

ART. XV.—*On the Origin of Double Stars.*

By Professor A. W. BICKERTON.

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

Plate IIA.

IN the former general papers on Partial Impact the probable formation of double stars by its means has been referred to with increasing emphasis. In the present maturing state of theory, probably, if we except temporary stars and some nebulae, there is no phenomenon that receives such an absolutely satisfactory explanation as does the origin of associated binaries. There are three possible explanations of the origin of double stars. 1st. They may have been associated at the birth of the visible Universe, either as stars or nebulae which afterwards condensed. 2nd. It is possible when three stars approach comparatively near each other, that by their mutual attraction one may have its proper motion increased at the expense of the other two. These latter may by their lessened motion become an associated pair. 3rd. A partial impact, in which the coalesced part is neither so small as to allow of escape of the non-colliding parts, nor so large as to produce complete coalescence. Between these two extremes all impacts must produce bodies free of each other, but associated by gravitation. This "partial impact" may have taken place when the two stars were in a nebulous state, and they may have coalesced into stars since; the reasoning which applies to stellar, also applies to nebular impacts, but is not capable of such complete demonstration.

It is the origin of binaries by impact that is studied in this paper, and I believe it will ultimately be found to account for nine-tenths of the double stars.* In all partial impacts, as above limited, the collision is attended with the formation of a central gaseous mass expanding into a nebula, and two parts which pass on,—these parts in this case form the pair of binaries under discussion. Recent criticism has shown it necessary to again most emphatically call attention to the fact that in such cosmical collisions there is no loss of momentum in the portion of the bodies that is not in actual collision, except that due to the work of sheering, and this I shall show to be insignificant.

The coalesced part will, however, exercise an increased attraction, which will prevent the non-colliding parts from attaining their former proper

* Mr. Croll in a foot-note to his paper on the origin of the sun's heat, calls attention to a paper by Mr. Johnson Stoney, in which he states that double stars may be due to a partial entanglement of two colliding stars.

motion in space, and may, in extreme cases, prevent their escaping the mass at all. It is this increased attraction after impact that is the force which causes the two bodies to become associated.

The following three lines of reasoning show how insignificant is the work of sheering compared to the available energy. It is known that a cannon ball, with a velocity of less than 2,000 feet per second, is capable of penetrating a plate of iron its own thickness. Now the velocity at impact of two suns is at least 200 miles per second, or an energy in equal mass of over 200,000 times as great as the cannon ball, but as the size increases the ratio of volume to section increases also; in fact, it is in the ratio of the diameter, for the section varies as the square, and the volume as the cube, of the diameter. So that were the density alike, its ratio would be about a thousand million times as great in a sun as a cannon ball, or the available energy is at least one hundred million of million times greater than required for sheering were both as hard as iron.

It has already been suggested that sheering force has its limits in the latent heat of fusion; this is probably the amount of energy required to separate the molecules from their fixed positions, but, in sheering, the molecules require only to be separated in a single plane,—an insignificant fraction of the whole in such a body as a cannon ball, and in a cosmical body so insignificant a fraction as to be disregarded.

But, even supposing it were required to separate all the molecules instead of those of a single plane, it has been shown that the energy required to do so is such an insignificant fraction of the whole as to be disregarded. In dealing with impacts of bodies such as our sun, if the body be liquid or gaseous of course there is no sheering force, and as in all of the collisions of the bodies under discussion the energy is incomparably greater than that necessary to volatilize the colliding parts, there is actually no sheering force to prevent the escape of the other parts.

From these several lines of reasoning it is evident that sheering force may be absolutely disregarded, and that there is nothing in the impact itself tending to destroy momentum in the non-colliding parts. The ratio that is required to be cut off in order for the stars to become associated depends largely upon the proper motion possessed by the original bodies.

If we take two such bodies as the sun as an illustration, their small proper motion would allow them to become associated if as small a part as one-thousandth were struck off each. In this case, however, the pair would move in orbits so highly eccentric as to almost, if not quite, graze at their perihelion. If they struck off any ratio above this up to about one-half, it is probable that they would still form binaries with increasingly circular orbits, but this problem is so much influenced by the distortion of the

bodies as to be incapable of an accurate solution. This ratio is certainly not far from the truth.

Some cosmical bodies, such as 1830 Groombridge, could not form binaries by impact, for were two such bodies to come into about complete collision, the parts not colliding would possess so much energy that they must escape the total attraction, and could by no means become an associated pair. Such a collision might, of course, form a pair of variables travelling away from each other, and there are many examples of such to be found in the heavens. It is even probable that, were they to completely collide, the heat would be so great that every molecule would escape the attraction of the mass and diffuse itself into space, thus producing a brilliant temporary star.

On the other hand, a colliding pair of stars, without original proper motion, must become associated no matter how small a part might be struck off each. If the amount cut off be so great that the non-colliding parts cannot escape the general mass, an annular nebula may be formed; or, if the impact be nearly complete, the two may form a star with a diameter only a small multiple of the original stars. Calculation has shown that it must be at least the sum of the original diameters.

Without proper motion it would appear that the chance of a binary being formed to that of coalescence is about four to one; but, as this is influenced by the amount of distortion before and during impact, and also by the density, it is impossible to calculate it accurately. With proper motion, and all stars appear to have more or less of this, the ratio becomes larger, so that, taking all impacts not cosmically insignificant into consideration, it is probable that something like a fourth are attended by escape of the non-colliding parts, about a sixth coalesce entirely, and the remainder form binary or multiple stars, associated by gravitation. The history of such a pair appears to be roughly represented by the following illustration:—

Suppose two equal stars with normal proper motion to come into partial impact and strike off a fourth of each; these two parts will coalesce and form a nebula. This coalesced part will exercise a large additional attractive power upon the retreating parts, and would associate the pair. For in order that the parts shall escape, the stars would have required approximately a proper motion equal in energy to three-quarters of the energy that a similar body would require to escape the independent attraction of the central body. And this is certainly enormously above a normal proper motion. Immediately after impact the associated pair will tend to move in highly eccentric elliptical orbits.

The extremely high temperature of the central body will make a temporary star of it, and although a nucleus consisting of the heavier atoms may

remain, yet most of the body will dissipate into space, or become an extremely rare nebula. I have shown in my paper "On Causes tending to alter the Eccentricity of Orbits,"* that this will certainly render the orbits more circular; although of course they may be left in their final state as a very long ellipse. The nebula will doubtless be gradually absorbed by the two stars, and as this absorption will be chiefly at perihelion, it will tend to make the orbit still more circular. What will become of the nucleus of the coalesced part itself is a difficult problem; not improbably it would become associated with one of the two stars in a highly elliptical orbit—making a triple star; or it may be drawn out into long trains by the unequal attraction its opposite sides would be subject to each time the stars passed near it, and finally be absorbed by the two stars.

The accompanying diagram (Plate IIa.) is intended to represent the several stages of the formation of such a pair of binaries. *A* and *B* represent the two stars at a distance. They describe the hyperbolic orbit represented, and if the bodies were in all respects the same, except that the volume was so small as to allow them to escape without collision, then they would pass away in a curve, represented by the dotted curve on the other side of the axis. If we suppose them to come into collision, and the middle piece to exercise such an additional attraction that the new orbit is represented by the long semi-ellipse,—then, on their return to the centre, instead of passing to *P'* it passes to *p*, its permanent perihelion, owing to matter passing outside its orbit and lessening the central attraction. On its several passages through perihelion it suffers resistance, and is brought to *a'a'*. After thus being retarded an indefinite number of times, it finally takes up the orbit represented by the thick line.

Of course, the centre of gravity of such a pair may have a motion of its own, and, doubtless, during the actions here illustrated, apsides would rotate; but, as such rotation is quite unimportant in accounting for the final orbit, the diagram is not complicated with its illustration.

It is probable that for many years after birth the two stars would be variable, as it is evident that the side from which the central mass was struck must be very much the hottest. Struve has discovered that more than a score of double stars are variable, and a very large number more are suspected of variability. The occasional variability of binaries seemed to be so certain on this theory of their origin that I was searching more than a year for evidence of their variability. Finally, my attention was called by the late Dr. Powell to a paper in the "Intellectual Observer" for 1862, in which I obtained this information. Assuming this theory to be right, these variable doubles are recently associated—probably they have not been

* See Art. XIII.

so more than a thousand years or so; for, cosmically, the variability of a star is a mere transitory state, as it appears certain that irregularities of surface temperature must ultimately right themselves, although it is singular what a number of phenomena seem to tend in the direction of keeping a star that has been unequally heated by partial impact from having its uniform temperature restored. This matter is fully discussed in a paper in preparation on variable stars. Many doubles are coloured. I shall show in the same paper that in all probability the final state of variability in a star is a metallic absorbing atmosphere producing a coloured star; so that coloured doubles are probably the next youngest pair to the variable binaries. But although the variability of a star is a temporary state, their association with each other is not so. After having once absorbed the nebula their orbit is fixed, nothing but another impact can separate them and that is more likely to make a multiple star of them.

The final coalescence of the visible Universe will only weld them into the general mass. It is not wonderful therefore that some 10,000 such pairs exist in the Universe. The fact that there are so few speaks to us in powerful language, telling us that the Universe is not so old as we have pictured it to be—that the first day is scarcely over in proportion to the time before its final coalescence. Without doubt this Universe is quite a new member of the Cosmos, of which it is not improbably as a mere drop in an ocean.

ART. XVI.—*On a simple Method of illustrating the Motions of the Earth.*

By Professor A. W. BICKERTON.

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Plate IIb.

THIS model is one of the extempore pieces of apparatus that I designed for the purpose of illustrating a course of experimental lectures, which were delivered with the special object of showing that many of the most important of physical phenomena might be illustrated by apparatus at a cost not exceeding a few pounds. The model itself cost less than a shilling, and I made it in about half-an-hour. Since it was made I have found it useful to illustrate so large a number of cosmical phenomena that I thought it of sufficient importance to bring before the Institute. A much larger number of phenomena may be illustrated by its means than by the expensive models usually sold for the purpose. Among these are day and