C. *Convective layer in the cepheids*

Eddington studied the question of the convective zone in the cepheids and explained, on the basis of the properties of the zone and the pulsatory instability of this group of stars: (1) the occurrence of the atmospheric pulsations as due to the energy-storing properties of this layer, (2) the existence of a period-luminosity relation, and (3) the occurrence of the well-known phase shift. Here the zone is much extended geometrically but only goes down to about 14000° K. because of the lower temperature gradient.

D. *Convective layer in the long-period variables*

Eddington and others have considered the long-period variables as a natural extension of the cepheids to later types. In particular, they are considered to be the group, among the coolest stars, having the same pulsatory instability as the cepheids. Hence, their pulsations, too, could be attributed to energy storage in the hydrogen convective zone. For these stars the zone is still more extensive and heat-storage capacity correspondingly greater. Using the figures given by Eddington for cepheids and applying dimensional (or homologous) arguments, it can be shown that the layer would give phase shifts greater than $5/4\pi$, and that the convective layer would be much more extensive and reach closer to the surface. The latter conclusion is supported by the recent calculations of Ueno and Matsushima who have found that for M-type giants, the top of the hydrogen convective zone is effectively at the surface of the star (log T a negative value). Thus, we believe that as a long-period variable pulsates, the top of the convective zone is visible to greater and lesser extents, the emission lines arising from recombination in the excess of ions brought up by the rising currents.

Referring to items (1) to (6) in the introduction, each one is readily explainable.

Furthermore, the general observation by Merrill that the strength of emission lines in the spectrum increases with light range, follows from our hypothesis.

Have we any other possible spectroscopic evidence or proof of our contention? We can refer to the case of the cepheids. Joy at Mount Wilson and Jacobsen here, have found a brief transitory, violet-shifted emission in the H and K lines at the phase corresponding to smallest extent of the star, for η Aquilae. Could this arise as we just, for a short while, glimpse the very top of the convective zone in the cepheids?

If our suggestion is found to be correct by further investigation, not only would there be an explanation for the occurrence and behaviour of the emission lines in the spectra of the long-period variables, but, perhaps of greater importance, we would have a means of investigating observationally the hydrogen convective zones of stars.

Discussion

Other possible cases in which the hydrogen convective layer may have spectroscopic significance.

(1) Emission lines in M-type dwarf stars, possibly related to flares of flare stars.

(2) Can *symbiotic* spectra such as those of Z And, BF Cygni, arise from single stars of very late type (TiO bands) and unusually low density in which the convective zone is seen all the time (to a somewhat varying extent, hence spectral and light variations).

15. THE MOTIONS OF THE ATMOSPHERE OF MIRA CETI

By Alfred H. Joy (*Presented by* I. S. Bowen)

The measurement of recent high-dispersion spectrograms of Mira Ceti makes it possible to review and revise some of the conclusions published in 1926 in regard to the atmospheric motions of this well-known long-period Me variable star.

Ninety-two coudé spectrograms, many of which were taken by Merrill, with the 100-inch telescope on Mount Wilson and by Bowen and O. C. Wilson with the 200-inch

Hale telescope on Palomar Mountain, were used to determine the radial velocities indicated by absorption and emission lines at different phases in a number of different cycles of the star's variation. With few exceptions the observations were limited to phases near maximum, from −40 days to +100 days, when the star was bright enough to permit the use of high dispersion.

A dispersion of 10 A./mm., which permits measurement of narrow absorption and emission lines with a mean error for a single line less than 1·0 km./sec. was usually employed, although dispersions as great as 2·3 A./mm. were found useful at some maxima.

The new measures confirm many of the essential features of the previous investigation which were based on greatly inferior observational material. The need for additional observations of the star at times of minimum light is still evident.

Velocities from absorption lines

For a determination of the radial velocity from the absorption spectrum metallic lines of moderate intensity, free from emission edges and the effects of blends, were chosen. The average number of lines measured was thirty-two per plate. A plot of the observed radial velocities against time indicates that a maximum velocity of recession usually occurs near the time of maximum light. The average phase of this maximum is 30 days after the light-maximum and ranges from −14 to +95 days. It is not possible to estimate how much of this variation is due to errors in the velocity-measures and how much to the determination of the time of light-maximum. A small lag in the velocity-maximum as compared with the light-maximum seems rather certain.

The maximum velocity attained varies from cycle to cycle between +60·5 and +68·3 km./sec., and the higher maximum velocities accompany brighter maxima of light. This correlation may be, in part, the effect on the wave-length of the lines of the well-known differences in temperature and spectral type at different maxima rather than to Doppler displacement.

In any cycle the range in velocity during the 100 days preceding or following the velocity-maxima is about 4 km./sec., a value somewhat smaller than that obtained in 1926.

The velocity curve published 25 years ago was formed by averaging the velocities according to phase from different cycles. In view of the irregularities in the velocity-curves for different cycles shown by the more accurate recent observations such a procedure cannot be justified without proper adjustment and the conclusion that a regular pulsation of the whole star's atmosphere in measurable amount is open to grave doubt. If such a pulsation exists it must be of considerably smaller amplitude than previously suggested and superposed upon it are irregular motions of the same order of magnitude which are related to the intensity of the outburst in any particular cycle.

Velocities from emission lines

The velocities determined from the emission lines of neutral iron, magnesium, and silicon seem less affected by irregularities than those arising in the absorbing strata. The accurate measurement of the hydrogen lines is hindered by the distortion produced by overlying absorption, but there is some indication that the behaviour of the hydrogen lines differs from that of the neutral metallic lines. The velocities from the enhanced bright lines of iron clearly are intermediate in velocity between the emission and absorption velocities.

The emission neutral metallic lines are accurately measured and, even though they are few in number at phases preceding and shortly after maximum, they give fairly consistent results at different cycles. While the velocities of recession increase from the time of their first appearance near the time of maximum light until minimum, covering a range of about 10 km./sec., the motion is always outward from the centre of the star *relative to the absorption layers*.

The greatest difference in velocity dark minus bright, is shortly before maximum light when the emission lines make their first appearance. The relative displacement of the bright lines becomes definitely less with time in any cycle. They first appear with a velocity-difference of 16 km./sec. which slows to 7 km./sec. 160 days after maximum. At minimum, the bright and dark lines have little relative motion.

For the hydrogen emission lines, which have been shown to originate in a lower stratum than the absorption lines of the reversing layer, the motions seem more irregular than those of the neutral metallic emission lines, but this effect may be due to less accurate measurement of the hydrogen lines which are often wide, overexposed, and broken up by overlying absorption. At maximum, the hydrogen emission layers seem to be rising at slower speed with respect to the reversing layer than the neutral metallic strata, but at phase +30 days they meet the neutral-line velocity curve and during later phases partake of the same motion.

16. SPECTROPHOTOMETRY OF χ CYGNI

By Yoshio Fujita. (*Presented by* Z. Suemoto)

Spectrograms of χ Cygni have been obtained with the Mills Spectrograph of the Lick Observatory. For the purpose of spectrophotometry, the intensity spots have been given to all the plates using the Mills sensitometer. These spectrograms have been traced by the photo-electric microphotometer at the Yerkes Observatory, and equivalent widths of nearly 215 atomic and molecular lines have been derived.

The curve of growth was constructed by two methods. One is to make use of the observed values of the transition probabilities. The other is to make use of the theoretical values assuming LS coupling. Although Wright has used both values for constructing a single curve of growth, we have used them separately.

(I) *Observed* gf *values*

In this case it is not possible to make a very well-defined curve of growth, because the number of lines available for this method is not very great. As the *gf* values of Ti, Fe and Cr have been derived from laboratory experiments we have tried to make use of these values. Assuming temperatures of 1800°, 2000°, 2200°, 2500°, 2800° we plotted $\log \frac{W}{\lambda}$ against $\log gf\lambda - \frac{5040}{T}\chi$. And by superposing the plots of each element, we got the best fit for a temperature of 2200°

To fix the origin we must compare these plots with some theoretical curve of growth. For that purpose, we have used the theoretical curve of growth calculated by Menzel using the Schuster-Schwarzschild model. It is given by the following equation:

$$\log \frac{W}{\lambda} = \log X_0 \frac{v\sqrt{\pi}}{c} - \tfrac{1}{2}\log(1+X_0) - \frac{\tfrac{1}{2}\log 4\sqrt{\pi}\,\frac{v}{c}\frac{\nu}{\Gamma}}{1+15e^{-2\log X_0}}, \tag{1}$$

where the optical depth at the centre of a line, X_0, is given by

$$X_0 = \frac{N\varpi}{b(T)}\, 10^{-\frac{5040}{T}\chi}\, \frac{\pi\epsilon^2}{mc}\, \frac{c}{\sqrt{\pi}\,\nu_0 v} f, \tag{2}$$

and

$$\varpi f = \frac{\nu}{3R}\,\phi\,\frac{S_s}{\Sigma_s}. \tag{3}$$

Recently, Wright has applied the theoretical curve of growth that Wrubel calculated following Chandrasekhar's method. However, as we have no exact knowledge about the