The Formation, Structure and Dissipation of Direct Electric Current Systems in the Solar Atmosphere

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The idea that direct electric current systems may play a role in heating the solar atmosphere can be traced back to Hoyle and Wickramasinghe. However, there have been relatively few efforts to quantify this idea by explaining how the large electric current densities which are required can be formed, and how the dissipation of such intense electric currents can account for the observations. The purpose of this dissertation is to present several quantitative models of the formation, structure and dissipation of direct electric current systems in the solar atmosphere.

This work was supported by NASA grant NAG5-500 and NAGW-294.

A Search for Polarization in Ellerman Bombs

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Ellerman bombs are transient brightenings at tiny (<1 arsec) points in the lower chromosphere. Their spectra are characterized by very thin and elongated emission wings on the hydrogen Balmer lines. Apparently, bombs occur below $T_{5000} = 0.4$, and no emission can be seen in spectral line cores. Emission at the line core is presumably lacking because of absorption in the overlying atmosphere or in the bomb itself. Despite the fact that there is currently no plausible explanation for the brightening, little attention has been paid to Ellerman bombs in recent years, except that Babin and Koval (1985, Izv. Krin. Astrofiz. Obs. 73, 3) recently found linear polarization levels as high as 10%. It is difficult to imagine a physical process that could produce such a high degree of polarization. We report here on an observational study of polarization in Ellerman bombs. Measurements of ~20 bombs were made through a 6 Å filter at the Sacramento Peak Vacuum Tower Telescope using a novel polarizing beamsplitter that splits an image into two interleaved polarized images. The images pass together through one set of optics and are separated only during data analysis. For calibration, images were obtained while a polaroid was placed in the beam and rotated. The sensitivity threshold of the measurements is ~1%. Linear polarization was detected just above this limit, but we cannot confirm the high levels of polarization reported by Babin and Koval.

Numerical Studies of Atmospheric Dynamics Driven by Energy Deposition in the Chromosphere

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A series of numerical simulations indicates that thermal energy releases of about $10^{28}$ to $10^{29}$ ergs in the middle or upper chromosphere can produce mass ejections into the corona in the form of pressure gradient generated jets, jets with pressure gradient and shock generated components, or high speed gas plumes. Key factors determining the form of the ejections are the location and physical extent of the heating source. Heating of the chromosphere to X-ray emitting temperatures occurs in association with gas plumes, perhaps generating X-ray microflares. Chromospheric UV microflares can occur in association with some jets, but do not generally occur in the simulations that produce spicule-like events.

This work was partially supported by basic research funds from the Naval Research Laboratory.

Diffusion of Helium in the Solar Transition Region

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In two previous papers (Fontenla, Avrett, and Loeser 1990, Ap. J., 355, 700, and 1991, Ap. J., in press) we have shown that at temperatures below $10^4$ K in the chromosphere-corona transition region, the diffusion of hydrogen atoms and ions is an essential process in both energy transport and resonance line emission, at least for stationary cases in the absence of mass flows. We have now completed a detailed study of the diffusion of helium atoms and ions together with hydrogen diffusion. When the effects of relative helium/hydrogen diffusion are ignored, helium diffusion resembles that of hydrogen: neutrals diffuse a short distance into the ionized region and ions diffuse a short distance into the neutral region. As a result, the He I number density is substantially greater for $T > 35,000$ K, and is smaller in the range 9000 to 25,000 K.

However, the cross section for elastic collisions between He I atoms and protons is much larger than that between He I atoms and neutral hydrogen. When the diffusion of helium relative to hydrogen is taken into account, the inward diffusion of protons relative to hydrogen atoms produces an inward diffusion of helium atoms. In order to reach a stationary state, the helium abundance must have a strong outward decrease in the lower transition region. The effect is substantial: using available cross sections we find that without mass flows and mixing, the inward diffusion of protons in the lower transition region tends to inhibit the presence of helium in this region and leads to a reduced helium abundance in the corona.

In order to account for available observations we expect that departures from the purely stationary, hydrostatic case are required, i.e., that mass and species outflows must be included.

Formation of the Infrared Emission Lines of Mg I in the Solar Atmosphere


The Mg I emission lines at 7 and 12 microns provide a sensitive measure of the magnetic and electric field strengths in the layers of the solar atmosphere where the observed emissions originate. Hence it is important to know how and where these lines are formed. Lenke and Holwegger (1987, A & A, 173, 375) studied the non-LTE formation of one of these lines, and found that emission could be produced high in the photosphere when the upper level is assumed to be in LTE. The computed population of the lower level results in a line source function that exceeds the Planck function. They did not show how such relative populations might occur. Hoang-Binh (1991 preprint) has suggested that relative overpopulation of upper levels can be due to strong collisional coupling between very high lying levels of Mg and the Mg continuum.

We have investigated these effects with a 41-level atomic model, including the additional charge exchange process Mg(0) + H$^+$ $\rightarrow$ Mg$^+$ + H(0) between magnesium and hydrogen. Using an average quiet Sun...