IUE - ULTRAVIOLET AND OPTICAL CHROMOSPHERIC STUDIES OF LATE-TYPE GIANTS IN THE HYADES CLUSTER*

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ABSTRACT

We present ultraviolet and optical observations of four bright, late-type giants in the Hyades cluster detected with IUE in order to study chromospheric and coronal activity in stars of the same age. Two of the giants, 77 Tau and γ Tau, clearly exhibit emission in the high-temperature ions such as N V, C IV, and Si IV at levels several times larger than the upper limits for the other two giants, δ Tau and ϵ Tau. Comparison of the Mg II h and k fluxes and the Ca II K emission strengths shows that 77 Tau and γ Tau have larger chromospheric radiative losses than δ Tau, ϵ Tau, and β Gem, a field giant which also displays low upper limits to emission from high-temperature ions. Coronal X-ray emission has been detected from the *Einstein* Observatory (HEAO-2) in 77 Tau and δ Tau. Obviously both 77 Tau and δ Tau have hot coronae, but the surface flux in X-rays is an order of magnitude brighter in 77 Tau than in δ Tau.

The Hyades giants are similar in age, temperature, gravity, and metallicity; none are known to be close binaries. Thus, our results indicate that another parameter determines the amount of chromospheric and coronal emission in late-type giants.

INTRODUCTION

The study of stars in the galactic cluster nearest the Sun, the Hyades, presents a unique opportunity to explore chromospheric and coronal emission in late-type stars. For the cluster stars, which are coeval, certain parameters which are thought to affect the chromospheric emissions can be controlled.

The Hyades cluster is several hundred million years old and the main sequence stars are younger on the average than corresponding main sequence field dwarfs in the solar neighborhood. Among the optically brightest members of the cluster are four stars near spectral type KO III. In addition to similar effective temperatures, gravities, and metallicities, their ages are all alike. The

* Supported in part by NASA grants NSG 5370 to the Harvard College Observatory and NAG-5-5 to the Smithsonian Astrophysical Observatory

photospheric similarity of these stars is borne out in detailed analyses of spectroscopic and photometric observations (ref. 1, 2). The cluster giants occupy similar positions in the H-R diagram. We have also chosen to compare the four Hyades giants with β Gem (KO III), a field star with photospheric properties resembling those of the Hyades giants, with the possible exception of a somewhat lower, more solar metallicity (ref. 2).

OBSERVATIONS

We observed both the optical Ca II K and ultraviolet Mg II h and k chromospheric emission cores in these giants (Figure 1). The optical data here are high-resolution echelle spectra obtained at Mt. Hopkins with the image-intensified, photon-counting Reticon array (ref.3). The spectral resolution is approximately 40 mÅ. From these Ca II K profiles we have measured the normalized emission in excess of a quadratic baseline fit to the bottom of the photospheric absorption core. The Ca II K cores show a factor of three range in this normalized emission. The two Hyades giants 77 θ^1 Tau and γ Tau both show stronger Ca II emission than δ and ϵ Tau. For comparison, the field giant β Gem has a Ca II emission strength comparable to those of ϵ and δ Tau.

The Mg II h and k profiles were obtained at high-resolution with IUE. The scales have been adjusted to allow the intercomparison of surface fluxes between the Hyades and β Gem. The fluxes of the Mg II chromospheric emission cores behave similarly to those of Ca II K: the surface fluxes of the integrated emissions have a range of about a factor of two. Again, the Hyades giants 77 Tau and γ Tau are brightest in Mg II, while δ Tau and ϵ Tau, along with β Gem, have lower integrated surface fluxes.

The low-dispersion, short-wavelength IUE spectra also show this same trend in the solar transition-region emissions. The lines formed above a temperature of about 20,000 K, such as C II, C IV, Si IV, and N V are clearly visible in 77 Tau and γ Tau (Figure 2). The surface fluxes are higher, by factors of 2-5, than detections or upper limits of non-detection for the same lines in δ Tau, ϵ Tau, and β Gem. For 77 Tau and γ Tau, which show stronger chromospheric Ca II and Mg II emissions, the surface fluxes of the transition-region lines are enhanced. The stars δ Tau, ϵ Tau, and β Gem are weak in both the high-temperature transition-region lines and in the chromospheric Ca II and Mg II emissions.

DISCUSSION

Several interesting conclusions can be drawn from these data:

(1) The solar transition-region fluxes are strongest in 77 Tau and γ Tau, compared to δ Tau, ϵ Tau, and β Gem. This is correlated with the strength of the Ca II and Mg II emissions. Thus, the surface fluxes of the transition-region lines are enhanced as the chromospheric mechanical energy deposition increases, as evidenced in the increased radiative losses observed in Mg II and Ca II. This result has also been found in late-type dwarfs (ref. 4).

(2) The Hyades giants δ Tau and 77 Tau have been detected, with the *Einstein* Observatory, as X-ray sources (ref. 5), while ϵ and γ Tau have not yet been observed. The X-ray surface flux of 77 Tau is about a factor of 10 larger than in δ Tau; the C IV emission is about 6 times higher in surface flux in 77 Tau compared to the upper limit in δ Tau. Thus, the X-ray emission strength is correlated with the strengths of the high-temperature transition-region lines and the larger Mg II and Ca II chromospheric radiative losses. The weak-chromosphere stars ϵ Tau and δ Tau presumably also have solar-like transition regions, but at a level below our detection limit in the IUE spectra. The ultraviolet and optical spectra may be used to predict the level of X-ray activity from these stars. On the basis of our spectra, we predict X-ray emission from γ Tau at a level comparable to that of 77 Tau, while ϵ Tau will show a lower X-ray luminosity, similar to that of δ Tau.

(3) The Hyades giants are located in a region of the H-R diagram in the vicinity of the onset of mass-loss indicators. For example, the Mg II and Ca II profiles can show a violet-to-red emission-peak asymmetry with $V < R$, the violet peak depressed relative to the red. For stars which show this asymmetry, often outflows and mass-loss may be inferred (ref. 6).

However, in the Hyades spectra V/R asymmetries of Mg II and Ca II chromospheric emission cores are not simply related to the strength of chromospheric and coronal emission. In fact, Mg II asymmetries showing $V < R$ (corresponding to outflows) occur here for the more chromospherically active stars. Additionally, the Ca II K profiles all show $V > R$, which can be opposite the Mg II asymmetry. As an explanation for the apparent inconsistency in the Ca II and Mg II asymmetries, variability may be invoked because the optical and ultraviolet spectra are not simultaneous. However, we have monitored the Ca II profiles in these stars over 6 months and we observed no changes in the shapes or the strengths of the line profiles. No changes are present, either, in two sets of ultraviolet spectra of the Hyades giants over the past year.

(4) Finally, chromospheric scaling laws which predict Ca II and Mg II fluxes as the basis of effective temperature and gravity alone (ref. 7, 8) are insufficient to explain the wide range of emissions among these Hyades giants which are all similar in effective temperatures, gravity, chemical composition, and age.

SUMMARY

The study of the Hyades giants, with extremely similar photospheres, has pointed out that chromospheric and coronal emission from these giants can be quite dissimilar. Present predictors of chromospheric emissions, which depend simply upon location in the H-R diagram, are insufficient to explain the wide range of chromospheric emissions observed here. Among the Hyades giants, large age differences may be ruled out as a cause of the range of chromospheric strengths. Additionally, none of these giants are known to be situated in close binary systems. Another parameter, such as rotation, may well be important for refining theories that predict the chromospheric emissions from these giants. Further, the ultraviolet and optical chromospheric data presented here may be used to predict the X-ray luminosity from these giants.

Stencel: Your Mg II profiles are fascinating. The X-ray source 77 Tau seems to have no central reversal. Assuming interstellar Mg II doesn't obscure the intrinsic information, what do you make of the "discrepant" asymmetries between Ca II K and Mg II K in these Hyades giants?

Baliunas: The interstellar contribution to Mg II profiles is an inconsistent explanation for the asymmetries. The radial velocities of these stars are all within a few km/sec, and the assumption of homogeneous cloud projected across the Hyades would produce similar Mg II asymmetries. Here, however, the asymmetry of Mg II in ϵ Tau is clearly opposite from the remaining Hyades giants. Differential flow velocites between the K_3 and k_3 line-forming regions may be a possible explanation.

Garrison: These four giants do have slightly different visual classifications, ranging from G8.5 III to K1 III. I'm sorry that I don't remember which is which, but it would be interesting to know if the emission line differences are in the same sequential sense.

Baliunas: Let us list the photospheric data for the Hyades giants as given by, say, Ref. 2.:

Star	T_{eff}	Spectral Type	log g
γ Tau	4900	K0 III	2.3
δ Tau	5000	K0 III	2.8
ϵ Tau	5000	K0 III	2.8
77 θ^1 Tau	5000	K0 III	3.0

The largest discrepancy here is that of γ Tau *vs.* 77 Tau. In fact, for these two stars with the largest range in temperature and gravity, the chromospheric emissions are quite similar. We should look elsewhere for an explanation of the spread in emissions.

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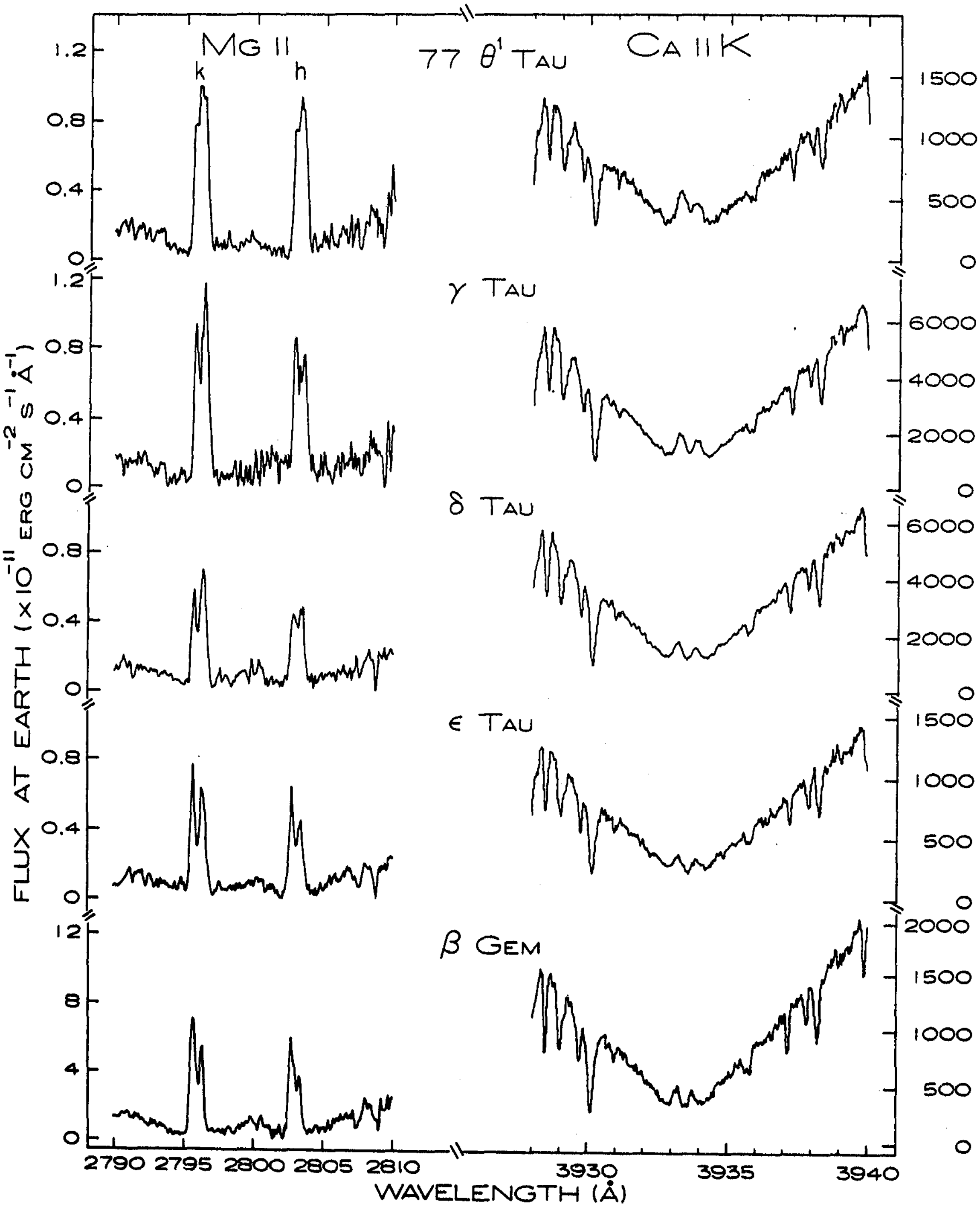

Figure 1. -- Mg II h and k (left) and Ca II K (right) profiles of the four Hyades giants 77 Tau, γ Tau, δ Tau, ϵ Tau, and the field giant β Gem. The observed fluxes at the earth have been determined by the calibration given in ref. 3. The chromospheric emission strengths are largest in 77 Tau and γ Tau.

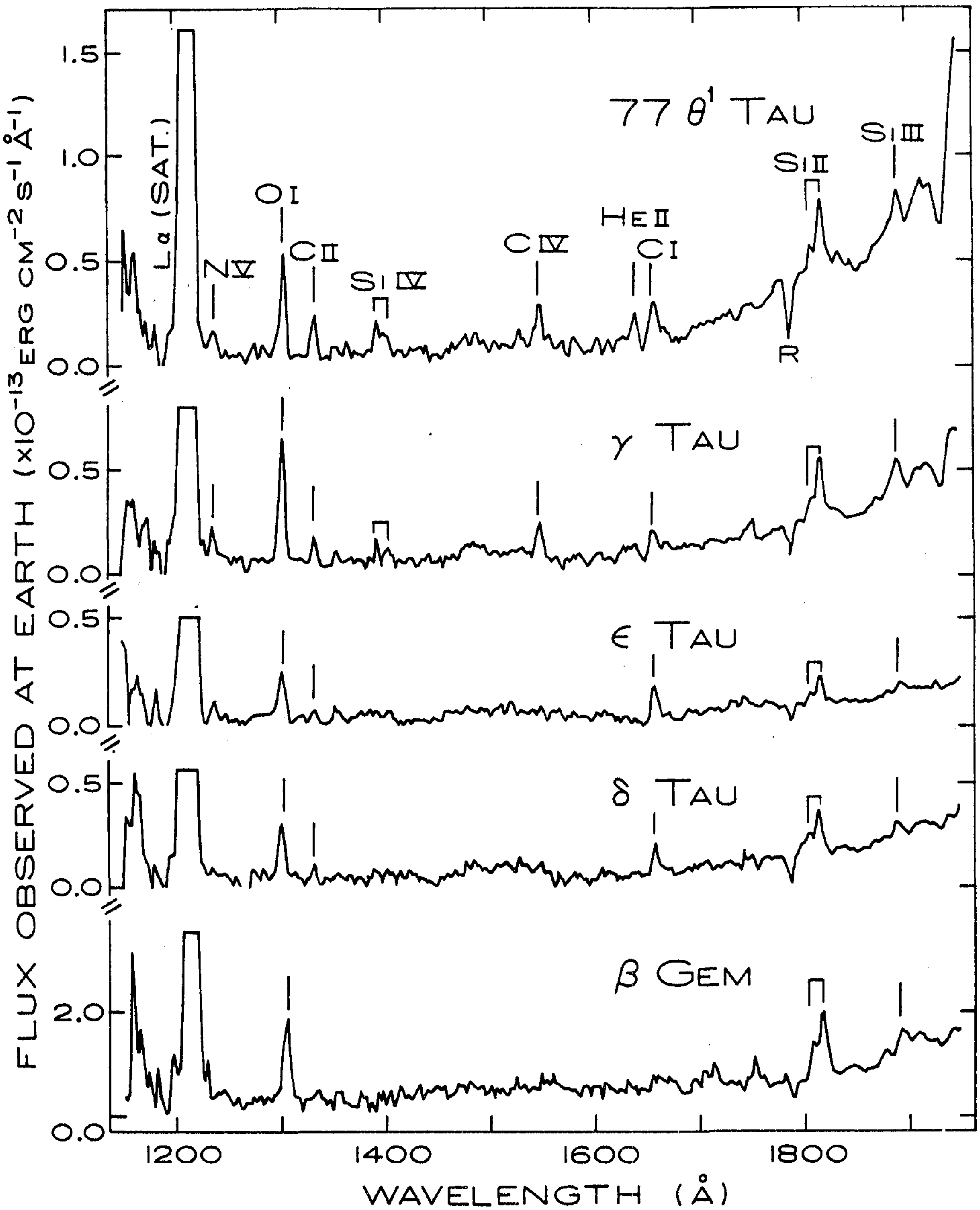

Figure 2. -- IUE short-wavelength, low-resolution spectra of the four Hyades giants and the field star β Gem. The high-temperature, solar-transition region lines are clearly present in 77 Tau and γ Tau. The enhancement of the ultraviolet emissions is correlated with the strong Ca II and Mg II chromospheric emissions in these stars.