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COMMISSION 12 — SOLAR RADIATION AND STRUCTURE

RAYONNEMENT ET STRUCTURE SOLAIRE

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TRIENNIAL REPORT 2009–20012

1. Introduction

Commission 12 of the International Astronomical Union encompasses investigations of the internal structure and dynamics of the Sun, mostly accessible through the techniques of local and global helioseismology, the quiet solar atmosphere, solar radiation and its variability, and the nature of relatively stable magnetic structures like sunspots, faculae and the magnetic network. The Commission sees participation of over 350 scientists worldwide.

A brief review of Commission activity and some important developments in the field in the framework 2009–2011 is reported below. Several of these developments came about during the deep, unusually long minimum of solar magnetic activity which manifested itself between 2008 and 2009, and which was observed by a number of new missions and advanced ground-based instrumentation, so providing for a clearer view of the "basic" quiet Sun structure. As always, the report is by no means exhaustive, merely reflecting the main interests of the Commission Organizing Committee.

2. Organizational activities

Commission 12 proposed and organized IAU Symposium 264 "Solar and Stellar Variability - Impact on Earth and Planets" (Rio de Janeiro, Brazil, August 3-7, 2009), IAU Symposium 274 "Advances in plasma astrophysics" (Catania, Italy, September 6-10, 2010), IAU Symposium 294 "Solar and astrophysical dynamos and magnetic activity" (Beijing, China, August 27-31, 2012). It also participated in the organization of IAUS 286 "Comparative magnetic minima: characterizing quiet times in the Sun and stars" (Mendosa, Argentina; Oct. 3-7, 2011) and IAUS 271 "Astrophysical dynamics - from stars to galaxies" (Nice, France, June 21-25, 2010).

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3. New observational facilities

The period of 2009-12 was marked tremendous advances in new observational facilities from the ground and space. These include the NASA's Solar Dynamics Observatory mission, launched in February 2010, for understanding the basics mechanisms of solar dynamics and variability, the PICARD mission (France) launched in June 2010 and dedicated to the simultaneous measurement of the absolute total and spectral solar irradiance, and the diameter and solar shape; Russian Solar mission CORONAS-Photon (Complex Orbital Observations Near-Earth of Activity of the Sun) to investigate the processes of free energy accumulation in the Sun's atmosphere, accelerated particle phenomena and solar flares, and the correlation between solar activity and magnetic storms on Earth. At the same time the previously launched space solar observatories: SOHO, STEREO, RHESSI and Hinode continue to operate. Together, these solar space telescopes have provided unprecedented amount of multi-wavelength data for complex investigations of the structure, dynamics and magnetism of the Sun from the deep interior to the outer corona.

In addition, first high-resolution observations of the Sun were obtained with two large telescopes: the 1-m optical telescope on balloon observatory SUNRISE which had the first 6-day flight in June 2009, and the 1.6-m New Solar Telescope (NST) at the Big Bear Solar Observatory. The telescope has a unique of-axis configuration that helps to solve the heat problem. This telescope in the first of the new generation of large solar telescopes. Two very large solar telescopes, Advanced Technology Solar Telescope (ATST) and European Solar Telescope (EST) are being developed.

The new telescopes combined with precise spectro-polarimetric instrumentation (del Toro Iniesta & Martinez Pillet 2010) provide important insight into the small-scale phenomena. This includes discovery of fine structure of magnetic elements in sunspot penumbrae, detection of small-scale vortices in granulation, overturning convection in penumbra filaments, superdiffusion of small magnetic elements etc.

Future observational projects include space missions: The Interface Region Imaging Spectrograph (NASA), Solar Orbiter (ESA), and InterHelioProbe and Polar Ecliptic Patrol (Russia).

The Interface Region Imaging Spectrograph (IRIS) (Lemen *et al.* 2011) addresses critical questions in order to understand the flow of energy and mass through the chromosphere and transition region, namely: (1) Which types of non-thermal energy dominate in the chromosphere and beyond? (2) How does the chromosphere regulate mass and energy supply to the corona and heliosphere? (3) How do magnetic flux and matter rise through the lower atmosphere, and what roles does flux emergence play in flares and mass ejections? These questions are addressed with a high-resolution imaging spectrometer that observes Near- and Far-VU emissions that are formed at temperatures between 5,000K and 1.5×10^6 K. IRIS has a field-of-view of 120 arcsec, a spatial resolution of 0.4 arcsec, and velocity resolution of 0.5 km/s. Members of the IRIS investigation team are developing advanced radiative MHD codes to facilitate comparison with and interpretation of observations.

The Solar Orbiter (Woch *et al.* 2008) orbit comprises initially a nearly Sun-synchronous phase at a distance of only 0.22 AU from Sun center. In a later stage, the orbital inclination will be raised, thus allowing Solar Orbiter to reach solar latitudes of about 35 degrees, and making it the first mission after Ulysses to study the Sun from a high-latitude vantage point. In contrast to Ulysses, however, Solar Orbiter will carry a complementary suite of both, in-situ and remote- sensing instruments, which will allow the study of the solar atmosphere to be extended to the largely unexplored polar regions of the Sun. The polar

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magnetic fields are responsible for the polar coronal holes driving the fast solar wind, but are poorly known. From its vantage point outside the ecliptic, Solar Orbiter will uncover the surface and sub-surface flows at the poles, the polar magnetic field structure and its evolution. It will provide new insights into the formation of the polar coronal holes, the nature of their boundaries and the acceleration of the fast solar wind emanating from the holes.

Phase B of the Interhelioprobe Mission (Zelenyi *et al.* 2004) started in 2009-2010. The mission is aimed at the study of the inner heliosphere and the Sun at short distances by using a spacecraft (SC) at heliocentric orbit formed by multiple gravity-assisted maneuvers at Venus. Interhelioprobe observations in the immediate proximity to the Sun combined with in-situ plasma measurements will contribute significantly to the solution of the problems of heating of the solar corona, solar wind acceleration, and the origin of major solar active events such as solar flares and coronal mass ejections. At the end of the mission, the gravity-assisted maneuvers at Venus can be used for inclining the SC orbit to the ecliptic plane and conducting out-of-ecliptic observations of the Sun, including its polar regions and ecliptic corona. The composition of the mission scientific payload has been determined. It will comprise the instruments for remote observations of the Sun (X-ray telescope-spectrograph, coronagraph, magnetograph, and photometer) and in-situ measurements in the heliosphere (magnetometer, solar-wind electron analyzer, plasma analyzer, analyzer of solar neutrons, detector of charged particles, gamma-ray spectrometer, X-ray spectrometer, and wave complex). The development of sketch design of the mission will be completed in July 2012.

Phase A of the Polar Ecliptic Patrol mission (PEP) started in 2009. The mission is aimed at the study of the global pattern of solar activity, including its manifestations in the heliosphere and near-Earth space. The mission will comprise two small satellites. By gravity-assisted maneuvers at Venus, the satellites will be placed on heliocentric orbits inclined to the ecliptic plane at an angle to each other at distances about 0.5 AU from the Sun. The satellites on the orbits will be shifted about one another by a quarter of a period (one period is about 130 days). Such a scheme will ensure continuous monitoring of the Sun-Earth line from one (and in some periods, from both) SC. When one SC is in the ecliptic plane, another is over one of the solar poles; as the first SC goes away from the ecliptic plane, the second one approaches it. Thus, simultaneous monitoring of the near-ecliptic and polar regions is carried. This will enable a continuous study of the slow- and high-speed solar wind and will provide a 3D pattern of the solar corona and ejections. Observing solar ejections from two spaced SC and from out-of-ecliptic position will allow us to determine their exact direction relative to the Sun-Earth line and their heliolatitude and heliolongitude extension. Stage A will be devoted to developing the details of the ballistic characteristics of the mission, its scientific tasks and instruments, and the tentative outward appearance of the spacecraft.

4. Research highlights

A revision of the progress made in these fields is presented. For some specific topics, the review has counted with the help of experts outside the Commission Organizing Committee that are leading and/or have recently presented relevant works in the respective fields.

4.1. *Solar irradiance and its variability*

Solar irradiance and variability has become a new hot topic during the past 3 years because of the unusual long minimum of solar activity in 2007-2009. During the recent

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minimum with an unusually long periods with no sunspots, TSI was also extremely low, namely 25% of a typical cycle amplitude lower than in 1996. Together with the values during the previous minima this points to a long-term change related to the strength of solar activity. On the other hand, activity indices as the 10.7 cm radio flux (F10.7), the CaII and MgII indices and also the Ly-α irradiance, showed a much smaller decrease. This means that proxy models for TSI based on the photometric sunspot index (PSI), and on e.g. MgII index to represent faculae and network have to be complemented by a further component for the long-term change (Fröhlich 2011). This problem was investigated in detail by Ball *et al.* (2011) and also by Steinhilber (2010) who studied how well modeled solar irradiances agree with measurements from the SORCE satellite, both for total solar irradiance and broken down into spectral regions on timescales of several years. It was found that a model that assumes that all variation in solar irradiance is the result of changes in the distribution of magnetic features on the solar surface captures 97% of the observed TSI variation. However, the modeled spectral irradiance (SSI) showed significant disagreement with the SIM instrument on SORCE. If the data are correct this disagreement implies that some mechanism other than surface magnetism is causing SSI variations.

The solar X-ray continuum emission at five wavelengths between 3.495 $\AA$ and 4.220 $\AA$ for 19 flares in a 7-month period in 2002-2003 was observed by the RESIK (REntgenovsky Spektrometr s Izognutymi Kristalami) crystal spectrometer on CORONAS-F (Phillips *et al.* 2010). In this wavelength region, free-free and free-bound emissions have comparable fluxes. With a pulse-height analyzer having settings close to optimal, the fluorescence background was removed so that RESIK measured true solar continuum in these bands with an uncertainty in the absolute calibration of $\pm 20\%$. With an isothermal assumption, and temperature and emission measure derived from the ratio of the two GOES channels, the observed continuum emission normalized to an emission measure of 1048 cm^{-3} was compared with theoretical continua using the CHIANTI atomic code. The accuracy of the RESIK measurements allows photospheric and coronal abundance sets, important for the free-bound continuum, to be discriminated. It is found that there is agreement to about 25% of the measured continua with those calculated from CHIANTI assuming coronal abundances in which Mg, Si, and Fe abundances are four times photospheric.

The variable Sun is the most likely candidate for the natural forcing of past climate changes on time scales of 50 to 1000 years. Evidence for this understanding is that the terrestrial climate correlates positively with the solar activity. During the past 10,000 years, the Sun has experienced the substantial variations in activity and there have been numerous attempts to reconstruct solar irradiance. The recent deep solar minimum provided an opportunity to investigate the Sun's properties in its "minimum activity" state, and then use this knowledge for reconstructing the past solar irradiance using activity proxies. Shapiro *et al.* (2011) assumed that the minimum state of the quiet Sun in time corresponds to the observed quietest area on the present Sun. Then they used available long-term proxies of the solar activity, which are ^{10}Be isotope concentrations in ice cores and 22-year smoothed neutron monitor data, to interpolate between the present quiet Sun and the minimum state of the quiet Sun. This determines the long-term trend in the solar variability, which is then superposed with the 11-year activity cycle calculated from the sunspot number. The time-dependent solar spectral irradiance from about 7000 BC to the present is then derived using a radiation code. It was found that the total and spectral solar irradiance that was substantially lower during the Maunder minimum than today. This leads to large historical solar forcing and indicates that the solar forcing probably played significant role in climate changes. However, a coupled climate model to explore the effect of a 21st-century grand minimum on future global temperatures, finding

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a moderate temperature offset of no more than -0.3 deg C in the year 2100 (Feulner & Rahmstorf 2010). This temperature decrease is much smaller than the warming expected from anthropogenic greenhouse gas emissions by the end of the century.

Currently, the solar irradiance is monitored by several satellites. The spectral irradiance is measured with high spectral and temporal resolution by the EVE instrument on SDO.

4.2. *Solar composition*

The chemical composition of the Sun is an important ingredient in our understanding of the formation, structure, and evolution of the Sun and the Solar System. Also, this is a reference standard for the composition of other astronomical objects (Asplund *et al.* 2009). Since about 2004, there have been debates among stellar physicists about the value of solar metallicity. Prior to 2004, the value of Z/X for the Sun was assumed to be 0.0231 (Grevesse & Sauval 1998)). In 2005, however, a series of papers were published with lower values for the abundance of O, C and N in the solar photosphere. Asplund *et al.* (2005) using a time-dependent, 3D hydrodynamical model of the solar atmosphere instead of 1D hydrostatic models determined that Z/X for the Sun is only 0.0165. This lowering of abundances has serious consequences for solar and stellar models. However, this new spectroscopically determined metallicity value disagreed with the standard solar models supported by helioseismology (Basu 2009). The problem of solar metallicity was studied in detail by the CIFIST team at the Paris Observatory Caffau *et al.* (2011). They found that a part of this effect can be attributed to an improvement of atomic data and the inclusion of NLTE computations, but also the use of hydrodynamical model atmospheres may also play a role as originally suggested by Asplund *et al.* (2005). The photospheric solar abundances of several elements, among them C, N, and O, was determined using a 3D simulation model of the solar atmosphere obtained with the CO^5BOLD code. The spectroscopic abundances were obtained by fitting the equivalent width and/or the profile of observed spectral lines with synthetic spectra computed from the 3D model atmosphere. It was found that, in fact, 3D effects are not responsible for the systematically low estimates of the solar abundances. The solar metallicity resulting from the new analysis is $Z = 0.0154$, and $Z/X = 0.0211$. This new result is in better agreement with the constraints of helioseismology than the previous 3D abundance results, but the discrepancy is still significant. This problem will certainly remain among the most important problems of solar physics and astrophysics.

Chlorine is an odd-Z element with low abundance in the solar photosphere and in meteorites. Chlorine has no photospheric lines in the visible spectrum available for abundance analysis. Cl XVI lines were observed with the RESIK crystal spectrometer on the CORONAS-F spacecraft during 20 solar flares, from which it was possible to determine much more definitively the Cl abundance for flare plasmas (Sylwester *et al.* 2011). The abundance of chlorine was determined from X-ray spectra obtained with the RESIK instrument on CORONAS-F during solar flares between 2002 and 2003. Using weak lines of He-like Cl, Cl XVI, between 4.44 and 4.50 A, and with temperatures and emission measures from GOES on an isothermal assumption, we obtained A(Cl) $= 5.75 \pm 0.26$ on a scale A(H) = 12. The uncertainty reflects an approximately a factor of two scatter in measured line fluxes. Nevertheless, this value represents what is probably the best solar determination yet obtained. It is higher by factors of 1.8 and 2.7 than Cl abundance estimates from an infrared sunspot spectrum and nearby H II regions. The constancy of the RESIK abundance values over a large range of flares (GOES class from below C1 to X1) argues for any fractionation that may be present in the low solar atmosphere to be independent of the degree of solar activity.

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4.3. *Structure of the solar interior*

Helioseismology received significant boost with the Helioseismic and Magnetic Imager on SDO. This instruments provides uninterrupted 4096×4096-pixel Doppler-shift oscillation data with high spatial (0.5 arcsec/pixel) and high temporal (45 sec) resolutions. These data resolve the whole solar oscillation spectrum from global low-degree modes to modes of very high angular degree and frequency and include all modes captured in the Sun's resonant cavity. To process such large amount of data special helioseismology tools ("pipelines") were developed and implemented in the Joint Science Operation Center (JSOC) at Stanford. In particular, a time-distance helioseismology pipeline provides full-disk maps of subsurface flows and wave-speed variations in the range of depths 0–20 Mm every 8 hours (Couvidat *et al.* 2010; Zhao *et al.* 2011a,b). In addition, pipeline processing is developed for global helioseismology, far-side imaging and ring-diagram analysis. The analysis data are available on-line on the Stanford JSOC web site.

New helioseismology experiment experiment SOKOL on board of CORONAS-PHOTON (2009) was directed to the study of characteristics and inner structure of the Sun on the basis of the spectra of global oscillations of the Sun (Lebedev *et al.* 2011). Such spectra were obtained by method of measurement of solar radiation intensity variations. This experiment was a continuation of the study of solar global fluctuations started on CORONAS-I and CORONAS-F satellites. Solar photometer SOKOL designed by IZMIRAN observed the variations of intensity of solar radiation in seven optical ranges from near ultra-violet up to infra-red range of the spectrum. The spectra of p-modes fluctuations of the Sun and the dependence of amplitude of oscillations from the wavelength are obtained.

Local helioseismology provides 3D maps of subsurface flows and wave-speed anomalies below the solar surface. This is a relatively new discipline which is rapidly developing. It shows great potential for understanding the physical processes inside the Sun that lead to generation and transport of solar magnetic fields, formation of sunspot and active regions, and also initiation of flares and CMEs. There is no doubt that subsurface flows in the subsurface turbulent boundary layer play a key role in the mechanisms of solar activity. Local helioseismology studies greatly benefit from the new Helioseismic and Magnetic Imager data from SDO and continuing operation of the Global Oscillation Network (GONG).

Among highlights of local helioseismology was a statistical study of the GONG team that established a relationship between vorticity and helicity of subsurface flows in a 7 Mm deep layer and flaring activity of active regions. Komm *et al.* (2011) applied a discriminant analysis to 1023 active regions and their subsurface-flow parameters, such as vorticity and kinetic helicity density, with the goal of distinguishing between flaring and non-flaring active regions. Synoptic subsurface flows were obtained by analyzing GONG high-resolution Doppler data using the ring-diagram analysis. It was found that the subsurface-flow characteristics improve the ability to distinguish between flaring and non-flaring active regions. For the C- and M-class flare category, the most important subsurface parameter is the so-called structure vorticity, which estimates the horizontal gradient of the horizontal-vorticity components. The no-event skill score, which measures the improvement over predicting that no events occur, reaches 0.48 for C-class flares and 0.32 for M-class flares, when the structure vorticity at three depths combined with total magnetic flux are used. This analysis provides a basis for developing new physics-based forecasts of flaring activity of active regions.

Another very promising result was recently obtained by Ilonidis *et al.* (2011), who by using a specially designed deep-focus time-distance helioseismology scheme detected

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subsurface signatures of emerging sunspot regions before they appeared on the solar disc. Strong acoustic travel-time anomalies of an order of 12 to 16 seconds were detected as deep as 65,000 kilometers. These anomalies were associated with magnetic structures that emerged with an average speed of 0.3 to 0.6 km/s and caused high peaks in the photospheric magnetic flux rate 1 to 2 days after the detection of the anomalies. Thus, synoptic imaging of subsurface magnetic activity may allow anticipation of large sunspot regions before they become visible, improving space weather forecast. This result is causing debates because the emerging flux has not been observed at such depth by other helioseismology techniques, and also because the detected travel-time anomaly is stronger than this was anticipated from theoretical models. We expect a significant progress in developing such new local helioseismology schemes that allow to extract weak signals of deep perturbations insight the Sun by observing acoustic oscillations on the surface.

A substantial progress has been made in solving very difficult problems of imaging the structure of the solar tachocline and measuring meridional flows. Both of these problems are critical for understanding the mechanism of solar dynamo. However, the helioseismic signal in both cases is very weak compared to the "realization" noise of stochastically excited solar oscillations, and thus robust measurements require averaging over long periods. This, in turn, requires very high stability of helioseismology instruments and taking account various systematic effects, for instance, effects caused by seasonal variations and instrumental distortions. Very important role in these studies is played by numerical simulations which provide artificial data oscillation data that model the internal perturbations and flows and solar oscillations simulating stochastic acoustic sources close to the surface. Such 3D wave simulations and helioseismology testing have been performed for the global spherical Sun models of subsurface sound speed variations (Hartlep *et al.* 2011a,b), for global-scale solar convection (Hanasoge *et al.* 2010), for the meridional circulation (Hartlep *et al.* 2011b), and also for local scale MHD models of sunspots (Cameron *et al.* 2011; Parchevsky & Kosovichev 2009; Parchevsky *et al.* 2010a,b). The helioseismology simulations not only provided means for testing helioseismic inferences (Birch *et al.* 2011; Hartlep *et al.* 2011b; Moradi *et al.* 2010), but also help to detect new helioseismology effect and develop new diagnostics. For instance, Hartlep *et al.* (2011a) showed that under certain conditions, subsurface structures in the solar interior can alter the average acoustic power observed at the photosphere above them. By using numerical simulations of wave propagation, it was found that this effect is large enough for it to be potentially used for detecting emerging active regions before they appear on the surface. In the simulations, simplified subsurface structures are modeled as regions with enhanced or reduced acoustic wave speed. Observations from the SOHO/MDI prior and during the emergence of NOAA active region 10488 were used to test the use of acoustic power as a potential precursor of the emergence of magnetic flux.

The subsurface structure and dynamics of sunspots continues to be a central topic of helioseismology. The main difficulties in the diagnostics of sunspots are due to the strong inhomogeneity, magnetic field effects that can cause systematic phase of acoustic waves, which are not accounted for by the wave propagation models, absorption and transformation of acoustic wave, and nonuniform distribution of acoustic sources and their spectral characteristics (for a recent review see Kosovichev (2010) and references therein). Local helioseismic diagnostics of sunspots still have many uncertainties. However, there have been significant achievements in resolving these uncertainties, verifying the basic results by new high-resolution observations, testing the helioseismic techniques by numerical simulations, and comparing results obtained by different methods.

For instance, a recent analysis of helioseismology data from the Hinode space mission (Zhao *et al.* 2010) has successfully resolved several uncertainties and concerns (such as

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the inclined-field and phase-speed filtering effects) that might affect the inferences of the subsurface wave-speed structure of sunspots and the flow pattern. Zhao *et al.* (2010) analyzed a solar active region observed by the Hinode Ca II H line using the time-distance helioseismology technique, and inferred wave-speed perturbation structures and flow fields beneath the active region with a high spatial resolution. The general subsurface wave-speed structure is similar to the previous results obtained from SOHO/MDI observations. The general subsurface flow structure is also similar, and the downward flows beneath the sunspot and the mass circulations around the sunspot are clearly resolved. Below the sunspot, some organized divergent flow cells are observed, and these structures may indicate the existence of mesoscale convective motions. Near the light bridge inside the sunspot, hotter plasma is found beneath, and flows divergent from this area are observed. The initial acoustic tomography results from Hinode show a great potential of using high-resolution observations for probing the internal structure and dynamics of sunspots.

Initial steps to developing waveform tomography based on measurements of travel-time delays and amplitude variations for cross-correlations representing effective point wave sources have been made (Chou *et al.* 2009; Cameron *et al.* 2011; Ilonidis & Zhao 2011; Zhao *et al.* 2011c).

4.4. *Structure of the chromosphere*

Chromospheric research has witnessed a strong forward momentum in the last few years, owing to several important theoretical and observational developments. Ground-based imaging spectro-polarimetry performed with instruments such as IBIS (Cavallini 2006; Reardon & Cavallini 2008) and CRISP (Scharmer 2006) is providing novel observations of chromospheric signatures, in particular using the IR CaII 854.2 nm line. Long overlooked, this spectral line has come strongly forward as one of the best diagnostics to study both the dynamics (Cauzzi *et al.* 2008) and the magnetic structure of the chromosphere (Pietarila *et al.* 2007; de la Cruz Rodríguez & Socas-Navarro 2011). High resolution, highly stable limb and on-disk observations with the broad-band CaII H filter on SOT/Hinode have been exploited for investigating the role of chromospheric structures, such as spicules, in coronal heating and mass replenishment (De Pontieu *et al.* 2009; Sterling *et al.* 2010). In a parallel development, realistic 3-D MHD modeling of the entire regime between the upper convection zone and the corona is now within reach (Abbett 2007; Fang *et al.* 2010; Gudiksen *et al.* 2011) albeit still with important limitations such as the small size of the computational domain or the approximate treatment of radiative transfer. These developments have clarified at least some of the small-scale, dynamic chromospheric phenomena, while others are still very much debated.

A coherent picture has emerged that identifies the propagation and dissipation of photospheric acoustic waves at their dominant frequencies (from ~ 2 to ~ 7-8 mHz) into the chromospheric layers as important shapers of the chromospheric structure. These waves, uniformly excited at the solar surface by turbulent motions, are selected and guided to propagate in the upper atmosphere by the local and highly variable magnetic topology. Thus, a crucial role is played by the magnetic field, at once "passive" (brought about by convection) and "active" (waveguide) agent (Wedemeyer-Böhm *et al.* 2009; Carlsson *et al.* 2010). In the quietest portions of the chromosphere, as in the center of supergranular cells or in coronal holes, small scale acoustic shocks are ubiquitous (Vecchio *et al.* 2009) but lead to limited spatio–temporal heating. The recent 2D radiation-MHD modelling of Leenaarts *et al.* (2011), that takes into account non-equilibrium ionization of hydrogen and other effects, shows that such chromospheric areas can be as cold as 2000 K or less, provided that no significant magnetic heating is present. Chromospheric

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acoustic shocks are present also in or near magnetic structures such as network points. The shocks are stronger than those occurring in quiet Sun, but at they appear at a lower temporal frequency as the presence of an inclined field lowers the atmospheric cutoff frequency (Jefferies *et al.* 2006; Stangalini *et al.* 2011). An alternate explanation invokes convective downdrafts in the immediate surroundings of magnetic elements as responsible for the excitation of the slow modes eventually leading to chromospheric shocks (Kato *et al.* 2011), but in any case it is now established that such shocks are the cause of the dynamic phenomenon known as "dynamic fibrils" present in plage and strong network (De Pontieu *et al.* 2007; Langangen *et al.* 2008a). While the shocks produce a tangible heating in and around the magnetic elements, as Cauzzi *et al.* (2009) deduced from temporal evolution of chromospheric line widths, it remains unclear whether other effects such as Alfvénic turbulence might be the primary heating agent of these magnetic structures (Vigeesh *et al.* 2009; van Ballegooijen *et al.* 2011). Finally, the role of neutrals within the magnetic chromosphere is starting to be addressed in a variety of studies (Fontenla *et al.* 2008; Arber *et al.* 2009; Krasnoselskikh *et al.* 2010; Zaqarashvili *et al.* 2011; Song & Vasyliūnas 2011) but results are still very preliminary at this moment.

Spicules are another recurrent chromospheric feature occurring at the borders of network and plage, but of a very different nature. Indeed, much attention has been given in the last few years to the so-called "type II spicules", thin and very dynamic features, almost vertical, reaching up to 10 Mm and rapidly swaying, probably from Alfvén waves. They have been observed in detail off the solar limb with the Hinode Ca II H filter (de Pontieu *et al.* 2007; De Pontieu *et al.* 2007), and identified on the disk in the blue wings of Ca II 854.2 nm and Hα (Langangen *et al.* 2008b; Rouppe van der Voort *et al.* 2009). The formation of these ubiquitous, jet-like, type II spicules has been attributed to magnetic reconnection (de Pontieu *et al.* 2007). This hypothesis might be validated by the occurrence of a spicule-II-like event in the MHD simulation of Martínez-Sykora *et al.* (2011), deriving from the creation of a tangential field discontinuity in the chromosphere after small-scale flux emergence. Observations of dynamical features with similar characteristics in coronal EUV lines, presenting spatio-temporal correlation with the chromospheric signatures (De Pontieu *et al.* 2009; Tian *et al.* 2011), have made type II spicules a prime candidate for establishing a link between corona and chromosphere. Recently, De Pontieu *et al.* (2011) traced type II spicules directly from chromospheric jets to coronal heating events as shown in UV SDO images; estimates of the mass and energy flux density into the corona are compatible with the amount required to sustain the energy lost from the active-region corona. An alternate view on these thin structures has been recently proposed by Judge *et al.* (2011), which suggest that at least some of them correspond not to flux-tube aligned flows, but to warps in two-dimensional sheet-like structures, perhaps related to the magnetic tangential discontinuities naturally arising in low-β plasma conditions. An important consequences of this suggestion is the drastic reduction of the mass flux into the corona, as some of the signatures can be interpreted in terms of phase speeds of warps and Alfvén speeds rather than in terms of real flows.

The direct measurement of magnetic fields in the chromosphere is a long-standing goal of solar physics, as it could provide a direct constraint on the magnetic free energy available in the corona, and in general more reliable boundary conditions for force-free extrapolations. However, it is still a difficult task, as fields are weak and their signature embedded in broad and very dynamic spectral lines. A number of studies on this subject have been conducted in the last few years, with important results. A study on the magnetic field of spicules at the limb, conducted by Centeno *et al.* (2010) exploiting the remarkable polarization properties of the HeI 1083 nm triplet, retrieved field values as high as 50 G. Exploiting imaging spectro-polarimetry in the CaII 854.2 nm line with CRISP,

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de la Cruz Rodríguez & Socas-Navarro (2011) investigated for the first time whether the chromospheric fibrils, as seen in line core intensity images, always trace the direction of the magnetic field, as is normally assumed. Their answer is mostly positive, with however a few dubious cases that warrant further studies on the subject. Using IBIS, Wöger *et al.* (2009) were able to derive the three-dimensional topology of a strong magnetic structure extending from photosphere to chromosphere. While the magnetic structure became weaker with height, it developed a filament-like structure at larger heights, hinting at the actual chromospheric canopy. These authors remark that currently available data still prevents, in most cases, the detection of weak field strengths, especially at the temporal resolution implied by the intensity variations seen in chromospheric diagnostics. However, as remarked by Judge *et al.* (2010), the use of high cadence, high angular resolution images of fibrils in Ca II and Hα can much improve the chromospheric magnetic field constraints, under conditions of high electrical conductivity and hence field-aligned flows. Such work is possible only with time series data sets from two-dimensional spectroscopic instruments, under conditions of good seeing. Finally, new instruments like the 4-slits Facility Infrared Spectropolarimeter (FIRS, Jaeggli *et al.* 2010) are also now available to achieve diffraction-limited precision spectropolarimetry in the chromosphere by performing fast spectrographic scans of active regions in the HeI 1083 nm triplet (e.g. Schad & Penn 2011).

5. Activities for the 2012 General Assembly

Commission 12 actively promoted and endorsed submission of several proposals for solar-related meetings to be held during the upcoming IAU General Assembly of August 2012. Two such proposals were selected: a full Symposium on Astrophysical Dynamos, and a Special Session on Large Solar Telescopes (see below). Together with a Joint Discussion on 3-D views of Solar and Stellar Activity, and a Special Session on Star-Planet Relation & Public Outreach (chairs L. van Driel-Gesztelyi and J.L. Bougeret, respectively) these will make 2012 a record year for solar events at a General Assembly, a very important venue to present our activities to the astronomical community at large.

5.1. *IAU Symposium 294 "Solar and astrophysical dynamos and magnetic activity"; chair A. Kosovichev*

The goal of this symposium is to discuss the most important results of recent studies of the cosmic dynamo processes: the origin and evolution of magnetic fields in various astrophysical objects from planets, to stars and galaxies, solar and stellar activity cycles, advances in dynamo theories and numerical simulations, similarities and differences between the solar and stellar activity of different scales, driving mechanisms and triggers of solar and stellar magnetic relaxation phenomena, connections between the dynamo mechanisms in various objects, and other hot topics related to the solar and astrophysical dynamos.

The symposium will overview the state of our understanding of dynamo mechanisms in different astrophysical conditions, discuss new observational results, theoretical models, similarities and differences of the physical processes leading to magnetic field generation and formation of magnetic structures. It will focus on the link between theory and observation, and identify critical problems for future observations and modeling.

The symposium will bring together observers and theorists, and encourage discussions and co-operations among solar, stellar, planetary and galactic astronomers. It will help in the development of new ideas regarding the fundamental dynamo processes, and in

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understanding links between these processes and magnetic activity on various cosmic scales.

5.2. *IAU Special Session 6 "Science with large solar telescopes"; chair G. Cauzzi*

Efficient high order adaptive optics systems (Rimmele 2004), and technological developments proving the feasibility of air-cooled, open solar telescopes have allowed for the planning of facilities with apertures sensibly larger than the existing evacuated solar telescopes. Indeed, several of these innovative projects have become operational in the last few years: the balloon-borne 1-m telescope SUNRISE had a successful first flight in June 2009 (Solanki *et al.* 2010); the 1.6 m off-axis New Solar Telescope at Big Bear has been commissioned in 2010 and is producing first scientific results (Goode *et al.* 2010, e.g.); the German 1.5 m on-axis telescope GREGOR on Tenerife has recently achieved first light. Their large collecting area and imaging stability provide for the increased spatio-temporal resolution and spectro-polarimetric sensistivity necessary to address critical scientific questions such as the magneto-convective nature of sunspots' penumbrae and umbrae (Scharmer *et al.* 2011; Ortiz *et al.* 2010); the distribution of weak magnetic fields in the quiet photosphere (Danilovic *et al.* 2010; Abramenko *et al.* 2010) or the role of chromospheric heating events in replenishing the corona (Langangen *et al.* 2008b; Rouppe van der Voort *et al.* 2009).

The next generation 4-m Advanced Technology Solar Telescope has been funded in 2010 by the USA National Science Foundation for construction on Haleakala, and is currently scheduled for first light in 2017 (Rimmele *et al.* 2011). It will become the most powerful solar telescope in operation and a leading facility for studying the dynamics and magnetism of the solar atmosphere, with a unique emphasis on coronal conditions. On this wake, many other projects for large optical telescopes are also in various stages of their design, e.g. the 1.5 m coronograph COSMO optimized for measurements of the coronal magnetic field; the 2-m Indian National Large Solar Telescope; the Chinese 1-m Space Solar Telescope; the 4-m European Solar Telescope; the Japanese-led project for a space-based 1.5 m optical telescope aboard Solar-C; the Chinese 8-m Giant Solar Telescope.

New challenges will accompany operations of these advanced facilities, including innovative solutions to efficiently extract accurate scientific results from the expected enormous data volume (of the order of hundreds of TB/day); the development of robust data reduction pipelines to provide science-ready data to a user base sensibly larger than the current one; the adoption of more efficient modes of operation, i.e. scheduling observations on a flexible basis in order to best match science programs to observing conditions. Discussion on these issues within the community is just starting, but in the next few years we expect that the operation and scientific results of the new facilities, as well as instrumental upgrades in existing telescopes (including developments of Multi-Conjugate AO or coronal polarimetry) will yield much novel insight into the peculiarities and possibilities of observations with large solar telescopes.

The Special Session 6 during the next IAU General Assembly in August 2012 in Beijing has thus been proposed as a timely and focused opportunity for discussing such topics. The solar physics community, and members of Commission 12 in particular, will be able to voice and address critical issues for the development of future facilities that will be at the forefront of solar astrophysics in the next decades.

A. Kosovichev
president of the Commission

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