Session IX

Current and future space missions and ground-based observing programs

Chair: C. Mandrini

Solar and Stellar Variability: Impact on Earth and Planets
Proceedings IAU Symposium No. 264, 2009
A. G. Kosovichev, A. H. Andrei & J.-P. Rozelot, eds.

doi:10.1017/S1743921309993127

Space solar missions

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Abstract. In the frame of Symposium 264 which concerns Solar and Stellar Variability we address the space solar missions devoted to the various aspects of solar activity. We describe them in three time categories: missions ready for launch, missions which will operate in the 2012-2015 time frame and ambitious missions to be launched after 2015. We focus on the contributions of these missions according to the following criteria: Understanding mechanisms of activity, Improving detection and characterisation, Working out some prediction. Major activity contributors and manifestations are addressed: Coronal Mass Ejections, Flares, Solar winds, Magnetism (including dynamo), Irradiance.

Keywords. space vehicles: instruments, Sun: activity, Sun: coronal mass ejections (CMEs), Sun: flares, Sun: magnetic fields

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1. Introduction

Outstanding space solar missions (from Yohkoh to more recent STEREO and Hinode) have been operating during the last 15-20 years and have brought a huge amount of information on the Sun, its atmosphere and its activity. Yohkoh obtained hard X-ray pictures of the Sun from the maximum of cycle 22 to the maximum of cycle 23. SoHO has provided a wealth of data (from the deep interior to the outer solar wind) over a time interval of more than 13 years quite uninterruptedly and can be considered as a powerful monitoring tool of solar activity over the whole cycle 23, e.g. a review by Fleck (2005). Since 2006, STEREO has provided "binocular" views of the solar outer atmosphere from corona to Earth and will continue to provide UV and white-light (WL) images of the Sun from very distinct viewpoints until the two spacecraft (S/C) will have a full view of the "other" side of the Sun in 2014 (for a review see: http://stereo-ssc.nascom.nasa.gov/publications.shtml). Since 2006 also, with its high resolution X-ray imager, EUV spectrometer and visible magnetometer, Hinode has provided a new view of the surface and coronal magnetism and of solar activity (see e.g. Tsuneta 2009). Others such as TRACE, CORONAS, CORONAS/PHOTON, RHESSI, have provided a local or global monitoring of the Sun in various wavelengths and energies.

These missions will continue their investigation of the solar atmosphere for still more years but new missions are being prepared which, through their lifetimes and objectives, will directly address the issue of solar activity. At a further horizon, missions are being prepared which will provide data before about 2015. They will partially overlap in time with present and immediate-future missions but will follow their own objectives. Finally, more ambitious missions for the post-2015 era are being discussed. They will be described because, as we shall see, their detailed contents is still a matter of compromise between scientific ambitions and actual capabilities.

What do we mean here by solar activity? Solar activity takes many forms in terms of electromagnetic radiation and particles and arises from various solar structures at all space and temporal scales. We limit our discussion to Coronal Mass Ejections, flares, solar winds, magnetism and irradiance in terms of events and physical quantities and we keep in mind what space can uniquely bring in terms of understanding the mechanisms of activity, of improving detection and characterisation, and finally on working out some prediction. Consequently, we exclude from this review, balloon and rocket experiments such as SunRise and Herschel. This does not mean in any way that they don't bring information on solar activity. Finally, the author apologizes in advance for space solar missions which would have been omitted in this limited overview.

2. Immediate space solar missions

Two of these missions (Solar Dynamics Observatory and PICARD) should be launched in February 2010 while PROBA2 was launched on November 2, 2009. This means that the solar community will have a fleet of three more fully operational S/C as soon as 2010.

Solar Dynamics Observatory. This NASA mission by itself offers splendid opportunities for doing excellent solar physics and for testing what could be done in the field of Space Weather (actually, it is launched in the frame of the NASA "Living With a Star" or LWS program). It is positioned on a geosynchronous orbit which allows for near uninterrupted observations all year long, except for a couple of weeks twice a year. This geosynchronous orbit will also provide an exceptionally high telemetry rate (about 160 Mbps), a first in space solar missions. The scientific goals of SDO are to improve our understanding of seven science questions:
1. What mechanisms drive the quasi-periodic 11-year cycle of solar activity?
2. How is active region magnetic flux synthesized, concentrated, and dispersed across the solar surface?
3. How does magnetic reconnection on small scales reorganize the large-scale field topology and current systems and how significant is it in heating the corona and accelerating the solar wind?
4. Where do the observed variations in the Sun's EUV spectral irradiance arise, and how do they relate to the magnetic activity cycles?
5. What magnetic field configurations lead to the CMEs, filament eruptions, and flares that produce energetic particles and radiation?
6. Can the structure and dynamics of the solar wind near Earth be determined from the magnetic field configuration and atmospheric structure near the solar surface?
7. When will activity occur, and is it possible to make accurate and reliable forecasts of space weather and climate?

As we shall see the three instruments (AIA, HMI and EVE) taken together address all of the above objectives.

1. AIA AIA stands for Atmospheric Image Assembly, which consists in four Science Telescopes offering eight Science Channels with four two-by-two common detectors (4096* 4096 CCD) providing a spatial resolution of 0.6 arcsec per pixel. The ten seconds cadence leads to about 1.1 Tbytes per day ! The Principal Investigator (PI) is A. Title (LMSAL). Main caracteristics of the instrument are presented in Table 1.

It should be noted that with its 13.1nm channel, AIA will observe "flaring" plasma at temperatures higher than $10^7 K$, which will allow to observe not only large flares but also flare-type activity at small scales as evidenced with RHESSI and Hinode/XRT (e.g. Reale *et al.* 2009). Such observations, will be critical for Parker-type heating models at small-scale, as proposed as early as 1994 by Cargill (Cargill 1994).

Table 1. AIA wavelength bands

Wavelength (nm)	Bandpass (nm)	Ion	Region of the atmosphere	Formation Temperature log(T)
Visible	–	Continuum	Photosphere	3.7
170	–	Continuum	Temperature minimum, photosphere	3.7
30.4	1.27	He II	Chromosphere, transition region	4.7
160	–	Continuum	Transition region, upper photosphere	5.0
17.1	0.47	Fe IX	Quiet corona, transition region	5.8
19.3	0.6	Fe XII, XXIV	Corona and Flare Plasma	6.1, 7.3
21.1	0.7	Fe XIV	Active Region Corona	6.3
33.5	1.65	Fe XVI	Active Region Corona	6.4
9.4	0.09	Fe XVIII	Flares	6.8
13.1	0.44	Fe XX, XXIII	Flares	7.0, 7.2

2. HMI HMI (Helioseismic and Magnetic Imager) will provide images, Dopplergrams and magnetograms in the Fe I line at 617.3 nm. It is a rather complex instrument (a follow-up of MDI on SoHO) with two 4096*4096 pixels CCD cameras providing a spatial resolution of 0.5 arcsec per pixel. The data acquisition cadence is 40 seconds. HMI will archive about 1000 Tbytes per year. It should be noted that because of its capacity to observe the full Sun, HMI will be very useful for local (and back-side) seismology and especially the emergence of magnetic flux from the convection zone into the outer atmosphere where it will be observed by AIA. More information can be found in T. Hoeksema's presentation in this Symposium. HMI P.I. is P. Scherrer (Stanford).

3. EVE EVE (Extreme u-v Variability Experiment) is a Full-Disk spectrometer with a complete EUV coverage from 0.1 to 122 nm with an excellent spectral resolution of 0.1 nm. Its high cadence (10s) will allow measuring the irradiance effect of flares. The low latency of data (3-5 min) will provide a high-value asset with respect to LWS and Space Weather activities. EVE PI is T. Woods (LASP/UC).

The launch of SDO is scheduled for February 2010.

Picard The payload of this French microsatellite mission consists in SOVAP (and BOS) which performs radiometric and bolometric measurements, PREMOS with a radiometer and 3 sunphotometers, and SODISM, a metrological imaging telescope dedicated to absolute and relative measurements of the solar radius. The interest of this instrumental space package has been demonstrated during the Symposium (see e.g. J.-P. Rozelot and S. Lefebvre contributions). The three instruments are built by IRM (B), PMOD (CH) and LATMOS (F) respectively. The mission PI is G. Thuillier (LATMOS). Launch is scheduled for February 2010.

PROBA2 This Project for On-Board Autonomy (PROBA) belongs to a series of technology demonstration missions of ESA. It includes a set of solar observation instruments:
1. a LYman-alpha RAdiometer (LYRA) built by ORB and CSL (B) which works in four bandpasses: 115-125 nm (including Lyman-alpha), 200-220 nm (Herzberg continuum range), 17-31 nm (including Helium II at 30.4 nm), and 1-20 nm. LYRA employs wide bandgap detectors based on radiation-hard diamond.
2. a Sun Watcher using AP-sensors and image Processing (SWAP) built by ORB and CSL (B): this EIT-type experiment provides a coronal image every minute after heavy data compression.

The PROBA2 payload also includes plasma instrumentation, a GPS receiver and a laser retroreflector array.

The above-mentioned missions (SDO, Picard and PROBA2) will be critical for the continuation of the International Living With a Star (IWLS) program as shown in Fig. 1. It is clear from Fig. 1 that these three missions will be essential contributions to irradiance variation measurements after 2010.

3. Space Solar missions in the 2012-2013 time frame

The missions we discuss now are supposed to be launched in 2012-2013 (or beyond). Their major feature is that they are approved.

PROBA3 The third PROBA mission of ESA is devoted to a technological test of Formation Flight (FF). A first S/C carries an external occulter about 1.2 m wide located 150 m in front of the main S/C which carries a coronagraph. Both S/C are precisely aligned along an axis centered on solar disk center at least during the FF phase (at apogee of the orbit). The resulting eclipse allows for a half field of view (FOV) which goes as close as 0.04 solar radius above the limb. The outer edge of the FOV is located at two solar radii above the limb. The pixel size is 3 arcsec for a 2K*2K detector, an exceptional spatial resolution in the corona. An A.O. for the payload was issued by ESA at mid-July 2009; answers were due for 15 September 2009, the selection should take place by the end of November 2009 and the flight is scheduled for Autumn 2013. Mission duration is two years.

IRIS IRIS (Interface Region Imaging Spectrograph) is a NASA SMEX mission led by A. Title (LMSAL). It addresses the issues of non-thermal energy and mass supply in the chromosphere and above, along with magnetic flux emergence in the chromosphere in relation with flares and coronal mass ejections (CMEs). Its 20 cm telescope allows for a pixel resolution of 1/6 arcsecond. Its channels include chromospheric lines such as Mg II h and k (excellent indicators of activity) with a resolution of 2.5 pm and TR lines such as C II, Si IV (with a 1.25 pm resolution). The Sun Synchronous orbit provides a 0.7 Mbits/s data rate. Launch is scheduled for December 2012.

4. Space Solar missions beyond 2015

The missions discussed here are being prepared by the relevant space agencies with inputs of the solar communities concerned. Most of them are very ambitious and should lead to major breakthroughs in solar physics. However, none of them has been formally approved at this date.

There are two major possible avenues for solar physics studies: either getting closer to our star in order to improve in-situ measurements (and combine them with remote sensing) or/and also to have polar views of the Sun, on one hand, or staying Earth-bound in order to increase the capabilities of remote-sensing instrumentation in terms of spatial, spectral and temporal resolution, of time coverage and of novel measurements (e.g. polarimetry), on the other hand.

With the first category, solar missions look like planetary exploratory missions which are constrained by low mass and volume, low telemetry and short observing time. As with planetary missions, they bring the ground truth for the local conditions which are being studied. The best example is the NASA Solar Probe Plus (SP+) mission which will diagnose the coronal plasma at less than ten solar radii from the Sun. Although it will not be discussed here in the frame of this Symposium devoted to solar and stellar activity (which can only be unravelled through continuous records) it is nevertheless a fascinating way of exploring our star.

With the second category, we have the possibility of bigger and more comprehensive missions which, step-by-step, and essentially by remote-sensing, improve the knowledge of the physics of the Sun. Increasing the apertures leads to increased spatial or/and temporal resolution. It allows for spectrography and possibly polarimetry with better Signal-to-Noise ratio. The Earth proximity allows for substantial telemetry (in the style of SDO) and a better control of the instrumentation in terms of flexibility, target choice, etc . . .

Solar-C This is a Japanese mission to be launched in 2016, whose PI is S. Tsuneta (NAOJ). Actually, there are two SOLAR-C mission concepts under study which epitomize the choice between exploratory and earth-bound missions.

In the first category ("Plan A"), Solar-C colleagues propose an out-of-ecliptic mission with an orbit staying at one astronomical unit (AU) but achieving an inclination (to the Solar equator) of 30 deg. in two years from launch and 45 deg. in five years from launch. Combined with other observations (e.g. Earth-bound), such a high-inclination orbit will allow to:

- Observe Doppler velocity at high latitudes without projection effects,
- Detect meridional flows at the pole,

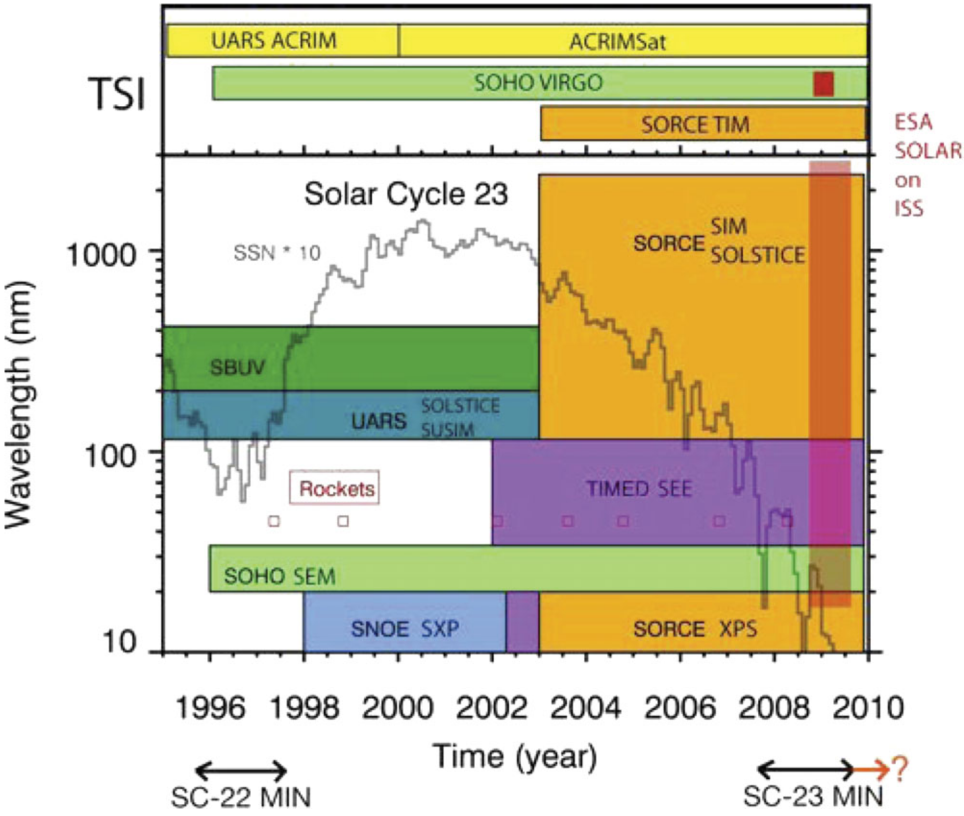

Figure 1. Irradiance missions in operations vs. time (abscissa) and wavelength (ordinate). The two horizontal sets of arrows indicate the time of activity minima for cycles 22 and 23. (Courtesy Tom Woods)

- Observe waves penetrating deep into the Sun: the magnetic field at the tachocline could be detected in this way (a 100kG module corresponds to a 25msec travel time difference).

The model payload would consist in: a Photospheric and chromospheric dopplergraph, a Stokes-polarimeter for photosphere and chromosphere and a X-ray/EUV imager. Optional is a total irradiance monitor.

In the second category ("Plan B"), the mission on Earth-bound orbit aims at high spatial resolution, high throughput, high cadence spectroscopic (polarimetric) and X-ray observations from photosphere to corona in order to investigate the magnetism of the Sun (and especially to solve the dynamo enigma) and its role in heating and dynamism of solar atmosphere. The model payload consists in:
a Near IR-Visible-UV telescope with an aperture of 50cm-1.5m ensuring that it is diffraction-limited, with a 0.1-0.4 arcsec resolution followed by a spectro-polarimeter,
an Ultra-high resolution EUV/X-ray telescope,
along with high resolution, high signal coronal spectroscopic capabilities.
Envisaged technology developments for SOLAR-C address Stokes polarimetry in UV (e.g. Ly-alpha) and EUV (e.g. 171 A) with Hanle effect, along with a Photon counting soft X-ray telescope with ultra-fast CMOS detector to obtain high-cadence high-quality global temperature maps. Working Groups have been established for evaluating the pros and cons of both "Plans".

Space Solar Telescope Continuing with projects from Eastern Asia countries, we have the Space Solar Telescope (SST) mission proposed by CNSA (China) for a launch no sooner than 2015. It consists in:

(*a*) The Main Optical Telescope (MOT) which consists in:
- a 1-meter optical telescope with a FOV of 2.8 by 1.5 arcmin, working at any wavelength within [393 nm-656 nm], a bandpass of 2 nm and a resolution of about 0.1 - 0.15 arcsec,
- a 2-D real-time polarization spectrograph providing 2-D Stokes parameter profiles and being tunable in wavelength. The wavelength range is 390-700 nm. Universal Birefringent Filters (UBF) have a Full Width at Half Maximum (FWHM) around 5 - 7.5 pm. Eight channels can be distributed in a spectral line or several spectral lines. The accuracy of polarization analyzer should be 2 10^{-4}. The wide-band filtergraph (380-550 nm) with bandpasses of 3 nm allow for an exposure time of 10^{-4} s. At the opposite, a set of vector magnetic field measurements requires up to 30s.
- A Correlation Tracker.

(*b*) A set of "auxiliary" instruments which include:
- an EUV Imager for the Solar Telescope (EUT) working at 17.1 (formed at 1.0 MK), 19.5 (1.3 MK), 21.1 (2.0 MK) and 12.9 nm (10 MK)
- a Wide Band Spectrometer (WBS)
- an H-alpha and White-light Telescope (HWT)
-a Solar and Interplanetary Radio-spectrometry (SIR).

The P.I. of SST is H. Zhang (NOAC).

Solar Orbiter This major mission by ESA and NASA, which was approved by ESA in 2000, is now being proposed in the frame of the ESA Cosmic Vision program. Its unique orbit features (getting as close as 48 solar radii -or 0.23 AU- from the Sun, viewpoints from about 30 deg. heliographic latitude) will allow for exploring unchartered innermost regions of the solar atmosphere, study the Sun from a co-rotation vantage point and provide images of the Sun's polar regions. Solar Orbiter (SO) will accommodate a set of remote-sensing and in-situ instruments which will have to overcome mission constraints such as increased thermal and particles exposures, limited telemetry and observing time (30 days at perihelion). Such constraints make the mission a challenge from both science and technology standpoints. Launch is scheduled for 2017 with operations starting about two years later. A suite of 10 instruments has been selected in March 2009 (see http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=44469) as the scientific payload for the ESA Solar Orbiter mission, which are described below.

Remote sensing instruments The array of remote sensing instruments includes:

(*a*) EUI, an Extreme U-V Imager, whose PI is P. Rochus (Belgium). It consists in a package of three instruments: a dual Full Sun Imager (FSI) working sequentially in 30.4 and 17.4 nm, and two High Resolution Imagers (HRI), a dual one covering 17.4 and 33.5 nm and the other covering the Lyman alpha line (121.6 nm). Note that the HRI pixel size corresponds, at perihelion, to 80 km on the Sun, a resolution comparable to the best resolution obtained in the visible from the ground with adaptive optics (see e.g. the Swedish Solar Telescope).

(*b*) SPICE (SPectral Imaging of the Coronal Environment), funded by NASA, is a two-channel UV spectrograph working in the two bands: 70.2-79.2 nm and 97.2-105 nm (and 48.6-52.5 nm in the second order). The one arcsec resolution translates into a pixel resolution of 170 km on the Sun at perihelion. The spectral resolution should allow for a velocity determination of about +- 3 km/s through centroiding technique. The lines span the solar atmosphere from the chromosphere to the corona. SPICE spectroscopic data will be compared with in-situ composition measurements, they will allow to map the origins of solar wind streams, to diagnose the acceleration of the extended solar wind and to look after the source region of energetic particles. The P.I. of SPICE is D. Hassler (SwRI, USA).

(*c*) PHI (Polarimetric & Helioseismic Imager) is an HMI/SDO type of imaging magnetograph which will fully benefit from SO properties. Its PI is S. Solanki (MPS). As a linkage science, it will provide the magnetic field information to EUV imagers and spectrometer. It will provide the first direct view of magnetic and velocity fields at the poles. Through SO corotation, it will allow to follow surface and subsurface temporal evolution of solar features such as active regions. It will perform stereoscopic helioseismology to probe the deep interior, it will measure the complete field of the Sun (with a 360 deg view) and also provide the magnetic context for SP+. PHI consists in a High Resolution Telescope (HRT) (aperture 14 cm and 160 km resolution at perihelion) alternately operating with a Full Disk Telescope (FDT) (aperture 2.5 cm), a Vector magnetograph providing full Stokes polarimetry in Fe I 617.3 nm and solar LOS velocities with a spectral resolution better than 10 pm.

(*d*) STIX STIX (Spectrometer/Telescope for Imaging X-Rays) is led by A. Benz (ETH, CH). It provides location, structure, timing and imaging spectroscopy of hard X-ray sources and offers a strong link between remote-sensing and in-situ observations of high-energy events. As with the HXT of Yohkoh, it works on the basis of indirect imaging with 64 subcollimators (i.e. 32 Fourier components). Angular resolutions range from 7 arcsec to 8.8 arcmin. The full Sun is imaged from 4 to 150 keV, with an energy resolution between 1 and 15 keV. The time resolution is about 0.1 s (or larger). Of particular interest, will be the search of the link between X-ray sources and the particles recorded with in-situ instruments on SO.

(*e*) METIS METIS stands for Multi Element Telescope for Imaging and Spectroscopy (PI: E. Antonucci (OAT, I)) will simultaneously image the visible and ultraviolet emission of the solar corona and diagnose, with unprecedented temporal coverage and spatial resolution, the structure and dynamics of the full corona in the range 1.2 to 3.0 solar radii from Sun centre, at perihelion during the nominal mission. It relies upon broadband imaging of the polarized visible K-corona (500-600 nm), narrow band imaging of the UV corona in the HI Ly-alpha, 121.6 nm, line and narrow band imaging of the EUV corona in the He II Ly-alpha, 30.4 nm. At perihelion, the cadence for a full measurement will be of one minute and the spatial resolution better than 3 arcsec.

(*f*) HI Heliospheric Imager (SoloHI) an instrument funded by NASA (PI: R. Howard, NRL, USA) is designed to pinpoint CMEs, shocks and other disturbances in the solar wind. The success of HI on the STEREO mission has shown the potential of such an instrument able to follow the propagation of CME plasma at a distance between 9 and 37 solar radii from the Sun with a 20 arcsec resolution. It will bridge the gap between remote-sensing (EUI, SPICE, XRT, METIS) and in-situ measurements (whether on SO itself or on other S/C in the interplanetary space, including SP+).

<u>In situ instruments</u>

(*a*) RPW The Radio and Plasma Waves (RPW) Instrument RPW will measure magnetic and electric fields at high time resolution, in order to determine the characteristics of electromagnetic and electrostatic waves in the solar wind from almost DC to 20 MHz. It will record waves from about 2-5 solar radii up to the SO orbit. It is, in a sense, both an in situ and remote sensing instrument. The PI is M. Maksimovic (LESIA/OP, F).

(*b*) EPD The Energetic Particle Detector will measure the properties of suprathermal and energetic particles: the sources, acceleration mechanisms, and transport processes of these particles. The PI is J. Rodriguez-Pacheco (SRG, Spain). It consists in SIS (Supra-thermal Ion Spectrograph) working in the range 8 keV/n to 10 MeV/n, EPT (Electron and Proton Telescope) (20 to 700-900 keV), LET (Low Energy Telescope) (1.5-12 MeV for protons), and HET (High Energy Telescope) whose range for electrons is 0.3 -20 MeV, for positrons 0.3-1 MeV, for protons 10-100 MeV and for ions heavier than He 50 -200 MeV.

(*c*) MAG This magnetometer (PI: T. Horbury (ICL, UK)) will measure the local magnetic field between 10^{-3} and 10 Hz with a signal much higher than the sensitivity of the instrument, a partial effect of the proximity to the Sun. It will be the first direct measurement of the coronal magnetic field at a distance of less than 50 solar radii.

(*d*) SWA Solar Wind Analysers (SWA) consist in a set of three instruments:
  i. PAS This Proton -Alpha particle Sensor will measure the velocity distribution of the major ionic species.
  ii. HIS This Heavy Ion Sensor will determine the charge states of O and Fe. It will also record pick-up ions of various origins.
  iii. EAS This Electron Analyser System will determine the electron velocity distributions of the solar wind core, halo and strahl with high temporal resolution.

The PI is C. Owen (UCL/MSSL, UK).

<u>InterHelio Probe</u> The mission inherits from the Interhelios mission already proposed by Russia. It has a mission profile rather close to Solar Orbiter with the main following features: in-situ measurements close to the Sun (about 30 solar radii), corotation and out-of-ecliptic observations, observations of the invisible side of the Sun. A launch is scheduled in 2018; PIs are S. Kuzin and V. Kuznetsov (Izmiran), L. Zelenyi (IKI).
The P/L includes:

(*a*) a magnetograph with a spatial resolution of 1 arcsec and a sensitivity of about 2 Gauss (*b*) an EUV imager-spectrometer with a 1 arcsec resolution in three bands; 17.1, 29.-31 and 13.2 nm.

(*c*) an X-ray imager in the range 50-100 keV with a 10 arcsec resolution

(*d*) an optical coronagraph with a 1 arcsec resolution over a FOV of 8 deg.

(*e*) a multichannel optical photometer working between 280 and 1550 nm.

(*f*) a set of in-situ instruments (solar wind analysers, magnetometer, radio and gamma spectrometers, neutron detector).

Solar Orbiter, Solar Probe Plus, and other missions synergies It is difficult to describe all the possible synergies between SO, SP+, Solar C and other Earth-bound missions (including GBO). Let us take a simple example with the objectives achievable only with SO and SP+, when SP+ is at its perihelion. When SO and SP+ will have their perihelions aligned, they will record the same (low velocity) plasma along the Sun-S/C line. It will be possible to measure, e.g., the change of the distribution functions between 10 and 48 solar radii. SO will also provide some remote-sensing information about the surface sources candidate for providing the plasma measured by SP+. When SO will be behind SP+ perihelion by about 60 deg, SO and SP+ will record about the same Energetic Particles which follow the spiral magnetic field. SO remote sensing will observe the acceleration site of these Energetic Particles. On the contrary, when SO will be 90 deg ahead of (or behind) SP+ perihelion, SO remote sensing will observe the plasma analysed in-situ and remotely (HI) by SP+. Of course, this potential will be increased by Solar-C (especially with its “A” version) and InterHelio Probe capabilities of multi-points and multi-viewpoints measurements.

5. Conclusions

Many other projects in all countries are being studied and proposed within different time frames: ADITYA (India), KuaFu (China), four solar proposals for Cosmic Vision at ESA (COMPASS, DYNAMICS, POLARIS, HiRISE), LYOT/DESIR/HEBS. As mentioned earlier-on, they fall into two categories: either an encounter (close-up or out-of-ecliptic but P/L and TM are modest) or Earth-bound missions providing high resolution but with an in-ecliptic view point from one AU only. Actually, we need **both !** because the information from both are complementary: the respective measured scales of the observed structures differ by many orders of magnitude. They also differ in sizes and ambitions but it may be worth mentioning the value of “small” (SMEX-size or smaller) missions for the advancement of science, technology and training of young scientists and engineers.

Other missions are being operated (and proposed) in the frame of Space Weather such as the GOES of NOAA which will also provide very valuable information about the solar activity.

One can add that joint observations and science coordination between the above mentioned space missions and the Ground-Based Observatories (GBO) will provide a superior synergetic science. One can think, for instance, of the super spatial resolution brought by future telescopes either in the visible and the infra-red (ATST, EST) or in the radio domain (LOFAR, SKA, FASR, ALMA).

Finally, huge amounts of various data (think of SDO !) will be gathered and such a windfall, which also is a constraint, calls for user-friendly open software and data access, such as proposed by the Virtual Solar Observatory (VSO), involving both space and GBO missions.

Acknowledgements

I deeply thank colleagues (mostly PIs) who provided me much material about their instrument/mission: E. Antonucci, A. Benz, P. Boumier, S. Kuzin, M. Maksimovic, P. Rochus, P. Scherrer, S. Solanki, A. Title, S. Tsuneta, T. Woods, H. Zhang along with E. Buchlin and J. Leibacher who helped me in the preparation of the manuscript. I also thank the S264 organizers who invited me for this review.

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