

Impact of SOHO, TRACE and Yohkoh on Solar Physics

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Abstract. Recent sophisticated space missions have led to substantial alterations in our picture of the physics of our nearest star. In particular the ESA/NASA Solar and Heliospheric Observatory (SOHO) has provided unique data to explore the Sun from its interior, throughout the hot and dynamic atmosphere, and to probe the solar wind and energetic particles. Analysis of the helioseismology data from SOHO has shed new light on a number of structured and dynamical phenomena in the solar interior, such as the absence of differential rotation in the radiative zone, subsurface zonal and meridian flows, and a possible circumpolar jet. Evidence for an upward transfer of magnetic energy from the Sun's surface toward the corona has been established. The ultraviolet instruments have revealed an extremely dynamic solar atmosphere where plasma flows play an important role. The source regions for the high speed solar wind have been identified and the acceleration profiles of both the slow and fast solar wind have been measured. The Japanese Yohkoh satellite has also contributed significant new knowledge about the Sun, in particular on the nature of solar flares. Coordinated observations with SOHO and Yohkoh, and more recently with TRACE have given us a new view of a very complex Sun. This paper tries to summarize some of the highlights from these missions.

1. Introduction

The first satellites dedicated to space solar physics were the *Orbiting Solar Observatories* (OSOs), the first of which was launched in 1962. Observations from satellites gave tremendous improvements in the amount of observing time compared to the typical 5 minutes available during a rocket flight. UV spectrometers on the Apollo Telescope Mount on board *Skylab* gave a wealth of new information of the upper solar atmosphere (Tousey 1977). *Skylab* was the first manned solar satellite observatory and provided much of our knowledge of the properties of coronal holes and coronal loops. A large number of EUV and X-ray rocket flights have been launched the last 20 years. Among these we should mention the innovative HRTS/NRL instrument (Bartoe & Brueckner, 1975), the SERTS/GSFC telescope (Thomas & Neupert, 1992) and the NIXT X-ray imager which has produced the yet highest spatial resolution images of the Sun in X-ray (Golub & Herant 1989). Even if they only provided a few minutes of observing time they are still very useful (and relatively low cost missions) to pursue special purpose

experiments. The Solar Maximum Mission (SMM) spacecraft, launched on 1980 February 14, carried seven instruments for the study of solar flares and other aspects of solar activity (Chipman 1981). SMM operated for almost 9 years until burning up in the Earth's atmosphere on 2 December 1989.

In this review paper I will summarize some of the scientific highlights from the Yohkoh mission, the Solar and Heliospheric Observatory (SOHO) and the Transition Region and Coronal Explorer (TRACE). These new observations have significantly contributed to a better understanding of the structure of the sun and the solar atmosphere. However, at the same time new and interesting challenges arise to interpret and model this highly dynamic and time variable star.

The Yohkoh satellite was launched in August 1991 by the Japanese Institute for Space and Astronautical Science (Ogawara et al. 1995). It carries a payload of four instruments designed to look at the high energy phenomena associated with solar flares and active regions. The instruments includes: the Soft X-ray Telescope (SXT), the Hard X-ray Telescope (HXT), the Bragg Crystal Spectrometer (BCS), and the Wide Band Spectrometer (WBS).

The SOHO mission is a cooperative mission between the European Space Agency (ESA) and the National Aeronautic and Space Administration (NASA) to study the Sun, from its deep core to the outer corona, and the solar wind (Domingo, Fleck & Poland 1995). The three principle scientific objectives of the SOHO mission can be summarized as:

- study of the solar interior, using the techniques of helioseismology,
- study of the heating mechanisms of the solar corona, and
- investigation of the solar wind and its acceleration processes.

To achieve these objectives SOHO includes twelve instruments, developed and furnished by twelve international Principle Investigator (PI) consortia involving 39 institutes from 15 countries. Nine of these consortia are led by European PIs, and the three others by US PIs.

TRACE is a Small Explorer Mission (SMEX) devoted to the study of the evolution and propagation of fine-scale magnetic fields and plasma structures throughout the solar atmosphere (Handy et al. 1998). TRACE includes three EUV bands at 171, 195 and 284 Å, UV bands as well as a “white light” channel. The 1024×1024 pixel CCD camera has a field of view of 8.5'×8.5' with a spatial resolution of 1".

2. Solar Interior

The helioseismology instruments on SOHO have provided many new discoveries regarding the structure and rotation of the solar interior as well as confirming some features of previous solar models. From f-mode frequency splittings of MDI data, Kosovichev & Schou (1997) detected zonal variations of the Sun's differential rotation Kosovichev et al. (1997) determined the spherically symmetric structure of the Sun by inverting the mean frequencies of split mode multiplets ν_{nl} of the MDI medium- l data. The observations confirm the temperatures previously calculated from models of the solar interior to within a fraction of a

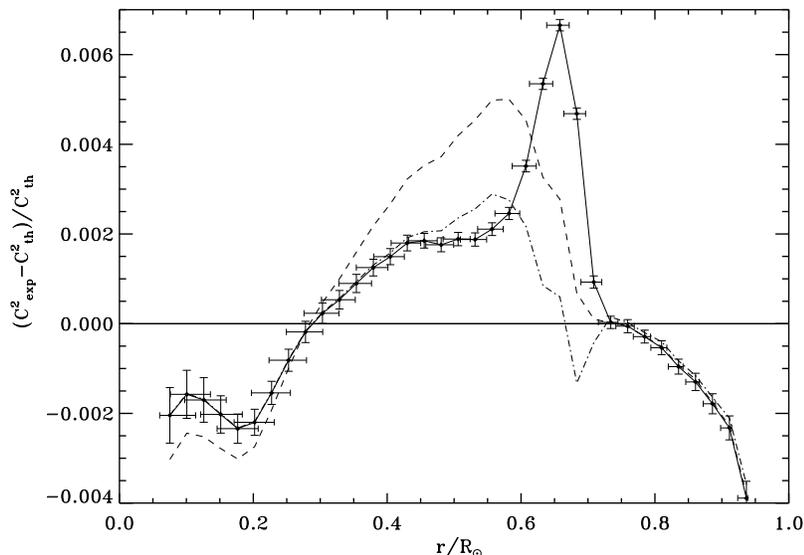


Figure 1. Relative differences between the squared sound speed in the Sun as observed by GOLF + MDI, and a the reference model (solid line) and two models (dashed lines) including microscopic mixing processes (Brun, Turck-Chieze & Zahn 1999).

percent. This gives confidence that we have a good basic understanding of stellar structures in general. However one found a conspicuous bump at about 0.68 R where the temperature is higher than predicted (See Figure 1).

Recent updated standard solar models failed to reproduce the radial profile of the sound speed at the base of the convection zone and failed to predict the photospheric lithium abundance. In order to resolve these discrepancies, Brun, Turck-Chieze & Zahn (1999) introduced a new term - macroscopic mixing below the convective zone - in the standard stellar structure equations. They show that the introduction of mixing in the tachocline layer partly inhibits the microscopic diffusion process and significantly improves the agreement with the helioseismic data and photospheric abundance data. In particular, the prominent bump around 0.68 R in the sound-speed square difference plot is practically erased by the introduction of the tachocline mixing as can be seen in Figure 1 (dashed and dot-dashed lines).

The latter result is also interesting to elementary particle physics, particularly as relates to the question of whether neutrinos have a mass. A deficit of 50-70% in the number of neutrinos sent out from the Sun has been observed in neutrino observatories during the last 25 years. This deficit could mean, either that the temperature in the interior of the Sun is lower than given by the models, or that the so called standard model of physics, describing the fabric of our universe, is incomplete and wrong. Since the temperature values of the Sun have been well confirmed by SOHO, the latter possibility now seems most likely.

Applying a new technique, called time-distance helioseismology, the first maps of horizontal and vertical flow velocities as well as sound speed variations in the convection zone just below the visible surface have been generated (Du-

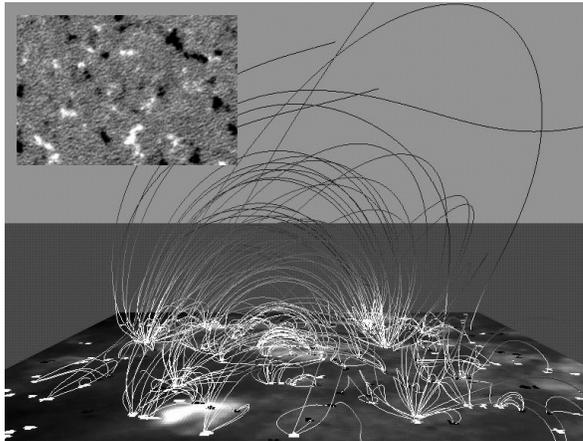


Figure 2. This image is a model of magnetic fields at the surface of the Sun developed using data from MDI and EIT. Between pairs of opposite polarity (white and dark features), magnetic field connections exist, represented here by lines based on computer calculations. The inserted panel shows a high resolution magnetogram from MDI showing a mixed polarity (Cortese MDI/EIT consortiums).

vall et al. 1997 and Kosovichev & Duvall 1997). It appears that the pattern of horizontal motions near the surface only persists to a few Megameters in depth, indicating that supergranular convection cells may be much shallower than previously assumed.

3. Solar atmosphere

MDI has also observed for the first time a sun-quake caused by a flare. In a series of Dopplergrams one observed sound waves emanating from the flare site, similar to the ripples from a pebble thrown into a pond. The seismic wave propagated more than 120 000 km from the flare epicenter with an average speed of 50 km/s, and was about 3 km high (Zharkova & Kosovichev 1998).

In addition to measuring velocity and intensity oscillations MDI also derives measurements of the photospheric magnetic field. From long uninterrupted MDI magnetogram series a continuous flux emergence has been observed. Small magnetic bipolar flux elements are rapidly swept by granular and mesogranular flows to supergranular cell boundaries. Figure 4 shows a small section of a high resolution magnetogram from MDI where the mixed polarity is evident (inserted panel). The large image reveals a model of magnetic fields at the surface of the Sun developed using data from MDI and EIT. Between pairs of opposite polarity (white and dark features), magnetic field connections exist, represented here by lines based on computer calculations. The rate of flux generation of this magnetic carpet (Schrijver et al. 1998) is such that all of the flux is replaced in

about 40 hours, with profound implications for coronal heating on the top side and questions of local field generation on the lower side of the photosphere.

A study of the temporal behavior of quiet Sun coronal bright points seen in EIT (Fe XII at 195 Å) and Yohkoh/SXT over a period of one day shows a good correlation with the changes of magnetic flux measured by MDI. Rough estimates of radiative and conductive energy losses of the bright points are comparable with the available energy of the associated magnetic flux (Preš & Phillips 1999).

3.1. Explosive Events and “Blinkers”

Several types of transient events have been detected in the quiet Sun atmosphere. High-velocity events in the solar transition region, also called explosive events, were first reported by Brueckner (1981), based on UV observations with HRTS. Explosive events in quiet regions have large velocity dispersions, $\approx \pm 100$ km s⁻¹, i.e. velocities are directed both towards and away from the observer causing a strong line broadening. Recently explosive events have been studied extensively by SUMER and some results support the magnetic reconnection origin of these features. Innes et al. (1997) reported explosive events that show spatially separated blue shifted and red shifted jets and some that show transverse motion of blue and red shifts, as predicted if reconnection was the source (Dere et al. 1991). Recent coordinated observations with SUMER and magnetograms obtained from ground and from MDI on SOHO have resulted in a better understanding of the mechanisms responsible for these events.

Some explosive events have been found to be associated with obvious canceling magnetic features in the photosphere (Tarbell et al. 1999). Chae et al. (1998a) also found the explosive events to occur during the cancellation of photospheric magnetic flux based on SUMER and ground based magnetograms. They furthermore found that explosive events rarely occur in the interior of strong flux concentrations, but preferentially appear in regions with weak fields and mixed polarity.

The existence of EUV flashes, known as blinkers have been identified in the quiet Sun network (Harrison 1997). The brightenings were most significant in the transition region temperature lines (O IV and O V), with modest or no detectable intensity increase at higher temperatures. No increase in temperature during the blinker events were found using temperature sensitive line ratios (O III, O IV, and O V). Thus, the enhanced emission is believed to be associated with an increase in density or filling factor in the quiet Sun network (Harrison et al. 1999). Recently Tarbell et al. (1999) compared the occurrence of blinkers with changes in the photospheric magnetic field from co-spatial MDI and CDS observations. They found the blinkers to occur during reduction of magnetic flux.

The question has been raised whether blinkers are related to explosive events. Several authors have compared these features (e.g. Harrison et al. 1999; Chae et al. 1999; Erderly et al. 1999). The typical properties of blinkers and explosive events have been summarized in Table 1. As can be seen the explosive events appear to be much smaller and short-lived. The CDS data do not show flows as high as 100-150 km s⁻¹. Chae et al. (1999) compared SUMER explosive events with coordinated CDS observations and magnetograms from Big Bear and found that the explosive events tend to avoid the centers of the

network brightening and are mostly located at the edges of such brightenings. While both types of events appear to be fairly common, it seems that they are two different classes of events. Clearly, further analysis is needed to establish the relationship between these two phenomena.

Table 1. Properties of explosive events and 'blinkers'

	Blinkers	Explosive events
Intensity:	Strong brightening	show little brightening
Life time:	6-40 min	1-2 min
Birth rate	12 s^{-1}	600 s^{-1}
Flows:	less evident (20 km s^{-1})	large shifts ($100\text{-}150 \text{ km s}^{-1}$)
Size:	$6000 \times 6000 \text{ km}$	$1500 \times 1500 \text{ km}$
Locations:	network	edges of network brightenings

3.2. Dopplershifted Emission in the Transition Region

For more than two decades we have known that the UV emission lines originating from the transition region of the quiet Sun are systematically redshifted relative to the lower chromosphere. In earlier investigations the magnitude of the redshift has been found to increase with temperature, reaching a maximum at $T = 10^5 \text{ K}$, and then to decrease sharply toward higher temperatures (2.5×10^5 (see Brekke 1993 and references therein). Systematic redshifts have also been observed in stellar spectra of late type stars, first with the International Ultraviolet Explorer (e.g., Ayres et al., 1983; Ayres, Jensen, & Engvold 1988; Engvold et al., 1988) and recently by the Hubble Space Telescope (Wood et al., 1996, 1997).

Early observations from SOHO extended the observable temperature range and suggested that the average redshift persists to higher temperatures than in most previous investigations (e.g. Brekke, Hassler & Wilhelm 1997, Chae et al. 1998b). Shifts in the range $+10\text{-}16 \text{ km s}^{-1}$ were observed in lines formed at $T=1.3 - 2.5 \times 10^5 \text{ K}$. Even upper transition region and coronal lines (O VI, Ne VIII, and Mg X) showed systematic redshifts in the quiet Sun corresponding to velocities around $+5 \text{ km s}^{-1}$ as shown in Figure 5 (filled circles). These measurements were made using the standard reference rest wavelengths reported in the literature (e.g. Kelly 1989).

More recent investigations using observations with SUMER have revisited this problem where also possible errors in rest wavelengths of lines from highly ionized atoms (e.g. Ne VIII, Na IX, Mg X, Fe XII) are discussed. Peter (1999) examined the center-to-limb variation of the Doppler shifts of C IV (1550 Å) and Ne VIII (770 Å) using full disk scans obtained with SUMER. Assuming that all effects of mass or wave motion on the limb should cancel out in a statistical sense they adopt the the line position on the limb as a rest wavelength. The line shifts obtained with this technique at disk center correspond to a redshift of 6 km s^{-1} for C IV and a blueshift of 2.5 km s^{-1} for Ne VIII. Similar results have been presented by Dammasch et al. (1999) and Peter & Judge (1999) who also found the Mg X line to be blueshifted by 4.5 km s^{-1} on the solar disk.

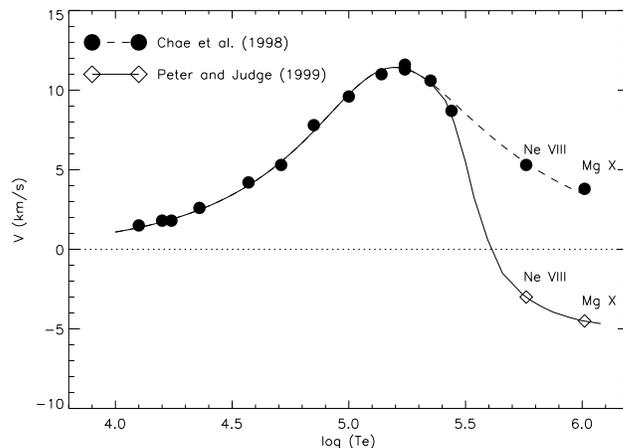


Figure 3. Variation of the Doppler shift at disk center for various ions measured from SUMER spectra. The filled circles are derived using rest wavelengths listed in the literature. Using the off-limb positions as 'rest' wavelengths recent studies find the hotter lines to be blueshifted at disk center (open squares).

The recent results suggest that the upper transition region and lower corona appear blueshifted in the quiet Sun, with a steep transition from red- to blueshifts above 5×10^5 K. This transition from net redshifts to blueshifts is significant because it has major implications for the transition region and solar wind modeling as well as on our understanding of the structure of the solar atmosphere. The results also motivates new laboratory measurements of the wavelengths of hotter lines since the choice of rest wavelengths used to derive these results are crucial for the interpretation of the data.

3.3. Polar Plumes

Wilhelm et al. (1998) determined the electron temperatures, densities and ion velocities in plumes and interplume regions of polar coronal holes from SUMER spectroscopic observations of the Mg IX 706/750 Å and Si VIII 1440/1445 Å line pairs. They find the electron temperature T_e to be less than 800,000 K in a plume in the range from $r=1.03$ to $1.60 R_\odot$, decreasing with height to about 330,000 K. In the interplume lanes, the electron temperature is also low, but stays between 750,000 and 880,000 K in the same height interval. Doppler widths of O VI lines are narrower in the plumes ($v_{1/e} \approx 43$ km/s) than in the interplumes ($v_{1/e} \approx 55$ km/s), confirming earlier SUMER measurements by Hassler et al. (1997). Thermal and turbulent ion speeds of Si VIII reach values up to 80 km/s, corresponding to a kinetic ion temperature of 10^7 K. For the O VI lines an upper limit for the bulk outflow speed of 18 km/s was deduced, whereas in Mg IX differential line-of-sight velocities up to 34 km/s could be seen.

These results clearly confirm that the ions in a coronal hole are extremely hot and the electrons much cooler. They also give a clear demonstration that the

assumption of collisional ionization equilibrium and the common notion that $T_e \approx T_{ion}$ in coronal hole plasma no longer hold.

The electron temperature as a function of height above the limb in a polar coronal hole has been derived from CDS and SUMER observations (David et al. 1998). Temperatures of around 0.8 MK were found close to the limb, rising to a maximum of less than 1 MK at $1.15 R_\odot$, then falling to around 0.4 MK at $1.3 R_\odot$. In equatorial streamers, on the other hand, the temperature was found to rise constantly with increasing distance, from about 1 MK close to the limb to over 3 MK at $1.3 R_\odot$. With these low temperatures, the classical Parker mechanisms cannot alone explain the high wind velocities, which must therefore be due to the direct transfer of momentum from MHD waves to the ambient plasma.

4. Active Region Structure and Dynamics

A large number of flares and active regions have been observed by the Yohkoh instruments. Some of the highlights from the Yohkoh mission includes the detection of a general outward movement of material in active regions (Uchida et al. 1992). Often the material can be related to the expansion of loop systems, but sometimes it appears to be unrelated to well defined structures. The velocity of expansion is in the range $5\text{-}30 \text{ km s}^{-1}$ and appear to be unrelated to CME's. Several Yohkoh observations showed active region loops suddenly reconnect to other regions located in the opposite hemisphere forming a trans-equatorial loop system (Tsuneta 1996). These events have also been confirmed by EIT on SOHO.

Recent observations made simultaneously with TRACE, Yohkoh, SOHO/CDS and the Swedish Vacuum Solar Tower (SVST - La Palma) of so-called "moss" have revealed the fine-scale structure of the upper transition region above active region plages (Berger et al. 1999). The "moss" is a bright, reticulated pattern of EUV emission (with dark inclusions) which is structured on spatial scales of 1 to 3 Mm and confined to a 1 Mm thick layer approximately 1.5 Mm above the photosphere. It is found only over magnetic plage regions that are associated with 3-5 MK coronal loops. For more details we refer to De Pontieu et al. (1999).

4.1. Oscillations in Active Regions

Brynildsen et al. (1999a, 1999b) studied 3-min transition region oscillations above sunspots by analyzing time series recorded in O V 629Å, N V 1238Å and 1242Å, and the chromospheric Si II 1260Å line. The 3-min oscillations they observed show larger peak line intensity amplitudes than reported before, clear signs of nonlinearities, significant oscillations in line width, and maxima in peak line intensity and maxima in velocity directed toward the observer that are nearly in phase. They also performed a simple test and calculated the velocity oscillations from the intensity oscillations (which, to a first approximation for optically thin lines, is proportional to ρ^2) using a standard text book equation for simple nonlinear acoustic waves. The agreement to the observed velocity is astounding, providing convincing evidence the oscillations they observed are

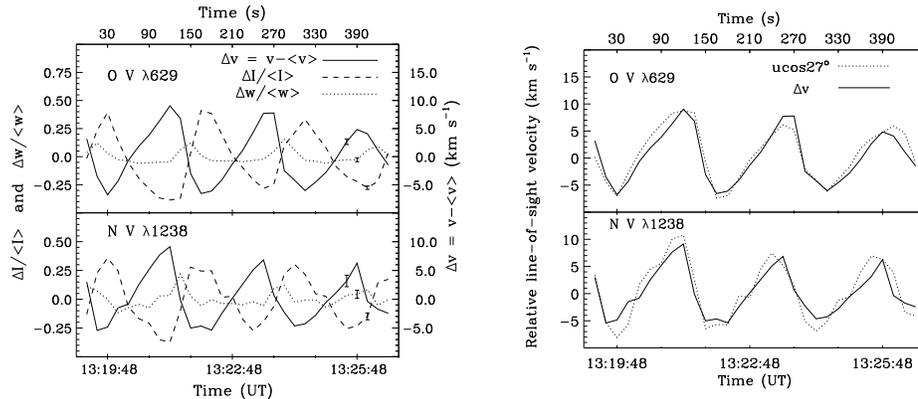


Figure 4. Left: Observed oscillations in relative line-of-sight velocity $\Delta\nu = \nu - \langle\nu\rangle$ (solid line), relative peak intensity $\Delta I/\langle I\rangle$ (dashed line), and relative line width $\Delta w/\langle w\rangle$ (dotted line), in the center of the umbra. Right: Temporal variations of the observed (solid line) and calculated (from the intensity variations) line-of-sight velocity $\Delta\nu$ of O V and N V. (From Brynildsen et al. 1999a)

upward-propagating, nonlinear acoustic waves. Similar oscillations have been observed in CDS observations (Fludra 1999a,b)

4.2. Flares and Coronal Mass Ejections

During flares the chromospheric and transition region plasma has been found to be redshifted during the impulsive phase with typical velocities around 30-50 km s⁻¹ (e.g. Bruner & Lites 1979; Cheng & Tandberg-Hanssen 1986). However, the coronal lines often show a blueshifted component of emission together with a strong stationary component during the impulsive phase (e.g. MacNeice et al. 1985; Mason et al. 1986). Based on a survey of 219 flares observed in soft X-ray with Yokoh, Mariska, Doschek, & Bentley (1993) found the centroid of flare profiles to be blueshifted with an average velocity of 58 km s⁻¹ during the early impulsive phase. The blueshifted components reached velocities up to 800 km s⁻¹. Non-thermal motions in flares have also been observed in soft X-ray emission lines (e.g., Doschek 1990, Antonucci & Doderio 1995).

EIT has made a number of observations of large-scale transient waves, also called Coronal Moreton Waves (Thompson et al. 1999). These events are usually recorded in the 195 Å bandpass, during high-cadence (≤ 20 minutes) observations. Their appearance is stunning in that they usually affect most of the visible solar disk. They generally propagate at speeds of 200-500 km s⁻¹, traversing a solar diameter in less than an hour. The theory behind similar waves was first discussed by Meyer (1968) and Uchida et al. (1973) explaining them as a fast-mode front expanding through the ambient corona.

EIT and LASCO have recorded the very onset and evolution of several Earth-directed CME's, a few of which actually hit the Earth's magnetosphere. Based on observations with EIT and Yokoh S-shaped active regions appear more likely to erupt into a CME than regions without such twist (Canfield et al.

1999). This type of observations can be an useful precursor for CME's and space weather forecast methods. The LASCO instrument has collected an extensive database for establishing firm statistics on CME's and their geomagnetic effects. During the period from 1995 through 1998 the daily CME rate increased from less than 0.5 per day to 3 per day (St.Cyr et al. 2000).

4.3. Dynamics of active region loops

The first observation of large Doppler shifts in individual active region loops was reported by Brekke, Kjeldseth-Moe & Harrison (1997). A more systematic investigation has been pursued by Kjeldseth-Moe & Brekke (1998). The investigation confirmed that high Doppler shifts are common in active region loops. Strong shifts are present in parts of loops for temperatures up to 0.5 MK (i.e. emission in lines from Ne VI). Regions with both red and blue shifts are seen. Typical values correspond to velocities of ± 50 -100 km s⁻¹, but shifts approaching 200 km s⁻¹ have been reported. At temperatures $T \geq 1$ MK, i.e. in Mg IX 368 Å or Fe XVI 360 Å, only small shifts are seen. Thus, the high Doppler shifts seem to be restricted to the chromosphere and transition region. Axial flow velocities as high as these are not obtained by any mechanism used in the common loop models (for a review see Mariska, 1992). Brekke, Kjeldseth-Moe & Harrison (1997) therefore considered interpretations involving magneto-sonic waves, where line shifts of this size may be obtained, see e.g. Hansteen, Maltby & Malagoli (1996), and Wikstøl, Judge & Hansteen (1998). The extremely time variable nature of the corona has also been shown effectively by Yohkoh satellite and the EIT, CDS instruments on SOHO. This has been even more evident after the launch of TRACE.

5. Solar wind

The UVCS coronagraph has revealed dramatic differences in the line widths of Lyman-alpha and O VI in coronal streamers and coronal holes at heliocentric heights from 1.25 out to 3.5 R_⊙. In particular the line width of the O VI line increase dramatic the first 2-3 R_⊙ to over 500 km/s. These large line widths imply extremely high kinetic temperatures of the O VI ions, which reach values in excess of 200 MK at 3.5 R_⊙. The line widths of Lyman alpha show less variation and increases from 200 to 250 km/S at from 1.25 to 3.5 R_⊙. Preferential acceleration of high mass ions affords one possible explanation of generating the observed velocities in the O VI ions (Kohl et al. 1998). However, two recent results might cast some doubt on this this picture. As ion-cyclotron heating should be mass to charge dependent, they have extended their studies to include other minor ions. Zangrilli et al. (1999) included the Si XII line which was found to be even hotter than O VI, although mass to charge ration is smaller than for O VI. One would have expected the reverse behavior. The Mg X heating profile presented by Esser et al. (1999) also is not in line with what one would expect from a mass or mass to charge dependent mechanism. Thus, there are still many open questions on this issue.

Using data from the SUMER spectrometer Hassler et al. (1999) presented measurements of outflowing material at the base of the corona. From a Dopplergram or velocity map obtained in the Ne VIII line at 770 Å, and superimposed

on the chromospheric network as derived from an intensity map in the chromosphere Si II line at 1533 Å they found the strongest blueshifts at the intersections of the supergranular network cells.

Time-laps sequences of white light images from the LASCO coronagraph, obtained during sunspot minimum conditions in 1996, have been used to measure, for the first time, the acceleration of the slow solar wind. The outflow of about 150 features in the streamer belt has been tracked between 3 and 30 R_{\odot} . The speed versus radial distance profiles cluster around a parabolic path characterized by a constant acceleration of about 4 m s^{-2} throughout the field of view. That profile is consistent with an isothermal solar wind expansion at a temperature of 1.1 mill K and a sonic point around 5 R_{\odot} (Sheeley et al. 1997).

6. Concluding Remarks

In particular the SOHO instruments has obtained exciting new results, seeing features on the Sun never seen before, or never seen so clearly, and providing new insights to fundamental unsolved problems all the way from the Sun's deep interior out to the far reaches of the solar wind. As the Sun gets more and more active as we approach the new solar maximum a considerable amount of the total observing time is now devoted to solar activity. Thus, the original science objectives have now shifted somewhat. SOHO is now studying long term variations in the irradiance, coronal structure, and solar wind as well as the frequency of CME's. This will allow us to better understand how the Sun influence on the Earth's environment and possible climate effects.

Discussion

P. Brekke: The Ne VIII velocity shifts do *not* give evidence for solar wind origing when correlated with Si II intensity as said by Hassler et al. 1999, because of geometrical effects. When Ne VIII intensities are correlated with Ne VIII velocities, one draws opposite (and more physical) conclusions than in the Hassler et al. paper. The greatest velocities are found in the DARKEST areas.

L. Landi: Hassler et al. do not claim that Ne VIII velocities correlates with Si II intensity. What they do say is that Ne VIII velocities correlates with the chromospheric magnetic network boundaries. In general, the chromospheric magnetic network boundary is outlined by enhanced Si II emission, but not completely. Si II emission can be used to trace the magnetic network boundary, but only by interpolating between the regions of bright emission. There is *no* strong correlation between the brightest Si II intensity and the fastest Ne VIII outflows. The Si II is only used in this case to outline the "network boundaries", which when overlayed on the Ne VIII outflows, *do* correlate.

P. Brekke: What fraction of the transition region line flux is produced by the explosive events?

J.L. Linsky: I don't think anyone have done this calculation yet. After checking around in the community the data to derive this fraction exists and have been

obtained by SUMER. This work is in progress by Amy Winebarger at CfA (private communication).

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