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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 x 3 arc sec^2) of the Solar Maximum Mission observations. Microwave solar radiation at 6.3 cm displays fluctuation, which has been observed simultaneously

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with two radio telescopes several 1000 kilometers apart. Most of the observed fluctuation must be associated with sources other than the sun. However, significant correlation was found in one run. A coherence length of 90 sec may indicate an association with explosive events in the transition zone (Benz and Furst, 1987).

Several investigations of the posible role of very fine structure (1 cm to 1 km) filaments in the transition zone and corona have been carried out. Filamentary electric currents in an ambient H field of 10 Gauss can dissipate enough energy in a Joule heating model of the lower transition zone (Rabin and More, 1984). Such filamentary structures can be the result of thermal instabilities in the presence of a magnetic field, the low frequency inhomogeneities are occuring along the magnetic field lines (Bodo et al., 1987). A new analysis of the "fill factor" in the transition zone supports these theoretical considerations (Dere et al., 1987) The fill factor is always smaller than 1% and can be as small as 10^{-4}. This leads to an upper limit for the dimension of the hyperfine structure of 100 km. The observations indicate, that these fine structure filaments can have a length of several thousand km and that they surround spicules. A consequence of this view of the transition zone is a revision of the amount of conductive heating in the transition zone from the corona (Bodo et al., 1987; Dere et al., 1987). The overall broadening of transition zone lines by plasma motions is sufficient to support a heating of the corona by Alfvèn waves (Brueckner, 1987).

Line profile analysis of Fe XIV in the quiet corona shows a periodic (235 s) intensity fluctuation but no periodicity of line width or Doppler velocity (Tsubaki, Saito and Suematsu, 1986). This result is in partial agreement with older measurements but it contradicts others. It confirms the intrinsic difficulty of such measurements in optically thin coronal lines. Measurements of resonantly scattered H-Ly-α radiation in the corona at solar maximum place an upper limit of 110 km s^{-1} for the combined thermal and nonthermal motions of hydrogen atoms in the corona (Withbroe, Kohl and Weiser, 1985). Observations of interplanetary scintillations with the VLA telescope show random velocities of 200-300 km s^{-1} along the bulk flow and 0-100 km s^{-1} perpendicular to it in the corona between 3 and 4.5 R_o. The mean speed of the solar wind seems to increase rapidly from 0 to several hundred km s^{-1} in the same region (Armstrong et al., 1986).

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VI. THE SUN AS A STAR

(L.E. Cram)

Studies of the global (spatially unresolved) output from the sun are important for two main reasons: (1) the global solar output directed towards the earth plays a central role in solar-terrestrial relations, and (2) global solar observations form a link between (neccessarily) global observations of stars and the more refined spatially resolved observations which are available for the sun. This report covers both aspects (insofar as they concern the sun), using the time-scales of various phenomena as a basic distinguishing characteristic. Note that certain studies of spatially unresolved solar output have not been discussed, since they are actually directed toward the investigation of phenomena of strictly limited spatial extent [e.g. radiospectrograph observations (e.g. Wiehl et al. 1985) and studies of X-ray bursts (e.g. Thomas et al. 1985)]. Collections of relevant papers may be found in De Jager and Svestka (1985) and Labonte et al. (1984), while a review of germane stellar work is available in Baliunas and Vaughan (1985) and solar-terrestrial work in Donnelly and Heath (1985). A comprehensive summary of the subject by Hudson will appear soon in Review of Geophysics and Planetary Physics.

(a) Long-term variations (> several months)

The first 5 years (1980 to 1985) of observations of total solar irradiance by the Active Cavity Radiometer Irradiance Monitor (ACRIM) aboard the NASA Solar Maximum Mission (SMM) satellite have shown a clearly defined decline of -0.019% per year (Willson 1984; Willson et al. 1986). The trend detected by ACRIM is consistent with observations made by the NOAA Nimbus-7/ERB experiment and by sounding rockets, although there is some inconsistency in the actual values of the slopes derived from the various experiments. The observed decline could represent a dependence of the solar luminosity on the solar magnetic cycle. Pap (1986a) noted that the amplitude of variations (on time scales of days to weeks) in the irradiance is smaller at sunspot minimum than at maximum, and she also claims that the dominant period of irradiance modulation increased from 23.5 days at sunspot maximum to 28 days at minimum.

In addition to work on long-term variations in total irradiance, there have been several reports on long-term variations in narrower spectral regions. Livingston and Wallace (1987) reported that several photospheric lines exhibit long-term variations after instrumental effects are removed. In particular, a small change in the central depth of CI λ 538 nm is reminiscent of the ACRIM result described above. Cavallini et al. (1986) have shown that long-term changes occur in the asymmetry and width of photospheric lines observed at disk centre, while Snodgrass (1984) has re-examined the long-term trends in a number of absorption line properties measured as part of the Mt. Wilson magnetogram program. Deming et al. (1987) have reported what seem to be significant long-term shifts in