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LITHIUM AND CHROMOSPHERICALLY ACTIVE SINGLE GIANTS

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ABSTRACT

Nine chromospherically active single K giants have been identified from several surveys of chromospherically active stars. These stars have $v \sin i$'s ranging from 6-46 km s^{-1}. Such large velocities are not explained by current scenarios of main sequence to giant star evolution. Fluxes of the ultraviolet emission lines of these stars are substantially less than those of FK Comae. Many of these giants have a moderate or strong lithium line strongly suggesting that these stars have just recently evolved from rapidly rotating A or early F stars as is suggested by their space motions. Thus, they are not spun down FK Com stars. The characteristics of these stars are such that they may be confused with pre-main-sequence stars. The primary difference may be that the post main sequence stars have strong Hα absorption lines while the pre-main sequence stars appear to have a weak Hα absorption line or possibly Hα in emission above the continuum.

Keywords: Giant Stars, Rapidly Rotating, Single, Chromospheric Activity, Lithium

1. INTRODUCTION

From spectroscopic surveys of active-chromosphere stars Fekel, Moffett, and Henry (Ref. 1) and Collier-Cameron, Lloyd Evans, and Balona (Ref. 2) have identified nine G8-K2 giants with moderate rotation ($v \sin i$ = 6-46 km s^{-1}) but no apparent velocity variations. Such stars are unusual. Gray (Ref. 3) determined values of $v \sin i$ for 23 G2-K2 giants and noted a sharp drop in $v \sin i$ from about 25 km s^{-1} to less than 5 km s^{-1} at spectral type G5 III. He argued that this drop in $v \sin i$ was the result of magnetic braking as the star evolved. Rutten and Pylyser (Ref. 4) claim that the magnetic braking timescale is substantially longer than the post-main-sequence evolutionary timescale for such giant stars. Instead they claim that this drop in $v \sin i$ is accounted for by changes in the moment of inertia and the stellar radius during the evolution from dwarf to giant. The rotational velocities of many of the active-chromosphere single giants are much too large for either theory.

2. PROPERTIES

The properties of these nine stars observed to date are given in Table 1. Columns 1-9 are HD number of the star, the V magnitude, $B-V$ color, the mean velocity of the star and its r.m.s. uncertainty, $v \sin i$, photometric period, $R \sin i$, the qualitative strength of Hα absorption and the qualitative strength of the lithium line. The values of $R \sin i$ were determined assuming the photometric period is the period of rotation. The depth of the Hα absorption feature is classified as weak if the line depth is less than 0.25, as moderate if the line depth is between 0.25 and 0.5, and as strong if the line depth is greater than 0.5. The lithium line is classified as weak if the line depth is less than 0.1, as moderate if the line depth is between 0.1 and 0.25, and as strong if it is greater than 0.25.

3. DISCUSSION

These stars may have evolved to their present evolutionary state in several ways. Bopp and Rucinski (Ref. 5) found several single rapidly rotating ($v \sin i$ = 50-100 km s^{-1}) G and K giants which were photometrically variable and had variable Ca II H and K emission and variable Hα emission. The prototype of the group is FK Comae. Bopp and Rucinski suggested that such a star results from the coalescence of a W UMa binary as predicted by the evolutionary models of Webbink (Ref. 6). Bopp and Stencel (Ref. 7) obtained ultraviolet spectra of FK Com and HD 199178 with the International Ultra-Violet Explorer (IUE) satellite. These spectra showed variable chromospheric and transition-region line emission. The flux in these emission lines is equal to or greater than that of the most active RS CVn binaries.

After coalescence the now single star would begin to lose angular momentum. Its active-chromosphere characteristics such as rotation and strong emission line flux would decrease with time. If the stars in Table 1 are spun down FK Com stars they would not necessarily be at odds with the scenario of Rutten and Pylyser (Ref. 4), since they did not evolve as a single star to their present state.

A second possibility is that single rapidly rotating G-K giant stars have evolved from very rapidly rotating early-type, A or early F, stars. Such stars could have large main-sequence rotational velocities and would evolve relatively rapidly to the K III stage. Bopp and Stencel (Ref. 7) rejected this possibility for the FK Com stars since if they evolved from main sequence stars without any loss of angular momentum, their main sequence rotational speeds would exceed the breakup velocity. If the stars of Table 1 have evolved from single A or early-F type stars, then their rotational velocities are inconsistent with the explanation of Gray (Ref. 3) and the simple models of Rutten and Pylyser (Ref. 4)

There appear to be several major differences between FK Com and similar stars such as HD 199178 and the stars in Table 1. First, most of the v sin i's in Table 1 are substantially less than 100 km s^{-1}. Second, except for HD 196818 all the stars have a moderate or strong Hα absorption line. Ultraviolet spectra with the IUE satellite have been obtained so far for seven of the stars listed in Table 1. In Table 2 their ultraviolet emission line fluxes are compared with those of FK Com. The observed fluxes of FK Com are substantially greater than those of the other single giants. Converting the observed fluxes to surface fluxes increases the flux differences relative to FK Com by factors of 2 to 18 depending on the star. Thus, the activity in the K giant stars of Table 1 as judged from their Hα line and ultraviolet fluxes is much less than that found in the FK Com stars.

From the line fluxes in Table 2 it is not possible to decide whether these stars are FK Com stars in the process of being spun down or are recently evolved early-type stars which have not been completely spun down.

Guinan, Bradstreet, and Robinson (Ref. 8) have concluded from an analysis of the space motions of W UMa stars that they are old disk population stars with a mean age of 5-10 billion years. Guinin and Robinson (Ref. 9) have shown that the space motions of FK Com itself indicate that it is a member of the old disk population. This is consistent with the suggestion that it is a coalesced W UMa star.

Collier-Cameron, Lloyd Evans, and Balona (Ref. 2) have compared the velocity dispersion of the single active subgiants and giants in their sample to those of mid-A, mid-F, and field subgiant stars. The single stars have a velocity dispersion midway between those of the mid-A and mid-F stars. This suggests that most of the stars in Table 1 have evolved from single main-sequence stars rather than coalesced W UMa systems.

If these stars have relatively recently become giants as evidenced by their still relatively rapid rotation, the giants would not have had a convective outer atmosphere for an appreciable time. Since it is believed that a star's surface lithium abundance is depleted when convective mixing causes dilution of the surface abundance, these giants could still have substantial lithium abundances. Lambert, Dominy, and Sivertsen (Ref. 10) found little or no lithium in inactive K giants.

Seven of the nine stars listed in Table 1 have been observed. The lithium feature was detected in all seven. The strongest lithium line was found in HR 454 = HD 9746 (Fig. 1). Its line depth of 0.8 reaches 0.2 on the intensity scale! Abundance determinations for the seven stars are being obtained with spectrum synthesis techniques. The detection of lithium in these stars is additional support for the theory that these stars have evolved from single early-type stars rather than coalesced from an old W UMa system.

The rapid rotation, ultraviolet and Ca II H and K emission, and strong lithium line seen in these post main-sequence stars are also characteristics of pre-main-sequence and very young main-sequence K stars such as HD 36705 (Ref. 11) and HD 82558 (Ref. 12), respectively. Thus, there is a serious possibility of confusing the evolutionary states, particularly for subgiants. The primary observa-

Table 1

Properties of Chromospherically Active Single K III Stars

HD	V	B-V	Velocity (km s^{-1})	v sin i (km s^{-1})	P phot (days)	R sin i ($R_\odot$)	Hα absorption	Li
9746	5 92	1.21	-42 4 ± 0 4	8	76	12	moderate	strong
17144	8.22	1.21	5.0 ± 0 4	15	16.2	5	strong	moderate
27536	6.27	0.91	5 1 ± 0 4	≤6	310	37	strong	weak
31993	7.53	1.14	13.2 ± 0.6	31	?	?	strong	strong
33798	7.0		22.0 ± 0.7	29	9.8	6	strong	weak
34198	6.92	1.12	3.0 ± 0.4	15	28.3	8	strong	weak
37434	6.09	1.17	16.0 ± 0.5	46	10.4	9	strong	
196818	8.06	1.12	-15.1 ± 0.4	15	20.6	6	weak	
203251	7.99	1.22	18.0 ± 0.6	40	?	?	strong	strong

Table 2

UV Emission Line Fluxes Observed at the Earth

(10^{-13} ergs cm^{-2} s^{-1})

Ion	Wavelength Å	HD 17144	HD 27536	HD 31993	HD 33798	HD 34198	HD 37454	HD 203251	FK Com
N V	1240	-	0 5	0.8	0 6	1 7	1 2	0 3	3 2
O I	1305	0 9	0 8	3.2	1 6	9.2	3 2	1 3	14.5
C II	1335	0.3	0 8	0.8	1 2	2 0	0 9	0 2	5 2
Si IV	1400	-	1 5	0 8	0 6	2 7	1.8	-	6.9
C IV	1549	0.4	0 7	1.4	2 2	4.7	2 6	1.0	13 5
He II	1640	-	-	0 3	0 8	0 9	0 3	0 2	4 0
C I	1657	0 6	-	0 5	1 2	2 3	0 9	1 1	3 1
Si II	1815	-	2 0	1 0	1 4	2 9	2 3	0.9	5 8
Mg II	2800	-	87.0	-	-	110 0	-	-	208 0

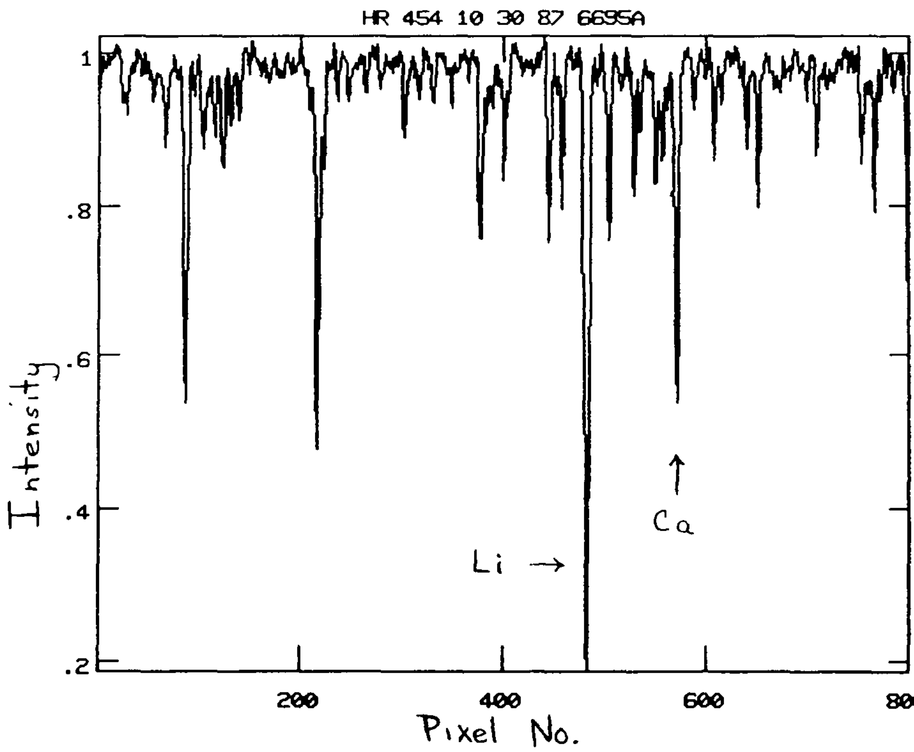

Figure 1. A spectrum of the lithium region showing the very strong lithium line (6708 Å) of HR 454 relative to its calcium line (6717 Å).

tional difference appears to be that the premain sequence and young main sequence stars have an Hα line which is a strong absorption feature. Secondly, the period of photometric variability which is usually identified as the rotation period is substantially greater for the post-main-sequence giants due to their larger radii. However, this may not be the case for subgiants.

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4. REFERENCES

1. Fekel F C, Moffett T J, and Henry G W 1986, Astrophys. J. Suppl. 60, 551.
2. Collier Cameron A, Lloyd Evans T, and Balona L. 1988 preprint.
3. Gray D F 1982, Astrophys. J. 262, 682.
4. Rutten R and Pylyser E 1988, Astron. Astrophys. 191, 227.
5. Bopp B W and Rucinski S M 1981, The Rapidly Rotating Giants of the FK Comae-Type, Fundamental Problems in the Theory of Stellar Evolution, Symp 93, Kyoto, Japan 22-25 July 1980, D. Reidel Publ. Co., p. 177.
6. Webbink R F 1976, Astrophys. J. 209, 829.
7. Bopp B W and Stencel R E 1981, Astrophys. J. 247, L131.
8. Guinan E F, Bradstreet D H, and Robinson C R 1987, Bull. Am. Astron. Soc. 19, 1085.
9. Guinan E F and Robinson C R 1986, Astron. J. 91, 935.
10. Lambert D L, Dominy J F, Sivertsen S 1980, Astrophys. J. 235, 114.
11. Vilhu O, Gustafsson B, and Edvardsson B 1987, Astrophys. J. 320, 850.
12. Fekel F C, Bopp B W, Africano J L, Goodrich B E, Palmer L H, Ouigley R, and Simon T 1986, Astron. J. 92, 1150.