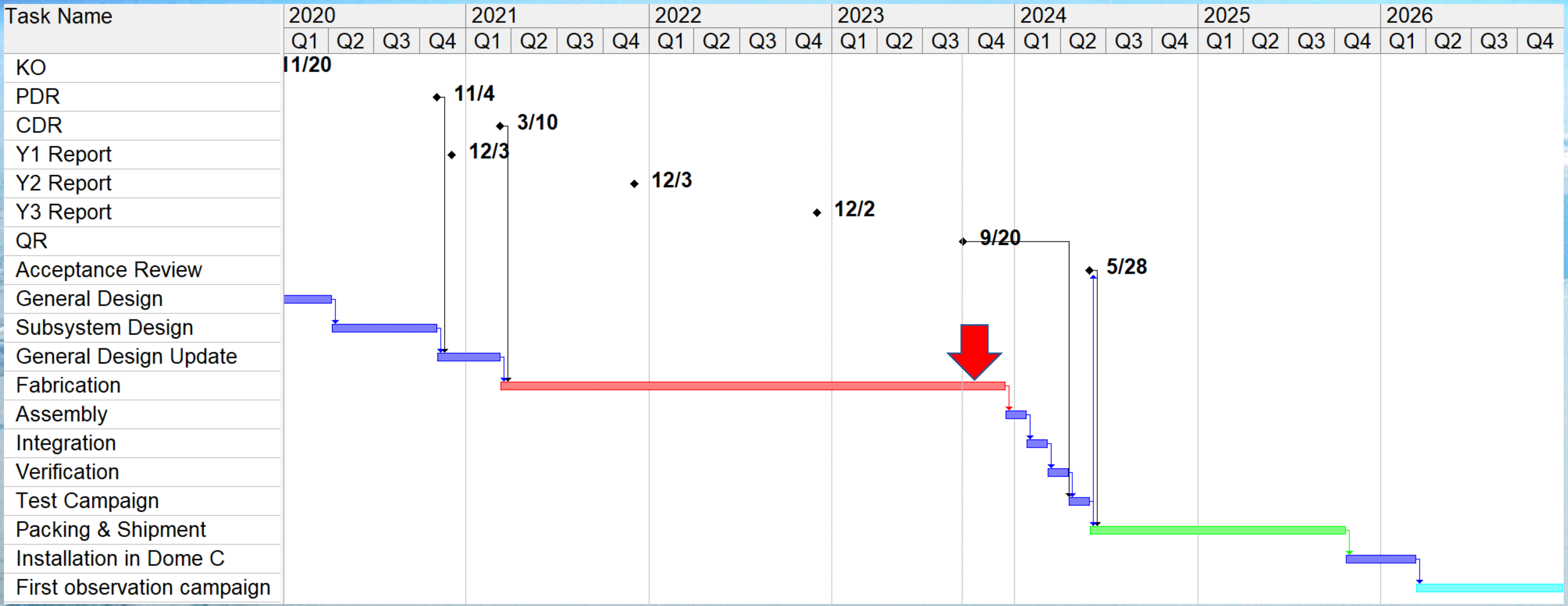






# COSMO - Top Level Schedule

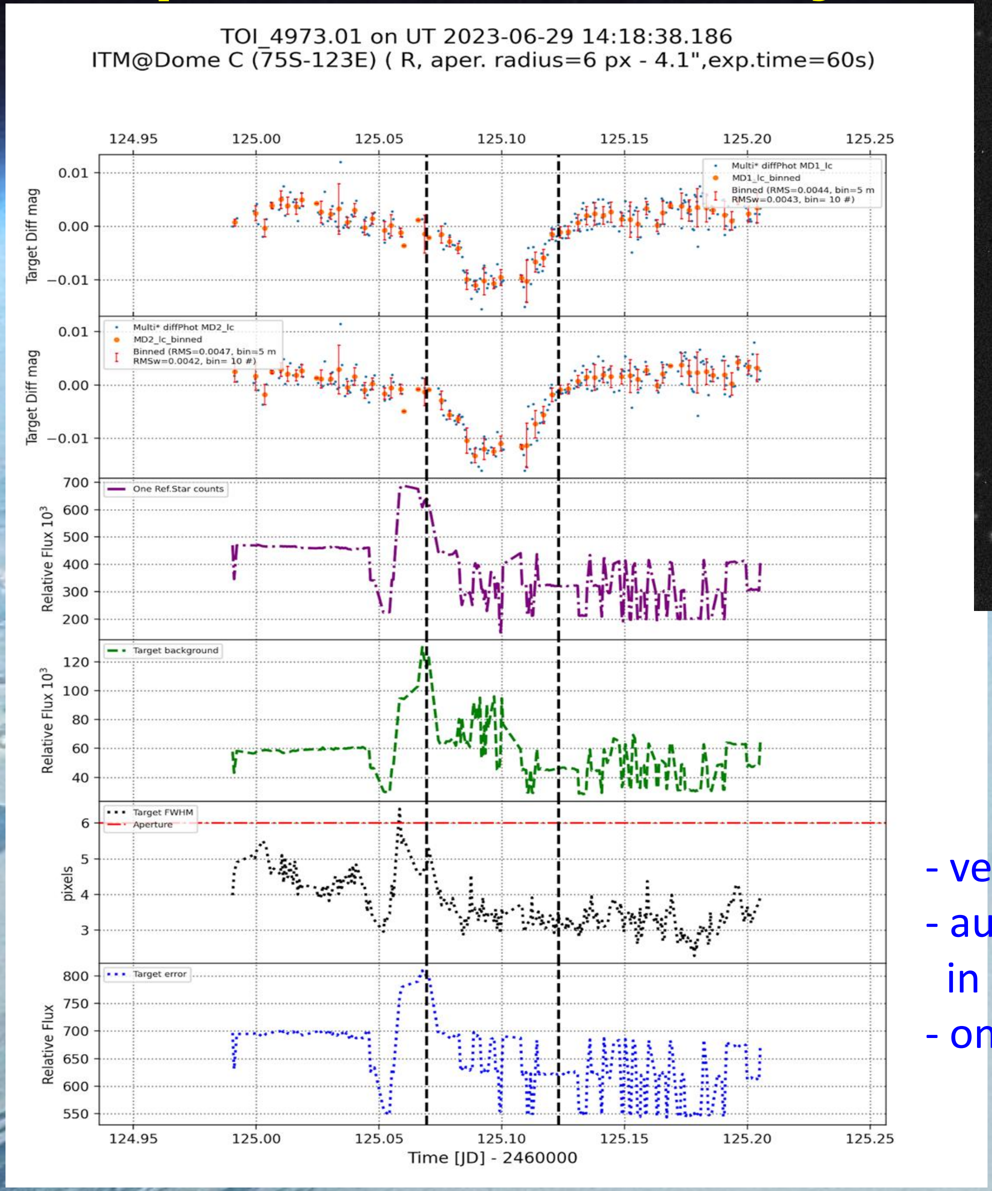
- We are currently near the end of the subsystems fabrication phase.
- In the current schedule, the first Antarctic winter observation campaign in Dome-C will be in 2026

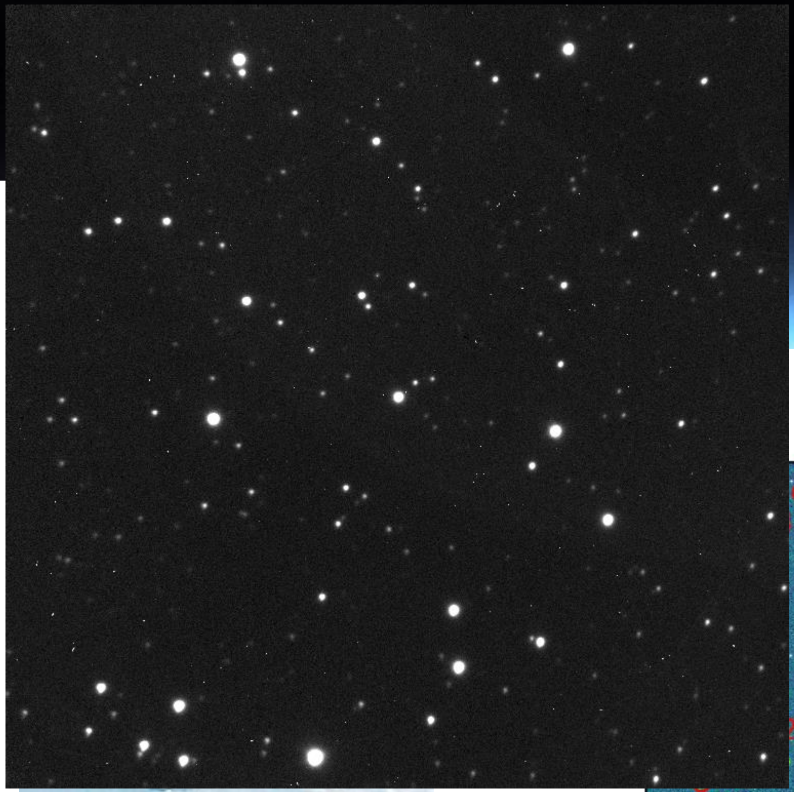


# ITM observatory - International Telescope Maffei
## Concordia – Dome C

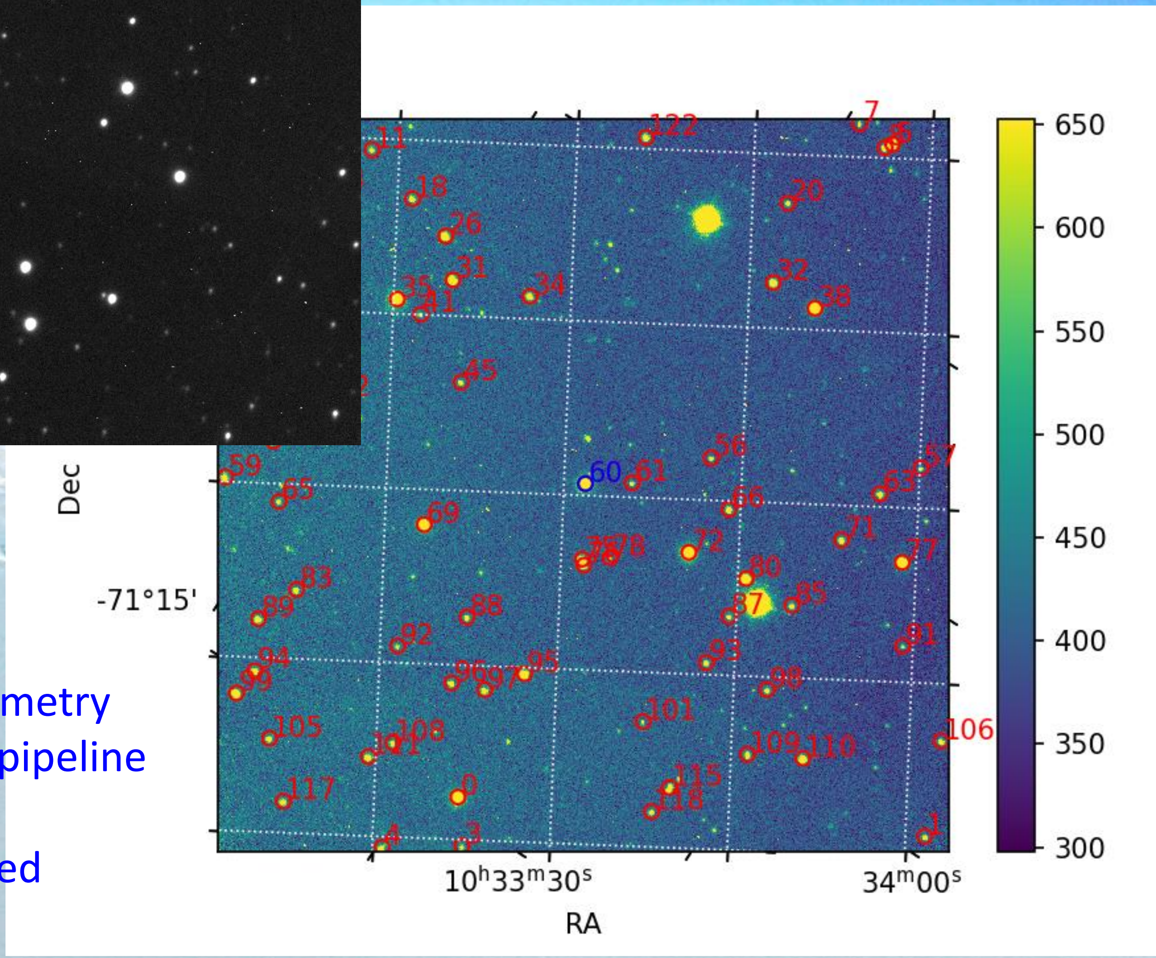
PI: Jean Marc Christille
Astronomical Observatory of the Autonomous Region of the Aosta Valley (OAVdA)

# Observations:
## Exoplanets Photometry



- Totally automatic acquisitions
- everything is "scriptable" in python to be fed into Indi Server
- Up to 98% of good meteo time usage for obs

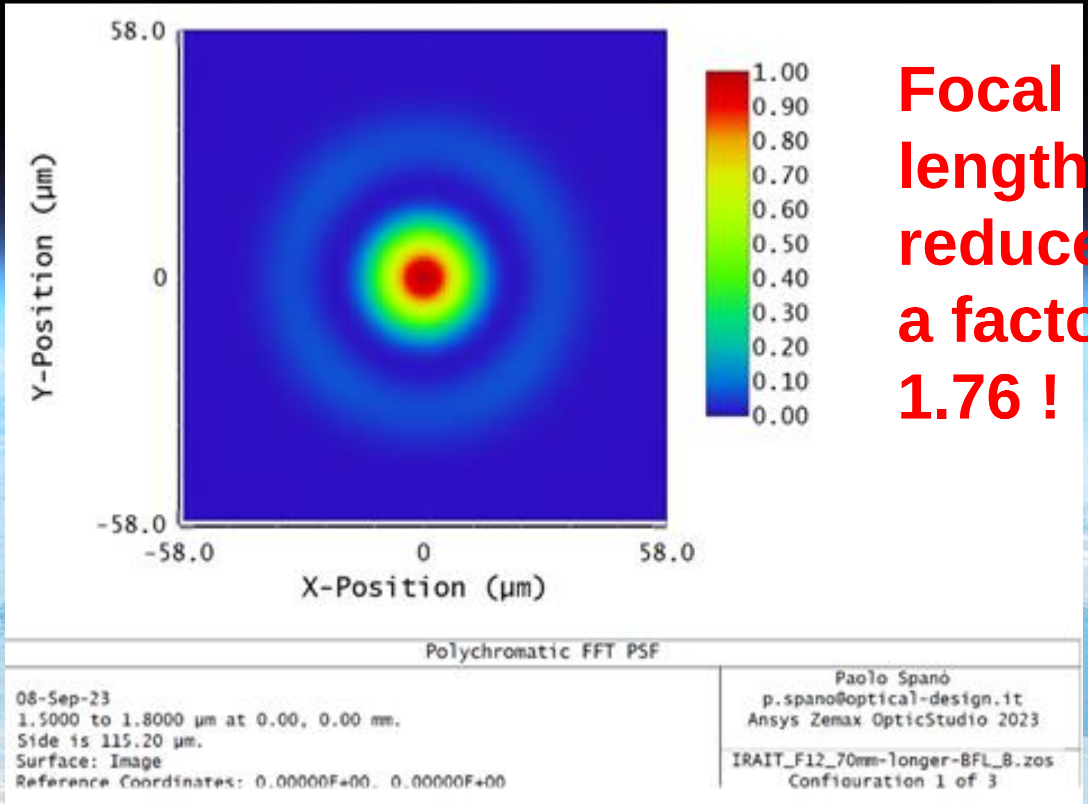



- very good quality photometry
- automatic photometric pipeline in Dome C
- only ASCII data exchanged

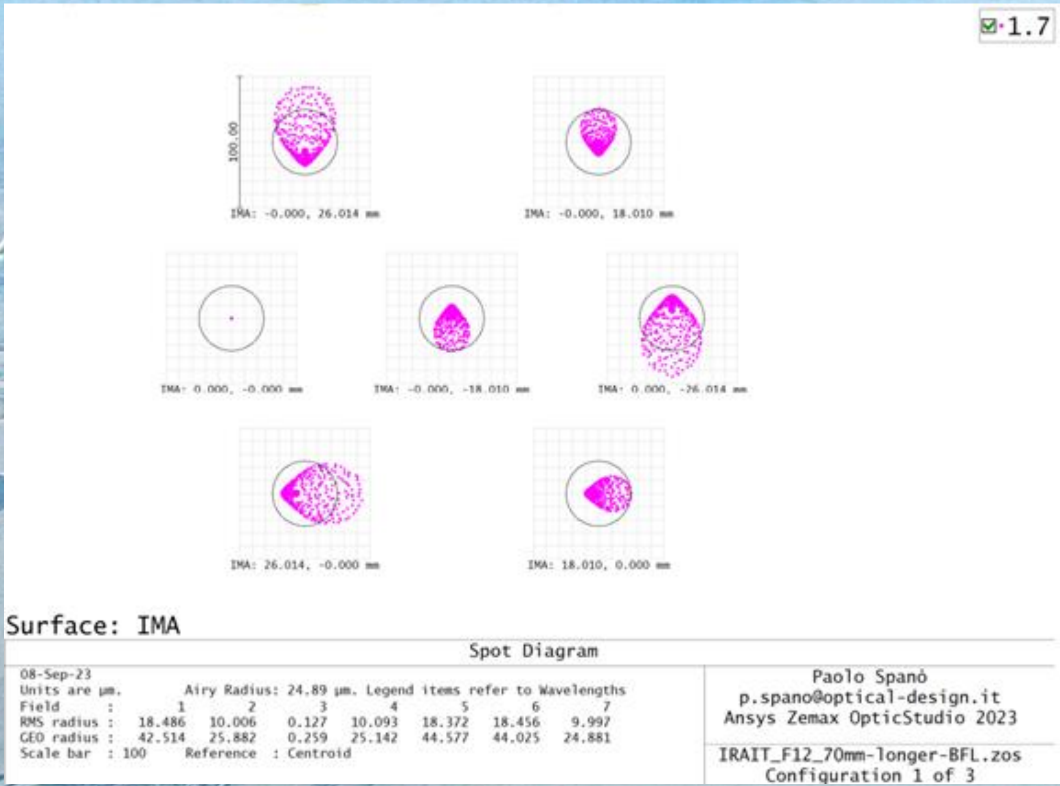
International Telescope Maffei, ITM, Dome C, PI: Jean Marc Christille, PhD

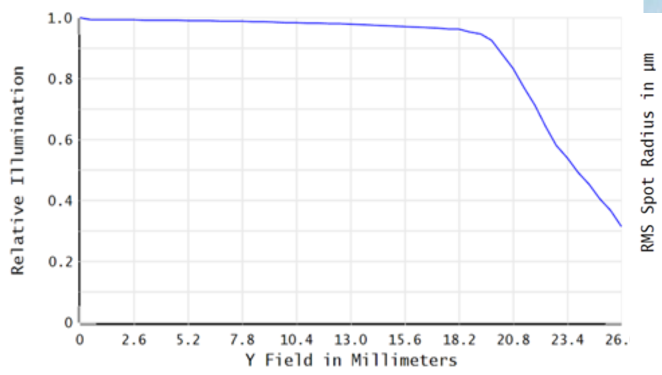
# ITM Upgrade: New mirrors!

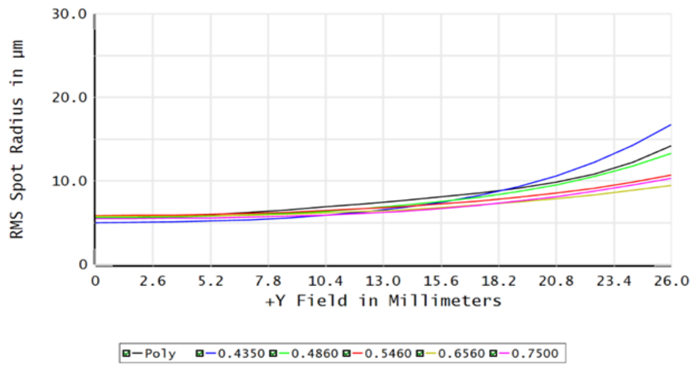
Configuration: RC
New Telescope focal length: **9600 mm (F/12)**
Unvignetted FOV: 22 arcmin diameter
Wavelength: UV-Visible-IR (300 nm – 10 um)




**Focal length reduced by a factor 1.76 !**



# PNRA activities: solar observations

- **ESCAPE** – Extreme Solar Coronagraphy Antarctic Program Experiment

- **SOLARIS** - a smart Solar imaging system at high radio frequency for continuous Solar monitoring and Space Weather applications

# ESCAPE Extreme Solar Coronagraphy Antarctic Program Experiment

PI: Silvano Fineschi; Expedition Leader: Gerardo Capobianco (INAF-Astrophysical Observatory of Torino)

Project PNRA: 2015/AC3.02 completed on June 2023

**Science**

Mapping the plasma (electrons) of the inner solar corona

**Site Characterization**

Demonstrate that Dome C is one of the very few sites on the Earth for solar corona observation

**Technology**

Demonstrate the feasibility of use of innovative micropolarizer array cameras for scientific purposes

**Space Demonstrator**

Validate the optical design of the ASPIICS coronagraph on board the ESA-PROBA3 mission (launch 2024)

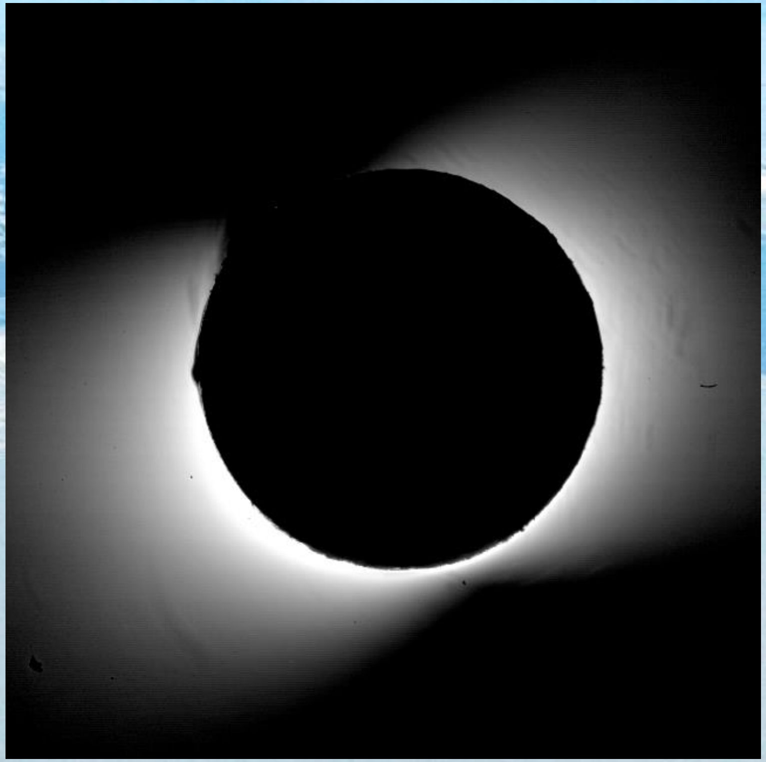

# ESCAPE Extreme Solar Coronagraphy Antarctic Program Experiment

PI: Silvano Fineschi; Expedition Leader: Gerardo Capobianco (INAF-Astrophysical Observatory of Torino)

## ESCAPE in a nutshell

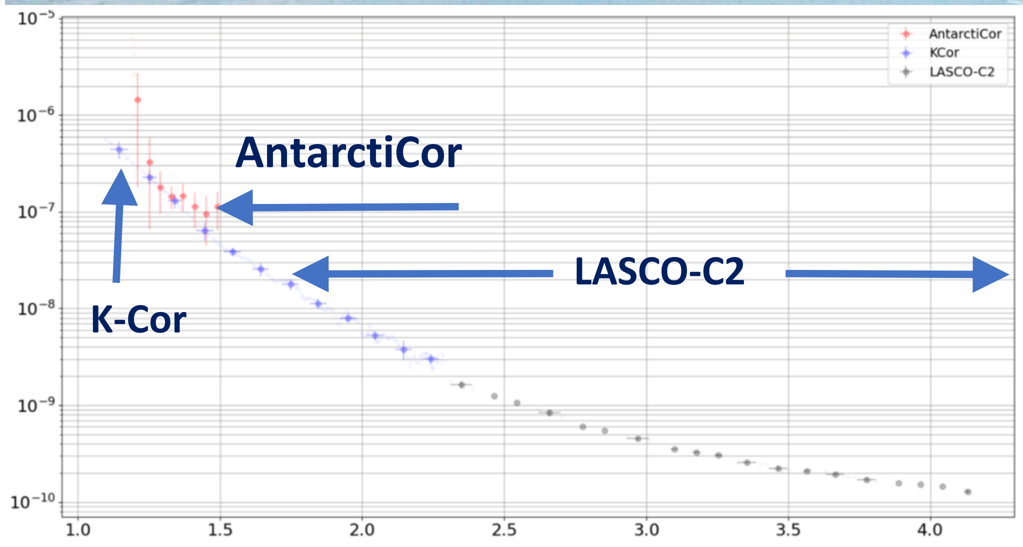
4: Antarctica campaigns
1: Partial eclipse observed from Antarctica
2: PhD students
5 (+2): Scientific Papers
1.E-6 (solar disk brightness): The sky brightness of Dome C
2.E+5 (MB): The data volume of the 4 campaigns

23/01/2020 The quiet solar corona



25/12/2021 Solar Cycle 25 just starting

Coronal polarized Brightness ($B_{sun}$)




Distance from Sun Center (Solar Radii)

## WHAT'S NEXT?

### Improvements from lessons learned

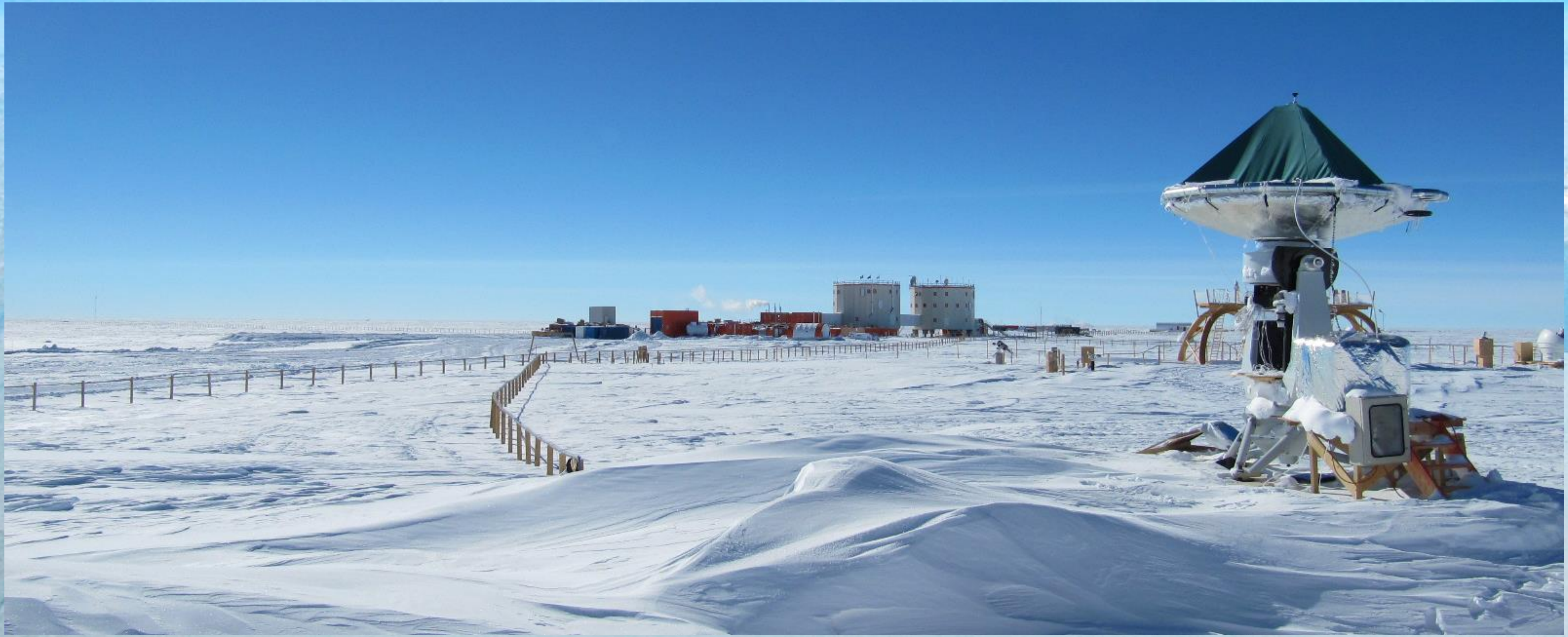
The very low sky brightness level of Dome C suggest the possibility to try to increase the signal at the external FoV by including an external occulter (to be used only with slow wind)

The use of a polarimeter based on liquid crystals device will increase the polarization contrast and provide measurements of the electron density with higher accuracy

The objective lens cleanliness is crucial for stray-light control. The use of a flow bench should help to perform the cleaning operation in a «clean» environment

# Solaris observatory

## a smart Solar imaging system at high radio frequency for continuous Solar monitoring and Space Weather applications



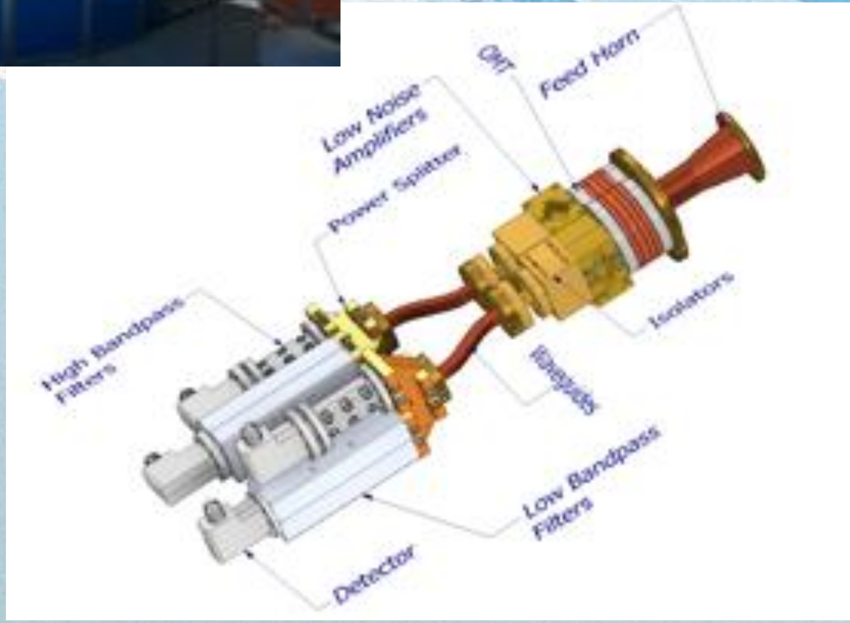
**A new permanent observatory in Antarctica**

Alberto Pellizzoni - INAF-Osservatorio Astronomico di Cagliari

https://sites.google.com/inaf.it/solaris

# Solaris observatory

- Solaris is a scientific and technological project aimed at the development of **a smart Solar monitoring system at high radio frequencies based on single-dish imaging techniques**.
- It combines the implementation of a dedicated and interchangeable **100 GHz receiver on existing small single-dish radio telescope systems** (2.6m class), to be adapted for Solar observations: **OASI** (MZS) and **COCHISE** (Concordia).
- Solaris can perform **continuous Solar imaging observations nearly 20h/day during Antarctic summer**, and it will be the only Solar facility offering continuous monitoring at 100 GHz.

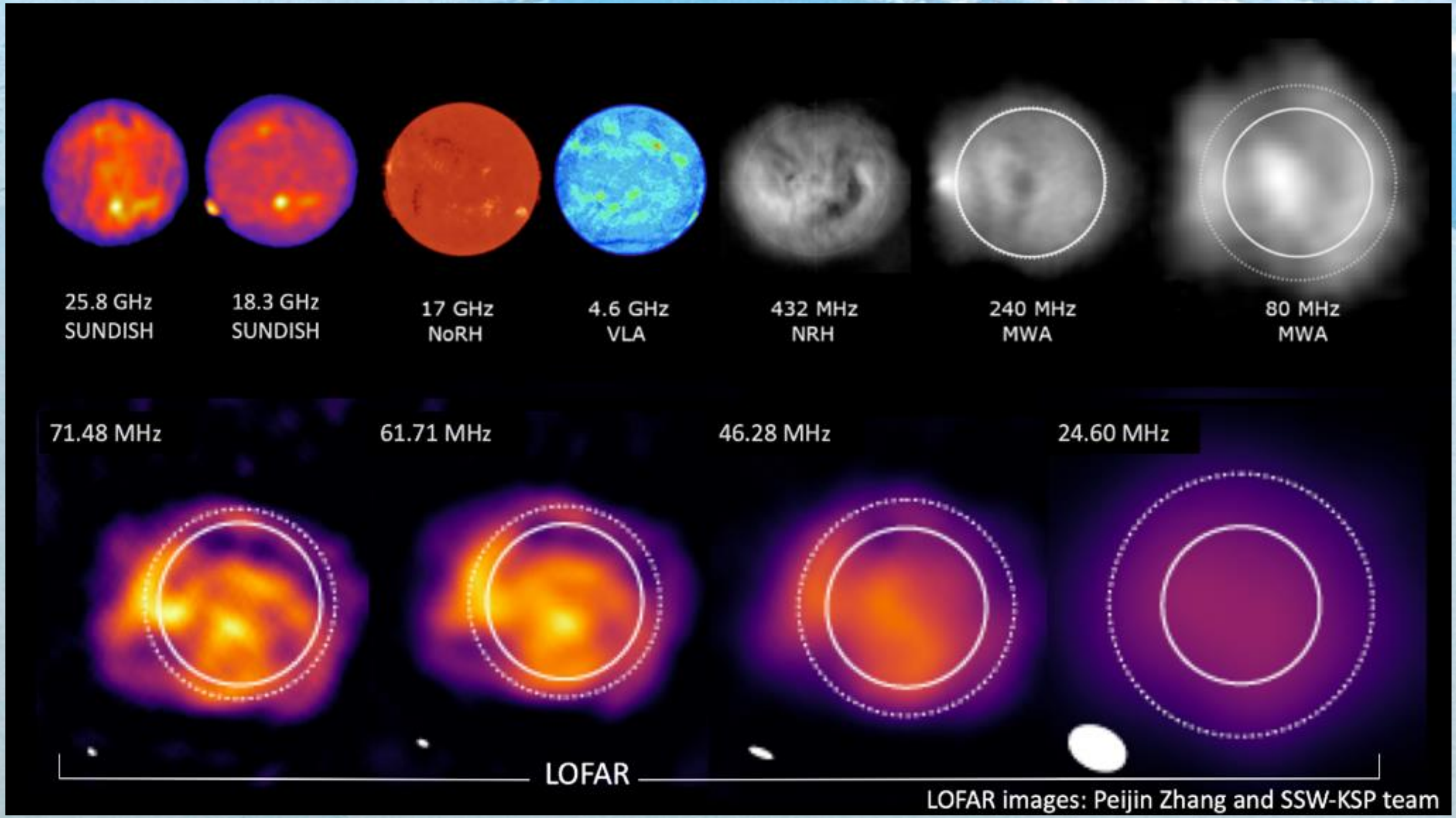


# Solaris observatory

**Solaris** is a heritage of the project **SunDish (Single-Dish Solar Imaging with INAF Radio Telescopes)**: Solar imaging & spectropolarimetry, 18-26 GHz (up to 100 GHz), 32m/64m antenna (**https://sites.google.com/inaf.it/sundish**)

**Solaris** extends the observations at a higher frequency, with perspectives of:

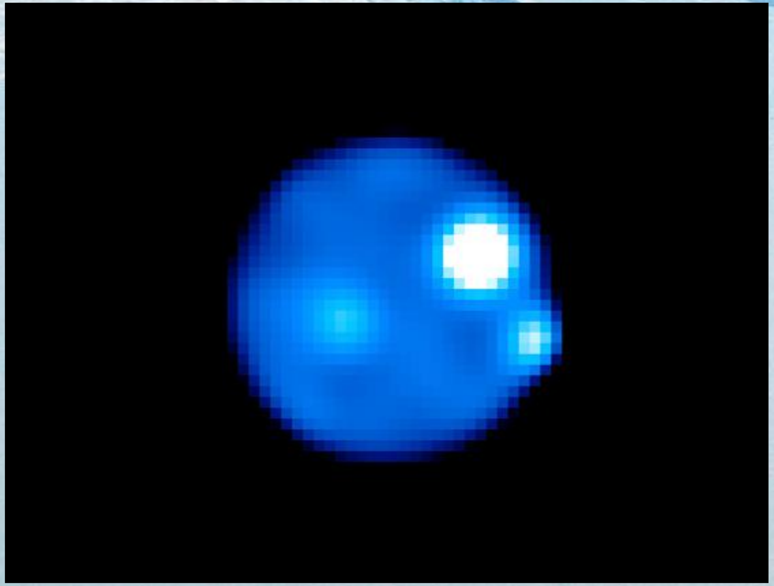
- Characterisation of the **flux density of the active regions and coronal holes** and their **spectral properties** and **evolution.**
- **Space Weather applications:** Significant spectral variations of solar active regions could be an important factor in predicting powerful flares and coronal mass ejections



# Solaris observatory

**Main Scientific Goals & Applications:**

- Unprecedented **continuous solar monitoring** at high radio frequency in optimal observing conditions (sky opacity & visibility).
- Constraining purely **non-thermal emissions** in the Quiet Sun and Active Regions components.
- **Active Regions** flux and spectral variability monitoring.
- **Solar Flares** detection and observations.
- Study of Flare **precursors** (Space Weather Forecast).
- Trigger for high-resolution follow-ups with other facility (including “zoom-in” with SRT 64m)



# PNRA activities: Ionosphere, Sun-Earth relations, Space Weather

- **Observatories**:
  - SuperDARN + Auroral cameras
  - ISACCO ionospheric observatories
  - Geomagnetic Observatory

- **International coordination efforts**:
  - AGATA, GRAPE

# Antarctica: a window in the magnetosphere and interplanetary medium

**Scientific Objective**: to study the plasma processes occurring in the near-Earth space:

- fundamental plasma processes
- potentially affecting human activities – very relevant for Space Weather

**Science Themes in more detail**:

- Solar Wind – Magnetosphere – Ionosphere interaction.
- Ionospheric Convection Dynamics
- Inter-hemispheric conjugacy of ionospheric phenomena
- Ionospheric irregularities and plasma structures (e. g. polar cap patches)
- MHD, ULF, Magnetic Field Line Resonances.
- Gravity waves, mesospheric winds, planetary waves

# Instrumentation and international framework

The complex **Magnetosphere-Ionosphere system** processes can be studied by measuring/observing on ground **magnetic field variations, ionospheric parameters, auroral displays**.

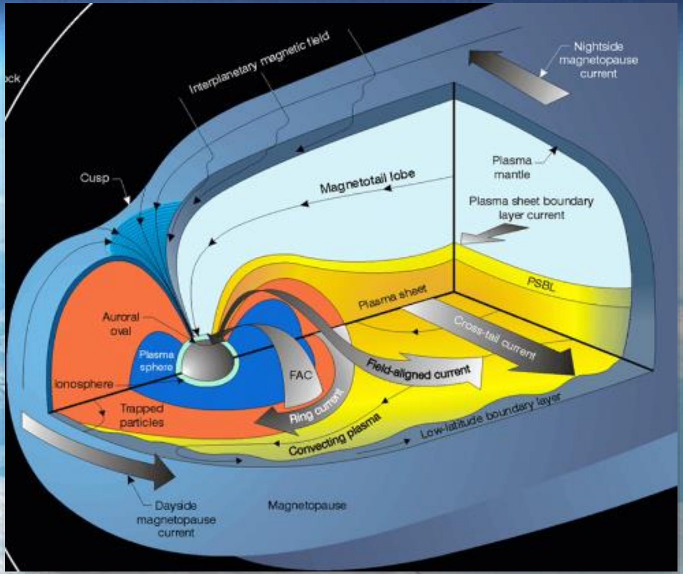
Such observations are usually performed in the framework of large international collaboration and are greatly **relevant for Space Weather**.

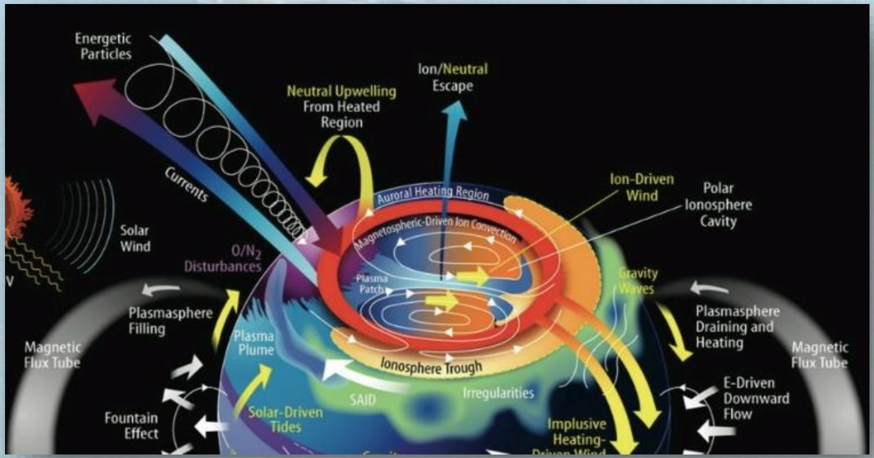
From: *Assessment and recommendations for a consolidated European approach to space weather – as part of a global space weather effort* by Opgenoorth et al., J. Space Weather Space Clim. 2019

…. *support the maintenance, modernisation and future augmentation of ground-based instrument networks* for space weather purposes to support the space assets for SWx observations.

*Present ground-based instrument networks comprise*: **Magnetometer networks*** and coordination through SuperMAG, coherent scatter radar systems **SuperDARN***, **GNSS receivers***, **Ionosondes**, Incoherent scatter radars like EISCAT-3D, **solar radio-observations***, LOFAR, GONG, **NMDB***, etc.

* Instrumentation already present or to be installed in Dome C



# The *Dome C East* and *Dome C North* HF ionospheric radars of the *Super Dual Auroral Radar Network (Oss-14)*

*A phased array of 16 antennae* gives over 10

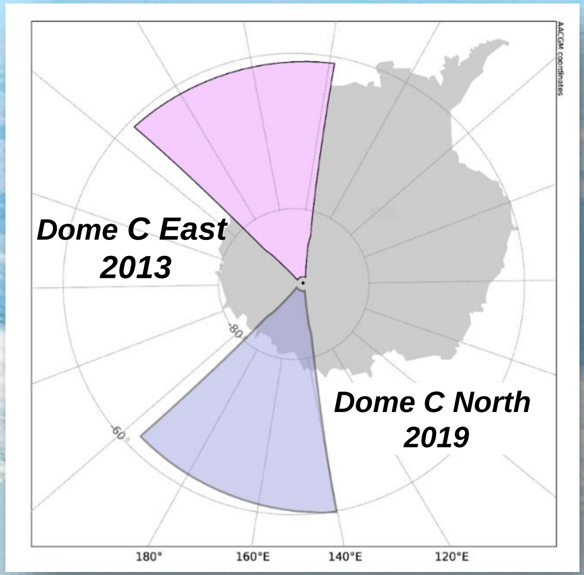
- the power of the backscattered signal
- the width of the Doppler power spectrum
- the line-of-sight component of the F-region plasma drift velocity.

At 1 minute time resolution

**With pair of radars observing the same area** the full two-dimensional horizontal velocity vector of the ionospheric plasma convection can be calculated.

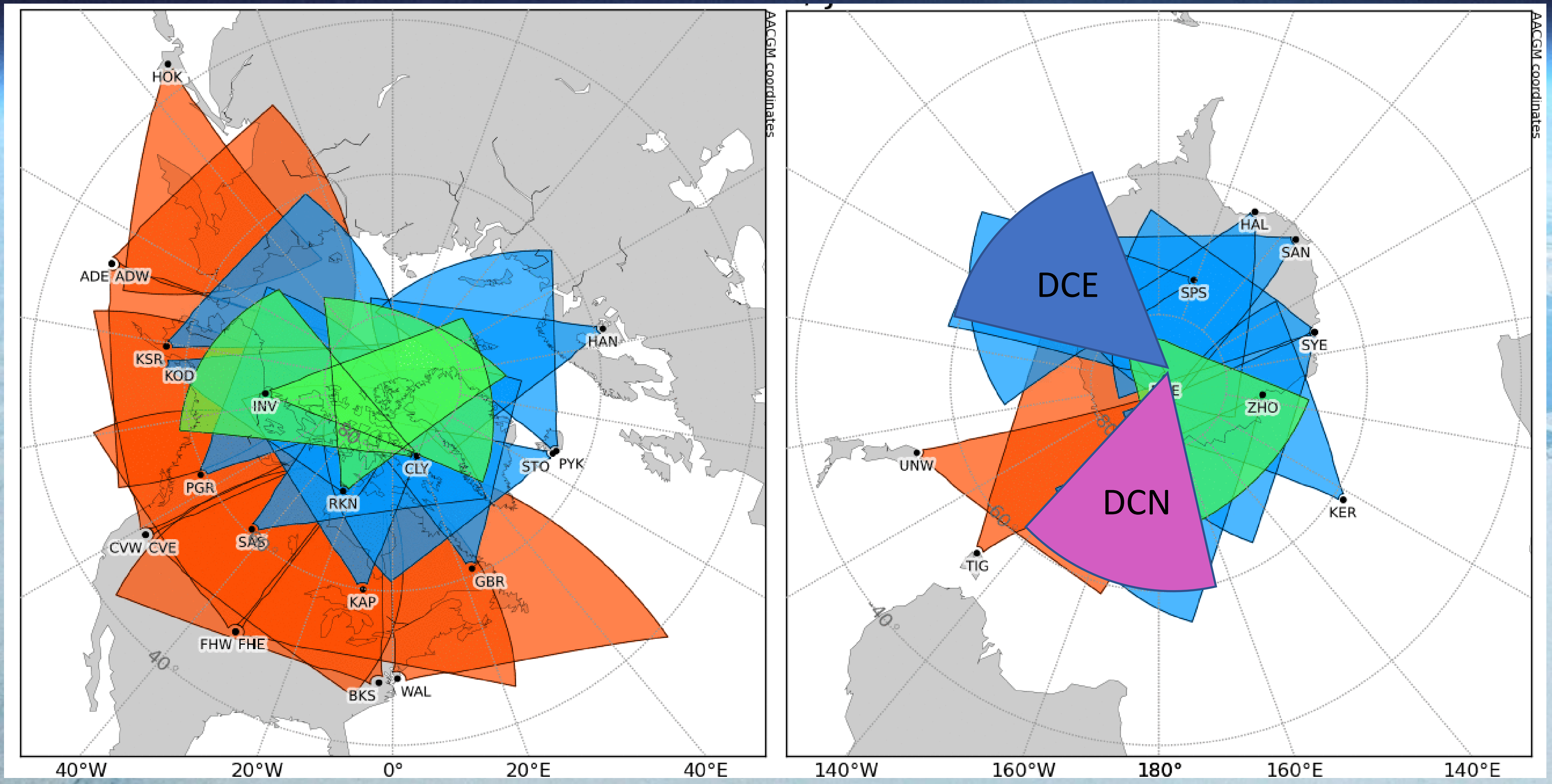
DCE and DCN are operated under the responsibility of **INAF-IAPS**. Team comprises **CNR** and **INGV**.

See also presentation on “Osservatori Permanenti”.





# The *Dome C East* and *Dome C North* HF ionospheric radars of the *Super Dual Auroral Radar Network (Oss-14)*



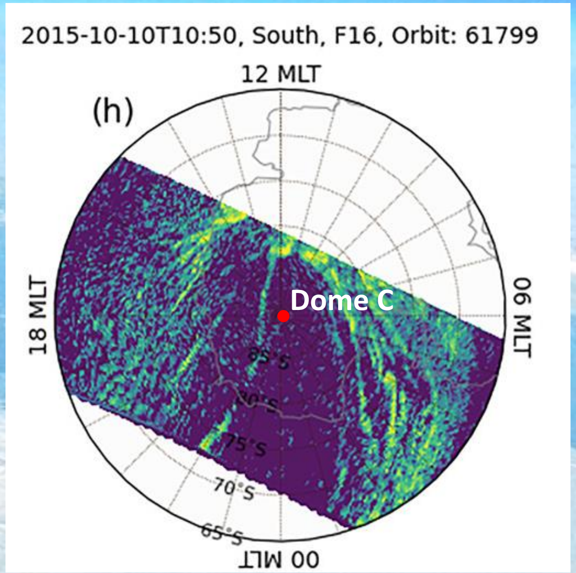

DCE and DCN are part of the international **Super Dual Auroral Radar Network (SuperDARN)** that consists of more than 30 low-power HF radars and continuously measures ionospheric convection in the southern and northern mid/high latitudes and polar caps.

# Possible new geospace instrumentation in Dome C

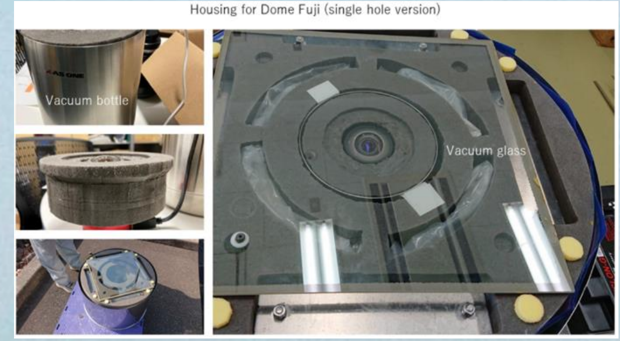
Installation of two **all-sky camera** in Dumont d'Urville and Concordia.
The two cameras will complete a network **to monitor the whole auroral activity** in Antarctica.

Scientific objective: better understand the solar wind-magnetosphere-coupling, to ultimately model the auroral oval (e.g. improve the state-of-the-art OVATION model of auroral oval and/or contribute to a new model) and study transpolar arcs, also known as theta auroras.

Proposal to IPEV by IRAP colleagues in collaboration with Japan – Italian participation: INAF and INGV.




SSUSI DMSP observations
Kullen and Cai https://doi.org/10.1029/2022JA030987

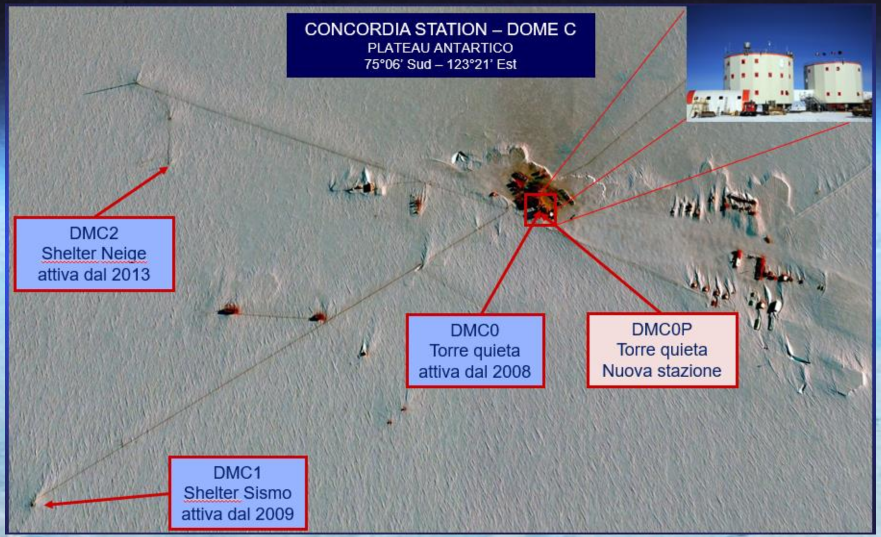


# Observatory of High Atmosphere Physics in Antarctica (ISACCO)

ISTITUTO NAZIONALE
DI GEOFISICA E VULCANOLOGIA

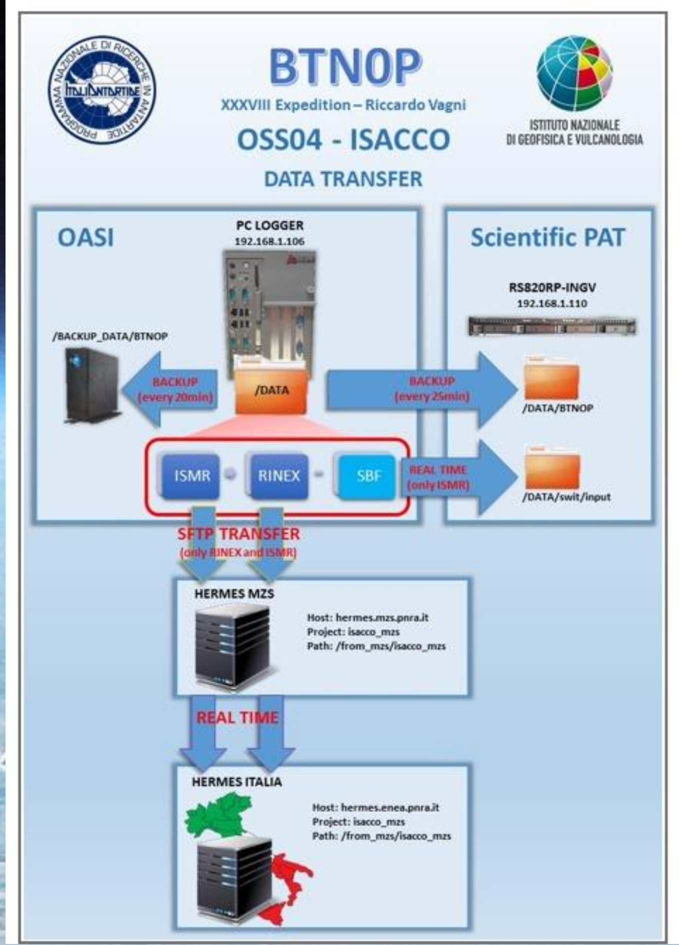
Consiglio Nazionale
delle Ricerche

Coordinator
Vincenzo Romano



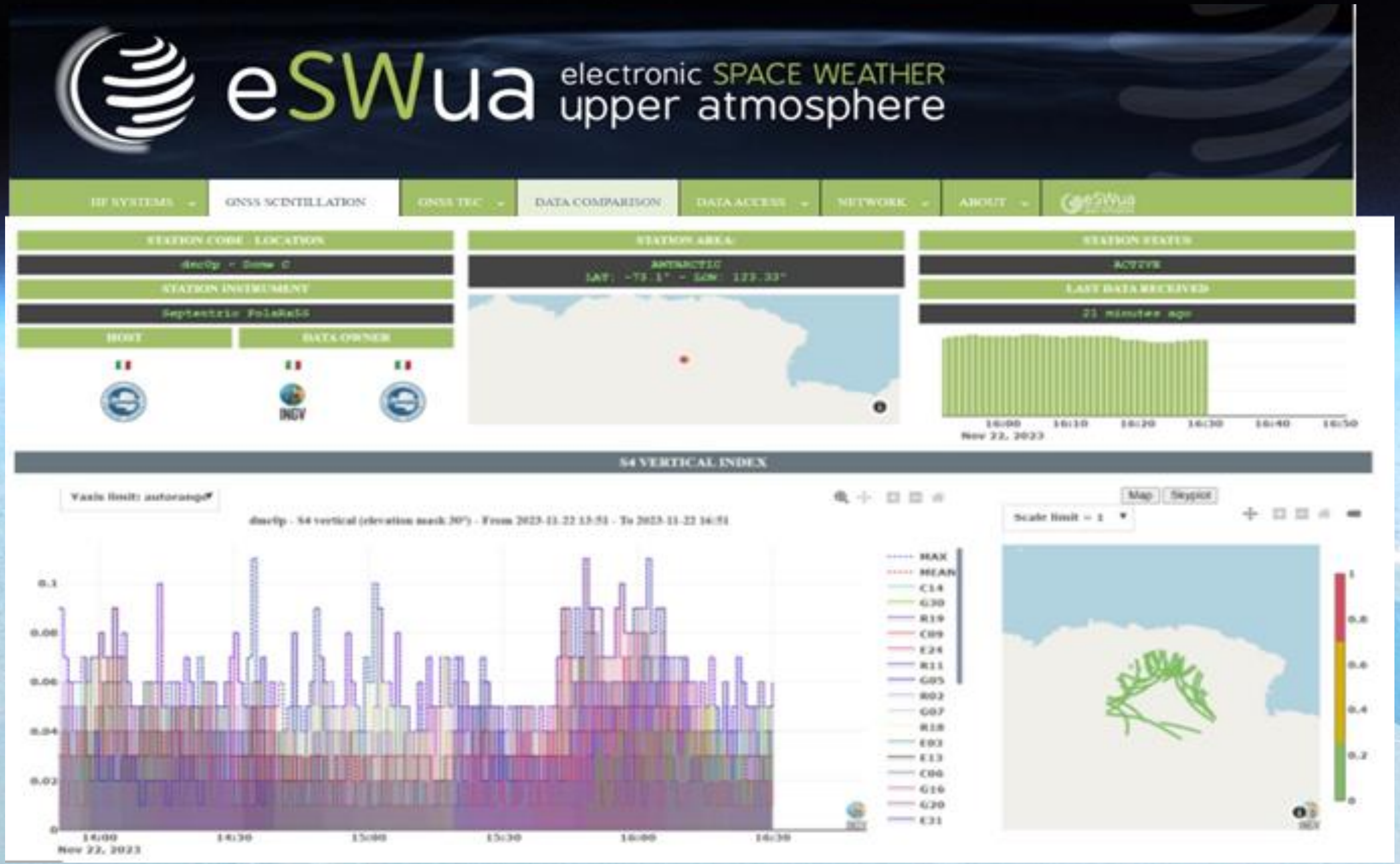

# Objectives

- Monitoring of the **upper polar atmosphere** in Antarctica (MZS, Concordia) and in the Arctic
- Study of the **climatology** and dynamics of **ionospheric scintillations** in polar areas
- Development of high-latitude ionospheric parameter prediction algorithms and tools
- Development of algorithms for ionospheric error **correction on GNSS systems**
- Consolidation of the data acquisition system to ensure data continuity and reliability
- Guarantee the acquisition of data from the new systems, data storage and accessibility, the interoperability of the System with other national and international projects



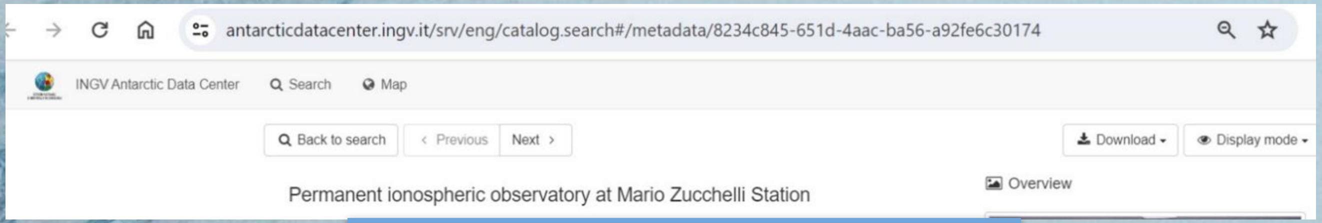

# Data flow

# Open Science Data




[WWW.ESWUA.INGV.IT](http://www.eswua.ingv.it)

# Data access




# Data registry

[HTTPS://ANTARCTICDATACENTER.INGV.IT/](https://antarcticdatacenter.ingv.it/)

# International coordination effort:
# the SCAR Program Planning Group AGATA
# *Antarctic Geospace and Atmosphere Researh*

Taking advantage of existing and planned instrumentation in Antarctica, in the Arctic and spacecraft observations, **AGATA**, a SCAR Programme Planning Group, aims for a ***coordinated, worldwide effort to monitor, investigate and better understand the physics of the polar atmosphere and the impact of the Sun-Earth interactions on the polar regions***. (https://www.scar.org/science/agata/home/)


See Lucilla Alfonsi presentation.

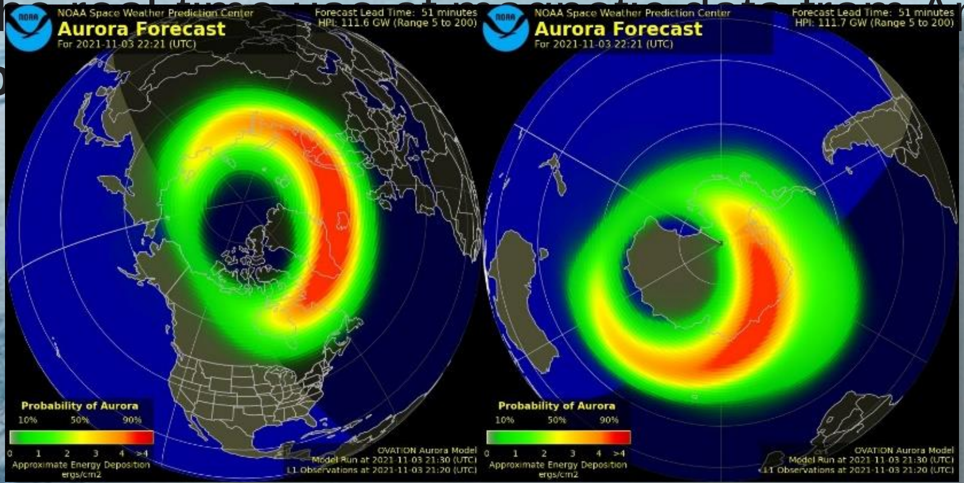
Inside the international polar context italian community is also involved in **GRAPE** and other SCAR coordination efforts.

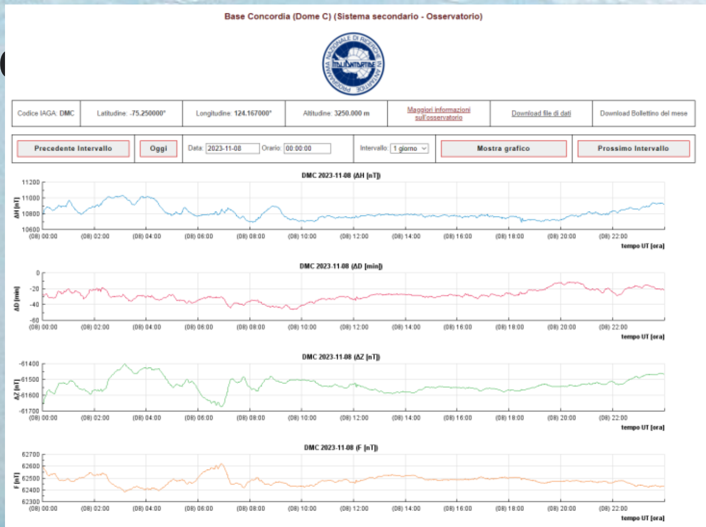
SCAR – SCADM
Standing Committee on
Antarctic Data Management

**GRAPE**
**"GNSS Research and Application for Polar Environment"**

# ITALIAN GEOMAGNETIC PERMANENT OBSERVATORIES FOR SOLID EARTH AND SPACE WEATHER STUDIES IN ANTARCTICA (PNRA0000036) PI: DOMENICO DI MAURO – domenico.dimauro@ingv.it

- Observations of the **Earth's magnetic field** are particularly important in the polar regions due to the increased intensity and dynamics of the field. Permanent observatories around the world focus on these observations, nevertheless the Southern Hemisphere, especially the polar areas, is poorly covered.
- Geomagnetic observatories at **Mario Zucchelli Station (TNB)** and **Concordia Station (DMC)** in Antarctica provide valuable data to fill this gap. With observation periods of almost 30 years for TNB and 20 years for DMC, these datasets contribute to the study of the geomagnetic field on different time scales.
- Th … ntarcti … **nowcasting and fo**



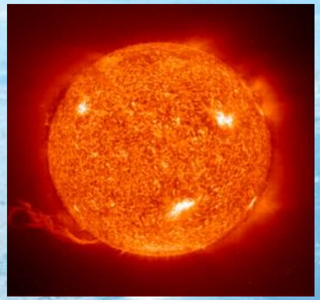



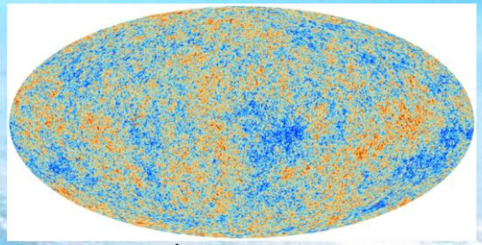

Magnetograms from DMC, distributed in real-time

**URL: geomag.rm.ingv.it**

# Astronomy/Astrophysics/Atmosphere

PNRA activities:
state of art





Thank you !!!!!