

THE ORIGIN OF THE SOLAR SYSTEM

BY

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THE problem of the origin of the solar system has defied all attempts at solution and it has been, for over a century, an outstanding challenge to mathematicians. Once it was considered to be essentially a hydrodynamical problem and it inspired a series of researches by Tchebycheff, Liapounoff, (Sir George) Darwin, Poincare, Jeans and others. With the accumulation of data the centre of enquiry shifted to the dynamical features of the system. And now, with our knowledge of the internal constitution of stars, we find the problem much more complicated than what it was originally understood to be.

WHAT DO WE MEAN BY THE SOLAR SYSTEM?

The solar system consists of the day star, that is, the sun, nine major planets with their twenty-eight satellites, over fifteen hundred planetoids and thousands of comets, not to mention the countless meteors and meteorites that cross the earth's way in the skies. The satellites move about their respective planets and the planets, planetoids and comets about the sun. The sun itself moves with the velocity, 300 km. sec.⁻¹, relative to the centre of the galaxy.¹⁶ But we are not concerned here with the solar motion as the system is practically isolated from the rest of the universe. Light does not take more than a few hours to go from one end of the solar system to another while the journey from the nearest star to the sun is a matter of no less than four years. The most striking feature of the isolated system is that while most of the matter is concentrated in the sun, most of the motion is associated with the rest. The solar mass is 744 times the mass of the rest although the sun's share of the total angular momentum of the system is hardly three per cent. It is also noteworthy that the central body, the sun, is self-luminous while the planets and satellites which represent practically all the matter and angular momentum of the rest, are opaque bodies reflecting the solar light. By the solar system we mean therefore a luminous mass, a star, surrounded by dark bodies, much

smaller in weight, moving fast enough to make the distribution of matter and motion extremely uneven as stated above.

IS THERE IN THE WHOLE UNIVERSE ONLY ONE SYSTEM LIKE THE SOLAR SYSTEM?

The tower of observation rises high above the mansion of theory. Whenever, therefore, observation gives one answer to a scientific question and theory another, the former is regarded as right and the latter indisputably wrong. Suppose that the nearest star,¹⁴ Wolf 424 (?), possesses a planetary system like ours. Can the planets at that distance from us be visible at all on the earth? Russell¹⁵ replies in the negative adding that they won't be visible through the most powerful telescope that we have or that we can construct. Observation cannot therefore provide a decisive answer to the question mooted above. Recourse is now had to theory and we stalk the question by enquiring how a system such as the solar system could originate in a primitive world of stars and nebulae. If we trace the history of the solar system backward, along the lines of evolution, we may arrive, at a fairly distant epoch, at diverse sets of plausible circumstances in which case we will conclude that there are many such systems in the universe. If, however, the circumstances as demanded by the theory at that epoch are highly improbable, in the then state of the world, the solar system will be regarded a freak of nature.

The matter is not however so simple. As E. W. Brown¹ has shown it is not possible to trace the evolution backward beyond a hundred million years without applying the complicated relativistic correction. According to the theory of space and time to which we are committed by our knowledge of gravitational and world situations a small primeval universe of matter became unstable and broke up into stars and nebulae some two thousand million years ago. Moreover, the geologist puts the age of the earth at several thousand million years on the evidence of uranium, thorium, helium

and lead in rocks. So we cannot ignore the relativistic correction in the treatment of the evolution of the system. It is required that on no account must theory outrun the limits of observation. If it is impossible to settle by observation whether there is only one solar system or more theory must give an equally ambiguous decision about the probability of the genesis of a planetary system in a world of stars and nebulae. The failure of the theoretical investigation is, therefore, a foregone conclusion. In non-trivial mathematics we reach a substratum of propositions that cannot be demonstrated, which are couched in terms that cannot be defined. Similarly, an investigation of trivial mathematics rests on some assumption that cannot be justified, which relates to circumstances that are never fully understood. It has been seriously suggested by some that the stars, the nebulae and the planetary systems (one or many that there are) must have all come into existence about the same time. This suggestion merely drives the required explanation further away into the unknown and the investigator who accepts it finds himself in a blind alley. An obvious implication of the suggestion is that the cosmic upheaval which was responsible for the genesis of millions of stars and nebulae might have produced numerous solar systems also.

The theoretical worker cannot visualize the detailed processes in the world catastrophe leading to the creation of stars, nebulae or the solar system. Under these circumstances it appears more probable that many systems possessing the two patent characteristics of the solar system were created. These are first thoughts; a closer scrutiny of the system reveals a number of regular features which deserve to be noted here.⁶ (1) Most of the matter outside the sun in the system is shared by the major planets all of which move practically in the same plane. (2) The solar axis of spin is nearly perpendicular to this plane. (3) Most planets and a majority of the satellites spin in the same sense as the sun, there being only nine or ten satellites with retrograde motion.² (4) The satellite systems of Jupiter and Saturn are miniature models of the solar system, the nearer satellites moving in the neighbourhood of the equatorial plane of the central planet. (5) The orbits of most of the planets are nearly circular. (6) The mean distances of the planets from

the sun and of the satellites from the corresponding central planets follow a simple empirical law which is a generalization of Bode's law.¹³ All these regularities are not just an aftergrowth achieved in the long period of evolution after the genesis of the system. The problem of the origin of the solar system is really to infer how these and other regular features came into being and developed. The hypothesis of a world catastrophe does not help us to solve the problem.

As we will presently see other theoretical lines of investigation are possible. Whatever answer they provide to the question under consideration will attain the status of a theoretical speculation only. This is due to our inability to settle the question by observation. In spite of this the theoretical study of the problem is vigorously pursued because, evidently, "the pursuit of truth is more precious to man than truth itself".

Those who reject the theory of a world catastrophe start with the assumption that the planets are the offspring of a star. Modern spectroscopic and geological research supports this assumption. The theories that are built upon this basis are not less objectionable than that of the world catastrophe. But they have one distinguishing characteristic which is that they make the birth of planets a very rare phenomenon. Thus neither theory nor observation can satisfactorily settle whether the solar system is a common or an uncommon feature of the universe.

IS THE SUN THE PARENT BODY?

Having decided to explore the possibility of the planets being born of a star one would examine whether the sun itself is not the parent body. Luyten,^{7, 8, 9} who has considered the question very thoroughly believes even to-day, on account of the regular features of the solar system, that no extraneous disturbing agent was responsible for its origin. This probably means that according to him, the sun is the parent body. Babinet's calculations³ of 1861, revised in later years by others, definitely show that a star having the mass and the angular momentum of the solar system and the density of the sun cannot break up through instability. The ruling conceptions about the internal constitution of stars and their energy generation do not warrant that a G-type dwarf like the sun was ever a variable star or a nova

or thermodynamically unstable in any way, at any time, in the past. Even if we concede the possibility that the sun was unstable once it will still require proof that its fission has led to the planetary system with all its features. The simpler problem about the origin of binary stars has not yet been solved in this way and experts are of the opinion that fission may have nothing to do with it. Even in the matter of the earth-moon system the idea of fission was finally abandoned, about twelve years back. The prevalent view is that mere mechanical or thermodynamical instability in the sun, in the absence of an outer influence, could not be a sufficiently effective agent for the genesis of the planets. Apart from that, even if a break-up occurred, as suggested, it is difficult to see how planets with their shapes, sizes, momenta and orbits were formed in this manner.

Attempts have been made to explain the formation of planets out of the solar material under the gravitational influence of a visiting star. There is the American theory of Chamberlin and Moulton which has been ignored in Great Britain and there is the British theory of Jeans and Jeffreys which has been ignored in America. While the two theories differ in their descriptive contents, in all essential respects and in all crucial matters, both have many identical weaknesses and fail equally miserably. Granted that matter is pulled out of the sun under the attraction of the visiting star we cannot decide whether the encounter should be too close or fairly distant. For unless the encounter is sufficiently distant the planets formed out of the ribbon of matter stretching from the sun to the star cannot have the large angular momentum per ton that they have. On the contrary, it seems that unless the encounter is very close sufficient matter cannot impinge upon the condensing planets to give them the required spin about the axis. These conflicting demands of the theories have rendered them invalid although the formation of a ribbon is suggested by the order of sizes and masses of the planets and their numbers of satellites from Mercury to Pluto. There is an additional difficulty also regarding the condensation of the material in the ribbon into planets. At the high stellar temperatures, it is not at all clear, how the hydrogen of the ribbon failed to escape from the weak forces of gravitation and how the con-

densations were formed.^{8,12} But then probably the very smallness of mass of the planets suggests that a good deal of the material escaped in the process of condensation. It is argued that hydrogen may have been reacquired later by accretion.

Thus it appeared that the formation of a ribbon was an essential stage in the genesis of the planets. It became also evident that a collision of the type envisaged by Jeans, Moulton or Jeffreys⁴ was not responsible for the ribbon. So now arose the theory of Russell and Lyttleton⁹ that the parent-body of the planets was some other star, out of which a ribbon was drawn by a very massive star in a near collision and that the sun, which happened to be in the neighbourhood, captured most of the material of the ribbon.

LYTTLETON'S THEORY

Lyttleton has to consider the three-body situation of the gravitational problem. Following Jeffreys he admits explicitly that, as precise details could not be given, he has confined himself only to the orders of magnitudes. He uses the three integrals of energy, momentum and angular momentum and considers a redistribution of the quantities as a result of the encounter without violating the principles of conservation. It is nowhere proved that such a redistribution is actually permitted by the equations of motion. The circumstances⁸ under which the redistribution as devised would actually occur are not known. It^{11, 12} is so arranged that the very massive star (of mass $8\odot$) collides with a star heavier than the sun (of mass $2\odot$) and snatches it away under its gravitational attraction. The sun is supposed to be sufficiently away from the scene of action so as not to be captured by the massive star. But it happens to be sufficiently near also to attract portions of the ribbon on which the gravitational actions of the others are balanced. It is argued, to make the situation more plausible, that the sun was a double star and that the companion, which was more massive, was enticed away by a visiting star. The planetary system is the relic of this encounter. This was described as 'the enticement theory' of the solar system by Knox-Shaw.

This theory has many features of an unsatisfactory nature. That the visiting star should be moving in the plane of the binary,

that its mass should be $8\odot$ or more while that of the sun's companion is about $2\odot$, that the sun should be very favourably situated to gain large chunks of the ribbon without falling into the gravitational trap of the visitor, that the ribbon should condense into planets with a large supply of hydrogen when all hydrogen is expected to escape, at the high stellar temperature, on account of the smallness of the gravitational attraction—all these make one feel that if the theory is right, "the solar system has narrowly escaped not coming into existence".⁵ Lyttleton's energy manipulations require the visiting star to be one like Capella A. Such stars appear to be very rare in space and they are not the right sort, on account of the low density, for getting considerable matter ($\cdot 05\odot$) into the ribbon. Luyten⁷ has, therefore, described this theory as 'astrophysically objectionable', 'dynamically untenable' and 'superlatively improbable'. We cannot say that it is dynamically untenable. But we believe that the onus is on the author to show under what circumstances it is tenable. Lyttleton has expressly avoided this, as the task undertaken by him is just to show that a solution on these lines exists.

Are we to reject Lyttleton's theory because the circumstances of the collision are highly improbable? We are not inclined to do so until another solution is in sight. But let us see what the solution offered by this theory means. Our original problem was to account for the curious regularities of the solar system. Some of them we have been able to trace to certain unusual circumstances of the origin of the system. The mysterious element has not been removed as a result of our enquiry; only its centre of gravity has been shifted. It must be admitted that when the enquiry was started by Kant or Laplace the object was to trace all the mysterious elements of the situation to general laws and unexceptional initial conditions. Apart from all this, we find that the theory is not applicable to the satellite systems of Jupiter and Saturn. Intrinsically there is nothing wrong in assuming

similar exceptional circumstances to prevail for the genesis of these systems. Once we have decided to entertain the 'mystic' element in our explanations, they are not hard to discover.

WHAT NEXT?

It looks as if the scientist has been blundering along like Dr. Watson in this investigation. We want a Sherlock Holmes to enter upon the scene. Probably he has been there already. But he has not yet discovered his patent clue, 'the cigarette ash', which may be anything in this about meteorites, planetoids, retrograde satellites, stars or even the comets that are so different in every way from the planets. Who knows? We may have to solve the problem of the double stars first. Our knowledge on the various astronomical fronts has advanced so rapidly in the last ten years and so many of our scientific views have been upset that the much needed clue may be found in a strange form and in an unexpected quarter. Until that happens we have to examine every bit of evidence at our disposal, by itself, and in all possible situations that are relevant.

¹ Prown, E. W., *U. S. Nat. Res. Council*, 1931, Bulletin 80, Part 5.

² Hunter, A., *Science Progress*, 1939, **33**, 760.

³ Jeans, Sir J. H., *Astronomy and Cosmogony*, 1929, p. 395.

⁴ Jeffreys, H., *M. N. R. A. S.*, 1932, **92**, 890.

⁵ Jones, H. S., *Life on Other Worlds*, 1940, 234.

⁶ Luyten, W. J., *Observatory*, 1938, **61**, 83.

⁷ —, *Ibid.*, 1940, **63**, 72.

⁸ —, *M. N. R. A. S.*, 1939, **99**, 692.

⁹ Lyttleton, R. A., *Ibid.*, 1936, **96**, 559.

¹⁰ —, *Ibid.*, 1938, **98**, 356.

¹¹ —, *Ibid.*, 1940, **100**, 546.

¹² —, *Observatory*, 1940, **63**, 206.

¹³ Narlikar, V. V., *Phil. Mag.*, 1931, **12**, 67.

¹⁴ *Observatory*, 1938, **61**, 167.

¹⁵ Russell, H. N., *The Origin of the Solar System*, 1935, p. 3.

¹⁶ Smart, W. M., *Stellar Dynamics*, 1938, p. 369.