inland markets or to satisfy with the limited quantities of these fish the demands of the potential fish-eating population. Whenever cold storage is spoken of, people only think about table-fishes, but publication of statistics like the report under review should open the eyes of capitalists and business people to the possibilities of developing a very virgin field; such a development would in addition to assuring a handsome return to the business people and the fishermen mean better and more balanced food for the poorer classes in the inland areas.

V. P. A.

GALACTIC DYNAMICS*

Polytropic Gaseous Configuration

A POLYTROPIC change of gaseous matter is defined to be a quasi-statical change of state brought about in such a way that specific heat remains constant during the entire process. A quasi-statical change is conducted infinitely slowly so that the state of the system at any instant may be regarded as that of equilibrium. It is found that if a gaseous configuration is polytropic the law $p = k\rho^{1+\frac{1}{n}}$ is satisfied where k and n are disposable constants, p being the pressure and ρ the density at any point of the gaseous mass. In the absence of any disturbing factors, an isolated non-rotating mass of gas will settle down into a spherical distribution. If the gaseous mass rotates with a small angular velocity ω the configuration will become slightly oblate. Assuming that ω is small and uniform throughout the mass, Milne, Ziepal, and Chandra Sekhar have tried to specify completely gaseous configurations for various polytropic models. P. L. Bhatnagar has examined the case of a rotating gaseous model for which ω, though small, is not uniform throughout but varies according to a certain law depending on the distance from the axis of rotation.

Chandra Sekhar has also considered the double star problem. He has found that the distortion of a "double-star" component is the same as if it is rotating like a rigid body about its own axis with the angular velocity ω and then tidally influenced by the other component at a distance r from its centre of gravity, the two effects being simply added.

In the case of eclipsing binaries, all the necessary data are available from observation, and it is found that the density condensations of these stars as calculated from Chandra Sekhar's theory come out to be rather higher than those obtained from direct interpretation of observed facts.

Kopal has attacked the problem of rotating gaseous configurations by an essentially different method, the starting point of his investigations being Clairaut's original papers which were published more than a century ago.

Eddington has discussed the case of non-uniform polytropic index n. He maintains that "all possible spherical distribution of matter can be described by a varying polytropic index n", which he has defined by the equation

$$1 + \frac{1}{n} = \frac{d \log p}{d \log \rho}$$

where p is the pressure and ρ the density at any point of the configuration.

Spiral Nebulæ

Telescopes reveal that about 97 per cent. of extra-galactic nebulæ have regular forms ranging from globular nebulæ and ellipsoidal figures to a series of spirals with open arms. These nebulæ can be divided into two main classes, *viz.*, elliptical nebulæ and spiral nebulæ including both normal and barred spirals. Several interesting theories have been suggested to account for the shapes of spiral nebulæ, but none of them has yet been able to give a satisfactory explanation for the formation of spiral arms. It is believed that in the outer regions of the equatorial extensions of the spiral nebulæ condensations in the shape of star clouds were first formed.

Jeans has examined the series of configurations which would be assumed, under increasing rates of rotation, by a quantity of matter consisting of an atmosphere of negligible mass surrounding a massive point nucleus. If $\bar{\rho}$ is the mean density of all matter inside the bounding surface of the configuration, and if $\bar{\rho}$ is greater than its critical value ρ_0 given by $\frac{\omega^2}{2\pi\gamma\rho_0} = 0{\cdot}36$, it is possible that surplus matter will stream out in the equatorial plane. The main defect in Jeans' theory is that he discards the possibility of star clouds existing in his model for nebular configuration, and this is not borne out by observation. A short time scale for the age of stars situated in the spiral arms of the nebulæ will solve many difficulties, but Jeans' theory requires that the time scale for the age of such stars should be long.

Brown has assumed that before the arms of a spiral nebula were formed it had been a highly flattened homogeneous ellipsoid of revolution. Some galaxies passing rather close to the homogeneous nebula might have caused perturbations which brought about minor variations in its density and ultimately led to the formation of spiral arms. To make allowance for the minor variations in the density, Brown superposes rather arbitrarily on the uniform density a small additional density consisting of a periodic term. He thus gets a spiral form and suggests that the spiral formation is a periodic phenomenon. There is no evidence, as yet, which supports the above suggestion about periodicity.

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* Summary of three lectures on "Galactic Dynamics" delivered by Professor A. C. Banerji (Allahabad University), under the auspices of the Lucknow University, February 15–17, 1940.

Vogt and Lambrecht have assumed that almost the whole of the mass of the spiral nebula is concentrated in the nucleus, and that there is a cosmic repulsive force proportional to the distance from the centre of the nucleus in addition to the gravitational force of attraction. It may be mentioned here that there is no justification for assuming a "Cosmic Force" of repulsion in Classical Mathematics. It is also not reasonable to suppose that the whole mass of the configuration is concentrated in the nucleus. Moreover Vogt's theory cannot give any cogent reason for the existence of two arms of a spiral nebula. Lambrecht attributes the formation of the pair of arms to encounters.

Lindblad, in his earlier investigations, has assumed a configuration which consists of a spheroidal galaxy of stars of uniform density having a small condensed nucleus at the centre. Any tidal action on it will produce perturbations and may lead to spiral formation. Lindblad has worked out the condition necessary for such formation of spiral arms. He has found that if the mass of the nucleus is small, there is greater possibility for formation of these arms.

From spectrographical observations we find that there is a fairly uniform angular velocity of rotation in the central part of a nebular configuration, and in the outer less dense regions the angular speed is far less than in the central part. Lindblad, in his later investigations, suggests that the rapid decrease in the speed of rotation as we proceed outwards from the central core may produce instability and cause the formation of spiral structure.

Lindblad maintains that for the formation of the observed spiral arms, considerable flattening of the spheroidal configuration corresponding to the meridional eccentricity 0·96 at least, is necessary. He has shewn that in the outer regions of the configuration, local condensations are likely to form. He suggests that if there be an encounter between two such condensations near the edge of the configuration, one of the condensations being ejected out of the system may depart in a spiral orbit. Recent investigations by Plaskett and Pearce about our local galaxy tend to show that "the whole galactic system is immersed in a gaseous substratum consisting of atoms of various elements ... The separate atoms, while obeying gas laws, participate in a rotational movement around a distant central mass in galactic longitude 325°."

"The observed rotational accleration seems to be same as that for the stars so that the atoms are not subjected to any appreciable radiation pressure from the central mass."

Depending on the above conclusions, Banerji, Nizamuddin, and Bhatnagar have assumed a model which consists of a rotating spheroidal central mass of finite dimensions and uniform density surrounded by a spheroidal structure of rotating compressible gas having variable density. They have also investigated the condition necessary for the formation of spiral arms. The size of the central mass is taken to be small compared to that of the outer boundary of the gaseous structure. If the angular velocity is small, the outer boundary of the gaseous configuration would differ little from a spheroid.

They have found that for spiral formation, the equatorial diameter of the central nucleus in the case of our Galactic System cannot be greater than 35 parsecs and in the case of Andromeda nebula cannot be greater than 600 parsecs.

Eddington's theoretical researches, and Plaskett and Pearce's observational investigations show that interstellar space (within the confines of our Galactic System) is not empty but is filled with a highly rarefied gas of substantially *uniform density*. Bearing this point in mind, Banerji has investigated the condition necessary for the formation of spiral arms in the equatorial plane of a rotating gaseous configuration of uniform density which surrounds a spheroidal homogeneous mass of incompressible material of relatively small size. It is evident that the density of the gaseous structure can only be uniform if the angular velocity ω is variable and satisfies a certain relation. Banerji has investigated this relation and has obtained the condition necessary for the spiral formation in a suitable form.

It is found that for spiral formation the equatorial diameter of the inner core in the case of our Galactic System must be less than 270 parsecs, and in the case of Andromeda nebula must be less than 560 parsecs.

The Origin of the Solar System

The planetesimal theory of Chamberlin and Moulton and the tidal theory of Jeans and Jeffreys regarding the origin of the solar system undoubtedly possess several distinct advantages, but they are also open to certain grave objections. In both these theories the sun and a passing star narrowly missed each other. It seems to be very improbable, if not almost impossible, that so much angular momentum as is observed in the planets could be put into the planetary matter when it was ejected from the sun during its (sun's) encounter with another star. Moreover, the formation and arrangement of satellites cannot also be satisfactorily explained by the above theories.

Russell has considered a number of new lines of attack on this problem. One of the theories, *viz.*, the sun might have been a member of a binary star having a companion much smaller than itself and that a collision between the companion and a passing star broke the former into fragments from which the present planets were formed, was examined by Russell critically. He abandons this theory as unpromising in view of the fact that it cannot explain satisfactorily how the companion of the sun was got rid of and how the terrestrial planets were ultimately formed. On the other hand, Lyttleton maintains that as the result of a close tidal encounter of a component of a double-star with an intruding star of average mass and velocity (at infinity) the binary system can be disrupted and all the three stars can subsequently escape from each other. He further asserts that under favourable conditions a portion of the tidal or planetary ribbon can be captured by the non-colliding component of the binary system and ultimately condensed into planets. He also suggests that "later encounters between pairs of planets while in the liquid state give promise of an explanation of the formation of satellites". Luyten and Hill have criticised Lyttleton's theory and have pointed out that the two colliding stars would retain about 94 per cent. of the length of the planetary ribbon and so only 6 per cent. of the length of the filament would become available for possible capture by the sun (the non-colliding component of the binary system) and subsequent formation into planets. Luyten has further pointed out that in order to capture even a part of the filament the sun must have been moving parallel to the filament for some considerable time and must itself have suffered a close approach or collision with the intruder. In the above case if the intruding start is more massive, the sun itself would be captured by it.

In a recent paper, Bhatnagar has shewn mathematically, that if there was collision between the sun's companion and a passing star, the distance between the sun and its companion would have been so much reduced that a second collision between the components of the binary system as well as between them and the intruder could not have been avoided. In the case of close approach between two stars without actual collision, Bhatnagar has calculated possible lengths of maximum tidal elongations and shewn conclusively that even at the instant of closest approach, no planetary ribbon joining the two stars is possible. It is evident therefore that so far no satisfactory theory about the origin of planets and satellites has yet been developed mathematically.

MANUFACTURE OF SCIENTIFIC INSTRUMENTS

BY

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THE manufacture of scientific instruments is an item of national importance, inasmuch as it occupies an eminent place in our scientific and engineering developments and corresponds to the manufacture of heavy chemicals in all chemical and allied industries. There is, of course, this important and obvious difference that the number of different heavy chemicals is small while the number of different kinds of scientific instruments is almost innumerable. The name *scientific instrument* indicates a classification suggesting that it represents a type of instruments employed in scientific pursuits in educational, industrial and research laboratories. Instruments employed in public utility services, like the telegraph, the telephone, motor cars, aeroplanes, air conditioners, etc., are also invariably scientific although they are not necessarily used in scientific institutions.

The present position as regards scientific instruments in this country is such that they are finding more and more employment in all spheres of life. With the spread of education, leading to higher standard of living and rapid industrial developments, the employment of scientific instruments is increasing rapidly. This is probably a good sign, suggesting progress, but unluckily the development is one-sided and somewhat unreliable, unless India can safely depend on manufacturing all the requisite instruments in this country and out of local raw materials. There have been and there are, even now, some enterprising concerns that endeavour to manufacture scientific instruments but the sum total of all such attempts is yet only a drop in the ocean. It would not be an exaggeration to say that the demand on scientific instruments and appliances is almost wholly met from articles of foreign manufacture.

The scientific instruments industry must occupy a peculiar position. It may not catch the imagination of the lay public, but it must be the special care of the industrialists, educationists and researchers, who should uniformly champion the cause of local manufacturers, because such a frame of mind alone can give proper encouragement to enterprising designers, inventers and mechanics. It should also be the anxiety of all industrial and scientific institutions to foster the spirit of depending, as far as possible, only on appliances of local manufacture.

There are already in existence about a score of manufacturers of scientific instruments in India, but most of them devote themselves to the construction of just those few articles that are usually employed in educational institutions. Their products are good and they serve a useful purpose, but the majority is still dependent on imported raw materials or ready-made components. In spite of this, the industry has made considerable progress. The passage through the assembly stage is unavoidable and yet very important; because it helps to train up workmen and develop confidence in their skill; it also gives the manufacturers time and opportunity to look about for local raw materials while the finished product, built out of foreign components, is becoming popular and attractive.

The other important question is as regards organisations which should control:

(i) the training and supply of skilled labour;
(ii) the testing and grading of scientific instruments; and
(iii) the marketing of the products.

Skilled labour for the various jobs in a scientific instrument maker's workshop is not easily available, and there is also no proper provision for training mechanics. Special faci-