PULSATIONS OF VARIABLE STARS

BY

PROF. A. C. BANERJI

(Allahabad University, Allahabad)

ASTRONOMERS are of the opinion[1] that the standard type of a variable star has approximately a spherical symmetry, and any observed phenomenon will look the same from all directions and will not depend on the position of the observer. So the rotational theory of Jeans[2] suggesting that changes in brightness depend on the rotation of a pear-shaped body is ruled out, as a pear-shaped figure has no spherical symmetry. Moreover from spectroscopic observations we find that Cepheid Variables show the strange phenomenon of lurching towards us when they are bright and away from us when they become faint. The accepted interpretation of this phenomenon first suggested by Shapley is that Cepheid Variables pulsate. This theory now holds the field as the best working hypothesis.

Cepheids are also giant stars, and according to Gamow,[3] the pulsation phenomenon observed for Cepheid Variables is due to "instability during the transition from the giant branch into the main sequence". Gamow further opines that "the energy production in ordinary Cepheids is due to hydrogen reactions with lithium, beryllium, and boron (for different values of periods) whereas the only source of energy in the long-period variables is given by the reaction between hydrogen and deuterium".

Eddington[4] considered small radial oscillations of a variable star conforming to the standard model of polytropic index 3, which are symmetrical about the centre and the square of whose amplitude could be neglected. The oscillations were assumed to be adiabatic. Sterne[5] has considered specific cases of small radial oscillations of a star of uniform density and also of a star in which the density varies inversely as the square of the distance from the centre up to a very small distance from the centre within which the density is constant. He neglected the square of the amplitude. It is found that only a sequence of modes of oscillations is possible in these cases.

The author[6] has investigated possible modes of oscillations by retaining the square of the amplitude in the differential equations. He has considered two models of a star, *viz.*, (1) a star of uniform density and (2) a star in which the density varies inversely as the pth power of the distance from the centre (where p is a positive integer excluding 1 and 3), except in a small finite core of constant density surrounding the centre. In both the cases it is found that the amplitude increases and becomes infinite at the boundary of the star, and consequently no mode of radial oscillations is possible. If we assume spherical symmetry for the star, p can have only even integral values; so we can exclude the values 1 and 3. Following the method of the author, H. K. Sen[7] has more recently shown that the solutions of the differential equations would be divergent at the boundary of the star for values of p greater than 3 even if we neglect the square of the amplitude. For $p = 2$ the oscillations would be stable only for a vanishing central core. In this case there will, however, be a singularity at the centre. To avoid this, Sen[7] has taken the following laws of density: (1) $\rho = a - br$ and (2) $\rho = a - br^2$. He has found that the radial oscillations are unstable. So we are led to the conclusion that our pulsating stars should be more or less homogeneous. The necessity for the Cepheids to be more homogeneous than "ordinary stars" has been emphasised by Eddington.[8] According to Chandrasekhar,[9] "the Cepheids and the Cluster-type Variables which occur in the "super-giant" region of the Hertzsprung-Russell diagram must be much less concentrated towards the centre than the typical main series stars". Kopal[10] opines that "with advancing spectral type the central condensations of stars seem rapidly to diminish, and the δ Cephei-F5 stars seem to approach the limit of homogeneity". So there is a unanimity of opinion among the astrophysicists that the Cepheids are more homogeneous and much less centrally condensed than the typical main series stars. Dynamically we have also come to the same conclusion.

The author has shown[6] that a passing star may bring about some sort of resonance phenomenon by increasing the amplitude of pulsation through tidal influence and thereby making the system unstable. The author's Cepheid theory of the origin of the Solar System has already been explained by H. K. Sen in a recent note to *Current Science*.

When a star is rotating about an axis through its centre, it assumes more or less an oblate spheroidal form. It has been found that a sequence of modes of small radial oscillations is possible for a slowly rotating oblate spheroidal Cepheid of small ellipticity if we retain terms only up to the order of the square of the angular velocity.[7] If due to loss of radiant energy the Cepheid begins to contract, the angular velocity would increase and the star would assume a more and more oblate shape causing an appreciable departure from homogeneity. The amplitude would increase, and the oscillations would become unstable. The Cepheid would then break up by fission[11] into two comparable, approximately homogeneous masses. This would give birth to a double star system. On the other hand, we have seen[6] that a passing star due to its tidal influence would help in the formation of a planetary system out of a pulsating Cepheid variable. It is significant that Kopal's investigations[12] have led him to conclude that "the components of a new-born binary are homogeneous or nearly so".

1 Merrill, P. W., "The Nature of Variable Stars." 1938, p. 116.

2 Jeans, J. H., "Astronomy and Cosmogony," 1929, p. 388.

3 Gamow, G., *Phys. Rev.*, 1939, **55**, 718.

4 Eddington, A. S., "The Internal Constitution of the Stars," 1926, pp. 186–208.

5 Sterne, T. E., *M.N.*, 1937, **97**, 582.

6 Banerji, A. C., "Instability of radial oscillations of a variable star and the formation of the planetary system," *Trans. Nat. Inst. Sci. India.* (In the press.)

7 Sen, H. K., "Radial oscillations of a variable star'; "Adiabatic pulsations of the Cepheid variable"; and "Radial oscillations of a slowly rotating star". Communicated to the *Nat. Acad. Sc. India.*

8 Eddington, A. S., *M.N.*, 1932, **92**, 480.

9 Chandrasekhar, S., *ibid.*, 1936, **96**, 656.

10 Kopal, Z., *ibid.*, 1938, **99**, 38.

11 Jeans, J. H., "Astronomy and Cosmogony," 1929, p. 266.

12 Kopal, Z., *M.N.*, 1936, **96**, 862.

SUGAR INDUSTRY OF INDIA, 1939–40*

THE year 1939-40 was an eventful one for Indian Sugar Industry. An excellent crop, a higher ruling price for sugar, and a longer duration of milling season in the U.P. and Bihar resulted in a high record for sugar production. The fixation of a minimum selling price for all grades of sugar by the Indian Sugar Syndicate and a poor demand for sugar in the early part of the season led to the accumulation of abnormally heavy stocks in factory go-downs and the situation was not eased until the Government withdrew the recognition of the Syndicate. Subsequently, however, the Syndicate was re-recognised subject to some conditions. The Syndicate's action in lowering the basic and the selling prices, and the Government's announcements regarding the restriction of output in the year 1940-41 improved the demand for sugar. During this season a sliding scale connecting the cane prices with the prevailing sugar prices was also instituted.

The total area planted with sugarcane this year was 3,619,000 acres which shows an increase of 16 per cent. over the previous year's planting. Leaving Bihar, Assam, Orissa and the C.P., the weather conditions in other cane tracts were not quite favourable.

Out of a total of 158 sugar factories existing in India, 145 worked during the season 1939-40 and produced 1,241,700 tons of sugar which is the highest record production for the industry in India, the previous record being 1,111,400 tons in 1936-37. The short production of sugar in 1938-39 necessitated very heavy imports from Java which took place in the official year (April-March) 1939-40. The quantity of sugar available for consumption in the year under review has been estimated at 1,074,000 tons.

The net production of gur in India in 1939-40 was 2,441,000 tons which is about 15 per cent. in excess of the production in the previous year. The production of molasses in the country was 485,300 tons by cane factories, 16,900 tons by gur refineries and 125,000 tons by khandsaris. Therefore the total production was about 625,000 tons as against 349,000 tons in the previous year.

The rate of excise duty of sugar was raised from Rs. 2 to Rs. 3 per cwt. and correspondingly the import duty on sugar became Rs. 9-12-0 as against Rs. 6-12-0 in the previous year.

The chief feature of Indian sugar industry at present is the large extent of Government control to which it is subjected specially in the U.P. and Bihar. In these provinces the industry has voluntarily submitted itself to this control. In almost all important sugar-producing countries this industry is subject to some form or other of Government control but in the U.P. and Bihar this control is exercised on established lines that have been tried with success elsewhere.

G. GUNDU RAO.

* Review by R. C. Srivastava, *Supplement to the Indian Trade Journal*, May 7, 1942.