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ROTATION OF Hα DARK MARKINGS NEAR THE EQUATOR COMPARED WITH OTHER DISC PHENOMENA.

BY

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Abstract.—In Kodaikanal Observatory Bulletin No 89, Dr Royds has investigated the rotation of Hα dark markings, from the spectroheliograms of the years 1926—1929 Owing to the paucity of markings near the equator during that period much weight cannot be attached to the values obtained for latitudes less than 15°. In order to obtain reliable data for the rotation of markings near the equator, the Hα spectroheliograms for the eight years 1918—1925 have now been examined

The results show that the speeds of rotation of Hα markings near the equator are in close agreement with the values of rotation of spots and that they are lower than those obtained from Doppler displacements of the Hα line by Adams. The polar retardation in the case of Hα dark markings is smaller than for sunspots. These results are in agreement with those of D'Azambuja for K_3 filaments

Dr. Royds' values of heights of Hα dark markings near the equator have to be slightly modified in consequence of the more accurate determination of rotation now available. A revised table is appended.

Introduction.

Dr. Royds has recently determined the speed of rotation of Hα absorption markings by measurements near the central meridian for successive rotations of the same marking, basing his results on the Kodaikanal Hα spectroheliograms for the years 1926—1929.[1] Not many measures were possible in the belt between 0° and 15° owing to the paucity of markings of long duration there. Much weight could not therefore be attached to the values obtained in this belt as has been indicated by dotted lines in Fig. 1, Bulletin No. 89.

Material and method.

With a view to obtain more accurate data for this region the Hα spectroheliograms for the period 1918—1925 were examined. The life of each marking was traced in the solar charts of the Kodaikanal Observatory for at least a revolution and a half, from the time it first appeared on the eastern limb to its second disappearance at the western limb. A few could be followed for two or three rotations and more.

[1] Kodaikanal Observatory Bulletin No 89 The rotation of hydrogen absorption markings and their height above the surface of the sun.

Out of 117 markings discussed 90 markings could be traced foi one rotation only 10 persisted for two rotations 1 for three and another for four rotations Each recurrent series of markings was then examined from the original photographs when they were near the central meridian Measures were made on the western edge of the absorption markings and the longitudes of the points on the marking at 5 intervals of latitude were noted In very many cases the photographs of two successive days were measured and the mean of the results taken

The times of actually crossing the central meridian were deduced for intervals of 5 of latitude assuming the approximate value of 13 per day for synodic rotation to reduce the positions near the central meridian to the actual time of crossing it The synodic periods of each marking at the several points were thus obtained from which the synodic daily angular motion were easily calculated Adding to this the daily angular motion of the sun in longitude at the time of the year the sidereal daily angular motion at the several points is obtained.

Results

The mean of all such velocities at various latitudes for the several years and for the whole period is given in Table I The results for 1926—1929 are taken from Dr Royds measurements The numbers in the brackets indicate the number of markings used to obtain the mean The results do not vary greatly from marking to marking in the same latitudes nor from year to year The difference in the hemispheres is not also marked

TABLE I—DAILY ANGULAR SIDEREAL MOTION IN DIFFERENT LATITUDES ACCORDING TO HEMISPHERE AND YEAR

Y ar	0	5		10		15	
		N	S	N	S	N	S
1918	14 37 (9)	14 38 (11)	14 51 (2)	14 37 (10)	14 48 (1)	14 34 (9)	
1919	14 51 (6)	14 49 (8)	14 51 (5)	14 36 (6)	14 40 (3)	14 38 (4)	14 28 (1)
1920	14 39 (6)	14 40 (6)	14 33 (7)	14 34 (8)	14 39 (7)	14 28 (8)	14 30 (7)
1921	14 35 (5)	14 31 (2)	14 33 (9)	14 27 (4)	14 29 (11)	14 24 (5)	14 30 (10)
1922	14 30 (5)	14 35 (5)	14 33 (2)	14 40 (2)	14 38 (3)	14 55 (1)	14 45 (1)
1923		14 34 (3)		14 26 (3)		14 26 (3)	
1924					14 15 (1)		14 28 (1)
1925	14 41 (1)	14 30 (3)		14 24 (4)		14 14 (5)	
1926		14 41 (1)		14 32 (1)	14 45 (2)	14 24 (6)	14 42 (8)
1927	14 48 (1)	14 55 (1)	14 59 (1)	14 37 (7)	14 46 (2)	14 26 (9)	14 36 (2)
1928	14 50 (1)	14 40 (2)	14 47 (1)	14 28 (1)	14 44 (2)	14 23 (3)	14 43 (5)
1929	14 66 (1)	14 51 (4)		14 40 (4)	14 06 (1)	14 29 (7)	14 34 (3)
M an	14 40 (35)	14 40 (46)	14 39 (27)	14 35 (33)	14 34 (50)	14 28 (60)	14 34 (38)

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Table II gives the mean values for the whole period at 5° intervals of latitude near the equator of the synodic period, daily synodic angular motion and daily sidereal angular motion. The motion is here assumed to be symmetrical with respect to the solar equator.

TABLE II.—MEAN ROTATION OF Hα ABSORPTION MARKINGS.

Latitude	0°	5°	10°	*15°	*20°	*25°	*30°	*35°	*40°	Measures of all 15 1°
Number of markings ...	35	73	83	93	47	40	30	23	6	
Synodic period	26·83	26 85	26 95	27 05	27·22	27·38	27 54	27 81	27 86	27 11
Daily angular velocity synodic	13·42	13 41	13 36	13 33	13·22	13 14	13·07	12·94	12·91	13·29
Daily angular velocity sidereal.	14·40	14·40	14·34	14·30	14·21	14 13	14 06	13 93	13·90	14 27

* From Table 1, Bulletin No 89.

In Table III has been collected, for purposes of comparison, the speeds of rotation of the sun at different latitudes as obtained from various disc phenomena. The values given are (*a*) for the sunspots those derived from Greenwich observations of recurrent sunspots (M.N. 85, April 1925), (*b*) for the faculae, those derived from Greenwich measures of recurrent faculae as given by formula II which is more in accord with the observed data (M.N. 84, April 1924); (*c*) [3] for the Calcium filaments, the values obtained from the formula derived by D'Azambuja from recurrent K_3 filaments (C.R. 176, p 950, 1923); (*d*) for spectroscopic results of the reversing layer [4] and the Hα line, the mean existing values (Handbuch-der Astrophysik, B.D. IV, ch. 2, ciph. 16, p. 169); and (*e*) for Ca prominences, the values obtained by Evershed (M.N. 89, January 1929). The speeds for the 5° zones have been computed, when necessary, as the mean of the speeds at the boundaries of the zone.

TABLE III.—VELOCITIES OF SOLAR ROTATION DERIVED FROM VARIOUS SOLAR PHENOMENA.

Daily sidereal motion / Zone of latitude.	Hα dark marking.	Sunspots.	Faculae.	Calcium filaments.	Spectroscopic determinations. Reversing layer.	Hα line	K prominences.
0 ± 5 ...	14 40	14 39	14 49	14 45	14 27	15 00	......
± 5 ± 10 ...	14 37	14 33	14 46	14 42	14·26	14 98	17 1 (9°)
± 10 ± 15 ...	14·32	14·25	14·40	14·36	14 16	14 94	...
± 15 ± 20 ...	14 26	14 13	14·30	14 28	14 02	14 88	17 1 (18°)
± 20 ± 25 ...	14·17	14 01	14 16	14 17	13·83	14·80	
± 25 ± 30 ...	14·10	13·85	13·96	14 04	13 60	14 70	20·2 (25°)
± 30 ± 35 ..	14 00	...	13·71	13·89	13 35	14 60	.....
± 35 ± 40 ...	...	...	13·39	13 75	13·07	14 48	16 6 (35°)
± 40 ± 45 ...	...	..	13 02	13 59	12 79	14 36	17 3 (51°)

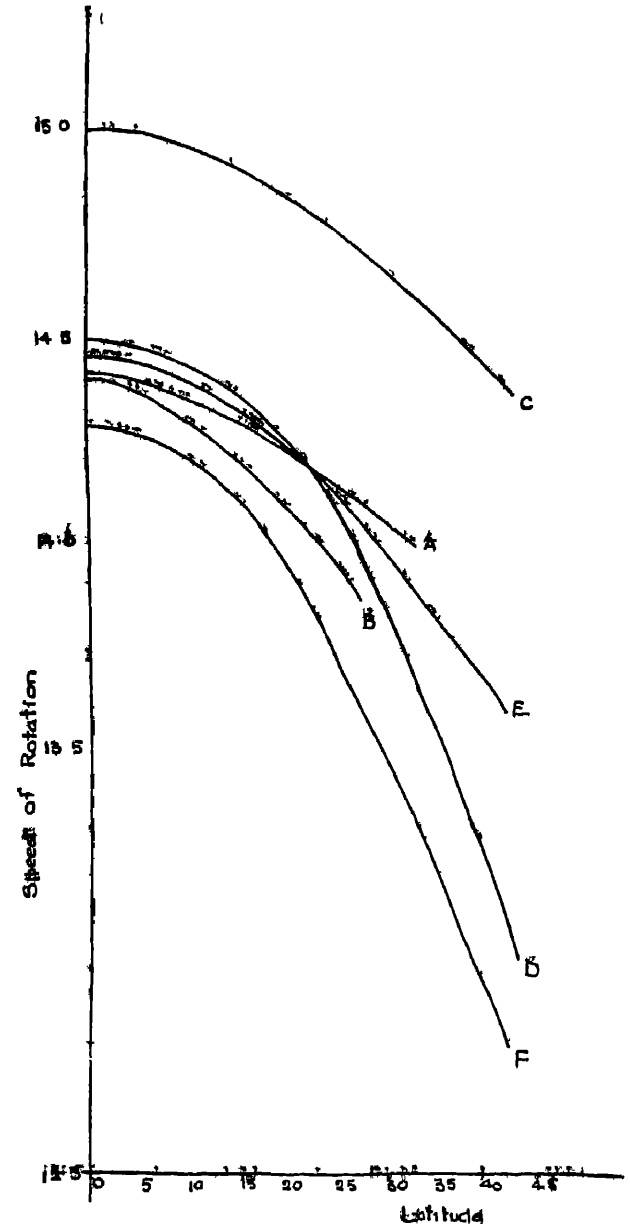
[3] See Handbuch-der Astrophysik, B.D. IV, ch. 2, ciph. 10, p. 105.

[4] This includes perhaps the results of Abetti and Novokova at the mean epoch 1928 8 . See Bulletin de la Societé Astronomique de France, Tome XLIV, 1930, p. 554

The above values are represented graphically in Fig 1 It will be noticed that the speed of rotation of the Hα dark markings is practically the same as that of sunspots in the equatorial regions but is greater in higher latitudes The difference near the equator is practically zero and is about 0 25° per day in the zone 25°—30° From the closeness of the values of the speeds of rotation of sunspots and Hα dark markings near the equator it is to be inferred that these markings in the equatorial regions are anchored to the sunspots It would appear that this is not true in higher latitudes where the speed of rotation of Hα dark markings is higher than that of sunspots in corresponding latitudes

FIG 1

Comparison of speeds of rotation



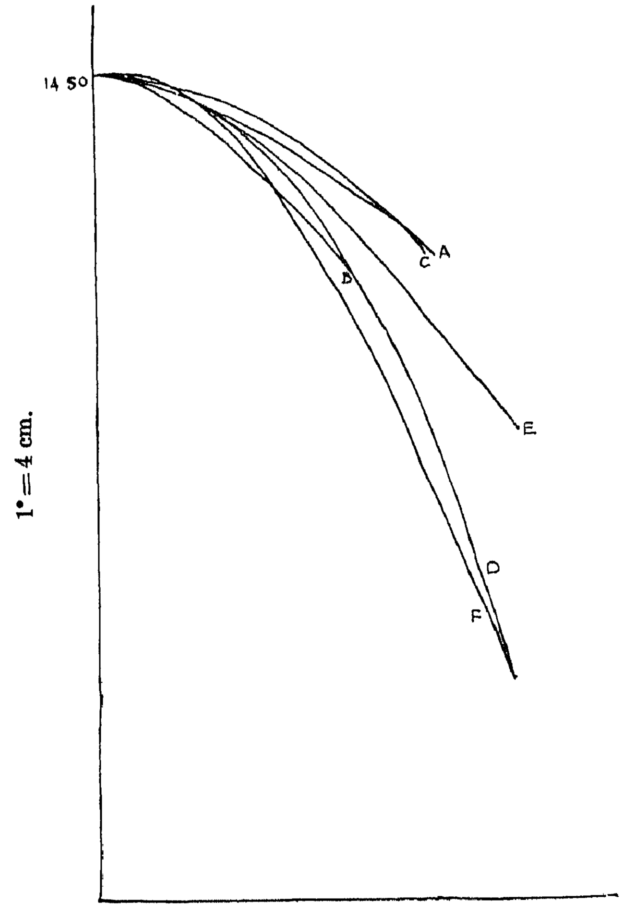
A. Hα dark marking
B Sunspots
C Hα line
D Faculae
E Calcium filaments
F Reversing layer

In order of increasing magnitude of equatorial velocities we have the reversing layer, sunspots, Hα dark markings, K dark markings, faculae, Hα line, and Ca prominences If, as is generally assumed, these dark markings are projections of the prominences on the sun's disc then since Evershed has shown the velocities increase with levels, it appears that an absorption marking moves slower than the gases constituting the prominence which exhibits itself as that marking.

Fig. 2 shows graphically the law of the polar retardation corresponding to the various solar phenomena. A difference in the rate of change of angular velocity with latitude is indicated by a lack of parallelism in the curves. To show this more clearly the values have all been reduced to a common origin (14·50°), by the addition of some constant quantities to the results. The spots and the faculae give values which are practically identical throughout. Intermediate between these and the Hα dark markings are the K_3 filaments. The Hα dark markings and the Hα line are also nearly identical and show notably less equatorial acceleration. The H and K lines of the Ca prominences, as far as the results could be relied on, show the least polar retardation.

FIG. 2.

Comparison of polar retardations.



1 cm. = 10°

Letters indicate same curves as in Fig. 1.

Heights of Ha absorption markings.

The values of h_1 and h_2 obtained by Dr. Royds require slight modification in view of the more reliable values now available for equatorial regions. The daily synodic rotation has been interpolated from Table II and λ is thence obtained. The values of ϕ have been taken as the means of the intervals and the heights deduced from the formula $2h = a \cos^2 \lambda \cos^2 \phi$ ($a = 960''$). The revised values are given in Table IV The difference in the values of h and h is not very appreciable and there is practically no change in the mean values The difference between h and h is also unaltered and so the main arguments of the paper continue to hold

TABLE IV—QUADRANTAL TIMES FOR Hα ABSORPTION MARKINGS AND THEIR CORRESPONDING HEIGHTS

Latitude	Number of markings	Edge nearer the limb				Edge farther from the limb			
		Quadrantal time T (days)	ξ	λ	Height h	Quadrantal time T (days)	ξ	λ	Height h
0— 5	6	45	13 42	73 1	40 5	5 47	13 42	73 4	39 1
6—10	1	5 30	13 38	70 9	50 4	5 42	13 38	72 5	42 6
11—15	19	5 59	13 34	74 6	32 1	5 74	13 34	76 6	24 5
16—20	29	5 54	13·26	73 5	35 0	5 [illegible]6	13 26	75 1	28 7
21—25	26	5 62	13 17	74 0	31 2	5 76	13 17	75 9	23 8
26—30	35	5 48	13 08	71 7	37 2	5 62	13 08	73 5	30 5
31—35	38	5 57	13 00	72 5	30 5	5 69	13 00	74 0	25 8
36—40	7	5 60	12 92	72 4	27 3	5 67	12 92	73 3	24 7
41—45	15	5 48	12 84	70 4	28 9	5 51	12 84	70 7	28 4
† 27 3		Weighted mean 5 5			33 4	Weighted means 5 650			27 9

From Table 2 Bulletin No 89
† Corresponding to the weighted means of ... ϕ

In conclusion I wish to express my thanks to Dr Royds Director for permitting me to work in the Observatory for setting me on to work at this problem and for his valuable guidance and many suggestions

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