THE DISTRIBUTION OF RADIAL VELOCITIES OF DARK *Hα* MARKINGS NEAR SUNSPOTS.

H. W. Newton.

(Communicated by the Astronomer Royal)

The radial velocities of *Hα* flocculi on the disc have been regularly observed at Greenwich since 1930 with the spectrohelioscope lent by the Mt. Wilson Observatory. These observations show that the distinction in appearance and position on the Sun's surface between the two main classes of dark flocculi is represented by typical distribution of their respective radial velocities. The two classes of dark flocculi * may be described in general terms as follows :—

(1) Markings that tend to avoid sunspots though not the sunspot zones. These flocculi are usually well-defined extensive filaments, though some are diffused patches. Their duration is of the order of days.

(2) Markings associated with sunspots and with the bright flocculi that accompany spots and outlive them. These markings are smaller than those of class (1), and include straight or curved filaments, as well as tiny dense patches. Their duration is usually of the order of hours or minutes.

The respective characteristics of the radial motions of these two classes given by Table I † are as follows :—

(1) Inappreciable or small radial motions generally, but larger velocities are not entirely absent (column (1)).

(2) Frequent large radial motions, although about 30 per cent. of these flocculi have no appreciable velocity (columns (2) *a* and (2) *b*).

The two classes of flocculi described above have their counterpart ‡ at the Sun's limbs, where (1) is represented by the large massive prominences and allied types, and (2) is represented by smaller type prominences of an eruptive nature. But, in at least one respect, there is a discordance (referred to later) between the "plan" picture given on the disc by the spectrohelioscope and the "elevation" picture given by the prominences at the limbs. It may be remarked that observations with the spectrohelioscope show very clearly the occurrence of active flocculi lasting for $\frac{1}{4}$ or $\frac{1}{2}$ hour in the neighbourhood of sunspots.

* See *Memoirs of the Kodaikanal Observatory*, vol. i, pt. ii, by J. and M. A. Evershed (1917); also "The Spectrohelioscope and its Work", by G. E. Hale, *Ap J.*, **70**, 291, 1929.

† Compiled from "Observations of Solar Flocculi made with the Spectrohelioscope", published in the *Greenwich Photoheliographic Results for* 1930–33, and *M.N.*, **91**, 593, 1931 ; **92**, 438, 1932 ; **93**, 168, 1933.

‡ *Kodaikanal Memoir, loc. cit.*

TABLE I

Percentage Frequency of Measured Radial Velocities of Dark Hα Flocculi, 1930–33

(1) Not associated with sunspots.
(2) *a*, Associated with sunspots (centre of disc).
(2) *b*, Associated with sunspots (whole disc).
(2) *c*, Associated with bright flocculi : sunspots absent.

Measured Radial Velocity km./sec.	(1)	(2)		
		a	*b*	*c*
0–4	83	32	27	66
5–9	14	7	6	11
10–19	2	5	6	4
20–29	1	17	20	9
30–39	$<\frac{1}{2}$	24	23	7
40–49	0	8	9	1
50–59	0	3	3	1
60–69	0	2	3	0
70–79	0	1	1	1
80–89	0	$<\frac{1}{2}$	$<\frac{1}{2}$	0
90–99	0	0	1	0
$\geqslant$100	0	1	1	0
Number of measures	1388	266	572	129

Note.—(i) The probable errors of the tabulated radial velocities are about 2 km./sec. The systematic error for the smallest velocities observed is less than $\frac{1}{2}$ km./sec., as is shown by measures of the Sun's equatorial rotation taken at the limbs.

(ii) In forming columns (2) *a*, *b* and *c*, when different parts of the same flocculus had differing radial velocities, the maximum radial velocity measured for that flocculus has been tabulated. In the case of the flocculi in class (1) this feature of differing velocities within the same flocculus is rarely observed.

(iii) Data for the centre of the disc given in column (2) *a* refer to flocculi within ± 30° of the central meridian and between latitudes ± 30°.

In view of the theoretical researches on the solar chromosphere by E. A. Milne, S. R. Pike, S. Chandrasekhar and others, the observation of radial velocities of absorption markings in areas containing bright flocculi and sunspots is of interest. Referring to the last three columns of Table I, the following features will be noted :—

1. Of the measured radial velocities of dark flocculi associated with areas containing sunspots, those which are appreciable exhibit a pronounced peak in their frequency distribution, with a maximum between 20 and 40 km./sec.*

2. When no attendant sunspot is present in the bright flocculi the large velocities tend to disappear. This fact suggests that the presence of a sunspot is an important factor directly or indirectly in the occurrence of the

* *Note added March* 9.—Dr. S. Chandrasekhar has drawn my attention to his theory of the solar chromosphere discussed in *M.N.*, **94**, 14, 1933, which includes the possibility of the emission of moderately high-speed particles with a limiting vertical velocity of 30 km./sec [equation (48), p. 25, *loc. cit.*].

large radial velocities observed in these regions. The reservation must be made, however, that the majority of these bright areas observed, not containing sunspots, represent the declining phase of sunspot disturbances.

The distribution of the sign of the velocities $\geqslant 5$ km./sec. corresponding to those in column (2) *b* is given in Table II, where − indicates outward motion from the Sun and + inwards. A feature, observed in nearly 30 per cent. of cases when measuring radial velocities of dark flocculi in the general neighbourhood of sunspots, is a progressive difference of velocity within the flocculus itself from one end to the other. The last five lines of Table II give the signs of these differential velocities.

It will be seen that the number of inward velocities observed exceeds those outwards.

TABLE II

Percentage Distribution of Outward and Inward Radial Velocities of Dark Hα Flocculi near Sunspots and Bright Flocculi, 1930–33

Direction of Motion		Percentage		
		−		+
Common velocity outwards (−) or inwards (+).		31		41
Differential velocities	Wholly −	1		
	Wholly +			10
	+ and − equal		1	
	− greater	2		
	+ greater			14
	Total	34	1	65

Reference may be made to the maximum velocities observed at Greenwich during the four years 1930–33. On two occasions outward velocities of 155 km./sec. and 450 km./sec. were observed in connection with dark markings arising from brilliant eruptions of *Hα* flocculi in the vicinity of sunspots. In both cases absorption markings were observed descending with velocities of 105 and 110 km./sec. respectively. Inward velocities of 90 or 100 km./sec. have also been observed on five occasions in connection with dark flocculi flowing into sunspots.

Flocculi moving into Sunspots.—Records of streams of hydrogen moving with high velocity into sunspots are rare on spectroheliograms, but the spectrohelioscope, which is particularly well-adapted to locate large radial velocities, can be successfully employed in observing this type of flocculus. In *Ap. J.* (71, 73, 1930) Dr. Hale gives the results of measures of a number of these dark flocculi observed from 1926 June to September. The maximum inward velocity observed was 115 km./sec. A significant feature is that the inward radial velocity increases as the sunspot is approached. Under good observing conditions the flocculus at its maximum velocity is often seen reduced to a dot at the outer edge of the penumbra of the sunspot.

The present observations at Greenwich record 49 flocculi of this type. This number represents 9 per cent. of the total number of flocculi measured

in sunspot regions. The percentage distribution of their radial velocities at the ends * coterminous with the associated sunspots is given in column (*a*) of Table III. The contribution of these values to column (2) *b* of Table I is given in column (*b*) of Table III.

TABLE III

Percentage Distribution of Maximum Radial Velocities of Dark Hα Flocculi moving into Sunspots

Velocity km./sec.	Percentage Frequency (*a*)	(*b*)	Velocity km./sec.	Percentage Frequency (*a*)	(*b*)
0–9	0	0	50–59	10	0·9
10–19	2	0·2	60–69	15	1·2
20–29	10	0·9	70–79	6	0·5
30–39	39	3·3	80–89	2	0·2
40–49	6	0·5	90–99	8	0·7
			100	2	0·2

The mean inward radial velocity of these 49 flocculi at the boundary of the sunspot is 48 km./sec. The radial velocities corresponding to the far end of the flocculus show a wide range from −41 km./sec. to +46 km./sec., the mean being −3 km./sec. The average distance over which a flocculus was visible (as shown by progressive settings of the line-shifter) is about 50,000 km.

It should be mentioned that two cases have been observed at Greenwich in which the hydrogen appeared to be flowing out of a sunspot.

The short life of this type of flocculus may partly explain their general absence in prominence records. In *Kodaikanal Memoirs* (*loc. cit.*, p. 106), the statement is made that "No case has been found in which prominences were falling into sunspots, but the reverse has several times been observed." A few typical sunspot prominences have been observed, however, both by Hale and Slocum to give velocities downwards towards spots of the same order of magnitude as the radial velocities measured on the disc with the spectrohelioscope. In addition Pettit † has found from measures of "splash" prominences that streamers were flowing into spots with velocities of the order of 30 km./sec.

A rather infrequent but interesting type of dark flocculus, observed at Greenwich in the general neighbourhood of sunspots, appears as a pair of closely adjacent, dense dots or small patches, possessing similar radial velocities but of opposite sign. In a few other cases a single marking was first observed with an outward velocity, which was replaced within a few minutes by an inward velocity of similar magnitude at, or nearly at, the same place on the Sun's disc. The measured velocities are closely grouped about 30–35 km./sec. These flocculi appear to represent narrow arches and jets

* In *Greenwich Photoheliographic Results* these measures are printed in heavy type.

† *Publications of the Yerkes Observatory*, **3**, pt. iv, p. 227.