PAPER 62

OPTICAL EVIDENCES OF RADIATIONAL AND CORPUSCULAR EMISSION FROM ACTIVE SOLAR REGIONS

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The detailed physical processes involved in centres of activity still remain obscure. Optical and radio noise observations enable us to state in increasing detail the phenomena that any comprehensive theory must explain. At times it seems that the complexity of the picture provided by these new data grows more rapidly than our ability to invent adequate theoretical models.

From the optical data it is clear that the solar atmosphere in outstanding active centres is characterized by very high temperatures, relatively high densities, and by rapid motions on a large scale. The temperature evidence comes from several directions. First, we know that in pronounced active centres the yellow coronal line is often strongly emitted. This line arises from Ca XV, with the highest ionization potential of any known solar spectrum lines [1]. Spectrum lines of the corona correspond to very small optical depths and nevertheless exhibit very large line-breadths over many active regions, strongly implying [2] that the temperatures lie in the range 2×10^6 to $6 \times 10^{6\circ}$ K. Active regions of pronounced character generally display not only stronger line emission than other regions for lines of all ionization potentials, but also relatively stronger coronal line emissions from higher ionization lines (for example, $\lambda 5303$ of Fe XIV compared to $\lambda 6374$ from Fe X). These facts also indicate their high temperature [3].

Active-centre prominences show line-breadth effects that appear to be thermal, since they depend on atomic weight [4]. These suggest temperatures of the order of $10^{5\circ}$, which is high compared with prominence temperatures elsewhere, but not compared with the corona. Line breadths from flares cannot be interpreted as thermal, because of self-absorption effects [5], and because of the excessive temperature values to which such determinations would correspond. But there is ample evidence

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that in association with solar flares very high temperature effects occur in the solar atmosphere.

Active regions in the solar atmosphere are not only hotter, but they are denser and probably patchier than the quiet solar atmosphere. The electron corona is generally brighter, eclipse photographs show, over active regions [6], implying also that the electron density is greater. Sun-spot-type prominences are generally abundant in such regions, and they too are probably much denser than quiescent prominences. They are certainly denser than the surrounding coronal space. The frequent surge prominences are undoubtedly very dense relative to prominences in general.

Goldberg, Dodson and Müller [5] have shown that flares are not only optically thick in H_α emission, but their line width is satisfactorily explained as radiation damping, if their density is considered to be high (number of H atoms on the second quantum level in line of sight $= 10^{15}$ to 10^{16} per cm.^{2}). The increased 5303 A and 6374 A emission of coronal lines from active regions, though the ratio is temperature dependent, also implies a definite increase over active regions of densities in the coronal line-emitting atoms [7], though the absolute coronal densities remain very low [8].

Active centres are characterized also by rapidly moving material in prominences [9]. This is particularly noticeable in looking at routine line spectrograms of the corona and prominences. Strong active regions have prominences with knots showing Doppler displacements corresponding to large average motions in the line of sight. The average velocities of such regions are well above the averages from prominences as a whole. One of the paradoxes, however, is that coronal lines rarely exhibit gross Doppler effects corresponding to such motions [10].

The trajectories of prominences over active regions often suggest a field of motion that is homogeneous throughout a very large volume (radius of the order of 10^5 km.). For example, trajectories of the outstanding active region of 26 February 1946 have been traced and analyzed by Dr Malcolm Correll and his assistants Miss Martha Hazen and Mr John Bahng at High Altitude Observatory this summer (Fig. 1). The trajectories suggest a magnetic field in the solar atmosphere like that of a dipole buried 0·2 solar radii below the photosphere, with the axis of the dipole approximately radial. If such fields do exist, the fact is of great significance in solar radio noise studies.

Before we can fully understand active regions, we must probably understand the 'normal' chromosphere. The behaviour of plages (chromospheric faculae) in active centres suggests that the active-region chromosphere may differ in many respects from the normal, and in particular that it is hotter. We have analyzed one such region and found it not only extended in height, but also hotter at given heights [7, 11]. The close connexion of coronal line emission and plages suggests this, too, and ultimately we may have to conclude that the abnormal chromosphere found at centres of activity is responsible for the coronal line emission maxima, or vice versa.

The trend towards higher temperatures in active centres emphasizes the relatively greater importance of the far ultra-violet and X-ray emission of

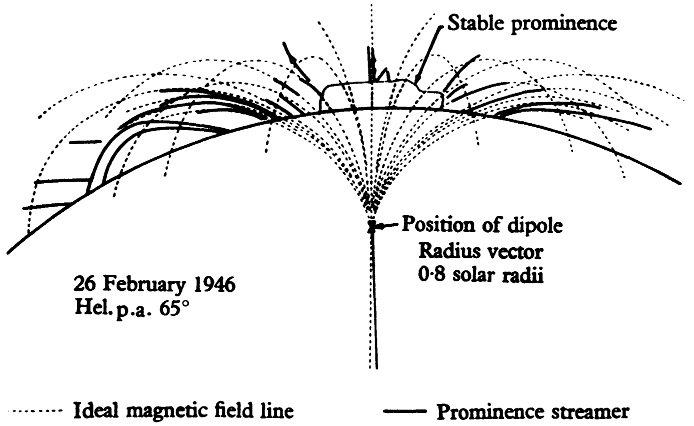

Fig. 1. Comparison between prominence streamers and magnetic lines of force.

the active regions. Specifically, we speculate that the role of the Lyman-like spectrum of ionized helium may be more important, relative to hydrogen emission, than previously recognized.

Direct optical evidence of solar corpuscular emission is scanty. The case for corpuscular solar emission is patched together from many fields, ranging from solar physics through cometary study, to auroras and geomagnetism; it is, however, a good case. Thus far, all efforts to prove directly the existence of ion streams by their absorption in the H and K lines of calcium have ended dubiously or negatively [12]. We are left with direct observations of surge prominences from active centres, but these surges have velocities well below those expected in order to fit geomagnetic evidence (600 to 3000 km./sec.), and with rather indirect speculations from the shape and spectrum of the electron corona above active centres. Above active centres, as mentioned above, there is usually heightened continuous emission from the electron corona. Eclipse photographs reveal that still higher in the solar corona there is a tendency towards a rayed structure, suggesting a diverging cone-like bundle of coronal streamers directed to space. Day-to-day observations of the electron corona are most important in establishing the orientation and directions of these streams, but do not hold out much hope for direct observation of the ejection velocities.

In the study of corpuscular emission the field of radio astronomy has much to offer. Among the high priority studies, as I see it, should be observations of polarization of radio noise bursts at metre wave-lengths. These should assist us to understand the magnetic field structure well up in the solar atmosphere. They should, therefore, be closely co-ordinated with the analysis of solar prominence motion for the same regions and times, and with studies of photospheric magnetic fields at the same times by techniques similar to those of the Babcocks [13] for the weak-field regions of the solar disk.

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