/ N - GODDARD

38264

p-9

FINAL REPORT

Grant No. NAG 5-425

CHROMOSPHERIC ACTIVITY OF COOL GIANT STARS

Principal Investigator: Thomas Y. Steiman-Cameron

Grantee Institution: Carnegie Institution of Washington
1530 P Street NW
Washington, D.C. 2005

(NASA-CR-177184) CHROMOSPHERIC ACTIVITY OF COOL GIANT STARS Final Report (Carnegie Institution of Washington) 9 p CSCL 03B

N87-12510

Unclas

G3/90 44913

Period of Grant: 1 July 1984 - 1 July 1986

23 November 1986

"Chromospheric Activity of Cool Giant Stars" (NAG 5-425)

Investigators: Thomas Y. Steiman-Cameron (P.I.)
Mt. Wilson and Las Campanas Observatories
of the Carnegie Institution of Washington

Hollis R. Johnson and R. Kent Honeycutt
Astronomy Department, Indiana University

Period of Grant: 1 July 1984 - 1 July 1986

During the seventh year of IUE we obtained twenty-six spectra of seventeen cool giant stars ranging in spectral type from K3 thru M6. Together with spectra of fifteen stars observed during the sixth year of IUE, these low-resolution spectra have been used to: 1) examine chromospheric activity in the program stars and late type giants in general, and 2) evaluate the extent to which nonradiative heating affects the upper levels of cool giant photospheres. The stars observed in this study all have well determined TiO band strengths, angular diameters (determined from lunar occultations), bolometric fluxes, and effective temperatures. Chromospheric activity can therefore be related to effective temperatures providing a clearer picture of activity among cool giant stars than previously available. Table I lists the stars observed.

The study of the correlations between spectral classes and various physical parameters of stars have proven fruitful in understanding a broad range of stellar atmosphere problems. The spectral classification of M giants is largely based on the observed TiO bandstrengths of these stars (Morgan and Keenan 1973). A plot of any given physical parameter (e.g., effective temperature) against spectral class for M giants always reveals an uncomfortable amount of scatter. This scatter persists when objective measures of spectral type, such as the Wing TiO index (White and Wing 1978), are used. The extent of this scatter is clear from a plot of effective temperature vs. spectral class using the data of Ridgway et al. (1980). When effective temperature is plotted against a wide-band color index, the amount of scatter is measurably reduced. This effect is cited by Scargle and Strecker (1979) in reference to a plot of effective temperature against the R-I color index for cool giant stars.

The spectra obtained with the IUE spacecraft have been used in an attempt to gain insight into possible sources of this scatter and to study various physical properties of cool giant atmospheres. A particular emphasis was placed on the study of the chromospheres of these stars, as manifest by the Mg II h and k emission lines. Mg II emission ($\lambda\lambda$ 2796,2803) is a major source of chromospheric cooling, therefore fluxes in the resonance lines provide a direct measure of the level of chromospheric activity.

Figure 1 shows the log of Mg II h + k flux, normalized to apparent bolometric flux, plotted against effective temperature. To decrease the uncertainty arising from those stars with poorly determined temperatures, we have omitted stars whose temperatures are uncertain by more than 200 K. In addition, we have omitted two stars (HD 75156 and BS

6861) whose effective temperatures differ greatly from that expected from their color temperatures, leading us to suspect the accuracy of its effective temperature. Finally, one star (BS 5301) is known to vary in spectral type and hence presumably effective temperature. Because of the uncertainty in its Teff at the time of the IUE observations we have omitted it. When this is done, twelve "well determined" stars remain from those in Table 1. A trend towards rapidly decreasing normalized Mg II flux, and hence chromospheric activity, with temperature is indicated in the Figure. With the exception of the star HD 29051, whose spectral type (as determined by TiO bandstrength) is abnormally early for its observed color, all the stars lie near a relatively well defined curve which shows a rapid decline in chromospheric activity with decreasing effective temperature. Such a decrease has been previously suggested (cf. Basri and Linsky 1979; Linsky 1980; Catalano 1983), though scatter in previous observations was such that the slope was poorly defined, and perhaps consistent with zero. The more accurate determination of effective temperature in our program stars allows for better definition of the relation between MgII flux and effective temperature.

A means of avoiding errors introduced by poorly determined effective temperatures is to plot Mg II flux against a well determined quantity, such as a wide band color. Figure 2 shows a plot of the normalized Mg II fluxes against V-K for all the stars of Table 1. While some scatter persists, the relation is much better defined than in Figure 1, and clearly shows that Mg II flux decreases with Teff. The only star which deviates significantly from the trend of Figure 1 (HD 29051) also is discordant in Figure 2. As mentioned above, this star is noted for having a spectral type which is abnormally early for its observed color. Figures 1 and 2 suggest that this star has a chromosphere which is underactive for stars of similar characteristics, or, that this is a binary or multiple star system.

Our sixth year IUE proposal suggested that the source of the scatter in spectral-type correlations of physical parameters may be due to differential chromospheric activity among similar stars. Briefly stated, our argument went as follows: In a cool extended stellar atmosphere, TiO forms in the outer layers of the photosphere. The abundance of this molecule is highly temperature sensitive. Backwarming of the upper photosphere by the chromosphere may reduce the amount of TiO below that which would be present with no backwarming. For evolved stars of a given effective temperature, there may exist differing degrees of chromospheric activity. This differential activity will result in differing TiO abundances if backwarming is effective. Given an effective temperature, one might, therefore, expect differing amounts of TiO and, thus, differing spectral classes. This would present a serious problem in making comparisons of observed TiO bandstrengths with those predicted by model stellar atmospheres (Steiman-Cameron and Johnson 1986). It would also call into question the usefulness of TiO bandstrengths as the indicator of spectral type for cool evolved stars.

With the data obtained from our IUE observations, we find that a correlation does exists between TiO over or under-abundance and chromospheric activity (Steiman-Cameron, Johnson, and Honeycutt 1985). However it is in the opposite sense to that predicted above by backwarming arguments. This is seen in Figure 3. Here we have plotted log of the specific intensity of Mg II h + k lines, defined as f_{MgII}/θ^2 where θ is the measured stellar angular diameter, against the color temperature determined from Wing photometry (White and Wing 1978). Stars from our sample with effective temperatures above 3800 K, and two stars for which we believe the effective temperatures to be in error, have been omitted from the figure. Solid circles represent those stars in which TiO, as measured by the Wing TiO index, is more abundant than the mean for stars of the same color, while open circles represent stars with TiO deficient relative to the mean. As is readily seen from the figure, at a given color temperature those stars deficient in TiO have less mean chromospheric activity, as measured by the specific intensity of Mg II, than stars with strong TiO (the reverse of what might be expected from backwarming arguments).

Without additional information it is difficult to determine the source of the dichotomy seen in Figure 3. We suggest, however, that the distinction between high and low activity (strong and weak TiO) stars might be explained by aging. It is known that a correlation exists between stellar rotation and chromospheric activity, with more rapid rotation generally leading to greater activity (cf. Wilson 1963; Skumanich 1972; Vaughn and Preston 1980; Hartmann et al. 1984). Order of magnitude variations in f(MgII)/f(bol) among main sequence stars of a given effective temperature have been attributed to this effect (Catalano 1983), and a correlation between rotation rate and Ca II emission is seen among cool giants. Cool giants undergo mass loss due to strong winds and these winds, in turn, carry away angular momentum. Thus as a giant ages, its rotation rate, and hence chromospheric activity, will be expected to decrease. In addition, as a giant ages it will begin to dredge up processed nuclear material. This will serve to enhance the abundance of carbon in its atmosphere. Since carbon has a much greater affinity for oxygen than does titanium, this enhanced carbon abundance will lead to a decrease in TiO. Therefore, open circles in Figure 3 may represent older giants in which the rotation rate has decreased due to mass loss, and carbon has been enhanced due to dredge up. Supporting this picture are two related observations: (i) both S stars and Carbon stars, which are presumed to be more evolved giants, have less active chromospheres than "normal" M giants (Johnson and O'Brien 1983; Johnson, Ake, and Eaton 1984; Eaton et al. 1984), and; (ii) one of the stars in this study (BS 5622, labelled CN in the figure) is classified as a strong CN giant. This star, which presumably has begun to dredge material to its surface, has substantially lower chromospheric activity than the "mean" for its color temperature.

A test of the hypothesis presented here would be provided by measuring CO abundances in several of these stars. If the above picture is valid, then those stars displaying decreased TiO should also exhibit enhanced CO. If aging effects do indeed lead to the division seen in Figure 3, then a means exists for separating younger M giants from older ones. This can be very useful in comparisons of theory and observation, and can lead to a better understanding of the aging process. High resolution optical spectra have been obtained for a number of the program stars. These spectra will be used to closer examine the hypothesis presented here.

BIBLIOGRAPHY:

"Chromospheric Activity in M Giants", Steiman-Cameron, T.Y, Johnson, H.R 1984, in Proc. of NASA Symposium, Future of Ultraviolet Astronomy Based on Six Years of IUE Research, ed. J.M. Mead, R.D. Chapman, and Y. Kondo, p. 441.

"Chromospheric Activity and TiO in M Giants", Steiman-Cameron, T.Y., Johnson, H.R., and Honeycutt, R.K. 1985, Bull. of the Amer. Astron. Soc., **16**, No. 4, 895.

"Chromospheric Activity and TiO in M Giants", Steiman-Cameron, T.Y., Johnson, H.R., and Honeycutt, R.K. 1985, Astrophys. Journ. Letters, 291, L51.

TABLE I
IUE OBSERVATIONS – YEARS 6 and 7

Star (HD)	Sp.	date obs.	camera	other name
4656	K4.8	6/20/84	LWP	δ Psc
5820	M2.4	1/01/84	LWR	
5820	M2.4	6/20/84	LWP	
6860	M0	2/10/85	LWP	β And
6860	M0	2/10/85	LWP	β And
12479	M3.3	1/01/84	LWR	
12479	M3.3	2/10/85	LWP	
18191	M5.9	1/01/84	LWR	RZ Ari
18191	M5.9	2/10/85	LWP	RZ Ari
29051	M1.1	1/01/84	LWR	
29051	M1.1	2/10/85	LWP	
44478	M3	2/10/85	LWP	μ Gem
44478	M3	2/10/85	LWP	μ Gem
61338	M0.0	10/09/83	LWR	74 Gem
75156	M3.3	10/09/83	LWR	
75156	M3.3	1/01/84	LWR	
86663	M1.7	1/01/84	LWR	π Leo
91232	M1.8	6/19/84	LWR	46 Leo
94705	M5	6/19/84	LWR	56 Leo
99998	M4.5	6/19/84	LWR	87 Leo
112142	M2.7	6/19/84	LWR	ψ Vir
112142	M2.7	6/20/84	LWP	ψ Vir
112142	M2.7	6/20/84	SWP	ψ Vir
112142	M2.7	6/20/84	SWP	ψ Vir
119149	M2.1	6/19/84	LWR	82 Vir
119149	M2.1	6/20/84	LWP	82 Vir
123657	M4	6/19/84	LWR	
123657	M4	2/10/85	LWP	
123934	M1.5	6/19/84	LWR	
123934	M1.5	6/20/84	LWP	
132813	M5	6/20/84	LWP	RR UMi
132813	M5	2/10/85	LWP	RR UMi
133774	K4.8	6/19/84	LWR	ν Lib
139663	K3	6/20/84	LWP	42 Lib
168574	M4.1	10/09/83	LWR	
172816	M5.2	10/09/83	LWR	
176124	M4.3	10/09/83	LWR	
196777	M2.1	10/09/83	LWR	
207005	M3.4	10/09/83	LWR	47 Cap
216386	M2.0	10/09/83	LWR	λ Aqr
219215	M1.5	10/09/83	LWR	ϕ Aqr
224062	M4.6	1/01/84	LWR	

REFERENCES

Basri, G. S., and Linsky, J. L. 1979, Ap. J., **234**, 1023.

Catalano, S. 1983, Mem. Soc. Astr. Ital., **54**, 553.

Eaton, J. E., Johnson, H. R., O'Brien, G. T., and Baumert, J. H. 1985, Ap. J., **290**, 276.

Hartmann, L., Soderblom, D. R., Noyes, R. W., Burnham, N., and Vaughn, A. H. 1984, Ap. J., **276**, 254.

Johnson, H. R., and O'Brien, G. T. 1983, Ap. J., **260**, 952.

Johnson, H. R., Ake, T. B., and Eaton, J. A. 1984, in Proc. Conf. on Cool Stars with Excess Heavy Elements, ed. P. Keenan and M. Jaschek (Dordrecht: Reidel).

Linsky, J.L. 1980, Ann. Rev. Astron. Astrophys., **18**, 439.

Morgan, W. W. and Keenan, P. C. 1973, Ann. Rev. Astron. and Astrophys., **11**, 29.

Ridgway, S. T., Joyce, R. R., white, N. M., Wing, R. F. 1980, Ap. J., **235**, 126.

Scargle, J. D. and Strecker, D. W. 1979, Ap. J., **228**, 838.

Skumanich, A. 1972, Ap. J., **171**, 565.

Steiman-Cameron, T.Y., Johnson, H.R., and Honeycutt, R.K. 1985, Ap. J. (Letters), **291**, L51.

Steiman-Cameron, T.Y., and Johnson, H.R. 1986, Ap. J., **301**, 868.

Vaughn, A. H., and Preston, G. W. 1980, Pub. A.S.P., **92**, 385.

White, N. M., and Wing, R. F. 1978, Ap. J., **222**, 209.

Wilson, O. 1963, Ap. J., **138**, 832.

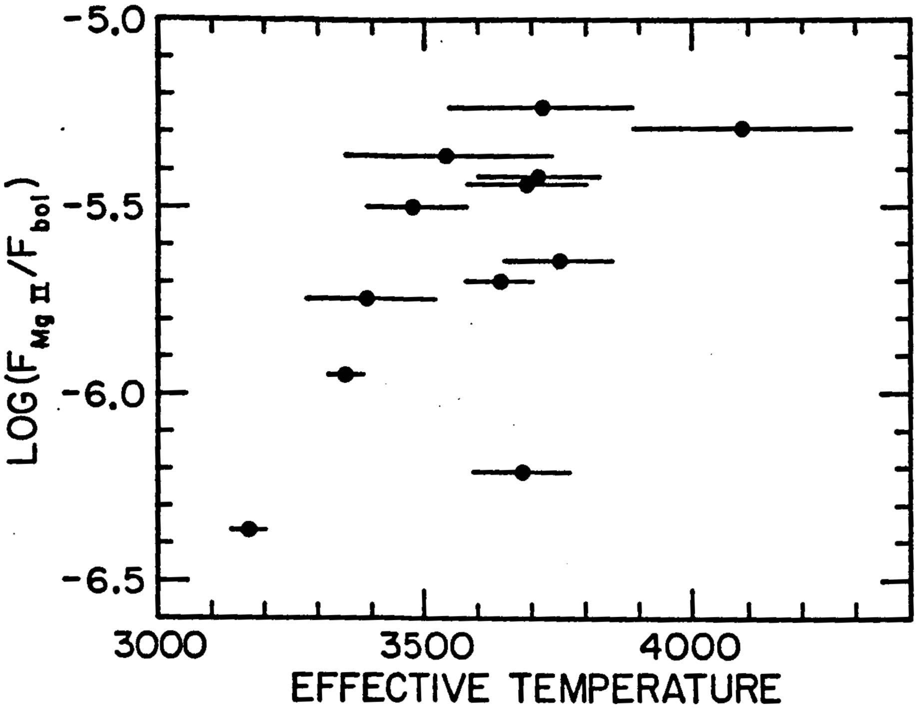


FIGURE 1

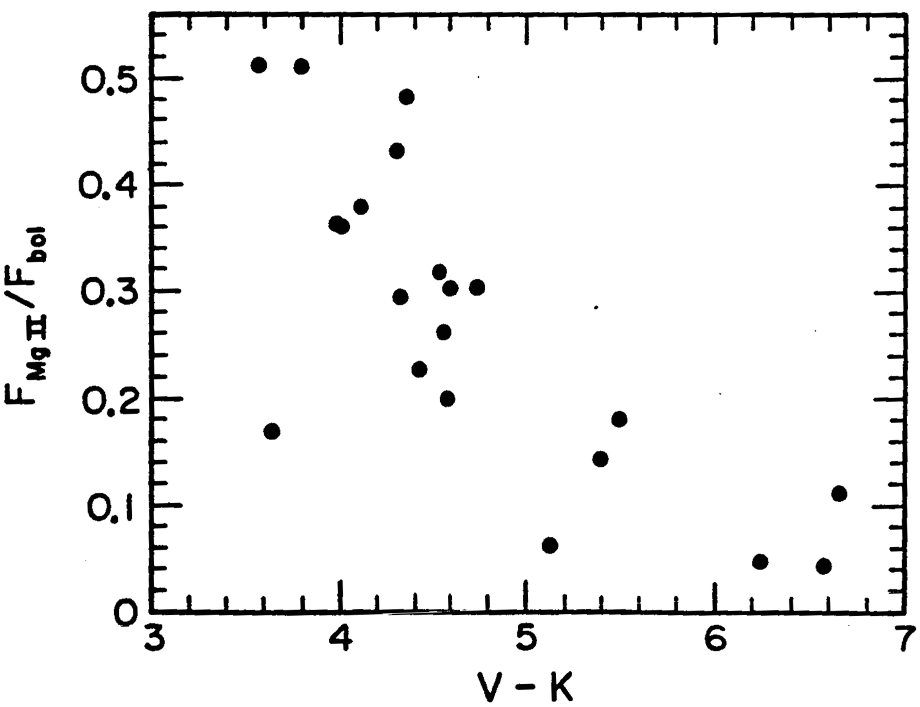
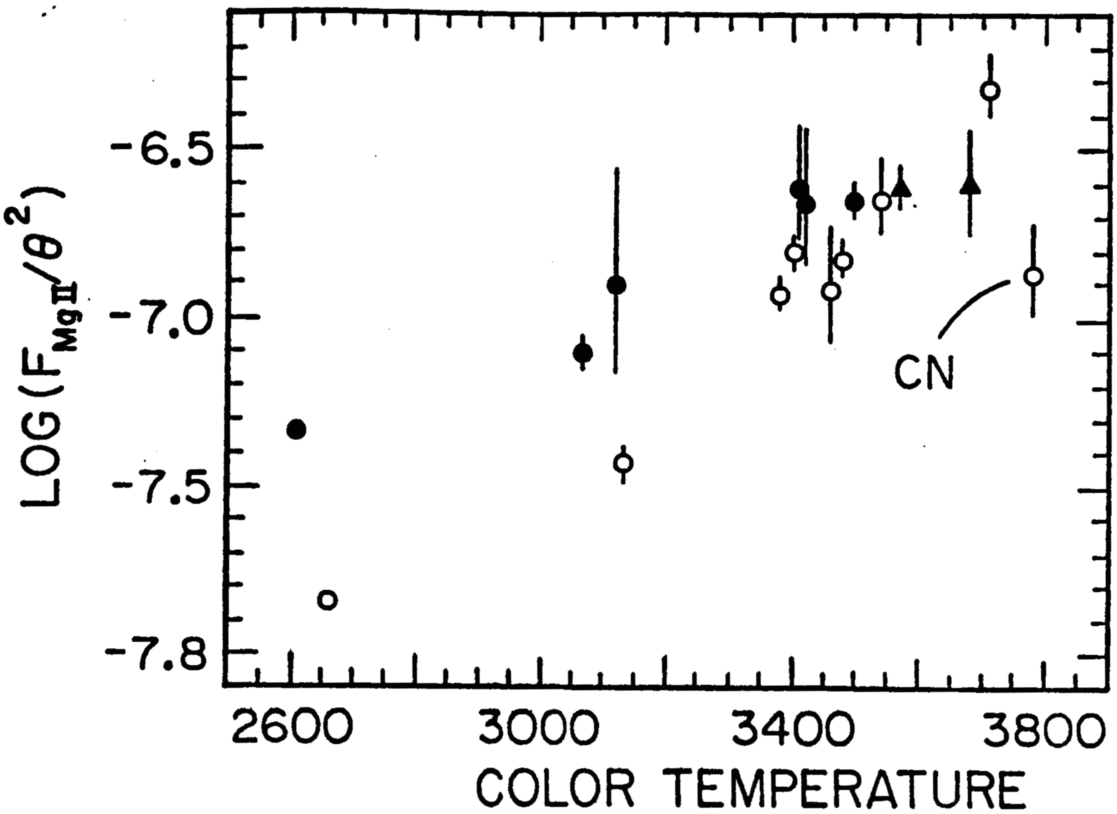


FIGURE 2



$\mathrm{LOG}(F_{\mathrm{Mg\,II}}/\theta^2)$
-6.5
-7.0
-7.5
-7.8
CN
2600
3000
3400
3800
COLOR TEMPERATURE

FIGURE 3