# Hε EMISSION IN LATE-TYPE STARS

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ABSTRACT

Intensities of Hε emission are estimated in 185 late-type stars and compared with those of the K line of Ca II. Although there is a statistical tendency toward a correlation between the Hε and K intensities, there is also a large scatter, indicating that the ratio of Hε to K is widely variable.

## I. INTRODUCTION

Many years ago (Wilson 1938)[1] the author called attention to the fact that the hydrogen line Hε appears in emission in the spectrum of Arcturus, and somewhat later the same observation was made independently by Wellmann (1940). The other members of the Balmer series in this star are absorption lines. Popper (1956) has noted the same phenomenon in the spectrum of ξ Bootis B. As far as I am aware, these are the only references to this subject in the literature, although, as will be shown, Hε emission is quite common in the spectra of stars of late spectral type.

The bright central reversals of H and K of Ca II which occur very commonly in G-, K-, and M-type stars undoubtedly arise in the stellar chromospheres, and the Hε emissions are presumably of chromospheric origin also. It is likely, therefore, that both the Ca II and the Hε emission can provide valuable clues to the physical conditions prevailing in the chromospheres of the stars, particularly since quite different ionization and excitation potentials are involved. For these reasons it is desirable to make a beginning in the study of Hε emission in the late-type stars and to attempt to answer such questions as these: Does the intensity of Hε emission correlate with that of H and K? How does it vary with spectral type and luminosity? In the present work these matters are investigated in preliminary fashion by means of visual inspection of a large number of spectrograms of late-type stars.

## II. OBSERVATIONS

The spectrograms used in the study of Hε emission are the same as those employed in a recent investigation of the H and K lines (Wilson and Bappu 1957), to which the reader is referred for further details. These plates, all of 10-A/mm dispersion, included stars of all luminosities, from the main sequence to the supergiants, having spectral types G0 and later. They were exposed primarily for the H and K emissions, which lie at the bottoms of the strong reversing-layer absorption lines, and some are, therefore, rather too dense at the position of Hε for optimum results. On the whole, however, they are reasonably satisfactory and undoubtedly comprise the largest homogeneous sample of late-type spectra in this region likely to be available for some time.

In the work mentioned above, eye-estimates of the emission intensity of the K line had been made for each star. When a similar procedure was tried for Hε, it was found to be extraordinarily difficult to arrive at consistent results. The vicinity of Hε contains several absorption lines, and these, together with the considerable range in plate densities and the sharply sloping background in the wing of H, rendered a realistic evaluation of the intensity of Hε virtually impossible. One must therefore be satisfied with results even less reliable than can usually be attained by straightforward eye-estimation.

[1] This reference contains a tracing of a high-dispersion plate showing Hε emission.

The adopted procedure was this: Since we know that Hε emission is present in the spectrum of Arcturus, a good 10-A/mm spectrogram of this star was selected as a standard. On this plate the line in question was, of course, clearly and distinctly visible. Every other spectrogram was then matched against this standard on a comparator carefully adjusted to equalize accurately the scale of the two spectra. Under these conditions, except for extremes of under- or overexposure, there was little doubt concerning the Hε emission if it either was comparable in strength to the line in α Bootis or was absent altogether. Between these extremes, however, was an intensity range of considerable difficulty for eye-estimation.

The best that could be done was to rate each spectrogram according to one of the criteria in Table 1. This was done by comparing each spectrum in the vicinity of Hε with that of α Boo and by looking for any asymmetry in the proper position in the wings of H as compared with those of K. The results are, of necessity, rough and crude. However, they merit some confidence, at least statistically, since for stars with more than one spectrogram it was found that the independent estimates from the various plates frequently

TABLE 1

SIGNIFICANCE AND NUMERICAL VALUES OF ESTIMATES

| Estimate | Significance | Numerical Value | Estimate | Significance | Numerical Value |
|---|---|---|---|---|---|
| Present | Hε similar in appearance to α Boo; undoubtedly a considerable range in true intensity is included | 4 | Possibly present | Doubtful, but more likely present than absent | 2 |
| Probably present | Appears weaker than in α Boo, but considered to be real emission line | 3 | Probably absent | Very doubtful; little probability of being real | 1 |
| | | | Absent | No emission; no absorption | 0 |
| | | | Absorption | Hε appears definitely as absorption line | −1 |

agreed and, in any case, seldom disagreed by more than one estimation unit. Finally, in order to have a basis for plotting, the estimates of the first column were assigned the numerical values shown in the third column. This is obviously not a true intensity scale, but it seems the best that can be done under the circumstances and should suffice to bring to light the major features of the problem. A value of −1 was arbitrarily assigned to all stars in which Hε appeared in absorption, merely to provide a place to plot them in the diagrams. Independent estimates were made of each plate for a given star, and the straight mean of these estimates (numerically, according to Table 1) was taken to be the Hε "intensity" for the star.

## III. RESULTS

The Hε emission intensities have been plotted against those of K in a series of diagrams. These K-line intensities are also eye-estimates (Wilson and Bappu 1957) and are thus not of high accuracy, but there can be no doubt that they are much superior to the Hε data.

Figure 1 contains the results for all the stars. There appears to be a distinct tendency for the Hε emission intensity to correlate with that of K, at least in the range of K-line intensity from weak to moderate. This trend is shown by the crosses which mark the means of the vertical columns of points. Apart from this, there is an enormous spread in the estimated Hε strength over most of the diagram. Part of this spread is doubtless due to the difficulty of estimating Hε, but a considerable amount is certainly real.

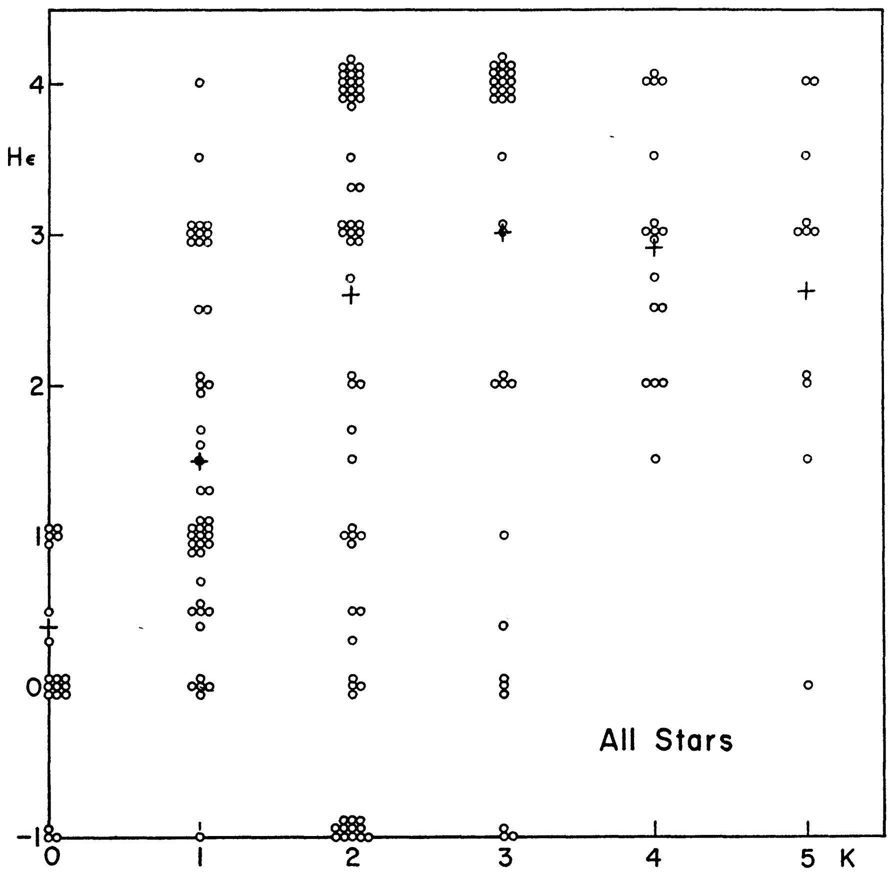


FIG. 1.—Hϵ emission intensity versus K emission intensity. All stars

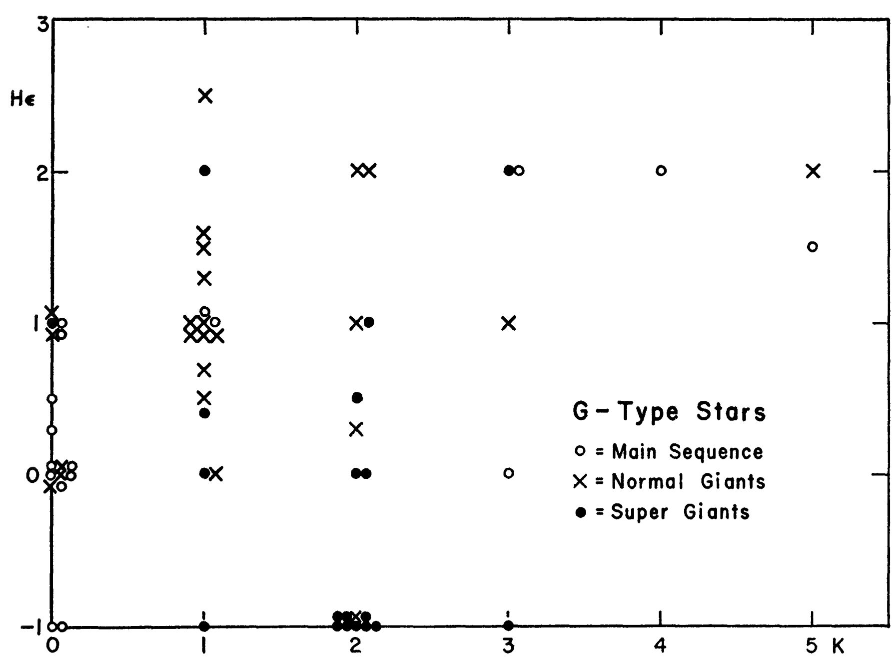


FIG. 2.—Hϵ emission intensity versus K emission intensity. G-type stars

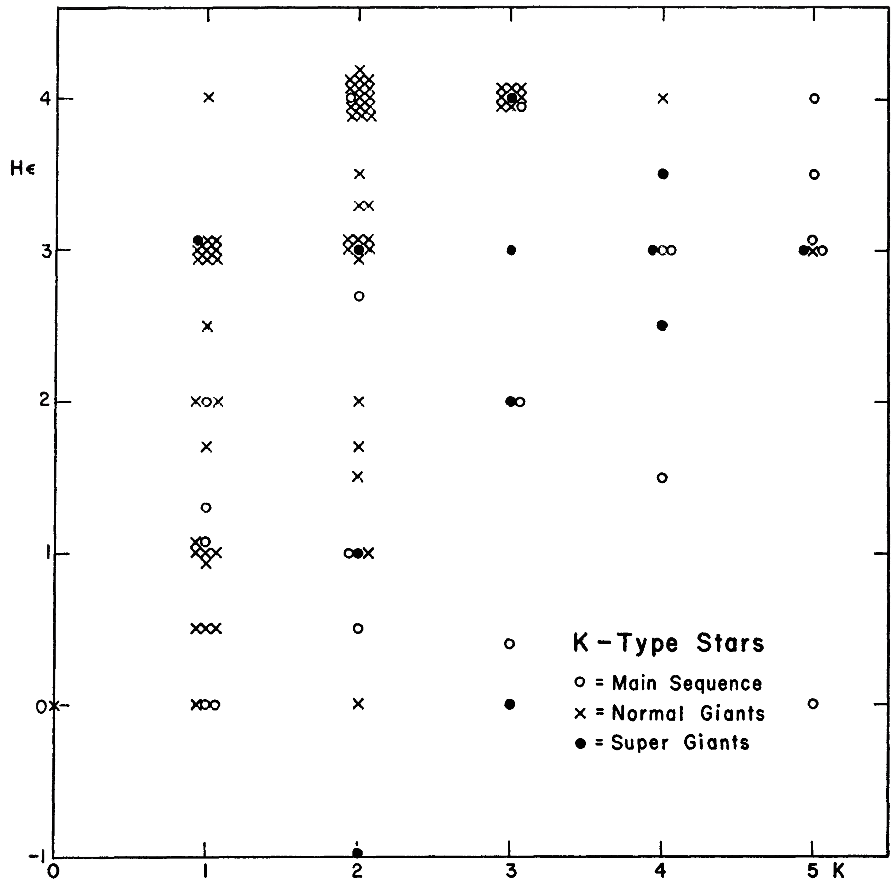


FIG. 3.—Hε emission intensity versus K emission intensity. K-type stars

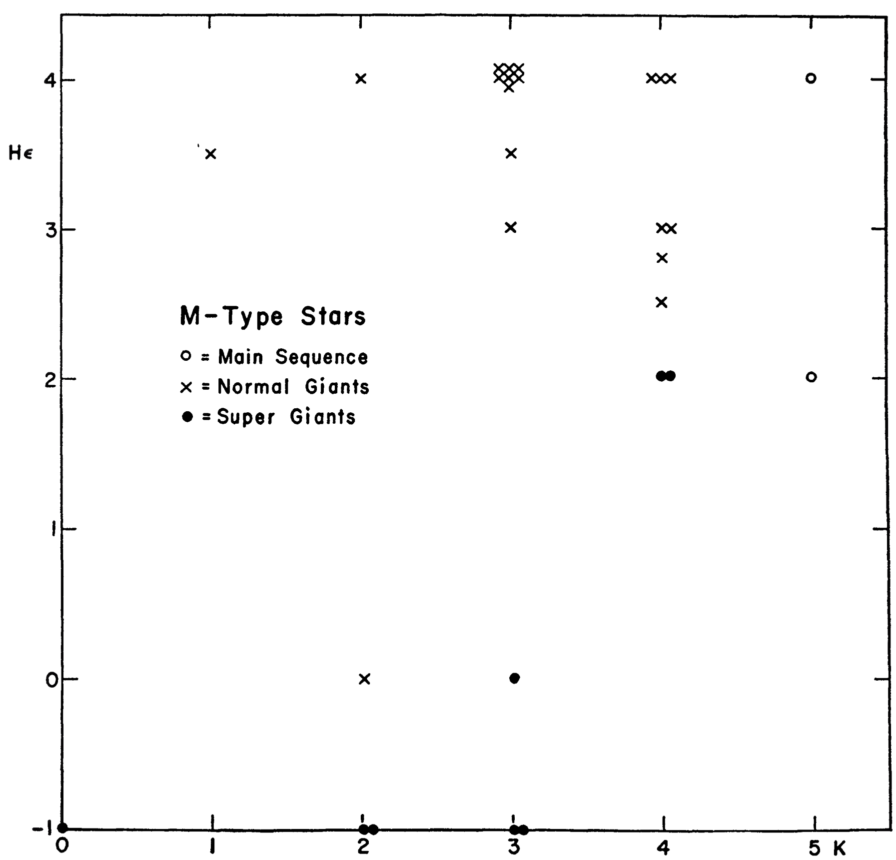


FIG. 4.—Hε emission intensity versus K emission intensity. M-type stars

The points in Figure 2 are for the G-type stars only. None of these stars has strong $H\epsilon$; indeed, one hesitates to state definitely that $H\epsilon$ emission is visible in any of them. In this diagram and the next two, open circles, crosses, and filled circles represent roughly main-sequence, normal giant, and supergiant stars, respectively. Note the large number of G-type supergiants in which $H\epsilon$ appears as an absorption line.

The K-type stars are shown in Figure 3. Here there is no doubt that many of the stars have $H\epsilon$ emission comparable in strength to that in Arcturus. Also, while there is a tendency toward a correlation between $H\epsilon$ and K intensities, there is a large vertical scatter, much of which must be real. The appearance of $H\epsilon$ in absorption is rare in these objects.

Figure 4 shows that $H\epsilon$ emission is the rule among the M-type stars, except that, as among the G stars, the M supergiants tend to have $H\epsilon$ in absorption.

## IV. SUMMARY

1. There is a statistical tendency for $H\epsilon$ emission to increase in strength with increasing K emission.

2. This relationship is not, however, of the nature of a one-to-one correspondence. Stars may have very strong Ca II emission without strong $H\epsilon$ emission. On the other hand, $H\epsilon$ emission has not been observed with certainty in any star in which Ca II emission is invisible.

TABLE 2

LIST OF SPECTRA

| Number | Star | Sp | $M_v$ | Number | Star | Sp | $M_v$ |
|---|---|---|---|---|---|---|---|
| 1 | HD 1337704 | K4 III | +1 8 | 8 | $\gamma$ Dra | K5 III | −1 0 |
| 2 | $\lambda$ And | G7 | +0 9 | 9 | $\pi$ Her | K3 II | −1 0 |
| 3 | 81 Gem | K5 III | +0 7 | 10 | $\mu$ Gem | M3 III | −1 3 |
| 4 | $\beta$ Cnc | K4 III | +0 6 | 11 | $\sigma$ Gem | K1p | −1 6 |
| 5 | $\alpha$ Sct | K3 III | +0 4 | 12 | $\gamma$ Aql | K3 II | −2 1 |
| 6 | 22 Psc | K4 II | +0 4 | 13 | $\epsilon$ Peg | K2 I*b* | −4 6 |
| 7 | $\beta$ UMi | K4 III | +0 1 | | | | |

3. The average $H\epsilon$ emission intensity increases steadily in the direction G → K → M, as does the average Ca II emission intensity. This point, obvious on inspection of Figures 2, 3, and 4, agrees with item 1 above.

4. The behavior of $H\epsilon$ in the supergiants, i.e., the tendency toward absorption in the G and M stars, is not paralleled by the Ca II.

To illustrate some of the statements concerning $H\epsilon$, spectra of thirteen stars are shown in Figure 5. They are listed in Table 2, together with spectral types and absolute visual magnitudes, the latter derived from the K-line widths (Wilson and Bappu 1957). Note that the intensity ratio of $H\epsilon$ to H varies considerably, even among the K-type stars.

## REFERENCES


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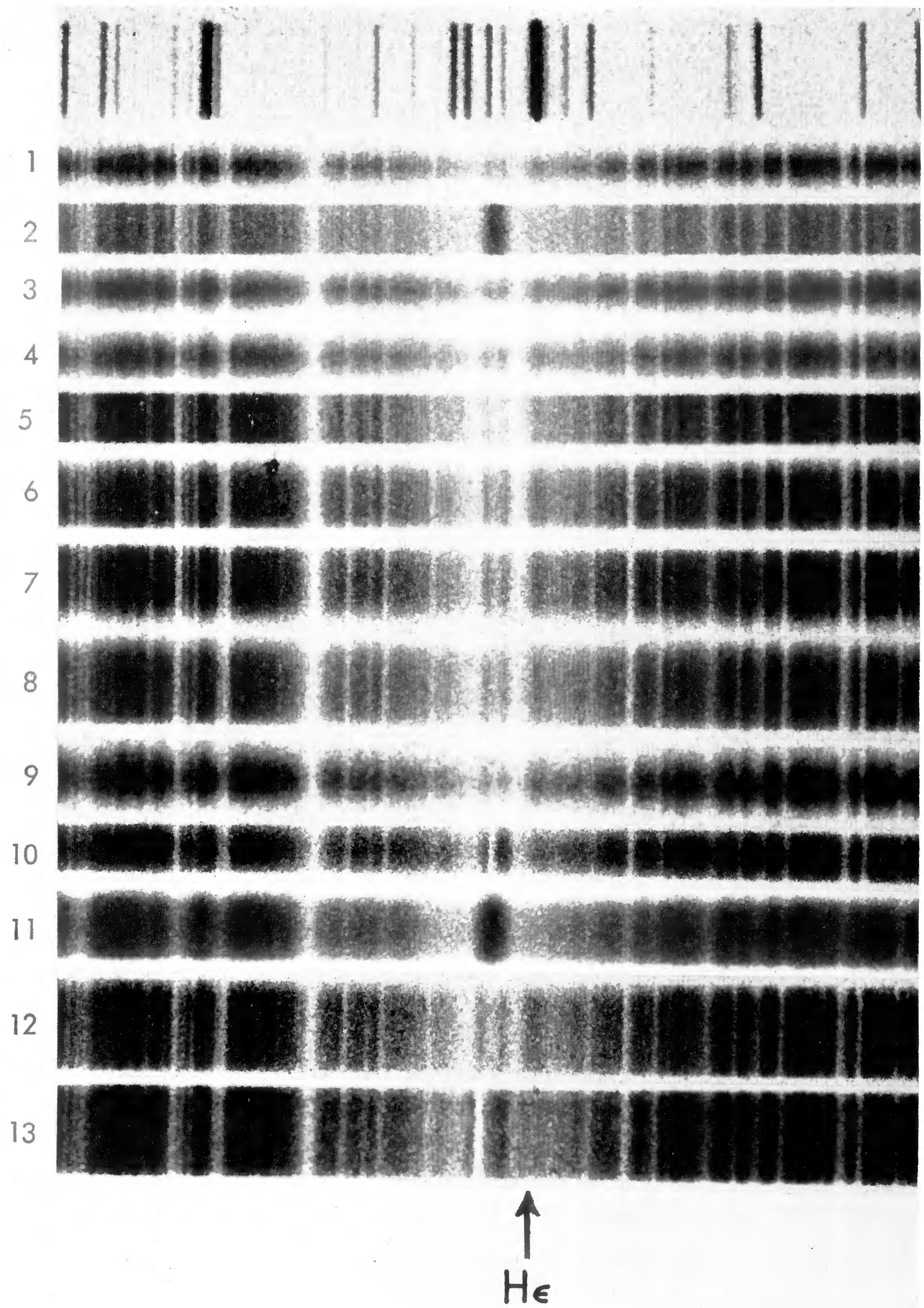


FIG. 5.—Spectra showing H and Hϵ