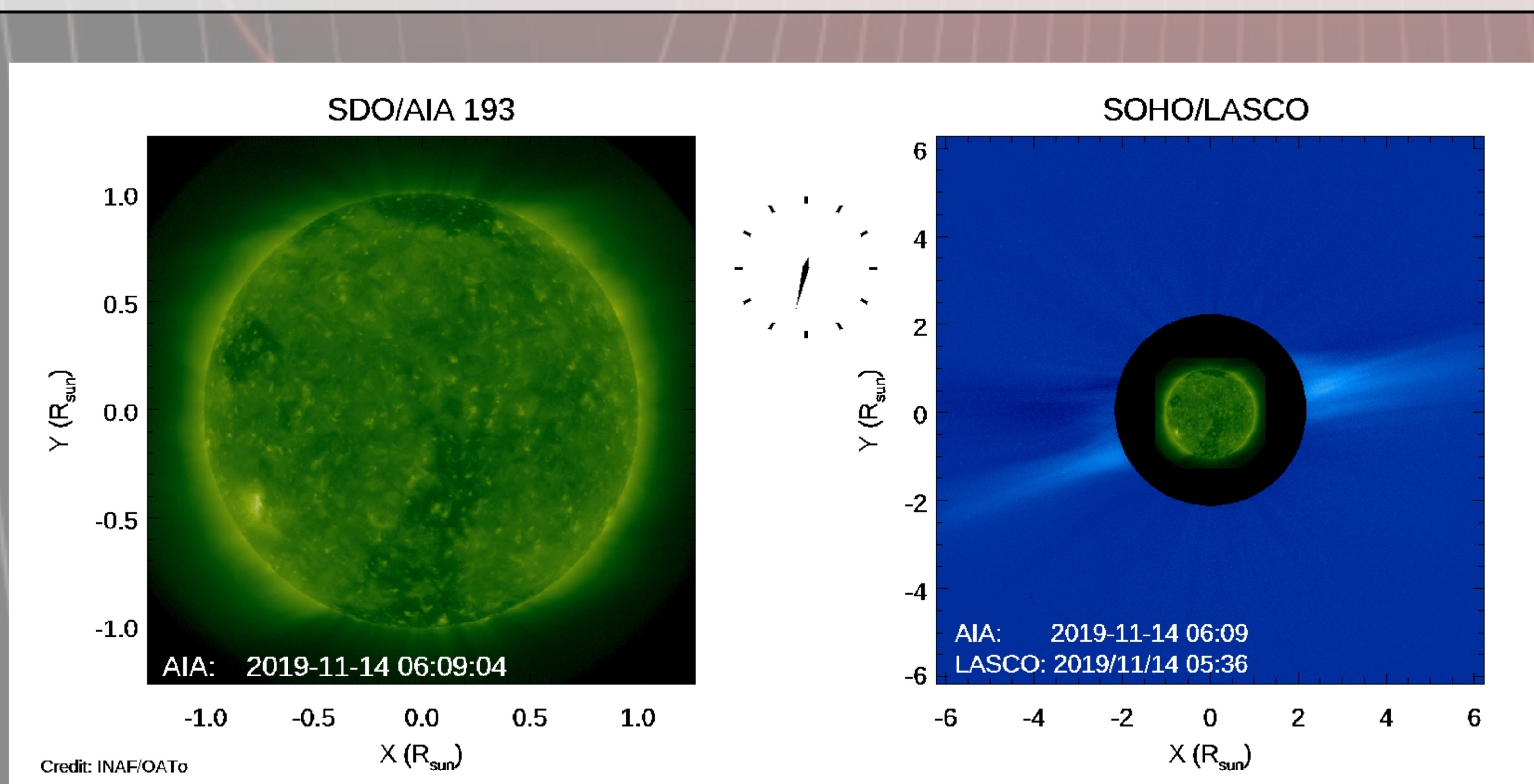
Introducing SWELTO - the Space WEather Laboratory in Turin Observatory

A. Bemporad[1*], S. Giordano[1], L. Zangrilli[1], R. Biondo[1,2], F. Reale[2], A. Mignone[3], F. Carella[1], C. Benna[1], A. Cora[1], S. Fineschi[1], F. Frassati[1], D. Gardiol[1], S. Mancuso[1], F. Salvati[1], R. Susino[1], A. Volpicelli[1]

[1]INAF—Turin Astrophysical Observatory, via Osservatorio 20, 10025 Pino Torinese (TO), ITALY
[2]University of Palermo, Physics & Chemistry Department, Piazza Marina 61, 90133 Palermo, ITALY
[3]University of Turin, Physics Department, Via Pietro Giuria 1, 10125 Torino, ITALY

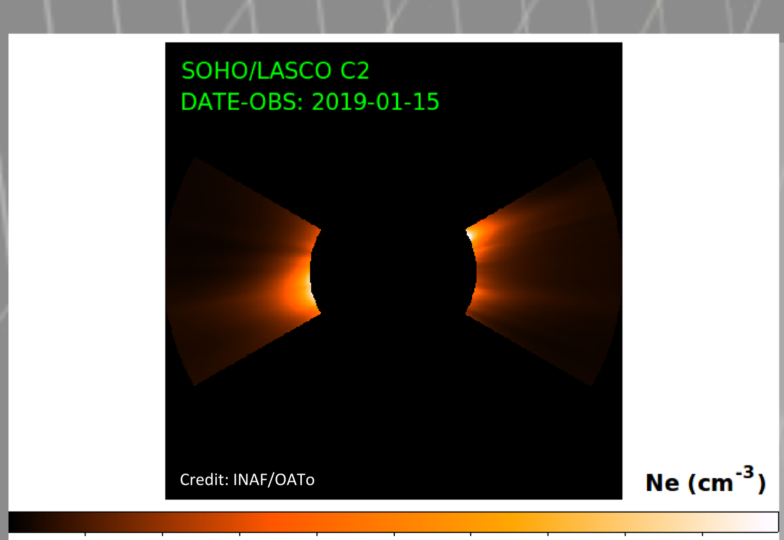
ABSTRACT

*The **SWELTO - Space WEather Laboratory in Turin Observatory** is a conceptual framework where new ideas for the analysis of space-based and ground-based data are developed and tested. The input data are (but not limited to) remote sensing observations (EUV images of the solar disk, Visible Light coronagraphic images, radio dynamic spectra, etc...), in situ plasma measurements (interplanetary plasma density, velocity, magnetic field, etc...), as well as measurements acquired by local sensors and detectors (radio antenna, fluxgate magnetometer, full-sky cameras, located in OATo). The output products are automatic identification, tracking, and monitoring of solar stationary and dynamic features near the Sun (coronal holes, active regions, coronal mass ejections, etc...), and in the interplanetary medium (shocks, plasmoids, corotating interaction regions, etc...), as well as reconstructions of the interplanetary medium where solar disturbances may propagate from the Sun to the Earth and beyond. These are based both on empirical models and numerical MHD simulations. The aim of SWELTO is to test new data analysis methods for future application for Space Weather monitoring and prediction purposes. The first modules that have been preliminarily developed are presented here, together with future directions.*



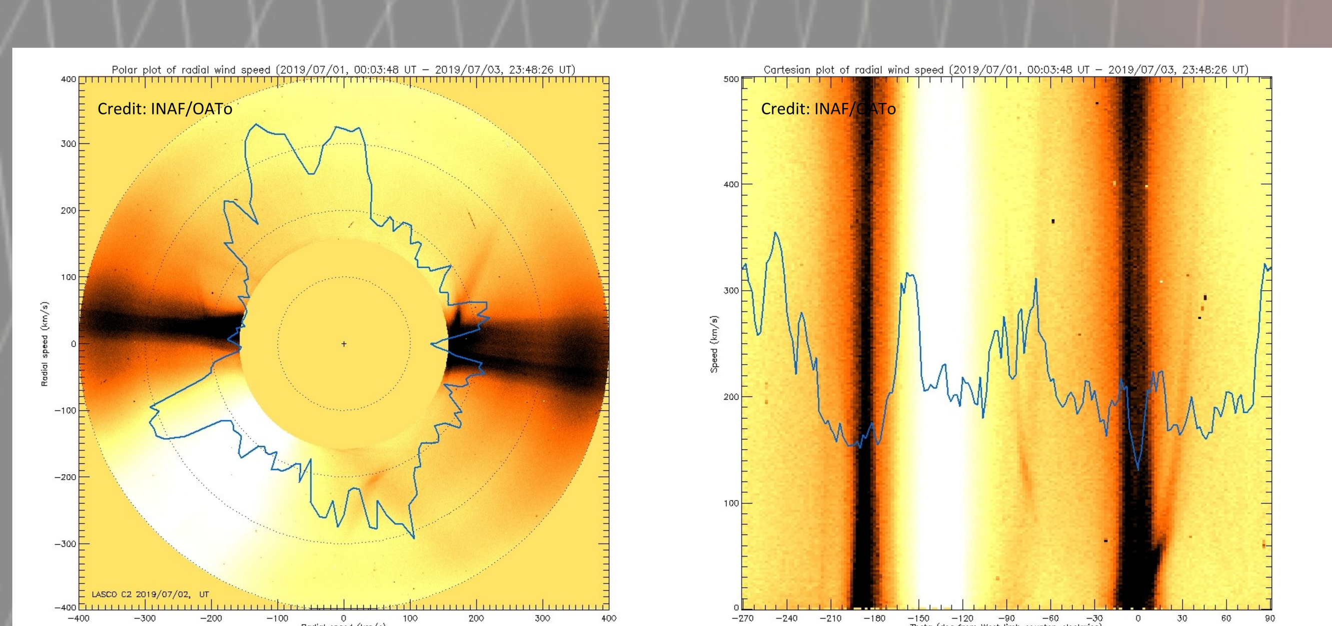
SUN NOW MODULE

This module is aimed at providing a quasi real-time information of the actual conditions in the solar atmosphere. The input data are sequences of visible light coronagraphic images acquired by the SOHO/LASCO-C2 coronagraph, and EUV full-disk images acquired by the SDO/AIA telescopes (193 Å channel). The LASCO images are calibrated with standard routines, monthly background models are applied to outline the K-corona by removing F-corona and stray light, and images are further enhanced by using the NRGF filter distributed within SolarSoftware. The AIA images (downloaded in full resolution) are calibrated with standard SolarSoftware routines and then enhanced with standard IDL filters. The time evolution as observed with these two instruments over the last 24 hours is then provided every 6 hours with a two-panel synchronized movie, where a time clock provides the UT hours and minutes.



CORONAL DENSITY MODULE

This module is aimed at providing a quasi real-time determination of the 2D distribution of coronal densities on the plane of the sky. The electron density distribution in the corona is obtained, with a regular cadence of one hour, from LASCO/C2 images, covering the FoV from 2 to 6 solar radii, and in coronal sectors 60 degrees wide across the equator. The aim is to provide electron density maps with the same cadence of images in the Sun-Now Module, and this can be done calculating the density from the total brightness data, and not starting from the pB measurements, which are acquired once per day. We used a standard inversion technique of the integral along the LOS of the total K-corona, which is due to Thomson scattering of the solar disk radiation from the coronal electrons. The K-coronal brightness is derived from the total coronal brightness, after subtraction of the F-corona distribution.

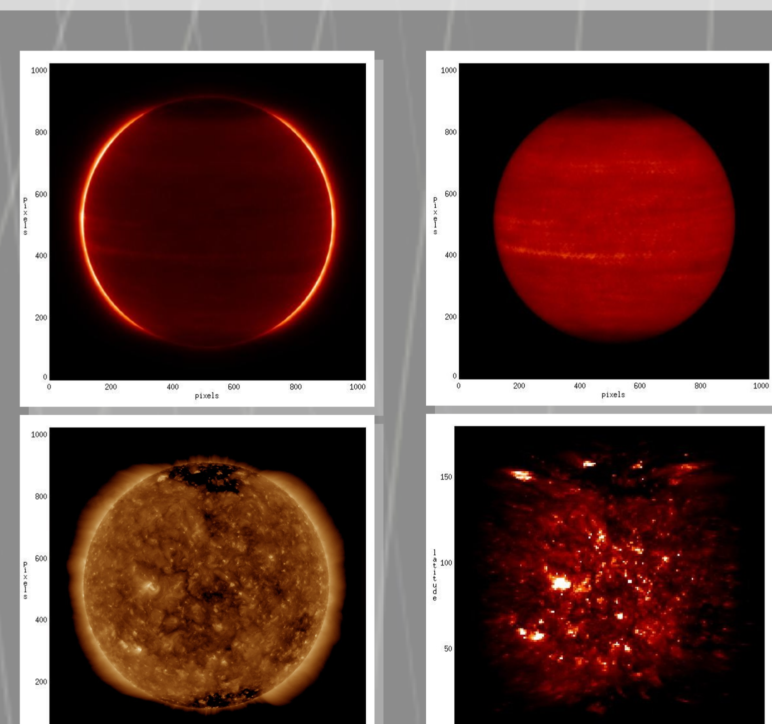


WIND SPEED MODULE

This module is aimed at measuring the solar wind speed near the Sun. The input data are sequences of visible light coronagraphic images, for the first test presented here we employed data acquired by the SOHO/LASCO-C2 coronagraph. All the total brightness images (orange filter) acquired over a period of 3 days are downloaded, calibrated with standard SolarSoftware routines, transformed in polar coordintes, and packed in a single datacube. The time evolution of intensities observed in each single pixel is de-trended to remove variations related with large scale coronal features, and identify small scale features such as plasma blobs and density inhomogeneities. At each single latitude, all the radial intensity profiles observed over the selected time interval are then analyzed with cross-correlation algorithm, measuring an average value of wind speed. The resulting latitudinal distribution of wind speed are finally shown in a polar plot superposed over one of the LASCO-C2 images normalized with a radial filter. The routine works with the latest available LASCO images in quasi real-time, providing a measurement of the actual wind speed on the plane of the sky daily every 6 hours.

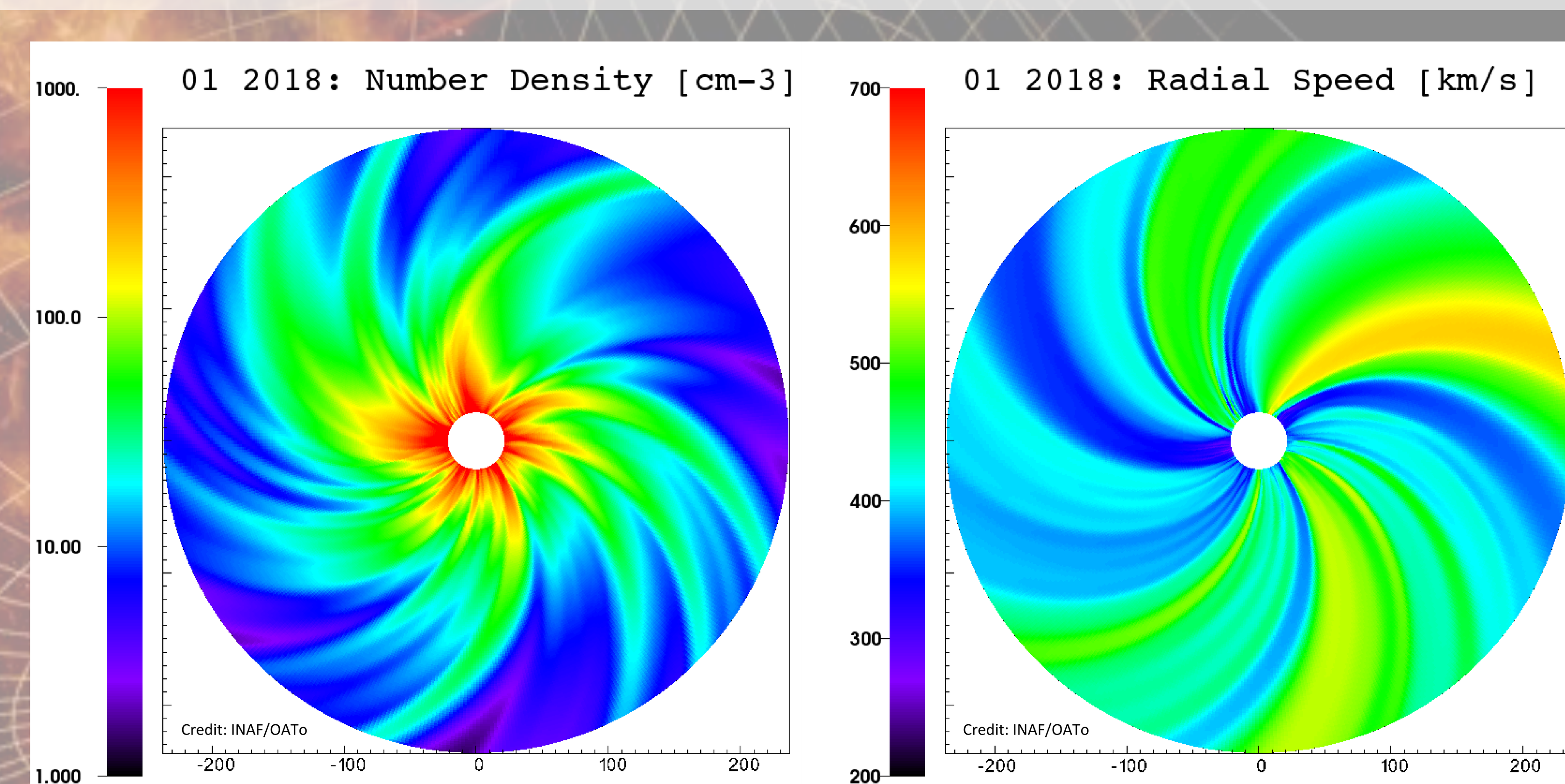
CORONAL HOLE MODULE

This module is aimed at providing a quasi real-time identification of high– and low-latitude coronal holes on the solar disk. The input data are the latest EUV full-disk images acquired by the SDO/AIA telescopes (193 Å channel). The module first download the latest 28 days of observations (quick-look reduced resolution, one image every 6 hours) to build an average image over the last solar rotation period. This average image is then employed to normalize the latest available actual frame. The resulting image of the visible hemisphere is then converted in polar coordinates and geometrically corrected for the limb brightnening effect. Normalized intensities in the resulting image will be then clustered and classified in 3 main sub-groups: "active sun", "quiet sun" and "coronal hole". The final output will be a 2D EUV image where boundaries of polar and mid-latitude coronal holes are authomatically identified and overplotted. A similar technique will be developed to identify possible locations for flares.



PARKER SPIRAL MODULE

This module is aimed at providing a quasi real-time numerical reconstruction of the actual state of the interplanetary Parker spiral. To this end, we developed a new approach to this problem called RIMAP - Reverse In situ data and MHD APproach. The plasma parameters in the inner boundary at 0.1 AU are derived directly from the in situ measurements acquired at 1 AU by ACE, and by applying a back reconstruction technique to remap them into the inner heliosphere. This remapping is done by using the Weber and Davies solar wind theoretical model to reconstruct the wind flowlines. The plasma is then re-propagated outward by running a MHD numerical simulation based on the PLUTO code. The simulation is carried out in 3D, but final results are representative only of the plasma conditions (speed, density, and magnetic field) on the ecliptic plane, because no information on these parameters are currently available in the inner boundary out of this plane.

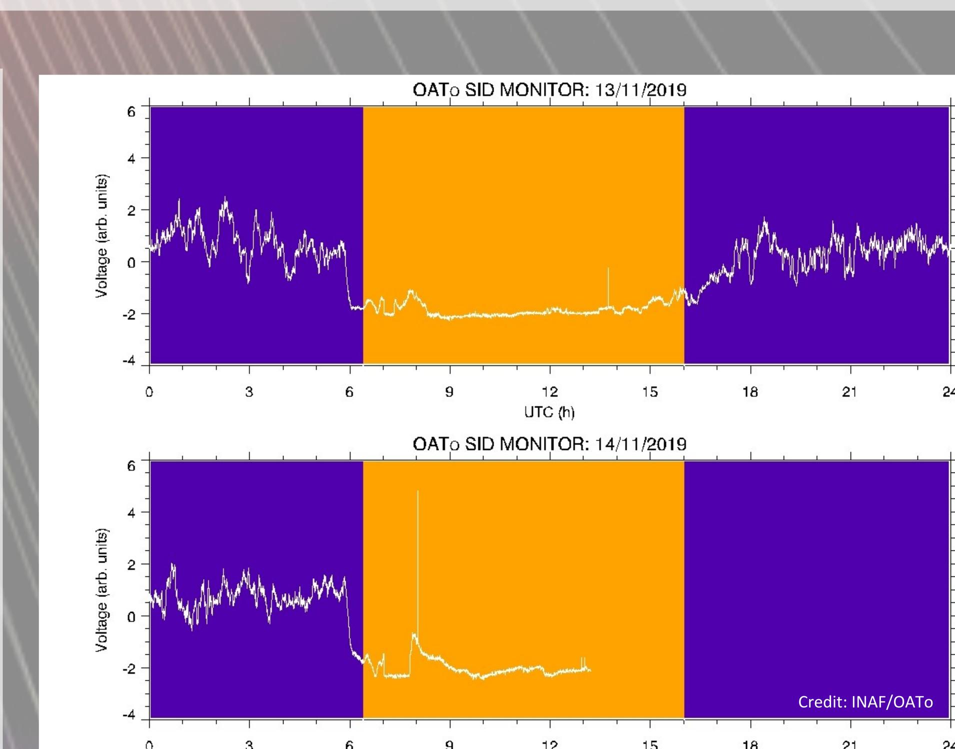


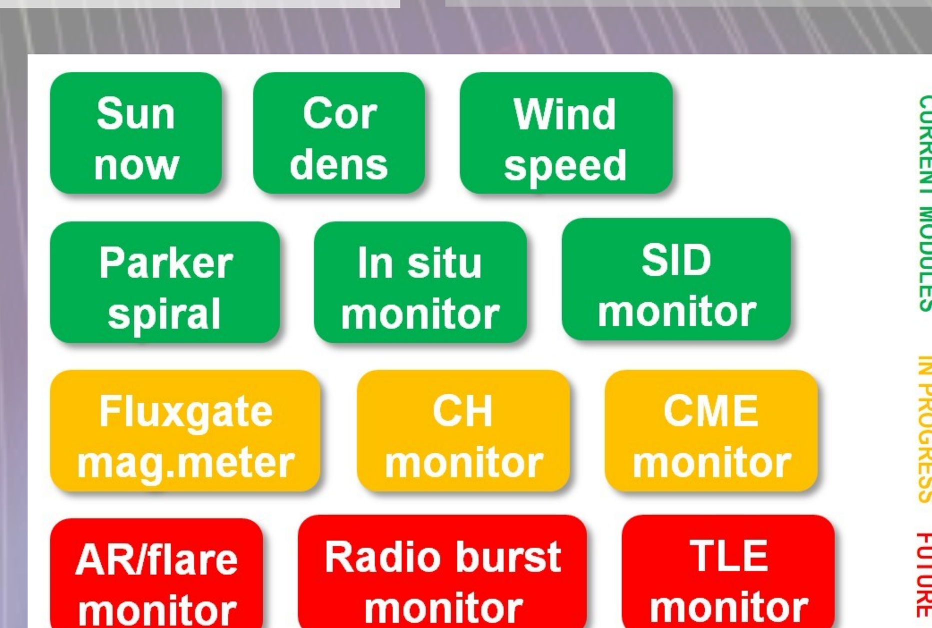
IN SITU MODULE

This module is aimed at providing a quasi real-time information of the actual conditions in the interplanetary space. The input data are sequences of plasma measurements acquired in quasi real-time by the ACE spacecraft located in the L1 Earth-Sun Lagrangian point. Among different acquired measurements, we selected the wind speed, density, and the three components of the magnetic field. Data acquired over the last 24 hours are extracted and plotted (1 min or 5 min average?); moreover the data are used also to show actual values of the Alfvén speed and wind Alfvénic Mach number (the employment of these parameters for possible space weather forecasting applications will be tested in the near future). The module also read in input all the measurements acquired over the last 28 days, in order to cover one full rotation of the Parker spiral. These measurements are then re-sampled, and provided in output as input parameters for the "Parker spiral module".

SID MONITOR MODULE

This module is aimed at providing real-time information about possible sudden ionospheric disturbances (SIDs) as observed with local data. A radio antenna was built, installed in the Observatory, and connected with a SID monitor provided by Stanford University. The monitor band-pass is centered on the frequency of 23.4 kHz and sample the signal emitted by a strong VLF station located in Germany at Rhauderfehn (DHO station at 53° 10'N 07°33'E). During day-time this signal propagates throught multiple reflections between the ground and the D layer of ionosphere, while during night-time the D layer disappears, and the signal is reflected by the E layer located higher up, leading to a typical night-day modulation of the signal. When a solar flare occurs, the enhanced ionization due to the increased X-ray and EUV flux from the Sun results in a clear associated increase in the strength of radio signal, due to the ionospheric disturbance related with the solar flare. The module automatically reads and plot real-time measurements acquired with the SID monitor.





FUTURE DEVELOPMENTS

The modules described here are currently in their first version and still under development and testing. A website on this project is now in preparation and will be linked to the Turin solar Physics Group webpage (http://www.oato.inaf.it/ricerca/aree-di-ricerca/sole-e-sistema-solare/fisica-solare/). Moreover, in the next future new modules are going to be developed and tested, such as:

CORONAL HOLE MODULE: based on SDO/AIA EUV images, to automatically track and measure high and low latitude coronal holes
FLARE DETECTION MODULE: based on SDO/AIA EUV images and GOES data, to automatically track active regions and monitor flares
RADIO BURST MODULE: based on radio dynamic spectra acquired from space and ground, to automatically identify type-II radio bursts
CME DETECTION MODULE: based on SOHO and STEREO WL coronagraphic images, to automatically identify and track Coronal Mass Ejections
GEOMAG FIELD MODULE: based on local (OATo) fluxgate magnetometer, to provide measurements of local geomagnetic disturbances
ATMOSPHERIC TLE MODULE: based on local (OATo) full-sky cameras, to identify possible Transient Luminous Events related with solar flares

*For any information or request about this project please contact alessandro.bemporad@inaf.it