

space—any mass escaping during, or immediately after, the impact would be exposed to a much higher attraction on escaping than on the return, because, on leaving them, the three bodies would be exercising attraction upon the body; but, on the return journey, there would be only one body. Thus its aphelion may not be near so distant as that of a body that had only the central mass acting on it in its outward journey; but this will not necessarily affect the eccentricity, but may do so in certain cases.

ART. XIV.—*The Origin of the Solar System.*

By Professor A. W. BICKERTON.

[Read before the Philosophical Institute of Canterbury 5th August, 1880.]

THE order displayed in the structure of the Solar System strongly suggests the idea that it must have originated in some single event. Laplace has calculated that the probability of such a system having originated in a common cause, is not less than four millions to one. It is evident, therefore, that its origin is a legitimate subject for scientific speculation, and in order to account for the peculiarities of the motions of the planets and satellites, Laplace himself suggested the now well known hypothesis of the release of nebular rings and their subsequent coalescence. This theory has found many supporters, but when it is examined in the light of the doctrine of the conservation of energy and the dynamical theory of gases, so many difficulties present themselves as to throw great doubt upon it, in fact, as Denison says, it has been so little accepted by English mathematicians that it has scarcely been discussed, and Faye has recently given his opinion that it must be given up. A modification of the theory is offered in Newcombe's "Astronomy,"—it is that the release of rings commenced on the inside.

I hope to examine a number of the difficulties of these theories in a future paper. Proctor has discussed the probability of the system having been formed by the coalescence of an immense number of meteorites, and to this hypothesis there appear to be fewer objections than to the other two. In fact it is highly probable that such an action has aided materially in giving symmetry to the system. But as the sole agent in the formation of the solar system these suggestions have two great objections:—the extreme slowness of the sun's present rotation; and the irregularities in the system, such as the eccentricity of the orbits, the inclinations of the axes and orbital planes, and retrograde motions. It cannot therefore be considered that a satisfactory solution of the problem has been given, and it is probable from its extreme

difficulty, that nothing but a nearer and nearer approximation is to be expected. It is this opinion that must be my apology for bringing before the society the somewhat crude suggestions of this paper.

Each of the hypotheses already mentioned assumes a previously existing rotating mass, extending beyond the orbit of Neptune. The papers already before the society distinctly show that a tangential collision between two cosmical bodies could certainly develop such a mass. A paper now in preparation on the origin of cosmical rotation is intended to exhibit some of these points more clearly, so that should future investigation ever reconcile the present difficulties of either of the above theories and cause their ultimate acceptance, there will still remain a probability that the original rotating mass was produced by the "partial impact" of two cosmical bodies.

The common direction of all the planets in their orbits, and the common direction of rotation of most of them, and the slight inclination of their orbital plane, unmistakeably point to a common origin of the sun and planets; while the eccentricity of the orbits, the slight difference of the orbital planes, the inclination of the axes and of the orbital planes of their satellites, and the retrograde motion of some, all point to some independent specific structure for each planet due to motions and structure existing before the common constructive agent had become effective, and not unlikely independent of that cause.

At the present stage of the enquiry there appear to be only two varieties of impact which do not possess insuperable objections, the most probable being that the solar system was formed by a moderately complete impact, and subsequent entire coalescence, of two very rare bodies possessing considerable proper motion, each of which had rotating around it in varied azimuths a number of bodies such as constitute the zodiacal light; but among them were some of planetary dimensions. It is not difficult to show how such bodies themselves may have originated.

This impact may have resulted in the whole of the two bodies spreading out into a large disk-shaped rotating nebula, ultimately extending beyond Neptune, with the separate bodies revolving around and through it. It is evident that any body revolving around another has a higher kinetic energy than an equal mass of the central body, as it has the energy of the general motion and also that of its revolution in its orbit, consequently, during impact, these bodies will pass away in advance of the nebula; but, on return, will be subject to all the agents tending to render the orbit circular that are discussed in the last paper.

It will be easily seen that supposing the satellites were originally revolving around the two bodies in all planes, at the impact the motion developed by

the mutual attraction of the two bodies would be so large a component of the whole, and would always be in one plane, that the orbital planes could not be inclined at any considerable angles to each other. Apparently the next most probable suggestion is the entire escape of the non-colliding parts, and the formation of a spindle-shaped nebula. On investigating the motions of the ends of those spindle-shaped nebulae which must often result from partial impact, it appears that the very unequal velocities of their two sides may develop centres of rotation, and these rotating masses from the end of the spindle will be generally the coolest, and composed of the densest elements. They may, therefore, have attractive power enough to keep together, and finally coalesce into planets.

It is not probable that either one or both of the non-colliding parts passed away from the central mass and returned. There are two reasons against this supposition; first, it appears very unlikely that the orbits of the planets would be so nearly circular as they are, and, secondly, it appears extremely likely that a double sun would have been formed had this been the case. In both the above suggestions of the origin of the planets the original rotation of the two colliding bodies, and also that of any body revolving around them before the collision, will tend to give an irregularity to the plane of the planets' orbits, and also to their axis of rotation; but the extreme inclination of the axis of Mercury and Venus, and the retrograde motion of Uranus, appear only explicable on the assumption that these bodies were independent satellites existing as such before the impact which gave birth to our system. Further research may, however, show that the original rotation of the colliding bodies may be sufficient to account for all irregularities.

Discussion of difficulties that have been met with in working out this theory.

One of the earliest which presented itself was the possibility of escape of the two original bodies. Many explanations have, however, suggested themselves, and it is now seen that such escape was non-essential. Any particle situated at the surface of the sun requires a velocity of 378 miles a second to escape the sun. Any mass, no matter how great, supposing its centre were situated at the same position, would require the same velocity. Supposing the sun had been formed by partial impact, it would have exerted an additional retarding influence, equal to three-fourths of its mass, upon the two retreating parts, greater than they exerted on each other in approach. The whole of this enormous energy must have been original proper motion.

Although it is not unlikely that originally the motion of the stars was much faster than at present, yet it is altogether unlikely they had a velocity of 300 miles a second. We must therefore look elsewhere for a solution, and the only one which has at present offered itself is that the distance of

the centres of the bodies at impact was much greater than the radius of the sun. A considerable distance may be due to two causes—first, the volume of the two bodies ; and, second, the amount of distortion into an egg-shape, at and previous to the impact. The former may be due to rareness, or to great mass. These two actions may have caused the centres to be many times the sun's present radius distant from each other. This distance may be sufficient to bring the original energy required for escape down to a reasonably proper motion. But, explained in any way, the increased attraction after impact is a serious difficulty in conceiving of the escape of the parts of the original bodies.

The most serious objection to the suggestion of the planets having been formed from parts of the general mass of the original bodies is that the temperature would be so very high as apparently to prevent such small bodies as the planets being kept together by their mutual gravitation. This action is fully discussed in treating of the origin of planetary nebulae. In accounting for planetary nebulae with nuclei, the germ of the present discussion will also be found. Planetary nebulae without nuclei may be caused by only outer parts of bodies colliding. Those parts of the original body that come into impact and retain the highest velocity after impact consist largely of the matter originally near the centre of the original mass.

Reasons have been advanced for supposing that the centre of bodies consists of the heaviest molecules, when the temperature becomes uniform. With such a mass these heavy molecules will, of course, have far less velocity than the light molecules. The escape of these light molecules from the mass will very probably take away a far larger proportion of the total energy than the proportion of their own mass to the total mass, thus leaving the attraction much more effective upon the heavy molecules. Again, when the mass has expanded considerably it may have cooled sufficiently to allow chemical union to take place, with the development of still heavier molecules, and certainly a partial destruction of the original molecular motion, and a development of atomic motion, which almost certainly gives rise to radiation. Consequently much of the energy of their union will be generally lost as radiant energy.

The ordinary principles of radiation tell us that the mass, as a whole, also will gradually lose energy during the impact and immediately after. I need not say that I have already suggested this to account for the extra brilliancy of temporary stars. The formation of these compound molecules would result in a number of small aggregations throughout the mass, and would tend to prevent dissipation into space.

Thus there are four influences at work which tend to prevent the complete dissipation of highly heated masses. 1st. Loss of heat by radiation.

2nd. Loss of energy by selective escape. 3rd. The formation of compound molecules, and 4th. The aggregation of molecules into liquid and solid particles. The extreme density of the smaller planets gives some probability to this theory of their origin. But even had they existed as independent bodies previously to the impact, there is but little doubt that the tendency to exchange of molecules, which I discussed in my last paper, would cause the nearer planets to consist almost entirely of the very heavy molecules. It is extremely probable that the atmosphere, and not unlikely the water, was picked up from the contracting nebular sun, as it gradually shrank within the orbit of the planet.

The slowness of the rotation of the inner planets as well as their density, compared with the outer planets, may also be accounted for by the much greater resistance that the inner part of the nebula would offer to their rotation, as well as to the much greater time that must elapse before the nebula shrunk within their orbit.

Mr. Cherrill's suggestion—that each of the two sets of planets may have been parts of either original body—is worth remembering. Another very serious objection to this theory of the origin of the planets is the order of the distances of the planets (Bode's Law); but this has been shown to be a very empirical and imperfect law. There are some agencies which have suggested themselves to account for it as it now stands,—one is the rotation of apsides. If we accept what is probably the case,—that, after the first revolution of the planets, their orbits had become so circular that the aphelion of the inferior did not extend much beyond the perihelion of the next superior; it appears reasonable to suppose that if the planet's apsides rotated, it would gradually tend to pick up any bodies which were revolving within those limits. This action would tend to cause the various planes of the orbits to coalesce; to render the orbits more circular; and to lessen the inclination of the axes. It might also tend to increase the rate of rotation, consequently we may imagine, as suggested in last paper, that Jupiter has been very active in this collecting action. It is certain that the apsides would rotate, for all the resistance of the nebula except that exactly at perihelion would have this effect, in addition to bringing the body nearer the sun. This rotation of apsides of more elliptical orbits therefore appears to offer a hint of the order of distance of the planets.

There are other points which have been suggested before, but which have not become more mature than when first suggested. The origin of the moons is another serious difficulty. It is possible that when the planets were in a half nebulous condition, these may have had their nuclei formed by bodies which the planet picked up in its collecting action during apsidal rotation.

Molecular exchange, resistance, and its collecting power, may have rendered its orbit circular, and have brought it into the plane of the planet's rotation. There seem no strong reasons, such as irregularity, etc., why Proctor's theory might not account for the formation of the moons. Another objection to this theory is the fact that there are comparatively few small bodies still travelling the system. There are, of course, a countless number of such bodies, but not so many as might be expected. The nebula would cause the bulk of the small bodies, except moons, to be absorbed into the sun; and the same action may have cleared the space about the planets of all matter except the satellites.

The motion of the sun and its system in space may be accounted for in so many different ways, and does not appear to offer any difficulties to any theory, that I shall not discuss it.

Recapitulation.

I recapitulate the more important of the points in what at present seems the most probable origin of the solar system.

Two rare bodies, moving with considerable velocity, rotating, and having revolving around them in all planes a large number of bodies, some of a large size, come within each others attraction, are brought together by gravitation, and come into tangential collision. During the collision most of the accompanying bodies fly off in directions which are approximately in one plane; the component of the motion not in the plane being due to their original orbital rotation. The new orbit of all the bodies tends to be highly eccentric, but the general mass expands, and by its agency the orbit becomes nearly circular. Among the vast number of bodies thrown off during impact, the larger gradually collect the lesser up, also much of the matter that coalesces from the nebula, and many heavy molecules. Where this action is very considerable, the original mass forms so small a fraction of the final planet, that its original irregular motion almost disappears, and its axis is almost rendered perpendicular. The nebular resistance will tend to lessen the distance of the smaller bodies, and convert them into zodiacal light, or absorb them entirely into the sun, except the moons, which cannot escape the planet's attraction. All the smaller planets and those nearer the sun are robbed of their lighter molecules, and become very dense compared to the general mass of the system, but, as the nebulae contract within their orbit, they again pick up the lighter molecules which become the atmosphere.