CHROMOSPHERIC ACTIVITY IN RED GIANTS, AND RELATED PHENOMENA

ARMIN J. DEUTSCH[†]
Mount Wilson and Palomar Observatories,
Carnegie Institution of Washington,
California Institute of Technology

Abstract. Normal red giants of a given spectral type are shown to be heterogeneous with respect to the following chromospheric features: the Balmer absorption lines, the emission line at Hε, and the double-reversed emission lines at Ca II H and K. These chromospheric lines are also shown to be strongly time variable, in at least some red giants, on a time scale of a few months or years. Other chromospheric features that require study lie in the infrared (He I 10830), the near ultraviolet (Fe II emission lines), and the vacuum ultraviolet.

When one intercompares spectrograms of normal stars having spectral types and luminosities that are accurately the same, one often finds the intensities of certain lines to differ appreciably from one object to another. Similar differences also occur among stars having the same color and absolute magnitude. As is well known, abundance anomalies are responsible for a large part of this heterogeneity of spectra among stars having the same values of effective temperature T_e and surface gravity g. Similarly, in late-type stars with the same classification, chromospheric effects are also responsible for appreciable spectroscopic differences.

In Figure 1, the Balmer lines are shown on enlargements from 10 Å mm^{-1} spectrograms of two M2 III stars, λ Aqr and φ Aqr. In both objects, the lower Balmer lines are far stronger than those to be expected from the reversing layer, where the metallic lines originate. The magnitude of the anomaly can be easily estimated if we note that in the spectrum of λ Aqr Hγ ($\chi = 10.15$ eV) has an equivalent width slightly larger than does Fe I 4376 Å ($\chi = 0$). If we may take the lines to be of roughly equal strength, and if both lines lie on the same curve of growth, they will then have approximately the same abscissa, $\log \eta_0$. In the notation of Aller (1963), we have

$$\log \eta_0 = -\,1.824 + \log N + \log gf - \theta\chi - \log K_\lambda V u(T).$$

Since $T_e = 3050°$ at M2 III, we may neglect ionization in both species. We may also neglect the relatively small differences in $\log \kappa_\lambda V u(T)$. Then

$$\log \frac{N(\mathrm{H})}{N(\mathrm{Fe})} \simeq \theta\left[\chi(\lambda 4340) - \chi(\lambda 4376)\right] - \log \frac{(gf)_{\lambda 4340}}{(gf)_{\lambda 4376}} \simeq 14.6\,.$$

But in the Sun, $\log N(\mathrm{H})/N(\mathrm{Fe}) \simeq 5.4$ (Goldberg *et al.*, 1960). The calculation shows that if Hγ were formed in the reversing layer, its overabundance relative to iron would be 10^9 times! Alternatively, if the abundances are normal, the strength of 4340 Å would indicate $T_{\mathrm{exc}} = 6600°$, or more than double T_{eff}.

[†] Deceased.

Houziaux and Butler (eds.), Ultraviolet Stellar Spectra and Ground-Based Observations, 199–208.

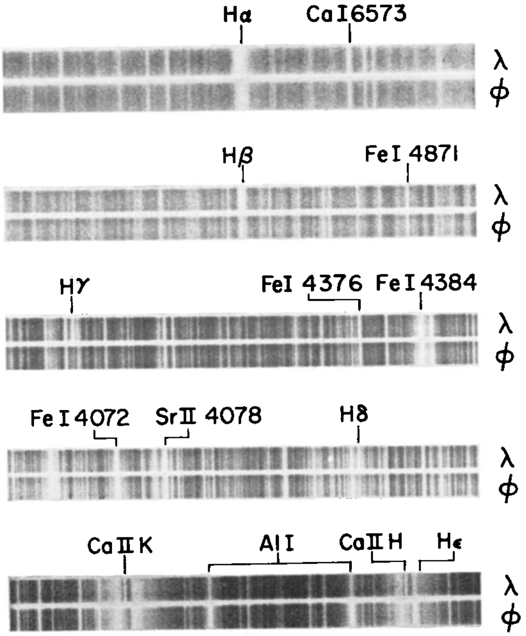

Fig. 1. The Balmer lines in λ Aqr (M2 III) and φ Aqr (M2.5 III). In the top strip, the plates are Pc 10883 (λ, 1968, Dec. 11) and Pc 10884 (φ, 1968, Dec. 12). In the next three strips the plates are Pc 10873 (λ, 1968, Dec. 10) and Pc 10874 (φ, 1968, Dec. 10). In the bottom strip the plates are Pc 10960 (λ, 1969, Jan. 8) and Pc 10809 (φ, 1968, Oct. 14).

The Balmer lines in M-type giants therefore represent an extreme case of super-excitation, as was first noted by Adams and Russell (1928). In discussing the spectrum of α Ori (M2 Iab), Spitzer (1939) found excitation temperatures of 2100° for the strong iron lines and 17000° for the Balmer lines. Many subsequent studies of red giants and supergiants have also made it clear that the Balmer lines are formed in a high-temperature region which lies above the reversing layer, and which is the stellar analogue of the solar chromosphere.

The spectrograms reproduced in Figure 1 show that the Balmer decrement is far steeper in φ Aqr than in λ Aqr. In the former star, Hδ has nearly disappeared, and Hε has gone into conspicuous emission. This regularity suggests the possibility that emission from some parts of the stellar chromosphere 'fills in' the absorption lines from other parts, and that the emission actually 'overfills' the weak absorption line expected at Hε. As yet, no quantitative formulation of this hypothesis has been attempted. Wilson (1957) has illustrated the Hε emission line in the spectra of a number of late-type giants.

Figure 1 also shows that these two M giants differ systematically in the metallic lines that are on the damping part of the curve of growth. These are stronger in φ Aqr, the star with the weaker Balmer lines. The difference cannot be attributed to a simple error in spectral classification, for the TiO bands are very nearly equal in the two stars. Also, there is close agreement in the intensity ratio of the relatively weak lines at 4020.4 Å and 4121.8 Å, which are sensitive criteria of temperature (Deutsch *et al.*, 1969). One can nearly match the strong, damped lines of φ Aqr with those of the M4 III star 51 Gem (actually, the lines are still slightly stronger in the former object); but then the TiO bands are much weaker in φ Aqr. According to the catalogue of Johnson *et al.* (1966), the colors of λ and φ Aqr are closely similar, with λ slightly the cooler. The weakness of the metallic lines in λ Aqr was noted earlier by Keenan, in Deutsch *et al.* (1969); in this paper, he slightly revised the classification to M2.5 III.

From intercomparison of 10 Å mm^{-1} spectrograms of about 15 other bright giants near M2 III, it has now been established that differences commonly are found which are similar to those illustrated in Figure 1. Few regularities have yet emerged from these observations; indeed, one can only be astonished at the ubiquity, the variety, and the amplitude of the effects that can be seen. For example, in the spectrum of α Cet (M1.5 III) Hγ and the damped metallic lines are nearly the same as in λ Aqr; but Hε is an emission line in α Cet, nearly equal to the one in φ Aqr.

These anomalies are not altogether new. Thus, Kraft *et al.* (1964) found that the half-width of Hα correlates with M_v for giants and supergiants earlier than M0, but not for the M stars. Again, Wilson (1962) has found that in K-type dwarfs "...the hydrogen lines are frequently erratic in behavior and have intensities which would indicate a spectral type somewhat different from that derived from the metallic lines". He has also noted discrepancies in the bands of CN and SiH. Metallic lines that are *weak* for the type are well known, of course, in many late-type stars of the halo population and the disk; these metal-deficient stars occur among giants and dwarfs, alike. Recent studies, e.g. by Spinrad and Taylor (1969) and by Taylor (1969), have recently established the existence of numerous late-type stars, both giants and dwarfs, which have metallic lines *stronger than normal* and appear to be 'super-metal-rich'. The relations are still not clear between these spectroscopic anomalies and the ones that have now emerged among the M giants.

A degree of caution is necessary before attributing all these line-intensity anomalies to abundance irregularities. For the Balmer lines, recent work has established that

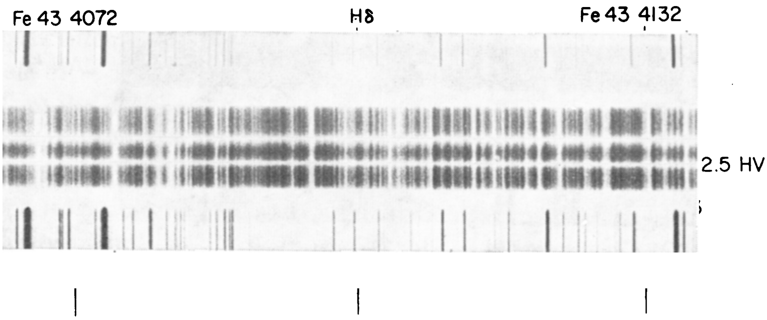

Fig. 2. Variation of Hδ in HR 6128 (M2.5 III). From top to bottom, the plates are Ce 13488 (1960, May 14), Pc 2477 (1956, Mar. 2), and Ce 11850 (1958, Apr. 9). The M3 III star is μ Gem. (Courtesy from *Astrophys. J.*, University of Chicago Press.)

the intensities are strongly variable with time in at least some of the M giants (Deutsch *et al.*, 1969). The spectra of Figure 2 show this effect. Similar changes of the Balmer lines have now been found in nearly half of the early M-type giants for which two or more suitable 10 Å mm^{-1} plates have been obtained during the last year. The time-scale of the changes is of the order of a few months. In a few stars – e.g. μ Gem (M3 III) and π Leo (M2 III) – the plates appear to show intensity variations of the damped metallic lines, as well. However, the changes in the metallic lines cannot yet be considered securely established.

Figure 1 shows the chromospheric components of Ca II H and K in λ and φ Aqr. These lines have also been illustrated in spectra of numerous late-type giants by Wilson and Bappu (1957). Deutsch (1960) has noted the occurrence of transitory chromospheric absorption components in some K-type giants, and of deep, non-variable circumstellar absorption components in most M-type giants. In Figure 1, the circumstellar lines are well shown in λ Aqr, but they cannot be seen in φ Aqr. The plates at hand suggest, but do not establish, that the profiles at H and K are generally uncorrelated with the strengths of the Balmer lines in K and M giants.

Following an unsuccessful search by Wilson (1954) for time-variations of the Ca II emission lines in a number of red giants, Griffin (1963) discovered that large changes are visible on higher-dispersion spectrograms of the K4p giant α Boo. Similar changes were subsequently found by Deutsch (1967a, b), Liller (1968), and Vaughan (1966) in other red giants; and by Wilson (1969) in a few red dwarfs.

Figure 3 shows the region of the K-line on four spectrograms of α Tau (K5 III).

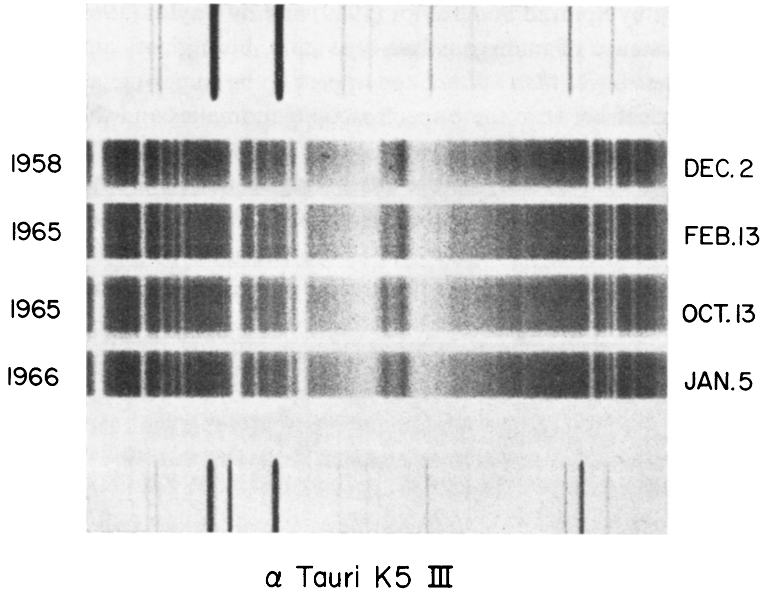

Fig. 3. The K line in α Tau (K5 III). The two strongest comparison lines are 2.4 Å apart; Wilson and Bappu (1957) measured the width of K_2 as 1.13 Å. The spectrograms are Pb 4214, Pb 8522 Pb 9012 and Pb 9121.

Adopting the notation of solar spectroscopy, we may designate the wide absorption wings as K_1V (for violet) and K_1R (for red); the emission peaks as K_2V and K_2R; and the central dip as K_3. These features change with time approximately in the way described by Liller for α Tau, and by Griffin for α Boo. As may be seen in Figure 3, the largest variations occur in the intensity of K_2V and in the depth of K_1V.

The spectrograms enlarged in Figure 3 have a dispersion of 4.5 Å mm^{-1} and a resolution of about 0.12 Å. Similar plates have been obtained during the last 10 years for about 30 of the brightest red giants. The number of spectrograms suitably exposed at H and K now ranges downwards from about 40 for α Tau, to only two or three for the least-frequently observed stars. For about 10 of the stars observed, existing plates show conspicuous variations more or less like those shown in Figure 3. For about half the remaining stars observed, the plates show similar variations of smaller amplitude; the other half of these stars have shown no changes large enough for reliable detection. Probably large-amplitude changes will eventually be recognized in many or most of the stars where they have not yet been established. In this connection we may note that, on the 15 Palomar spectrograms obtained in the last 4 years, the star α Boo has exhibited only relatively small profile variations, although this is the star in which Griffin first demonstrated large changes in K_2.

The time scale of the changes seen at H and K in the Palomar spectrograms is of the order of a few weeks or months. The α Tau observations appear to show a cyclical phenomenon with a quasi-period of ~ 350 days. Since K_2 is modulated in the integrated solar spectrum by solar rotation (Bumba and Růžičková-Topolová, 1967; Sheeley, 1967), the possibility exists that 350 days is the rotation period of α Tau. The equatorial velocity of rotation would then be 3.6 km sec^{-1} for a K5 III star, and this velocity would be consistent with the sharpness of the weaker Fraunhofer lines. A rotational period of about 350 days would conform with the hypothesis that α Tau is a metamorph of an A-type main-sequence object which has lost most of its angular momentum through a stellar wind, in a process like that described by Wilson (1966) and Kraft (1967) for late-type dwarfs. Equally well, the 350-day period could be reconciled with an evolutionary track starting from the position of a dwarf star on the main sequence near F5 or G0.

The Palomar spectrograms of α Tau required exposure times of about 30 min, on the average. These plates therefore could not show the intensity fluctuations of ~ 20% in the peak intensity at K_2V, which Liller sometimes found to occur in α Tau on a time scale of ~ 15 min. Some of the Palomar observations were repeated after time intervals of the order of 0.1 day, or 1 day, or 10 days. None of these closely spaced spectrograms yield unequivocal evidence of profile changes.

Microphotometer tracings (in the transmission mode) have been obtained for 23 of the spectrograms of α Tau, and on these tracings intensities have been determined at the intensity minima in K_1V, K_3, and K_1R; and at the maxima in K_2V and K_2R. Similar measurements have also been made on tracings of 14 plates of γ Aql (K3 II), another star (Figure 4) that has exhibited high activity at H and K. On both sets of tracings, the intensity was taken as unity in a conventional 'continuum' which is well-

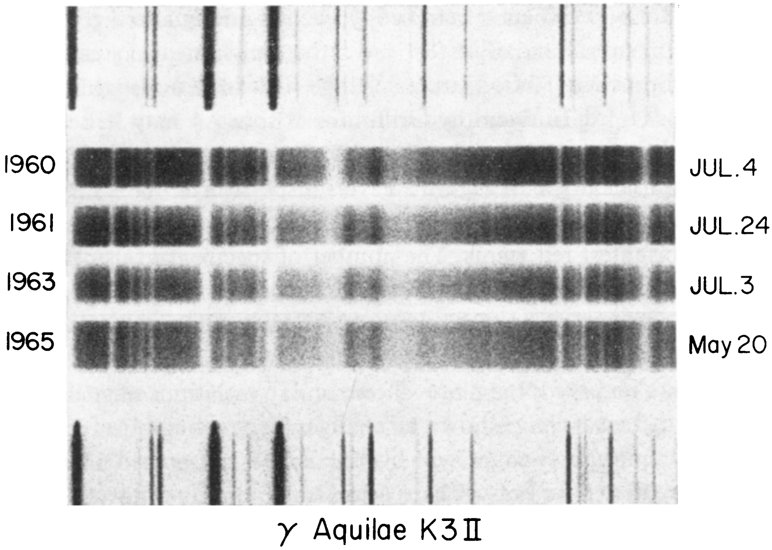

Fig. 4. The K line in γ Aql (K3 II). The spectrograms are Pb 5156, Pb 6021, Pb 7340, and Pb 8715.

TABLE I

Extreme intensities (%) measured in the K lines of α Tau and γ Aql, 1954–68

Star	α Tau	γ Aql
Spectral Type	K5 III	K3 II
No. Plates	20	14
'Continuum'	100	100
K_1V	6–18	6–22
K_2V	40–61	46–49
K_3	23–49	40–48
K_2R	54–73	60–74
K_1R	8–19	14–30
K_2V/K_2R	48–91	68–107

defined by intensity 'plateaux' near 3927 Å and 3940 Å. The details of these measurements and others like them will be reported elsewhere. Meanwhile, Table I summarizes the measurements by giving the extreme values recorded to date.

Following recent discussions of H and K in the solar spectrum (Sheeley, 1967; Linsky, 1968), we may take $K_2 \simeq 0.06$ near sunspot minimum and about half again as large near maximum. The intensities of K_2 recorded in Table I therefore might appear very high compared with those found in integrated sunlight. However, it is necessary to keep in mind that near the K line the photosphere has a much lower surface brightness at K5 III than at G2 V. If both continua were Planckian, the Sun would have 32 times the surface brightness of α Tau at 3933 Å. Line-blocking will then reduce the K-star continuum by another large factor relative to the solar continuum, as Liller

(1968) has pointed out. Together, these two effects can easily account for the prominence of K_2 in late-type giants relative to the weak emission in G2 dwarfs like the Sun. With respect to α Tau, e.g., one can show that if K_2 originates chiefly in chromospheric masses that have the same monochromatic surface brightness at K as do plages in the solar chromosphere, then these stellar plages need cover only a far smaller fraction of the photosphere than solar plages cover near sunspot maximum – about 20%, according to Sheeley (1967).

In many of the red giants observed at H and K, the Palomar spectrograms at 4.5 Å mm^{-1} show fine structure in the profile of K_2 and K_3, down to the resolution limit of the plates. This is about 0.12 Å, or 12% of width of K_2 in luminosity class III (Wilson and Bappu, 1957). Of course, it is still unknown what processes and structures in red-giant chromospheres are responsible for this fine structure. The intensity measures in the H and K profiles of α Tau and γ Aql confirm the visual impression that even the principal features of the chromospheric profiles are subject to complex variations, which are not easily subsumed by any simple description. In particular, one finds little correlation between intensities measured at different points in the profile.

The absorption line He I 10830 provides additional evidence for chromospheric activity in stars. Vaughan and Zirin (1968) have reported finding this feature in a 'substantial number' of G and K giants, and preferentially in those that have intense emission lines at H and K. Wilson and Aly (1956) have found the absorption line 5876 Å of He I in at least two of nine late-type stars which they examined. Both these He I lines are very weak or absent in integrated sunlight, but both are often conspicuous absorption lines over plages or along the borders of the chromospheric network. The infrared helium line is usually wider than other lines, as it is in the solar spectrum. In most G and K giants, it is Doppler shifted towards shorter wavelengths, and in some of these stars the intensity appears to be time variable, on some spectrograms the line going over into emission.

In the ground-accessible ultraviolet, near 3200 Å in the spectra of α Her (M5 II) and α Sco (M1 Ib), Herzberg (1948) found permitted emission lines arising from Fe II levels at excitation potentials of about 5 eV. In reporting these lines, he conjectured that "...if one were to investigate the solar spectrum in the far ultraviolet, where the intensity of the continuous spectrum corresponding to the temperature of the photosphere is negligible, it seems certain that one would find it to consist of coronal emission lines of rather high excitation. In stars like α Her the corona would be expected to have a much lower temperature than that of the Sun, so that Fe II lines (rather than Fe X) might become prominent. In addition, on account of the lower temperature of the photosphere, the coronal emission becomes visible at longer wavelengths than it would for the Sun."

Bidelman and Pyper (1963) have also found these chromospheric emission lines in various cool stars, including β Peg (M2+II – III) and other objects of similar luminosity. In β Peg and in α Ori (M2 Iab), high-dispersion plates have shown that the Fe emission lines present wide and complex profiles that are reminiscent of the structure seen in H and K (Weymann, 1962). It comes as no surprise, therefore, to find that some of the Fe II emission lines are strongly time-variable. Figure 5 shows some effects of chromospheric activity in the near-ultraviolet spectrum of α Ori.

Few generalizations can yet be made about the behaviour of chromospheric features in stars of various types. From the data at hand, it appears that K giants show large profile variations at K_2 more often than M's. As compared with the G and K giants, the M's also have less intense lines at 10830 Å, if any. However circumstellar absorption lines appear in most M-giant spectra, and not in the K's. At a given spectral type, rough correlations appear to exist between the intensities of chromospheric lines arising from different elements. However, the time-variations seem not to be synchronous in Ca II and H, e.g., as we would expect them to be if the lines arise together in long-lived plages which rigid stellar rotation carries across the visible hemisphere.

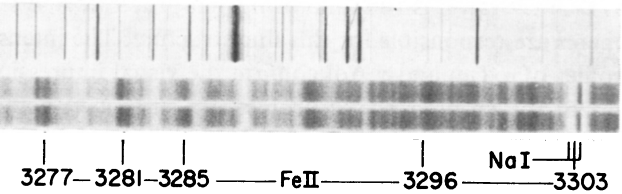

Fig. 5. Part of the near-ultraviolet spectrum of α Ori (M2 Iab). The spectrograms are Ce 14132[1] (1960, Dec. 31) and Pb 8283 (1964, Oct. 22).

The possibility should not be disregarded that related time-variations occur in the reversing layers and photospheres of some red giants. We have already cited some evidence for such effects in the profiles of strong damped metallic lines. Very recently, Eggen (1969) has shown that, among red giants of a given spectral type, there is a considerable temperature range, as indicated by the red-infrared colors. Wilson (1962) has demonstrated similar effects in the red dwarfs. In Eggen's report, HR6128 (Figure 2) appears to be the coolest of the four M2 III stars he has observed – as cool, to judge from the color index, as some M4 III stars. In addition, Eggen confirms an early result by Stebbins and Huffer (1930) that light variation occurs, with amplitude greater than $0\overset{\mathrm{m}}{.}05$, in virtually all giants having black body color temperatures lower than 3400° (spectral type about M2 III). Since colors and spectra are not usually observed simultaneously, time-variations in both quantities may account for a significant part of the dispersion found in the correlations between them.

In all probability the chromospheres of red giants are no more nearly homogeneous than is that of the Sun. In a given star, temperatures, densities, velocities, and magnetic fields are likely to vary appreciably with location and with time. Arguing by analogy with the Sun wherever this is possible, we may nevertheless hope to discover the mean structure of these atmospheric layers; the scales of their irregularities; and the nature of their coupling with the reversing layer below and the circumstellar wind (corona?) above.

For this program, our observational data are still very fragmentary. It is clear that much remains to be done in ground-based spectroscopy and photometry, to elucidate the apparent heterogeneity of these cool stars. In addition, we may now look ahead to observations in the vacuum ultraviolet, of a kind that will facilitate the comparison of stellar chromospheres with the solar chromosphere. The strongest chromospheric emission line in the Sun is Lyman α, with a mean flux at 1 AU of ~ 5 erg cm^{-2} sec^{-1} (Tousey, 1967). At a distance of 10 pc, this flux would amount to ~ 0.1 photons cm^{-2} sec^{-1}. This is the same order of magnitude as the faintest ultraviolet fluxes that have been measured in OB stars by the Wisconsin experiment in the Orbiting Astronomical Observatory (Bless, 1969). In the brightest red giants, the Lyman α flux ought to be of the order of ~ 10 photons cm^{-2} sec^{-1}; and there is the realistic prospect of observing in them a number of the other strong chromospheric lines that characterize active regions of the solar chromosphere. These would include the Mg II D-lines near 2800 Å, C II 1335 Å, He I 584 Å, and He II 304 Å. Scattering by the interstellar medium should represent no significant impediment to such observations among stars that lie within 100 pc.

References

Adams, W. S. and Russell, H. N.: 1928, *Astrophys. J.* **68**, 9.

Aller, L. H.: 1963, *Astrophysics: The Atmospheres of the Sun and Stars*, second edition, The Ronald Press Company, New York, p. 377.

Bidelman, W. P. and Pyper, D. M.: 1963, *Pub. Astron. Soc. Pacific* **75**, 389.

Bless, R. C.: 1969, private communication.

Bumba, V. and Růžičková-Topolová, B.: 1967, *Solar Phys.* **1**, 216.

Deutsch, A. J.: 1960, in *Stars and Stellar Systems*, Vol VI: *Stellar Atmospheres* (ed. by J. L. Greenstein), University of Chicago Press, Chicago, p. 543.

Deutsch, A. J.: 1967a, Reported by H. W. Babcock in *Carnegie Inst. Yearbook* **65**, 139.

Deutsch, A. J.: 1967b, *Publ. Astron. Soc. Pacific* **79**, 431.

Deutsch, A. J., Wilson, O. C., and Keenan, P. C.: 1969, *Astrophys. J.* **156**, 107.

Eggen, O.: 1969, *Konkoly Bull.* No. 355.

Goldberg, L., Müller, E. A., and Aller, L. H.: 1960, *Astrophys. J. Suppl. Ser.* **5**, 1.

Griffin, R. F.: 1963, *Observatory* **83**, 255.

Herzberg, G.: 1948, *Astrophys. J.* **107**, 94.

Johnson, H. L., Mitchell, R. I., Iriarte, B., and Wisniewski, W. Z.: 1966, *Commun. Lunar and Planetary Lab.* **4**, 99.

Kraft, R. P.: 1967, *Astrophys. J.* **150**, 551.

Kraft, R. P., Preston, G. W., and Wolff, S. C.: 1964, *Astrophys. J.* **140**, 235.

Liller, W.: 1967, private communication.

Liller, W.: 1968, *Astrophys. J.* **151**, 589.

Linsky, J. L.: 1968, Smithsonian Astrophys. Obs., *Special Report* 274.

Sheeley, N. R., Jr.: 1967, *Astrophys. J.* **147**, 1106.

Spinrad, H. and Taylor, B. J.: 1969, in preparation. (abstract) 1967, *Astr. J.* **72**, 320.

Spitzer, L. Jr.: 1939, *Astrophys. J.* **90**, 494.

Stebbins, J. and Huffer, C. M.: 1930, *Publ. Washburn Obs.* **15**, 139.

Taylor, B. J.: 1969, in preparation.

Tousey, R.: 1967, *Astrophys. J.* **149**, 239.

Vaughan, A. H., Jr.: 1966, private communication.

Vaughan, A. H., Jr. and Zirin, H.: 1968, *Astrophys. J.* **152**, 123.

Weymann, R. J.: 1962, *Astrophys. J.* **136**, 844.

Wilson, O. C.: 1954, 'The Atmospheres of Giant and Supergiant Stars', in *Proc. Nat. Science Foundation Conference on Stellar Atmospheres*, Indiana University, p. 147.

Wilson, O. C.: 1957, *Astrophys. J.* **126**, 46.

Wilson, O. C.: 1962, *Astrophys. J.* **136**, 793.

Wilson, O. C.: 1966, *Astrophys. J.* **144**, 695.

Wilson, O. C.: 1969, in *Low-Luminosity Stars* (ed. by S. S. Kumar), Gordon and Breach, London, p. 103.
Wilson, O. C. and Aly, M. K.: 1956, *Publ. Astron. Soc. Pacific* **68**, 149.
Wilson, O. C. and Bappu, M. K. V.: 1957, *Astrophys. J.* **125**, 661.

Discussion

Severny: Do you not think that the effect of asymmetry of emission in the K-line that you found in late type-stars could be ascribed to the St. John effect in flocculae which is connected with the predominant downward motions?

Deutsch: The velocities associated with the flow in the chromospheric network are only 1 or 2 km/sec in the Sun. But the width of K_2 is ~ 35 km sec^{-1}. It would therefore suppose that this explanation is not possible, even in the Sun. On Aldebaran, the width of K_2 is nearly 70 km/sec, and velocities as large as this would be quite unexpected.

Feast: Do you know anything about possible light variations in the two M giants that you contrasted?

Deutsch: No. (But any possible light variations would have to be small – less than 0.3 magnitudes, in all probability.)

Glushneva: Some years ago Essipov and myself (Sternberg Institute, Moscow) observed the emission line He I 10830 in the spectrum of Algol. It appeared during the primary minimum of Algol. But it was absent during our observations of Algol in the primary minimum the next year. It is probable that this line could have a chromospheric origin.

Henize: When we are studying mass ejection from high luminosity stars, it is of interest to consider those extreme examples in which the ejected gas has formed a visible nebulosity. I would like to call attention to three stars in the southern hemisphere which probably fall in this category. These are (1) the Of central star of NGC 6164–65 which Dr Feast has already mentioned, (2) AG Car, a P Cygni-like star which is the central star of a ring planetary nebula, and (3) HD 88643 which shows a nova-like spectrum, even though there has been little change in brightness in 50 years, and which lies in a nebulosity the morphology of which suggests that it was ejected from the star. It would be very interesting to have UV spectra of each of these stars.

Gingerich: On Griffins' atlas of the Arcturus spectrum, Hε is very nicely in emission even though the other Balmer lines are in absorption. This arises because the combined opacity of the Ca$^+$ and Hε lines move the depth of formation out into the chromosphere. Does the Hε emission show a correlation with the Wilson-Bappu effect?

Deutsch: I think not. But Wilson has found that the strength of K_2 correlates loosely with the strength of Hε. My plates show that K_2 can vary with time, while Hε shows no appreciable change.