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NOTES FROM OBSERVATORIES

NOTES ON STELLAR SPECTRA

OTTO STRUVE
Berkeley Astronomical Department
University of California

1. *Turbulence in supergiant atmospheres.*—Epsilon Aurigae was one of the first stars in which turbulent motions were detected from the shapes of their curves of growth.[1] More recently K. O. Wright and Elsa van Dien[2] found a strange relation between the average turbulent velocity and the excitation potential for various groups of spectral lines. A coudé spectrogram of ε Aurigae obtained at the Mount Wilson Observatory on March 23, 1951, shows striking differences in the profiles of individual lines. The very strong lines of *Ti* II λλ 3759 and 3761, which originate from the low metastable level a^2F, excitation potential 0.6 volt, have exceedingly sharp shortward edges, perhaps with some shortward emission borders. The profiles are broad, deep, and flat at the bottom. The longward edges slope gently upward, as do the edges of most other lines. These lines are often greatly enhanced in shell stars, such as 17 Leporis, and their profiles in ε Aurigae resemble the profiles observed in shells. The strong *Ti* II lines λλ 3901 and 3914, whose lower metastable level is a^2G, excitation potential 1.1 volt, have an entirely different profile. These lines are slightly unsymmetrical, with their longward edges slightly steeper than their shortward edges. There is thus direct, visual evidence that these two sets of *Ti* II lines are produced in different layers, whose kinematical properties are not the same. The usual curve-of-growth analysis can give only a crude approximation to the true description of the atmosphere. It is probable that the classical, aerodynamical theory of turbulence does not satisfactorily explain the distribution of the motions at various levels of a supergiant atmosphere. The latter must probably be thought of as a network of prominences activated by forces that play no role in the theory of turbulence.

The *Fe* II absorption lines of ε Aurigae are also unsymmetrical, showing in an exaggerated manner the features of *Ti* II λλ 3901 and 3914. There are probably broad, diffuse emission borders on the longward sides of these absorption lines. The *Na* I absorption lines D1 and D2 are conspicuously double: strong and fairly narrow shortward absorption cores appear flanked on their longward sides by shallow broad absorption lines having normal, bell-shaped profiles. $H\alpha$ is a moderately strong absorption line, flanked on both sides by emission borders, the ratio V/R being about 2.

The problem of ε Aurigae was attacked in 1937 by Kuiper, Strömgren, and the present writer.[3] It is now possible to improve the theory in the light of recent advances in astrophysics. The next eclipse should begin about the middle of 1955. But it will be preceded by an "atmospheric eclipse" that may last two or three years, or even longer. It is possible that even now the light of the F-component is passing through absorbing layers of gas which are connected with the I star, or which are moving as independent streams through the system.

2. *The physical nature of a supergiant star.*—Epsilon Aurigae possesses the characteristic features of a supergiant. In particular, the Balmer absorption lines are sharp and narrow. It is therefore surprising to find that the Paschen absorption lines (photographed at Mount Wilson on March 23, 1951) are diffuse and broad. This resembles a result previously announced by W. A. Hiltner[4] for 67 Ophiuchi and several other stars of high luminosity. In ε Aurigae the series can be traced to P 25, but the last four or five lines are exceedingly diffuse and shallow. This remarkable difference between the sharpness of the Balmer series (which can be discerned with certainty to *H* 29, and could probably be seen even further if it were not for some heavy blends with metallic lines), and the diffuseness of the Paschen series is probably caused by the metastability of the 2s level of hydrogen. Moreover, it seems probable that our line of sight penetrates through the outer, semitransparent structure of a maze of gaseous streams at very low pressure, into deeper atmospheric layers of higher pressure, where Stark broadening is appreciable. These deeper layers differ less conspicuously from the reversing layers of dwarf stars than has usually been inferred: the combined absorption spectrum in the photographic region is dominated by lines produced at very high

atmospheric, or perhaps we should say chromospheric, levels. This conclusion probably has a bearing upon the problem of the internal structure of a supergiant star. An appreciable part of the volume of the star, as inferred from the eclipse observations, may not be uniformly filled with gas, but may rather consist of those same prominences or streams the existence of which we inferred from the *Ti* II absorption lines.

3. *Shallow line profiles in W Ursae Majoris binaries.*—The absorption lines of all stars of this class are exceedingly diffuse and shallow. This has usually been accounted for by the Doppler effect of axial rotation and by the overlapping of two displaced spectroscopic components. But can these effects really explain the remarkable weakness of the absorption lines, especially those that are intrinsically strong and broad? Consider, for example, the K line *Ca* II. In the sun, a normal G dwarf, its profile is broad and very deep. If we take the profile from the Minnaert *Atlas*, and treat it in the usual manner with a broadening function corresponding to a width of 3 or 4A—which is ample for the rotational effect—the resulting profile will be almost as deep as the original one—say 85 percent of absorption. But the observed profiles in W Ursae Majoris stars are never anywhere near as deep.

To examine this question I obtained several coudé spectrograms of the W Ursae Majoris variable 44(i) Boötis B, using a dispersion of 10 A/mm. On all these spectrograms, which cover the epoch of conjunction of the two components, as well as that of elongation, the profiles of the *Ca* II lines are very shallow, and the central intensities must be of the order of 60 percent. On one plate the spectrum of 44(i) Boötis A, spectral type G0, was recorded alongside the spectrum of the variable (component B), whose spectral class is given as G2 + G2. Yet, the *Ca* II lines of component A are very much deeper than those of component B.

Several other W Ursae Majoris binaries have diffuse central emission lines of *Ca* II. No such lines are visible in 44(i) Boötis B, yet there must be some kind of emission that overlies the broad absorption line. There is no evidence of any continuous source of emission (such as might come from an unresolved, blue companion). Hence I believe that the binary system must contain vast numbers of emitting *Ca* II atoms whose motions are distributed at random and numerically exceed the velocities of rotation and of the orbital revolution of the stellar components.

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[1] *Ap. J.*, **79,** 409, 1934.
[2] *Contr. Dom. Ap. Obs.*, Victoria, No. 17, 1949.
[3] *Ap. J.*, **86,** 570, 1939.
[4] *Ap. J.*, **105,** 212, 1947.

FLARE-UP OF KRÜGER 60 B

Peter van de Kamp and Sarah Lee Lippincott
Sproul Observatory, Swarthmore College

Krüger 60 A,B ($22^{\rm h}\,24^{\rm m}.5$, $+57^\circ\,12'$, 1900)is a binary[1] with a period of 44.52 years and semi-axis major of $2''.362$; the parallax is $+0''.256 \pm ''.004$. The components have visual magnitudes of 9.9 and 11.4, and spectra of class dM4 and dM4.5e, respectively.[2,3] The visual absolute magnitudes are 11.9 and 13.4, the masses $0.26\odot$ and $0.14\odot$.[4] Since 1931, this star has been photographed at the Sproul Observatory in each year except 1936. The series of 162 plates, with a total of 532 exposures, covers the interval 1931 November 8–1950 October 26. The aggregate exposure time is approximately 17.5 hours. The exposure times range from eleven minutes to twenty seconds, the average being approximately two minutes.

Among the large number of exposures there is one, and only one, on which the faint component equals the other one in brightness; normally it is 1.5 magnitudes fainter. On 1939 July 26 Armstrong Thomas took four plates, each with four exposures of 2¼ minutes' duration. Eastman I-G emulsion and Wratten filter K2 were used. The plates are of good quality, both as to seeing and freedom from guiding error. On the last exposure of the third plate, at $2^{\rm h}\,12^{\rm m}$ EST, the fainter and the brighter components are of equal brightness; the preceding exposure on this plate, taken three minutes earlier, shows no abnormality (Plate VII). On the four exposures of the fourth plate the faint component appears slightly brighter than normal, appreciably so on the first exposure, at $2^{\rm h}\,16^{\rm m}$ EST.