THE BODIES OF SPACE,

THEIR ARRANGEMENTS AND FORMATION.

It is familiar knowledge that the earth which we inhabit is a globe of somewhat less than 8000 miles in diameter, being one of a series of eleven which revolve at different distances around the sun, and some of which have satellites in like manner revolving around them. The sun, planets, and satellites, with the less intelligible orbs termed comets, are comprehensively called the solar system, and if we take as the uttermost bounds of this system the orbit of Uranus (though the comets actually have a wider range), we shall find that it occupies a portion of space not less than three thousand six hundred millions of miles in extent. The mind fails to form an exact notion of a portion of space so immense; but some faint idea of it may be obtained from the fact, that, if the swiftest

race-horse ever known had begun to traverse it, at full speed, at the time of the birth of Moses, he would only as yet have accomplished half his journey.

It has long been concluded amongst astronomers, that the stars, though they only appear to our eyes as brilliant points, are all to be considered as suns, representing so many solar systems, each bearing a general resemblance to our own. The stars have a brilliancy and apparent magnitude which we may safely presume to be in proportion to their actual size and the distance at which they are placed from us. Attempts have been made to ascertain the distance of some of the stars by calculations founded on parallax, it being previously understood that, if a parallax of so much as one second, or the 3600th of a degree, could be ascertained in any one instance, the distance might be assumed in that instance as not less than 19,200 millions of miles! In the case of the most brilliant star, Sirius, even this minute parallax could not be found; from which of course it was to be inferred that the distance of that star is something beyond the vast distance which has been stated. In some others, on which the experiment has been tried, no sensible parallax could be detected; from

which the same inference was to be made in their case. But a sensible parallax of about one second has been ascertained in the case of the double star, *α á*, of the constellation of the Centaur,* and one of the third of that amount for the double star, 61 Cygni; which gave reason to presume that the distance of the former might be about twenty thousand millions of miles, and the latter of much greater amount. If we suppose that similar intervals exist between all the stars, we shall readily see that the space occupied by even the comparatively small number visible to the naked eye, must be vast beyond all powers of conception.

The number visible to the eye is about three thousand; but when a telescope of small power is directed to the heavens, a great number more come into view, and the number is ever increased in proportion to the increased power of the instrument. In one place, where they are more thickly sown than elsewhere, Sir William Herschel reckoned that fifty thousand passed over a field of view two degrees in breadth in a single hour. It was first surmised by the ancient philosopher, Democritus, that the faintly white zone which

* By Mr. Henderson, Professor of Astronomy in the Edinburgh University, and Lieutenant Meadows.

spans the sky under the name of the Milky Way, might be only a dense collection of stars too remote to be distinguished. This conjecture has been verified by the instruments of modern astronomers, and some speculations of a most remarkable kind have been formed in connexion with it. By the joint labours of the two Herschels, the sky has been "gauged" in all directions by the telescope, so as to ascertain the conditions of different parts with respect to the frequency of the stars. The result has been a conviction that, as the planets are parts of solar systems, so are solar systems parts of what may be called astral systems—that is, systems composed of a multitude of stars, bearing a certain relation to each other. The astral system to which we belong, is conceived to be of an oblong, flattish form, with a space wholly or comparatively vacant in the centre, while the extremity in one direction parts into two. The stars are most thickly sown in the outer parts of this vast ring, and these constitute the Milky Way. Our sun is believed to be placed in the southern portion of the ring, near its inner edge, so that we are presented with many more stars, and see the Milky Way much more clearly, in that direction, than towards the north, in which line our eye has

to traverse the vacant central space. Nor is this all. Sir William Herschel, so early as 1783, detected a motion in our solar system with respect to the stars, and announced that it was tending towards the star λ, in the constellation Hercules. This has been generally verified by recent and more exact calculations,* which fix on a point in Hercules, near the star 143 of the 17th hour, according to Piozzi's catalogue, as that towards which our sun is proceeding. It is, therefore, receding from the inner edge of the ring. Motions of this kind, through such vast regions of space, must be long in producing any change sensible to the inhabitants of our planet, and it is not easy to grasp their general character; but grounds have nevertheless been found for supposing that not only our sun, but the other suns of the system pursue a wavy course round the ring *from west to east*, crossing and recrossing the middle of the annular circle. "Some stars will depart more, others less, from either side of the circumference of equilibrium, according to the places in which they are situated, and according to the direction and the velocity with which they are put in motion. Our sun is

* Made by M. Argelander, late director of the Observatory at Abo.

probably one of those which depart furthest from it, and descend furthest into the empty space within the ring."* According to this view, a time may come when we shall be much more in the thick of the stars of our astral system than we are now, and have of course much more brilliant nocturnal skies; but it may be countless ages before the eyes which are to see this added resplendence shall exist.

The evidence of the existence of other astral systems besides our own is much more decided than might be expected, when we consider that the nearest of them must needs be placed at a mighty interval beyond our own. The elder Herschel, directing his wonderful tube towards the *sides* of our system, where stars are planted most rarely, and raising the powers of the instrument to the required pitch, was enabled with awe-struck mind to see suspended in the vast empyrean astral systems, or, as he called them, firmaments, resembling our own. Like light cloudlets to a certain power of the telescope, they resolved themselves, under a greater power, into stars, though these generally

* Professor Mossotti, on the Constitution of the Sidereal System, of which the Sun forms a part.—*London, Edinburgh, and Dublin Philosophical Magazine*, February, 1843.

seemed no larger than the finest particles of diamond dust. The general forms of these systems are various; but one at least has been detected as bearing a striking resemblance to the supposed form of our own. The distances are also various, as proved by the different degrees of telescopic power necessary to bring them into view. The farthest observed by the astronomer were estimated by him as thirty-five thousand times more remote than Sirius, supposing its distance to be about twenty thousand millions of miles. It would thus appear, that not only does gravitation keep our earth in its place in the solar system, and the solar system in its place in our astral system, but it also may be presumed to have the mightier duty of preserving a local arrangement between that astral system and an immensity of others, through which the imagination is left to wander on and on without limit or stay, save that which is given by its inability to grasp the unbounded.

The two Herschels have in succession made some other most remarkable observations on the regions of space. They have found within the limits of our astral system, and generally in its outer fields, a great number of objects which, from their foggy appearance, are called *nebulæ;* some

of vast extent and irregular figure, as that in the sword of Orion, which is visible to the naked eye; others of shape more defined; others, again, in which small bright nuclei appear here and there over the surface. Between this last form and another class of objects, which appear as clusters of nuclei with nebulous matter around each nucleus, there is but a step in what appears a chain of related things. Then, again, our astral space shews what are called nebulous stars,—namely, luminous spherical objects, bright in the centre and dull towards the extremities. These appear to be only an advanced condition of the class of objects above described. Finally, nebulous stars exist in every stage of concentration, down to that state in which we see only a common star with a slight *bur* around it. It may be presumed that all these are but stages in a progress, just as if, seeing a child, a boy, a youth, a middle-aged, and an old man together, we might presume that the whole were only variations of one being. Are we to suppose that we have got a glimpse of the process through which a sun goes between its original condition, as a mass of diffused nebulous matter, and its full-formed state as a compact body? We shall see how far such an idea is supported by

other things known with regard to the occupants of space, and the laws of matter.

A superficial view of the astronomy of the solar system gives us only the idea of a vast luminous body (the sun) in the centre, and a few smaller, though various sized bodies, revolving at different distances around it; some of these, again, having smaller planets (satellites) revolving around them. There are, however, some general features of the solar system, which, when a profounder attention makes us acquainted with them, strike the mind very forcibly.

It is, in the first place, remarkable, that the planets all move nearly *in one plane*, corresponding with the centre of the sun's body. Next, it is not less remarkable that the motion of the sun on its axis, those of the planets around the sun, and the satellites around their primaries,* and the motions of all on their axes, are *in one direction*—namely, from west to east. Had all these matters been left to accident, the chances against the uniformity which we find would have

* The orbitual revolutions of the satellites of Uranus have not as yet been clearly scanned. It has been thought that their path is retrograde compared with the rest. Perhaps this may be owing to a *bouleversement* of the primary, for the inclination of its equator to the ecliptic is admitted to be unusually high; but the subject is altogether so obscure, that nothing can be founded on it.

been, though calculable, inconceivably great. Laplace states them at four millions of millions to one. It is thus powerfully impressed on us, that the uniformity of the motions, as well as their general adjustment to one plane, must have been a consequence of some cause acting throughout the whole system.

Some of the other relations of the bodies are not less remarkable. The primary planets shew a progressive increase of bulk and diminution of density, from the one nearest to the sun to that which is most distant. With respect to density alone, we find, taking water as a measure and counting it as one, that Saturn is $\frac{1}{3}\frac{1}{3}$, or less than half; Jupiter, $1\frac{1}{4}\frac{1}{4}$; Mars, $3\frac{2}{7}$; Earth, $4\frac{1}{2}$; Venus, $5\frac{1}{1}\frac{1}{5}$; Mercury, $9\frac{2}{1}\frac{9}{0}$; or about the weight of lead. Then the distances are curiously relative. It has been found that if we place the following line of numbers,—

0 3 6 12 24 48 96 192,

and add 4 to each, we shall have a series denoting the respective distances of the planets from the sun. It will stand thus—

4	7	10	16	28	52	100	196
Merc.	Venus.	Earth.	Mars.		Jupiter.	Saturn.	Uranus.

It will be observed that the first row of figures

goes on from the second on the left hand in a succession of duplications, or multiplications by 2. Surely there is here a most surprising proof of the unity which I am claiming for the solar system. It was remarked when this curious relation was first detected, that there was a want of a planet corresponding to 28; the difficulty was afterwards considered as in a great measure overcome, by the discovery of four small planets revolving at nearly one mean distance from the sun, between Mars and Jupiter. The distances bear an equally interesting mathematical relation to the times of the revolutions round the sun. It has been found that, with respect to any two planets, the squares of the times of revolution are to each other in the same proportion as the cubes of their mean distances,—a most surprising result, for the discovery of which the world was indebted to the illustrious Kepler. Sir John Herschel truly observes—"When we contemplate the constituents of the planetary system from the point of view which this relation affords us, it is no longer mere analogy which strikes us, no longer a general resemblance among them, as individuals independent of each other, and circulating about the sun, each according to its own peculiar nature, and con-

nected with it by its own peculiar tie. The resemblance is now perceived to be a true *family likeness;* they are bound up in one chain—interwoven in one web of mutual relation and harmonious agreement, subjected to one pervading influence which extends from the centre to the farthest limits of that great system, of which all of them, the Earth included, must henceforth be regarded as members."*

Connecting what has been observed of the series of nebulous stars with this wonderful relationship seen to exist among the constituents of our system, and further taking advantage of the light afforded by the ascertained laws of matter, modern astronomers have suggested the following hypothesis of the formation of that system.

Of nebulous matter in its original state we know too little to enable us to suggest how nuclei should be established in it. But, supposing that, from a peculiarity in its constitution, nuclei are formed, we know very well how, by virtue of the law of gravitation, the process of an aggregation of the neighbouring matter to those nuclei should proceed, until masses more or less solid should become detached from the rest. It is a well-

* Astronomy, Lardner's Cyclopædia.

known law in physics that, when fluid matter collects towards or meets in a centre, it establishes a rotatory motion. See minor results of this law in the whirlwind and the whirlpool—nay, on so humble a scale as the water sinking through the aperture of a funnel. It thus becomes certain that when we arrive at the stage of a nebulous star, we have a rotation on an axis commenced.

Now, mechanical philosophy informs us that, the instant a mass begins to rotate, there is generated a tendency to fling off its outer portions—in other words, the law of centrifugal force begins to operate. There are, then, two forces acting in opposition to each other, the one attracting *to*, the other throwing *from*, the centre. While these remain exactly counterpoised, the mass necessarily continues entire; but the least excess of the centrifugal over the attractive force would be attended with the effect of separating the mass and its outer parts. These outer parts would, then, be left as a ring round the central body, which ring would continue to revolve with the velocity possessed by the central mass at the moment of separation, but not necessarily participating in any changes afterwards undergone by that body. This is a process which might be repeated as soon as a

new excess arose in the centrifugal over the attractive forces working in the parent mass. It might, indeed, continue to be repeated, until the mass attained the ultimate limits of the condensation which its constitution imposed upon it. From what cause might arise the periodical occurrence of an excess of the centrifugal force? If we suppose the agglomeration of a nebulous mass to be a process attended by refrigeration or cooling, which many facts render likely, we can easily understand why the outer parts, hardening under this process, might, by virtue of the greater solidity thence acquired, begin to present some resistance to the attractive force. As the solidification proceeded, this resistance would become greater, though there would still be a tendency to adhere. Meanwhile, the condensation of the central mass would be going on, tending to produce a separation from what may now be termed the *solidifying crust.* During the contention between the attractions of these two bodies, or parts of one body, there would probably be a ring of attenuation between the mass and its crust. At length, when the central mass had reached a certain stage in its advance towards solidification, a separation would take place, and the crust would become a detached

ring. It is clear, of course, that some law presiding over the refrigeration of heated gaseous bodies would determine the stages at which rings were thus formed and detached. We do not know any such law, but what we have seen assures us it is one observing and reducible to mathematical formulæ.

If these rings consisted of matter nearly uniform throughout, they would probably continue each in its original form; but there are many chances against their being uniform in constitution. The unavoidable effects of irregularity in their constitution would be to cause them to gather towards centres of superior solidity, by which the annular form would, of course, be destroyed. The ring would, in short, break into several masses, the largest of which would be likely to attract the lesser into itself. The whole mass would then necessarily settle into a spherical form by virtue of the law of gravitation; in short, would then become a planet revolving round the sun. Its rotatory motion would, of course, continue, and satellites might then be thrown off in turn from its body in exactly the same way as the primary planets had been thrown off from the sun. The rule, if I can be allowed so to call it, receives a

striking support from what appear to be its exceptions. While there are many chances against the matter of the rings being sufficiently equable to remain in the annular form till they were consolidated, it might nevertheless be otherwise in some instances; that is to say, the equableness might, in those instances, be sufficiently great. Such was probably the case with the two rings around the body of Saturn, which remain a living picture of the arrangement, if not the condition, in which all the planetary masses at one time stood. It may also be admitted that, when a ring broke up, it was possible that the fragments might spherify separately. Such seems to be the actual history of the ring between Jupiter and Mars, in whose place we now find four planets much beneath the smallest of the rest in size, and moving nearly at the same distance from the sun, though in orbits so elliptical, and of such different planes, that they keep apart.

It has been seen that there are mathematical proportions in the relative distances and revolutions of the planets of our system. It has also been suggested that the periods in the condensation of the nebulous mass, at which rings were disengaged, must have depended on some par-

ticular crises in the condition of that mass, in connexion with the laws of centrifugal force and attraction. M. Compte, of Paris, has made some approach to the verification of the hypothesis, by calculating what ought to have been the rotation of the solar mass at the successive times when its surface extended to the various planetary orbits. He ascertained that *that rotation corresponded in every case with the actual sidereal revolution of the planets, and that the rotation of the primary planets in like manner corresponded with the orbitual periods of the secondaries.* The process by which he arrived at this conclusion is not to be readily comprehended by the unlearned; but those who are otherwise, allow that it is a powerful support to the present hypothesis of the formation of the globes of space.*

* M. Compte combined Huygens's theorems for the measure of centrifugal force with the law of gravitation, and thus formed a simple fundamental equation between the duration of the rotation of what he calls the producing star, and the distance of the star produced. The constants of this equation were the radius of the central star, and the intensity of gravity at its surface, which is a direct consequence of its mass. It leads directly to the third law of Kepler, which thus becomes susceptible of being conceived *à priori* in a cosmogonical point of view. M. Compte first applied it to the moon, and found, to his great delight, that the periodic time of that satellite agrees within an hour or two

The nebular hypothesis, as it has been called, obtains a remarkable support in what would at first seem to militate against it—the existence in our firmament of several thousands of solar systems, in which there are more than one sun. These are called double and triple stars. Some double stars, upon which careful observations have been made, are found to have a regular revolutionary motion round each other in ellipses. This

with the duration which the revolution of the earth ought to have had at the time when the lunar distance formed the limit of the earth's atmosphere. He found the coincidence less exact, but still very striking in every other case. In those of the planets he obtained for the duration of the corresponding solar rotations a value always a little less than their actual periodic times. "It is remarkable," says he, "that this difference, though increasing as the planet is more distant, preserves very nearly the same relation to the corresponding periodic time, of which it commonly forms the forty-fifth part,"—shewing, we may suppose, that only some small elements of the question had been overlooked by the calculator. The defect changes to an excess in the different systems of the satellites, where it is proportionally greater than in the planets, and unequal in the different systems. "From the whole of these comparisons," says he, "I deduced the following general result:—Supposing the mathematical limit of the solar atmosphere successively extended to the regions where the different planets are now found, the duration of the sun's rotation was, at each of these epochs, sensibly equal to that of the actual sidereal revolution of the corresponding planet; and the same is true for each planetary atmosphere in relation to the different satellites."—*Cours de Philosophie Positif.*

kind of solar system has also been observed in what appears to be its rudimental state, for there are examples of nebulous stars containing two and three nuclei in near association. At a certain point in the confluence of the matter of these nebulous stars, they would all become involved in a common revolutionary motion, linked inextricably with each other, though it might be at sufficient distances to allow of each distinct centre having afterwards its attendant planets. We have seen that the law which causes rotation in the single solar masses, is exactly the same which produces the familiar phenomenon of a small whirlpool or dimple in the surface of a stream. Such dimples are not always single. Upon the face of a river where there are various contending currents, it may often be observed that two or more dimples are formed near each other with more or less regularity. These fantastic eddies, which the musing poet will sometimes watch abstractedly for an hour, little thinking of the law which produces and connects them, are an illustration of the wonders of binary and ternary solar systems.

The nebular hypothesis is, indeed, supported by so many ascertained features of the celestial scenery, and by so many calculations of exact

science, that it is impossible for a candid mind to refrain from giving it a cordial reception, if not to repose full reliance upon it, even without seeking for it support of any other kind. Some other support I trust yet to bring to it; but in the meantime, assuming its truth, let us see what idea it gives of the constitution of what we term the universe, of the development of its various parts, and of its original condition.

Reverting to a former illustration—if we could suppose a number of persons of various ages presented to the inspection of an intelligent being newly introduced into the world, we cannot doubt that he would soon become convinced that men had once been boys, that boys had once been infants, and, finally, that all had been brought into the world in exactly the same circumstances. Precisely thus, seeing in our astral system many thousands of worlds in all stages of formation, from the most rudimental to that immediately preceding the present condition of those we deem perfect, it is unavoidable to conclude that all the perfect have gone through the various stages which we see in the rudimental. This leads us at once to the conclusion that the whole of our firmament was at one time a diffused mass of nebulous mat-

ter, extending through the space which it still occupies. So also, of course, must have been the other astral systems. Indeed, we must presume the whole to have been originally in one connected mass, the astral systems being only the first division into parts, and solar systems the second.

The first idea which all this impresses upon us is, that the formation of bodies in space is *still and at present in progress.* We live at a time when many have been formed, and many are still forming. Our own solar system is to be regarded as completed, supposing its perfection to consist in the formation of a series of planets, for there are mathematical reasons for concluding that Mercury is the nearest planet to the sun, which can, according to the laws of the system, exist. But there are other solar systems within our astral system, which are as yet in a less advanced state, and even some quantities of nebulous matter which have scarcely begun to advance towards the stellar form. On the other hand, there are vast numbers of stars which have all the appearance of being fully formed systems, if we are to judge from the complete and definite appearance which they present to our vision through the telescope. We have no means of judging of the seniority of systems;

but it is reasonable to suppose that, among the many, some are older than ours. There is, indeed, one piece of evidence for the probability of the comparative youth of our system, altogether apart from human traditions and the geognostic appearances of the surface of our planet. This consists in a thin nebulous matter, which is diffused around the sun to nearly the orbit of Mercury, of a very oblately spheroidal shape. This matter, which sometimes appears to our naked eyes, at sunset, in the form of a cone projecting upwards in the line of the sun's path, and which bears the name of the Zodiacal Light, has been thought a residuum or last remnant of the concentrating matter of our system, and thus may be supposed to indicate the comparative recentness of the principal events of our cosmogony. Supposing the surmise and inference to be correct, and they may be held as so far supported by more familiar evidence, we might with the more confidence speak of our system as not amongst the elder born of Heaven, but one whose various phenomena, physical and moral, as yet lay undeveloped, while myriads of others were fully fashioned and in complete arrangement. Thus, in the sublime chronology to which we are directing our inquiries, we first find ourselves called upon

to consider the globe which we inhabit as a child of the sun, elder than Venus and her younger brother Mercury, but posterior in date of birth to Mars, Jupiter, Saturn, and Uranus; next to regard our whole system as probably of recent formation in comparison with many of the stars of our firmament. We must, however, be on our guard against supposing the earth as a recent globe in our ordinary conceptions of time. From evidence afterwards to be adduced, it will be seen that it cannot be presumed to be less than many hundreds of centuries old. How much older Uranus may be no one can tell, much less how more aged may be many of the stars of our firmament, or the stars of other firmaments than ours.

Another and more important consideration arises from the hypothesis; namely, as to the means by which the grand process is conducted. The nebulous matter collects around nuclei by virtue of the law of attraction. The agglomeration brings into operation another physical law, by force of which the separate masses of matter are either made to rotate singly, or, in addition to that single motion, are set into a coupled revolution in ellipses. Next centrifugal force comes into play, flinging off portions of the rotating masses, which

become spheres by virtue of the same law of attraction, and are held in orbits of revolution round the central body by means of a composition between the centrifugal and gravitating forces. All, we see, is done by certain laws of matter, so that it becomes a question of extreme interest, what are such laws? All that can yet be said, in answer, is, that we see certain natural events proceeding in an invariable order under certain conditions, and thence infer the existence of some fundamental arrangement which, for the bringing about of these events, has a force and certainty of action similar to, but more precise and unerring than those arrangements which human society makes for its own benefit, and calls laws. It is remarkable of physical laws, that we see them operating on every kind of scale as to magnitude, with the same regularity and perseverance. The tear that falls from childhood's cheek is globular, through the efficacy of that same law of mutual attraction of particles which made the sun and planets round. The rapidity of Mercury is quicker than that of Saturn, for the same reason that, when we wheel a ball round by a string and make the string wind up round our fingers, the ball always flies quicker and quicker as

the string is shortened. Two eddies in a stream, as has been stated, fall into a mutual revolution at the distance of a couple of inches, through the same cause which makes a pair of suns link in mutual revolution at the distance of millions of miles. There is, we might say, a sublime simplicity in this indifference of the grand regulations to the vastness or minuteness of the field of their operation. Their being uniform, too, throughout space, as far as we can scan it, and their being so unfailing in their tendency to operate, so that only the proper conditions are presented, afford to our minds matter for the gravest consideration. Nor should it escape our careful notice that the regulations on which all the laws of matter operate, are established on a rigidly accurate mathematical basis. Proportions of numbers and geometrical figures rest at the bottom of the whole. All these considerations, when the mind is thoroughly prepared for them, tend to raise our ideas with respect to the character of physical laws, even though we do not go a single step further in the investigation. But it is impossible for an intelligent mind to stop there. We advance from law to the cause of law, and ask, What is that? Whence have come all these beautiful regulations?

Here science leaves us, but only to conclude, from other grounds, that there is a First Cause to which all others are secondary and ministrative, a primitive almighty will, of which these laws are merely the mandates. That great Being, who shall say where is his dwelling-place, or what his history! Man pauses breathless at the contemplation of a subject so much above his finite faculties, and only can wonder and adore!