ROTATION AND Hα EMISSION ACTIVITY IN F8–G3 DWARFS

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Abstract. A study of the dependence of chromospheric Hα emission strength on rotation period in F8–G3 dwarfs is made from the published data. The emission strength shows strong correlation with rotation irrespective of age and spectral type. Furthermore, the measurement of Hα emission in late-type dwarfs can be used for the determination of rotation period.

1. Introduction

The dependence of chromospheric activity on stellar rotation, age and spectral type in late-type stars has been a subject of detailed studies by many investigators (e.g., Kraft, 1967; Skumanich, 1972). The *Skylab* X-ray and EUV observations of the Sun showed the effects of magnetic fields in the outer solar atmosphere. The activity in late-type stars is induced by the magnetic field generated by the dynamo process resulting from the interaction between rotation and convection. Several reviews (Linsky, 1983a, b, 1985; Duncan, 1984; Mewe *et al.*, 1983; Marcy, 1983) discuss in detail the direct and indirect evidences for the heating of chromosphere, transition region and corona of late-type dwarfs and RS CVn-binaries by the magnetic field. From *Einstein* X-ray observations, Pallavicini *et al.* (1981) have shown that the coronal X-ray luminosity increases with the rotational velocity in late-type dwarfs. An analysis of the then available observations of Ca II K line, the C IV line at 1550 Å and soft X-ray emissions led Marilli and Catalono (1984) to the conclusion that the chromosphere, transition region, and corona are heated by a common process which depends strongly on the stellar rotation period.

The common diagnostics of stellar activity are X-ray and ultraviolet emission lines, thermal microwave emission and a few spectral features in the visible and infrared. The emissions in Ca II K and H lines are the most frequently used indicators of chromospheric activity. Catalano and Marilli (1983) and Middelkoop (1982) found a correlation between Ca II K emission flux and rotation in lower Main-Sequence stars. However, Noyes *et al.* (1984) showed the dependence of Ca II K emission flux on rotation and spectral type. Their analysis indicated a tight correlation between the fractional chromospheric flux in the line and the dimensionless Rossby number R_0; R_0 being the ratio of the rotational period to the theoretically derived convective turn over time. Based on this relationship, they could derive rotation periods of several late-type dwarfs with known Ca II K flux. Dwarfs with active stellar chromospheres have shallow Hα absorption due to the partial filling in by chromospheric emission. Herbig (1985) made a survey of chromospheric emission in Hα line in F8–G3 dwarfs and tried to correlate

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the decay of Hα emission strength with stellar age. In this paper we have made a study of the trend of Hα emission strength on rotation period and spectral type in late-type dwarfs using published data.

2. Data and Their Discussion

The chromospheric Hα emission strengths are from Herbig's (1985) survey and the quantity RHα is the fraction of total stellar emission in the Hα line. If several observations exist for a star, the average value of RHα is used. The rotation values are the calculated periods of Noyes *et al.* (1984) and Marilli and Catalano (1984). Table I lists the stars in the present study and column 6 gives the Rossby number R_0, the ratio of

TABLE I

Rotation periods, Hα emission strengths and Rossby numbers of F8–G3 dwarfs

Star HD No.	Spectral type	$B - V$	$\log P$ (d)	RHα (10^{-5})	$\log R_0$ ($= \log P/\tau_c$)
1835	G2V	0.66	0.826	0.580	−0.273
13974	G0V	0.61	0.997	0.910	0.010
16673	F6V	0.52	0.799	1.020	0.100
19373	G0V	0.61	1.161	0.280	0.176
30495	G1V	0.61	0.903	0.780	−0.082
35296	F8V	0.54	0.519	1.320	−0.254
39597	G0V	0.59	0.771	1.195	−0.160
72905	G0V	0.62	0.730	1.340	−0.280
78366	G0V	0.60	1.025	0.780	0.066
88737	F9V	0.56	0.892	0.740	0.052
97334	G2V	0.61	0.778	0.975	−0.207
100180	G0V	0.57	1.158	0.410	0.286
114710	G0V	0.58	1.086	0.510	0.184
115383	G0V	0.58	0.690	1.063	−0.212
136202	F8V	0.54	1.124	0.290	0.351
141004	G0V	0.60	1.267	0.260	0.308
142373	F9V	0.57	1.225	0.000	0.353
143761	G2V	0.60	1.294	0.180	0.335
154417	G0V	0.57	0.785	1.230	−0.087
187691	F8V	0.56	1.164	0.750	0.324
206860	G0V	0.58	0.643	1.320	−0.259

the rotation period to the convective turn over time τ_c with the parameter $\alpha = 1.9$ where α is the ratio of mixing length to scale height. The convective turn over time is calculated using the empirical function defined by Noyes *et al.* (1984), of the form

$$\log \tau_c = 1.362 - 0.166x + 0.025x^2 - 5.323x^3, \quad \text{where} \quad x = 1 - (B - V).$$

Figure 1 is a plot of the Hα emission strength and the rotation period and shows a well defined dependence of chromospheric Hα emission on rotation with very little scatter.

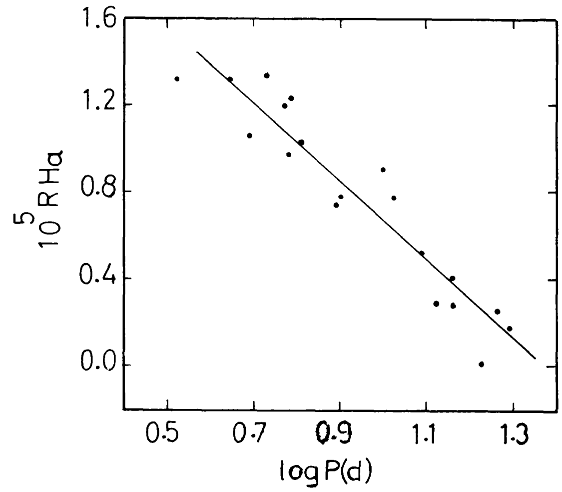

Fig. 1. The Hα emission strength plotted versus rotation period. The solid line is the least-squares fit.

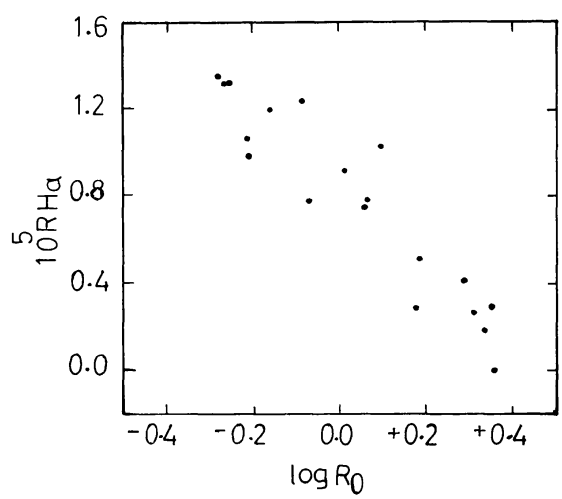

Fig. 2. The RHα plotted versus the Rossby number R_0.

Further to test the trend of Hα emission with respect to the spectral type, a plot of RHα versus R_0 is made in Figure 2. Though the emission strengths tend to increase as the Rossby number decreases, the dispersion of points is larger than in Figure 1 and, hence, the spectral type has little influence on the Hα emission strengths for F8–G3 dwarfs. A least-squares fit of the points in Figure 1 gives the following relationship between RHα and the rotation period:

$$10^5 \, \mathrm{RH}\alpha = 2.447 - 1.787 \log P .$$

However, we should point out that the two stars HD 1835 and HD 187691 are not included in Figure 1. HD 1835 has very low Hα emission compared to its Ca II K emission strength and rotation period and HD 187691 shows abnormally large Hα emission. From solar observations we know that the chromospheric emission mainly originates from the active regions like plages that overly the photospheric spots. From IUE observations of RS CVn binaries, Marstad *et al.* (1982) found that the ultraviolet emission flux is anticorrelated with the photometric light level. This implies that the emission is due to the active areas overlying the photospheric dark spots and so the emission strength indicates the activity at the stellar surface that faces the observer at the time of observation. Thus the stars that exhibit abnormal emission strengths may have highly varying activity levels.

The strong dependence of Hα emission on rotation implies that the measurement of the strength of chromospheric Hα emission is an excellent tool to establish the rotation periods of late F and G dwarfs. These stars often have weak Ca II K emission and thus monitoring in this line is rather difficult for the determination of the rotation periods.

3. Conclusions

The chromospheric Hα emission strengths in late-type dwarfs is a good diagnostics of rotation period in accordance with the dynamo theory. Though the late-type Main-Sequence stars generally show a decreasing trend in chromospheric activity as the age increases, rotation is the dominant factor that dictates the level of activity. Evolved stars like the cooler components of RS CVn binaries show enhanced stellar activity due to the faster rotation induced by synchronization. Recently, Young *et al.* (1984) reported the discovery of a rapidly rotating field M dwarf with rotational velocity of the order of 70 km s^{-1} and strong Hα emission. The Hα emission strengths show very little dependence on spectral type. However, a few stars exhibit anomalous behaviour. Most of the active late-type stars have variable levels of activity due to the nonhomogeneous distribution of stellar plages and spots. So it will be ideal to study the behaviour of Hα emission strength by observing the stars over a few rotation periods, and use the mean value of emission strengths to establish the rotation-activity relationship. Checking the validity of the Hα emission strength-rotation relationship in late G and K dwarfs will be interesting as these stars have deeper convection zones.

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