Space Weather services for flare and CME forecasting supported by a multi instrument database

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Abstract: The Sun continuously releases energy into space in the form of electromagnetic and particle radiation (e.g., CMEs, flares, and Solar Energetic Particles). These emissions can vary very quickly and dramatically change the Sun-Earth environment, i.e., the Space Weather. Understanding Space Weather is extremely important for our technological society, since it can damage or destroy satellites, GNSS, communication, and power distribution systems. In the framework of supporting the regional, national and EU resilience to these effects, the Space Weather Team at University of Rome Tor Vergata is realizing a database for ground-based and space-born instrument with specific capabilities for the Space Weather activity. On top of this database, we have implemented an automated flare detection and forecasting system based on the detection of magnetic active regions and associated flare probability estimation. Also, we have realized and tested an evolution of the Drag Based Model for CME propagation. We present here the concept of a service which capitalize on all these contributions to provide the likelihood of a CME to hit Earth and the relative time of arrival and velocity at 1AU. Regional and European funds support the development and realization of the database.

SWERTO: Space-Weather at the University of Rome Tor Vergata

The SWERTO project is supported by regional (Lazionnova, FILAS) and European funds (Tender IPS) for the realization of a database centre for satellite-borne (e.g., PAMELA, ALTEA) or ground-based instruments (e.g., IBIS, MOTH) which are relevant to the determination of Space-Weather conditions, such as CMEs, flares and Solar Energetic Particles (SEP) parameters.

The centre allows the registered user to access scientific data from instrumentation available to the Physics Department researchers through national and international collaborations, and will provide fluent software for the selection and visualization of such data, promoting the access to technical and scientific information from the industries which employ technologies vulnerable to Space-Weather effects. A Fowchart of the SWERTO basic idea is shown in Fig. 1.

SWERTO real time information will also feed algorithms for the computation of forecasting parameters: starting from magnetograms of active regions (ARs), the project involves the development of algorithms for AR detection and for the compute of proxies for flare forecasting, such as the unsigned flux R on the inversion polarity line in each AR: this value, according to Schrijver, 2007, is correlated to the probability of the AR to flare (for values of log(R)>5 there is an 80% probability to have an M1 class flare, 35% of an M3 flare, 20% of an X1 flare and 1-2% of a X3 flare).

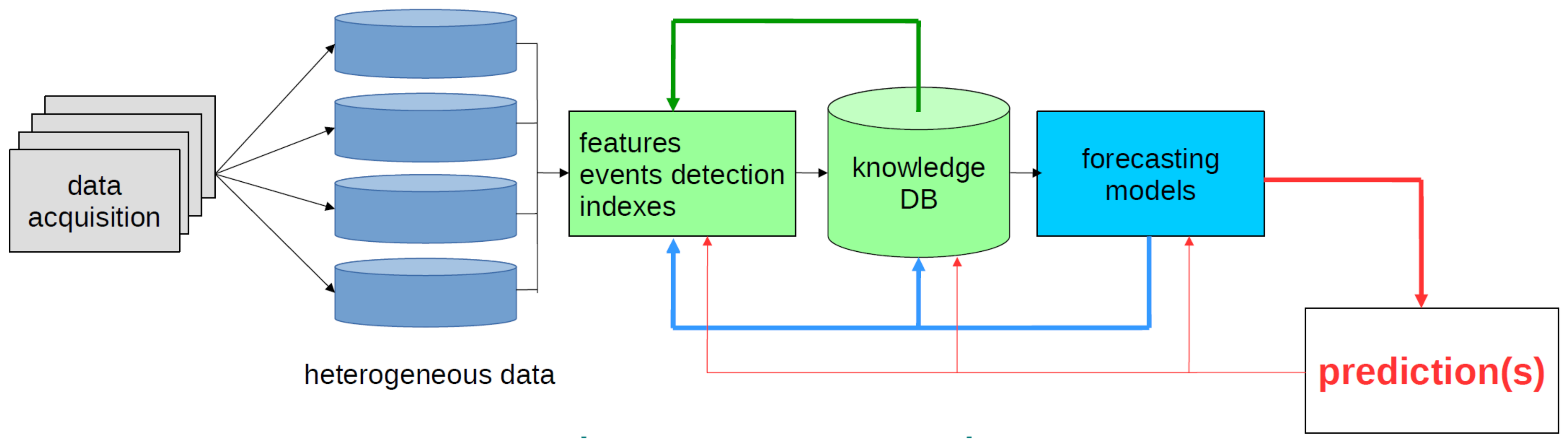


Fig. 1 Scheme of the SWERTO database concept.

Flarewatch: automated flare detection software

As part of the SWERTO database, an automated software named Flarewatch is under development, based on H-alfa data and compared to the correspondent magnetogram, for a near-real time flare detection, described in Fig. 2.

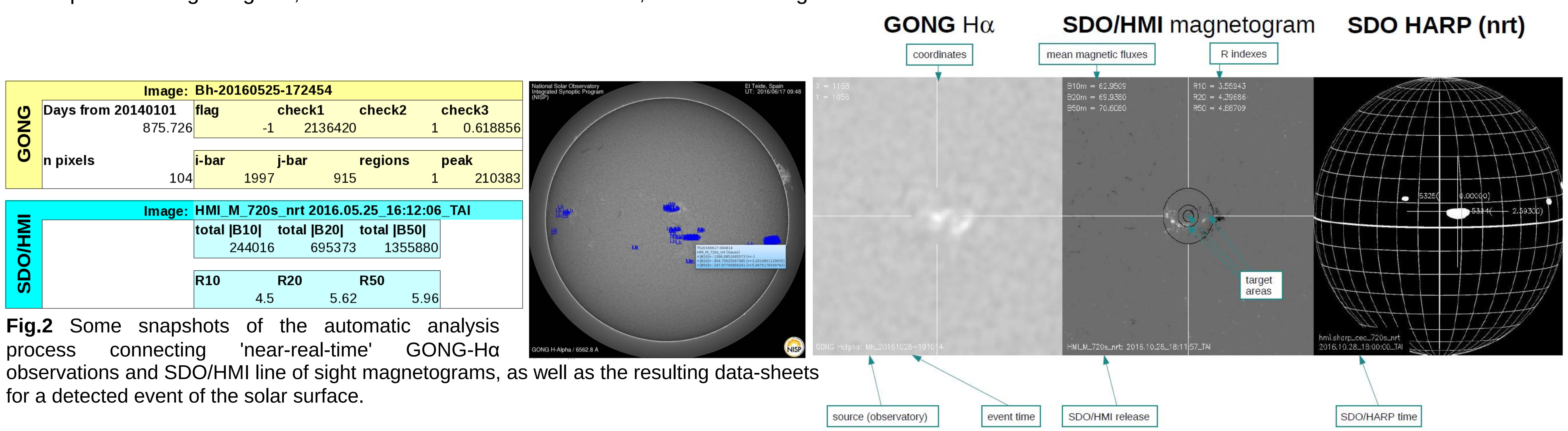
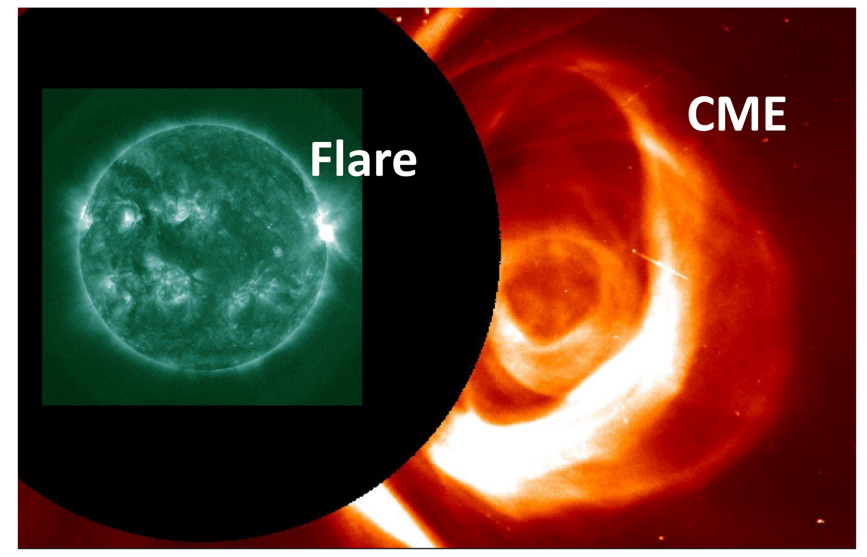
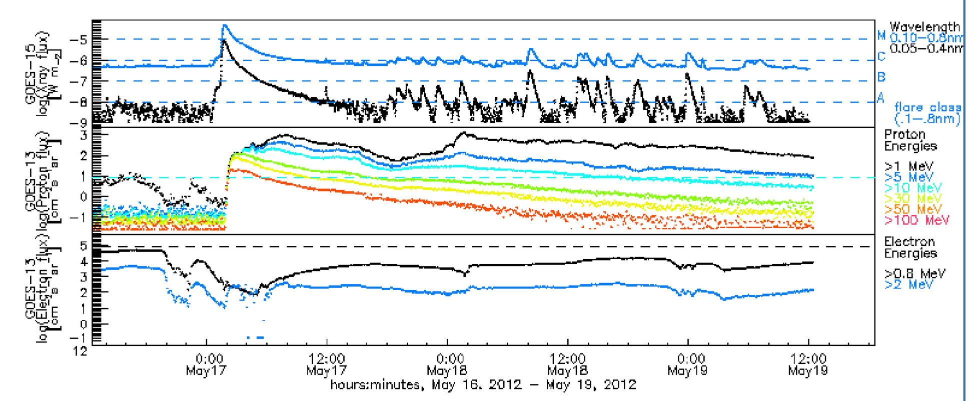


Fig.2 Some snapshots of the automatic analysis process connecting 'near-real-time' GONG-Hα observations and SDO/HMI line of sight magnetograms, as well as the resulting data-sheets for a detected event of the solar surface.

Solar extreme events

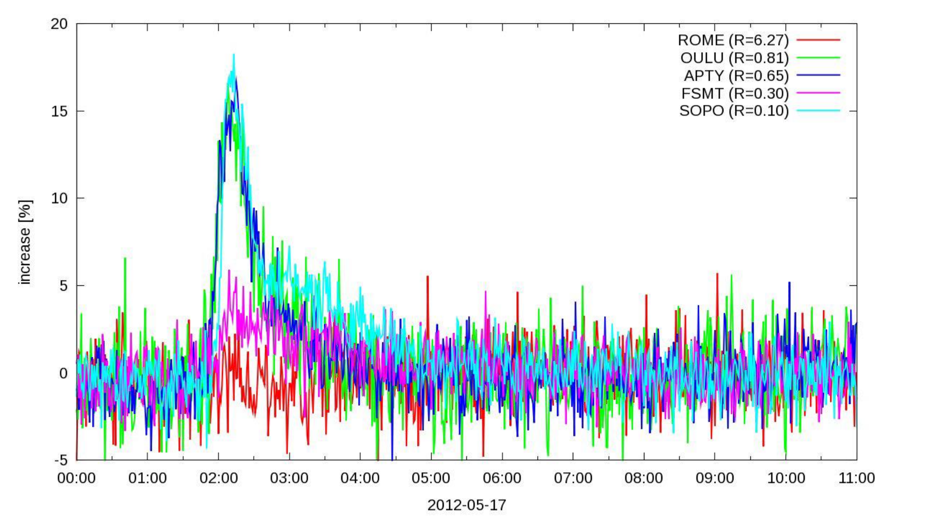


Xray & particle flux enhancements



During a period of strong solar activity, sudden events such as solar flares, coronal mass ejections (CME), high-speed solar wind, X-ray emissions and high energetic particles emissions are frequent. These phenomena are important drivers of Space Weather, which is associated with geomagnetic storms, energization of the Van Allen radiation belts, ionospheric disturbances and scintillation of satelliteto- ground radio signals and long-range radar signals, aurora and geomagnetically induced currents at Earth's surface.

neutron monitor ground level enhancements



CMEwatch: modeling and forecasting of CME

The project also include a section relative to the CME nowcasting and forecasting. The CME nowcasting database will be built on parameters obtained from space-born instrument observations. An example of CME nowcasting is shown in Table 1. CME propagation forecasting is carried out using a drag based model (DBM).

Table 1. Example of nowcasted CME parameters.

Ncme	t_reading	t0_cme	dt0	Ang	width	v	dv	vmin	vmax	halo
7	15-Dec-2016 22:00:00	15-Dec-2016 07:48:00	0	83	28	1488	314	1077	1953	
6	15-Dec-2016 22:00:00	14-Dec-2016 19:00:00	1	305	8	376	88	256	452	
5	15-Dec-2016 22:00:00	12-Dec-2016 17:48:00	2	116	14	117	19	93	154	
4	15-Dec-2016 22:00:00	12-Dec-2016 06:36:00	2	323	96	341	43	240	430	II
3	15-Dec-2016 22:00:00	12-Dec-2016 06:24:00	2	226	14	214	22	176	243	
2	15-Dec-2016 22:00:00	10-Dec-2016 20:12:00	0	282	6	368	640	269	1644	
1	15-Dec-2016 22:00:00	10-Dec-2016 17:24:00	2	272	70	289	28	228	359	

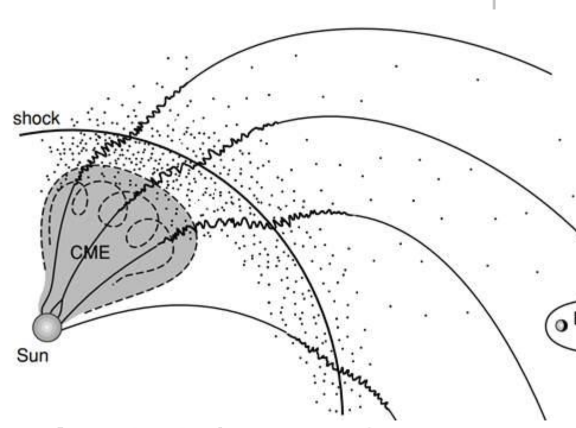


Fig. 3 Scheme of a CME propagation.

CME Drag Based Model

A detailed description of the motion of an CME by numerical simulations of MHD equations, involves in general a large amount of data, time and computational power. The DBM approach is based on the interaction between a CME propagating in interplanetary space and the solar wind (SW). By means of this model, CME is described in a way similar to a body immersed in a fluid and moving throughout it. This model relies on two parameters: the drag parameter, related to geometrical features of the system, and the SW speed. Due to large uncertainties in these quantities, a statistical distribution of their values, rather than a precise choice, is introduced in the form of a probability density function. For the purpose of forecasting CME arrivals at the Earth, such an approach leads to a prediction on the time of arrival in the form of a distribution of times, allowing the determination of an uncertainty on such a prediction.

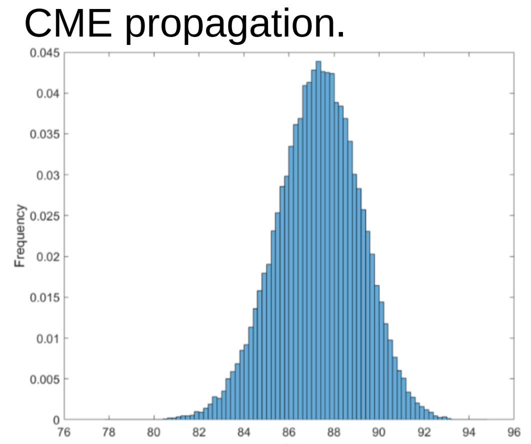


Fig. 4 Result of the computation of the CME arrival times forecasted by the DBM.

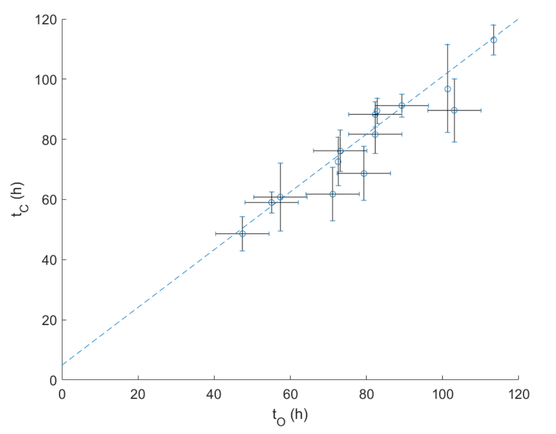


Fig. 5 CME arrival times obtained with a probabilistic approach compared to the observed arrival time.

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