

Letters to the Editor

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Relation between Temperature and Radius in the Cepheid Variables

THE most important objection raised against the pulsation theory of Cepheid variation lies in its failure to explain the observed phase relation between temperature and radial velocity. In a pulsating star it would appear that maximum temperature and luminosity should coincide in phase with minimum radius. Actually, however, observations of radial velocity show that at maximum light the stellar atmosphere possesses its greatest velocity of approach towards the observer. Eddington has shown that this phase-displacement cannot be explained as due to a lag of energy-flow introduced in the upper, non-adiabatic, layers of the star.

A possible explanation of the phenomenon, however, is that the observed radial velocity, measured as it is from the displacement of absorption lines in the stellar spectrum, is not an index of the radial pulsations of the star as a whole, but that the oscillations of the stellar atmosphere differ in phase by approximately one quarter of a period from the pulsation of the body of the star.

In this case, measurements of radial velocity variation will give an incorrect picture of the radial pulsations, and the stellar radius, that is, the radius of the photosphere, must be determined throughout the light cycle by some other means. The interferometer is at present incapable of producing results of the required accuracy, and more doubtful methods must be employed.

On the assumption that these stars radiate approximately as black bodies, their temperatures and bolometric luminosities can be determined at various phases from the visual and photographic light-curves. The material available for this purpose is extremely scanty, mainly on account of the lack of continued observations based on a standard magnitude sequence. But one extended series of standardised observations was available to me; namely, that on RS Bootis, due to Seares and Shapley¹. From these observations of magnitude and colour index, the bolometric magnitude B , the temperature T , and the radius R have been computed for different phases over the entire light-curve. A harmonic analysis of the resulting curves over a light-cycle gives the following results:

$$B = 10.33^m + 0.53^m \cos(v - 246^\circ) + 0.26^m \cos(2v - 270^\circ) + 0.20^m \cos(3v - 281^\circ)$$

$$T = 7,900^\circ + 2,080^\circ \cos(v - 71^\circ) + 1,130 \cos(2v - 96^\circ) + 950 \cos(3v - 106^\circ)$$

$$R = 0.148 + 0.033 \cos(v - 256^\circ) + 0.019 \cos(2v - 281^\circ) + 0.010 \cos(3v - 288^\circ)$$

It appears, therefore, that maximum temperature and luminosity and minimum photospheric radius nearly coincide in phase.

A further result leading to the same conclusion is that in this star the temperature and radius throughout the cycle satisfy closely the relation

$$R.T = \text{constant,}$$

$$\log RT = -5.95 \pm 0.01.$$

This result has been tested for a number of stars for which the available data are not so complete, and appears to hold, with a larger degree of scattering. The maximum probable error of the mean value of $\log RT$ for any group of observations was found to be eight per cent.

The conclusion of the pulsation theory, therefore, that maximum temperature and minimum radius should coincide, is borne out by the available material. The behaviour of the atmosphere is a problem that still requires theoretical investigation. The relation between radius and temperature found above has not been explained, but further work is being undertaken in this connexion, particularly in the light of the recent paper by Prof. Milne².

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¹ Seares and Shapley, *Astrophys. J.*, **48**, 214; 1918.

² Milne, *Mon. Not. Roy. Astro. Soc.*, **94**, 418; 1934.

Preparation of Protium Oxide and Determination of the Proportion of Deuterium in the Hydrogen of Normal Water

WE have recently prepared specimens of highly purified water almost free from deuterium and have compared their densities with that of similarly purified, ordinary water. The preparations were effected by electrolysis, by the decomposition of water with metals, and also, partly, by fractional distillation.

The relative densities were determined by a float method, which allows comparisons to be made with an accuracy of about 1 part in 10^7 . Of the specimens of water examined, that which has the lowest density should contain at the most a few units per cent of the original deuterium: it is nearly pure 'light water', or protium oxide. It proves to be lighter than purified London and Leeds tap-water by 12 parts per million at 20°C. Our samples of purified London and Leeds tap-water have an identical density, which was made the standard of the comparisons.

From this value and Taylor and Selwood's determination of the density of deuterium oxide, we calculate that the molecular proportion of heavy water in our standard water is 1 in about 9,000; that is to say, there are about 110 atoms of deuterium per million in the hydrogen of the standard water. This proportion is considerably smaller than is usually assumed: it is possible that the further experiments now in progress may cause some increase, but any large change seems unlikely.

Accepting this value provisionally as a lower limit, it is of interest to calculate from Aston's measurements the chemical atomic weight of normal hydrogen. For H^1 Aston has obtained the value 1.00778 on the scale $O^{16} = 16$. Using our value, the atomic weight of normal hydrogen should be 1.00789 on the same scale. Corrected to the chemical scale by means of Mecke and Childs' factor, this becomes 1.00767, whilst if Babcock and Naudé's factor is employed the value obtained is 1.00777. The most probable value as calculated from chemical data is given by Birge as 1.00777, but it is doubtful whether the ratio $H:O$ has ever been determined using gases of normal isotopic composition.

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