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COMMISSION 12: RADIATION AND STRUCTURE OF THE SOLAR ATMOSPHERE (RADIATION ET STRUCTURE DE L'ATMOSPHERE SOLAIRE)

President: M. Kuperus Vice president: J. Harvey

I. INTRODUCTION

(M. Kuperus)

Solar Physics has been traditionally divided into Structure and Radiation of the Solar Atmosphere (commission 12) and Solar Activity (commission 10). There has been increasing evidence that solar activity, which is basically of magnetic origin, occurs on a great variety of scales and thus immediately touches upon the structure of the solar atmosphere as well as the structure and dynamics of the convection zone. As a consequence progress in the field of origin and evolution of solar magnetic fields from a large scale, 'the dynamo', to small scale is included in this report. In the past few years particular attention has been paid to the fact that the fluctuations in the magnetic field are much larger than the mean field and that the dynamo modes may be stochastically excited. The question whether there is a magnetic reservoir at the bottom of the convection zone still remains to be resolved. The interaction of the convection and the magnetic field resulting in an enhancement of the magnetic field in the intergranular lanes is studied by numerical modelling.

A real understanding of the magnetohydrodynamics of the subphotospheric layers requires a detailed study of the solar oscillations. The excitation of the so-called p-modes is likely to take place in the turbulent convection zone. Helioseismology will make it possible to study the thermodynamic and magnetohydrodynamic structure of the solar interior, thus preparing a foundation for stellar seismology, a field of growing interest, which will lead to a new understanding of stellar interior structure.

The outer solar atmosphere seems to consist primarily of structures that are shaken or sheared by photospheric motions. There is some evidence that the powering of the outer layers is magnetic of origin, though the actual mechanism is still a matter of debate.

It is of great importance to Astronomy and Astrophysics that the above mentioned outstanding problems of solar interior structure, solar magnetohydrodynamics and solar outer atmosphere are understood so that further progress can be made in stellar physics. For this to occur new resolution solar instrumentation is needed.

The president of commission 12 thanks the authors of this report for their contributions. He also wishes to thank the organizing committee for their support during the last three years.

II. SOLAR INTERIOR STRUCTURE

(Ken C. Libbrecht)

A great deal of progress has been made in recent years in the field of helioseismology (for a review of the field see Deubner and Gough 1984, Christensen-Dalsgaard et al. 1985, and Leibacher et al. 1985). Although it's been less than a decade since individual p-modes were first identified in solar velocity data (Grec et al. 1980), measurements have recently been made (unpublished) which isolated thousands of p-modes and determined each of their frequencies with accuracies as high as a few tenths of a microhertz, or to a part in 10^4. While in the past makers of the standard solar model were constrained to duplicate little other than the measured mass, radius, and luminosity of the sun, measured p-mode frequencies now provide thousands of additional model constraints. Solar p-mode frequencies have quickly risen to be among the most accurately determined physically significant quantities in all of astrophysics. (For contrast, pulsar period measurements have been made to accuracies of 10^{12} or greater, but this reflects simply a rotation rate of a neutron star, which returns no physical understanding of the phenomenon. Pulsar period derivatives are physically interesting, but their measurements are not nearly so precise, to a part in 10^4 with the binary pulsar 1913+16, for example.

Using the p-mode frequency measurements to determine the interior structure of the sun promises to be a very interesting but difficult task. Current standard solar models are able to reproduce most of the mode frequencies to of order one percent (unpublished) which confirms our basic understanding of the oscillations but is far from reproducing the frequencies at the level of their measurement uncertainties. Theoretical efforts are currently under way to better understand the basic properties of the solar interior, such as the equation of state and the opacity of the solar plasma, in order to produce an improved solar model which will better fit the observations.

Another approach to using the p-mode data is to invert the measured frequencies into a measurement of the speed of sound as a function of radius in the solar interior. A first result in this direction has been given by Christensen-Dalsgaard et al. (1985), where the sound speed determined from p-modes agreed quite well with that from the standard model calculation. Although the p-mode frequencies do not provide a very sensitive probe of the deep solar interior below one-half to one-third of a solar radius, they do provide a very good probe of the convection zone and the transition region between the radiative zone and the convection zone.

Measurements of the rotatonal splitting of p-mode frequencies have also been proceeding apace, with recent contributions by Duvall et al. (1986) and Brown and Morrow (1987). Efforts to invert the measurements to infer the solar rotation rate as a function of depth and latitude are still in progress, but it is likely that helioseismology will provide a quite accurate determination of the rotation rate throughout the convection zone. Such a measurement will be invaluable for comparison with computer models of the solar convection zone (Glatzmaier 1985), and is important input for understanding the solar dynamo. Recent measurements of the surface rotation rate determined by the 60-year Mt. Wilson white-lightplate collection (Gilman and Howard 1984) showed a one percent increase in the surface rotation rate during solar minimum. If true it should be possible to measure this increase using p-modes as well.

While the p-mode frequencies provide input for understanding the solar interior structure, their measured amplitudes reflect the dynamics of the mode excitation and damping mechanisms. Calculations of overstability mechanisms, such as the κ-mechanism, are still unable to confidently determine if the p-modes are stable or overstable, owing to our poor understanding of turbulent viscosity in the convection zone. However it is beginning to appear that the modes must be stable, since if they were unstable it is likely that a few modes would grow to very large amplitudes, as is seen in other oscillating stars such as the Cepheids, in contrast to the millions of low-amplitude p-modes observed in the sun.

A more likely mechanism for exciting the p-modes is via turbulent convection, originally proposed by Goldreich and Keeley (1977). The acoustic noise generated in the convection zone is trapped inside the solar acoustic cavity, and results in the excitation of the sun's normal modes. Recent work by Goldreich and Kumar (1986) predicts the energy E of a solar p-mode is given by the familiar-looking formula $E = mc^2$, where m is the mass of a resonant turbulent eddy, and c is the sound speed inside the eddy. For 5-minute oscillations, a resonant eddy is simply a solar granule, and the predicted energy is of order 10^{28} ergs, which is in fairly good agreement with observation (Libbrecht et al. 1986).

The theoretical work by Goldreich and Kumar represents a fundamental improvement in our understanding of the interaction of turbulence with sound waves, and is good example of how "basic" research in astrophysics can have broad implications. This work, which describes the emission and absorption of sound waves by turbulence, is an extension of the seminal work by Lighthill (1952) which described the emission of sound by turbulence, with the most common application being none other than airport noise.

Other helioseismology results include the report by Woodard and Noyes (1985) of the detection of solar cycle shifts of p-mode frequencies of 0.1 μHz per year between 1980 and 1984. This result has yet to be confirmed, however, and other workers (unpublished) have placed upper limits of approximately 0.1 μHz/yr on p-mode frequency shifts. While it appeared in the past that g-modes had also been detected on the sun (see Solar Phys. vol. 82 1983, Delache and Scherrer 1983), more recent measurements have turned up negative, and the general agreement of the solar community is that g-mode detections have not been confirmed.

The solar neutrino problem remains a problem, but recently the MSW theory of neutrino oscillations (Mikheyev and Smirnov 1986, Wolfenstein 1979) has been accepted as an attractive solution to the dilemma. Although the oscillation of electron neutrinos into other neutrino states (the μ and τ neutrinos) was suggested some time ago as a possible explanation of the solar neutrino measurements, the MSW authors showed that the theory of the weak interaction indicated resonance interactions in the presence of matter that greatly enhance the neutrino oscillation phenomenon. The theory also suggests a number of other measurements to constrain the neutrino mass and mixing angle (Dar and Mann 1987), including measuring the difference in the daytime and nighttime solar neutrino flux owing to oscillation inside the earth. Where in the past it was thought that neutrinos would pass effortlessly through light-years of lead shielding, now it is not even clear that they can pass through even the earth unscathed. However the MSW theory is not the only explanation of the neutrino measurements; it has been shown by Gilliland et al. (1986) that a sufficient number of weakly interacting massive particles (WIMPs) inside the sun could also reduce the flux of solar neutrinos.

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III. THE SOLAR DYNAMO

(M. Stix)

Traditionally the theory of the solar dynamo has been divided into two parts. The first, more difficult part, is the derivation of equations governing the mean magnetic field; the second, easier, is the solution of this equation, and the interpretation of the result in terms of observed solar magnetism. This report follows the traditional division.

1. Mean Field Equations

Mean field equations contain the effects of turbulence in form of transport coefficients, notably the turbulent diffusivity β, and the regeneration coefficient, α, for the mean poloidal field. These coefficients have often been calculated in the "approximation of second order correlations" (= "first order smoothing"). A formally complete solution has been given by Hoyng (1985). For the case of isotropic turbulence Nicklaus (1987), using an ensemble of polarized waves (Drummond et al., 1984) and the formalism of ordered cumulants, calculated corrections arising from fourth order correlations. These are proportional to $S^2 = (u\tau/l)^2$, which unfortunately is of order 1 in the solar convection zone. Moreover, not only the α-coefficient, but also the correction to the β-coefficient depends on the helicity of the turbulent flow.

In a different approach, Drummond and Horgan (1986) used the same set of polarized waves and calculated the exact Lagrangian solution of the induction equation. For the purpose of averaging they computed the paths of a large number ($\approx 10^5$) of fluid particles. In the examples treated they obtained α and β coefficients which were surprisingly close to the results of the second order correlation approximation. The Lagrangian approach was also employed by Molchanov et al. (1984) and by Vainshtein and Kichatinov (1986) in more general investigations of a magnetic field in a turbulent medium of high conductivity.

A different derivation of an α-coefficient was given by Schmitt (1984, 1985) on the basis of dynamically unstable magnetostrophic waves (propagating in a magnetic layer at the base of the convection zone, see below).

The role of magnetic field fluctuations (on the Sun, these are large compared to the mean field!) in dynamo theory was emphasized by Hoyng (1987a,b). He derives a new equation for the tensor $\langle \mathbf{BB} \rangle$ and shows that, in addition to α and β, a third important transport coefficient, related to the mean vorticity, occurs.

2. Solar Dynamo Models

Solutions of the mean field equation in a spherical geometry have been systematically studied by Rädler (1986a), Bräuer and Rädler (1987), and Yoshimura (1984a,b,c). These studies bear on the question of mode selection, e.g. whether a mean field of odd or of even parity will be excited first, or whether the field is oscillatory or steady. Hoyng (1987b) suggests that a number of dynamo modes could be simultaneously present at any one time due to stochastic excitation, and that these modes should be compared to the modes analysed by Stenflo and Vogel (1986). The dominant mode found by these authors is a combination of odd zonal harmonics, all with the same period of 22 years, and corresponds to the leading mode predicted by most $\alpha\omega$-dynamos. Non-axisymmetric modes are strongly opposed in $\alpha\omega$-dynamos by the differential rotation (Rädler, 1986b).

Parker (1984) points out that the traditional boundary condition of vanishing toroidal field, $B = 0$, should be replaced by the condition $\partial B/\partial r = 0$ because of the difficulty the field has to escape into the highly conducting corona. The new condition somewhat lowers the critical dynamo number and increases the period of the oscillatory dynamo solution (Choudhuri, 1984).

Much attention was paid to dynamos operating in an overshoot layer at the base of the Sun's convection zone. Such a dynamo would not suffer from rapid loss of magnetic flux due to instabilities. Thanks to a sign reversal of α in the lower part of the convection zone it would perhaps also avoid the poleward migration of the field which is found in dynamos based on hydrodynamic and hydromagnetic calculations (Glatzmaier, 1984, 1985a; Gilman and Miller, 1986; for the sign of α s.a. Krivodubskii, 1984b).

Inversion of p mode frequencies (Christensen-Dalsgaard et al., 1985) suggests that the base of the convection zone lies at a depth of $\simeq$ 200000 km. An overshoot layer at this depth, obtained through a non-local version of the mixing-length theory, is $\simeq$ 15000 km thick and quite capable of storing enough magnetic flux to account for the observed activity (e.g. Pidatella and Stix, 1986; for a more general approach, with "plumes", see Schmitt et al., 1984).

Unfortunately there is no indication of a concentrated shear layer at a depth of $\simeq$ 200000 km. Rotational splitting of p mode frequencies (Duvall and Harvey, 1984) yields a gradual inwards decrease of the angular velocity, i.e. $\partial\omega/\partial r > 0$, at low latitude (Duvall et al., 1984); dynamic considerations extend this functional behaviour of ω to the cylindrical isorotation surfaces known from the work of Gilman, Glatzmaier, and others (s.a. Rosner and Weiss, 1985). To concentrate magnetic flux generated in a broader shear region (and to counteract the effects of instability) one must possibly rely on mechanisms which transport flux downward into the overshoot layer. An example is the diamagnetic effect, as recently again suggested by Krivodubskii (1984a).

Independent evidence for a magnetic layer at the base of the convection zone could also come from p mode frequencies: Woodard and Noyes (1985) and Fossat et al. (1987) found a mean decrease of $\simeq$ 0.4 μHz between 1980 and 1984 for frequencies of degree 0 to 3, and attribute the change to the solar cycle. The change has been disputed by Pallé et al. (1986). Moreover, a change of 0.4 μHz would require a field strength of order 10^6 G, which is much larger than theoretically expected (Roberts and Campbell, 1986)! So the question is open. In any case it is interesting to note that a narrow magnetic layer would cause a more subtle effect: in addition to a mean term, we would expect a frequency shift which (for any given degree) is periodic in the frequency itself (Vorontsov, 1987), and perhaps detectable by this signature.

A kinematic $\alpha\omega$-dynamo model for the overshoot layer has been constructed by DeLuca (1986; s.a. DeLuca and Gilman, 1986). It employs a shear with $\partial\omega/\partial r > 0$, and $\alpha < 0$ (in the northern hemisphere; $\alpha > 0$ in the south), so that the mean field migration is equatorwards as desired. These ingredients to the kinematic model are confirmed in the full dynamic calculation of Glatzmaier (1985b). The model of Schmitt (1987) is a similar $\alpha\omega$-dynamo, he employs the α-effect arising from the magnetostrophic waves. Unfortunately all these models seem to predict the wrong phase relationship between the mean poloidal and toroidal field components (Stix, 1987).

Aperiodic behaviour, such as the Maunder minimum in the 17th century, has been attributed to the dynamic properties of the mean field equation. Non-linear interaction terms allow for the desired chaotic solutions (Weiss et al., 1984) although a different explanation, based on a stationary field in the core, has been offered by Pudovkin and Benevolenska (1985).

Reviews on the solar dynamo include those by Belvedere (1985), Gilman (1986), Moss (1986), Stix (1984, 1987), and Weiss (1986, 1987).

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IV. SMALL SCALE MAGNETIC FIELDS

(S.K. Solanki)

Considerable progress has been made during the last four years in the theoretical and empirical investigation of the small scale solar magnetic field and associated phenomena. Although the basic outlines established in the 1970s of the structure of the field, namely small fluxtubes or magnetic elements with kilogauss fields embedded in a relatively field free medium have survived, many of the details have changed and some of the large gaps in our knowlegde of these captivating structures have been filled. In the following we briefly outline some of the highlights.

One direction in the thrust for a better understanding of magnetic elements has been towards the construction of comprehensive theoretical models, e.g. by Deinzer et al. (1984a,b) in 2-D slab geometry and by Nordlund (1986) in 3-D. Although these models still lack some essential features (too small spatial resolution in the 3-D models, no proper treatment of the radiative transfer in the 2-D models; the latter shortcoming is being remedied at the moment by a number of groups), they do illustrate the physics and give rise to the hope that within a decade models of magnetic elements of equal detail and generality as the granulation models of Nordlund will be available. However, considerable hurdles must be surmounted first, since magnetic elements are considerably more difficult to model than granulation. Waves, for example, cannot be neglected, since wave heating (perhaps involving dissipation via shocks, cf. Herbold et al., 1984) is probably quite important even in the photospheric layers and is certainly so in the chromosphere. The work of Ayres et al. (1986) actually supports the conclusion that the hot chromosphere only exists within fluxtubes. Another complexity facing 3-D fluxtube modellers is the possible presence of a boundary current sheet, which requires very fine grids for a proper treatment. Two dimensional models, like the ones of Deinzer et al. or of Steiner et al. (1986), have the advantage that they can take such boundary layers into account in detail.

A breakthrough in the radiative transfer of polarized light was achieved by Van Ballegooijen (1985). He presented a method for obtaining the formal solution of the radiative transfer equations for polarized light in the presence of a magnetic field. Besides providing deep insight into the process of solution, his method also allows contribution functions to be defined and calculated. Thus the determination of the heights of formation of the Stokes profiles has been placed on a secure theoretical footing. This advance will play an important role, not only for the proper diagnostics of observations, but also for interpreting the spectra produced by the emerging breed of comprehensive fluxtube models. The one remaining problem with his definition is that it mixes the contribution to the lines with that to the continuum. However, a remedy is already in sight.

Given the present state of theory, observational and empirical work is still indispensible. The main observational advance has come from the extension of the Fourier transform spectrometer (FTS) at the NSO McMath telescope into a spectral polarimeter, which is currently capable of registering Stokes I, V, and Q in thousands of spectral lines simultaneously at very high spectral resolution. Data from this instrument, built by J.W. Brault and converted into a polarimeter by J.W. Harvey and J.O. Stenflo, have led to a considerable fraction of the observational advances concerning small scale magnetic fields in the last three to four years. Although such data do not have high spatial or temporal resolution, the amount of information they contain is still enormous and only a fraction of it has so far been extracted. Some of the progress has been a result of the derivation of an approximate form of the unpolarized line profile, Stokes I, formed exclusively inside the magnetic elements form the observed Stokes V (Solanki and Stenflo, 1984). This allows the rich array of diagnostic techniques available for the unpolarized spectrum to be applied for the first time to light arising solely from inside a magnetic element. When combined with FTS observations this technique yields a complete atlas of a fluxtube spectrum. New empirical models of the fluxtube temperature structure have been deduced from such profiles (Solanki, 1986). It has also been possible to obtain information on the vertical gradient of the magnetic field (Stenflo et al., 1987), as well as the inclination of the fluxtubes to the vertical. Some of the other results obtained from these data are mentioned further below.

Much effort has gone into the (mostly theoretical) investigation of dynamical phenomena associated with a concentrated magnetic field. Of particular importance has been the emergence of the non-linear treatment of such phenomena. For example, the convective collapse of fluxtubes as a means of concentrating the field into small bundles with field strengths well in excess of the value expected through equipartition with photospheric motions, has been studied in detail numerically (e.g. Nordlund, 1986; Hasan, 1985). One outcome of these calculations has been that the final state is one of overstable oscillations. Also, a number of mechanisms for exciting and amplifying the various wave modes and oscillations in fluxtube have been recently proposed. Interesting is the result of Venkatakrishnan (1986), who has found that very high amplitude oscillations and waves can be excited resonantly inside fluxtubes by external pressure fluctuations. In view of such non-linear results and the rich literature on linear calculations of fluxtube waves (see Roberts, 1986 for a review), it appears surprising that until recently no evidence for non-stationary mass motions in fluxtubes, except low amplitude 5-minute oscillations (Giovanelli et al., 1978; Wiehr, 1985), existed at all. The reason is that fluxtubes cannot be resolved, so that usually more than one fluxtube is present in the resolution element. Only the oscillations or waves which are in phase in all of these give an oscillating Doppler shift signal. However, an analysis of line widths by Solanki (1986) has shown that rms velocities of 2-4 km s^{-1} are present inside the magnetic elements, from which he has inferred the presence of non-stationary mass motions with amplitudes (in the vertical direction) larger than in the surrounding quiet photosphere. Unfortunately, such an analysis is not able to differentiate directly between the signatures of different wave modes etc. Very high spatial and temporal resolution observations, as are expected to become available from the Canary islands and perhaps later from space, are required for this. The discovery of an asymmetry in the Stokes V profile by Stenflo et al. (1984) is also suggestive of mass motions, although its proper interpretation is still unclear.

Downflows inside fluxtubes and in their immediate surroundings were widely observed in the 1960s and 1970s, but more recently Stenflo and Harvey (1985) and Solanki (1986) among others have ruled out flows faster than 0.25 km s^{-1} in the photospheric layers of fluxtubes. Miller et al. (1984) and Solanki and Stenflo (1986) have shown that the previous positive detections of downflows were due to poor spectral resolution and a neglect of the (then partly unknown) asymmetry in the unpolarized (Stokes I) and polarized (Stokes V) line profiles. Hasan and Schüssler (1985) have provided theoretical support for the absence of net downflows.

A field of ever-growing importance concerns the interaction of the magnetic field with its surroundings. Observational evidence for such interaction is still sparse, but the investigation is gaining momentum. The classical study of line bisectors has shown that convection is affected quite strongly by magnetic fields (Cavallini et al., 1985, 1987) as theoretically predicted earlier. An analysis of time sequences of white light pictures from Spacelab 2 also beautifully demonstrates that the granulation changes dramatically in character in the vicinity of magnetic elements (Title et al., 1987a). The convection pattern in magnetic regions is considerably more stable than in non-magnetic regions. Individual granules appear to live almost twice as long as on the quiet Sun. Furthermore, Title et al. (1987b) have found that magnetic elements are mainly concentrated in the intergranular lanes, as had been previously theoretically anticipated, e.g. by Nordlund's (1986) 3-D calculations of fluxtube convective collapse. His models as well as those of Deinzer et al. (1984b) take the interaction with the non-magnetic atmosphere into account in detail. Deinzer et al. have stressed the presence of a convective cell surrounding the fluxtubes, produced by the inclination of the surfaces of constant temperature in the immediate vicinity of the fluxtubes. This inclination is due to the cooling of this region by the magnetic elements through the influx of radiation and the inhibition of convection.

The Sun, being the only resolvable star, plays a central role in our understanding of stellar magnetic activity as a whole. Thus it is the only star on which the detailed structure of the magnetic field can be investigated more or less directly. Furthermore, since the solar fluxtubes are spatially unresolved, their study has often led to the development of instrumentation and techniques which can be applied to the measurement of stellar magnetic fields or stellar activity. Older examples are the Babcock magnetograph (used to measure the field on Ap stars) and the use of Ca II H and K flux as a measure of stellar activity. Newer examples are the use of powerful statistical techniques, originally developed for the analysis of solar spectra, to Ap stars (Mathys and Stenflo, 1986) and to active G and K main sequence stars.

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V. HEATING AND DYNAMICS OF CHROMOSPHERE AND CORONA

(G.E. Brueckner)

The crucial role of magnetic fields in any mechanism to heat the outer solar atmosphere has been generally accepted by all authors. However, there is still no agreement about the detailed function of the magnetic field. Heating mechanisms can be divided up into 4 classes: (I) The magnetic field plays a passive role as a suitable medium for the propagation of Alfvén waves from the convection zone into the corona (Ionson, 1984). (II) In closed magnetic structures the slow random shuffling of field lines by convective motions below the surface induces electric currents in the corona which heat it by Joule dissipation (Heyvaerts and Priest, 1984). (III) Emerging flux which is generated in the convection zone reacts with ionized material while magnetic field lines move through the chromosphere, transition zone and corona. Rapid field line annihilation, reconnection and drift currents result in heating and material ejection (Brueckner, 1987; Brueckner et al., 1987; Cook et al., 1987). (IV) Acoustic waves which could heat the corona can be guided by magnetic fields. Temperature distribution, wave motions and shock formation are highly dependent on the geometry of the flux tubes (Ulmschneider and Muchmore, 1986; Ulmschneider, Muchmore and Kalkofen, 1987).

The emphasis of the literature, both theoretical and observational, is shifting to detailed investigations of fine structures, inhomogeneities, assymetries, singularities and the interaction of waves with changing conditions in the surrounding media (Steinolfson et al., 1986; Lou and Rosner, 1986; Van Ballegooijen, 1985; Einaudi and Mok, Yung, 1987; Davila, 1987). In order to explain the increase of the smeared out emission measure distribution function Q(T) at lower temperatures, a mixture of cool and hot loops has been introduced (Antiochos and Noci, 1986). Low lying, small scale loops ($h < 5000$ km) are assumed to be the main source of the cooler emission. A possible explanation of the dominant redshifted 100,000° K emission is based on assymetries in the loop geometry or heating rate (McClymont and Graig, 1987). Spicules are possible manifestations of upflows over regions of increased heating rate in a similar model invoking inhomogeneous heating (Athay, 1984). An analysis of high resolution C IV transition zone spectra showed that blueshifted (upward moving) material at 100,000° K cannot compensate for the observed predominant redshifted (downward moving) material at the same temperature. The upward mass flow is 3 orders of magnitude lower than the downward mass flux (Dere, Bartoe and Brueckner, 1986).

The role of transition zone explosive events and jets in the heating process of the transition zone and corona has been reevaluated using much more comprehensive observations from Spacelab-2 (Cook et al., 1987). Although there are many more events present on the sun than earlier estimates from sounding rockets indicated, their total kinetic energy is only 2.5×10^4 ergs cm^{-2} s^{-1}, which seems to be insufficient to compensate for the energy losses of the corona. However, these estimates are based on an analysis of a rather narrow temperature regime, therefore they represent only a lower limit. An analysis of intensity fluctuations and Doppler-shifts of the NV lines ($T \sim 250{,}000$ K°) results in an upward energy flow of 10^3 ergs cm^{-2} s^{-1} if interpreted as acoustic waves (Bruner and Polleto, 1984). This is again a lower limit because of the rather coarse spatial resolution (3×3 arc sec^2) of the Solar Maximum Mission observations. Microwave solar radiation at 6.3 cm displays fluctuation, which has been observed simultaneously