CHAPTER 1

PREVIOUS STUDIES OF THE CHROMOSPHERE

The chromosphere is the middle layer of the sun's atmosphere. Its height is about 5000 km. from the photosphere, with a jagged upper boundary. It emits line spectra instead of continuous spectra and has small optical depth in the white light. Early in the nineteenth century, the observations of the chromosphere were made only along the limb during total eclipse, but its fine structure were not found. C.A. Young (1871) was the first to observe the flash-spectrum. Secchi (1877), later made visual observations in the absence of an eclipse through a spectroscope attached to a 15 - inch refractor and the chromospheric fine structures were first recorded on his sketch which revealed the resolved spikelike structures. Since then, the inhomogeneous property of the chromosphere has been known and from the photographs of the chromospheric limb, taken both during total eclipse and by artificial eclipse the general characteristics of the spikelike structures, latter called "spicules" by Roberts(1945) have been studied. The results obtained by many investigators, however, were in general agreement as shown in Table 1 - 1 (after R. Bhavilai, 1964).

The invention of the spectroheliograph by Hale in 1891 led to a new technique in the study of the chromosphere. By such instruments, the chromospheric disk has been taken in the monochromatic light of strong Fraunhofer lines. The relations between the limb and disk chromospheric structures, however, were not studied until recent years. Following the spectroheliograph, came the birefringent filter, first designed by Lyot (1944), which has enabled observers to obtain both the normal filtergrams and time lapse cinematographic filtergrams of the chromosphere in the H_α line. Photographs of the chromospheric limb taken through the Lyot filters of wide bandpass were also used by several observers for studies of the spicules (Table 1 - 1).

However, using the spectoheliograms and filtergrams several investigators later paid attention to the chromospheric disk and limb relations. Menzel 1931, Kiepenheur 1953, and Unsold 1955 agreed to the classification of spicules, seen against the limb, as a type of prominence and identified them as the dark fine mottles on the chromospheric disk. This identification was also supported by the work of de Jager (1957), Macris (1957), Brusek (1957), Cragg, Howard and Zirin (1963) and Beckers (1963). In the attempts to prove this identification, the general charateristics of the dark fine mottles have been measured by the investigators as shown in the Table 1 - 2.

Although the agreement between these investigators has been very strong, the spicules, however, cannot be traced directly from the limb down onto the disk. From the filtergrams obtained through $\frac{1}{8}$ Å H_α-filter + 3 Å interference filter and additional "supplymentary plate" at Sydney, Bhavilai, Norton and Giovanelli (1965) have shown that the inner limb appearing in the "double limb" phenomenon is due to the effect of stray light and when this unwanted light has been eliminated the connection of the spicules along the limb to the bright features on the disk is quite obvious. As summarized by de Jager (1966), at the colloguium given at the Capri Conference on Solar Fine Structure, June, 1966, "The spicules show as bright structures on the disk (original suggestion by Bhavilai and now also supported by Beckers and Sheeley)".

Table I-I

The general characteristics of spicules.

Observers.	Instruments.	Investigators.	Diam. sec. of arc.	Height sec. of arc.	Lifetime min.	Velocity km/sec.	No./rad.
Secchi (I877)	spectroscope	Secchi (I877)	0.2-0.4				
Roberts (I945)	coronagraph+ filter	Roberts (I945)	3-4(max.)	I0(max.)	4-5 (av.)	30 (typical)	24
------	-------	Bugoslavskaya (I946, I950)	II(av.)				86
Marriot (I930)	in white light (total eclipse)	Mohler (I95I)	I.8	6.7			I7I
Lyot	birefringent filter	Dizer (I952)	[illegible]	8-I4(av.)	2-2.5	20(act. area) 40(non-act)	
Roberts (I945)	coronagraph+ filter	Rush & Roberts (I954)	2.8	7-20	3.3	3I	42
Dunn (I960)	3 A. bandwidth filter	Lippincott (I957)	I.4	26(max.) I2(pole) I0(eq.)	5.I mean	I9(ascending) 24(descending)	
Dunn (I960)	3 A. bandwidth filter	Dunn(I960)	I.I (av.)	26-28(max.) II-I2.5(av.)	5-I5		I20-250
Suemoto & Hiei(I962)	spectrograph	Suemoto & Hiei(I962)	3.0				

Table I-2

Characteristics of dark fine mottles.

Investigators	Data	Region on disk	Width in sec. of arc	Height in sec. of arc	Lifetime (min.)
de Jager (1957)	spectroheliogram, centred at $H_\alpha + 0.0$	Centre of disk	1.0-2.2		
Macris (1957)	spectroheliogram, centred at $H_\alpha + 0.0$			5.5	5.5
Bruzek (1959)	filtergram, centred at $H_\alpha + 0.0$	Near the limb		11 - 17	13
Beckers (1963)	filtergram, centred at $H_\alpha + 0.5$	Centre of disk	0.7-1.8	4.5 (mean)	15.5
Bhavilai (1964)	filtergram, centred at $H_\alpha \pm 0.75$	Centre of disk	2-3	5-15	

With the developements of birefringent filters and spectroheliographs, photographs of the chromospheric disk have been taken through the light across the line profiles of several strong Fraunhofer lines and from these photographs motions on the chromosphere have been found by Leighton (1960, 1961). Evans and Michard (1961, 1962 a, 1962 b, 1962 c), on the other hand, have obtained the same results by using high resolution spectrograms. The types of motions found are as follows:-

1) The horizontal motion which appears in long - lived cellular cells of diameter about 1.6×10^4 km. Material is found flowing from an internal source to boundary of each cell with the r.m.s. velocity o.5 $km/_{sec.}$ They are uniformly distributed over the entire solar surface.

2) The vertical quasi-oscillatory motion with a period of 296 ± 3 sec. This type of motion occurs in the elements of size about $2 - 3 \times 10^3$ km. with a velocity amplitude of about 0.4 $km/_{sec.}$ It is found in all medium strong lines and lasts for only 3 cycles.

3) The random turbulent velocity which increases witb height. It occurs in the same regions as the former types, hut individual motions are too much small to be resolved in observations.

Although these motions occur only in the photosphere and low chromosphere and bave not been found in the study of the spectroheliograms taken in H_α- line, the network structures appearing in H_α- disk do show a correlation with the horizontal motion cells. As found by Simon, the networks correspond to the bright networks of K - spectroheliograms which in turn coincide with the boundaries of the cells, and de Jager (1966) concluded that the chromospheric networks and the horizontal motion cells are identical.

From the study of the Doppler field in the centre of the disk in the light of $H_\alpha - 0.3$ to $H_\alpha + 0.3$ Å, Bhavilai (1964), however found equal numbers of mottles moving up and down. This suggested another type of motion, the loop motions of chromospheric material.

In this thesis, the general characteristics of dark fine mottles at the limb, taken in $H_\alpha + 0.75$ Å through $\frac{1}{8}$ Å birefringent filter are studied. The identification of spicules as bright features on the disk has been confirmed from the isophotal contour map of the chromospheric limb and finally, the loop model ofthe dark fine mottles is obtained.